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Activity on single dwarf stars

Invited Talk

K. Oláh[1]

[1] Konkoly Observatory of HAS, H-1525 Budapest, Pf. 67, Hungary

E-mail: [1]olah2@konkoly.hu

Abstract
The importance of studies of late-type, low-mass active stars is discussed, with emphasis on the possible dynamo mechanisms that can be constrained through observing results.
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1 Introduction

In close binaries the magnetic activity is influenced by the other component from the weak gravitational influence to the common magnetic fields of the components depending on several factors (e.g. masses of the two stars, orbits, age). Although there are several advantages of observing close binaries, like the precise orbital - and thus a good approximation of the rotational - period, precise inclination value (in case of eclipses) or a good estimate of it (in case of no eclipses), precise stellar parameters of the components etc., but on return there are the proximity effects that may modify the work of the dynamo. In single active stars the strength of the activity and its manifestations are not affected by the common gravitational field of the binary system, and by all what follows from that. For this reason, to study such stars is important for understanding the stellar magnetic activity. The different types of possible dynamo mechanisms can also be studied on low-mass single active stars.

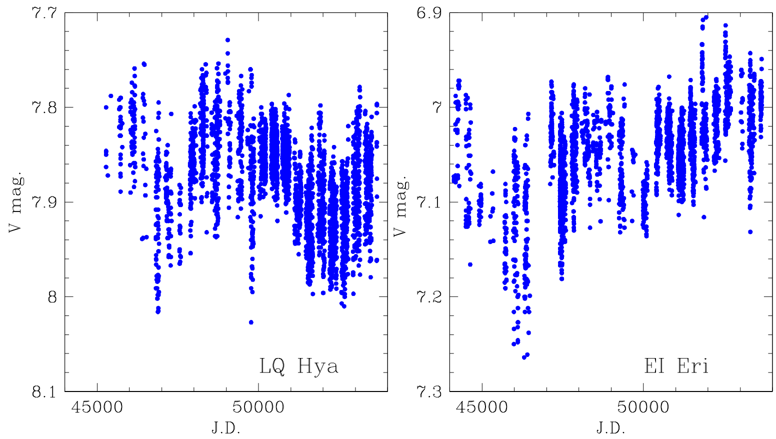

Figure 1: *Long-term photometric variability of two active stars, plotted on the same time and magnitude scales. Left: LQ Hya, single star,* P_{rot}*=1.67 days. Right: EI Eri, binary,*$P_{rot,orb}$*=1.95 days. The long-term changes are similar for both the single and the binary star. See Oláh et al. (2000) and Oláh & Strassmeier (2002) for more.*

2 Observations: single or binary?

From photometric observations alone it is not easy (if at all possible) to distinguish between single and binary stars, if no eclipse is observed. Fig. 1 shows long-term photometric measurements of one single (LQ Hya, see Kővári (2002)) and one binary (EI Eri) star for similar time intervals. The rotational periods and the magnitudes of the observed activity are also similar. Both objects show cyclic magnetic activity, evident from Fig. 1. Knowing just the long-term photometry one cannot distinguish between the single and the binary: the appearance of activity is the same.

Figure 2 shows Doppler images of one single and one binary dwarf stars. It is well seen that the surface structures are similar. This case of couse we *know* which is the binary. On the other hand, there are *effectively* single stars, just like the well-known young solar proxy EK Dra, with a secondary component in a 45 years long orbit. For the details see König et al. (2005). These wide binaries evolve like single stars, since the effects of the secondaries are negligible because of their distances.

Figure 2: *Left: HD 171488, P_{rot}=1.34 days, single star surface. Right: σ^2 CrB, $P_{rot,orb}$=1.16 days, surface of both components of a binary. The surface structures are similar in the two cases (see: http://www.aip.de/groups/activity/DI/results.html).*

3 Rotation-activity connection

The strength of activity grows with faster rotation. Numerous rotation-activity studies were published in the past decades. One of the most powerful activity index is the X-ray to bolometric luminosity ratio. Pizzolato et al. (2003) finds that from 5 days down to 0.4 days rotational periods the activity index is constant: $\log(L_X/L_{bol}) \approx -3$, and they claimed that the activity of stars with these periods are saturated. However, Mullan & MacDonald (2001) find that the saturation limit is around $\log(L_X/L_{bol}) = -1.8$. Earlier James et al (2000) using the same activity index for only M dwarf stars showed that althought the index is flat between 5-0.4 periods, but it may *decrease* later, for even shorter periods. The correlations are plotted in Fig. 3, where the place of two active single dwarfs EY Dra (Vida, 2006) and LO Peg (Csorvási, 2006) are given.

The existence or not-existence of the saturation limit, and the question until how short rotational period is the activity index constant, and what happens at even shorter periods, leads us to the next question about the stellar dynamo(s) operating in active stars.

4 Cyclic and turbulent dynamos

Two basic types of stellar dynamos are known: the interface or shell dynamo (operates near the interface between the radiative core and the convective envelope of the star) and the distributive dynamo (driven by the turbulence in the convective zone). It is quite a possible scenario if we consider the two types

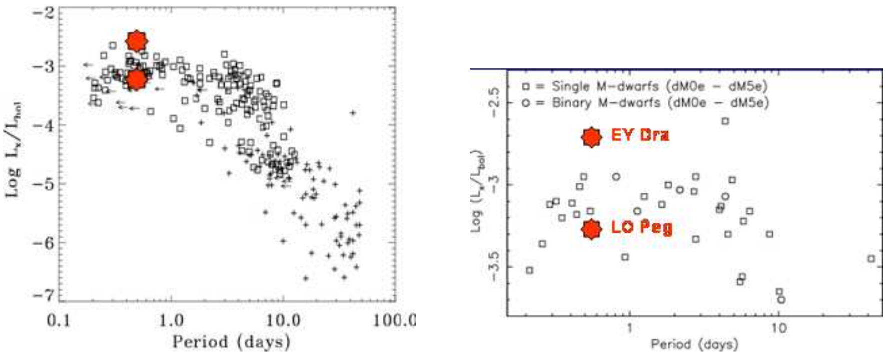

Figure 3: *Left: Rotation-activity connection of dwarf stars from Pizzolato et al. (2003). Right: Rotation-activity connection of M dwarfs from James et al (2000). In both figures positions of two single dwarf stars EY Dra and LO Peg are marked.*

of dynamos existing together in the stellar interiors. The question is, how it is possible to distinguish between these two dynamo types? Magnetic measurements show that the strength of the flux depends on the rotation (as discussed in the previous section about the X-ray flux), but there exist the so-called "flat-activity" stars that do now show variation in the strength of activity (which is low) with the rotation. Those stars that obey the rotation-activity relation should have an interface dynamo (besides a possible distributive one), whereas whose magnetic flux is lower and do not depend on rotation may held just a distributive dynamo. See Saar (1996, 1998) for more on this subject.

Another difference is, that the interface dynamo shows cycles ($\alpha - \Omega$ dynamo), while the distributive dynamo does not. Observations show that the stellar cycle lengths correlate with the rotational rates, as Fig. 4 displays. Studying active stars with very short periods is thus of fundamental importance. In Fig. 4 the possible position of cycles are plotted for two single, fast rotating active stars, that have rotational period of less than 0.5 day, EY Dra and LO Peg. New photometric observations and modelling of these two stars are published in the present volume by Vida (2006) for EY Dra and by Csorvási (2006) for LO Peg. These stars are near the border where the transition occurs to complete convection, and in the fully convective stars, evidently, the interface dynamo cannot work.

Figure 5 shows the position of active dwarf stars in the radius-effective temperature diagram. Theoretical results from Baraffe & Chabrier (1997) are plot-

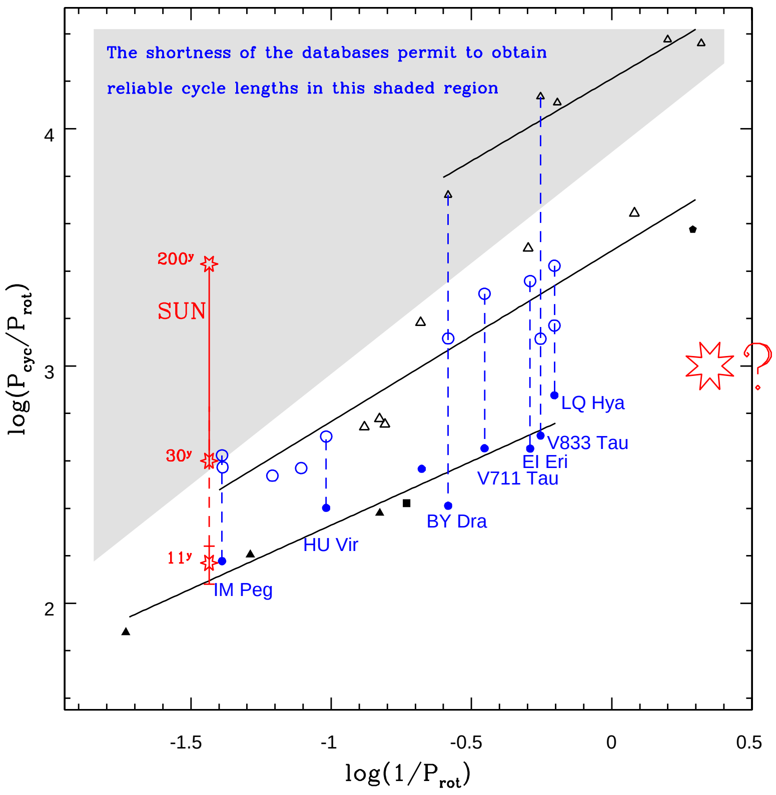

Figure 4: *Normalised cycle lengths in the function of inverse rotational periods, in logarithmic scales. Faster rotating stars have shorter cycles. Note the multiple cycles in several cases. The red star on the right shows the hypothetic position of the shortest cycle lengths of EY Dra and LO Peg, which remains to be verified or rejected.*

ted with dashed and dotted lines, for different metallicities. The observed radii and temperatures put the active stars to the right and lower than the theory predicts: they seem to be cooler and bigger than suspected. The cause of this discrepancy possibly is, that no magnetic field was taken into account in the modelling. Mullan & MacDonald (2001) in their enlightening paper show evidence that if strong magnetic fields are taken into acoount in the modelling, than the observed and theoretical positions of the stars in the radius-effective tem-

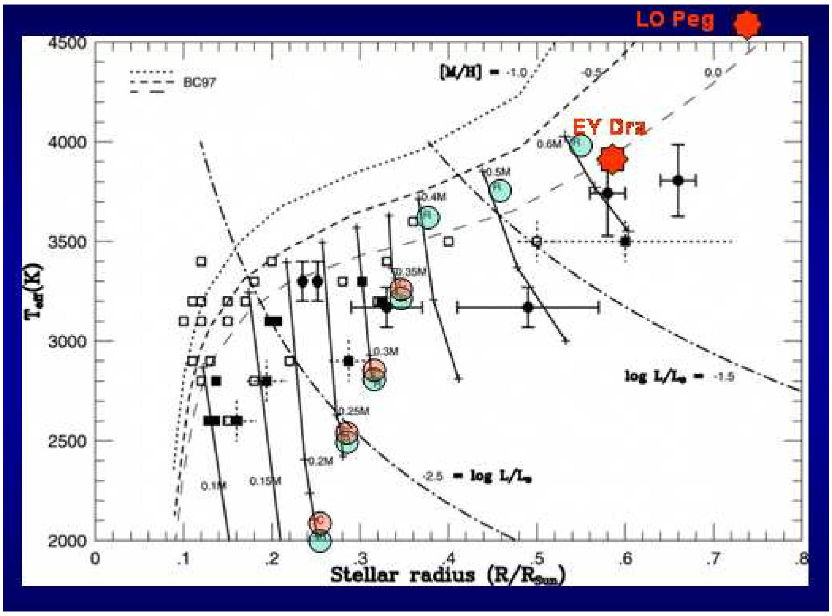

Figure 5: *The effective temperatures of M dwarf stars in the function of stellar radius. Filled squares mark known variable stars (flare stars, spotted stars) and filled circles denote eclipsing binaries. Theoretical models are plotted by dotted and dashed lines, solid lines connect positions of modelled stars with the same masses but with different magnetic parameters. Green circles show the models with radiative cores (R), pink circles show where the model is completely comvective (C). The positions of EY Dra and LO Peg are indicated. From Mullan & MacDonald (2001).*

perature diagram can be reconciled, their model result in bigger, cooler stars. Another important result is, that Mullan & MacDonald (2001) find radiative core down to about 0.2 solar masses, which makes possible to held an interface dynamo, in the corresponding spectral types of about M5-M6, and complete convection stars afterwards.

Thus, we showed, that monitoring of very low mass, late type stars is of fundamental importance. See also Bartus et al. (2006), in this volume. Unfortunately, though these stars make up more than half of the galactic stellar population, but their low luminosity makes most of them invisible, and there are only a few which can be studied in sufficient details.

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