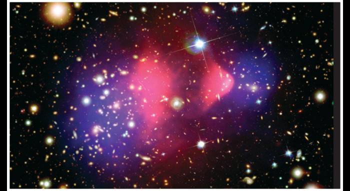
NASA's Marshall Space Flight Center, Huntsville, Ala., manages the Chandra program for the agency's Science Mission Directorate. The Smithsonian Astrophysical Observatory controls science and flight operations from the Chandra X-ray Center in Cambridge, Mass.

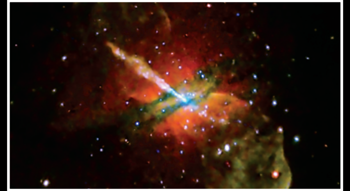
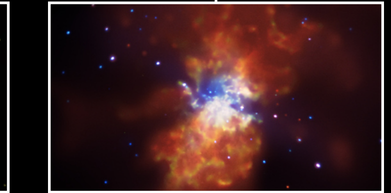
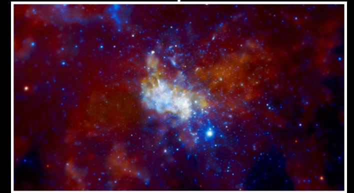
http://chandra.si.edu

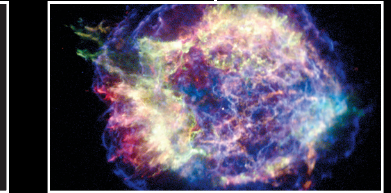
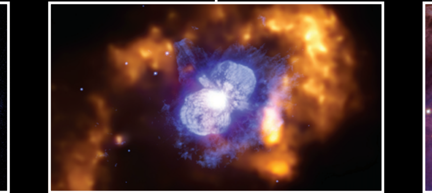
THE UNEXPECTED

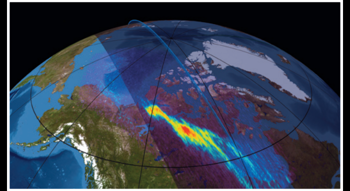
from NASA's Chandra X-ray Observatory

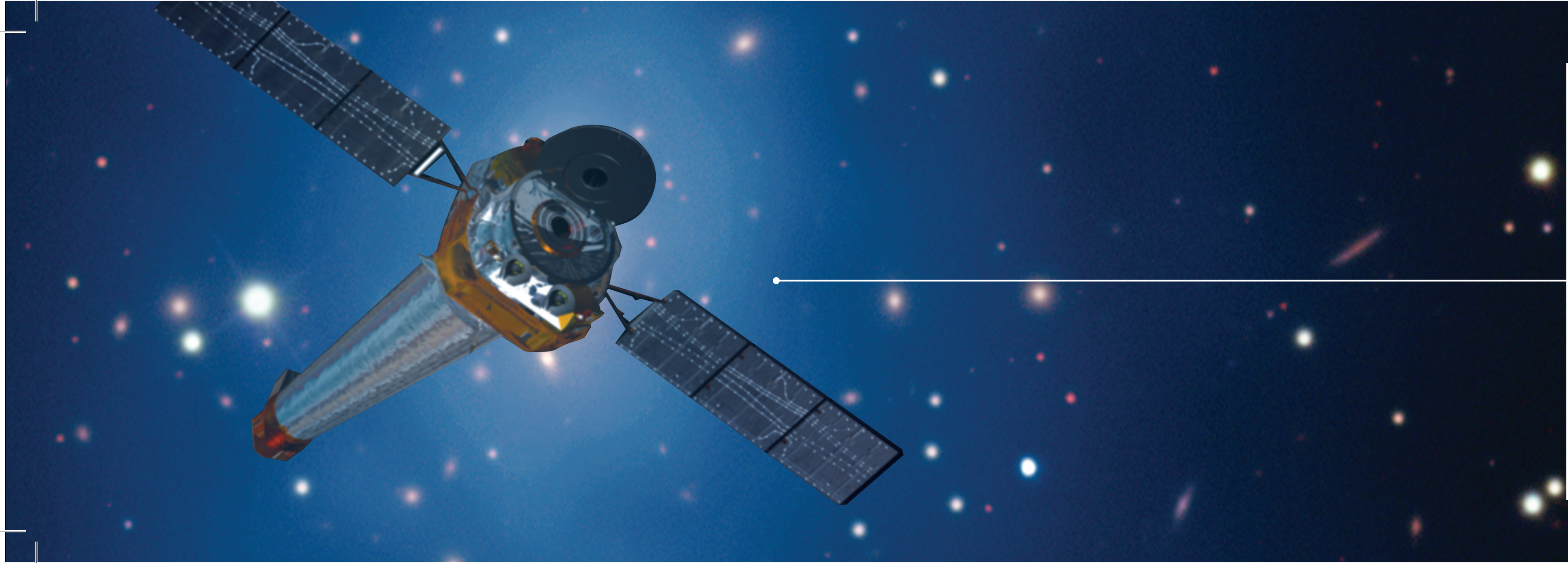








NASA's Chandra X-ray Observatory

Named after the Indian-American astronomer Subrahmanyan Chandrasekhar, Chandra was launched and deployed by Space Shuttle Columbia on July 23, 1999. Chandra is unique because of its sensitivity and its extremely high precision mirrors.

These features have led to discoveries in many areas of astronomy, especially in relation to the life cycles of stars, the role of supermassive black holes in the evolution of galaxies, and the study of dark matter and dark energy.

Looking back on the accomplishments of NASA's Chandra X-ray Observatory over the past dozen years, and trying to predict what it will find in the future, one thing is certain: we can expect the unexpected. This booklet lists some of the expectations for the Chandra mission along with some of the unexpected discoveries.

Top 5 Chandra Facts

Chandra flies more than 1/3 of the way to the Moon.

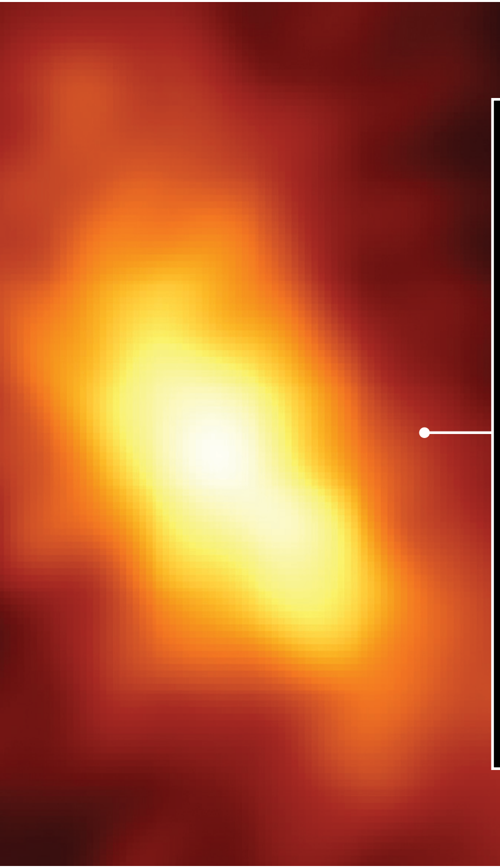
Chandra can observe X-rays from clouds of gas so vast that it takes light five million years to go from one side to the other.

Chandra's resolving power is equivalent to the ability to read a stop sign at a distance of twelve miles.

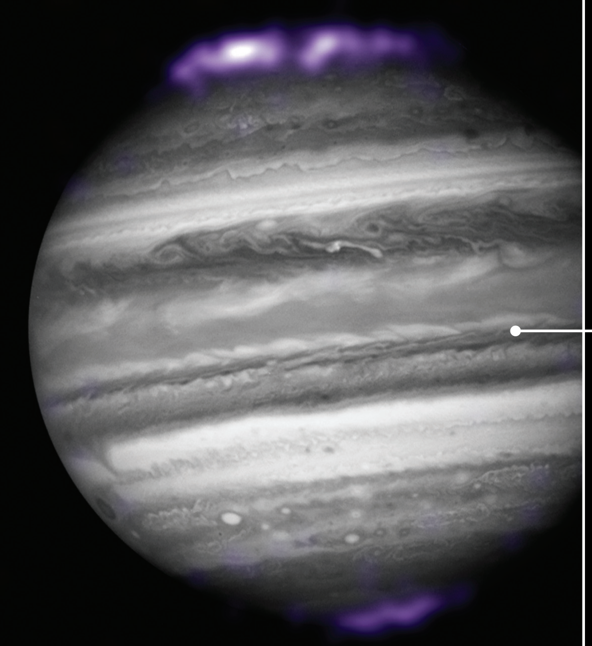
At 45 feet long, Chandra is the largest satellite the Space Shuttle has ever launched.

Chandra can observe X-rays from particles up to the last second before they fall into a black hole.

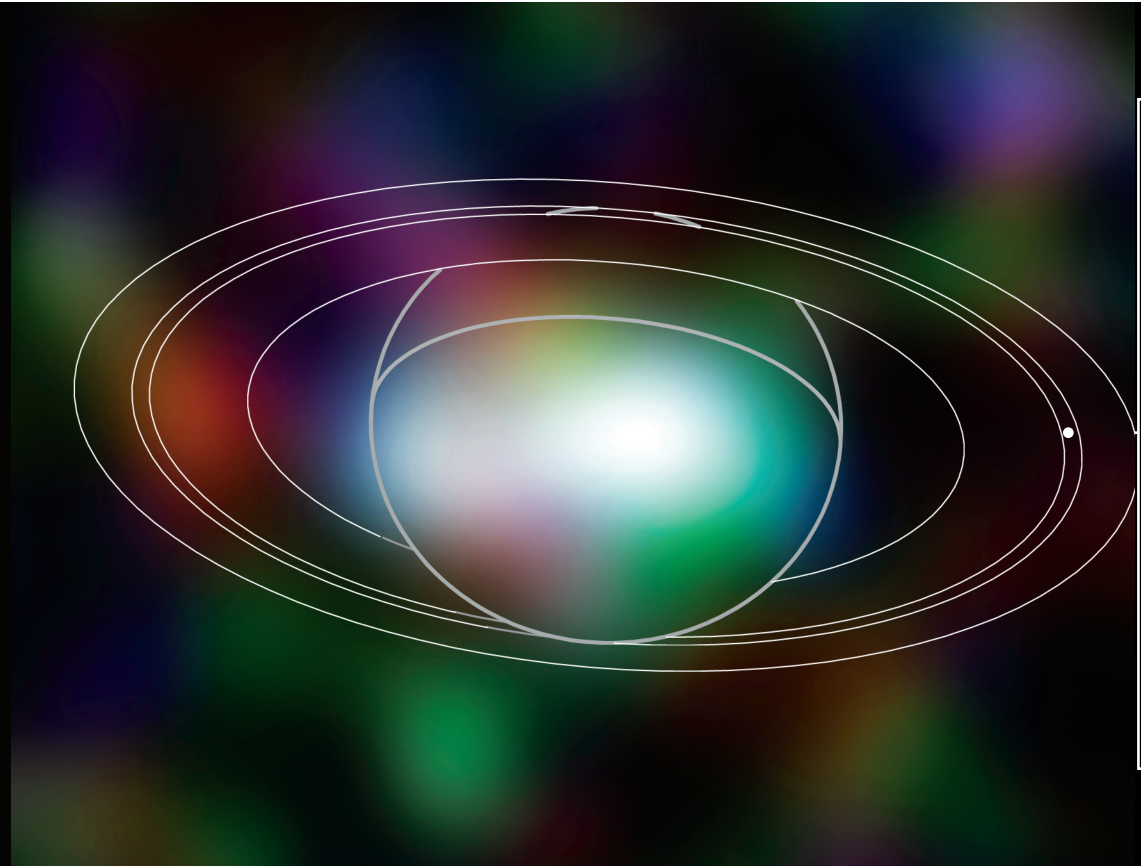
SOLAR SYSTEM



EXPECTED AND DETECTED: X-ray emission was detected from the atmospheres of planets and comets. The X-rays are produced when solar X-rays and high-speed particles flowing away from the Sun hit these atmospheres. The observed X-radiation provides information on the outer atmospheres of these objects that is difficult to obtain with other telescopes.



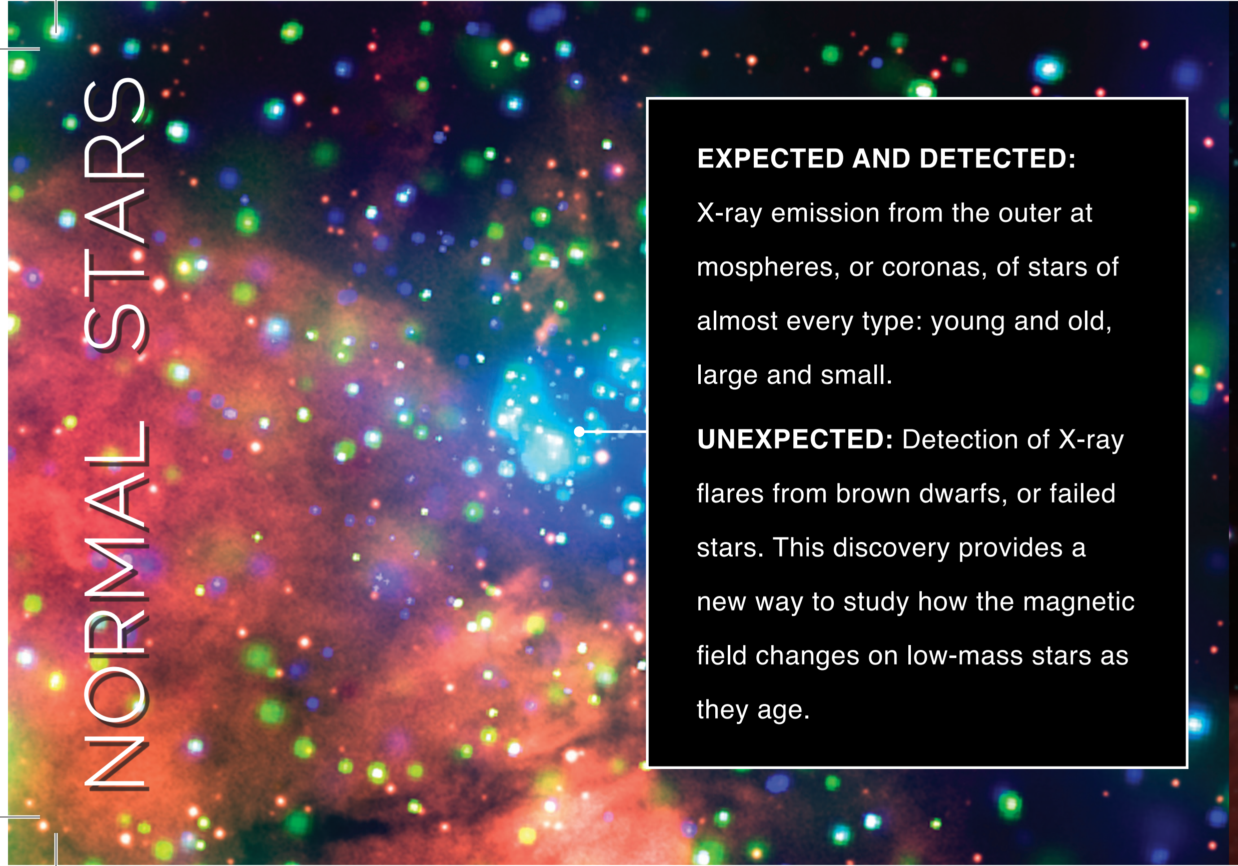
UNEXPECTED: The X radiation from Jupiter's aurora, the equivalent of Earth's Northern Lights, was discovered to be located very near Jupiter's poles, suggesting that the auroral X rays are produced by particles streaming along Jupiter's magnetic field all the way from Jupiter's moon Io.



UNEXPECTED: The strongest X ray emission from Saturn came from its equatorial regions and varied with solar activity, suggesting that Saturn acts like a surprisingly efficient X ray mirror that reflects X-rays from the Sun.

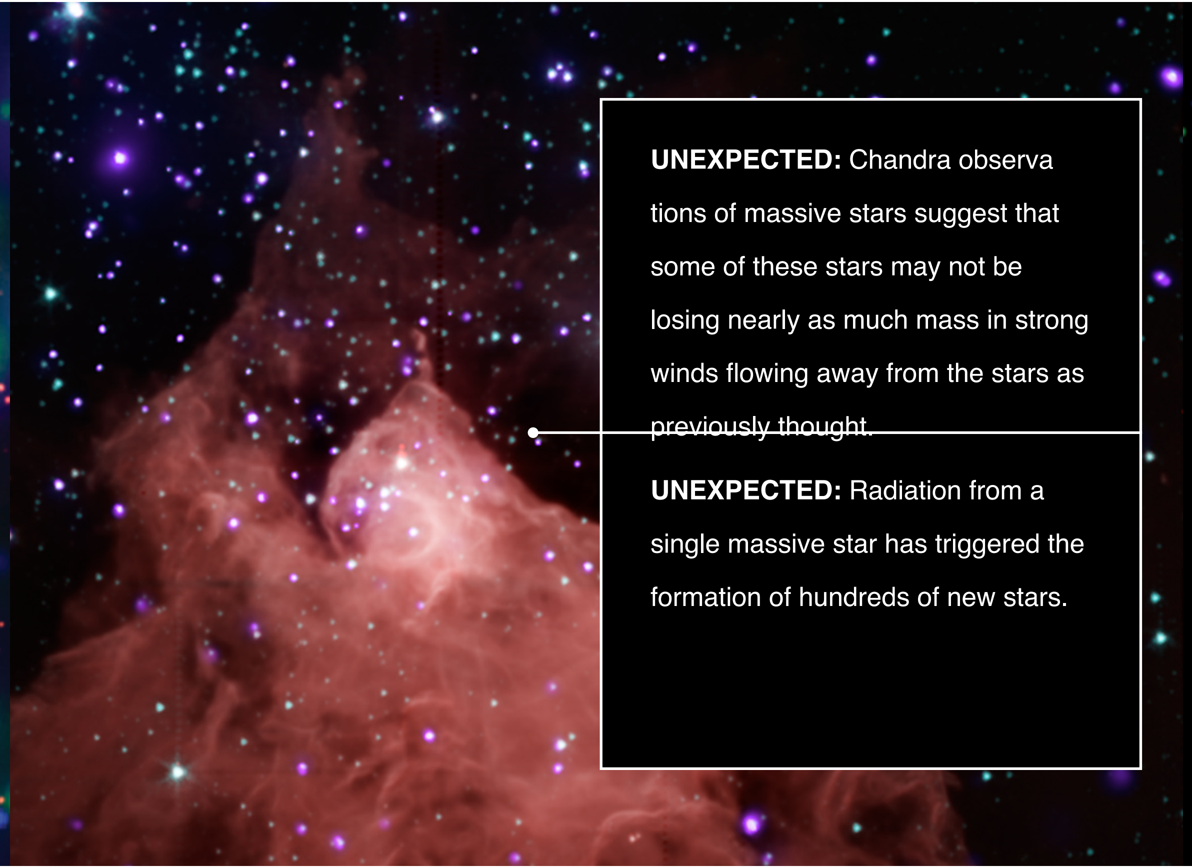
UNEXPECTED: The discovery of X-rays from Saturn's rings, from a source that is still unknown. It could be due to beams of energetic electrons produced in lightning storms on Saturn.

NORMAL STARS



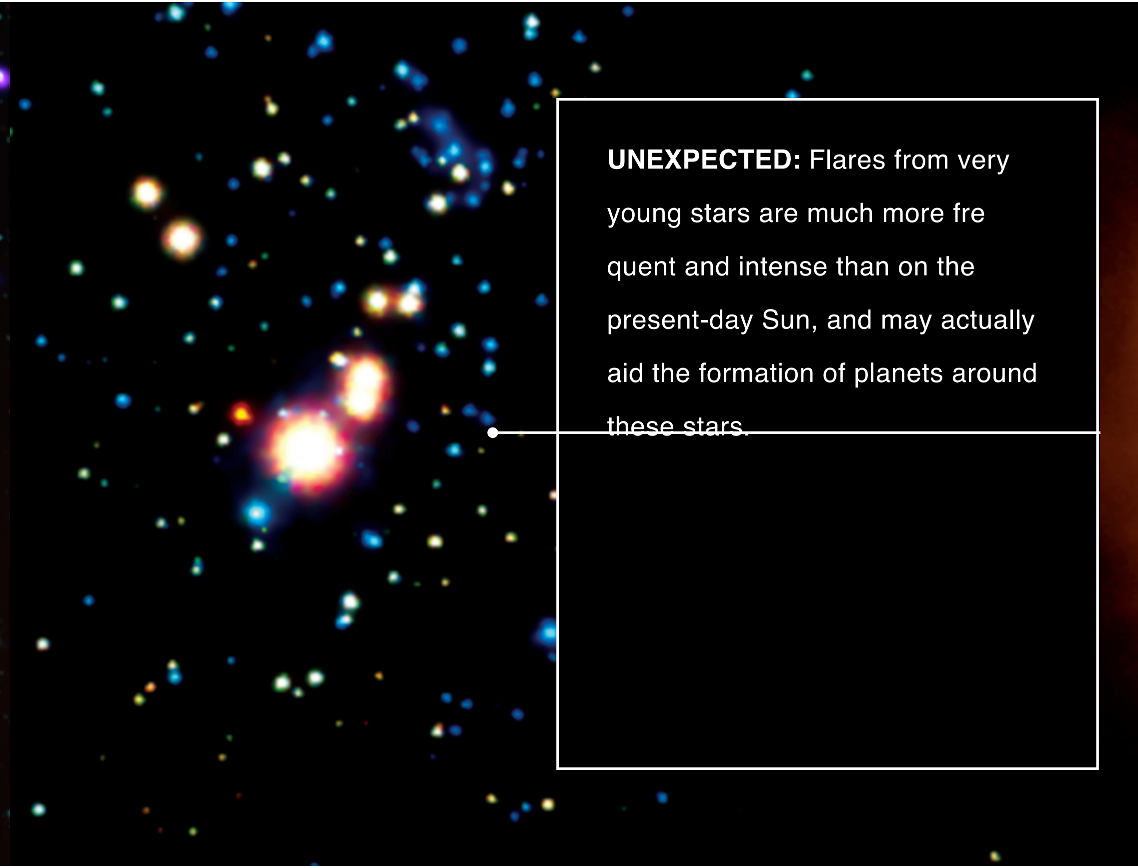
EXPECTED AND DETECTED: X-ray emission from the outer atmospheres, or coronas, of stars of almost every type: young and old, large and small.

UNEXPECTED: Detection of X-ray flares from brown dwarfs, or failed stars. This discovery provides a new way to study how the magnetic field changes on low-mass stars as they age.

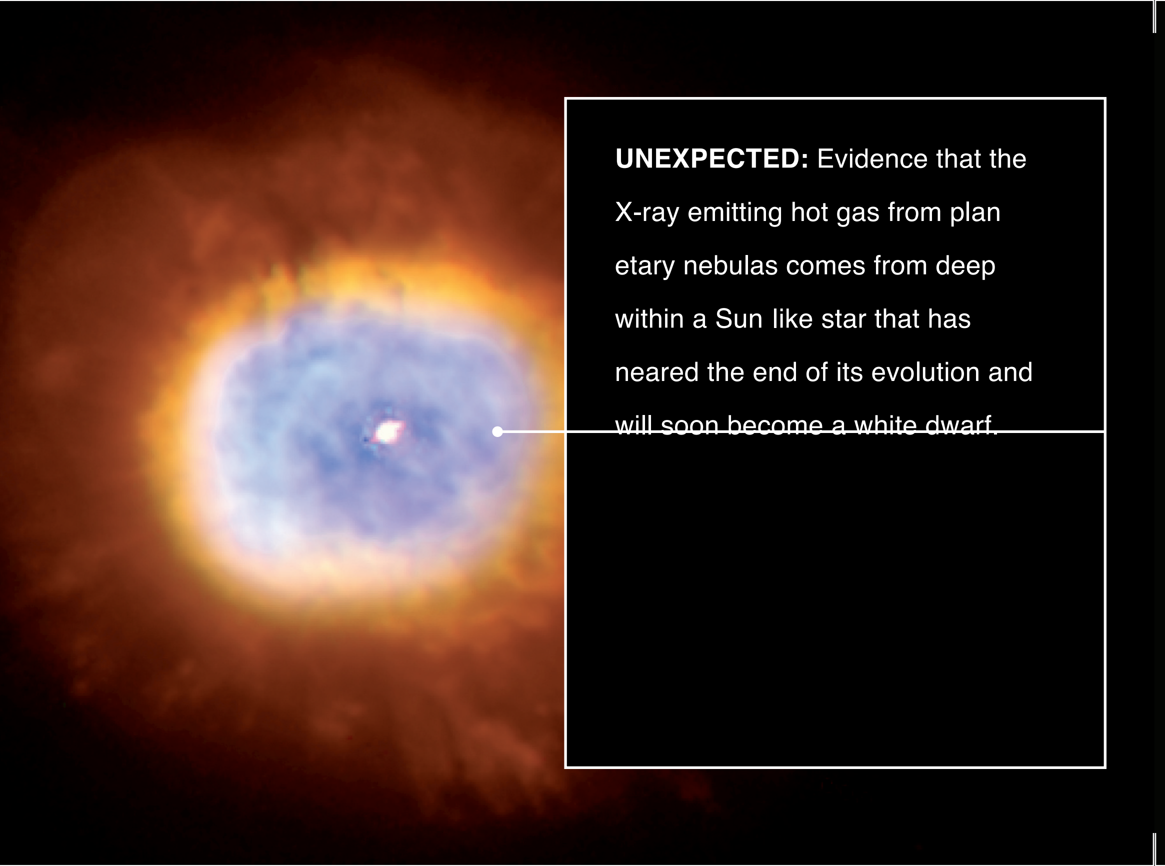


UNEXPECTED: Chandra observations of massive stars suggest that some of these stars may not be losing nearly as much mass in strong winds flowing away from the stars as previously thought.

UNEXPECTED: Radiation from a single massive star has triggered the formation of hundreds of new stars.



UNEXPECTED: Flares from very young stars are much more frequent and intense than on the present-day Sun, and may actually aid the formation of planets around these stars.

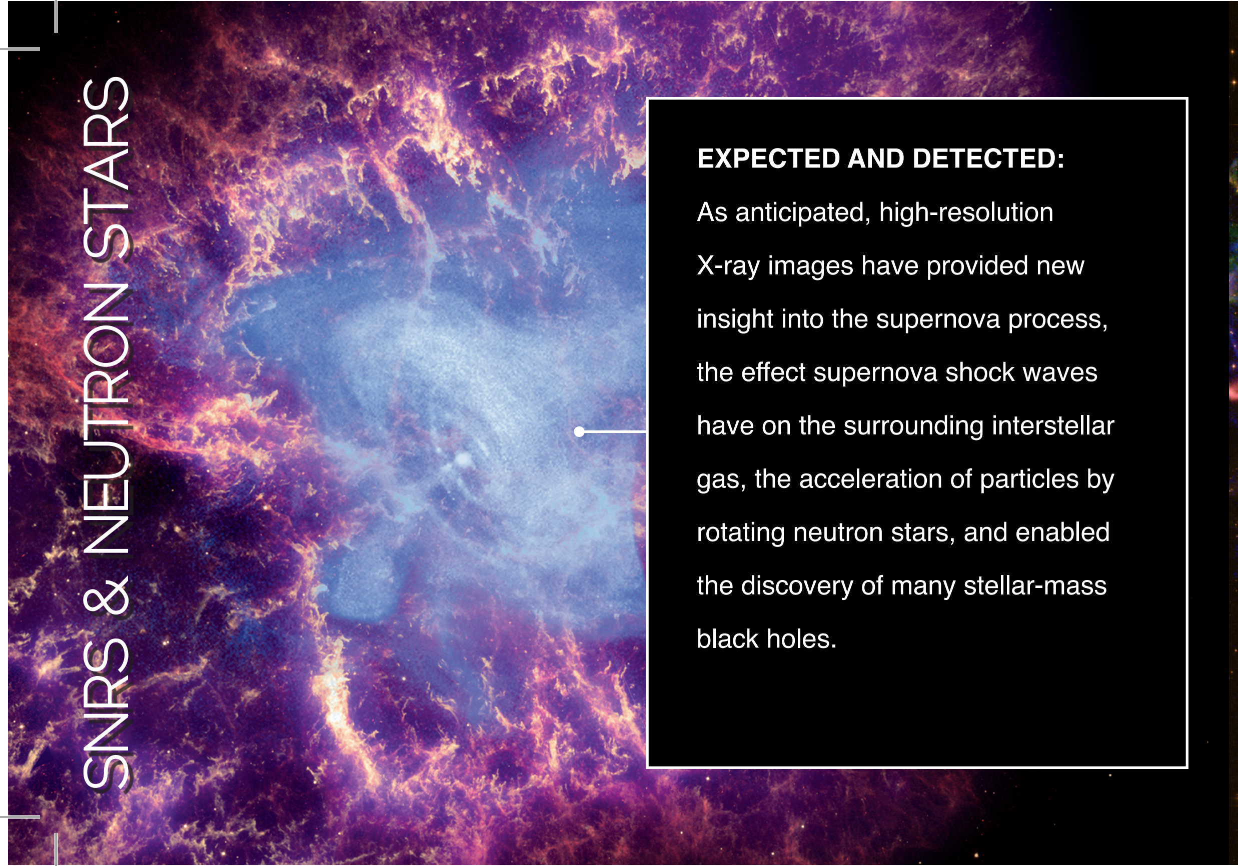


UNEXPECTED: Evidence that the X-ray emitting hot gas from planetary nebulas comes from deep within a Sun like star that has neared the end of its evolution and will soon become a white dwarf.

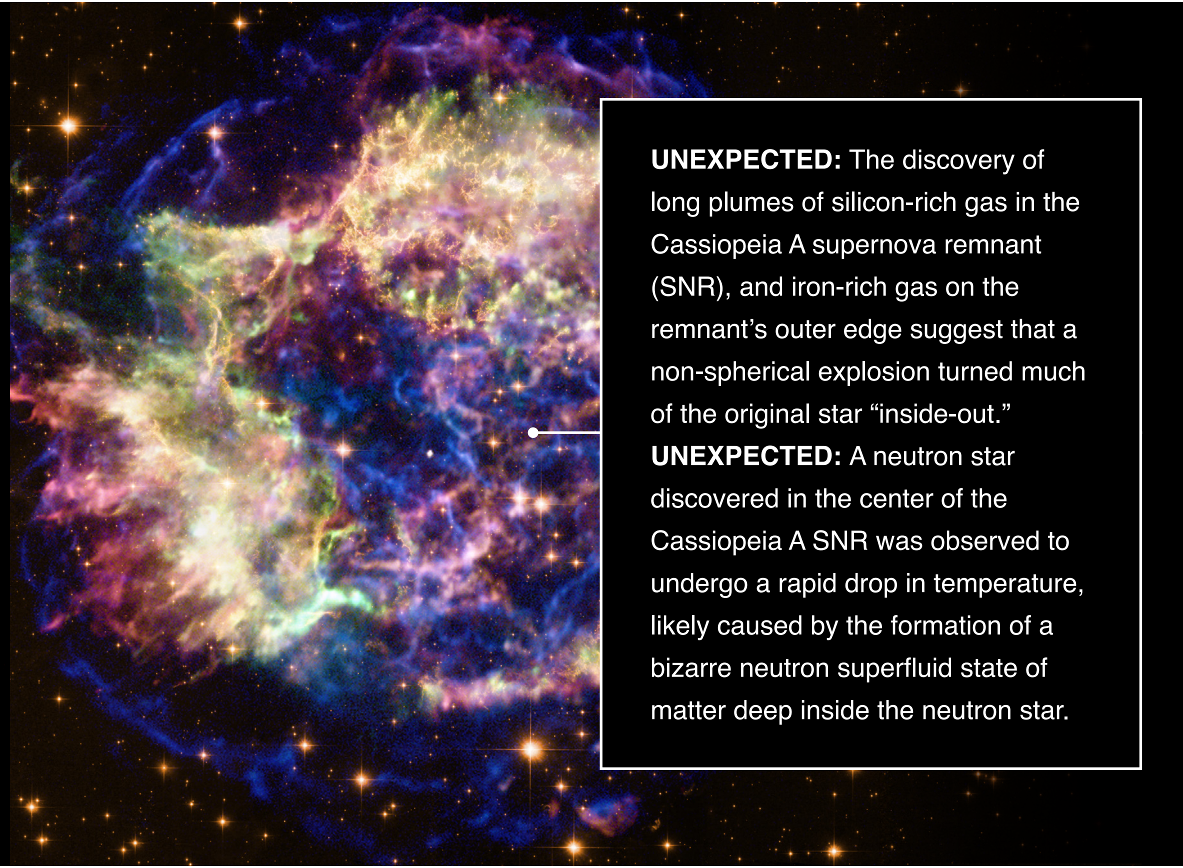
CARINA NEBULA

EXPECTED AND DETECTED: Located a mere 7,500 light years from Earth, the Carina Nebula has long been a favorite target for astronomers. Chandra's ultrasharp X ray vision has found over 14,000 young stars in Carina, improving the census of young stars in this region. Chandra also revealed a diffuse X ray glow, seen less clearly before, which likely comes from both the winds of massive stars and the remains of stars that have exploded as supernovas.

SNRS & NEUTRON STARS

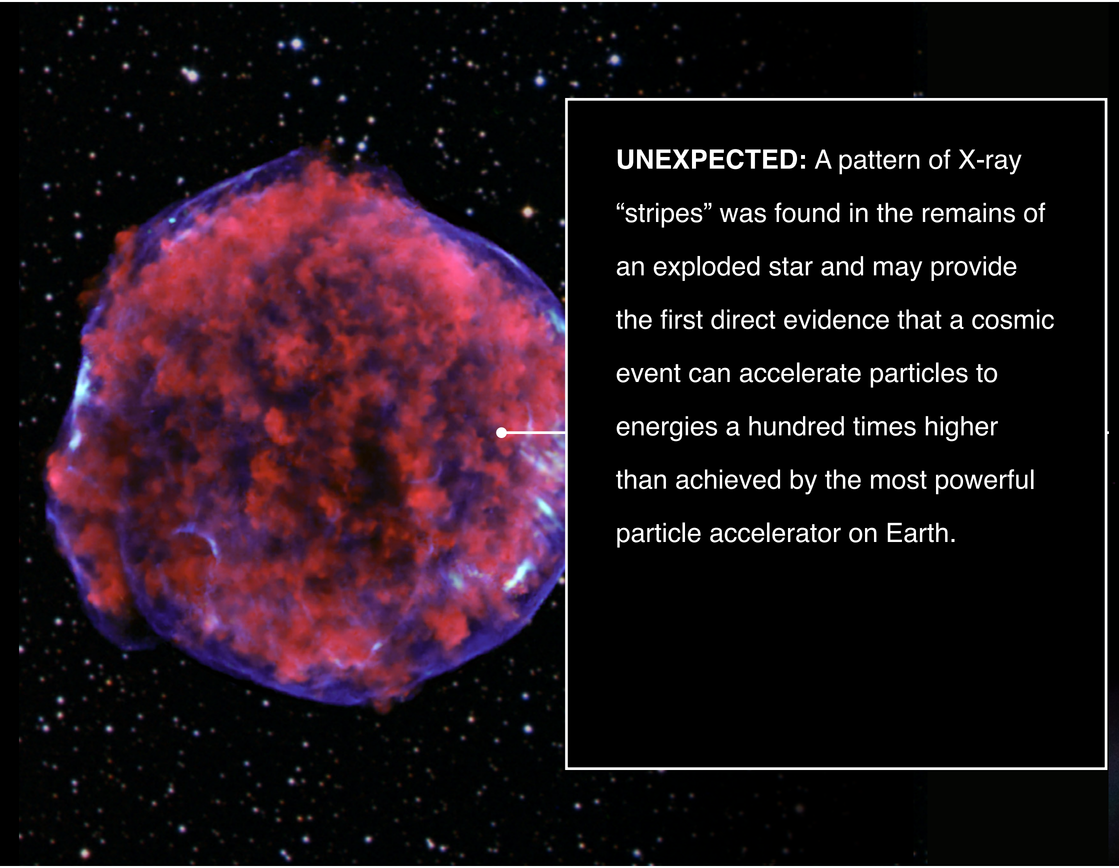


EXPECTED AND DETECTED: As anticipated, high-resolution X-ray images have provided new insight into the supernova process, the effect supernova shock waves have on the surrounding interstellar gas, the acceleration of particles by rotating neutron stars, and enabled the discovery of many stellar-mass black holes.

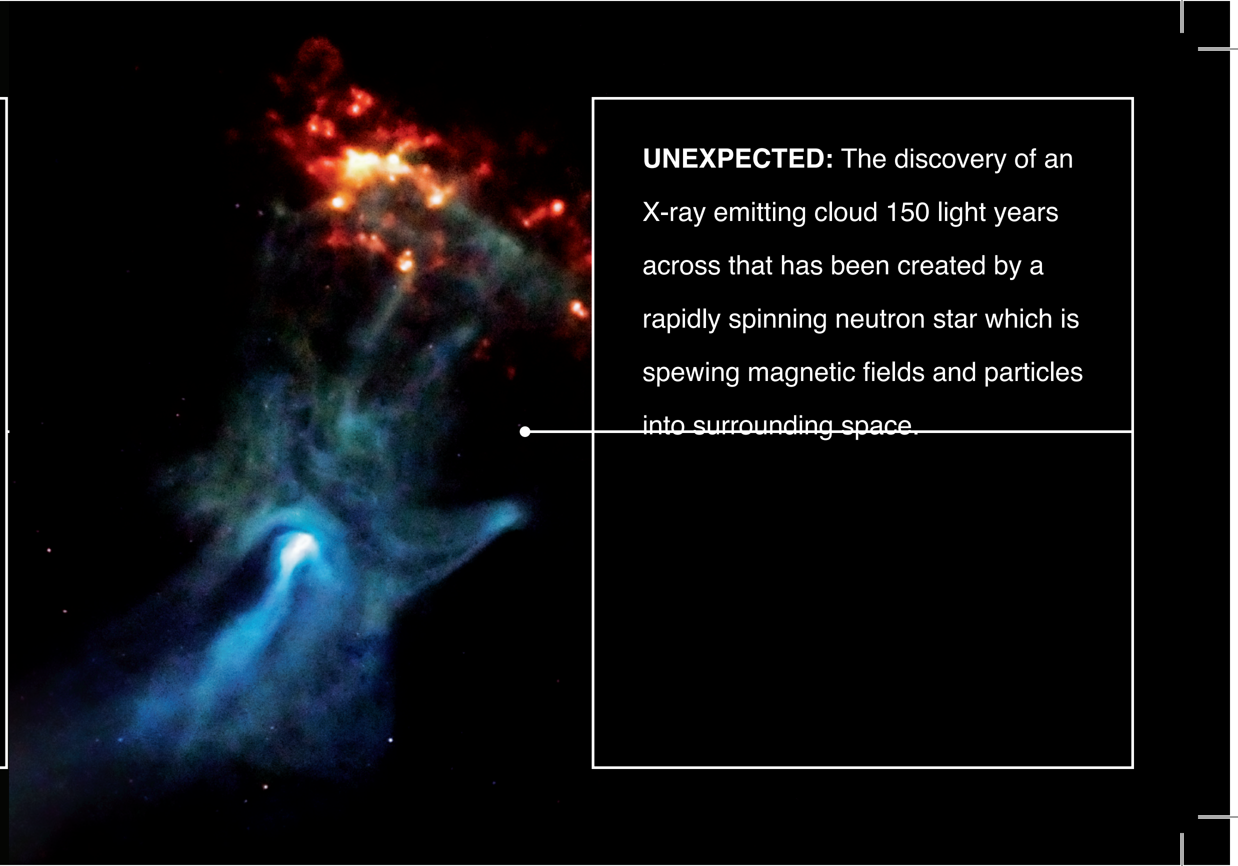


UNEXPECTED: The discovery of long plumes of silicon-rich gas in the Cassiopeia A supernova remnant (SNR), and iron-rich gas on the remnant's outer edge suggest that a non-spherical explosion turned much of the original star "inside-out."

UNEXPECTED: A neutron star discovered in the center of the Cassiopeia A SNR was observed to undergo a rapid drop in temperature, likely caused by the formation of a bizarre neutron superfluid state of matter deep inside the neutron star.

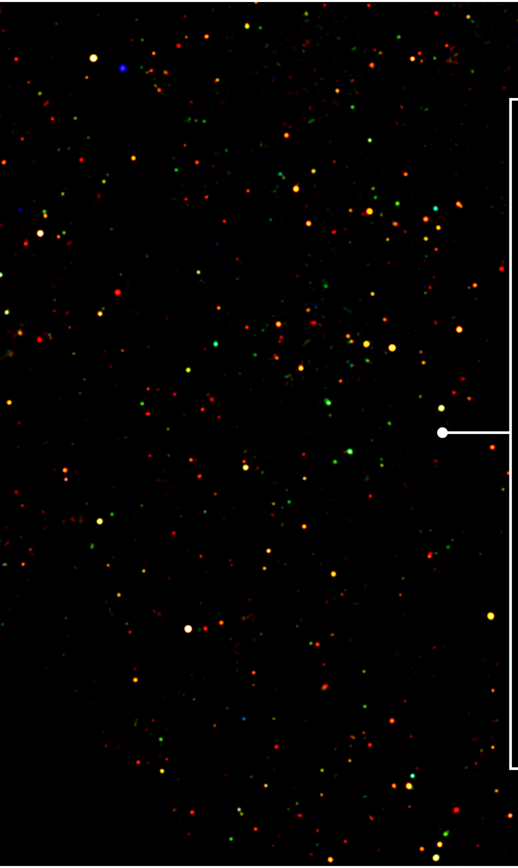


UNEXPECTED: A pattern of X-ray "stripes" was found in the remains of an exploded star and may provide the first direct evidence that a cosmic event can accelerate particles to energies a hundred times higher than achieved by the most powerful particle accelerator on Earth.



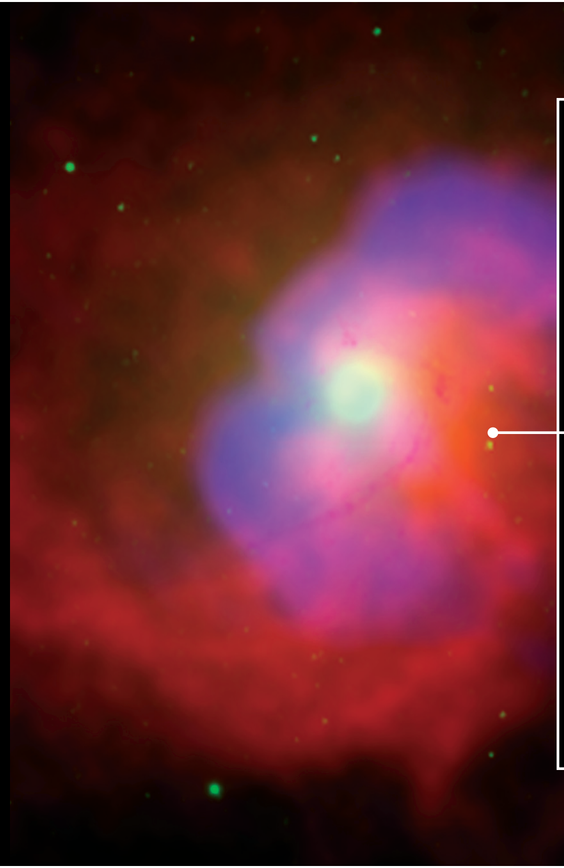
UNEXPECTED: The discovery of an X-ray emitting cloud 150 light years across that has been created by a rapidly spinning neutron star which is spewing magnetic fields and particles into surrounding space.

SUPERMASSIVE BLACK HOLES

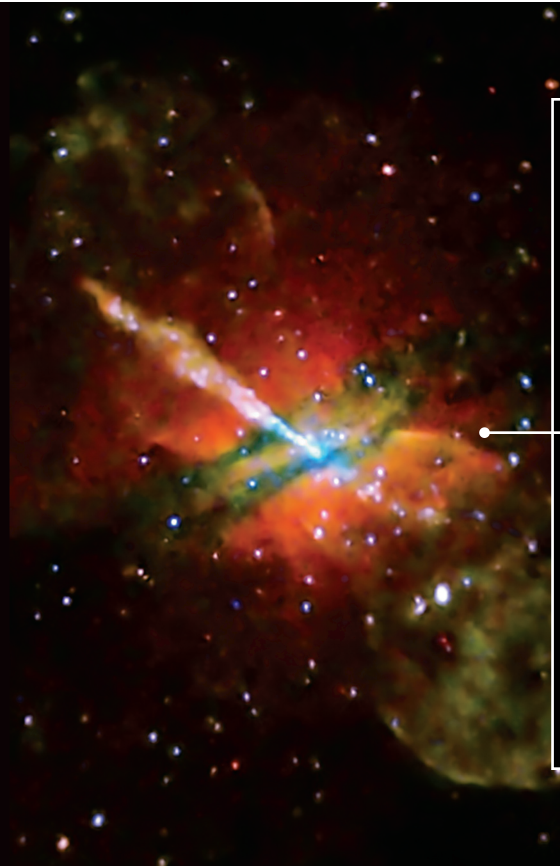


EXPECTED AND DETECTED: Thousands of supermassive black holes. These black holes are located in the centers of galaxies and Chandra has shown they exhibit a wide range of sizes and levels of explosive activity.

UNEXPECTED: Finding a black hole a million times more massive than the Sun in a star-forming dwarf galaxy is a strong indication that supermassive black holes can form more quickly than the galaxy they reside in. This has implications for understanding the formation of galaxies and black holes in the early universe.



UNEXPECTED: A Chandra survey of nine galaxies shows that most of the energy released by matter falling toward supermassive black holes in these galaxies is in the form of high-energy jets traveling at near the speed of light away from the black hole.

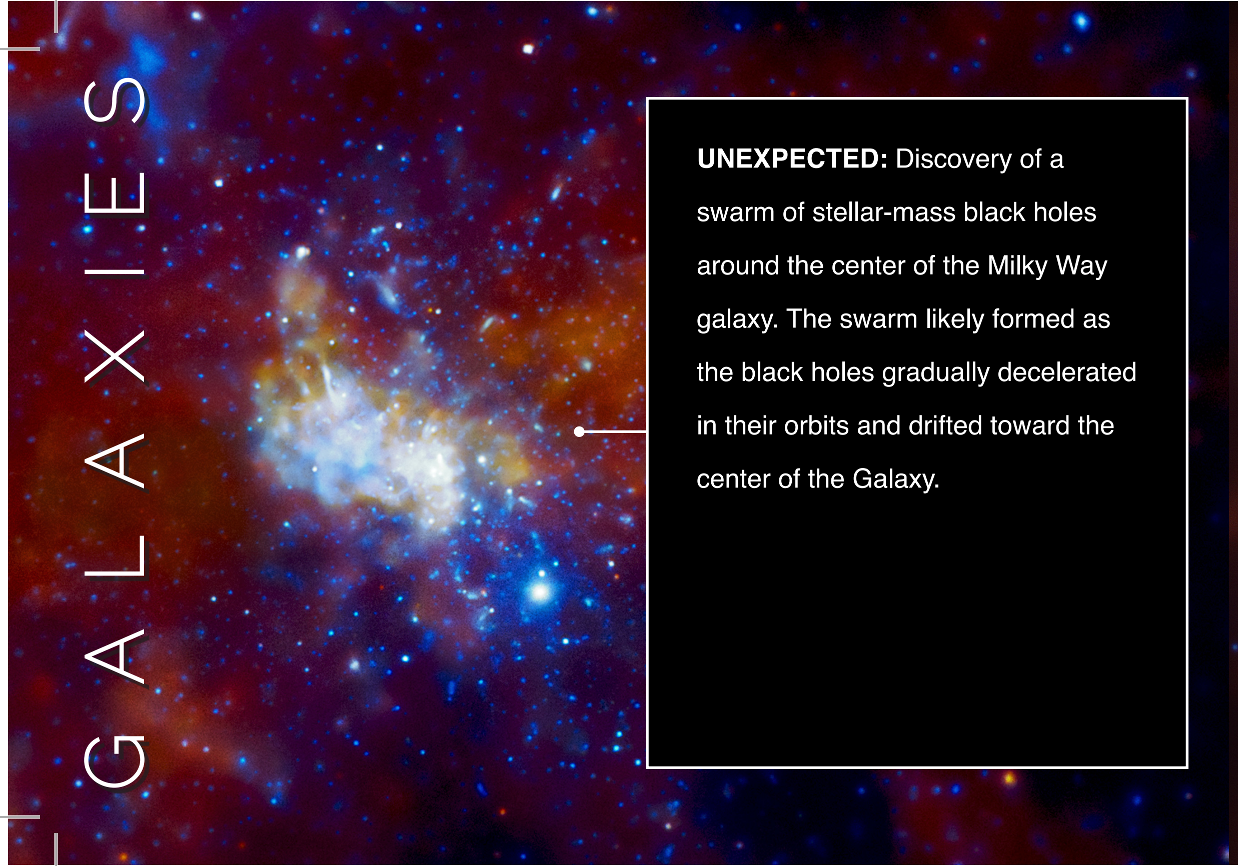


UNEXPECTED: Chandra images have revealed that many galaxies have jets of high-energy particles that extend to the outer reaches of the galaxy and affect the appearance and evolution of these galaxies. These jets are generated by matter falling toward supermassive black holes in the centers of the galaxies.

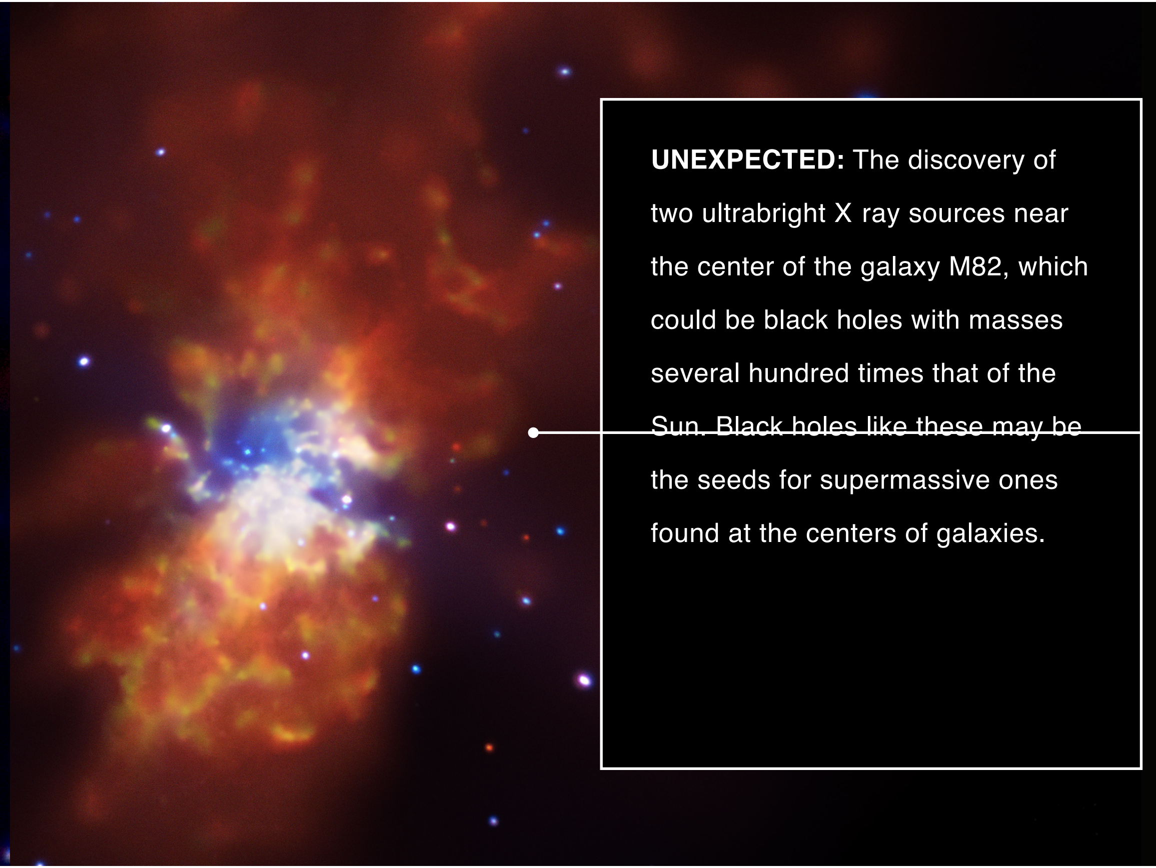
MILKY WAY

EXPECTED AND DETECTED: Long known to be a violent and chaotic region, high resolution images of our Milky Way galaxy from Chandra reveal the presence of hundreds of neutron stars and stellar mass black holes as well as outflows from the supermassive black hole in its center.

GALAXIES



UNEXPECTED: Discovery of a swarm of stellar-mass black holes around the center of the Milky Way galaxy. The swarm likely formed as the black holes gradually decelerated in their orbits and drifted toward the center of the Galaxy.



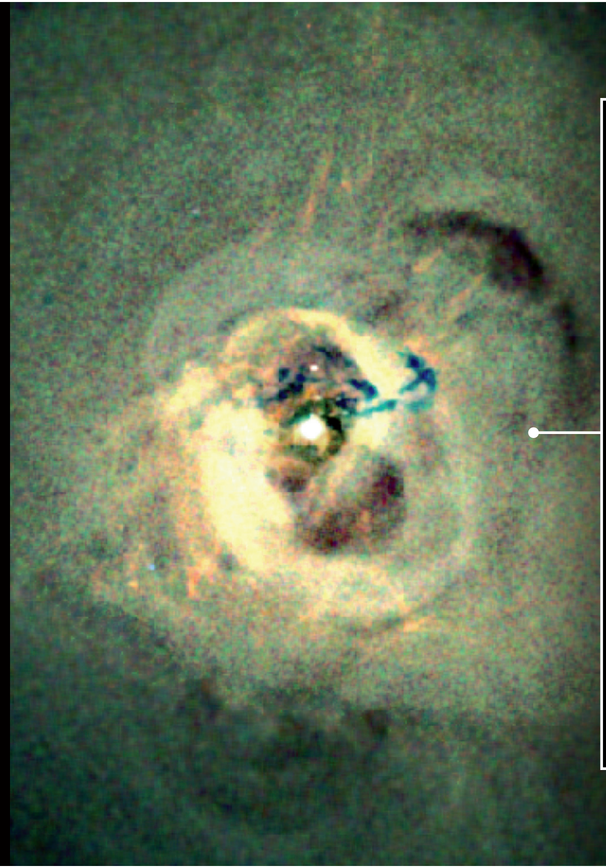
UNEXPECTED: The discovery of two ultrabright X ray sources near the center of the galaxy M82, which could be black holes with masses several hundred times that of the Sun. Black holes like these may be the seeds for supermassive ones found at the centers of galaxies.

UNEXPECTED: Discovery of dozens of black holes and neutron stars strung out across tens of thousands of light years around an elliptical galaxy, as the remains of a collision between galaxies a few billion years ago.

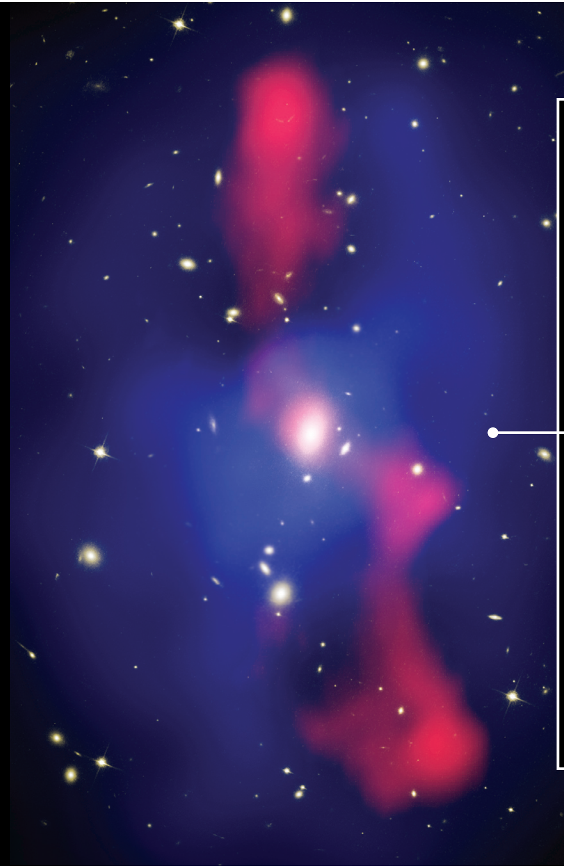
UNEXPECTED: Discovery of an excess of X ray sources in the outer reaches of the Sombrero and other galaxies. The origin of this excess is still unknown.

CLUSTERS OF GALAXIES

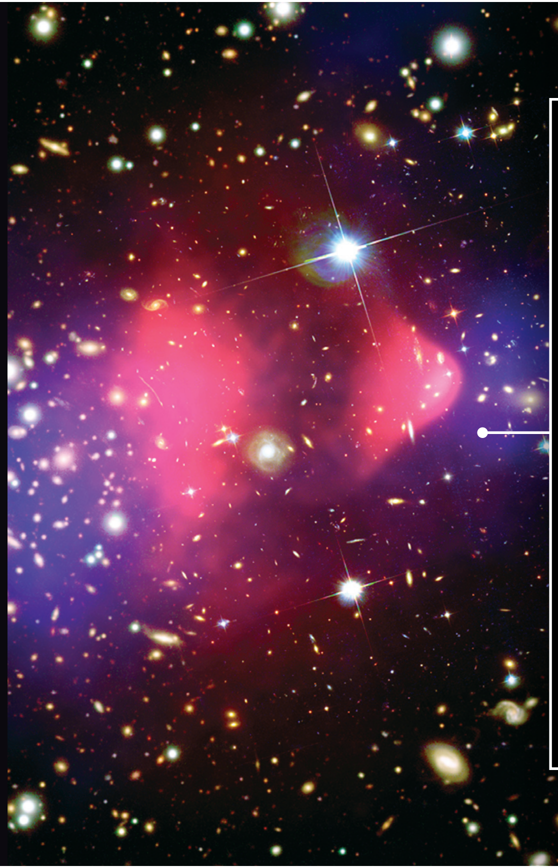
EXPECTED AND DETECTED: High-resolution images of the hot gas in clusters of galaxies that would provide insight into: how clusters are formed, the heating and cooling of the gas in clusters, and the amount and distribution of dark matter that is holding the clusters together.



UNEXPECTED: Discovered ripples in the hot gas in the Perseus cluster. These ripples are likely caused by sound waves produced by repetitive explosions every few million years that are generated by matter falling toward a supermassive black hole in the center of the cluster. This explosive activity could be preventing the formation of millions of stars in the cluster.



UNEXPECTED: A Chandra image of a distant galaxy cluster revealed two vast cavities in the cluster's hot gas (blue). These cavities are filled with energetic particles (red), and were created by a titanic explosion generated as a supermassive black hole swallowed matter with a mass equal to that of 300 million suns over the course of millions of years.



UNEXPECTED: Combined data from Chandra and optical telescopes showed that a high-speed collision between galaxy clusters produced a detectable separation of normal, visible matter (pink) from most of the matter in the clusters (blue). This result provides direct evidence that dark matter exists and is the dominant form of matter in the universe.