ROSAT OBSERVATIONS OF PSR 0355+54 and PSR 1642–03 [1]

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ABSTRACT

PSR 0355+54 and PSR 1642–03 are both radio pulsars whose X-ray behavior was left unresolved by *Einstein* observations.[1,2] In each case, faint emission was detected near the sources, but appeared to be concentrated 1–2 arcmin from the known pulsar positions. This was interpreted as evidence of either extended emission or of the presence of a serendipitous background object. We have carried out ROSAT PSPC observations of these two pulsars to determine the nature of the emission; here we report on the results of preliminary analysis.

1. Introduction

PSR 0355+54 is a moderate age pulsar ($T_{\rm char} = 10^{5.75}$ y) with a fairly short period (156 ms). The primary properties determined from radio observations[3] are summarized below:

PSR	P (s)	$\dot{P}/10^{-15}$ (s s^{-1})	$\log \dot{E}$ (ergs s^{-1})	$\log T$ (years)	DM (cm^{-3} pc)	D (kpc)	$\log B$ (Gauss)
0355+54	0.156	4.4	34.66	5.75	57	2.07	11.92
1055–52	0.197	5.8	34.48	5.73	30	1.53	12.04
1642–03	0.388	1.8	33.08	6.54	36	2.90	11.93

Using the spin-down energy loss rate as an indicator, PSR 0355+54 is a good candidate for observable X-ray emission; only 10 of the 119 radio pulsars closer than PSR 0355+54 have larger values of $\dot{E}/D^2$, and 8 of these are known X-ray emitters. Observations carried out with the *Einstein* Observatory were inconclusive, however. Weak emission from a position ~ 1.7 arcmin from the radio position was detected, which was interpreted as possible evidence of extended emission from an associated synchrotron nebula.[1] The similarity between this pulsar and PSR 1055–52 (see Table above), which is a known X-ray source[4,5] and has been recently detected as a γ-ray source[6], makes further study particularly interesting.

Einstein studies of PSR 1642–03 provided results similar to those for PSR 0355+54; faint emission concentrated ~ 1 arcmin from the pulsar position was observed, and this was interpreted as possible evidence for an extended synchrotron nebula.[1] The derived luminosity[2] $L_x = 8.5 \times 10^{31}$ ergs s^{-1} is very high given the available spin-down power (see Table above). Assuming the emission is actually associated with the pulsar, this suggests either a particularly efficient mechanism for converting $\dot{E}$ into X-rays, or the presence of an additional energy source. Cooling of the neutron star interior does not seem a viable interpretation, however, given the age of the pulsar. Further study is thus of interest to determine whether the emission is actually associated with the pulsar and what implications the large luminosity may have for emission models as well as for detectability of other pulsars with moderate values of $\dot{E}$.

2. ROSAT Observations

PSR 0355+54 was observed for 19,144 s using the ROSAT Position Sensitive Proportional Counter (PSPC). After cleaning, 16,644 s of good data remain for analysis; here we present a summary of the results from the full analysis.[7] A faint X-ray source is detected at the position of the radio pulsar with a count rate $R = 4.2(\pm 1.3) \times 10^{-3}$ s^{-1}. We have smoothed

[1] From *New Horizon of X-Ray Astronomy – First Results from ASCA* (Eds. F. Makino & T. Ohashi)

the image with a 32 arcsec Gaussian smoothing scale, and subtracted a scaled and similarly smoothed point source for the PSPC to reveal weak residual emission concentrated ~ 1.6 arcmin from the pulsar, in the northeast. Inspection of the surrounding PSPC field reveals a number of similar weak sources, suggesting that this emission is likely to be associated with a background source rather than from an extended pulsar component. We have searched for pulsations at the known radio period of 156 ms but find no evidence using all data (61 counts) from a 30 arcsec circle centered on the point source. Given the small number of counts, this is not surprising; the null detection permits us to establish a 3σ upper limit $f < 77\%$. Most pulsars have pulsed fractions smaller than this. PSR 1055–52 has $f \sim 85\%$ at higher energies, but a corresponding effect would not be seen for PSR 0355+54 due to lack of photons.

With only ~ 70 counts, there is not sufficient information to perform spectral model fitting. Instead, we have considered two cases: 1)a Crab-like power law which might be associated with magnetospheric emission; and 2)blackbody emission from the entire surface of the neutron star (NS), which could result from cooling of the NS interior. By using hardness ratios defined in the standard processing of PSPC spectral data, we have compared the observed spectrum with that predicted by model spectra convolved through the telescope spectral response. Assuming a column density $N_H = 3 \times 10^{21}$ cm^{-2} (derived by scaling the Crab value by the ratio of DM values) we find a surface temperature $T = 1.33(\pm 0.07) \times 10^6$ K (corrected for gravitational redshift) is required to reproduce the PSPC count rate. This temperature is consistent with predictions from current cooling models. However, we find that models for emission from the entire surface of a NS with $R = 10$ km are unable to reproduce the observed hardness ratios, and are particularly poor representations for any reasonable values of N_H. We conclude that the emission is not associated with cooling of the NS interior; rather, it is derived from the pulsar spin-down. This does not rule out the possibility of blackbody emission at a higher temperature, from smaller regions on the NS surface. Such a scenario could result from bombardment of the polar caps by energetic particles accelerated in the pulsar magnetosphere. A Crab-like spectrum power-law spectrum ($\alpha = 2$) yields $L_x(0.1-2.4 \text{ keV}) = 8.0 \times 10^{31}$ ergs s^{-1}, consistent with observed luminosities for other pulsars. In particular, it is very similar to that derived for the power-law component from PSR 1055–52.[7] This similarity suggests that PSR 0355+54 is a good candidate for γ-ray observations.

Our scheduled 40 ks observation of PSR 1642-03 was cut short to ~ 3 ks. Emission from the vicinity of the pulsar is clearly detected, but as in the *Einstein* data the emission is offset from the pulsar position. The shortened observation yielded only ~ 35 counts, insufficient to assess whether the emission is associated with the pulsar or a background source. Using a Crab-like power law spectrum with $N_H = 1.5 \times 10^{21}$ cm^{-2}, scaled from the Crab value, the observed count rate would indicate a pulsar luminosity $L_x(0.1-2.4 \text{ keV}) \sim 2 \times 10^{32}$ ergs s^{-1}. This is extremely large relative to other pulsars given the spin-down energy $\dot{E} = 1.2 \times 10^{33}$ ergs s^{-1}. If correct, the result has strong implications relative to the emission mechanisms. PSR 1642–03 proper motion measurements indicate large velocity (~ 660 km s^{-1}) directed $\sim 30°$ south of east - in reasonable agreement with the direction of the emission. Models for synchrotron emission from a ram-pressure confined wind[8] may explain the offset emission; luminosity values appear problematic, however. Further analysis of this interpretation is in progress.

3. References

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