Evidence for a double coronal cycle in the young solar analog 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 recent 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 may offer us the unique possibility to observe for the first time a double coronal cycle similar to those observed in the chromosphere of other stars.

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	Possible double cycle
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 is the only single star 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.

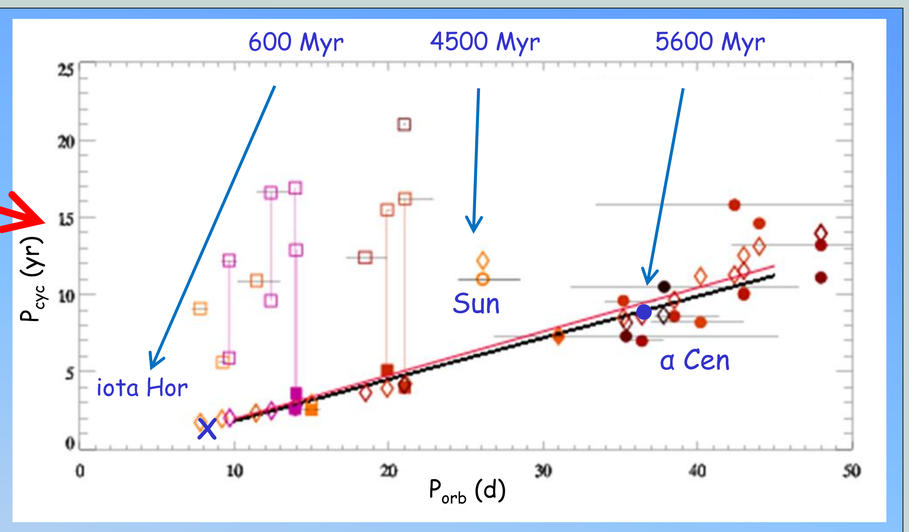

Figure 1. Stellar chromospheric (Ca II H&K) cycles with their rotational and cycle periods (adapted from Lorente & Montesinos 2005). Shorter period stars tend two display a double chromospheric cycle following the "active" and "inactive" branch (Bohm-Vitense 2007) Three cases of known coronal cycles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

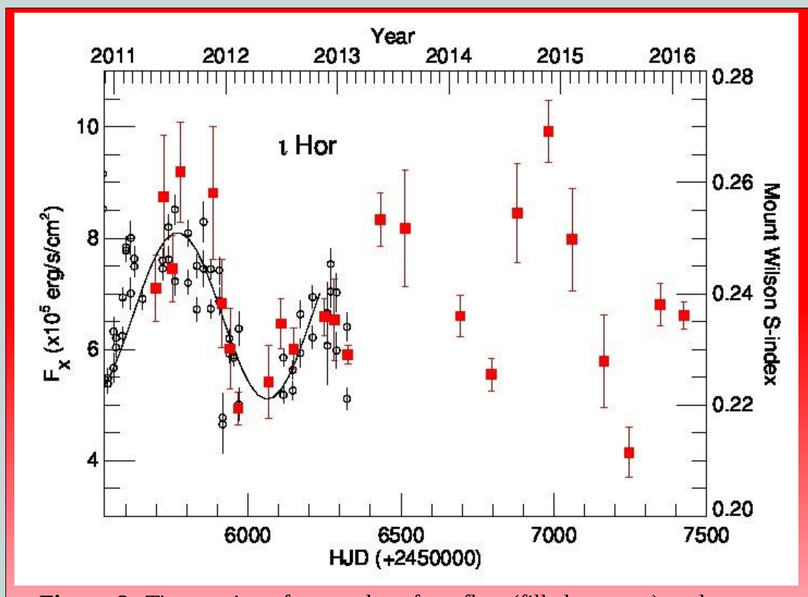

Figure 2. Time series of coronal surface flux (filled squares) and chromospheric S-index (open dots) for ι Hor. The solid line indicates the cycle calculated in Metcalfe+ (2010), shifted by 395 d. "Error" bars of coronal X-ray surface flux are based on flux variations within each snapshot (adapted from Sanz-Forcada+ 2013)

XMM-Newton confirmed the presence of a coronal cycle of 1.6 yr, in agreement with the chromospheric data (Sanz-Forcada et al. 2013). The combination with former Ca II H&K data (Metcalfe et al. 2010) and new XMM-Newton observations is suggesting the presence of a double coronal cycle. Such cycles are observed in the chromosphere of some stars with shorter periods than the Sun.

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 talk by Alvarado-Gómez)

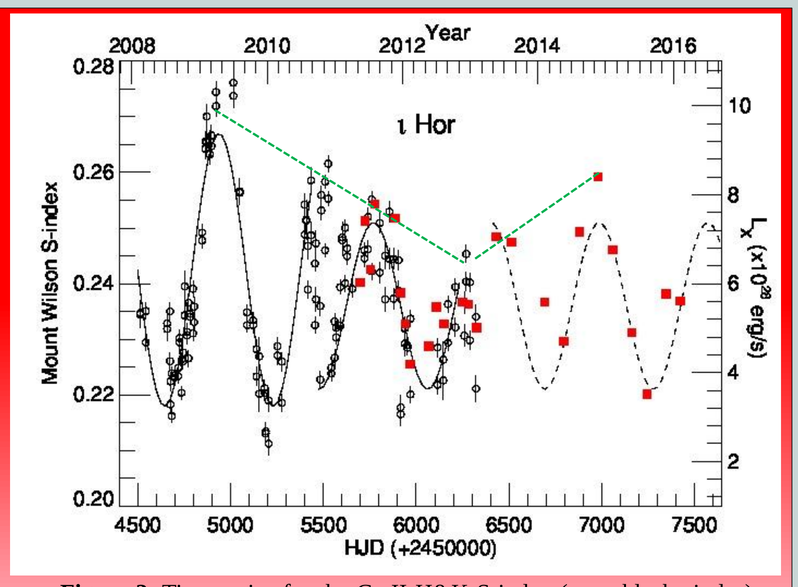

Figure 3. Time series for the Ca II H&K S-index (open black circles), and coronal X-ray luminosity (filled red squares) of ι Hor. The solid line indicates the cycle as in Metcalfe+ (2010) and Sanz-Forcada+ (2013). A dashed line follows the tentative new cycle with same period. A dotted line is displayed marking the long-term trend of the cycle maxima.

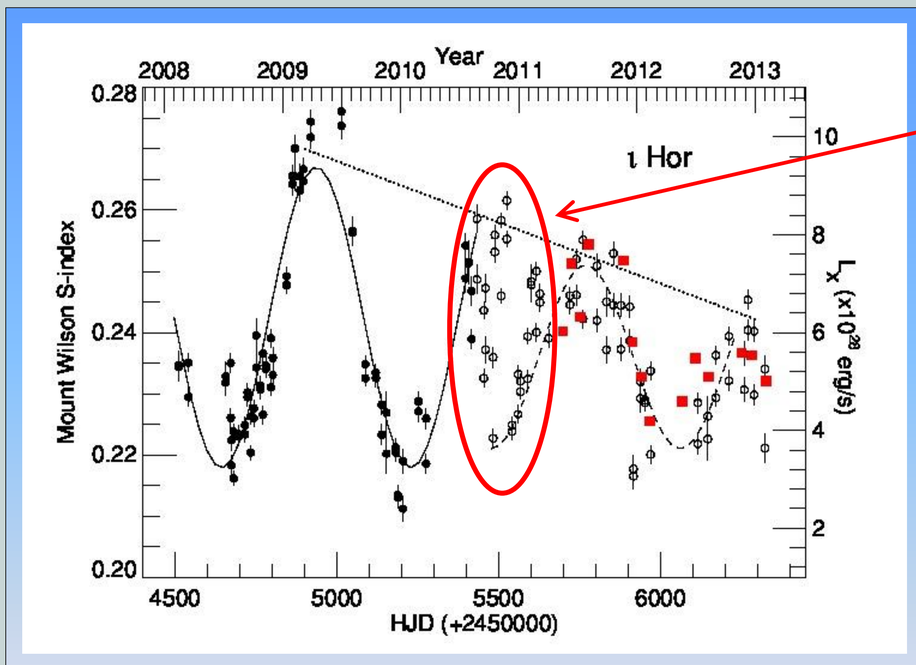

Figure 4. Chromospheric and coronal cycles of iota Hor up to 2013 (Sanz-Forcada et al. 2013 – SF13). Black filled circles are chromospheric data from Metcalfe et al. (2010), open circles from SF13, and red squares are coronal data with statistical errors. A dotted line guides through a possible longer cycle in the activity maxima. Dashed and solid lines correspond to cycles with a period of 1.6 yr.

A geometrical effect could explain this strange "reset" of the stellar activity cycle.
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 iota Hor, its inclination of ~60º would introduce an asymmetry in the global light curve depending on which hemisphere is more active.

CONCLUSIONS

- A coronal cycle of 1.6 yr of period is confirmed in iota Hor after 5 years of monitoring with XMM-Newton
- A second, longer period cycle, seems to ongoing: a decline in the cycle maxima between 2009 and 2013, is followed by an apparent increase in the new maxima described by the coronal data.
- 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)