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Search for Old Neutron Stars in Molecular Clouds

Abstract

We performed a systematic search for old neutron star (ONS) candidates in two giant molecular clouds (Cyg OB7 and Cyg Rift), making use of the ROSAT PSPC archive. Four of the soft X-ray sources in our fields could not be optically identified down to a limit of m_v ~20. A detailed theoretical calculation of the expected number of detections predicts a number of sources considerably larger than what observed, indicating that the assumptions and/or the range of parameters of theoretical models need to be revised.

I Introduction

The detection of old neutron stars (ONS) accreting from the interstellar medium is a long-sought goal of X-ray astronomy. Systematic studies of the observability of ONS with ROSAT were carried out by Treves & Colpi (1991), Blaes & Madau (1993) and Zane et al. (1995). To date, good evidence for ONS candidates has been presented by Stocke et al. (1995) and Walter, Wolk & Neuhäuser (1996). As shown by Blaes & Madau (1993), Colpi, Campana & Treves (1993) and Zane et al. (1995), some molecular clouds in the vicinity of the Sun represent the most favorable sites for the observability of these sources.

We have performed a systematic investigation of the X-ray sources detected by the ROSAT PSPC in the direction of the two molecular clouds Cygnus Rift and Cygnus OB7. A more exhaustive report can be found in Belloni, Zampieri & Campana (1997).

II Theoretical expectations

In order to calculate the number of ONS detectable in the direction of Cygnus Rift and OB7, a number of assumptions have been made:

- Structure of the ISM: we adopted three different ISM densities on the line of sight: $\sim$0.6 cm^{-3} for the local ISM ($<$ 100 pc), 1 cm^{-3} for the ISM $>$ 100 pc and $\sim$30 cm^{-3} for the molecular clouds.

- Space and velocity distribution of ONS: we adopted the distribution derived by Zane et al. (1995).

- Total number of ONS in the Galaxy: $N_{\rm tot} = 10^9$.

- Magnetic field: we assumed that a relic magnetic field, $B = 10^9$ G, is present. The B field channels the accretion flow into the polar caps, but all its radiative effects have been neglected.

- Emitted spectrum: we adopted the spectrum calculated by Zampieri et al. (1995) for a non-magnetized neutron star accreting well below the Eddington limit.

- Observational coverage: we took into account the uneven coverage of the clouds and the different sensitivity levels of different pointings.

In summary, our calculations predict the detection of a total of $\sim$40 sources in the fraction of the clouds covered by ROSAT pointings at the sensitivity limit of 10^{-3} c s^{-1}.

III Observations

We selected pointings from the ROSAT PSPC archive, for a total of $\sim$127 ksec of total exposure. The total spatial coverage was around 5% for both clouds. Sources were detected using the standard EXSAS procedure (see Zimmermann et al. 1994), limited to the central 20$'$ of the detector in order not to degrade the resulting positional accuracy. All sources were visually checked. *A total of 109 sources were detected.*

67 sources were identified with entries in the Guide Star Catalog (Lasker et al. 1990). 35 sources contained possible counterparts with $m_v < 20$ in the Palomar plates. Three of the remaining objects were known X-ray sources. *4 sources remained without possible optical identification* (two sources per cloud, see Table 1).

IV Results

All four sources are close to the sensitivity limit and have a good robust position. Three sources are hard and could be inside the clouds, while the remaining might be a foreground ONS.

Table 1: The four ONS candidates

Name	α (2000)	δ (2000)	Δr ($''$)
Rift–1	$20^h19^m27^s\!.96$	$+38°38'27''\!.6$	10.5
Rift–2	$20^h19^m47^s\!.05$	$+41°12'01''\!.3$	19.2
OB7–1	$20^h53^m07^s\!.35$	$+55°13'29''\!.0$	13.4
OB7–2	$21^h25^m31^s\!.12$	$+51°48'31''\!.5$	9.2

The values of $\log(f_x/f_o)$ for our four candidates are between -0.4 and +0.1. They could still be BL Lacs, clusters of galaxies, young SNRs or PMS stars. Deeper optical/IR observations are needed in order to establish their nature.

However, it is clear that the theoretical number of detectable ONS exceeds the number of candidates by roughly one order of magnitude. This means that the assumptions and/or the range of parameters of theoretical models need to be revised.

References

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