PRESS RELEASE

Astronomers Watch Exploding Stellar Fireball with Unprecedented Clarity

MOUNT WILSON, CALIFORNIA – Astronomers have observed the expanding thermonuclear fireball from a "nova" that erupted last year in the constellation Delphinus. A nova occurs following the buildup of a thin layer of hydrogen on the surface of a white dwarf – a highly evolved star with the diameter of the Earth and the mass of the sun. The hydrogen is provided by a close companion, which is a normal star, in a binary star system, wherein the two stars orbit about their center of mass. The normal star sheds a small amount of its mass through a stream onto the white dwarf's surface that gradually builds up a hydrogen "ocean". When that ocean is perhaps 200 meters (about 650 feet) deep, the enormous surface gravity of the white dwarf produces pressures at the bottom of the hydrogen layer sufficient to trigger thermonuclear fusion, essentially a stellar H-bomb. The light from the explosion will significantly exceed the binary system's normal brightness and the object may suddenly appear to the naked eye in a location not previously noted to have a bright star. Over ensuing weeks, the star will slowly fade as the fireball expands, cools and dissipates. Surprisingly, this seeming cataclysm on the white dwarf's surface has no real effect on the star or its companion, and the flow of material will resume so that the detonation will likely repeat at a future date.

Because these objects are generally very far from the sun and faint until the explosion occurs, they do not appear on classical star maps. Instead, a "new" star suddenly appears where there was none before. The famous 16th century Danish astronomer Tycho Brahe described this sudden appearance of stars in his 1572 book *De Stella Nova*, and the Latin "nova" for "new" became attached to this phenomenon, which also manifests itself through far more energetic processes that are destructive of the exploding star in a "supernova".

On August 14, 2013, the Japanese amateur astronomer Koichi Itagaki discovered what was promptly named Nova Delphinus 2013. Within 15 hours of the discovery announcement and 24 hours following the actual explosion, astronomers at Georgia State University's Center for High Angular Resolution Astronomy (CHARA) had trained the six telescopes of the CHARA Array, located on the grounds of historic Mount Wilson Observatory in the San Gabriel Mountains of Southern California, onto Nova Del in order to image the fireball and measure its size and shape. The CHARA facility uses the principles of optical interferometry to synthesize for the purpose of very high resolution a telescope with an equivalent size of over 300 meters diameter. This makes it capable of seeing details far smaller in angular extent than traditional telescopes on the ground or in space. The results of these observations are described in the current issue of Nature.

CHARA's first measurement showed the fireball to have an angular diameter of 0.4 milli-arcsecond, or about a ten-millionth of a degree. This is equivalent to the angular diameter of a U.S. nickel seen from a distance of about 11,000 kilometers (about 6,800 miles). During the 43 days following detonation while CHARA observed the event, the fireball expanded at a velocity of more than 600 km per second and grew twenty-fold to nearly 12 milli-arcseconds in diameter. The size of the fireball was measured on a total of 27 nights during this time frame, the first measurement comprising the earliest of a fireball size yet obtained for a nova event. Researcher Gail Schaefer says, "It was very exciting to see the size of the nova increasing on a night-by-night basis."

CHARA's measurements of the angular expansion rate of the nova combined with measurements of the expansion velocity from independent spectroscopic observations permit the determination of the distance to the star. Nova Delphinus 2013 was found to be 14,800 light years from the sun with an uncertainly of about 13% of that value. This means that, while the explosion was witnessed here on

Earth last August, it actually took place nearly 15,000 years ago.

Knowing the nova's distance along with its angular size allows the determination of the physical size of the fireball at the different times of observation. The fireball's radius in terms of the size of our solar system when first measured by CHARA on August 15, 2013 was very nearly the size of Earth's orbit. Two days later, it was already the size of Mars' orbit, and by day twelve, the fireball surface would extend out to the orbit of Jupiter. When last measured nearly 43 days following the detonation, the fireball radius would reach out to a distance nearly that of Neptune, the outermost planet in our system. This incredible expansion rate of more than 600 kilometers-per-second (over 1.3 million miles-per-hour) was fueled by the violence of the thermonuclear explosion of the hydrogen on the white dwarf's surface.

By observing at the early dates after the explosion with all six telescopes of the CHARA Array, actual images of the fireball were created from the interferometric measurements. Those images confirm a small deviation from spherical deduced from diameter measurements that show the fireball's shape to have an ellipticity of about 13% from spherical. This may result from a slight preference for ejection of material from the nova's poles rather than uniformly around the surface of the white dwarf.

Changes in the size of the nova over time provide insights into the structure of the ejecta. During the first few nights, when the nova was smallest and most compact, the outer layers appeared opaque. After the nova reached maximum brightness during the first week, the CHARA measurements showed an apparent slowing of the expansion, which can be interpreted as the outer layers becoming more transparent as the ejecta expands and cools, allowing us to see deeper into the slower moving, denser layers below. During this phase the nova can be modeled as an opaque core surrounded by an envelope of diffuse emission. After about 30 days, the size of the nova jumped to a larger diameter, while the brightness of the nova increased again in the infrared. These two observations can be explained if dust formed in the cooler, outer layers of the nova, providing additional thermal emission that provides more light at larger diameters.

Studying the structure of novae at the earliest stages can help astronomers understand how material is ejected from the surface of the white dwarf during the explosion. The new measurements follow the expansion through its very early relatively compact stages and transition to a fireball surface nearly the size of our solar system. They will bring new insights to theoretical models of the details of novae eruptions.

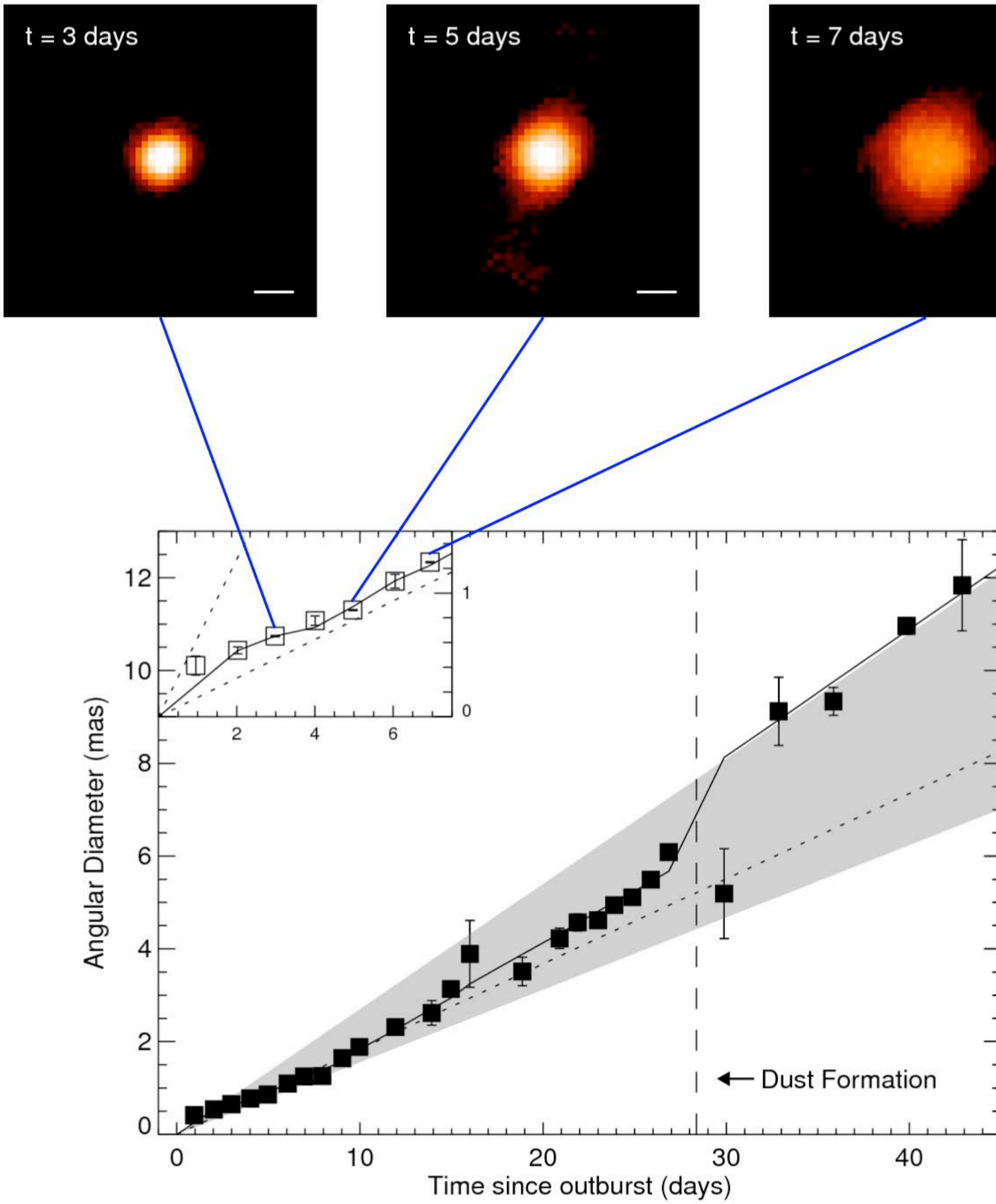

Figure and Caption: The accompanying figure shows the measured angular diameter in milli-arcseconds (one milli-arcsecond is a thousandth of an arcsecond; 1 arcsecond is 1/60 of an arcminute; and, 1 arcminute is 1/60 of a degree) plotted against the day of observation following the detonation of the nova. Several of the measurements have larger uncertainties than others, and so their error bars show as vertical tick marks extending from the mean measurement. For the others, the uncertainties are smaller than the size of the measurement box. The diameters increase with a modest departure from a linear relation until after day 27, after which there is a jump in the diameter. CHARA measurements of the brightness of the system at infrared wavelengths indicate that the brightness began to increase once again, likely due to the formation of circumstellar dust in the outer layers, leading to a larger effective size of the nova. The grey region shows the expansion rate of the opaque core (lower edge) and the surrounding, more diffuse envelope (upper edge).

The inset at the top left of the plot shows the diameter measurements in greater detail up through day seven following detonation. The dotted lines show examples of how the diameter would change assuming a linear expansion. The three panels connected to that inset are actual images of the fireball produced from CHARA observations on days 3, 5 and 7. The color indicates relative brightness of the fireball and not actual color since these observations were obtained at near infrared “H-band” wavelengths centered around 1.6 microns rather than in the visible part of the spectrum. The horizontal bar at bottom right of each image corresponds to an angular size of 0.5 milli-arcseconds and a linear size of 2.27 astronomical units (1 AU = distance of the Earth from the sun) at the measured distance of Nova Del.

The images are consistent with a model consisting of an opaque core surrounded by a halo of fainter emission. The small departure from a spherical shape is apparent in the images from days 5 and 6.

Credits: The CHARA Array of Georgia State University (located in Atlanta) is operated by funding the GSU College of Arts and Sciences and the National Science Foundation (NSF). Operational since 2005, the facility was constructed with support from the NSF, GSU, the W. M. Keck Foundation, and the David and Lucile Packard Foundation. This work resulted from a collaboration of astronomers from 19 institutions, many of whom gave up their time on the CHARA Array in order to obtain nova observations.

Contacts:

Dr. Gail Schaefer, principal author, Schaefer@chara-array.org

Dr. Hal McAlister, CHARA director, hal@chara.gsu.edu

Links:

Animation of Fireball expansion – http://www.chara.gsu.edu/NovaDelMovie.gif

CHARA Array – http://www.chara.gsu.edu

Georgia State University – http://www.gsu.edu

National Science Foundation Division of Astronomical Sciences – http://www.nsf.gov/div/index.jsp?org=AST

Mount Wilson Observatory – http://www.mtwilson.edu