TILTED COMPONENT TELESCOPES PART II

by Dick Suiter

The Yolo

Focal ratio is high in TCTs for a simple reason. The angles where a simple 2-mirror TCT has balanced coma are not the same as the angles where astigmatism is balanced. Kutter's schief corrects for astigmatism, because it so much worse than coma in that configuration. There is another angle for the secondary mirror that corrects coma (the final image is angled even farther out), but the astigmatic image is big and blotchy. You can deform the secondary in this one, too, with the result called the Neo-Brachyt ("new short") reflector. The focal plane is tilted badly in this case, too, and the angles are so tilted that there is a tri-lobed residual aberration (called trefoil) induced by perspective alone.

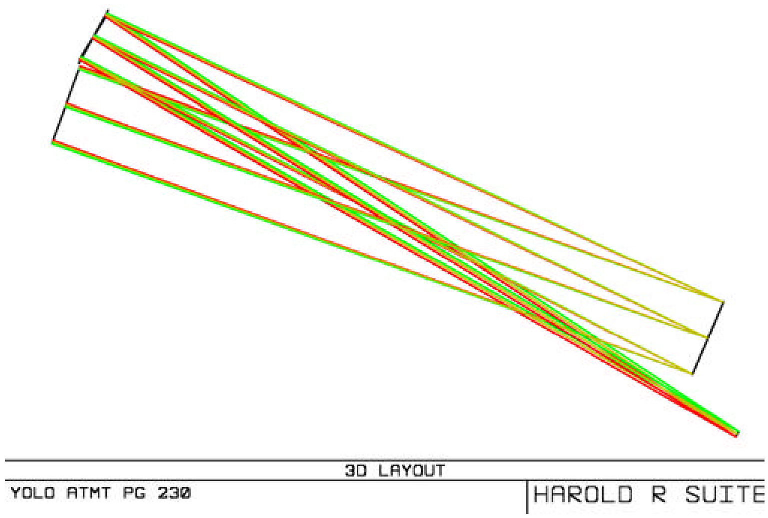

Figure 4. The Yolo TCT

In the early 1960s, optical designer Arthur Leonard had a different idea. He turned the system toward the solution that corrects coma, and cured astigmatism another way. He started with two identical concaves (not a concave and convex, as did Kutter) thus abandoning even the tenuous connection with any on-axis design such as the Cassegrain. Because the secondary was of the same sign as the primary, the coma-balancing position was kicked back toward the primary, not kicked out. The optical path was thus bent into a triangle, like a coat-hanger instead of the letter Z. His secondary mirror had a warping harness on it; if we imagine the mirror disk as a compass, it bends the east and west sides of the disk downward, and pulls the north and south side upward, giving a net deformation that looks like a Pringles potato chip. All this is independent of alignment (which also must be done); it is meant only to correct astigmatism.

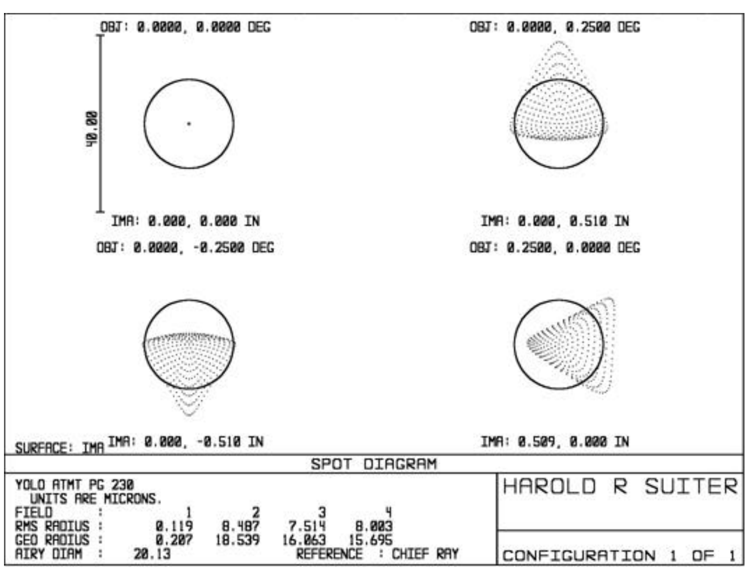

Figure 5. Yolo spot diagram.

He called this telescopic system the Yolo, which is a geographic location, if I remember correctly. It appears in Figure 4.

How much deformation is necessary? Surprisingly little — only 0.00011 inch. This difference bends the radius of curvature of the secondary mirror on one axis 3.5 inches farther than the other axis. The aperture is increased to 6 inches (150 mm) and the focal ratio is greatly improved to f/15. There is almost no tilt to the final focal plane, which is a great improvement. The focal plane is tilted only 1 degree, an angle that is easily neglected. Another thing that is better is the central imaging quality, as shown in Figure 5.

The mirrors are both concave and con be tested with the Foucault method. At a radius of curvature of 24 feet, the tested mirror is small, but that is relatively close compared to the tertiary in some tri-schiefspieglers.

The primary has a tiny conic correction that is difficult to measure, let alone apply. The only reason that it is used here is the designer tidying-up.

The one thing that is not improved over the schiefspiegler is the edge-of-field performance. However, this is so much faster a telescope that such comparisons are not really fair. The Strehl ratio at the edge of the half-degree field is diminished to less than 0.6. This sounds bad, until you remember that the average Newtonian is much worse. (The Strehl of the center is over 0.99)

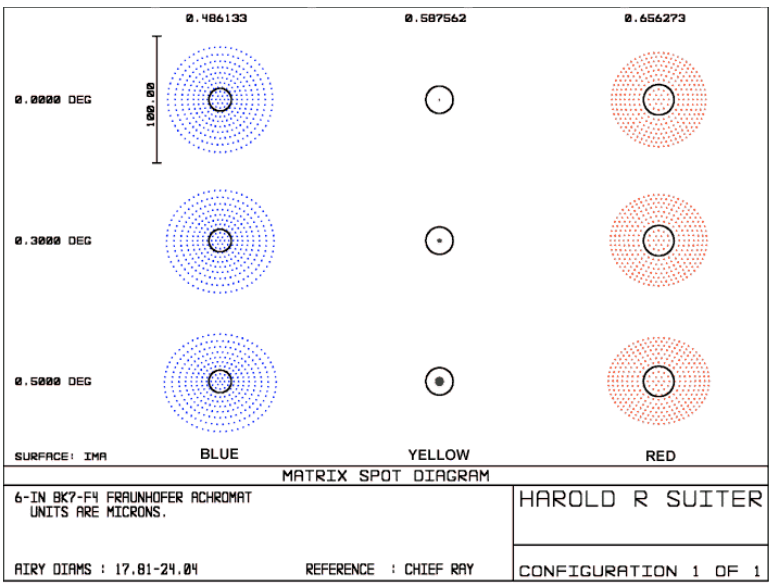

Figure 6: Classic 6-inch f/15 refractor

This 6-inch f/15 Yolo invites comparison with that other classic, the 6-inch f/15 refractor. The refractor is easier to baffle. Because the Yolo bends the optical path back across the entering beam, it can't even use the little tube of the schiefspiegler. You must cover the entering optical path as well as the returning beam with a series of figure-eight baffles. However, the Yolo isn't impossible to baffle either. You just have to remember to design baffling into the tube.

Where the Yolo really shines is the performance in other wavelengths. The blue and red colors are 3 to 4 times the size of the Airy disk in the refractor. You can see the spreading with color in Figure 6, with the blue channel being the left column of images and the red being the column on the right. Yet people think of refractors as being perfect imagers. The Yolo performs the same in all colors because it doesn't involve refraction. The main mirrors are identical and concave. They can be ground against the same tool. The resulting system has two mirrors, which means that star charts and planetary images need not be reversed right-to-left (of course, use of a star diagonal subverts this, as it does with all scopes).

The important factors in construction are the crossing angles. It seems odd that a geometrical property should impact heavily on the correction, but it is responsible completely for the elimination of coma at the center of the field.

ADVANCED YOLOS

Jose Sasian and others have of late been making Yolos without their warping harnesses, actually grinding the mirrors with astigmatic shapes to begin with. While it is advantageous to have a Yolo that does not require fiddling, it is not necessary. If you switch the mirror onto which you apply warping pressure from the secondary to the primary, you can also achieve much the same imaging performance and have the added advantage of looking through the eyepiece at the same end as the warp adjustment. That way warping isn't a difficult process of looking at the image, lowering the telescope, walking around to the front, wiggling the adjustment, walking back around, relocating the object, and repeating. You just look through the eyepiece and tighten the warping screw for the roundest images.

ARE TCTS ANY BETTER?

To hear people talk about them, TCTs are the end of all optical problems. I said at the beginning that they gave a better opportunity for improvement because of increased number of degrees-of-freedom. But the promise of TCTs has yet to be delivered. People have been so drenched with sweat to correct the aberrations induced by tilting the mirrors that they have not noticed that the amateur telescopes they have designed have really been too long. If ever a simple-to-make f/8 TCT could be designed with good field of view and good central correction, I would say they finally have something.

So why do people wax ecstatic at the views through their TCT? I would say ease of baffling and enhanced operation of the eyepiece. It is too bad that more people can't remember the days of f/10 Newtonians. The views through those would take your breath away because of the dark backgrounds

Nevertheless, I have heard of quad-schiefs, tetra-schiefs, catadioptric schiefs, Schupmann medials, and every variety of overcomplicated TCT using every sort of difficult-to-make surface and the Yolo is the only TCT that doesn't give me the willies. It seems to be actually possible to make and adjust easily.

PS: THE DESIGN

The inverted Yolo

#	Type	Radius(inches)	Dist.	Glass	Diam.	Conic	Notes
1	TOROIDAL	-288.938/-287.828	-51.0975	MIRROR	6	0	tilted from incoming axis 3.0666 degrees
2	REGULAR	-288	56.5409	MIRROR	4.5	-22.6198	tilted from incoming axis 8.909 degrees
3	IMAGE	-		-	0.765		tilted from the ray bundle 1 degree

The toroid is meant to be made spherical with the same 288-inch radius of curvature as the other mirror, and then deformed to the two radii indicated. The conic constant sounds severe, but the aspheric deformation is really quite small on such a long focal length. The negative radii on the mirrors are meant to indicate that both are concave (they are not the same sign in the design program). The diameter of the final image includes a 1/4 degree field. The 8.909 degree angle is twice 3.0666 (mirrors reflect at twice the angle of tilt) plus an extra 2.7756 degrees from the ray bundle. The focuser axis should be 11.684 degrees from the direction of incoming light. Separation between centers is 51.09 inches and focus is about 6 inches behind the primary.

The best way to make a TCT is to see what radii your mirrors end up with, and tweak the design program (such as ZEMAX or Oslo) to find what the optimum configuration is using the true radii.