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The Influence of Binarity on Stellar Activity

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Abstract. Activity of late type stars is enhanced by fast rotation, which is maintained in nearly synchronized close binary systems. Magnetic activity originates in the deep convection zones of stars from where magnetic flux tubes emerge to their surfaces. The gravitational forces in binaries help the clustering of activity features giving rise to active longitudes. These preferred longitudes are observed in binaries from dwarfs to giants. Differential rotation is found in many active stars that are components of binary systems. If these binaries are circularized and nearly synchronized, then there will be a corotation latitude in their surfaces, and its position can be determined by observations and by theoretical calculations. Enhanced activity in binaries could have a reverse effect as well: strong magnetism in a binary component can modify the orbital period by the cyclic exchange of kinetic and magnetic energy in its convective envelope.

Keywords. stars: spots – stars: activity – stars: atmospheres – stars: late-type – stars: magnetic fields – stars: binaries: close

1. Introduction

Signatures of stellar activity like spots, plages, flares, enhanced radio and X-ray radiation, activity cycles, are observed on a great variety of single and binary stars with spectral types later than F. The nearest active star to us showing all the mentioned features of magnetic activity is the Sun. In spite of its closeness and the detailed three dimensional picture of its activity drawn from observations across the whole electromagnetic spectrum, the functioning of the solar magnetic dynamo, that produces the activity features, is still not fully understood.

Phenomenologically the observed activity features are the same for both single and binary stars. However, it is obvious that binarity itself has some effect on the activity of stars in binary systems. The reverse situation may work too: stellar activity caused by strong magnetic field may modify the orbits of some binaries.

Statistically, the strength of the activity is higher on stars in binary systems than on single stars. This is well documented by Montes *et al.* (1996) comparing excess CaII H&K and Hϵ measurements on 73 chromospherically active binaries with those measured on single stars with similar temperature and rotational rate. The reason for this difference is probably the following: the magnetic dynamo working inside the active stars is affected by the internal rotation, which is not the same in single and binary stars due to their different rotational history.

Late-type stars have deep convection zone, which, coupled with fast rotation, excites the hydromagnetic dynamo. Due to the strong tidal interaction in close binaries late type stars in these systems maintain fast rotation and consequently show high level of activity. In this paper the special activity features due to binarity, such as the existence of preferred longitudes and the position of corotation latitudes are summarized. The effect of magnetic cycles on the orbital period changes is briefly discussed.

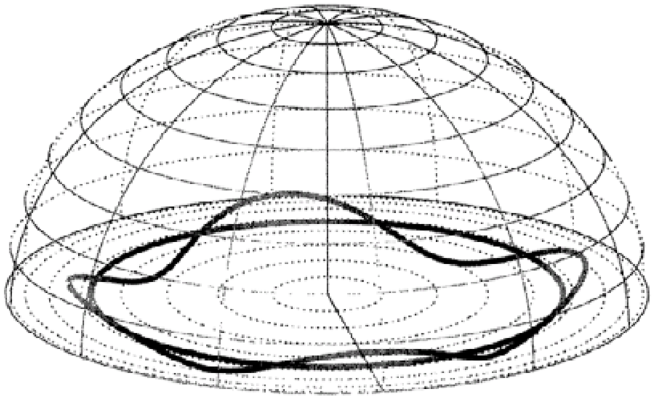

Figure 1. Instability of a toroidal flux tube in the bottom of the convection zone, perturbed by a displacement of wavenumber m=4. From Schüssler (1996).

2. Magnetic dynamo

The origin of the observed stellar activity features is the magnetic dynamo. Unfortunately, the functioning of the solar dynamo is not clearly understood, and our knowledge is even more limited in case of stellar dynamos. Comprehensive reviews and books give detailed picture of our present knowledge on this subject (Covas *et al.* 2005; Moss 2005 and references therein; reviews in: Proceedings of IAU Symp. No. 176, *Stellar Surface Structure*, 1996, eds. Strassmeier & Linsky).

At the beginning we give a brief description of the present idea(s) of the stellar dynamo, which helps one to understand the following sections. The present conception of the strong-field dynamo theory suggests, that the internal rotation changes sharply between the convection zone and the radiative core of stars in the shear layer, which generates a strong toroidal field ($\geqslant 10^5$ G), often called a "cycle dynamo". At the same time throughout the convection zone a turbulent weak-field dynamo operates generating an irregular field from the turbulent flow. These two dynamos are coupled: the weak-field ($< 10^4$ G) dynamo generates some fraction of the field for the cycle dynamo in the overshoot layer, while this large-scale dynamo feeds back the turbulent scale field through different processes (e.g., subsurface reconnections).

The observed activity features (e.g., spots and plages) indicate that the magnetic field in the stellar surface and beyond is not homogeneous; rather, the magnetic flux is concentrated in *flux tubes* surrounded by much less magnetized plasma. The activity features thus originate from the emergence of the magnetic flux tubes from the stellar interior. It is believed that the tubes are formed, intensified and stored in the bottom of the convection zone. After the flux tubes exceed a critical field strength, they lose stability and rise to the stellar surface due to the buoyancy force. More details on the hydromagnetic dynamo are found in the comprehensive book of Schrijver & Zwaan (2000).

Figure 1 shows a scenario with a stable and a perturbed toroidal flux tube in the bottom of the convection zone of a star, where the unstable loop starts to emerge, from Schüssler (1996). The emergence coordinates of flux tubes on the stellar surfaces depend on many parameters: their initial coordinates and magnetic fields, the depth of the convection zone they have to cross, the physical circumstances around (gas pressure, density), the rotational rate of the star and on binarity. In the following, the last two effects are discussed in more details.

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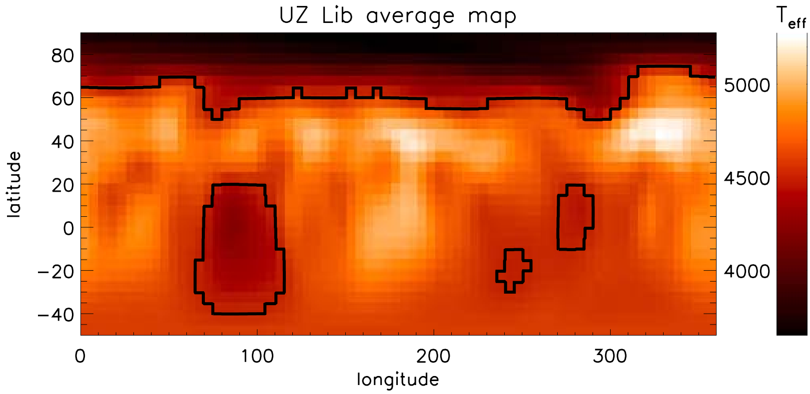

Figure 2. The surface of the non-eclipsing K0III giant UZ Lib, averaging all Doppler maps over 7 years. Note the active longitudes at 90° and at 270°, i.e., the substellar point and opposite. Due to the orbital elements 0° is the time of the quadrature with the primary receding. See Oláh *et al.* (2002b) for more.

3. Preferred longitudes in the binary reference frame

Active stars in eclipsing binaries have been monitored for decades. Earlier, researchers did not assume spots on the components as the cause of the observed light curve distortions outside eclipses, which were found in many cases, and tried to find other explanations (for a comprehensive review of the history of starspots see Hall 1994). Using these old measurements, and with the new knowledge that the distortions may also be caused by starspots, a lot of evidence have been gathered for the existence of preferred longitudes in active close binaries, dating back to almost a century.

One example is the eclipsing binary RT And (types F8V + K0V) which has active components, and has continuously been observed from the early 20th century. The light curves reveal two active longitudes on the quadrature positions all the time (Zeilik *et al.* 1989; Pribulla *et al.* 2000). Other main sequence eclipsing binaries (CG Cyg, BH Vir, WY Cnc, UV Psc) have also two preferred longitudes of spots at the quadrature positions, whereas non-eclipsing giants (IM Peg, HK Lac, UZ Lib) have active longitudes at the substellar points and their antipodes. Binaries with subgiant active components (AR Lac, SZ Psc, RT Lac) show active longitude at the substellar points and at other longitudes as well. Literature of the mentioned binaries is found in Oláh (2006). Figure 2 shows the surface of UZ Lib as an example for active longitudes at the substellar point and opposite, based on Doppler images from spectra averaged over 7 years (Oláh *et al.* 2002b). The figure is a co-added image of the stellar surface of 24 individual images from 7 years. The fact that a definite structure appears (instead of an even surface which would be the result of co-adding images with spots at random positions) means, that indeed, stable active regions are present on the stellar surface throughout the whole observed time interval of 7 years.

A natural explanation, at least partly, for the existence of active longitudes comes from the idea that the gravitational force of the component star affects the emerging flux tubes of the active star in such a way that they cluster around favoured, stable positions. Modelling such scenarios were carried out by Holzwarth & Schüssler (2002, 2003a,b) supposing a hypothetical binary of $1M_\odot + 1M_\odot$, with an orbital and rotational period of 2 days and solid body rotation. A tidally–deformed solar model was used to describe the internal structure of the primary, whereas the component star was supposed to be a mass point. Beside the tidal effect, the Coriolis force in rapidly rotating stars plays

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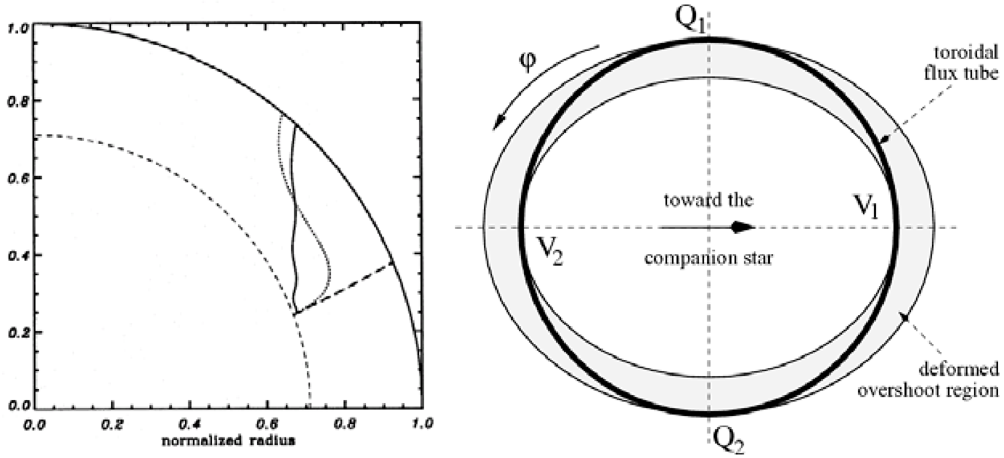

Figure 3. Left: the effect of the Coriolis force on the emerging flux tubes for the initial magnetic field of B=2×10^5 G. Flux tube paths for solar rotational period of 27 days (dashed line), for 9 days rotational period (dotted line) and for 3 days rotational period (solid line) are depicted from Schüssler & Solanki (1992). Right: toroidal flux tube in a tidally deformed overshoot region, from Holzwarth & Schüssler (2003a). The flux ring runs through different environments. V_1 and V_2 mark the substellar points and opposite, where the tube is in a deeper layer than at the quadrature points Q_1 and Q_2.

a significant role by deflecting the flux tubes to higher latitudes (Schüssler & Solanki 1992) in such a way that flux tubes with low initial latitudes (closer to the equator) are much more deflected than the ones originating at high latitudes (Holzwarth & Schüssler 2003b). This was also taken into account in the modelling. In addition to these forces, the strength of the initial magnetic field is a very important factor for finding the emergence place of the flux tubes. The influence of the Coriolis force and the effect of the tidal force are depicted in Figure 3.

The modelling results of Holzwarth & Schüssler (2003a) (see especially their Figure 7) show stable and unstable regions in longitude at the bottom of the convection zone of a binary component for single and double loops (wavenumber equals 1 and 2, respectively), giving the probability that a loop penetrates to the superadiabatic part of the convection zone and rises to the surface. It is found that in the case of single loops, the preferred longitude is the surroundings of the substellar points, whereas for double loops a wide area around the quadratures are favoured by the flux tubes.

The emergence longitude of flux tubes and their clustering depend on many factors. In the quoted literature detailed parameter studies are found assuming different initial magnetic field and initial position (longitude and latitude) of the flux tubes at the bottom of the convection zone. It is discussed, how the accumulation of the tidal effect influences the emergence pattern on the stellar surface during the emergence time of the flux tubes, which can last from months to years. However, these studies suppose solar type stars only, and very few attempts were made to broaden the calculation to evolved systems (see Holzwarth 2004). But the results for solar-type stars are promising and seem to support the observed facts on preferred longitudes of active stars in binary systems. As an example Figure 4 shows resulting flux distributions on the stellar surface with different initial parameter values from the modelling, and an observed example for spots at quadratures of UV Psc by Kjurkchieva *et al.* (2005).

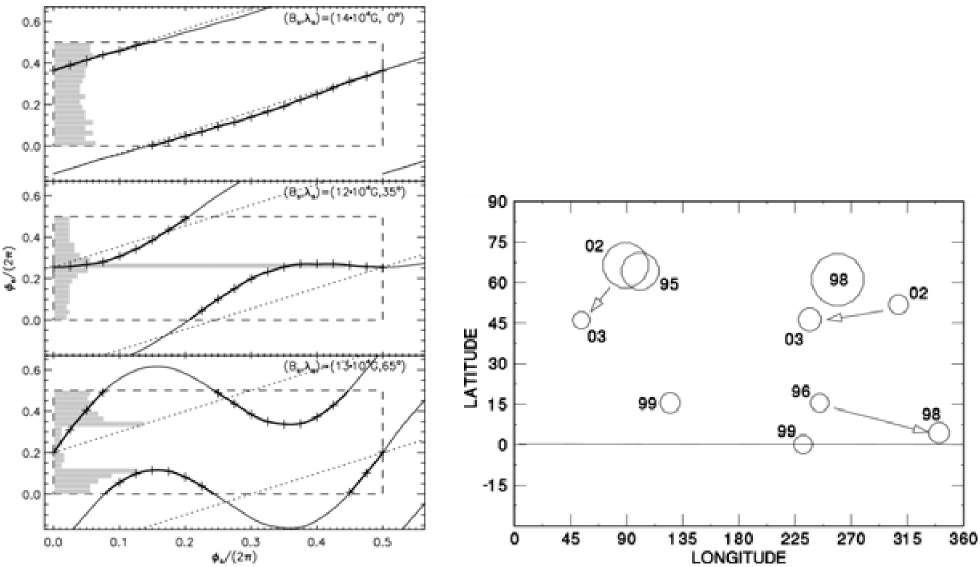

Figure 4. Left: examples of flux distribution on the stellar surface due to tidal effects, from Holzwarth & Schüssler (2003b). Thick lines show the modelled eruption longitudes in the function of initial longitudes at the bottom of the convection zone. The eruption longitude depends also on the initial latitude and magnetic field, given in the top right corners. The grey bars in the left show histrograms of the eruption longitudes on half a stellar surface: (from top to bottom) flat distribution, preferred longitude at quadrature, and two preferred longitude ranges. Right: Preferred longitudes at the quadratures on UV Psc derived from observations by Kjurkchieva *et al.* (2005).

4. Differential rotation - corotation latitude

4.1. *Observing the differential rotation*

The differential rotation of the Sun is evident and naturally, searching for stellar differential rotation started with the advent of studying stellar activity. In principle the task is easy: one should find the latitude of the major spots (spot groups) which cause the light variation, derive the corresponding period of the rotational modulation for several seasons and find the function between them. But in practice this method fails in most cases, because the spot latitudes cannot be derived from photometry with acceptable accuracy (see Kővári & Bartus 1997), and the period determination from a short dataset is also not accurate enough (but during longer time the spots may change their position drastically). Only the most recent photometry from space with accuracy better than a millimagnitude may be useful for this: Croll *et al.* (2006) succesfully deduced differential rotation of ϵ Eri for the first time, from modelling a very accurate light curve (accuracy of the unbinned data is 0.00025 mag.), obtained by the photometric satellite *MOST*.

Migrating waves on the light curves of eclipsing binaries originate from active regions on the surface of a component star producing light variation (usually sinusoidal) on top of the eclipsing light curves, which show continuous shifts measured in the orbital reference frame. Periods of light variability in non-eclipsing binaries usually differ from the accurately known binary periods. Such observational evidence in binaries points toward the presence of differential rotation. (Other reasons of differences between the orbital and rotational periods could be a.) pseudosynchronous rotation in slightly eccentric systems and b.) incorrect orbital period due to unrecognized apsidal motion.)

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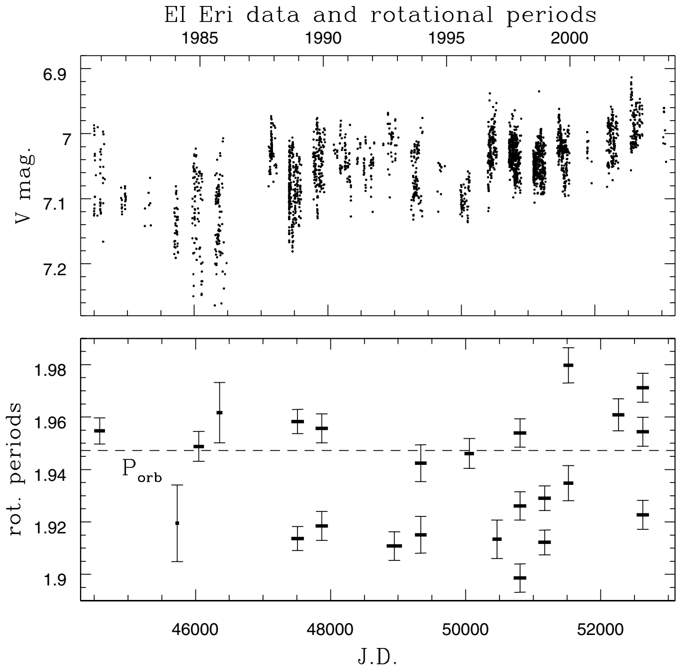

Figure 5. Top: observational data in V colour of EI Eri from the literature and from the Vienna APT (Strassmeier *et al.* 1997). Bottom: rotational periods, sometimes multiple periods, from photometric data for each season, with the errors of the period determinations. Horizontal bars show the lengths of the seasons. The orbital period of the system (P_{orb}) is marked with the horizontal dashed line.

From high resolution spectroscopic data differential rotation for several stars (both for single stars and binary components) were deduced from Doppler imaging, which gives good surface distribution of the starspots. Generally, differential rotation on active stars, both for dwarfs, subgiants and giants in binaries, is found to be much (about an order of a magnitude) weaker than on the Sun (cf., Kővári *et al.* 2004; Oláh *et al.* 2003; Weber & Strassmeier 1998; Weber *et al.* 2005).

4.2. *Differential rotation and the corotation latitude*

The corotation latitude is where the orbital and rotational periods are equal, in case of circularized and nearly synchronized binaries. The only detailed theoretical calculation about the position of the corotation latitudes on binary systems with active components dates back to the early 1980's, by Scharlemann (1981, 1982). He calculated the isorotation surfaces inside the star for various differential rotation laws assuming very deep convection zones. The latitude where the isorotation surface intersects the stellar surface is the corotation latitude.

The rotational periods defined by spots of active stars in binary systems show variability in time. A good example is given in Figure 5 where a long-term dataset of the active binary EI Eri is shown together with the seasonal rotational periods, sometimes multiple periods. The rotational periods were derived using simple Fourier analysis on photometric data for each season separately. If the different periods are due to differential rotation, the spots should belong to distinct active regions at different latitudes. In Figure 5 the orbital period of the system is also marked, and it is well seen that periods shorter and

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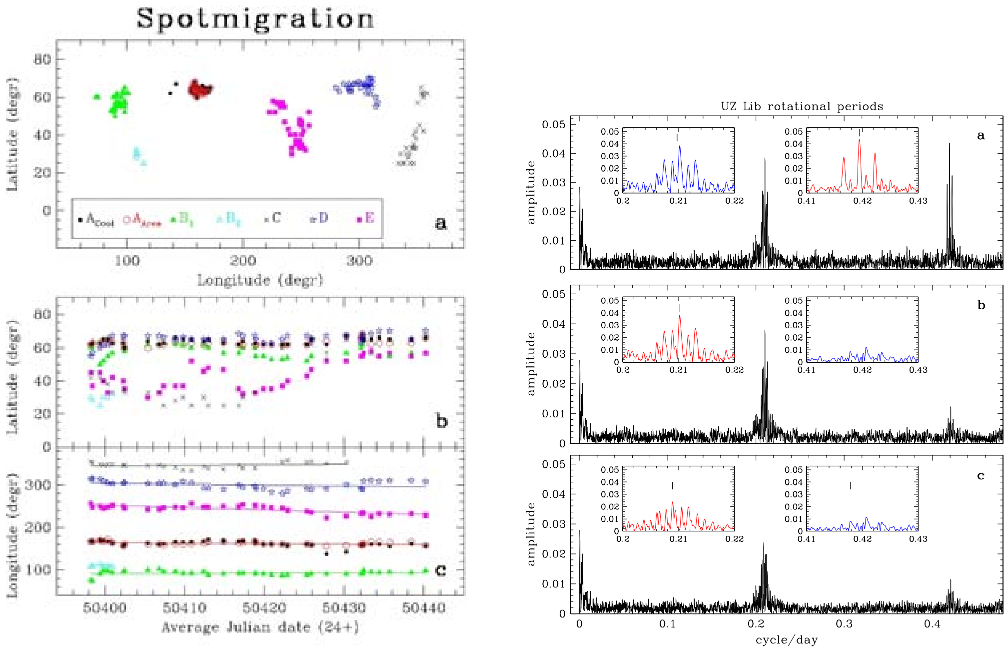

Figure 6. Left: meridional motions of spots on V711 Tau from Strassmeier & Bartus (2000). Note that Vogt *et al.* (1999) put the corotation latitude to about 60° to where the spots tend to move. Right: amplitude spectra of UZ Lib using data from 9 consecutive years. (a): the strongest peak is the first harmonic of the most prominent rotational feature of double humped shape belonging to the spots on the equator. (b): after prewhitening the data with the main frequency and its harmonic, another frequency is revealed caused by high latitude features. (c): removing the second frequency a significant signal still remains, caused possibly by transients. See text.

longer than the orbital period are present throughout the observed time interval. The corotation latitude thus should be somewhere at mid-latitudes on EI Eri.

4.3. *The corotation latitude of HK Lac, V711 Tau and UZ Lib*

The corotation latitude from observations could be deduced directly from the different latitudes of active regions and the corresponding rotational periods. An early study of the active giant HK Lac using photometry was made by Oláh *et al.* (1985), and though the resulting corotation latitude of 32° was uncertain for the reasons detailed in Sect. 4.1, but the value turned out to be reasonable taking into account the theoretical model calculations of Scharlemann (1981, 1982).

Vogt *et al.* (1999) found the corotation latitude of about 60° and antisolar differential rotation (i.e., equator rotates slower than higher latitudes) for V711 Tau using Doppler imaging. A time series analysis of Doppler images on V711 Tau by Strassmeier & Bartus (2000) revealed a poleward latitudinal migration of spots of $+0\overset{\circ}{.}41$/day. Spots which appear at lower latitudes move upwards to about 60°, i.e., to the latitude which seems to be the corotation latitude and where most spots stay, see Figure 6, left panel. In the case of V711 Tau thus the higher latitudes corotate with the orbit.

A corotation latitude and small antisolar differential rotation were determined for the active giant UZ Lib by Oláh *et al.* (2003) comparing Doppler images (cf. Figure 2) with Fourier analysis of contemporaneous photometric data over 9 years. When differential

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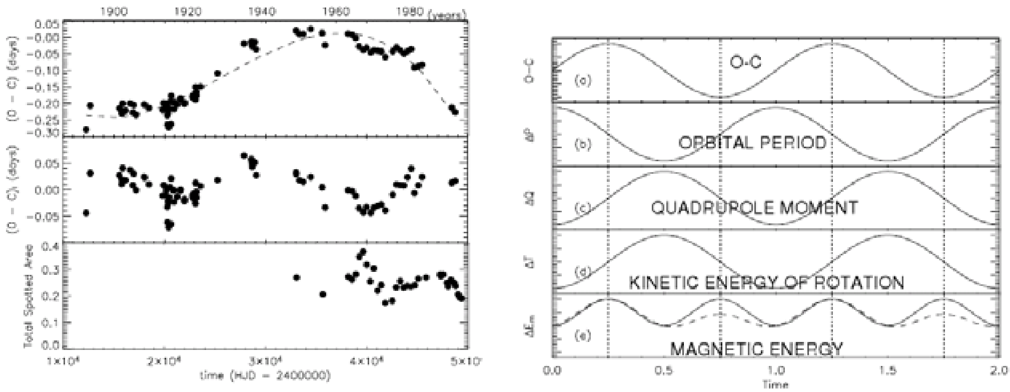

Figure 7. Left: Orbital period variation of RS CVn with a long-term trend (top panel), after removing the long-term trend (middle panel) and the change of the total spotted area on the star (lower panel). Right: Result of theoretical calculations showing the period and phase relations of different quantities of orbital period changes and magnetic cycles. From Lanza & Rodonò (2004).

rotation is present, large spots at different latitudes may result in close but distinct peaks in the amplitude spectrum revealing different periods.

For UZ Lib the rotational frequencies are near 0.21 cycle/day (≈4.76 days), but the highest peak of the amplitude spectrum is found at 0.41944 cycle/day (top of Figure 6, right panel), which is the first harmonic of the most prominent rotational feature of double humped shape, showing that it originates from the two spots placed oppositely on the stellar equatorial zone (see Figure 2), so the main rotational period indicated by these spots is 4.7683 days. After prewhitening the data with the dominant frequency and its harmonic, other two frequencies appear (0.21017 cycle/day = 4.7581 days and 0.20890 cycle/day = 4.7870 days) that should belong to the high latitude features and some transients (middle and lower panels of Figure 6, right panel), which together point toward antisolar differential rotation. See Oláh *et al.* (2003) for more details concerning the identification of the spectral features with spots from Doppler maps. The rotational period belonging to the highest peak, caused by the two equatorial spots agrees with the 4.76824 days orbital period of the system. This means that for UZ Lib the corotation latitude is on the equator.

At present the connection between the corotating latitude and spot clustering in latitude is an open question. The theoretical background of the existence and position of preferred longitudes in binaries is still not well established. The binarity through tidal forces affects spots clustering both in latitudes and longitudes, but many other physical circumstances should also be taken into account. Hopefully, in the future, more and detailed modellings will be carried out to explain the special activity features observed in close binary systems.

5. Orbital period changes due to activity

The above sections deal with the effect of binarity on stellar activity, however, the reverse situation is also interesting: does the stellar activity itself affect the binary system, and if yes, how?

The similarity between timescales of $O - C$ variations and magnetic cycles of certain eclipsing binaries hints the possibility of some connection, as noted first by Hall (1990). An example of such a variation was given by Hall (1991) who showed antiparalel behaviour between the cyclic changes of the $O-C$ diagram and the light variation of CG Cyg. The effect of a third body as a simple explanation for the observed sinusoidal shape of the $O-C$ diagram was ruled out by the fact that these changes were not strictly periodic, whereas the perturbation caused by a third (hierarchical) companion should have to be so.

To gather enough information on the connected orbital period changes and light variability which reflects the magnetic activity, is unfortunately a matter of decades long observations. Data on a few systems (RS CVn, AR Lac, RT Lac) are already available and are summarized in a recent paper by Lanza & Rodonò (2004). As an example in the left panel of Figure 7 the $O-C$ of the orbital period and the spottedness variations of RS CVn are shown. For all systems discussed by Lanza & Rodonò (2004) the cycle timescale of the spottedness variation is about half of the $O-C$ variation.

Different physical mechanisms were proposed to explain the connection between the cyclic magnetic activity and orbital period modulation. Varying magnetised stellar wind cannot account for the observed orbital period variation, since the observed mass loss rates are much smaller than required to explain the observed changes, and the tidal timescale is too slow to couple the spin angular momentum change to the orbital motion. Simple mass transfer would cause not cyclic, but one-way orbital period change.

A possible mechanism to explain the above connection is, that the quadrupole moment of the active component varies during an activity cycle, consequently the outer gravitational potential of the star changes and that induces an immediate change in the orbital period. This model was suggested first by Applegate & Patterson (1987) supposing variation of the stellar radius due to variation of the magnetic pressure gradient, but this idea failed since the required energy for such a change was far too high (Marsch & Pringle 1990). Thus later the model was modified by Applegate (1992) assuming that the internal angular velocity of the star is changing during a magnetic cycle (instead of the radius), which results in the oblateness change, i.e., quadrupole moment change of the star. Recent quantitative calculations by Lanza & Rodonò (2004) show that it is possible to explain the observed connection between the orbital period variations and magnetic cycles, though the observed amplitudes of the $O-C$ diagrams are smaller than that predicted by the model. The phase and period relations between the orbital period, $O-C$ and magnetic cycle of the model agree with the observations and are depicted in the right panel of Figure 7. It is interesting to compare the time and phase behaviour of the observed (RS CVn) and calculated orbital period variation and magnetic cycles. The paper of Lanza & Rodonò (2004) gives much more details for the interested reader.

6. Summary

In the previous sections a brief description of the influence of binarity on stellar activity and *vice versa* has been given. It is known that binarity helps to achieve and maintain fast rotation through spin-orbit coupling. The fast rotation, together with the convective envelope and strong magnetic field of late-type components, results in the operation of hydromagnetic dynamo. Therefore, active close binaries generally show higher level of activity than coeval single stars.

The tidal effects of binaries may organize preferred longitudes and latitudes of activity on the stellar surfaces. However, the efficiency of the tidal force on organizing the emerging flux tubes into certain places depends on several other parameters like the Coriolis force, strength of the magnetic field, depth of the convection zone, initial longitudes and latitudes of the flux tubes at the bottom of the convection zone, etc.

Observations show that in binaries preferred longitudes exist on main sequence stars mostly at quadratures while on giant components at the substellar points. Since the existence of differential rotation is proven for many active stars in binaries, in case of circularized and nearly synchronized systems a corotation latitude should exist on the stellar surface, where the rotational and orbital periods are the same. For the active giant UZ Lib the corotation latitude is the equator (Oláh *et al.* 2003) whereas for the subgiant V711 Tau it is at about 60° (Strassmeier & Bartus 2000), and in both cases spots seem to cluster near these corotating latitudes.

The similarity of the timescales of cyclic behaviour of the orbital period changes and magnetic cycles indicates a connection between them. It is shown by Lanza & Rodonò (2004) that the orbital period modulation and magnetic cycles are connected by the exchange of kinetic and magnetic energy and back, in the convective envelope of stars.

As a conclusion we can say, that the *interaction* between stellar activity and binarity is a very interesting problem, and its exploration has just begun. In the future, hopefully, this special area of stellar activity will attract more interested colleagues who plan, and have the possibility, to work in this field *longer than the PhD timescale*.

Acknowledgements

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References

Applegate, J.H. 1992, *ApJ* 385, 621, 99
Applegate, J.H. & Patterson, J., 1987, *ApJ* 322, L
Covas, E., Moss, D., & Tavakol, R. 2005, *A&A* 429, 657
Croll, B., Walker, G.A.H., Kuschnig, R., & Matthews, J.M. 2006, *ApJ* 648, 607
Hall, D.S. 1990, in: *Active Close Binaries*, NATO ASI Series C, Kluwer, ed.: C. Ibanoglu, Vol. 319, p. 95
Hall, D.S. 1991, *ApJ* 380, L85
Hall, D.S. 1994, *IAPPP Comm.* No. 54, 1
Holzwarth, V. 2004, *AN* 325, 408
Holzwarth, V. & Schüssler. M. 2002, *AN* 323, 399
Holzwarth, V. & Schüssler. M. 2003a, *A&A* 405, 291
Holzwarth, V. & Schüssler. M. 2003b, *A&A* 405, 303
Kjurkchieva, D.P., Marchev, D.V., Heckert, P.A., & Ordway, J.I. 2005, *AJ* 129, 1084
Kővári Zs. & Bartus J. 1997, *A&A* 323, 801
Kővári Zs., Strassmeier, K.G., Granzer, T., Weber, M., Oláh, K., & Rice, J.B. 2004, *A&A* 417, 1047
Lanza, A. & Rodonò, M. 2004, *AN* 325, 393
Marsch, T.R. & Prongle, J.E., 1990, *ApJ* 365, 677
Montes, D., Fernández-Figueroa, M.J., Cornide, M., & De Castro, E. 1996, *A&A* 312, 221
Moss, D. 2005, *A&A* 432, 249
Oláh, K. 2006, *AP&SS* 304, 145
Oláh, K. Eaton, J.A., Hall, D.S., & Henry, G.W. *et al.* 1985, *AP&SS* 108, 137
Oláh, K., Strassmeier, K.G., & Granzer, T. 2002a, *AN* 323, 453
Oláh, K., Strassmeier, K.G., & Weber, M. 2002b, *A&A* 389, 202
Oláh, K., Jurcsik, J., & Strassmeier, K.G. 2003, *A&A* 410, 685
Pribulla, T., Chochol, D., & Milano, L. 2000, *A&A* 362, 169
Ransom, R.R., Bartel, N., Bietenholz, M.F., Lebach, D.E. *et al.* 2002, *ApJ* 572, 487
Schrijver, C.J. & Zwaan, K., 2000, *Solar and Stellar Magnetic Activity*, Cambridge Astrophysical Series No. 34, Cambridge University Press
Scharlemann, E.T. 1981, *ApJ* 246, 292
Scharlemann, E.T. 1982, *ApJ* 253, 298

Schüssler, M. 1996, in Proceedings of IAU Symp. No. 176: *Stellar Surface Structure*, eds. Strassmeier & Linsky, p. 269
Schüssler, M. & Solanki, S. 1992, *A&A* 264, L13
Strassmeier, K.G. & Bartus, J. 2000, *A&A* 354, 537
Strassmeier, K.G., Boyd, L.J., Epand, D.H., & Granzer, Th. 1997, *PASP* 109, 697
Vogt, S.S., Hatzes, A.P., Misch, A.A., & Krster, M. 1999, *ApJS* 121, 547
Weber, M. & Strassmeier, K.G. 1998, *A&A* 330, 1029
Weber, M., Strassmeier, K.G., & Washuettl, A. 2005, *AN* 326, 287
Zeilik, M., Cox, D.A., de Blasi, C., Rhodes, M., & Budding, E. 1989, *ApJ* 345, 991

Discussion

Mercedes Richards: Results of Doppler tomography suggest that the distribution of gas flows can be influenced by coronal mass ejections. So there are direct implications of stellar activity on the mass transfer process.

Styliani Kafka: What would be the expected activity signatures in the case where one or both components of the binary are M stars, especially when they are fully convective?

Oláh: The activity signatures like spots, flares, etc. of M stars in binaries are similar to those observed on earlier type stars; see, e.g., the cases of YY Gem and CM Dra. If cyclic behaviour of the activity is found, than it is the signature of a large-scale dynamo in the bottom of the convection zone. Inside the convection zone, a turbulent, weak-field dynamo operates which may produce activity signatures as well, but not cycles. The mass limit for fully convective stars is generally thought to be about 0.3–0.4 $M_\odot$, but some calculations show that it might be as low as 0.1–0.2 $M_\odot$ (Mullan & McDonald 2002, *ApJ* 559, 353).

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