Squeezing of Pulsar Wind Nebulae

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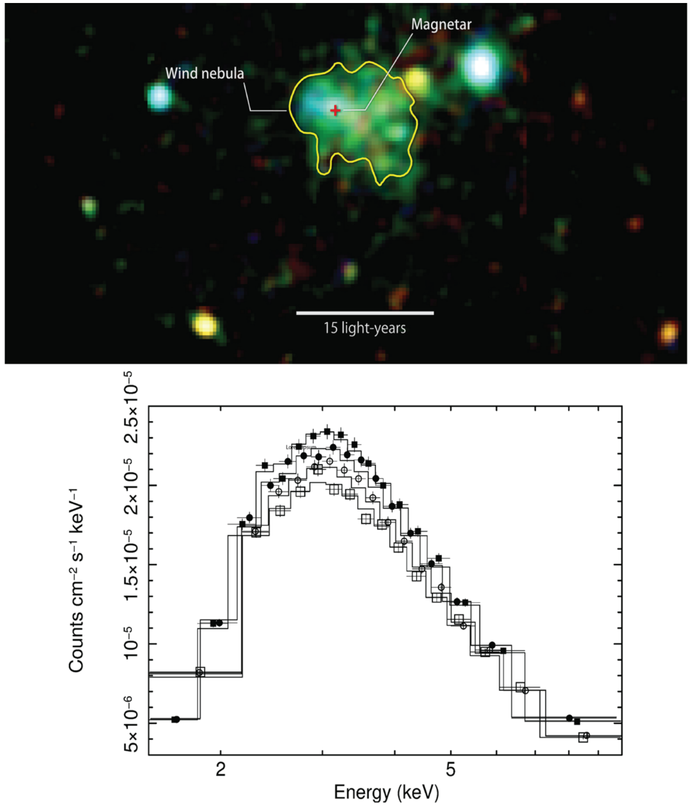

Background: XMM-Newton image of the extended emission around a source known as Swift J1834.9-0846, a rare ultra-magnetic neutron star called a magnetar. The glow arises from a cloud of fast moving particles produced by the neutron star and corralled around it. Color indicates different X-ray energies. Credit: ESA/XMM-Newton/Younes et al. (2016). Foreground: Athena/WFI spectra of the Swift J1834.9-0846 nebula at four different epochs. Credit: Torres et al. (2019).

Even though pulsars are best-known for their periodic pulses, their pulsed electromagnetic radiation is usually not more than a few percent of their total energy release. Pulsars dissipate the bulk of their rotational energy via the emission of a relativistic wind of particles, the so-called pulsar wind. We observe them as pulsar wind nebulae.

These pulsar winds – supersonic with respect to the interstellar medium – produce a termination shock where particles are accelerated. And since these nebulae are rich in photons and threaded with magnetic fields, these particles emit at all frequencies via non-thermal processes such as synchrotron and inverse Compton.

In the simplest case, the pulsar wind expands isotropically within the expanding shell of the supernova ejecta. However, the reverse shock of the supernova remnant is travelling backwards. After some time, the reverse shock can start pushing at the expanding pulsar wind nebula to a point where it in fact stops expanding and contracts. When this happens, the medium is providing energy to the nebula rather than the other way around, heating its particle content and compressing its magnetic fields. This period continues until the internal pressure of the nebula is high enough to stop the contraction. Then, reexpansion begins.

For a short period that could typically last for a few hundred years, the energetics of the nebula may not be dominated by the rotational power of the pulsar, but rather by the compressional heating of the medium. That is, the amount of energy that the nebula could emit at different energies may not only be a significant fraction of the rotational energy as a whole but it could even exceed it. This is called superefficiency.

When identified, contracting PWNe may be running on the path towards their maximum efficiency, which could be perhaps only a few hundred years ahead. Probably the best candidate for this study is the recently detected PWN around the magnetar J1834.9-0846. If this PWN is indeed contracting, changes in its flux and spectrum should be detectable by *Athena*. This would allow studying the contraction phase of PWN as never before, and –if indeed lucky – the bounce itself.

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