University Lowbrow Astronomers
Ann Arbor, Michigan

REFLECTIONS / REFRACTIONS

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University Lowbrow Astronomers

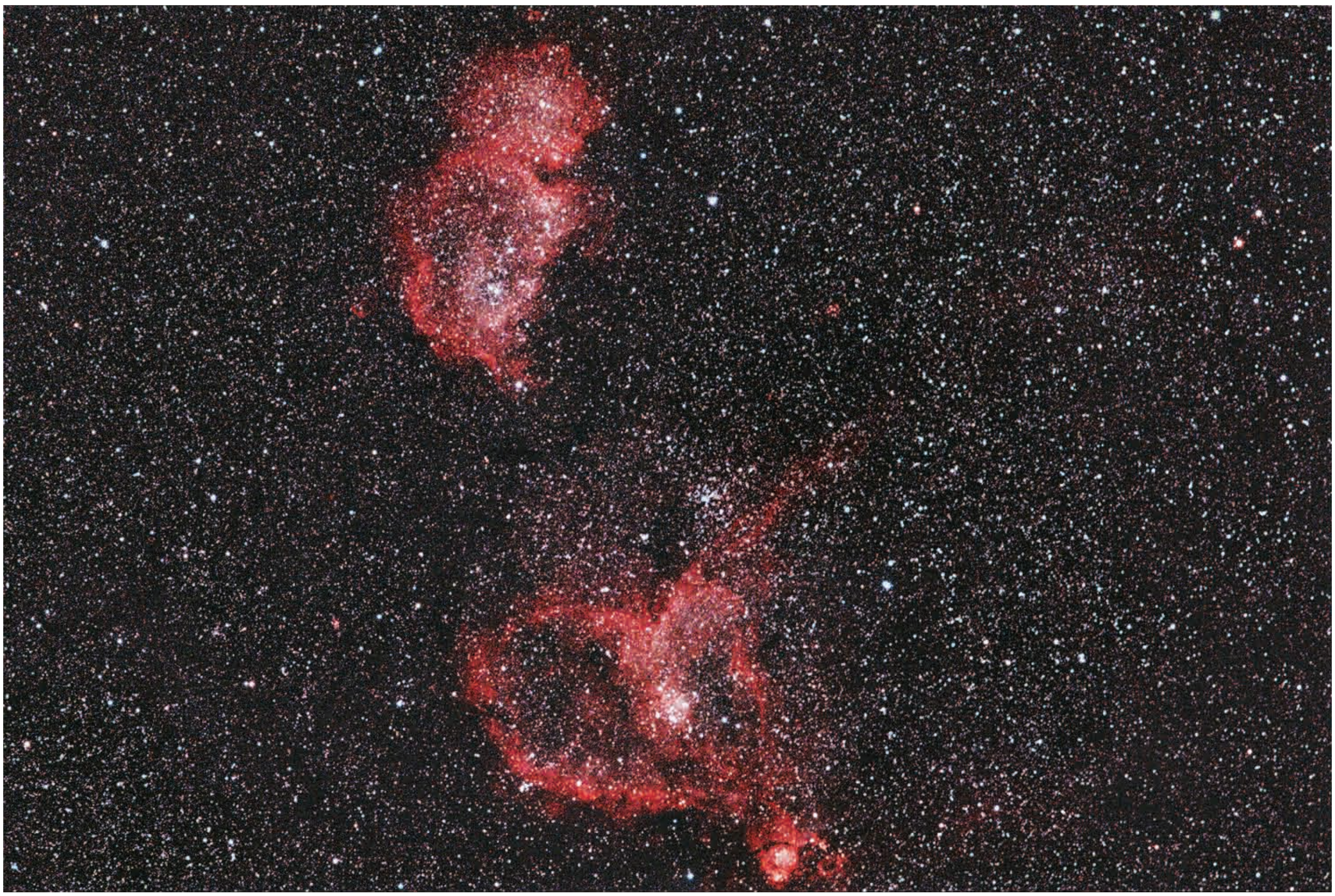
DECEMBER, 2014

VOLUME 38, ISSUE 12

IC 1805 & IC 1848

Heart & Soul

By Clay Kessler

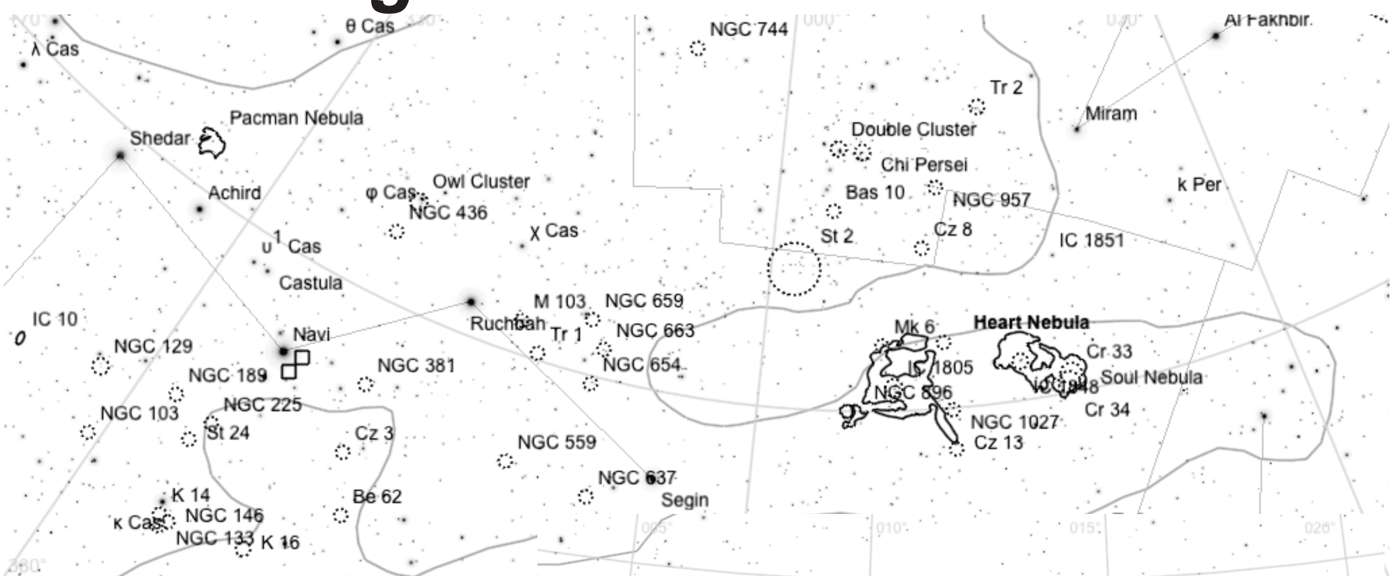


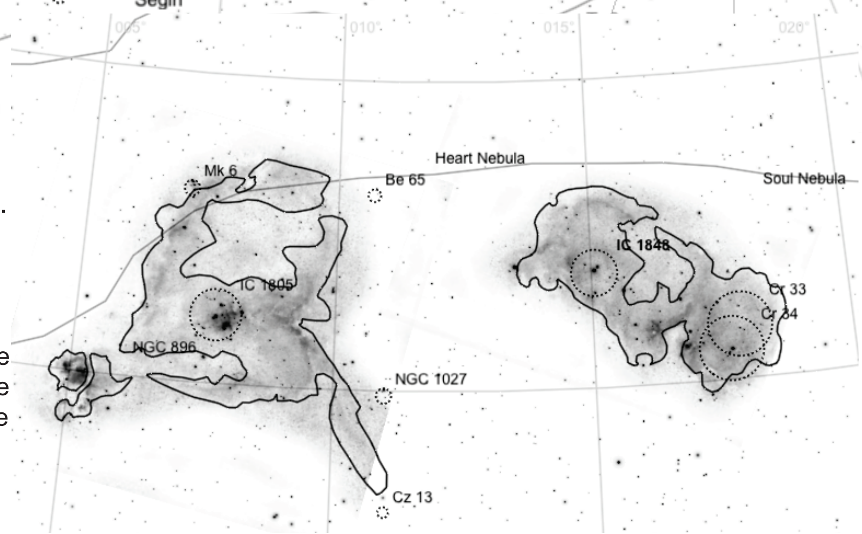
This is the last of three deep sky astrophotos Clay Kessler sent in a year ago. Clay gives us this information: "The astrophoto was taken with the Nikon 180mm f2.8 ed lens and my Canon 60Da. The field of view is 7.5 degrees X 4 degrees: Exposure--10 X 240 seconds at ISO 1600. BTW - the camera and lens were stabilized in a TSS* piggyback guided camera adapter. This was clamped to the top of my Meade 10" SCT riding on my G11 mount." ***(*TSS or Telescope Support Systems is author's company, a supplier of astrophotography accessories. The company's products are designed to solve many of the flexure and precision problems involved in photographing the night sky.)***

Club Meeting December 19

7:30 PM, Room G115, Angell Hall. James Cutler (Associate Professor, Aerospace Engineering, University of Michigan): "CubeSats and Space Exploration."

Wandering Around the Heart & Soul





Charts Drawn in Sky Safari

IC 1805 and IC 1848 are difficult visual objects for most backyard telescopes. These are both large, extended objects, 60'x 60' and 60'x30' respectively making for low surface brightness, and thus hard to see, despite their visual magnitudes of 6.5. Even though these objects are high overhead in the evening this time of the year, you'll need a dark sky, all the aperture you can manage and an OIII or UHC filter to have a chance.

The cluster at the "heart" of the Heart Nebula, Melotte 15, is a 21', mag 6.5 object. This cluster fuels the nebula with a couple of 8th mag stars and as many as 60 fainter ones have been seen in a 4.5" newtonian. NGC 896 is a bright patch of nebula just off the northeast side of IC 1805 with most of its 10th mag light contained in a 10'-15' area, making this nebula a possibility for an amateur scope.

The cluster fueling the Soul shares the same catalog designation as the nebula. A 7th mag and an 8th mag star stand out, surrounded by 50 11th mag and fainter stars in a 30' area. The two Collinder clusters, Cr 33 and 34 will be harder to pick out. While the clusters are fairly bright at 5.9 and 6.8 respectively, the 100 stars of Cr 33 covers a 39' area and Cr 34 is 25'. While this qualifies both as BASS clusters, they overlap and are hard to distinguish from background stars and each other.

Markarian 6 (Mk 6) is a tiny, six star cluster taking up but 6 arc minutes of sky. Some observers claim to have seen it in binoculars, and they may have as the cluster shines at mag 7.09. But picking it out from the background stars with binos would be a good trick. A couple of the stars are mag 7 and 8 with the rest around mag 10. A four inch scope should easily resolve the cluster.

Berkeley 65 has two mag 10 stars and seven or eight more that are much dimmer. Czernik 13 also has two mag 10 stars, but the other two known members are both mag 14. Size estimates vary but neither is larger than 6'. Bk 65 is rated mag 10.19 and Cz 13 mag 10.39. Neither will stand out from background stars and will not be easy to see in southeast Michigan without 8-10 of inches aperture and clear, dark skies.

NGC 1027 consists of 50 stars in a 20' area. There is one mag 7, 5 mag 10 and 20 or more mag 11-13 stars. Unlike many of the others, this one should stand out. There are many other clusters and nebula nearby. Some are obscure and need aperture and superb conditions to be seen, but others are easily within the range of small scope.--Jim Forrester

Evaluating the Paraboloid

Part One

by Doug Scobel

During the October meeting's presentation on the construction of our new 17.5" Newtonian-Dobsonian, Jack Brisbin did a nice job describing how Lowbrow members Doug Nelle, Tom Ryan, and he refigured the primary mirror. That mirror originated in the Coulter Odyssey telescope that was donated to the club several years ago, and was not a good mirror at all. He described how they transformed the mirror from having a "bad" figure to having a "good" figure. But what constitutes "bad" and "good"? He described wave errors, zones, Foucault testing, peak-to-valley, null tests, and more. It's enough to make your head spin. I can imagine that many of you attending the meeting were asking yourselves "What does it all mean?"

Fortunately for the reader, there is far too much to the subject than I can describe here in a short article or two. Entire books have been written on the subject of Newtonian mirror making and analysis, and I'm sure neither you nor I want to go into all that here. Besides, I'm hardly an expert on the subject - I'm just an amateur who's made a small handful of mirrors, and I've learned just enough to be dangerous. So I'll try to explain some of the test information that Jack presented at the meeting in a little more detail without making this a chore to read.

The test information I'm speaking of is the Foucault test measurements the team made during figuring. "Figuring" refers to the process of modifying the polished mirror's shape, or "figure", from a surface that is simply polished to one that is capable of producing a good image. The Foucault test, AKA the "knife-edge" test, while having some deficiencies, is by far the most widely used test utilized by amateur Newtonian mirror makers. It is not perfect, but many thousands if not tens of thousands of good amateur and professionally made primary mirrors have been figured using this test. It lets the mirror maker fairly accurately and quantitatively analyze the mirror's surface to determine the quality of the images it will produce.

[Rant alert! Foucault is pronounced "foo-co", not "fo-cault". Leon Foucault, the inventor of the test, was a Frenchman, and French names that end in "ault" end with a long "o" sound. An example is the French car brand Renault, which is pronounced "Ren-o", not "Ren-ault". Please, no more "fo-cault"; rather, say "Foo-co". Thanks for bearing with me.]

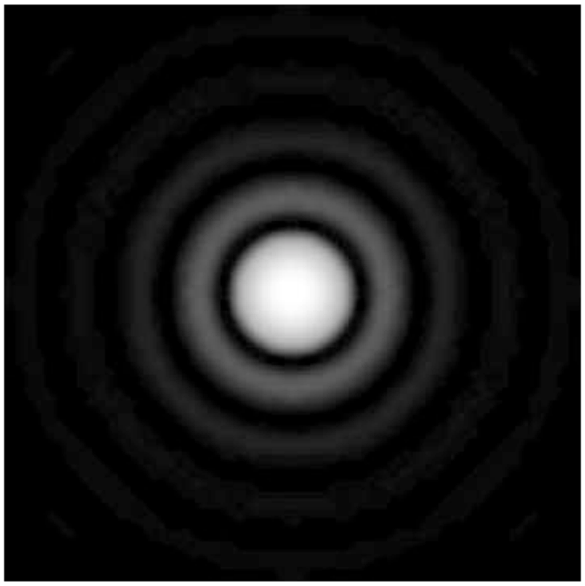
Now that I've gotten that off my chest, back to the subject at hand. The purpose of testing the mirror's surface during figuring is to determine how much it deviates from the ideal shape. In a Newtonian reflector, the ideal shape is a paraboloid - the shape that results when you rotate a parabola about its axis. More importantly, if the mirror's surface deviates from a true paraboloid, and in reality all mirrors do, then is the deviation enough to degrade the resulting image? To determine that, one needs to begin with an understanding of what the possible errors are.

Zones

Imagine a perfect mirror, where the entire surface perfectly matches a paraboloid. All on-axis parallel light rays (for all practical purposes stars can be considered to be at infinity) reflect off the surface and come to a focus at the exact same point. Well, not exactly the same point. Light, besides behaving like a particle, also behaves like a wave. Its wave nature means that all the reflected rays do not meet at one exact point, but are distributed about that point in a regular pattern. With reasonably good optics and a circular aperture, the image created by a star is referred to as the diffraction pattern. The diffraction pattern consists of a central disk, called the Airy disk (named after Sir George Airy, a nineteenth century English scientist and astronomer, not because it is "airy"), and a series of surrounding, concentric rings. With perfect, unobstructed optics, 84% of the light goes into the Airy disk, and the rest is distributed into the rings, with less light being seen in each successive ring. This pattern is the result of the wave nature of light, the central disk and rings being produced by alternating constructive and destructive interference of the light waves forming the image.

That being said, like the frictionless billiard ball table you read about in high school physics, let's pretend all the light rays end up at the same point. Impossible assumptions notwithstanding, our hypothetical perfect mirror creates the best image possible.

Of course, in reality there is no such thing as a perfect mirror. No matter how we try, the technology does not exist that lets us make a perfect paraboloid. Real mirrors always deviate from the ideal by some amount. The mirror's surface will consist of ar-



Diffraction pattern of a point source produced by a circular aperture. With a perfect optic the center "Airy disk" contains 84% of the light, and the rest is distributed in the rings. ***"Image courtesy Oliver Pettenpaul, www.astro-imaging.de"***

eas that are high relative to the ideal shape, and areas that are low compared to the ideal shape. Considering a diametric cross-section, we fit the best reference parabola between the high and low areas. Fortunately, most mirrors are more or less smooth and symmetrical about their axis, so these high and low areas are seen as zones. Zones are rings that are pretty much circular and of pretty much uniform "highness" and "lowness" all the way around. I know, I'm throwing a lot of "more or less"s and "pretty much"s around here. Real mirrors are seldom perfectly uniform across all diameters, but are approximately so, so stay with me.

These zones typically produce two errors of major concern during figuring, namely wavefront (longitudinal) error and Transverse (lateral) error. Yes, there are other errors about which to be concerned, but it is only these two biggies that I'll address here.

Wavefront Error

This is the error that is most often quoted, but perhaps not always understood. Imagine that we have a low zone on our mirror. Light rays that hit that low zone have to travel a little past the reference parabola to reach the mirror's surface, and then have to travel a little farther again after being reflected on their way to the focus. So these light rays arrive a little late and hence will be displaced a little closer to the mirror at the focus than they should. Remembering that light behaves like a wave, these "late" light

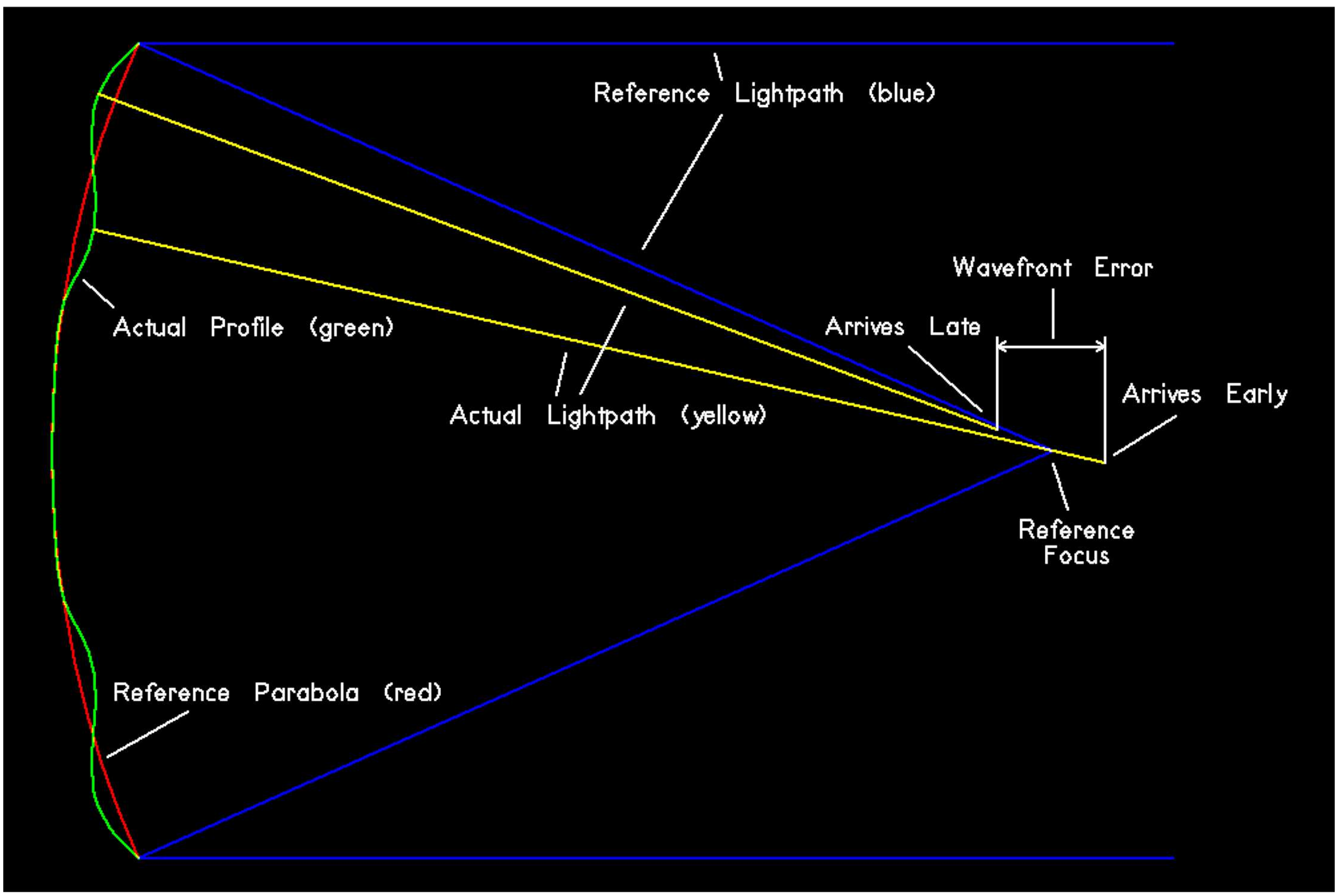


Illustration of wavefront error. Note that the longitudinal error at the focus is roughly double the depth or height of the defect on the mirror's surface. ***Diagram created by the author.***

rays are out of phase with those that arrive “on time”. Likewise, light rays that hit a high zone are reflected before they reach the reference parabola, so they arrive at the focus a little early and are displaced farther away from the mirror than they should. They are out of phase as well. This distance between the earliest arriving light rays (high zone) and latest arriving light rays (low zone), is called the wavefront error. It has the effect of putting less light into the Airy disk and more light into the surrounding diffraction rings, degrading the image. Wavefront error is reported as a fraction of the wavelength of visible light.

Note that the wavefront error I’m talking about here is the total distance from the earliest and latest arriving light rays. Hence, this method of measuring wavefront error should be accompanied by a peak-to-valley qualifier. This is to differentiate it from other calculations, for example a root-mean-square (RMS) average. It is also important to note that it should be reported at the focus. Quoting wavefront error at the mirror’s surface makes the mirror appear to be twice as good as it really is.

So how much wavefront error is acceptable? The commonly accepted standard is called the Rayleigh criterion, named after Lord Rayleigh, who lived from 1842 to 1919. Rayleigh stated that the total peak-to-valley error at the wavefront (focal plane) must not exceed 1/4 of the wavelength of yellow-green light. Usually we strive to be better than that, say 1/8 wave at the focus. Still, a quarter wave mirror is a pretty good mirror, as long as it is smooth, relatively zone-free, and absent of significant transverse error (which I’ll describe a little later), and will beat the atmospheric steadiness nine nights out of ten.

On the preceding page is an illustration depicting wavefront error. Note that this drawing is nowhere near to scale, and the discrepancy between the ideal mirror profile and the actual profile is highly exaggerated. It is intended only to help you visualize the concept.

Transverse Error

Transverse error is the red-haired cousin of wavefront error that many amateur mirror makers tend to marginalize or even ignore. But it is an important part of the equation, particularly with large, fast mirrors. While wavefront error is a measure of longitudinal (that is, along the optical axis) errors at the focus, transverse error, as its name implies, is a measure of lateral errors perpendicular to the optical axis.

Again, imagine our imperfect mirror, with high zones and low zones. If there is a high zone next to a low zone, then the mirror’s surface between the zones is sloped incorrectly relative to the reference parabola. So light rays that hit that sloped region will be deflected laterally away from the focal point. If the surface is sloped enough, then light rays can be deflected outside the Airy disk. Just like with wavefront error, more light is scattered into the surrounding diffraction rings, degrading the image. It is reported as a percentage of the Airy disk radius.

So what constitutes a “good” mirror?

That depends on who you ask. Some only quote wavefront error and are satisfied with that. Again, 1/4 wave at the wavefront is generally regarded as the minimum, but half that is more desirable. But just having a good wavefront number is not necessarily good enough. For a mirror to be declared truly good then transverse error must be considered also. The late Jean Texereau’s “How To Make A Telescope” is generally considered the seminal authority when it comes to reducing Foucault test data. There Texereau defines a good mirror as one that has a wavefront error of 1/4 wave (at the focus) or less, and maximum transverse error of less than one Airy disk radius. This is known as the Millies-LaCroix tolerance, and with large and fast mirrors can be a very difficult tolerance to satisfy. Other criteria are the Marechal criterion, which uses a root-mean-square calculation and is more stringent than the Rayleigh standard, and Danjon-Couder conditions, which are more stringent yet. Time and space here do not permit explaining these standards in detail. My main point here is that wavefront error calculations do not necessarily suffice, and transverse error should be given equal consideration when evaluating an optic.

Why the indifference to Transverse Error?

As I stated earlier, much of the time, transverse error tends to be ignored, or at least marginalized by amateur mirror makers. I’m not sure why that is, but I have my theories. Back before the Dobsonian revolution, most folks that made their own mirrors made pretty small mirrors, mainly eight inches and under. Plus they tended to be slow, with f/8 to f/6 being typical. Small, slow mirrors tended to be polished and figured on full-size laps, and bad technique notwithstanding, tended to be rather smooth and not too “zoney”. So with small, slow mirrors, wavefront error tends to dominate, and if you take care of wavefront error, then transverse error pretty much takes care of itself (whoops, there’s another “pretty much”). Many

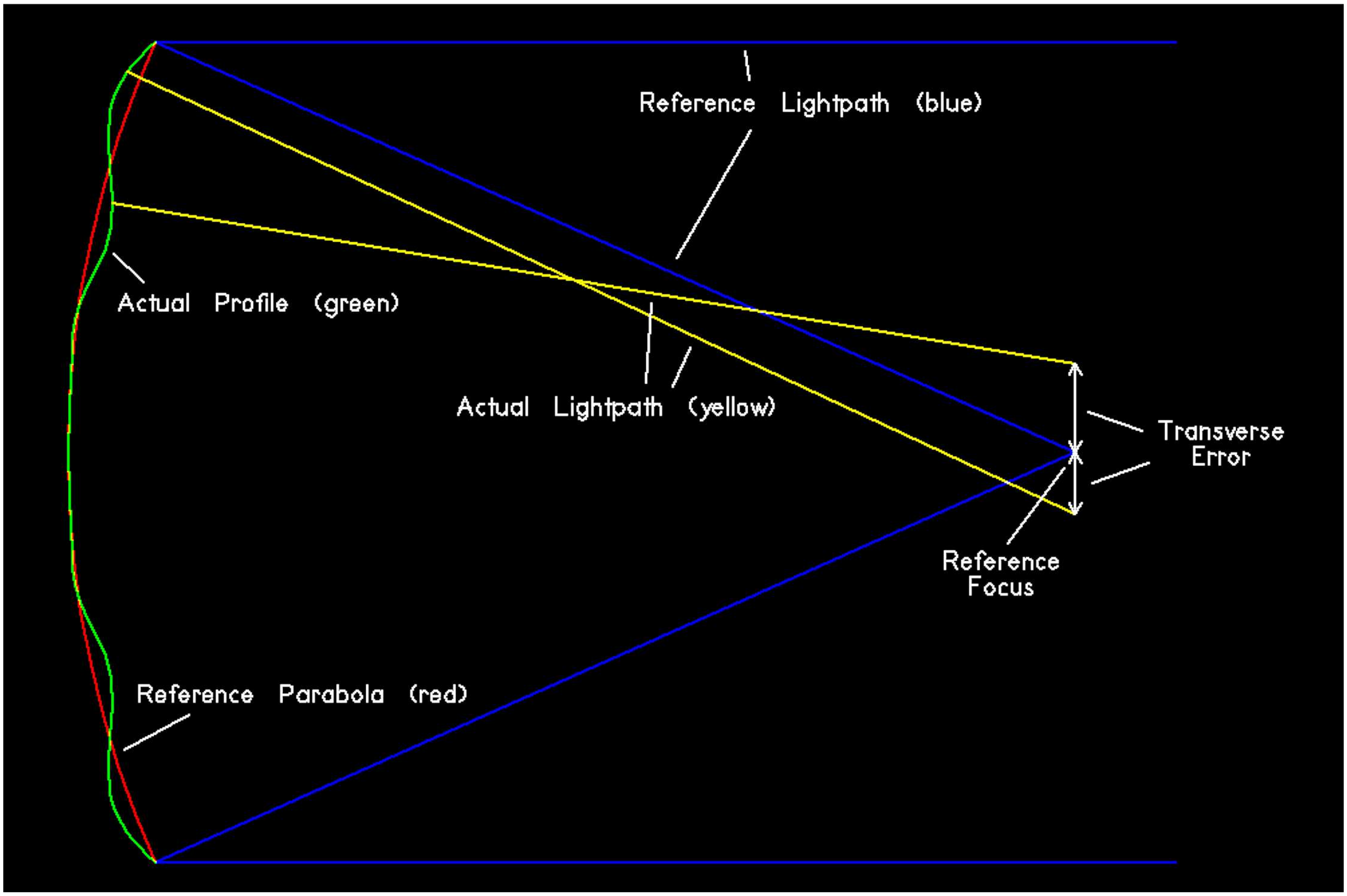


Illustration of Transverse error. Note that Transverse error is quoted as the worst case value as measured from the optical axis (the upper offset in this example). ***Diagram created by the author.***

older instructional texts on mirror making (Thompson, Howard, etc.) don't even mention transverse error. We old-timers who made our first mirrors decades ago probably never even heard about transverse error back then, maybe even not until just now in this reading!

But transverse error cannot be ignored with today's large and fast (say f/5 and faster) mirrors. Large, fast mirrors are very difficult to figure accurately, and keeping both wavefront and transverse error under control (i.e., meeting the M-L tolerance) is a really big challenge. Because by definition they have a deep curve and steep slopes to begin with, the tolerances are very narrow, and they get tighter as you approach the mirror's edge. Moreover, of the two errors, transverse error can be more difficult to keep in bounds. To keep it in check the mirror must have a really good edge zone, cannot have any pronounced zones, and the transitions between the zones that do exist (they are inevitable) must be smooth and gently-sloped. That's why there are precious few opticians that can produce really good large, fast mirrors. You can almost count them on one hand. On the other hand, amateur made large mirrors tend to be "zoney", and you will often find that even with good wave front numbers the transverse error is out of tolerance.

Next Time

Okay, I'm sure that by now your eyes are starting to glaze over, so this should be a good time to stop. Next time I'll go over some real world mirror examples, and a handy piece of free software that makes reducing and interpreting your Foucault test data a snap.

For Further Reading

This list not exhaustive, but here are a few resources that have played a role in my understanding of making Newtonian mirrors. They provide a much more in-depth explanation of what I'm describing here.

•*How to Make a Telescope*, by JeanTexereau. This is generally considered the seminal authority when it comes to making small Newtonian optics (in this book's case an 8-inch f/6), and the rest of the telescope as well. As of this writing the second edition is available at Willmann-Bell, Inc., who also carry most still-in-print telescope making books.

•*Making Your Own Telescope*, by Allyn J. Thompson. This is the book I used as a reference when I made my first telescope back in the '60s. It takes you through the building of a 6-inch f/8. Thompson goes into nowhere near as much depth in making a mirror as Texereau, but still I was able to make a decent mirror, one that got me hooked on astronomy. As of this writing it is still available at various online booksellers.

•*Testing Paraboloidal Mirrors*, by Dick Suiter, *Telescope Making #32*. (Suiter is also the author of the book *Star Testing Astronomical Telescopes*.) This is the best article I've ever read regarding the testing of paraboloidal mirrors! Suiter goes into great detail and at the same time provides a very readable and understandable explanation of the Foucault data reduction methods presented in Texereau, the daunting Test Data Sheet in particular. *Telescope Making* is long out of print but I have a copy of issue #32 you can borrow if you have any interest. Just let me know. (*Telescope Making* was published by Kalmbach, the company that also publishes *Astronomy*. Issue #32 can be ordered through the Kalmbach Bookstore web site.--ed.)

•Here's a nice web page by John Lightholder (Lightholder Optics) that does a good job describing the various optical quality standards: http://www.lightholderoptics.com/lhframe1.htm then click on *"Optical Talk"* found in the frame on the left-hand side of the page.

Lowbrow Discount for Slooh (Accessing Telescopes Remotely)

by Dave Snyder

Would you like remote access to a telescope? You might want to consider using Slooh. Slooh provides the following benefits:

- Robotic control of Slooh's three telescopes in the northern (Canary Islands) and southern hemispheres (Chile)
- Schedule time and point the telescopes at any object in the night sky. You can make up to five reservations at a time in five or ten minute increments depending on the observatory. There are no limitations on the total number of reservations you can book in any quarter.
- Capture, collect, and share images, including PNG and FITS files. You can view and take images from any of the 250+ "missions" per night, including those scheduled by other members.
- Watch hundreds of hours of live and recorded space shows with expert narration featuring 10+ years of magical moments in the night sky including eclipses, transits, solar flares, NEA, comets, and more.
- See and discuss highlights from the telescopes, featuring member research, discoveries, animations, and more.
- Join groups with experts and fellow citizen astronomers to learn and discuss within areas of interest, from astrophotography and tracking asteroids to exoplanets and life in the Universe.
- Access Slooh activities with step by step how-to instructions to master the art and science of astronomy.

There is a promotional discount for Slooh available for members of the club. To take advantage of the discount, you must go to the page: http://mbsy.co/7TcWC

It will ask for a credit card - you will be charged $29.95 for the first three months of service. Thereafter, Slooh will bill your credit card $74.85 for quarterly membership dues every 3 months (unless you cancel). Slooh will automatically forward your initial payment of $29.95 to the University Lowbrow Astronomers.

At the Leslie Science Center

Telescope Lecture and Observing

It was a great night for the Lowbrows November 7. Thanks to Larry Halbert, Jack Brisbin, Jim Forrester, Dave Snyder., Dave Jorgenson., Brian Ottum and Chris Sarnecki for making it possible. LSNC had 30 people signed up and 32 or 33 of them showed up. Yes, I typed those numbers correctly. More than 100% turnout. Sure, the sky did not cooperate with us, but the Lowbrows are a hardy bunch. After my 45 minute presentation, Brian Ottum did a remote connect to his observatory in New Mexico, where the skies were beautiful. Very Cool! Then Jim Forrester snuck up on the Moon with his fine TMB refractor and showed what he could of the Moon.--Charlie Nielsen

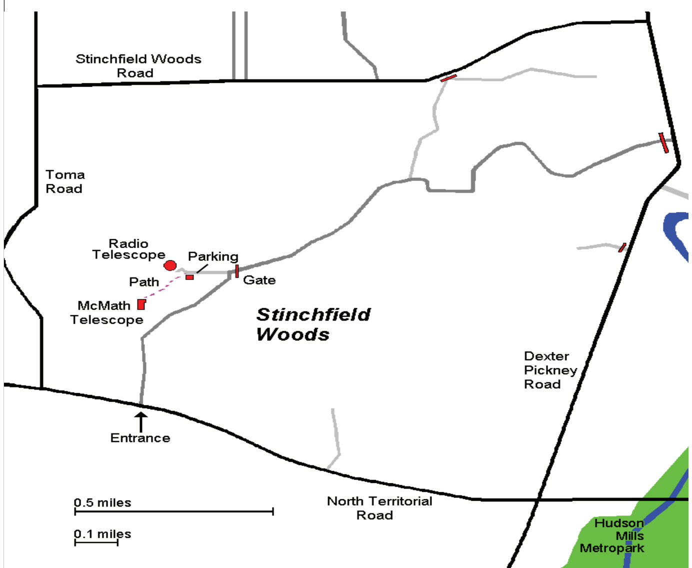
Club President Charlie Nielsen explains the operation of the various types of telescopes. As usual, Fearless Leader did a fine job explaining the nuts and bolts of what we do to the general public.
Photos: Jack Brisbin

Brian Ottum demonstrates his remote controlled observatory to those attending the November 7 event. The skies in New Mexico were clear and Brian was able to take real time photos of several clusters as well as the Andromeda Galaxy. Quite a treat! There are a few obstacles to smooth operation, though. Summer produces violent lightening strikes in the desert that are a danger to electronics. One bolt toasted the mother board of one of the observatory's computers as well as some of the wiring to the building. As a result, Brian and his partner replaced the copper wire internet feed with fiber optic cable run well below ground.

Places & Times

Monthly meetings of the University Lowbrow Astronomers are held the third Friday of each month at 7:30 PM. The location is usually Angell Hall, ground floor, Room G115. Angell Hall is located on State Street on the University of Michigan Central Campus, between North University and South University Streets. The building entrance nearest Room G115 is the east facing door at the south end of Angell Hall. A club observing session at the Peach Mountain Observatory, weather permitting, often follows the meeting.

Peach Mountain Observatory is the home of the University of Michigan's 25 meter radio telescope as well as the University's McMath 24" telescope, maintained and operated by the Lowbrows. Located northwest of Dexter, MI; the entrance is off North Territorial Road, 1.1 miles west of Dexter-Pinckney Rd. A maize and blue sign marks the gate. Follow the gravel road to the top of the hill to a parking area south of the radio telescope, then walk About 100 yards along the path west of the fence to reach the McMath Observatory.



Public Open House / Star Parties

Public Open Houses / Star Parties are generally held on the Saturdays before and after the New Moon at the Peach Mountain observatory, but are usually cancelled if the sky is cloudy at sunset or the temperature is below 10 degrees F. For the most up to date info on the Open House / Star Party status call: (734)332-9132. Many members bring their telescope to share with the public and visitors are welcome to do the same. Peach Mountain is home to millions of hungry mosquitoes, so apply bug repellent, and it can get rather cold at night, please dress accordingly.

Membership

Membership dues in the University Lowbrow Astronomers are $30 per year for individuals or families, $20 per year for students and seniors (age 55+) and $5 if you live outside of the Lower Peninsula of Michigan.

This entitles you to the access to our monthly Newsletters on-line at our website and use of the 24" McMath telescope (after some training).

A hard copy of the Newsletter can be obtained with an additional $18 annual fee to cover printing and postage. Dues can be paid at the monthly meetings or by check made out to University Lowbrow Astronomers and mailed to:

The University Lowbrow Astronomers

P.O. 131446

Ann Arbor, MI 48113

Membership in the Lowbrows can also get you a discount on these magazine subscriptions:

Sky & Telescope - $32.95 / year $62.95/2 years

Astronomy - $34.00 / year or $60.00 for 2 years

For more information contact the club Treasurer at:

lowbrowdoug@gmail.com

Newsletter Contributions

Members and (non-members) are encouraged to write about any astronomy related topic of interest.

Call or Email the Newsletter Editor: **Jim Forrester (734) 663-1638 or jim_forrester@hotmail.com** to discuss length and format. Announcements, articles and images are due by the 1st day of the month as publication is the 7th.

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	Dave Jorgenson	
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Lowbrow's Home Page

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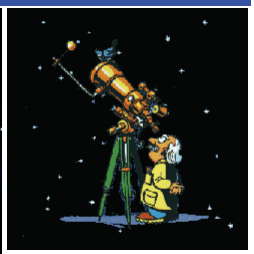
Reflections & Refractions



Website
www.umich.edu/~lowbrows/

Lowbrow Calendar

***Friday, December 19*--Monthly Club Meeting, 7:30 PM, Room G115, Angell Hall, Ann Arbor, MI--**James Cutler (Associate Professor, Aerospace Engineering, University of Michigan): "CubeSats and Space Exploration."

***Friday, January 16*--Monthly Club Meeting, 7:30 PM, Room G115, Angell Hall, Ann Arbor--**Claude Pruneau (Professor of Physics, Wayne State University): "The mini-bang: How studies at the CERN Large Hadron Collider inform us about the Big Bang!" Meetings of the University Lowbrow Astronomers are free and open to the public.

***Saturday, January 24, 01:26 EST*--Triple Shadow Transit of the moons of Jupiter!** Set up anywhere you can see Jupiter. The solar system giant will be 63 degrees above the horizon in the south-southeast. This unusual event lasts only 25 minutes. Don't be late!

***Comet c/2014 Q2 (Lovejoy)*--**Now at 7th magnitude in Puppis, the comet will brighten to magnitue 5 by the beginning of the year. December 29, c/2014 Q2 will be 2 degrees from M79 at magnitude 5.4. The comet will be at magnitude 5 for much of the winter, an easy binocular object and possibly naked eye from a dark site!

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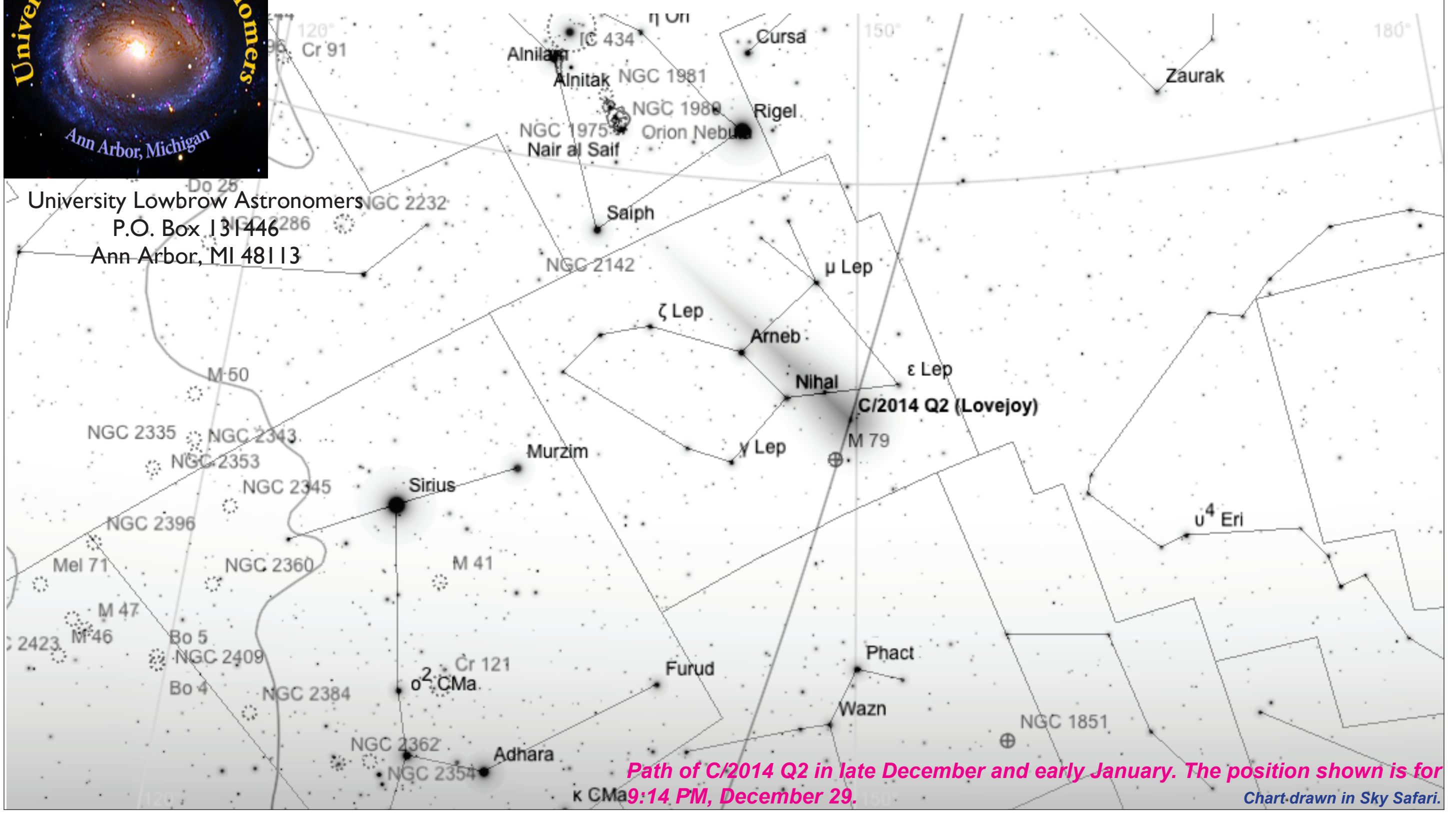

Path of C/2014 Q2 in late December and early January. The position shown is for 9:14 PM, December 29.

Chart drawn in Sky Safari.