Pulsar wind nebulae

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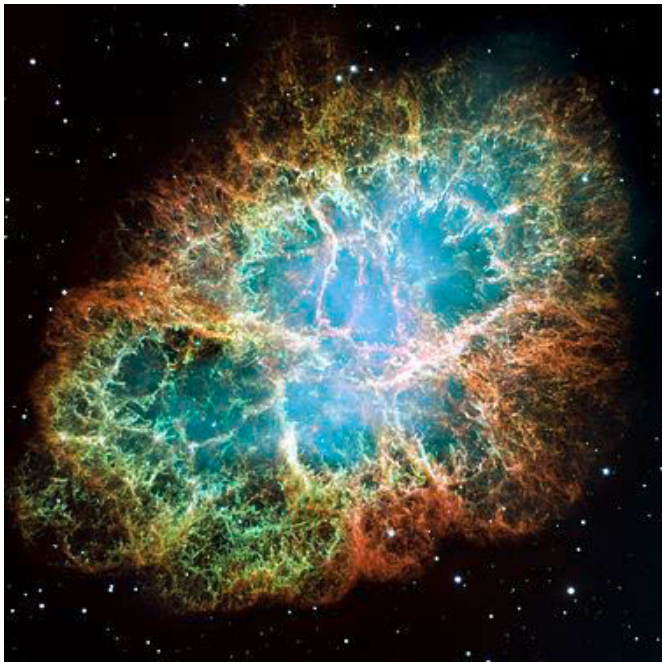

The Crab Nebula seen in the optical by the Hubble Space Telescope. The Crab is an example of a pulsar wind nebula. Astronomers have modeled the detailed shape of another pulsar wind nebula to conclude, among other things, that the pulsar's spin axis is pointed almost directly towards us. Credit: NASA/ Hubble Space Telescope

Neutron stars are the detritus of supernova explosions, with masses between one and several suns and diameters only tens of kilometers across. A pulsar is a spinning neutron star with a strong magnetic field; charged particles in the field radiate in a lighthouse-like beam that can sweep past the Earth with extreme regularity every few seconds or less. A pulsar also has a wind, and charged particles, sometimes accelerated to near the speed of light, form a nebula around the pulsar: a pulsar wind nebula. The particles' high energies make them strong X-ray emitters, and the nebulae can be seen and studied with X-ray observatories. The most famous example of a pulsar wind nebula is the beautiful and dramatic Crab Nebula.

When a pulsar moves through the interstellar medium, the nebula can develop a bow-shaped shock. Most of the wind particles are confined to a direction opposite to that of the pulsar's motion and form a tail of nebulosity. Recent X-ray and radio observations of fast-moving pulsars confirm the existence of the bright, extended tails as well as compact nebulosity near the pulsars. The length of an X-ray tail can significantly exceed the size of the compact nebula, extending several light-years or more behind the pulsar.

CfA astronomer Patrick Slane was a member of a team that used the Chandra X-ray Observatory to study the nebula around the pulsar PSR B0355+54, located about 3400 light-years away. The pulsar's observed movement over the sky (its proper motion) is measured to be about sixty kilometer per second. Earlier observations by Chandra had determined that the pulsar's nebula had a long tail, extending over at least seven light-years (it might be somewhat longer, but the field of the detector was limited to this size); it also has a bright compact core. The scientists used deep Chandra observations to examine the nebula's faint emission structures, and found that the shape of the nebula, when compared to the direction of the pulsar's motion through the medium, suggests that the spin axis of the pulsar is pointed nearly directly towards us. They also estimate many of the basic parameters of the nebula including the strength of its magnetic field, which is lower than expected (or else turbulence is re-accelerating the particles and modifying the field). Other conclusions include properties of the compact core and details of the physical mechanisms powering the X-ray and radio radiation.

More information: Deep Chandra Observations of the Pulsar Wind Nebula Created by PSR B0355+54. arxiv.org/abs/1610.06167

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