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Letter to the Editor

Detection of optical pulsations from RX J0558.0+5353

B.N. Ashoka[1], T.M.K. Marar[1], S. Seetha[1], K. Kasturirangan[1], and J.C. Bhattacharyya[2]

[1] ISRO Satellite Centre, Airport Road, Bangalore 560 017, India
[2] Indian Institute of Astrophysics, Sarjapur Road, Bangalore 560 034, India

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Abstract. We report the detection of optical pulsations at a period of 272.785 s ± 0.003 s from the newly discovered intermediate polar RX J0558.0+5353. This period nearly coincides with the X-ray period reported by Haberl et al. (1994). In the optical band the folded light curve of the star reveals a non-sinusoidal pulse with a pulsed fraction of 10.8%.

Key words: binaries: close - stars: individual: RX J0558.0+5353 - stars: cataclysmic variables-X-rays: stars

1. Introduction

RX J0558.0+5353, a new soft x-ray source from the ROSAT galactic plane survey (Motch et al. 1991) was recently discovered as an intermediate polar (IP) by Haberl et al. (1994). Intermediate polars form a subgroup of cataclysmic variables having a magnetised white dwarf that accretes matter from its late type companion. The rotation of the white dwarf is not phase-locked to the binary period of the system and the magnetic field of the white dwarf is about an order of magnitude lower than that in polars. An accretion disc is usually present in IPs, unlike the case in polars. The disc is however disrupted by the magnetic field close to the white dwarf and the accreted material is then funneled along the field lines on to the magnetic polar caps of the white dwarf. An offset between the rotation axis and the magnetic dipole axis of the white dwarf causes pulsations in the x-ray and optical wavelength bands .The x-ray pulsation period is identified as the spin period of the white dwarf and is usually much lower than the orbital period in IPs. In addition to spin and orbital periods, evidence for beat periods caused by reprocessing of x-rays at some part of the system that revolves at the binary period is also seen in most intermediate polars. For a recent review on intermediate polars (DQ Her stars), see Patterson (1994).

Send offprint requests to: T. M. K. Marar

Haberl et al. (1994) have determined the x-ray pulsation and orbital periods in the intermediate polar RX J0558.0+5353 as 272.74 s ± 0.02 s and 4.15 hour respectively. In order to detect optical pulsations at or near the x-ray pulsation period and to search for other periodicities in the system, we conducted high speed photometric observations of this star during Jan-Feb 1995. Optical pulsations were unambiguously detected at the X-ray period during the very first night of our observations on January 8 (IAUC no. 6129). We present in this paper results from all our observations, spanning a total duration of 15.9 hours so far.

2. Observations and analysis

RX J0558.0+5353 was observed on January 8 using a 3 channel (2 star + sky) photometer and during February 6-8 using a two star photometer attached to the one metre telescope at Vainu Bappu Observatory, Kavalur. A log of the observations is given in table 1. The programme star was observed in the first channel, a nearby field star in the second channel, and the sky background in the third channel. Data was collected at 10s sampling intervals in white light (approximately 3000 to 5000 Å), employing a PC based data acquisition and analysis system (see Nather et al. (1990)).

In order to remove the sky contribution in the three channel data, the sky channel was fitted with a polynomial and was subtracted from the program star data. In the case of two star data, sky readings were interpolated and sky contribution was removed from both channels. The extinction trend was later removed for all runs by fitting the light curve with a third order polynomial and dividing it by this polynomial. For the runs k271 and k273 the light curve of the program star was also divided by that of the comparison star and normalised by the mean count rate of the program star. This procedure tends to reduce the amplitude of the long term trends in the data. The

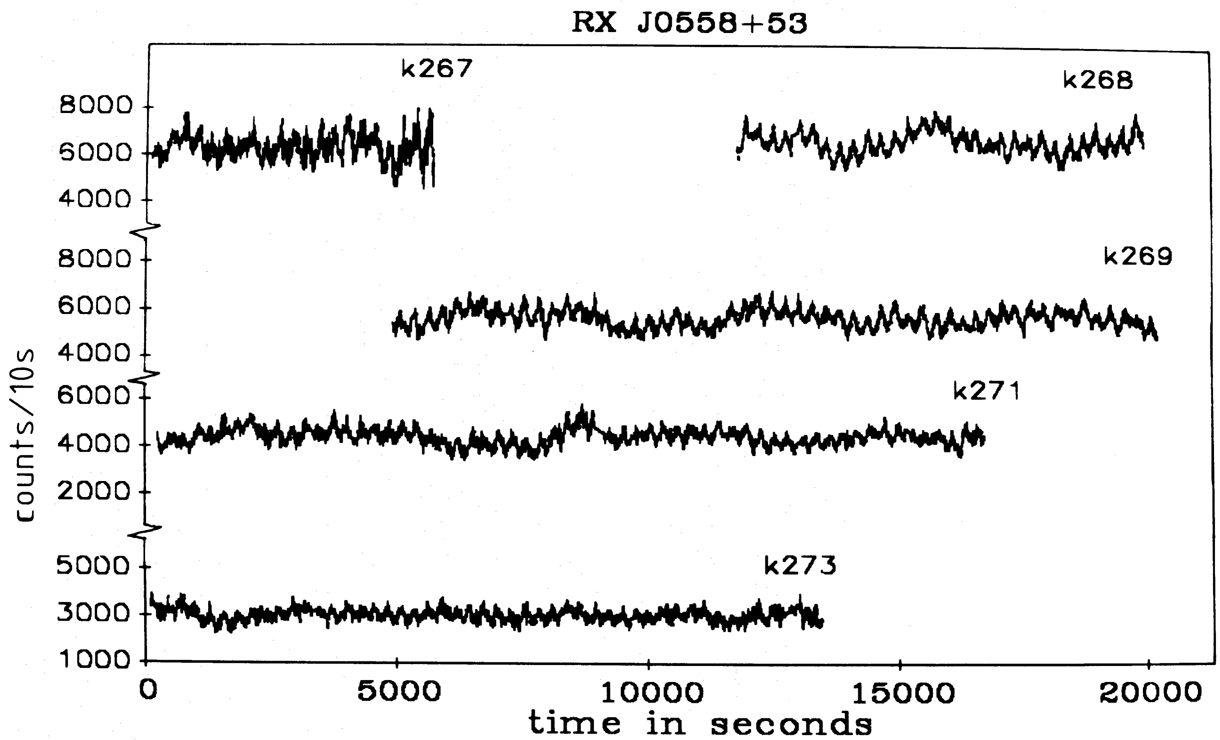

Fig. 1. Reduced light curves of RX J0558.0+5353. Integration time was 10s. There are 1500 data points in a run like k269. The dominant oscillations in each run correspond to a period of 273s

same could not be done for the earlier runs because the brightness of the comparison star chosen by us turned out to be unsuitable for this purpose. A mosaic of the reduced light curves is presented in Fig. 1. In order to emphasise the nature of optical pulsations, a small portion of the light curve from the run k269 is shown expanded in Fig. 2.

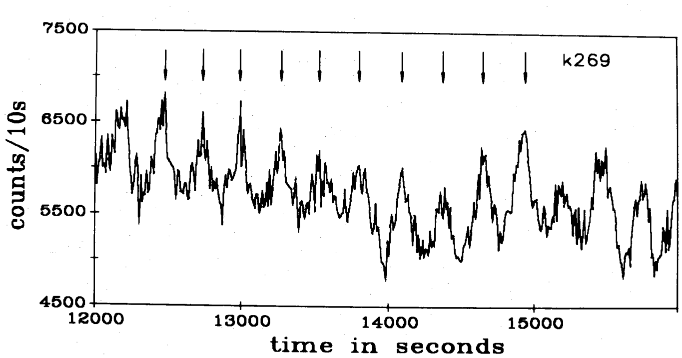

Fig. 2. A portion of the light curve of k269, expanded to show the nature of the 273s pulsations

3. Results and discussion

Figures 1 and 2 clearly indicate the presence of pulsations with a period around 270s. The percentage modulation (defined as the peak to peak amplitude divided by the mean) is as high as 15%. RX J0558.0+5353 is thus one among the large amplitude intermediate polars. Modulation of the pulsation amplitude (say, for example, due to the beating of pulsation and orbital frequencies) is not evident in our data.

The reduced light curves of each run was independently subjected to a discrete Fourier transform analysis in order to search for the exact periodicities in the system. The most prominent peak in the power spectrum of each run was that of the 273s period. Figure 3 shows the amplitude spectrum corresponding to runs k268 and k269. Table 1 gives the period, its amplitude and remarks on the presence of first and second harmonics of the pulsation period in the DFT. In addition to the 273 s period in the DFT, peaks are also seen at the harmonics of 136.3 s and 90.8 s but with lower amplitudes. We also searched for the lower side band corresponding to the beat between the pulsation period and the orbital period of 4.15 hours as well as peaks at twice the 273s period and its side bands. No conclusive evidence exists for the above periods in our

Table 1.

Run no	Date	Run start time (UT)	Run length (hr)	DFT results: Dominant pulsation period (s)	Amplitude (mma)*	Remarks+
k267	1995 Jan 8	16:51:38	1.57	270.75	67	1H, 2H seen
k268	1995 Jan 8	20:05:22	2.30	271.99	49	1H, 2H seen
k269	1995 Feb 6	15:51:45	4.17	272.78	51	1H, 2H seen
k271	1995 Feb 7	14:07:46	4.13	273.02	47	-
k273	1995 Feb 8	15:54:10	3.71	273.22	50	-

+ 1H and 2H are the first and second harmonic of the pulsation period
* mma stands for millimodulation amplitude derived from Fourier transform of fractional intensity light curves.

data. The appearance of the two harmonics in the DFT may result from a non-sinusoidal nature of the 273s optical pulsation. In order to verify this, we folded the k269 light curve which had a relatively lower sky background contribution due to the moon and was also the longest data run. The folding was done at the pulse period of 272.78s. The resultant pulse profile is shown in Fig. 4. The pulse shape is clearly peaked and non-sinusoidal. This shape is therefore the likely cause of the presence of harmonics in the DFT. The optical pulse shape looks different from that in the x-ray band (see Fig. 5 of Haberl et al.). Hence eventhough the optical and x-ray pulsation periods are nearly equal, the geometry of the emission region, the radiation pattern and/or the occultation regions are different in the two wavelength bands. The pulsed fraction defined as peak to peak amplitude divided by maximum (as compared to division by average as is usually used for light curves and used above in this section) in the optical band is 10.8%, which may be compared to the values of 45.4% and 12.5% in the x-ray energy ranges of 0.1 - 0.4 keV and 0.5 - 2.0 keV respectively (Haberl et al.).

The dominant presence of the spin period in x-ray and optical emissions from the system indicates observability of a single pole. Based on theoretical models (Wynn and King 1992) asymmetric accretion with respect to the two magnetic poles of the white dwarf could also give rise to the presence of spin period in the DFT. The asymmetry could be due to differences in size or shape or luminosities of the polar caps. The absence of any beat periods with the orbital period would also suggest accretion through a disc as likely. Further longer duration data will be necessary to detect the presence of orbital modulations and other low amplitude variations in this star.

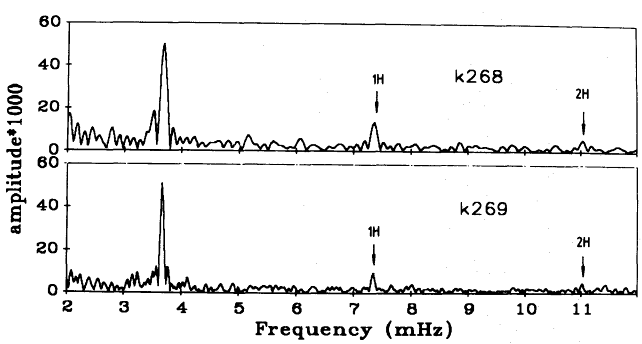

Fig. 3. Fourier amplitude spectrum of k268 and k269 runs showing the spin period of 273s and its harmonics at 136.3 s and 90.8 s

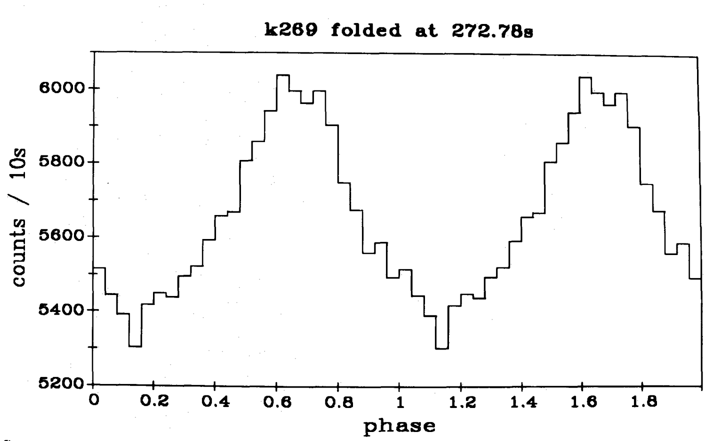

Fig. 4. Light curve of k269 run folded at 272.78s

In order to determine an ephemeris for the 273 s pulsation period, we carried out a non-linear least square sine wave fit for each of the runs separately. (The run k267 was relatively noisy and was therefore excluded). The sine fit gave the epoch T_o of zero crossing for each of the runs. The values of T_o were then converted to T_{max} values for the pulse maxima. The corresponding cycle numbers were calculated with k268 run as the reference. A fit of T_{max} versus cycle number (E) gave the following ephemeris for the pulse maximum :

$$T_{max}(\text{HJD}) = \underset{\pm 0.0002}{2449726.3474(\text{HJD})} + \underset{\pm 0.00000003}{0^d.00315723\text{E}}$$

and the pulsation period is determined as 272.785 s ± 0.003 s. Note that the runs of k269, k271 and k273 are clustered with one day difference between each other and the k268 run is separated from these three runs by 28 days. Hence long term observations will be needed to determine the stability of the 272.785s period.

4. Conclusions

We report that the intermediate polar RX J0558.0+5353 exhibits optical pulsations at 272.785 s ± 0.003 s close to the spin period determined in the x-ray band. The folded pulse profile in the optical band shows a non-sinusoidal peaked appearance with a pulsed fraction of 10.8%. The Fourier transform hence shows harmonics of the 273 s period at 136.3 s and 90.8 s. The system is most probably a single pole accretor with a certain amount of disc accretion.

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