24-26 MM EYEPIECE COMPARISON

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(As Viewed in: 10” Dob / 4” APO / 2.4” Achromatic / 1.6” Solar Telescope)

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Explore Scientific 68 – TeleVue Panoptic – Meade 5000 SWA – Sterling Plossl – Takahashi LE
TeleVue Plossl – University Optics Konig – Vernonscope Brandon – Celestron “Silvertop” Plossl
University Optics Ortho – Zeiss ABBE Ortho (ZAO-I) – Celestron (1980’s) Ortho

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I. Introduction

Eyepieces in the 24mm to 26mm focal length range hold a special place for many observers. The 24mm TeleVue (TV) Panoptic has become the time-honored gold standard for wide fields allowing close to the maximum True Field of View (TFOV) that is capable from a 1.25" barrel, and the 25mm ZAO is arguably the gold standard for this focal length from the classic optical designs (i.e., those without integrated Smyth/Barlow groups in the barrels). Initially this comparison was meant to be a simple head-to-head between the 24mm TV Panoptic and the new 24mm Explore Scientific 68 degree series. However, once the word was out a flurry of other eyepieces in this focal length range, both old and new, came knocking at my door from fellow observers to join in the competition.

With a field of competition where the Apparent Fields of View (AFOV) of the eyepieces ranges from 40 degrees to 68 degrees, how is comparison even possible? Many observers, myself included, usually don't compare wide fields to narrow fields as the added perspective of the larger Field of View (FOV) usually trumps our perceptions as something better, and we therefore think of wide fields as a separate class of eyepieces. For this comparison, I therefore did not try to assess any advantages or disadvantages of AFOV when comparing the eyepieces and tried as much as possible to treat them all as equals, observing how they performed both on-axis and off-axis regardless of the size of their AFOV, and ignored any target-based advantages from greater context of surrounding star fields. As example, if an eyepiece had a poor off-axis that takes up 50% of its AFOV, it matters little how large that AFOV is as either the wide field or narrow field serves up only one half of its FOV very well, and your perceptions convey to you that half of what is available to view in unsatisfactory. During the course of this comparison I found this to be very true as there was no advantage to a wide field over a narrow field if they both showed an equal percentage of their FOV poorly. Conversely, I also found that AFOV size did not seem advantageous if the FOV of the eyepiece was rendered beautifully across the entire FOV as an excellent view still remained an excellent view and a wonderful experience regardless if the AFOV was 40 degrees or 68 degrees or anything in between. In the end, I discovered that observing satisfaction was linked less to AFOV size and more to exactly how well the eyepiece performed with whatever AFOV it presented. This comparison therefore gives no preference or attention to the size of the AFOV other than validating that the manufacturer's claims matched the actual size of the AFOV observed. In this way, all the eyepieces could maintain an equal footing with each other with biases from AFOV mitigated as much as possible from the comparison.

As a special note, much appreciation goes out to the several Cloudy Nights members: Ed Zarenski (Edz), Jamie Crona (Jaimo!), Jeff Houser (houser23), and James Cunningham, who generously and graciously contributed some of these wonderful eyepieces. In addition, the following astronomy hobbyists contributed their astrophotography and sketches: Mike Hankey (www.mikesastrophotos.com), Andy Strappazzon (http://www.smallmadtv.com), Darren Jehan (http://darrenjehan.me.uk), Bob Gaskin (http://gaskin-astro.org), and Brian Combs (www.bcastropics.com). Without the help and support of all these fellow amateur astronomers, this comparison would not have been possible.

II. A Caution about Results

Before the detailed observations and results are reported for each eyepiece, a cautionary statement -- all observers should remember that no matter what the outcome of this or any other review, your individual results may vary and those variations may sometimes be significant. Even if each of the eyepieces in this comparison only varied little from production unit to production unit (which one cannot guarantee), the seeing conditions we each have, our primary telescopes, our individual physiology, and our own unique psychology and observing habits (i.e., likes, dislikes, expectations) introduce variables into the optical chain which can sway what you will see and your individual results. Therefore, like any review or comparison you read, remember that it should be viewed only as a guideline which can indicate general likelihood of how similar equipment may perform for you. So all things may *not* be equal when used by you in your equipment or at your observing locations due to the many variables which affect the view at the eyepiece.

III. Methodology and Reporting of Results

The methodology used for this comparison was to have a single experienced observer evaluate all eyepieces during each observing session. Each observing session used either one or more telescopes, and evaluated no more than two performance criteria on one or two celestial targets. This approach, while greatly increasing the number of observing sessions required, also greatly reduced possibilities of both confusion and fatigue as each observing session then allowed concentration and focus on only a limited number of comparisons. For each test conducted, the eyepieces were rank ordered from very best to lest best based on specific criteria established for each individual test. Tests were then re-conducted on subsequent evenings to validate results.

Observations for the nighttime comparisons were performed through a variety of scopes: 10-inch (254mm) Orion XT10 f/4.7 Dobsonian, 4-inch (102mm) Takahashi TSA-102 f/8 APO, 2.4-inch (60mm) Skylight F15m f/16.7 Achromat (all pictured above). For daytime solar comparisons a 1.6-inch (40mm) Meade Personal Solar Telescope (P.S.T) was used (not pictured). Each instrument was thoroughly checked for proper collimation prior to each observing session, and was given the necessary time to reach thermal equilibrium to ensure peak optical performance. Each instrument, except the Skylight F15m, was equipped with fine-focusing capability to ensure critical focus was easily and fully achieved for each observation.

The observations for this comparison was conducted over several weeks during many evenings from November 2011 through January of 2012 from a light-to-moderately light polluted suburban Virginia location west of Washington D.C. At this location, the typical limiting magnitude varied between 3.5 and 5.5. Seeing conditions for each recorded observation ranged between Pickering 6 to 7. All results were confirmed through repeated evaluations on multiple evenings using multiple scopes – so in no case is a reported ranking or performance based solely on a single evening's observation of a given target.

For this comparison, a letter-based ranking system is employed where A is considered best and Z worst. With this ranking, sometimes multiple eyepieces attained the same letter rank. When this happens it simply indicates that the performance between them was either too close to call or so small that they were judged to be within class rather than something so distinguishing as to be in a separate class. If an eyepiece was exceptionally high or low within its class, as to be almost worthy of moving to the nest class, it was given a "+" or "-" qualifier to the letter rank. It is also worthy to note that just because an eyepiece may have been ranked with the lowest letter score, this does not mean that its performance was poor, but only means that relative to the others being compared it did not do as well. Summary ranking tables are shown throughout the Comparison Results section of this report. Rankings, in addition to being letter-based, are also color coded in the tables to quickly show the top and bottom groupings. Blue is used to indicate top performer rankings, light gray indicated middle of the pack rankings, and yellow indicates bottom of the pack rankings. Since there may be more than three letter rankings for an evaluation, the color codes may group multiple letter ranks. In the narratives which follow each table of rankings, details are provided as to what assessment criteria was chosen for the evaluation and why an eyepiece attained its particular ranking for the specified assessment.

IV. Considerations in Selecting a Long Focal Length Eyepiece

Because of their longer focal length, these eyepieces will naturally produce lower magnifications in many telescopes. With a lower magnification, the corresponding TFOV will be larger, as will the exit pupil. Given these, major considerations when selecting longer focal length eyepieces are:

- Will the exit pupil produced with the intended scope will be larger than desired (e.g., if >7mm than the background sky may appear too bright to show nebula and galaxies well and you may lose light if your eye's pupil cannot dilate that large);
- How well will your scope's design handle the larger TFOV (e.g., if using a fast Newtonian will off-axis coma become an issue); and
- How well will the eyepiece handle your scope's focal ratio (i.e., if using a fast focal ratio scope will the eyepiece be able to maintain aberrations to a minimum off-axis).

Also important to consider is for what type of targets or observing the eyepiece be used. Examples of how intended use may impact choices are as follows:

- If intended as a finder eyepiece, then AFOV becomes important so you can maximize the TFOV visible;
- If intended for observing and scanning rich star fields, then off-axis star point performance and minimized rectilinear distortions could be important considerations (note – some observers have negative physiological reactions when scanning with eyepieces with noticeable rectilinear distortion);
- If intended for observing nebula and galaxies, then fully multicoated optics and excellent light control become important as highest possible transmission and contrast allow these target types to be viewed more effectively;
- If intended for double stars, then color fidelity becomes an important factor so colorful doubles are presented with rich saturated colors and off-axis lateral color, scatter control becomes important to minimize any unwanted glow around the stars which would detract from the aesthetics, and off-axis sharpness could also be important if the observer does not have a tracking mount and the doubles will be viewed drifting through the FOV;
- If intended for Open or Globular clusters, then color fidelity becomes an important factor as many clusters contain richly colored carbon stars, off-axis lateral color and sharpness can be important if the clusters are large and will show prominently bright stars in the far off-axis, multicoatings and light control becomes important as the best transmission possible will bring in more faint stars within the clusters and both the coatings and light control features will help maximize contrast allowing the cluster to give a better dimensional perception when observed, and finally scatter control can be important if there are any very bright stars within the cluster so unwanted glow around these components is minimized; and finally,
- If intended for lunar and planetary observations, then an important consideration is how effectively the eyepiece behaves when used with a Barlow (i.e., does eye relief become too long making eye positioning too sensitive, is there any vignetting of the FOV, etc.), scatter control becomes important as increased scatter reduces contrast which is critical for planetary details, and off-axis lateral color and sharpness might be a factor if the observer does not have a tracking mount and the planet will be viewed drifting through the FOV.

VI. The Eyepieces Being Compared

The field of competition for this comparison represents an incredible range in both price and availability, with street prices ranging between $40 to over $600, and several eyepieces being no longer in production and difficult to acquire on the used market. Pictured below are close-ups of each eyepiece for a comparison of their size relative to each other (photos are to scale).

Close-ups of each eyepiece from the top and bottom are pictured below for a detailed view of each eyepiece's eye lens and its internal barrel construction (photos are to scale). Note that the Meade 5000 SWA pictured had its external housing removed by the owner to reduce its overall size and allow more usable eye relief. The green felt was added by the owner as a protective surface to prevent eyeglass scratches from contact with the top housing.

The table below represents the vital statistics on each eyepiece as presented in, in part, from their available marketing information. Due to the vintage of some of the eyepieces, some of the vital statistics marketed about the eyepieces are no longer available. If the marketing information could not be readily found then this is indicated by "?" in the table.

Eyepiece	Price New Retail / Street (2011)	Approx. Price Used (2011)	Elements/ Groups	Claimed AFOV	Claimed Coatings	Claimed Eye Relief
24mm Explore Scientific 68 (Ar)	$200 / $160	-	6 / ?	68°	FMC	18mm
24mm TeleVue Panoptic	$395 / $278	$220	6 / 4	68°	FMC	15mm
24mm Meade 5000 SWA	Discontinued	$80-$120	6 / ?	68°	FMC	18mm
24mm University Optics Konig	Discontinued	$70	5 / 3	60°	MC	10mm
25mm Sterling Plossl	$55 / $46	$30-$40	4 / 2	55°	FMC	15mm
24mm Takahashi LE	$304 / $255	$125-$175	5 / 3	52°	FMC	15mm
25mm TeleVue Plossl	$160 / $110	$75	4 / 2	50°	FMC	17mm
26mm Celestron Silvertop Plossl	Discontinued	$30	4 / 2	?	Coated	?
25mm Zeiss ZAO-I	Discontinued	$600+	4 / 2	45°	FMC	16mm
24mm Vernonscope Brandon	$235	$140	4 / 2	50°	Coated	?
25mm University Optics Ortho	$86	$45	4 / 2	47°	MC	?
25mm Celestron Ortho	Discontinued	$30	4 / 2	?	Coated	?

VI. Field Observation Results

Comparison results are categorized into the following sections:

a. Category I: Build and Field Handling Impressions
b. Category-II: Physical Measurements
c. Category III: Optical Performance Assessment
d. Category IV: Impressions Observing Celestial Targets

For each of the telescopes used in this comparison, the eyepieces produced magnifications with TFOV's as follows:

Eyepiece	XT10		TSA-102		Skylight F15m	
	Mag.	TFOV	Mag.	TFOV	Mag.	TFOV
Explore Scientific 68 (Ar)	50x	1.29	34x	1.90	42x	1.55
TeleVue Panoptic	50x	1.29	34x	1.90	42x	1.55
Meade 5000 SWA	50x	1.29	34x	1.90	42x	1.55
University Optics Konig	50x	1.14	34x	1.67	42x	1.36
Sterling Plossl	48x	1.07	33x	1.58	40x	1.29
Takahashi LE	50x	1.01	34x	1.49	42x	1.21
TeleVue Plossl	48x	1.01	33x	1.49	40x	1.21
Celestron Silvertop Plossl	46x	1.05	31x	1.54	38x	1.26
Zeiss ZAO-I	48x	1.00	33x	1.47	40x	1.20
Vernonscope Brandon	50x	0.85	34x	1.25	42x	1.02
University Optics Ortho	48x	0.84	33x	1.24	40x	1.01
Celestron Ortho	48x	0.88	33x	1.29	40x	1.05

a) <u>CATEGORY-I RESULTS</u>: ** **BUILD AND FIELD HANDLING IMPRESSIONS** **

Eyepiece	Build Quality	Lens Edge Blackening	Internal Barrel Blackening	General Handling
Explore Scientific 68 (Ar)	A	Yes	B	A
TeleVue Panoptic	A	Yes	B	A
Meade 5000 SWA	A	Yes	C	A
University Optics Konig	A	Yes	C	B
Sterling Plossl	A	Yes	B	A
Takahashi LE	A	Yes	B	A
TeleVue Plossl	A	Yes	B	A
Celestron Silvertop Plossl	A	Yes	B	B
Zeiss ZAO-I	A	Yes	A	B
Vernonscope Brandon	A	No	D	B
University Optics Ortho	A	Yes	B	B
Celestron Ortho	A	Yes	B	B

Note – Numbers indicate rankings (A is best); If a number is repeated for several eyepieces, then this means too close to call a difference with assurance; narratives contain detailed information about eyepiece's rating. Blue indicates top-ranking performers and Yellow indicates bottom-ranking performers.

Overall, all the eyepieces showed a good quality to their build. None of them had any apparent plastic or other non-durable parts. All eyepieces conveyed a solid feel, showed good attention to fit and finish, possessed precisely applied graphics that appeared would be long wearing, and many had additional features such as rubberized grips and static or movable eye guards. The only eyepiece that possessed a less than durable element was the University Optics Ortho, which had a sticker on the side of the housing saying "Japan" with the Circle-T optical house mark. Over time, these stickers become frayed on the edges and lose some of their black background color from wear, or fall off.

All eyepieces had blackening inside the barrel, however the blackening inside of the Brandon, University Optics Konig, and Meade SWA possessed a bit of a shine and reflectivity not present in others, with the Brandon showing the worst. The ZAO was the only eyepiece to have a flat surface inside of the barrel blackened with an extremely non-reflective paint, which upon visual inspection shows visually better, reflecting less light than others. All others had the threading grooves present inside the full length of the barrel.

Visual examination through the eye lens showed all eyepieces appeared to have blackened edges on the optical elements except for the Brandon, which showed the bright white lens edge as well as what appeared to be some irregularities between the cemented elements.

In the cold evening weather during the tests (35-45 degrees Fahrenheit), the smaller eyepieces without any rubberized grips felt less secure while handling due to reduced feelings in my hand from exposure to the cold. For cold weather observing, it would be an improvement if small form factor eyepieces had diamond cut housing sides or rubberized panels for increased security of handling. For larger eyepieces, this is also helpful, but not as necessary as it is easier to maintain a secure grip due to their size.

Eyepieces without barrel undercuts showed a distinct advantage during the comparison as those with undercuts (TV Panoptic, TV Plossl, ZAO, and Meade SWA) were constantly sticking on the compression ring in the focuser every time they were removed from the focuser. Finally, a small point, but the eyepiece top cap provided for the Explore Scientific 68 (ES-68) was frustrating at times, as when placed on the eyepiece it provides an air-tight seal. This air-tight seal made its removal very difficult due to the vacuum it created. A recommended mod would be to drill a very small hole as far off-axis as possible in the top cap so this problem would be alleviated (note – this is a feature of the Meade 5000 UWA line’s top caps).

b) CATEGORY-II RESULTS: ** **PHYSICAL MEASURES** **

Eyepiece	AFOV (+/- 1 deg) *	Eye Relief Actual - Usable (+/- 1 mm) **	Eye Lens Diameter (mm)	Field Stop (mm) ***	Out-Focus (mm) ****
Explore Scientific 68 (Ar)	68	17 - **12**	23	27.1	3
TeleVue Panoptic	68	15 - **10**	23	27.1	6
Meade 5000 SWA	68	16 - **13**	23	27.1	3
University Optics Konig	58	10 - **8**	20	23.8	5
Sterling Plossl	58	17 - **12**	29	22.5	-9
Takahashi LE	52	17 - **11**	22	21.2	1
TeleVue Plossl	50	17 - **11**	20	21.2	6
Celestron Silvertop Plossl	50	17 - **15**	24	22.0	8
Zeiss ZAO-I	49	20 - **15**	21	20.9	1
Vernonscope Brandon	44	18 - **7**	21	17.8	7
University Optics Ortho	41	24 - **20**	19	17.6	11
Celestron (1980's) Ortho	42	23 - **18**	16	18.4	10

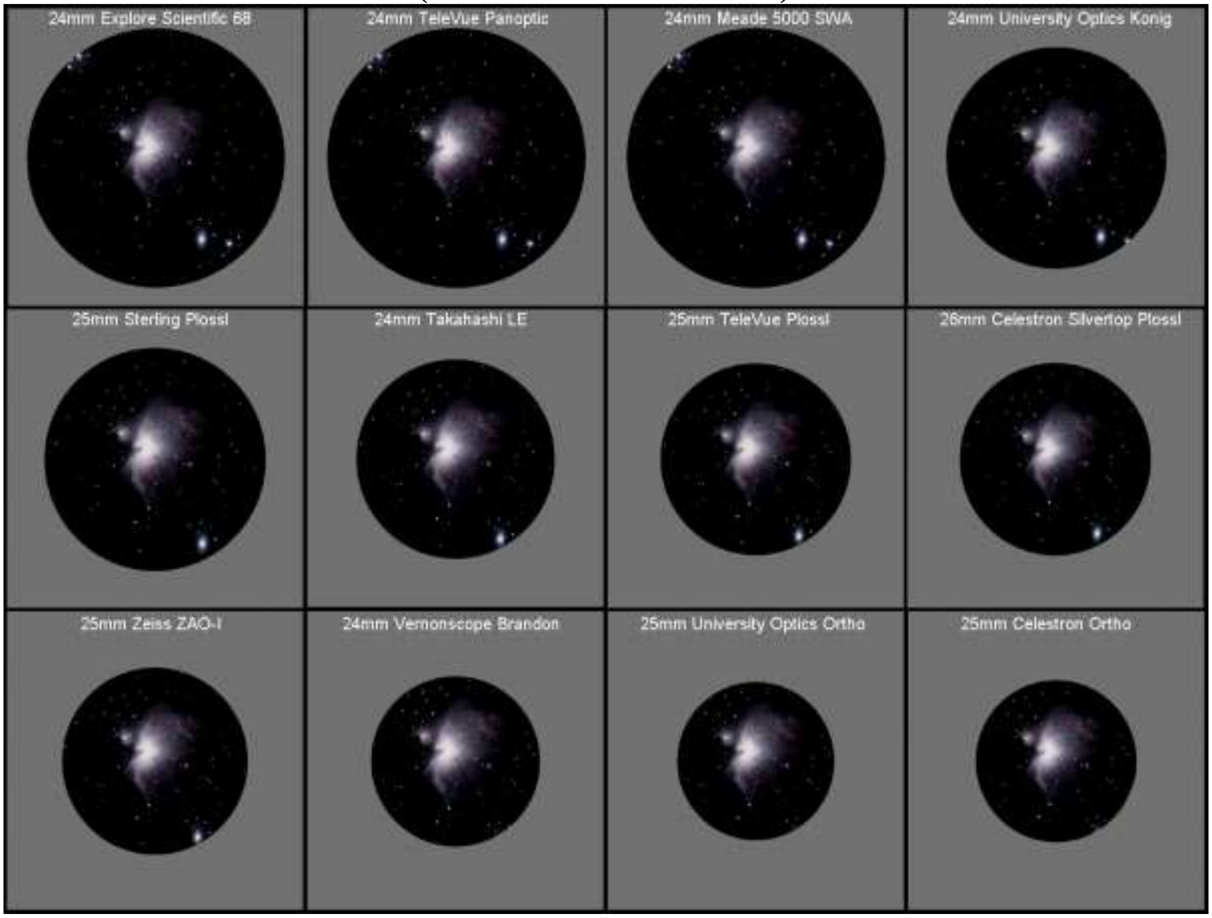
Note –Blue indicates top-ranking performers and Yellow indicates bottom-ranking performers.
*   AFOV measured on bench test using technique based on work of David Knisely
**   Usable eye relief is from top surface of eyepiece (if it had an eye guard then it was folded down)
***   Field stop measure calculated based on TFOV measures from drift tests and bench tests (+/- 5%)
**** Out-focus measured in millimeters (telescope focal point to eyepiece shoulder; negative = in-focus).

The Apparent Field of Views (AFOV) for each eyepiece was generally accurate compared to manufacturer claim. The exceptions were the Sterling Plossl and the ZAO, both of which had larger AFOVs than claimed (58 vs. 55 for the Sterling and 49 vs. 45 for the ZAO). AFOV measures were validated through both bench test measures as well as visually comparing the AFOVs (e.g., viewing through both the Sterling Plossl and the UO Konig simultaneously showed both AFOV exactly coincident and smaller than the Takahashi LE, etc.). Also of note is how the 24mm Brandon used in this comparison apparently deviates from what many observers report with this eyepiece. The 24mm Brandon has a fairly well established reputation for having a larger AFOV than other Brandon focal lengths, typically reported to be around 53 degrees. The 24mm Brandon supplied for this comparison, which was recently purchased new by the owner, had a measured AFOV of only 44 degrees and a measured TFOV that was consistent with this measured AFOV.

The True Field of View (TFOV) of each eyepiece was determined both by bench test, i.e., observing the actual field visible on a measuring tape at a fixed distance, then performing the appropriate geometric calculations, and additionally verified using a star drift test. These TFOV measures were then used to calculate the field stop size based on the manufacturer's stated focal length for each eyepiece. The following illustration shows how the Great Orion Nebula (M42) appears with each eyepiece using the Orion XT10 Dobsonian. The simulation shows the AFOV's to relative scale with the actual TFOV that was visible through each of the eyepieces.

AFOV – TFOV COMPARISON SIMULATION

(FOV in 10” f/4.7 Orion XT10)



Astrophotography of M42 by Mike Hankey, Freeland MD; www.mikesastrophotos.com

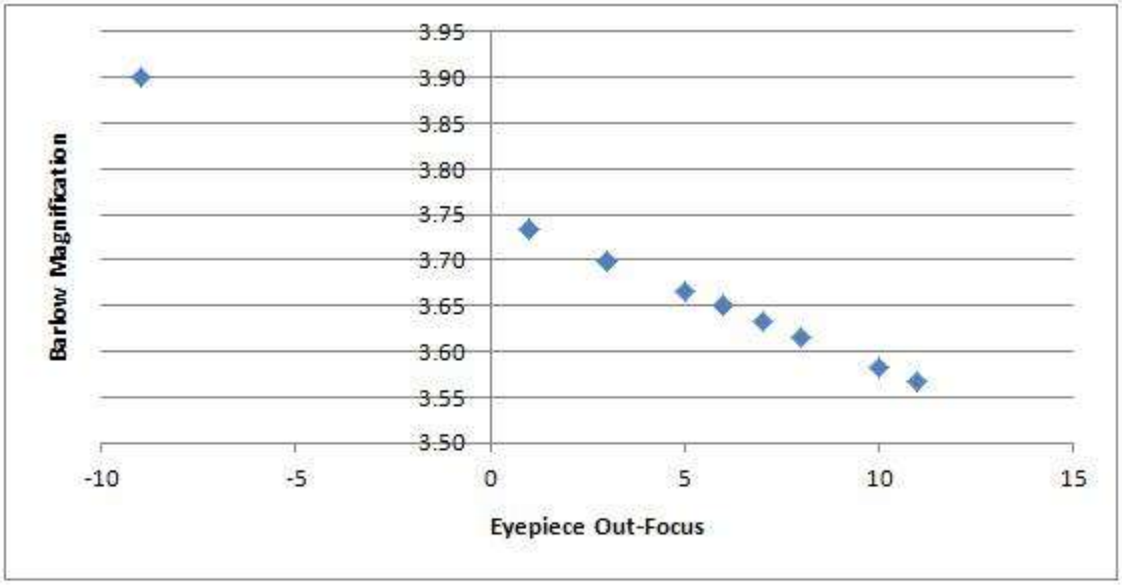
Eye relief figures deviated by several millimeters from manufacturer claims for several of the eyepieces. Note that eye relief is a measure from the center of the eye lens, which may be concave, to the focal point of the image. More critical though, is the actual usable eye relief of an eyepiece as the eye lens is often inset deeper into the housing; this and varying heights of eye guards reduce usable eye relief even further. The usable eye relief is the measure from the highest point on the top of the eyepiece housing that would contact the surface of the lens of an eyeglass wearer to the focal point of the image. For this measure, any eye cup was positioned at its lowest or folded down position. As can be seen from the figures, the Brandon had the largest discrepancy between usable eye relief and optical eye relief due to the very deep inset of the eye lens group into the housing. For the Brandon, Takahashi LE, and TeleVue Plossl, who had the thickest rubber eye guards, removal of the eye guards from the eyepiece would probably allow up to an extra millimeter of usable eye relief.

The amount of out-focus varied greatly between the eyepieces tested. Out-focus (or in-focus) is the measure of where the field stop is located in the eyepiece relative to the shoulder of the eyepiece that contacts the focuser housing when inserted into the focuser. Most notable were the extreme amount of in-focus needed for the Sterling Plossl, and the extreme amount of out-focus needed for the UO Ortho and Celestron Ortho. The impact of the relative in-focus or out-focus from the zero point is more than just focuser travel, but can also greatly impact Barlow behavior. Barlows, and some telecentric amplifiers (e.g., TV PowerMate, etc.), alter their magnification if you extend the eyepiece out of the barrel. When the field stop is not at the shoulder of the eyepiece, this not only determines in-focus or out-focus differences between eyepiece, but is also has the same impact as seating an eyepiece higher or lower in a Barlow. Barlows, and sometimes Telecentrics, will vary their magnification differently depending on how far the eyepiece's focal plane (i.e., field stop position) is positioned from the Barlow/Telecentric's shoulder. You can see this relationship if you visit the TeleVue website and look at the charts they provide under Accessories for Eyepieces, Barlows or Powermates. For the TeleVue 3x Barlow, as example, a 9mm shift in the eyepiece's focal plane or field stop position, like that of the 25mm Sterling Plossl which has the field stop offset 9mm below the shoulder of the eyepiece, and will alter the magnification the TeleVue 3x Barlow delivers from 3.20x to 3.35x. Similarly, the TeleVue 5x Powermate when used with the 25mm Sterling Plossl will produce 5.35x instead of its design of 5.10x. So the out-focus offset of each eyepiece is an important consideration when one uses Barlows, particularly if the observer is trying to compare a Barlowed longer focal length eyepiece with an un-Barlowed shorter focal length eyepiece.

For the Siebert 4x Barlow used for this comparison, its magnification was tested and calculated to vary as follows: Magnification = -0.0167 x Eyepiece Out-Focus Offset + 3.75. So the bench testing revealed that if an eyepiece has a zero out-focus offset, then the Barlow operates at 3.75x instead of the marketed 4.0x. In the case of the Sterling Plossl with its -9mm offset, the resulting Barlow magnification was 3.90x based on the formula, whereas the University Optics Ortho with its +10mm offset resulted in the Barlow producing only 3.57x. The chart below summarizes how the out-focus offset impacted the Barlow used for this evaluation, along with the resulting magnifications produced with the XT10 and TSA-102 telescopes. As you can see from the chart, with the Barlow and the same focal length 25mm eyepieces used in this comparison, the resulting magnification varied from 171x to 187x because of the varied field stop position for each of the eyepieces. While seemingly a small range of magnifications, for planetary observing these small difference can yield significantly different results so extreme care should always be exercised when comparing Barlowed eyepieces to ensure you have offset the eyepiece properly in the Barlow so the magnifications are exact for any comparison.

Eyepiece	Out-Focus (*mm*)	Predicted Barlow Magnification	Magnification with XT10	Magnification with TSA-102
Sterling Plossl	-9	3.90x	187x	127x
Takahashi LE	1	3.73x	187x	127x
Zeiss ZAO-I	1	3.73x	187x	127x
Meade 5000 SWA	3	3.70x	185x	126x
Explore Scientific 68 (Ar)	3	3.70x	185x	126x
University Optics Konig	5	3.67x	183x	125x
TeleVue Panoptic	6	3.65x	182x	124x
TeleVue Plossl	6	3.65x	182x	124x
Vernonscope Brandon	7	3.63x	182x	124x
Celestron Silvertop Plossl	8	3.62x	167x	113x
Celestron (1980's) Ortho	10	3.58x	172x	117x
University Optics Ortho	11	3.57x	171x	116x

Note –Blue indicates top-ranking performers and Yellow indicates bottom-ranking performers.



c) <u>CATEGORY-III RESULTS:</u> ** **OPTICAL PERFORMANCE ASSESSMENT** **

Optical performance results are presented in two sections, each with their own summary ranking table. The first section (see table immediately following) addresses comparison results relative to the off-axis sharpness performance of each eyepiece for the Orion f/4.7 XT10 (without coma corrector), Orion f/4.7 XT10 (with coma corrector), Takahashi f/8 TSA-102, and Skylight f/16.7 F15m. The second section, which has a separate summary table, addresses: Scatter, Lateral Color, Angular magnification (AM), Rectilinear Distortion (RD), Stray Light Control, Lightening at the Field Stop, and Vignetting with Barlow.

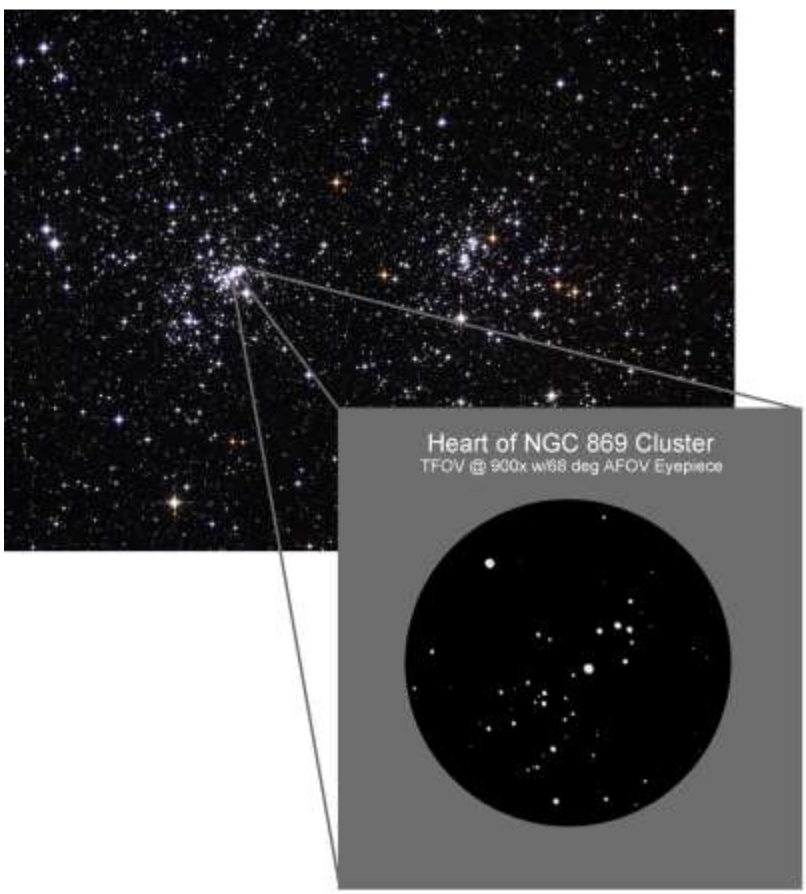
Eyepiece	Off-Axis Star Points 10" f/4.7 Dob (*no Paracorr*)	Off-Axis Star Points 10" f/4.7 Dob (*with Paracorr*)	Off-Axis Star Points 4" f/8 APO	Off-Axis Star Points 2.4" f/16.7 Achro
Explore Scientific 68 (Ar)	B	B	B	A
TeleVue Panoptic	A	A	A	A
Meade 5000 SWA	B	B	B	A
University Optics Konig	C	C	E	C
Sterling Plossl	B	C	C	B
Takahashi LE	B	C	C	A
TeleVue Plossl	A	B	C	A
Celestron Silvertop Plossl	B	B	E	B
Zeiss ZAO-I	B	C	C	A
Vernonscope Brandon	A	C	D	A
University Optics Ortho	B	A	A	A
Celestron (1980's) Ortho	B	B	D	C

Note – Numbers indicate rankings (A is best); If a number is repeated for several eyepieces, then this means too close to call a difference with assurance; narratives contain detailed information about eyepiece's rating. Blue indicates top-ranking performers and Yellow indicates bottom-ranking performers.

Off-Axis Star Points

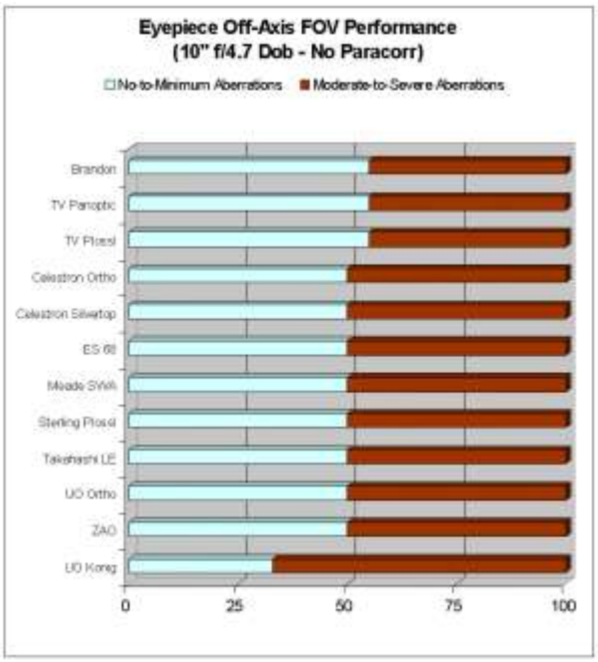
To determine how to best judge off-axis performance of the eyepieces, I wanted to use a more controlled process than is my normal. I consulted with CloudyNight's Ed Zarenski (Edz), who has noteworthy skill in this area with his work in assessing binoculars. The process Ed employs is to use a double star with a separation that is appropriate to the magnification being used (i.e., a double with an approximately 4 arcsec separation if observing at 70x, or an 8 arcsec separation at 35x, etc.). Then allow the star to be drift timed through the FOV until the aberrations are severe enough that they obscure the separation of the double. This methodology is very precise, standardized, and has excellent quantified precision. However, since this was a new process I found that I was not skilled enough in using the process since eye positioning on the exit pupil is critical and could I not get results as consistent as I wanted. As I gain experience using the method I will employ it in future assessments.

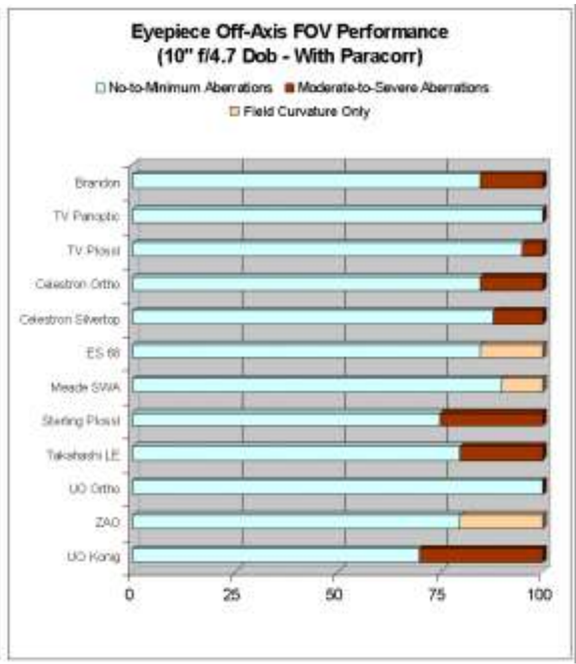
For this comparison, I therefore decided to fall back on a more familiar, although less precise, methodology by using a very familiar stellar target that was also richly detailed so that aberration impacts could be readily judged. I chose NGC869, one of the clusters in the Perseus Double Cluster. I placed the cluster in the center of the FOV of each eyepiece, then moved it off-axis in half steps (i.e., 50% from center to field stop, then 25%, etc.) and evaluated how it looked. While not the most accurate method for "exact" positions, it does work well enough to get a good feel for the off-axis performance.



(Left) Astrophotography of Perseus Double Cluster by Bob Gaskin; http://gaskin-astro.org
(Right) Astrosketch of NGC869 by William Paolini; Orion XT10, 4mm Hyperion, TV 3x Barlow

The criteria for judging when aberrations were in the moderate-to-severe category where when the formation of stars in the heart of the NGC869 cluster showed aberrations sufficiently severe as to obscure their familiar asterism pattern and separation. Before the point in the FOV where the heart of NGC869 was moderately obscured, each eyepiece obviously showed some level of aberration to the stars, but the aberrations were small enough as to not be distracting and the tiny pattern of stars in the heart of the cluster remained very much identifiable. Off-axis performance of the eyepieces in the XT10, with and without the TV Paracorr coma corrector, is shown in the graphs below.

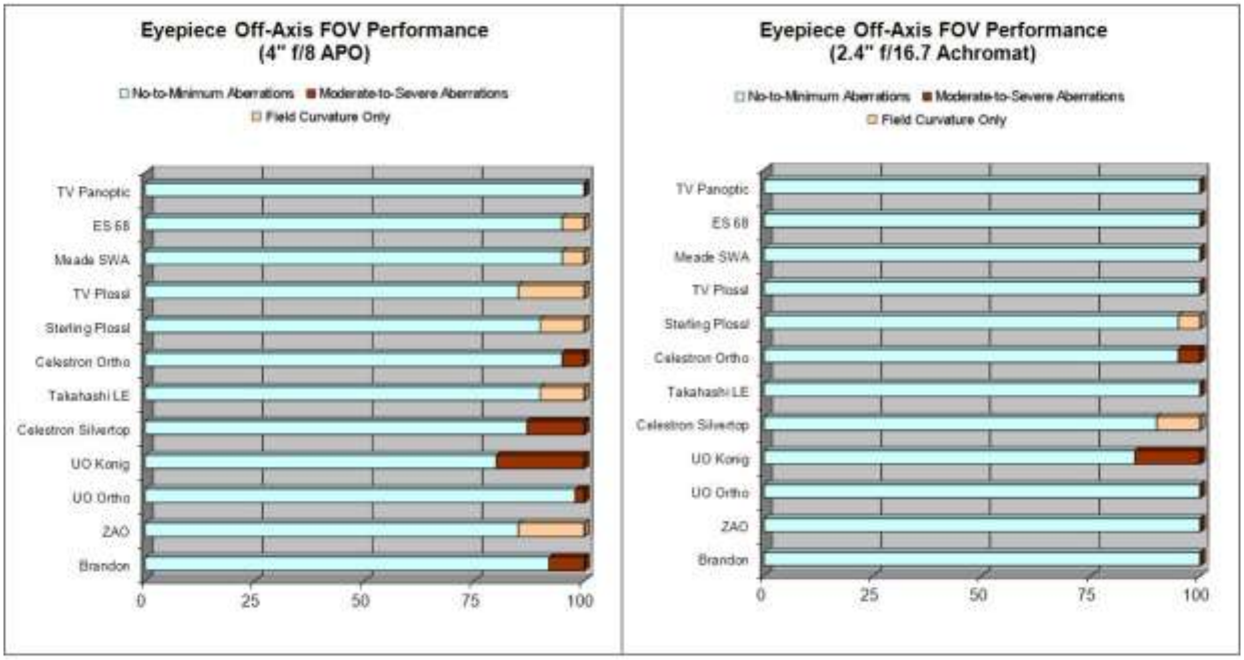




As can be seen from the charts above, without a TeleVue Paracorr in place on the fast optics of the Orion XT10's f/4.7 mirror, coma obscured the central asterism of NGC869 sufficiently to make it unrecognizable only 50% from center FOV to the field stop in almost all the eyepieces. The UO Konig was the expected exception as this optical design, while providing a wide AFOV, it does not perform well with fast focal ratio scopes.

The second chart shows how the performance improved in the XT10 with the TeleVue Paracorr. The Paracorr's top was tuned for each eyepiece to find the position that removed the most coma and provided the best star points both in center and off-axis. The off-axis aberration that remained for the ZAO, ES-68, and Meade SWA (lighter colored bars in the graph) was only field curvature, so a slight turn of the focuser knob would bring them to fairly nice star points all the way to the field stop. For the remaining eyepieces, astigmatism combined with field curvature was the predominant aberration and no amount of focusing would bring the heart of the cluster into a tolerable level of reduced aberrations. Note – it is highly unusual to see astigmatism off-axis in a TV Plossl. Other owners do not report this. Therefore, this particular unit may be uncharacteristic and inadvertently slipped through TeleVue's normally excellent quality control, or have been damaged by previous owners.

The TSA-102's and the Skylight F15m's performance were more forgiving given their longer f/8 and f/16.7 focal ratios and their lack of coma which is characteristic of parabolic mirrors. It also needs to be noted that the presence of Field Curvature in the test may not indicate an issue with the eyepiece but could be coming from a telescope's objective. This is particularly true of the TSA-102 which is known to have some Field Curvature. If a Petzval refractor, like the TeleVue NP-101 or NP-127 were used for this test, both of which have flat curvature-free fields, then any noted Field Curvature could more confidently be attributed to the eyepiece.



As can be seen in the charts above, off-axis performance was quite good in both scopes with aberrations or other issues for the main part only occurring in the outer 10% or so of the FOV for most eyepieces. The exception being the UO Konig, which even in the f/8 refractor had a significant amount of astigmatism in almost a fourth of the FOV. In the f/16.7 refractor the astigmatism was still present, although much milder and nearer the field stop. When evaluating these charts, one needs to remember that star points are a harsh test for an optic. As example, while the UO Konig in the Skylight F15m showed astigmatism in the outer 20% of the FOV which obscured the very small star pattern at the heart of NGC869, using this same scope and eyepiece for observing the Moon showed much better with Lunar features appearing acceptably sharp and detailed near the field stop. Moving to more diffuse targets like galaxies and nebula, the impact of the level of astigmatism the Konig off-axis in the Skylight F15m was inconsequential.

In this next section of Optical Performance Results, Scatter, Lateral Color, Angular magnification (AM), Rectilinear Distortion (RD), Stray Light Control, Lightening at the Field Stop, and Vignetting with Barlow were assessed and ranked for each eyepiece.

Eyepiece	Scatter	Lateral Color	AM	RD	Stray Light Control	Lightening at Field Stop	Vignetting with Barlow
Explore Scientific 68 (Ar)	D	C	C	C	B	No	Some
TeleVue Panoptic	C	C	B	C	B	No	Some
Meade 5000 SWA	C	C	A	C	B	No	Some
University Optics Konig	B	A	A	A	C	Yes	None
Sterling Plossl	B	B	D	C	C	No	None
Takahashi LE	B	A	A	A	C	Yes	None
TeleVue Plossl	B	A	A	B	B	No	Some
Celestron Silvertop Plossl	B	C	A	A	A	No	None
Zeiss ZAO-I	A	B	A	A	B	No	None
Vernonscope Brandon	A	A	A	B	B	No	None
University Optics Ortho	B	A	A	A	B	No	Moderate
Celestron (1980's) Ortho	B	A	A	B	C	No	Severe

Note – Numbers indicate rankings (A is best); If a number is repeated for several eyepieces, then this means too close to call a difference with assurance; narratives contain detailed information about eyepiece's rating. Blue indicates top-ranking performers and Yellow indicates bottom-ranking performers.

Scatter

Jupiter and various bright stars, including magnitude zero Capella, were used to assess scatter. Assessing absolute levels of scatter is generally not possible in the field as atmospheric water vapor levels and pollution particulates can easily give the appearance of scatter around a bright object. It is relatively easy however to assess relative levels of scatter between the eyepieces. During the testing, two eyepieces showed an obviously lesser amount of scatter around very bright objects, the ZAO and the Brandon. All other eyepieces showed a very similar level of scatter without any significant difference that I could reliably discern. Of the two top performers, the ZAO showed the better of the two. Both however were obviously better than the rest of the eyepieces in the comparison. For the multi-element complex design 68 degree wide field eyepieces, more scatter was easily noticeable when observing Jupiter as opposed to bright stars (with it showing the worst in the ES-68 on Jupiter). The scatter around Jupiter was also obviously more in these complex design eyepiece compared to the simpler 4 and 5 elements design eyepieces, with the ES-68 showing the most scatter with Jupiter of the three wide field eyepieces. So scatter behaved somewhat differently when viewing stars vs. planets, with planets showing it more noticeably.

Lateral Color

About half of the eyepieces showed some lateral color when bright objects such as Jupiter, very bright stars, or the Lunar limb were positioned off-axis in the FOV. In no eyepiece was the level of lateral color viewed considered significant or distracting. In the most severe test, the Lunar limb, if lateral color was present it showed as only a very thin yellow-green color just off the lunar limb with no bleeding onto the lunar surface. The Celestron Silvertop

Plossl, TV Panoptic, Meade SWA, and Explore Scientific 68 all showed a small amount of lateral color with the Celestron Silvertop showing it over more of the FOV than the others, starting at in the last 10% of the FOV to the field stop. The Sterling and ZAO showed even less lateral color, what I would characterize as a minuscule amount. All other eyepieces showed no lateral color.

Angular Magnification (AM)

Angular magnification was observed as a change in image magnification at or near the field stop. This was most easily seen when observing Jupiter and the Moon as these objects would go out of “round” when portions of their orbs were near the field stop. The Sterling Plossl showed the most angular magnification, followed by the TV Panoptic, then followed by the Explore Scientific 68. All other eyepieces, including the Meade SWA wide field showed virtually no appreciable angular magnification. As targets were purposefully placed in this zone, I would characterize the degree of angular magnification at less than moderate for the TV Panoptic and Explore Scientific, but more than moderate for the Sterling Plossl. The amount of angular magnification right near the field stop in the Sterling Plossl I would characterize at a level as to be distracting when extended targets like the Moon or planets are in that zone. When observing star fields however, the angular magnification present did not cause any distractions or have any obvious impacts during typical star field and deep sky object observations.

Rectilinear Distortion

Rectilinear Distortion (RD) is typically seen in wide field eyepieces when the AFOV extends beyond a radian (i.e., >57 degrees). For star points to remain sharp off-axis, the eyepiece designer typically needs to balance a mix of angular magnification and rectilinear distortion to keep things like field curvature and astigmatism at a minimum. Of these distortions and aberrations, most optical designers choose rectilinear distortion as the lesser of two evils. However, most designers feel Angular Magnification is less preferred as it impacts the appearance of extended objects (e.g., it widens the perceived distance between double stars, elongates round objects like planets, etc.). Of all the eyepieces in this comparison, four showed readily noticeable levels of RD. In rank order from worst to best they were: Sterling Plossl and TV Panoptic being tied, then the Meade SWA, followed by the ES-68 showing the least of this grouping. While the RD was more significant in these eyepieces than any others tested, I did not find the level of RD that impactful while scanning star fields. Panning the FOV across rich star fields, either quickly or slowly, showed the off-axis stars tracing a curved path, but not so much as to convey that queasy feeling some observers have noted when panning using an eyepiece with excessive RD. However, if you are an observer who finds the TV Panoptic’s RD bothersome when panning, then the Sterling Plossl should be avoided. On the other hand, the ES-68 showed less RD than the TV Panoptic so it could be a better alternative to the TV Panoptic if a wide field is desired.

The next group of eyepieces, the TV Plossl, Celestron Silvertop Plossl, and Celestron Ortho, all showed a much smaller amount of RD compared to the Sterling, TV Panoptic, and ES-68. While they showed RD on critical evaluation, it was not an amount that was distracting enough to readily notice during observing sessions. All remaining eyepieces tested showed minuscule to no levels of obvious RD.

Stray Light Control

For this test, the Moon and Jupiter were moved throughout the FOV, and also just outside the field stop to see if any internal reflections caused by these bright objects would enter the FOV as flashes or flares of light. The Celestron Silvertop Plossl was the only eyepiece to show no unwanted light artifacts during any of these tests. The ZAO, Brandon, TV Plossl, and UO Ortho were the next best showing only a very brief and very small flash of flare when the Moon was just outside the field stop. All other eyepieces showed flaring under the same conditions, but the length of the flare in the FOV was larger. However, even for the group that fared the worst, I would still only characterize the flare as minimal, and of little consequence as it only happened briefly and only during this one specific observing condition.

Lightening at Field Stop

Lightening at the field stop is when the darkness of the background FOV is not uniformly dark but is a little brighter in the region neared the field stop. In my observations, I have noticed that if an eyepiece does possess this characteristic, it usually shows more prevalently under light polluted skies than it does under very dark skies. For some observers this is a distracting characteristic for an eyepiece and detracts from the aesthetics of the view. The Takahashi LE and UO Konig were the only two eyepieces to show this distracting characteristic at a readily noticeable level during all the testing and observations. The region of lightening was not large and confined to the outermost portion of the FOV nearest the field stop. While I would not characterize it as more than minor, it nevertheless was obvious after viewing through an eyepiece that did not show this lightening. As a point of reference, this lightening is well noted by observers for the Hyperion line of eyepieces, and the lightening in the Takahashi LE and UO Konig I would characterize as less than what is typically observed through the Hyperions.

Vignetting with Barlow

During the course of observations I used 3 different Barlows, a 1.25" Meade 2x shorty, a 1.25" Siebert 2.4x standard, and a 2" Siebert 4x-8x Zoom Barlow at the 4x setting (actually measured to be 3.75x). In all these Barlows, six of the eyepieces displayed vignetting of the FOV with an accompanying fuzzy field stop. These eyepieces were: TV Panoptic, Meade 4000 SWA, ES-68, TV Plossl, UO Ortho, and Celestron Ortho. The level of vignetting in the three wide fields and the TV Plossl was slight as the dimming region was confined to very close to the field stop. For the UO Ortho this dim region was about twice as large as with the TV Plossl and wide fields. Finally, the Celestron Ortho showed severe vignetting, so severe that it was extremely bothersome and distractive for even casual observing when Barlowed. Given the wider AFOV of the TV Panoptic, Meade 4000 SWA, and ES-68, the vignetting was least noticeable and not distracting at all when observing. Given the much smaller AFOV of the TV Plossl, I did find the vignetting more than slightly distracting and a little annoying. When Barlowing the UO Ortho and Celestron Ortho, the vignetting of the FOV's proved very annoying. Note – while this phenomenon looks like vignetting, it is more likely to be caused by the field lens element of the eyepiece being too small in diameter to receive all the light rays from the Barlow.

d) CATEGORY-IV RESULTS: ** **IMPRESSIONS OBSERVING CELESTIAL TARGETS** **

The summary table below represents a subjective qualitative assessment of how each celestial target type was presented by each eyepiece. If the target showed more details, more stars, showed stars more brightly, showed colors more vividly, showed an apparent greater contrast (i.e., brighter whites and darker blacks), showed more of a nebula's or galaxy's outer reaches, and overall presented a more aesthetically pleasing rendering of the target (ignoring AFOV considerations), then the eyepiece was ranked higher.

Eyepiece	Resolution / Contrast / Transmission (*overall performance on each target class*)						Color Fidelity (*carbon stars & colorful doubles*)	Image Tone
	Bright Star Fields & Clusters	Dim Star Fields & Clusters	Galaxies & Nebula	Moon	Planets (*w/Barlow*)	Sun		
Explore Scientific 68 (Ar)	C	C+	B	A	C	A	C	--
TeleVue Panoptic	E	C	B	B	B	A	C	--
Meade 5000 SWA	D	C	B+	A	B	A	B	--
University Optics Konig	F	D	C	C	B	B	C	--
Sterling Plossl	B	B	B	C	B	B	A	--
Takahashi LE	D	C	C+	B	A	A	C	--
TeleVue Plossl	D	C	C	B	B	A	C	--
Celestron Silvertop Plossl	F	D	C	C	B	B	C	--
Zeiss ZAO-I	A	A	A	A	A	A	A	--
Vernonscope Brandon	D	C	C	C	A	A	A	Warmer
University Optics Ortho	F	D	C	B	B	B	A	Warmer
Celestron Ortho	F	D	C	B	B	B	C	--

Note – Numbers indicate rankings (A is best); If a number is repeated for several eyepieces, then this means too close to call a difference with assurance; narratives contain detailed information about eyepiece's rating. Blue indicates top-ranking performers and Yellow indicates bottom-ranking performers.

Bright Clusters

M45, M36, M38 and the Perseus Double Cluster (NGC869 & NGC866) were observed as a range of bright clusters to evaluate how each eyepiece performed on this class of clusters. M36 and The Perseus Double Cluster were observed more intently however as they are more representative in my opinion as the mid-range of brighter open clusters. M38 I feel is more of a transitional cluster, between the bright and dim classes, as it is mainly populated by smaller dimmer stars. However, it still has enough bright prominent stars that I feel it represents aspects of brighter clusters. The qualitative criteria for evaluation included: how visually bright the cluster appears against the background sky, the impression of dimensionality (i.e., how 3-D it looks), the degree of presence or "pop" of the brighter stars compared to the dimmer stars, how starkly dark the background FOV appeared relative to the stars, and color fidelity (i.e., richness of color) of any red or orange carbon stars in the cluster.

Astrophotography of M36 by Andy Strappazzon; http://www.smallmadtv.com

The Rank-A eyepiece for bright clusters was the ZAO. This eyepiece showed the clusters in this category noticeably better than the other eyepieces, with brighter stars showing more prominently in the FOV, giving the clusters a much greater impression of dimensionality. The ZAO also showed a much greater wealth of dimmer stars visible than with any other eyepiece -- in effect, the clusters appeared to be over flowing with a dusting of dimer stars in the background in the ZAO compared to what the other eyepieces were producing. Carbon stars were also portrayed particularly well with the ZAO, showing as very strong and prominent colors.

The middle ranked eyepieces, Ranks B through E, provided a range performance difference for these clusters (Sterling Plossl, ES-68, TV Plossl, Meade SWA, Takahashi LE, Brandon, and TV Panoptic). The Rank-B Sterling Plossl by far showed more of the clusters to be filled with numerous dim pinpoint stars than the other eyepieces in the middle of the pack (but still not near what the Rank-A ZAO showed). This characteristic was particularly prominent on both M36 and M38 making them appear richer and more populated, like the dark spaces all of a sudden became filled with a diamond dusting of fine stars between the more prominent and brighter stars. For the 68 degree AFOV wide fields, the ES-68 was definitely in a class by itself compared to the other wide fields showing the clusters with a good deal more "pop" and dimensionality from its very prominent showing of the brighter stars in the cluster. The ES-68 also showed a richer background darkness than the others in these middle ranked eyepieces. This richer background was immediately apparent when switching from another eyepiece in this ranking zone to the ES-68, even when switching from the simpler designs such as the TV Plossl. Over the course of the comparison, this feature became a distinguishing hallmark of the ES-68 as every time its turn came in the focuser, there was an immediate impression of a brighter view with a richer dark background than with any of the other wide fields.

Astrophotography of M38 by Darren Jehan; http://darrenjehan.me.uk

The TV Panoptic gave the dimmest view of the Rank B through E eyepieces. In comparison to the ES-68, the brightest of the eyepieces in this group, the TV Panoptic's view looked much dimmer overall with a greatly reduced dimensionality. To the TV Panoptic's credit though was the precision at which it rendered star points, seeming just a little more refined and tighter in the TV Panoptic compared to any other eyepieces in the middle of the pack.

The Brandon deserves some special attention as a member of the middle performing Rank B through E eyepieces. Initially I ranked the Brandon with the Rank-F eyepieces on these clusters because it was just not as bright as the other eyepieces in the Rank-B through E class. However, after many days and weeks of observations I began to see a subtly unique way that the Brandon presented stars. Like the TV Panoptic, the star points in the Brandon appeared a level finer or more refined in its presentation than most others. The starkness of the background immediately around the stars also appeared to be a level better than most eyepieces, showing very little scatter. After becoming more and more familiar with these attributes, I began to appreciate how these characteristics were very much akin to the ZAO, the Brandon just lacking the brightness and transmission excellence of the ZAO. The beauty of these subtle nuances in the view provided by the Brandon then began to overcome the slightly dimmer view it provided compared to others that ranked in the middle of the pack, which was just slightly less bright than the TV Panoptic's view. As I used the Brandon more, the subtleties I missed in initial sessions I began to notice and very much appreciate as a valued characteristic.

Finally, at the bottom of the pack performers, were the Rank-F eyepieces (Celestron Silvertop, Celestron Ortho, UO Konig, and UO Ortho). All these eyepieces showed the clusters well, just at a level less bright and more "flat" looking than the middle-pack performers.

Dim Clusters

M37 was used as a target representative of dimmer open clusters. This cluster appears as a patch of very fine and dim star points. In smaller instruments, like the 4" APO used in this comparison, M37 conveys a very haunting presence as a patch of dim diamond dust spread across a small section of the FOV when using a long focal length eyepiece. The qualitative criteria for evaluation included the same criteria used for evaluating Bright Clusters, but with special emphasis on transmission and contrast to show the dimmest stars possible in the cluster.

For this cluster the Rank-A eyepiece was the ZAO. Its performance was stunning as it decisively showed an abundance of dimmer stars with direct vision more than any of the other eyepieces. The cluster looked very much like a field of diamond dust against a richly black background. The ZAO was without a doubt the "show stealer" on this cluster, so much so that at times I felt I was off-target and observing a different and much richer cluster than I was with the other eyepieces. M37 also has relatively bright orange star at the heart of the cluster which showed more prominently with the ZAO that perceptually served as an anchor for the cluster giving the view another special character with the ZAO.

Astrophotography of M37 by Bob Gaskin; http://gaskin-astro.org

The Rank-B eyepiece was the Sterling Plossl. Compared to the lower ranking eyepieces, the Sterling showed M37 more prominently, brighter, and filled with a dusting of more dim star points than with the eyepieces that ranked lower. Both the ZAO and the Sterling eyepieces gave a distinct impression that the cluster was filled with diamond dust sprinkled across the background. This impression was certainly more prominent in the ZAO, but the Sterling still delivered this impression quite nicely and more so than any of the other eyepieces. In smaller aperture instruments, like the TSA-102, the ability of these two eyepieces to pull in so many more dim stars was well appreciated, and gave M37 a very haunting impression when moving from direct vision to adverted vision as the cluster seemingly instantly filled with a multitude of more stars. These ZAO and Sterling, and to a lesser extent the ES-68 (the brightest of the next lower rank) were wonderful performers in smaller scopes for this very beautiful and delicate cluster.

Finally, the Rank-C eyepieces (ES-68, Brandon, TV Plossl, Meade SWA, Takahashi LE, and TV Panoptic) and Rank-D eyepieces (Celestron Silvertop, Celestron Ortho, UO Ortho, and UO Konig), all performed well on M37, each rank showing the cluster dimmer and less distinct. In the larger aperture XT10 this was less of an issue than in the smaller TSA-102 where every photon of improved performance is critical, especially when not observing from a pristine dark site. Nevertheless, they all provided a nice view of M37.

Galaxies/Nebulas

The Great Orion Nebula (M42) and the Andromeda Galaxy (M31) were the two objects of note observed for this test. The qualitative criteria for evaluation included: the impression of how bright the target appeared, the outer extent of the nebula/galaxy visible, amount of structure or detail visible, how starkly the perceived contrast was between the object and the background space, and the amount of aesthetic appeal and interest the view generated.

Astrophotography of M36 by Andy Strappazzon; http://www.smallmadtv.com

By far, the ZAO was a clear notch above all others on this target. Brightness and structure were outstanding. M31 showed larger and brighter, and details within M42 were so abundant that at times it felt like I was immersed within the nebula and navigating through its many eddies and wisps. The mottled structure of the nebula was most pronounced in the ZAO compared to all others. Next best in performance were the three wide fields (ES-68, TV Panoptic, and Meade SWA) and the Sterling Plossl. This group primarily showed both M42 and M31 brighter and with easily noticeable greater extent. As example, the “wings” of M42 were immediately and noticeably longer, M43 showed as obviously brighter and larger, the core of M31 was brighter and the faint reaches of the spiral arms could be seen extending further.

There was also a pecking order of performance in these Rank-B eyepieces that was subtle, but noticeable. The Meade SWA showed the targets best overall with the FOV appearing to have a little higher contrast (i.e., the objects stood out more prominently in the FOV, the background looked more richly dark and the targets more detailed and bright against the background). Next best were the Sterling Plossl and the ES-68 in a tie for performance, followed by the TV Panoptic which appeared to show the targets as being the dimmest for the Rank-B eyepieces.

The final Rank-C eyepieces (UO Konig, Takahashi LE, TV Plossl, Silvertop Plossl, Brandon, UO Ortho, Celestron Ortho) performed more or less equally, showing the targets all very nicely, but not as brightly or as extensive as the Rank-A or Rank-B groups. Of the Rank-C's the standouts were the Celestron Silvertop Plossl, Takahashi LE, UO Konig, and UO Ortho. All performed at the top of their ranking class showing the targets with slightly more detail in the mottled structure of M42 and the appearance of a slightly higher contrast rendering – basically a slightly more pristine impression of the targets. The Takahashi LE was in fact quite close to the TV Panoptic's on-axis rendering of the targets, closer than any other of the Rank-C eyepieces. An honorary mention also needs to go to the Celestron Silvertop Plossl, and to a lesser extent the UO Ortho. This vintage Plossl and basic ABBE Ortho, more than any of the other Rank-C eyepieces, gave the consistent initial impressions of a very clean and honest view of the targets. They left me with the impression of being rather unique and special in an understated way, consistently providing a no-nonsense and satisfying view with a good amount of ease-of-use.

Astrophotography of M42 by Mike Hankey, Freeland MD; www.mikesastrophotos.com

In observing M42, as already mentioned, it has a somewhat unique attribute in that the nebula has a very nice lattice structure of denser and less dense filaments that is often described by observers as a "mottled" appearance or structure. At higher magnifications this structure will usually pop out very prominently, but at lower magnifications it is not always rendered well. In this comparison, the field of eyepieces fell into three groupings as to how well they showed the mottled structure of the nebula. The first group, which did best included only one, the ZAO. By far this eyepiece showed a wealth of mottled structure in the nebula conveying a real dimensionality worthy of the nebula's name as the "Great" Orion Nebula. The next group of eyepieces, the ES-68, Meade SWA, Sterling Plossl, Takahashi LE, and Celestron Ortho all showed the mottled structure nicely, ranging from detailed to very detailed. The remaining eyepieces in the comparison, the TV Panoptic, UO Konig, TV Plossl, Celestron Silvertop, Brandon, and UO Ortho all showed the mottled structure very weakly and portrayed the nebula as more milky in nature rather than as being composed of a strong lattice work of nebula filaments. Note - when the eyepieces were Barlowed for increased magnification, they all showed the mottled structure of M42 very nicely as expected, and all eyepieces when Barlowed with the XT10 easily showed Trapezium components A through F as bright and steady stars with direct vision.

<u>The Moon</u>

At the low magnifications afforded by eyepieces in this focal length range in the telescopes used, Lunar observing involved full disk observing of the Moon, so the full Moon easily fit within the FOV of all the eyepieces, regardless of their AFOVs. When observing the Moon at such low magnifications, the contrast is usually quite spectacular, and it was no exception during this comparison. However, while the contrast between the Lunar Highlands and Maria features were excellent in all, a few of the eyepieces presented notably more contrast than others on many Lunar features.

Astrophotography of the Moon by Bob Gaskin; http://gaskin-astro.org

The eyepieces which took top honors showing the starkest blacks and brightest whites on the Lunar landscape, as well as showing the best level of shading gradations within Maria, were the ZAO, ES-68, Meade SWA, and Sterling Plossl. These eyepieces showed a level of contrast difference and subtle shading gradations that gave a much better impression of depth and dimensionality in the view. Two example Lunar features where this was readily evident were Schroeder's Valley and the Crater Clerke region. As example, with these eyepieces Schroeder's Valley gave the impression of extreme depth and detailed three dimensional relief, with such a rich range of greys and blacks throughout the region that the valley "popped" out from the surrounding Lunar landscape like it was reaching out to the observer to come and observe.

When using the Skylight F15m telescope for low power Lunar observing, with its very long f/16.7 focal ratio, all eyepieces were able to deliver sharp to the edge with very little or no CA showing on the Lunar limb. The Brandon and Konig however were sensitive to eye placement for a sharp edge to be seen. Interestingly, the Skylight F15m was the only instrument where I have ever been able to see a Konig show sharp and etched to the edge! Using the Konig in the Skylight 15m made me realize how wonderful of a design this eyepiece must have been for observers in the earlier days of telescopes as its AFOV is quite large and immersive compared to the typical ABBE Ortho or Plossl. Lunar observing in the Skylight F15m was really quite an enjoyable treat regardless of the eyepiece used.

Moving on to my faster instruments, including the f/4.7 XT10 (with Paracorr), the eyepieces which could not maintain sharp to the edge performance were primarily UO Konig which had about a quarter of its FOV aberrated, followed by the Brandon, Sterling Plossl, and Silvertop Plossl all of which showed about 10% or less of their FOVs near the field stop as less than sharp. It also needs to be noted that the Moon is a more forgiving target for off-axis performance compared to stars. If you reference the chart on off-axis star sharpness there are more than four eyepieces which could not maintain sharp to the edge performance in the XT10 with Paracorr, yet on the Moon only four were found to be less than sharp at the edge. This points out that the degree of off-axis aberration in the UO Konig, Brandon, Sterling Plossl, and Celestron Silvertop Plossl was a level worse than the others that showed some off-axis aberration on stellar targets.

Finally, it should be noted that the Sterling Plossl, TV Panoptic, Meade SWA, and ES-68 all showed off-axis impacts from angular magnification, so when the limb of the Moon approached near the field stop it would deform out-of-round to some extent (this is also very obvious when a planet is placed near the field stop). Similar to angular magnification, rectilinear distortion can also have an impact beyond simply showing stars tracing a slightly curved path near the off-axis when panning. Rectilinear distortion can be seen when observing the Moon in several situations. A test that will show this is to place the Lunar Terminator of the Moon in the center of the FOV of the eyepiece, then slowly pan the telescope so the Terminator is near the field stop. When this is done you can observe the Terminator, which is straight while in the center of the FOV, bow into an arc shape when near the field stop. Similarly, crater walls of larger craters, rilles, and other strongly linear features can be observed to distort in shape near the off-axis in eyepieces with rectilinear distortion. Some observers are more sensitive to these distortions than others, so the best advice is to try to view through a wide field eyepiece using the observing scenarios explained to determine how critical this may be to your perceptions. See the Section IVc of this report for more details on the Angular Magnification and Rectilinear Distortion observed in these eyepieces.

Planets

Astrophotography of Jupiter by Brian Combs; www.bcastropics.com

For planetary observations a Siebert 4x Barlow was used with the eyepieces. As already mentioned, all Barlows alter their magnifications depending on where the field stop is in relation to the shoulder of the eyepiece housing that seats on the Barlow. Given the various out-focus positions of the eyepieces as presented in the table in Section VIb, the magnification of the Siebert Barlow varied between 3.57x and 3.90x depending on the eyepiece. While these magnification differences may seem trivial, they are highly critical for the planetary observer who is trying to carefully tune their magnification to the maximum the atmospheric seeing will allow during the observing session. As example, in this comparison when Jupiter was viewed with the 25mm UO Ortho and 25mm Sterling Plossl using the Siebert 4x Barlow, since their out-focus field stop offsets were so different, +10mm vs. -9 mm, the UO Ortho produced 171x in the XT10 whereas the Sterling produced a higher 187x. If the atmosphere was only allowing up to 170x to show the best detailed view of the planet when observed, then one could have easily judged the Sterling as being less capable if they did not realize the magnification differential of the Barlow because of each eyepiece's unique out-focus field stop offset!

Since the Siebert 4x Barlow used in this comparison has a "zooming" feature that takes advantage of the magnification changes based on distance (i.e., a sliding housing to lengthen the Barlow), the zooming feature was used to ensure the magnifications of each eyepiece was constant for the tests. In the end, the eyepieces that performed best for planetary observing with Barlow were the ZAO, Brandon, and Takahashi LE. The XT10 was used as the primary planetary instrument since it would generate the most magnification. Jupiter was the planetary target best available and showed a wealth of details during observing sessions. The feature on Jupiter that was most difficult to discern between the eyepieces, and eventually selected as the basis of the ranking criteria, was the series of eddies/ovals that have recently formed in trail of the GRS. These features were visible in all the eyepieces, however for the top ranking ones the brighter interior regions of the ovals and eddies were very much whiter and the borders a much darker shade than in the rest of the eyepieces. This greater contrast made selecting best focus, acquiring and observing the fine details in and around these features much easier and more aesthetically pleasing with these top ranked eyepieces. With the other eyepieces, more fine focusing trial and error adjustments were necessary to try to "dial in" the details and once acquired, they were more flat and washed out in appearance. The simulation below illustrates the approximate difference in the views of the GRS and trailing eddies on Jupiter between the lowest ranked eyepiece (left image panel) and the highest ranked eyepieces (right image panel). In the simulation, note how the borders of the GRS and around the eddies to the left of the GRS are darker and more defined. Also note how the lighter regions within the eddies to the left of the GRS are more prominently brighter as opposed to being dim grey in the left panel. While the simulation using this outstanding October 23, 2011 astrophotograph by Brian Combs does not show the exact feature as it appeared during observations for this eyepiece comparison, it nevertheless accurately represents the subtle differences between the eyepieces that were observed.

Crop of astrophotography of Jupiter by Brian Combs; www.bcastropics.com

Focusing on just the three wide fields in the planetary role, the Meade SWA did the best overall, showing a better level of contrast and crisper rendering of Jupiter's features. The TV Panoptic followed the Meade SWA very closely also providing a surprisingly detailed and high contrast view of Jupiter's abundant features visible through the XT10. The ES-68 performed a more distant last place of the three wide fields, and in fact probably performed worst of all the eyepieces in the planetary role. Contrast was lacking compared to the other two wide fields for planetary, and the trailing GRS ovals and eddies were very washed out and indistinct compared to the other eyepieces.

The Sun

Solar observing was conducted using the 40mm f/10 Meade Personal Solar Telescope (P.S.T.). All the eyepieces showed excellent, detailed, and bright views of the solar disk and surface features. Prominences were equally bright and detailed in all the eyepieces as well. Where there were differences to note, they were primarily in usability. There was no readily noticeable or obvious difference in how each eyepiece showed solar details. However, the aspect of the eyepiece which made the most difference for use in daytime solar observing ended up being the presence of an eye guard. All the eyepieces of Rank-A have eye guards and this feature enabled holding of the exit pupil much easier in daylight observing -- this was the only real advantage to the Rank-A eyepieces. If solar observations were conducted with a hood, it probably would have made no difference whether an eyepiece had an eye guard or not. As a side note, the UO Ortho could not reach focus in the P.S.T. and needed to be set higher in the focuser in order to reach focus (this eyepiece has a measured 11mm out-focus). Also note that the Meade 5000 SWA was placed in the Rank-A class because in its normal configuration it has an integrated and adjustable eye guard (not pictured in any of the photos in this comparison as it was removed by the owner).

Color Fidelity

Color fidelity, or how vividly the eyepieces showed colorful carbon stars as the criteria selected, varied slightly between the eyepieces. The ZAO, Brandon, Sterling Plossl, and UO Ortho showed carbon stars more strongly than the other eyepieces in this comparison. The differences were more than subtle between these and the rest of the eyepieces. Colorful double stars, although not observed during the testing, would probably be rendered quite exquisitely in these eyepieces. As examples of how color fidelity can impact an observation, with M37 there is a prominent central orange star in the cluster that is portrayed as bright and strong compared to the many dim and delicate stars making up this cluster. In other eyepieces this central star would lose its prominence compared to how it was rendered by these Rank-A eyepieces. Similarly, the Perseus Double cluster has a nice carbon star sitting about mid-way between the two clusters. In these Rank-A eyepieces that carbon star gave a distinct and “stand-out” impression in the FOV like a hot burning coal in the midst of cooler stars. The Meade SWA performed next best where carbon stars still notably “popped” somewhat in the FOV. In the remaining lower ranked eyepieces, no such impression was conveyed and in comparison these carbon stars were not near as notable.

Tone

Tonal differences between the eyepieces was subtle and not obvious unless you compared two eyepiece immediately side by side. All but two of the eyepiece gave the impression of a consistent tone between them across all targets. However, when the Brandon and UO Ortho were used, some targets took on a distinctively creamier appearance. This was most obvious during Lunar observing and when viewing Jupiter. When viewing stellar and DSO, there was no readily apparent indication of tonal differences. The cream-tone characteristic of the Brandon or UO Ortho was not judged to be of any advantage or disadvantage during Lunar observing, which would be the only practical planetary task for eyepieces of this long focal length. Tonal differences were not obvious during observing of Jupiter with Barlow. Tonal differences therefore did not appear to impact to the eyepiece’s performance on any of the targets during this comparison.

VII. Parting Thoughts

In my review of 6mm Planetary eyepieces, conclusions and overall rankings were very much easier given the narrow focus of the observing task for the eyepiece -- features on the Moon and planets. With the long focal length eyepieces in this comparison, observing tasks can and do include all aspects of astronomical observing. With such a wide variety of potential targets (i.e., scanning, star clusters, nebula, galaxies, double stars, etc.) and considering the differing nature of these targets, no single eyepiece can really be expected to handle all situations absolutely best. Instead, long focal length eyepiece choices might be better based on the subset of performance criteria that is uniquely important to both the observer and the preferred targets to be observed. As example, if the observer's intent is to primarily use the long focal length eyepiece with a Barlow so that the comfort of a large eye lens and long eye relief could be enjoyed for planetary observing, then best choices would be the ZAO, Brandon, or Takahashi LE. If the primary function is observing star vistas where off-axis star points will be meticulously rendered using a fast focal ratio telescope, then eyepieces that performed like the TV Panoptic would be excellent choices. If the same task is desired, but the observer intends to use a more comfortable longer focal ratio telescope, then the field of candidates is very much widened. If the primary task is viewing dim nebula or wanting to observe the dimmest reaches of any galaxy or nebula, then the three 68 degree wide fields, the ZAO and the Sterling Plossl would be best candidates from which to make a choice. So given the range of possible tasks, and the particular equipment the observer uses, a best choice could very well be not one, but several eyepieces in this focal length class.

However, at the end of the day, after spending many weeks of observing with this cadre of eyepieces, what impressions are left if the choice has to be only one? At the beginning of this exercise, my thinking was that AFOV would end up being too seductive to ignore and therefore make one of the three 68 degree wide fields the inevitable obvious choice. But this is not at all the impression I have at the end of this comparison. Instead, I am left with fond impressions provided by a number of the eyepieces because of the particular strengths they each had. The wide fields were of course all wonderful experiences. I particularly liked the precision of the star points in the TV Panoptic, yet often found myself reaching to the ES-68 as a preferred viewing choice because of the brighter image it provided, impression of a darker background, and the more engaging character it gave the target being viewed. The Meade SWA however gave some stunningly wonderful views on particular targets and at times showed better than the wide fields. As an owner of the TV Panoptic used in this comparison, and as much as I hate to say it, I feel of the three wide fields the TV Panoptic would come in last since I am not a stickler for having a perfect star point to the very edge at all times and am more interested in the center field characteristics. But still, the TV Panoptic is an old observing companion so doubt we will easily part, should that happen. The ZAO was also a favorite because of the sheer magnificence of the imagery it provided regardless of the target, and how some targets, like M42, were so intense when viewed through the ZAO that it made me feel like I was literally within the nebula rather than just observing it from afar. This eyepiece, more than any other, comes closest to being a perfect performer. The Brandon was also a memorable view, sharing some of the unique attributes of the ZAO with so little scatter and providing a "cleanliness" to the view where others fell short. The Celestron Silvertop Plossl also ranks high on my list as while not the best of them all, it never failed to satisfy or made me feel lacking. Then the UO Konig, with its reputation for a difficult off-axis, surprised me with the excellence of its image and how marvelous it was when mated with a long focus achromat, showing such a sharp and wide field performance capably coming from such a tiny little eyepiece. Finally, the FOV of the UO Ortho, while small and unassuming in comparison to the others, still provided a uniquely special character to its view that was intensely pleasing to behold, not once letting me feel like its FOV, although lacking in size, was ever lacking in heart.

So my personal winner of this comparison turned out not to be one, but many, because each served up something special about their views that others could just not replicate. In the end, the best for my tastes (i.e., ZAO, ES-68, Sterling Plossl, UO Ortho) were not determined because of off-axis precision or optical distortion and aberration control, but was about where each eyepiece excelled, and how those special characteristic allowed me to understand the celestial target I was observing with both more intimacy and more insight. After my experience with this field of long focal length eyepieces, I can definitely say that more rewards come from the observing journey with the attributes that each eyepiece uniquely possesses, rather than expecting the rewards will come from some destination related to an eyepiece's aberration control or apparent field of view size. As Ralph Waldo Emerson said: "Life is a journey, not a destination." And so it is also true with observing and observing equipment, and each eyepiece was therefore a winner in its own right!

ACRONYM AND ABBREVIATION LIST

3-D	Three Dimensional
ABBE	Specific optical design for an eyepiece developed by Ernst Karl Abbe
AFOV	Apparent Field of View
AM	Angular Magnification
APO	Apochromatic Refractor
Ar	Argon
Arcsec	Arc Second or Second of Arc (angular measure)
Dob	Dobsonian Telescope
ES-68	Explore Scientifics' line of 68 degree AFOV eyepieces
ES	Explore Scientific (astronomical equipment company)
F/ #	Focal Ratio (e.g., f/8, f/4.7, etc.)
F15m	A telescope marketed by Skylight Telescopes of London, England
FC	Field Curvature
FOV	Field of View
GRS	Great Red Spot storm on Jupiter
LE	Long Eye Relief
M ##	Messier Object (astronomical object catalog; e.g., M42, M37, etc.)
Mag.	Magnification
mm	Millimeter
NGC ###	New General Catalog (astronomical object catalog; e.g., NGC869, etc.)
Ortho	Common name for an eyepiece of the ABBE design
P.S.T.	Personal Solar Telescope (marketed by Meade Corporation)
Paracorr	Accessory to correct a mirror's coma made by TeleVue
RD	Rectilinear Distortion
SWA	Super Wide Angle
TFOV	True Field of View
TSA-102	A telescope marketed by Takahashi Seisakusho of Tokyo, Japan
TV	TeleVue (astronomical equipment company)
UO	University Optics (astronomical equipment company)
XT10	A telescope marketed by Orion Telescopes & Binoculars of Watsonville, CA, USA
ZAO	Zeiss ABBE Orthoscopic Eyepiece ("I" suffix means first production run)

For a formatted PDF version of this comparison, contact the author at wapaolini@hotmail.com.

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