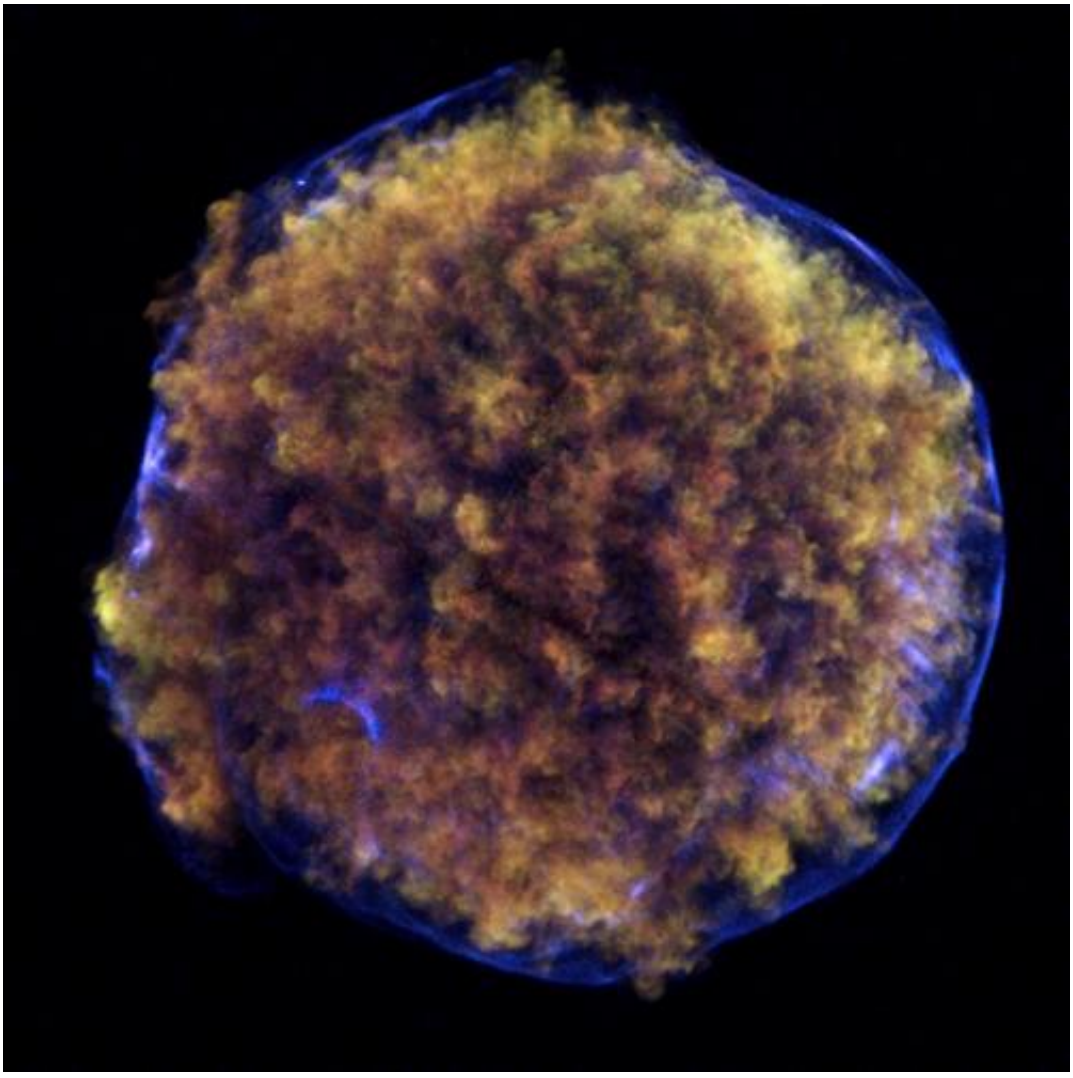
Tycho's supernova remnant: New evidence on origin of supernovas found

April 26 2011



This Chandra image of the Tycho supernova remnant contains new evidence for what triggered the original supernova explosion. Tycho was formed by a Type Ia supernova, a category of stellar explosion used in measuring astronomical distances because of their reliable brightness. In the lower left region of Tycho is

a blue arc of X-ray emission. Several lines of evidence support the conclusion that this arc is due to a shock wave created when a white dwarf exploded and blew material off the surface of a nearby companion star. This supports one popular scenario for the trigger of a Type Ia supernova. Understanding the origin of Type Ia supernovas is important because they have been used to determine that the Universe is expanding at an accelerating rate. Credit: NASA/CXC/Chinese Academy of Sciences/F. Lu et al

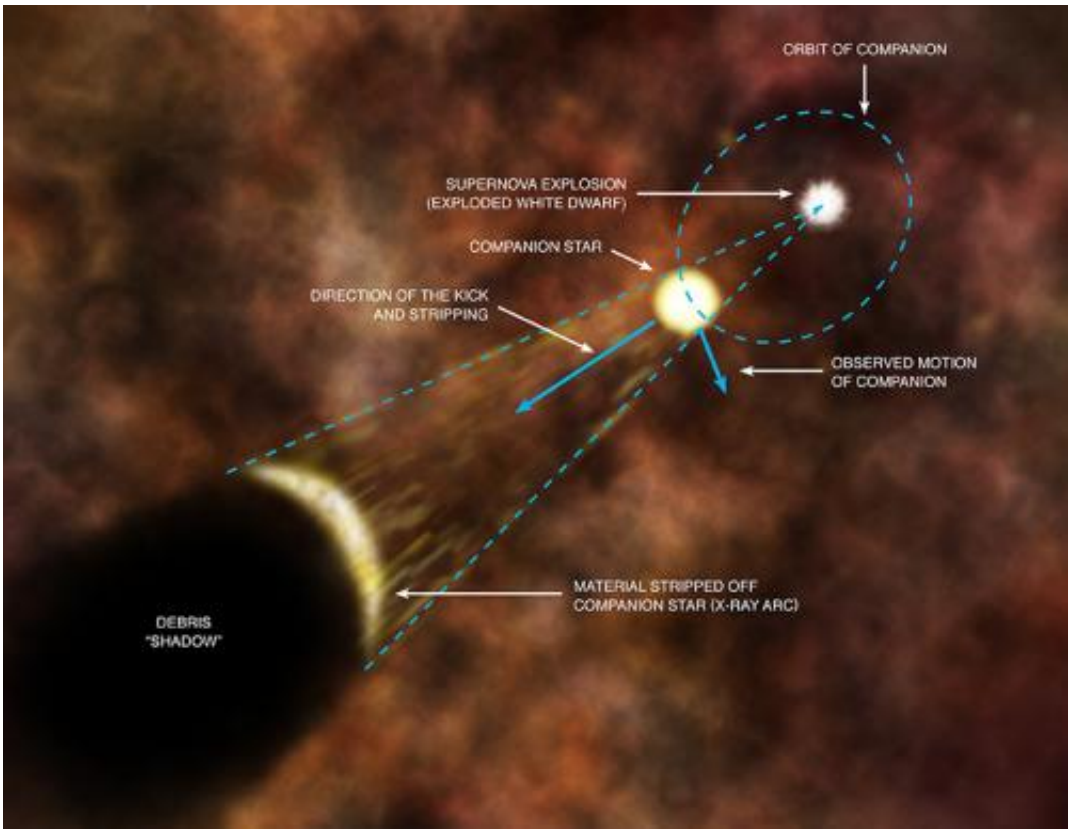
(PhysOrg.com) -- Astronomers may now know the cause of an historic supernova explosion that is an important type of object for investigating dark energy in the universe. The discovery, made using NASA's Chandra X-ray Observatory, also provides strong evidence that a star can survive the explosive impact generated when a companion star goes supernova.

The new study examined the remnant of a supernova observed by the Danish astronomer Tycho Brahe in 1572. The object, dubbed Tycho for short, was formed by a Type Ia supernova, a category of stellar explosion useful in measuring astronomical distances because of their reliable brightness. Type Ia supernovas have been used to determine that the universe is expanding at an accelerating rate, an effect attributed to the prevalence of an invisible, repulsive force throughout space called dark energy.

A team of researchers analyzed a deep Chandra observation of Tycho and found an arc of X-ray emission in the supernova remnant. Evidence supports the conclusion that a shock wave created the arc when a white dwarf exploded and blew material off the surface of a nearby companion star.

"There has been a long-standing question about what causes Type Ia supernovas," said Fangjun Lu of the Institute of High Energy Physics, Chinese Academy of Sciences in Beijing. "Because they are used as

steady beacons of light across vast distances, it is critical to understand what triggers them."



This is an artist's impression showing an explanation from scientists for the origin of an X-ray arc in Tycho's supernova remnant. It is believed that material was stripped off the companion star by the explosion of the white dwarf in the Type Ia supernova explosion, forming the shock wave seen in the arc. The arc has blocked debris from the explosion, creating a "shadow" behind the arc. The force of the explosion imparted a kick to the companion star, and this combined with the orbital velocity of the companion before the explosion to give the "observed" motion of the companion. Previously, studies with optical telescopes have revealed a star within the remnant that is moving much more quickly than its neighbors, showing that it could be the companion to the supernova. The size of the companion's orbit is not shown to scale here: the separation between it and the white dwarf before the explosion is estimated to have only been about a millionth of a light year, while the full scale of the illustration is over 10 light years. Credit: NASA/CXC/M. Weiss

One popular scenario for Type Ia supernovas involves the merger of two white dwarfs. In this case, no companion star or evidence for material blasted off a companion should exist. In the other main competing theory, a white dwarf pulls material from a "normal," or sun-like, companion star until a thermonuclear explosion occurs. Both scenarios may actually occur under different conditions, but the latest Chandra result from Tycho supports the latter one.

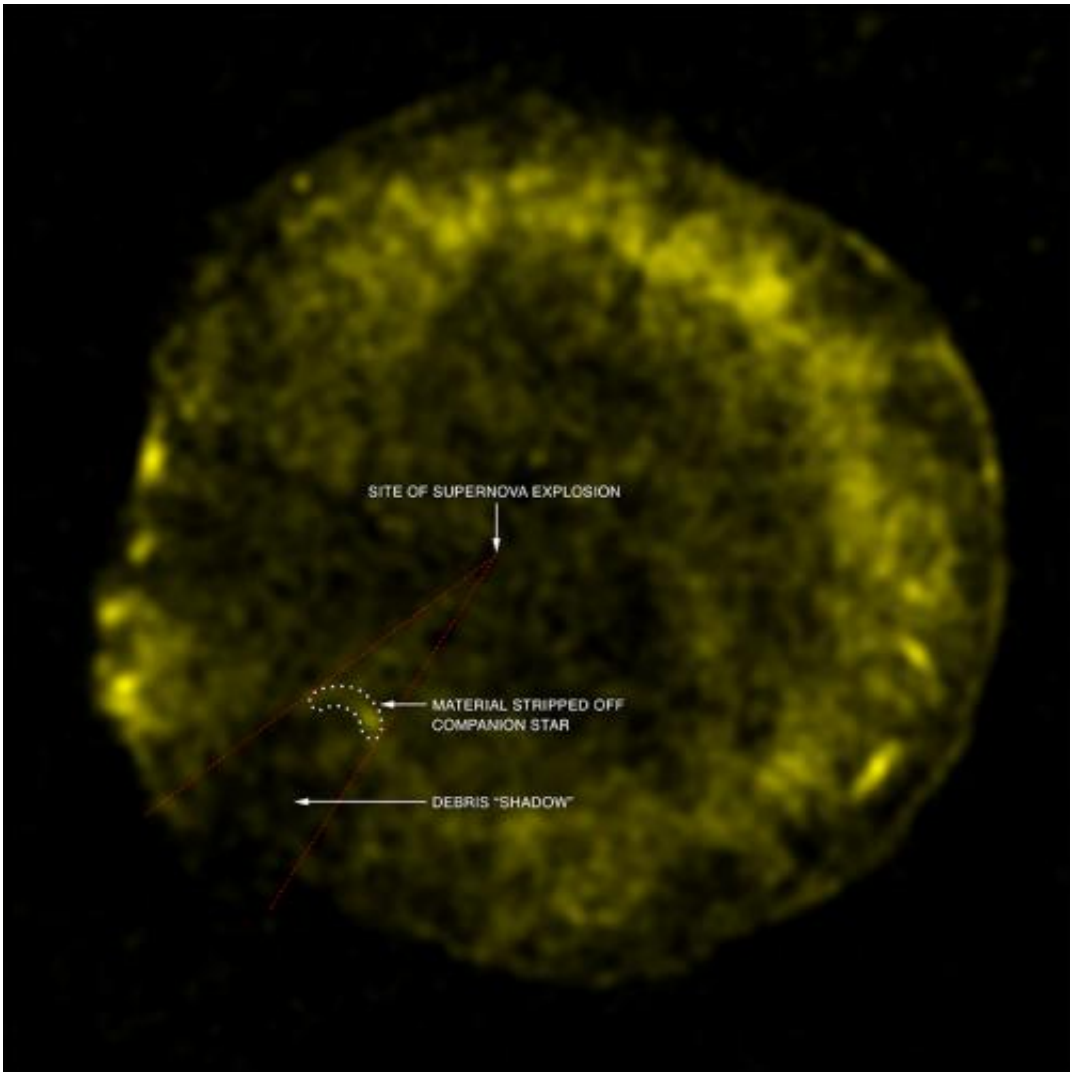
In addition, the Tycho study seems to show the remarkable resiliency of stars, as the supernova explosion appears to have blasted very little material off the companion star. Previously, studies with optical telescopes have revealed a star within the remnant that is moving much more quickly than its neighbors, hinting that it could be the missing companion.

"It looks like this companion star was right next to an extremely powerful explosion and it survived relatively unscathed," said Q. Daniel Wang of the University of Massachusetts in Amherst. "Presumably it was also given a kick when the explosion occurred. Together with the orbital velocity, this kick makes the companion now travel rapidly across space."

Using the properties of the X-ray arc and the candidate stellar companion, the team determined the orbital period and separation between the two stars in the binary system before the explosion. The period was estimated to be about 5 days, and the separation was only about a millionth of a light year, or less than a tenth the distance between the Sun and the Earth. In comparison, the remnant itself is about 20 light years across.

Other details of the arc support the idea that it was blasted away from

the companion star. For example, the X-ray emission of the remnant shows an apparent "shadow" next to the arc, consistent with the blocking of debris from the explosion by the expanding cone of material stripped from the companion.



This image shows iron debris in Tycho's supernova remnant. The site of the supernova explosion is shown, as inferred from the motion of the possible companion to the exploded white dwarf. The position of material stripped off the companion star by the explosion, and forming an X-ray arc, is shown by the white dotted line. This structure is most easily seen in an image showing X-rays from the arc's shock wave. Finally, the arc has blocked debris from the explosion

creating a "shadow" in the debris between the red dotted lines, extending from the arc to the edge of the remnant. Credit: Credit: NASA/CXC/Chinese Academy of Sciences/F. Lu et al

"This stripped stellar material was the missing piece of the puzzle for arguing that Tycho's supernova was triggered in a binary with a normal stellar companion," said Lu. "We now seem to have found this piece."

The shape of the arc is different from any other feature seen in the remnant. Other features in the interior of the remnant include recently announced stripes, which have a different shape and are thought to be features in the outer blast wave caused by cosmic ray acceleration.

These results will appear in the May 1st issue of *The Astrophysical Journal*. The other authors of the paper include M.Y. Ge, J.L. Qu, S.J. Zheng and Y. Chen from the Institute of High Energy Physics, and X.J. Yang from Xiangtan University. NASA's Marshall Space Flight Center in Huntsville, Ala., manages the Chandra program for NASA's Science Mission Directorate in Washington. The Smithsonian Astrophysical Observatory controls Chandra's science and flight operations from Cambridge, Mass.

Provided by Chandra X-ray Center