Seven years in the cyclic coronal life of iota Hor

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Introduction

Activity cycles are commonly found among late type stars through the chromospheric Ca II emission. Their coronal counterpart, however, remains elusive in most cases, despite of the clear X-ray cycle observed in the solar corona, spanning as much as 1.7 dex in L_x. The discovery of a Ca II cycle in iota Hor of just 1.6 yr, the shortest to date, offered us a unique opportunity to monitor its X-ray counterpart in short time. The star offers also two more interesting properties: a planet of ~1.9 M_J orbits the star at 0.9 a.u., and with an age of only ~600 Myr and spectral type F8V, ι Hor represents a young solar analog, so its cycle might be the paradigm of the first activity cycles in the life of a solar-like star. Our XMM-Newton observations show the first coronal cycle in a single star. In good agreement with Ca II contemporaneous observations, the long term XMM-Newton light curve suggests also a long-term trend that seems to modulate the 1.6 yr cycle. Iota Hor shows us a remarkably stable coronal cycle. The irregularities observed in the chromospheric cycle can be explained as a geometrical effect. This effect is much smaller in the corona because it comes from a more extended material.

Star	Prot	Pcyc	Δ Lx	Reference (coronal cycle)	Notes
AB Dor	0.5 d	No	< 2	Sanz-Forcada+ 2003, Lalitha+ 2013	Photospheric cycle ~20 yr
iota Hor	8 d	1.6 yr	2.4	Sanz-Forcada+ 2013	Single star
epsilon Eri	11 d	2.9 yr	1.8	Coffaro+ 2018	See talk
61 Cyg A	35 d	7.3 yr	3	Hempelmann+ 2006, Robrade+ 2012	Star in binary system
HD 81809	(vsin i=3 km/s)	8.2 yr	4.5	Favata+ 2004, 2008	Binary system (unresolved in X)
α Cen B	37 d	8.8 yr	6	Robrade+ 2005, 2012, Ayres+ 2009, 2014	Star in multiple system
Sun	27 d	11 yr	~ 30-50	Orlando+ 2001, Judge+ 2003	

Table 1. Coronal activity cycles researched up to date. Attempts to find coronal activity cycles in stars more active than iota Hor have failed so far (see also Gudel 2004 on EK Dra). Iota Hor and epsilon Eri are the only single stars other than the Sun with a known coronal cycle.

Is the coronal cycle period an effect of stellar evolution?

Stellar rotation is related to age, and activity cycles are related to rotation.

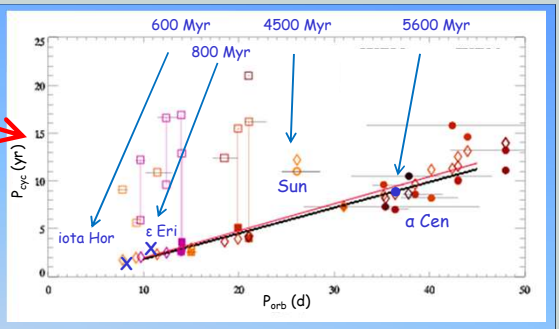


Figure 1. Stellar chromospheric (Ca II H&K) cycles with their rotational and cycle periods (adapted from Lorente & Montesinos 2005). Shorter period stars tend to display a double chromospheric cycle following the "active" and "inactive" branch (Bohm-Vitense 2007) Three cases of known coronal cycles are marked in blue, along with their age.

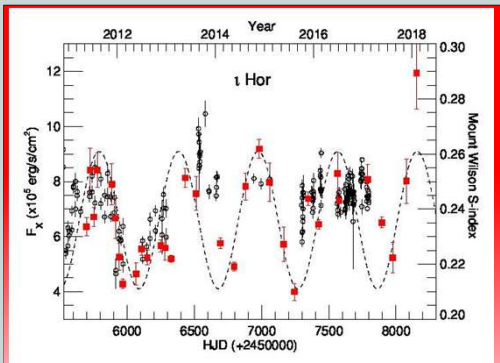
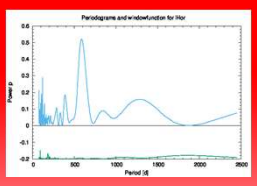


Figure 2. Time series of coronal surface flux (filled squares) and chromospheric S-index (open dots) for ι Hor. The dashes line indicates the cycle calculated with just X-rays data (591 d). Error bars of coronal X-ray surface flux are based on standard deviation within each snapshot (chromospheric data from Metcalfe+ 2010 and Alvarado+ 2018)

XMM-Newton confirmed the presence of a coronal cycle of 1.6 yr, in agreement with the chromospheric data (Sanz-Forcada et al. 2013).



Iota Hor is an interesting object:

- Is a solar ancestor (F8V, 600 Myr old)
- It has a planet (1.8 M_J) orbiting at ~1 a.u.
- It is being studied with ZDI techniques (see Alvarado-Gómez+ 2018) with interesting results

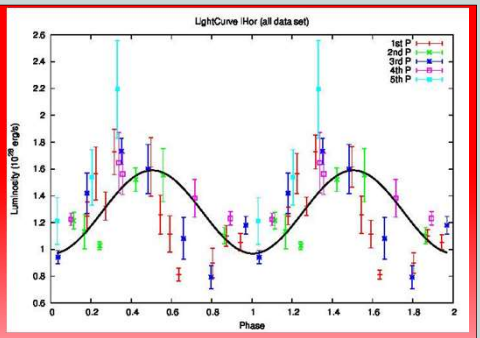


Figure 3. X-ray long term light curve of iota Hor, folded with stellar activity cycle. Note the remarkable stability in amplitude and duration, despite of the irregularities observed in the chromospheric data

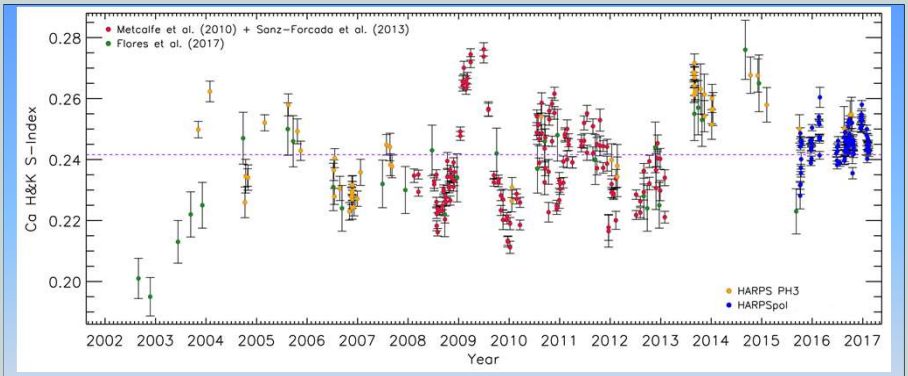


Figure 4. Chromospheric data of ι Hor since 2002 (Alvarado-Gómez+ 2018). A geometrical effect could explain the irregular behavior of the chromospheric cycle in contrast with coronal counterpart. X-rays show more extended material, disminishing possible geometrical effects of the Ca II data: Northern and Southern stellar hemispheres may show "independent" stellar cycles in the Sun. During the solar Maunder Minimum only the Southern hemisphere showed stellar activity. In the case of ι Hor, its inclination of ~60º would introduce an asymmetry in the global light curve of Ca II depending on which hemisphere is more active.

CONCLUSIONS

- A coronal cycle of 1.6 yr of period is confirmed in iota Hor after 7 years of monitoring with XMM-Newton
- A second, longer period cycle, apparent in the chromospheric data, is discarded in the coronal. A geometrical effect could be responsible of the differences observed.
- The iota Hor behavior may well be representing the earliest coronal cycles in the Sun, once the star exited from the activity saturation regime.
- The particular layout of the iota Hor planetary system is interesting to research the environment at the time when life appeared on Earth (age ~500 – 1000 Myr)