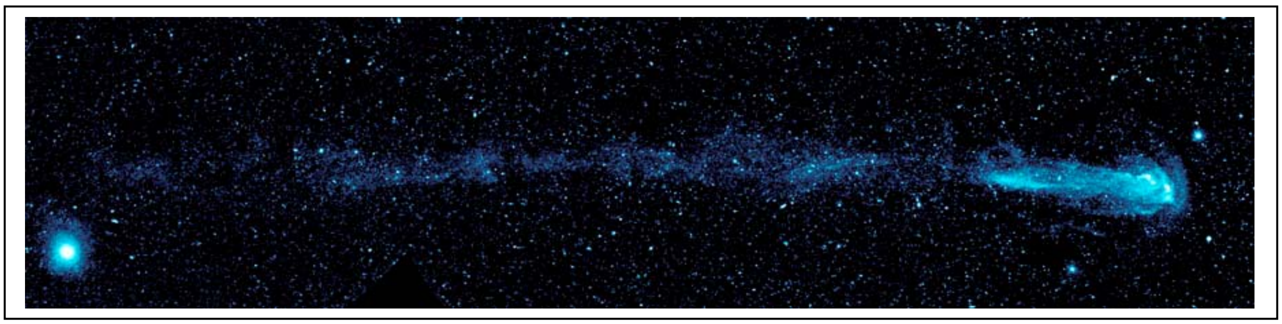
A Star Sheds a Comet Tail!

For 400 years, astronomers have carefully watched the star Mira in the constellation Cetus the Whale, made famous for its variable brightness. This red giant star is very old, and it is in its last few million years of life before evolving onto a planetary nebula and white dwarf 'combo'. Our own sun will reach a similar stage in about 7 billion years. While astronomers thought they knew quit a lot about this star after decades of satellite and ground-based telescopic study, the NASA, Galaxy Evolution Explorer (GALEX) satellite uncovered a surprising new twist to this famous star. Using its sensitive ultraviolet telescope while routinely mapping the light from stars across the entire sky, GALEX detected faint light from an enormous tail of dust stretching over 13 light years from Mira.

Red giant and red supergiant stars are known to be factories for producing dust grains in their cooling outer atmospheres where temperatures can reach a chilling 1,500 K - enough for molecules like silicon dioxide to condense out like raindrops, solidifying into small dust grains. These are then driven away from the star by radiation pressure. Some stars form spherical shells that can be so dusty that the star literally fades from optical view behind a dense obscuring wall of dust. But Mira does something different. It seems to be ejecting large quantities of oxygen, carbon and nitrogen!

Mira is known to be a fast-moving star traveling at a speed of 130 km/sec (or about 300,000 miles per hour). As its atmosphere sheds these gases in vast clouds, these clouds are left behind the star as it plows through the gases in the Interstellar Medium. Mira sheds about 10 Earth masses worth of dust and gas every ten years. The distance to Mira is 350 light years, and at this distance, the picture below spans an area 15 light years long and 4 light years wide.



Problem 1 - From the speed of Mira, how long did it take for it to travel 13 light years?

Problem 2 - What is the scale of the image in units of light years per centimeter?

Problem 3 - From your answer to Problem 1, what is the scale of the gas tail in thousands of years per centimeter, rounded to the nearest thousands?

Problem 4 - Did Mira emit gas in a steady rate during the period of time estimated in Problem 1?

Problem 5 - Can you create a chronology for Mira that tells about the sequence of events, in time, of its history of ejecting gas during the time that the dust tail was produced?

Problem 1 - From the speed of Mira, how long did it take for it to travel 13 light years?

Answer: First, a light year is the distance light travels in one year at a speed of 300,000 km/sec. There are 31 million seconds in a year, so $(3 \times 10^5$ k/s) x $(3.1 \times 10^7$ sec/yr) = 9.3×10^{12} kilometers. The speed of Mira is 350 kilometers/s, so the time required is just

T = (13 light years * 9.3×10^{12} km/LY)/130 km/sec
= **9.3×10^{11} seconds** or
= **30,000 years**.

Problem 2 - What is the scale of the image in units of light years per centimeter?
Answer: 14.5 centimeters = 13 Light years so 13 LY/14.5 cm = **0.9 light years/cm**

Problem 3 - From your answer to Problem 1, what is the scale of the gas tail in thousands of years per centimeter, rounded to the nearest thousands?
Answer: 30,000 years / 14.5 centimeters = **2000 years/cm**

Problem 4 - Did Mira emit gas in a steady rate during the period of time estimated in Problem 1?
Answer: No, because the gas ejected by the star during the last 30,000 years is clumpy with many gaps. This means there were periods when the star was ejecting gas, and periods where this process seems to have temporarily stopped.

Problem 5 - Can you create a chronology for Mira that tells about the sequence of events in its history of ejecting gas during the time that the tail was produced?

Answer: The current period of gas loss seems to extend back to about 3000 years ago. There is then a gap of about 1,000 years when there seemed to be little gas production. Then about 4,000 years ago and extending back to about 23,000 years ago, the gas production was occurring but at a reduced level from recent times (more intense during the last 3,000 years). There is then another gap between about 23,000 years ago and 27,000 years ago with reduced gas production, followed by an earlier brief phase of gas production extending from about 27,000 to 30,000 years ago.

Note: Some of the fading of the tail may be due to the interaction of the gas with the interstellar medium which may be trying to dissipate the tail. Some of this interaction may also be partly responsible for the detailed clumpiness in the tail, so it is probably not a good idea to analyze the tail structure finer than centimeter differences.