FR Cnc Nature Revisited

M.C. Gálvez, A. Golovin, M. Hernán-Obispo, E. Pavlenko, M. Andreev, D. Montes, J.C. Pandey, A. Sergeev, Yu. Kuznyetsova, and V. Krushevska

Abstract The results of photometric and spectroscopic monitoring of FR Cnc reported a tricky nature. We carried out several observations at different observatories in India, Russia, Ukraine and Spain during several years to characterize and discover the source of its radial velocity (RV) variations. After discard a binary nature in first instance due to its high level of activity, further detailed and complete study lead as to still take into account the presence of a stellar companion possibility. We present here the study of this star and preliminary conclusions about its real nature.

1 Observations

We obtained high and low resolution spectroscopic observations of FR Cnc in three observing runs: March-April 2004, using the Fibre Optics Cassegrain Echelle Spectrograph (FOCES) ([13]) in the 2.2 m. telescope at the German Spanish Astronomical Observatory (CAHA) (Almería, Spain). April 2004 using the Himalaya Faint

M.C. Gálvez
Centre for Astrophysic Research, University of Hertfordshire, AL109AB, U.K., and Universidad Complutense de Madrid, E-28040 Madrid, SPAIN e-mail: M.Galvez-Ortiz@herts.ac.uk

A. Golovin, Yu. Kuznyetsova and V. Krushevska
Main Astronomical Observatory of National Academy of Science of Ukraine, Kyiv, UKRAINE

M. Hérnan-Obispo and D. Montes
Departmento de Astrofísica, Universidad Complutense de Madrid, E-28040 Madrid, SPAIN

E. Pavlenko
Crimean Astrophysical Observatory, Nauchny, UKRAINE

M. Andreev and A. Sergeev
Terskol Branch of Institute of Astronomy RAS, RUSSIA

J.C. Pandey
The Indian Astronomical Observatory, Mt. Saraswati, Hanle, INDIA

Object Spectrograph And Camera (HFOSC) in the 2.2 m telescope of The Indian Astronomical Observatory (Hanle, India). And March 2008, using The Fibre-fed Echelle Spectrograph (FIES) in the 2.56 m. Nordic Optical telescope (NOT) at the Roque de los Muchachos Observatory (La Palma, Spain).

We obtained the photometry at CrAO (Crimean Astrophysical Observatory, UKRAINE) on November 2006, with a 38-cm Cassegrain telescope and SBIG ST-9 CCD camera, as well as in Terskol Observatory (Terskol, RUSSIA) in March 2007 and February 2008, using 0.29-m telescope and Apogee-47 Alta CCD camera.

2 Chromospheric activity indicators

Classified as a K8V in Simbad and as a K5V by [11] in a detailed photometric study (with a T_{eff}=4250±250 and $\log g$=4.50±0.5), we used our high resolution echelle spectra to derive a K7V spectral type, and a rotational velocity of $\approx$ 35 km/s (See e.g. [2], [3] and [9] for used technique). So it is expected to show activity features.

We determined the chromospheric contribution of different activity indicators by using the spectral subtraction technique, see e.g. [9]. We measured and average value of absolute superficial flux $\log F_S(H\alpha)$= 6.5 and $\log F_S$(Ca II IRT) = 6.2. Examples of the profiles of the Hα and Ca II IRT (8498, 8542 Å) lines are plotted in Fig. 1. Hα line is always in emission above the continuum in the observed spectra. Absorption of the three, Hβ, Hγ and Hδ lines filled-in with emission are seen too, sometimes with emission above the continuum. Also, a clear emission filling the absorption line is observed in the core of the Ca II IRT absorption lines. To study the origin of the emission lines, we used two known relations between Balmer lines ([6]) and between Ca II IRT lines ([1]). We obtained that Balmer lines comes from prominences-like structures above the stellar surface, while Ca II IRT emission arises from plage-like regions at the stellar surface.

3 Photometry

First photometry allows us to detect a flare in FR Cnc on 23 November 2006 with a total duration of about 41 minutes. The flare had a maximum amplitude of $1^m.02$ in the B band. Noteworthy, in 8 minutes after the flare's maximum a notable "spike" was observed in B and V bands (in other bands the amplitude was probably too low) during the brightness decline. It is remarkable that FR Cnc remained to be about $0.^m05$ brighter for at least an hour after the flare began comparing with brightness before flare. Following [7], we calculated the intensity and absolute energy output the flare, for details see [5]. Further photometry follows up allow us to obtain a light curve, see Fig. 2. As could be clearly seen, one-humped $0.^m17$ variations with the rotational period are clearly distinguishable. No further flares were detected (2007 and 2008 follow up) that could imply that flares is a rare event for FR Cnc.

4 Line bisector analysis

FR Cnc is a very active star (Sect. 2.), so it is expected that activity features produce rotational modulation of light from its surface as well as produce RV variations (see Fig. 2). To study spectroscopic variations produced by spots we used bisector techniques. The relationship of bisectors of the cross-correlation function (CCF) and RV is a powerful method to discriminate if the RV variation is due to stellar activity, light contamination from an unseen stellar companion or dynamical motion of a star-planet system ([14], [9]). The CCF determined was limited to regions ranging from 6300 to 6465 Å and 6670 to 6760 Å, which includes lines commonly used in Doppler imaging. We calculated the bisector for the CCF and to quantify its changes, the bisector inverse slope (BIS) was computed (defined as the difference between average values of the top and the bottom zones of the bisector). First results showed that the RV variations could be due to changes in profile lines caused by the presence

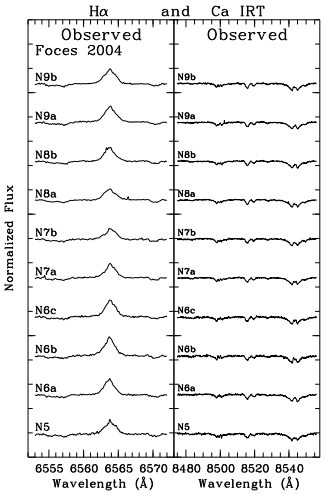

Fig. 1 Examples of the profiles of the Hα and Ca II IRT (8498, 8542Å) lines are plotted. Hα line is observed always in emission above the continuum in the observed spectra. Also, a clear emission filling the absorption line is observed in the core of the Ca II IRT absorption lines.

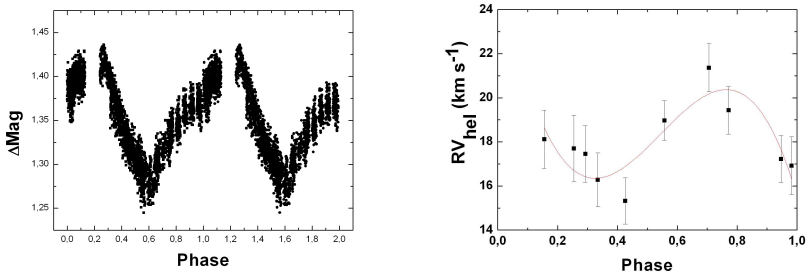

Fig. 2 Left: Light curve folded with rotational period (0.8267d) for 2008 season. Right: RV folded with the rotational period.

of spots [15]. However, the clear correlation between RV and the BIS, with positive slope, suggests that a possible stellar companion could explain the RV variation.

5 Summary

FR Cnc is a very young (35-55 Myr), fast rotator (vsini = 35.58 km/s) K7V chromospherically active star. Here we found spectroscopic and photometric evidences of spots as well as prominence-like structures (inferred from the chromospheric activity indicators).

It is not a flaring star although we detected a large optical flare in *BVRI* bands on 23 November 2006. But during quiescence state (in 2007 and 2008), we detected $0.^m17$ brightness modulations with rotational in *B*-band.

We found variations in RV, that could come from the activity features, but also from a companion. We have found a RV variations correlated with the rotational period and with line asymmetries quantified with the line bisectors.

Further bisector and photometry studies are actually on going to help us to finally discriminate the source of the RV variation and clarify the real nature of FR Cnc.

Acknowledgements This work was partly supported by Science & Technology Centre in Ukraine, grant #4134 and grant of the FRSF F25.2/139. And partly supported by the Spanish Ministerio de Educación y Ciencia (MEC), Programa Nacional de Astronomía y Astrofísica under grant AYA2005-02750, and the "Comunidad de Madrid" under PRICIT project S-0505/ESP-0237 (ASTROCAM). A. Golovin is thankful to Universidad Complutense de Madrid for hospitality and for all efforts and help during his visit of Spain in July 2008. A. Golovin work was partly supported by Ekialde Foundation.

References

1. M.M. Chester, PhDT 9C, Pennsylvania State Univ. (1991)
2. R.C. Dempsey, B. Boop et al., ApJ, **392**, 187 (1992)
3. M.C. Gálvez, PhD Thesis, Universidad Complutense de Madrid, (2005)
4. M.C. Gálvez, D. Montes, M.J. Fernández-Figueroa et al., A&AS, **389** 524 (2002)
5. A. Golovin, E. Pavlenko, Yu. Kuznyetsova, V. Krushevska, IBVS, **5748**, (2007)
6. J.C. Hall & L.W. Ramsey , AJ, **104**, 1942 (1992)
7. A.V. Kozhevnikova, I. Yu. Alekseev et al., IBVS, **5723**, 1K (2006)
8. J. López-Santiago, D. Montes et al., A&A, **411**, 489 (2003)
9. A.F. Martínez-Fiorenzano, R.G. Gratton et al. A&A, **2442**, 775 (2005)
10. D. Montes, J. López-Santiago, M.C. Gálvez et al., MNRAS, **328**, 45 (2001)
11. J.C. Pandey, PhD Thesis, Kumaun University, Naini Tal, (2005)
12. J.C. Pandey, K.P. Singh, R. Sagar & S.A. Drake, JApA, **23**, 9P (2002)
13. M.J. Pfeiffer, C. Frank, D. Baumueller et al, A&AS, **130**, 381 (1998)
14. D. Queloz & G.W. Henry, A&A, **379**, 279 (2001)
15. S.H. Saar & R.A. Donahue, ApJ, **485**, 319 (2007)
16. A.R. Upgren, J Speraukas & R.P. Boyle, BaltA, **11**, 91U (2002)