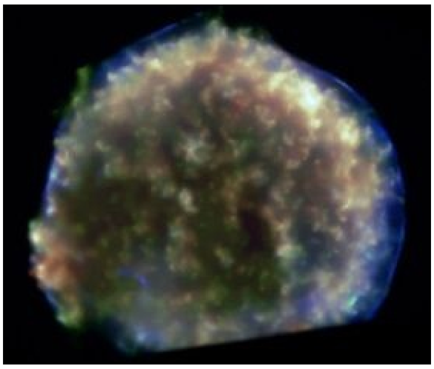
Tycho's Star



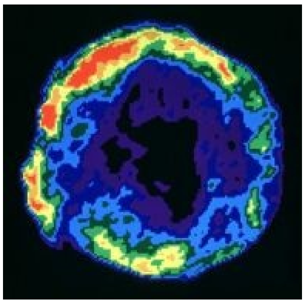
CXC, SAO, NASA

Larger x-ray image.

Colored according to x-ray energy intensity, this supernova remnant's bluish shockwave bubble is twice as hot as the mottled gaseous debris expanding behind at 10 million degrees Celsius (more at Astronomy Picture of the Day and CXC).

- **Type-Ia Supernovae**

"Tycho's star" was a supernova that appeared in 1752 CE. According to Robert Burnham, Jr. (1931-93), this "guest star" was first noted by Wolfgang Schuler (?-1575) as early as November 6, 1572, but was seen by many observers throughout Europe and in the Far East, shattering locally held beliefs in the immutable nature of stars. While Tycho Brahe (1546-1601) was not the first to observe the supernova in Cassiopeia, he became known as a respected astronomer after publishing his careful observations about the "new star" -- Stella Nova in Latin -- two years later (more history and links from Hartmut Frommert and Christine Kronberg). Tycho found it at first as bright as Jupiter, but the supernova soon grew as brilliant as Venus (around -4 magnitude). For about two weeks the star could be seen in daylight, but at the end of November it began to fade and change color, from bright white over yellow and orange to faint reddish light, finally fading away from visibility in March, 1574, having been visible to the naked eye for almost 16 months (more about Brahe's "acid tongue and silver nose," the cultural shock of the "new star," and how supernovae create high-energy radiation from Wallace H. Tucker).

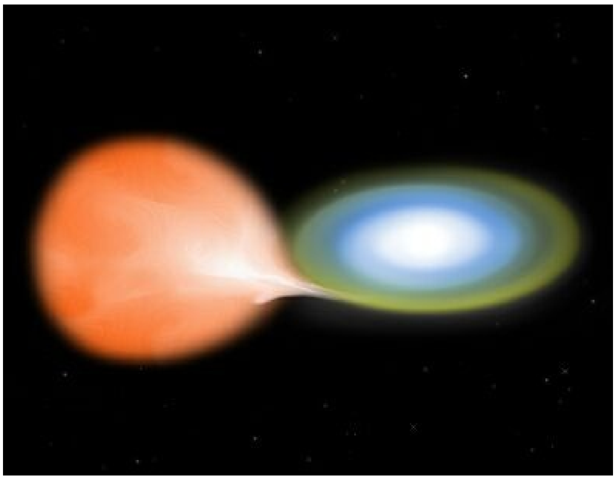


VLA, NRAO, AUI, NSF

Larger radio image at 1.4 GHz.

Tycho's supernova remnant, which lacks a central point source, was first found by radio telescope (more).

The remnant of the supernova was not found until 1952, with the help of the Jodrell Bank radio telescope (Brown and Hazard, 1953), catalogued as radio source 3C 10. Shortly thereafter, faint optical wisps in the same location were discovered using the 200-inch telescope at Mt. Palomar during the 1960s, when an extremely faint nebulosity was identified on photo plates. The gas shell is now expanding at about 5,600 miles (9,000 km) per second -- much more than the Crab Nebula's expansion speed of about 600 miles (1,000 km) per second) -- and has grown to about 3.7 arc-minutes -- around 24 light-years (ly) wide according to one estimate. However, no central point source has been detected within the Tycho supernova remnant (SNR), which is consistent with other evidence that the SNR was created by a Type-Ia supernova.

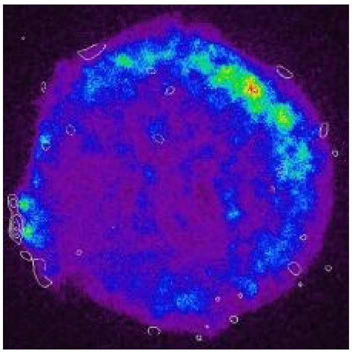


M. Weiss, CXC, NASA

Larger illustration.

"Tycho's Star" may have begun as a white dwarf that accreted too much mass from a close companion star and exploded as a Type-Ia supernova (more).

Supernovae are classified as Type I if their light curves exhibit a sharp peak and then fades away smoothly and gradually. In theory, such supernovae are caused by the detonation of a relatively high-mass white dwarf composed mostly of carbon and oxygen (a stellar remnant whose progenitor star was too low in mass to progress to the core fusion of heavier elements) when infalling matter from the gaseous envelope of a moderately massive, binary companion eventually creates enough gravitational pressure to overcome the electron degeneracy holding up the white dwarf (illustrations of accretion theory). Already more massive than Sol, the white dwarf accretes sufficient additional mass to exceed the critical limit of 1.4 Solar-masses ("Chandrasekhar mass limit"). Such supernovae can also occur when two closely orbiting, however, white dwarfs collide and merge to create a single object that exceeds 1.4 Solar-masses. The spectra of these supernovae are hydrogen-poor relative to the more common Type II supernovae, which is consistent with the presumption the white dwarf progenitors of Type I have already blown off most of their outer layers of hydrogen and helium in planetary nebulae. Moreover, the smooth decline of their light is also believed to result from the gradual decrease in energy available with the radioactive decay of the unstable heavy elements produced in Type-I supernovae.

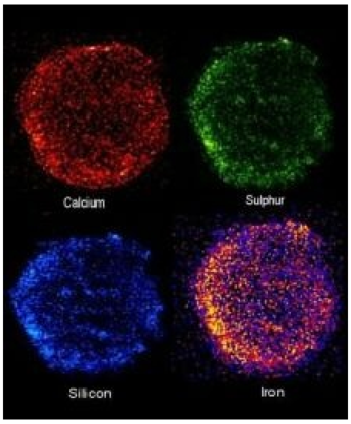


ROSAT, MPE, CXC, NASA

Larger x-ray image.

Contours show spatial and spectral changes observed over 4 years time as shocks expand into interstellar gas and dust (more at CXC).

In the accretion scenario, the white dwarf accretes mass from its companion relatively rapidly. Moreover, any "nova outbursts" that occur on the white dwarf are relatively weak and eject little matter, so that the white dwarf grows in mass. (This is different from the mechanism of a "nova" in which the white dwarf doesn't reach the Chandrasekhar limit and collapse, but merely ignites nuclear fusion in the matter that has accreted on its surface) When the accretion has raised the white dwarf's mass to the critical mass of about 1.4 solar masses, the density and temperature in the star's center become so severe that carbon and oxygen start fusing ("burning") explosively. Within roughly one second, the burning front moves all the way to the surface, making the entire white dwarf into one huge nuclear fireball (more illustrated discussion of novae versus supernovae). A thermonuclear shockwave races through the supernova's expanding stellar debris, fusing lighter elements into heavier ones and producing a brilliant visual outburst that can be as intense as the light of billions of stars. The entire star explodes and destroys itself, without leaving a compact central object. All of the star's matter -- namely, the products of the nuclear burning (iron, nickel, silicon, magnesium, and other heavy elements) plus unburned carbon and oxygen -- are ejected into space at speeds ranging from about 6,000 to 8,000 miles/second (20 to 30 million miles/hour). The supernova explosion and the sudden dispersion of its gravitational mass presumably flings its companion star away at high velocity. Unlike supernovae of Type II, the matter ejected in Type-I supernovae consists almost entirely of the heavier elements (spectrum of some elements in Tycho's SNR), as there is very little hydrogen left on white dwarfs. While the tremendous increase in luminosity is given by energy liberated by the explosion, its gradually fading light is fueled by radioactive cobalt decaying into iron.

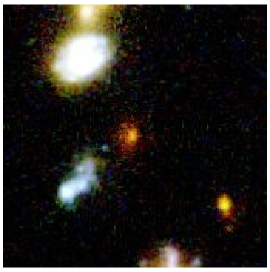


XMM-Newton, ESA,

Larger x-ray image.

Some of the elements created by Tycho's supernova are: Calcium (red), Sulphur (green) Silicon (blue), and Iron (multicolor to yellow) (more from ESA).

In contrast to Type-Ia supernovae, Type Ib and Type Ic do not exhibit silicon lines and are even less understood than Type Ia. Types Ib and Ic are believed to correspond to stars ending their lives (as Type-II supernovae), but such stars would have lost their hydrogen before, and so hydrogen lines don't appear on their spectra (more). A Type Ib supernova may result from a high-mass star that has blown off much of its outer hydrogen and helium shells and so most closely resembles a Type Ia supernova. It is somewhat dimmer as much of the light is absorbed by the surrounding nebula of material that the star has just recently blown off, and no helium seen in their spectra. A Type Ic supernova may be produced by a high-mass star that has blown off much of its outer hydrogen layer while still retaining a significant helium layer, and so it is similar to a Type Ib except that helium is seen in its spectrum.



Adam Riess, STScI, NASA, NERSC, LBL

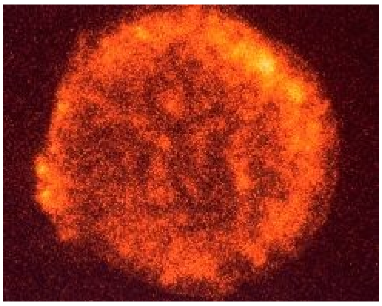
Larger infrared and collage images.

Type-Ia supernovae (such as SN 1997ff located around 11.3 billion light-years away) are useful "standard candles" for their very distant host galaxies (more).

Supernovae of Type I lend themselves well to research into cosmological parameters because they are intrinsically very bright and, hence, can be seen to great distances. These supernovae all have nearly identical intrinsic luminosities, and so comparisons of their actual, observed luminosities with their known intrinsic luminosities allows astronomers to determine their distances (more on their usefulness as "standard candles" (Branch and Tammann, 1992). Moreover, the wavelength distribution of the light from the supernovae indicates how fast they are receding from Sol. Estimating both the distance and recession speed of ancient Type-Ia supernovae allow astronomers to calculate the expansion of the universe, back during an era when matter in the universe was still relatively dense and expansion was still slowing under the influence of gravity and before its later hypothesized, subsequent acceleration from a mysterious repulsive force (more from NASA's Observatorium and NERSC's press release).

Tycho's Supernova Remnant

Tycho's supernova remnant (SNR) is located around 7,500 light-years (ly) from Sol in the north central part (0:25:17+64:8:37, J2000; and 0:25:13+64:8.7, ICRS 2000.0) of Constellation Cassiopeia, the Lady of the Chair -- north of Kappa Cassiopeiae and Shedar (Alpha Cassiopeiae); northeast of Caph (Beta Cassiopeiae); northwest of Gamma Cassiopeiae, Ruchbah (Delta Cassiopeiae), Achird (Eta Cassiopeiae), M103, and the Double Cluster, and southeast of Errai (Gamma Cephei). Useful catalogue numbers and designations for this supernova remnant include: Tycho'S SN, Tycho SNR, SN 1572, SNR 021.0+63.0, SNR 120.1+01.4, SNR 120.2+01.4, NOVA Cas 1572, X Cep X-1, B Cas, GRS 120.10 +01.40, and BD+63 39a.



Steven L. Snowden, ROSAT, MPE, NASA

Larger x-ray image.

Tycho's supernova remnant is located around 7,500 ly away in Cassiopeia (more at Astronomy Picture of the Day and HEASARC).

The SNR now found at the location of Tycho's star is outlined by a shock wave produced by the expanding debris (shown by the strikingly sharp blue circular arcs of 20 million degree Celsius gas seen on the outer rim of the Chandra x-ray image at the top of this web page). The interior stellar debris has a "cooler" temperature of about 10 million degrees and is visible only in X-rays (seen as mottled yellow, green and red fingers of gas in the same Chandra x-ray image at top). In radio wavelengths, the shell of Tycho's SNR is brightest to the northeast. Faint filaments and knots in the north northwest, northeast, and east can be seen through optical telescopes. The shell in x-rays is coincident with the radio shell and is brighter to the northeast. A faint radio source near center of the remnant appears to be extragalactic. Although absorption in ionized hydrogen suggests that the SNR is about 13,000 to 16,000 ly (4,000 to 5,000 pc) away (Schwarz et al, 1995), analysis of its optical proper motion and modelled shock velocity provides a distance of about 7,500 ly (2,300 pc) (more at T. Joseph W. Lazio's Tycho's Supernova Remnant).

Tycho's SNR has particular features can be contrasted with the Cassiopeia A (Cas A) supernova remnant, which is a product of a Type-II supernova. The debris shell for Tycho is distributed in clumps (Dickel et al, 1991) rather than knots as in Cas A, and its outer shockwave bubble can be seen in smooth and continuous arcs rather than being fragmented, as in Cas A. Lastly, Cas A appears to have a central point source of high-energy radiation from a presumed neutron star or black hole.

- **Other Information**
  - Radio astronomer T. Joseph W. Lazio has a web page on Tycho's Supernova Remnant with spectral tomographic maps.
  - Up-to-date technical summaries on this star are available at: NASA's ADS Abstract Service for the Astrophysics Data System; and the SIMBAD Astronomical Database mirrored from CDS, which may require an account to access.
  - With its stars shaped in a "W," the northern Constellation Cassiopeia was named by the Ancient Greeks for the mother of Andromeda who claimed to be more beautiful than the daughters of Nereus, a god of the sea. Cassiopeia's vanity so angered the sea god Poseidon that he had Andromeda chained to a rock of the coast as a sacrifice for Cetus (the monstrous whale) until Perseus rescued her. For more information on stars and other objects in this Constellation and a photograph, go to Christine Kronberg's Cassiopeia. For an illustration, see David Haworth's Cassiopeia.
  - For more information about stars including spectral and luminosity class codes, go to ChView's webpage on The Stars of the Milky Way.