A NEW RONCHI NULL TEST FOR MIRRORS

TELESCOPE MAKERS have long admired the Ronchi test. Originally conceived by the Italian physicist Vasco Ronchi in 1923, the test uses a grating of fine, parallel lines instead of the knife-edge of the Foucault test. Usually the grating has 5 to 10 lines per millimeter, either painted on glass or recorded on clear photographic film.

Readers who haven’t tried the Ronchi test can get a quick feel for its power and simplicity by pointing a telescope at a star. Take off the eyepiece and place your eye so that the telescope’s objective lens or mirror fills with starlight. Without moving your head, bring the grating in front of your eye so that a few of the lines appear greatly enlarged and shadowy, as if lying right on the objective’s surface. The best position for the grating is just slightly inside or outside the telescope’s focus.

If the optics are good, these bands will appear quite straight. Any curvature or waviness means the optical system is defective, not fully corrected. Similar straight bands are seen in a Ronchi test of a spherical mirror when it is tested with a pinhole or slit light source at the center of curvature. The eye is an excellent judge of straightness, making the test a sensitive and definite one — a so-called null test.

However, if the mirror is a paraboloid tested at its center of curvature, the bands will have a curved or bowed appearance. Judging whether they have just the right amount of curvature — not too much, not too little — is an uncertain process and the chief drawback of the Ronchi test of a paraboloidal mirror.

In the November, 1974, issue of *Sky & Telescope* (page 325), Eric G. H. Mobby described a modified Ronchi test that avoids this difficulty. A similar approach was proposed independently by G. Popov in *Communications of the Crimean Astrophysical Observatory*, 45, 188, 1972. Their novel idea was to make a special grating with inward-curving lines, as shown at top on the facing page, which exactly compensates for the outward-curving lines just mentioned. The result is that you end up with straight and even bands if the mirror is a good paraboloid.

The main difficulty with the Mobby-Popov grating lies in calculating and drawing the rather complex curves. They arise because of the requirement to create parallel bands with an aspheric mirror. Yet such a mirror does have axial symmetry, suggesting that a grating of circular lines might be tried instead. Once again, though, if the concentric circles are drawn with equal steps of radius, the test is a null only for a spherical mirror.

The next step is evident. Why not use a modified circle grating with *uneven* spacings? These can be chosen in such a way that the mirror, when correctly figured to a paraboloid, restores the circles to an easily judged pattern. The optician simply figures the mirror until the test shows a perfect bull’s-eye of evenly stepped rings!

![Ronchi Test Principle](image_url)

In any type of Ronchi test, the eye sees enlarged and shadowy bands “projected” against the surface of the mirror on the stand. These bands are caused by the particular lines of the grating that cross the cone of light just in front of the eye. Here, the spacing between pinhole and grating is exaggerated for clarity; they should be as close as possible.

Conducted by Roger W. Sinnott
This example of a Mobsby-Popov grating would be suitable for testing a 300-mm (12-inch) f/3.37 paraboloidal mirror. Note the varying shapes of the lines, which in this case were calculated by trigonometric ray tracing and solving a set of five linear equations. Adapted from a paper by D. Malacara and A. Cornejo in Applied Optics, August, 1974, page 1,778.

Valeriy Terebzhiz holds an enlarged paper version of a circle grating, which he will then photograph at a much-reduced scale for testing optics. After studying astronomy at Leningrad University, he worked from 1966-73 at the Byurakan Observatory in Soviet Armenia. Now he is a staff astronomer at the Sternberg Astronomical Institute's station in Crimea. Behind him is the station's 1.25-meter reflector, whose new mirror he tested with a circle grating. Copyright 1989 Roger Ressmeyer — Starlight.

This circle grating, drawn by the author, could be used to test a paraboloidal 250-mm (10-inch) f/2.5 mirror (see the example in the text). As the next-to-last column of the table on page 315 indicates, it should be reduced photographically to a radius of 5.23 mm.

I first proposed this type of grating in 1984, in Astronomical Circular 1355 of the U.S.S.R. Academy of Sciences. Since then I have used it, along with other methods, to test a new mirror for our 1.25-meter (49-inch) reflector here at Sternberg's Crimean Station.

The main advantages of this test over that of Mobsby and Popov are as follows:

• The calculations are simpler, because you only need a single formula that relates the size of each circle on the grating to that on the mirror.

• Drawing the grating is also simpler, requiring only a compass. From the calculated inner and outer radii of each band, you draw circles and blacken the alternate spaces between them. Instead of attempt-

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ing a tiny ink-on-glass grating, it is easier to make an enlarged version of the grating on paper and photograph that, being careful to reduce the image to its correct scale.

- Finally, the axial symmetry of the circle grating will reveal at a glance any astigmatism (warping) of the mirror's figure. Astigmatism will cause the circular bands to appear elliptical.

CALCULATING THE GRATING

Deriving the formula for a circle grating is straightforward. In order for the test to work with not only paraboloidal but also ellipsoidal and hyperboloidal mirrors, I started from the general equation of a conic section:

\[ y^2 = 2Rx - (1 - e^2)x^2, \]

where \( R \) is the radius of curvature at the mirror's center and \( e \) is the conic eccentricity. The value of \( e \) is 0 for a sphere and 1 for the paraboloidal mirror of a Newtonian or Cassegrain reflector. However, a Dall-Kirkham reflector has an ellipsoidal primary (\( e \) between 0 and 1), while a Ritchey-Chrétien uses a hyperboloid (\( e \) greater than 1).

The facing diagram shows the geometry of the test along with the exact formulas involved. If the mirror is large, faster than about \( f/3 \), or highly aspheric, these exact formulas should be used to design the grating. But for the mirrors most amateurs use the following approximate formula also holds:

\[ r = Y(d + Re^2Y^2), \]

where \( Y = y/R \) and \( d \) is the distance from the center of curvature to the grating.

For example, suppose you want to test a 250-mm (10-inch) \( f/2.5 \) paraboloidal mirror. The grating will have 10 circles, and it is placed \( d = 40 \) mm inside the center of curvature. The focal length of this mirror is 625 mm, and the radius of curvature, \( R \), is 1,250 mm.

Results of the grating calculation for this mirror are tabulated on the facing page. For each ring from 1 to 10 on the mirror surface, begin by writing down radius values, \( y \), for the inner and outer edge of each one, as measured in millimeters on the mirror. (Notice that the values have been chosen to make the rings equally spaced.) The next column is the set of corresponding \( r \) values, measured in millimeters on the grating. I calculated these from the exact formula. The lower diagram on page 313 shows the result.

The last column shows another set of \( r \)
GRATING CALCULATIONS
(Eccentricities 1.0 and 1.4142)

<table>
<thead>
<tr>
<th>Ring no.</th>
<th>Radius (%)</th>
<th>$r$ (mm)</th>
<th>$y$ (mm)</th>
<th>$r$ (mm)</th>
<th>$r$ (mm)</th>
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<td>1</td>
<td>9</td>
<td>0.361</td>
<td>0.362</td>
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<tr>
<td>11</td>
<td>13.75</td>
<td>0.442</td>
<td>0.443</td>
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<tr>
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<td>3</td>
<td>29</td>
<td>1.190</td>
<td>1.219</td>
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<td>38.75</td>
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<td>39</td>
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<tr>
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<td>125.00</td>
<td>5.230</td>
<td>6.421</td>
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</tbody>
</table>

In these exact formulas for making a circle grating, $Y = y/R$. If the mirror is a paraboloid,

$$ r = Y \frac{d + RY^2 (1 + Y^2 / 2)}{1 + (1 + Y^2)Y^2 / 2}. $$

If the mirror is any other conic of revolution,

$$ r = Y \frac{d + s}{1 - X + s/R}. $$

where

$$ X = \frac{1}{1 - e^2} \left[ 1 - \sqrt{1 - (1 - e^2)Y^2} \right], $$

$$ s = 2Re^2 X \frac{1 + e^2 X}{1 + e^2 (1 - e^2)X^2}. $$

By assuming the pinhole light source lies at the mirror’s center of curvature, the author used this geometry to derive the exact equations at upper right for calculating a circle grating. See the text for a simplified formula, adequate in many cases.

PRACTICAL HINTS

Unlike some other versions of the Ronchi test, this one requires a pinhole light source. A slit won’t work. Moreover, the light should only pass through the grating on its return path to the eye.

Strictly speaking, the pinhole should be...
located at the center of curvature of the mirror's central zone, and the grating should be closer to the mirror by the predetermined distance $d$. (My formulas were derived under this assumption.) But experience shows that a slight shift of the pinhole to one side and the grating to the other, as you face the mirror, does not invalidate the test. Also, for ease in getting the eye close to the grating, it may help to locate the grating and pinhole at the same distance from the mirror. I have examined several cases like this mathematically and verified that the circle-grating test is no more sensitive to misalignment than the traditional Ronchi and Foucault tests.

In any event, when setting up to perform the test, adjust the locations of the pinhole and grating until the outermost circle just coincides with the rim of the mirror. When this condition is satisfied, you can check to see whether the other circles appear equidistant — the criterion for a well-figured mirror.

In short, a grating of concentric circles is easy to make and use. I feel it offers amateur telescope makers a very simple and powerful null test when figuring aspheric mirrors.

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EDITOR'S NOTE: Conventional Ronchi gratings on glass are available from Edmund Scientific Corp., 101 E. Gloucester Pike, Barrington, N. J. 08007. In the 1-inch-square size, rulings of 50 to 250 lines per inch cost less than $10 each. Mobsby-Popov gratings are listed in the catalogue of Willmann-Bell, Inc., P. O. Box 35025, Richmond, Va. 23225.

Currently the only way to obtain a circle grating for Valeri Terebizh's innovative test is to make it yourself! As he suggests, prepare an enlarged version on paper and photograph it from far enough away that the photographic image is of the proper size. Suppose the enlargement factor is 40. Multiply the camera lens's focal length by 40 and set up the camera that far away from the paper chart.

When Eric Mobsby experimented with photographic gratings 16 years ago, he found that Kodachrome film had the necessary high contrast for good results. Also excellent were black-and-white films intended for high-contrast reproductions, in which case the drawing should be prepared as a "negative" of the grating you want (that is, blackened where the clear areas are to be). Today, Kodak Tech Pan 2415 would be worth a try, for it offers fine grain and high contrast.