Pulsars : Problems & Progress
ASP Conference Series, Vol. 105, 1996
S. Johnston, M. A. Walker and M. Bailes, eds.

The X-ray synchrotron nebula around PSR 1509-58

K.T.S. Brazier

Dept. of Physics, University of Durham, South Road, Durham DH1 3LE

1. Introduction

PSR 1509-58 is one of the youngest and most powerful pulsars known and is visible not only in soft X-rays, but in gamma-rays. Observations of its supernova remnant (MSH 15-52) offer a rare chance to study such a young pulsar and to explore its surroundings, which in X-rays include the pulsar's 10×6 arcmin X-ray synchrotron nebula and the peculiar, filamentary optical nebula, RCW 89, that sits on the limb of MSH 15-52 (Seward & Harnden 1982, Seward et al. 1983). This paper will concentrate on the morphology of the synchrotron nebula.

2. The synchrotron nebula around PSR 1509-58

The main structure of the synchrotron nebula surrounding PSR 1509-58 is visible in the ROSAT PSPC image (Figure 1). The large-scale features form into a right-angled cross centred on the pulsar, with further substructure also visible. The longer of the two perpendicular "axes" stretches from the northwest to the southeast: the southeast arm curves away at large distances to the east (c.f. Trussoni et al., 1996) and the northwest arm terminates close to RCW 89 (Kawai - this volume). The shorter axis is confined to within ~ 3 arcminutes of the pulsar and is roughly perpendicular to the long axis. The flux in the synchrotron nebula is calculated to be 0.32 ± 0.01 counts/second in the ROSAT HRI band, which amounts to 8 times the total flux from the pulsar itself and around 10 times the pulsed source (Brazier et al. 1996).

While synchrotron nebulae seem to be common features around young pulsars, the Crab Nebula remains the best studied example. In X-rays, the emission is concentrated in linear "jets", which are interpreted as tracers of the pulsar spin axis, and an elliptical torus that is thought to be in the equatorial plane. Although the mechanisms that concentrate the emission into these features are not well understood, simple geometric models gain support from the symmetry of the Crab at optical and X-ray wavelengths (Hester et al. 1995) and from the two long X-ray jets connected with the Vela pulsar (Smith & Zimmermann, 1985, Markwardt & Ögelman, 1995).

The X-ray nebula around PSR 1509-58 is also remarkably symmetric, and the ratio between the nebula and pulsed fluxes is similar to the ratio in the Crab. An attractive proposal is that the systems are also similar morphologically. Neither axis of the PSR 1509-58 nebula can be resolved into the ring-like shape seen in the Crab, but if one axis of the nebula is an equatorial torus viewed at high inclination, then that inclination is more than $i \gtrsim 75$ degrees. This is also suggested by the position of the pulsar under both arms of the cross: relativistic

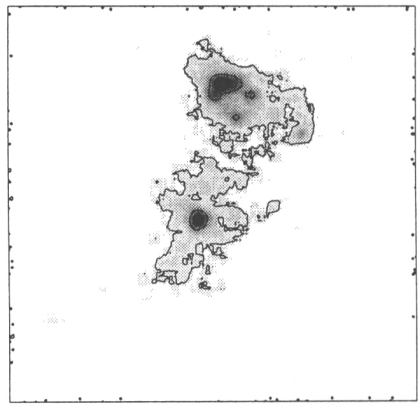

Figure 1. Figure 1. A soft X-ray image of MSH 15-52, showing the pulsar, surrounding synchrotron nebula and the complex emission around RCW 89.

beaming would cause one side of a torus with intermediate inclination to be brighter on one side of the pulsar. RCW 89 in this scenario is the analogy of the Vela X region at the end of the softer Vela X-ray jet. The location of RCW 89 on the limb of the SNR is again consistent with a high pulsar inclination.

While this description is a simplification of the real structure, it accounts well for the major features. The estimate that the pulsar inclination is more than 75 degrees is in contrast to a previous estimate of 34-52 degrees (Beskin et al. 1993), which was made on the assumption that the X-rays were from a hot polar cap. That assumption now seems unlikely, as the soft X-ray pulse is very similar to the one seen in γ-rays and probably originates in the magnetosphere.

Acknowledgments. KTSB acknowledges receipt of a PPARC postdoctoral research fellowship.

References

Beskin V.S., Gurevich A.S. & Istomin Ya.N., 1993, "Physics of the pulsar magnetosphere", Camb. Univ. Press

Brazier K.T.S., et al. 1996, in preparation

Hester J.J. et al. 1995, ApJ, 448, 240

Markwardt C.B. & Ögelman H. 1995, Nature, 375, 40

Seward, F.D. & Harnden F.R. Jr. 1982, ApJ, 256, L45

Seward, F.D, Harnden F.R. Jr., Murdin P. & Clark D.H. 1983, ApJ, 267, 698

Smith A. & Zimmerman H.U. 1985, Space Sci.Rev., 40, 487

Trussoni E., et al. 1996, submitted to A&A