Estimating Vignetting in Binoculars Using Stars at Night

By Anton Jopko

My major peeve with binocular reviews is the missing discussion of vignetting in binoculars. Vignetting means that not all of the light entering the objective lens of a binocular reaches the exit pupil and observer's eye.

I think it is fair to say that most aberrations in lenses occur around the periphery. To reduce or eliminate these requires much effort and cost. One benefit of vignetting is that this is an easy way to block these aberrations so to reduce costs but improve the image quality that remains. A major disadvantage of vignetting for astronomers is that you could lose a half magnitude or more of brightness at the periphery of the field of view. So quality costs.
Many years ago, I was able to examine a pair of Zeiss binoculars. Zeiss had a reputation for excellent optics. To my dismay I discovered that only the centre of the field of view was fully illuminated.

The purpose of this first part of the article is to try and assess the amount of vignetting at the edge of the field of view compared to the center of the field of view by observing a pair of stars in the night sky. We assume the very center of the field of view is fully illuminated. That is, there is no vignetting there, which is usually the case.

You will need to find the locations of the pairs of stars below in their constellations. The brighter stars are labelled by lowercase Greek alphabet letters. Below is a table of the Greek alphabet whose letters are used to identify stars in star atlases and the internet. Another solution is to enter the name of the star in Wikipedia search window. It will show you the constellation and circle the given star in it.

Alpha	Beta	Gamma	Delta	Epsilon	Zeta	Eta	Theta	Iota	Kappa
α	β	ϒ	δ	ε	ζ	η	θ	ι	κ

Lambda	Mu	Nu	Xi	Omicron	Pi	Rho	Sigma	Tau	Upsilon
λ	μ	ν	ξ	ο	π	ρ	σ	τ	υ

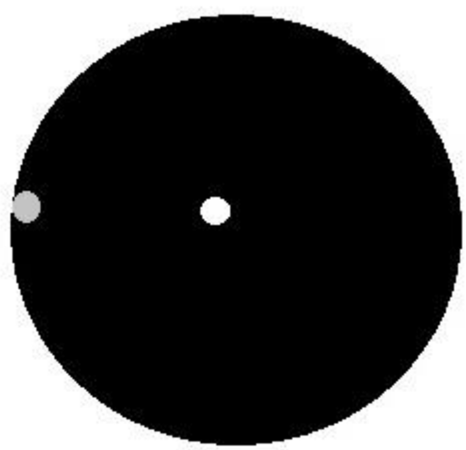
Phi	Chi	Psi	Omega
ϕ	χ	ψ	ω

These pairs are found in the Table A below. The first column gives the right ascension of the star in hours. The second column gives the declination in degrees. The third column is the name of the star, then V Mag, is apparent Visual magnitude of the star, then, Delta Mag, the difference in magnitude between the pair, the separation of the stars in the pair in degrees and finally the illumination (or brightness) of the fainter star compared to the brighter star. Recall that magnitude has the inverted property that the larger the magnitude the fainter the star. A magnitude 4 star is fainter than a magnitude 3 star. Most of these stars are variable but the amplitude of these is usually around 0.05 and less than 0.10. My search was limited to stars brighter than magnitude 4 and whose declination was greater than -20 degrees which left about 300 stars. Note that some pairs may have significantly different colours and that might limit precision. Note that visual precision is typically not better than 10% so the values in the Illum column would have 10% uncertainty as well.

Table A						
RA	DEC		Visual	Delta	Sep	
Hours	Degrees	Name	Mag	Mag	Degrees	Illum
1.91	20.81	6 Bet Ari	2.64			
2.12	23.46	13 Alp Ari	2.00	0.64	3.91	0.55
2.16	34.99	Bet Tri	3.02			
2.29	33.85	Gam Tri	4.00	0.98	1.97	0.40
2.72	3.24	86Gam Cet	3.47			
3.04	4.09	92 Alp Cet	2.53	0.94	4.81	0.42
3.08	53.51	23Gam Per	2.93			
2.84	55.90	15 Eta Per	3.76	0.83	3.10	0.47
3.74	32.29	38 Omi Per	3.83			
3.90	31.88	44 Zet Per	2.85	0.98	2.12	0.41
3.75	42.58	41 Nu Per	3.77			

3.96	40.01	45 Eps Per	2.89	0.88	3.53	0.44
4.33	15.63	54Gam Tau	3.65			
4.48	15.87	78The2Tau	3.40	0.25	2.15	0.79
5.13	-5.09	67 Bet Eri	2.79			
5.29	-6.84	20 Tau Ori	3.60	0.81	2.99	0.47
5.53	-0.30	34 Del Ori	2.23			
5.60	-1.20	46 Eps Ori	1.70	0.53	1.39	0.61
5.55	-17.82	Alp Lep	2.58			
5.78	-14.82	Zet Lep	3.55	0.97	4.56	0.41
5.60	-1.20	46 Eps Ori	1.70			
5.68	-1.94	50 Zet Ori	2.05	0.35	1.36	0.72
5.80	-9.67	53 Kap Ori	2.06			
5.59	-5.91	44 Iot Ori	2.77	0.71	4.85	0.52
7.43	27.80	60 Iot Gem	3.79			
7.58	31.89	66 Alp Gem	1.98	1.81	4.50	0.19
8.92	5.95	16 Zet Hya	3.11			
9.24	2.31	22 The Hya	3.88	0.77	5.97	0.49
9.06	47.16	12Kap UMa	3.60			
8.99	48.04	9 Iot UMa	3.14	0.46	1.15	0.65
9.76	23.77	17 Eps Leo	2.98			
9.88	26.01	24 Mu Leo	3.88	0.90	2.72	0.44
10.12	16.76	30 Eta Leo	3.52			
10.33	19.84	41Gam1Leo	2.61	0.91	4.28	0.43
10.28	23.42	36 Zet Leo	3.44			
10.33	19.84	41Gam1Leo	2.61	0.83	3.66	0.47
11.24	15.43	70 The Leo	3.34			

11.40	10.53	78 Iot Leo	3.94	0.60	5.45	0.58
14.53	30.37	25 Rho Boo	3.58			
14.75	27.07	36 Eps Boo	2.70	0.88	4.41	0.44
17.72	4.57	60 Bet Oph	2.77			
17.80	2.71	62Gam Oph	3.75	0.98	2.16	0.41
19.77	10.61	50 Gam Aql	2.72			
19.92	6.41	60 Bet Aql	3.71	0.99	4.77	0.40
22.10	-0.32	34 Alp Aqr	2.96			
22.36	-1.39	4Gam Aqr	3.84	0.88	4.11	0.44



To make it easier to compare the brightness It is suggested you defocus the binoculars so the stars appear as small disks. These disks will cover a larger portion of the retina and reduce flaring. They should also be the same size. If not, then adjust the focus of the variable eyepiece until they are.

Suppose we have a pair of stars whose magnitude difference is 0.75 and a separation of half of the field of view as in the figure above. This corresponds to an illumination or brightness ratio of 50% for the fainter star. So, if the brighter star at the edge appears as equally bright as the fainter star near the center, then you know the vignetting is 50% at the edge. If the edge star is brighter then the center star then you know the illumination of the edge star is greater than 50%.

Part 2

The purpose of part 2 is to try and estimate the portion of the central field of view that is fully illuminated using the stars in Table B below. The column Labelled Delta Mag is the difference in magnitude of the two stars and ideally should be zero.

Sep is the separation of the two stars and Amp Mag is the amplitude of variation in magnitude of each star. I eliminated pairs where the Delta Mag was greater than 0.15. Also note that for small values of Delta Mag such as 0.10, for example, there is about a 10% change in the brightness ratio. So, the fainter star is about 10% fainter than the brighter star. Clearly better to use smaller Delta Mags if possible.

These will be used as described below. It is surprising that so few of such pairs exist that have small Amp Mag.

In the name column, there is often a number before the letters. For example, 29Ups UMa means 29 Upsilon Ursa Majoris. 29 is a numerical designation of the star, called the Flamsteed number, seen on star atlases and corresponds to Upsilon etc. Unfortunately, I could not find pairs with smaller Delta Mag differences and small variability. Table B has pairs sorted by increasing separation.

A bonus use for these tables is to determine the actual field of view of your binoculars. Find a pair whose separation is one-half, or one-third etc of the field of view then double or triple your result to get actual field of view.

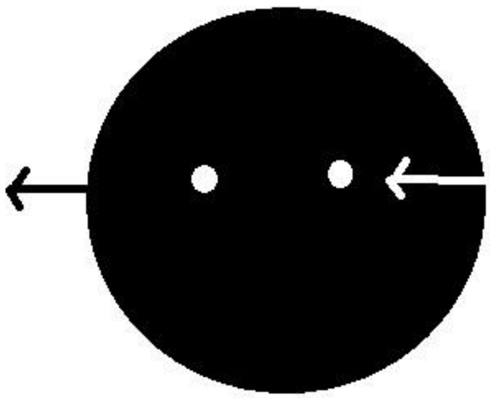
Table B

RA Degrees	Dec Degrees	Name	Visual Mag	Delta mag	Sep Degrees	Amp Mag
3.45	9.73	2 Xi Tau	3.74			0.040
3.41	9.03	1 Omi Tau	3.60	0.14	0.91	0.030
20.66	15.91	9 Alp Del	3.77			0.020
20.63	14.60	6 Bet Del	3.63	0.14	1.41	0.020
4.33	15.63	54 Gam Tau	3.65			0.040
4.38	17.54	61 Del1Tau	3.76	0.11	2.06	0.000
4.48	15.96	Thet1 Tau	3.84			0.00
4.38	17.54	Del1 Tau	3.76	0.08	2.07	0.00

4.48	19.18	74 Eps Tau	3.53			0.00
4.48	15.87	Thet2 Tau	3.40	0.13	3.31	0.04
9.53	63.06	23 UMa	3.67			0.020
9.85	59.04	29 Ups UMa	3.80	0.13	4.74	0.040

How to use the Above Table B

As before it is suggested you defocus the binoculars so the stars appear as small disks.



The idea at left is to look at a pair of these stars and shift the binocular along the line through the pair, to the left in this case, to see if the stars continue to look equally and fully bright. This would imply they are both fully illuminated at this particular location. If one star appears fainter than the other in a location, then you would know the fainter star is not fully illuminated. This should help identify the fraction of the field of view that is fully illuminated or has zero vignetting.

I give huge thanks to Dr. Doug Welch, a professional astronomer at McMaster University in Hamilton, for supplying me with a spreadsheet with all of the 9400 stars in the sky down to magnitude 7 with which I used to find the pairs of stars in this article. Here is a link to that database VizieR (unistra.fr) He also supplied links for finding which stars are variable stars and suggested to bring stars to out-of-focus slightly while observing with binoculars to make it easier to compare brightness of the pair.

Here is a link that allows you to find current values of the apparent Visual magnitude of variable stars https://www.aavso.org/LCGv2/ .

I also thank Chris Vaughn, Dave Chapman, and Scott Young, for their suggestions.

Comments, corrections and test results are welcome at
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