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Evolution of magnetic activity in intermediate-mass giants

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Abstract. The X-ray surface fluxes of intermediate-mass G and K giants are correlated with their rotation periods and Rossby numbers. Empirical relationships are presented that accounts for the X-ray luminosity evolution of single intermediate-mass giants, such as FK Comae-type stars, and of giants in close or long-period binaries, such as RS CVn-type systems, as they evolve off the main sequence towards the top of the red giant branch.

1. Introduction

A major topic of stellar activity is to explain how magnetic phenomena depend on stellar parameters such as rotation and convection. One magnetic field diagnostic for cool stars is coronal X-ray emission. A relation between X-ray luminosity and rotation has been reported for late-type dwarfs but the connection between rotation, convection and magnetic activity is less evident among giants.

Intermediate-mass giants have early-F, A and late B-type progenitors on the main sequence that have no outer convection zones and that are typically rapid rotators (Royer *et al.* 2002). As they evolve off the main sequence, in the shell hydrogen burning stage, they develop thin outer convection zones. The increasing convection zone depth combined with fast rotation is expected to trigger dynamo processes that generate magnetic fields that, by analogy with the Sun, cause the X-ray emission of their outer stellar atmospheres.

2. Rotation-activity relationships and activity evolution on giants

A sample of intermediate-mass G and K giants with $1.5\ M_\odot \leqslant M \leqslant 3.8\ M_\odot$ and with known rotational periods was defined from a sample of single G giants with known rotation periods (Gondoin 2005), and from a list of binaries compiled by Gondoin (2007).

I found evidence that the X-ray surface flux F_X of intermediate-mass G and K giants is correlated with their rotation period P. Confidence in the degree of correlation is not higher when the Rossby number is used in place of the rotation period, but it significantly improves when stellar gravity g is taken into account (Gondoin 2007). The empirical relations are given by:

$$\log(F_X) = -0.73 \times \log(P) + 0.64 \times \log(g/g_\odot) + 7.9 \quad (2.1)$$

$$\log(F_X) = -0.83 \times \log(Ro) + 0.75 \times \log(g/g_\odot) + 6.6 \quad (2.2)$$

In order to estimate the X-ray luminosity evolution of single giants and of giants in long-period binary systems, I used empirical models of rotation evolution of single intermediate-mass stars (Gondoin 2005; see Fig.1 left). These rotation evolution models were combined with convection turnover times derived by Gunn *et al.* (1998) to estimate the evolution of the Rossby numbers of intermediate-mass stars during their evo-

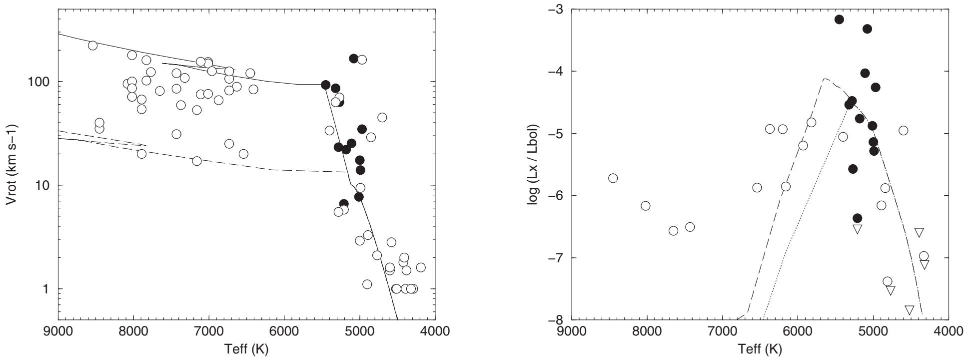

Figure 1. Left: equatorial velocity of a sample of single G giants (black circles) as a function of effective temperature. The open circles are the projected rotational velocities of A,F, G and K single field giants. The solid lines describe rotation evolution models for 2.5 $M_\odot$ (lower curve) and 2.0 $M_\odot$ stars (upper curve) with equatorial velocities of 50 and 300 km s^{-1}, respectively, on the main sequence. Right: X-ray to bolometric luminosity ratio as a function of effective temperature. The lines represent empirical models of L_X/L_{bol} evolution for 2.5 $M_\odot$ (dotted line) and 2.0 $M_\odot$ single stars (dashed line) using rotation evolution models (Gondoin 2005). The triangles represent giants for which only upper limits of the X-ray luminosity are available.

lution off the main sequence. The X-ray fluxes of these giants were then calculated from Eq. 2.2. Evolutionary models computed by Schaller *et al.* (1992) were used to determine the stellar radii and bolometric luminosities of the stars and to infer their X-ray luminosities and X-ray to bolometric luminosity ratios as a function of effective temperature.

The results (see Fig. 1 right) indicate that the X-ray luminosity of single giants, including FK Comae-type stars and giants in long-period binary systems increases by three to four orders of magnitudes between the mid-F and mid-G spectral types due to a deepening of their convection envelope and then decreases sharply as the stars ascend the red giant branch due to a strong rotational braking.

3. Conclusion

I conclude that (i) a relation exists between rotation and X-ray emission among intermediate-mass giants, that do not directly depends on the presence of a companion and that applies to all intermediate-mass giants with either G or K spectral type, (ii) this relation accounts for the large magnetic activity level of single intermediate-mass giants (such as FK Comae-type stars) as they evolve near the bottom of the red giant branch, (iii) gravity is an important parameter in determining the X-ray surface flux of giants, and (iv) a major role played by binarity in the magnetic activity level of intermediate-mass giants in close binaries (such as RS CVn systems) is to provide a mechanism that maintain rapid rotation at a late stage of stellar evolution.

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