Photometric magnetic activity and active-region lifetimes of solar-like stars

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Abstract

Rotational modulation due to dark spots co-rotating with the stellar surface allows us to constrain rotation and magnetic properties of solar-like stars. The long-term observations collected by *Kepler* (and those that will be collected by PLATO) are preferred for a better characterization of magnetic activity. In this work, we investigate the temporal variability of the photometric magnetic activity proxy S_{ph}, as well as the characteristic timescale of active-regions in solar-like stars.

Target sample & data

Solar data:

- ⋆ VIRGO/SPM (A. Jiménez, private commun.)
- ⋆ Sunspot areas, SA (solarcyclescience.com)
- ⋆ Flux at 10.7 cm, $F_{10.7}$ (ngdc.noaa.gov)

Kepler data:

- ⋆ FGKM stars w/ rotation period P_{rot} [+55k stars; **POSTER by Breton+**] (Santos+ 2019, 2021a; Breton+ 2021)
- ⋆ KEPSEISMIC lightcurves† (García+ 2011)
- ⋆ stellar properties (Berger+ 2020)

Artificial data:

- ⋆ Explored parameters: observation length; stellar inclination; spot latitude and longitude; spot size, evolution, and lifetime; stellar rotation (tools from Santos+ 2015, 2017)

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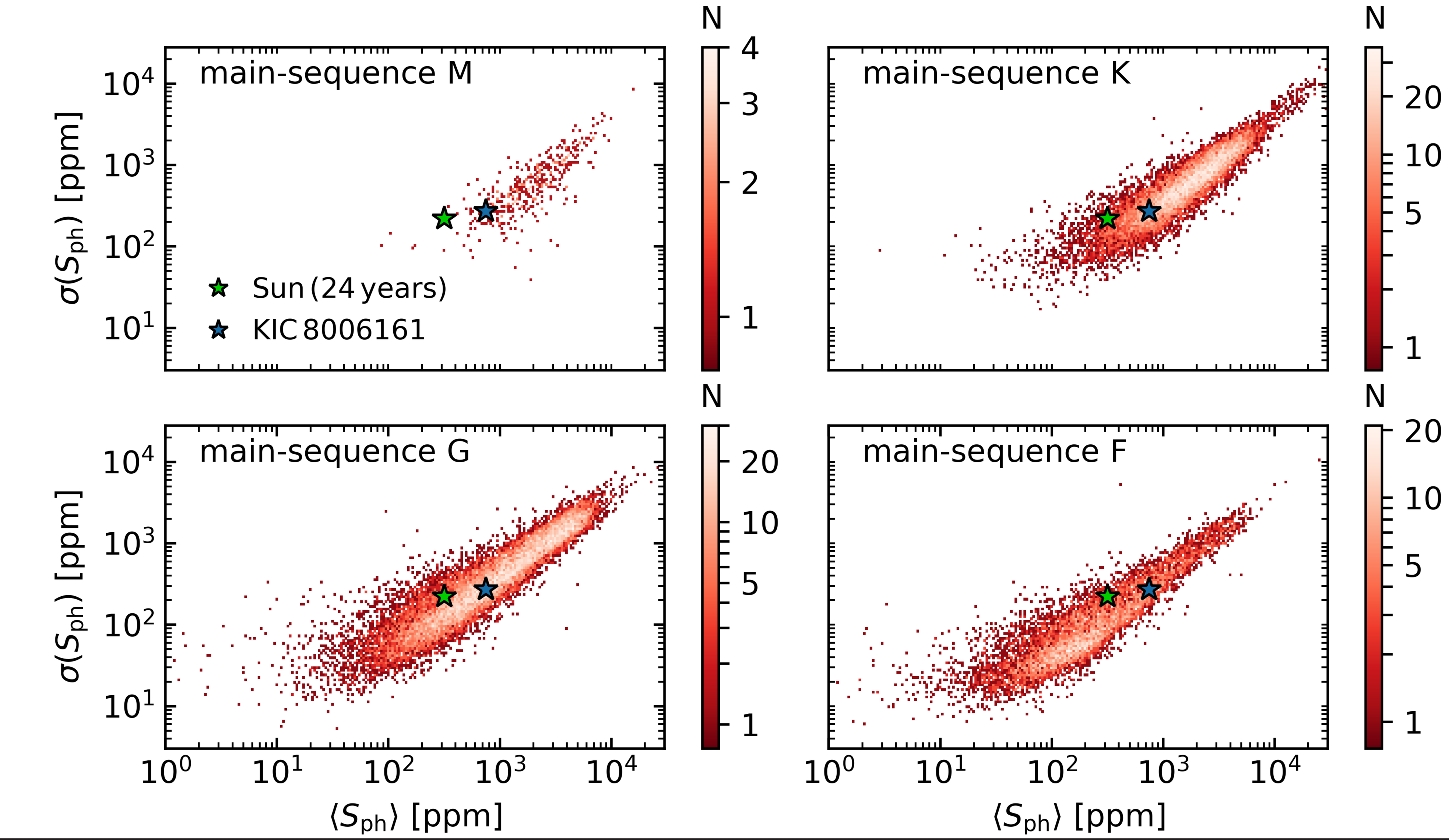
S_{ph} variability in *Kepler* solar-like stars

(Santos + in prep.)

- ⋆ S_{ph} - standard deviation of the stellar flux over $5 \times P_{rot}$ segments (Mathur+ 2014)
  - suitable photometric magnetic activity proxy (Salabert+ 2016, 2017)
- ⋆ $\langle S_{ph} \rangle$ - average photometric magnetic activity level over the 4 years
- ⋆ $\sigma(S_{ph})$ - photometric magnetic variability over the 4 years
- ⋆ Ground-based spectroscopic observations showed that stars that are in average more active are also more variable in time (e.g. Lockwood+ 2007; Radick+ 1998, 2018)
- ⋆ *Kepler* photometric observations show the same behaviour



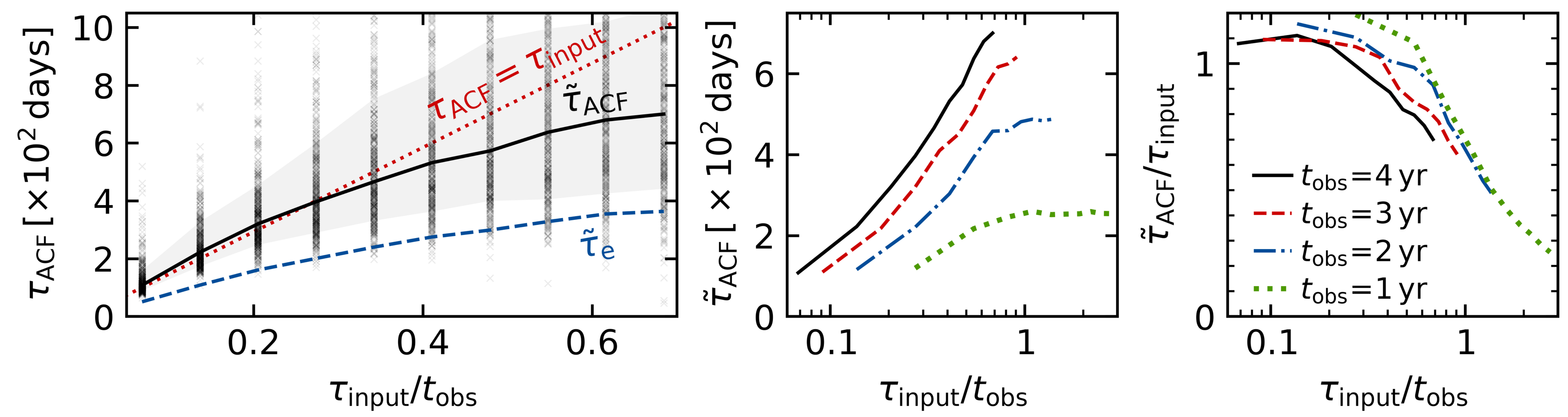
ACF decay timescale, τ_{ACF}

(Santos + 2021b)

- ⋆ ACF - autocorrelation function of lightcurves of spotted stars
- ⋆ The ACF had been described as an underdamped harmonic oscillator and its e-folding time, τ_e, had been interpreted as the active-region lifetime (Giles+ 2017)
- ⋆ τ_e systematically underestimates the spot lifetimes and the linear decay timescale, τ_{ACF}, is a better estimate of the lifetimes (Santos+ 2021b)

The ACF model: $$y(t) = \left(1 - \frac{t}{\tau_{ACF}}\right)\left[a\cos\left(\frac{2\pi t}{P_{ACF}}\right) + b\cos\left(\frac{4\pi t}{P_{ACF}}\right) + y_0\right]$$

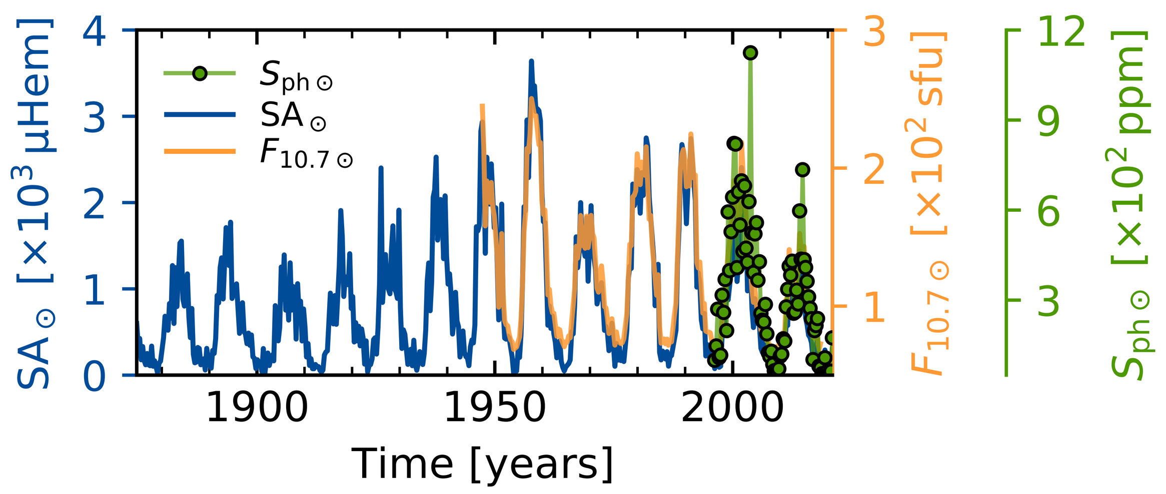
Artificial data:



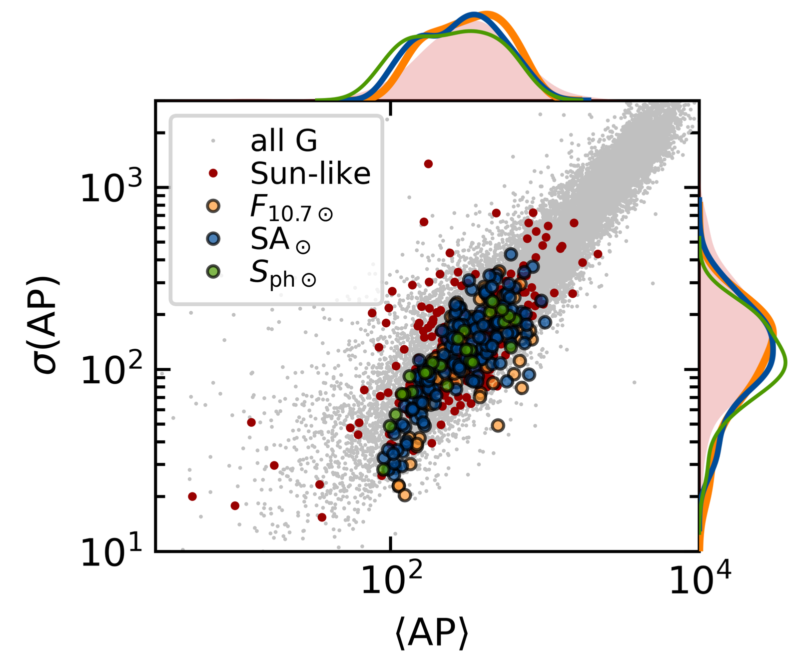
- ⋆ the observation length t_{obs} is an important limiting factor to τ_{ACF}
- ⋆ 1-yr light curves: τ_{ACF} and input lifetimes τ_{input} are uncorrelated
- ⋆ differential rotation affects τ_{ACF}, but τ_{ACF} and τ_{input} are still well correlated

S_{ph} properties: Sun vs. Sun-like stars

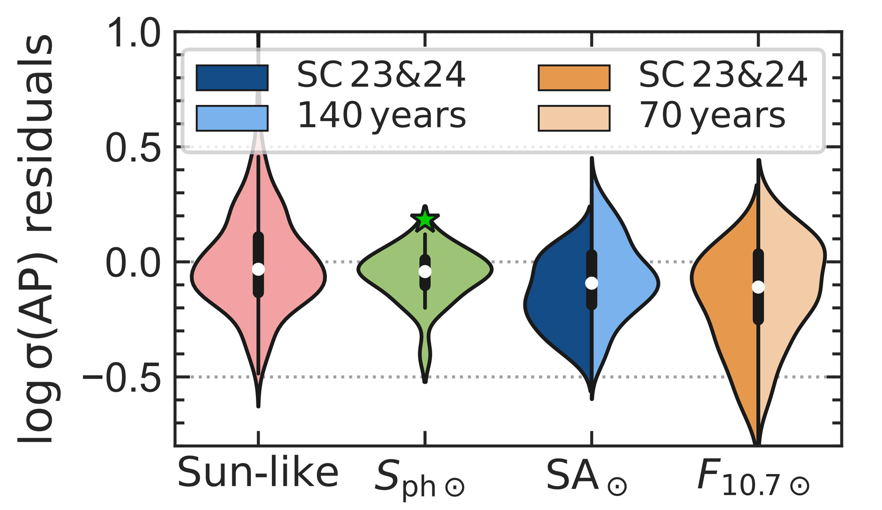
(Santos + in prep.)



- ⋆ $S_{ph\odot}$ computed from VIRGO/SPM g+r
- ⋆ To complement the solar observations, sunspot areas ($SA_\odot$) and flux at 10.7cm ($F_{10.7\odot}$) are re-binned and scaled to the $S_{ph\odot}$
- ⋆ The data are split in 4-year segments to compare with *Kepler* data (overlap of 75% between consecutive segments)

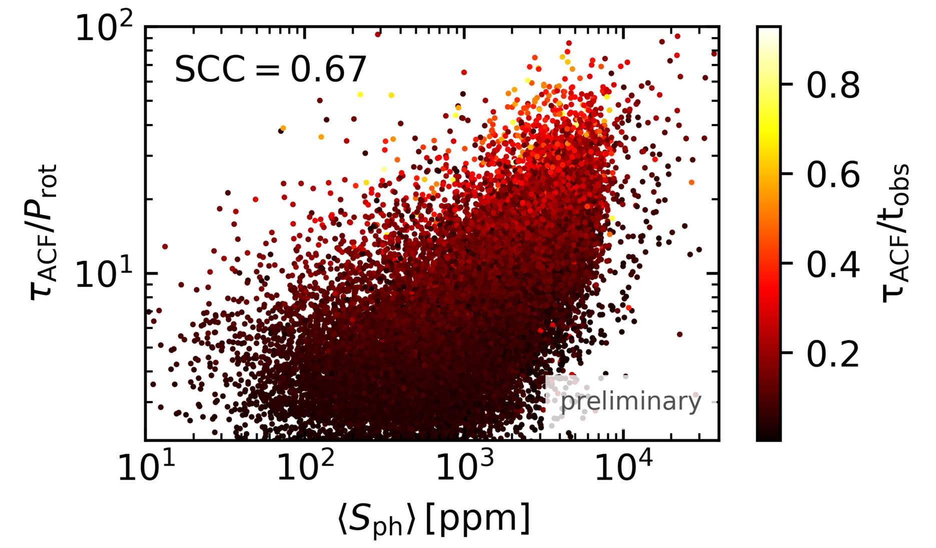


- ⋆ For each segment, the average and standard deviation of the activity proxy (AP) are obtained
- ⋆ Sun-like stars: $T_{eff\odot} \pm 100$ K; $\log g_\odot \pm 0.1$; $P_{rot\odot} \pm 2$ days



- ⋆ $\log \sigma(AP)$ residuals – corrected for dependencies on T_{eff}, $\log g$, P_{rot}, and [Fe/H]
- ⋆ $\langle S_{ph} \rangle$ and $\sigma(S_{ph})$ for the Sun are reasonably consistent with those of the Sun-like stars

τ_{ACF} for *Kepler* stars



- ⋆ Spearman correlation coefficient: 0.67
- ⋆ More active stars have longer-lived active regions than less active stars
- ⋆ t_{obs} may affect τ_{ACF} even with 4-year observations

Acknowledgements: Antonio Jiménez; STFC grant ST/T000252/1SFCT; SSI; NASA grant NNX17AF27G; PLATO & GOLF CNES grants; Spanish ministry grant RYC-2015-17679; FCT/MCTES grants UIDB/04434/2020, UIDP/04434/2020 and PTDC/FIS-AST/30389/2017; FEDER grant POCI-01-0145-FEDER-030389