



Mira: A Real Shooting Star!

When people say they see a shooting star after noticing a momentary streak of light in the night sky, what they really see are meteors burning up as they enter the Earth's atmosphere—nothing to do with stars at all.

However, Mira, the star on this poster, really *is* a shooting star—traveling at supersonic speed and trailing a glowing tail. Go ahead make a wish. You have some time to come up with a good one. The length of the tail and the speed of the star means it has been doing this for at least 30,000 years.

Mira (pronounced “my-rah”) is also known as Omicron Ceti. Mira is the only normal star known to have a tail. You can't even see Mira very well in the image because it is tiny compared to the tail. Mira is 350 light-years from Earth. If you could see the star and its tail with your naked eyes, it would be as long as the width of four full Moons! The tail stretches an astonishing 13 light-years. If our Sun had a tail like this, it would reach far beyond the edge of the solar system and extend nearly three times further than Proxima Centauri, the closest star to the Sun. In fact, the 20 nearest stars to the Sun are closer than the length of Mira's tail.

The Tale of the Tail

So what is going on? In a nutshell, two things:

- (1) Mira is traveling through space at a very high speed, and
- (2) It is shedding large quantities of gas in what is called a stellar wind.

Like the bow wave of a boat traveling through water, a bow shock forms ahead of the star in the direction of its motion (toward the right in the poster image). Gas in the bow shock is heated. The heated gas then mixes with the cooler gas in the stellar wind as it flows around and behind the star, forming a wake—again, like a fast boat moving through water.

Why has the tail not been seen before? Mira has been thoroughly studied for more than 400 years, so you might think someone would have noticed. Well, the hot gas from the bow shock, mixing with the cooler gas in the tail, causes the gas to emit a special kind of light when it cools off. This light is called **far-ultraviolet light**. Your eyes and ordinary telescopes cannot see ultraviolet light. Even if you could see it, far-ultraviolet light is absorbed by the Earth's atmosphere. What you would need is a telescope not only sensitive to far-ultraviolet light, but up in space, orbiting above Earth's atmosphere.

Well, NASA has one!

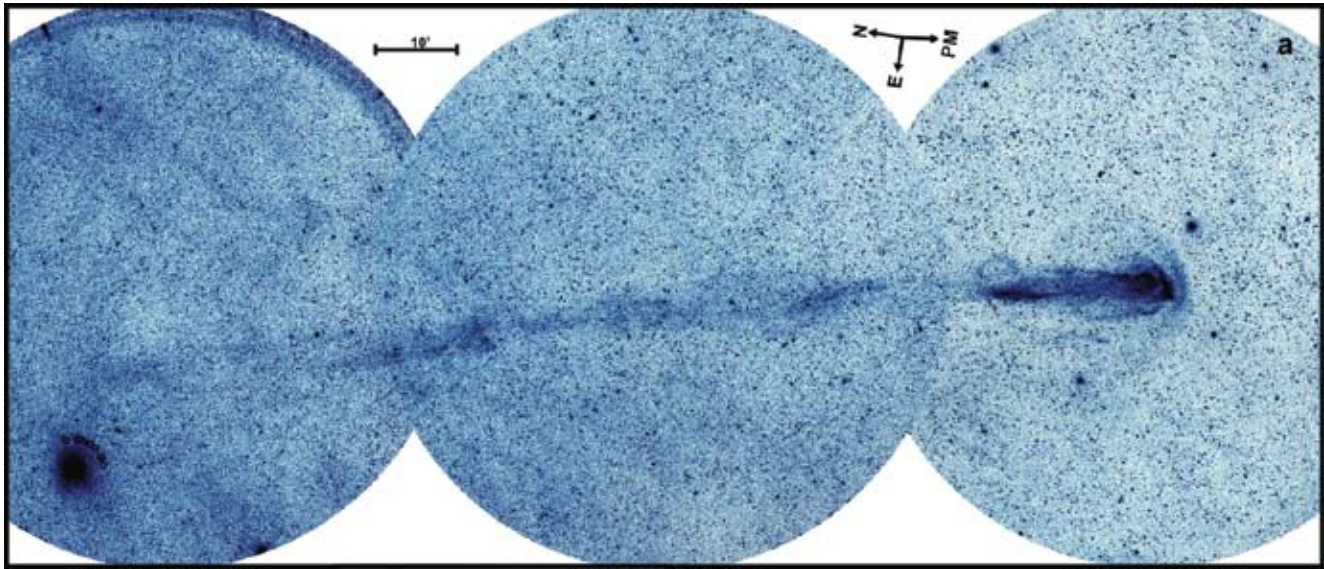
The orbiting telescope is called the Galaxy Evolution Explorer. It's small compared to some of its cousins, like the Hubble Space Telescope, the Spitzer Space Telescope, and the Chandra X-ray Observatory. Nonetheless, Galaxy Evolution Explorer collects vast quantities of data.



On the top is Mira in far-ultraviolet light. On the bottom is Mira in visible light. (Credit: GALEX and Digitized Sky Survey.)

The picture above compares two images of Mira. The one on the top is the brightest part of Mira's tail in the far-ultraviolet taken from space by Galaxy Evolution Explorer. The one on the bottom is a visible light image taken from the ground. Mira is much brighter in visible light than it is in ultraviolet because it has a surface temperature of only 3,000 degrees Kelvin, which is about 5,000 degrees Fahrenheit—quite cool for a star. If it were hotter, it would shine more brightly in ultraviolet than it does.

Mira's tail offers a unique opportunity for astronomers to study how stars like our Sun die and leave material



The Galaxy evolution Explorer captured the image of Mira and its tail in just three “frames.” (The bright star near the faintest end of the tail on the left was removed for clarity on the poster image.) The three images span 13 light-years, and take up four full Moon-widths of the sky. (Credit: Martin, Seibert, Neill et al., Caltech/Carnegie Institute, 2007.)

behind that can seed new solar systems. As Mira hurtles along, its tail sheds carbon, oxygen and other important elements needed for new stars, planets, and possibly even life to form.

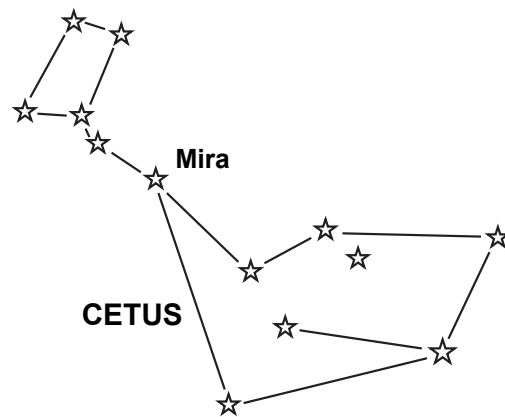
At this stage in Mira’s life, it ejects enough material to make a new Earth every 10 years. It has released enough material over the past 30,000 years to seed at least 3,000 Earth-sized planets or nine Jupiter-sized planets!

The Tale of the Star

Mira was discovered by David Fabricius in 1596. Mira is a **periodic variable star**. That means it changes brightness on a regular “schedule.” In Mira’s case, its brightness cycle takes 332 days. The variability occurs because it physically expands and contracts (pulsates) every 332 days.

For several months, it is bright enough to see with the naked eye. But then it dims to about 1/1500th of its former brightness to become invisible. Because it appeared to turn on and off, it was given the name Mira (Latin for The Wonderful).

When it is bright, you can see Mira for yourself without a telescope or binoculars while the constellation **Cetus** (the whale) is visible, which is around October through February in the Northern Hemisphere. You won’t be able to see Mira’s tail from the ground. Mira itself is visible for at least one and one-half months before it reaches maximum brightness (for example on January 1, 2008), and for two and one-half months after maximum brightness. Cetus is most easily seen during November. So look for Mira in mid-November.



Mira is found in the tail of the whale that is the Cetus constellation.

Fittingly, Mira is located in the tail of the whale. It may sound like a whale of a tale, but in the tail of the whale is a star with a whale of a tail.

Mira is about the same mass as the Sun. Mira is an old, **red giant star**. Someday (in about 5 billion years) the Sun will reach this stage of its long life and also become a red giant. As a red giant, Mira sheds a lot of mass in the form of dust and gas in a fairly gentle wind. It has swollen up to over 400 times the size of the Sun, despite having about the same amount of mass as the Sun. If Mira were located at the Sun’s position, it would swallow Mars—and Earth too, of course.

Mira is also a **binary star**. It has a sister, although not a twin by any means. The two are bound together by gravity. The dominant red giant star is called Mira A and its much fainter companion (possibly a white dwarf) is



called Mira B. When we say “Mira,” we mean Mira A. The distance between them is 70 times the Earth-Sun distance or more than twice the average Earth-Pluto distance. It takes about 500 years for the pair to orbit each other. Mira B is too close to Mira A and too faint to be seen in the GALEX image.

The Tale of the Picture

The image on the poster was made from a mosaic of just three images from the Galaxy Evolution Explorer. (See picture at the top of Page 2.) This space telescope sees a much bigger piece of the sky at once than do the Hubble and Spitzer Space Telescopes and the Chandra X-ray Observatory. Because of its **wide field of view**, Galaxy Evolution Explorer was able to capture a large portion of Mira’s tail in one frame. The images were taken in November and December of 2006.

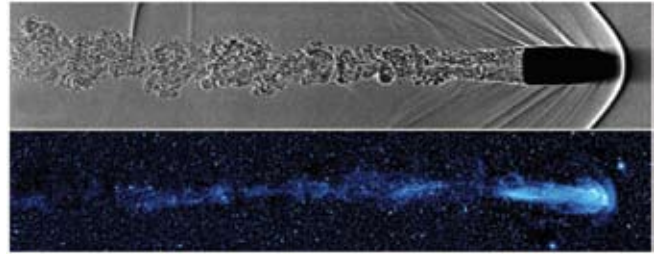
Five new features around Mira that were discovered in this image are:

1. The 13 light-year long extended tail seen in far-ultraviolet light.
2. The brighter region of the tail closer to the star.
3. A fascinating loop extending off the near-tail.
4. A bow-shock detected in both the far and near-ultraviolet, but more extended in the far-ultraviolet.
5. Knotted streams extending from Mira visible in both the far and near-ultraviolet.

Mira is traveling at a very high speed. In calculating Mira’s speed, astronomers must take into account the motion of our whole local region of space as it rotates around the center of the galaxy. But even within that space, Mira is zipping along at 291,000 miles per hour. This is 10 times faster than the Sun travels.

The space through which Mira travels is not entirely empty. It contains very thin gas and dust that floats around in space between the stars. This sparse space matter is called the **interstellar medium**. Mira’s high velocity relative to the interstellar medium compresses the gas and dust ahead of it, forming the bow shock.

Mira’s tail forms because its stellar wind, laden with dust and gas, mixes with the hot, compressed interstellar medium in the bow shock, and then flows around and behind Mira. Mira’s wind flow becomes turbulent (or chaotic) instead of remaining laminar (or smooth). Indeed, the extended tail of Mira looks very much like a turbulent wake.



Mira vs. a speeding bullet. Mira is over 250 times faster! (Credit: Bullet shadowgraph — A Davidhazy/Rochester Institute of Technology; Mira — Martin, Seibert, Neill et al., Caltech/Carnegie Institute, 2007.)

The picture above is a fun comparison between Mira and a shadowgraph* of a speeding bullet. The bullet is traveling at 1.5 times the speed of sound. The bullet forms a leading shock wave in the same way Mira forms a bow shock. Trailing behind the bullet is a classic turbulent wake.

The End of the Tale (Tail?)

What does the future hold for Mira? In less than one million years, Mira will eject the rest of its outer gas envelope (10%-20% of its total mass) into space, leaving only the dense, hot core, made of carbon and oxygen. The newly glowing core will cause the ejected envelope material to glow as a **planetary nebula**. Instead of a being perfectly round like a sphere, Mira’s planetary nebula will likely become highly distorted due to Mira’s high space velocity. It might look something like the planetary nebula Sharpless 2-188 shown here.

After a few tens of thousands of years, the nebula will disappear. The carbon-oxygen core will rapidly cool, contract, and fade as it becomes a **white dwarf**—a bizarre ball of ultra-dense material containing half the mass of the Sun in an object about the size of Earth.

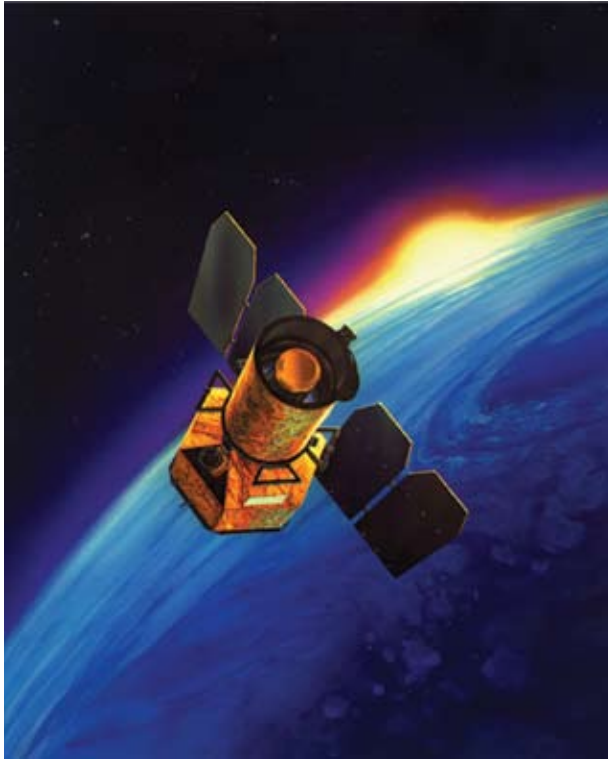


Planetary nebula Sharpless 2-188. Will Mira end up like this? (Credit: Chris Wareing/University of Leeds.)

* A shadowgraph is a photo of the shadows caused by the differences in density of air, water, or something else transparent. The shadows are cast because light travels at different speeds through the substance, depending on its density.



The Tale of the Telescope



Artist's rendering of the Galaxy Evolution Explorer in Earth orbit.

Galaxy Evolution Explorer has been orbiting Earth since 2003. The telescope observes galaxies in ultraviolet light. Because Earth's atmosphere blocks most ultraviolet light, an ultraviolet telescope must be above the atmosphere.

This special telescope is looking at tens of millions of galaxies spanning much of the universe. A galaxy is a grouping of stars, gas, dust, planets, moons, and various strange objects such as black holes all held together by gravity. All but a few stars in the universe live in galaxies. Our Sun is just one of at least 200 billion stars in our own Milky Way Galaxy. The entire universe probably contains over 100 billion galaxies.

Stars, planets, galaxies, clouds of dust and gas, and other matter in space are sending out energy all the time. This energy, called **electromagnetic energy**, travels in **waves**. Like waves traveling through the ocean, electromagnetic waves can be very long, very short, or anything in between.

Therefore, the light we see from the Sun and other stars—the visible light—tells only a small part of the story of the stars. To get the complete picture, we must extend our vision to include other wavelengths or energies of light. That is why scientists and engineers have invented different kinds of telescopes. For example, we have special telescopes for the long radio waves; special telescopes for the infrared waves that we cannot see but rather feel as heat; and we have special telescopes such as Galaxy Evolution Explorer for detecting invisible ultraviolet waves.

Galaxy Evolution Explorer can detect stars and galaxies that are about 40 million times fainter than ones we can see with our unaided eyes from even the darkest skies here on Earth. It is the first mission to map most of the sky in ultraviolet light at a great enough distance to survey galaxies outside our own galaxy. Its all-sky map will also help astronomers find the most interesting looking galaxies for future study in detail using other telescopes.

The Galaxy Evolution Explorer mission is managed by the Jet Propulsion Laboratory and the California Institute of Technology.

See some of the other amazing images from the Galaxy Evolution Explorer at www.caltech.edu.

To Learn More

- ✦ Galaxy Evolution Explorer Web site: www.galex.caltech.edu
- ✦ How far is a light-year? starchild.gsfc.nasa.gov/docs/StarChild/questions/question19.html
- ✦ Ultraviolet light and the electromagnetic spectrum: spaceplace.nasa.gov/en/kids/cosmic
- ✦ Constellations: spaceplace.nasa.gov/en/kids/st6starfinder/st6starfinder.shtml (activity also)
- ✦ White dwarfs: imagine.gsfc.nasa.gov/docs/science/know_12/dwarfs.html
- ✦ Binary stars: imagine.gsfc.nasa.gov/docs/ask_astro/binary.html
- ✦ Mira A and B in X-ray: chandra.harvard.edu/photo/2005/mira/
- ✦ Mira A and B in visible light: hubblesite.org/newscenter/archive/releases/1997/26/image/a/
- ✦ Planetary nebulas: spaceplace.nasa.gov/en/educators/posters/GALEX/GALEX2_poster_all.pdf