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Radio monitoring of Stellar Activity in Active Binary Sistems

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Abstract. We summarize recent results from a long-term single-dish monitoring program of a sample of active binary stars at 5 GHz, carried out with the 32m radiotelescope of INAF Istituto di Radioastronomia at Noto.
Even if the principal aim of this monitoring programm was to activate *ad-hoc* VLBI observations, once the onset of a strong radio flare had been detected, the collection of a quite large database has allowed us to study the variability of radio emission from active binaries on short as well as long timescales that contributes to our understanding of stellar coronae.

Key words. Stars: activity – Stars: coronae – Stars: flare – Star: individual: HR 1099 – Star: individual: Algol – Radio continuum: stars

1. Introduction

The term Active Binaries refers to two different class of objects: RS CVn and Algol systems.
RS CVn type systems are detached close binaries, typically a F or G main sequence star and a cooler K subgiant. *Algol* type binaries are semidetached systems the less massive member (a K or G cold subgiant) of which fills its Roche lobe and transfers mass to the primary object, a A or B main sequence star. Even if they show different evolutions, the two classes share a number of common features. In particular they display all the manifestation of solar-like activity (spots, chromospheric active regions, X-ray and radio emission, flares), but to a greater degree because of the presence of strong magnetic fields generated by an efficient dynamo action.
The radio flux density is highly variable and it usually shows two different regimes: active periods, characterized by a continuous strong flaring lasting up to several days, and quiescent periods, during which the flux density goes down to a few mJy. Circular polarization ($\pi \leq 30\%$) is often measured during quiescent periods. It tends to decrease as the flux density increases.
The above characteristics indicate the non-thermal nature of the radio emission, which is driven by the magnetic activity observed in other spectral regions. In this scenario, the radio flux arises from the interaction between

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the magnetic field on one or both components with mildly relativistic particles, i.e. gyrosynchrotron emission. (Mutel et al. 1987)

2. Observations

In 1991 we started a 6 *cm* single dish monitoring of active binary systems, using the 32*m* telescope at the Noto VLBI station of the INAF Istituto di Radioastronomia. Single dish observations were obtained with the *on-off* technique, reaching a flux density limit of about 30 mJy in a total integration time of about one hour.
In order to study the energy release in the stellar atmosphere we carried out (in Sep.-Oct. 2004) H_α observations at the Mt. Etna *M. G. Fracastoro* Station of INAF Catania Astrophysical Observatory. While radio emission is typical of stellar corona, H_α is formed in the chromosphere and the detection of a flare in both bands indicates that it involves at least a large part of the stellar atmosphere. The possibility to obtain simultaneous radio and optical data allows us to compute the non-thermal energy emitted by the electron in the corona and compare it with chromospheric thermal H_α losses, which should be comparable. (Gudel et al. 2002)

2.1. HR 1099 (=V711 Tau)

At a distance of 29 pc, HR 1099 is the nearest and brightest known RS CVn type active binary. Is a non-eclipsing system with a 2.8 day orbital period and about 4 mas angular dimension (at 5 GHz). The two components of the system are a cold sub-giant (K1 IV), the more active component, and a main sequence star (G5 V). (Bopp & Fekel 1976; Umana et al. 1995).

Fig.1 shows the radio flux density at 5 GHz during a long monitoring period from June 2004 to April 2005. In September 2004 the system was found in an active period, a continuous strong flaring which lasted for several days with a flux density (F_{5GHz}) that reached ~ 700 mJy. From our datas it appears that HR 1099 tends to undergo extended periods of activity, during which flares occur one after the other and the radio flux never reaches its quiescent level. The observation of this strong activity phase allowed us to activate an *ad-hoc* VLBA observation on 26^{th} Sep, that has been proven to be a good technique to probe the topology of coronal magnetic fields that confines the hot coronae of these systems because the angular resolution (~ 1 mas) is comparable with the emitting region dimension.

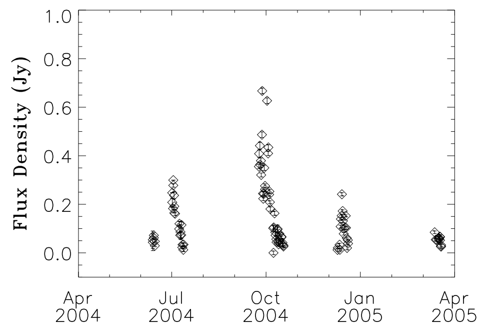

Fig. 1. HR 1099 flux density variation at 6 *cm* during the Jun 2004 - Apr 2005 run of observations. In September - October 2004 the source was found in a strong active period.

2.2. Algol

Algol is a multiple system in which the inner one is an eclipsing system made up of a cold sub-giant (K IV) and an early type main sequence star (B8 V). Even for this system, the continuous radio monitoring allowed us to observe the rise and fall of a large flare on 24-25 April, 2005 (fig.2). During this event the flux varied quickly: it rised from 50 mJy to 500 mJy in about 10 hours and did fall to its quiescent period in one day or less. This is a different behavior than on HR 1099 where the constant flux over the quiescent level for a longer time (few days) was probably due to different geometries.

During this campaign we also observed quiescent periods, as shown in fig.3. Although the flux density is characteristic of quiescent

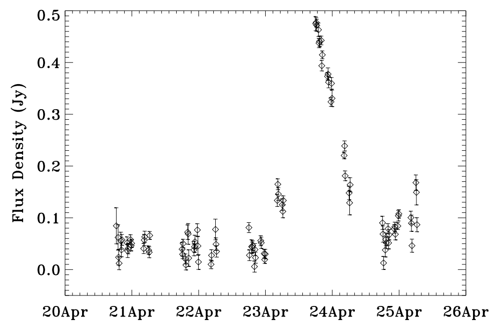

Fig. 2. Algol flare at 6 *cm* observed in Apr 2005. The flux raises in a few hour from the quiscent level, about 50 mJy, up to 500 mJy.

level ($F_{5GHz} \sim 50$ mJy) a modulation with the orbital phase ϕ is evident.

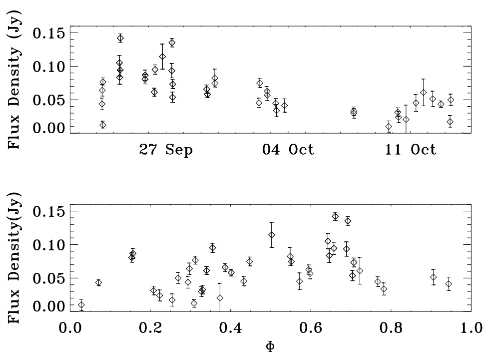

Fig. 3. Top panel: the Algol flux density observed at 6 *cm* from Sep 23^{th} to Oct 13^{th}; bottom panel: the flux modulation with orbital phase ϕ. The ephemerides used to find the system orbital phase are epoch=2441773.4894 and P=2.8673285.

3. Conclusions

Radio observations of active binaries offer the opportunity of studying the coronal plasma and of relating the radio emission with other activity diagnostic in solar-like magnetic structures. In this scenario it is very important to compute the amount of energy released in the chromosphere during active period (from $H\alpha$) and compare it with the energy released in the corona (from radio emission). As a matter of fact, from these observations the non-thermal energy emitted by the radio corona and the chromopheric thermal $H\alpha$ losses can be computed, providing important implications on energy release models [i.e. chromospheric evaporation model, (Gudel et al. 2002)] operating during flares. Optical data are still in a reduction phase. Another topic is the possibility of investigate the magnetic structure surrounding these systems. VLBI observations, with their high resolution comparable with the systems angular size ($\sim$ 1 mas), should allow us to study the topology of the magnetic field and to understand whether radio emission originates from magnetic structure surrounding the binary system, and probably formed by the interaction of the magnetic field loops of the individual stars, or it is originating from a large loop connected to only one of the stars. Also VLBA data are at present in a reduction phase.

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