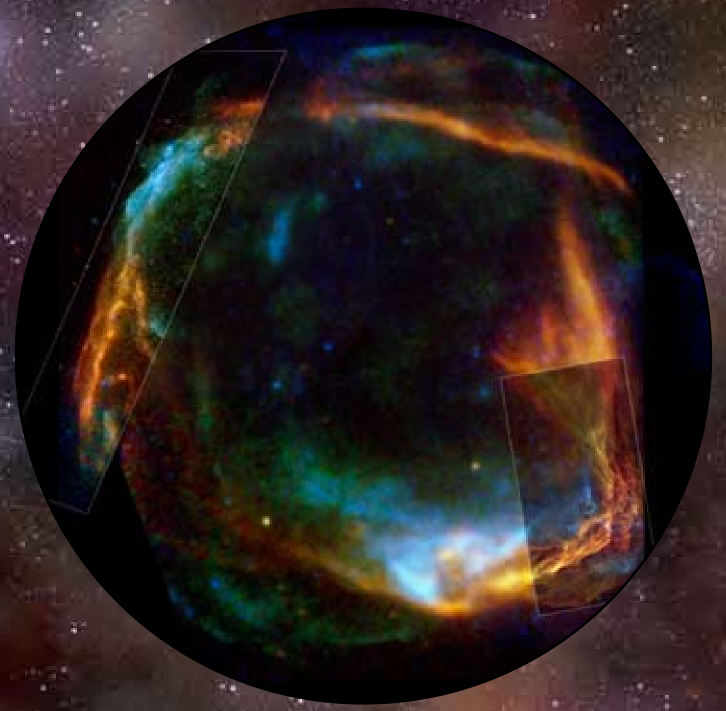
BLASTS from the PAST: Historic Supernovas



185

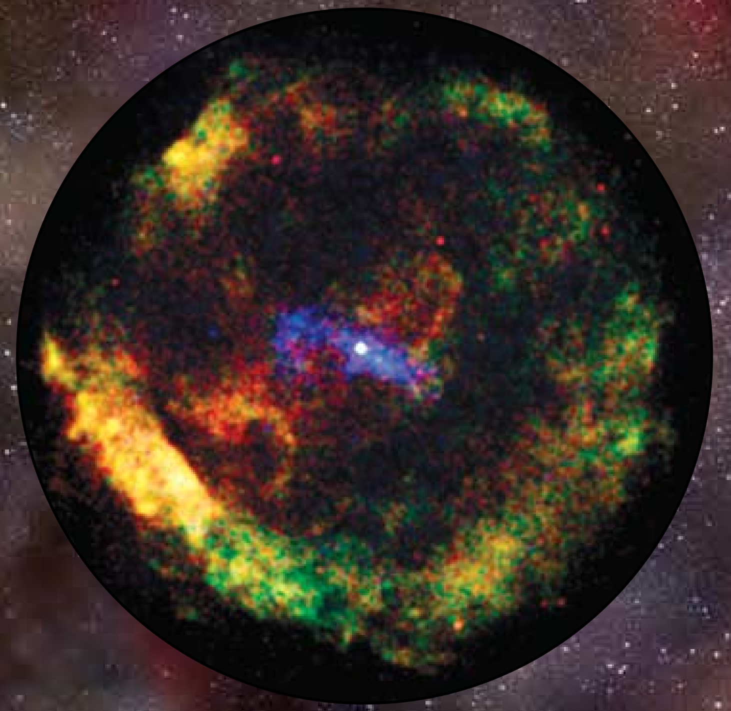
RCW 86

Historical Observers: Chinese

Likelihood of Identification: Possible

Distance Estimate: 8,200 light years

Type: Core collapse of massive star



386

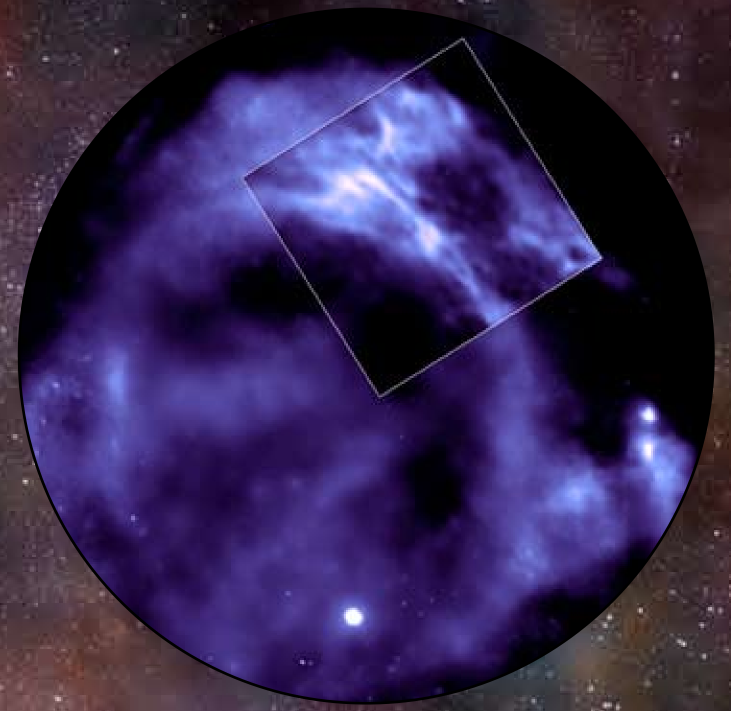
G11.2-0.3

Historical Observers: Chinese

Likelihood of Identification: Probable

Distance Estimate: 16,000 light years

Type: Core collapse of massive star



393

G347.3-0.5

Historical Observers: Chinese

Likelihood of Identification: Possible

Distance Estimate: 3,000 light years

Type: Core collapse of massive star?

1006

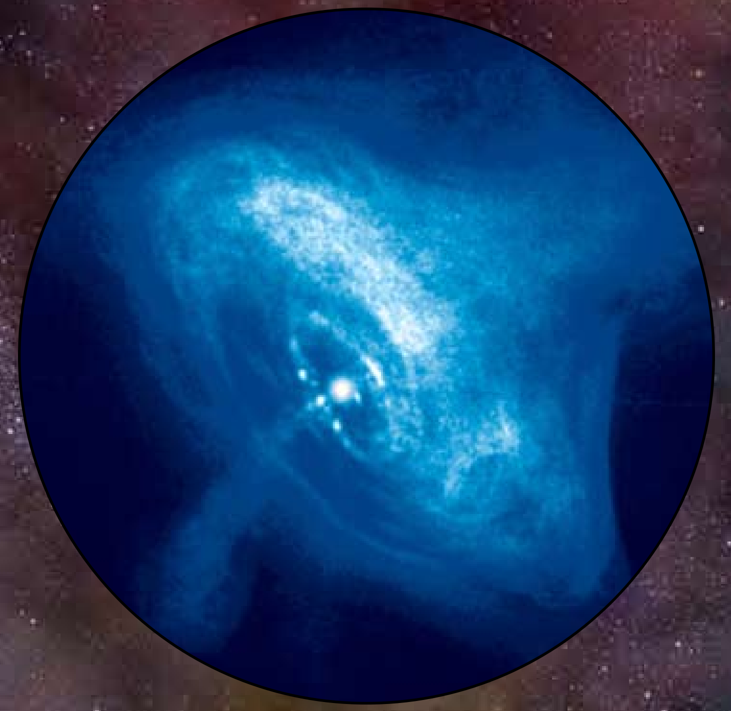
SN 1006

Historical Observers: Chinese, Japanese, Arabic, European

Likelihood of Identification: Definite

Distance Estimate: 7,000 light years

Type: Thermonuclear explosion of white dwarf



1054

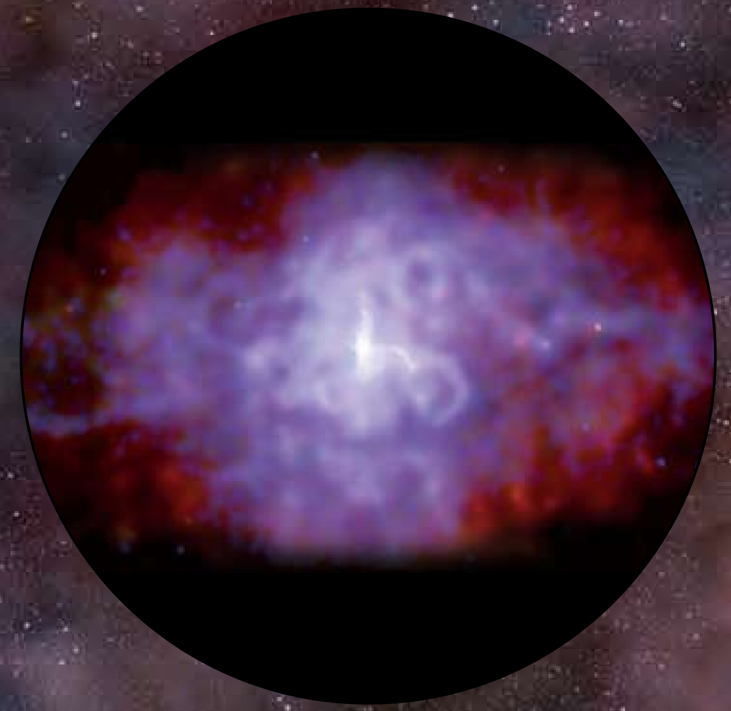
Crab Nebula

Historical Observers: Chinese, Japanese, Arabic, Native American?

Likelihood of Identification: Definite

Distance Estimate: 6,000 light years

Type: Core collapse of massive star



1181

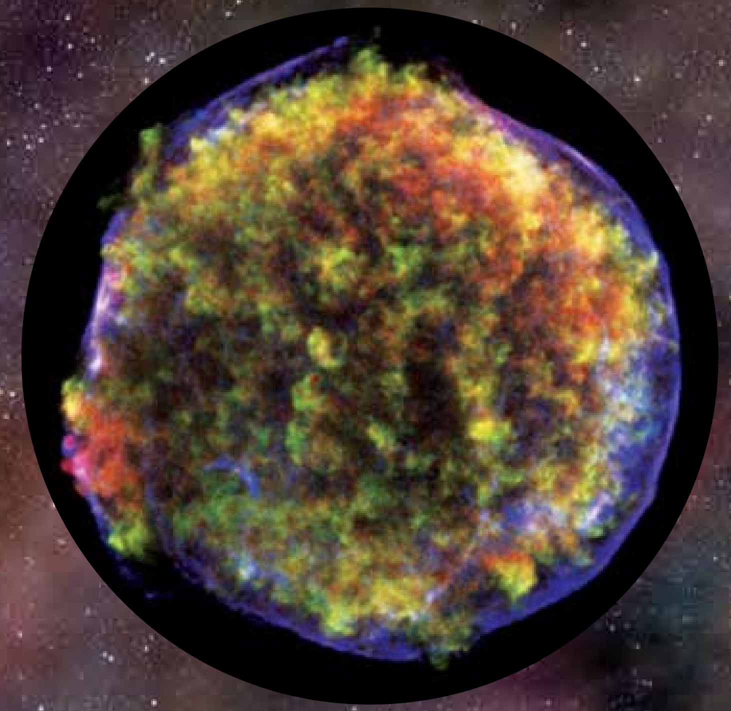
3C58

Historical Observers: Chinese, Japanese

Likelihood of Identification: Possible

Distance Estimate: 10,000 light years

Type: Core collapse of massive star



1572

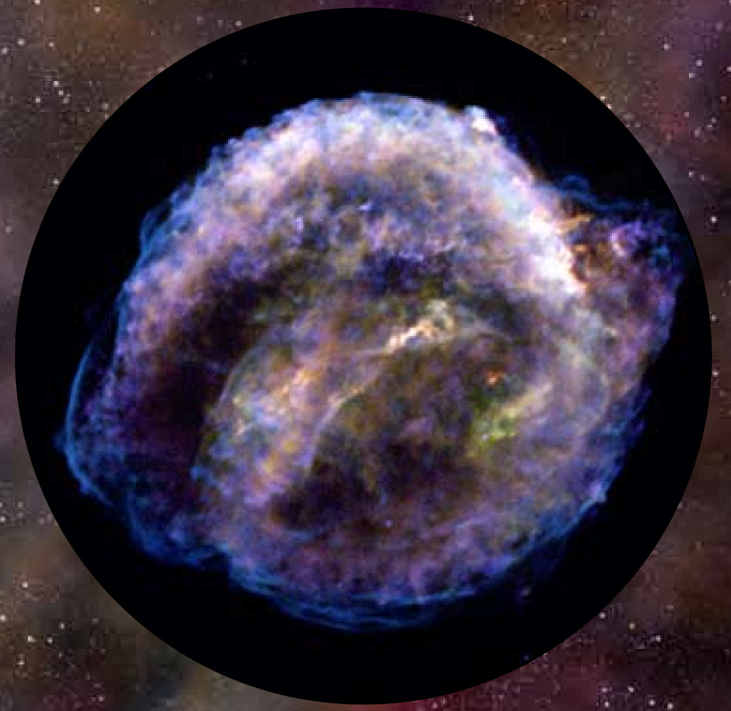
Tycho's SNR

Historical Observers: European, Chinese, Korean

Likelihood of Identification: Definite

Distance Estimate: 7,500 light years

Type: Thermonuclear explosion of white dwarf



1604

Kepler's SNR

Historical Observers: European, Chinese, Korean

Likelihood of Identification: Definite

Distance Estimate: 13,000 light years

Type: Thermonuclear explosion of white dwarf?

1680

Cassiopeia A

Historical Observers: European?

Likelihood of Identification: Possible

Distance Estimate: 10,000 light years

Type: Core collapse of massive star

NASA's Chandra X-ray Observatory

HISTORIC SUPERNOVAS

Every 50 years or so, a star in our Galaxy blows itself apart in a supernova explosion, one of the most violent events in the universe. The force of these explosions produces spectacular light shows. Explosions in past millennia have been bright enough to catch the attention of early astronomers hundreds of years before the telescope had been invented.

Since supernovas are relatively rare events in the Milky Way, they are best studied by combining historical observations with information from today. This cosmic forensic work involves interdisciplinary research by historians and astronomers, and can provide valuable clues about supernovas in our Galaxy in the relatively recent past.

Historical observations were made using optical light, but today the material from the destroyed star can be studied across the full electromagnetic spectrum, including X-ray light. Because material is heated to millions of degrees, the remnants of supernova explosions often glow brightly in X-rays for thousands of years. The Chandra X-ray Observatory images on the front of this poster shows the remnants of historic supernovas that occurred in our galaxy. Eight of the best examples are shown.

Based on the evidence, there is a range of confidence about whether the historical record can be definitively tied to the remnant seen today. For example, astronomers are fairly certain that an event seen in 1572 resulted in a beautiful supernova remnant now seen with Chandra and other observatories. Although telescopes had yet to be invented, Tycho Brahe, a Danish amateur astronomer, used an ingenious array of instruments to make accurate measurements of the position of the “new star”. For 18 months, the brightness of the star declined steadily until it became invisible. The explosion of the star shattered forever the widely accepted doctrine of the incorruptibility of the stars, and set the stage for the work of Kepler, Galileo, Newton and others. The supernova remnant, appropriately, became known as “Tycho”.

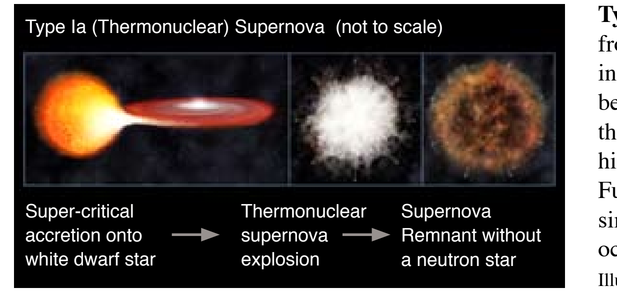
Other relatively secure identifications include supernovas observed in 1006 and 1054 A.D. The supernova of 1006 (SN 1006) was the brightest supernova ever seen on Earth, outshining Venus. It was, by historical accounts, visible to the unaided eye for several years. There is also strong evidence to show that the supernova of 1054 A.D. was the explosion that produced the Crab Nebula.

A much less solid historical association comes with the supernova remnant Cassiopeia A (Cas A). The observed expansion of the remnant indicated that it should have been observed around 1671 AD. In 1680 a star was reportedly seen — but never seen again — near the position at which the Cas A remnant was detected in radio wavelengths in the 20th century.Therefore, it might have been the explosion that produced Cas A, but this identification is controversial, since it was reported by only one person.

Current estimates suggest that about three dozen supernovas should have occurred in the Galaxy over the past two millennia. However, there have been many fewer than that reported. This relative scarcity may be due to several factors, including the omission of supernovas that were only visible from the Southern sky (most historical astronomical recordings come from observers in the Northern Hemisphere). Also, any supernovas that exploded on the far side of the Galaxy would have not been seen with the unaided eye, nor would those that were embedded in obscuring clouds of dust and gas.

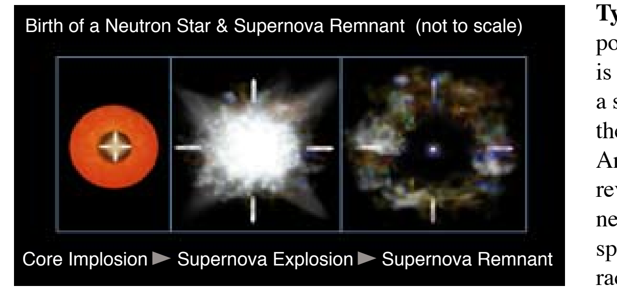
Why go to all of this trouble? Supernovas are extremely important for understanding — among many other topics including the history of the universe — the origin of the elements that are necessary for life. Massive stars take simple hydrogen and helium and turn them into heavier, more complex elements, which are then distributed into space when the star explodes. By understanding supernovas, we help to understand ourselves.

CHANDRA X-RAY OBSERVATORY


Type Ia (Thermonuclear) Supernova (not to scale)

Type-Ia supernova: When accretion of gas from a companion star in a binary system increases the mass of a white dwarf star beyond 1.4 solar masses, temperatures in the core of the white dwarf become high enough for carbon fusion to occur. Fusion begins throughout the star almost simultaneously and a powerful explosion occurs, leaving no remnant.

Illustrations: NASA/CXC/M.Weiss


Birth of a Neutron Star & Supernova Remnant (not to scale)

Type-II supernova: When the nuclear power source at the core of a massive star is exhausted, the core collapses. In less than a second, a neutron star (or a black hole if the star is extremely massive) is formed. An enormous amount of energy is released, reversing the implosion. All but the central neutron star is blown away at tremendous speeds, accompanied by a shock wave that races through the expanding stellar debris.

RCW 86

As reported in a single Chinese record, the supernova of 185 AD was visible for at least 8 months and reached a brightness comparable to Mars. Optical, radio, and X-ray emission observed at a location consistent with the Chinese record make RCW 86 the prime candidate for the remnant of SN 185 AD. Combined images from the Chandra (upper left and lower right boxes) and XMM-Newton X-ray observatories show low, medium and high-energy X-rays in red, green, and blue respectively. By studying the amount of X-rays at different energies, and measuring the remnant’s size, scientists now surmise that RCW 86 was created by the explosion of a massive star roughly 2,000 years ago.

Credit: Chandra: NASA/CXC/Univ. of Utrecht/J.Vink et al.;
XMM-Newton: ESA/Univ. of Utrecht/J.Vink et al.

G11.2-0.3

The new star of 386 AD was recorded by Chinese observers and was visible for about three months. Although there are several supernova remnants in the vicinity of the reported outburst, G11.2-0.3 is the prime candidate. G11.2-0.3 is a circularly symmetric supernova remnant that contains a dense, rotating dead star at its center (white). In Chandra’s X-ray image, the pulsar and a cigar-shaped cloud of energetic particles, known as a pulsar wind nebula, are predominantly seen as high-energy X-rays (blue). A shell of heated gas from the outer layers of the exploded star surrounds the pulsar and the pulsar wind nebula and emits lower-energy X-rays (represented in green and red).

Credit: NASA/CXC/Eureka Scientific/M.Roberts et al.

G347.3-0.5

The supernova of 393 AD was recorded by the Chinese and was visible for about 8 months, reaching the brightness of Jupiter. There are several supernova remnants within this region, so it is difficult to identify the remnant of SN 393 AD with certainty. X-rays from G347.3-0.5 are dominated by radiation from extremely high-energy electrons in a magnetized shell rather than radiation from a hot gas. The remnant, seen by Chandra (inset box) and XMM-Newton, is also a source of very high-energy gamma rays. The bright, point-like source on the lower right in the image (which shows only the upper portion of the entire remnant) is similar to other known neutron stars and indicates that G347.3-0.5 is the remnant of a core-collapse supernova.

Credit: Chandra: NASA/CXC/SAO/P.Slane et al.;
XMM-Newton:ESA/RIKEN/J.Hiraga et al.;

SN 1006

Numerous observers reported that supernova of 1006 AD (now known as SN 1006) attained a brightness greater than the planet Venus, making it the brightest supernova recorded as seen from Earth. A number of lines of evidence — its location well above the Galactic disk, the detection of significant amounts of cool iron gas in its interior, the absence of any evidence for a neutron star, and the implication from the historical record that it remained visible for several years — imply that SN 1006 was the result of the explosion of a white dwarf star. The Chandra image shows X-rays produced by high-energy particles (blue) and multimillion degree gas (red/green).

Credit: NASA/CXC/Rutgers/J.Hughes et al.

Crab Nebula

The Crab Nebula is the remnant of a supernova observed in 1054 AD. Its brightness was comparable to the planet Venus. The bright nebula, which has been known optically since the early 18th century, is due to the activity of a neutron star (bright white dot in the center of the image) that is rotating 30 times a second and spewing out a blizzard of extremely high-energy particles. Chandra’s image of the Crab Nebula reveals rings and jets of high-energy particles that appear to have been flung outward over great distances from the neutron star. The diameter of the inner ring is about 1,000 times the diameter of our solar system.

Credit: NASA/CXC/ASU/J.Hester et al.

3C58

The new star of 1181 AD was extensively observed in both China and Japan, and reached a peak brightness comparable to the bright star Sirius. Its reported position is close to the supernova remnant 3C58. The discovery of a rapidly rotating neutron star (inside the bright spot in the center of the image) in the remnant, and the overall similarity in appearance to the Crab Nebula argue in favor of an identification consistent with an age of somewhat less than 1000 years. However the rate at which the filamentary shell of gas is expanding is much too slow to have reached its present size in 826 years, so the association of 3C58 with SN 1181 is listed as possible rather than definite.

Credit: NASA/CXC/SAO/P.Slane et al.

Tycho’s SNR

In 1572, the Danish astronomer Tycho Brahe observed and studied the explosion of a star that became known as Tycho’s supernova. More than four centuries later, Chandra’s image of the supernova remnant shows an expanding bubble of multimillion degree debris (green and red) inside a more rapidly moving shell of extremely high-energy electrons (filamentary blue). Stellar debris moving at 6 million miles per hour has created two X-ray emitting shock waves: one moving outward into the interstellar gas, and another moving back into the debris. These shock waves produce sudden, large changes in pressure and temperature, like an extreme version of sonic booms produced by the supersonic motion of airplanes.

Credit: NASA/CXC/Rutgers/J.Warren & J.Hughes et al.

Kepler’s SNR

The “new star” of 1604 AD was reported by astronomers in Europe, China and Korea. At its peak, the brightness of the supernova was greater than that of Jupiter. It is called Kepler’s supernova, because Johannes Kepler determined an accurate position for the supernova and recorded its steady decline in brightness. Chandra’s image of the remnant shows high-energy X-rays (blue) from extremely energetic electrons at the location of a rapidly moving outer shock wave generated by the explosion. The interior contains gas heated to millions of degrees by a more slowly moving shock wave. The composition of the hot gas and the absence of a neutron star indicate that Kepler’s supernova was a Type Ia event.

Credit: NASA/CXC/NCSU/S.Reynolds et al.

Cassiopeia A

The nature of the explosion that produced the Cassiopeia A (Cas A) supernova remnant is an enigma. The observed expansion of the remnant indicates an age of about 336 years, so the event should have been observed around 1671 AD, yet no reliable reports of the supernova exist. Recent calculations indicate that Cas A was possibly produced by a star that lost much of its mass to a companion star so that a relatively small fraction of its explosion energy was emitted as optical light. In the Chandra image, blue, wispy arcs show where particles are accelerated to extremely high energies by an expanding shock wave generated by the explosion. The red and green regions show material from the destroyed star that has been heated to millions of degrees by more slowly moving shock waves.

Credit: NASA/CXC/MIT/UMass Amherst/M.D.Stage et al.

NASA’s Marshall Space Flight Center, Huntsville, Ala., manages the Chandra program for the agency’s Science Mission Directorate.
The Smithsonian Astrophysical Observatory controls science and flight operations from the Chandra X-ray Center in Cambridge, Mass.

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