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Differential rotation on active late-type stars observed with *Corot*

P. Gondoin[1], **M. Fridlund**[1], **D. Gandolfi**[2] **and E. Güenter**[2]

[1]European Space Agency, ESTEC - Postbus 299, 2200 AG Noordwijk, The Netherlands

[2]Thüringer Landessternwarte Tautenburg, Sternwarte 5, 07778 Tautenburg, Germany

Abstract. One major topic in studying stellar activity is to explain how phenomena seen on the Sun and stars, and specially magnetic phenomena, depend on stellar properties such as rotation and age. Differential rotation is an important physical process in theories of stellar magnetic field generation. The solar surface differential rotation was initially discovered via the simple method of tracking the rotation rates of individual starspots at different latitudes. Adopting a similar principle, high accuracy light curves of active stars observed with the *CoRoT* satellite are analyzed using a model based on the rotational modulation of the visibility of active regions.

Keywords. stars: activity, stars: late-type, stars: rotation, stars: spots

1. Introduction

Differential rotation measurements have been performed on F and early G dwarfs (e.g. Reiners & Schmitt 2003; Reiners 2006) by studying the rotational broadening of spectral lines with a Fourier transform method. Differential rotation has also been measured using Doppler imaging techniques on a few young rapidly rotating G and K stars (e.g. Donati *et al.* 2000; Petit *et al.* 2002; Collier-Cameron & Donati 2002; Marsden *et al.* 2004; Barnes *et al.* 2005).

One magnetic-field diagnostic for cool stars is the presence of starspots. Starspots cooler than the unperturbed photosphere can account for the rotation modulated attenuation of stellar fluxes in broad optical pass-bands. The photometric periods of active stars have been measured by studying the rotation modulation of long sequences of broad-band photometric measurements (e.g. Hall 1991; Henry *et al.* 1995; Messina & Guinan 2003). We have analyzed high accuracy light curves of active F, G and K stars, that were obtained with the *CoRoT* satellite during its initial run.

2. Lightcurves analyses

The *CoRoT* satellite (Baglin *et al.* 2006; Auvergne *et al.* 2009) simultaneously registers the visible lightcurves of a large number of stars for durations of several months with the aim to detect extrasolar planets by the transit method. *CoRoT* observations started with a pointing direction close to the anticenter of the Galaxy. This initial run lasted from February 6th to April 2nd 2007 and supplied high accuracy lightcurves. These time series are nearly continuous over 57 days with only a small number of gaps that mainly result from the crossing of the South-Atlantic Anomaly. A fraction of these light curves have a periodic modulation indicative of starspots.

The rotation modulation of stellar photometric lightcurves by stellar active regions can be modelled using two numerical approaches: the surface integration methods and the analytical method (Ribarik *et al.* 2003). The former assigns a temperature to each pixel of the spherical integration net and then varies each value until an optimal fit to the data is achieved. In this study, we use the analytical approach described by Lanza *et al.* (2006) and based on a model used to fit the time variations of the solar bolometric and spectral irradiance.

The relative flux variations of active stars are fitted with a two or three spots model. Best fit models to the lightcurves are obtained by minimizing the sum of squared residuals. The fixed parameters in the simulations included stellar parameters determined spectroscopically (Gandolfi *et al.* 2009) and active region parameters. The surfaces, longitudes, latitudes and rotation periods of the active regions are left as free parameters. The analyses of the lightcurves are performed as a grid search using a two or three spots model and iterating on 8 or 12 variable parameters. Series of fitting processes varying the inclination of the star rotation axis are conducted in order to identify the inclination angle that minimizes the overall χ^2 and the fitting parameters for which the difference in χ^2 becomes significant at a more than 80 % confidence levels.

3. Preliminary results

Preliminary analysis were conducted on a sample of active dwarfs that were arbitrarily selected. One first result of this analysis is that all high accuracy lightcurves with evidence for rotation modulation cannot be parameterized with a simple two or three spots model. This may be due to complex topologies, time evolution or latitude migration of the active centers during the observing run. Among an initial sample of six dwarfs, the lightcurve of only one star could be fitted with a two spots model on the entire 57 days observation duration (see Fig. 1 top). The lightcurves of two other sample stars (see Fig. 1 middle and bottom) could be fitted on a large fraction (about 45 days) of the observing run.

Nevertheless, within the frame of the analysis method, differential rotation has been detected at a significant confidence level on these three stars. The differential rotations ΔP between the high and low latitude spots are 0.03, 0.42 and 0.5 days for average rotation periods of 3.05, 4.24 and 15.23 days, respectively. Although these first results may be underestimates of the latitudinal differential rotation shear, comparisons with measurements obtained with different analysis methods support the trend of increasing differential rotation rate $\Delta P/P$ with increasing rotation period.

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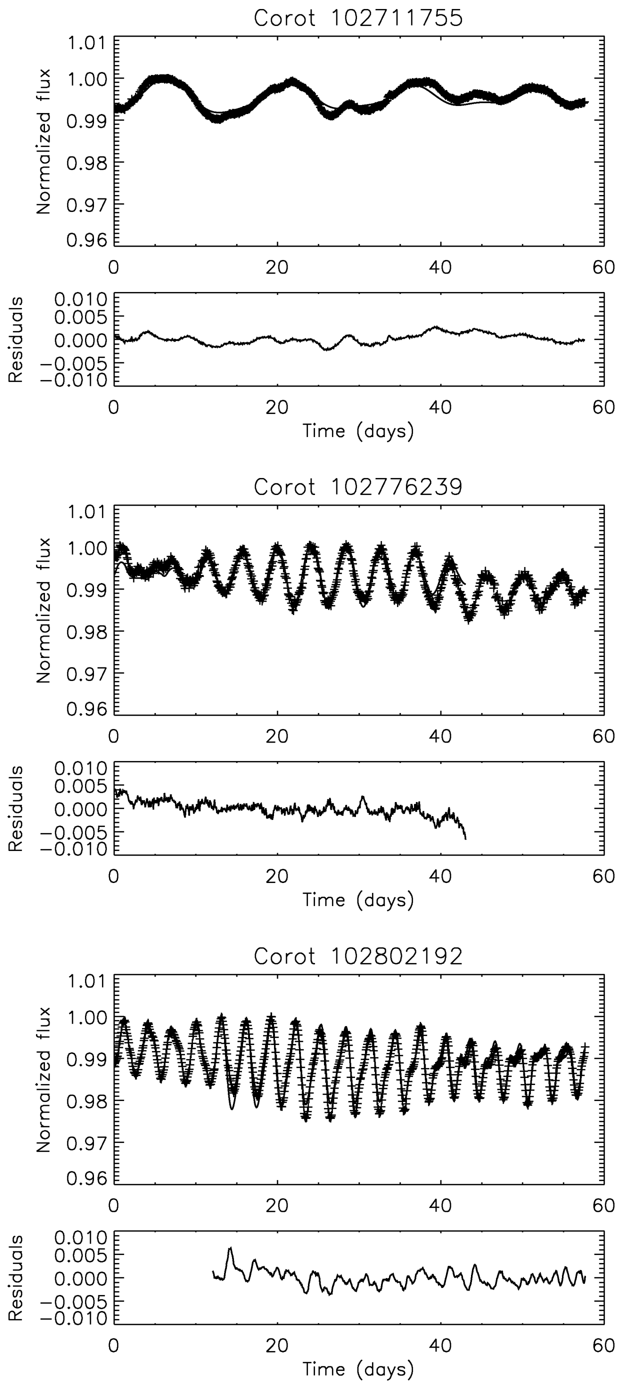

Figure 1. Best fit models and residuals to the light curve of a sample of active dwarfs observed with *Corot*.

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