Improved 'Rotation-Activity' relations in low-mass main-sequence stars from CoRoT photometry

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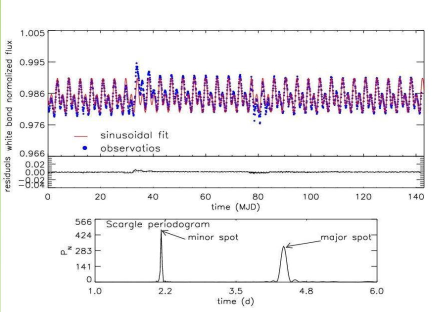
The level of magnetic activity in the photosphere of main-sequence late-type stars depends on the stellar rotation period and the mass. Specifically, as the rotation rate and the depth of the convection zone increase, stars display a larger photometric variability amplitude, which arises from an increasing amount of photospheric magnetic fields. Empirical relations which describe how the photometric variability amplitude depends on rotation and mass have been found by Messina et al. (A&A 366, 215, 2001; A&A 410, 671, 2003) using photometric data of about 265 field stars and members of young open clusters. The available data have a precision of about 1 percent, which not allowed us to extend such relations to the slow rotation regime (P>15d), where the photometric variability hardly reaches 1 percent amplitude. Furthermore, the light curve amplitude-rotation relation seems to have a discontinuity at about P=1.1d, suggesting that magnetic activity has in the ultra fast (P<1.1d) a different rotation dependence than in the fast (P>1.1d) rotation range.Due to the day-night duty cycle of ground-based observations, it turns out to be very difficult to determine reliable rotation periods close to 1 day. The ultra-high precision and uninterrupted time series provided by CoRoT for thousands of late-type main-sequence stars allow us to derive hundreds of new rotation periods at activity levels much lower than those accessible by ground-based observations. The data provided by CoRoT allow us to extend the light curve amplitude-rotation relation to much slower rotation regimes and to better explore the discontinuity at 1.1 day, the CoRoT time series being free of any significant aliasing effect. Improved light curve amplitude-rotation relations make feasible direct comparisons between observations and theoretical predictions about the generation and evolution of magnetic fields and their impact on the stellar internal structure.

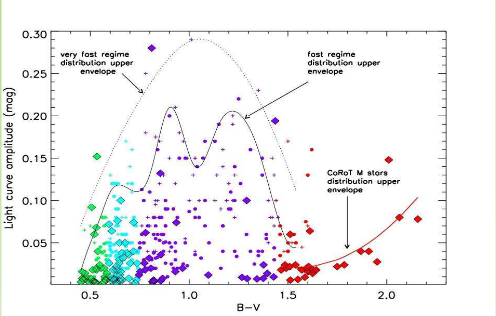
Here we compare the distributions of light curve amplitudes vs. rotation period and vs. B-V color of two stellar samples. One sample consists of 55 field + 209 cluster stars (IC2602, IC4665, IC2391, alpha Persei, Pleiades) which have been observed with ground-based facilities (Messina et. al. 2003, A&A 410, 671; Messina et al. 2001, A&A 366, 215). The other sample consists of 156 stars (41 F stars; 40 G stars; 37 K stars; 38 M stars) which have been observed by CoRoT and whose rotation period could be determined by us.

A) Rotation period search



The stellar rotation period is determined by means of a Fourier analysis of the white band normalized flux time series (top panel). Stellar spots are carried in and out of view by the stellar rotation, making the observed stellar flux periodically variable. Scargle and Clean algorithms are used to identify periodicities to be attributed to the rotation period (lower panels) [Scargle 1982, ApJ 263, 835; Roberts et al. 1987 AJ 93, 978]

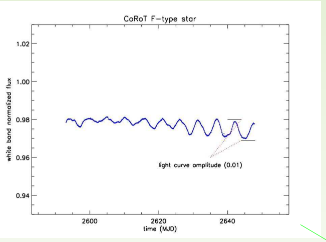
B) Distribution of light curve amplitude vs. B-V color



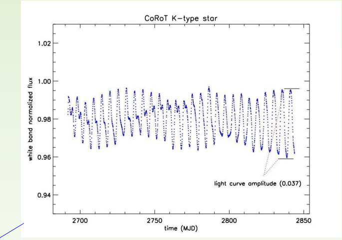
Ground-based photometry of field and cluster stars shows that the maximum level of photospheric activity increases as the depth of the convection zone increases, from F- to K-type stars and then decreases towards early M-type stars. This result is apparent both in the very fast rotation regime (P<1.1 days) and in the fast rotation regime (P>1.1 days). There is some marginal evidence that toward later spectral type (late M) the activity level starts increasing again.

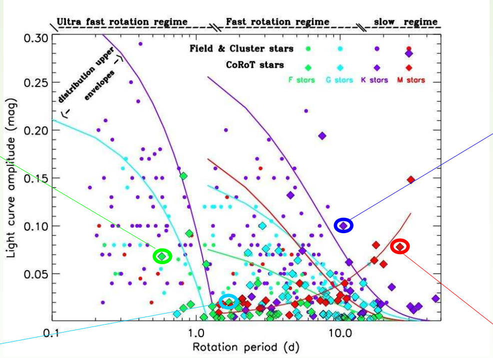
This behaviour seems to be confirmed by recent CoRot data which clearly show that later M stars tend to show a photometric variability larger than earlier M stars.

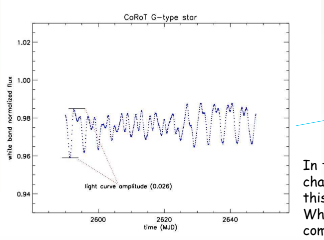
C) Distribution of light curve amplitude vs. rotation period

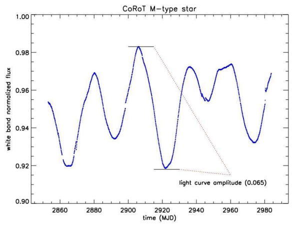


Ground-based photometry of field and cluster stars shows that the maximum light curve ampplitude decreases as the rotation period increases. This behaviour is evident when looking at the upper envelopes of the light curve amplitude distribution and it is present both in the very fast rotation regime (P<1.1 days) and in the fast rotation regime (P>1.1 days). CoRot M-type stars show an opposite behaviour, that is they tend show a larger photometric variability as their rotation period increases.









In this study we have first summed up and then normalized the flux in the red, green and blue channels to obtain a light curve in the (white) band 300-1100 nm. The equivalent wavelength of this white band is longer than that in the Johnson V-band, used to observe Field&Cluster stars. White band CoRoT light curve amplitudes have been multiplied by a factor 2 (estimated comparing synthetic light curves in both white and V bands) in order to make them camparable to the V-band light curve amplitudes.

Preliminary results: a) We are discovering a large fraction of slow rotators (P>15d) which allow us to extend the rotation-light curve amplitude relation into the slow rotation regime; b) M stars tend to display an increasing photometric variability as the rotation period increases, which cannot be explained easily in the framework of the alpha-omega dynamos; c) CoRoT stars with light curve amplitude larger than about 0.10 mag have been found to be very rare, yet.

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