Telescope Optics Myths

There are a number of myths which have been prevalent lately that could do with some explanation. Misunderstanding telescope designs can lead to an amateur astronomer purchasing a telescope which is not ideal for his needs. So without further ado, here are four of the most common misconceptions we hear at Starizona.

Refractors Give the Best Planetary Images

Refractors *can* give great planetary images, but they don't necessarily do so. Refractors come in two varieties, achromatic and apochromatic. Achromatic refractors use two lens elements made of ordinary types of glass, while apochromats ("apos") use special low-dispersion glass and often employ three or four elements.

Achromats suffer from chromatic aberration due to the various wavelengths of light not coming to focus at the same point. What this means in practice is that you end up with purple halos around bright objects such as planets. Because all the light is not focusing to the same point, you lose contrast, which is critical for planetary viewing.

Apos do not suffer from chromatic aberration, so you get very high-contrast views. This would seem to mean great planetary observing, but the other important factor in viewing is aperture. The more aperture your telescope has, the greater the resolution, which is just as important as contrast for planetary observations. The problem is, most apos are small, and the big ones are extremely expensive. I will admit that the best planetary view I've ever had was through a refractor, but it was a 10" apo, which cost $40,000 and required three people to (very carefully) set up. A high-quality Newtonian reflector, well collimated, with around 16" of aperture would likely perform as well or better on the planets.


10" refractor image by Scott Tucker

So why would someone buy an achromatic refractor versus a reflector in the moderate price range (say, under $1000)? We primarily recommend achromats for people who want to do terrestrial observing as well as stargazing. This is because a refractor gives a correct image while a reflector inverts the view. But for just stargazing, you can get more aperture and a higher-contrast view for the money with a reflector.

You Can't Get Good Planetary Images with a Large Central Obstruction

This is related to the refractor myth above. The idea is that refractors give better planetary images partly because they don't have a central obstruction like a reflector or Schmidt-Cassegrain telescope. There are two reasons this myth arises. One is that large-aperture (6-8") apo refractors tend to give great planetary images, while reflectors and SCTs in the same range often appear to not be as sharp. The other reason is that mathematically, you should get a better image without an obstruction.

I think the main reason people tend to get better images out of refractors than reflectors or SCTs is collimation. For high-power planetary viewing, the alignment of the optics is critical. Refractors come factory-collimated and tend to never come out of alignment (barring dropping the scope!), while reflecting scopes occasionally need alignment. A slight misalignment can result in a degradation of the image, especially at high magnification. But a properly collimated telescope, even an SCT with its 30% central obstruction, can give amazing planetary images. Some of the best planetary images I've seen have been through a well-tuned 11" SCT, and I say this having also owned a number of very high-quality refractors.

If you look at the physics of optics, it appears that an SCT, with its large obstruction, should not be able to give as high contrast images as a refractor of the same aperture. This is not due to the fact that the obstruction blocks light (a 30% obstruction is only 9% of the total light-gathering area of the scope), but that diffraction of light by the secondary obstruction causes the light to be spread out more, lowering contrast and resolution. (See Rick Blakley's article on diffraction in the Articles section of starizona.com.) But in practice, this effect is very difficult to discern. For proof, try placing an obstruction in front of a high-quality refractor. Tests have shown that most people cannot detect even a 30% obstruction.

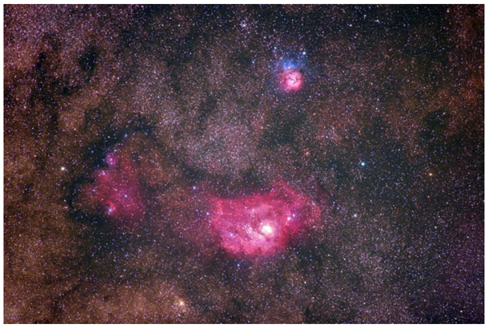
For planetary imaging, aperture and focal length are key. Due to the fact that many images are stacked and enhanced in the process of capturing planetary images, the effects of the central obstruction are mostly negated. A 14" SCT would be preferred for planetary imaging over a 6-8" refractor, which would cost much more. See, for example, the stunning planetary images taken by Damian Peach in the UK with an SCT.

Small Refractors are the Best Wide-Field Imaging Telescopes

As a qualification, let me say that small apo refractors can be excellent wide-field imaging systems. But are they necessarily the only way to go? Small refractors (3-4") are very common as imaging instruments. They typically have focal lengths of 400-600mm, providing a field of view of around 2-5 degrees, depending on the camera used. Other systems providing a similar focal length (and hence field of view) are telephoto camera lenses, Newtonian (or similar variant) astrographs, and the HyperStar system.

As a cost comparison, small apo refractors tend to cost $2000-5000. A good quality telephoto lens may be in the same range, as will be many astrographs, and the HyperStar system, including the SCT telescope it integrates with, is similar as well. So what are the advantages of each system?

Telephoto lenses are ideal for use with modified DSLR cameras since they are already designed to work with these imagers. CCD cameras can often be adapted to telephoto lenses as well. The main advantage of a telephoto lens over a refractor is speed. In a similar price range, lenses will typically have focal ratios of f/2.8 to f/4, up to 4 times faster than the typical refractor focal ratio of f/5 or f/6. Of course, refractors have the advantage that they can also be used visually, making them more versatile.


300mm f/2.8 telephoto image by James McGaha

Speed is also an advantage of astrograph systems. Most wide-field astrographs have focal ratios of f/2.8 to f/3.5. As a specific example, Takahashi's Epsilon 180 astrograph is equivalent to a 500mm f/2.8 lens. It has the same focal length as the usual small refractor, but has 7 inches of aperture and much more speed. So why are small refractors, including Takahashi's own offerings, so much more popular than the astrograph? One reason is collimation, which is not required for a refractor, while it is critical and somewhat difficult on an astrograph.


180mm f/2.8 astrograph image by James McGaha

As for the HyperStar system, speed is everything. HyperStar operates at f/2 (6 times faster than an f/5 refractor) and offers apertures up to 14". Also, because HyperStar converts a standard SCT into a wide-field imaging system, you have the option of removing the HyperStar lens and going back to the standard SCT configuration for narrow-field, high-resolution imaging. Collimation is still required but tends to be fairly simple.

And what about image quality? All the systems give very high-quality images over flat fields. HyperStar provides the most speed plus star images comparable to or slightly better than a good apo refractor!


HyperStar C14 image by Scott Tucker

So why are small refractors so popular? Part of the reason is that many users of refractors also have long-focal-length telescopes such as a Ritchey-Chrétien or SCT as a primary imaging instrument and the refractor compliments that system. Of course, the other options similarly compliment those systems as well. But a refractor is easy to piggyback on the main telescope, which explains part of the popularity. That said, a camera lens is easily piggybacked as well. And for those who do not need to piggyback an instrument, any of the other options are viable.

That said, refractors are still an excellent choice for portable setups and piggybacked systems. They are compatible with the widest variety of cameras, and do not require collimation. For these reasons they will continue to be very popular for wide-field imaging, but they are by no means the only options available for the job.

Ritchey-Chrétiens Have Aberration-Free Flat Fields

I'm not sure where this myth arose, but it is very common. Neither true RCs or Meade's ACF series of Schmidt-Cassegrains have flat fields, despite the common belief otherwise. All SCTs have curved fields, and to my knowledge no one has designed a field flattener for these systems. While very good for imaging, especially for the price, SCTs still suffer from enlarged stars at the edge of the field due to the fact that the focal plane is curved while the CCD sensor is not.

A more common myth yet is that RCs produce flat fields with little or no aberrations. A true RC has field curvature (on the same order as a comparable SCT, which is quite a bit), and suffers from astigmatism, which elongates the star images at the edge of the field. The primary advantage of an RC over a SCT or classical Cassegrain system is that astigmatism is preferable—in certain circumstances—to the coma aberration generated by the latter systems. What circumstances? Astrometry: the measuring of star positions. Astigmatism does not offset the star positions, while coma does. But for taking pretty pictures, astigmatism is not necessarily any better than coma.

An RC *can* give a flat, aberration-free field of view with a field corrector, which is normally available, but does not do so inherently. Most professional telescopes are RCs, and they do employ field correctors. With such a corrector in place, the image quality of an RC is exquisite. However, other designs exist, such as the Hyperion telescope, which can produce similar aberration-free fields of view without the expense of the difficult-to-manufacture hyperbolic mirrors of the RC.

Hyperion image by Scott Tucker & Gil Esquerdo