X-ray observations investigate radio pulsar PSR J1420-6048 and its nebula

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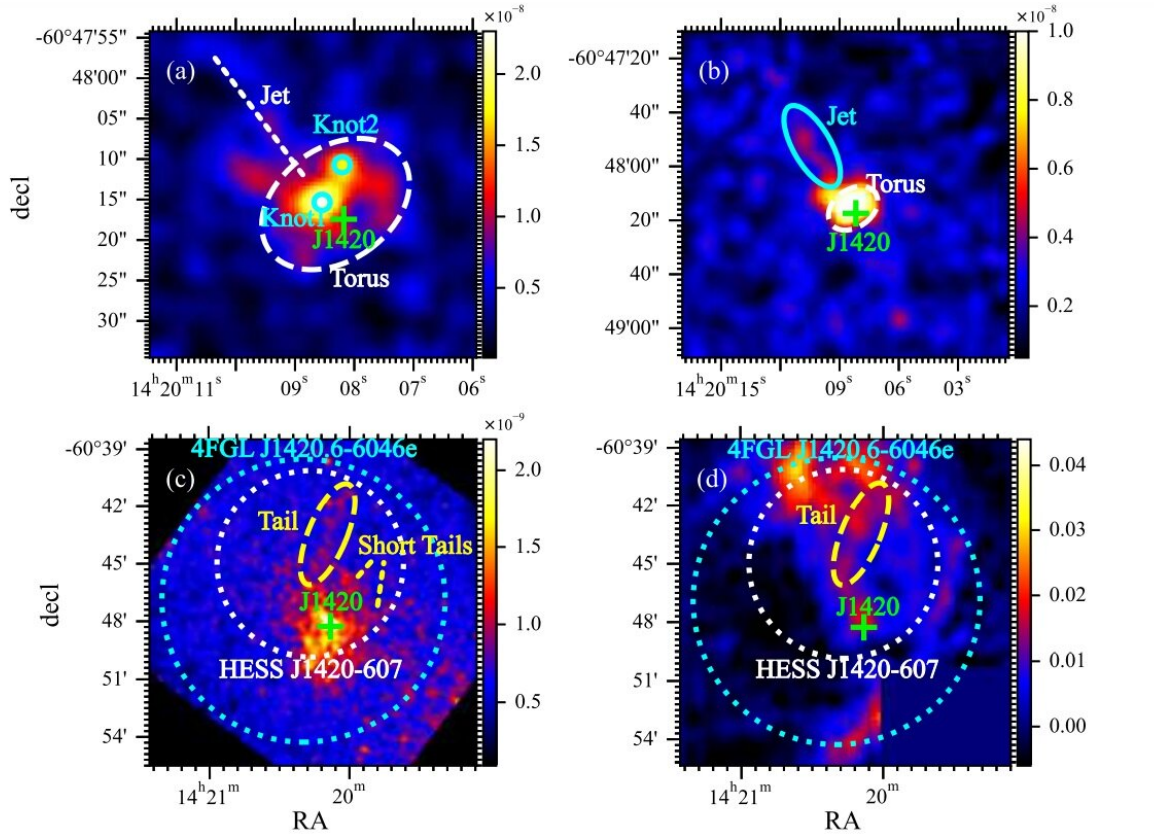

2–7 keV Chandra images of the K3 PWN on various spatial scales (a–c) and a SUMSS 843 MHz image (d). Credit: Park et al, 2023

Using various space telescopes, astronomers have performed X-ray observations of a radio pulsar known as PSR J1420–6048. Results of the

observational campaign, published January 27 on the *arXiv* pre-print server, shed more light on the nature of this source and its pulsar wind nebula.

Pulsars are highly magnetized, rotating neutron stars emitting a beam of electromagnetic radiation. They are usually detected in the form of short bursts of radio emission; however, some of them are also observed via optical, X-ray and gamma-ray telescopes.

Pulsar wind nebulae (PWNe) are nebulae powered by the wind of a pulsar. Pulsar wind is composed of charged particles; when it collides with the pulsar's surroundings, in particular with the slowly expanding supernova ejecta, it develops a PWN.

Particles in PWNe lose their energy to radiation and become less energetic with distance from the central pulsar. Multiwavelength studies of these objects, including X-ray observations, especially using spatially integrated spectra in the X-ray band, have the potential of uncovering important information about particle flow in these nebulae. This could unveil important insights into the nature of PWNe in general.

At a distance of some 18,200 light years, PSR J1420−6048 is a radio pulsar in the so-called Kookaburra region—a complex of compact and extended radio/X-ray sources along the Galactic plane. The pulsar has a characteristic age of 13,000 years and a high spin-down luminosity of about 10 undecillion erg/s.

PSR J1420−6048 showcases radio pulsations with a period of 68 milliseconds, confirming its association with a pulsar wind nebula detected in the radio and X-ray bands, designated K3. The PWN has an X-ray spectrum with a photon index of about 2.0, seen to soften with increasing distance from the pulsar.

Given that still very little is known about PSR J1420−6048 and its surrounding PWN, a team of astronomers led by Jaegeun Park of Chungbuk National University in Cheongju, South Korea, decided to investigate these objects using Chandra, XMM-Newton, and NuSTAR space observatories.

Based on the broadband X-ray data, the researchers managed to characterize the emission properties of PSR J1420−6048 and K3. They found that the X-ray pulse profile of the pulsar exhibits a sharp spike and a broad bump separated by approximately 0.5 in phase. The astronomers also found a hint of a spectral softening with increasing distance from PSR J1420−6048, which is in accordance with the previous measurements of the spectral softening in the K3 PWN.

When it comes to K3, the team was able to identify its sub-structures: two knots, a torus-jet structure, and large-scale tails extending in the northwest direction. Furthermore, a bright diffuse emission region has been found to the south.

According to the authors of the paper, the results suggest that in the case of K3, particles are accelerated to very high energy (about 1 PeV), the nebular magnetic field is low, and that the particles are transported primarily by advection in the PWN.

"Our detailed study of the PWN may be suggestive of (1) particle transport dominated by advection, (2) a low magnetic-field strength (B ~ 5μG), and (3) electron acceleration to ~PeV energies," the scientists concluded.

More information: Jaegeun Park et al, X-ray studies of the pulsar PSR J1420-6048 and its TeV pulsar wind nebula in the Kookaburra region, *arXiv* (2023). DOI: 10.48550/arxiv.2301.11549