ROTATION AND SPOT ACTIVITY OF YOUNG SOLAR-TYPE STARS FROM LONG-TERM PHOTOMETRIC MONITORING

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TIME SERIES ANALYSIS

We have recently performed a study of the spot activity of 21 young and active solar-type stars of spectral types F9–K4 (Lehtinen et al. 2016), using ground based B- and V-band photometry gathered since 1987. We used the Continuous Period Search method (Lehtinen et al. 2011) to extract seasonal light curve means M, amplitudes A, periods P, and minimum epochs $t_{\min}$ from the photometry (Fig. 1). These were used to study the differential rotation (P variations), activity cycles (M and A variations), and active longitudes (phase distribution of $t_{\min}$) of the stars.

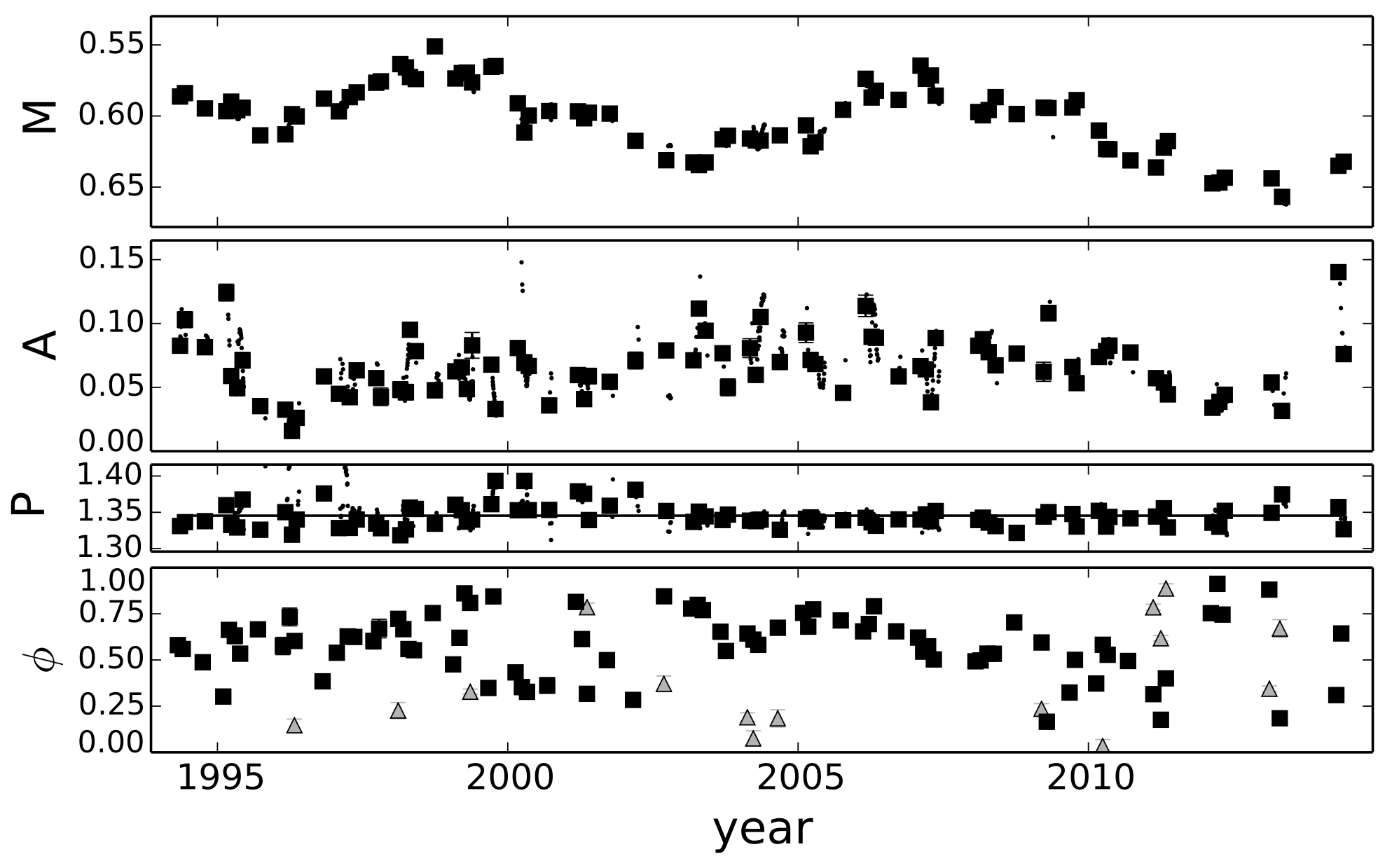

Figure 1 : Period analysis results for the photometry of V889 Her ($t_{\min}$ converted into rotational minimum phases $\phi_{\min}$).

DIFFERENTIAL ROTATION

From the variations seen in P, we find larger surface differential rotation coefficients towards slower rotating stars, $k \propto \Delta P/P \propto P_{\rm rot}^{1.36}$, and only weak rotational dependence of the equator to pole shear, $\Delta\Omega \propto \Omega^{-0.36}$. There is no temperature dependence in the differential rotation within our sample ($4500\,{\rm K} < T_{\rm eff} < 6000\,{\rm K}$).

REFERENCES

Cole, E. et al., 2014, ApJ, 780, L22
Lehtinen, J. et al., 2011, A&A, 527, A136
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ACTIVITY CYCLES

Spot cycles are common in M and also appear in A. Plotting the ratios of rotation to cycle periods $P_{\rm rot}/P_{\rm cyc}$ against the inverse Rossby number ${\rm Ro}^{-1} = {\rm Co} = 2\Omega\tau_c = 4\pi\tau_c/P_{\rm rot}$ and the chromospheric activity index $\log R'_{\rm HK}$ puts the cycles on the activity branches of Saar & Brandenburg (1999) (Fig. 2). We find a turnoff point between the "Active" and the "Transitional–Superactive" branches at $\log {\rm Ro}^{-1} = 1.42$ and a new split into two parallel sub-branches, indicative of different simultaneously excitable cycle modes.

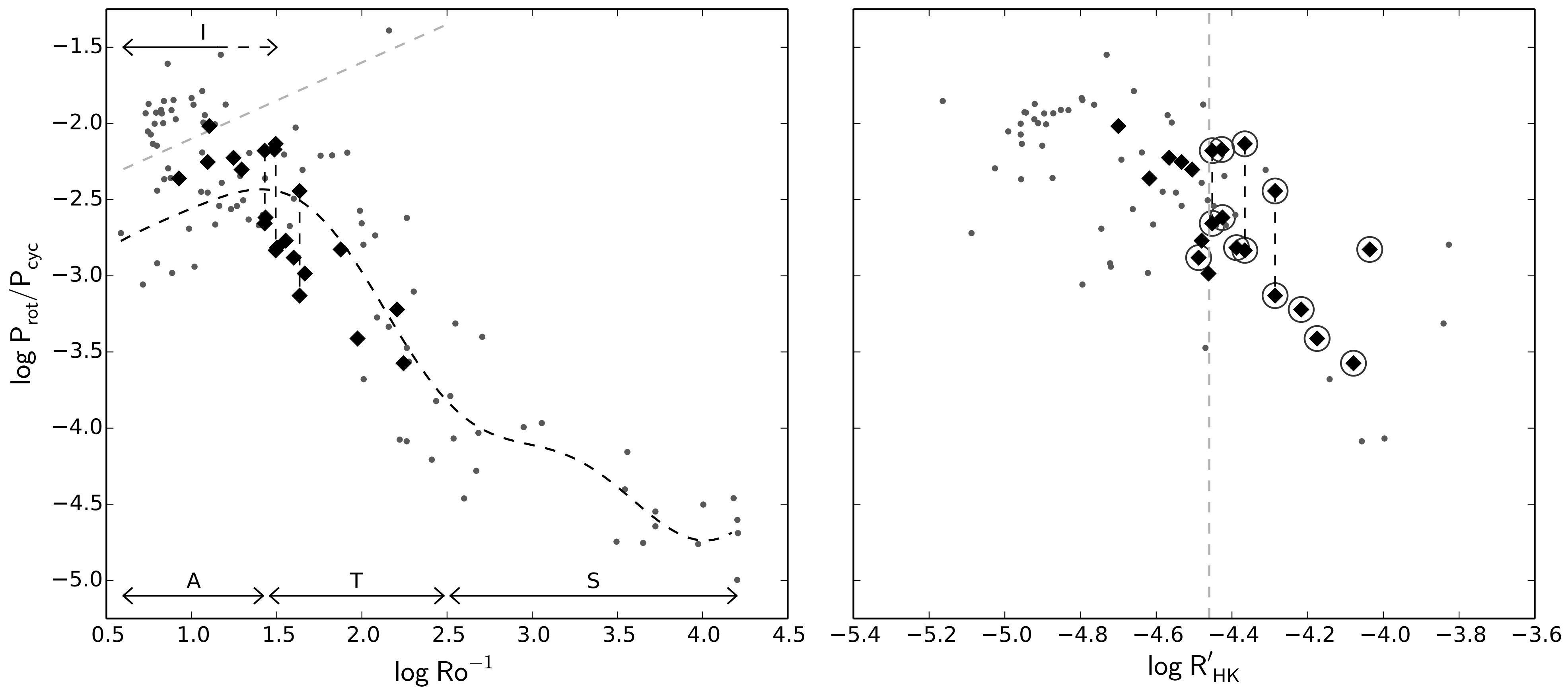

Figure 2 : $\log P_{\rm rot}/P_{\rm cyc}$ (◆) shown against $\log {\rm Ro}^{-1}$ and $\log R'_{\rm HK}$ with reference data from Saar & Brandenburg (1999) (•). On the right, stars with detected active longitudes are shown with circled symbols. If a star has two simultaneously detected cycles, they are connected by vertical dashed lines.

ACTIVE LONGITUDES

Persistent active longitudes are nearly universally found from the $t_{\min}$ of highly active stars (Fig. 1, bottom panel) while on the less active stars the long-term spot activity appears scattered in longitude (Fig. 2, right panel). We find a sharp boundary at $\log R'_{\rm HK} = -4.46$ separating the two regimes. This boundary may correspond to a transition between dynamo modes having axisymmetric and non-axisymmetric field configurations.

On many stars we find a significant difference between the estimated surface rotation periods, $P_{\rm rot}$, and the rotation periods of the active longitude patterns, $P_{\rm al}$. In most cases we find $P_{\rm al} < P_{\rm rot}$ (Fig. 3). This pattern may result from radial differential rotation or it may be a sign of azimuthal dynamo waves in non-axisymmetric dynamos (Cole et al. 2014).

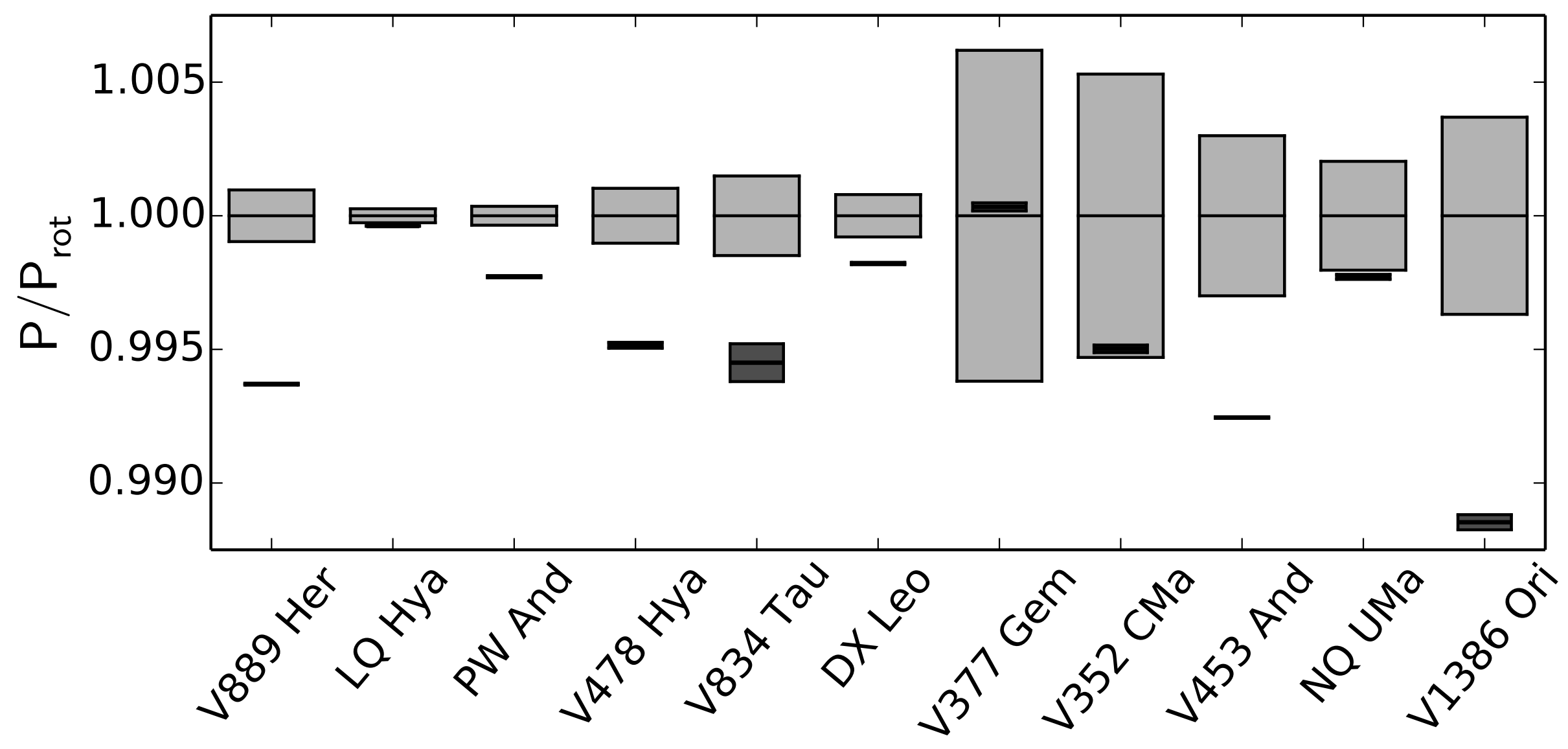

Figure 3 : Photometric rotation periods $P_{\rm rot}$ (*light grey*) and active longitude rotation periods $P_{\rm al}$ (*dark grey*) and their 1σ errors normalized by $P_{\rm rot}$.

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