SPECTACLES *for* Spectacular Skies

By Joshua Roth

Go the final mile to correct your eyes' worst astronomical shortcomings, and you may see a whole new sky at night.

ALAN DYER

UNDEREXPLORED VISTA Light pollution is one reason that some stargazers are relatively unfamiliar with the Milky Way's richly textured star clouds and dust lanes, but another reason may be that they've never been able to bring the "naked-eye" sky into crisp focus.

MOUNT PINOS, CALIFORNIA, CIRCA 1990. A half decade into a newfound hobby, I found myself part of the monthly new-Moon gathering upon the 8,300-foot-high mecca of Los Angeles–area astronomy. Entranced with the magic of star-hopping, I had demoted the naked-eye sky to a scattering of celestial steppingstones — mere highway signs telling me where to point my Coulter 8-inch (20-centimeter) Dobsonian and begin doing real astronomy.

It wasn't just that I had fallen under the spell of finding distant galaxies and ghostly nebulae with my recently acquired reflector. The stars had never really looked that sharp to my "naked" (that is, telescope-free) eyes anyway, even when my glasses were on. And unlike my telescope, my glasses didn't come with focusing knobs.

But one night, on impulse, I borrowed a fellow stargazer's much stronger eyeglasses — I was modestly nearsighted, while my companion was blind as a bat without optical aid — and slipped them on. I felt as if I'd stuck my head into an upside-down fishbowl. But despite the distortion I saw more stars, and they seemed a bit brighter and sharper than usual.

The proverbial light bulb went on over my head: maybe my regular glasses didn't quite cut it for stargazing. But more than a decade would pass before I would gain any real insight into my modest discovery or fully exploit it by ordering eyeglasses that fully compensate for my nocturnal nearsightedness.

Now, though, such eyeglasses have become my most important piece of optical equipment. Using them when my eyes are fully dark-adapted, I can detect stars about a half magnitude fainter than the dimmest ones that my regular glasses bring into view. My stargazing spectacles have sharpened the richly textured edges of the Milky Way's dark lanes and pools; they have enabled me to spy the planet Uranus where *Sky & Telescope*'s charts place it

among the stars; and they have brought a number of deep-sky objects into naked-eye view for the first time.

Now I routinely resolve Perseus's Double Cluster into two distinct knots of starlight, and sometimes I can see the Coathanger's hook in Vulpecula's faux cluster, Collinder 399. Then there are the challenging double stars I now can split in Taurus's Hyades. Not bad for an investment that ran about $300 — less than some premium eyepieces — and will last for several years!

One Phenomenon, Many Theories

Why wouldn't the eyeglasses I'd been getting since fifth grade (with an exam and an updated prescription every few years) work particularly well for stargazing? Simple, I naively figured: the wall chart with the increasingly little letters wasn't at infinity, so each part of the chart sent slightly diverging rays through my eyes to the corresponding part of my retinas. In contrast, the light rays from each star on the dome of the sky are essentially parallel because they are vastly more distant.

But it turns out this wasn't really the reason. Rather, a phenomenon called *night myopia* was the culprit. The term first came to my attention thanks to Barry Santini, a New York–based optician who has optimized eyeglasses for a dozen-plus amateur astronomers. Night myopia, Santini explains, is the tendency of people to become more nearsighted in darkness than they are in daylight. It was this effect — and not the wall chart's relative proximity — that made the stars come into better focus when I used eyeglasses that were stronger than my nominal daytime prescription.

All the optometrists, opticians, and vision scientists I interviewed for this story had heard of night myopia. But they don't entirely agree on what causes it!

Like Santini, Colorado optometrist and amateur astronomer Keith Bowen attributes night myopia mostly to *instrument myopia,* a hardwired psychological and physiological reflex that causes us to focus on nearby things in the absence of strong visual stimuli. Because most people lose the ability to focus nearby as they age, night myopia should diminish with advancing age as well, Bowen adds — and indeed, one 55-year-old amateur astronomer, Joel M. Moskowitz of New York, has watched his own night myopia diminish significantly over the past decade. A day-to-night offset of 1/2 or 3/4 **diopter*** is typical, says Bowen, who prescribes night-driving glasses for some patients.

Indiana University optometry professor Arthur Bradley blames the eye's **chromatic aberration** as well as the "unwanted accommodation" that Bowen describes. The human eye brings light of different colors to focus at different distances from the cornea, Bradley explains. Moreover, the rods on the periphery of the retina (which are principally responsible for night vision) are sensitive to light that is slightly bluer than the light most easily seen by the cones at the retina's center (which are optimized for daylight). Although the wavelength difference between the peak sensitivities of retinal rod and cone cells is only a modest 50 nanometers (roughly one-tenth the wavelength of yellow light), it can produce a half diopter's worth of night myopia when combined with the eye's substantial chromatic aberration, says Donald Miller, also at Indiana University.

A third camp includes two scientists who study the eye as an optical system: Jim Schwiegerling, a University of Arizona professor of ophthalmology and optical sciences, and David R. Williams, director of the University of Rochester's Center for Visual Science. Schwiegerling and Williams both

*** Highlighted terms** *are defined in the glossary on page 35.*

Smart Shopping for Stargazing Glasses

While the primary advantage of stargazing eyeglasses is their ability to compensate for night myopia, other factors can be optimized as well. Note that these should be considered even if you're not modifying your nominal eyeglass prescription.

LENS MATERIALS. **New York–based optician Barry Santini recommends normal plastic (index of refraction 1.50), medium-index plastic (1.55), or crown (1.53) or hi-crown (1.60) glass — though he particularly favors spherical hi-crown glass lenses, which are particularly scratch-resistant. "Refrain from the use of polycarbonate lenses," he warns, "which, although lightweight and very impact-resistant, are soft (scratch easily) and exhibit the worst color aberration of any ophthalmic lens material available."**

COATINGS. **Eyeglasses for astronomical use can benefit from antireflection coatings, whether or not night myopia is an issue. But don't use any yellowish "night-driving" tints on stargazing glasses, warns optometrist Keith Bowen: they reduce light transmission. And bear in mind that antireflection coatings do require frequent cleaning, since oily deposits from one's skin render them ineffective and can permanently damage them if not removed for a long time. (Some experienced stargazers do without coatings for just this reason.) Bowen recommends first rinsing coated eyeglasses with water (to remove dust) and then using mild dish soap or a specialty spray cleaner and a soft cloth to remove smudges.**

LENS AND FRAME DESIGNS. **Some of Santini's clients have especially enjoyed the spherical eyeglass lens shape that comes from Contour Optics (see the upper photo at right). These "wraparound" lenses give a nearly all-sky view, without the peripheral cutoff from conventional eyeglasses. As far as mechanical factors go, I especially like the double-sprung hinges on my eyeglasses (lower photo); these allow me to repeatedly remove the glasses without worrying about wearing out**

S&T: CRAIG MICHAEL UTTER (2)

give the lion's share of the credit (or blame) for night myopia to the eye's substantial **spherical aberration,** which becomes noticeable only when pupils are dilated. Light striking the periphery of a dilated pupil comes to a focus farther ahead of the retina than does light striking the pupil's center, they explain. And while "you're not actually fixing the spherical aberration of the eye" by augmenting your myopia correction, Schwiegerling stresses, you are pushing the "minimum-blur circle" — the most concentrated bundle of starlight that your dilated eye can provide — onto the retina, enhancing night vision.

Schwiegerling estimates that an amateur astronomer whose dark-adapted pupils span 6 millimeters typically will experience a half diopter of night myopia, while the rare stargazer whose pupil can open up as wide as 8 mm may experience a 1½-diopter effect — though both numbers vary widely within the human population. Since one's pupil size, whether light- or dark-adapted, gradually diminishes with age, this also could explain anecdotal evidence for night myopia's being less severe in older astronomers.

Measuring Night Myopia

Scientific uncertainty about its cause notwithstanding, night myopia is "a documented effect," says Bowen — in fact, it has been documented at least since 1789, when Nevil Maskelyne described it to the Royal Society of London. But if you're a nearsighted amateur astronomer who already wears eyeglasses or contact lenses, is it reason enough to get a separate pair of glasses or contacts for stargazing? And if so, how can you optimize your prescription? If you normally don't wear eyeglasses, should you consider getting a pair just for astronomical use? And if you normally wear bifocals, can you optimize them for use under the stars? Let's address each scenario in turn.

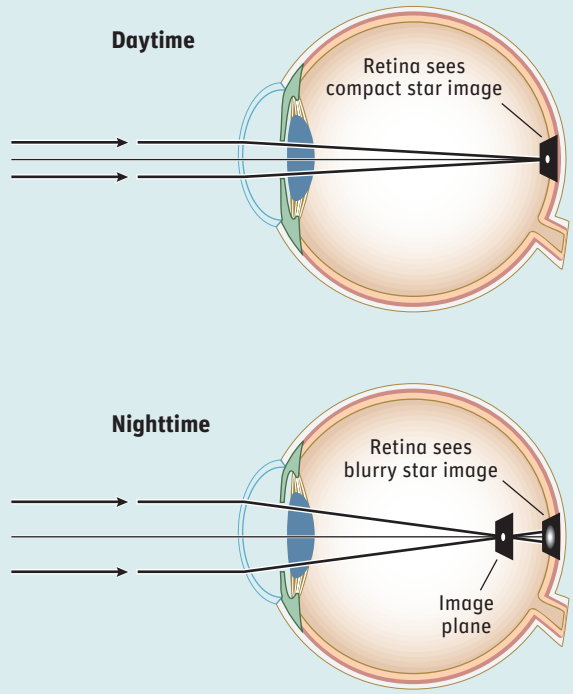
Nearsighted astronomers already wearing glasses for general daytime use. Ideally, say Bowen and Santini, buy or borrow a tool used by optometrists: a handheld quartet of lenses called a "flipper." (One vendor who has agreed to take orders from *S&T* readers is listed below.) When held in front of your eyeglasses, each of the flipper's two lens pairs augments your preexisting correction by a certain amount (measured in whole or fractional diopters).

Santini recommends progressing in quarter-diopter steps from –0.25 D to –1.00 D or even –1.50 D. (The minus sign denotes a negative focal length, which counters myopia.) Once your eyes are dark-adapted under clear, moonless skies, look through your eyeglasses at a familiar star field. Then move the flipper in and out of place and compare the views.

Next, determine your limiting visual magnitude with a wide range of flipper-augmented "prescriptions," holding each lens pair in place for some time. Inspect naked-eye clusters like the Pleiades or the Hyades and look for any "new" stars that may appear. Seek out a few deep-sky objects that may have eluded naked-eye scrutiny — possibly M33 in Triangulum, the Double Cluster in Perseus, or the Orion Nebula.

Finally, consider the possibility that each of your eyes experiences a different amount of night myopia.

Bowen and Santini both caution that you may well find



NOCTURNAL NEARSIGHTEDNESS

Night myopia refers to the tendency — shown by many but by no means all humans — to become more nearsighted (that is, to focus farther in front of the retina) when in the dark.

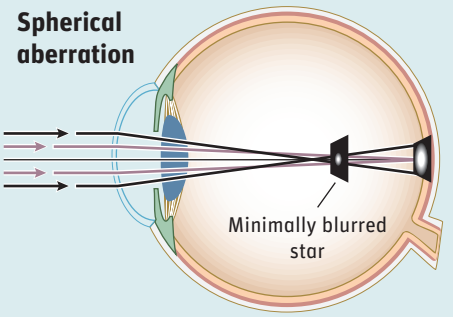
S&T: CASEY B. REED (5)

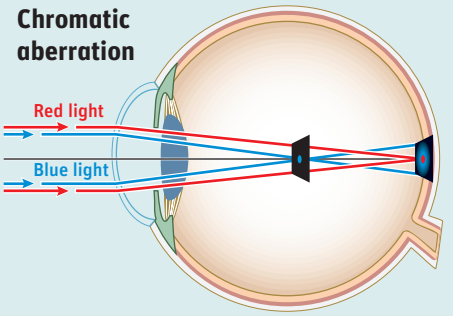
S&T: CRAIG MICHAEL UTTER

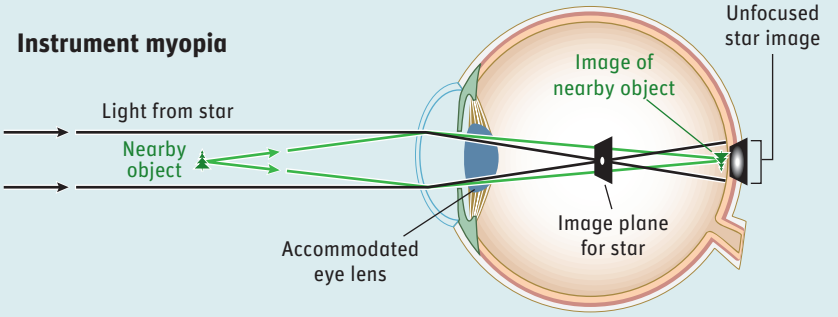
Finding Flippers

Optego Vision, Inc. (www.optego.com), based in Canada, carries a full line of flippers. Most *Sky & Telescope* readers interested in experimenting with night myopia will want the Night Myopia Flipper Set, whose two hand-held flippers provide the following lens pairs: –0.25, –0.50, –0.75, and –1.00 diopter. Each set sells for $29.90 US ($14.95 per flipper). Delivery in the US costs $5.95 for the first set, plus $1.00 for each additional set. (Canadians pay $19.95 CAN per flipper or $39.90 per set, plus $5.95 to ship the first set and $1.00 to ship each additional set in the same order.) Other lens powers can be ordered separately, and flippers can be shipped to other countries. Inquire for details at:

Optego Vision, Inc.
19 Woolsthorpe Crescent
Thornhill, ON, Canada L3T 4E1
Telephone: 877-OPTEGO-4
Fax: 877-471-6001







EXPLAINING NIGHT MYOPIA

Three competing theories for night myopia, each of which has its proponents and each of which may operate to differing degrees in different people:

Spherical aberration causes parallel light rays that strike a pupil's outer edge to converge more steeply than parallel rays striking the eye's central zone (or vice versa in some cases).

Chromatic aberration brings blue light to a steeper focus than red light. Chromatic aberration can induce night myopia, some say, because the rod cells used in dim conditions are sensitive to bluer light than are the cones that provide daytime vision.

Instrument myopia describes a reflex that makes people focus nearby when strong visual stimuli are absent.

that nothing is gained by augmenting the eyeglasses used in your flipper tests. Even if those tests do tantalize you with enhanced views, don't rush to the optometrist's office to order the strongest stargazing glasses imaginable. Take the time to find out whether a particular correction gives you a headache, creates eye fatigue, or makes you "seasick" when you walk around your observing site. Ideally, repeat your experiments on another clear night. Take careful notes on your experiences. Then discuss the results with your eye-care professional, who should be willing to prescribe a pair of stargazing glasses incorporating your findings.

Nearsighted astronomers already wearing contacts for general use. Proceed as a nearsighted eyeglass wearer would, using flippers to calibrate your night myopia. If you wear contact lenses by day and experience a measurable amount of night myopia with them on, you may wish to augment your contacts with night-myopia glasses rather than getting a second set of contacts — particularly if you favor extended-wear contacts, or if you are likely to have trouble reading your star charts with souped-up vision. (In the latter case, you will need to be able to slip the glasses on and off, or you may want to get bifocals that offer both your night-myopia prescription and your reading prescription.)

Astronomers who don't normally wear glasses or contacts. You may well benefit from correcting night myopia for stargazing even if you don't normally wear glasses, says Bowen. Proceed as a nearsighted amateur would, using flippers, or possibly borrow a mildly nearsighted friend's eyeglasses. Ask your optometrist to test you carefully for **astigmatism:** small amounts routinely are not diagnosed by examiners, says Santini, but they can noticeably compromise astronomy, both with the naked eye and at the eyepiece of a telescope.

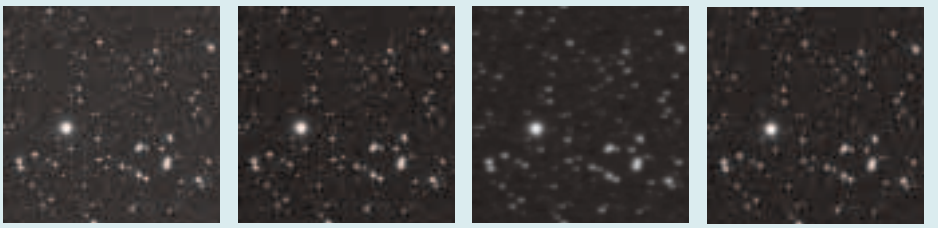
Farsighted astronomers who don't have to wear glasses or contacts for stargazing. Although it's unlikely, even a farsighted astronomer may require a night-myopia correction to best see the stars once dark-adapted. So tests with flippers are worthwhile for farsighted observers as well. In some cases, night myopia may fortuitously cancel out farsightedness, allowing for true naked-eye stargazing.

Astronomers who normally wear bifocals. If you have difficulty focusing on nearby objects through your normal daytime glasses, you suffer from **presbyopia** — and you're not alone. The malleable lens within the human eye stiffens with age, and consequently almost 10 million bifocal eyeglass prescriptions are written in the US yearly. Bifocals hold out the promise of bringing the stars into focus and enabling you to read star charts with the same pair of glasses.

However, as Georgia-based amateur astronomer Michael A. Covington sees it, standard bifocals aren't ideal for amateur astronomers because the reading, or close-up, portion of the lens cuts too deeply into the distance portion through which you view the sky. Covington suggests that for stargazing purposes, the line between distance and close-up vision should be lowered from its standard position until it is 12 mm below the pupil center. Bowen cautions that Covington's approach may not be practicable with progressive bifocals, in which the correction changes smoothly rather than abruptly. But Covington also has a low-tech remedy: using a large magnifying glass to read star charts may obviate the need for bifocals or for slipping eyeglasses on and off while comparing charts to the night sky.

The Tip of the Visual Iceberg?

Three moderately myopic and astigmatic *S&T* editors have tweaked their eyeglasses for naked-eye stargazing thus far. Rick Fienberg and I both have added a full diopter of myopia correction to our nominal prescriptions, and we both find that this has driven our respective visual limits down by about a half magnitude while greatly enhancing our views of the Milky Way. Tony Flanders similarly enjoys his



Raw photo | 3-mm pupil | 6-mm pupil | 6-mm pupil with night-myopia correction

Category	Prescription
Sphere (nearsightedness)	–0.63 D
Cylinder (astigmatism)	–0.33 D
Axis (astigmatism)	165.67°
Night-myopia correction	–1.40 D

A STELLAR SCENE

University of Rochester visual-sciences researcher Li Chen took *S&T* editor in chief Rick Fienberg's clean astrophoto of the Hyades star cluster and modeled the deleterious effects of a nearsighted subject's optical aberrations (in one eye) to produce the simulated views shown here. The subject's eyeglass prescription is shown in the table above. This person would need nearly 1½ diopters of "extra" myopia compensation in order for this eye to see the stars most clearly when dark-adapted.

stargazing eyeglasses, with their ¾-diopter augmentation.

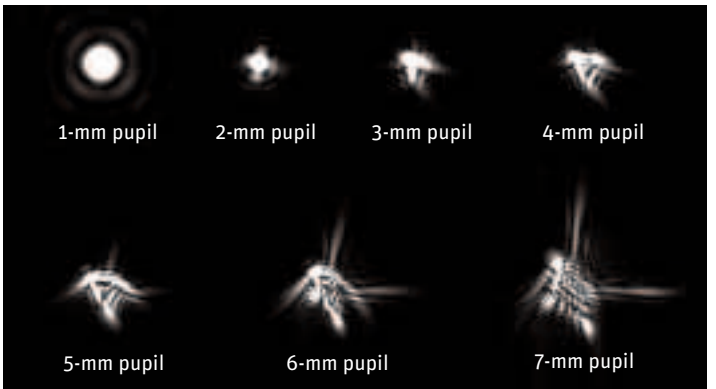
Among Santini's patients, solar-eclipse aficionado Craig Small of New Jersey is "very happy" with his stargazing eyeglasses, which feature wraparound lenses and antireflection coatings. "They certainly have sharpened things up" at night, says Small, though "my vision isn't really that terrible" without them (he too is moderately myopic and astigmatic). Moskowitz recently added a half diopter to his eyeglass prescription for moderate myopia after experimenting with flippers. This "definitely gets me about a magnitude deeper in naked-eye observing," says Moskowitz.

You may decide against spending good money for eyeglasses that you need only for "naked-eye" stargazing (see the box on page 31 for other factors to consider when ordering a pair). If you rarely star-hop and do most of your observing at the eyepiece of a Go To telescope or one with accurate setting circles, you'll need glasses (or Tele Vue's new Dioptrx lens) only if your eyes are astigmatic, and even then only at relatively low magnifications (*S&T*: September 2004, page 132) — after all, you can compensate for mere near- or farsightedness when focusing a telescope. On the other hand, if you especially enjoy naked-eye or binocular observing or star-hopping, night-myopia spectacles may well be worth some trouble and expense. Just be aware that you may have to buy and use more than one pair before you find the optimal correction — I did!

In any case, all amateur astronomers should have their eyes examined fairly frequently, perhaps annually, says Bowen, and they should confirm that their corrective optics protect their eyes from ultraviolet rays (eyeglasses with plastic lenses already meet this criterion).

Even if you do attack night myopia with customized eyeglasses, your eyes' other aberrations remain in force. The latest developments in laser surgery hold out the promise of reducing these aberrations (see the following article), though no one really knows how reliably they can do so, or how long the benefits of a single operation may last. Contact lenses can eliminate astigmatism in many patients, and contacts that negate spherical aberration may become available soon, says Williams. Ophthonix, Inc., of San Diego, California, has just introduced eyeglasses that compensate for higher-order aberrations to the US marketplace. Clearly, the next generation of amateur astronomers will have more options than ever for enhancing their views of the stars.

But the field remains in its infancy, Maskelyne's trailblazing 18th-century experiments notwithstanding. Thus we at *Sky & Telescope* eagerly solicit your testimonials. Let us know (at vision@SkyandTelescope.com) how you address your own eyes' shortcomings, and what, if anything, your astronomy-enhanced corrective lenses (and/or refractive surgery) have done for your stargazing. Not only will your fellow amateur astronomers be eager to know how you fare; eyecare professionals and vision scientists will be keenly interested as well. ✶

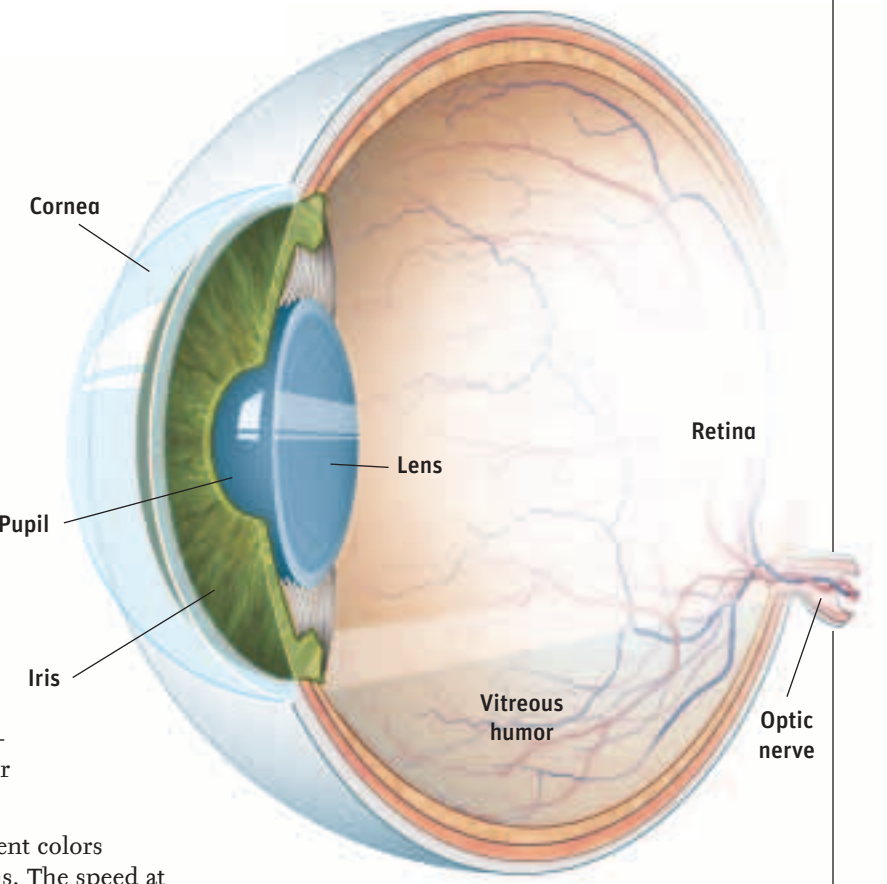


WHY STARS LOOK SPIKY

University of California, Berkeley, optometry professor Austin Roorda used data from one adult subject to produce these representative point spread functions (PSFs), which show how the human eye's optics spread out light from a point source like a distant star. Labeled by pupil diameter, the PSF first shrinks as the eye's diffraction limit improves. But aberrations typically dominate once the pupil spans 4 mm.

Thanks to his growing appreciation of night myopia, senior editor Joshua Roth *finally has gotten over being called "four-eyes" in the fifth grade.*

Eyeball Optics



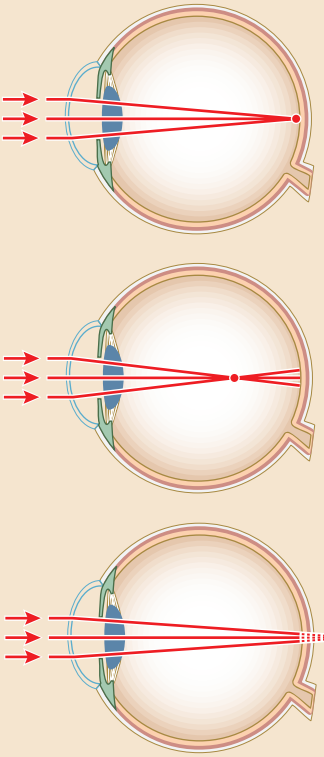
Diopter: a measure of a lens's focusing (or defocusing) power, given in inverse meters. Examples: a positive lens with a focal length of 1 meter has a strength of 1 diopter, or +1.00 D (glasses for farsighted eyes use positive lenses). A negative lens with a focal length of 1 meter has a strength of –1 diopter, or –1.00 D (glasses for nearsighted eyes have negative lenses). A negative lens with a focal length of 50 cm (1/2 meter) has a power of –2.00 D. When calculating the effective power of two thin lenses stacked together, you can simply add their powers in diopters.

Presbyopia: the inability to change the focal length of one's eye to view nearby objects by exerting the muscles attached to the eye's lens. Caused by the lens's diminishing flexibility, presbyopia typically becomes noticeable at middle age and makes bifocals or reading glasses a necessity for many.

Chromatic aberration: blurring caused by light of different colors coming to focus at different distances behind the lens. The speed at which light travels through a lens depends on the wavelength of that light, with bluer (shorter-wave) light always being refracted (bent) more than red (long-wave) light.

Spherical aberration: blurring caused when the light striking the center of a lens comes to focus at a different place than light striking the lens's edge. In the human eye, this effect becomes significant when the pupil is dilated, as typically occurs under low-light conditions.

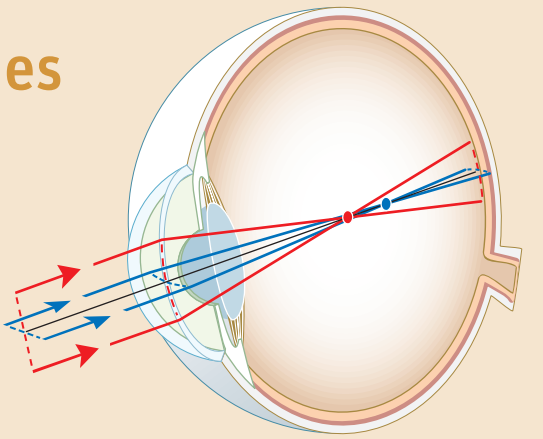
Vision Categories



Perfect vision: parallel light rays from a point of light, such as a star, all meet at one point on the retina.

Myopia: nearsightedness, or the inability to bring distant objects clearly into focus (the image of a distant object comes to focus in front of the retina).

Hyperopia: farsightedness, or the inability to bring nearby objects into focus (the image of such an object is focused as if it could come to a focus behind the retina).



Astigmatism: distortion caused by light in different planes — such as from an X or cross of light shining onto your eyeball through two slits 90° apart — coming to focus in different places. Astigmatism is common among eyeglass wearers and in low-quality telescopes and binoculars. You cannot compensate for your eyes' astigmatism when using binoculars or a telescope by merely refocusing the instrument, though this trick can negate mere near- or farsightedness. (The eye shown above suffers from both astigmatism and myopia.)

S&T: CASEY B. REED (5)