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~20 yr of stellar activity for M stars

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M dwarf stars are prime targets in current and upcoming exoplanet surveys, due to their ubiquity in the solar neighborhood and the high occurrence of small exoplanets in their habitable zones. However, their magnetic activity could hinder the detection of orbiting planets and also seriously contrains the habitability of the terrestrial planets.

During the last decade, new debates about the mechanism responsible for the magnetic activity of M stars have emerged in the dynamo theory. Information on the long-term activity of partially and fully convective M stars would allow us to understand whether their underlying dynamo is responsible for the detected activity cycles.

Since 1999, the HKα Project is operating in the Argentinian observatory CASLEO (Complejo Astronómico El Leoncito), exclusively dedicated to observe a set of F3V to M5.5V stars. To date, our database presents more than 6000 mid-resolution spectra with a wavelength range from 389 to 669 nm, which constitutes an ideal dataset to study long-term activity.

Throughout these twenty years, we have found evidence of cyclic activity in M stars under different regimes: the fully-convective stars Proxima Centauri, Ross 128 and Gl 729 (Cincunegui et al. 2007, Ibañez Bustos et al. 2019b, 2020), partly-convective stars (GJ 229 A and GJ 752 A, Buccino et al. 2011; AU Mic, Ibañez Bustos et al. 2019a) and in the convective threshold (the binary system GJ 375, Díaz et al. 2007; AD Leo, Buccino et al. 2014).

In the present work, we show the first evidence of activity cycles for the fully convective M dwarf Gl 729. We study the magnetic activity from reliabale time series of ~20 year length employing the Mount Wilson *S* Index.

We found two cycles for this dM4e star (~1500d and ~300d). In Fig 1 top, we show the time series for Gl 729 and its respective periograms (Fig 1 middle and bottom) obtained with different techniques.

The activity-rotation relationship is a fundamental key to study which kind of dynamo could be operating in a star. To study that, we calculated the activity indicator without the photospheric contribution, log(R'_{HK}).

In Fig. 2 we show the log(R'_{HK}) – Prot diagram including the fit of Astudillo-Defru et al. 2017 (gray solid lines). We show six M dwarfs whose activity cycles were detected using CASLEO spectra. The activity cycle of Gl 699 was detected by Toledo-Padrón et al. (2019) employing seven independent sets of spectroscopic observations. Here, is clear that Gl 729 is an outlier from the saturated regime (Prot < 10 d) indicating which the rotation does not driving the activity.

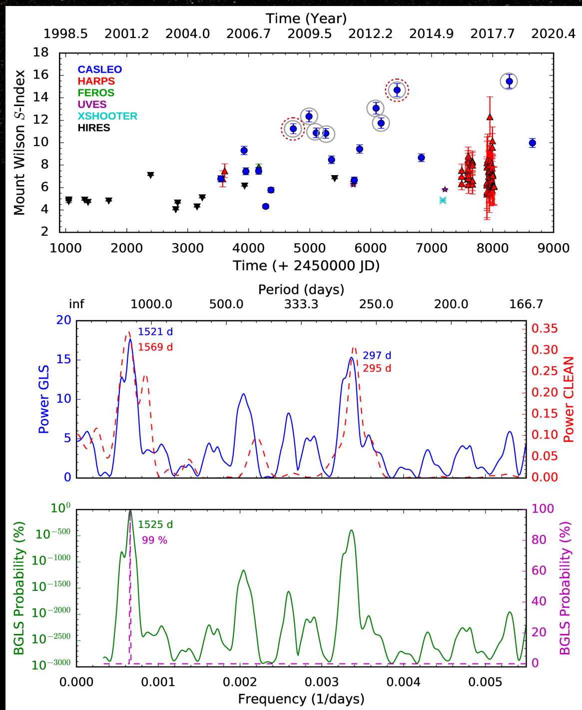

Fig 1. *Top.* Mount Wilson time series for Gl 729. *Middle.* GLS (solid blue line) and CLEAN (dashed red line) periodograms. *Bottom.* Bayesian percentage probability.

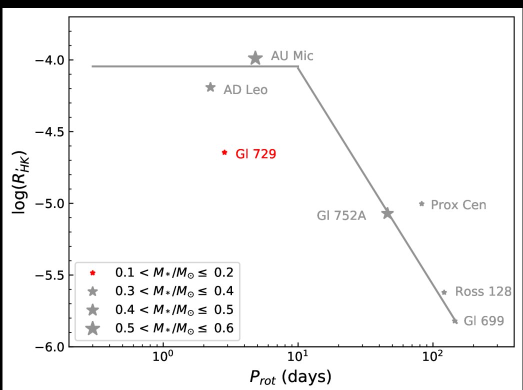

Fig. 2. log(R'_{HK}) – Prot diagram including the fit of Astudillo-Defru et al. 2017 (gray solid lines)

In order to explore the nature of the mechanisms responsible for the cyclical long-term activity detected in Gl 729, we analyzed its surface differential rotation, which is a necessary ingredient for the αΩ dynamo operation (Charbonneau 2010), whereas it seems not to be determinant in turbulent α^2 dynamos (e.g., Durney et al. 1993; Chabrier & Küker 2006). To do so, we studied the Kepler light curve (see details in Ibañez Bustos et al. 2020) with the spot model and we identified two active longitudes (see Figure 3, bottom right).

We note some indication of an oscillation in the longitude of the dominant center of activity. However, the amplitude of this migration, which is about 50º, is comparable with the longitude resolution achieved by our spot modeling and it is therefore no evidence of surface differential rotation.

Thus, the activity cycle of Gl 729 could be driven by a turbulent α^2 dynamo.

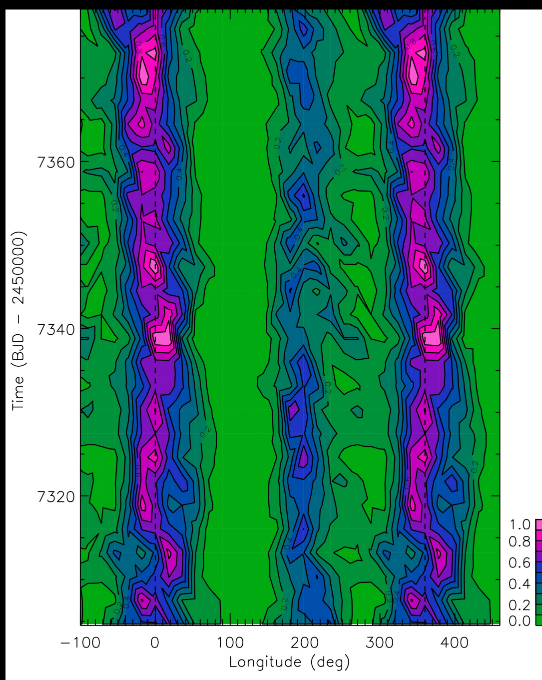

Fig 3. Distribution of the spot filling factor versus longitude and time as derived by our maximum-entropy spot model.

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