Limiting Magnitude in Binoculars

Methods Used for Determining BLM
Testing Results of Some Common Binoculars
Conclusions Based on Field Observations

by Ed Zarenski [Click to Email Author]

Editors Note

This article is an astounding accomplishment. Author Ed Zarenski has spent the past 3 months performing field testing and research to answer what appears to be a simple question - "what is the limiting magnitude in Binoculars?". As you will soon learn, the answer is not so simple. Nor is the research path to reach the answers. I'm sure you will agree that this is both a superb article and a monumental achievement for an amateur astronomer. Well done Ed.

Sept. 2003

Introduction

One performance characteristic of optics, **Limiting Magnitude (LM)**, is used to judge the seeing depth or the faintest object visible with an instrument. Although there are many other performance characteristics, this one is used to judge which instrument will perform better for a specific task, ”How deep can you see?”

In addition to using some select relevant notes from past observations, over a period of several weeks I gathered enough information from field observations with binoculars to reach realistic conclusions relative to **Binocular Limiting Magnitude (BLM).**

My purpose of this study is not only to provide verified field observations that give a good indication of this binocular performance limit, but also to gather enough real data that will help with verification of results obtained from predictive formulae. In addition I will try to provide a clear understanding for the determination of these limits.

This is not an effort to develop a new formula for predictive purposes. There are several formulae available for that purpose and a tremendous effort to explain those formulae and limits in the Clark, Blackwell, Carlin and Schaefer papers. Although some of the math and terms can be difficult to understand, referencing these articles for a complete understanding of the concepts is encouraged.

Observing BLM is straightforward, record the faintest star that can be seen. But if the field information is to be useful for verification of other formulae, then records must include BLM, instrument and conditions, i.e., **Naked Eye Limiting Magnitude (NELM)** at the time and location of the observation.

Get to know these terms, LM, BLM and NELM. They will be used from here on forward throughout the body of this article.

LM = Limiting Magnitude
BM = Binocular Limiting Magnitude
NELM = Naked Eye Limiting Magnitude

I will not address all the issues of quality in binoculars in this article. Significant skewing of results could occur if one high quality binocular were compared to one of significantly lower quality. I believe the selection of equipment used in this analysis does not contribute to such differences with any exceptions noted.

With available formulae, in order to predict BLM, NELM must be assumed or determined by direct observation. Binoculars, and optics in general, provide an increase in LM beyond what the naked eye can see. The two most significant factors affecting that increase are aperture and magnification. These are by no means the only factors. Results will show the relative weight magnification holds over aperture. For everything other than maximum light gathering, aperture in binoculars is not used to full potential.

Every night of observation, more than one binocular was used. This helps provide for comparison of the influence of different attributes of the binoculars. Also, observations were made on nights of differing NELM. This provides comparative information useful for determining the influence of NELM. The LM in binoculars (or scopes) will increase as NELM increases, however you will soon see actual field results shows the relationship is not linear.

What Factors Affect Limiting Magnitude

Many factors have an impact on LM. Some are listed here.

- As aperture increases and more light is gathered, LM increases.
- As magnification increases exit pupil decreases. Unlike extended sources, the light from point sources is not diminished with magnification. Extended light sources get darker but point sources do not. Sky background, because it is an extended object, gets darker. As magnification increases, the light from point sources appears amplified, as long as the point source is bright enough so that it is not viewed as an extended object. (Magnification so high as to create image blur in the Airy disk, turning the point source into an extended object, would not occur in binoculars.) This improves contrast between point sources and background light, resulting in deeper LM.
- As contrast in the optical system is improved by the use of better components, i.e., higher quality coatings and baffles, glass with better light throughput, LM increases;
- As the eye is kept to the eyepiece for a longer duration, dark adaptation improves to the level of the light provided by the eyepiece only and not by the surrounding ambient light, increasing observed LM;
- The color of a star will have an impact on LM. For two stars of equal magnitude, a red star will appear fainter, a blue star will appear brighter. The observer would reach a deeper LM if observing a field of blue stars.
- The observing conditions, affected by seeing and transparency, will have an impact on LM. In a simplified method, recorded as NELM, as it increases, LM increases.
- The acuity of the observer will have an affect on LM. An observer with better acuity will record a deeper NELM observation but also the more acute observer may in fact see fainter stars in the eyepiece.
- The altitude of the stars observed will have an affect on LM. Skies closer to zenith are observed through less air and also have a better chance of being darker.
- The experience, persistence, concentration level and patience of the observer will have an impact on LM.

Tools and Equipment Used

"The Backyard Astronomer's Guide", by Dickinson and Dyer, has an excellent NELM chart of the Little Dipper on page 117. In addition, I have marked up a chart from SkyAtlas 2000.0 in the area of the Circlet of Pisces. These are just two charts I use to determine NELM.

"Astrophotography for the Amateur" by Covington, has two limiting magnitude charts (for astrophotography use but also well suited for use with binoculars or small scopes) on pp. 127 and 128. CR399, Brocchi's Cluster, commonly called "The Coathanger", and M45, The Pleiades, show stars to mag 12. The stars shown with magnitudes do need to be verified by a current star database. While most labels appear correct, some sources show different values for a few and a much greater variety is needed.

Computerized star charting software was used to verify the magnitudes of all stars on the charts used in the field.

Binoculars I used were:

- Oberwerk Deluxe 20x80
- Fujinon 16x70 FMT-SX
- Oberwerk '03 15x70
- Oberwerk '02 15x70
- Pentax WP 16x60
- Pentax PCF III 12x50
- Orion Ultraview 10x50
- Swift Ultralite 8x42

All binoculars were mounted on stable tripods.

- Celestron G5 125mm f11 SCT used for verification of targets
- Stellervue AT1010 78mm f6.2 Ref used for verification of targets
- Various eyepieces

Recording BLM – Verifying a Star Field

On the first night I spent considerable effort attempting to determine BLM with my 16x70 Fujinon and my 15x70/03 Oberwerk. I used Covington's Coathanger (CR399, Vul) LM chart. I carefully noted the star patterns as compared to the chart, taking special note to visually compare distance between stars in the pattern to confirm which are seen. I observed each pattern in each binocular twice.

My first discovery was the variety of labeled stars was not broad enough to show any minor differences that exist between the two binoculars. There were stars on the chart labeled as mag 10.4 and 10.5, but in the areas I noted, there were none labeled between 10.5 and 10.9. I had already reached the extent of variety available on this chart and needed a broader selection. I needed a chart with stars labeled every 0.1mag between 10th and 11th mag.

Later verification by star chart program proved there were many within this range, and differences were noted. In the absence of labeled magnitudes on the chart, I began to label stars with letter designations and I recorded observations accordingly. It would be several weeks later before I knew the actual magnitude values for many of my observations.

Experience as a Factor

After revisiting the same area several times, the order of magnitude of the fainter unlabeled stars on the CR399 chart became apparent. After several nights of observation, there was a pattern to which stars are visible and which are most difficult to see. Also, it became easier to orient to the chart. The pattern of stars is now familiar. I would say at some point that experience became a factor improving BLM, at least to a small extent.

Why Use a Scope for Testing Binoculars?

I used a 5”(125mm) SCT and 3”(78mm) Ref scopes to view areas of planned study and establish some comparisons between those stars observed and those not seen. Magnitude progression on published star charts seemed fairly accurate with few exceptions. The exceptions are noted.

The scope observations helped me identify the progression of the magnitudes in the sequence and helped verify the stars that could be seen. It is useful to know where to look. Also, scope observations helped me estimate the magnitude of some stars that are either labeled wrong or may be variable in magnitude. Early questioning of some labeled magnitudes was tested by scope and found justified. Several stars are woefully off the mark in both the book published chart and the computerized charts.

I established scope LM. With the 5”(125mm) SCT, a 12.0 mag star was not seen with a 26mm Meade SP at 53x. It was glimpsed using 18mm UO ortho at 76x and was seen steady using 12.5 mm UO ortho at 110x. The increase of magnification needed in the SCT to see a mag 12.0 star gives a very good indication of the increase magnification provides to LM. Also, it gives a pretty good indication of what it would take to see a mag 12.0 star. Stars E13 and S18, both mag 11.0, were seen in the 3” (78mm) scope at 40x and 53x. A mag 11.4 star was not seen at 40x and was barely seen in the 3”(78mm) scope at 65x. Assuming a 20% gain for two-eyed vs. one-eyed viewing, a 78mm aperture is approximately equivalent to a 70mm binocular.

Several stars that have close companions were tested to determine if the companion star was providing an increased integrated magnitude. Star S9, two stars both of 10.5, is a wide pair at 40x. It appears brighter than S8-10.2 and S10-10.1 and is estimated at mag 10.0. Star S12, 10.04 with a nearby component of 11.33, is very wide at 40x and appears unaffected in magnitude. Star E8, a sub-arcminute pair of 10.65 and 11.36, could not be seen as double at 40x. At 65x the mag 11.4 companion was just barely seen. Star E8 appears to have an integrated mag. increase, maybe only slightly by 0.1 to 0.2 mag. These stars are adjusted on my chart and magnitude noted with an “e” to represent estimated. For a discussion on the determination of integrated magnitude, see “Amateur Astronomer’s Handbook”, J. B. Sidgwick, chapter 1.

Star S4 is labeled as 9.8 on the chart in Covington’s book. At least one computer star chart program identifies this star as mag 9.8. Maybe it's an error that has been carried forward through the years, or maybe it’s an unidentified variable, but it is definitely not mag 9.8. In the 5”scope, the star is found exactly as charted. Using the scope, it was compared to and found to be fainter than every star observed in binoculars. It is fainter than almost every other star observed in the telescope. I estimated it as mag 11.4. Similarly, star S17 is identified as 10.5 on the chart, however my estimate puts it at mag 11.2. Both these stars were never seen in any binoculars even under the best conditions.

From here onward I will list stars by their chart sequence designation, most times followed by magnitude, i.e., C13-10.73 is star C13 and it is magnitude 10.73.

In addition to the stars noted above, several others are modified and included in this list of adjustments:

- N10-10.3 never seen (in binocs), fainter than N11, estimated 10.8+
- S9a-S9b 10.5/10.5, integrated magnitude, estimated 10.0
- S17-10.5 never seen , fainter than S16 and S18, estimated 11.2
- S4-9.8 never seen, fainter than S17, S16, S18, estimated 11.4
- E8 –10.65/11.4, increased integrated magnitude, estimated 10.5
- E7- 10.6, suspected only once, estimated 10.8
- E11-10.72 is fainter than E12-10.76 brighter than E13-11.0, estimated 10.8
- C12-10.5 never seen, estimated 10.8+

Brocchi’s Cluster, The Coat Hanger

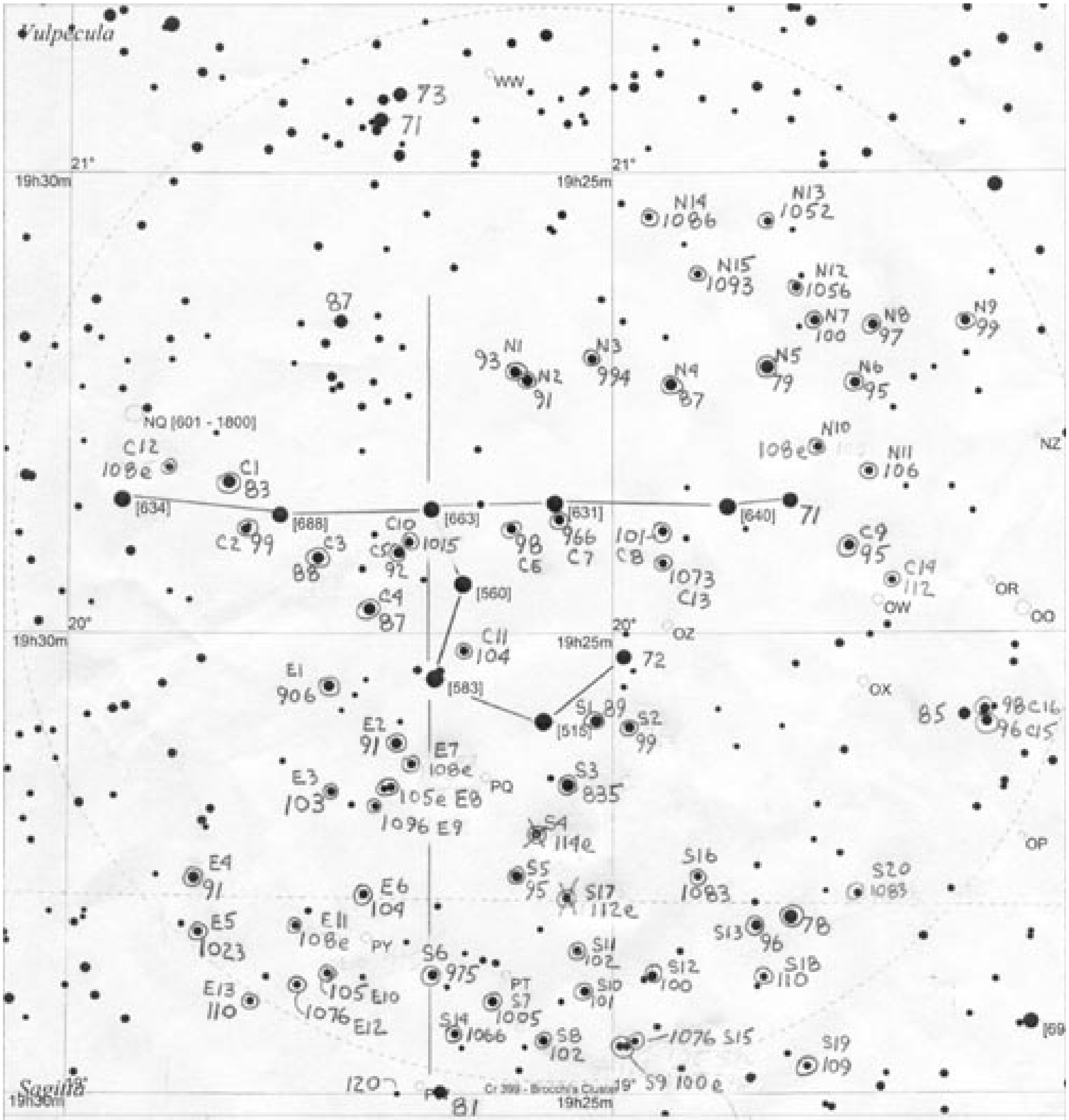

Chart 1 CR399 – Brocchi's Cluster, The Coat Hanger

Star Sequences on CR399 chart															
NEW chart	mag	orig chart	obsv	NEW chart	mag	orig chart	obsv	NEW chart	mag	orig chart	obsv	NEW chart	mag	orig chart	obsv
N1	9.3		x	C1	8.3		x	E1	9.06	85	x	S1	8.9		x
N2	9.1		x	C2	9.9		x	E2	9.08	90	x	S2	9.9	F2	x

N3	9.94		x		C3	8.8		x		E3	10.3	102	x		S3	8.35	83	x	
N4	8.7	88	x		C4	8.7		x		E4	9.07	89	x		S4	11.4e	98		
N5	7.9	78	x		C5	9.2		x		E5	10.23	103	x		S5	9.5	95	x	
N6	9.5	93	x		C6	9.8	F6	x		E6	10.4	104	x		S6	9.75	97	x	
N7	10.0		x		C7	9.66		x		E7	10.8e		x		S7	10.05	A	x	
N8	9.7	95	x		C8	10.1	F5	x		E8	10.5e	F3ab	x		S8	10.2	B	x	
N9	9.9		x		C9	9.5	95	x		E9	10.96				S9	10.0e	Dab	x	
N10	108e	103	x		C10	10.15		x		E10	10.5	F4	x		S10	10.1	C	x	
N11	10.6		x		C11	10.4		x		E11	10.8e	F8	x		S11	10.2+	G	x	
N12	10.56		x		C12	10.8e				E12	10.76	F7	x		S12	10.0	Eab	x	
N13	10.52		x		C13	10.73		x		E13	11.0				S13	9.6	H	x	
N14	10.86				C14	11.2									S14	10.66			
N15	10.93				C15	9.6		x							S15	10.76			
					C16	9.8		x							S16	10.83	F1	x	
															S17	11.2e	105		
orig chart published in CN Forums															S18	11.0			
e = estimated															S19	10.9			
															S20	10.83		x	

Table 1

Assessing and Recording NELM

There is some difficulty associated with determining NELM. It seems much more difficult observing a star unaided at the limits of vision than it does observing the limits of vision through optics. Add to my previous discussion that observing LM requires considerable persistence and you can see that determining NELM may require just as much effort as determining LM in an instrument. In NELM 5.8 skies, while I can observe stars of 4.5 to 5.0mag directly rather quickly, it sometimes requires 5 minutes of concentrated gazing to record a 5.7 or 5.8mag star.

There sometimes may not be a sufficient variety of magnitudes in close proximity to step up in progression without moving the gaze to an entirely different area of the sky. Although I have at least five different indexed charts that I use for determining limiting magnitude, there are some gaps on every one of those charts, usually on the order of 0.2 to 0.3 mag. Determining LM almost always requires observing and noting more than one location.

When stars are too close in proximity to one another it can be difficult to tell how many are seen. CR399, Brocchi's Cluster has a good array of stars ranging from mag 5.2 to 7.2, however the 5.2, 5.6 and 5.8 stars are so close together (separated by 15 arcminutes) for naked eye observation, even when it can be determined more than one star is visible, seldom can it be determined if three or only two are being seen. So, with this target, often times I cannot differentiate between mag 5.6 and 5.8. Both very dark skies and excellent visual acuity would help with this effort.

If double stars are included in the survey, the integrated magnitude must be determined. A good example of this is gamma Delphinus. With components of mag 4.5 and 5.5 separated by 9.6" (4.5-5.5/9.6"), it has an integrated magnitude of 4.15 that can easily be seen when compared to the other stars in Delphinus.

If conditions appear to be changing throughout the evening, NELM should be recorded again. On more than one occasion I have had NELM improve or decline in less than an hour.

NELM can vary from one area of the sky to another and certainly will vary from horizon to zenith. Observations should be made in the vicinity of the planned targets.

A sufficient variety of stars, even of similar magnitude, should be attempted. Sometimes observations of fainter stars can be recorded while nearby brighter stars go unseen. An example of this is several observations of TX Pisces at mag 5.8 (Aug-Sep '03) having been recorded while a nearby 5.7 mag star remained unobserved. Color index may be contributing to this condition.

NELM should be considered as that faintest star that can be confirmed whether seen direct, averted or even glimpsed. The key is that it is confirmed. It is much easier to determine the NELM in a transparent sky than in a washed out moonlit or hazy sky. Observation is made more difficult when contrast between a brightly lit sky and a star is so much reduced. So, while I am confident I saw mag 5.8 TX Pisces on the best of nights, and I've seen 5.6 and 5.7 mag. stars in UMi, Del and Cr399 several times, I am not as confident that the sky was so low as mag 4.0 on the worst of nights.

Recording the BLM Observations

Aug 19, 2003
NELM direct 5.2mag direct and 5.6mag averted on Ursa Minor and at zenith.

Transparency good to very good.
Seeing good to very good, (6-8? out of 10).

Although the sky background in the 16x70 Fujinon looked slightly darker and it seemed the faintest stars were slightly easier to see, I got the same results with both binoculars.

The binoculars were 16x70 and 15x70/03. On this night, I was not able to see the star labeled S17-10.5 mag or beyond. The faintest stars observed (labeled and identified on the chart) in both binoculars were E5-10.2 and E3-10.3.

Wed. 8-20-03 11:00PM to 12:45AM

Fujinon 16x70s and Oberwerk 15x70/03
Skies slightly better tonight.
NELM UMi 5.2 direct, 5.5 averted
NELM CR399 5.2 direct 5.6 averted
Transparency and Seeing vg to ex.
Cygnus Milky Way faintly visible.

Last night efforts resulted in verified E5-10.2 and E3-10.3 mag stars. Started over again tonight to verify these. Some persistence required to see mag 10.2 and 10.3, but found without question.

There is a star identified E6-10.4 on the chart and I went after it tonight. I was getting lost in the area so I started plotting all found stars in a sketch. Took about 30-45 minutes, but I finally found the 10.4 star and verified it’s proximity to other stars several times.

There is a star identified on the original chart labeled 9.8, now designated S4. That 9.8 star is not seen. Maybe it's an error on the chart, or maybe it’s a variable, but it is definitely not seen in any binoculars.

There is a star identified on the original chart labeled 10.5, now designated S17. Spent the next 45 minutes sighting and plotting every star around this vicinity attempting to capture this one. In hopes of capturing S17, I plotted 6 stars S7, S8, S9, S10, S11, S12, all near S17 and all fainter than nearby S5-9.5 and S6-9.75, but did not get the S17. (Those 6 nearby stars later proved to be all between 10.0 and 10.5).

Further verification of S9-10.5 shows it has a close companion S9b, also10.5, that may be close enough to be causing a brighter integrated magnitude. Several times it appeared brighter than other stars in that group.

Plotted and verified everything seen last night. So results now tally a 10.2, 10.3 and a 10.4. But significant efforts did not capture S17-10.5.

By the end of this evening I had produced a sketch of approximately 40 stars that all but 2 or 3 verified very accurately with locations as shown on published star charts. I have since added to that sketch and it now numbers nearly 60 plotted stars.

Sat. 8-23-03 10:00PM to 1:00AM

Fujinon 16x70s and Oberwerk 15x70/02
Skies best of three nights so far.
NELM UMi 5.5 direct, 5.6 averted
NELM CR399 5.6 direct
NELM Circlet Pisces 5.8 direct
Transparency 9-10 and Seeing vg

Tonight, in addition to really putting effort into reaching the limit with the Fujinon 16x70, I brought out my Oberwerks 15x70/’02. Previously I used the ’03 Oberwerks. The E6-10.4 star was seen again in the Fujinon and was also seen with the 15x70/’02 Oberwerks. The S17 star was not seen with any binocular.

Two additional stars S16 and E8 were seen with the Fujinon and their locations plotted. Locations were verified with the published chart, but they were not identified with a magnitude. These were observed with the 5” scope to be nearly equally faint as the identified S17 star. Based on scope comparison to S17, and based on magnitude of stars seen and stars not seen, I estimated S16, the faintest star in question, at 10.45. Later it was discovered S17 is incorrectly labeled and S16 was verified to be 10.83.

The small pair labeled E8 was seen by both binoculars. This star was later identified as mag10.65. The E8 star has a faint mag 11.36 companion. It may be close enough to create a brighter integrated magnitude for E8. In a scope, it does not appear to be brighter than 10.5 - 10.6. I have estimated it at 10.5.

Star S16-10.83 seen with the Fujinon 16x70s could not be found with the Oberwerk 15x70/'02. With the ’02 Oberwerks E8-10.5e was the faintest star that could be seen. The Fujinon 16x70, verified at 10.83, did go a definitive step further beyond the Oberwerk 15x70/’02 at 10.5.

I will note here, even though on future nights I observed several stars of mag10.7 and 10.8, that S17 star has never been observed in any binocs. No matter how hard I tried, even under excellent conditions, the Fujinon 16x70s and the Oberwerk 15x70s would not see that S17 star. Later critical comparison with telescopes revealed the star S17 is fainter than most stars in the observing field. It has been estimated at 11.2. The nearby questionable star S4 is even fainter. It has been estimated at 11.4.

Sept 10th,11th and 12th.

Full moon on the 10th, sky washed out but NELM in vicinity of CR399 improving from about 4.0 on the 10th to 4.5 on the 11th to 5.0 on the 12th.

On the 10th and 11th the 15x70/’03 Oberwerk could see E5-10.2 and E3-10.3 but not the close pair E8-10.5e. The Pentax 16x60 could only see E5-10.2 for brief moments. The E6-10.4 star was not seen in either binoc. In the faint string of stars S7 thru S13, the 15x70s could see 5 of 7 stars, the faintest S10-10.1 while the 16x60 Pentax could only find 4 stars, the faintest S12-10.0.

Neither binocular could see S2-9.9 after several tries.

On the 12th, NELM was estimated at 5.0.

The Oberwerk 15x70/’03 could see E6-10.4 direct and saw the faint string of 10+ mag stars S7 to S13 except for faintest S11-10.2+. The 15x70s missed S17-10.83, the faintest star previously observed with the Fujinon. Also I did not record seeing E8-10.5.

The Pentax 16x60 see E5-10.2 and E3-10.3 directly but could only momentarily glimpse E6-10.4. The Pentax missed S8-10.2 and S11-10.2

On this night, the 15x70/’03 reached LM 10.4 and the 16x60s reached LM 10.3, but also glimpsed 10.4. Both binoculars missed several fainter stars.

9-14-03

Pentax PCF WP 16x60 and Oberwerk 15x70/’03 and Pentax PCF III 12x50
Skies better than previous three nights. Moonrise interferes after 10:30.
NELM UMi 5.0 direct, 5.2 averted, sky washed out
Transparency 8-9 and Seeing good

The 15x70/’03 could see S17-10.83 constant.

The Pentax 16x60s saw S7 thru S13 including S9-10.0e

The 12x50s could see E5-10.2 but not E3-10.3. Also saw S10-10.1 but none fainter in S7-S13 string. S2-9.9 was not seen.

Numerous occasions have now been recorded where brighter stars were missed while fainter stars were observed.

9-16-03

Fujinon 16x70s, Oberwerk 15x70/03, Pentax 16x0, Pentax 12x50
NELM CR399 5.6 direct confirmed, 5.8 suspected
NELM Delphinus 5.5 direct, 5.7 averted
Transparency 9-10 and Seeing vg. seeing improved with time

Pentax 12x50s could not see E6-10.4 star. Later did see E10=10.5 averted and E3-10.3 difficult. C8-10.1 could only be seen averted. S9-10.0e and S12-10.0 were seen. S9 is brighter due to an integrated magnitude. S2-9.9 was not seen.

Fujinon 16x70s found two new stars tonight, designated F7 and F8, later identified and charted as E12-10.76 and E11-10.8e. E6-10.4 and E10-10.5 were seen direct. S16-10.83 was seen popping in & out of view.

Pentax 16x60 see E8-10.5e difficult. Easily see E6-10.4 direct. S2-9.9 was only seen averted. See all seven stars in S7 to S13 nets S11-10.2+. Observed E10-10.5 faint and E12-10.76 only after seen with Fujinon. S16-10.83, the faintest star was not seen after several tries.

Oberwerk 15x70/03 see E6-10.4 and E8-10.5e seen direct. S2-9.9 was seen with the Oberwerk. Saw S11-10.2, it is a difficult star. S16-10.83, the faintest star, was barely seen glimpsed several times.

9-21-03

Fujinon 16x70s, Oberwerk 15x70/03, Pentax 16x0, Pentax 12x50
NELM Delphinus 5.14 direct, 5.4 averted
Transparency 9-10 and Seeing vg. Large cloud patches cut night short

Oberwerk 15x70/’03 recorded 50 observations, 37 successful sightings. Best observations, C11-10.4, S8-10.2, E3-10.3, E6-10.4, E6-10.5e and E10-10.5 and E8-10.5e. Significant stars not seen were C10-10.15 and S11-10.2+.

The results from the Fujinon and Pentax were incomplete and discarded.

9-22-03

Fujinon 16x70, Oberwerk 15x70/03, Pentax 16x0 and 12x50, Orion 10x50, Swift 8x42
NELM CR399 5.6 direct, 5.8 suspected at start
NELM Delphinus 5.1 direct, 5.43 averted at start
NELM Circlet of Pisces 5.4 direct, 5.8 averted, 5.7 missed, recorded at end of session
Transparency 9-10 and Seeing vg. seeing improved with time
Attempted over 250 observations. Recorded over 200 successful sightings.

For each binocular I have listed the number of stars seen, including in the counts only stars listed in Table 1. The brightest stars that make up the CR399 asterism, all brighter than every star counted here, are not included in Table 1.

Swift 8x42 -16 stars seen. Image scale small but very sharp. Saw N1/N2 at 1.5 arcmin as one elongated object. Best observations in each area were N6-9.5, C9-9.5, S5-9.5. Returned to this binocular later and recorded C15-9.6 averted and S6-9.75 averted. S9-10.0e was suspected averted.

Orion 10x50 - 24 stars seen. Although wide-field exhibit poor sharpness in outer 40% of fov. LM was not seen in outer 40%, needed to be on-axis to see best LM. Best observations were, N8-9.7, C2-9.9 averted, C16-9.8, S6-9.75, S7-10.05, S12-10.0

Pentax 12x50 - 33 stars seen. Best observations, S8-10.2, C8-10.1, N7-10.0, E3-10.3 averted, E5-10.2 averted and E6-10.4 averted suspected.

Pentax 16x60 - 44 stars seen. Best Observations S8-10.2, S11-10.2+, N13-10.52, C8-10.15, E8-10.5e, E10-

10.5, E12-10.76, E11-10.8e averted, E7-10.8e averted suspected. Did not see N11-10.6 and N12-10.56, C13-10.73, S16-10.83

Oberwerk 15x70/'03 – 44 stars seen. Best Observations were S8-10.2, S11-10.2+, C11-10.4, N11-10.6, E8-10.5e, E10-10.5, E12-10.76. Did not see N13-10.52, and N12-10.56, C10-10.15, C13-10.73, E11-10.8e, E7-10.8e, S16-10.83.

Fujinon 16x70 – 52 stars seen. Found several new stars tonight. Saw N11-10.6, N12-10.56, N13-10.52, C13-10.73. Saw both S16-10.83 and S20-10.83 at the same time. . Saw E12-10.76 and E11-10.8e at same time. Did not see N14-10.86, N15-10.93, S19-10.9, E9-10.96, E13-11.0.

What Affect Does NELM Have?

What is significant about the Sept. 10, 11 and 12 observations is the drop in NELM from 5.8 on best observation nights to 4.0/5.0 for these moonlit nights.

The formula developed by Nils Olaf Carlin is used to predict increases in BLM. To apply the results of this formula, increases calculated with the formula are added to NELM. Harald Lang has posted an extension of this formula showing the calculated increases plus an eye pupil constant are added linearly to NELM.

After numerous observations, I have found such an application produces results that will fall within the predicted range around NELM 5.0, but as NELM gets either higher or lower it begins to vary from field measure. With a drop in NELM from 5.8 down to 4.5, for 70mm and 60mm binoculars the BLM was observed to drop only from 10.8/10.6 down to 10.3/10.2 mag. The application of Carlin's formula would have predicted a difference in observed BLM equal to the drop in NELM, that is to say, if NELM drops by 1.5mag then BLM would be predicted to also drop 1.5 mag. Actual results show, while the drop in NELM was 1.3 mag, the actual drop in BLM was no more than 0.5 mag. The significance of this is not so much the variance in the predicted magnitudes as it is the variance in the predicted drop due to NELM. This begins to show the influence of NELM on the final BLM.

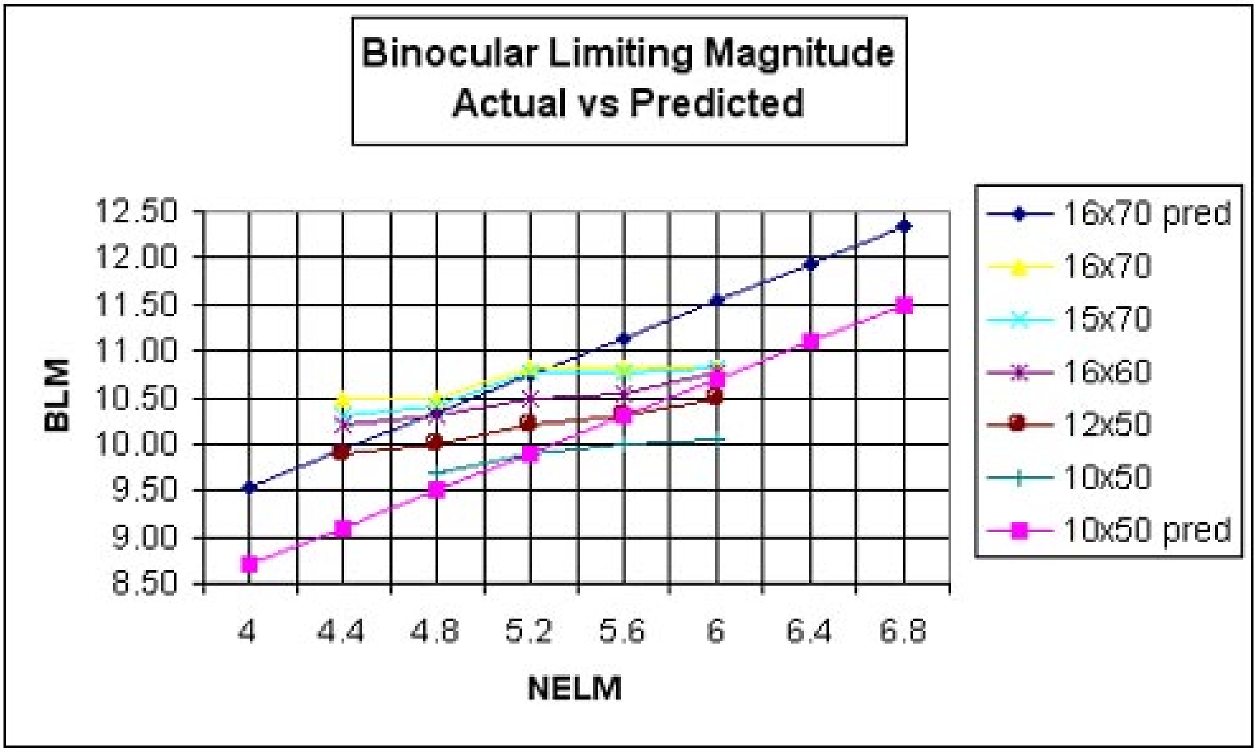

Chart 2

To remain conservative, I underestimate the recorded variances in NELM and state the maximum drop in observed BLM. While I could interpret my field observations to indicate a NELM drop of 1.8mag and a BLM drop of only 0.4mag, note that I have stated for my conditions, using apertures of 2”(50mm) to 2.75”(70mm), a NELM magnitude drop of approx 1.3mag (minimum drop) resulted in a difference in observed BLM by a drop of only 0.5 mag. (maximum). This has the effect of reducing the variance between field observations and predictive formula. Based on my field notes, in reality the differences may have been greater and the variance larger. However, due to the difficulty in assessing low NELM, I take this approach to remain conservative.

Is Carlin's formula incorrectly applied by assuming the calculated increase in magnitude should be added linearly to current NELM? My results indicate BLM does not vary linearly with NELM. Chart 2 clearly shows the difference in predicted affect of NELM vs actual affect of NELM. Dozens of critical observations with numerous binoculars, three of which represent the best I own and some which might be considered as the best available in their range for binocular observing are producing consistent results that NELM may cause far less fluctuation in BLM than predicted.

The limiting magnitude in binoculars (or scopes) will increase or decrease as NELM changes, however the relationship is not linear.

Testing for Affect of Aperture

Aperture’s primary function is to gather light. A larger aperture gathers more light. What is significant to note though is aperture requires an optimum magnification to allow the eyes to utilize its fullest potential. Without the optimum magnification, any eye may not see all the light the lens has gathered, especially faint light. At binocular magnifications, the utilization of aperture for the detection of LM is not at optimum. Because of this, aperture may have far less influence than previously thought for the determination of limiting magnitude.

I test binoculars for the affect of aperture by using several binoculars, each at two different apertures, full aperture and masked to 50mm. I then compare the results of each binocular to itself. For this test, several binoculars including 20x80s, 16x70s, 15x70s and 16x60s were used with a 50mm mask over the objective lens, giving 20x50, 16x50, 15x50 and 16x50. This I think gives the best possible representation of this test because it keeps all other attributes of each binocular exactly the same. The attributes that do change would be only those that are affected by an aperture/magnification relationship, exit pupil and focal ratio. Probably some aberrations might be reduced, but none that would have an affect on limiting magnitude.

Carlin's formula predicts a 0.062 change in BLM for every 10% change (step up or down) in the area from the previous size of the aperture, regardless of magnification or NELM. To understand that correctly, a 80mm (5026sqmm) lens is not 256%, or 25 steps above a 50mm lens (1963sqmm). The question is "How many 10% increases (110%) compounded = a 256% increase?" That is the same as saying 110% raised to what power = 256%. The answer is 10% increases compounded approximately 9.6 times. So it would predict 9.6 x 0.062mag = 0.6 mag drop from 80mm to 50mm.

binocular	area	formula	change	Actual
aperture	aperture	predicted	from	change
in cm	sq mm	LM gain	50mm	
81	5093	2.72	0.62	0.3
77	4630	2.66	0.56	
73	4209	2.59	0.50	
70	3826	2.53	0.43	0.1
67	3478	2.47	0.37	
63	3162	2.41	0.31	
60	2875	2.35	0.25	0.2
58	2613	2.28	0.19	
55	2376	2.22	0.12	
52	2160	2.16	0.06	

50	1963	2.10		

Table 2

The table shows area of aperture increasing in steps 10% greater than the previous area. The binocular aperture is calculated from the area increase. The sizes conveniently fall on or very near the common sizes used. The formula predicts a 0.6 magnitude change for a drop from 80mm to 50mm aperture The actual drop was only half that for 80mm to 50mm. It predicts a 0.43 magnitude change for a drop from 70mm to 50mm aperture and a 0.25 magnitude change from 60mm to a 50mm aperture.

The losses recorded were, drop 0.3mag from 80mm to 50mm, drop 0.1mag from 70mm to 50mm, drop 0.1mag from 70mm to 50mm, drop 0.2 mag from 60mm to 50mm.

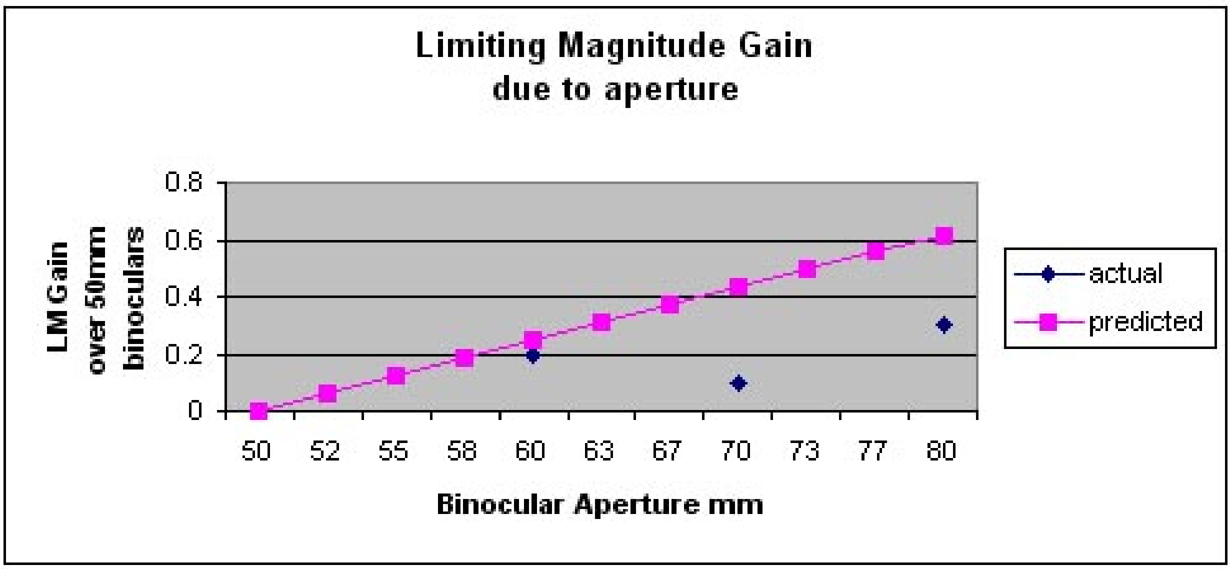

Chart 3

Actual field results indicate changes of 0.1 to 0.2mag in BLM due to changes in aperture of these sizes, much less than predicted by formula. Actual increases were more like 0.03 to 0.05 mag. BLM for every 10% increase on aperture.

Testing for Affect of Magnification

Magnification allows you to see. If objects are very faint, sometimes additional magnification will show the object that low magnification would not allow you to see. If you will recall, with the 5"SCT, a 12.0 mag star was not seen at 53x. It was glimpsed at 76x and was seen steady at 110x. The increase of magnification needed in the SCT to see a mag 12.0 star gives a very good indication of the improvement magnification provides to LM. This same thing is going on at some level for every magnification. Considering the low magnification used in binoculars, BLM will be considerably less than LM for a scope. However, any change in magnification will have an affect on BLM.

Carlin's formula predicts a 0.083mag change in BLM for every 10% change in magnification, regardless of aperture or NELM. This predicts a 0.41 magnitude change from a 10x to a 16x magnification.

binocular	formula	formula		binocular	formula	formula	actual
power	gain	change		power	gain	change	change
increase	predicted	by 10%		common	predicted	from	from
by 10%		increase		sizes		10 power	10 power
25.9	2.83	0.083		25.0	**2.80**	**0.80**	
23.6	2.75	0.083		22.0	**2.68**	**0.68**	
21.4	2.66	0.083		20.0	**2.60**	**0.60**	0.9
19.5	2.58	0.083		18.0	**2.51**	**0.51**	
17.7	2.50	0.083		16.0	**2.41**	**0.41**	0.78
16.1	2.41	0.083		15.0	**2.35**	**0.35**	0.71
14.6	2.33	0.083		14.0	**2.29**	**0.29**	
13.3	2.25	0.083		13.0	**2.23**	**0.23**	
12.1	2.17	0.083		12.0	**2.16**	**0.16**	0.3
11.0	2.08	0.083		11.0	**2.08**	**0.08**	
10	2.00			10.0	**2.00**		
changes in power by 10%				powers adjusted to intergers			

Table 3

This is more difficult to test than aperture as the only way to get changes in magnification is to use many different binoculars and quality issues can come into play. For instance, my 20x binoculars almost always are nearly equaled in performance by my higher quality 16x binoculars. Binoculars that don’t match up in quality could skew the results.

Results were recorded for several binoculars, all at 50mm aperture at various magnifications to determine the affect of magnification on overall performance. The noted difference in recorded BLM across the range of magnifications from 10x to 12x to15x to 16x was an increase of 0.78 mag.

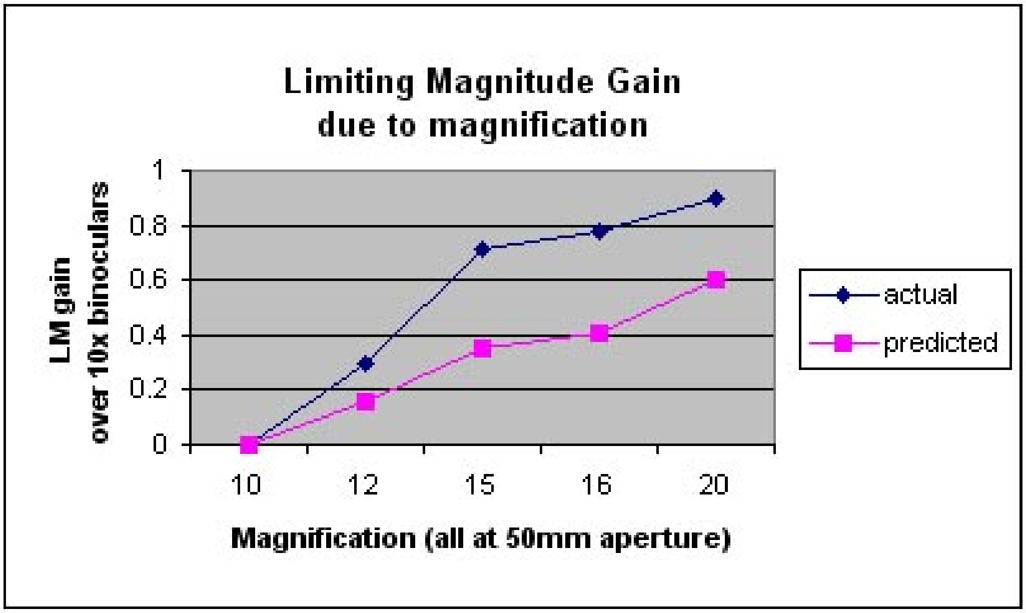

Chart 4

Actual results recorded on same night observations indicate a jump from 10x to 12x results in an increase of 0.3 mag. BLM. A jump from 12x to 15x results in an increase of another 0.4 in LM observed. The total change same night from 10x to 20x gives an increase of 0.9 mag. BLM observed. Formula would predict a total of 0.6 mag change over the whole 10x to 20x range.

Actual field results indicate changes in BLM due to magnification were always more than predicted by formula. Actual increases were more like 0.12 to 0.15 mag. BLM for every 10% increase on magnification.

Binocular Performance Indexes

There are a number of methods used to predict binocular performance, some simple like this one, magnification x aperture. In another article I addressed this rule and showed what I feel to be its shortcomings. Here you would have a performance index that gives a factor of 7 (or 10 or 15) to magnification and then a whopping factor of 35 (or 50 or 70) to aperture. Except maybe for faint extended objects, I can’t think of an application where that kind of weighting would give a good indication of binocular performance.

Allan Adler has given us what I consider a better representation of actual performance. Adler says rate your binocular optics by magnification times the square root of aperture. Since this approach more closely equalizes the factors for magnification and aperture, this formula puts greater emphasis on magnification.

These are not scientific formulae, but a simplified method to indexing performance. Based on the aperture masking tests I’ve done on binoculars in the past, results at that time seemed to indicate that magnification holds greater weight. Just how much weight may be the question? I've adopted Adler for reasons stated previously, but in addition I've said adjust Adler's Index with a factor for contrast and resolution, attributes of binocular quality. I apply a 10% +or- adjustment to Adler's Index to account for coatings and baffles. You can find that explanation in my CN Binocular Performance Article.

There are several published well-read articles and graphs providing the amateur with an attempt to theorize what a binocular should see. Some of these develop predictions based on the laws of aperture, possibly failing to take into account the full impact of the inability of aperture to perform to its full potential if anything less than optimum magnification is used. This is the actual case of the employment of aperture in binoculars. For everything other than maximum light gathering, aperture is not used to its full potential. (Another entirely different discussion would need to take place if we were to address the employment of that same aperture to observe faint diffuse extended objects.)

The preceding two sections of this article should give the user a clear indication of the importance of magnification versus aperture in any Binocular Performance Index. Actual field results indicate changes in BLM due to magnification were always more than predicted by formula. Actual field results indicate changes in BLM due to changes in aperture were always less than predicted by formula.

Actual results are showing incremental increases in magnification have far more influence on BLM gain than incremental increases in aperture. Changes to magnification or aperture (area of the lens) in increments show for every 10% change magnification was measured to have approximately three to four times the affect on the gain in BLM. This is the conclusion I reached from previous masking test studies on star field counts. Now with definitive magnitude readings, it is my opinion this more stringent testing proves the results and eliminates any question from the claim. When it comes to the question "How deep can you see?" in binoculars, magnification has greater influence on performance than aperture.

What it Takes to See Faint Stars

It was very difficult even with the best 70mm binoculars to see stars beyond mag 9.7. A passing glance in the eyepiece would not show stars beyond 10th mag. It required a concentrated period at the eyepiece, allowing gaze to move around. Once glimpsed, stars beyond mag10 could then be seen directly.

Even stars of 9.7mag could not be seen if the binoculars were moving. Seeing stars of this magnitude required a completely quieted binocular on a stable mount, viewing without touching the eyepieces.

More than once I noted that bumping the binoculars and causing any minor shake eliminated most stars over mag 9.0 from view. As soon as they settled quite after 5 or 10 seconds, 9.5 and 9.7 mag stars were readily seen. Absolute steadiness and some persistence is required to see mag 10.2 and 10.3. Continued persistence and effort is required to see mag 10.4. Stars beyond that are not seen in any binocular without expending a considerable concentrated effort, sometimes over as much as several minutes.

What Can the Average Observer See?

I think it is significant to note that without a steady mount the average observer is probably not seeing beyond mag 9.5 with any binocular up to 70mm, and without considerable effort is not seeing much beyond mag 10.2

to 10.3. The practiced observer using 70mm binoculars will see stars of 10.5 to 10.8 only with considerable effort and absolutely still binoculars. For quality 80mm and 100mm binoculars, you could add roughly 0.3 to 0.6 mag respectively to the above stated for 70mm.

The following table is not scientific derived from formula. It is based on extrapolation from the results of my field observations. It does take into consideration separately the influence of magnification, aperture and NELM on BLM gain. It may give a fairly good indication of what could be reached for various other binoculars that where not included in the study.

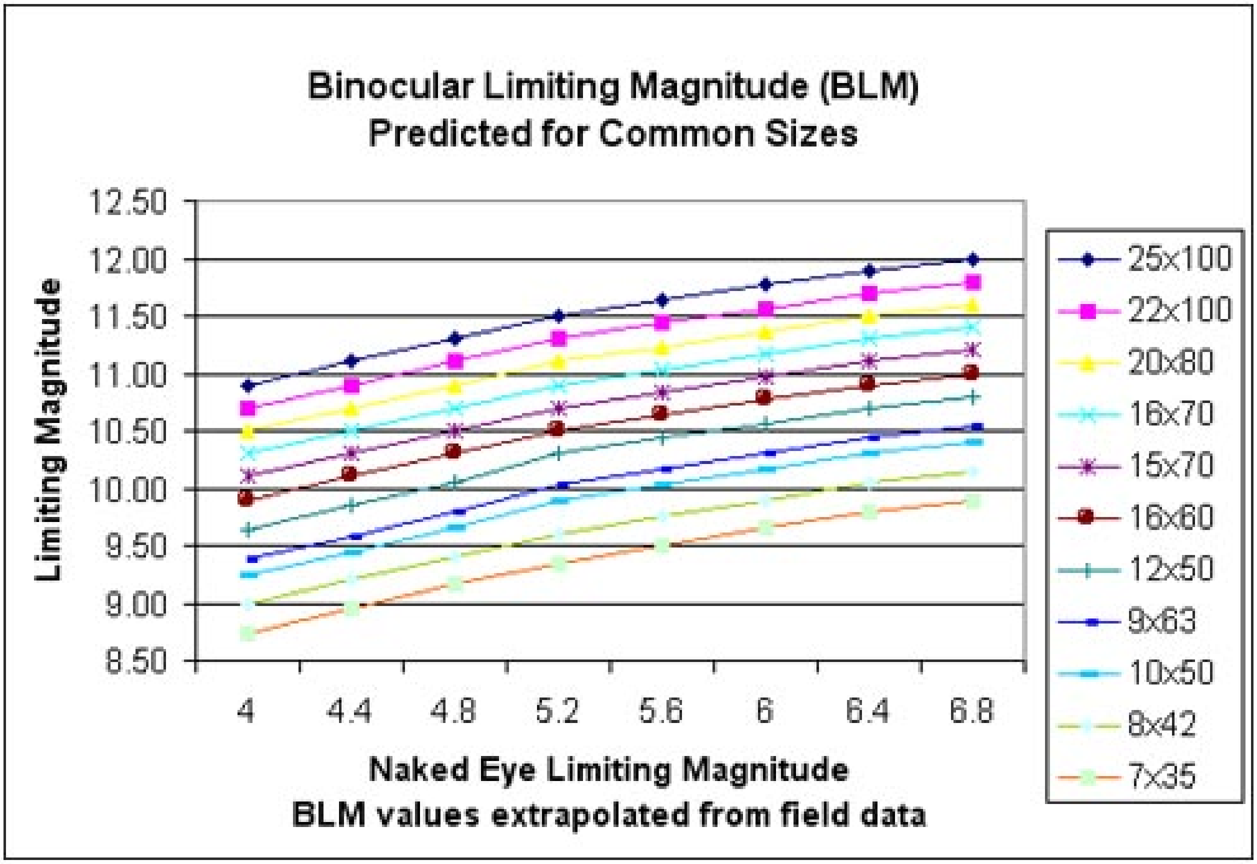

Chart 5

How Can You Improve Your Limits?

The observer might be concerned with how to improve ability to see deeper. The obvious answer would be to get a larger aperture or increase magnification. But there are other means that can be employed to improve performance with the equipment already in hand.

Using a sturdy mount that eliminates all movement will increase LM by as much as 1.0mag. This alone could double the number of stars seen.

If you can use a parallelogram mount that allows you to view from a seated position, by all means do so. When you are comfortably relaxed in a chair without craning you neck, you will be able to see more. The most notable difference in seated viewing is it was just so much easier to sit back and look with two eyes that everything popped into view and a few averted vision stars appeared that I did not see when I was standing.

As the eye is kept to the eyepiece for a longer duration, dark adaptation improves to the level of the light provided by the eyepiece only, increasing observed LM.

Move the objects slowly thru the field of view. Sometimes an object moving thru the view is easier to pick out than a stationary object.

Learn how to use your averted vision. Some areas of the vision have higher gain from averted vision than other areas. Learn where your most sensitive area of gain is by moving objects around in the field of view. Take note of where the objects are in the field, at 2 o'clock?, at 10 o'clock?, when your averted vision first picks them out.

Learn to observe for long periods of time. In the star field I used, it became relatively easy to see stars to mag10.2 to 10.4. But it never became easy to see the faintest stars of 10.6 to 10.8. Sometimes it took a concentrated effort of five minutes to gaze around the area and spot a mag10.7 star. For most observing we are not concerned with reaching the absolute limits of performance, but there are objects that will require you to develop the skill of observing. Persistence and patience are two qualities of a good observer.

LM for One Eyed Viewing vs. Two Eyed Viewing

On a night when the faintest 10.83 star was observed, several attempts were made with the Fujinon to record a difference in two-eyed vs. one-eyed views. 10.83 could not be seen with the Fujinon when attempted using only one eye, my normal observing eye. The star E6-10.4 could still be seen with the Fujinon when attempted with only one eye. Star E8-10.5e was seen with the Fujinon when using only the dominant eye. Other previous tests on rich star fields showed a difference estimated about 0.2 magnitude in two-eyed vs. one-eyed results. Results were very similar with this test. Based on a previous work, assuming a 20% gain for two-eyed vs. one-eyed viewing, a 78mm aperture is approximately equivalent to a 70mm binocular.

LM Viewing of Faint Stars in the Outer FOV

In the Fujinon 16x70, mag 10.2 and 10.3 stars were still visible at 85-90% out from center. The mag 10.4 star was lost from view about 80% out from center. With the '02 Oberwerks, the mag 10.2 and 10.3 stars were lost from view about 80-85% out and the mag 10.4 star was lost by 80%. Both these binoculars were previously tested for sharpness across the fov and both proved to consistently measure among the sharpest binoculars. The sharpest binoculars are losing about 0.5 mag in the outer 20% of the field of view.

An Orion 10x50 Ultraview begins dropping off LM at 50% to 60% out from center. I would estimate by 70 to 80% out from center it had lost 1 whole magnitude.

What Else is Seen with the Best Binoculars

On one of the best observing nights, to wrap up the night I scanned around with the Fujinon and easily saw M71 faint but distinct, M27 bright, M56 small, M57 almost starlike, both E(sigma)2470 and E2474 cleanly split, saw much of the Gulf of Mexico area of the North America Nebula, and I faintly suspected seeing the eastern portion of the Veil Nebula.

I continued with the Fujinon and easily found 7790 a glow in Cas, 457 the Owl cluster, 659 difficult, 663 easy, 654 difficult, Stock 2 very broad, 869/884, Tr2, Mel 15, suspected nebulosity in this region I 1805?, Kembles Cascade down to 1502, E485 in 1502, M34, M31, M110 faint and M32 easy, 752 broad and finally M33 faint.

After so much concentrated study, it’s a relief to wander around the sky and see so many different kinds of objects. Skies don't get much better than this in the summer around here. Winter skies will be darker, but this is a pretty good indication of results that can be achieved with 16x70 binoculars.

How is BLM Different than LM in a Scope?

You’ve heard time after time, in a scope “Aperture Rules”. It is the primary factor in light gathering and controls the LM. But what if you only use your scope with low magnification. Are you reaching LM? NO! You will not reach LM with a scope unless you use optimum magnification. The best explanation I have found for this comes from “Amateur Astronomer’s Handbook”, by Sidgwick.

That’s the biggest difference between LM in a scope and BLM in binoculars. The scope allows you to vary the magnification. In the binoculars, magnification is fixed. Sidgwick explains clearly how we arrive at the optimum magnification and it usually falls between 24D and 30D, where D is aperture in inches. Binoculars are a lot closer to minimum magnification than optimum magnification. Minimum is generally accepted as that which produces a 7mm exit pupil, the exit pupil that would provide maximum brightness.

Based on this, it becomes apparent that normal lens formulae that base calculations on optimum performance cannot always be used for binoculars. With the exception of brightness, binoculars do not operate at optimum to utilize the full potential of the aperture. In binoculars, because optimum magnification cannot be utilized, BLM will be considerably less than what can be achieved in an equivalent size scope. In binoculars, aperture does not always rule.

Summary and Conclusions:

There are at least 10 different areas of observation in this star field. Some areas contain several stars and some areas consist of just a single star. There were ~50 stars observed, not counting the bright stars that make up the Coathanger asterism. Of those 50, 25 stars mag 10.0 or fainter and within those 25, 12 stars range between mag 10.5 to mag 10.83. There were other mag 10.7, 10.8, 10,9 and 11.0+ stars in the field that were never seen even under the best conditions.

In total I have recorded well over 500 observations on different nights with skies recorded as 6 different NELM using eight different sizes binoculars.

The mags of all the stars in the field have been verified using current available information at my disposal as well as by direct telescope comparison to other field stars. Several discrepancies with other published information have been noted.

The faintest star observed was mag 10.83. There were two stars at this magnitude seen on several observations with the Fujinon 16x70s and the Oberwerk 15x70/'03 and the Oberwerk 20x80s. No fainter stars were found with 20x80s, although that can be attributed to some difference in quality and a lower NELM observation.

Verified results, in NELM 5.6-5.8 skies:

- Fujinon 16x70 see 10.83 direct.
- Oberwerk 15x70/03 see 10.7 direct, 10.83 glimpsed averted.
- Oberwerk 15x70/02 see 10.5 direct, 10.6 averted.
- Pentax 16x60 see 10.5 direct, 10.65 averted, some brighter not seen.
- Pentax 12x50 see 10.3 direct, 10.5 averted, some brighter not seen.
- Orion 10x50 see 10.05 direct, none fainter averted.
- Swift 8x42 see 9.5 direct, 9.75 averted.

Oberwerk Dlx 20x80 see 10.83 direct, none fainter averted in mag 5.0 skies

Fujinon 16x70 see 10.6 direct when viewed with only one eye

in NELM 4.0 skies

- Oberwerk 15x70/03 see 10.3 direct, but lost 3 brighter.
- Pentax 16x60 see 10.3 direct, but lost 4 brighter.
- Oberwerk 15x masked to 50mm see 10.3, but lost 5 brighter
- Pentax 16x masked to 50mm see 10.1 but lost even more brighter.

Several times, in the poorer NELM skies noted above or with apertures of 50mm and 60mm, there were faint stars seen while brighter stars were not seen. A review of the article "Telescopic Limiting Magnitudes" by Bradley Schaefer may provide a possible explanation for this phenomenon. " ...the reported magnitudes of stars are in the V magnitude system... consider the case of two stars with equal V magnitude but different color. ...if night vision were being used the redder of the two stars would appear fainter."

To remain conservative, I underestimate the recorded variances in NELM and state the maximum observed drop in BLM. This has the effect of reducing the error between field observations and predictive formula. In reality, the variances may have been greater and the error larger. Note for my conditions, using apertures of 2”(50mm) to 2.75”(70mm) with a NELM magnitude drop of approx 1.3mag (minimum drop), the difference in observed BLM varied by a drop of only 0.5 mag. (maximum).

Again referencing Schaeffer’s article, he shows clearly that as NELM drops from 6.0 to 4.0, for magnifications at 100x, telescopic limiting magnitude would drop only 0.3mag for a 2” lens and 0.7mag for a 5” lens. As aperture increases, the instrument experiences a greater affect from NELM. The entire 2.0 mag drop in NELM would not be realized in the instrument until up in the range of 15” to 20” aperture.

Carlin’s formula for determining the BLM is derived to calculate the increase over NELM, or magnitude gain due to aperture and magnification. It closely predicts the LM differences I obtained between the various 70mm to 50mm and 16x to 12x binoculars, with variation only in tenths of a magnitude. However the formula predicts compensating variances in the gain relative to aperture versus the gain relative to magnification as compared to actual field results.

If the formula calculations are taken in 10% increments separately for both aperture and magnification, the formula would show for every 10% incremental change aperture has a nearly equal impact (0.062mag gain) on the outcome as does magnification (0.083mag gain). This relationship was not found in actual field results.

Field results show magnification, more so than aperture, has a much greater impact on observed BLM. Previously, for Binocular Performance tests, I used masked binoculars to test magnification vs. aperture on star fields. Similar results were found in those tests.

Changes to magnification or aperture (area of the lens) in increments show for every 10% change magnification was measured to have three to four times the affect on the gain. Increases in magnification appear to have far more influence on BLM gain than increases in aperture.

On a recent Sept’03 visit to the optometrist, I had my dark-adapted pupils measured at over 6.5 to 7mmin in subdued room light. All the binoculars I used provided an exit pupil of 5.25mm or less, all smaller exit pupils than dark-adapted eye pupil. Therefore no adjustment is needed to the formula to account for eye pupil smaller than exit pupil.

Applications I have seen of Carlin’s formula posted by Harold Lang add calculated increase in binocular magnitude plus a constant to NELM to arrive at BLM. The formula follows:

m = 3 Log aperture(cm) + 2 Log mag + 0.6 + NELM

example: for a 16 x 70 Fujinon in mag 5.8 skies, m = BLM

m = 3 x Log 7cm + 2 x Log 16 + 0.6 + 5.8
m = (3 x 0.845) + (2 x 1.204) + 0.6 + 5.8
m = 2.535 + 2 .408 + 0.6 + 5.8
m = 11.343 for mag 5.8 skies

m for 15x70s would be just less than 0.1 mag lower.

You can see by Chart 2, the actual BLM very closely matches the formula prediction in the range to just both sides of mag 5.2 NELM. But the formula prediction produces results too high (by 0.5) at mag 5.8 NELM and equally to low at mag 4.4 NELM. In Lang's application of Carlin's formula results are added to NELM, producing a constant slope as shown in Chart 2. Since the greatest differences in results seem to be not in the calculation of additive performance but in the linear addition to NELM, it is expected the variations from field-measured performance would increase greater outside this tested range of NELM. The formula application predicting BLM appears to operate well in a narrow range. Outside that range it gets increasingly further from results indicated by field tests.

The calculated values, if added to NELM with no constant applied, would all be very close to field-measured values at mag 6.0 NELM. I have done no work here to test the significance of the constant.

Field results indicate, and Schaeffer's article supports, optical Limiting Magnitude does not vary equally as NELM varies.

The results obtained from Carlin's formula cannot simply be added to NELM, with or without a constant, to arrive at BLM. The affect of NELM does not act constantly with magnification and aperture. It varies and this must be taken into consideration.

NELM cannot be added directly to calculated increase. Predicted binocular performance should be adjusted to reflect that narrow range.

Schaeffer's article shows us a graph supporting my previous statement that aperture in binoculars is underutilized. From Schaeffer, "as either …aperture or magnification is increased, a visual observer will see fainter stars."

Claims that magnitude 12.0 stars can be observed with 16x70 binoculars, even under NELM 6.5-7.0 skies are highly suspect, especially since a 70mm telescope at optimum has only a 12.0+/- limiting magnitude. Binoculars have substantially lower LM than telescopes of equal aperture for several reasons, including low magnification, number of additional optical surfaces and probable lack of diffraction-limited optics, at least in most binoculars.

LM published for telescopes generally represent apertures used in NELM 6.0-6.5 skies with optimum magnification (from Sidgwick, 24D to 30D inches). For 70mm (2.75") binoculars, that would require a magnification of at least 66x to 82x to reach the potential LM of the lens. Magnification does allow you to see more. Further, for extended objects, although highlighting the importance of maximum light gathering (one of the primary designs of binoculars), Sidgwick discusses the importance of magnification even for seeing faint extended objects. This clearly shows, quality being equal (quality not being the point of this discussion), magnification should be given greater importance in binoculars.

In the absence of field tested data and verification, it may be reasonable to assume a quality binocular used under the best possible conditions could reach BLM no better than 1.0 mag below that of an equivalent aperture telescope operating at optimum. Using Schaeffer's predicted upper limits of optimum performance for scopes, my assumption would predict an approximate maximum BLM for a 100mm binocular at 12.0 mag, for 80mm 11.6mag, for 70mm 11.4mag and for a 50mm binocular 10.8 mag. These magnitudes would be considered the upper limits on any scale plotting predicted performance vs. NELM.

edz
Sept, '03

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