An X-ray halo around the BSPWN in PSR B1853+01

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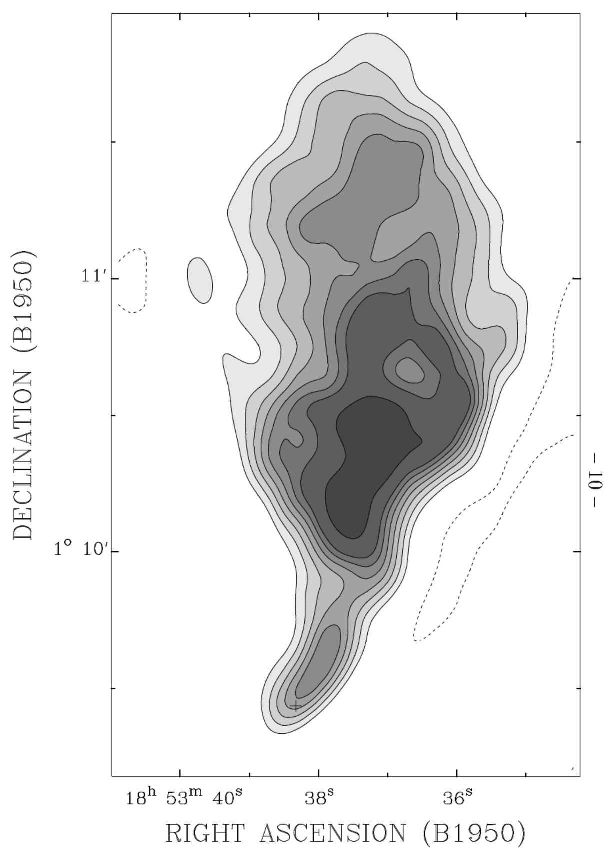
A *Chandra* observation twenty years ago revealed an asymmetric nebula trailing behind PSR B1853+01's apparent motion direction, located within the W44 supernova remnant (SNR G34.7/04). Here we report on the analysis of archival observations of the nebula taken with *Chandra*, XMM-*Newton* and NuSTAR, providing an unprecedented close view of the PWN morphology and improved measurements of its spectral properties in X-rays from 0.5 to 79 keV. In addition to the tail, our observations reveal the presence of several extended structures, including "antennae-like" features extending for about 60" ahead of the pulsar, as well as a large, extended "X-ray halo" surrounding the whole PWN. Measurements of the spectral index of these features show a harder photon index with respect to that of the pulsar and the PWN tail. We argue that these extended structures are produced by high-energy particles escaping the PWNe, as it has been proposed for several well-known BSPWNe, where detection of "TeV halos" in gamma-ray band are recently reported.

PSR B1853+01 and W44 (G34.7-0.4)

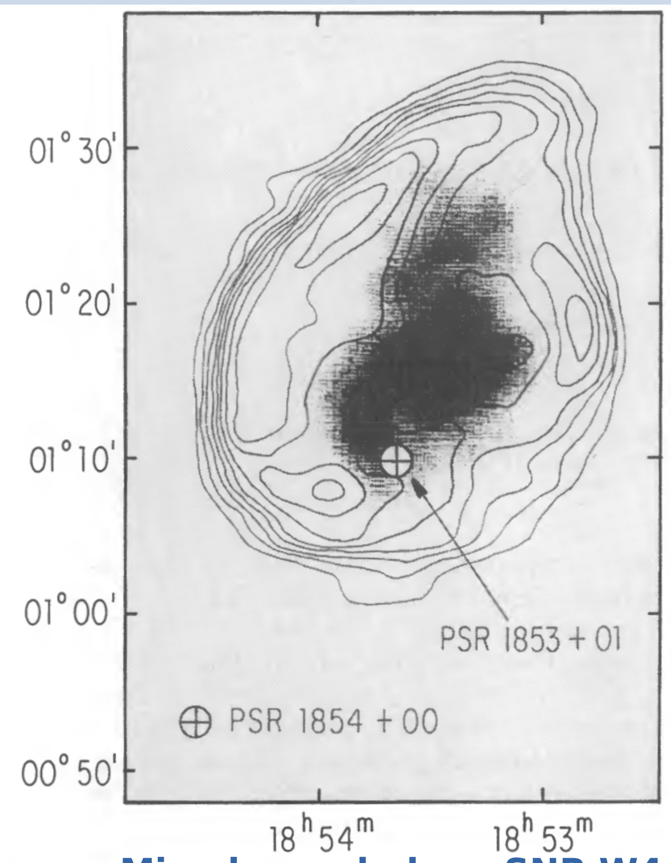
- ☑ PWN location: southern edge of W44's X-ray emission region
- ☑ Age: PSR τ_c ~ 20,000 yr; W44 ≧ 10,000 yr [9]
- ☑ Distance: PSR ~ 3.2 kpc; kinematic distance W44 ~3.1 kpc
- ☑ Association with W44 projected velocity > 200 km/s [6]
- ☑ W44: over-ionized plasma at center [3]
- ☑ PWN emission dominates above ~ 4 keV

BSPWN



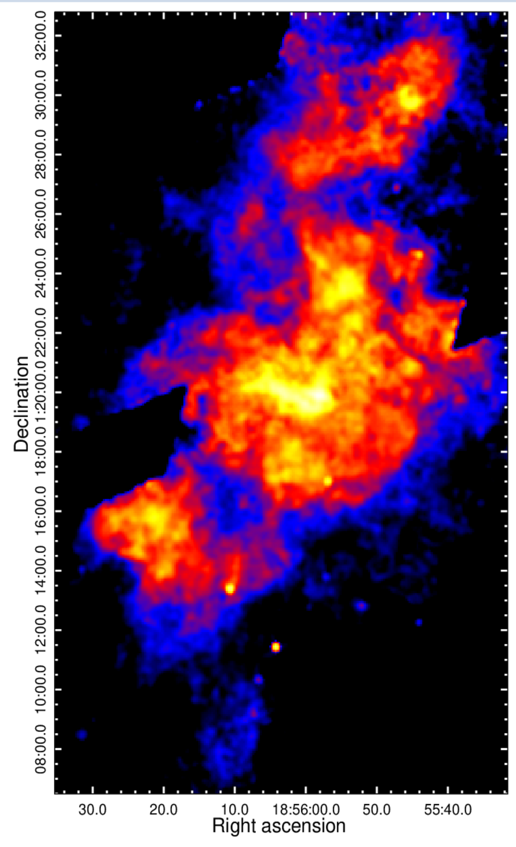
3.6 cm radio image of W44 PWN

Frail et al. 1996



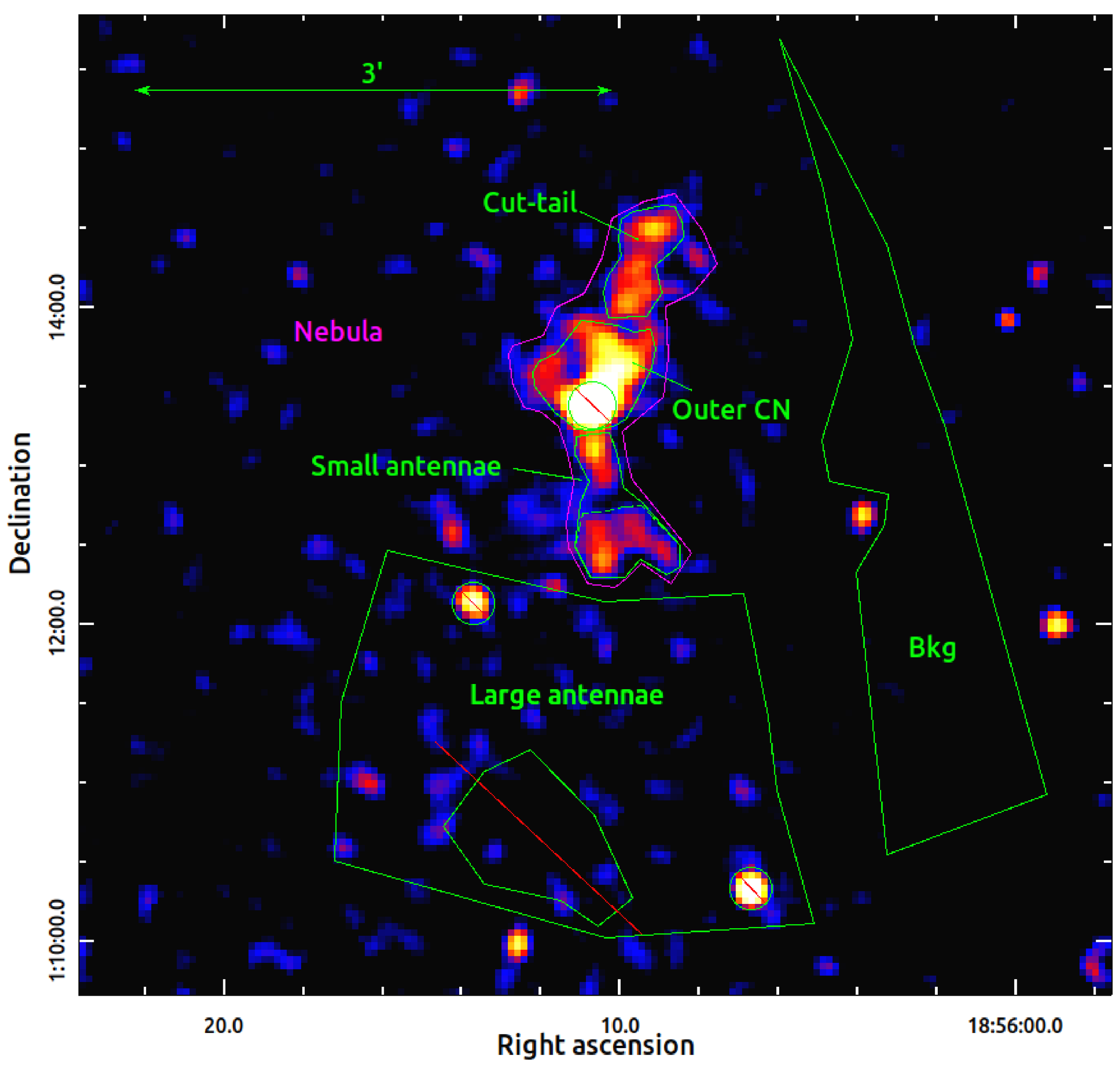
Mixed morphology SNR W44 (contours: radio; grey shades: X-rays)

Wolszczan et al. 1991



Chandra 0.5 - 7.0 keV flux image

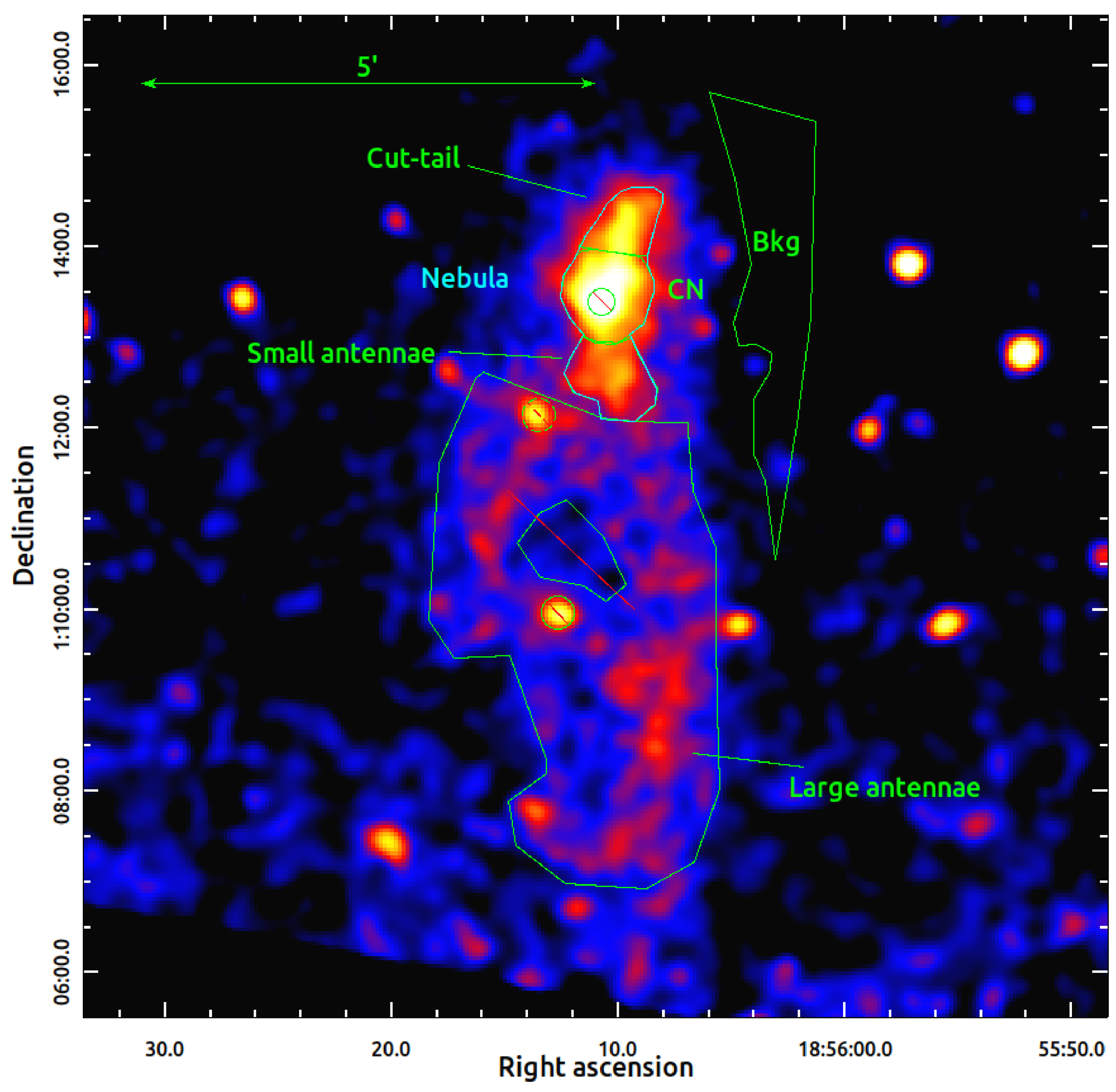
The Structure of the Bow Shock Nebula Surrounding PSR B1853+01 in X-rays



Chandra 4.0 - 8.0 keV flux image

Total Exposure ~ **135 ks**

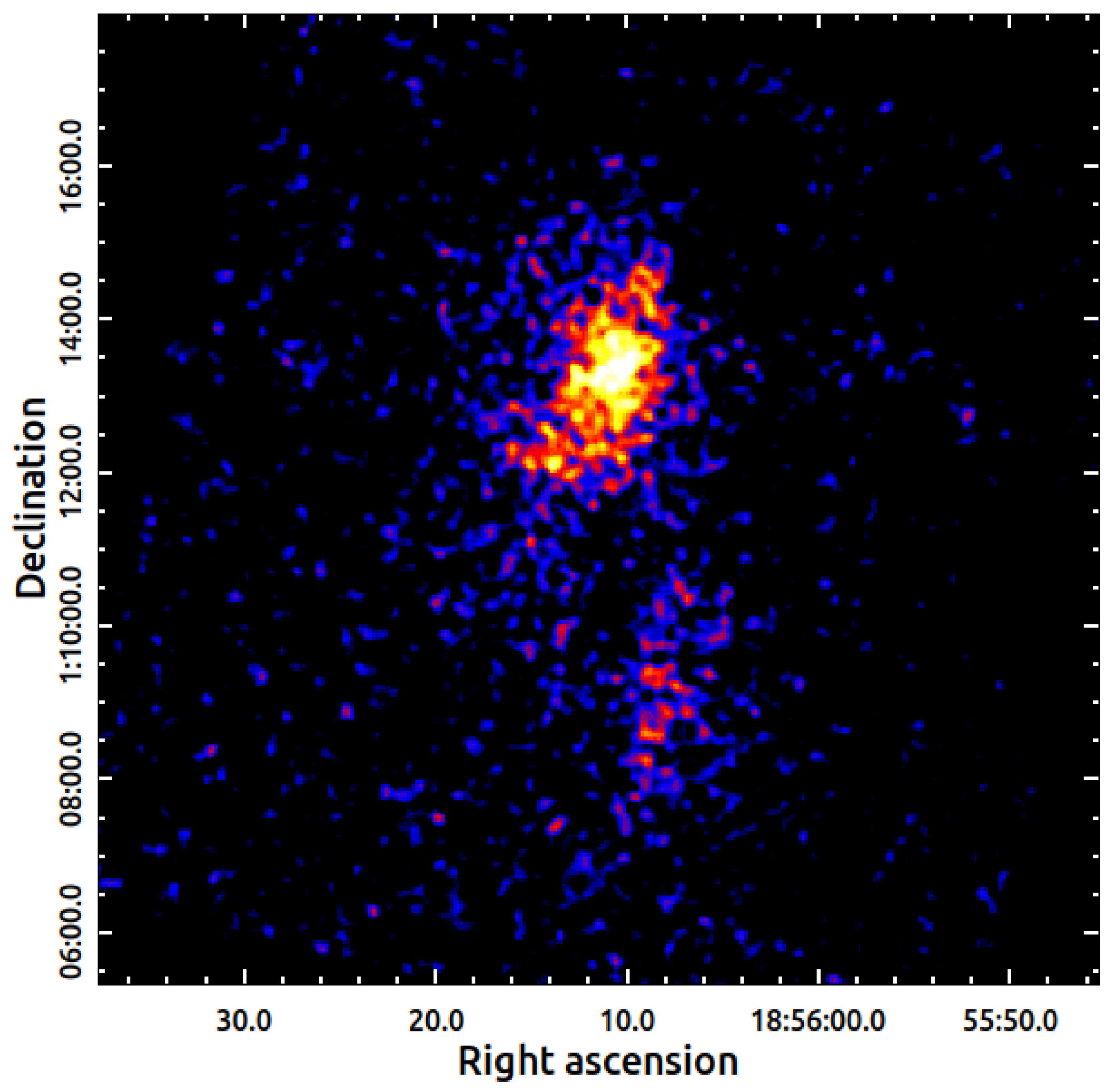
Branched small antennae like emission ahead of the pulsar.



XMM-*Newton* 4.0 - 10.0 keV exposure corrected image

Total Exposure ~ **450 ks × 3** (MOS1+MOS2+pn)

XMM-*Newton*'s unique surface brightness sensitivity above 3 keV!



NuSTAR 3.0 - 20.0 keV mosaic image

Total Exposure ~ **105 ks × 2** (FPMA+FPMB)

Resolved spectroscopy

(*Chandra* only; fit from 2.0-8.0 keV)

Regions	Photon Index	N_0	$\chi^2_{reduced}$
Pulsar	1.85±0.26	1.60× 10^{-5}	0.82
Circle 9"	1.66±0.16	2.37× 10^{-5}	1.03
Outer CN	1.87±0.14	4.29× 10^{-5}	0.92
Cut-Tail	2.03±0.17	3.48× 10^{-5}	0.83
Whole Tail	1.82±0.09	8.92× 10^{-5}	0.90
Small antennae	1.44±0.20	0.49× 10^{-5}	0.98
Whole nebula	1.95±0.08	19.4× 10^{-5}	0.91
Large antennae (part of the Halo)	1.29±0.19	5.50× 10^{-5}	1.55

N_0: photons/keV /cm2/s@1keV; N_H fixed at 0.54 × 10^{22} cm^{-2}

Antennae seem to have harder photon index than those of regions trailing behind the pulsar.

Discussion

- **Misaligned jet-like outflows** have been observed in many BSPWNe, e.g. in the Guitar and the Lighthouse nebulae [1, 4].
- Detection of a large-scale **"X-ray halo"** similar to that was observed in the **Snail PWN** [11] and resembling those recently reported **"TeV halos"** at gamma-rays, e.g. around the **Geminga** and **Monogem** BSPWNe.
- A common origin of both the jet-like features as well as the halo-like structures in some BSPWNs is suggested. **Escape of of high-energy particles** may be quite common in BSPWNe[1, 2, 7, 10].

References

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