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# Possible Magnetic Activity Cycles of Four Chromospherically Active Binaries: ER Vul, UV Psc, AR Lac and BH Vir

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**Abstract.** The study of a possible connection between magnetic activity and orbital period variation in close binaries is a very interesting work. Recently, the orbital periods of four chromospherically active binaries, ER Vul, UV Psc, AR Lac and BH Vir, are analyzed. It is discovered that the orbital periods of UV Psc and BH Vir oscillate with periods of 61 and 9.12 years, and the orbital periods of ER Vul and AR Lac show periodic variations with periods of 31 and 47 years respectively while they undergo secular decrease. The mechanisms that could explain the changes in the orbital periods of the four systems have been studied. The period variation of UV Psc may be caused by the cyclical magnetic activity in the primary component, and the magnetic activity in secondary component of AR Lac can explain its periodic component in the orbital period changes. For the other two systems, BH Vir and ER Vul, the cyclical magnetic activity in one or both of the components can explain the cyclical orbital period changes of BH Vir and the periodic component in the changes of the orbital period of ER Vul. These results suggest that the periods of the orbital period oscillations in the four systems may be the magnetic activity cycles.

## 1. Introduction

As the long-term variability in the surface activity occurred on the Sun, Chromospherically active stars, especially RS CVn-type stars, also display sun-like activity phenomena but a much stronger degree than the Sun itself. One of the outstanding properties of this kind of binaries is the cyclic change in the orbital period. Hall (1990) have proposed that quasi-periodic change of orbital period is common among binaries in which at least one component is late-type star and this kind of period change is rarely seen for binaries in which both components are early-type stars. This suggests that the period oscillation may be correlated with the magnetic activity of the late-type component, and magnetic activity cycle has been studied by many authors as a mechanism to explain the periodic change in the orbital period of chromospherically active binary.

Recently, the orbital period changes of four RS CVn-type eclipsing binaries, ER Vul, UV Psc, AR Lac and BH Vir, have been studied (Qian et al., 1998, 1999a, 1999b, 2000). Here, the orbital period changes and their possible connections with the magnetic activity cycles in the four systems are reported. Hall (1976) classified the four systems as members of RS CVn stars, on the basis of strong emission cores in the H and K lines of CaII and a variable light curve (due to dark spot activity). The general properties of these stars are listed in Table 1. All of them are detached eclipsing binaries with high mass ratio ($q > 0.77$). They are also double-line spectroscopic binaries containing at least one G-type main-sequence component which rotates very faster than the Sun does ($\Omega > 14\Omega_\odot$).

Table 1. The general properties of four RS CVn-type close binaries

| Star name | Type | Sp. | $P_{orb}$ (days) | $q$ | Rotational velocity $\Omega$ |
|---|---|---|---|---|---|
| AR Lac | detached | G2V+K0IV | 1.98322 | 1.00 | $\approx 14\Omega_\odot$ |
| UV Psc | detached | G5V+K0V | 0.86105 | 0.77 | $\approx 32\Omega_\odot$ |
| BH Vir | detached | G0V+G2V | 0.81687 | 0.89 | $\approx 34\Omega_\odot$ |
| ER Vul | detached | G0V+G5V | 0.69809 | 0.96 | $\approx 40\Omega_\odot$ |

## 2. Orbital period change and magnetic activity

All available times of light minimum of the four systems have been compiled and the changes in the orbital periods have been analyzed by Qian et al. (1998, 1999a, 1999b and 2000). It was found that the orbital periods of UV Psc and BH Vir oscillate with periods of 61 and 9.12 years. A weak evidence also suggests another small amplitude oscillation (with a period of 52.7 years) superimposed on the periodic period change of BH Vir. For the other two systems, ER Vul and AR Lac, the periodic variations (with periods of 31 and 47 years) are discovered to superimpose on a secular decrease. The properties of orbital period changes of the four binaries are shown in Table 2 where $\Delta P$ and $T$ are the amplitude and the priods of the cyclical period variations, and $dP/dt$ the long-time period change in units of $10^{-7}$ days/year.

Table 2. Orbital period changes of four sun-like close binaries.

| Star name | $\Delta P$ (days) | $T$ (years) | $dP/dt$ | Ref. |
|---|---|---|---|---|
| AR Lac | $1.56 \times 10^{-5}$ | 47 | −8.28 | Qian et al. (1999a) |
| UV Psc | $2.10 \times 10^{-6}$ | 61 | — | Qian et al. (1999b) |
| BH Vir | $1.05 \times 10^{-5}$ | 9.1 | — | Qian et al. (2000) |
| | $0.85 \times 10^{-6}$ | 53 | — | Qian et al. (2000) |
| ER Vul | $3.20 \times 10^{-6}$ | 31 | −0.78 | Qian et al. (1998) |

The oscillations in the orbital periods of the four RS CVn stars can be explained as a consequence of possible magnetic cycles in their components. The relationship between the orbital period change $\Delta P$ and a variation of the quadruplole momentum $\Delta Q$ was put forward by Matese & Whitmire (1983):

$$\frac{\Delta P}{P} = -9\frac{\Delta Q}{Ma^2} \tag{1}$$

where $M$ is the mass of the active star and $a$ is the semi-major axis of the orbit. This equation tell us that the cyclic change of $Q$ may produce a modulation

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of the orbital period. In chromospherically active binaries, magnetic activity of the sun-like component can be thought as a driving mechanism to to cause the cyclic variation of $Q$ and Several physical scenarios have been proposed to produce such a change in $Q$ (Applegate & Patterson, 1987; Warner 1988; Applegate, 1992; Lanza et al., 1998; Lanza & Rodono, 1999).

This mechanism was first suggested by Matese & Whitmire (1983) who considered a relative change of radius $\Delta R/R$ of the active component may induce the needed variation of quadrupole moment. Their suggestions were developed by Applegate & Patterson (1987) and Warner (1988), Who pointed out that an isotropic radius change may be produced by a variation of the magnetic pressure at the base of the convection zone of the active star. However, this model was discarded by Marsh & Pringle (1990), they pointed out that the invoked isotropic expansion of the active star requires more energy to expand the star against its own gravitational field than it is radiated by the star during a cycle of magnetic activity. In 1992, a detailed improvement on the theory was made by Applegate who overcame the energetic problem. He proposed that a quasi-periodic exchange of angular momentum between the inner and the outer parts in the convection zone may induce a modulation of stellar oblateness and consequently of its quadruple moment. Therefore, the orbital period will be changed. Recently the details of Applegate's mechanism have been studied by Lanza et al. (1998, 1999). They pointed out that apart from the redistribution of the internal angular velocity, the change in the azimuthal field intensity can likewise produce a change in the oblateness of the active component (Lanza et al., 1998), and the stability of the azimuthal magnitude field was addressed by considering a more general magnetic field geometry (Lanza et al., 1999).

For the four chromospherically active binaries, Qian et al.'s studies (1998, 1999a, 1999b, 2000) have shown that the orbital period oscillation of UV Psc can be explained by the cyclical magnetic activity in the primary component, and the periodic component in the orbital period changes of AR Lac may be resulted from the magnetic activity in its secondary. The magnetic activity in one or both of the components can explain the cyclical orbital period variations of BH Vir and the periodic component in the orbital period changes of ER Vul. As for the secular orbital period decrease in AR Lac and ER Vul, which may be caused by angular momentum loss via magnetic braking.

## 3. Discussions and conclusions

In previous section, I have reported the orbital period changes of four RS Cvn binaries and their possible explanation by magnetic activity in the components. If the periodic changes in the orbital periods are really caused by magnetic activity of the sun-like components. Thus the period of orbital period oscillation is the magnetic activity cycle. This will offer a simple method to determine the cycle of magnetic activity for chromospherically active binaries. The possible magnetic activity cycles ($T$) of some RS CVn-type binaries are listed in Table 3.

Although the oscillation character of the orbital period can also be explain by a light time effect via the presence of a third body, this mechanism needs a strictly periodic variation of the O-C residuals, which is usually not observed when data covering several cycles are available (e.g. CG Cyg). However, for some samples listed in Table 3, the available data only cover a single cycle. In order to check if the variations are strictly periodic, more timings are needed.

Table 3. Possible magnetic activity cycles for some RS CVns.

| Star name | sp. | $P_{orb}$ (days) | T (years) | Ref. |
|---|---|---|---|---|
| SV Cam | G5V+G3V | 0.59307 | 73 | Hall and Kreiner (1980) |
| SS Cam | G1III+F5V | 4.82425 | 60 | Hall and Kreiner (1980) |
| CG Cyg | G9.5V+K3V | 0.63114 | 50 | Hall (1991) |
| RS CVn | F4V+K0IV | 4.79789 | 38.8 | Rodonò et al. (1995) |
| AR Lac | G2V+K0IV | 1.98322 | 47 | Qian et al. (1999a) |
| RT Lac | G9IV+K1IV | 5.07395 | 80.7 | Keski et al. (1994) |
| UV Psc | G5V+K0V | 0.86105 | 61 | Qian et al. (1999b) |
| SZ PSC | K1V+F8V | 3.96579 | 56 | Kalimeris et al. (1995) |
| V471 Tau | K0VEA+DA | 0.52118 | 24.6 | İbanoğlu et al. (1994) |
| XY UMa | G2V+K5V | 0.47899 | 30.5 | Chochol et al. (1998) |
| BH Vir | G0V+G2V | 0.81687 | 9.1 | Qian et al. (2000) |
| | G0V+G2V | 0.81687 | 53 | Qian et al. (2000) |
| ER Vul | G0V+G5V | 0.69809 | 31 | Qian et al. (1998) |

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