Saturn in Binoculars

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Some thoughts, and observations, on the visibility of the rings of Saturn at 7X.

Theory says no problem, trivial, assuming perfect optics, including the eye. I have a "calibrated milliradian" in the form of a "golf-ball" water tank several miles away, the ball part subtends one milliradian (mr), (3.44 arc min.) and another one farther away that subtends about 0.67mr (2.3 arc-min). I have no trouble resolving that smaller one with the naked eye in daylight. At 10X the ball of Saturn will look like about 1 mr, and the major axis of the rings will subtend 1mr at 4.6X, as will the disk of Jupiter. From this purely geometric argument it would seem trivial to see Saturn's rings at 7X where the major axis of the ring system would now subtend over 1.53mr

(5 arcmin), better than 5X the resolution of the "standard" eye. I think, however, one should be cautious playing with these numbers. If one looks at the images of the relative apparent sizes of the planets, for example, on Sky & Telescope's Sun Moon and Planets, (p 103 in the Nov. issue) shows that Saturn is considerably smaller than Jupiter, although the maximum angular dimensions of each are comparable.

Practice: No way. (Or so it would seem) My first astronomical instrument was the Zeiss 8X30 binos I had mentioned in earlier editions of this column. Early on I had mounted these on a tripod and with then childish enthusiasm looked at everything I could. The planets were a big disappointment, and I thought a telescope was necessary to see anything at all. After acquiring my first 'scope, (40mm Polarex (Unitron)) and looking at Jupiter and Saturn at 40X - 50X I thought anything much under 20X would not show much. The real reasons for the inability to resolve these small structures is, while we think the world of binoculars, especially if we paid many bucks for 'em, they really aren't very good as optical instruments go. Secondly, our eyes, which operate close to the diffraction limit during the day (Arc-minute resolution, 2mm pupil), are more than likely pretty awful "wide open" at 6 or 7mm. Mine sure are! On top of all of this,the retina's resolution gets poorer in low light, the effect of "bigger pixels". (Roger Clark in his book Visual Astronomy of the Deep Sky discusses this effect) On the first point it would be interesting to try and quantify "goodness". I was thinking of setting a bino up, at infinity focus, in front of the interferometer and looking at the transmitted wavefront. While I have no prescription for a typical 30mm bino objective, I fiddled around with the computer analysis of a "typical" 30mm f/4 cemented achromatic objective. From the Melles Griot catalog/database, I exhumed a "Precision laser grade achromatic doublet" of 100 mm focal length, scaled it to 120mm FL, gave it an aperture of 30mm (f/4). and had at it. The peak-to-valley (P-V) wavefront is ~0.77 waves and the circle containing 75% energy is 28 arcsec in diameter, 90% energy, 32 arcsec. compared to the ideal airy disk of about 9.2 arcsec. The Strehl came up 0.159, which is meaningless. The Strehl is the ratio of the amount of energy in the Airy disk to the ideal number in a perfect image. Strehl of 0.8 roughly corresponds to a 0.25 wave system, and numbers much less than 0.2 or so means the calculation is getting lost. Yes, as supposed, this thing is pretty awful by telescope standards. Yes, again, the prisms in the binocular will introduce their brand of aberrations, but if you are designing the "precision grade" lens for a prism binocular, you'd include the prisms as part of the system and come close to the above results anyhow. Stopping this down to 16mm (F/7.5, 2mm exit pupil at 8X) now gives a P-V wavefront of .074 waves, and encircled energy of 16 arcsec for 75% and 32 arcsec at 90%, the diffraction disk is now 17.3 arcsec and the Strehl is 0.98. MUCH improved. The size of Saturn's disk these days is about 19 arcsec. (I used a wavelength of .55um for the Airy calculations, the aberration and wavefronts were at the lens' design wavelength of .587 um.) The punchline here is that the binocular, as well as the eye will perform very poorly "wide open" and the light from one of these planets won't make the eye "stop down". In addition, irradiation and glare from a bright nearly point image will further hide the real shape of the object. I propose the following observational experiment: Use the 7X or 8X glasses stopped down to a 2mm exit pupil and see what happens, and try with a little 6X15 (2.5mm exit pupil).

The Observations

Saturday,Oct 10/98, ~6:00 or so UT (Midnight, local) I made the following observations of Jupiter and Saturn. The instrument was a 7X35 monocular, made from a very tired 7X35 widefield bino. I don't remember the make (I misplaced the backplate with the name on it) It has an 11 deg. field and fully coated optics. I stopped the objective to about 14mm (2mm exit pupil) and braced it against a solid support. The disk and moons of Jupiter were unmistakable (I even imagined I could detect the major equatorial belts). Saturn did appear elongated, I wasn't sure if I could detect the space between the ball and ring or the ball bulging from the ellipse of the ring. This was difficult. Again referring to the apparent sizes of these objects as pictured, this difficulty comes as no surprise. The diffraction disk, at this aperture, is comparable with Saturn's disk and I'm sure helped wash out this finer detail. I then stopped it down to about 10mm. The result seemed to be about the same. At 10mm the resolution should be noticeably poorer due to diffraction.

(NOV.. 5, ~3:00 UT) I stopped the Zeiss 8X30s to about 15mm (1.9mm exit pupil) and took a look at Jupiter and Saturn with them tripod mounted. Jupiter's disk was apparent and Saturn appeared elongated, but without much more than looking like a short line or possibly a tiny ellipse. As a control I set up my 60mm refractor at 32X to be sure the seeing was good enough for this test. It sure as hell ought to be for a 15mm aperture, but this is Denver. I stopped the 60mm to 15mm. Saturn still sort of showed the space between the ball and the ring, but it was easy to imagine I was seeing three disks in a line. 15mm @ 32X isn't much different than Galileo's telescope. Stopping to 10mm, still at 32X, Saturn looked like an ellipse with a bright central bulge, or a fuzzball with short wings. Clouds finished that and I switched to Jupiter. The disk was obvious, but no detail was seen at 10mm, at 15mm I imagined a dark equatorial belt. At full aperture the North and South Equatorial Belts were apparent. I doubt I really saw anything at the 15mm aperture.

At the Astronomy Day open house I looked at Saturn through a friend's Cannon 15X42 image stabilized binos. The rings were obvious even hand held, however releasing the stabilize button rendered them useless, hand held. That feature really worked, and with a 2.8mm exit pupil, the eye aberrations were not too bad. At 15X the image was twice as large in apparent size, which helped a lot.

(Nov. 22, 7:00 U.T.) I again set up the 60mm refractor, this time using the 15mm and 10mm apertures at 16X and 20X. The appearance of Saturn was as the earlier observation. I then mounted, in turn, the 6X15, 7X35 monocular and the 8X30 Zeiss. With the 6X15s (2.5mm exit pupil) Saturn appeared as a short line, and did appear non stellar. Jupiter's disk was apparent, noticeably larger than the image of a star. With the 7X35, stopped to 15mm, the planet's appearance was the same as before, and with the 8X30, again stopped to 15mm the planets were maybe a bit more obvious. With the 8X30s at full aperture, there was considerable flare and although I now knew what to look for and what to expect, I'd have to say that Saturn didn't look like Saturn. The flare and irregularity of the image brought about by glare and eye aberrations masked the already difficult image. I could probably convince myself that Jupiter was non-stellar, but again the brightness and glare probably masked the real disk.

The conclusions from all of this is that, yes, one should be able to tell the shape of Saturn and Jupiter with magnifications in the range of 6X to 8X but it isn't easy. One must be careful to maximize the performance of the binocular and mitigate the brightness of the image with aperture stops which give a 2mm exit pupil, and reduce the glare. I would say that the rings of Saturn probably will not be apparent to a casual observer, but if the above precautions are taken the planet will show its shape. As the inclination of the rings increase over coming years they should become easier to detect. It helps to know what to look for and what to expect at these low magnifications. How often have we not been able to see a faint star or something in a small telescope until it is shown to us in a larger instrument. Then it becomes visible and we can't understand not having seen it before.

Postscript to the planet observations at 6X-8X
To: Peter Abrahams, Binocular list editor.

No sooner than your latest bino list hit the street than I got a response from D. Buchroeder alerting me to a plethora of papers, in the Sept. Journal of the Optical Society of America, part A, (JOSA-A), on the eye's optical performance. I think he sent you a copy of his note as well. I looked over some of the papers, and was amazed at how well and how poorly the eye works. Well, in that at a 2mm pupil it seems we are equipped with 1/10th wave optics. Poorly in that the wavefront falls to about 1 wave at 4.5mm aperture and to almost 3 waves at 5.5mm! Really bad compared to the 30mm bino objective I analyzed earlier. Small wonder that stopping things to a 2mm pupil helps as much it does This last comment was from the paper by Thomas O. Salmon, Larry N. Thibos & Arthur Bradley "Comparison of the eye's wave-front aberration measured psychophysically and with the Shack-Hartmann wavefront sensor" in the aforementioned JOSA-A. My estimate of .77 waves with the bino lens was at a focus setting to minimize the wave aberration. At the paraxial focus of the bino lens, the optical path difference (OPD) is 3.2 waves P-V. add that to the eye's approximate .5 wave at the 3.75 pupil diameter, (8X), and no small wonder things look terrible! With a lower magnification, larger exit pupils, things get even worse rather rapidly.

Also, with the 30mm objective, at its paraxial focus, field curvature and astigmatism gives a P-V wavefront error in the vicinity of 20 waves at the edge of a 8-deg. full field, that of my 8X30! Makes one wonder how one can see anything at all with these things!

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