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October, 1999

SUPERNOVAE

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SUPERNOVAE

Cassiopeia A, E0102-72, and N132D are examples of what happens after a massive star explodes. Material from the explosion rushes outward at supersonic speeds in excess of a million miles per hour. As this matter crashes into gas that surrounded the former star, shock waves analogous to awesome sonic booms heat the gas and heat the ejected matter. These beautiful pictures made by the Chandra X-ray Observatory reveal shells of hot gas that have temperatures of millions of degrees. The shells are too hot to be seen with optical telescopes.

Cassiopeia A, or Cas A, is the 320 year old remnant of a massive star that exploded in the constellation of Cassiopeia. At least two shock waves have heated the gas to 50 million degrees: an inner shock thought to be due to the collision of ejecta from the explosion with surrounding matter, and a faster outer shock racing away from the site of this collision. The point-like object near the center of the remnant may be the long sought neutron star or black hole left by the supernova explosion. The colors in this picture show the brightness of the X rays, where lighter areas represent the most intense X-ray emission. *Image made with the Advanced CCD Imaging Spectrometer (ACIS).*

E0102-72 is a supernova remnant in the Small Magellanic Cloud, a satellite galaxy of the Milky Way. Located in the constellation Tucana, this galaxy is 190,000 light years from Earth. The remnant is approximately a thousand years old. Stretching across forty light years of space, the multi-million degree source resembles a flaming cosmic wheel. *Image made with ACIS.*

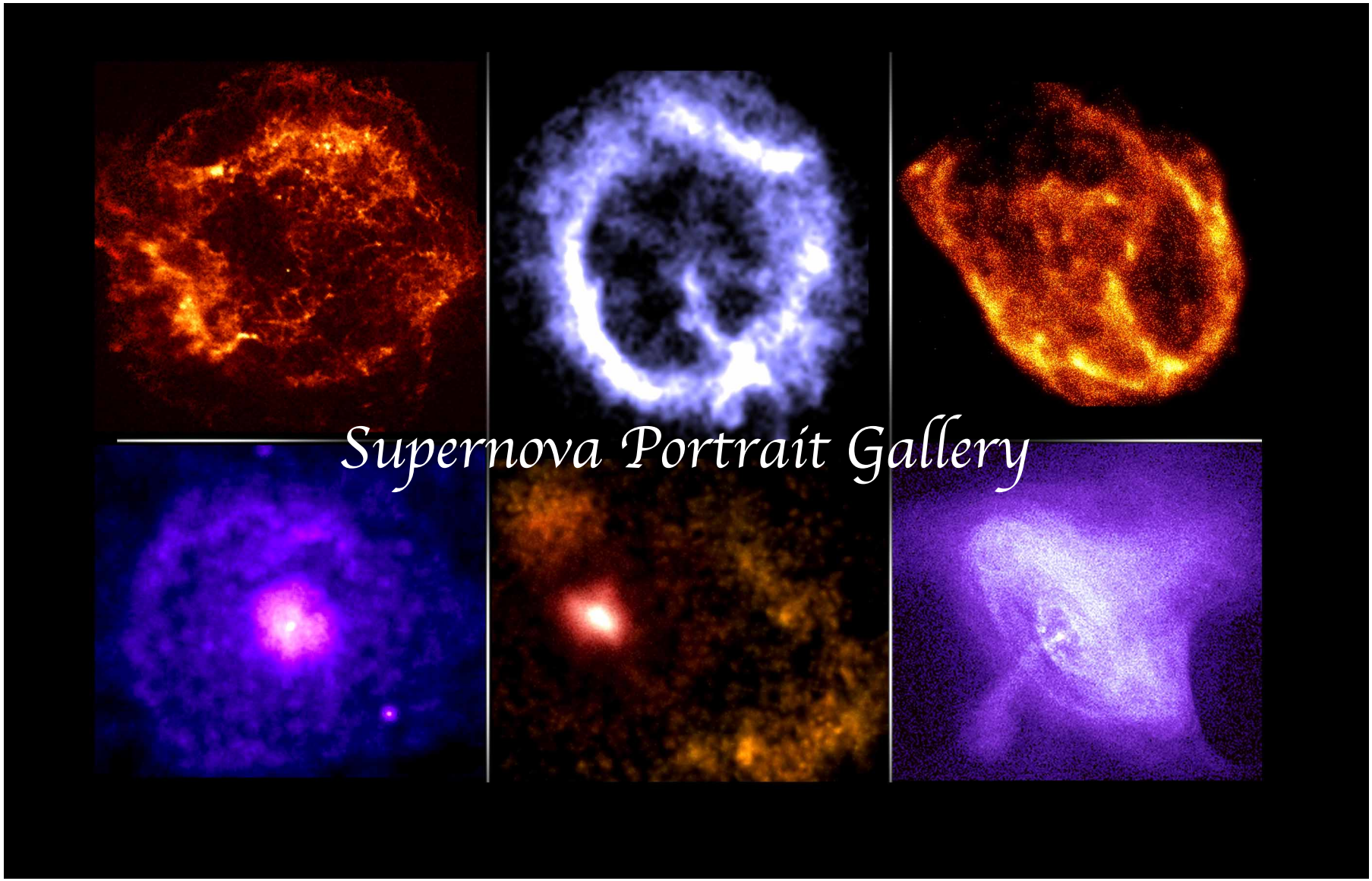
N132D is the remnant of an exploded star in the Large Magellanic Cloud. The Chandra image shows a highly structured remnant, or shell, of 10-million-degree gas that is 80 light years across. The remnant is thought to be about 3,000 years old and appears to be colliding with a giant molecular cloud, which produces the brightening on the southern rim of the remnant. The relatively weak X radiation on the upper left shows that the shock wave is expanding into a less dense region on the edge of the molecular cloud. *Image made with the High Resolution Camera (HRC).*

The Crab Nebula, PSR 0540-69, and G21.5-0.9 are also the remains of massive stars that have exploded, but the effect of a collapsed core in the form of a neutron star, or pulsar, is visible. The central pulsars are rotating rapidlyand pumping energetic particles into the surrounding space. These energetic particles produce X rays through a process known as synchrotron radiation. This process occurs when energetic particles, such as electrons, spiral around magnetic field lines.

The Crab Nebula in the constellation Taurus is the remnant of a supernova explosion that was seen on Earth in 1054 AD. It is 6000 light years from Earth. At the center of the bright nebula is a rapidly spinning neutron star, or pulsar that emits pulses of radiation 30 times a second. Chandra's X-ray image of the Crab Nebula directly traces the most energetic particles being produced by the pulsar. This amazing image reveals an unprecedented level of detail about the highly energetic particle winds and will allow scientists to probe deep intothe dynamics of this cosmic powerhouse. *Image made with ACIS/ High Energy Transmission Grating (ACIS/HETG).*

PSR 0540-69 is 180,000 light years away from Earth in the Large Magellanic Cloud. It is a supernova remnant with a central neutron star, or pulsar, at the that makes a complete rotation every one-twentieth of a second. It is similar in many ways to the famous Crab Nebula pulsar. Both objects are spinning rapidly, are about 1,000 years old and are surrounded by a cloud of gas and high energy particles. The large outer ring is due to hot multi-million degree gas produced by the supernova explosion. *Image made with HRC.*

G21.5-0.9, located in the constellation Scutum, is thought to be the remnant of a supernova explosion based on indirect evidence from radio and X-ray observations. At both radio and X-ray wavelengths, it appears as a round patch in the sky. Detailed observations with radio telescopes confirm that the radio waves are produced by high energy electrons spiraling around magnetic field lines. The X-rays are probably produced by the same process, but the electrons involved have energies many thousands times higher than those that produce the radio waves. *Image made with ACIS.*



Clockwise from top left: Cassiopeia A, E0102-72.3, N132D,
Crab Nebula, PSR 0540-69, G21.5-0.9

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