The middle-aged pulsar J1740+1000 and its PWN

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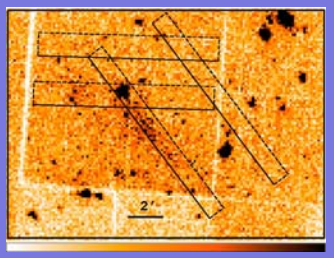
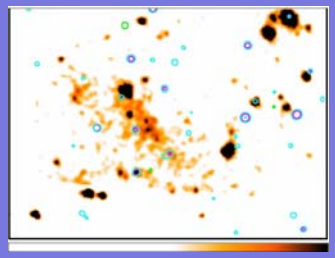
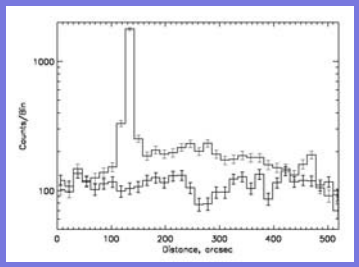
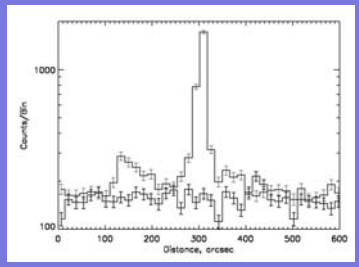
Extremely long parsec-scale tails associated with pulsars have been detected in recent X-ray and radio observations. We present XMM-Newton and Chandra observations of the middle-aged pulsar J1740+1000, with a tail extending up to 3 pc. The tail has a relatively hard spectrum with a photon index of ~1.4-1.5 and a luminosity of 1-2e30 ergs/s in the 0.3-10 keV band. The pulsar spectrum is best fit by a combination of two black-body components with temperatures of ~0.15 and ~0.07 keV, and a power-law with a photon index of ~1.2. The X-ray data shows 154-ms sinusoidal-shaped pulsations with the pulsed fraction of ~20-30%.



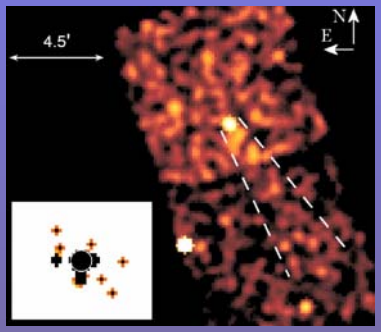


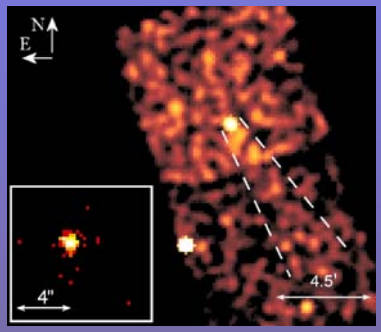
18' × 13' 0.3 – 10 keV images of the field around J1740+1000 combining MOS1/MOS2 data of the XMM-Newton observations 0403570101 and 0403570201. The top panel shows a binned image (pixel size ~8'') while the bottom image (pixel size ~4'') is adaptively smoothed to obtain a signal-to-noise ratio of 10. The top panel shows the regions from which the linear profiles (shown on the right) were extracted. The overlaid contours in the bottom image show optical and radio sources from the DSS2-blue image (shown in cyan), DSS2-red image (magenta), and NVSS Survey (green).



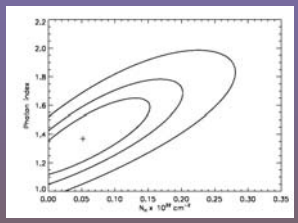


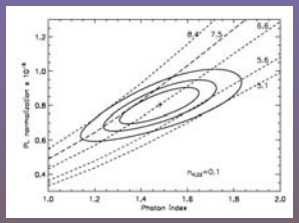
Left:
Linear profiles of the tail and the background obtained by extracting the counts from the rectangular regions along the tail, and a parallel source-free region located north-east from the tail (the two 1' × 11.5' rectangular regions shown in Figure on the left).
Right:
Linear profiles of the regions across the pulsar in the direction west-east and a parallel source-free background region farther north (the two 1.3' × 10.3' rectangular regions also shown in Figure on the left). The unsmoothed MOS1/MOS2 image in the 0.3-10 keV band, combining the two XMM-Newton observations, was used for the extraction.



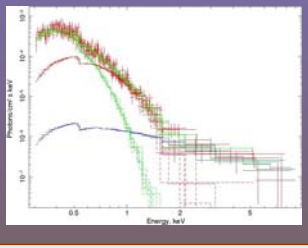


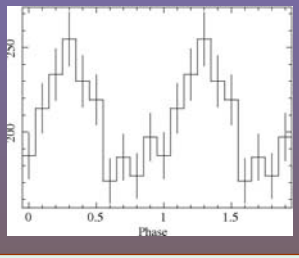
ACIS-S images of the J1740+1000 field. Faint emission from the extended tail is seen within the region between the dashed lines. The 24'' × 18'' insets show the vicinity of J1740+1000. The inset image on the left is produced in the 0.3 – 8 keV energy band and its resolution is maximized by applying a sub-pixel resolution tool . The image was then smoothed with a Gaussian of FWHM 1''. The position of the pulsar is indicated by a 1.5'' circular region. The right panel inset image is produced in the 0.5 – 6 keV energy band and the resolution is maximized by applying a sub-pixel resolution tool. The pixel size in the image is 0.25''.





Left:
68%, 90% and 99% confidence contours computed for the two interesting parameters for the best-fit PL model fitted to the spectrum of the tail of the pulsar J1740+1000 in the 0.4 -10 keV band.
Right:
68%, 90%, and 99% confidence contours for a fixed nH = 1 × 10e21/cm³. The dashed lines are the loci of the constant unabsorbed flux in the 0.4-10 keV band; the flux values are in units of 10e-14 ergs/cm² s.





Left:
The unfolded spectra of the pulsar extracted from the PN, MOS1, and MOS2 cameras of the two XMM-Newton observations, and fitted simultaneously. The best-fit BB+BB+PL model includes a soft black-body component (kT = 70 eV, R ~ 4 – 9 km) with the thermal radiation emerging probably from the NS surface, while the hard thermal emission (kT = 150 eV, R ~ 600 m) emerges from the heated polar caps. The PL photon index is relatively hard (Γ ~ 1.2 – 1.4).
Right:
The pulsed profile in the 0.3-10 keV energy band, showing a pulsed fraction of ~20-30%.