Telescope Reviews: Mini Reviews of Over 25 Telescopes (old & new) up to 28 cm Aperture

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Abstract: Reviews of telescopes and long focal length camera lens herein are from a cumulative series of reviews that incorporate my own user impressions, and in some cases measurements, of several telescopes and lenses over a period of almost forty years. The emphasis is on optical tube assemblies (OTA's). There are a few side by side comparisons, but not a full comparison matrix, since it obviously was not possible to own or otherwise access all of the reviewed items at once. Emphasis is on Cassegrain telescopes, but some others (Newtonian, refractor) are also covered. Some reviews examine telescope light baffle problems, since these are among the most common non-optical flaws in commercial telescopes. In a few cases, camera lenses are tested to assess usefulness as telescopes. The content assumes that readers are familiar with the basic differences between various types of telescopes, including Maksutov and Schmidt Cassegrain telescopes. A few telescope reviews may still be in other parts of the eclipsechaser.com and versacorp.com web sites. These will gradually be migrated to the present work, which may later be supplemented with other reviews. In general, reviews herein are ordered according to ascending aperture size. One chapter of this work covers telescope accessories such as star trackers, Barlows, ADC's, etc.

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1.0) **Introduction** (Telescope Types, Optical Figures, Spherical Aberration Correctors, etc.)

This introduction is a brief review of different types of telescopes. It also briefly covers the optical figures specific to most basic types, and touches on spherical aberration correctors.

1.1) Types of telescopes

There are three basic types of telescopes, but a myriad of variations within each type. Each was considered as a candidate for an *accessible telescope* prototype. These are summarized below.

1.1.1) Refractor. A refractor telescope consists of a lens (two or more elements) at the front, a lens cell, a tube or other support structure, baffles, a focuser, and an eyepiece and/or camera interface. A diagonal mirror or prism is often used to provide more comfortable viewing angles at the eyepiece. Variations of refractors include types of glass used in the lens, whether the light path is folded, and whether or not field flattening lenses are used for wide field astrophotography.

1.1.2) Newtonian. A Newtonian is one of the most elegant telescope designs. It consists of a concave primary mirror with a paraboloidal optical figure, a flat secondary mirror to direct the light path to one side, and a support structure for the optics. Variations of the Newtonian include whether a spherical primary mirror is used in conjunction with a corrector lens (corrector is usually at the front), and whether or not coma correcting, etc., lenses are used relatively near the focal surface. Some variations may also utilize unconventional secondary mirror angles.

1.1.3) Cassegrain. A Cassegrain has a concave primary mirror at the back, a convex secondary mirror at the front, light baffles, and a support structure. The primary mirror usually has a hole in its center to permit light reflected from the secondary mirror to exit the rear of the telescope. Variations include optical figures of the primary and secondary mirrors, and whether a spherical primary mirror is used with front or rear refracting spherical aberration correction optics. The latter is usually called a catadioptric telescope. Most catadioptrics have a Maksutov or Schmidt corrector at the front. (Larger Schmidt tested better.) Others have a concave secondary mirror, and still others may fold the light path to one side out in front of the primary mirror. Cassegrain telescopes are comparatively small and light, since the folded light path can fit in a shorter tube.

1.2) Correcting Spherical Aberration in Variations of Each Type of Telescope

When a single *refracting* lens element having only spherical surfaces is used by itself, it will produce an image that has both spherical aberration and chromatic (or color) aberration. If two lenses of appropriately different types of glass are used, and these lenses both have appropriately paired curvatures, it is possible to correct almost all spherical aberration, and to correct chromatic aberration so that two different colors reach focus at the same longitudinal position. Appropriate correction for two colors reduces the severity of chromatic aberration for other colors, but does not completely correct it. When at least one lens is made of extra low dispersion (or "ED") glass, chromatic aberration is reduced a bit more. Three lenses, each of appropriately differing glass types, can bring three different colors to the same focus. Such lens is called an apochromat.

When a *reflector* telescope has a *primary mirror* in the range of f/ratios that most are accustomed to (f/2.8 to f/6 for a Newtonian telescope, f/2 to f/4 for a Cassegrain telescope) the optical figure of the mirror cannot be spherical unless correction of spherical aberration is provided by means including a corrector lens, or the optical figure of another mirror such as a secondary mirror.

In all designs, a balance must be struck between achieving diffraction limited performance in the center of the image, the amount of coma allowed in off-axis parts of the image, and complexity.

A conventional Newtonian telescope uses a concave aspheric primary mirror figure (specifically, a paraboloidal mirror figure) rather than a spherical one, though spherical mirrors have been used for extremely small aperture, slow f/ratio versions (7.5 cm f/10, for example).

If the primary mirror of a larger aperture or faster f/ratio *Newtonian* telescope does not have a paraboloidal aspheric figure, it will not provide high resolution images. That is, unless the spherical mirror is used with a refracting corrector element, such as a Schmidt or Maksutov corrector. Such correctors are most often used well out in front of the primary mirror, but a few telescopes use smaller corrector lenses that are located relatively close to the focal plane.

In their various forms, Cassegrain telescopes may utilize a variety of mirror figures and refracting corrector components. Four Cassegrain designs (Classical, Dal-Kirkham, Ritchey-Chretien, Presman Camachel) use no refracting corrector elements at all, since the figures of their primary and secondary mirrors alone adequately correct on-axis spherical aberration. Other Cassegrain telescopes use refracting corrector elements. These may consist of a large corrector element out in front of the primary mirror, a mangin (i.e. second surface) mirror, or smaller corrector lenses that are relatively close to the focal plane. Each has its advantages and disadvantages. More details about this are in section 3.0.1: "Basic Types of Small Telescopes and Mirror Lenses".

1.3) Design Considerations for Complex Telescopes

The Cassegrain design is one of the most difficult to implement properly, because there are more optical and mechanical details to consider. Some of the most frequent design errors made in commercial Cassegrain telescopes are related to the light baffles. In a proper light baffle design, the back of the secondary baffle, front of the primary baffle, and any retaining flange in front of the primary mirror, will all appear to be close to the same size when viewed from the focal plane.

But in a catadioptric Cassegrain telescope having a front corrector lens, it is usually better if the primary mirror is *slightly* oversized, and if the primary light baffle OD (as seen from the center of the focal plane) appears to be *slightly* smaller than the other light baffles, while the inner and outer edges of the secondary baffle should appear to be *slightly* larger than other baffle elements. These details ensure that, for the axial image, the entrance pupil is defined by the aperture stop in the front corrector lens cell, plus the outer boundary of the secondary baffle. This minimizes longitudinal distortion of the exit pupil when a long focal length (low power) eyepiece is used.

In reviews that follow, the importance of proper light baffle design in a Cassegrain telescope will become evident. This is because improper baffle design can impair performance of a telescope, even if the optics are excellent. Appendix A, which follows the reviews, includes details about several light baffle design errors in telescopes that I have I owned or otherwise had access to over time. Most catadioptric telescopes are mass produced, so if design errors are found in a sample, it often (unfortunately) means that the error was implemented in numerous telescopes that many may have paid good money for. Some baffle errors can be corrected in an existing telescope; but other errors cannot be corrected without "starting over" with at least new optical coatings.

1.4) Telescope Sizes.

Telescopes are available in a variety of shapes and sizes. Amateur telescope apertures range from less than 3.6 cm up to more than a meter. More common sizes range from 6 cm to 31 cm, though telescopes as large as 61 cm are getting more common. A good part of the reviews are for small aperture (10.2 cm or smaller) telescopes and lenses, since these are the most portable.

2.) Conventions, List of Reviewed Telescopes; Summary of Selected Results; Astro Images

2.1) Conventions: Some reviews start with a brief list of quality and performance criteria, with ratings (0 to 5, 5 being best; or Poor to Excellent) for each category. Conventions are similar to those in the telescope and photographic industries. Reviewing telescopes and camera lenses in the same document can cause some confusion unless conventions and a few terms are explained.

2.1.1) Telescope Conventions: The aperture and focal length of a telescope is usually expressed in terms of the aperture, followed by the f/ratio. Multiplying the aperture by the f/ratio provides the focal length. For example, a 18.0 cm f/15 telescope will have a focal length of 2,700 mm (180mm*15). The f/ratio is simply the ratio of the aperture to the focal length, and differs from the "T" (or transmission) value often used in cinematography. Some Cassegrain telescopes may have up to half an f/stop less transmission value than what their f/ratios would indicate.

2.1.2) Camera Lens Conventions: Camera lenses are usually specified in terms of focal length and f/ratio. To determine aperture, simply divide the focal length by the f/ratio. For example, a 500 mm f/8 camera lens will have an aperture of 62.5 mm (500/8). However, some better mirror lenses are designed to approximate the "T" (transmission) value for the specified f/ratio. Here, such lenses may have apertures close to 10 percent larger than what the f/ratio would indicate. This is common in vintage Nikon mirror lenses. Lens dimensions are for Nikon mount versions.

To help track of the telescope and camera lens terms, aperture is usually specified in centimeters (*except in summary tables*), but focal length is specified in mm, or is followed by the letters "FL"

2.1.3) Image Quality Information for Telescopes and Camera Lenses: Specifications and image quality information are usually shown at the beginning of each review summary. In the area that summarizes image quality, an extra row of information is shown for camera lenses that is not shown for telescopes. This information is cryptically shown under the following criteria:
ShVid = Maximum aperture that no axial aberrations seen with a 4 mm eyepiece.
ShAx = Maximum aperture that axial aberration "film grain limited" (or 7 micron pixel limited)
Sh34 = Maximum aperture at which off-axis aberrations at corner of 4:3 aspect area acceptable.
FAFm = Max. aperture to illuminate full format w/o lens barrel cutoff (or % mirror lens ap. used)
FA34 = Max. aperture that illum. 4:3 aspect of format w/o cutoff (or % mirror lens aper. used)
UseAt = Maximum aperture for sharp, well illuminated image over 4:3 aspect area of FX format

2.1.4) Review Status Indication: Many telescopes below either have been reviewed and a mini review has been either started or completed. However, some telescopes are still on a short list of scopes to finish writing up review results for. Status is shown in the right column of the list of reviewed scopes in part 2.2, below. An asterisk (*) after "complete" indicates some values TBR.

2.1.4) Review Photos: Compared to the number of reviews, there are few photos. The number of reviewed telescopes is too great to include photos of each in the available time. Images are included in parts of the appendix that cover servicing or light baffle flaws, since it is difficult to communicate some of that without illustrations. In sample pictures, relative magnification may be referred to as a "percent crop". This relates to the *pixel scale* when a browser is set to display photos at 100 percent of the posted size. It is *not* the percentage of the original image format.

2.2) List of Reviewed Telescopes, with Status of Each Review:

	Status:	
3.) Telescopes (& Camera Lenses Used as Telescopes) up to 6.4 cm Aperture:		p. 10
3.1) Specwell 8x20 Monocular with Microscope Attachment (used for astro imaging)	Complete *	
3.2) Leica 50 mm f/1.4 Summilux-M ASPH lens (used as a telescope!)	Complete	
3.3) Coronado PST, 4.0 cm f/10 integrated solar telescope	Complete	
3.4) Rokinon 300 mm f/6.3 compact mirror lens (camera lens used as telescope)	Complete	
3.5) TeleVue 60 ED refractor (6.0 cm f/6)	Complete	
3.6) Ednar/Pentax Mirror Scope 500 (500 mm FL f/8)	Complete	
3.7) Tamron 500 mm f/8 Mirror Lens (used as a telescope)	Complete	
3.8) Nikon 500mm f/8 Reflex Nikkor-C (used as a telescope)	Complete	
3.9) Celestron C65 (1980's version)	Complete	
3.10) Nikon 300 mm f/4.5 ED Nikkor lens	Complete	
3.11) Vivitar 800 mm f/11 Solid Cat Mirror Lens (used as a telescope)	Partial *	
3.12) Sologor/Vivitar 600 mm f/8 “stovepipe” lens	Complete	
3.13) Vivitar 600 mm f/8 modular “telephoto” lens (used as telescope)	Complete	
3.14) Ad Astra III, 7.8 cm Maksutov-Cassegrain telescope	Complete	
3.15) Vivitar 500 mm f/6.3 telephoto lens	Complete	
4.) Telescopes (and Camera Lenses Used as Telescopes) from 8.0-9.9 cm Aperture:		p. 34
4.1) B&L 800 Mirror Lens and Telescope (8.0 cm f/10 Hybrid)	Complete	
4.2) Kasai Pico-8 Maksutov-Cassegrain telescope (8.0 cm f/11.2)	Complete	
4.3) Leica 560 mm f/6.8 Telyt-R lens (used as telescope)	Complete	
4.4) Questar 3.5 Mak-Cass telescope (8.9 cm f/14.4)	Complete	
4.5) Celestron 90 Mak-Cass telescope (9.0 cm f/11)	Complete	
4.6) Meade ETX-90 Mak-Cass (9.0 cm f/14.4)	Complete	
4.7) Nikon 1000 mm f/11 Reflex Nikkor-C (used as telescope)	Complete	
4.8) Vernonscope 94 mm f/7 triplet refractor telescope (9.4 cm f/6.9)	Complete	
5.) Telescopes (and Camera Lenses Used as Telescopes) from 10.0-11.9 cm Aperture:		p. 51
5.1) Nikon 500 mm f/5.0 Reflex Nikkor lens (used as an astrograqph)	Complete	
5.2) Soligor/Vivitar 800 mm f/8 "stovepipe" lens (10.0 cm f/8, used as telescope)	Complete	
5.3) Tokina/Vivitar 800 mm f/8 “telephoto” lens (10.0 cm f/8, used as telescope)	Complete	
5.4) OTI Quantum 4 Mak-Cass telescope (10.0 cm f/15)	Complete *	
5.5) Bausch & Lomb Criterion 4000 Schmidt-Cassegrain telescope (10 cm f/12)	Complete *	
5.6) Edmund 101.6 mm f/15 doublet refractor (vintage objective lens)	Complete	
5.7) Meade 2045 LX-3 Schmidt-Cassegrain (SCT) telescope (10.2 cm f/10)	Complete *	
5.8) Meade ETX-105 Mak-Cass telescope, UHTC version (105 mm f/14)	Complete *	
6.) Telescopes of 12.0 cm and Larger Aperture:		p. 63
6.1) Celestron 5 Schmidt-Cassegrain (SCT) telescope (12.7 cm f/10)	Almost done *	
6.2) Intes MN56 Maksutov-Newtonian telescope (12.7 cm f/6)	Partial *	
6.3) “Mystery Mak" Mak-Cass telescope (13.0 cm f/15.4 no brand name)	Complete	
6.4) Intes MN61 Maksutov-Newtonian telescope (15.0 cm f/6)	Partial *	
6.5) OTI Quantum 6 Mak-Cass telescope (15.0 cm f/16.7)	Complete *	
6.6) Astro-Tech AT6RC Ritchey-Chretien astrograph (15.2 cm f/9)	Complete	
6.7) Skywatcher 180 Mak-Cass telescope (18.0 cm f/15)	Complete	
6.8) Celestron 8 Schmidt-Cassegrain (SCT) telescope (20.32 cm f/10)	Almost done *	
6.9) Celestron Ultima 11 SCT telescope (27.9 cm f/10)	Almost done *	
7.) Telescope Accessories of Note that are Also Reviewed:		p. 79
7.1) Trackers / 7.1.1 AstroTrac TT320x 7.1.2 Fornax LighTrack II Mount	Partial *	
7.1.3 iOptron SkyTracker 7.1.4 Vixen Polarie	Barely started *	
7.2) Optical Accessories / 7.2.1 ZWO Atmospheric Dispersion Corrector (ADC)	Partial *	

2.2.1) Telescope and Camera Lens Specification and Performance Summary Table:

This table summarizes the specified aperture, measured aperture, obstruction size (when present), dimensions, central resolution, contrast, ghosting, and maximum useful f/ratio (when adjustable).

Sec. No.	Telescope/Lens Make/Model	Spec. Aper.	f/#	FL (mm)	Act. Aper.	Obs (%)	Wide (mm)	High (mm)	Long (mm)	Wght (g)	Ctr. Res	Cont. / Flr..	Blm/ Ghst	Use at f/	Notes
3.1	Specwell 8x20	20.0	NA	NA	20.0	0	32	36	91	79	Exc	F-G	Fair	NA	Monoc
3.2	Leica 50/1.4 Slx	36.8	1.40	51.6	36.5	0	53.5	60.5	52.5	335	Exc	VG+	Good	1.7	DfLt17
3.3	Coronado PST	40.0	10.0	400	40.0	0	60	134	380	1305	Exc	G	Fair	10.0	SolarT
3.4	Rokinon 300/6.3	47.6	6.3	300	51.0	61	65	65	74	250	VG	G	G	6.3	NoTpS
3.5	TeleVue 60 ED	60	6.0	360	60.0	0	81	108	258	1340	Exc	VgE	Exc	6.0	DifLtd
3.6	Ednar MS 500	62.5	8.0	500	66.0	52	81	104	136	772	G	Fair	F-P	8.0	SphAb
3.7	Tamron 500/8	62.5	8.0	500	67.0	52	84	92	93	680	VG	G	G	8.0	ShpOA
3.8	Nikkor-C 500/8	62.5	8.0	500	72.0	53	91	101	152	953	VgE	VG	Fair	8.0	83 CA
3.9	Celestron C65	65.0	12.6	816	65.0	35e	79e	86e	300e	650e	G	G	Fair	12.6	Erct.Im
3.10	Nikon 300/4.5	66.7	4.5	300	66.7	0	80	93.5	193	1110	VgE	G	G	6.8	w/2p2x
3.11	Vivitar 800/11	72.7	11.0	800	72.0	56	108	119	118	1498	G	G	Fair	11.0	w/hood
3.12	Vivitar 600/8 s	75.0	8.0	600	75.0	0	90	93	556	1873	VG	VG	Exc	11.0	w/o hd.
3.13	Vivitar 600/8 t	75.0	8.0	600	75.0	0	94	127	452	1930	VgE	VG	VG	9.0	Modul
3.14	Ad Astra III	78.0	9.75	760	75.0	44	100	104	189	990	Exc	G	VG	9.75	DifLtd
3.15	Vivitar 500/6.3	79.4	6.3	500	79.3	0	95	95	425	1700	Gvg	Fair	Fair	10.0	Sym63
4.1	B&L 800/10	80	10.0	800	72.0	56	95	102	195	900	P-F	F-G	Fair	11.0	Hybrid
4.2	Kasai Pico-8	80	11.2	900	79.0	38	98	110	247	1140	Bad	Poor	Poor	12.2	w/cap
4.3	Leica 560/6.8	82.4	6.8	560	82.4	0	98	98	526	1816	VgE	Exc	VG+	9.5	2A-GS
4.4	Questar 3.5	89.0	14.4	1280	89	32	108	186	274	1499	Exc	VG	G	14	Duplex
4.5	Celestron 90	90.0	11	1000	89.0	38	121	130	197	1476	F-G	Fair	F-G	11	Sph.Ab
4.6	Meade ETX 90	90.0	14.4	1300	87.0	37	110	136	283	1271	VgE	G	G	144	PlstTps
4.7	Nikkor 1000/11	90.9	11.0	1000	101.0	46	136	130	235	1930	VG	VG	G	11.0	Filt.W.
4.8	Vernonsc. 94/7	94.0	7.0	644	93.0	0	123	130	521	4404	Exc	VG	VGE	6.9	w/ring
5.1	Nikkor 500/5	100	5.0	500	111	54	125	136	190	1725	Fair	G	Fair	5.0	w/35hd
5.2	Sol/Viv. 800/8	100	8.0	800	100	0	110	120	812	3180	VgE	Exc	VG	13.0	Vivf15
5.3	Tok/Viv. 800/8	100	8.0	800	100	0	116	130	571	2315	Fair	Fair	Fair	16.0	Vivf19
5.4	OTI Quantum 4	100	15.0	1500	100	36	131	121	360e	2950	Exc	F-G	F-G	15.0	Heavy
5.5	B&L Crit. 4000	101.6	12.0	1200	100e	34	120e	130e	305e	950e	F-G	Fair	Fair	12.0	VrSmp
5.6	Edmund 101/15	101.6	15.0	1524	101.6	0	114	114	1416	4500	Exc	VG	G	15.0	HmMd
5.7	Meade2045LX3	102	10.0	1000	99.0	46	120	130	264	2200	VG	F-G	F-G	10.0	AllMet
5.8	Meade ETX 105	105	14.0	1470	102	33	127	153	340e	2040	Exc	VG	VG	14.0	UHTC
6.1	Celestron 5"/10	127.0	10.0	1250	126.0	42	146	159	305	1700	Ex-	G	G	10.0	LtWt
6.2	Intes MN56 5/6	127.0	6.0	762	127.0	25	216	159	749	5675	Exc	VG	G	6.0	57HelF
6.3	Mystery Mak 5"	130.0	15.4	2000	125.0	49	159	168	437	4540	VG	Poor	Poor	15.4	PrBafD
6.4	Intes MN61 6/6	150.0	6.0	900	150.0	19	253	178	937	7945	Exc	G	F-G	6.0	BestRs
6.5	OTI Quantum 6	150.0	16.7	2500	150.0	33	190	178	TBD	TBD	Exc	G	G	16.7	GdBaf
6.6	AstroT. AT6RC	152.0	9.0	1370	152.0	50	190	203	498	5500	VG	G	G	9.0	Astrog.
6.7	SkyWatcher 180	180.0	15.0	2700	172.0	34	218	228	541	7260	VgE	G	G	15.0	PrBafD
6.8	Celestron 8"/10	203.2	10.0	2032	203.2	34	232	245	457	5680	Exc	G	G	10.0	w/TpA
6.9	Celestron Ult11	279.0	10.0	2790	279.0	36.4	317	330	TBD	12ke	Exc	G	G	10.0	25kgm

2.3) Sneak Preview of Selected Telescope Review Results

Even though data from some aspects of the reviews has not been integrated into the matrix for the present document, it was possible to rank some of the above telescopes in terms of maximum useful magnification (in good seeing) and planetary image quality. Results may surprise some:

The list below is ordered by aperture. Rankings are in columns for each tested attribute. Rankings (1 is best) are for contrast, real detail, max. useful magnification, etc:

Telescope	**Specification**	**Contrast**	**Ang.Res**	**Best Mag**	**Max.Useful Mag**	**Notes**
* TeleVue 60	6.0 f/6 ED Refr	03	12	144x	218x	Custom 1.65mm, 2.5 Nag.
* Ad Astra III	7.8 f/9.7 Mcass	07	11	217x	217x	3.5 mm Nagler
* B&L 800	8.0 f/10 Hybrid	14	14	089x	160x	OR9,OR5 (others,yr) 120x?
* Kasai Pico-8	8.0 f/11.2 MCass	15	15	100x	100x	OR9, 5 Bad Img. (at 74mm) Worst
* Questar 3.5	8.9 f/14.4 MCass	04	07	182x	273s	7mm Nagler,1.5xB
* Celestron 90	9.0 f/11.0 MCass	12	13	111x	167x	OR9, OR6; Astig. + spherical ab.
* Vernon. 94	9.4 f/6.85 Refr	05	08	230x	258x	2.8 Tak, 2.5 Nag.
* Meade 2045	10.2/f/10 SCTel	08	10	167x	200x	OR6,5 (other yr)
* Meade Etx 105	10.5 f/14 MCass	06	06	245x	245x	OR6 (other year)
* Celestron 5	12.7 f/10 SCTel.	10	05	260x	357x	4.8mm, 3.5mm Nagler; Slt. astig.
* Intes MN56	12.7 f/6 MakNwt	02	04	272x	305+	2.8mm Tak. HI OR, 2.5 Nagler
* Mystery Mak	13.0 f/15.4 MCas	13	09	129x	222x	15.5RG, OR9, 7Nag, Others
* Intes MN61	15.0 f/6 MakNwt	01	01	321x	394x	2.8Tak,2.5N,16w/7xB Best
* Skywatcher 180	18.0 f/15 MCass	11	03	300x	386x	OR9, 7 Nag SensitiveToTubeCur
* Celestron 8	20.3 f/10 SCTel.	09	02	290x	423x	7mm, 4.8mm Nagler

These results cover only image quality, but the image is influenced by more than just the optics. As we will see, *light baffles* and mechanical alignment stability also play significant roles.

2.4 Sample Lunar and Planetary Images

The sample lunar and planetary images below are intended to show the difference in performance between telescopes of various apertures. Most were taken during similar atmospheric turbulence (or "seeing") conditions, and about half were taken from the same location. One of the Mars images is with an extremely large 1.5 meter telescope, for purposes of showing the diminishing return for large increases in aperture that often results because of atmospheric conditions.

The majority of planetary images here are single exposures, as opposed to being stacked images. Where stacked images are used, the stacks consist of less than 3 or 4 different images. The images provide some of the information that some people may be looking for when evaluating a telescope. For reference, when each telescope was used visually, it was not unusual to visually observe twice as much detail than what is shown in the planetary photo with the same telescope.

Most of the planetary images below are through telescopes that have relatively few design and implementation flaws. Image anomalies caused by design and implementation flaws are covered mostly in Appendix A. The reviews immediately follow the lunar and planetary images.

Fig. 2.4A. Moon, with TeleVue 60 ED Telescope. Pentax Q camera at prime focus. Most larger telescopes (excluding poor quality units like Pico-8) can provide lunar images at least this good.

Fig. 2.4B. Mars. Imaged with different telescopes. LEFT: Mars, 10 Aug. 2003, Vernonscope 94 mm f/7 refractor. Afocal image, taken by pointing camera and lens into eyepiece. CENTER: Mars, through Intes MN61 150 mm f/6 Mak-Newtonian with Barlow, mounted on photo tripod (no sidereal drive used) in 8/2018. RIGHT: Afocal picture taken though 1.5 meter telescope at Mount Wilson, CA, 16 Aug. 2003.

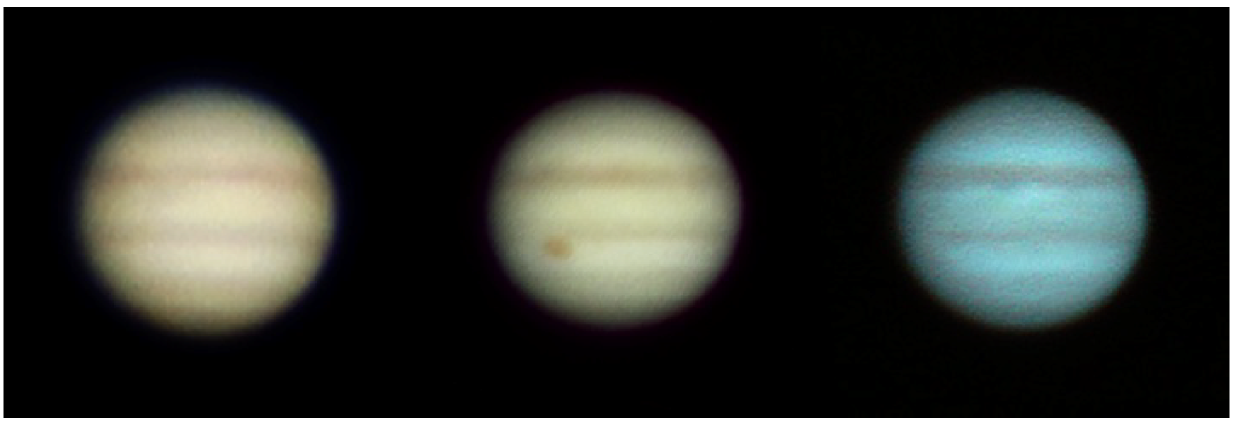

Fig. 2.4C. Jupiter. LEFT: Imaged with TeleVue 60 mm f/6 ED refractor telescope in 7/2018. CENTER: Taken with Questar 3.5 Maksutov-Cassegrain telescope in 6/2018. RIGHT: Afocal image with Celestron 8 Schmidt-Cass. telescope in 7/2006. Has most detail, but noise from older camera. These are not fancy "stacked" images. Visually, planets usually look about twice as sharp as the photos from each telescope.

Fig. 2.4D. Saturn. LEFT: Imaged with TeleVue 60 mm ED refractor telescope in 7/2018. CENTER: Imaged with Celestron 8 SCT via relay lenses in 8/2018. RIGHT: Imaged with Celestron 8 SCT, circa 12/2003, on a night when atmospheric seeing conditions were a little better than average for my area. Color balance is different on all three of the right-most images because a different camera was used.

3.) Small Telescopes (and Camera Lenses Used as Telescopes) up to 7.9 cm Aperture:

Small telescopes have had a following for some time. This is partly because it is easier to transport a small telescope, and the telescope you have with you is the one that will get used. Numerous small telescopes have been available for decades, ranging from converted camera lenses to the high end Questar 3.5 inch (89 cm) Maksutov-Cassegrain telescope.

This chapter is limited to even smaller telescopes, specifically those smaller than 8 cm aperture. Some of these small telescopes are even more portable than 9 cm class telescopes made by Celestron, Meade, and Questar. The emphasis is on Cassegrain telescopes and mirror lenses (because these are smaller), though one refractor example is briefly reviewed for comparison.

Limiting the lineup in this section to telescopes smaller than 8 cm aperture, and emphasizing Cassegrains, reduces the number of considered telescopes to only a few, though the number grows a little if we go back in time and also look at some better known telescopes of yesteryear.

Figure 3A. Some of the small telescopes and photographic mirror lenses reviewed in this chapter. Most of the mirror lenses have been adapted to accept standard telescope eyepieces. From left to right:
* Rokinon 300 mm f/6.3 mirror lens (Nikon mount) with custom made 0.965" diagonal
* Ednar Mirror Scope 500, with its standard 45 degree roof prism and 20 mm eyepiece
* Tamron Adaptall 500 mm f/8 mirror lens
* Nikon 500 mm f/8 Nikkor-C mirror lens
* Vivitar 800 mm f/11 Solid Catadioptric mirror lens
* TeleVue 60 ED refractor
* Ad Astra III Maksutov-Cassegrain telescope.

Among the many older small aperture telescopes, very few are reviewed or discussed because they were not very compact for their aperture. For example, Meade made an 8 cm Cassegrain telescope in the 1980's, but its physical size was not much different than that of their 9 cm f/11 Maksutov Cassegrain telescope. Others are not reviewed because their performance usually was not very good. For example, many 8 cm f/5 doublet refractors had severe chromatic aberration. When all of these telescopes are excluded, we are left with only a hand full of older small scopes.

If we limit the list of both old and new telescopes only to physically small ones that are (or were) relatively well known, and to those that *can be adapted to* use standard eyepieces, we are left with only a few. A few camera lenses that I have used as telescopes are also listed here:

* Ad-Astra III, a 78mm f/9.75 Maksutov-Cassegrain from the 1970's (reviewed in some detail)
* B&L 800, an 80 mm f/10 Cassegrain telescope (compared to newer Kasai Pico-8 in chapter 4).
* Celestron C65 (1980's version), a telescope that provides an erect image (briefly reviewed).
* Ednar Mirror Scope 500 (also sold as Kenko, Pentax, etc.; briefly reviewed).
* Kasai Pico-6 (similar scope also sold as MightyMak; listed here, but not reviewed).
* Kasai Pico-8 (similar scope also sold as MightyMak; reviewed and compared in detail).
* Nikon 300mm f/4.5 ED Nikkor (camera lens w/eyepiece adapter for comparison, not reviewed)
* Nikon 500mm f/8 Reflex-Nikkor (camera mirror lens; briefly reviewed).
* Vivitar 800mm f/11 Solid Catadioptric (camera mirror lens; reviewed in moderate detail).
* Various brands 60-73mm class short focal length ED refractors (one reviewed in this section).

In the reviews that appear in later chapters, the "useful" or "working" aperture is the lesser of:
A.) The maximum aperture that provides an acceptable medium to high magnification image, or,
B.) The maximum aperture that is actually utilized for the axial image, based on the light baffle design. The latter is usually the same as what is referred to as the "working" aperture.

Figure 3B. Three small amateur telescopes of similar aperture that were made in different eras. Unfortunately, quality has declined over the years. From left to right, the pictured telescopes are:
* Ad Astra III, a high quality 7.8 cm Maksutov-Cassegrain telescope from the late 1970's.
* Bausch & Lomb 800, a low cost hybrid Cassegrain mirror camera lens and telescope from the 1990's. Finder scope is custom addition. Standard telescope does not have a finder scope or a way to attach one.
* Kasai Pico-8, a *disappointingly awful* Maksutov-Cassegrain telescope I acquired *new* in 2018. In general, a telescope performs better than a camera lens that is used as a telescope, but *this one* does not.

3.0.1) Basic Types of Small Telescopes and Mirror Lenses

Telescopes and mirror lenses in this and the next chapter utilize six different design approaches:

A.) Modified Maksutov-Cassegrain: The Kasai Pico telescopes fall into this category, as does the original 1970's version of the Celestron 90. The Maksutov corrector curvature at the secondary mirror spot provides a final f/ratio of about f/11 (not the usual f/15). This is *not* the optimum curvature for a Maksutov corrector. Therefore, the faster f/11 f-ratio is achieved at the expense of failing to fully correct spherical aberration. This is practical in extremely small telescopes, because the angular size of the Airy disk is fairly large. If properly implemented, this design can provide good views of terrestrial objects as well as the moon and planets. However, my sample of the Pico-8 may be the worst telescope I've ever tested, and is almost useless on planets. The vintage 250 mm f/5.6 Lentar mirror lens is a Maksutov-Cass, and it also has spherical aberration.

B.) Optimized Maksutov-Cassegrain: The Ad-Astra III telescope of the 1970's is of this design. The Maksutov corrector is designed to provide the best correction of spherical aberration (this usually causes the secondary spot to provide an f/15 Cassegrain focus) but the secondary mirror spot has a longer radius of curvature than the rest of the corrector, to provide f/9.75. Samples of the Ad-Astra I've seen are diffraction limited, though the secondary obstruction is large enough (about 44 percent of the aperture diameter) that the inner diffraction ring is fairly bright. Some later Ad-Astra scopes had greenish mirror coatings, caused by oxidation from a volatile adhesive.

C.) Erect Image Gregorian Maksutov-Cassegrain: The original Celestron C65 of the 1980's is the only popular small aperture telescope of this design. The Maksutov corrector is located beyond the focus of the primary mirror, and oriented with the convex side toward the front. The C65 provides an erect image at Cassegrain focus, so an erecting prism is not needed for the terrestrial viewing for which the C65 was designed. If used with a 0.965" eyepiece of 40mm focal length, the C65 provides enough eye relief for just about anyone with eyeglasses. It has a few design flaws, including a tendency for the long secondary baffle to fall off.

D.) Sub-Aperture Spherical Aberration Corrector. The B&L 800 telescope is an unusual though inexpensive design with a flat front optical window, a spherical primary mirror, a flat secondary mirror, and refracting lenses inside the primary baffle tube that both correct spherical aberration and increase the focal length 3 to 4 fold over that of the primary mirror. Its mechanical design is elegant, but spherical aberration is not fully corrected and it has some field curvature. Correction is adequate for viewing and photographing the moon, but is not quite good enough for planets.

E.) Full Aperture Corrector Combined with Sub-Aperture Optics: The Ednar Mirror Scope 500, and most mirror lenses, including Vivitar 800 mm Solid Cat lens, fit this category. All have full aperture optics at the front, and smaller optics in the primary baffle tube area, with the latter also being used in part to flatten the field. Lenses of this type were initially designed to be compact camera lenses, so most usually are not diffraction limited in the center of the field.

F.) Refractor with One or More Extra Low Dispersion (ED) Elements: The Nikon 300mm f/4.5 ED Nikkor and certain short focal length ED refractors share this design. The Nikkor has more elements to provide a flat field, though field flatteners are available for some short focal length refractors. The ED Nikkor lenses I've tested have not been diffraction limited even in the center of the field unless stopped down to about f/6.8, but most short focal length ED refractors are diffraction limited at full aperture.

Schmidt correctors have seldom been used in telescopes or lenses smaller than about 10 cm, partly because the corrector would be very thin. Individual reviews start on the next page.

3.1) Specwell 2.0 cm, 8x Monocular with Microscope Attachment (used for imaging)

Specifications (measured values in mm are shown instead of published spec's, when different):
Aper.Spec / f/Ratio / FL / Aper.Act. / C. Obs / Obs% / Width / Height / Length / Weight / Notes
20.0 mm / NA / 51.6 / 20.0 mm / None / -0- / 32.0 / 36.0 / 91.0 / 79 g /

C. Resol. / E. Resol. / Contrast / Flare / Bloom / Ghost / CamShake / Notes 2 (No S/N)
Excellent / V Good / Good / Fair / Good / Fair / Poor / DifSpikeSomeSubj.

It has been said that: "the telescope you have with you is the one that gets used", and this has proved to be true in practice. Back around 1984, I bought a Specwell 8 x 20 monocular with its microscope attachment, and have often had it with me ever since. The minimum focus distance is an extremely close 30 cm, and the physical size of the monocular itself is very small. Optical quality is good for the intended magnification of only 8x, and it even has a little overhead. Since the time I acquired this monocular, other manufacturers have introduced correct image 8 x 21 finder scopes that work about as well, except that they have a reticle and do not focus as close.

There have been occasions when declining health combined with work was significant enough that I did not feel up to looking into whether astronomical events such as eclipses or occultations were coming up, then I'd be blind-sided when events such as a partial solar eclipses occurred at work. Having the Specwell monocular with me at such times made it possible to view and image such events via eyepiece projection. Conjunctions were at times imaged via the afocal method.

Figure 3.1A. Projecting a partial solar eclipse via monocular; photo of projected eclipse image. LEFT: On 23 Oct 2014, a partial solar eclipse was in progress when I arrived at work. The eclipse happened while a large sunspot group was visible, so it was more dramatic than most partials. Here, the Specwell 8 x 20 monocular is used to project an image of the eclipse onto some paper that is used as an impromptu projection screen on my walker. The monocular is held in a way that my hand shades the projection "screen" around the image. RIGHT: Close up photo of projected image that is rotated and flipped to approximate the orientation of the eclipse in the sky. There is some distortion of the sun's circular shape due to the angle of the projection versus the camera position, but it is far better than having no picture at all of this memorable event. A few passers by stopped to look at the projection during the brief time it took to take this picture.

3.2) Leica 50 mm f/1.4 Summilux-M ASPH Lens (used as a telescope, believe it or not!)

Specifications (measured values in mm are shown instead of published spec's, when different):

Aper.Spec	f/Ratio	FL	Aper.Act.	C. Obs	Obs%	Width	Height	Length	Weight	Notes
36.8 mm	f/1.40	51.6	36.5 mm	None	-0-	53.5	60.5	52.5	335 g	

Image Quality (measured): Thresholds for (see section 2.1.3 for definitions of each column):

Make	Model	Serial No.	ShVid	ShAx	Sh34	FAFm	FA34	UseAt	Cont/F	Notes 1
Leica	S'lxM	4264258	2.4	1.4	2.4	3.8	3.1	1.7	VG+	ResSatRings

C. Resol.	E. Resol.	Contrast	Flare	Bloom	Ghost	CamShake	Notes 2
Excellent	V Good	High	V Good	V Good	V Good	Excel	MaxUsefulF: 1.4

It is not often that one thinks of a 50 mm focal length camera lens as a telescope, but the Leica 50 mm f/1.4 Summilux-M ASPH lens is noted here because it is just barely capable of imaging the rings of Saturn, both at full aperture and at f/1.7. This is unusual for a 50 mm f/1.4 lens, and requires a resolution close to 500 lines per millimeter. The moon looks acceptable in the same lens, but there is slight longitudinal chromatic aberration, as one might expect. It is unlikely that anyone will want to use a 50 mm FL lens as a telescope, but the Summilux is noted here just because it actually (sort of) works as one. Of course, it costs as much as a high end telescope.

Figure 3.2A. Saturn and moon, using Leica 50 mm Summilux lens as a "telescope objective". LEFT: These cropped images of Saturn were taken with a Leica 50 mm FL f/1.4 Summilux-M ASPH lens. A microscope objective and extension tubes were used behind the lens to provide an effective focal length of about 2.500 mm. The Leica lens was used at full aperture for the upper left image, and at f/1.7 for the image just to its right. The lower left image is a stack of about 3 images. The photo just right of the stacked image is of a ruler (millimeter scale), imaged from a distance of 5 meters with the same optics. RIGHT: Moon, with same optics that were used for Saturn images. The extreme right image shows a Panasonic GX7 camera attached to the setup.

3.3) Coronado PST, Integrated Solar Telescope (4 cm f/10, pre-Meade version)

Specifications (measured values in mm are shown instead of published spec's, when different):
Aper.Spec / f/Ratio / FL / Aper.Act. / C. Obs / Obs% / Width / Height / Length / Weight / Notes
40.0 mm / f/10.0 / 400 / 40.0 mm / None / -0- / 60.0 / 134 / 380 / 1305 g /

Image Quality (measured; SN 95245)
C. Resol. / E. Resol. / Contrast / Flare / Bloom / Ghost / CamShake / Notes (Dif. Limited)
Excellent / V Good / Good / Good / Fair / Fair / Good / SomeHadCoatFail

Build and performance is summarized in this table:
*** Build Quality / Materials: 4** / Brass tube with anodized aluminum rear housing.
*** Optical Quality / Details: 4** / Sharp images, but some ghosting in the filter's "sweet spot".
Summary Notes:
* Build is a 4 instead of a 5 only because the feel of some aspects is good but not excellent, and because some units developed coating degradation that made them useless unless repaired.
* Optical quality is shown as a 4 because there is are obvious ghost images in parts of the field.
*** Pluses:** Integrated solar telescope with tunable filter, relatively compact size, complemented by good matching eyepieces, built-in sun finder, low price for sub-Angstrom Hydrogen-Alpha filter.
*** Minuses:** Not enough back focus for a camera unless a Barlow is used, some ghosting.

The Coronado PST is no ordinary telescope. Instead, it is the closest thing to an "idiot proof" Hydrogen Alpha solar telescope that has ever been made. It's all integrated into a 4 cm scope.

The objective lens at the front has coatings that serve as the energy rejection filter (to keep out-of band wavelengths from fogging the image or heating the inside of the telescope) a built-in solar finder, internal focusing, and a tunable Hydrogen Alpha filter, for which the tuning ring has a stop at the optimum setting, depending on solar rotation Doppler effects. Turning the filter ring to slightly short of the stop accounts for Doppler effects. There is no risk of leaving the solar energy rejection filter off because it is built-in. And the images are great. The PST shows more than just prominences. It also shows Hydrogen Alpha features on and in front of the solar disk.

The PST has a 1.25 inch eyepiece holder, and is also available in a CAK (Calcium line) version. Coronado offered (and maybe still offers) a line of "CeMax" eyepieces that are optimized to minimize spherical aberration in the 650 nm range, as opposed to the usual 550 nm. CeMax eyepieces are made in focal lengths of 12, 18, and 25 mm, and a 2x Barlow was also offered. After having compared CeMax eyepieces to other eyepieces on the PST, I can say that I have seen a difference, especially with the 12 mm. The CeMax eyepieces work better on the PST.

Capturing solar images with the PST can be done by using a camera in afocal mode, where the camera lens is pointed into the eyepiece, or by using a Barlow lens to provide enough back focus for a camera having a removable lens. The latter usually provides pictures with fewer artifacts.

Some early PST telescopes developed what some called coating "sickness" that compromised the energy rejection and out of band cleanup filtering effects of the telescope. When this developed, the telescope had to be sent in for repair. The PST I acquired second hand previously had this problem, and had been sent in for repair by its previous owner. It has worked fine since then.

3.4) Rokinon 300 mm f/6.3 Compact Mirror Lens (used as telescope)

Specifications (measured values in mm are shown instead of published spec's, when different):

Aper.Spec	f/Ratio	FL	Aper.Act.	C. Obs	Obs%	Width	Height	Length	Weight	Notes
47.6 mm	f/6.3	300	51.0 mm	31.0 mm	61%	65.0	65.0	74.0	250 g	58 filt.

Image Quality (measured) Thresholds for (see section 2.1.3 for definitions of each column):

Make Model	Serial No.	ShVid	ShAx	Sh34	FAFm	FA34	UseAt	Cont/F	Notes 1
Rokinon Mir.	E215H1382	OKvid	8.0	8.0	60perc	70perc	8.0	G+	LargeCentObs

C. Resol.	E. Resol.	Contrast	Flare	Bloom	Ghost	CamShake	Notes 2
V. Good	Good	Good	Good	Good	Fair	Fair	No Tripod Socket

Summary:
*** Build Quality / Materials: 3** / Metal lens mount, lens barrel mostly plastic, no tripod mount.
*** Optical Quality / Details: 3-** / Reasonably good resolution and color saturation versus size.
Summary Notes:
* Build is 3 because most of the lens barrel housing is plastic and there is no tripod socket. However the lens has an adequately solid feel and reasonably good focus damping.
* Optical quality is a 3- because large (61% diameter) central obstruction influences the image.
*** Pluses:** Smallest "telescope" I use regularly; good image quality vs physical size, fits Nikon.
*** Minuses:** Mostly plastic construction, no tripod mount (but it is a "lens", not a telescope).

The Rokinon 300 mm f/6.3 mirror lens lacks a tripod socket, so it was not initially considered as a compact telescope. However, it has enough back focus for a custom made compact diagonal attachment, and its central optical performance is good enough to provide a decent lunar (or solar eclipse) image. It can also reveal limited planetary detail. This lens is reviewed here because, when adapted to a tripod mount and combined with a commercial or custom eyepiece holder, it can be made into an extraordinarily compact telescope. This is useful when there is no space to for a conventional telescope while traveling, etc.

The clear aperture at the front of the lens is 55 mm, but the secondary light baffle is configured in a way that only 51 mm of the aperture is used in forming the central image. This is often done in mirror lenses to reduce vignetting. It is good practice in mirror lenses, but not in telescopes that are intended for planetary viewing. Details on this are in review of 500 mm f/8 Nikkor-C lens.

The Rokinon lens works well on Micro 4/3 and APS formats. It is even capable of covering the full FX format, but vignetting is more obvious in that case. Minimum focus is close: 1.1 meters!

I was going to use the Rokinon 300 mm lens with a custom 90 degree diagonal mirror and an 18 mm eyepiece (17x magnification) at the 2017 total solar eclipse, but had to use an Ednar Mirror Scope 500 (reviewed below) instead, after health insurance acquisition issues consumed all time I'd have used for projects like this. (Some in Europe may be laughing at the privatized American healthcare system because of such long standing and widespread healthcare availability issues that Europe had corrected decades ago. Well, keep on laughing until we get it right over here!)

3.5) TeleVue 60 ED Compact Refractor Telescope (6 cm f/6)

Specifications (measured values in mm are shown instead of published spec's, when different):
Aper.Spec / f/Ratio / FL / Aper.Act. / C. Obs / Obs% / Width / Height / Length / Weight / Notes
60.0 mm / f/6.0 / 360 / 60.0 mm / None / -0- / 81.0 / 108 / 258 / 1340 g /
Image Quality (measured, SN 1001629)
C. Resol. / E. Resol. / Contrast / Flare / Bloom / Ghost / CamShake / Notes (Dif. Limited)
Excellent / Fair / VG-Exc / V Good / V Good / Excel / Fair-Good / NoFocusLock

Build and performance is summarized in this table:
*** Build Quality / Materials: 4** / Aluminum tube with metal draw tube and helical focuser.
*** Optical Quality / Details: 4** / Acceptably symmetrical Airy pattern after collim.; field curvat.
Summary Notes:
* Build is a 4 instead of a 5 only because the dew shield in my sample could slide too easily, so it fell backwards when the telescope was pointed up. Lack of provision for precise collimation by the user (when it is likely that it will lose collimation with thermal cycling) is another factor.
* Optical quality is shown as a 4 because field curvature is significant, (enough to see in a 12 mm eyepiece) yet no field flattener is available. Other aspects of the optical quality are very good.
*** Pluses:** Compact size, good lunar and planetary performance versus aperture, good contrast and minimal artifacts on crescent moon with earthshine, no observable false color for most subjects, helical focuser minimizes vibration when focusing telescope while it is on a light tripod.
*** Minuses:** Field curvature obvious even on Micro 4/3 format, slight glow around bright objects, my sample needed collimation, high price, no focus lock, slight lateral focuser play (which would not be issue if it had focus lock!), telescope slowly slides on tripod socket rail even when lock screw tight, logo is on delicate label; draw tube is short, so plan on getting 1.25" extension tube.

Fig. 3.5A. Compact TeleVue 60 ED refractor telescope, shown mounted on a Vixen Polarie star tracker. I use a flip cap on the front to minimize time that the objective lens is exposed to the elements.

The TeleVue 60 ED refractor is a 6 cm f/6 ED doublet refractor telescope that utilizes a heavy aluminum optical tube. It was not the small telescope I had initially decided to buy, based on a list of what I wanted to do with a small telescope, but the physical size of the TV 60 was enough smaller than the telescope I had my sights on (a Borg 76 ED) that I got a used TeleVue instead.

Mechanically, the TeleVue 60 has a solid feel. It is somewhat heavy for its small size because its tube is aluminum, and parts of it are fairly thick. A small helical focuser at the back has an adjustment range of about 17 mm, but the telescope has a draw tube that extends the focus range by another 53 mm. When the draw tube is pulled all the way out and a diagonal is used, the TeleVue 60 can focus down to just over 3 meters.

The sole rear interface is a 1.25" eyepiece holder. There is no threaded interface for heavy accessories. A less common version with a 2" focuser was made at some point in the past, but I have not seen it in current TeleVue literature. The front of the dew cap is threaded for 77 mm camera lens filters, and the tripod socket is on a rail that can slide front to back a few centimeters. The fitting that holds the rail “looks” too small, but it does not have any wobble in practice.

The TeleVue 60 delivers planetary images that are quite good, especially when considering the small physical size and the fast 1:6 f/ratio of the telescope. No false color is visible on any planet except Venus, and the image of Jupiter is very clean. I have used it at magnifications as high as 218x by using a custom 1.65 mm equivalent focal length eyepiece. Image quality is much better in the 150x range, but it’s nice to know that the 200+ magnification range is possible.

There is considerable curvature of field, and some coma off-axis, so the format size will be limited when using the TeleVue 60 for photography. It does well on a small sensor camera such as a Pentax Q or Q7, and small cameras like these are a good match for the small telescope size.

The TeleVue 60 does only fair at the edges of the Micro 4/3 digital sensor format because of field curvature. Corners of the APS format may be pushing it too far, depending on the subject. Field curvature is fairly obvious in any eyepiece having a field stop larger than about 12 mm. No field flattener is made for the TeleVue 60 that I know of, but it would be a very useful accessory.

Optical glasses used in the 2 element objective are kept close to the vest by TeleVue, but since the instruction manual includes precautions about exposing the front element to water spray or other forms of moisture, it is probably safe to assume that one element is a synthetic fluorite, like or similar to FPL-53. The color correction is too good for it to be FPL-51. Contrast is also good.

When looking at the objective lens from the focal plane while a strong light is just to one side to strongly back light it, it has an unusual appearance. Instead of the usual slight haze or cloudiness you might expect when viewing even the best of brand new optics under such harsh light, the backlit features of the TeleVue 60 objective lens are a multitude of small round spots that each look somewhat brighter than the rest of the lens. The small round spots are all of remarkably consistent size, with each being about 1 mm in diameter.

3.5.1) Initial TeleVue 60 Collimation Adventures

The tested TeleVue 60 telescope was acquired used. It needed some tweaking before it could provide a symmetrical star image or satisfying planetary images. Even though there was no trace of tampering, it was not collimated when I received it, and upon inspection, it was evident there had not been any tampering at all. Thermal cycling explains it all based on the following:

The TeleVue 60 was initially so far out of alignment that there were parts of two diffraction rings on one side of the Airy disk, and no trace of any diffraction rings or segments on the other. Tilt of the objective cell has no repeatable adjustment. Instead, three button head screws are in small recesses under the sliding dew shield. The sliding dew shield in my sample also moved so easily that it fell backwards when I pointed the telescope up, so I added some felt to increase resistance.

Loosening the button head screws (which TeleVue literature discourages) allows the entire lens cell to tilt, but then it must be held at the proper tilt angle while all three button head screws are evenly tightened. Theoretically, this should easy to accomplish by placing appropriate “thickness gauges” in a groove behind the lens cell. In practice, it was not this easy with my sample. This is because the lens cell tilt angle required for proper collimation results in enough tilt of the lens cell that the cell’s tilt will invariably decrease as the screws are even moderately tightened.

The solution was to make a small crescent shaped partial washer that could fit into the screw hole, right next to the collimation screw that has to be farthest from the front of the main tube to achieve proper tilt of the lens cell. When inserted next to the correct side of the screw, the brass partial washer keeps the screw from moving in a direction parallel to the optical axis as it is tightened. Shims were then added in the gap between the front cell and the tube at clock angles corresponding to the other two collimaton screws. The partial washer for one screw, plus shims corresponding to the others, keep thermal cycling from gradually causing the screws to creep back to the positions they were in when I received the telescope. Originally, the cell had no tilt at all. After adjustment, the telescope provided a symmetrical Airy pattern at the center of the field.

Now that we’ve covered that little adventure, we can move on to the next telescope.

3.6) Ednar/Pentax Mirror Scope 500 (500 mm f/8 camera lens and 25x visual telescope)

Specifications (measured values in mm are shown instead of published spec's, when different):

Aper.Spec	f/Ratio	FL	Aper.Act.	C. Obs	Obs%	Width	Height	Length	Weight	Notes
62.5 mm	f/8.0	500	66.0 mm	34 mm	52%	81.0	104	136	772 g	

Image Quality (measured) Thresholds for:

Make	Model	Serial No.	ShVid	ShAx	Sh34	FAFm	FA34	UseAt	Cont/F	Notes 1
Ednar	MirSc	5800046	OKvid	8/0	8.0	50perc	60perc	8.0	F-G	MildSphAb

C. Resol.	E. Resol.	Contrast	Flare	Bloom	Ghost	CamShake	Notes 2
Good	Good	Fair	Fair-Good	Good	Poor	Poor	No Photo Tripod S.

Summary:
*** Build Quality / Materials: 4-** / Aluminum mechanical components with rubber focus grip.
*** Optical Quality / Details: 3-** / Slight spherical aberration. Some samples have other aber.
Summary Notes:
* Build quality is similar to vintage "made in Japan" mirror lenses, such as those marketed by Tokina. Focus is smooth, but has very little damping. The method used to mount the 45 degree prism in its housing can result in some reflection anomalies developing over time due to oil migration. To prevent fungus growth, this must corrected by removing and cleaning the prism.
* Optical quality is a 3- because there is some variation in optical quality between samples. All have a slight amount of spherical aberration that limits the maximum practical magnification to between 50 and 80x, but some have slightly asymmetrical aberrations at the center of the image.
*** Pluses:** Compact size, attractive industrial design, screw-in eyepiece has secure fit, optical quality is adequate for lunar, solar, and terrestrial viewing at low to medium magnification; can be used as camera lens when the combined prism / eyepiece assembly is removed from the back.
*** Minuses:** Slight spherical aberration limits usefulness for planetary viewing, some variation in optical quality between samples, limited selection of eyepieces due to proprietary thread size.

The Ednar Mirror Scope 500 has been marketed under many names over the years, including Ednar, Jason, Kenko, and Pentax. It is a 500 mm f/8 mirror lens that includes a matching 45 degree correct image prism and a screw-in (proprietary thread) 20 mm eyepiece. Ednar, Jason, and Pentax versions have T-thread (M42 x 0.75 mm), but the Kenko has P thread (M42 x 1 mm). In the 1980's, an optional 1.5x converter was offered for the Kenko version. Mirror Scopes were also available in a 300mm f/5 version, but resolution of the 300 mm left something to be desired.

The front of the Mirror Scope 500 is threaded to accept 72 mm filters. Minimum focus distance is about 2.5 meters. The standard 20 mm eyepiece provides a magnification of 25x. The shorter 10 mm FL eyepiece that comes with the 300 mm version of the Mirror Scope provides a 50x magnification when used in the Mirror Scope 500. There is no provision to attach a finder scope.

A mirror scope 500 is one of those optical gadgets that you may feel you just have to pick up and look at due to its still unique industrial design. Optical quality is satisfactory but not outstanding. I used one to view ingress during the 2012 Venus transit, and it exhibited the "black drop effect" until almost 20 seconds later than the highest resolution telescope I was using that day.

3.7) Tamron 500 mm f/8 Adaptall Mirror Lens (used as a telescope)

Specifications (measured values in mm are shown instead of published spec's, when different):

Aper.Spec	f/Ratio	FL	Aper.Act.	C. Obs	Obs%	Width	Height	Length	Weight	Notes
62.5 mm	f/8.0	500	67.0 mm	35 mm	52%	84.0	92.0	93.0	680 g	w/NikAd

Image Quality (measured) Thresholds for:

Make	Model	Serial No.	ShVid	ShAx	Sh34	FAFm	FA34	UseAt	Cont/F	Notes 1
Tamron	AdAl	906694	OKvid	8.0	8.0	60perc	70perc	8.0	G+	Sharp OffAxis

C. Resol.	E. Resol.	Contrast	Flare	Bloom	Ghost	CamShake	Notes 2
V. Good	Good	Good	Good	Fair	Good	Fair	Focus to 1.7m; 82 filt.

Summary:
*** Build Quality / Materials: 4-** / Almost all components except optics are made of metal.
*** Optical Quality / Details: 4** / Image that is comparable to high end lenses, if stopped down..
Summary Notes:
* Build is 4- instead of 5 because the barrel is relatively thin, and it can flex enough to distort the mirror and adversely impact image quality under some circumstances. Includes nesting hood.
* Optical quality is 4 due to some asymmetry in star images, while flare is acceptably low and consistent. However, the thin barrel can cause temporary reductions in image quality.
*** Pluses:** Good image quality vs size, flare is low enough to use for crescent moon or total solar eclipse, measured aperture exceeds specified aperture, close focus, rear filters, some models have tripod mount; nesting lens hood is long enough to actually be useful, well integrated with case.
*** Minuses:** Some asymmetry in star images, construction might be a little too light, black outer covering on fitted case is delicate and flakes off as case ages.

The Tamron 500 mm f/8 Adaptall lens is a compact but sharp mirror lens that can focus down to about 1.7 meters. It has an oversized front aperture that is a little larger than the 67 mm diameter area that is utilized for imaging at the center of the focal surface. This additional aperture is used only for off-axis parts of the image. This reduces vignetting but does not completely eliminate it.

Resolution and contrast are comparable to a 500 mm f/8 Nikkor-C mirror lens, though sharper photos may result from a Nikkor because it has a heavier tripod mount. Flare is more consistent than most mirror lenses, so it can capture adequate images of the crescent moon with earthshine.

There is some variation between samples of the Tamron 500 mm lens. The best samples are almost diffraction limited at the center of the image, while others have visible astigmatism or asymmetrical aberrations. However, samples with such aberrations still tend to produce central spot sizes less than twice the size of what the Airy disk would be in a diffraction limited image.

There are at least two versions of the Tamron 500 mm f/8 lens. One has a rotating tripod mount, and the other does not. There is also a difference in how the Adaptall mount receiver assembly attaches to the back of each version. A 350 mm f/5.6 version of the Tamron Adaptall mirror lens was also made, but it is not evaluated here due to its larger central obstruction.

3.8) Nikon 500 mm f/8 Reflex Nikkor-C Mirror Lens (used as a telescope)

Specifications (measured values in mm are shown instead of published spec's, when different):

Aper.Spec	f/Ratio	FL	Aper.Act.	C. Obs	Obs%	Width	Height	Length	Weight	Notes
62.5 mm	f/8.0	500	72.0 mm	38 mm	53%	91.0	101	152	953 g	R39filt

Image Quality (measured) Thresholds for:

Make	Model	Serial No.	ShVid	ShAx	Sh34	FAFm	FA34	UseAt	Cont/F	Notes 1
Nikon	Reflex	565068	OKvid	8.0	8.0	53perc	62perc	8.0	VGood	83 mm CA

C. Resol.	E. Resol.	Contrast	Flare	Bloom	Ghost	CamShake	Notes
VG-Excel	Good	V Good	Good	Poor	Fair	Good	Almost Dif. Ltd.

Summary:
*** Build Quality / Materials: 4+** / Almost all parts except optics are made of metal; precise feel.
*** Optical Quality / Details: 4** / Reasonably good resolution & color saturation; average flare.
Summary Notes:
* Build is 4+ instead of 5 only because focus has no damping and central obstruction is large.
* Optical quality is 4 due to some asymmetry in star images, and flare is too uneven for a TSE.
*** Pluses:** Good image quality vs physical size, measured aperture exceeds specified aperture, rear filters, solid feel, solid tripod mount.
*** Minuses:** Some asymmetry in Airy pattern, uneven flare could adversely affect eclipse images.

The 500 mm f/8 Reflex Nikkor-C is one of the first mirror lenses that I tried using as a compact telescope. Its performance for this is not bad for everyday use. It provides good low to medium magnification (28 to 56x) images of wildlife and the moon, but struggles when imaging planets at 100x or more. It can easily image the belts of Jupiter or the rings of Saturn, but it can't quite image detail in Jupiter's belts, or details such as the dark Cassini division in Saturn's rings.

The Nikkor has a solid casting for its tripod mount, and is one of the better compact mirror lenses in terms of resistance to camera shake. The minimum focus distance of 3.9 meters is close enough to view and photograph birds, but is a bit distant for photographing small insects. The Nikkor is not as compact as most 500 mm f/8 mirror lenses, but its images are better than most.

To reduce vignetting, the Nikkor lens has an 83 mm clear aperture. This is considerably larger than the 72 mm diameter area that is utilized for imaging at the center of the focal plane. The additional aperture is used only for off-axis parts of the image. This helps reduce vignetting. This limited use of the available aperture at the center of the focal surface works well in camera lenses, but it is not a practice that should be used in telescopes that are intended for high magnification (i.e. narrow field of view) imaging, because it reduces the working aperture in the center of the field, which in turn reduces both the theoretical and actual angular resolution.

When the primary mirror is strongly illuminated, it shows numerous subtle concentric marks that are reminiscent of the look of a flat surface that was turned on a lathe. These do not appear to impact the image, since scattered light is minimal compared to other mirror lenses or telescopes.

3.9) Celestron C65 Maksutov-Cassegrain (Mak-Cass) Telescope (1980's version)

Specifications (*estimated* values in mm are shown instead of published spec's, when different):
Aper.Spec / f/Ratio / FL / Aper.Act. / C. Obs / Obs% / Width / Height / Length / Weight / Notes
65.0 mm / f/12.6 / 816 / 65.0 mm / 23 est / 35% / 79 est / 86 est / 300 est / 650g est /

Image Quality (measured; SN TBD)
C. Resol. / E. Resol. / Contrast / Flare / Bloom / Ghost / CamShake / Notes
Good / Fair / Good / Fair / Good / Good / Poor / MaxUsefulF: 10

Summary:
*** Build Quality / Materials: 2** / Plastic optical tube and light baffles. Plastic helical focuser.
*** Optical Quality / Details: 3-** / Considerable variation in samples. Some are good, some bad..
Summary Notes:
* Build quality is just fair. The plastic optical tube is adequate, but its length was sized so that half of the focus range is not useful (focuses well past infinity), and this pushes the close focus distance out to about 3 or 4 meters. The low rating of 2 is because the unusually long and heavy secondary baffle fell off of the Maksutov corrector in some samples, where it can scratch mirror coatings. Focusing rotates the back of the OTA, so the C65 is not well suited to photography.
* Optical quality is a 3- because there is some variation in optical quality between samples. Some samples provide diffraction limited images, while others have asymmetrical central spots. The latter is probably a result of the plastic tube assembly failing to provide adequate alignment.
*** Pluses:** Erect image without using any attachments, long focal length allows use of long eye relief eyepieces, which is very useful for people wearing eyeglasses. To this day, there is nothing else like it that can provide good eye relief in a compact telescope for eyeglass wearers.
*** Minuses:** Variation in optical quality between samples, secondary baffle subject to falling off in some samples, rotation of rear cell while focusing is complicates use for photography.

The Celestron C65 is a true Gregorian Maksutov-Cassegrain telescope that provides an erect and correctly oriented image at the eyepiece without the need for a diagonal or any other attachment. It does this by reversing the Maksutov corrector so that the convex side is toward the front. This obviously places the concave rear surface of the corrector toward the back, where the secondary mirror spot is also concave. This in turn means that the tube must be longer than that of the average 65 mm aperture Cassegrain, because the light bundle reflected from the primary mirror must reach focus and then begin to diverge again before it reaches the secondary mirror surface.

The eyepiece holder at the back accepts 0.965" eyepieces. The long focal length and absence of prisms near the eyepiece provides an extraordinarily clean low magnification image. The long focal length also makes it practical to use longer focal length eyepieces such as a 25 mm orthoscopic or the Meade 40 mm MA. When the C65 was used with the latter eyepiece, it proved to be the only telescope that my mom was ever able to successfully use with glasses on.

3.10) Nikon 300 mm f/4.5 ED Nikkor Lens (used as a telescope)

Specifications (measured values in mm are shown instead of published spec's, when different):

Aper.Spec	f/Ratio	FL	Aper.Act.	C. Obs	Obs%	Width	Height	Length	Weight	Notes
66.7 mm	f/4.5	300	66.7 mm	None	-0-	80.0	93.5	193	1110 g	MinVg

Image Quality (measured) Thresholds for:

Make	Model	Serial No.	ShVid	ShAx	Sh34	FAFm	FA34	UseAt	Cont/F	Notes 1
Nikon	ED	226301	6.8	5.0	6.3	7.5	5.6	5.6-6.3	VG	No def ghost img.

C. Resol.	E. Resol.	Contrast	Flare	Bloom	Ghost	CamShake	Notes 2
V Good	V Good	V Good	V Good	Fair-G	Exc	V Good	Dif. ltd. at f/6/8

Summary:
*** Build Quality / Materials: 4+** / Almost all parts except optics are made of metal; precise feel.
*** Optical Quality / Details: 4** / Reasonably good resolution & color saturation; average flare.
Summary Notes:
* Build is 4+ instead of 5 only because the helical focus mechanism has a little backlash.
* Optical quality is 4 due to some asymmetry in star images, and visible chromatic aberration in images of many subjects at apertures wider than about f/6.8. Works for piggyback photos at f/5.
*** Pluses:** Good image quality vs physical size, close focus, solid feel, solid tripod mount.
*** Minuses:** Some asymmetry in star image; does not become diffraction limited until about f/6.8.

The 300 mm f/4.5 ED Nikkor was one of my most frequently used small "telescopes" between 1995 and when my condition prevented having the stamina to even rarely use a telescope in the early 2000's. The 300 mm ED Nikkor lens was and is used with two of my inventions (and thus, Versacorp products) to convert it into a versatile telescope. These inventions and products are: the DiaGuider, a combined adjustable off-axis guider and flip mirror; and the VersaScope (TM) Adapter, which used a 1.5x Questar-Dakin Barlow lens (working at 2.2x) to provide enough back focus to use the DiaGuider behind the lens. Combined with these items, the 300 mm ED Nikkor was used to both view and photograph the 24 October, 1995 total solar eclipse in Thailand. A few years later, when I set up 300 mm ED Nikkor with the same accessories for public viewing of comet Hale-Bopp at CalTech, a few people commented that they liked the 32x view in the 300 mm ED Nikkor lens better than their views through the larger neighboring telescopes.

As a telescope, performance of the 300 mm f/4/5 ED Nikkor is more than adequate for everyday use. It provides good low to medium magnification (27 to 54x) images of wildlife and the moon, and can reveal some planetary detail even when used around 100x. However, diffraction limited performance is not reached until the lens is stopped down to about f/6.8. For a telescope, the 300 mm ED Nikkor does not do quite as well as the 500 mm Tamron or Reflex Nikkor mirror lenses, but the ED Nikkor also performs well (and has a faster f/ratio) for deep sky astrophotography.

The 300 mm f/4.5 ED Nikkor uses two solid castings for the rotating tripod mount that is located fairly near the back end, so it has good resistance to camera shake. The minimum focus distance of 2.5 meters is close enough to view and photograph many different subjects.

3.11) Vivitar 800 mm f/11" Solid Cat" Mirror Lens (used as a telescope)

Specifications (measured values in mm are shown instead of published spec's, when different):

Aper.Spec	f/Ratio	FL	Aper.Act.	C. Obs	Obs%	Width	Height	Length	Weight	Notes
72.7 mm	f/11.0	800	72.0 mm	40 mm	56%	108	119	118	1498 g	w/hood

Image Quality (measured) Thresholds for:

Make	Model	Serial No.	ShVid	ShAx	Sh34	FAFm	FA34	UseAt	Cont/F	Notes 1
Vivtar	SolCat	44845072	OKvid	11.0	11.0	70perc	80perc	11.0	G	Large C. Obs.

C. Resol.	E. Resol.	Contrast	Flare	Bloom	Ghost	CamShake	Notes 2
Good	Good	Good	Fair	Fair	Fair	Excel	Haze on 1 element

Summary:
*** Build Quality / Materials: 4** / Almost all components except optics are made of heavy metal.
*** Optical Quality / Details: 3-** / Reasonably good resolution/color saturation; but uneven flare.
Summary Notes:
* Build is 4 instead of 5 only because one element rotated in the original assembly process.
* Optical quality is 3- due to some asymmetry in star images, and flare is too uneven for a TSE.
*** Pluses:** Long focal length, reasonable image quality vs physical size, rear filters, solid feel, reasonably solid rotating tripod mount, eye catching design (if you are into that sort of thing).
*** Minuses:** Asymmetry in star images, uneven flare is issue for crescent moon and eclipse pix.

In the 1970's, Perkin-Elmer partnered with Vivitar (Ponder & Best) to manufacture and market what is commonly referred to as a solid catadioptric (a.k.a. "solid cat") lens. Well known versions are the Vivitar 600 mm f/8 and 800 mm f/11 solid cats. The Vivitar 800 mm f/11 Solid Cat lens is a multi-element lens that is loosely based on a 680 mm f/12 Perkin-Elmer mirror lens.

In practice, performance of a good sample of a Vivitar Solid Catadioptric lens is similar to that of conventional mirror lenses made by camera manufacturers such as Minolta and Nikon, and is somewhat better than conventional mirror lenses marketed as Soligor or Vivitar (etc.) products.

The reviewed sample of the 800 mm solid cat lens is not diffraction limited, but it has more than adequate resolution the film photography for which it was designed. It is a little soft for crop sensors (Micro 4/3, etc.), but is reasonably sharp for a 24 MP class full frame digital sensor.

Resolution and contrast of the 800 mm f/11 solid cat lens is a little better than that of a low cost imported mirror lens, but not as good as better mirror lens such as a Reflex Nikkor-C or Tamron 500 mm. Build quality is good, with a nicely damped feel to the focus. The minimum focus distance is about 7 meters. The front thread is not standard, but the back accepts 35.5 mm filters.

Vivitar Solid Cat lenses have about the same physical length as conventional mirror lenses of similar focal length and aperture, but are heaver. The diameter of the solid cat lens cell is relatively large when compared to its useful aperture. This is necessary because the heavy helical focusing threads must encircle the entire lens assembly *and* its cell, as opposed to being part of the lens cell itself. Build quality is good and the focus ring has a smooth, damped feel.

Since the solid cat lenses were manufactured more than 40 years ago, it is not unusual for some samples to have coating degradation. Some references mention that the units actually made by Perkin-Elmer had a higher susceptibility to this than others, but I can't confirm if it is true. [Some may even have separation between elements 3 and 4. Since the location of the cemented surfaces is subject to TWO passes of the light, separation can be a big problem if it develops.]

According to the patent, the optical design of the solid cat lens was intended to provide more optical surfaces that could be used to correct aberrations. The term "solid catadioptric" is in conflict with having more optical surfaces than some other mirror lenses.

This is because the 800 mm f/11 solid cat lens isn't really solid. It isn't made from a single solid piece of glass. Far from it, in fact. The main body of the lens actually consists of four elements, three of which are as wide as the full aperture. It is even possible that at least one element is even plastic, being made by a company then known as "U.S. Precision Lens". In addition to these larger elements, the Vivitar lens also has some small refracting optics at the back.

The 800 mm f/11 version of the Solid Cat consists of three thick full aperture air spaced lenses, with the air spaces being very thin. The air spaces make it possible for each surface to have a different curvature. The rear full aperture element is annular and has an aluminized back surface that forms the primary mirror. The secondary mirror surface is on a separate, smaller diameter optic that is cemented to the center of the front full aperture lens. A few small elements are in the back, surrounded by the before mentioned annular full aperture element.

The front element is actually a small element that has a reflective surface on its front side that serves as the secondary mirror. This element is cemented to the center of the second element, which is a bi-convex lens of about 10 mm center thickness. The entrance pupil is at this second element. The third element is a fairly thick element that has a concave front surface that is not far from the radius of the second element's rear surface. The forth element is annular, and the mirror coating on its back side is the primary mirror surface. It is cemented to the third element.

In addition to the main 4 elements, some smaller refracting elements are mounted in a conical cell that resides in the center hole of the annular forth element.

When light passes through the solid cat lens, it passes through the elements in this order: Light first enters an annular area of element 2, then passes through elements 3, and 4. The light reflects from the mirror surface at the back of element 4, then passes forward through elements 4, 3, 2, and 1. At this point, the light reflects from the mirror surface at the front of element 1, and passes back through elements 1, 2, and 3. The light exits at the center of element 3 and passes through the rear lenses that reside in the center hole of element 4, then goes on to the focal plane. This represents a lot of passes through quite a few air to glass optical surfaces. When combined with the effects of a central obstruction larger than 50 percent, the contrast is understandably low.

Performance Details: The 800 mm Solid Cat is not very good for long exposure corona shots though, because it failed the "Crescent Moon Test" (see photo 0763), which is less rigorous than the "Half Moon Test". So there is no need to even do a half moon test on Monday.

The issue on the crescent moon test is that the lens has a 1.5-2 mm radius flare artifact in the center when a bright object is in the field of view. This artifact would result in a 3-4 mm diameter ring in the center of the moon during totality. It would start to become detectable in a 1/2 second exposure. So, not a good lens to use for earthshine on the moon during totality. (Need a long exposure for that anyway.)
The Solid Cat flare artifact is about 1 percent as bright as the bright feature in the image. This is brighter than artifacts from most other slow mirror lenses, but not as bad as artifacts in fast mirror lenses such as the 500 mm f/5 Nikkor. It is about the same brightness as artifacts from a Nikon 1.5x tele-converter, but not as bad as artifacts from a Nikon 2x tele-converter.

The Solid Cat was close to diffraction limited, but the diffraction pattern was biased into a coma fan shape that was about 3 diffraction rings in length. This could be due to de-centering issues. There is no visible light between the diffraction rings, which means that bright scattering is well controlled. It split both components in the Lyra Double-Double, but the coma was visible. In a picture of the moon (#765), I could see that the lunar limb was well defined at the bottom and up to the 3:00 position, but the limb became less defined toward the 2:00 position and up to the top. This is due to the coma fan, which runs more or less toward a 1:00 position in the picture.

The lens is stated to be f/11. With 72 mm of utilized aperture on-axis, the actual f-stop comes out to f/11.11. But when you consider the 40 mm secondary obstruction, the resulting aperture area is only equivalent to a 59.87 mm un-obstructed aperture. An additional 11 percent is probably lost to the coatings (same as having 0.943 as much aperture area) so the final “effective” aperture is 56.5 mm, for a transmission value of f/14.1. This was seen in star tests, since stars looked dim.

After evaluating the Solid Cat lens and seeing that there is some coma from de-centering, my impression is that the Solid Cat concept, as implemented in the Series 1 Solid Cat lenses, may be just a gimmick. One of the claims is that the optical surfaces cannot get out of alignment, but in reality they can to the same small extent that is possible in any other mirror lens, since the primary and secondary mirror surfaces are not on the same optical substrate. [[Haze.]]

One little known fact about the Vivitar 800 mm f/11 Solid Cat lens is that it can be adapted to certain medium format cameras. In my sample, the infinity stop can be moved to almost an inch past the infinity mark and still maintain adequate clearance between the second full aperture element and the rear element groups. The rear element groups have a negative focal length (and therefore act like a Barlow lens), so the full working aperture is available even if the focus is adjusted to provide a significantly longer back focus distance.

Ultimately, it was found that the back focus could be extended to about 3mm farther than what is needed to work when close coupled to a Pentax 6x7 camera, and the modified 800 mm lens covers almost the entire 6x7 format, due in part to the extended back focus distance!

Now we’ll cover the less desirable aspects of the 800 mm Solid Cat lens, and ways that some of these can potentially be corrected in an existing sample.

The three full aperture elements in the Vivitar Solid Cat are intended to provide superior correction of aberrations, but in my sample, each of these elements had enough centering and other flaws that the result was simply a lens that could be "tuned" to have different aberrations. The "tuning" is done by rotating the larger elements with respect to each other.

At one extreme, the solid cat lens had strong astigmatism and a lesser degree of other aberrations, but provided high contrast for features larger than the spot that is formed when imaging a point light source such as a star. At the other extreme, the lens had no astigmatism at all, but instead had severe spherical aberration, which lowered contrast. There was no rotational position that could produce a diffraction limited image.

All three elements were marked with a line down one side when the lens was made, but it was obvious that the front element had rotated a little when the front spanner ring was first installed. I eventually came up with a very slightly different rotational combination that produced a somewhat better image than the original alignment.

Other detrimental aspects could not be altered. For example, my sample had haze on the back of the front element. Seeing this, the lens was disassembled to see if the haze could be removed. However, the haze was found to be permanent, and it appeared to a case of the lens not quite having been fully polished prior to adding the AR coating. The haze was very consistent and there was no trace of fungus.

Vivitar 800 mm f/11 Solid Cat Flaws (and corrections, where practical):

A.) Solid cat optics initially produced a relatively large and asymmetrical central spot, w/coma.
* FIXED by slightly rotating the three full aperture elements with respect to each other. The resulting image still is not quite diffraction limited. (But, it is a camera lens, not a telescope.)

B.) Back side of front element has significant haze, and a 2 mm gray spot.
* NOT corrected. Appears surface may have been AR coated prior to adequate polishing. Gray spot was covering a small area having no AR coating.

C.) Light baffles reduce 75 mm clear aperture to 72.5 mm working aperture at center of field.
* NOT changed, can't be changed. Not unusual for mirror lens that is made for photography. Outer parts of aperture are utilized in off-axis parts of field.

D.) 40 mm secondary obstruction is over half of the 72.5 mm working aperture diameter.
* NOT changed, can't be changed. Large obstruction is to prevent fogging at edge of format, and the baffles seem to be somewhat effective for this.
E.) No provision to attach a finder scope.
* NOT ccorrected. The Solid Cat lens was designed to be a camera lens, not a telescope.
F.) Minimum focus distance is about 22 feet (6.7m).
* MODIFIED to focus to 18 ft (5.5m). Even 22 ft is good for an 800 mm lens from the 1970's!

3.12) Soligor/Vivitar 600 mm f/8 "Stovepipe" Lens (used as a telescope)

Specifications (measured values in mm are shown instead of published spec's, when different):

Aper.Spec	f/Ratio	FL	Aper.Act.	C. Obs	Obs%	Width	Height	Length	Weight	Notes
75.0 mm	f/8.0	600	75.0 mm	None	-0-	90.0	93.0	556	1873 g	w/ohd

Image Quality (meas.) Thresholds for:

Make	Model	Serial No.	ShVid	ShAx	Sh34	FAFm	FA34	UseAt	Cont/F	Notes 1 (56 mm hood)
Soligor	T Lng	9692397	11	10	11	11	10	10	V	Rd v grn astig; mn.frng, d11
Vivitar	T Lng	66133	12	11	11	11	10	11	V-	Rd v grn astig; R/G, lowcf8

C. Resol.	E. Resol.	Contrast	Flare	Bloom	Ghost	CamShake	Notes 2
VG-Excel	V Good	V Good	V Good	Good	Exc.	V Good	MaxUsefulF: 10~11

Summary:
*** Build Quality / Materials: 4** / Almost all components except optics are metal; iris delicate.
*** Optical Quality / Details: 3-** / Resolution not as good as tele. version; variation betw. samp.
Summary Notes:
* Build is 4 instead of 5 mainly because the iris mechanism is typical for lenses in its price range.
* Optical quality is a little soft at f/8, but diffraction limited by f/16. Less flare at f/11 than f/8.
* **Pluses:** Good image quality (when stopped down enough), relatively light and easy to handle.
* **Minuses:** Astigmatism and some spherical aberration from f/8 to f/11, best image quality not reached until f/16; 60 cm long lens does not break down for transport; non-standard front thread.

The Vivitar 600 mm f/8 "stovepipe" lens is optically a "long" (i.e. not telephoto) lens that is physically 100 mm longer than the modular "telephoto" 600 mm f/8 lens. It is 556 mm long and has a rotating tripod socket. It does not break down for transport, but it is not particularly heavy. The iris diaphragm in this and most other reviewed long FL refracting lenses (except Leica 560 mm) is a "pre-set" type, where one ring sets the aperture and the other manually stops it down.

Compared to other types of Vivitar, Tokina, or Soligor refracting lenses of 600 mm or longer focal length, performance is about average. It is better than "telephoto" versions of the 800 mm lens, but not as good as the telephoto version of the Vivitar 600 mm f/8 lens. Image quality is acceptable for full frame terrestrial photos by about f/11, but the lens must be used at nearly f/16 for optimum performance on crop sensor camera such as Micro 4/3. Minimum focus is 13 m.

As a visual telescope, rich field (i.e. wide field, low magnification) views are acceptable wide open, better at f/11, and diffraction limited at about f/16. Wide open, predominant aberrations are moderate spherical aberration, longitudinal chromatic aberration, and astigmatism, combined with lesser amounts of other aberrations that cause star images to have an irregular shape, though still a relatively small angular size. Flare is relatively low because there are only two air to glass surfaces. As with the 560 mm Leica lens, off-axis image quality is a little below average at wide apertures due to a lack of any type of field flattening (etc.) lenses near the back.

3.13) Vivitar 600 mm f/8 Modular Telephoto Lens (used as a telescope)

Specifications (measured values in mm are shown instead of published spec's, when different):
Aper.Spec / f/Ratio / FL / Aper.Act. / C. Obs / Obs% / Width / Height / Length / Weight / Notes
75.0 mm / f/8.0 / 600 / 75.0 mm / None / -0- / 94.0 / 127 / 452 / 1930 g /

Image Quality (measured) Thresholds for:

Make	Model	Serial No.	ShVid	ShAx	Sh34	FAFm	FA34	UseAt	Cont/F	Notes 1
Vivitar	Tele.	37901302	9.5	8.0	10est	11est	10est	8.0	VG+	Brother's lens
Vivitar	Tele.	37901615	11.0	9.0	10est	11est	10est	9.0	VG+	f/8 ok full frm

C. Resol.	E. Resol.	Contrast	Flare	Bloom	Ghost	CamShake	Notes
VG-Excel	V Good	V Good	V Good	Good	V Good	V Good+	MaxUsefulF: 9.5

Summary:
*** Build Quality / Materials: 4+** / Almost all components except optics are made of metal.
*** Optical Quality / Details: 3** / Image quality comparable to high end lenses, if stopped down.
Summary Notes:
* Build is 4+ instead of 5 only because the iris mechanism is typical for lenses in its price range.
* Optical quality is a little soft at f/8, but diffraction limited by f/11. Flare is acceptably low.
*** Pluses:** Very portable when disassembled and stored in its standard case, long lens hood nests around lens when stored in case, built-in sights, 10 meter minimum focus. Better than average optical quality for a long telephoto lens of low to moderate price, especially if stopped down.
*** Minuses:** Some spherical aberration at maximum aperture, astigmatism (SN ..1615) persisting into smaller apertures, but smaller than Airy Disk by f/11; fine threads on lens segment assembly ring increase time required to assemble the lens in the field; non-standard front thread size.

The Vivitar 600 mm f/8 modular lens is a telephoto lens that is physically about 10 cm shorter than "stovepipe" versions of 600 mm f/8 lenses. It breaks down into two parts that store neatly in its compact case. Compared to other types of Vivitar, Tokina, or Soligor tele lenses, it performs well. At f/11, its image quality compares even to higher end lenses such as a 560 mm f/6.8 Leica Telyt-R. It does not equal an ED Nikkor unless used at about 1 f/stop slower than the Nikkor.

The Vivitar 600 mm f/8 lens is good wide open *on film*, but falls short for *digital* unless stopped down to f/9.5. Wide open, it has astigmatism and slight spherical aberration. Optimum image quality is between f/10 and f/11, where the central image is diffraction limited. Astigmatism can then be detected in a de-focused image, but is not evident in a focused image. Flare is relatively low, and off-axis image quality is better than average due to field flattening lenses near the back.

The lens has a good rotating tripod mount, and sights. Minimum focus distance is 10 m, which is closer than the 13 m of a "stovepipe" versions of the 600 mm lens that were covered earlier.

3.14) Ad Astra III Maksutov-Cassegrain Telescope (7.8 cm f/9.75)

Specifications (measured values in mm are shown instead of published spec's, when different):
Aper.Spec / f/Ratio / FL / Aper.Act. / C. Obs / Obs% / Width / Height / Length / Weight / Notes
78.0 mm / f/9.75 / 760 / 75.0 mm / 33 mm / 44% / 100 / 104 / 189 / 990 g / Dif.Ltd

Image Quality (measured; SN 3F0261, 3F0315)
C. Resol. / E. Resol. / Contrast / Flare / Bloom / Ghost / CamShake / Notes
Excellent / Good / Good / Good / V Good / Excel / Fair-Good / 2.3 m Min Focus

Summary:
*** Build Quality / Materials: 4+** / Almost all components except optics and an O-ring are metal.
*** Optical Quality / Details: 5-** / Large obstruction, but near textbook diffraction limited image.
Summary Notes:
* Build is 4+ instead of 5 only because moderately delicate labels are used for logo in center of corrector, and for the distance scale. Tripod socket is also well in front of CG when camera used.
* Optical quality is diffraction limited, and the large (by percentage) central obstruction is the only thing that degrades the image in comparison to an APO refractor of the same aperture.
*** Pluses:** Diffraction limited image, compact size, close 2.3 m minimum focus distance, well made with good mechanical heft and feel, proprietary quick release diagonal and camera adapter on some models (some may love it, some may hate it); camera adapter has 48 mm filter holder.
*** Minuses:** Labels used for logo and distance scale, small tripod mount is well in front of CG, no means to mount finder scope (in some models), supplied diagonal only has 20 mm clear aperture, causing vignetting with wide field 1.25" eyepieces. All except lack of a finder mount are minor.

In the mid 1970's the late Max Bray showed us what a small, affordable, high quality telescope should be like, but few seemed to notice. The telescope is the Ad Astra III, a 78 mm f/9.75 Maksutov-Cassegrain that was also sold as a camera lens. Unlike most small, moderately priced telescopes, the Ad Astra III is diffraction limited, providing an almost "Questar-like" image.

The biggest feature of the Ad Astra III is its optics. Unlike almost every other small Mak-Cass faster than f/15, the Ad Astra has a different radius of curvature on its secondary mirror spot than it does on the rest of the corrector. The corrector lens curvature is near that of an f/15 Mak, but the secondary spot has a longer radius of curvature to provide the f/9.75 f/ratio. These attributes reduce spherical aberration. As a star is de-focused, light is visibly transferred to the diffraction rings, rather than just into a blur. The light baffles are also well designed, which is a rare thing.

In the late 1970's Kimball (same company that makes pipe organs) acquired Ad Astra, and full page ads for the Ad Astra III were run in Sky and Telescope magazine. The price was as low as similar size offerings by larger telescope makers, but the Ad Astra never took off. At the time, I had never seen one in person at a telescope store or anywhere else, but a Montana newspaper had a photo of one in an article about the 26 Feb. 1979 total solar eclipse. In about 1984, a customer brought one into a telescope store where I worked in show it off. It was nice. In his sample (and in another sample a friend gave me), an in-focus star image is diffraction limited and symmetrical (SN ..315 or almost symmetrical (SN ..261). In de-focused images, the outer edge is only slightly harder inside focus than outside. The Ad Astra III provides good images of Saturn up to 217x.

A few versions of the Ad Astra were made before the version that was widely advertised. In all versions, a helical focuser at the front moves the Maksutov corrector forward or back. This is by design. Max Bray said he deliberately avoided designs that moved the primary mirror via a rear focus knob. He used front helical focusing instead, because mirror slop (image shift) that occurs when sliding a mirror thimble on a primary baffle tube results in too much misalignment for the image quality Max wanted. Another aspect he did not mention is that back focus with respect to the optics can be reduced if the primary mirror is *not* moved to adjust focus. And collimation is permanent because the outer edge of the centered primary mirror registers directly to the tube.

Early models of the Ad Astra III have a single start helical focus thread, so it takes several turns of the front cell to focus from infinity down to the minimum focus distance. Later versions have multiple start helical threads of about 8 mm pitch. The tapered front cell has flutes neatly machined into its side. In most models, the mirror cell is a casting, and other parts are machined from aluminum tubing. Some versions have black finish all over, while others have natural aluminum finish in the flutes on the front cell, and on parts of the rear quick release grip ring.

Another area models vary is the means used to attach a star diagonal or camera coupling. Early models have T-thread on the back, and a diagonal or camera coupling screws directly onto the back. The diagonal has a screw to lock its rotary position. The widely advertised version of the Ad Astra III has a quick release ring on the back that pushes a flexible ring, into a proprietary groove on the front of fittings for the matching star diagonal and camera coupling attachments.

When the Ad Astra III was still available new, multi-layer anti-reflection coatings (as opposed to Magnesium Fluoride) were just starting to appear on a few smaller telescopes. These were not used on Ad Astra telescopes, and Max explained that there was a good reason for it. At the time, multi-coating processes that were cost effective (as in costing less than the telescope!) caused the glass being coated to get quite hot. The heat was enough that Max was concerned it could undo some of the benefit of previous annealing of the glass, so he avoided the multi-coatings. Heating glass that is only used as a lens is one thing. Heating glass that includes a mirror surface (which must be about 4 times more accurate than a refracting surface) is something else entirely. The main concern was that the corrector could take on a camber that would introduce astigmatism.

The physical size of the Ad Astra III is small enough that it can be taken more places than many other telescopes or similar or larger aperture. It can go where a C90 or Pico 8 cannot, since it has a precision feel, and good enough optics that people will *want* to bring it along. It is also shorter than either scope, and the difference in length is more pronounced when using a diagonal. With a diagonal, the Ad Astra is still smaller than either of the mentioned scopes without a diagonal.

The Ad Astra III is infinitely better than the imported Mak-Cass telescopes of similar aperture. The comparison reveals just how bad the imported telescopes really are. The Ad Astra III is a telescope that should be introduced again, and it should be made right, just like it was made right the first time around. This means that it, and its essential parts, should be made in the USA, and/or in one of the few other countries that still know how to manufacture good telescopes.

In the 1970's, a visionary telescope maker showed what a small telescope can do, and what one should be like. His design shows “how it should be done”. Now, it’s just a matter of a company that knows how to build *good* telescopes having the vision to pick up the ball and run with it.

3.15) Vivitar 500 mm f/6.3 Telephoto Lens (used as a telescope)

Specifications (measured values in mm are shown instead of published spec's, when different):

Aper.Spec	f/Ratio	FL	Aper.Act.	C. Obs	Obs%	Width	Height	Length	Weight	Notes
79.4 mm	f/6.3	500	79.3 mm	None	-0-	95.0	95	425	1700 g	

Image Quality (measured) Thresholds for:

Make	Model	Serial No.		ShVid	ShAx	Sh34	FAFm	FA34	UseAt	Cont/F	Notes 1
Vivitar	Tele.	70186	9.5	11	9.5	11	13	9.5	11	V-	RdVGnAst;Sym63

C. Resol.	E. Resol.	Contrast	Flare	Bloom	Ghost	CamShake	Notes
Fair	Fair	Fair	F-Good	Fair	Fair	Fair	Sml.Tps; MaxUsefulF: 10.0

Summary:
*** Build Quality / Materials: 3** / Almost all parts except optics are metal, but tripod mount small.
*** Optical Quality / Details: 2** / Image quality is average at best, but star image is round at f/6.3.
Summary Notes:
* Build is a 3 because the tripod mount is ridiculously small and the iris mechanism is delicate.
* Optical quality is soft at f/6.3, though a star image is round, contrast is low at wide apertures.
*** Pluses:** Star images are round, though a little large and not uniformly colored at maximum aperture; tapered barrel design could make it the center of attention in a retro lens display.
*** Minuses:** Spherical aberration with astigmatism and longitudinal chromatic aberration, with the latter two persisting into smaller apertures, but with artifacts becoming smaller than the Airy disk by about f/11; non-standard front thread size.

The Vivitar 500 mm f/6.3 telephoto lens is a relatively light weight design, in that it uses the same relatively small focus mechanism as some 180 mm f/3.5 and 200 mm f/3.5 lenses. It has an interesting taper along most of its length, making it one of Vivitar's more unusual looking lenses. The lens hood is a metal 99 mm diameter screw-in stepped design that adds 59 mm of length.

The tripod socket is a ridiculously small chrome fitting with less than a 30 mm diameter. The small tripod mounting surface almost makes camera shake inevitable, but the lens can be used to more advantage if the tripod socket fitting is removed, and the tapped 1/4-20 hole that secures the fitting to tripod mount casting is instead used as the tripod mount. Minimum focus is 10.5 m.

The image characteristics are unusual, in that the lens has spherical aberration and astigmatism, combined with chromatic aberration that is obvious at all apertures wider than f/11. However, at the maximum aperture of f/6.3, the image of a star is symmetrical, with two opposing sectors of its edge being pale green, and the other two sectors being pale red. Upon stopping down slightly, the round image gives way to a plus sign shape, and the red and green artifacts become more saturated. The image begins to round out again as the aberration artifacts shrink to a size smaller than the Airy disk at about f/11. Contrast is low at all apertures wider than f/10 to f/11.

4.) Telescopes (and Camera Lenses Used as Telescopes) from 8.0-9.9 cm Aperture:

Figure 4A. Some of the *refracting* telescopes and camera lenses reviewed in this and other chapters. From left to right, the pictured telescopes and lenses are:
* Nikon 300 mm f/4.5 ED Nikkor (reviewed in chapter 3) [not yet pictured]
* Leica 560 mm f/6.8 Telyt-R modular lens (reviewed in this chapter)
* Vivitar 600 mm f/8 "stovepipe" lens (reviewed in chapter 3)
* Vivitar 600 mm f/8 modular telephoto lens (reviewed in chapter 3)
* Vernonscope 94 mm f/7 Refractor telescope (reviewed in this chapter) [not yet pictured]

[Figure 4B]

Figure 4B. Some *reflecting* telescopes and mirror lenses reviewed in this chapter. Left to right:
* B&L 800 mm f/10 Hybrid Cassegrain camera lens and telescope
* Kasai Pico-8 Mak-Cass telescope
* Meade ETX 90 Mak-Cass telescope
* Questar 3.5 Maksutov-Cassegrain telescope
* Nikon 1000 mm f/11 Reflex Nikkor-C mirror lens
* Celestron 90 Mak-Cass telescope (lower right inset) [not yet pictured]

4.1) B&L 800 mm Mirror Lens and Telescope (8.0 cm f/10 Hybrid)

Specifications (measured values in mm are shown instead of published spec's, when different):

Aper.Spec	f/Ratio	FL	Aper.Act.	C. Obs	Obs%	Width	Height	Length	Weight	Notes
80.0 mm	f/10.0	800	72.0 mm	40 mm	56%	95.0	102	195	900 g	

Image Quality (measured; P/N 61-8080)

C. Resol.	E. Resol.	Contrast	Flare	Bloom	Ghost	CamShake	Notes
Poor-Fair	V Good	F-Good	Fair	Fair	Fair	Good	MaxUsefulF: 10

Summary:
*** Build Quality / Materials: 3** / Almost all parts except the optics are metal, design is simple.
*** Optical Quality / Details: 2** / Residual spherical aberration, significant off-axis aberrations.
Summary Notes:
* Build is only a 3 because the secondary baffle limits the aperture to 72 mm. Front and rear cell threads are also a loose fit to the tube. This can cause collimation instability with rough handling.
* Optical quality is shown as a 2 because attempting to correct all spherical aberration with small lenses near the back of the telescope does not provide as much full field resolution as would be the case for a full aperture corrector in front. But the low price reflects this simplicity.
* **Pluses:** Compact size, close minimum focus distance, good mechanical heft and feel, built-in low profile 1.25" eyepiece and camera adapter interface minimizes back focus, comes with diagonal and 2 eyepieces, has a comparatively low price, acceptable lunar and terrestrial images.
* **Minuses:** Residual spherical aberration limits planetary performance, off-axis aberrations limit full frame photo resolution, large central obstruction, secondary baffle clips aperture to 72 mm.

The B&L 800 is an interesting hybrid telescope that looks like an ordinary SCT on the outside, but has very different optics on the inside. The primary mirror has a slightly slower f/ratio than most, and the secondary mirror is flat rather than being convex. Spherical aberration is corrected with small lenses that reside inside the primary baffle tube. Correcting spherical aberration with only a few small lenses close to the focal surface results in considerable off-axis aberration.

The B&L 800 provides satisfying terrestrial and lunar images below about 80x magnification, but the image gets soft at higher magnifications. The softness is particularly obvious on planets. The mechanical feel of the telescope is unusually good for such a small, low priced telescope.

The B&L 800 was introduced in the 1990's, and was available for some time after that. Even though it was not billed as being highly compact, it is *smaller* than the Kasai Pico-8 and many other "compact" scopes, and it is relatively light. The tube has a diameter of 95 mm and a length of 164 mm. The focus knob adds another 31 mm, for a total length of 195 mm with no diagonal.

The B&L weighs only 0.9 kg, not counting a diagonal or eyepiece. The built-in combined 1.25" eyepiece / diagonal holder and camera adapter interface at the back of the telescope protrudes slightly less than the focus knob. The removable diagonal prism is relatively close coupled to the telescope, so the physical length with a diagonal and eyepiece is also fairly short. On it's box, it is called a "Mirror Lens with Added Accessories", rather than a telescope.

The B&L 800 comes with a 1.25" diagonal prism and two mediocre eyepieces (18 and 30 mm) that provide visual magnifications of 27x and 44x. It also comes with a T-mount (M42x0.75 mm thread) camera coupling that allows the camera to be rotated without using the small screws on a camera T-ring. A 1/4-20 tripod mount is at the back, which permits use of a third party dew cap.

Image quality is good up to about 70x, fair up to 90x, and acceptable up to maybe 120x to 160x, depending on the subject. At higher magnifications, diffraction from the large 40 mm secondary obstruction has about as much effect on the image as the residual spherical aberration and moderate chromatic aberration. At a given magnification, the B&L images are a little better than those from a 300 mm ED Nikkor lens, Ednar Mirror Scope 500, or an unmodified Kasai Pico-8.

Focusing is accomplished with a small knob at the back that moves the primary mirror. The minimum focus is only 2.75 m from the front optical window, and there is almost no backlash.

Build quality is good, and the entire mechanical tube assembly is metal. Threads on the front and rear cells feel a bit loose if the cells are removed or installed, but removing the optical cells is not something the average user would do. I have found myself looking at the compact and seemingly rugged B&L optical tube just for fun, but wishing it provided sharper images.

The B&L 800 was introduced when film cameras were popular, but smaller format digital cameras (APS and Micro 4/3) adapt well to the B&L 800 by simply using a standard 1/25" to T-thread camera adapter that fits where the diagonal normally does. When combined with an appropriate T-ring and the included camera coupling, this makes two ways to mount small digital cameras: Via the included camera coupling, or via a third party T-thread to 1.25" adapter.

The flat front window of the B&L 800, as well as the rear correction lenses, are anti-reflection coated, but might not be multi-coated. On the other hand, reflections from the front window of the B&L look dimmer than reflections from the Pico-8 Maksutov corrector. The sub-aperture correcting lenses in the primary baffle tube act as a dust seal to keep dust out of the optical tube.

The primary and secondary mirrors appear to have standard aluminum coating. Mirror coating on my second hand B&L scope is quite durable, withstanding a thorough cleaning to remove slight haze. Collimation adjustment is at the secondary mirror, and it retains collimation well.

A telescope's box is not usually worth mentioning, but the B&L 800 box is fairly small and has a custom cut Styrofoam insert that accommodates the telescope with a diagonal and two eyepieces. After cutting out an additional area for a third eyepiece, I found myself using the box as a case because it provides adequate padding, and is not much larger than a conventional case would be.

That covers the basics. Next, we will briefly cover the few undesirable aspects, and how some can be corrected in an existing sample of the B&L 800 telescope.

4.1.1) B&L 800 Telescope, Details About Undesirable Aspects (and fixes, where possible):

The B&L 800 telescope does not include a finder scope, nor does it include any tapped holes that can be used to mount a finder bracket. This limits its usefulness as an astronomical telescope.

However, its simple mechanical design makes it possible for a person of reasonable (but better than average) mechanical skill to temporarily but carefully remove the primary mirror (along with its attached mirror thimble) and tap holes in the rear cell that can be used to mount a finder scope. The alternative to modifying a B&L 800 like this is to use adhesive to mount a finder.

4.1.1.1) List of B&L 800 Telescope Flaws (*and corrections, where practical*):

A.) Outer 3 percent (1.2 mm) of primary mirror has turned down edge, but this has little effect on the central image. Fortunately, this part of primary mirror is not used for the axial image at long subject distances (see item C). However, the outer edge of the primary mirror is used at close subject distances, and for off-axis parts of the image.
* Status for corrections to telescope hardware: NOT corrected, can't be corrected unless mask off.

B.) Optical design does not fully correct for spherical aberration.
* Status: NOT corrected. (But it is a low cost telescope and camera lens, not a Questar.)

C.) Secondary mirror and secondary baffle clip telescope aperture to 72 mm at center of field.
* Status: NOT corrected. (Not uncommon for camera lens, and obstruction is already large.)
Measured by placing transparent ruler on front of scope and viewing it from focal plane.

C.) Large 40 mm central obstruction exceeds 50 percent of 72 mm working aperture diameter.
* Status: NOT corrected and cannot be corrected. (A flat secondary has to be large.)

E.) No mounting holes for a finder scope bracket.
* Status: FIXED by temporarily removing primary mirror and tapping holes in rear cell.
* Adhesive can be used to mount light finders such as low cost astronomical red dot finders.

F.) Soft plastic front lens cap fits so air-tight that it is difficult to remove quickly. (This is not actually a flaw, since you can’t really fault a manufacturer for making a front cap that fits well!)
* Status: FIXED by adding small air hole near front end of cap to let air in as cap removed.

4.2) **Kasai Pico-8 Mak-Cass** (8.0 cm f/11.2) The Worst Telescope I Have Ever Owned.

Specifications (measured values in mm are shown instead of published spec's, when different):

Aper.Spec	f/Ratio	FL	Aper.Act.	C. Obs	Obs%	Width	Height	Length	Weight	Notes
80.0 mm	f/11.2	900	79.0 mm	30 mm	38%	98.0	110	247	1140 g	w/cap

Image Quality (measured)

C. Resol.	E. Resol.	Contrast	Flare	Bloom	Ghost	CamShake	Notes
Abysmal	Poor	Poor	Poor	Poor	Good	Fair	Plastic Rear Cell

Summary::
* **Build Quality / Materials: 1** / Aluminum tube, but plastic rear cell. Poor build quality.
* **Optical Quality / Details: 0** / Turned down primary mirror edge, apparent surface roughness..
Summary Notes:
* Build is only a 1 because of numerous defects that are covered below. Everything from a bad internal paint job to a full turn of backlash at the focus knob. It seems that if it was possible to do something in the wrong way, it was done in the wrong way in this Kasai Pico-8 telescope.
* Optical quality is shown as a 0 (lowest possible rating) because the telescope was not even useful for terrestrial observation above about 50x magnification, and was lousy for astronomical observation at any magnification. The aperture has to be masked down to 72~74 mm to be of any use for astronomy at all, due to a severely turned down edge on the primary mirror.
*** Pluses:** Moderately compact size, Vixen dovetail is heavy enough to be a good paperweight.
*** Minuses:** Very bad build quality that is not confidence inspiring, even for a paperweight. Details are below, because the list of minuses is too long to include in this summary.

Details: The Kasai Pico-8 is without a doubt the worst telescope I've ever owned. It is incapable of producing a spot smaller than about an arc minute (yes, an arc minute!) in diameter. It also has very poor light baffles. The primary baffle has no stops or visible threading on the inside of its front half, and there is no secondary baffle at all. This causes serious veiling flare. Minimum focus distance is way out at 8 meters, which is very distant for a telescope of this small size.

The cause of the huge 1 arc minute spot? *A turned down edge on the primary mirror!* A mistake that people rarely made even when some made their own mirrors at home. In all, the outer 4 mm of the primary mirror (8 mm of its diameter) is severely affected. The telescope won't produce an acceptable APS format photo unless stopped down to 76 mm, and planetary images are awash in spherical aberration unless the Pico-8 is stopped down to 74 mm or less; preferably to 72 mm. Even when the Pico-8 is stopped down, its image is still washed out from the light baffle flaws. The turned down edge on the primary mirror is the tallest tent pole, but not the only tent pole.

What about that so-called "small" secondary obstruction in the Kasai Pico-8? Not so small when you consider the USEFUL aperture of the telescope! The obstruction measures 30 mm, as seen from the focal plane (caused by the front end of the primary baffle tube being too close to the secondary mirror spot), and measured via a transparent ruler right at the front of the telescope. Given that the useful aperture is only 72 mm to 74 mm, the obstruction is a relatively large 40 percent (30/74). That's as large as the obstruction in some photographic mirror lenses.

And there is more. Black paint inside the tube is uneven and badly blistered, as though painted by a child in grade school. (Who knows, being made in China, maybe it was!) In addition, the primary mirror has small holes in its reflective coating. The glass where the coating holes are looks white rather than clear, as though it is not fully polished. The plastic rear cell also lets the primary mirror assembly ring like a tuning fork whenever a camera with a mechanical shutter is used, so it has often been impossible to get good photos through the Pico-8 with such a camera.

I bought the Pico-8 telescope <u>new</u> through a dealer, rather than get a lower cost no-name version of this Chinese scope online. I *thought* that if a Japanese trading company put their name on a scope, QC may be better. But this experience shows maybe this is not so. I provided feedback to Kasai via the dealer, but there was no response. Ironically, when I ordered the Pico-8, it was one of the few times I gave a dealer a *"heads up" that I was reviewing the telescope*. Image quality of the Pico-8 is so poor that I can't sell it, so it's quite literally being used as a *paperweight!*

The Pico-8 reminded me of the aberrations my C90 had, but the Pico 8 is worse, in that its spherical aberration is at least 2x worse than the C90, even when stopped down to 74 mm. You can see image flaws on stars at even 30x, and the image is not useful at all above about 100x.

Image quality is only slightly better than the Vivitar 800 mm f/11 Solid Cat lens, and flare is far worse because of the lack of a secondary baffle, etc. An 800 mm f/8 Soligor lens from the 1970's, stopped down to f/13, will beat the Pico-8 on planets any day. Images from a 1000 mm f/11 Reflex Nikkor are vastly superior to those from the Pico-8, but the Nikkor is a lot heavier.

Some of the Pico-8 spherical aberration arises from using a non-optimum prescription for the Maksutov corrector. A Maksutov corrector works best when its radius of curvature is fairly small. This corresponds to a secondary spot curvature that increases the focal length by a factor of 7 or 8 over that of the primary mirror, so with an f/2 primary mirror, Cassegrain focus would become f/14 to f/16. But in the Pico-9, the focal length is only increased 5.6 times, to f/11.2.

The *cheap* way to get f/11.2 is to change the radius of curvature of the entire Maksutov corrector so that the secondary spot has the correct radius. However, correctors of this shape prevent full correction of spherical aberration, or result in excess chromatic aberration if modified to correct spherical aberration. The Pico-8 also has additional aberrations that are just from sloppy telescope making. These include the severely turned down edge on the primary mirror.

The superior Ad-Astra 3 achieved its f/9.75 Cassegrain focus by using a conventional Maksutov corrector, but then figuring the secondary spot to have a different radius of curvature. This is the only way to do a fast f/ratio Mak right. An Ad-Astra is slightly heavier than the Pico-8, but not any larger. The Ad-Astra with its low profile diagonal is actually a little *shorter* than the Pico-8.

At night, the Pico-8 can do just OK, but only if there are not any bright stars in the field. But even at 45x, a bright star has a visible glow around it. Part of this might be because the mirror finish does not look fully polished, having hundreds of polishing marks that can scatter light.

The moon looks OK in the Pico-8 at 45x, but only if it is positioned in the eyepiece field so that it is not overwhelmed by flare from the shiny primary light baffle. (The baffles cause flare even on the moon!) Spherical aberration is evident at even 100x. Here, the moon's image starts to get sharp, but contrast drops just as it is getting to be sharpest. This is what spherical aberration does. Lunar photos came out about like what you'd ordinarily get with a 4 cm aperture refractor.

The Pico-8 probably would *not* be a viable total solar eclipse lens, due to all of the scattered light inside the primary baffle tube. If masked to 72 mm, it might work for short exposures of the inner corona, prominences, and Baily's beads, but it won't work for earthshine on the moon, etc.

The Kasai Pico-8 may be the worst optic I ever tested in regard to its ability to image earthshine on the moon without excess glare. The glare is worst when the sunlit part of the moon is just outside the field of a Micro 4/3 camera. Some of this could be improved by adding baffle stops inside the primary baffle tube, much like what I eventually did with my C90 in the early 1980's.

It is fairly certain that the Pico-8 would not be up to sharply imaging the ISS when it transits the sun, due to its spherical aberration. *If* the Pico-8 had been implemented correctly, it could have been something. A properly implemented version would be good for long focal length photos from a compact tracking mount, and (if sharp) would also be a good guide scope and planetary scope. But the Kasai Pico-8 isn't any of those things. Instead, it's being used as a paperweight.

As in some of my other telescope reviews, less than desirable aspects of the telescope are listed here, along with any fixes or corrections that seemed to improve performance:

4.2.1) Kasai Pico-8, Details About Numerous Flaws (and corrections, where practical):

A.) Optics have spherical aberration, turned down primary mirror edge, and other aberrations.
* Status for hardware corrections: NOT fully corrected. Outer 6-10% of primary mirror has a severely turned down edge. This causes a 2~3 arc minute diameter glow around star images and radically lowers planetary contrast. Masking the primary mirror edge significantly improves performance, but reduces the aperture to 72-76 mm, and it still is not quite diffraction limited.

B.) Primary mirror has a few small spots (holes in coating, some up to 1 mm wide) near one edge. Mirror substrate glass looks frosted (rather than smooth) in these spots.
* Status: NOT corrected and can't be corrected. Possibly from incomplete polishing before coating and/or impurities in the coating chamber.

C.) Primary mirror has numerous thin sleeks that appear concentric with points around its edge. These are too consistent (were made by machine) to have been made after mirror was installed.
* Status: NOT fixed and can't be fixed. Possibly from incomplete polishing before coating.

D.) Focus knob has a FULL TURN of backlash.
* FIXED by adding custom 0.015" thick brass washer, made from shim stock, under focus knob.

E.) Black paint on inside of the oprical tube is blistered in large areas. This is obvious to anyone looking at the telescope, and just *screams "cheap"*.
* Status: NOT corrected, other than flaking off lose paint that could get on mirror or into camera.

F.) Finder bracket screw projects into tube far enough to damage primary mirror.
* Status: FIXED by shortening screw and limiting forward motion of primary mirror.

G.) Plastic finder dovetail shoe gusset causes finder to fit crooked in dovetail mount.
* Status: FIXED by filing gusset. Finder could not be lined up to scope otherwise.

H.) Vixen dovetail has extremely sharp and jagged corners that can easily cause cuts.
* Status: FIXED by filing corners of dovetail, but results in loss of black finish where filed.

I.) Built-in camera T-adapter has too much back focus, clips 2 mm of aperture.
* NOT fixed. Caused by excess primary baffle length vs diameter and back focus. See Item L.

J.) One collimation screw lacks enough travel to achieve proper collimation.
* Status: FIXED by making custom 0.015" thick brass shim washer from shim stock.

K.) No secondary baffle at all, so light can fog corners of frame.
* Status: NOT fixed (yet). Custom part needed. Secondary baffle diameter should be 30-32 mm.

L.) Inside of primary baffle tube has no effective anti-reflection threads or paint, etc.
* Status: NOT fixed (yet). Causes low contrast image, especially if subject backlit. (I may try using a blackened coil spring as a spiral baffle stop.)

M.) Front of primary baffle is too close to secondary. Increases real world obstruction.
* Status: NOT fixed. Increases functional central obstruction from 27.2 mm to 30 mm.

N.) Front end of primary baffle tube has dent and large bur.
* Status: FIXED by filing and painting affected part of baffle tube.

O.) Minimum focus distance is 25 feet (7.6m). This seems too distant for a small telescope.
* Status: NOT corrected, and can't be changed without lengthening tube about 3 mm.

P.) Plastic rear cell and adjustable rear primary mirror thimble support can vibrate.
* Status: NOT fixed, and probably can't be fixed. Rules out mechanical shutters. Caused by thin cross section of plastic rear cell, combined with how collimation adjustment (via tilting entire primary mirror and baffle assembly) is implemented.

The Kasai Pico-8 has a disappointing number of flaws. Many are from poor implementation, and could be corrected during manufacture with <u>*basic*</u> *quality control measures*. If a Pico-8 owner is not willing to put in the time needed to address several of its serious shortcomings, the Pico-8 would be an unacceptable excuse for a telescope. For the most part, it again comes down to implementation. Based on my sample, the Pico-8 is poorly made, period. A 20 year old B&L 800 is much nicer in some ways. Manufacturers of small telescopes could learn a thing or two by looking at the comparatively superior mechanical design and implementation of a B&L 800 mm.

This review may be updated if I get access to a better Pico-8 sample, or another new telescope of similar or smaller size. However, many photons have gone under the bridge in the months since acquiring the Pico-8. The *poor* quality of each new *imported* telescope sample I've reviewed herein could also be the quality of the telescope that *you* may get. The Kasai Pico 8 is *not* the only *imported* telescope to be of *poor* quality. Most reviewed scopes from China were poor.

4.3) **Leica 560 mm f/6.8 Telyt-R lens** (used as a telescope)

Specifications (measured values in mm are shown instead of published spec's, when different):
Aper.Spec / f/Ratio / FL / Aper.Act. / C. Obs / Obs% / Width / Height / Length / Weight / Notes
82.4 mm / f/6.8 / 560 / 82.4 mm / None / -0- / 98.0 / 98.0 / 526 / 1816 g /

Image Quality (measured) Thresholds for:

Make	Model	Serial No.	ShVid	ShAx	Sh34	FAFm	FA34	UseAt	Cont/F	Notes 1
Leica	TelytR	2849409	11.0	9.5	11.0	11.0	9.5	10.0	Exc	2 Air-G Surf.

C. Resol. / E. Resol. / Contrast / Flare / Bloom / Ghost / CamShake / Notes 2 (MxUF:9.5)
VG-Excel / Good / Excel / V Good / V Good / Excel / Fair-Good / Unbalanced TP Skt

Summary:
*** Build Quality / Materials: 4+** / Almost all components except optics are made of metal.
*** Optical Quality / Details: 4-** / Image that is comparable to high end lenses, if stopped down..
Summary Notes:
* Build is 4+ instead of 5 only because the tripod mount is so close to the back that the lens is severely unbalanced. The focus also lacks any type of fine control. Round iris is a good feature.
* Optical quality is a little soft at f/6.8, but diffraction limited by f/11. Flare is quite low..
*** Pluses:** More image snap at f/9.5 to f/11 than Vivitar, etc., 600 mm lenses; very light weight.
*** Minuses:** Image wide open is too soft for planetary observation; no fine focus control.

The Leica 560 mm f/6.8 Telyt-R is a modular refracting lens that uses the same focus assembly as the Leica 400 mm lens of the same f/ratio. The focuser is a "follow focus" of sorts, in that focus is adjusted by pressing a button while manually sliding the focus mechanism forward or back, then releasing the button when a desired focus setting is reached. There is no helical focus. This is somewhat difficult to use for amateur astronomy, but it is workable if focus is set to just past infinity, then the eyepiece is moved in and out of an eyepiece holder for fine tuning focus.

The Leica 560 mm is reviewed here because, even though its optics consist only of a cemented doublet that may not even use ED glass, the image it provides at f/11 is diffraction limited. It also has unusually low flare, thanks to only two are to glass surfaces and well designed baffles. The iris also has numerous blades, so the aperture is effectively round at any setting. The weight is only 1.8 kg, and it feels almost like a feather when setting it up. Minimum focus is about 6 m.

The tripod mount looks almost like an afterthought, being located close to the back of the lens. This makes it front heavy (and spongy) when used on a tripod. This can be fixed by mounting the lens on a rectangular metal bar of about 33 cm length that has a tripod mount near its center.

When the 560 mm f/6.8 Telyt-R is used at f/9.5 or slower, its images are comparable to those of an ED Nikkor lens of similar focal length, used at f/6.8 to f/8. The Telyt-R image has notably more snap than images from a Tokina, Vivitar, or Soligor, etc., lens of similar focal length, but the modular 600 mm Vivitar lens comes close. My sample did not come with a case, but I found that the "medium" sized rectangular Promaster tripod case works well as a soft case for the lens. This allows the 560 mm lens to be stored and transported in its fully assembled configuration.

4.4) Questar 3.5 Maksutov-Cassegrain Telescope (8.9 cm f/14.4)

Specifications (measured values in mm are shown instead of published spec's, when different):
Aper.Spec / f/Ratio / FL / Aper.Act. / C. Obs / Obs% / Width / Height / Length / Weight / Notes
89.0 mm / f/14.4 / 1280 / 89.0 mm / 30 mm / 34% / 108 / 186 / 274 / 1499 g / Dplx

Image Quality (measured; SN 1-DP-Z-8086-BB)
C. Resol. / E. Resol. / Contrast / Flare / Bloom / Ghost / CamShake / Notes (159h w/o ep)
Excellent / Good / V Good / Good / Fair / Good / Fair / Light Weight

Summary:
*** Build Quality / Materials: 5-** / Almost all components except the optics are metal.
*** Optical Quality / Details: 5** / Residual spherical aberration, significant off-axis aberrations.
Summary Notes:
* Build is a 5- because a few things that could have been corrected over the years have not been corrected. These include that noticeable image shift during focusing can develop over time, and the retainer for the fork mount that attaches to the polar axis is still of very light construction.
* Optical quality is a 5 because it is as good as it gets in a commercial amateur telescope.
*** Pluses:** Excellent image quality, compact size, light weight, close 3 m minimum focus, built-in flip mirror, metal tripod mount, eyepieces securely screw in, built-in switchable Barlow lens, built-in sliding dewcap, some versions have star charts and moon map, built-in solar filter for finder, mount has smooth slow motion controls that do not require use of manual lock levers.
*** Minuses:** High price, too delicate to leave unattended in many settings, proprietary camera coupling and eyepiece threads, incompatible with some heavy cameras unless used with a cradle.

Most who are into amateur astronomy have probably heard of the Questar 3.5 telescope. When seeing one for the first time, it is hard to imagine that most of its features were developed in the 1950's. This is because it does not seem outdated at all, even though it is not a “go to” telescope. The optical quality is superb, and it is the only Cassegrain I have used other than an Ad Astra III in which I have seen almost “textbook” diffraction limited Airy patterns when looking at stars.

The Questar 3.5 is fun to either look at or use. The manual slow motion controls on its mount and sidereal drive motor base work smoothly, and it is not necessary to lock anything down when the telescope is pointed in the desired direction. Just let go of the slow motion controls and the telescope stays put. Another plus is that the slow motion controls also have safety clutches. So, if anyone tries to just grab the telescope tube and slew it by hand, the clutches prevent damage to the slow motion controls. The Questar an almost mirror smooth metal finish. This is nice to look at, but it can feel pretty cold to the touch on a sib zero degree winter night.

I was impressed enough by a Questar that it was about the only high priced gadget I owned during the late 1980's, which were not exactly good years economically because I could not get health insurance, and thus medical care. I was a dealer for Questar during this time, because it was a product I could be enthusiastic about. They later employed a manager that terminated most of the individual dealerships, and (predictably) Questar went Chapter 11 only a few years later. This may be partly because some dealers they kept used a Questar to *sell against*, rather than sell.

The Questar OTA dimensions and weight are shown above, but it is still compact and lightweight with the motor base (178w, 356h, 210d, 3541 g) or in its fitted case (229w, 420h, 245d, 6107 g).

During the time I was still a dealer, Questar introduced the PowerGuide II as an optional upgrade in new telescopes. When installed, it replaced the standard 115 V AC clock motor with a small DC gear motor and electronics that could run the telescope for up to 24 hours on a 9 Volt battery. The electronics look very similar to those used in early versions of Celestron Ultima telescopes that were not computer controlled "go to" telescopes.

The PowerGuide II has a power switch, a hemisphere (North or South) switch, and a drive rate switch with lunar and sidereal drive rates. All an observer needed to do was to turn on the power, polar align, and then the scope would track. A compact hand control plugged into the bottom of the Questar motor base for guiding. It had much needed tactile feedback on its fast, slow, and declination control buttons. The declination motor was an optional accessory.

The PowerGuide II could be ordered with a brand new Questar, but Questar also offered retrofit the PowerGuide II to an existing Questar telescope mount for a reasonable (for Questar) price.

The PowerGuide II was superseded by the PowerGuide III in the mid teens of the 21st century. The PowerGuide III is also available on new Questar telescopes, and it can he retrofitted to existing Questar fork mounts. Unfortunately, the PowerGuide III does not operate the telescope drive *unless* the hand control is plugged in (so I'm told by Questar). And, the hand control uses a *touch screen*, which has *no tactile feedback*. Anyone who has guided deep sky astro photos can see how a touch screen is a *non-starter* for manually guided astrophotography, since you can't even tell where on the touch screen you have to touch (for fast or slow) without *looking away* from the guide star and *looking at* the touch screen. Also, looking at a light emitting screen is not the best thing to do when trying to keep track of what could be a relatively dim guide star! Some people, including me, can't reliably use a touch screen due to tremor or other reasons.

So, in the opinion of some customers, that may not have been one of Questar's better moves. Others may love it, since it is rumored to be "go to" enabled, even though the telescope mount itself is not go to enabled as yet. In the past, Questar was slow to embrace even as much change as going to LED's in an illuminated reticle eyepiece, but they may have tried to jump too far into tech with the PowerGuide III, at least in the view of some. Having to attach a touch screen hand control *just to enable basic tracking* does not seem very convenient. Attaching two items (a small battery and a compact old school drive corrector) enables tracking with an older mount.

I was going to get a PowerGuide II added to my Questar mount in 2017, until I found it was no longer available, and the PowerGuide III is the *only* option. So now, I often just use my Questar in alt-azimuth mode with no drive running at all, and use its slow motion controls to periodically re-center objects. A Questar with no all-internal battery powered drive lacks the convenience of a TeleVue 60 or Ad Astra on a Vixen Polarie, so the Questar has been used less of late.

Apart from the PowerGuide III shortcomings, the Questar 3.5 is a well made telescope that is fun to use for observing wildlife or astronomical objects. It balances well with modern (small) digital cameras on the back. A Questar has also provided my only "good" ISS solar transit photo to date.

4.5) Celestron 90 Maksutov-Cassegrain Telescope (9.0 cm f/11)

Specifications (measured values in mm are shown instead of published spec's, when different):

Aper.Spec	f/Ratio	FL	Aper.Act.	C. Obs	Obs%	Width	Height	Length	Weight	Notes
90.0 mm	f/11.0	1000	89.0 mm	34 mm	38%	121	130	197	1476 g	

Image Quality (measured)

C. Resol.	E. Resol.	Contrast	Flare	Bloom	Ghost	CamShake	Notes
Fair-Good	Fair	Fair	Fair	Good	Good	Poor	Spherical Aber.

Summary:
*** Build Quality / Materials: 3-** / Most parts except optics and baffles are metal; sloppy focus.
*** Optical Quality / Details: 2+** / Residual spherical aberration, significant flare.
Summary Notes:
* Build is a 3 because even though the front and rear tube sections are both metal, the focus has a huge amount of play, and this results in major image shift while focusing. Both light baffles are plastic, and the primary baffle is not of an optimum design.
* Optical quality is only a 2+ because the C90 has some spherical aberration, astigmatism, flare.
*** Pluses:** Optics are adequate for terrestrial or lunar viewing, semi-compact size versus aperture, close minimum focus, thick castings for front and rear parts of tube, solid camera interface.
*** Minuses:** Spherical aberration limits planetary performance (fuzzy over 120x), very significant image shift from excessive play in focus threads, undersized 3.75" primary mirror limits working aperture to 89 mm, included eyepieces and diagonal are small 0.965" size, rather than 1.25" size.

The Celeston C90 (1970's version) is a 9 cm f/11 Maksutov-Cassegrain telescope. A C90 was my first Cassegrain telescope, but was not one of Celestron's best efforts. The C90 has an f/ratio of f/11, but unlike the Ad Astra III telescope, the radii of curvature for the C90 secondary mirror spot and the Maksutov corrector are the same This results in Maksutov corrector curvatures that are *not* optimum for correcting spherical aberration. Predictably, C90 images have a significant amount of spherical aberration. My sample also had a slight amount of on-axis astigmatism.

Early versions of the C90 came in a very compact plywood case that was covered with a black overlay. Later versions came in less compact blow molded plastic cases. Standard accessories included a 0.965" star diagonal, an 18 mm Kellner eyepiece, and a 2.5x achromatic Barlow lens.

The camera interface on the back has the same 1.375"-24 thread that the visual back on a C8 has, so it can directly accept the original Celestron eyepiece projection tube. The original C90 camera adapter was a short machined part about 3 cm long that had T-threads on the back.

A C90 camera adapter with rotating T-threads was introduced in the early to mid 1980's, but the front end of some of these attached via only a press fit to the back, and some of these separated with changing temperatures. Meade then came out with a compatible adapter that used threads throughout, and it inspired more confidence.

The C90 has a primary baffle tube that does not extend very far in front of the primary mirror. At the front of this baffle tube, a flat ring that blocks some of the stray light that can get past edges of the secondary baffle on the back of the Maksutov corrector. Unfortunately, this is *not* an optimized baffle design, and stray light entering around the secondary baffle can flood the edges of the 35 mm camera format when taking pictures. In addition, stray light reflected from the relatively smooth inside surface of the primary baffle tube causes obvious flare terrestrial photos. This was intolerable.

Since I had a background with some camera repair experience by the time I acquired my C90, I decided to get into the telescope and modify the primary light baffle. I extended the baffle forward by adding a conical section about 2.5 cm long that was made from sheet metal and epoxy, then painted black. I also added a baffle stop ring behind the original stop. The latter stop complicated using the Barlow lens, but it paid off in performance. The modifications greatly reduced flare in my C90. While I was at it, I tapped some holes in the C90 barrel that could be used to adapt it to a Quantum 4 motor base.

Planetary images from the C90 just never seemed to cut it, and the sloppy C90 focus amplified camera shake in photos. I improved on the latter by adding a focus lock screw, but locking focus before every photo is not very convenient. But planetary image quality obviously stayed the same. I eventually sold both the C90 and the Quantum 4 motor base and got a used Questar 3.5.

I've since seen other C90 samples. All have about the same amount of spherical aberration as the one I used to own, but some lad less astigmatism. Only one had no visible astigmatism at all.

4.5.1) Possible Historical Significance of the Celestron 90

I have often wondered if introduction of the C90 might have been a pivotal event in the amateur astronomy industry, in that it may have been Celestron's first *mediocre* telescope. Performance of the C90 is marginal when compared to Celestron SCT's. And only a few years after the C90 came out, other telescope makers successfully marketed telescopes of similar size.

After the high quality Ad Astra III telescope went off the market only a few years after the C90 was introduced, a vacuum was created in the domestic small telescope market. There were no *affordable* small domestic Cassegrain telescopes on the market other than the C90, and the Russian (then Soviet Union) MTO scopes were not very common. It was not long before other manufacturers took advantage of this vacuum and began to introduce small Cass. telescopes.

It was an unusual market situation, because the C90 didn't even set the bar high enough to require that other manufacturers provide *good image quality*. Instead, even a telescope with the *same* optical performance as a C90, but *without* the extreme image shift, would be satisfactory for many customers.

Both Criterion (then associated with the Bausch & Lomb name) and Meade introduced 10 cm SCT's, and Meade also introduced 8 cm and 9 cm Cassegrain telescopes. In this situation, and following a few later product gaffes, Celestron gradually lost market share, Meade expanded, and the rest is history.

4.6) Meade ETX-90 Maksutov-Cassegrain Telescope OTA (9.0 cm f/14.4)

Specifications (measured values in mm are shown instead of published spec's, when different):

Aper.Spec	f/Ratio	FL	Aper.Act.	C. Obs	Obs%	Width	Height	Length	Weight	Notes
90.0 mm	f/14.4	1300	87.0 mm	32 mm	37%	110	136	283	1271 g	

Image Quality (measured, UHTC version, no S/N)

C. Resol.	E. Resol.	Contrast	Flare	Bloom	Ghost	CamShake	Notes
Excellent	Good	Good	Good	Fair	Good	Poor	Plastic Tripod Mt.

Summary:

*** Build Quality / Materials: 3** / Tube and front cell are metal, but a good deal of back is plastic.
*** Optical Quality / Details: 4** / Some minor axial aberrations, significant off-axis aberrations.
Summary Notes:
* Build is a 3 because the secondary baffle limits the aperture to 87 mm, and plastic is used for important parts including tripod mount support structure; focus threads (might) also be plastic.
* Optical quality is shown as a 4 rather than a 5 because of residual aberrations that may result in part from the primary baffle tube not being parallel with the axis of the telescope tube.
*** Pluses:** Compact size, light weight,. close minimum focus distance, built-in low profile flip mirror with 1.25" eyepiece holder and camera adapter interface, low profile finder scope.
*** Minuses:** Primary baffle tube is not parallel with tube axis (oval obstruction), secondary baffle clips aperture to 87 mm, plastic tripod mount structure is too unstable for photography without camera shake, lower front of flip mirror housing is open and admits light / contaminants, no S/N.

The Meade ETX-90 Maksutov-Cassegrain telescope has a metal front cell, a thin wall metal tube, a plastic rear cell, and a plastic flip mirror box with a metal eyepiece holder and camera adapter interface. The slightly larger ETX 105 is of similar construction, except that it has a metal rear cell in front of its plastic flip mirror housing. The plastic flip mirror housing on both includes the tripod socket, and the resulting flex in the plastic makes the telescope susceptible to excessive vibration when using a camera with a mechanical shutter.

The ETX-90 is the first of what could be called Meade's optically "good" telescopes. Unlike the earliest Meade SCT's, every Meade ETX series Maksutov-Cassegrain telescope I encountered has had good optics. The Meade ETX-90 provides considerably more resolution than the f/11 version of the Celestron 90 Mak-Cass, but does not quite equal a Questar 3.5.

The ETX-90 may have compared more favorably to the Questar 3.5 if it was not for the fact that the inside diameter of the ETX-90 secondary light baffle is too small, so it effectively clips the working aperture to about 87 mm. The Sky Watcher 180 review herein covers this particular light baffle design flaw in detail. The ETX 105 has a similar, but lesser, secondary baffle flaw.

Meade made other Mak-Cass telescopes of similar aperture and f/ratio, but different mechanical characteristics. Most of these optically perform about as well as an ETX-90, but one model has a secondary baffle that clips its aperture to about 82 mm, which is more clipping than in the ETX.

4.7) Nikon 1000 mm f/11 Reflex Nikkor-C Mirror Lens (used as a telescope).

Specifications (measured values in mm are shown instead of published spec's, when different):

Aper.Spec	f/Ratio	FL	Aper.Act.	C. Obs	Obs%	Width	Height	Length	Weight	Notes
90.9 mm	f/11.0	1000	101.0 mm	46 mm	46%	136	130	235	1930 g	39fw

Image Quality (measured) Thresholds for:

Make	Model	Serial No.	ShVid	ShAx	Sh34	FAFm	FA34	UseAt	Cont/F	Notes 1
Nikon	Reflex	140017	OKvid	11.0	11.0	53perc	60perc	11.0	VG	SltTriangSpot

C. Resol.	E. Resol.	Contrast	Flare	Bloom	Ghost	CamShake	Notes
V Good	V Good	V Good	V Good	Fair	Good	Fair-Poor	101mm CA; RFiltW

Summary:
*** Build Quality / Materials: 4+** / Almost all parts except the optics are metal; precision feel.
*** Optical Quality / Details: 3+** / Star images have slight asymmetrical triangular shape..
Summary Notes:
* Build is a 4+ vs 5 because triangular star images indicate possible optical component stress.
* Optical quality is 3+ due to slightly triangular star images, but planetary detail is still visible.
*** Pluses:** Reasonably good image quality in spite of odd shaped star images, measured aperture exceeds specified aperture by 10 percent, central obstruction size comparable to that of some small telescopes, reasonable focus damping, built-in 39 mm filter wheel, compact for capability.
*** Minuses:** Asymmetrical star images, residual aberrations limit planetary performance.

The Nikon 1,000 mm f/11 Reflex Nikkor-C is a mirror lens that I hoped would work well as a telescope. As has been the case ever since online retailers put most *walk-in camera stores* out of business, the only way to get access to a lens to try it out is to buy it or rent it. In the day of walk in camera stores, one could just go to a larger camera store and inspect a lens in person. This made it possible to zero in on the best lens before buying even one of them, then to only buy the lens that was best suited to what it would be used for. Sadly, the days when walk-in camera stores (and many other types of brick and mortar stores) are long gone. But the online retailers that put camera stores out of business are not the ones who get my money now. Most reviewed lenses were acquired from individuals who sold their own equipment on eBay, not from dealers.

The 1,000 mm f/11 Reflex Nikkor-C lens has a build quality that most telescope manufacturers (except Questar and a few others) can only dream of. It has the fine finish of any Nikkor camera lens, and includes a built-in 4-position filter wheel. Filters in the wheel are: L37 (UV), Yellow 48, Orange 56, and Red 60. The camera mount rotates 90 degrees, with detents at both positions.

As a visual telescope, the 1,000 mm Nikkor is very good at low to medium magnifications, but struggles to pull in much fine planetary detail. It has better planetary images than Cassegrain telescopes of similar or smaller aperture that are imported from China, but that isn't saying much. Flare was consistent enough that the Nikkor may be useful for total solar eclipse images. It provides outstanding images of the moon, though there is some flare around a crescent moon if it is overexposed enough to reveal earthshine on the part that is not directly illuminated by the sun.

4.8) Vernonscope 94 mm f/7 Triplet Refractor Telescope (9.4 cm f/6.9)

Specifications (measured values in mm are shown instead of published spec's, when different):
Aper.Spec / f/Ratio / FL / Aper.Act. / C. Obs / Obs% / Width / Height / Length / Weight / Notes
94.0 mm / f/7.0 / 644 / 93.0 mm / None / -0- / 123 / 130 / 521 / 4404 g / w/rng.

Image Quality (measured; no S/N)
C. Resol. / E. Resol. / Contrast / Flare / Bloom / Ghost / CamShake / Notes (Slt Fld Curv)
Excellent / V Good / V Good / V Good / V Good / Excel / Excel. / Added Iris Dia.

Summary:
*** Build Quality / Materials: 4** / All parts except optics are metal. Has a Unitron 2" focuser!
*** Optical Quality / Details: 4-** / Slight residual spherical aberration, and possibly some wedge.
Summary Notes:
* Build is a 4 because .. TBD
* Optical quality is shown as a 4 because .. TBD
*** Pluses:** Moderately compact size (very compact after I modified it), draw tube in Unitron 2" focuser provides a wide range of back focus distances and very close minimum focus distance.
*** Minuses:** No AR coatings on rear surface of objective, some glow around bright objects, some asymmetrical false color, heavier than average, no sliding dew shield (until I added one), no S/N.

This mini-review of the Vernonscope 94 mm refractor will cover some aspects of two versions.
* The first is the more common original version, and
* The second is the lightweight (or "LW") version.

The main differences between the original and the LW versions included the thickness of the cemented triplet objective lens, the type of objective lens cell, and the type of rings used.

A light baffle just forward of the center of the tube limits the axial aperture to about 93 mm. A Vernonscope 92 mm telescope had been on the market just prior to the 94 mm, so it is possible the same tube was used for both. The 92 mm had a white tube, while the 94 mm has a blue tube. The baffle was fixed when I made other modifications to the OTA, as noted later in this review.

The original version of the 94 mm has a thick lens, a lens cell with collimation adjustment, and conventional tube mounting rings. The LW version uses an objective lens that is about 3 mm thinner, and a cell that has no collimation adjustment. The LW uses a clamshell type tube ring. Optically, there were obvious differences between the two samples I used. The LW objective I had showed obvious spherical aberration unless stopped down to an aperture of about 80 mm.

My own version of the Vernonscope 94 mm is unusual, in that it is a LW tube assembly that I modified to use the thicker objective lens from the original version. This came about because the thin lens in my LW did not have acceptable planetary image quality unless stopped down, and Vernonscope informed me that this was not supposed to be the case. I was a Vernonscope dealer when I ordered the LW94, but ceased to work in that capacity after moving a short time later.

By the time I received my LW 94 and evaluated its performance, Vernonscope had no other LW objectives left, but they did have one of the original objectives in which the back surface of the rear element had been re-figured a little after it had been coated and cemented. This meant that there were no AR coatings on the rear surface of the objective lens group, but it was a normal objective in other respects. And it didn't have the spherical aberration my LW objective had.

At the time, I could still use machine tools, so it was no problem to modify the front cell of the LW tube to accept the thicker lens. The lens was not quite collimated when placed in the non-adjustable front cell of the LW 94, but collimation was quickly achieved by removing the front cell and filing a slight angle onto the front of the outer tube, then re-installing the lens cell. The rotational orientation of the lens obviously needed to be maintained from then on. The image was not quite a textbook Airy pattern, possibly due in part to why the lens had been re-figured.

I also modified my Vernonscope to have a little more back focus, a sliding dew shield, and an iris diaphram that is adjustable between f/7 and f/32, with click stops at every full f/stop. This makes it practical for use as a long FL camera lens, though it is a bit heavy compared to a tele camera lens. The tube was shortened to 483 mm for air travel prior to 1991 total solar eclipse in Mexico.

Image quality of the full thickness lens of the original 94 mm (and my hybrid version) is very good for its day, but it is not quite as good as a diffraction limited f/15 achromatic objective lens of the same aperture. It has less false color, but does not quite have the fine detail of an f/15.

The Vernonscope 94 mm objective lens (as other lenses made by Astro Physics at the time) is not a true apochromat. This is partly because two of the elements are not made of glass that differs enough to cause 3 colors to come to a common focus. (Doing this is the definition of an APO.)

Instead, the 94 mm objective brings only two colors to a common focus. However, instead of being corrected to bring C and F (blue and red) colors to a common focus, the lens is designed to bring a blue-violet color and red to a common focus. In addition, the glass used results in significantly less difference between the common blue-violet and red focus, and the differing green focus, than would be the case for a simple two element achromatic lens.

Since blue-violet is brought to about the same focus as red, violet light is closer to being in focus than is the case for a C-F corrected objective. Combined with the above glass characteristics, this results in a smaller violet glow around bright light sources, particularly in photographs.

Visually, blue-violet and red being at a common focus does not offer as much of an advantage. This is because the human eye is about equally sensitive to C and F light, but it is less sensitive to blue-violet light than it is to red light. This results in slight visible red fringing on some subjects.

However, as a whole, the triplet lens provides better color correction than that of a conventional doublet. It would be interesting to see what a visual image would be like in such a triplet that is optimized to bring C and F light to a common focus. It may not do as well for photos, but it might have a slight edge visually, in that it might replace the relatively bright visible red fringing with a dimmer violet fringe that has far less extent than fringing from a conventional doublet.

5.) Telescopes (and Camera Lenses Used as Telescopes) from 10.0-11.9 cm Aperture

[Figure 5A]

Figure 5A. Some *refracting* telescopes and camera lenses reviewed in this chapter. Left to right:
* Tokina 800 mm f/8 *telephoto* lens
* Vivitar 800 mm f/8 “stovepipe” lens
* Edmund 101.6 mm f/15 telescope objective with cell. (Objective and cell are at front of long piece of aluminum irrigation pipe shown at the extreme right of this circa 1981 photo.)

[Figure 5B]

Figure 5B. Some *reflecting* telescopes and mirror lenses reviewed in this chapter. Left to right:
* Nikon 500 mm f/5.0 Reflex Nikkor mirror lens
* Meade 2045 LX3 102 mm f/10 Schmidt-Cassegrain telescope
* Meade ETX 105 mm f/14 Maksutov-Cassegrain telescope

5.1) Nikon 500 mm f/5.0 Reflex Nikkor Mirror Lens (used as an astrograqph)

Specifications (measured values in mm are shown instead of published spec's, when different):

Aper.Spec	f/Ratio	FL	Aper.Act.	C. Obs	Obs%	Width	Height	Length	Weight	Notes
100.0 mm	f/5.0	500	111.0 mm	60 mm	54%	125	136	190	1725 g	w/35hd

Image Quality (measured) Thresholds for:

Make	Model	Serial No.	ShVid	ShAx	Sh34	FAFm	FA34	UseAt	Cont/F	Notes 1
Nikon	Reflex	182863	MedV	5.0	5.0	65perc	75perc	5.0	Good	SphAb5arcsec

C. Resol.	E. Resol.	Contrast	Flare	Bloom	Ghost	CamShake	Notes
Fair	Fair	Excel	Good	Poor	Fair	Good	116mm CA, 35 hood

Summary:
*** Build Quality / Materials: 4+** / Almost all components except optics are made of metal.
*** Optical Quality / Details: 4-** / Reasonable resolution; minimal vignetting, some uneven flare.
Summary Notes:
* Build is 4+ instead of 5 only because there is no focus lock and the central obstruction is large.
* Optical quality is 4- due to some spherical aberration, and flare is too uneven for a Total Sol E.
*** Pluses:** Good image quality vs size and weight, no false color, rear 39 mm filters, solid feel, solid tripod mount. (Very small and light compared to gigantic 500 mm f/4 Sigma mirror lens!)
*** Minuses:** Some spherical aberration, uneven flare could adversely affect eclipse images.

The 500 mm f/5 Reflex Nikkor mirror lens is one of the few relatively fast lenses of 500 mm or longer focal length that is light enough to successfully use on a portable star tracker rather than a telescope mount. It is the first lens of more than 300 mm focal length that I successfully used for unguided "deep sky" photos from within a major city. A few sample images are at this link: http://www.eclipsechaser.com/eclink/image/strtlt11.htm

The 500 mm f/5 Nikkor was never intended to be a telescope. And it was never intended to be used with small format digital cameras, since none of these existed when the lens was made. Nonetheless, the 500 mm f/5 Reflex Nikkor lens works adequately for lunar imaging. It does not produce very good planetary images because it has enough spherical aberration that dimmer parts of a star image from it can approach 5 arc seconds in width. This corresponds to 40 lines per millimeter, which is not bad for a lens designed decades ago, mainly for use with high speed film. On Micro 4/3 and larger format digital cameras, the Nikkor produces reasonably good astro photos, and it can resolve objects such as the ring nebula in relatively short 1 minute exposures.

For terrestrial use, the contrast is a bit low. Unlike many mirror lenses, focusing is via a helical focuser at the back, so the minimum focus distance is 15 meters. I was going to sell my 500 mm f/5 lens because I now use a lighter Tamron 500 mm f/8 more.

However, I kept the Nikkor because it may not sell for very much due to it having had a slight amount of fungus etching on the primary coating since even before I acquired it. This problem has not gotten worse because I think I got all the fungus cleaned off.

5.2) Soligor/Vivitar 800 mm f/8 "Stovepipe" Lens (10.0 cm f/8, used as telescope)

Specifications (measured values in mm are shown instead of published spec's, when different):

Aper.Spec	f/Ratio	FL	Aper.Act.	C. Obs	Obs%	Width	Height	Length	Weight	Notes
100.0 mm	f/8.0	800	100.0 mm	None	-0-	110	120	812	3180 g	

Image Quality (measured) Thresholds for:

Make	Model	Serial No.	ShVid	ShAx	Sh34	FAFm	FA34	UseAt	Cont/F	Notes 1
Vivitar	Long	10991	15	9.0	10	11	10	9.0	Exc.	Best Sample

C. Resol.	E. Resol.	Contrast	Flare	Bloom	Ghost	CamShake	Notes
VG-Excel	Good	Excel	V Good	V Good	Excel	V Good	Dif. Ltd. f/13~22**

Summary:
*** Build Quality / Materials: 4-** / All components except the optics are metal, light weight.
*** Optical Quality / Details: 3** / Spherical aberration, off-axis aberrations, but good color sat.
Summary Notes:
* Build is a 4- because the delicate iris mechanism is typical for lenses in this price range, and because the threads used to assemble the lens are fine enough that they are easy to cross thread.
* Optical quality is a 3 for astronomical applications because the image is a little soft at full aperture, but becomes diffraction limited by f/13 to f/22,** depending on the sample. However, for terrestrial use, performance at maximum aperture is adequate and color saturation is good.
*** Pluses:** Good color saturation, diffraction limited at f/13 (Soligor) to f/15 (Vivitar), lightweight for focal length and aperture, tapered tube reduces volume, (slowly) separates into two parts for transport, rotating tripod mount, has enough back focus to use as telescope, looks cool!
*** Minuses:** Residual spherical aberration limits planetary performance. Vivitar sample has some axial astigmatism, but the Soligor does not. (** Vivitar 10939 is worse.) Off-axis aberrations are an issue for full frame astro photos, but usually not terrestrial photos; iris diaphragm is delicate.

In the 1960's and 1970's, Soligor and Vivitar offered 800 mm f/8 lenses with optics consisting only of a cemented doublet at the front end. This meant that the lenses were not true “telephoto” lenses, in wich negative focal length elements toward the back permit the physical length of the lens to be shorter. Instead, the optical design was similar to that of an achromatic telescope. As a result, the physical length of the lens is about the same as the focal length. Many call these “stovepipe” lenses, because their long and tapered barrels look a lot like a stovepipe.

While the mechanical components appear to be identical in all respects except for the type of grip on the focus ring (Soligor has scallops, Vivitar has knurling) there is a wide variation in the optical quality between brands, and between samples within the Vivitar brand. In the 1970's, I was partial to Soligor lenses. This is because, even though photography magazine tests showed that Vivitar lenses were slightly sharper than Soligor versions of the exact same lens, my own experience was exactly the opposite, in that I found that Soligor lenses had better optical quality. A notable exception is that Vivitar made a stunning, though large, 20 mm wide angle that (unlike most of their other lenses) was not of the same optical design as the closest Soligor equivalent.

This review covers three different samples of the Soligor and Vivitar 800 mm "stovepipe" lenses. The table below compares these to the "telephoto" versions of the Vivitar and Tokina 800 mm lenses. In all, this chapter considers five different 800 mm f/8 T-mount preset lens samples.

* Soligor 800 mm f/8, SN 9690336, an 800 mm "Stovepipe" lens.
* Vivitar 800 mm f/8, SN 10991, an 800 mm "Stovepipe" lens.
* Vivitar 800 mm f/8, SN 10939, an 800 mm "Stovepipe" lens.
* Tokina 800 mm f/8, SN 8200506, an 800 mm "Telephoto" lens.
* Vivitar 800 mm f/8, SN 379000933, an 800 mm "Telephoto" lens.

Performance threshold data for all five lenses is compared here. None of them are diffraction limited at maximum aperture. The diffraction limited aperture is in the "ShVid" column.

Make	Model	Serial No.	ShVid	ShAx	Sh34	FAFm	FA34	UseAt	Cont/F	Notes 1
Soligor	Long	9690336	13	8.0	10	11	10	8.0	E	Sharpest Samp
Vivitar	Long	10991	15	9.0	10	11	10	9.0	Exc.	MinimalVig
Vivitar	Long	10939	22	19	20	11	10	19.0	VG	TriangStarImg
Tokina	Tele	8200506	16	11	11	11	10	16	V	RVGrnAstLca
Vivitar	Tele	379000933	18	13	13	11	10	16	V	RVGrnAstLca

A Soligor 800 mm f/8 lens was my first "good" telescope. It was not diffraction limited at full aperture, but neither was the 6 cm f/11.6 Jason refractor that my brother and I had shared in our youth. A few months before getting the 800 mm Soligor, I had acquired a used Tasco 7.5 cm f/12 Newtonian reflector. It was not bad even on planets, but its aperture size was limiting.

The 800 mm Soligor has almost twice the aperture area of the Tasco 7.5 cm, and I could use it at low magnifications. Using a telescope of 10 cm aperture telescope at low magnification is not something I'd been able to do before. I was impressed by views in the 15x to 25x range. I also used the 800 mm to view planets at 89x and 133x, but it did not become diffraction limited unless stopped down to about 60 mm, so its planetary views were similar to those of the Tasco.

The Soligor 800 mm f/8 lens is also outstanding for wildlife photography, even at full aperture. This was in the days of film photography. For modern digital photography, the 800 mm does better if stopped down to just past f/10. This cuts down on false color and increases resolution.

In the early 1990's, I sold my 800 mm lens to my brother to help finance getting a Veronscope 94 mm refractor. The Vernonscope was sharper, but it lacked the contrast and color saturation of the Soligor 800 mm lens when used for wildlife photography.

In the early years of the 21st century, I was able to again afford an 800 mm lens. I could not find the Soligor anywhere, but found a Vivitar version (SN 10991) on eBay. When I used the Vivitar for visual observation, it did not impress me as the Soligor lens had, and it had to be stopped down to f/15 (rather than f/13) for diffraction limited performance. The Vivitar had slight astigmatism, while the Soligor did not. This was confirmed later, when my brother and I used both lenses in side by side comparisons.

Up to the point I acquired the Vivitar 800 mm lens (SN 10991), I had not seen any truly “bad” samples of the 800 mm “stovepipe” lenses from Soligor or Vivitar. But that changed when I bought a *second* Vivitar 800 mm lens in 2018, to use as a backup and maybe a loaner. The second Vivitar 800 mm (SN 10939) was on a different, and much lower, plane than the others.

The second Vivitar 800 mm lens has a 7 mm long row of 0.5 mm diameter air bubbles in the balsam between the elements. (This defect was not disclosed by the seller.) The bubbles are located about 20 mm from one edge, and there is no separation of the balsam around them A defect like this can *only* happen at the time of manufacture, and it is not the same as “separation”.

At full aperture, the second Vivitar lens also produced *triangular* star images almost 20 arc seconds across, with the brightest part being in one corner. The triangular shape gets smaller as the lens is stopped down, but the lens does not provide a diffraction limited image until stopped down to between f/20 and f/22.

The brightest part of the image is considerably brighter than the triangular artifact even at wide apertures, and the defect may not be obvious in terrestrial photos. However, it is obvious in star images. Loosening the lens retaining ring did not help, so it is *not* a case of “pinched” optics. Seeing this sample is why it is noted that thee can be a *wide* variation between different samples.

But, a *good* sample of an 800 mm stovepipe lens is a “keeper” that may be useful for a lifetime.

Details for the modular “telephoto” version of the Vivitar 800 mm ff/8 lens are covered next. A Tokina branded sample of the same telephoto lens was also tested.

5.3) Tokina/Vivitar 800 mm f/8 "Telephoto" Lens (10.0 cm f/8, used as telescope)

Specifications (measured values in mm are shown instead of published spec's, when different):

Aper.Spec	f/Ratio	FL	Aper.Act.	C. Obs	Obs%	Width	Height	Length	Weight	Notes
100.0 mm	f/8.0	800	100.0 mm	None	-0-	116	130	571	2315 g	

Image Quality (measured) Thresholds for:

Make	Model	Serial No.	ShVid	ShAx	Sh34	FAFm	FA34	UseAt	Cont/F	Notes 1
Tokina	Tele	8200506	16	11	11	11	10	16	V	RVGrnAstLca
Vivitar	Tele	379000933	18	13	13	11	10	16	V	RVGrnAstLca

C. Resol.	E. Resol.	Contrast	Flare	Bloom	Ghost	CamShake	Notes
Fair	Fair	Fair	Good	Poor	Fair	V Good	Dif. Ltd. at f/16

The telephoto versions of the 800 mm f/8 lenses can be more easily separated into two parts than is the case for the "stovepipe" version,, for easier transport. A threaded ring holds the two main parts of the lens together, not too unlike the ring for the Vivitar 600 mm modular lens covered in an earlier chapter. Like the 600 mm version, the telephoto 800 mm lenses have built-in sights. Build quality is similar to, and maybe even a little better than, the 800 mm "stovepipe" lenses.

The assembled length of the 800 mm telephoto lens is considerably shorter than the "stovepipe" version, with the length being 571 mm (22.5") rather than 812 mm (32"). The optical design of the telephoto version is 4 elements in 4 groups, so there is no balsam between any of the elements. The appearance of the telephoto version is more refined (but less impressive) than the stovepipe. Both samples have minor coating defects on the front surface of the rear element.

Unfortunately, the optical design of the 800 mm telephoto lens is flawed, because red is brought to a significantly different focus than green and blue, resulting in obvious red fringing. The fringing would probably be visible even in film images at full aperture, but would be reduced enough for film by f/11. However, for digital, the lens has to be stopped down to f/16 (Tokina) to f/19 (Vivitar) to provide a digital image without obvious color fringing. The Vivitar has to be stopped down more than the Tokina because it has more on-axis astigmatism than the Tokina version of the same lens. Inspection of elements in the Vivitar lens show that the astigmatism is only in one element, so it does not help to rotate one element with respect to another.

When the 800 mm telephoto lenses are compared to the best two out of three 800 mm *stovepipe* lenses, the stovepipe versions are *clearly* better. And the difference is in the *optical design*, in that the telephoto version is not designed as well as the stovepipe version. This means that the telephoto versions may have less variation between samples (since none of them are very good). However, the third stovepipe lens (Vivitar SN 10939) is inferior to the 800 mm telephoto lenses, which shows that there can be a wide variation between samples of the stovepipe version.

The telephoto version of the 800 mm lens works relatively well for wide field observation of stars and deep sky objects, but red fringing will be obvious on the moon even at low to moderate magnifications unless the lens is stopped down to about f/16. The fact that none of the elements are cemented may help the lens better tolerate temperature extremes or rough handling.

5.4) OTI Quantum 4 Mak-Cass Telescope (10.0 cm f/15)

Specifications (measured values in mm are shown instead of published spec's, when different):
Aper.Spec / f/Ratio / FL / Aper.Act. / C. Obs / Obs% / Width / Height / Length / Weight / Notes
100.0 mm / f/15.0 / 1500 / 100.0 mm / 36 mm / 36% / 131 / 121 dia / 360e / 2950g est /

Image Quality (measured; SN not recorded, but was version with special coatings)
C. Resol. / E. Resol. / Contrast / Flare / Bloom / Ghost / CamShake / Notes
Excellent / V Good / Fair-G / Fair-G / V Good / V Good / V Good / Heavy mount

Summary:
*** Build Quality / Materials: 4+** / Almost all metal except for optics and focus belt, paint so-so.
*** Optical Quality / Details: 5-** / Exit pupil distortion affects some low magnification images..
Summary Notes:
* Build is a 4+ because the primary baffle tube increases the secondary obstruction to 36 percent, and because the blue paint on the tube and mount is not particularly durable. It is also heavy.
* Optical quality is shown as a 5- because the reflection of the primary baffle in the secondary mirror causes longitudinal distortion of the exit pupil with long focal length ($\geq$32 mm) eyepieces.
*** Pluses:** High resolution, mount slow motion controls are well placed for terrestrial viewing, mount bolt pattern fits Celestron 8 wedge.
*** Minuses:** Average to low contrast, exit pupil distortion, eyepiece position cannot be rotated, eyepiece is sideways when used as a spotting scope apart from its mount, friction fit eyepiece holder, non-standard 36 TPI threads used instead of T-threads, heavy for a 10 cm telescope.

The OTI Quantum 4 telescope was a unique product in some ways. It borrowed some attributes from Questar, but went beyond the minimal limitations of a Questar 3.5 in a few specific ways. The basic optical tube assembly is a 10.0 cm aperture, f/15 Maksutov-Cassegrain. One notable difference between it and most other smaller Cassegrain telescopes is that its primary mirror is f/2.5 rather than f/2.0. The slower primary increases the size of the diffraction limited field.

The OTA itself was available as the "Quantum 100", but the most popular version was the "Quantum 4", which has a flip mirror *control box* on the back that also (like Questar) includes a flip-in visual Barlow lens. The Quantum 4 accepts 1.25 inch eyepieces in a friction fit eyepiece holder. The construction is fairly heavy, with the optical tube having a 2.3 mm wall thickness.

The back of the Quantum 4 has threads for a proprietary camera coupling. The camera coupling is specified as having T-thread (42 mm diameter x 0.75 mm pitch thread), but the actual coupling hardware has a 36 TPI pitch thread of a slightly smaller diameter than a true 42 mm T-thread. The back focus required for a camera was long enough that the photo focal length was 1800 mm.

The Quantum 4 was available with or without enhanced coatings. The one I used had enhanced coatings. In spite of only 10 cm of aperture, the Q4 provided good images of many deep sky objects. A dim view of M51 through it with a 16 mm Konig eyepiece is memorable to this day.

The OTI Quantum 4 had some unusual image attributes, and it took some digging to find out why. To this day, I am not absolutely certain of the cause, but I'm reasonably sure about it. The Quantum 4 performed really well at magnifications of 90x or more, including when used with a 16x Konig eyepiece. However, when I used at a low magnification eyepiece such as a 32 mm Brandon, the image took on an odd quality. It was as though my eye was trying to focus on two things at once. Looking at the images also gave an impression of double image that were only separated about the same as the visible threshold of resolution even though I could not actually see two distinct images. It was most pronounced on solar images, when using the OTI solar filter, but it was also visible on other subjects. It also seemed to change a little with eye centering.

The owner of the telescope, my friend the late Louis Lubeski, had the same impression. My vision was 20/10 at the time, and this didn't happen with other scopes. Before I could determine a cause for the odd low magnification image, Lou returned his Quantum 4 telescope to the dealer and bought a Questar 3.5 instead. (He was also fed up with the Q4 polar legs.) Future inspection of the Quantum 4 to find a cause for the odd image attributes then had to happen at the dealer.

My first clue came when I looked into the eyepiece holder when no eyepiece was installed. As I moved my eye side to side, I became aware that the secondary obstruction was not defined by the secondary baffle. Instead, it was defined by the front end of the primary baffle tube, as seen in the reflection from the secondary mirror spot. The reflection of the baffle moved in relation to the outside of the aperture when my eye centering was changed even a little. After this, I put in a 32 mm eyepiece and looked at the sky. As my eye centering changed, there was an impression that a faint but large shadow was moving around in the field. Next, I placed a transparent ruler in front of the telescope and looked at it from the focal plane. This confirmed the likely cause:

The Quantum 4 has a 100 mm aperture, and it is noted for its small 33 mm central obstruction. However, when I looked into it from the back, the transparent ruler in front indicated that the obstruction is really 36 mm, and that the front end of the primary baffle tube causes the enlarged obstruction. Its reflection in the secondary occupies more of the aperture width than is the case for the secondary baffle, so the latter isn't visible. This causes some longitudinal distortion in the exit pupil, since the image of the aperture is not on the same plane in the pupil as the image of the central obstruction. This would be hard to notice when the exit pupil is small, but when the size of the telescope is small and focal length if the eyepiece is long, the longitudinal distance between features in the exit pupil is larger. The Quantum 6 does not share this minor flaw.

The Quantum 4 single arm fork mount and motor base was one of my favorite gadgets. The OTA can be detached from it without tools, and the single arm design provides a versatile platform for various cameras or astrographs for astrophotography. I even used a 4"x5" film camera on it once. After my friend returned his Quantum 4, I bought the Quantum 4 motor base from the dealer. I could not afford a Quantum 4 OTA at the time, so I adapted my C90 to the mount.

Tracking accuracy of the Q4 mount is not all that good due to a spur gear drive, but for terrestrial or other alt-azimuth use, it has no equal. The single fork arm design permits the azimuth slow motion control to be on the left side of the mount, so your hands just fall into place on the slow motion knobs. It is somewhat less optimized an equatorial mount, but it is still workable. The mount is relatively heavy, but it has the same mounting bolt pattern as a Celestron 8 motor base.

5.5) Bausch & Lomb Criterion 4000 Schmidt-Cassegrain (SCT) Telescope (10 cm f/12)

Specifications (measured values in mm are shown instead of published spec's, when different):
Aper.Spec / f/Ratio / FL / Aper.Act. / C. Obs / Obs% / Width / Height / Length / Weight / Notes
101.6 mm / f/12.0 / 1200 / 101.6 mm / 35 mm / 34% / 120est / 130est / 305est / 950g est /

Image Quality (measured; SN's not recorded)
C. Resol. / E. Resol. / Contrast / Flare / Bloom / Ghost / CamShake / Notes
Fair-Good / Fair / Fair / Fair / Good / Good / Good / All metal tube

Summary:
*** Build Quality / Materials: 3** / Almost all parts except optics are metal, but is some inaccuracy.
*** Optical Quality / Details: 3-** / Wide variation between samples; but not as wide as for Meade.
Summary Notes:
* Build is a 3 because several finishing touches (such as dress nuts vs hex nuts) were omitted.
* Optical quality is a 3- due to a wide variation between samples, and many are only fair to good.
*** Pluses:** Compact size, lighter than other Cassegrain telescopes of similar or slightly smaller aperture (not counting Questar), small secondary obstruction (for a small f/12 Cassegrain), close minimum focus distance, comes with diagonal and at least one eyepiece, moderate price, samples I have seen in person have good lunar and terrestrial images, reasonable deep sky and planetary.
*** Minuses:** Wide variation in optical quality between samples, does not use standard SCT rear threads, requires dedicated low profile diagonal to access polar declinations if used on its mount; fork mount polar shaft interface is not accurately made and has a lot of play if screw comes loose.

A few years after Celestron introduced the somewhat mediocre C90 Mak-Cass telescope, other manufacturers began offering telescopes in the 10 cm aperture range. Speculation as to why is in the review of the C90 telescope in chapter 4.

The small telescope introduced by Criterion (then associated with the Bausch & Lomb name) is the Criterion 4000, a 101.6 mm f/12 Schmidt-Cassegrain telescope (SCT). The B&L Criterion 4000 is unusual for an SCT, in that it is f/12 rather than f/10. When used as a camera lens, this gives it almost as much "reach" as a Celestron 5, but the Criterion 4000 has a smaller size (due in part to having 25 mm less aperture), lighter weight, and lower price. An f/12 design also permits use a smaller secondary mirror, resulting in a smaller secondary obstruction.

The Criterion OTA proved to be comparatively light. At the time, it was the only 100 mm aperture OTA that was light enough to be practical for most people to bring along on a hike. (The Meade 10 cm f/10 SCT was a great deal heavier.) Performance of the Criterion 4000 is average. Images from are better than a C90, but there is considerable variation between samples.

Less than admirable attributes of the Criterion 4000 include a fit and finish that is not quite up to par with the Meade 10 cm. For example, an ordinary hex nut is visible between the focus knob and the optical tube. The corrector lens is also fairly thin and delicate, though it might not be any thinner than a C5 corrector. The Criterion 4000 can be used for deep sky observing. It provided visual images of M51 and M57 that were as good as most other telescopes of similar aperture.

5.6) Edmund 10.16 cm f/15 doublet refractor (vintage telescope objective lens)

Specifications (measured values in mm are shown instead of published spec's, when different):
Aper.Spec / f/Ratio / FL / Aper.Act. / C. Obs / Obs% / Width / Height / Length / Weight / Notes
101.6 mm / f/15.0 / 1524 / 101.6 mm / None / -0- / 114 / 114 / 1416 / 4500g est /

Image Quality (measured; no S/N)
C. Resol. / E. Resol. / Contrast / Flare / Bloom / Ghost / CamShake / Notes
Excellent / V Good / V Good / Good / V Good / V Good / V Good / Home made tube.

Summary:
*** Build Quality / Materials: 2, 3+** / Kludged to start with, but improved over time (home made)
*** Optical Quality / Details: 5-** / Typical false color for f/15 doublet, but symmetrical images.
Summary Notes:
* Build is a 2, then 3+ because it started out kludged, using only hose clamps to attach the OTA to the mount. But then it was improved on by both myself and others who owned if over time.
* Optical quality is a 5- because even though planetary images have outstanding detail, false color is typical for a 10 cm f/15 refractor, with obvious violet glow around planetary images.
*** Pluses:** Amazing planetary detail for aperture, small diameter tube and pier store under a bed.
*** Minuses:** Medium to low contrast for terrestrial photos, long tube with only 1.25" focuser, tall and relatively heavy pier has some vibration in wind, small 75 mm clock drive gear.

This is a telescope I built myself from various components and aluminum irrigation pipe in 1980. I actually owned it twice, and still wish I had it. The first time I had to sell it was out of financial necessity in the mid 1980's. Years later, it was advertised in the newspaper and I bought it again. While it was owned by others, tube rings and a clock drive were added. After acquiring it again, I made some improvements to the drive. But then, I had to sell it again when I moved from Arizona to California to start a new job. I was at first renting only a room, so there was no place to keep the telescope, so I put it on consignment at "Mr. Telescope", a telescope store in Arizona.

Images from the Edmund 4" f/15 achromatic objective lens have an obvious violet glow around bright objects, but the violet color becomes less obvious with longer periods of observation, since my eye would gradually become less sensitive to it. Visual resolution on planets is outstanding, revealing festoons and other features within Jupiter's belts. Planetary photos through it are OK, but it is obvious that the violet haze lowers contrast a little on photos of small planetary features.

Resolution is also outstanding for terrestrial viewing, but the contrast seems a bit low due to atmospheric haze being compounded by the violet haze from the objective. Contrast in wildlife photos is a bit lower than photos taken with an 800 mm f/8 Soligor camera lens, probably because the air spaced refractor has more air to glass surfaces, and slightly less effective AR coatings. But during "golden hour" shortly before sunset, atmospheric turbulence often settles down and the telescope can really pull in detail on front-lit subjects.

The Vernonscope 94 mm f/7 triplet refractor I have used since then has less false color, but it does not quite seem to have the snap of the f/15 telescope for fine planetary detail.

5.7) Meade 2045 LX-3 Schmidt-Cassegrain Telescope (10.2 cm f/10)

Specifications (measured values in mm are shown instead of published spec's, when different):

Aper.Spec	f/Ratio	FL	Aper.Act.	C. Obs	Obs%	Width	Height	Length	Weight	Notes
102.0 mm	f/10.0	1000	99.0 mm	46 mm	46%	120*	130	264	2200g est	

Image Quality (measured; SN on motor base: 428578)

C. Resol.	E. Resol.	Contrast	Flare	Bloom	Ghost	CamShake	Notes
V. Good	Good	Fair-G	Fair-G	Good	Good	Good	All metal tube

Summary:
*** Build Quality / Materials: 3+** / Almost all components except the optics are metal.
*** Optical Quality / Details: 3+** / Wide variation between samples. Some very good, some bad.
Summary Notes:
* Build is a 3+ because the threaded interface between the front and rear cells and the thin wall tube are very loose, which can lead to loss of collimation if either cell comes partly unscrewed. The secondary obstruction is an unusually large 46 percent.
* Optical quality is only a 3+ because there is a VERY wide variation in the quality of different samples. One sample could not produce a star image smaller than 20 arc seconds, due entirely to spherical aberration, while other samples are diffraction limited. I suspect that, from some error in manufacture, the former had an optical flat instead of a Schmidt corrector. It was the worst telescope I'd ever seen in the 1980's, and held that distinction until I got a Kasai Pico-8 in 2018.
*** Pluses:** Solid build except for fit of front and rear cells to tube, OTA includes tripod thread for use as spotting scope when removed from fork mount, accepts standard SCT accessories, close minimum focus distance, acceptable lunar and terrestrial images, drive operates on 12 Volts DC.
*** Minuses:** Variation in optical quality between samples, relatively heavy for a 10 cm SCT, stiff focuser, large secondary obstruction results in mediocre planetary images, average contrast, low clearance behind rear cell when scope pointed to celestial pole requires dedicated 1.25" diagonal

The Meade 2045 has been available in different versions over the years. The OTA remained relatively unchanged, but the motor base in early models used 115 V AC clock motors. The reviewed LX3 model runs on 12 Volts DC. Weight with the motor base is 6350 g (14 lbs).

The OTA is relatively heavy for a 10 cm SCT, but is lighter than the average Mak of the same aperture. The standard 2"-24 SCT threads on the cast metal rear cell can accept relatively heavy accessories, but the mount gets in the way of larger accessories at high or low declinations. But when used apart from the mount as a spotting scope or telephoto lens, large accessories fit well.

The rear sides of the OTA are threaded for the fork mount interface castings, the top has holes for a finder scope bracket, and the bottom has a tripod interface plate. However, there are no extra holes for accessories such as counterweights or a piggyback camera mount. The focus knob is somewhat stiff and mushy. This is not unusual for Meade SCT's, because these typically don't utilize ball bearings in the focus mechanism in the way that Celestron SCT's do. A Meade 2045 is not a telescope that wows you when you see it, but a good sample can perform reasonably well.

5.8) Meade ETX-105EC Mak-Cass Telescope (10.5 cm f/14, version with UHTC coatings)

Specifications (measured values in mm are shown instead of published spec's, when different):

Aper.Spec	f/Ratio	FL	Aper.Act.	C. Obs	Obs%	Width	Height	Length	Weight	Notes
105 mm	f/14.0	1470	102 mm	34 mm	33%	127	153	340*	2040g est	

Image Quality (measured, UHTC version; no S/N on OTA)

C. Resol.	E. Resol.	Contrast	Flare	Bloom	Ghost	CamShake	Notes
Excellent	Good	V Good	V Good	Fair	Good	Poor	Plastic Tripod Mt.

Summary:
*** Build Quality / Materials: 3+** / Main tube is metal, but other important parts are plastic.
*** Optical Quality / Details: 5-** / Very good planet images, but some asymmetry in Airy pattern.
Summary Notes:
* Build is a 3+ because the PLASTIC flip mirror housing also incorporates the tripod interface, and this makes for very unstable use as a telephoto lens, excessively exaggerating camera shake. The secondary baffle limits the real world aperture to 102 mm at the center of the focal surface.
* Optical quality is shown as a 5- only because there is a little asymmetry in the Airy pattern, in comparison to telescopes such as the Questar 3.5 or the Ad Astra III.
*** Pluses:** Diffraction limited optical performance that provides noticeably more planetary detail than 90 mm telescopes, reasonably compact for its aperture and performance, relatively close minimum focus distance, reasonably small central obstruction, moderately good light baffles.
*** Minuses:** Integral plastic flip mirror box and tripod mount structure flexes too much, lower front of flip mirror housing is open and admits light and contaminants, mount is noisy and takes a long time to align in comparison to manual alignment of an "old school" equatorial fork mount. Poor clearance for camera at moderate to high elevation angles due to mount's large top surface.

The Meade ETX 105 OTA has very good if not excellent optics. However, its benefit cannot be fully utilized because plastic is used in the integral rear flip mirror housing and the tripod mount. The actual tripod threads are brass, but the substrate around the thread inserts is plastic. If the ETX mount is also considered, using the Meade ETX 105 can become downright frustrating.

Use of noisy motorized slewing is required for alignment. This means it should not be set up late at night in the city, since the motors can wake up neighbors. The only practical way to use the it on the mount proved to be manually pointing it as you would if the OTA was on a simple photo tripod. But I got a decent manually tracked image of the ISS by using the scope this way in 2008.

If considering only the OTA *with* its plastic flip mirror box, it still falls short because the tripod mount is not stable, and the lower front of the flip mirror box is open to the elements.

But if the OTA is considered all by itself, maybe with a custom machined metal rear cell and tripod mount, it could be a really good telescope. It has enough more resolution than a Questar that it would be worth hanging on to if it was possible to make a custom metal back end for it. Unlike the ETX 90 and 125 OTA's, the ETX 105 was not widely sold as a spotting scope. Too had, since this would make it possible to better utilize what *could* be a good 105 Mak-Cass OTA.

6.) Telescopes of 12.0 cm and Larger Aperture:

[Fig. 6A]

Figure 6A. Some of the domestic and Russian telescopes reviewed in this and other sections. The left three were made in the USA, and the right one was made in Russia. From left to right:
* Questar 3.5 Maksutov-Cassegrain (shown for size comparison; reviewed in chapter 4)
* Celestron 5, a 127 mm f/10 Schmidt-Cassegrain telescope (reviewed in this chapter)
* Celestron 8, a 203 mm f/10 Schmidt-Cassegrain telescope
* Intes MN56, a 127 mm f/6Maksutov-Newtonian telescope

Figure 6B. Some of the *imported* telescopes reviewed in this and other sections. Most of these did *not* do as well as vintage domestic or Russian telescopes. Left to right, these telescopes are:
* Kasai Pico-8 (reviewed in chapter 3 with other small telescopes; covered further in Apndx. A).
* Mystery Mak, a 13 cm f/15.4 Maksutov-Cassegrain with no brand name. This telescope *had* amazingly poor light baffles. These were improved on before the telescope was worth using.
* Astro-Tech AT6RC, a 15.2 cm f/9 astrograph. This was the best of the bunch in some ways.
* Sky Watcher 18 cm f/15 Maksutov-Cassegrain telescope. A nice looking telescope that (sadly) has two types of light baffle design errors that limit its performance, though not too severely.

6.1) Celestron 5 Schmidt-Cassegrain (SCT) Telescope (12.7 cm f/10)

Specifications (measured values in mm are shown instead of published spec's, when different):
Aper.Spec / f/Ratio / FL / Aper.Act. / C. Obs / Obs% / Width / Height / Length / Weight / Notes
127.0 mm / f/10.0 / 1250 / 126.0 mm / 53 mm / 42% / 146 / 159 / 305 / 1700 g / w/o fndr

Image Quality (measured; SN 500956)
C. Resol. / E. Resol. / Contrast / Flare / Bloom / Ghost / CamShake / Notes
Excellent / Good / Good / Good / V Good / Good / Good-VG / Some FX vig.

Summary:
*** Build Quality / Materials: 3+** / Significant play in mount's lower right ascension bushing..
*** Optical Quality / Details: 4-** / Some astigmatism in tested sample (but it was tampered with).
Summary Notes:
* Build is a 3+ because the secondary baffle is a relatively large 42 percent, the fork mount motor base has visible play in the lower right ascension bushing, and because the fork base is retained on the polar shaft only by an E-ring, which has some vertical play. The OTA itself would be a 4.
* Optical quality is shown as a 4- because there is some astigmatism. Caveat: *But the test sample had been tampered with*, and looked almost like it had been in muddy water. Took 2 days to fix it, including restoring acceptable rotational and centering orientations of secondary and corrector.
*** Pluses:** Lightweight (1700 g OTA, 5900 g with mount), optical quality in test sample supports over 300x magnification, focus knob turns easily (less vibration when focusing), baffles effective even when pointed within 10-20 degrees of the sun, close 3.7 meter minimum focus distance.
*** Minuses:** Motor base diameter is large compared to telescope, astigmatism (*see caveat*), large central obstruction (but effective baffling), telescope is back heavy even with 1.25" diagonal.

The Celestron 5 (a.k.a. C5) has been available in many versions. This review is limited to the 12.7 cm f/10 Schmidt Cassegrain telescope that was made when most Celestron telescopes still had the orange and light brown color scheme.

The Celestron 5 OTA.. (...) TBD

As for the entire telescope with fork mount: The original version of the C5 had a very compact motor base with an outer diameter of only about 18 cm. This made the entire telescope more portable, because the original C5 could fit in a fairly slim case, even a "carry on" size case.

Later, the diameter of the C5 motor base was increased to be the same size as the C8 motor base, since this allowed it to share the same mounting bolt pattern as the C8. The problem with this arrangement was that this made the C5 "thicker" in one dimension, which made it a little less portable. This all but ruled out the C5 comfortably fitting carry on luggage. It also complicated using a smaller tripod with the C5, and this reduced portability of the C5 compared to the C8.

Later, when Celestron introduced the C90 Astro model, its base had a small (~18 cm) diameter similar to the original C5 motor base. But the C90 wasn't very sharp, and Celestron never took advantage of the small C90 motor base size and bolt pattern by going back to the original smaller

C5 motor base size. If this had been done, the C5 could potentially have been used on a compact tripod, just like a C90. Leaving the C5 with a large motor base size left the market without an affordable, truly portable quality telescope in the 9 to 13 cm aperture range. This opened the door for Meade and Criterion (by then B&L) to introduce telescopes in the 10 cm aperture range.

But apart from the motor base, the C5 OTA is small and light enough that it is practical to use it on a tripod as small as a Gitzo Studex, and (for visual) on a tripod head as small as the Gitzo R3.

In the early years, a separate tripod adapter was required to use early versions of the *orange* C5 OTA on a tripod. Even in the late 1970's, the *orange* version of the C5 was only available as an astronomical telescope with the (larger) fork mount motor base.

Back then, if one wanted a Celesctron 5 OTA by itself, the only option was a black OTA with a gold band around the back that included the Celestron name and other information. The black version was sold as a telephoto lens, and it lacked the tapped holes needed to mount a finder scope bracket. This was problematic if one wanted to get a C5 OTA for astronomical use on a different telescope mount, or to use a C5 OTA as a spotting scope. In the 1990's, Celestron at long last corrected this when they began to include Vixen-compatible dovetails with C5 OTA’s.

The original C5 is an area that I’ve wanted to see Celestron bring back a “blast from the past”, while incorporating some modern features. An ideal new version of the C5 would use a compact motor base, but incorporate a sidereal drive (maybe similar to that in the Ultima) that can run several hours on a 9 Volt battery. Ideally, the small motor base would have a worm drive, even if the worm wheel is only 90 to 100 mm in diameter. The declination setting circles should be flat or recessed (as on an older C5) since flat circles are less likely to inadvertently be misaligned.

A quick release for the OTA would be useful, but not as necessary if the motor base is small. It would also be better if the OTA went back to the original rear casting, since the original OTA had a more compact appearance and was comparatively easy to handle.

Accessories could include a table top wedge similar to the vintage one, a compact tripod not too unlike the Meade ETX tripod, and an adapter plate to adapt a compact C5 base to a C8 wedge. An alternative to an adapter plate would be to incorporate three shallow protrusions on the side of a compact motor base that have threaded holes that fit the bolt pattern of a C8 wedge. A compact mount can even be oval, as long as it is narrow in at least one dimension in order to reduce the overall envelope.

A telescope like the original C5 would potentially be faster and easier to set up than is the case for computerized “go to” telescopes. Setting up the original C5 does not involve making noise like that which results from having to use slewing motors to acquire alignment stars. Just a simple and silent manual polar alignment is all that is required to set up for serious observing.

I did not acquire a C5 until 2018. After using it a while, I can see that, in the late 70's, it would have been a better choice than a C90. I struggled to see deep sky objects in my C90 that are easy to see in a C5. But a C5 would have cost over twice as much as my used C90 did back then, and the cost in terms of work hours needed to pay for a C5 was higher then than was the case later.

6.2) Intes MN56 Maksutov-Newtonian Telescope (12.7 cm f/6)

Specifications (measured values in mm are shown instead of published spec's, when different):
Aper.Spec / f/Ratio / FL / Aper.Act. / C. Obs / Obs% / Width / Height / Length / Weight / Notes
127.0 mm / f/6.0 / 762 / 127.0 mm / 32 mm / 25% / 216 / 159 / 749 / 5675 g / w/cs ring

Image Quality (measured; SN 9.313)
C. Resol. / E. Resol. / Contrast / Flare / Bloom / Ghost / CamShake / Notes
Excellent / Good / V Good / Good / V Good / Excel / Excel / LP 57mm helical foc

Summary:
*** Build Quality / Materials: 4+** / Almost all components except the optics are metal.
*** Optical Quality / Details: 4** / Very slight spherical aberration, significant off-axis coma.
Summary Notes:
* Build is a 4+ rather than 5 because focuser attaches to tube via oversized holes, and there are no eccentrics to prevent large lateral changes in focuser position if removed for maintenance.
* Optical quality is shown as a 4 because there is slight spherical aberration and the coma-free field is very small.
*** Pluses:** Very sharp with relatively high contrast images, compact size for Mak-Newt, small central obstruction, low profile helical focuser has enough back focus for camera, second draw tube and long 1.25" adapter to adjust back focus distance; light clamshell ring; baffles relatively well designed (but long); primary mirror has edge mask to reduce flare; minimal tube currents.
*** Minuses:** Larger and heavier vs SCT of same aperture, some vignetting from small secondary, image not as sharp vs aperture as Intes MN61.

The Intes MN56 is a lighter weight design versus aperture than the Intes MN61. The Intes MN56 tube has less wall thickness, but includes several internal light baffle stops.

TBD, weighs less than Mystery Mak and has radically better images. (...)

6.3) *Mystery Mak*, a 13 cm f/15.4 Maksutov-Cassegrain Telescope w/no Brand Name

Specifications (measured values in mm are shown instead of published spec's, when different):
Aper.Spec / f/Ratio / FL / Aper.Act. / C. Obs / Obs% / Width / Height / Length / Weight / Notes
130.0 mm / f/15.4 / 2000 / 125.0 mm / 61 mm / 49% / 159 / 168 / 437 / 4540 g /

Image Quality (measured; no S/N)
C. Resol. / E. Resol. / Contrast / Flare / Bloom / Ghost / CamShake / Notes
V Good / Good / Poor / Poor / Fair-Poor/ Good / Excel. / Poor baffle design

Summary:
*** Build Quality / Materials: 3** / Almost all parts except optics are metal, but baffles very poor.
*** Optical Quality / Details: 2** / Only slight spherical aberration, but significant flare f/baffles.
Summary Notes:
* Build is a 3 because build may be a bit heavier than necessary, and light baffle design is very poor, being close to a tie for the worse baffle I have ever seen. But the mount interface is good.
* Optical quality is shown as a 2 partly because of slight spherical aberration, but mostly due to flare from the excessively smooth interior surfaces of the primary baffle tube. Optical quality would be 3 (which isn't bad) if the baffle issues are corrected.
*** Pluses:** Average image quality (but only after light baffle design errors corrected), solid interface fitting for mount fits contour of thick wall tube and is very stable.
*** Minuses:** Extremely poor light baffle design lowers contrast and increases secondary obstruction size to 49 percent, which reduces image quality across the board; slight spherical aberration, rear accessory interface is only 1.25" eyepiece holder (no threads for mounting heavy accessories); gummy feeling focus mechanism, minimum focus is a very distant 30 m, no S/N.

This nameless imported telescope is referred to as the "Mystery Mak". It was acquired used, and looks like most of the Chinese-made Mak-Cass telescopes in the same aperture class. I bought it partly because I wondered if it might be a prototype or pre-production model (so it would be an interesting piece), and it was also fairly inexpensive. Due to its severe light baffle flaws, I really *do* hope that it is a *prototype*, and that the manufacturer *learned* some lessons from its poor light baffle performance *before* going into production!

Mechanically, the *Mystery Mak* it is built like a tank, but it is clearly a Chinese telescope because the rounded rear cell is exactly like that on some other Chinese Maks in the same aperture class. The tube wall is about 2 mm thick, and the cells at each end are metal. Its minimum focus is a very distant 30 meters (unusually distant), which would reinforce the *prototype* theory. It weighs 4540 grams (10 lbs!), which is 2.5 times heavier than a Celestron 5 Schmidt-Cassegrain OTA.

The *Mystery Mak* has some spherical aberration that is obvious when comparing star images inside and outside of focus, but aberration is not so bad as to keep it from producing an Airy disk with clearly defined and fairly symmetrical diffraction rings in the *in-focus* image. However, its aperture is not really 130 mm. The front cell has an aperture of only 127 mm, and the back side of the cell limits the aperture to 125 mm (due to refraction by the Maksutov corrector), so it is really a 125 mm telescope. A telescope can't have more aperture than what its front cell admits.

But it was the light baffles that were its undoing. The primary light baffle tube is very large in comparison to the aperture of the telescope, and it does not taper down much toward the front. Given its outer diameter, the primary baffle tube is almost *three times* longer than it should be!

Specifically, as seen from the focal plane, the reflection of the front end of the primary baffle tube in the secondary mirror spot causes the effective central obstruction to be a huge 61 mm in diameter. The secondary baffle is a lot smaller than this, but *the size of the secondary baffle is irrelevant when something else blocks the view of its edge from the focal plane*. Given the actual 125 mm aperture of the telescope, the 61 mm central obstruction is a whopping 49 percent! I can only hope that this was a prototype, because if this light baffle flaw was in *production* telescopes, people would be very disappointed in the image quality, especially compared to what it could be.

It was possible to correct the primary baffle tube problem in terms of its effect on the central obstruction. This reduced the working central obstruction to just under 46 mm, or 37 percent by diameter. However, since I can't use machine tools now, I can't make a proper baffle tube to replace the existing one, so I opted for a marginal baffle like that in a C90, by adding a flat ring with a center hole of the appropriate size as a stop gap. I kept the original baffle tube intact because it is close to the most extreme example of an excessively long primary baffle tube I have seen in person. It provides *a good example of a bad baffle design*.

6.4) Intes MN61 Maksutov-Newtonian Telescope (15.0 cm f/6)

Specifications (measured values in mm are shown instead of published spec's, when different):
Aper.Spec / f/Ratio / FL / Aper.Act. / C. Obs / Obs% / Width / Height / Length / Weight / Notes
150.0 mm / f/6.0 / 900 / 150.0 mm / 28 mm / 19% / 253 / 178 / 937 / 7945 g / w/o rings

Image Quality (measured; no S/N)
C. Resol. / E. Resol. / Contrast / Flare / Bloom / Ghost / CamShake / Notes
Excellent / Good / Good / Fair-G / Excel / V Good / Excel / Sharpest on planets

Summary:
*** Build Quality / Materials: 4** / Almost all parts except the optics are metal, but is quite heavy.
*** Optical Quality / Details: 5** / Best central image quality of any telescope I have ever used.
Summary Notes:
* Build is a 4 instead of 5 because the Intes MN61 is heavy (7945 g w/o rings), and because the three rear Maksutov corrector retainers have very little contact area, placing pressure on the corrector edge that could potentially result in chipping with even moderately rough handling.
* Optical quality is a 5 because it doesn't often get better than this for planetary observation.
*** Pluses:** Excellent optical quality and small central obstruction, 2" Crayford focuser can handle heavy eyepieces (and even relay lenses) in spite of light appearance; minimal tube currents.
*** Minuses:** Very heavy for 15 cm telescope; rings are heavier than clamshell ring like that on MN56, back focus distance too limited to use camera without adding Barlow lens; poor dust seal around corrector, and especially in focuser; some vignetting from small secondary mirror; light baffle effectiveness is only fair; no S/N.

The Intes MN61 is a 15.0 cm f/6 Maksutov-Newtonian with a heavy tube and excellent optics. The sample I have has been my "gold standard" for planetary observation. When paired with an Atmospheric Dispersion Corrector (ADC) and high quality Barlow lens (such as a TeleVue PowerMate, to provide the back focus needed for an ADC), it provides clearer planetary images than any other telescope I have used that is less than twice its aperture.

The MN61 includes a front light and dew shield. This shield is essential in avoiding stray light.

Focuser seems light, but worked well with 46 cm long relay lens prototype. Etc. (...)

There is less to say (other than "Wow!) when a telescope is this good!

6.5) OTI Quantum 6 Maksutov-Cassegrain Telescope (15.0 cm f/16.7)

Specifications (measured values in mm are shown instead of published spec's, when different):
Aper.Spec / f/Ratio / FL / Aper.Act. / C. Obs / Obs% / Width / Height / Length / Weight / Notes
150.0 mm / f/16.7 / 2500 / 150.0 mm / 50 mm / 33% / 178 / 178 / 5xx / 3200g est /

Image Quality (measured; SN not recorded)
C. Resol. / E. Resol. / Contrast / Flare / Bloom / Ghost / CamShake / Notes
Excellent / V Good / Good / Good / V Good / V Good / Excel / Heavy mount

Summary:
*** Build Quality / Materials: 4+** / Almost all metal except for optics and focus belt; paint so-so.
*** Optical Quality / Details: 5** / Almost textbook Airy Pattern, but contrast seems a little low.
Summary Notes:
* Build is a 4+ because the blue paint on the OTA and mount is not particularly durable, and because the telescope is very heavy for a 15 cm Maksutov-Cassegrain.
* Optical quality is shown as a 5, even though contrast is a little lower than in a Questar or a refractor, possibly because the corrector lens coatings seem to have relatively high reflectivity.
*** Pluses:** High resolution, mount slow motion controls are well placed for terrestrial viewing and OK for astronomy; mount bolt pattern fits Celestron 14 (TBR) wedge.
*** Minuses:** Average contrast, eyepiece position cannot be rotated, eyepiece is sideways when used as a spotting scope apart from its mount, comparatively insecure friction fit eyepiece holder, non-standard 36 TPI threads used instead of T-threads, heavy for a 15 cm telescope.

This review of the Quantum 6 is based on several mini star parties that my friend Larry Grampp and I had at each others homes in the late 1970's and early 1980's. At the time, Larry had a Quantum 6, while I had a Celestron 90 that was mounted on a Quantum 4 motor base, plus a Soligor 800 mm f/8 lens that I used as a telescope. In 1980, I added a home grown 10.2 cm f/15 refractor that was based on an Edmund air spaced objective lens.

The Quantum 6 was fairly heavy owing in part to its large motor base, but it had a good feel in its focus mechanism and the slow motion controls on its motor base. The feel wasn't as good as a Questar, but it had a better feel than anything else I had encountered except a Questar. I liked the fact that you did not have to deal with tightening clamps when letting go of the slow motion controls. The Quantum 6 lacked any means to add a piggyback camera mount, but Larry came up with a home grown version that was workable.

The Quantum 6 performed very well on planets, and provided respectable views of some brighter star clusters, nebulae, and galaxies. It showed slightly better planetary images than my 10.2 cm refractor when the seeing was good, but my refractor edged out the Quantum 6 by the slightest margin when seeing was poor. The only time the refractor was more satisfying on planets than the Q6 in good seeing was during the ring plane crossing of Saturn. During this event, the rings looked razor thin in my refractor, but looked thicker in the Q6 because more light was in the first diffraction ring due to the 33 percent diametrical obstruction. We could see the rings for one extra day before and after the ring plane crossing in the refractor than in the Quantum 6.

6.6) Astro-Tech AT6RC Ritchey-Chretien Astrograph (15.2 cm f/9)

Specifications (measured values in mm are shown instead of published spec's, when different):
Aper.Spec / f/Ratio / FL / Aper.Act. / C. Obs / Obs% / Width / Height / Length / Weight / Notes
152.0 mm / f/9.0 / 1370 / 152.0 mm / 76 mm / 50% / 190 / 203 / 498 / 5500 g /

Image Quality (measured; no S/N)
C. Resol. / E. Resol. / Contrast / Flare / Bloom / Ghost / CamShake / Notes
V Good / V Good / Good / Good / Good / Good / V Good+ / RC Astrograph

Summary:
*** Build Quality / Materials: 3** / Almost all parts except optics are metal; focuser is so-so.
*** Optical Quality / Details: 3+** / Residual central astigmatism, minor off-axis aberrations.
Summary Notes:
* Build is a 3 because the tube is somewhat heavy and the focuser is so-so. The tube is certainly impressive, but it is not necessarily optimized in terms of weight distribution. Baffles are good.
* Optical quality is 3+ because there is some residual astigmatism on-axis (seen visually), even after collimation. Secondary obstruction is large enough to impair planetary performance, but since this is a low cost astrograph and not a planetary telescope, this does not lower its rating.
*** Pluses:** Good wide field performance typical of a Ritchey Chretien, good back focus distance, three extension tubes included to optimize back focus, very good light baffles, includes 2" focuser with 1.25" adapter and attached Vixen dovetail; original box is adequate for transport.
*** Minuses:** Residual on-axis astigmatism at high visual magnifications, but it probably is not enough to impact photos; somewhat heavy for its aperture, 50 percent central obstruction, no SN.

The Astro Tech AT6RC is marketed as an astrograph rather than as a visual telescope, so good visual performance at high magnification is not a claimed feature. Given its large 50 percent diametrical central obstruction, it would not be realistic to expect high resolution planetary images from it, owing to the large amount of energy that is in the diffraction rings. But most samples of the AT6RC I have seen are diffraction limited. Its just that its images will invariably have a lot more visible diffraction rings than the average telescope.

The AT6RC comes with a dual speed 2" Crayford focuser having 34 mm of travel. Since this is not enough travel to accommodate a variety of back focus distances, the telescope also comes with three threaded extension tubes that fit between the focuser and the optical tube assembly. There are two tubes of 25 mm length, and one 50 mm tube. Using the 50 mm tube between the focuser and OTA, plus the included 1.25" to 2" adapter tends to accommodate visual observation with most standard 1.25" diagonals. Use of all extension tubes is needed for straight through viewing, and even these may not be enough for such viewing with certain eyepieces.

The main purpose of the AT6RC is to be an astrograph. Its light baffles reduce stray light over a large area of the focal surface, though this is at the expense of the above noted large central obstruction. The telescope is capable if illuminating an image circle larger than 50 mm. The back focus distance behind the OTA is 150 mm or slightly more. An RC telescope generally makes a good astrograph. The AT6RC performs adequately, especially in light of its low price.

6.7) Sky Watcher 180 Maksutov-Cassegrain Telescope (18.0 cm f/15)

Specifications (measured values in mm are shown instead of published spec's, when different):
Aper.Spec / f/Ratio / FL / Aper.Act. / C. Obs / Obs% / Width / Height / Length / Weight / Notes
180.0 mm / f/15.0 / 2700 / 172.0 mm / 59 mm / 34.3% / 218 / 228 / 541 / 7260 g / w/o fndr

Image Quality (measured; no S/N)
C. Resol. / E. Resol. / Contrast / Flare / Bloom / Ghost / CamShake / Notes (AftBafMod)
VG-Excel / Good / Good / Good- / Fair-G / V Good / VG-Excel / Baffle design errors

Summary:
*** Build Quality / Materials: 3** / Most parts except optics and one baffle are metal, but tube thin.
*** Optical Quality / Details: 4-** / Some glow around bright objects, some off-axis aberrations.
Summary Notes:
* Build is a 3 because, even though front and rear castings look well made (but poorly painted), tube is very thin, and Vixen dovetail attaches ONLY to the tube. Also has baffle issues: Primary baffle too long, secondary baffle too small at front, central obstruction is larger than necessary.
* Optical quality is shown as a 4- because there is more glow around bright sources than is case for even a 30-year old SCT (may indicate surface roughness), had moderate to low contrast (until baffles modified to improve this), highly susceptible to tube currents.
*** Pluses:** Reasonably good lunar, planetary, and terrestrial images (but not as good as either 20 cm f/10 SCT sample it was compared to), works well for imaging birds at a distance, smooth focus mechanism (after I serviced it), impressive to look at (if you are into that sort of thing).
*** Minuses:** Central obstruction is same percentage as 20 cm f/10 SCT (too large for f/15 scope), secondary light baffle needlessly clips working aperture to 172 mm, glow over and around bright sources lowers planetary contrast, even compared to a 30-year old SCT; heavy, minimum focus distance is 20 meters, when a 20 cm SCT can focus to about 11 meters; expensive, yet is no S/N.

I acquired a Sky Watcher 180 after finding that planetary images in my Celestron 8 SCT looked really good during nights with good seeing, but also looked fairly bad on nights with bad seeing. In the latter case, smaller apertures, and more particularly, smaller central obstructions, seemed to help when the seeing was poor.

Up to this time, an Intes MN61, a 150 mm f/6 Mak-Newtonian, with its tiny 19% (diameter) central obstruction, was the only telescope of similar to smaller size I'd encountered that could actually beat my C8 for planetary imaging. The MN61 has been my "gold standard" for planetary viewing, frequently providing sharp images north of 400x. But it is heavy, and I have to use a Barlow lens to get enough back focus for an Atmospheric Dispersion Corrector (ADC).

Thus began the search for a telescope with more back focus and lighter weight, yet also having a small obstruction. Thus began the search for a so-called "planet killer" Cassegrain telescope.

I could not find a spec for the Sky Watcher 180 mm Maksutov-Cassegrain central obstruction, but a similar telescope by Orion was said to have a small 41 mm (23 percent by diameter) central obstruction. I went for the Sky Watcher because Sky Watcher telescopes have not had the rear cell O-ring problems that I had read people were having with other brands. The Sky Wacher 180 can't have an O-ring problem, since its rear cell interface has no O-ring at all!

I really wanted to like the 180 mm Sky Watcher Maksutov-Cassegrain scope. Unfortunately, it has *two* of the three most common light baffle design errors. Only one of these can be corrected in an existing telescope. It does *not* by any means have the worst baffle design errors I've seen (far from it), but it does have two different types of error. Because of this, the Sky Watcher 180 review (and Appendix A) are good places to discuss light baffle design issues for *any telescope*.

The most common three Cassegrain telescope light baffle design errors are described here:

<u>A.) Secondary baffle is too small, and limits the aperture of the telescope.</u> For example, in the B&L 800, the secondary baffle clips the aperture to 72 mm, rather than the claimed 80 mm. In the Meade ETX 90, the secondary baffle clips the working aperture of the scope to about 84 mm.

<u>B.) Primary baffle tube is too short, and allows light in from around the secondary baffle</u>. The original f/11 version of the Celestron 90 Maksutov-Cassegrain telescope has this design flaw.

<u>C.) Primary baffle tube is too long</u>, so its reflection in the secondary mirror causes it to *define the boundary of the central obstruction*. This may make the obstruction larger than a manufacturer's specifications. For example the Quantum 4 primary baffle caused the central obstruction to be 36 percent rather than 33 percent. The "Mystery Mak" noted above *had* this problem in spades.

6.7.1) Two Light Baffle Design Errors in Sky Watcher 180 mm Mak: Errors A & C:

The extent of <u>design error A</u> is significant, partly because it compounds the problem caused by the other design error (C). Specifically, the secondary baffle is about 2 mm too small where it meets the secondary mirror spot. This makes it impossible for the outer 4 mm of the telescope aperture radius (8 mm of the diameter) to contribute to the central spot. This flaw is easy to see if looking into the front of the telescope while a short focal length eyepiece and a diagonal are on the back, and when the telescope is focused to infinity. You can't look backwards into outer edge of the aperture and see a reflection of any light from the eyepiece. If you start a cm or two closer to the center of the telescope aperture, then move so that light from the eyepiece is viewed from closer and closer to the outer edge of the front aperture, the eyepiece image will disappear when you reach 4 mm to 5 mm from the edge of the aperture. (Pictures of this test are in Fig. 6.1.1C.) The end result is that the benefit of *<u>9 percent</u> of the front aperture area is lost!* It is functionally only a 172 mm telescope on-axis, yet you have to carry around the weight of a 180 mm telescope.

The second problem is <u>design error C</u>. The primary baffle tube is about 20 mm too long, in light of its relatively large outer diameter at the front. The baffle tube does not step or taper down much toward the front, and it extends too far forward. The result is that the primary baffle tube (viewed from the focal plane, as reflected in the secondary mirror spot, with a transparent ruler at the front of the telescope to take measurements) causes an effective cental obstruction of 59 mm, which is larger than the optical size that even the tapered secondary baffle would appear to be.

Think that 180 mm Mak is a “planet killer” in comparison to a 203 mm SCT? Think again! I've done side by side comparisons, and even on planets, the C8 beats this 180 mm Mak hands down.

The reason the Mak images are *inferior* to the C8 is obvious when you consider the above light baffle design flaws. Remember the loss of the outer 8 mm of aperture from design flaw A? This sample of a 180 mm Mak is really a 172 mm scope! *The size of the front aperture doesn't matter if something else prevents seeing the edge of the aperture from the center of the focal plane*.

Now, let's look at that 59 mm central obstruction, caused by the excessively long (considering its outside diameter) primary baffle tube. In terms of percentage, the central obstruction of the 180 mm Sky Watcher Mak must be calculated based on the *actual* working aperture of 172 mm. Therefore, 59/172 = 34.30 percent central obstruction. This is virtually indistinguishable from the 34.37 percent obstruction in a Celestron 8 SCT! So, for all practical purposes, the "planet killer" Mak does <u>*not*</u> have a smaller central obstruction than a C8. And it has 23 mm (actually 31 mm) less aperture than a C8 SCT! (I don’t know if this applies to *all* Chinese 180 mm Maks, but if you see one in person, you can inspect it in much the same way as I did mine <u>*before*</u> you buy.)

The Sky Watcher Mak tube wall is also fairly thin, and the Vixen dovetail is only attached in two places. This flexes the tube and results in vibration. If the dovetail had the wider footprint of the dovetail base plate of the "Mystery Mak" above, then the thin tube wall would not be an issue. The minimum focus distance of the Sky Watcher 180 mm (really 172 mm) Mak-Cass is about 20 meters. This is somewhat distant when compared to the 11 meter close focus distance of a C8.

It was possible to correct the problem of the primary baffle tube being too long by simply cutting off the front, filing it to have a tapered front end, then adding a smaller diameter front section. This reduced the real world central obstruction to just under 56 mm. The new, smaller, central obstruction is now defined by the secondary baffle and/or primary mirror retaining flange. The new obstruction is about 32.5 percent (56/172). Not a huge difference, but every little bit helps.

It was <u>*not*</u> possible to correct the problem of the secondary baffle being too small, partly because the cement used to hold the secondary baffle in place probably prevents removing the secondary baffle (to modify it) without spoiling the mirror coating in the area where the baffle is attached. The secondary baffle is *flawed*, and turns the Sky Watcher 180 mm into a 172 mm telescope.

6.7.2) But there's More: A “Glaring” Problem with the Primary Mirrors!

The flaw discussed here is not unique to the Sky Watcher 180. In fact, the SkyWatcher 180 has a little *less* of this flaw than most other “made in China” Cassegrain telescopes I’ve encountered.

All three Chinese Maks evaluated in this work have glare over and around the planetary images they form. This reduces contrast. The glare is at least 4 times brighter, and significantly wider in extent, than any glare around the planetary images of either C8 SCT that I compared to the Maks. Glare in the Chinese Maks is even greater when compared to a Newtonian telescope.

The cause of this glare is not known for sure, but I would not be surprised if it is from failure to adequately *fine polish* the primary mirror before coating it. This impression is supported by the appearance of the Kasai Pico-8 primary mirror in the area occupied by coating holes, and the "frosted" look that strong lighting causes the other Chinese primary mirrors to have.

The primary mirrors in my SCT's do NOT have this “frosted” look under similar lighting conditions, and the coatings in my SCT’s are 30 years old! The glare problem in Chinese Maks that have it (which is *all* of them I’ve seen) cannot be corrected. True "planet killer" telescopes don't have this much glare.

6.7.3) Collimation Instability in Some Chinese-Made Maksutov-Cassegrain Telescopes

Another thing many Chinese Maks have given up is stability. One of the selling points for a Mak *used to be* that you never had to collimate it. The primary mirrors used to be accurately fixtured when attached to the mirror thimble, so Maks were stable in terms of collimation. Mirror mounts were also robust, and did not oscillate enough to adversely influence observations and photos.

But the Chinese made Maks cantilever the primary baffle tube and primary mirror out in front of relatively thin collimating plates. This sacrifices the collimation stability that was formerly associated with Maks, and also increases susceptibility to vibration. And it’s a *needless* sacrifice. Because of this, you can feel some Chinese Mak OTA's vibrate for a fraction of a second after tapping them. This vibration also happens when a camera with a mechanical shutter is used!

Also, when the primary mirror optical axis is not accurately fixtured to be coaxial with, or at least parallel to, the primary baffle tube, the baffle tube will point at a slight angle toward one side when the telescope is properly collimated. This requires margin in the baffle design, making the baffle a little less effective. Proper mirror fixturing always trumps *flimsy* collimation assemblies.

6.7.4) Other Shortcomings of this and Other Telescopes that are *Made in China*

None of the reviewed Chinese-made telescopes have serial numbers. Lack of a serial number is highly unusual on an optical product as expensive as the Sky Watcher 180 in particular. Lack of a serial number is undesirable because there is no way to for the manufacturer to retroactively assess quality control based on serial number, and there is no traceability for the telescope owner. But maybe the latter is in keeping with the Communist doctrine that is common in China!

6.8) Celestron 8 Schmidt-Cassegrain (SCT) Telescope (20.32 cm f/10)

Specifications (measured values in mm are shown instead of published spec's, when different):
Aper.Spec / f/Ratio / FL / Aper.Act. / C. Obs / Obs% / Width / Height / Length / Weight / Notes
203.2 mm / f/10.0 / 2032 / 203.2 mm / 69.8 mm / 34.4% / 232 / 245 / 457 / 5680 g / w/TpAd

Image Quality (measured; SN's 429294, 807971)
C. Resol. / E. Resol. / Contrast / Flare / Bloom / Ghost / CamShake / Notes
Excellent / Good / Good / Good / V Good / Good / Excel / Good all-rnd. scope

Summary:
*** Build Quality / Materials: 4+, 3** / Almost all parts except optics metal; older C8 more stable.
*** Optical Quality / Details: 4+** / Not quite textbook Airy pattern; susceptible to tube currents.
Summary Notes:
* Build is a 4+, then a 3 because early C8 telescopes were built from heavier castings, and were more stable. This made less difference in the OTA than it did in the mount. Early C8's also had a metal secondary holder and used fiber surfaces (rather than rubber) around the corrector edges. Early OTA's had a short focus knob, which was more compatible with close coupled accessories.
* Optical quality is a 4+ because the Airy pattern (when seeing is good enough to see it) is not quite textbook; has off-axis coma (like any SCT w/Schmidt corrector closer than primary ROC).
*** Pluses:** Excellent optical quality versus weight and price, relatively close 11 meter minimum focus distance, good integration with fork mount, OTA can be removed from fork mount, central obstruction percentage is as small or smaller than that of many slower Maksutov-Cass. scopes; collimation is not the big deal that many say it is, and collimation has remained stable for years.
*** Minuses:** Some samples are not as good as others, some image shift from mirror thimble play during focusing, off-axis aberrations limit full frame deep sky photo resolution in off-axis areas.

The first time I looked through a Celestron 8 (i.e. a C8) was in 1980. It was a pivotal moment in my amateur astronomy experience. It was the first time I'd looked through telescope larger than a Quantum 6, and the extra 5 cm of aperture in the Celestron 8 made a significant improvement in the visual appearance of deep sky objects. The first object observed was M13.

A C8 was soon on my wish list, and I was finally able to acquire a used one in 1983. After getting a C8, my smaller scopes did not get as much use, though I still often used a Soligor 800 mm f/8 camera lens as an RFT.

The Celestron 8 was fairly ubiquitous in its early days. In the larger astronomy clubs common in big cities, one or more people had a C8. Most have good optics, though there was a lapse shortly before Comet Halley, when production was apparently ramped up to meet higher demand, and a few samples fell short of the norm. But in general, C8's from most periods have good optics.

The C8 may be one of the most under-appreciated telescopes of our day. Most samples easily provide better planetary images than the imported so-called "planet killer" Maksutov-Cassegrains of similar to slightly smaller aperture that people have been buying in droves. But in side by side tests, the C8 wins. And a C8 will usually maintain collimation better than the imported Maks.

Contrary to popular opinion, the central obstruction percentage for a C8 is similar to that of many imported Mak-Cass telescopes that are promoted for planetary observation. This is based on measuring the actual hardware, not the published specs. After looking through both, I can only assume that people who think the imported scopes are “good” just have not looked through a C8.

A vintage Celestron 8 has a somewhat utilitarian appearance in comparison to many more recent telescopes, but it was also more practical in a way. In climates with cold winters, the dull spatter finish paint on the mount and both ends of the OTA is a lot easier to deal with than the machined mirror finish metal surfaces that are common on some more recent telescopes.

The protruding center of the rear cell of a vintage C8 also helps provide better clearance for one’s head when wearing a hat. This is not the case for some newer telescopes (including even newer Celestron SCT scopes and larger imported Maks) that have a fairly flat back OTA surface.

Meade came out with a series of SCT’s in the early 1980's, but I did not see a sample of a Meade SCT that had optics comparable to a C8 until about 1994. Since then, the Meade SCT’s I’ve seen have been relatively good. The Meade SCT is not reviewed here because I have not spent enough time with a good sample to write about it in much detail.

6.9) Celestron Ultima 11 Schmidt-Cassegrain (SCT) Telescope (27.9 cm f/10 SCT)

Specifications (measured values in mm are shown instead of published spec's, when different):
Aper.Spec / f/Ratio / FL / Aper.Act. / C. Obs / Obs% / Width / Height / Length / Weight / Notes
280.0 mm / f/10.0 / 2800 / 280.0 mm / 102 mm / 36.4% / 317 / 330 / 5xx / 12700g est / w/rail

Image Quality (measured, Starbright coating version)
C. Resol. / E. Resol. / Contrast / Flare / Bloom / Ghost / CamShake / Notes
Excellent / Good / Good / Good / V Good / Good / Excel /

Summary: __SUMMARY NOT DONE__
*** Build Quality / Materials: 3** / Almost all parts except optics are metal, but some inaccuracy.
*** Optical Quality / Details: 4** / Produces Airy pattern with slight asymmetry, slight scattering.
Summary Notes:
* Build is a 3 because the motor base and fork arms have some flex, and axes not perpendicular.
* Optical quality is shown as a 4 because star images have slight asymmetry and slight scattering.
*** Pluses:** Good optical quality versus weight and price, central obstruction percentage is smaller than Meade 25 cm, but not smaller than Meade 30 cm, large format rear threads plus standard 2"-24 rear threads; smooth focus action, motor drive runs on 9 Volt battery.
*** Minuses:** Some image shift from mirror thimble play while focusing, one place on corrector plate edge has mill edge of original glass rather than chamfer, motor base and fork arms barely of adequate thickness, OTA front heavy on mount, hand control cord can be caught by fork arm.

The Celestron Ultima 11 (not Ultima 2000) is the largest complete telescope I have owned or used regularly. At the time I bought it used in 2003, I was on the fence between it and a Meade 12" f/10 LX 200 SCT. I chose the Ultima 11 because it was 7 kg (15 pounds) lighter, and its 25 kg (55 lb) weight (including the fork mount) was right at the upper limit of what I could lift by myself. (My lifting capacity diminished only a few years later, and I had to drop back to a C8.)

The Ultima 11 uses the same motor base as the Ultima 8, so it is a little spongy for stabile images if there is much wind. The tracking motor runs on a 9 Volt battery, so there is no need to lug around an extra power supply. For me, that was a big advantage over the Meade, even though the C11 does not have alt-azimuth tracking. One drawback of the Ultima 11 mount is that the declination setting circles protrude on either side, so they can easily become mis-calibrated.

The Ultima 11 OTA differs from the original C11 in that the center part of the tube does not protrude on the back. This is somewhat of a disadvantage when using physically short eyepieces in a 1.25" diagonal, because an extender is required to move the eyepiece position back enough to provide clearance for one's head. (OTA designs like this always make me wonder of the designer ever actually looked through a telescope!)

Image quality in my sample is very good. In reasonable seeing conditions, C11 planetary images are better than those of almost any other commercial telescope I've used, though Intes MN61 images are close to being a tie. Compared to most samples of the Meade 25 cm f/10 SCT I've seen, the C11 is noticeably better on planets. Deep sky performance is a little better as well.

7.) Conclusions Concerning the Reviewed Telescopes; Disclaimer, etc:

Conclusions for each range of apertures can be gleaned from each section.

Unexpectedly, user impressions from the telescope samples I have seen in person has led to a fairly general impression (and thus conclusion) about quality versus the country of manufacture. Observed defects in some telescopes are both optical and mechanical, with a good part of the mechanical defects being related to light baffles. The “baffling” details follow, in Appendix A.

It appears that making quality small telescopes has become a lost art, and this may be due in part to excessive “exporting” of labor used for telescope design and manufacture. There is some evidence for this when correlating telescope performance to the country of origin for each scope.

Small telescopes used to be of acceptable or even good quality, with the Ad-Astra III being a good example. This does not appear the case any more. Of the reviewed 8 cm and smaller Cassegrain telescopes *now available new*, *none* were worth using for more than casual daytime observation or low magnification viewing the moon. Planetary performance was very poor.

If available telescopes in the 8 cm aperture range did not have to be "stopped down" to provide a good image, such telescopes would be worth using. For astronomical observation, there is little point in having a small telescope that is incapable of providing acceptable planetary images, then having to lug around a slightly larger (and better made) telescope for planetary viewing. Better to just get the larger telescope, then chuck the idea of getting a smaller new (80 mm) scope, and be done with it. And larger telescopes of similar origin also appear to be inferior to vintage optics.

Several higher quality options are available in the slightly larger 9 cm aperture range. If smaller telescopes cannot be manufactured with acceptable quality any more, it makes more sense to step up to a 9 cm aperture. For the same price as the new 80 mm and smaller offerings, it is usually possible to get a used Celestron 90 or Meade ETX90 OTA. These are much more satisfying, but at the expense of a little more size and weight. If money is no an object, the Questar 3.5 is an excellent choice if one can get by with a visual field of view that is limited to about 0.8 degrees.

7.1) Flaws that may be Common to Groups of Telescopes. What Does all of this Mean?

<u>In summary, it means one may be better off with a used domestic scope than a new imported one!</u>

It is obvious that the Chinese Cassegrain telescopes I have personally seen are designed *poorly*, and to a degree, implemented poorly. I can't say if the same applies to Chinese made Newtonians and refractors. But after being 3 for 3 on acquiring poorly designed (and poorly implemented) Chinese Maksutov-Cassegrain telescopes, and having paid well over $1k for the lot, only to have this experience, I’m not inclined to try other Chinese telescopes any time soon, at least at current prices. The *refractors* I have now are by TeleVue and Vernonscope. *Neither* is made in China.

I will not get into how to correct the poor baffle designs, since such advice should be reserved for domestic telescope makers, and certain aspects of such advice might also be export controlled.

Domestic telescope makers may not even need such advice, since in general, telescopes *were* made properly when they were made here in the USA, or in Japan or Russia. Chinese copies of Russian Mak Newtonians gave up many advantages of the Russian designs they were based on.

Want a good telescope? Buy scopes *made* in the USA, Japan or Russia. These are becoming an endangered species, but are worth looking for, if only to end up with a scope that *works properly*.

It may even save money to *buy American*: You can buy a vintage USA-made SCT that may blow away a 180 mm (functionally 172 mm) Chinese Maksutov-Cassegrain telescope: A used C8 with the fork mount, tripod, and wedge often goes for less than just the OTA of a 180 mm Mak. A used C8 OTA alone can cost even less, and is more like comparing apples with apples.

Also, a C8 is advertised to have 203 mm of aperture, and it really *does* have 203 mm of aperture. No clipping of its aperture by improperly designed baffles! And it has much less glare over and around planetary images, compared to the Chinese Mak-Cass telescopes I've seen in person.

It is worth checking out a telescope in person *before* you buy. Important things to check are in-focus star images and planetary images at magnifications of at least 15x per cm of aperture. Star tests that *don't* look about the same on either side of best focus can reveal if there is spherical aberration that is not obvious in the in-focus image of a star, but that could adversely impact the contrast of planetary images. In this age of online marketing and fewer walk-in stores, this is more difficult. But maybe you can see samples of various telescopes at a local star partly.

7.2) Disclaimer:

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8.0) Telescope Accessories of Note that are Also Reviewed:

This chapter includes reviews of telescope accessories, rather than telescopes or camera lenses.

8.1) Tracking Mounts: Comparisons Without Guiding

Star Tracker Tests, Reviews and Comparisons
Long Focal Length Deep-Sky Photography Without Guiding!

This section includes reviews of tracking mounts, with detailed reviews of only a few of them.

8.1.0.1) Introduction:

Figure 8.1.0.1A. Popular past and present tracking mounts. The left two have good payload capacity. The four tracking mounts shown here are reviewed or otherwise noted. These are:
* LEFT: AstroTrac TT320x star tracker. Optional polar alignment scope immediately to its right.
* CENTER: Fornax LighTrack II mount. Optional CG5 polar alignment scope is to its upper left.
* UPPER RIGHT: Vixen Polarie tracker. Its optional polar alignment scope is just to its left.
* LOWER RIGHT: iOptron SkyTracker. Its included polar alignment scope is just above it.

Compact star trackers that are sized for use with cameras and lenses (versus full size telescopes) are very useful astrophotography accessories. If you want to travel light, all you may need is your camera, a star tracker, and a reasonably heavy photo tripod.

If a tracking mount tracks accurately enough for your purposes without having to guide, there is no need to bring a guide scope or even an autoguider. Some digital cameras can be programmed to take long exposures at set times, which means you can enjoy the night sky while the tracking mount and camera are sitting there unattended, yet taking numerous tracked astrophotos.

This review emphasizes only two of the more accurate star trackers, though two more compact but less accurate trackers are also briefly covered. For the trackers that are promoted as being capable of providing respectable *unguided* results with camera lenses up to 200 mm focal length on a full frame 35 mm digital camera (or fields of view down to well under 15 degrees on other formats), satisfactory results are defined herein as those averaging less than one pixel of elongation in a star image during a 1 minute unguided exposure. This high bar for performance limits the present comparison to only a couple of star trackers that I was able to obtain: The AstroTrac TT320 series, and the Fornax LighTrack II. These are reviewed in some detail.

This review only briefly covers a couple of smaller trackers (iOptron SkyTracker, Vixen Polarie) that are not as accurate. All of the tested trackers were purchased at customary prices on the new and used market, so this is *not* "paid" review.

For comparison only, a few *telescope mounts* are mentioned. Unguided, *none* of the evaluated telescope mounts tracked as well as either the AstroTrac or the Fornax LighTrack II mounts. The following ranks a few of the telescope and camera tracking mounts I have used over the years in terms of unguided accuracy. This is only a ranking, as opposed to definition of absolute tracking accuracy. The iOptron and Vixen trackers have not yet been used enough to rank them here.

* Fornax LighTrack II (about 1.8 arc seconds accuracy in 1 minute on first unit; 3 arc sec on 2nd)
* AstroTrac TT320x star tracker (2nd best; more like 5 arc seconds accuracy, so far)
* Celestron Ultima 11 telescope mount with worm gear drive (3rd best)
* Aus-Jena German equatorial mount with customized internal motor drive (4th best)
* Celestron 8 telescope with spur gear motor drive (3 samples over the years) (5th place)
* Questar 3.5 telescope clock motor drive (two 115V samples over the years) (6th place)
* OTI Quantum 4 telescope motor drive (two 115V samples) (7th place; not particularly good)
* Small imported telescope mount with motor drive (8th place, and not very good)

Telescope mounts are only briefly mentioned because they are not as portable as the trackers, nor are they as accurate when used *without* guiding. This review does not go into great detail about why a tracking mount is needed for astrophotography, though a few basics are covered below.

8.1.0.2) Purpose of Tracking Mounts in Astrophotography

Simple forms of astrophotography are possible with ordinary cameras and even cell phone cameras without using any form of star tracking. These include pictures of the crescent moon at twilight, star trails or sequences (if camera can tale long exposures), and other basic astro images.

Things get more complicated when taking pictures of constellations or nebulae in the night sky with anything except an extremely wide angle lens. For example, if the object is to photograph nebulae, a relatively long focal length is usually needed, as is a long exposure time. Longer exposures are obviously needed at night because the night sky is dim, as are nebulae.

Since the earth rotates relative to the sun and stars, the sun and stars always appear to move across the sky. Because of this motion, a sufficiently long exposure of the stars will make them look streaked in images taken from a simple camera on a tripod.

The amount of image streaking from earth's rotation can be significant. For example, if you take even a short 1 minute exposure of a part of the night sky near the celestial equator with a camera and 200 mm lens on a tripod, images of the stars will be streaked about 1 mm at the focal plane.

When the object is to obtain an image that is not streaked, it is necessary to counteract rotation of the earth Since the earth predictably rotates on an axis defined by its north and south poles, it is possible to align a telescope mount or star tracker so that its axis of rotation is parallel to the earth's polar axis. Once this alignment is complete, the mount need only rotate at the same rate as the earth, but in the opposite direction in order to track the stars. Stars are very distant, so the parallax between a tracking mount and the earth's polar axis is insignificant.

8.1.0.3) Tracking Accuracy

A simple tracking mount can provide good results on exposures up to a couple of minutes (and sometimes longer) with a wide angle to normal camera lens, provided that it is properly polar aligned. As either the exposure time or the focal length gets longer, it becomes more and more important that the mount tracks accurately. For good accuracy, a tracking mount should have different tracking rates that correspond to rates of motion for the sun, moon, or stars.

The earth makes one rotation relative to the sun once every 24 hours on average. However, since the earth's orbit is not exactly circular, there is a slight change in the solar rate throughout the coarse of a year, but it averages 24 hours per day. The small variation is not caused by any change in earth's true rotation rate, but is instead caused by libration as the earth moves faster or slower in parts of its orbit. The slight variation in solar rate is insignificant for a tracking mount.

Relative to the stars, the earth rotates about 4 minutes faster per day, so a slightly faster tracking rate is required. This faster tracking rate is called the sidereal rate. Here again, the earth's true rotation rate is not different. Instead, the difference is a result of the earth's orbit around the sun. Each year, there is one more "sidereal day" than the number of solar days.

The earth has a constantly varying rate of rotation relative to the moon, but most mounts have a lunar rate that is a good average. The difference is caused by motion of the moon relative to the earth, combined with the earth’s rotation. The lunar rate is slower than the other rates, and it varies according to the moon's changing distance from the earth, and from other factors.

Additional variations in the lunar rate are dependent on whether the moon is near the meridian or if it is closer to rising or setting. This dependence is due to the moon being close enough to the earth that its position relative to different observers on the surface of the earth can influence its apparent rate of motion as the earth rotates. A good part of the difference associated with the moon's position in the sky is caused by the earth rotating in the same direction as the moon's orbit. This has the effect of slowing the lunar rate relative to an observer while the moon is up, with the rate being slower when the moon is near the meridian. The exact rate of lunar motion relative to the stars depends on a combination of the moon's position in the sky, the observer's latitude, and other variables.

8.1.0.4) Tracking Mount and Telescope Mount Basics

When a proper tracking rate is selected on a tracking mount, the quality of the results are dependent on a number of things. Some of the more significant are:

* Accuracy with which a tracking mount is polar aligned.
* Stability of the tripod (etc.) supporting the tracking mount.
* Quality of the camera lens, and accuracy of focus.
* *Periodic error* and *bias error* of the tracking mount.

Inadequate polar alignment causes star images to be streaked considerably in an *unguided* photo. In a *guided* photo, inadequate polar alignment *also* causes star images to be streaked, but the streaks in a *guided* photo appear to be centered around the guide star. An unstable tripod or head can cause star images to appear enlarged or even streaked in unusual ways. A poor quality lens will often cause asymmetrical star images, and poor focus results in enlarged star images.

Some fast f/ratio camera lenses will not perform well for astronomical imaging when used "wide open" at their maximum apertures. This does not necessarily mean that the camera lens is of poor quality, since sharply imaging stars over the full format of a camera is one of the most demanding tests of a lens. Many extremely fast lenses (50 mm f/1.2, 135 mm f/2, etc.) may not work well for astronomy wide open, but will often work fine if stopped down 1.5 f-stops or so. Stopping down also reduces vignetting, for less darkening at the image corners.

Periodic error in a tracking mount causes streaked star images because the mount periodically tracks slightly too fast or slightly too slow. Such streaks usually are not very long if the mount is properly polar aligned. If the mount is *not* polar aligned, periodic error may cause longer jagged streaks, or even a “stair step” appearance to a streaked star image. Deliberate misalignment is one way that some people test telescope drives and tracking mounts. *Bias error* in a tracking mount is an error in the *average* tracking rate that results in streaked images that get longer with exposure time. Some bias error will obviously result if the wrong rate is set on a tracking mount.

8.1.0.5) Camera Tracking Mounts Versus Telescopes with Mounts

When I took up astrophotography decades ago, there was no such thing as a commercial amateur tracking mount (or even an affordable telescope mount) that was accurate enough to provide good long exposure astro photos with even a medium telephoto lens (200 mm) without guiding.

The lack of tracking accuracy without guiding in turn meant that an entire telescope and its mount had to be transported to a dark site for even the most basic deep sky astrophotography. A piggyback camera mount is then used to attach a camera to the side of a telescope, or sometimes to the counterweight shaft on a German Equatorial Mount (GEM).

Once everything is set up, the telescope can be used as a guide scope, and a drive corrector is used to "speed up" or "slow down" the telescope drive motor in order to compensate for the drive's tracking errors. When I first got into astrophotography, the drive rate had to be controlled manually, while looking in a reticle eyepiece to keep a guide star centered. My longest manually guided exposure was 110 minutes. Today, most use autoguiders instead of reticle eyepieces.

If a telescope is not accurately polar aligned, or if the subject is relatively low in the sky, it is also necessary to make corrections in declination. Such corrections compensate for slight polar alignment errors and for atmospheric refraction. Photographs through a telescope are also possible, by using either an off-axis guider or a separate guide scope.

Since a telescope mount must support the weight of an actual telescope, the mount and its tripod or pier must be relatively heavy, especially if the telescope is of significant size or has an extremely long focal length. To say the least, this does not make for a very portable setup.

This is where a tracking mount comes in. A tracking mount, and the tripod used to support it, need only be heavy enough to provide stability for the camera and lens it supports. There is no need for an everyday tracking mount to be so heavy that it can support a medium to large telescope. This makes a tracking mount much more portable.

However, a tracking mount must track accurately in order to be of any benefit for long exposures with long focal length lenses. Only a hand full of tracking mounts are accurate enough for *unguided* photos with moderately long telephoto lenses (200 to 500 mm). When performance with a long focal length lens is needed, only a few tracking mounts have the required accuracy.

8.1.0.6) Details and Ancillary Equipment Common to Tracking Mount Testing

The tested tracking mounts were used on both small and large tripods in order to arrive at the lightest tripod that is adequate for a given focal length lens in various wind conditions. The quest for a lighter tripod weight, and smaller equipment volume in transport, is driven by my physical condition. However, greater portability is something that anyone can benefit from. In my case, everything has to be transportable in a single trip when using a 4-wheel walker that has a seat and various other means to transport items.

Test results so far have shown that, in calm air to very low wind, each mount is adequately supported by a Gitzo Reporter (i.e. Series 2) or larger tripod and a sufficiently heavy low profile head that is Series 1 or larger, such as the G1270. Really solid support for use in moderate wind is provided by a Gitzo Studex (Series 3) or larger tripod and a Series 3 or larger *low profile* head.

After being disturbed, settling times with a dual camera bracket carrying a 250 mm and 500 mm lens were 9 seconds with a Gitzo Reporter tripod and a G1270 head, 4 seconds with a Gitzo Studex tripod and a G1270 head, and less than 2 seconds with a Gitzo Studex tripod and a Series 5 low profile head such as a PL5. Settling times are faster when only one of the two cameras is on the mount. I have not tested the dedicated tracking mount wedges.

For critical tracking, a lighter tripod suffers from the distinct disadvantage that polar alignment must be performed *every time* the center of gravity for the cameras is changed significantly, while repeated polar alignment is not needed with larger tripods and heads.

All tests to date were performed in calm to very low wind conditions. A 40 mm ball head was initially used on each tracer, but I later used a Gitzo G1270 head, then even a G1370 head, on some of the larger trackers. At times, each tripod head was used with a dual camera bracket. A dual camera bracket can support either two cameras, or one camera and a small guide scope. My smallest guide scope is based on a tiny 300 mm f/6.3 mirror lens.

8.1.0.7) Test Methodology and Overview of Tested Mounts

The main purpose of this review is to compare only tracking mounts that have an unguided accuracy better than that of most low to moderate cost amateur telescope mounts. The review is also constrained by the range of mounts that I can own or otherwise have considerable access to during the review period.

All of the above constrains the scope of rigorously tested mounts to only two:
* AstroTrac TT320X, and
* Fornax LighTrack II.

Detailed levels of review are limited to these mounts, in large part because most other portable mounts I have been exposed to (or seen results from) are not accurate enough to provide good unguided long exposure results with a long focal length lens. If it's worth taking the time to do something, it is (when possible) worth making the investment to do it right.

The scope of testing is simply an assessment of results obtained when like or similar cameras and support equipment are used in similar conditions to photograph the same object with either mount. Details are in the side by side comparison section, which is a work in progress, being a cumulative part of this review that is will be added to over a considerable period of time. Now, we will get to the specifics of each mount.

8.1.0.8) Tracking Mount Comparison Table

Mount Make/Model	Wide (mm	High (mm)	Long (mm)	Wght. (g)	Track Time (m)	Spec. Accur. (ArcSec/M)	Act. Accur. (ArcSec/M)	Notes
AstroTrac TT320x	97	44	437	1110	120 spec.	5" over 5 m	3.0" per m	Lead Screw
Fornax LighTrack II	135	78	278	1310	108 act.	2" over 5 m	2.2" per m	Friction Sec.
iOptron SkyTracker	152	178	76	1250	Continu.	None Spec.	__” per m	80.0 Worm
Vixen Polarie	137	94	59	740	120 (bat)	4"/2m (imp)	__” per m	57.6 Worm

8.1.1) AstroTrac TT320X Tracking Mount with Polar Alignment Scope

Specifications (measured values in mm are shown instead of published spec's, when different):
* Physical size in mm: 97 wide x 44 high x 437 long. Weight in grams is: 1110

Summary:
*** Build Quality / Materials: 3+** / Metal w/some plastic; guide rods unstable; plastic polar scope.
*** Functionality / Details: 3+** / Easy to use in sidereal, but not other rates; polar scope poor.
Summary Notes:
* Build is a 3+ because the drive nut guide rod anchor points are unstable, polar scope is plastic.
* Functionality is shown as a 3+ because of the following: Drive nut guide rod instability can influence accuracy, polar scope does not facilitate as accurate of alignment as CG5, etc., scopes; setting mount up for solar or lunar rates is not intuitive and can't be changed on the fly.
*** Pluses:** Second most accurate of tested trackers, good payload capacity, large tripod mounting surface, thin profile for travel, some visual and audible indication of tracking time remaining.
*** Minuses:** Drive nut guide rod instability degrades accuracy, expensive polar alignment scope does not retain alignment well and attaches with magnets; setting rates other than sidereal not intuitive, fast "partial resets" not possible in tine-critical applications; strain on 8x AA batteries.
.
The AstroTrac TT320X is tracking mount that uses a rotating drive screw to move a nut at the end of a tangent arm that is attached to the camera platform. It is similar in concept to "barn door" mounts that amateur astronomers have used over many decades, except that, at a basic level, the AstroTrac uses a finer thread pitch drive screw, and uses a thrust surface for the polar axis instead of a long shaft or hinge.

The AstroTrac also varies the speed of the drive screw according to where the drive nut is located along its length. Motor speed is automatically varied to compensate for tangent error, which is a tracking rate error that closely follows the cosine of the angle of the tangent arm with respect to a right angle to the rotational axis of the drive screw.

The AstroTrack is set up by attaching it to a tripod or wedge, plugging in the power, then installing the polar alignment scope. At this point, you roughly polar align it, then attach a camera or other payload. Finally, accurate polar alignment is performed via the polar alignment scope while the weight of the camera is on the mount. Deployment of the AstroTrac drive mechanism can be done either before or after polar alignment. I deploy it before polar alignment so the camera can be positioned prior to getting polar alignment really accurate.

To deploy and activate the AstroTrac drive, you rotate the drive motor and drive screw assembly until it stops about a 90 degree angle to the tangent arm. The direction you rotate it depends on if you are in the north or south hemisphere. You then push the power button and the drive motor quickly spins the drive screw until the tangent arm drive nut is about 3 cm away from the motor end of the drive screw. Pushing the same button again starts the mount tracking at sidereal rate. Another button next to the start button rewinds the drive for purposes of resetting it for more tracking, or for transport and storage. The other two buttons are function buttons that double for setting solar and lunar rates. Use of the function buttons for this purpose is not at all intuitive.

[Figure 8.1.1A]

Figure 8.1.1A. AstroTrac TT320X mount, and initial results obtained with it.
LEFT: The AstroTrac can carry a fairly heavy payload. Here, two large camera lenses are mounted on an aluminum bar, which is in turn mounted on a 40 mm ball head that is attached to the AstroTrac. The left lens is a 350 mm f/4.8 Leica Telyt-R, and the right lens is a 300 mm f/4.5 ED Nikkor, with a Nikon TC-201 2x tele-converter. Both lenses are on Micro 4/3 cameras. These lenses are suitable for a solar or lunar eclipse, but for deep sky photography, it is better to use the 300 mm lens without the tele-converter. The picture of M51 below was taken with a much smaller 180 mm lens, then cropped.
RIGHT: This extreme 100 percent crop of M51 is a stack of three 40 second exposures with dark frame and what I call "gray frame" subtraction (where de-focused sky is subtracted). Exposures were limited to 40 seconds because tracking was not good enough at one minute. The camera is a Panasonic GX7 with a Voigtlander 180 mm f/4 Apo-Lanthar lens (discontinued), used wide open at f/4. The lens did not quite focus to infinity with its cheap Chinese Micro 4/3 adapter, so the adapter was later thinned to allow infinity focus. Brighter stars look large due to slight de-focus combined with the extreme enlargement of this crop. The image was taken at the Riverside Telescope Makers Conference (RTMC) near Big Bear, CA on 27 May, 2016. It was my first attempt at using the AstroTrac for deep sky astrophotography.

8.1.1.1) Advantages and Disadvantages of the AstroTrac TT320x

Advantages of the AstroTrac include that it is capable of tracking with a relatively heavy camera, and that it folds to a size that is small in two dimensions, though fairly long (over 42cm) in the other dimension. In concept, the AstroTrac should provide good results, but a number of real world shortcomings limit its usefulness for long exposures with long focal length lenses.

Disadvantages of the AstroTrac include the real world shortcomings noted below.

8.1.1.2) AstroTrac Idiosyncracies

The AstroTrac often tracks very well compared to even an unguided C8 mount, but it still is not as accurate as the Fornax LighTrack II mount. I found a couple of possible reasons why. It comes down to the polar alignment scope and its support, plus the relatively poor anchoring of the guide rods that run parallel to the drive screw. The main shortcomings included:

* Tendency of drive nut guide rods to tilt and "walk out" of their anchor points.
** Details about this AstroTrac issue are covered in detail below.
* Polar alignment scope that seems somewhat kludged, to put it mildly.

8.1.1.2.1) AstroTrac Drive Nut Guide Rod Instability

[Fig 8.1.1.2.1A]

Figure 8.1.1.2.1A. Functional Idiosyncracies with My Sample of the AstroTrac TT320X
Drive nut guide rod instability of sample AstroTrack TT320X:
UPPER LEFT: When I received my used AstroTrac, the drive nut guide rods had "walked out" of their anchor points near the drive motor, leaving the outer end of the threaded drive screw unsupported.
UPPER CENTER: Uneven guide rod positons at the anchor point, which is somewhat flimsy, given how critical the guide rods are. It would not surprise me if guide rod instability is common in this model.
UPPER RIGHT: Plastic fitting at outer end of guide rods. When deploying and stowing the AstroTrac, this fitting has moved up to 4 mm laterally, in each "step" of the rods walking out of their anchor points.
LOWER LEFT: Preparing to fix guide rod instability. AstroTrac did not respond, so I was on my own.
LOWER RIGHT: The present fix for the guide rod instability included drilling small holes in the sides of the guide rods, very near the ends, then placing pins in the rods after they were installed, followed by using super glue at the guide rod anchor points. This improved performance, but is not a complete fix. Better guide rod stability will result from adding some elongated metal guides just outboard of the guide rod anchor points, to support the guide rods from their outer sides for the first 10 cm or so of their length.

In fairness, the AstroTrac was acquired used. However, when I contacted the company about the unit, they were not responsive. The initial question was simply if they could retrofit an autoguiding port to the unit, but all I got was an automated email about a ticket having been originated, but then nothing after that. As of this writing, it's been years, and still no response.

When I first received the used AstroTrac, its guide rods had "walked out" of their anchor points to such an extent that the outer end of the drive screw was not even in its plastic bearing. Since AstroTrac had not responded to a previous simple question, I was on my own in regard to this problem. Fortunately, I have had considerable experience with mechanical devices of similar to greater complexity, though I can't use machine tools any more.

The guide rod anchor problem was *temporarily* corrected with some effort by "'walking" the guide rods back into their anchor points, but this did not last. The guide rods still had a tendency to move slightly from side to side each time the AstroTrac was stowed or deployed, and to again walk out of their anchor points a little each time. This was corrected to a more *permanent* degree by adding pins hat keep the rods from walking out beyond a certain point. I also made small changes to reduce resistance required to move the AstroTrac in and out of its stow position.

In the end, the AstroTrack generally did not perform as I'd hoped. It is fine for tracking the sun or moon, and is useful for deep sky images with wide angle to medium telephoto lenses. But it has not yet tracked accurately enough for good deep sky photography with long FL lenses.

8.1.1.2.2) AstroTrac Polar Alignment Scope Idiosyncracies

The AstroTrac polar alignment scope appears to be another weak point. It attaches to the polar scope interface ring only with magnets, and it is all to easy to bump it, which almost always causes it to fall off. When I got the used AstroTrac with its polar scope, it was obvious that the polar alignment scope had previously experienced at least one *epic encounter with the ground*, and possibly even pavement. To prevent mishaps while I was using the AstroTrac, I looped a rubber band around the polar scope barrel and its battery holder. This kept the polar scope from falling to the ground if it was bumped, but it was still unsettling to see it come loose so easily.

Also, while the AstroTrack polar alignment scope reticle is accurately set up, and the polar scope ring on the AstroTrac maintains its alignment moderately well as it is moved about the mount's polar axis, imaging results frequently have field rotation.

The AstroTrack is the only medium to high cost telescope mount or tracker I've used in the last 35 years that I could not reliably polar align with its own polar alignment equipment. My first impression is that the *thin plastic tube* that holds the polar scope objective lens can bend a little at the drop of a hat, which effectively moves the optical axis of the lens relative to the reticle.

When I first acquired the AstroTrac, the plan was to ultimately use two mounts at once on rare occasions I could get away from city lights. This maximizes the number of pictures that can be captured on a given outing. I was going to use one AstroTrac mount and one Fornax LighTrack II mount. However, the AstroTrac and its polar scope seemed to need a lot of tweaking.

Ultimately, I found that the best way to tweak or optimize an AstroTrac for deep sky photography is to get a Fornax mount and leave the AstroTrac in the closet. So, I eventually decided to get two Fornax LighTrack II mounts instead of one. The Fornax mount is covered next.

8.1.2) Fornax LighTrack II Tracking Mount with Separate CG5 Polar Alignment Scope

Specifications (measured values in mm are shown instead of published spec's, when different):
* Physical size in mm: 135 wide x 78 high/deep x 278 long. Weight in grams is: 1310

Summary:
*** Build Quality / Materials: 4** / Metal with plastic cover; drive capstan relatively small.
*** Functionality / Details: 4-** / Easy to use, but tracking time less than spec; no time indicator.
Summary Notes:
* Build is a 4 because the drive capstan is a relatively small 4 mm and is no run time indication.
* Functionality is shown as a 4- instead of a 5 only because of the following: There is no run time remaining indicator or audible warning for end of run time, and tracking time is less than in spec. Error light does not always come on if tracking fails due to low voltage; all lights same color.
*** Pluses:** Most accurate of tested trackers, with first sample being slightly better than the second. Size and weight are not excessively more than compact trackers such as the iOptron; easy to use, tracking rate is displayed and can be changed on the fly.
*** Minuses:** Tracking time is less than spec (but spec changed after I informed Fornax); no run time remaining indication, no audible warning for end of tracking, low voltage does not always trigger error light, N/S hemisphere indicator lights are same color, polar scope ring hard to move.

The Fornax LighTrack II is a friction drive tracking mount in which a smooth sector is driven by friction via a capstan that is attached to a motor having accurately controlled speed. There are no gear teeth to cause the usual type of periodic error, though small centering errors on the capstan can theoretically cause some error. There is no tangent error to worry about, because the drive surface is a sector. In practice, tracking with the first brand new unit has seems to be quite good.

Setup is extremely simple. Some steps are similar to setting up the AstroTrac, except that the LighTrack II starts tracking as soon as power is applied and it is turned on. Its status lights also make it clear what tracking mode it is in. The LighTrack II mount is a good deal wider and thicker than an AstroTrac, but it is not as long. The shorter length may help it fit into a smaller case for transport and storage.

The Fornax LighTrack II mount was acquired brand new, partly because I could not find any used ones. In fact, being in the USA, I had never even seen a LighTrack II mount in person until I bought one. Exposure to the Fornax mount had previously been limited to a couple of brief reviews and a few pictures people posted online.

The Lightrack II mount has two buttons that slew the mount to the east or west. These buttons exist mainly to reset the drive when the end of the drive sector is reached, but the buttons can also be used to center an object in the right ascension without having to loosen the tripod head that is carrying the camera.

8.1.2.1) Fornax LighTrack II Mount, Un-boxing and Initial Results

[Figure 8.1.2.1A]

Figure 8.2.1A. Un-boxing and initial setup of Fornax LighTrack II mount
LEFT: Un-boxing the Fornax LighTrack II mount. The LighTrack II mount comes in a fairly compact box. The custom cut dense foam in the box is suitable for transfer to a carrying case, or the box with its foam can be used as a case of sorts.
CENTER: The Fornax mount comes with a manual, test data sheet, brochure, and a few very basic accessories. The accessories include a cable that plugs into an automotive 12 Volt lighter jack, an autoguider cable, a ring that secures a Celestron CG-5 polar alignment scope to the Fornax mount, and two 5mm socket head screws. It does *not* include a polar alignment scope, a separate 5.5mm power plug, batteries, or a battery holder for eight AA cells. However, the optional and compatible CG-5 polar alignment scope does appear to be fairly stable.
RIGHT: Cluster of 3 cameras on the Fornax LighTrack II mount. The left camera is an Olympus E-P3 with a Tamron 500 mm f/8 mirror lens. The center camera is a small Panasonic camcorder with a Nikon 3x converter, mounted on a slow motion head. The camera at right is an Olympus E-P2 with a Leica 250mm f/4 Telyt-R type 2 lens. The lenses and slow motion head are all attached to a 200 mm wide Arca compatible dovetail bar, which is in turn mounted on a Matthews 40 mm ball head. The ball head is mounted directly to the Fornax mount, which is in turn mounted on a Gitzo Reporter tripod and a relatively compact G1270 head that acts as the wedge. The M42 photo below was taken with all cameras except the small camcorder attached. For the 2017 total solar eclipse, I mounted the LighTrack II on a Gitzo Sudex tripod and a large PL5 head, then used the G1270 head on the Fornax mount.

[Figure 8.1.2.1B.]

Figure 8.1.2.1B. Initial Deep Sky Results with the LighTrack II
LEFT: M42 nebula, taken with the Fornax LighTrack II mount and an Olympus E-P3 micro 4/3 camera with a lightweight Tamron 500mm f/8 mirror lens. Since this is a case of using a 500mm lens on a small

format Micro 4/3 camera, the field of view for the full MFT format is equivalent to that of a 1,000mm lens on 35 mm format. This 33 percent crop includes less than half of the original image width, so the cropped area has a field of view similar to that of a 2,000 mm focal length on 35 mm format. This image was taken from the city, less than 15 meters from the nearest street light. It is a stack of three 1-minute exposures. Two were at ISO 800, and the other was at ISO 1600. A Hoya red "Intensifier" was used to reduce light pollution effects by about 2 f-stops. This was my first attempt at imaging a nebula with the LighTrack II mount. A full resolution 100 percent crop of the same photo is at this link: _Link_TBD_
RIGHT: The Fornax LighTrack II mount fits in this very compact (5x12x16 inch) case, along with a small Gitzo Sport tripod (top) and G1270 head (lower left). The case also holds the polar alignment scope (top) spare batteries (left), cables and a dual camera bracket (center), a ball head (in black bag right of center), and filters (bottom). The mount is kept in the padded box at center to protect it from compression or surrounding hard surfaces. A heavier tripod is used when there is no need to be this portable.

8.1.2.2) Advantages and Disadvantages of the Fornax LightTrack II Mount

Advantages of the Fornax LighTrack II mount over the AstroTrack, etc:
* Shorter stored length than the AstroTrac.
* Easier to set up (except for stiff polar scope holder)
* Ran 2 hours on batteries that would not power [an] AstroTrac any more.
** This means [the] Fornax might get up to 14 hours from 8 AA batteries.
* Slew/reset buttons for RA can be used in for centering subject in RA.
* [Has] enough buttons and indicator lights that it is easy to use.
* More accurate unguided tracking than anything else I ever used.
* Nearly all pictures with LighTrack (not just half) are properly tracked.
* Cost with CG-5 polar scope is not much more than smaller, less accurate mounts.

Disadvantages:
* Polar scope support arm positioning is stiff (5 kg force to move).
** However, the polar scope support arm is not as stiff on the second unit.
* Minimal operational documentation (but same goes for AstroTrac).
* Can accidentally press "south" button [and not know it] if not careful.
* Small 57mm bearing surface on tripod or wedge (but can enlarge w/plate).

8.1.2.3) Fornax LighTrack II Idiosyncracies

Initially, the only disturbing thing the mount has done was to vibrate and make a sound like a cell phone buzzing if slewing it to a start of stow position was attempted at a time when the batteries were apparently running low. When it does this, it is no longer capable of tracking without changing the batteries, and the error light does not always blink. I was concerned that such rapid vibration of the motor could be hard on the drive sector, so I wondered if the mount might benefit from shutting itself off when power is inadequate to slew the drive.

To date, the Fornax mount has only been used for a several hours of tracking during the day and at night. The first sample has thus far provided a higher percentage of properly tracked night sky images than the AstroTrac, while the second sample performs about the same as the AstroTrac.

As the Fornax mount was being used over time, I noticed that the upper and lower edges of the drive sector surface started to look shiny compared to the center. This gives the impression that the capstan may intentionally have a slightly larger diameter at the ends than in the middle.

TBD Smaller than optimum drive capstan diameter (4 mm vs 6 mm); no run time remaining indication, does not run as long as indicated in original specification (107~108 m vs approx. 2h)

Variation between units. Polar alignment scope holder too tight/stiff in one, OK in the other.

Run time shorter than specified.

[Figure 8.1.2.3A]

Figure 8.1.2.3A. Consequences of a shorter than specified tracking time at a total solar eclipse! LEFT: Diamond ring at 2017 eclipse. The eclipse is cut off by the edge of the frame because the Fornax LighTrack II mount stopped tracking 4 minutes before this video frame was taken. The actual tracking time proved to be only 107 minutes on one mount, and 108 minutes on the other. This differs from the “approximately 2 hours” in the specification. However, Fornax changed the specification to match the actual run time after I informed them what happened at the eclipse. RIGHT: Run time remaining indication that I added to the LighTrack II mount after the eclipse.

8.1.2.4) Suggested Tweaks to Fornax LighTrack II Mount

* Add run time remaining indication, with audible warning when end of tracking imminent.
* Incorporate two lunar tracking rates. One for near meridian, one for when moon low.
* Use a different LED color (orange?) for S. hemisphere setting, so obvious if selected.
* Reduce resistance needed to move polar alignment scope interface arm. About 1 kg force OK.
* Offer optional accessory for fine declination pointing (can be similar to heavy tripod leveler).
* Consider adding prompt auto shut off if motor violently vibrates from low battery power.

Until using the Fornax LighTrack II, I didn't think an unguided image could be tracked this accurately. It's a new experience. Hopefully, the LighTrack II mount will continue to perform well as it is used over time.

The FMW-200 wedge may later be acquired and tested against a Gitzo PL5 tripod head. The wedge could benefit from an adjustable post that its head can rest on when set to an appropriate latitude. One of my long standing polar alignment methods is to leave a tripod head or wedge set at the correct angle, then level the tripod and move the wedge only in azimuth only to get polar alignment. I use a 3 cm diameter ball bearing on a flat surface as the level (rather than a bubble level) so leveling can be very accurate.

8.1.3 iOptron SkyTracker Tracking Mount with Included Polar Alignment Scope

Specifications (measured values in mm are shown instead of published spec's, when different):
* Physical size in mm: 152 wide x 178 high x 76 long/deep. Weight in grams is: 1250

Summary: __SUMMARY NOT DONE__TEST RESULTS NEEDED TO FINISH__
*** Build Quality / Materials: 3+** / Metal with plastic battery cover; latitude head relatively small.
*** Functionality / Details: 3+** / Reasonably compact, ease of use is average.
Summary Notes:
* Build is a 3+ because the latitude adjustment head is less stable than a medium size tripod head, but it is integral to the unit and cannot be removed; thin plastic battery cover, changing batteries requires removing 4x AA battery holder.
* Functionality is a 3+ due to the following: Latitude adjustment head is too light (as noted under build) so unit can move over time; battery changes are not very easy, but are not required often.
*** Pluses:** Reasonably compact, polar scope is small enough that it does not significantly increase storage and transport area required, (...)
*** Minuses:** Built-in latitude adjustment head is less stable than many tripod heads, and since it cannot be removed, it is a weak point in the mount's stability; envelope larger than spec, (...)

The iOptron SkyTracker (...)

The worm drive gear is an 80 mm diameter, 156 tooth worm wheel. (...)

The included case is on the small side. If the same people who made this case were making clothes, you should order the clothes in 1-2 sizes larger than your actual size. (...)

8.1.4 Vixen Polarie Tracking Mount with Optional Polar Alignment Scope

Specifications (measured values in mm are shown instead of published spec's, when different):
* Physical size in mm: 137 wide x 94 high x 59 long/deep. Weight in grams is: 740.

Summary: __SUMMARY NOT DONE__TEST RESULTS NEEDED TO FINISH__
*** Build Quality / Materials: 3+** / Metal w/plastic battery cover; small drive gear/mount surface.
*** Functionality / Details: 3+** / Easy to use, except polar alignment not as easy as other units.
Summary Notes:
* Build is a 3+ because the tripod mounting interface is small, due in part to rounded corners on the front and back, the Polarie casting also flexes a little in this *critical* area. The finish is nice and the unit *feels* solid - except it flexes around the tripod mount (one of most critical places!)
* Functionality is shown as a 3+ because the Polarie is easy to use for casual applications, but is more difficult to set up than an AstroTrac or Fornax LighTrack II when accurate results needed.
*** Pluses:** More compact and lighter weight than other reviewed mounts (though this changes when the large optional polar scope is considered), several indicators built-in, only requires two AA batteries; batteries can be changed while unit is on a tripod, no reset required.
*** Minuses:** Mounting surface around tripod socket is needlessly too small, and there is some flex of the casting in this area, which reduces accuracy. Polar alignment scope is an (expensive) optional accessory, (...)

The Vixen Polarie (...)

For visual applications, the Vixen Polarie kept planets centered in a TeleVue 60 ED telescope for several minutes, even at magnifications slightly above 200x. However, there was considerable vibration each time the telescope was even touched due to the small tripod mounting surface. (...)

8.2) Optical Accessories

This section includes reviews of accessories that incorporate optical elements or prisms. For now, an Atmospheric Dispersion Corrector (ADC) is the only optical accessory reviewed here.

8.2.1) ZWO Atmospheric Dispersion Corrector (ADC)

Specifications (measured values in mm are shown instead of published spec's, when different):
* Physical size in mm: _ wide x _ high x _ long. Weight in grams is: _

Summary:
*** Build Quality / Materials: 4-** / Almost all parts except optics are metal; adjust handles small.
*** Optical Quality / Details: 5-** / No obvious degradation of image when prisms set to null.
Summary Notes:
* Build is a 4- because the eyepiece holder is slightly undersized, and adjust handles are delicate.
* Optical Quality is a 5- because the wedge prisms appear to be clear and accurate enough that it is difficult to tell when the ADC is between the eyepiece and telescope when it is set to null.
*** Pluses:** Compact size, reasonably low cost, does what it is supposed to do very well.
*** Minuses:** Requires __ mm of extra back focus (can be issue for Newtonian) and is no optional Barlow to increase back focus while minimizing magnification; no manual or even URL for one. There are not many other minuses, but it could use observer-defined click stops.

8.2.1.1) What an ADC is, and what it Does (ADC is as ADC does)

Atmospheric Dispersion Correctors (ADC's) have been around in various forms for many years. Early commercial ADC's consisted of sets of wedge prisms, with each prism correcting a certain range of elevation angles. An ADC does this by dispersing the color spectrum to the same degree as, but in the opposite direction from, what the atmosphere does along the line of sight.

But there are other ways to make an ADC. Many amateur astronomers may have been using ADC's for decades without even knowing it! Some may have noticed that the "sweet spot" for viewing planets at low elevation angles is not in the center of the field of certain eyepieces. In many cases, this is because lateral chromatic aberration in a high or low part of the eyepiece field is compensating for atmospheric dispersion. A dedicated ADC does the same thing, except that correction is not dependent on the position of a planet in the eyepiece field of view. An ADC is more applicable now because today's better eyepieces have less lateral chromatic aberration.

ZWO (and some other) Atmospheric Dispersion Correctors have two identical wedge prisms. The prisms are rotated with respect to each other in order to adjust the wedge angle (and thus dispersion) of the dual prisms. When the ADC is set for no correction at all, the wedge in one prism is oriented 180 degrees from that of the other prism. In these positions, the prism set acts like a flat glass plate. But as one prism is rotated with respect to the other, the combination of both prisms becomes a wedge, and the angle of the wedge increases as the prism is rotated.

When using an ADC, the wedge angle is only half of the required adjustment. The other half is the *axis* of the wedge. The wedge must be *optically* aligned with a vertical direction with respect to the horizon. For this reason, an ADC is initially set up in such a way that the wedge angle of both prisms is aligned to a purely vertical direction with respect to the horizon.

When the ADC is adjusted, both prisms are rotated equal angles, but they are rotated in opposite directions. This keeps the axis if the wedge formed by both prisms oriented correctly. Now that we’ve covered the basic concept of an ADC, we’ll go into details about the ZWO ADC itself.

8.2.1.2) The ZWO ADC

The tested sample of the ZWO was purchased new from Agena Astro. Contents of the box included the ADC with its 1.25" adapters ONLY. There were no instructions, no quick start card, and no URL for where to download a manual. This is a major omission, even though a PDF of the manual was acquired via a simple web search. And I had even given the dealer a “heads up” that I would be reviewing the unit, which is something I rarely do.

The ZWO ADC consists of three basic parts. (Body of unit, 1.25 adapter, 1.25 eyepiece holder.)
(...) TBD

When a planet is below about 25 degrees elevation angle, an ADC can make make more difference than the telescope that is used. For example, the C8 beats the MN61 if the ADC is used on the C8, but not on the MN61.
(...) TBD

Also to review (TBR):

8.2.2 Dakin 1.5x (Questar) / 1.7x (Vernonscope) Barlow lens. (Long FL for less field curvature.)
8.2.3 TeleVue 5x PowerMate
8.2.4 Selected eyepieces? (Brandon, TeleVue 2.5mm T6, 7mm T1 Nagler, 16mm T5, etc?)

9.0 Appendices. (Common Telescope Design Flaws, Maintenance of an SCT, etc.)

9.1) Appendix A: Baffled by Telescope Light Baffles? So Are Some Telescope Manufacturers!

Is the ultimate "planet killer" telescope an expensive Maksutov-Cassegrain telescope? You may be surprised to find that it may not be. Some *larger* Mak-Cass telescopes that enjoy a reputation for excellent planetary images may, in reality, provide planetary images that are *inferior* to far less expensive Schmidt-Cassegrain telescopes (SCT's) of similar aperture. The reason for this? It is often *poor light baffle design* in the Mak telescopes. Several examples of poor baffle design were encountered when I inspected a relatively wide array of catadioptric telescopes over time.

But people have been getting good planetary images with these Maksutov-Cassegrain telescopes, haven't they?" Perhaps. However, this may be partly because people who *think* they have a good "planetary" telescope will use their telescope for planetary imaging. Other people may in fact have *better* telescopes for planetary observation and imaging, yet seldom use them for that purpose because they *don't think* they have a telescope with good planetary performance.

In reality, if you have a *USA-made* 8" Schmidt Cassegrain telescope (SCT), you may very well have a planetary telescope that is *superior* to *imported* Maksutov Cassegrain telescopes of similar to slightly smaller aperture that many use for planetary observation. A Celestron 8 or similar SCT has a central obstruction that is 34 percent of the aperture width. And so do many Mak-Cass telescopes! The Mak-Cass specs just *don't admit it.* As we will see, some large, expensive Mak-Cass telescopes may, in terms of percentage, have larger central obstructions than 8" SCT's.

We will start with the state of telescope light baffles when I first got into amateur astronomy decades ago. Back then, few if any telescopes were imported from China. For consumer catadioptric telescopes, there were a fewer choices than there are today, but *quality* was better. (In the context of this material, "catadioptrics" are reflector telescopes with refracting correctors.)

Early on, there was Celestron, with its recently introduced C90 Mak-Cass and its well established line of SCT's, in apertures of 5, 8, and 14 inches. The C11 was then about to become the new kid on the block. Another company, Criterion, made Dynamax SCT's in 6 and 8 inch apertures.

There was of course Questar, with their precision 3.5 and 7 inch Maksutov-Cassegrain telescopes (12" was not out yet), and the newly formed Optical Techniques (OTI), which made the Quantum 4 and 6 inch Maksutov-Cassegrain telescopes, and also had an 8" telescope in their brochure.

Other than these, there was the Ad-Astra III, a 78 mm Maksutov-Cassegrain, a few imported Cassegrain telescopes that were made in Russia (then the Soviet Union), and a few others.

A good percentage of the available catadioptric telescopes that I was able to see in person were *not* baffled properly. But a few were also *good* examples of light baffling. The Questar 3.5, the Quantum 6, and the Celestron 8 telescopes were almost textbook quality in terms of the diameter and length of their internal light baffles. In most of these, the interior surfaces of the light baffles lacked adequate knife edge stops, so they were not by any means baffled to perfection.

Other telescopes had light baffle flaws, but most were not as serious as flaws in later telescopes:

* The original Celestron 90 Mak-Cass has a primary baffle tube that does not extend very far in front of the primary mirror. At its front, there is a flat ring that blocks some of the stray light that can get past edges of the secondary baffle on the back of the Maksutov corrector. Unfortunately, this is not an optimized design, and stray light entering around the secondary baffle can flood the edges of the 35 mm camera format when taking pictures. In addition, stray light reflected from the inside surface of the primary baffle tube caused obvious flare terrestrial photos. This was intolerable, so I extended the baffle forward by adding a conical section about 2.5 cm long that was made from sheet metal and epoxy, then painted black. This greatly reduced flare in my C90.

* The OTI Quantum 4 has a 100 mm aperture. It is noted for its small 33 mm central obstruction. However, if you look into it from the back (while holding a transparent ruler across the front) it is obvious that the obstruction is really 36 mm, and that the front end of the primary baffle tube is causing the enlarged obstruction. Given the diameter of its front end, the primary baffle tube is too close to the secondary mirror spot on the back of the Maksutov corrector. This causes its reflection in the secondary to occupy more of the aperture width. The exit pupil seemed odd when I used a Quantum 4, so I checked and found the baffle issue. It causes some longitudinal distortion in the exit pupil, since the image of the aperture is not on the same plane in the pupil as the image of the central obstruction. The Quantum 6 does not share this minor flaw.

So, at the time, light baffle issues were comparatively minor. This would change in later years.

A short time later, Meade introduced an 8" Schmidt-Cassegrain telescope (SCT), the 2080, then followed with a 10" SCT. The primary mirror in the 2080 was advertised to be almost 2 percent larger than the primary mirror in the Celestron 8. But there were *other* changes. The primary baffle tube was shorter and the secondary baffle was larger. This gave the Meade 2080 a central obstruction of almost 37 percent, while the Celestron 8 obstruction was only about 34.4 percent. This was not a big deal for most observers, but it deviated from the comparatively optimized design of the Celestron 8 light baffles. The *big* light baffle changes were still many years away.

In the 1990's, Meade introduced the ETX series of telescopes. The ETX 105 was a well baffled telescope, but in the smaller ETX 90, the secondary baffle was too small. This clipped the outer part of the light bundle from the primary mirror, reducing the aperture used for the axial image by more than 5 mm. Other telescopes from various manufacturers would follow in the same decade, but their light baffle flaws still were not huge in terms of percentage.

After 2000, telescopes from China began to be more common. Some people said they were good telescopes and some said they were bad. I did not have an opinion one way or the other until I bought a Chinese Mak-Cass in 2018. After that, I had an opinion, and it wasn’t a favorable one!

I found that the Chinese-made Mak-Cass telescope produced poor images for several reasons. Later, I bought another Chinese Mak, then finally another. These too were flawed, and their light baffles were among the most significant flaws. At this point, I was through with Chinese Maks. It is here that our adventure of exploring “acceptable” to even “poorly made” telescopes begins!

In order to help others avoid the same pitfalls when looking for a telescope, some design flaws that I encountered are addressed in this section. I can't say if other telescopes of the same brand are as *poor* as my samples. However, to purchase 3 Chinese-made telescopes, then find that *all 3 have significant defects*, may speak volumes about Chinese Cassegrain telescopes in general.

The flaws of each Chinese-made Mak-Cass telescope I acquired during and after early 2018 are described below. The magnitude of some of the flaws may blow your mind. Some of the most significant flaws are related to *light baffles*, but one also had major optical flaws. Some baffle flaws can be corrected; others cannot. Think that imported Mak is a planet killer? It may not be!

Here are three real world examples of Chinese Mak-Cass telescopes that I inspected in the last year. The three examples are pictured below, then described in more detail after the photos.

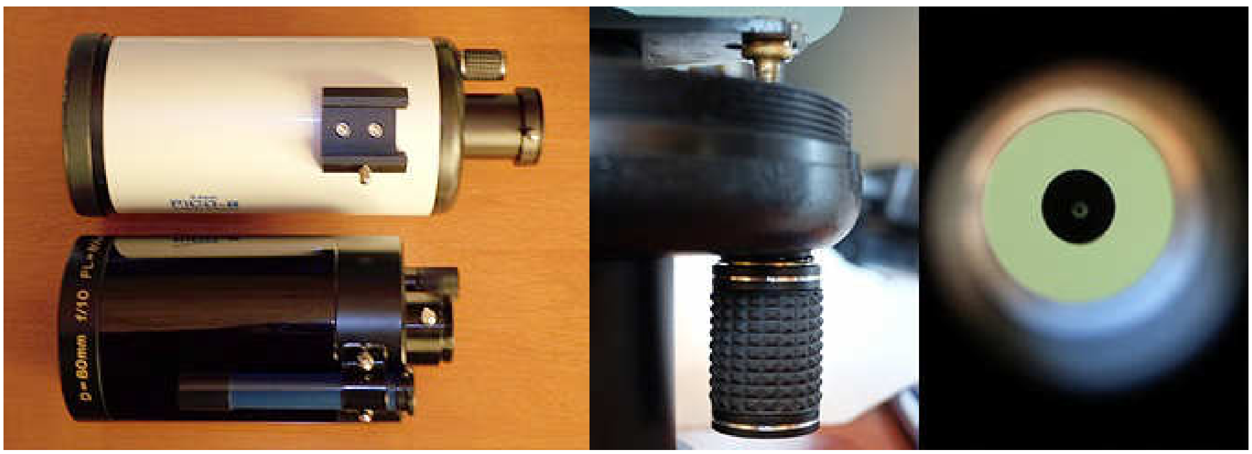

Figure 9.1A. The Kasai Pico-8 I bought in 2018 has *many* significant flaws. Where do I start?
LEFT: This Kasai Pico-8 was made in China. It is not as small as the 20 year old B&L 800 mm below it, and it is not as sharp either. However, it <u>*could*</u> have been a better telescope *if it had been made properly*. It has some of the most elementary design and build flaws I've ever seen.
CENTER: The focus knob had over 0.5 mm of end play, for very sloppy focus, and there is no adjustment for focus knob play, while there is in the B&L. I made a brass washer to correct this.
RIGHT: Bright reflections in primary light baffle tube cause obvious flare, even on the moon.
Primary baffle is also too close to the secondary, effectively increasing central obstruction size.

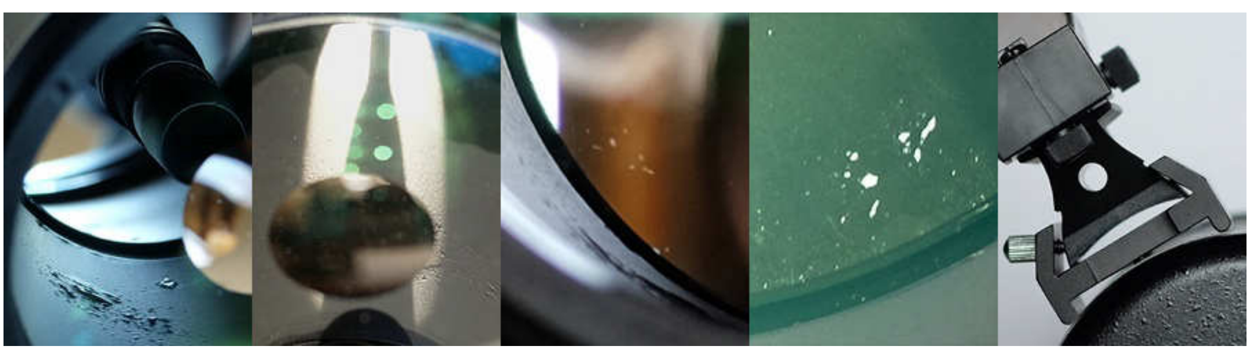

Figure 9.1B. Kasai Pico-8 flaws... But wait, there's more!
LEFT: Badly blistered paint *inside* the optical tube. And this is a "brand NEW" telescope!

SECOND FROM LEFT: More blistered paint, and dark stains toward front (top sides of image). CENTER: Pictured white spots are HOLES in the primary mirror coating, not spots on surface. SECOND FROM RIGHT: Detail of *holes* in primary mirror coating, along with possible surface roughness. The mirror, as seen through the holes in the mirror coating, appears to be white, as though mirror was not fully polished before it was coated. On top of this, the mirror has a turned down edge that causes the telescope to have a spot size larger than an *arc minute!* Planetary viewing wasn't even possible until the outer few millimeters of the primary mirror were masked off. Even then, the Pico-8 does not perform as well as some photographic mirror lenses. RIGHT: The red dot finder dovetail does not properly fit the telescope, because its side gusset gets in the way. The finder is then tilted so much that the dot can't be adjusted to match the telescope. It was fixed by filing the shown notches in the gusset so it can clear dovetail fitting on the scope. Small telescopes can be accessible, but it may be good to *avoid scopes like this one!*

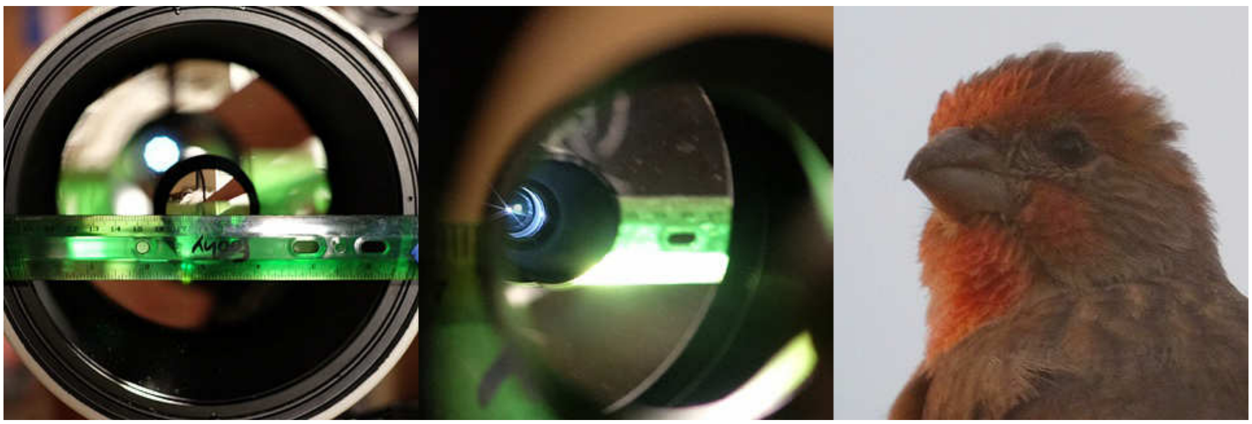

Figure 9.1C. Preparing to Measure Light Baffles; Bird After Modifying SW 180 Mak Baffle. The simple setup shown here is used to measure the effective aperture and central obstruction size of the pictured Sky Watcher (SW) 180 mm f/15 Maksutov-Cassegrain and other telescopes. LEFT: To measure the real world aperture and the light baffles, a transparent ruler is placed in front of the telescope, then the aperture is observed under moderate magnification (but with a small pupil lens) from the focal plane. Tested telescopes are focused to infinity prior to making measurements. Results of these tests for two telescopes are shown in the next figure (6.1.1D). CENTER: Testing the secondary baffle of the Sky Watcher (SW) 180mm f/15 Mak-Cass. This photo is taken from about 5 mm inward from the left outer edge of the Maksutov corrector at the front of the telescope. It shows the secondary mirror spot, as reflected from the primary mirror. The small spot of bright light at the left is at the center of the focal plane. The spot of light is beginning to be blocked by the tapered secondary baffle, and is extinguished when viewed from another millimeter toward the outer edge of the front aperture. This indicates that the secondary baffle (which is too small where it meets the secondary mirror spot) limits the aperture (as seen from the center of the focal plane, *which is what counts*) to 172 mm. The outer aperture visible to the left of the bright spot (just left of baffle reflection) is not being used. This blocks 9 percent of the aperture. This conclusion is confirmed below, by other methods of testing for the problem. RIGHT: Sharpened crop of small bird, photographed from just over 20 meters, after the SW 180 light baffles were modified to reduce flare and slightly reduce the size of the central obstruction. Original *SW 180* images are all a little soft due to presumed primary mirror surface roughness, but *spherical aberration correction* appears to be *better than average* for a Chinese-made Mak.

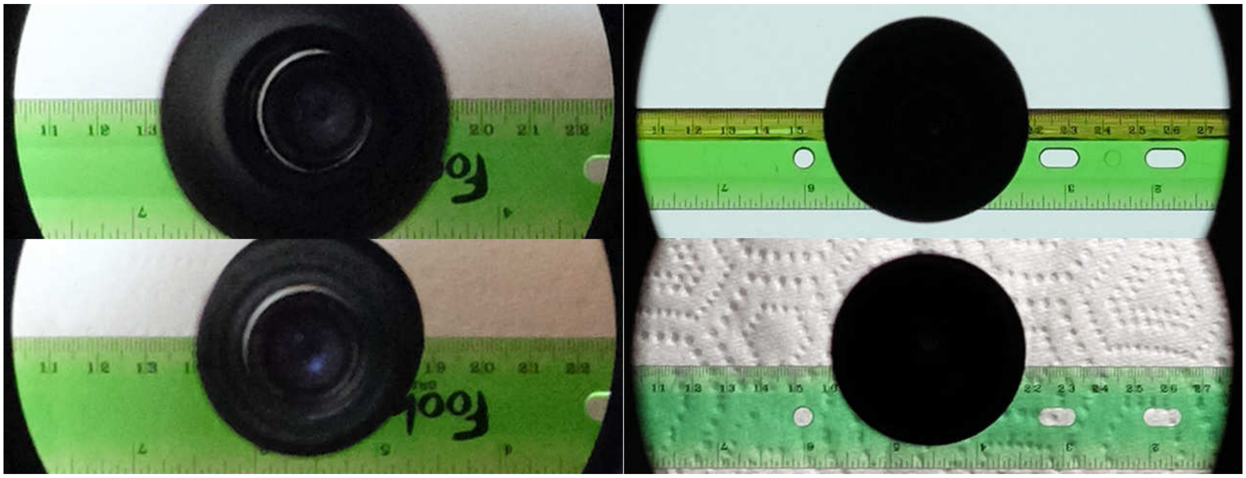

Figure 9.1D. Before and after measurements of *Mystery Mak* and Sky Watcher 180 apertures. These telescope entrance pupil images were taken from the center of the focal plane, at a back focus distance that is equivalent to using a typical 2" diagonal mirror attachment at the back. A small aperture is used in the camera lens to get enough depth of field to identify components that define the aperture and central obstruction in each telescope.
UPPER LEFT: The primary light baffle in this un-branded 130 mm f/15.4 Mak-Cass telescope is so long (and large at the front) that it defines the central obstruction, making it excessively large. It obscures fully 61 mm (49 percent!) of the real world telescope aperture diameter. Its effect is compounded by the fact that the *true* aperture of the telescope (as shown by the ruler) is only 125 mm, *not* the 130 mm shown on the telescope bezel. *(Each picture is scaled so the aperture will go to the edges of each image IF it meets manufacturer specifications).* LOWER LEFT: After replacing the huge primary light baffle tube with a more appropriate one, the central obstruction is reduced to only 46 mm, or about 37 percent. This *significantly* improved image quality. But the smaller obstruction by the primary baffle betrays that the primary mirror is not coaxial with either its mirror thimble or the baffle tube, evidenced by the oval shape of the central obstruction after the telescope is collimated. This is a weakness of many Chinese-made Mak telescopes.
UPPER RIGHT: This Sky Watcher 180 mm f/15 Maksutov-Cassegrain telescope has *two* design flaws in its light baffles. As with the "Mystery Mak", the front end of the primary baffle tube is too close to the secondary baffle, given its front diameter. This results in an effective central obstruction of 59 mm. The second design issue is that the secondary baffle is too small where it is cemented to the secondary mirror spot. This limits the real world aperture to only 172 mm. Unfortunately, this second problem cannot be corrected, because the edges of the secondary spot probably would not survive removing the secondary baffle in order to modify or replace it. In light of the working 172 mm aperture, the central obstruction width is 34.3 percent (59/172) of the aperture, which is the *same percentage* as the central obstruction of a Celestron 8 SCT!
LOWER RIGHT: After modifying the front end of the primary baffle tube, the effective central obstruction is reduced to about 56 mm. Not a huge difference, but it brings the linear obstruction percentage down to about 32.5. More importantly, replacing the front 20 mm of the SW primary baffle tube with a slightly shorter and thinner wall tube that also has a smaller inside diameter reduces flare from stray light, compared to the original primary light baffle configuration. The primary mirror of the Sky Watcher 180 mm is not quite co-aligned with its mirror thimble or the primary baffle tube, but the error is not as bad as that of the "Mystery Mak" noted above.

9.2) APPENDIX B: Basic Servicing Celestron 8 SCT (and Similar) Telescopes

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9.2.1) Introduction.

Occasionally, it may be necessary to clean or service a Celestron 8 or similar Schmidt-Cassegrain telescope (SCT). This material covers only variations of *non*-computerized Celestron SCT's up through the Ultima. Many aspects may apply to Celestron 5, 9.5, and 11 SCT's of similar age. Newer versions (Edge, etc.) are not covered because I don't own one and have not serviced one.

9.2.1.1) Versions of the Celestron 8 (up to the Ultima):

Before getting into the actual process of servicing a Celestron 8 (C8), we will first cover a few variations of the C8 Optical Tube Assembly (OTA) and the C8 fork mount motor base. Each item is broken down into the aspects that differ. The following may not cover all variations:

9.2.1.1.1) Celestron 8 OTA Versions:

* Heavy castings, metal secondary mirror cell, metal corrector plate retainer, orange tube color.
* Thin castings, plastic secondary cell, metal corrector plate retainer, orange tube color.
* Thin castings, plastic secondary cell, plastic corrector retainer, orange or black tube color.
* Heavy castings, plastic secondary cell, plastic corrector retainer, black tube color (Ultima).

9.2.1.1.2) Celestron 8 OTA Schmidt Corrector Plate Cell Versions:

* Thick casting, metal corrector retainer, 8 screws, fiber washers for corrector, no mirror slots.
* Thick casting, metal corrector retainer, 8 screws, fiber washers for corrector, two mirror slots.
* Thin casting, metal corrector retainer, 6 screws, fiber washers for corrector, two mirror slots.
* Thin casting, plastic corrector retainer, TBD screws, rubber washers for cor., two mirror slots.

9.2.1.1.3) Celestron 8 OTA Secondary Mirror Cell Versions:

* Thick front casting, metal secondary cell, secondary secured with center screw, collimated with 3 *set screws*. (Removing collimating screws to add knobs NOT recommended with this version.)
* Thin front casting, plastic secondary cell, secondary back plate pivots on raised surface at center of secondary cell, and is secured only by the three oval or *button head* collimating screws.

9.2.1.1.4) Celestron 8 OTA Focus Mechanism Versions:

* Thick casting, pin and fitting connection to primary, retaining screw inside short focus knob.
* Thin casting, pin and fitting connection to primary, retaining screw inside long focus knob.
* Thin casting, focus screw hard mounted to mirror cell, retaining ring inside long focus knob.
* Note 1: Celestron focus mechanisms retain the brass focus fitting with twin ball bearings.
* Note 2: Meade SCT telescopes do not have focus shaft ball bearings. Only have washers.

9.2.1.1.5) Celestron 8 Fork Mount Motor Base Versions: (Thick fork arms may be sand cast.)

* Thick round base casting, thick fork arms w/holes, 2 AC motors, spur gear, round power jack.
* Thin round base casting, thin ribbed fork arms, two AC motors, spur gear, oval power jack.
* Thin elongated base casting, thin ribbed fork arms, one AC motor, spur gear, oval power jack.
* Thin elongated base casting, thin ribbed fork arms, Byers worm gear, oval power jack.
* Thick elongated base casting, thick fork arms, worm gear, runs on 9V battery (Ultima).

9.2.2) Servicing the Celestron 8, Basic Steps:

This section covers servicing of the Celestron 8 OTA at a basic level. Servicing the fork mount motor base is not covered in this initial version. There were several versions of the fork mount.

9.2.2.1) Servicing the Celestron 8 OTA, Basic Steps:

Note: Servicing a C8 OTA may take between 1 and 6 hours, depending on what needs done. To begin, you'll need a proper work space and a few appropriate simple tools (Allen wrenches, etc.).

Figure 9.2.2.1A. Servicing a Celestron 8 SCT: Photos of some of the steps described below. UPPER LEFT: Preparing the focus mechanism, to facilitate later removal of primary mirror. A retaining screw or ring (depending on model) must be removed from the end of the focus bolt that is visible inside the brass fitting on the telescope. This version uses a retaining ring. UPPER RIGHT: Schmidt corrector plate removed, set in safe place. A cover is recommended. LOWER LEFT: C8 OTA with corrector plate removed. Primary mirror removal slots are at the top and bottom of the photo for this model. C-ring around primary baffle tube must be removed. LOWER RIGHT: Removing the primary mirror by tilting it so it will fit through the mirror removal slots in the front cell, without marring the mirror coating. Take care to keep the mirror edge from hitting the cell or baffle tube, since this can cause chips. The OTA is pointed vertical for this step. The focus bolt is toward the upper left of the photo, sticking out behind the mirror.

9.2.2.1.1) Part 1: Preparing the Focus Mechanism:

* Set telescope focus within a turn or two of where it is normally set when observing.
* Remove focus knob.
* Measure/note position of focus bolt end relative to back end of brass focus fitting.
* Remove focus bolt retaining screw or ring (must focus so mirror toward back to remove ring).
* Clean threads at end of focus bolt (especially if focus bolt is type with retaining ring).
* Take note of which focus direction moves mirror forward, but do not adjust focus very far.
* Replace focus knob.
* Prepare a safe, level, secure location in which to set the corrector plate and primary mirror.

9.2.2.1.2) Part 2: Removing the Schmidt Corrector Plate:

* Secure telescope so that the front end of the OTA is reliably locked to be pointing straight up.
* Remove screws that are used to attach the Schmidt corrector retaining ring (at the front).
* Note rotational orientation of retaining ring to OTA. Make marks if necessary.
* Remove Schmidt corrector plate retaining ring.
** If ring is stuck to the corrector, do NOT force it off. Lift gently for a while (up to minutes).
* Note rotational orientation of the corrector relative to OTA. Make marks if necessary.
* Note the locations of any shims around the edge of the corrector plate.
** If corrector edge shims are loose, remove them and note the position of each one.
* Securely grasp front of the secondary cell and GENTLY lift Schmidt corrector out of telescope.
** If the corrector is stuck, do NOT pull hard, pry, or try to force it out. Instead:
** Re-attach the corrector retaining ring with its screws, then back screws out about 1.5 turns.
*** Invert OTA so front end is down. After sitting a few hours, the corrector should come loose.
*** Point OTA with front up again, securely lock in place. Remove ring screws, ring, corrector.
* Set corrector with the attached secondary in safe, secure, clean place, with secondary down.

9.2.2.1.3) Part 3: Servicing the Secondary Mirror (ONLY DO THIS IF NECESSARY!):

* Removal or servicing of the secondary mirror may be needed if a lot of debris is inside scope.
* It is not necessary to remove the primary mirror if the secondary is all that requires service.
* Determine which type of secondary mirror cell your C8 has (see 6.2.1.1.3, above).
* Note the rotational position of the secondary mirror relative to its cell or the corrector plate.
* Prepare a short tube with a soft non-abrasive front surface (cotton, etc.) that is sized to fit inside secondary baffle, yet only contact less than outer 3mm of secondary mirror. The soft ended tube should have a flange that is large enough that the secondary baffle can rest on it, yet keep the soft end of the tube from touching the secondary mirror by a margin of 1 to 2 mm. OR:
** Prepare tapered shim stock band that fits around perimeter of the secondary, to hold it (best).
* Prepare soft non-abrasive work surface that the secondary mirror can safely fall onto.
* *Hold the corrector assembly so that the secondary mirror is pointing up.*

* **3A**: If the secondary cell uses three *set screws* for collimation, try these steps.
** Note the longitudinal position of the collimation set screws to within 0.5 mm.
** Loosen and remove center screw that holds secondary mirror in place. Note how tight it was.
** If secondary mirror rotates with the center screw, evenly tighten collimating screws a little.
** If the secondary mirror still rotates, make a shim stock band to hold it by its perimeter.

* **3B**: If the secondary cell uses three oval or *button head* collimation screws, try these steps:
** Evenly loosen all 3 collimation screws (1 turn each) until they fall out of the front of the cell.
** Note tightness of first screw while loosening it.
* Then, for <u>*either*</u> type of secondary mirror cell:
* When the secondary mirror is free, insert the prepared soft ended tube into secondary cell so that it barely does not touch the secondary mirror. Verify that the soft end of tube is not touching secondary mirror. If it touches, modify it, or (if the cell uses set screws for collimation) back off the collimation set screws to provide clearance. (This is to keep the weight of corrector plate from resting on the secondary mirror surface via the prepared soft ended tube.)
* After the above steps, invert the corrector plate *while* the soft ended tube is held in place.
* After the corrector has been inverted so its front side is up, slowly lift it off of the secondary mirror, taking care not to laterally move the secondary mirror on the soft ended tube.
* When the secondary mirror is free, service it as necessary.
* Clean the secondary mirror cell in the area normally covered by the mirror.
* If secondary cell uses set screws for collimation, return the screws to their normal positions.
* Orient the Scnmidt corrector so that secondary mirror will point up when installed.
* Rotationally orient the secondary mirror so that it is in its original orientation.
* Gently lower the secondary mirror into the secondary baffle. (Shim stock band works best.)

* **3C**: If the secondary cell uses *set screws* for collimation, try these re-assembly steps.
** Install the center screw that retains secondary mirror (install it from below), and screw it in.
** If the secondary mirror rotates, use the shim stock band from step 3A to prevent rotation.
** When the secondary mirror retaining screw is just short of having any resistance, gently rotate secondary mirror (using shim stock band) to feel for detents made by collimation screw tips.
** Verify proper rotational secondary position and tighten center screw to original tightness.

* **3D**. If secondary cell uses oval or *button head* collimation screws, try these re-assembly steps:
** Place thin wire or allen wrench through one screw hole in front of secondary cell, and insert it into a hole in the secondary mirror mounting plate. Keep it in place until first screw is installed.
** Insert a collimation screw into another hole and gently thread it in about 2 turns.
** Verify that proper rotational orientation of secondary mirror has been maintained.
** Insert a second collimation screw and thread it in two turns. Repeat with the third screw.
** Evenly tighten all collimation screws (1 turn each) until all at their original tightness.
* Then, for <u>*either*</u> type of secondary cell:
* Verify secondary mirror does not tip, rattle, or rotate when corrector cell is moved.
* Proceed with other steps of servicing telescope, as needed (see below).
* Collimate telescope after full re-assembly (see Part 10). Collimation may initially be WAY off.

9.2.2.1.4) Part 4: Removing the Primary Mirror

* Remove the metal C-ring that is 8-10 cm behind the front end of the primary baffle tube.
** Take care that ends of C-ring do not scratch primary baffle tube (can try sliding it on shims).
* Turn focus knob to move the primary mirror forward until the focus bolt at the back is free.
** This may take a LOT of focus knob rotations.
* Carefully grasp the primary mirror thimble, taking GREAT care not to touch the mirror surface.
* If the primary mirror thimble is free, slide it forward and off of primary baffle, AND,
* Carefully tilt primary mirror so both it and focus bolt will clear front corrector cell, AND,
* Carefully remove primary mirror, while orienting it so its edges pass through any mirror slots.
* Carefully set the primary mirror in a secure, clean, safe place, with its back end down.
** Note: The primary mirror is accurately cemented to its thimble. Do *not* try to separate them!

9.2.2.1.5) Part 5: Servicing:

* Perform service (cleaning, etc.) See other references for optical cleaning techniques.
* Do not attempt to clean mirrors unless they are dirty enough to obviously impact image quality, or if they have mud, mildew, or fungus on them. * Do NOT use acetone on any mirror surfaces.
* Inspect the Schmidt corrector plate for dirt, haze, or fungus. Clean it if necessary.
* Remove focus knob from brass focus fitting (for inspection and preparation for re-assembly).
* Remove focus knob assembly from back of telescope by removing the 3 screws near its edge.
* Inspect the focus knob assembly and bearings for grit, and clean and re-lube it if necessary.
* Inspect back of primary mirror thimble to ensure that it is free of grit. Clean it if necessary.
* Do not use thick, fibrous, or sticky grease on mirror thimble or primary baffle tube.
* Optional: Grind or file extreme tips of C-ring, to round off where ends will touch baffle tube.

9.2.2.1.6) Part 6: Preparing OTA for Re-assembly:

* Wash hands.
* Point the front end of OTA tube down, and blow clean air into it, to remove dust.
* Again secure telescope so front end of OTA is pointing up.

9.2.2.1.7) Part 7: Re-Installing the Primary Mirror:

* When picking up primary mirror by its thimble, note rotational location of focus bolt.
* Carefully tilt and insert primary mirror into OTA, leveling it after it is inside, AND,
* Carefully and slowly center the mirror in the OTA, and slide it down over primary baffle tube.
* If needed, rotate primary mirror as it nears back of OTA, to align focus bolt with hole in OTA.
* Replace metal C-ring, taking care not to scratch primary baffle tube or let it fall onto primary.
** OTA can be oriented so that it is *securely* pointing UP at a 15 to 45 degree angle for this step.

9.2.2.1.8) Part 8: Attaching and Adjusting the Focusing Assembly.

* This step is best performed when the telescope is oriented so that it is pointing level.
* Screw the brass focus fitting onto the back end of the focus bolt.
** In older C8's, take care *not* to slide the focus bolt end fitting off of the mirror thimble pin!

* Turn focus fitting until previously measured bolt position is reached when focuser pushed in.
* Attach the focuser cover with its three screws, and evenly finger tighten the screws.
* Attach the focus knob (this is a temporary step).
* Check focus knob for smooth action. If it is rough or tight, adjust centering of focuser cover.
* Evenly tighten (but do not over-tighten) focuser housing screws after adjustment is complete.
* After the focus works smoothly, remove the focus knob.
* Re-attach the focus bolt retaining screw or ring, then re-attach the focus knob.
* Run focuser back and forth several turns. If gets rough, try adjusting the focuser cover again.
* Clean focus knob and back of OTA to remove any new grease.   * Wash hands.
* Clean off the primary baffle tube OD and mirror thimble OD, *without* touching mirror surface.
* Wash hands again.

9.2.2.1.9) Part 9: Re-installing the Schmidt Corrector Plate:

* **9A**: Point front end of telescope OTA down, gently blow clean air into it, to remove dust.
* Again secure the telescope so that the front end of the OTA is pointing up.
* Securely grip the front of the secondary cell, blow any new dust off of Schmidt corrector plate.
* Install the Schmidt corrector plate, being careful to restore its proper rotational orientation.
* Look through corrector to inspect inside of telescope, to see if entry of new dust was excessive.
** If internal dust is excessive, remove the corrector plate, then repeat steps 9A onward.
* Install any original shims around the edges of the Schmidt corrector plate.
* Install the corrector plate retaining ring, being careful to restore proper rotational position.
* Check to be sure that the corrector plate retaining ring is properly seated all the way around.
* Insert retaining ring screws, then evenly finger tighten them.
** If screws bind against some retaining ring holes, it may help to slightly enlarge such holes.
* Back off retaining ring screws 1/4 turn, lightly press on retaining ring, then finger tighten again.
* Do not tighten corrector plate retaining ring screws beyond a “tight” variety of “finger tight”.
* Verify that the retaining ring is fully seated and the corrector does not slide from side to side.

9.2.2.1.10) Part 10: Testing and Collimation:

* Star test telescope at different elevation angles.
* Collimate if necessary. (Collimation may not be needed if secondary not disturbed.)
** Collimation should be done on a night with good seeing, be done only after the telescope has adjusted to ambient temperature, and utilize a star with an elevation angle of at least 45 degrees.
* This completes servicing of your C8 OTA!

Comments: Collimating knobs are NOT recommended as part of proper servicing of a C8. When collimation is properly set, it should remain set for years. Many image flaws that some *think* are collimiation errors are actually caused by tube currents. Collimation knobs make it all to easy to inadvertently *lose* proper collimation adjustment!

9.2.2.2) Servicing the Fork Mount Motor Base. (Not covered in this version.)

Appropriate service methods are highly dependent on the version of fork mount being serviced.
Clear skies, Jeff C.