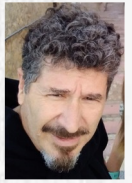

Simultaneous NICER and NuSTAR observations of the anomalous pulsar 4U 0114+65

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7th Heidelberg International Symposium on High-Energy Gamma-Ray Astronomy

Abstract:

We present an X-ray spectro-temporal analysis of simultaneous NuSTAR and NICER observations of 4U 0114+65, to characterize the nature of the source. We extract source light curves in the range 0.2–79 keV and identified two types of flares, *large* and *mini* flares. A pulsation period of 9275 ± 2 s is obtained from the light curve analysis. This is consistent with previously found values associated with a secular spin down. Time-resolved spectra are extracted from each identified interval and modeled with several different phenomenological components. We searched in detail for the presence of cyclotron-resonant scattering features in the spectra of both intervals, but features were not found in any of them. In order to obtain physical parameters, we fit the Becker-Wolff self-consistent cyclotron line model, giving as a main result an estimate of the magnetic field of the order of 10^{12} G. This challenges the magnetar hypothesis.

Universidad de Jaén
Plan de Recuperación, Transformación y Resiliencia
Financiado por la Unión Europea NextGenerationEU

Context

4U 0114+65 (also 2S 0114+65) is a peculiar high-mass X-ray binary (HMXB) containing a neutron star (NS), orbiting the B1Ia supergiant star companion (V* V662 Cas). The system located at a distance of 7 kpc emits persistent X-rays. The source shows an orbital period of 11.6 days, although is not an eclipsing binary. The pulsar's period is ~2.6 hr, making it one of the slowest spinning X-ray neutron stars.

Bonning & Falanga (2005) identified cyclotron lines at ~22 keV and 44 keV, implying a magnetic field strengh of 2.5×10^{12} G for the accreting NS, although over the years the source was observed again and the detection of cyclotron features could not be confirmed (den Hartog et al. 2006; Masetti et al. 2006; Farrell et al. 2006; Pradhan et al. 2015).

The explanation of the long period in pulsars is still a matter of great debate (see e.g., Li & van den Heuvel 1999; Ikhsanov 2007; Shakura et al. 2012; Wang & Tong 2020). Whether or not 4U 0114+65 is a magnetar can help to shed light on this debate. NSs with inferred $B > 10^{14}$ G, are called *accreting magnetars*.

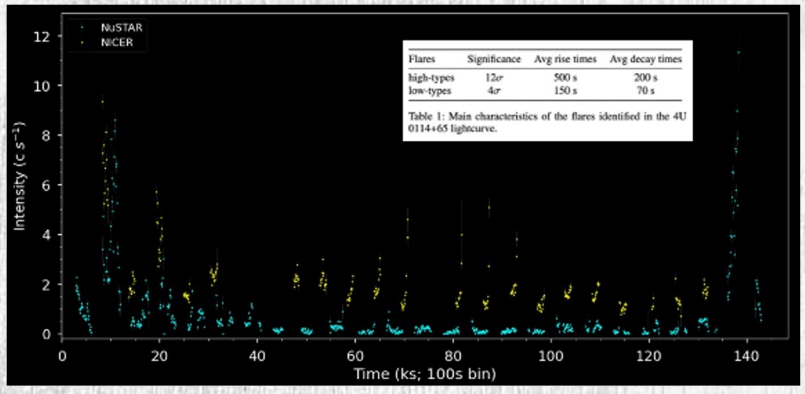
NICER and NuSTAR DATA

The Neutron star Interior Composition ExploreR (NICER) is an X–ray satellite equipped the X-Ray Timing Instrument (XTI) detector stationed on the International Space Station and operated by NASA. XTI detects soft X-rays in the 0.2-12 keV energy range with high temporal resolution. We analyzed NICER's ObsIDs 2200930101-03 ranging from October 27, 2019 to October 29, 2019. We have performed the standard data processing using HEASoft v.6.30 and NICER data analysis software (NICERDAS).

The Nuclear Spectroscopic Telescope Array (NuSTAR) is an X–ray satellite equipped with two detectors, FPMA and FPMB, operating in the 3 to 79 keV energy range. It was observed in October 19, 2019 (ObsID 30501016002), with a coverage time of 143 ks and livetime of 75 ks. Data was reduced using NuSTARDAS-v. 2.0.0 analysis software from HEASoft v.6.30 and CALDB (V.20211221) calibration files.

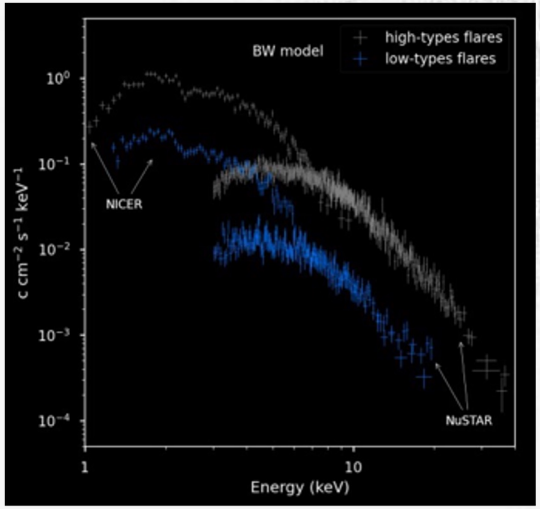
Results

The light curve of the source with a binning of 100 s in the 0.2-79 keV energy range obtained using NICER and NuSTAR simultaneous data. We identified two type of flares according to their relative intensities. We called them *large* and *mini* flares. The main characteristics associated to these flares are presented in Table 1.



Flares	Significance	Avg rise times	Avg decay times
high-types	12σ	500 s	200 s
low-types	4σ	150 s	70 s

Table 1: Main characteristics of the flares identified in the 4U 0114+65 lightcurve.



Parameters	Long flare	Mini flare
ξ	15.4±1.2	17.5±0.4
δ	0.26±0.03	0.27±0.05
Electron temp. T_e (keV)	3.7±0.2	2.9±0.3
Column radius r_0 (m)	13.2±1.1	33.6±5.3
Magnetic field B (10^{12} G)	$2.77^{+0.14}_{-0.07}$	$2.36^{+0.34}_{-0.29}$
Mass accretion rate[a] (10^{16} g/s)	3.5±0.3	7.6±0.8
Source flux (1-40 keV)[b]	4.60 ± 0.08	0.49 ± 0.03
χ^2/dof	660/626	355.36/349

Table 1: Parameters associated with the B-W model. [a] Mass accretion rate is calculated by considering a distance of 7 kpc (reig et al). [b] Unabsorbed flux in unit of 10^{-11} erg cm^{-2} s^{-1}

We fitted the Becker-Wolff self-consistent cyclotron line model to obtain physical parameters of the source including the magnetic field strength.

Conclusions

The NICER and NuSTAR observations allowed us to study in detail the spectral characteristics of the source. We searched for the cyclotron absorption lines mentioned by Bonning & Falanga (2005) but there was no trace of it. At the same time, the BW model was fitted to extract relevant physical parameters, especially the magnetic field, which was found to be of the order of 10^{12} G. This suggests that 4U 0114+65 might not be a magnetar.

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