Is a 4U 0114+65 an wind-accreting magnetar?
a glimpse of NuSTAR and NICER

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Abstract. 4U 0114+65 is an X-ray pulsar with one of the slowest pulsations known to date. The most accepted hypothesis is that this is an accreting magnetar. We present an analysis of a simultaneous observation of NuSTAR and NICER telescopes. We searched for the presence of cyclotron-resonant scattering features in the spectra. No cyclotron resonant dispersion features are found in any interval. In order to obtain physical parameters of the system, the Becker-Wolff self-consistent cyclotron line model was fitted, obtaining in both intervals a magnetic field of the order of 10^{12} G.

Context

4U 0114+65 (also knows as 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 this is not an eclipsing binary . The pulsar's period is 2.6 hr, making it one of the slowest spinning X-ray neutron stars.

Although Bonning & Falanga (2005) identified cyclotron line absorption at~ 22 keV and 44 keV, implying a magnetic field of 2.5×10^{12} G for the accreting NS, in the last years it 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 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 shed light on on this question. For NS that obtained $B > 10^{14}$ G, it has been called accreting magnetars.

NICER and NuSTAR DATA

The Neutron star Interior Composition ExploreR (NICER) is an X-ray telescope 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 telescope 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

We show in Figure 1 a light curve of the source with a temporal binning of 100 s in the 1-79 keV energy range. Non statistical changes in the count rate are observed, especially at the beginning and end of the observation. We identified two intervals, one associated with an intermediate flare and the other with a high flare.

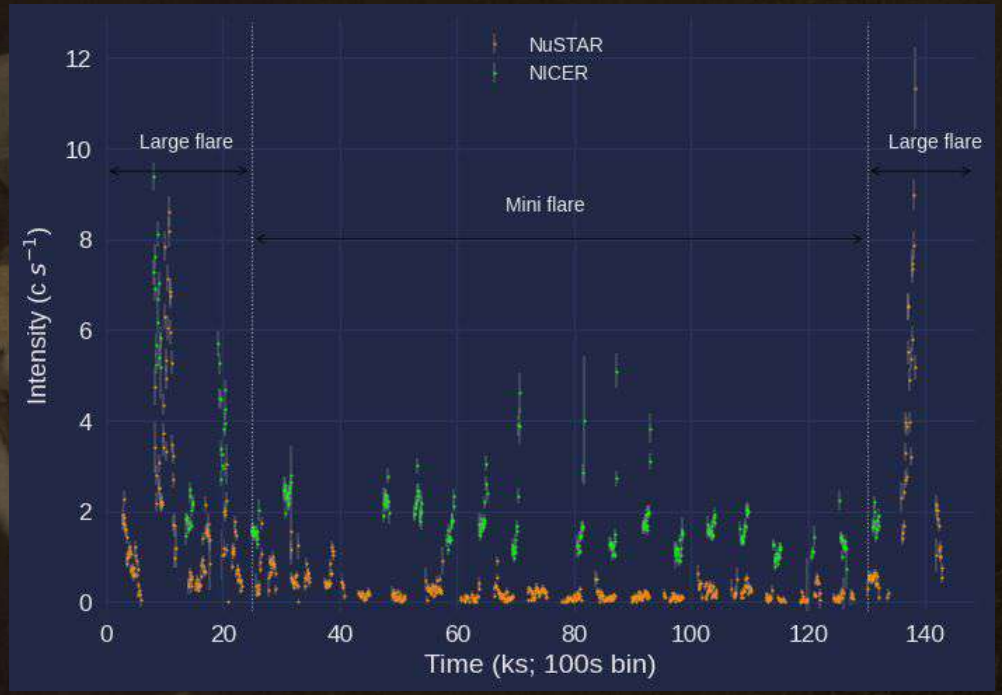

Figure 1

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 (BW) to obtain physical parameters of the source including the magnetic field. The fit is shown in Figure 2 and the associated parameters in Table 1

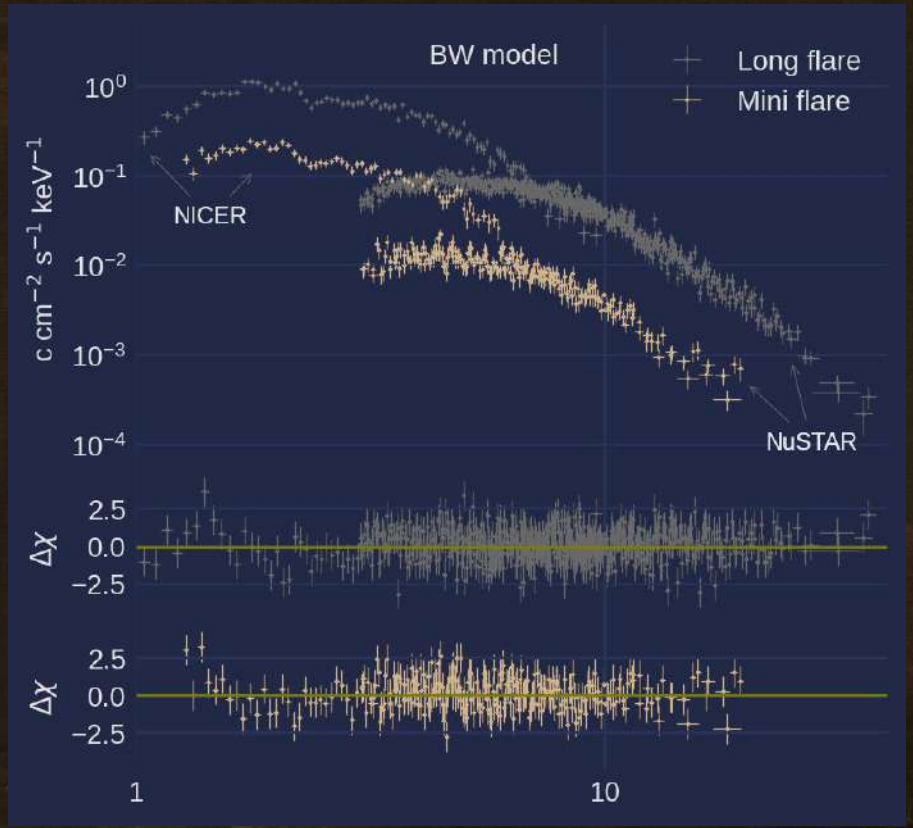

Figure 2

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 does not allow us to say that 4U 0114+65 is possibly not a magnetar.

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