Eyepiece Framing
A Target-Based Approach

While the raison d'être of an eyepiece is to magnify the image provided by the objective, with maximum contrast and minimum distortion, one of the considerations in eyepiece selection is Framing. Let us define “framing” as the ability of an eyepiece to provide a view of the object with enough surrounding dark sky to provide context and contrast (object vs. sky).

The amount of sky an eyepiece shows is directly (but not solely) related to the field stop of the eyepiece. From a purely mathematical perspective, if one 17 mm eyepiece has a field stop of 24 mm and another 17 mm eyepiece has a field stop of 29 mm then one is 100% correct to say the latter shows more sky because 29 is always larger than 24.

But is such a difference *relevant*? With the advent of 100 degree (and more) apparent field of view (AFOV) eyepieces the marketing pitches of eyepiece manufacturers (and some people on the Eyepiece discussion forum), you could easily conclude that one “needs” these eyepieces to properly frame DSO’s and if you have the previous generations of wide field glass, you’re just not “getting it”.

Is this reality, or just marketing-induced groupthink? To find out, lets take a quantitative look at the DSO’s that are commonly observed. With an understanding of objective data, we are in a much better position to understand and compare various eyepieces classes, which we will then do.

My premise is that given the confluence of typical telescope focal lengths, eyepiece field stops, and bright DSO’s most of the 100 degree AFOV “hyper wide” class of eyepiece provides framing advantage only in limited circumstance.

Methodology

Let us being by analyzing the size distribution of commonly observed DSO’s. AstroPlanner was used to generate a list of all DSO’s (by category) brighter than magnitude 12 and north of Declination -45. SkySafari Pro was used to fill in any missing size or magnitude data.

The reason for the choices in declination and magnitude was to make the article relevant to the broadest audience as well as make the amount of data more manageable once exported to spreadsheet. The magnitude 12 limit is within the theoretical limit of the smallest of astronomical telescopes, and for the rest of us represents “easy” objects. In astronomy the rule of thumb is Brighter = Bigger, so fainter limits would skew the data smaller.

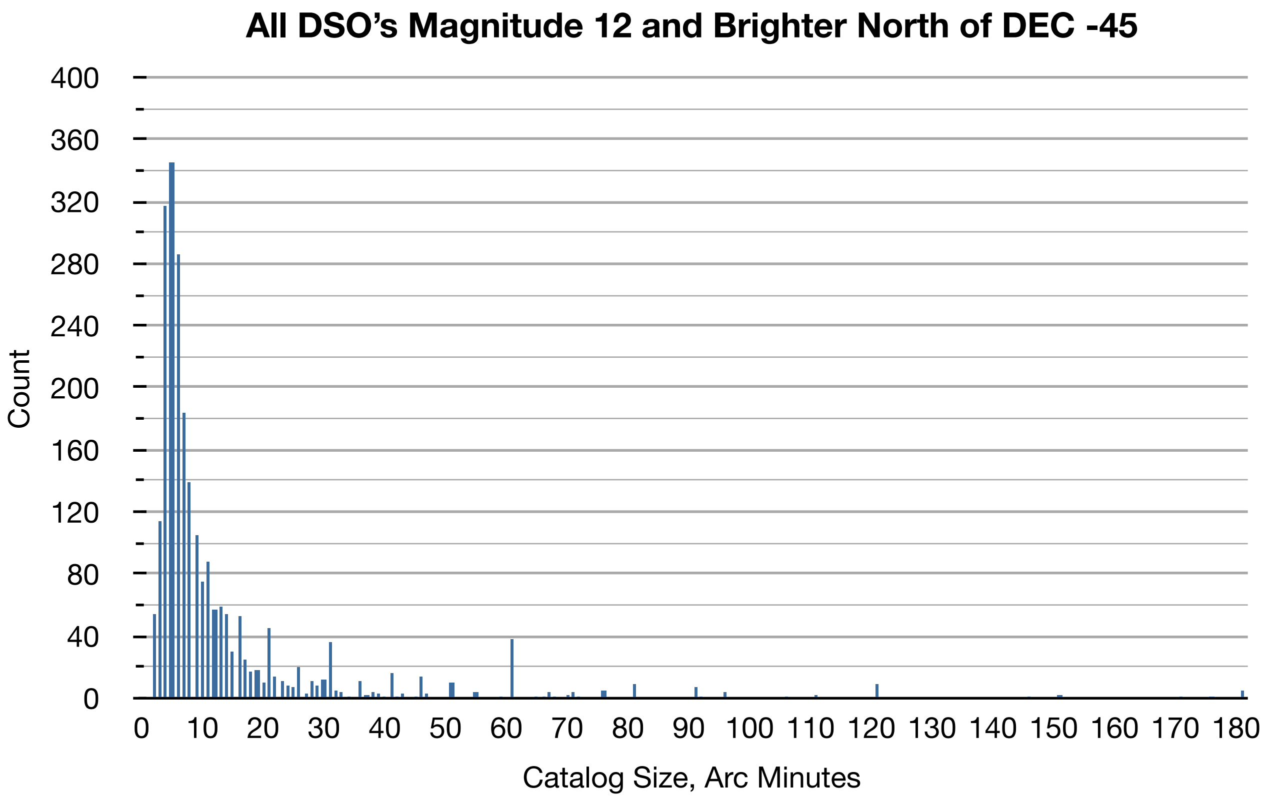
When the idea of quantifying true field occurred to me, I thought that given modern planning software and catalogs it would be a matter of a few searches, sorts, export to a spreadsheet for summary statistics and viola! But not so fast - as those of you who have delved into such software know there are database issues:

- Photographic magnitudes are often discordant between catalogs;
- Photographic sizes are usually larger than what we see visually;
- Magnitudes may be missing entirely;
- Objects may be purely photographic targets; and
- Dark nebula are not emitters, and have no magnitudes at all.

While the data may not be perfect it is the best we have. Given the large sample sizes a few missed or overstated objects will not materially affect results.

Meet the Data

When we think of bright DSO's, the normal tendency is to think large because the first objects that come to mind are in fact large: Andromeda, M45, M7, the Rosette, Veil, etc. The reality is quite the opposite:



The search criteria return 2,405 objects. The average size is 14.1 arc minutes. However, this is far from a standard bell curve, it quite obviously is skewed left with a median size of 5.8 arc seconds. Yes folks, it's true - for many of us a Monocentric eyepiece could frame the bright DSO's 50% of the time.

While the showpiece targets dominate mindshare, the list of bright DSO's greater than 1 degree in extent yields 78 targets. Not even enough for a Messier Marathon! If you are building a scope around showing these objects, you will run out of targets very quickly indeed.

Once you pick your jaw up off of the ground, you may think "hey, the curve is skewed by lumping in inherently small classes of objects like galaxies and planetary nebula". They are included - but it doesn't matter. The graph shows the actual counts, not averaged data. But for those of you curious about individual classes of objects, let's look at them.

Planetary Nebula
Most observers recognize that this class of DSO is generally small, often times stellar in appearance. A search of all Planetary Nebula north of Declination -45 with a magnitude 12 cut-off reveals 59 targets with an average size of 2.0 arc minutes. For perspective, that is about 3x the size of Jupiter.

Globular Clusters
While some large Globulars jump to mind (such as Messiers 4 and 22), these are the exception, not the rule. But even if Omega Centauri was far enough north to make the list, it would not be large enough to skew even this small sample. The total number of Globulars that fit the search criteria is 116 with an average size of 9.3 arc minutes.

Galaxies
Even with a magnitude 12 cut-off, who knew that there were this many? The number is staggering if you never thought about it before. The search revealed 1,244 targets with an average size of 6.0 arc minutes.

Most catalog discrepancies occur with Galaxies. I included very deep catalogs in an effort not to miss anything. (If it happened to Messier, it could happen to me.) There were no magnitudes given for 14,000+ galaxies. Researching the missing magnitudes would be a full-time job and if any of you want to pick up the torch on this one, we'll be anxious to hear back from you.

The big question is, would all that missing data affect the size distribution? Of the 14,000+ galaxies with missing magnitudes, about 9,500 did list sizes. The average size of this population is 1.4 arc minutes with a standard deviation of 0.69 arc minutes. Leaving the Mystery Magnitude question aside, inclusion of this group would skew the data to smaller sizes. Thus we have "only" 1244 galaxies to consider and the answer is "small".

A note here on shapes - many DSO's have irregular shapes, and in all cases I used the longest (greatest) catalog dimension for this analysis.

Bright Nebula
Moving rapidly up the size scale, we come to Bright Nebula. As alluded to earlier many of these are photographic and I made no effort to screen them out. While I suspect many of these are large, they could just as easily be small. And as filter technology improves, we have already seen many of yesteryears "photographic" targets become every-night fare for todays observer.

Astroplanner breaks these down by type. These distinctions are important to professional astronomers, for amateurs the only substantial difference is "which filter will work best on it?" So in the interest of space and efficiency, I grouped them all together. The combined count of Bright Nebula was a surprisingly small 155 targets with an average size of 24.0 arc minutes.

The astute reader may realize that some popular nebula actually consist of several smaller catalog entries. Does that affect the size distribution or averages? To answer this I scanned Uranometria Volumes I and II to identify such nebula. Two targets clearly fall into this category: The Veil and the Rosette. Other calls are tougher: Should one treat for example M42 and M43 as a single object? How about the Delta Cygni region? Therein lies the key - regions. As soon as we start talking "regions" we are starting to enter the realm of binoculars.

Combining the portions of the Veil and Rosette increases size to 180 arc minutes and 90 arc minutes respectively while eliminating several "small" nebula from the list. This reduces the target count to 150 and raises the average size to (drum roll please) 24.6 arc minutes. The moral of the story - even the Bright Nebula are mostly small targets, and a few large targets don't make a dent in the overall distribution.

<u>Dark Nebula</u>
Dark Nebula have no listed magnitudes, so effectively we get the entire Barnard catalog to examine, from the smallest patches to the large Milky Way rifts. There are 349 of them with an average size of 24.3 arc minutes.

<u>Open Clusters</u>
We save the best for last. Open clusters have a large spread of sizes above magnitude 12, all the way up to Collinder 285 at a whopping catalog value of 1400 arc minutes. Astroplanner turned up 541 targets, with an average of size of 24.5 minutes. How can this be with clusters like the Hyades and Cr285? Well, because once again even above magnitude 12 most of the Open Clusters are quite small.

Meet The Equipment

True Field is determined by the eyepiece field stop divided by the objective focal length (and multiplied by a constant of 57.3 to yield degrees, which I then converted to arc minutes). Note that telescope focal ratio and eyepiece AFOV do not figure into the True Field calculation at all! Zip, zero, nada.

Since all I needed where focal lengths and field stops I proceeded to pick three hypothetical scopes for the analysis:

- The Small scope such as the APO refractor or small fast Dob, focal length 1000 mm;
- The Medium scope based on today's popular sentiment to have a Newtonian that does not require a ladder. Based on average human stature this allows a focal length of around 1700 mm; and
- The Large scope (my own in this case) with a focal length of 2800 mm.

Eyepiece selection is a bit more problematic. There are two brands of hyper wide eyepieces in widespread distribution - Tele Vue and Explore Scientific. ES does not appear to publish field stop data while Tele Vue does. Like them or hate them, most still consider Tele Vue the "King of the Hill" in eyepieces. Therefore I decided to use Tele Vue eyepieces for comparison.

Using Tele Vue eyepieces did present another issue - the crown jewel of the Ethos line, the 21 mm, is an unusual focal length. Likewise, the high power Ethoi are in rather uncommon focal lengths and I suspected this is where Ethoi would yield their greatest advantage. Eyepiece Low/Medium/High pairings seemed impossible.

Then the idea occurred to me to run the comparison by assuming the use of commercially available barlows to get the closest focal length match possible. So why not just mathematically adjust focal lengths and field stops to create exact matches? Because observationally we can not do this and I wanted the comparison to match what a visual observer could replicate in the field.

Some may cry "foul!" in that 2" eyepieces and 2" barlows can be awkward and unlikely in actual use. This is true, but I would counter that if you want maximum field in a 2" eyepiece the 21 Ethos would be an unlikely choice with its unimpressive field stop. Remember, we are trying to create faux-Ethoi comparisons as best we can to see if and when the hyper-wide really does provide relevant advantage. And just for fun, I threw Plossls into the mix. So in the end I ended up with these match-ups:

- Low Power - 21 Ethos, 35 Panoptic with 1.7x Barlow, and 55 Plossl with 2.5x barlow;
- Medium Power - 13 Ethos, 13 Nagler T6, and 32 Plossl with 2.5x barlow; and
- High Power - 3.7 Ethos SX, 9 Nagler with 2.4x barlow, and 11 Plossl with 3x barlow.

This left me with the last choice: What constitutes adequate framing? Looking at the conventional world for answers was not helpful. For example, picture frames, phone bezels, and computer monitors are surrounded by rather thin borders. Clearly the telescopic observer wants a little more border to differentiate target from sky.

I considered the 50/50 approach, where the border widths equal the size of the object. But then we fail the basic mission of the eyepiece, which is to magnify. Simply put, at 50/50 it could be bigger and faced with a 50/50 situation most of use would reach for the next highest power eyepiece almost every time, barring horrible seeing conditions.

The answer suggested itself by the lowest common denominator of eyepiece used in this article, the Plossl. Four element eyepieces are not well corrected near the edges, particularly compared to more complex eyepieces. Using my own experience with Orthoscopics, Plossls, and Brandons the inner 75% of the field is reasonably sharp while aberrations grow pronounced beyond this. Therefore I decided an object that is smaller than 75% of a given true field is adequately framed.

Now let's look at each category of eyepiece against the combined list of 2,405 DSO's brighter than magnitude 12 and north of Declination -45.

Low Power Comparison, 1000 mm Telescope

	Frame Field Arc Min.	Objects Framed	Percent Framed	Gain from Previous
21 Ethos	93.3	2,363	98.3%	3.1%
35 Panoptic/1.7x Barlow	58.8	2,289	95.2%	0.6%
55 Plossl/2x Barlow	47.4	2,274	94.6%	n/a

Low Power Comparison, 1700 mm Telescope

	Frame Field Arc Min.	Objects Framed	Percent Framed	Gain from Previous
21 Ethos	54.9	2,288	95.1%	3.0%
35 Panoptic/1.7x Barlow	34.6	2,215	92.1%	2.7%
55 Plossl/2x Barlow	27.9	2,149	89.4%	n/a

Low Power Comparison, 2800 mm Telescope

	Frame Field Arc Min.	Objects Framed	Percent Framed	Gain from Previous
21 Ethos	33.3	2,215	92.1%	5.2%
35 Panoptic/1.7x Barlow	34.6	2,089	86.9%	4.1%
55 Plossl/2x Barlow	16.9	1,991	82.8%	n/a

Looking into the "low power" results one can see that at equal magnification all of the eyepieces do reasonably well. Had I been able to locate an appropriate 2" barlow and used the 31 Nagler, the Ethos advantage would have been slimmer yet.

Medium Power Comparison, 1000 mm Telescope

	Frame Field Arc Min.	Objects Framed	Percent Framed	Gain from Previous
13 Ethos	57.5	2,288	95.1%	0.7%
13 Nagler	45.4	2,271	94.4%	5.0%
32 Plossl/2x Barlow	27.8	2,149	89.4%	n/a

Medium Power Comparison, 1700 mm Telescope

	Frame Field Arc Min.	Objects Framed	Percent Framed	Gain from Previous
13 Ethos	33.8	2,215	92.1%	3.1%
13 Nagler	26.7	2,140	89.0%	6.3%
32 Plossl/2x Barlow	16.4	1,988	82.7%	n/a

Medium Power Comparison, 2800 mm Telescope

	Frame Field Arc Min.	Objects Framed	Percent Framed	Gain from Previous
13 Ethos	20.5	2,075	86.3%	3.6%
13 Nagler	16.2	1,988	82.7%	14.3%
32 Plossl/2x Barlow	9.9	1,645	68.4%	n/a

At medium powers, we again see the standard widefield eyepiece (in this case, a Nagler) holding up well against the Ethos.

High Power Comparison, 1000 mm Telescope

	Frame Field Arc Min.	Objects Framed	Percent Framed	Gain from Previous
3.7 Ethos SX	18.2	2,021	84.0%	5.8%
9 Nagler/2.4 Barlow	13.3	1,880	78.2%	16.4%
11 Plossl/3x Barlow	7.8	1,486	61.8%	n/a

High Power Comparison, 1700 mm Telescope

	Frame Field Arc Min.	Objects Framed	Percent Framed	Gain from Previous
3.7 Ethos SX	10.7	1,717	71.4%	9.6%
9 Nagler/2.4 Barlow	7.8	1,486	61.8%	21.8%
11 Plossl/3x Barlow	4.6	963	40.0%	n/a

High Power Comparison, 2800 mm Telescope

	Frame Field Arc Min.	Objects Framed	Percent Framed	Gain from Previous
3.7 Ethos SX	6.5	2,021	84.0%	42.7%
9 Nagler/2.4 Barlow	4.8	994	41.3%	25.4%
11 Plossl/3x Barlow	2.8	383	15.9%	n/a

Things start to get interesting now that we get into the meat of the DSO size distribution curve. Clearly great news if you are upgrading from Plossls.

Conclusions

First and foremost, the vast majority of DSO's - even bright DSO's - are very small.

Framing is primarily dictated by the focal length of the telescope in question. Once you choose your telescope, the battle is largely over. With a specific scope chosen eyepieces can help you within a small range, but they are not going to turn (for example) an 8" SCT into a RFT.

While many scopes are too large to be what is commonly accepted as a RFT, we all want at least one eyepiece that gives a panoramic view for enjoyment as well as navigation. The key to doing this is getting the maximum field stop for a given eyepiece barrel size. For the ubiquitous 2" focuser this means a field stop of 46 mm as typified by the 55 Plossl or 41 Panoptic. In the Newtonian community exit pupils come into play and with today's common focal ratios, maximum true field usually comes from the 31 Nagler with it's impressive 42 mm field stop. Everything else is a big step down.

Having achieved a maximum true field capability with your low power eyepiece, one has to ask themselves in light of the small size of bright DSO's whether or not they want to keep attempting to maximize true field at every eyepiece focal length. Since this is an individual value proposition each buyer must decide whether this is a worthwhile endeavor or high-dollar wild goose chase.

At comparable focal lengths an Ethos-class eyepiece shows "more sky" vs. The Nagler-class (a mathematical truism) but the gain in the number of discrete objects framed is quite marginal. A conventional wide field design as typified by the Nagler design does extremely well a very high percentage of the time.

The size distribution curve of bright DSO's suggests that the hyper-wide eyepieces will distinguish themselves when telescopes become very large and/or magnifications become very high. (Which is another way of saying usable true fields drop to relatively small diameters.) In looking at the data, this is exactly what we see. When true field approaches the median size of bright DSO's the Ethos offers more substantial advantage relative to Naglers and huge gains over Plossls.

While I have focused on single discreet targets, some readers may be thinking in terms of framing regions of sky. But once again, the very best way of covering large regions, structures, or Milky Way fields is a telescope of shorter focal length (or binoculars). The 80 mm refractor will give stunning wide field views with a wide variety of eyepiece designs and focal lengths, explaining their popularity as secondary scopes. I have purposely avoided the economics of wide field viewing since this is largely an individual value proposition, but I will say that given the current prices of small ED doublets the economic arguments of the second scope are compelling. Lastly, consider that not every large bright DSO lies along the plane of the Milky Way. Many are located in very sparse areas surrounded by nothing but empty black sky.

Closing Thoughts

All of us are vulnerable to getting caught in the marketing hype and groupthink, forgetting the fundamentals and basing decisions more on Wants than Needs. Afterall, the function of marketing is to create Wants. Anyone who frequents the Eyepiece Forum knows people react very differently and often emotionally to a specific eyepiece (or eyepiece type).

I hope that this article will briefly get your attention away from the megaphone of eyepiece manufacturers. By Factoring out the Marketing Majesty and getting back in contact with a few objective truths you will make better informed decisions - whatever they may be.

So is the hyper-wide eyepiece a bad value to be avoided? I have studiously avoid the discussion of Value as Value is always a personal decision which includes Priorities and Disposable Income. There are many reasons to buy hyper-wide eyepieces, but based on data I would not count “framing” as one of them.

What I believe is that our hobby needs is more equipment that makes people excited, whether it is a 30 degree Monocentric or 100 degree Ethos. To the extent that a piece of equipment meets expectations and can draw more people under the stars, so much the better for all of us.