Harvard-Smithsonian Center for Astrophysics News

Release No.: 04-03 For Release: 9:20 a.m. EST, Tuesday, January 6, 2004

Note to Editors: An image to accompany this release is online at: http://cfa-www.harvard.edu/press/pr0403image.html

STORMS OF HOT AND COLD GAS RAGE IN BETELGEUSE'S TURBULENT ATMOSPHERE

Atlanta, GA — A team of astronomers, led by Alex Lobel of the Harvard-Smithsonian Center for Astrophysics (CfA), announced today at the 203rd meeting of the American Astronomical Society in Atlanta that Hubble Space Telescope observations of a nearby supergiant star directly show hot gas escaping its boiling atmosphere at a larger distance than from any other star. The expelled hot gas somehow survives the cold and harsh conditions in the star's bloated upper atmosphere.

New observations with the Space Telescope Imaging Spectrograph (STIS), Hubble's high-precision and ultra-sensitive spectrometer, show that the warm chromosphere of Betelgeuse extends out to more than fifty times its radius in visible light, a size five times larger than the orbit of Neptune. (The chromosphere is an inner layer of a star's atmosphere, between the photosphere and the corona. The Sun's chromosphere is visible as a thin reddish line during a total solar eclipse, and extends outward for only a fraction of a solar radius.)

STIS detected the spectral signatures of tenuous hot gas in cold, remote, and dusty places of Betelgeuse's mammoth atmosphere. The observations help to determine the mechanisms that form and sustain warm gaseous envelopes in many other red and yellow stars, including the Sun.

The team investigated the atmosphere of Betelgeuse, the brightest star in the constellation Orion, over the past five years with the STIS instrument aboard Hubble. They found that the bubbling action of the chromosphere tosses gas out one side of the star, while it falls inward at the other side, similar to the slow-motion churning of a lava lamp.

"Betelgeuse's upper chromosphere extends into the enormous cloud of cold dust around this supergiant star. Our basic knowledge of how chromospheres form should explain how it sends this warm gas so far into space. There is plenty of gas below 2000 degrees Fahrenheit because of dust, but this gas is apparently joined by much hotter ionized gas from the chromosphere near the star's surface" said Lobel.

-- cont --

Harvard College Observatory *Smithsonian Astrophysical Observatory*
60 Garden Street Cambridge MA 02138 617.495.7461 Tel 617.495.7468 Fax pubaffairs@cfa.harvard.edu

Before the discovery, telescopes on Earth detected the warm gas in the star's weak chromosphere up to only about five times the star's radius, a size bigger than Saturn's orbit. (The photospheric surface of Betelgeuse is about as large as Jupiter's orbit.)

When a match flame warms the air above it, the heat quickly disperses into the cooler surrounding air. In Betelgeuse's upper atmosphere, hot and cold gas mix together, but the warm gas does not entirely dissipate away until far above the heights where much colder gas is observed.

The new STIS spectra in ultraviolet light show that very remote parts of the chromosphere contain hot gas above 4220 degrees Fahrenheit (2600 Kelvin). The cold neighboring gas, however, is not warmer than 2240 degrees F (1500 K). Higher temperatures would destroy the dust particles that glow in infrared light at a large distance from the supergiant.

Running Shock Waves

The astronomers considered several explanations for the joint presence of hot and cold gas in the upper chromosphere of this gargantuan star. One explanation calls for long trains of shock waves which run through the chromosphere. The front of a shock wave compresses the gas and heats it up. It chills in the expanding wake of the passing wave. The shocks are strong enough to warm up a large volume of gas far above the supergiant's surface. The temperature in their long wakes, however, decreases so rapidly that dust grains can form without being completely destroyed by following waves.

The new observations also show that the outflow of warm gas accelerates with larger distance in the upper chromosphere and dust shell. "This further supports the shock wave model," said Lobel. "If the atmosphere were static, the observed temperature differences would disappear with the natural exchange of heat."

Warm material moves far above the surface of Betelgeuse in a dynamic balance of heat with colder gas inside its dust cloud. When large volumes of warm and cold air collide in Earth's atmosphere, devastating tropical storms can form with wind powers that lift up cars. Similarly, the chromosphere of Betelgeuse is very turbulent. The STIS spectra show that the speed of the turbulence is faster than the local sound velocity. This supersonic turbulence could result from running shocks or from the flow of energy between the newly discovered warm and cold gas.

-- cont --

Pulsations of the Chromosphere

Other models without shock waves consider oscillations of the chromosphere. Parts of the star's unstable surface sometimes vigorously bulge out in different directions, piercing long warm plumes into the cold dust envelope. At large distances from the surface, the density of the cold atmosphere strongly decreases, which prevents it from absorbing the heat carried by the intruding warmer plumes. These plumes cool off only far beyond the regions observed by STIS, where the density decreases to levels similar to the cold gas, like a plume of steam cools higher above the nozzle of a boiling kettle.

The team plans to request new high-precision observations to find out if the chromospheres of other nearby supergiants also extend so far into space. "We would like additional observations to confirm the presence of warm gas at distances as great as fifty stellar radii," said team member Jason Aufdenberg, a former research fellow at CfA, now at the National Optical Astronomy Observatory.

The search for the reasons why chromospheres are produced around stars started decades ago with pioneering observations of the faint chromosphere of the Sun, which extends only a few percent of the radius above the surface. One out of million stars in our Galaxy is a supergiant like Betelgeuse, which even at a distance of 425 light-years is the seventh brightest star visible in the northern hemisphere. The new observations of its puffed-up chromosphere with the Hubble Space Telescope bring scientists an important step closer to completing that search.

The team presented parts of the research in this release at a meeting of the International Astronomical Union of last July. See also http://arXiv.org/abs/astro-ph/0312076 .

This research was supported by NASA and the Smithsonian Astrophysical Observatory. The science team mentioned in this press release consists of Drs. Alex Lobel, Andrea Dupree, Robert Kurucz, Robert Stefanik, Guillermo Torres (Harvard-Smithsonian Center for Astrophysics, Mass.), and Jason Aufdenberg (National Optical Astronomy Observatory, Arizona).

Headquartered in Cambridge, Mass., the Harvard-Smithsonian Center for Astrophysics is a joint collaboration between the Smithsonian Astrophysical Observatory and the Harvard College Observatory. CfA scientists, organized into six research divisions, study the origin, evolution and ultimate fate of the universe.

-- cont --

For more information, contact:

David Aguilar, Director of Public Affairs
Harvard-Smithsonian Center for Astrophysics
Phone: 617-495-7462   Fax: 617-495-7468
daguilar@cfa.harvard.edu

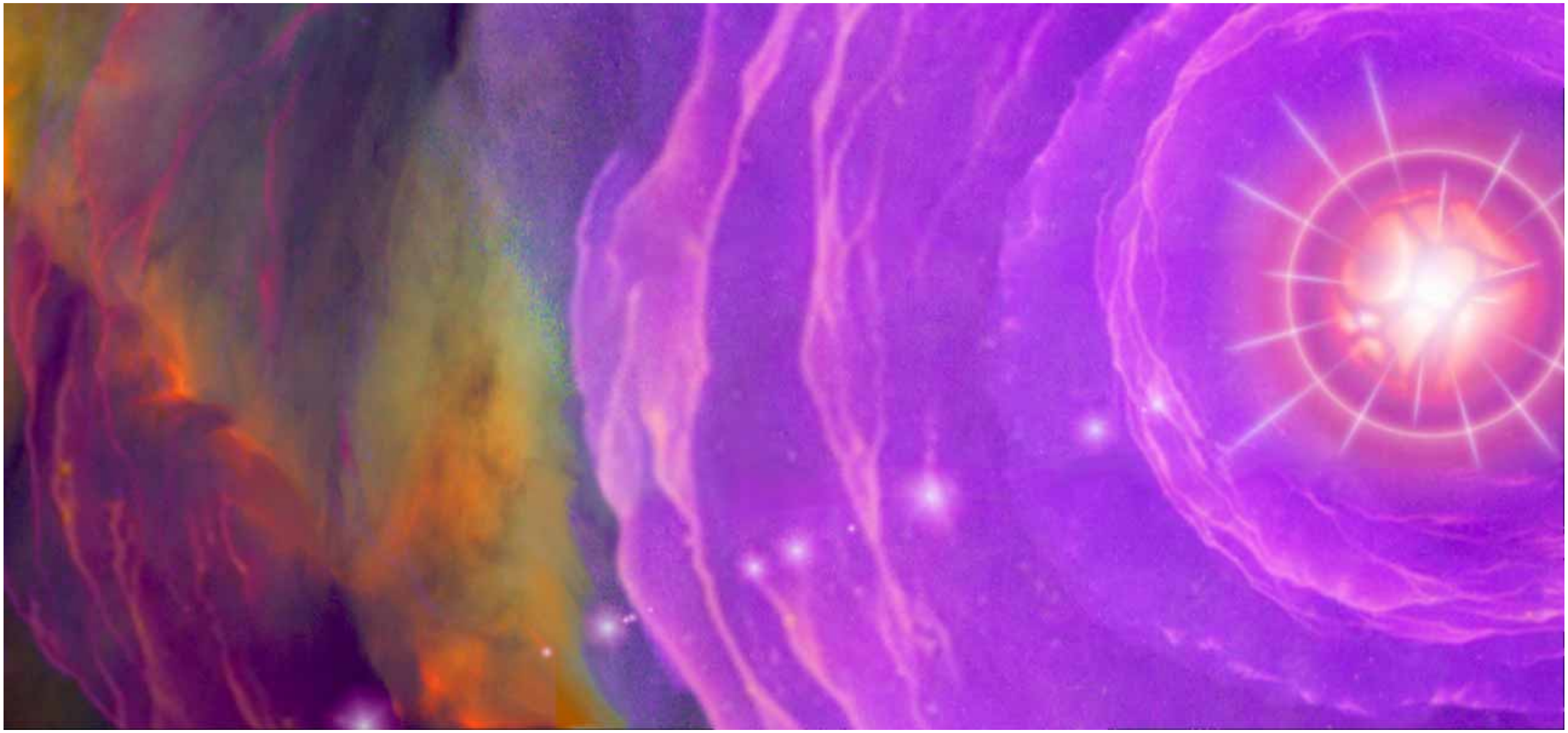
Christine Lafon, Public Affairs Specialist
Harvard-Smithsonian Center for Astrophysics
Phone: 617-495-7463   Fax: 617-495-7016
clafon@cfa.harvard.edu

Science Contact Information:

Dr. A. Lobel
Harvard-Smithsonian Center for Astrophysics
60 Garden Street
Cambridge, MA 02138
Phone: 617 496 7919
Fax: 617 495 7049
E-mail: alobel@cfa.harvard.edu
Web: http://cfa-www.harvard.edu/~alobel

# # # #

ARTWORK CREDIT: Alex Lobel, Harvard-Smithsonian Center for Astrophysics



New observations of Betelgeuse with the Hubble Space Telescope show that warm gas from the supergiant's upper chromosphere is present inside its cold and dusty outer gas envelope. In this artist's impression of the upper chromosphere, shock waves from the star's huge pulsating surface traverse the chromosphere (shown in violet and blue colors) and enter into the cooler dust envelope (in orange and black). The waves produce the warm gas which mixes with the cold gas.

This image accompanies CfA press release 04-03. High-resolution image is available online at:

http://cfa-www.harvard.edu/press/pr0403image.html