A Little About Me

- Born/Raised: Grand Rapids, MI
- Undergrad: Chemistry, 1976, Rensselaer Polytechnic Institute (RPI)
- Grad: Applied Math, 1981, Cornell
- Postdocs:
  - NSF Fellow, Math, NYU
  - Visiting Lecturer, Math, Univ. of Illinois Urbana/Champaign
- Industry:
  - AT&T Bell Labs, Math Research Center
- Academia: Princeton, 1990-present
- Hobbies/Passions:
  - Soaring
  - Tennis
  - Astronomy
  - Photography
  - Math/Computation
  - Local Warming, Purple America, etc.
Most Pics Were Taken From My Driveway
My Smaller Telescope is a Questar...
The Dumbbell Nebula (taken in Oct 2018)...
Blink and You’ll See It

The author’s serendipitous rediscovery of a Mira variable recalls the decidedly singular way the star was originally found.

THE DUMBBELL NEBULA, also known as Messier 27 and NGC 6885, is one of my favorite nebulae, and over the years I’ve taken many pictures of it. I like to joke to my friends that it’s named after me — the dumbbell.

Last October, I invited my freshman seminar astronomy class to my home to show them how to do some astrophotography. Eight students came. We snapped images of stars and other objects before I suggested we take a sequence of pictures of M27. They agreed, and over the next few hours my telescope and camera did just that while my students and I enjoyed tea and brownies inside and talked astronomy.

The resulting photo came out pretty nicely — almost as nicely as one I’d taken two years earlier with the same telescope and camera. Seeing the similarity between the two, I thought it’d be fun to combine the pair, thereby achieving a better picture. So I loaded both photos into a stacking program and set about aligning the images.

As I flipped back and forth between the two photos, I noticed that a fairly prominent star in the 2016 image was entirely missing from the 2018 one. This caught me completely by surprise.

I uploaded the earlier photo showing the star to astrometry.net to get an astrometrically annotated version of the picture in FITS, the widely used digital file format. I loaded that into my planetarium program and determined the mysterious star’s right ascension and declination. Finally, I entered these coordinates into the SIMBAD website. The database revealed that the star is a known Mira-type variable star.

Although a thrill for me, my accidental rediscovery pales in interest next to the unusual manner of the original identification, which occurred as recently as 1990.

While creating a map of M27, Czech amateur astronomer Leos Ondra consulted the covers of that year’s May issue of Astronomy and Autumn issue of Deep Sky, both of which, by chance, featured photos of the Dumbbell Nebula. To his astonishment, Ondra noticed a red star on the Astronomy cover that was altogether missing from the Deep Sky image. After the star was confirmed as a newly identified Mira star, he dubbed it the Goldilocks Variable.

Prior to my own “discovery,” I was unfamiliar with Mira stars, though I’ve long had an interest in RR Lyrae variables and the globular clusters in which they lie. Noticeably blue, RR Lyrae stars have a period that’s typically shorter than a day, and they vary in brightness by only a modest amount. Mira variables, on the other hand, are red giants with long periods — on the order of a year — and dramatic dips in brightness.

It is this last property that astonished me the most after my find. It means that, as my two pictures above show, a Mira star can seemingly disappear and then return, phoenix-like, from the sidereal ashes. A few days after my revelation, I blinked the two pictures for my class, and they were as dumbfounded as I’d been.

Robert Vanderbei is a professor at Princeton University, affiliated with several departments, including Astrophysics. He coauthored, with J. Richard Gott, Sizing Up the Universe: The Cosmos in Perspective (National Geographic). A mathematician by training, he’s interested in variables of all sorts.
Is The Earth Flat?

A Picture’s Worth a Thousand Words...
How Aristarchus measured the size of the Moon.
How Big Is Earth?

A picture I took of a sunset over Lake Michigan.
A close-up.

Using this picture, some geometry, and a little trigonometry, I was able to compute that the Earth’s radius is about 5000 miles.
Angular Size

Let’s start by looking at the angular size of things.

That’s just a first step toward learning the actual size.

For that, we also need to know the distance.
Our Solar System – Pictures from my Driveway
The Moon and the Big Dipper
The Andromeda Galaxy and the Moon
Distance Measurements

There are various ideas/methods for measuring distances.

The simplest is called \emph{parallax}.

Using parallax, we can measure the distance to nearby stars.

For things further away, we need more clever/subtle methods.
Parallax: Distance to the Stars

Why didn't people believe Aristotle?

Because Aristotle had a killer argument for why Earth did not move. If Earth circled the sun, the stars should show a parallax effect—and this was not seen. As Earth circled the sun, Earth's position relative to the stars should oscillate, causing the stars' positions to oscillate once a year in the sky. This is explained in the figure opposite. The true situation is as shown at the top—just as Aristarchus envisioned it. Earth circles the sun once a year. Assume the stars and the sun remain at fixed positions. How does it look from Earth? We are riding on Earth, so it looks to us like Earth is not moving.

It looks to us like the sun moves in a small circle of radius 1 AU around Earth once a year (that's why it circles the celestial sphere once a year). The stars do not move relative to the sun, so as seen from Earth, stars must, like the sun, also seem to move in 1 AU circles over the course of a year. We should be able to see the stars trace these circles in the sky every year. These parallax circles represent the reflex motion of the stars relative to Earth produced by the motion of Earth as it circles the sun, creating changing viewing angles during the year to those stars (top right). If the distance from Earth to the sun is 1 AU, then the radius of all these parallax circles would also be 1 AU. The angular radius of the parallax circle depends on the distance to the star. A nearby star has a larger angular oscillation in the sky as seen from Earth than a distant star (bottom right).

If we look at a constellation, the nearby stars should oscillate more during the year than the distant stars. So the positions of nearby stars should shift during the year relative to more distant stars. The ancients thought that the stars were close enough that these oscillations should have been visible to the naked eye. But none were seen. Aristotle thought that proved Earth didn't move.

Aristarchus proposed an answer—no parallax effects were seen because the stars were infinitely far away. Parallax effects get smaller the farther away the stars are. Put the stars twice as far away, and the parallax effects become half as large. Put them infinitely far away, and the parallax effects disappear entirely. It was almost the right answer.

In 1453 Nicolaus Copernicus (1473–1543) published a sun-centered model based on Aristarchus's work. In it he was able to explain in a simple manner the main motions seen in the solar system. Mercury and Venus oscillate back and forth ahead of and behind the sun as the sun circles the sky once a year. Copernicus said this is because they, like Earth, orbit the sun but are closer to the sun than Earth is.

Before Copernicus, people had explained this motion with epicycles: The planet was supposed to circle a point that itself circled Earth. The big circle carrying the point was called the deferent, and the small circle around that point was called the epicycle. Venus and Mercury had large deferent circles exactly synchronized with the sun. Their epicycles produced their oscillations around the sun. The outer planets (Mars, Jupiter, Saturn) had big deferent circles that traced their slow orbits around the sky and epicycles with periods of one year each, which in reality showed the reflex (parallax) motion relative to Earth caused by Earth's movement around the sun.
Barnard’s Star
Barnard’s Star
Barnard’s Star
Barnard’s Star
Barnard’s Star
Barnard’s Star
The measured parallax is 0.5478 arcsecs. Corresponds to a distance of 5.97 lightyears.
Is The Universe Infinitely Big? – Olbers’ Paradox
Here are some more pictures of my favorite things
M13 – The Great Globular Cluster in Hercules
M27 – The Dumbbell Nebula
M31 – The Andromeda Galaxy
M42 – The Great Orion Nebula
M51 – The Whirlpool Galaxy
M57 – The Ring Nebula
NGC7635 – The Bubble Nebula
IC1396 – The Elephant Trunk Nebula
Thank You
Thank You
Questions?