

## FR Cnc = BD +16°1753 - A YOUNG ACTIVE MAIN-SEQUENCE STAR

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The star BD +16°1753 ( $\alpha_{2000} = 08^h32^m30^s.5$  and  $\delta_{2000} = +15^\circ49'26''$ ) of  $V = 10.43$  mag and spectral type K8V is an optical counterpart of the bright soft X-ray source 1ES 0829 + 15.9 = 1RXS J083230.9+154940 (Elvis et al. 1992; Schachter et al. 1996; Voges et al. 1999). BD +16°1753 is  $33 \pm 2$  pc distant (Perryman et al. 1997) implying an absolute magnitude of 7.8 and a ratio of X-ray to bolometric luminosity  $f_x/f_{bol}$  of  $\sim 10^{-3}$  which shows that the star has an active corona at at the ‘saturation’ limit. It has been classified as an ‘unsolved’ Hipparcos variable star (FR Cnc) of 0.17 magnitudes amplitude variability (Perryman et al., 1997), and as a suspected BY Dra-type variable, i.e., having variability due to the rotational modulation of starspots, by Kazarovets et al. (1999). Using the mean radial velocity of 25.5 km/s (Upgren et al. 2002) and the Hipparcos Catalogue distance and proper motions, the galactic space velocity components (U, V, W) of BD +16°1753 are  $(-24.1, -22.8, -5.1)$  km/s. This clearly places the star inside the young disk population boundaries in the (U, V) and (V, W) diagram (Montes et al. 2001).

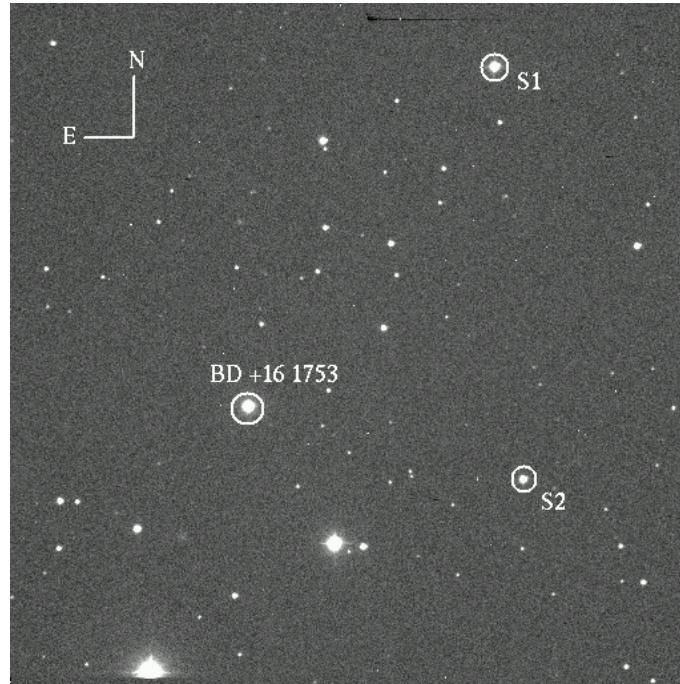
Broad band BVR photometric observations of FR Cnc were carried out from the State Observatory Naini Tal using the  $2K \times 2K$  CCD camera during the years 2001 - 2002. We have also taken low resolution spectra from 104-cm telescope at State Observatory Naini Tal using the HR-320 spectrograph with the  $1K \times 1K$  CCD camera. The dispersion of the spectrograph was 100 Å/mm.

Both photometric and spectroscopic data were reduced using the standard packages under IRAF<sup>1</sup>. We have been able to do accurate differential photometry as both the comparison (S1) and check (S2) stars are within the  $13' \times 13'$  field of view of the CCD camera as shown in Fig 1. The corresponding USNO-A2.0 numbers for S1 and S2 are 1050-05766844 and 1050-05766589. The comparison star (S1) is also identified as TYC 1392 2110 1. Correlated periodic variations have been observed in the  $V$  magnitude and the  $(V - R)$  colour of FR Cnc. The top and the middle panels of Fig. 2 show the differential magnitude and the  $(V - R)$  colour variations folded against the most significant period of 0<sup>d</sup>827 found (see below). An arbitrary epoch of JD 2451943.1980 has been used. The data shown are from observations carried out in 27 November - 5 December 2001 (Fig. 2a), 11 December 2001 - 1 January 2002 (Fig 2b) and 31 January

<sup>1</sup>IRAF is distributed by the National Optical Astronomy Observatories, USA

- 4 February 2002 (Fig. 2c). The star was found to become redder when fainter and bluer when brighter. The differential magnitudes of the check star with respect to the comparison star are also plotted in Fig. 2 (bottom panels). No significant light variation was detected between the different measures of the comparison and check stars, indicating that the light of the comparison star was indeed constant during the observations. The full set of data was analysed using the standard period finding techniques and photometric period  $0^d.827 \pm 0.002$  was found. The amplitude of variation in  $V$  band and change in phase of the minima are tabulated in Table 1. The errors in determination of  $\Delta V$  and phase minima are  $\pm 0.003$  mag and  $\pm 0.03$  to  $\pm 0.06$ , respectively. The light curves for the epochs (a) and (c) clearly show the secondary minima indicating the presence of two spots (or groups of spots) separated by 0.5 in phase. Secondary minima could not be determined during the epoch (b) observation.

Figure 3 shows a low-resolution normalized spectrum of FR Cnc taken on 29 April 2002.  $H_\alpha$  emission is clearly seen. In late type stars  $H_\alpha$  emission is a good indicator of chromospheric activity. Changes of the photometric amplitude and phase on a time scale of a few rotations are quite commonly seen among active stars as their spot distributions vary. The observed rotational period of FR Cnc is unusually short, however.

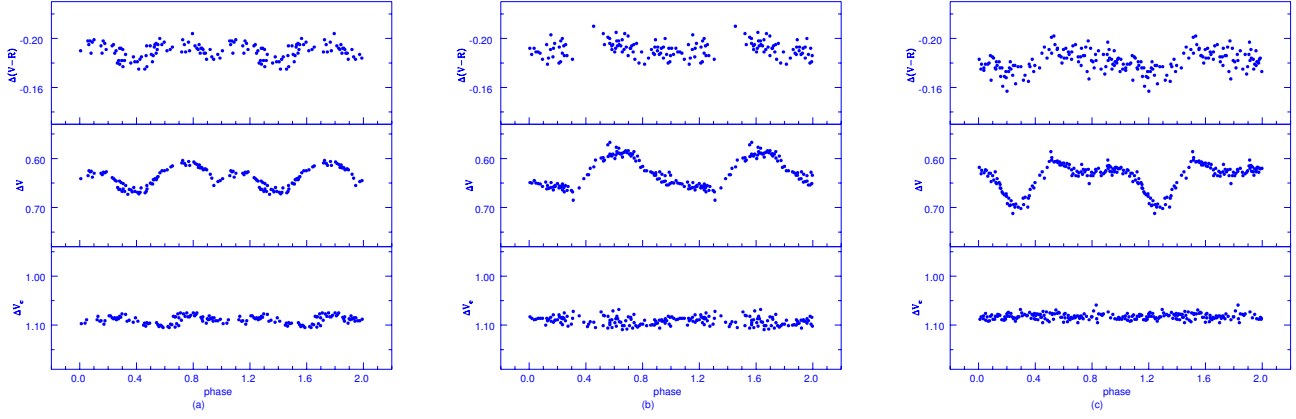


**Figure 1.** Identification chart of FR Cnc, Where S1 and S2 are comparison and check stars, respectively.

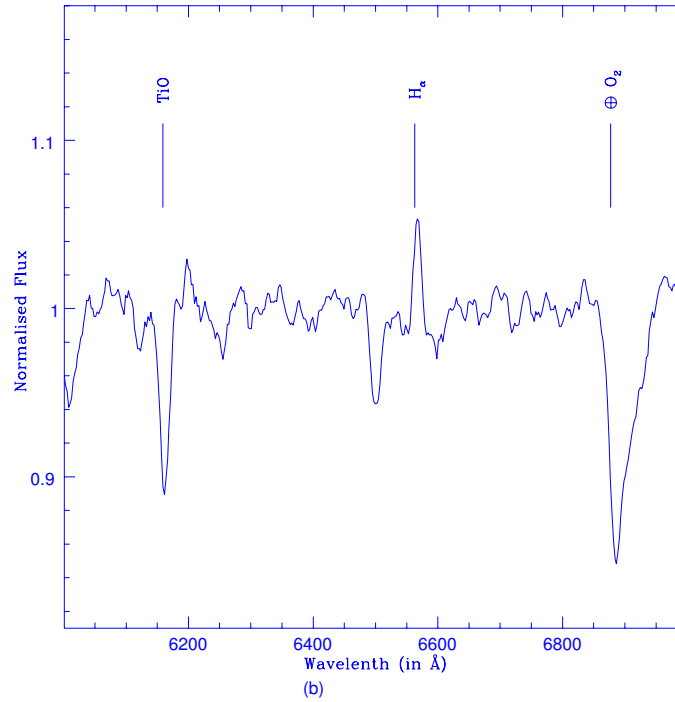
Its youth, amplitude variation, phase change,  $H_\alpha$  emission and soft X-ray emission suggest that the star FR Cnc is an active and spotted star with photometric period of  $0^d.827 \pm 0.002$  (the likely stellar rotation period). It is more likely to be a single star than a binary star, given the lack of radial velocity variations (based on two measurements!), although the fact that its absolute magnitude is  $\sim 0.8$  magnitudes brighter than that of a canonical K8 V star is a weak evidence for a binary status. However, to further understand the nature of this star, high-resolution spectroscopic observations coordinated with simultaneous photometric observations are urgently needed. We are accordingly planning to monitor this object further.

Table 1: Maximum amplitude in  $V$  band ( $\Delta V$ ) and phase of the minima at different epochs

Epoch	$\Delta V$ (mag)	Phase minima	
		I	II
(a) 27 Nov - 5 Dec 2001	0.06	0.40	0.90
(b) 11 Dec 2001 - 1 Jan 2002	0.10	0.30	—
(c) 31 Jan - 4 Feb 2002	0.10	0.27	0.78



**Figure 2.** Differential  $V$  and  $(V - R)$  light curves of the star BD +16°1753 and differential  $V$  light curve of the comparison star: (a) during 27 November - 5 December 2001; (b) 11 December 2001 - 1 January 2002; and (c) 31 January - 4 February 2002



**Figure 3.** Low-resolution spectrum of BD +16°1753

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