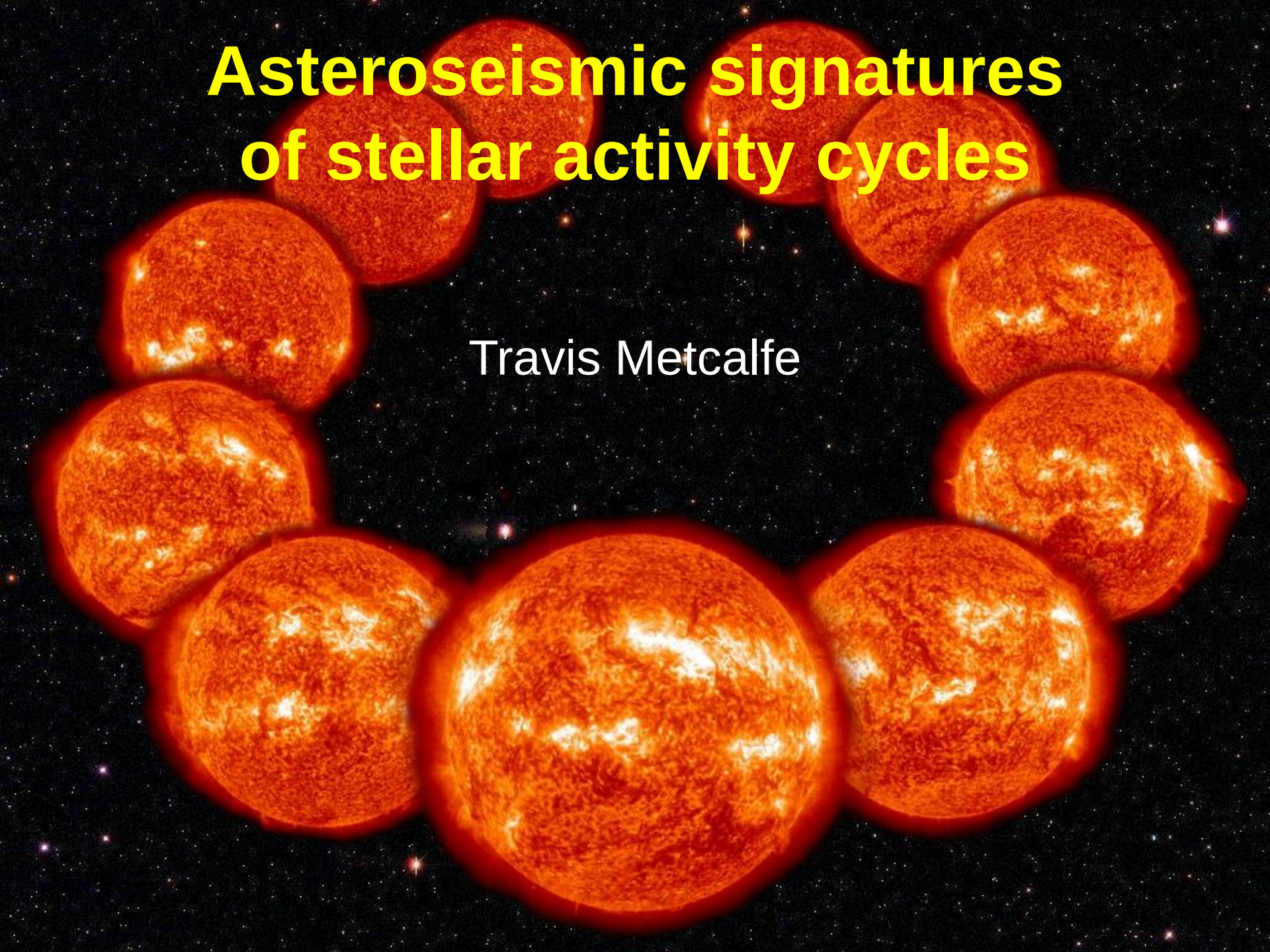
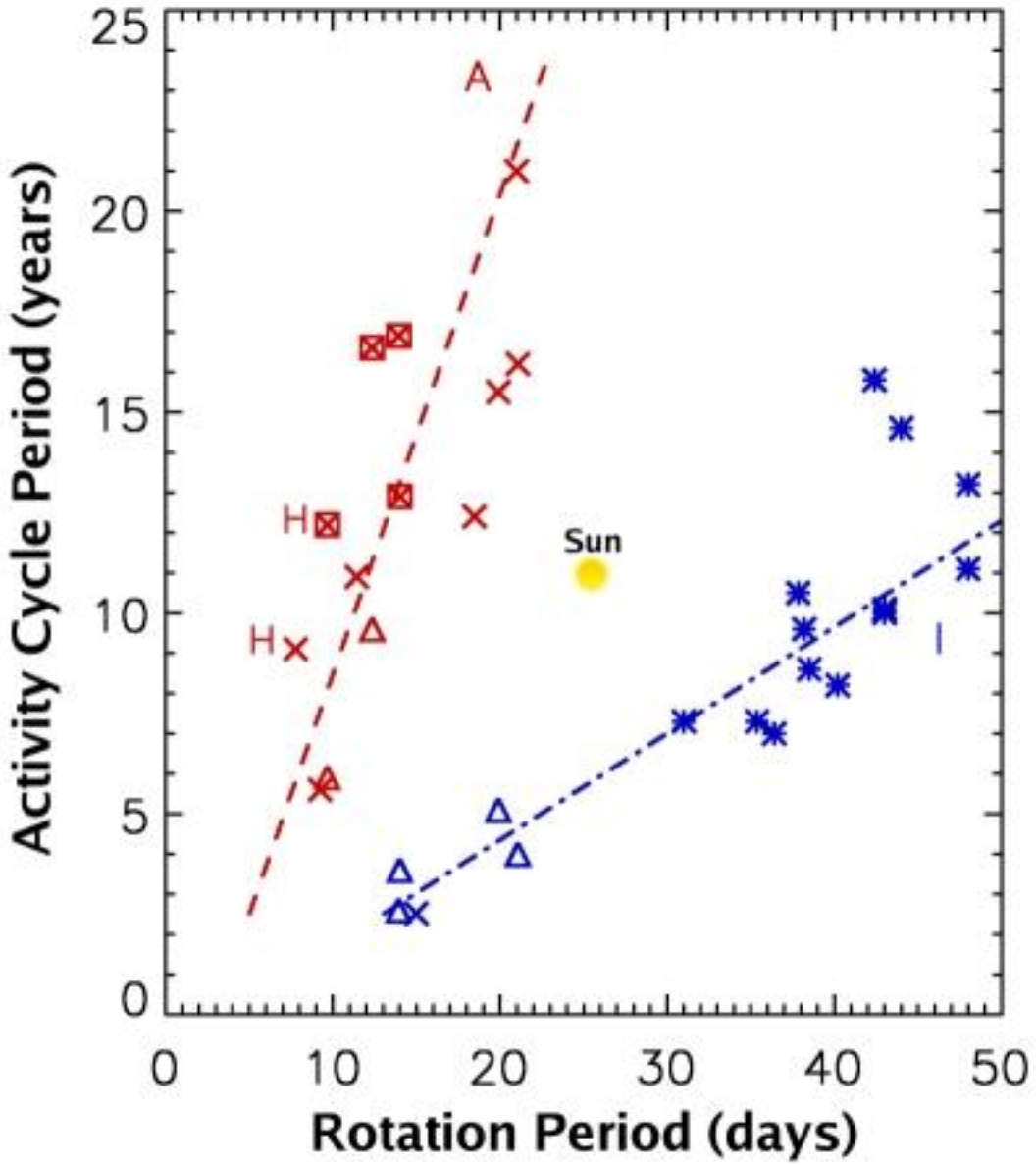
Asteroseismic signatures of stellar activity cycles



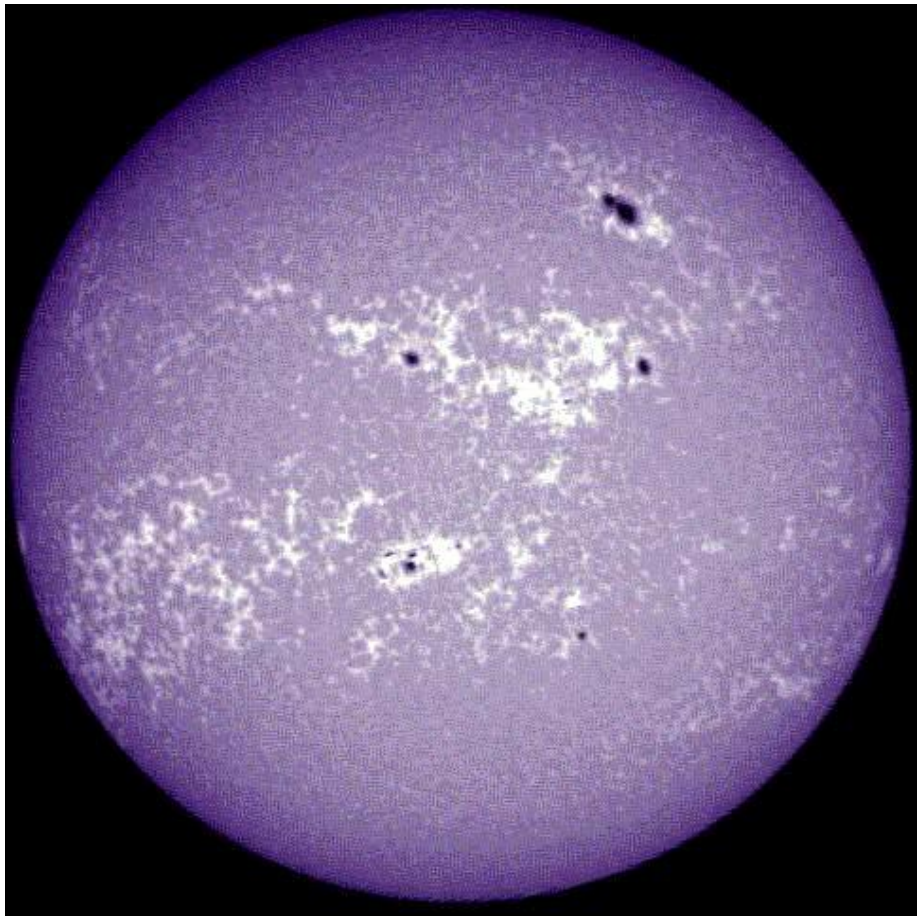
Travis Metcalfe

Population as context



Böhm-Vitense (2007)

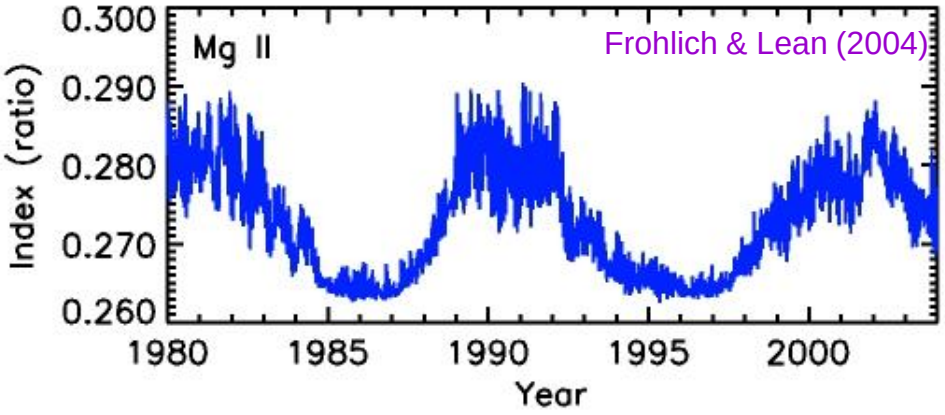
Solar activity

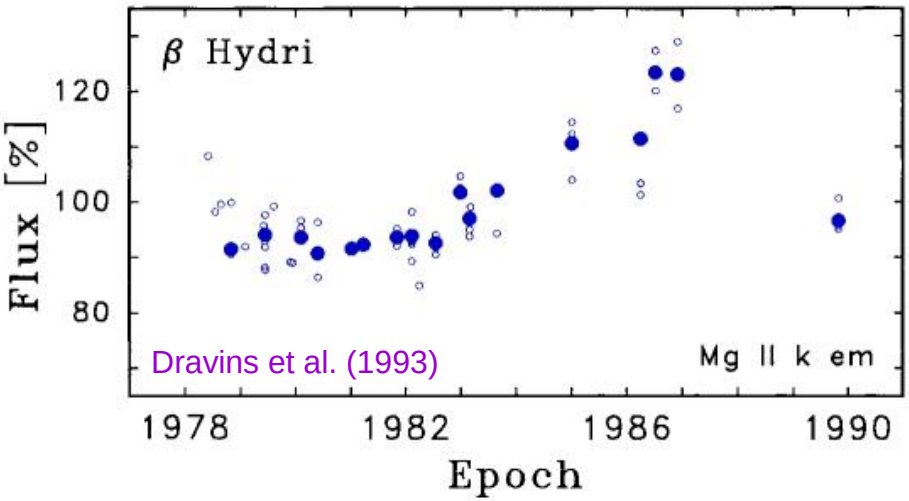


- Magnetic regions on the Sun are bright in Mg II (UV) and Ca II (optical)
- Measure ratio of total emission in line cores to flux in the wings
- Use disk-integrated time series measurements to track magnetic cycles

http://spacescience.spaceref.com/

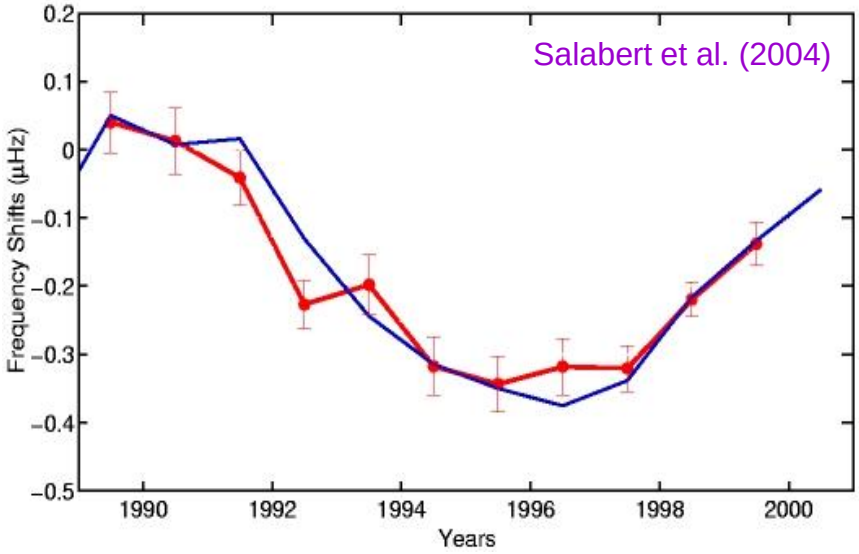
Stellar activity cycles

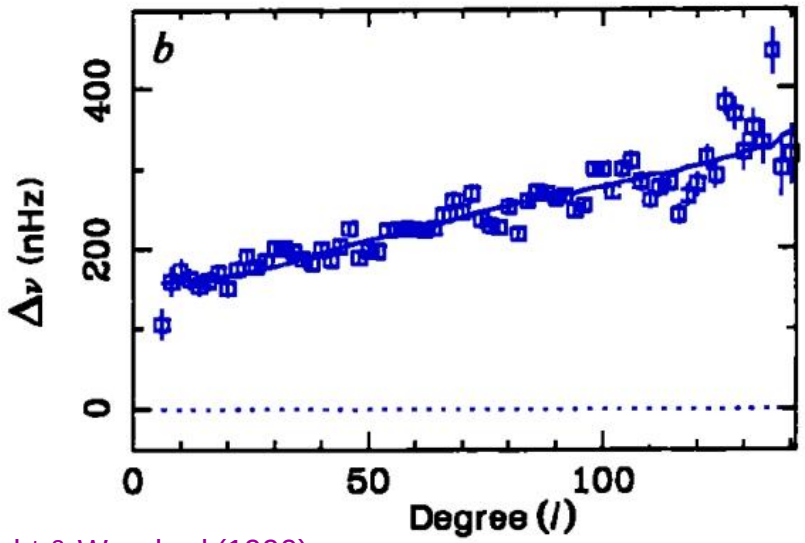




- Sun-as-a-star data show 10% variation in the Mg II index through solar cycle
- Similar magnetic activity cycles can be observed in other solar-type stars
- Mean activity level and cycle period scale with Rossby number (P_{rot} / τ_c)

Frequency shifts

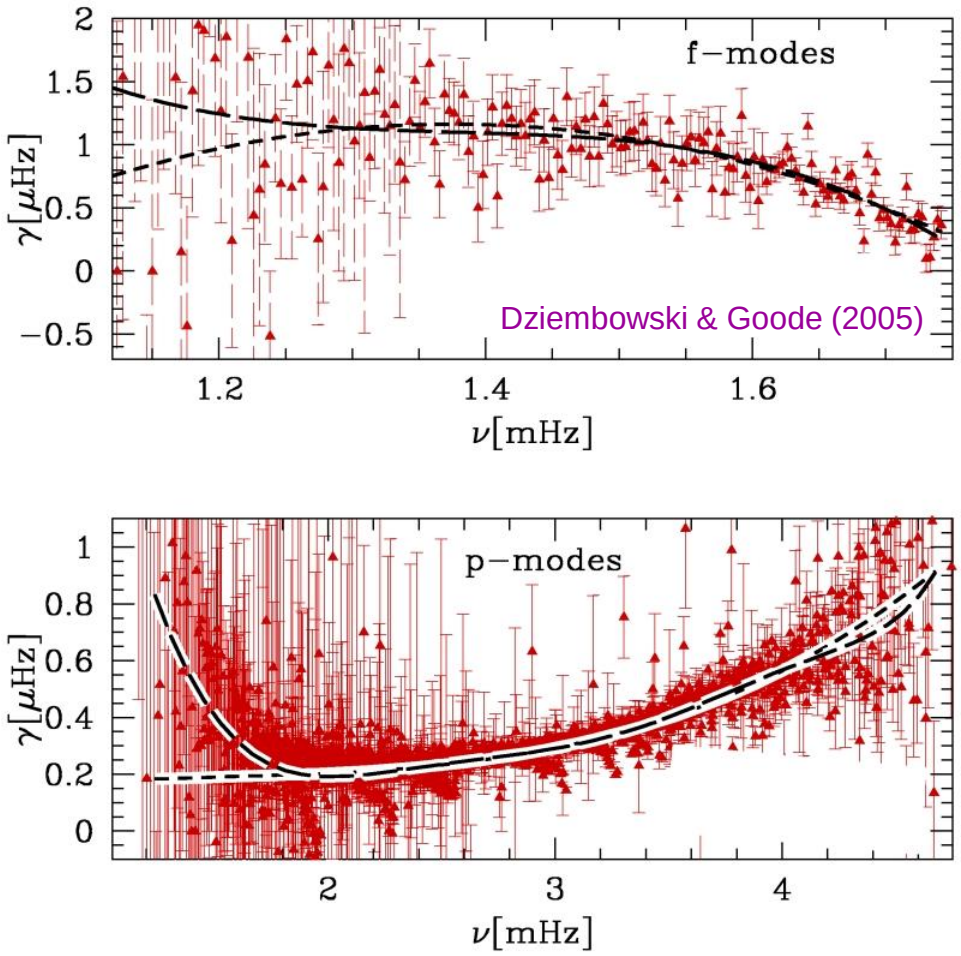




Libbrecht & Woodard (1990)

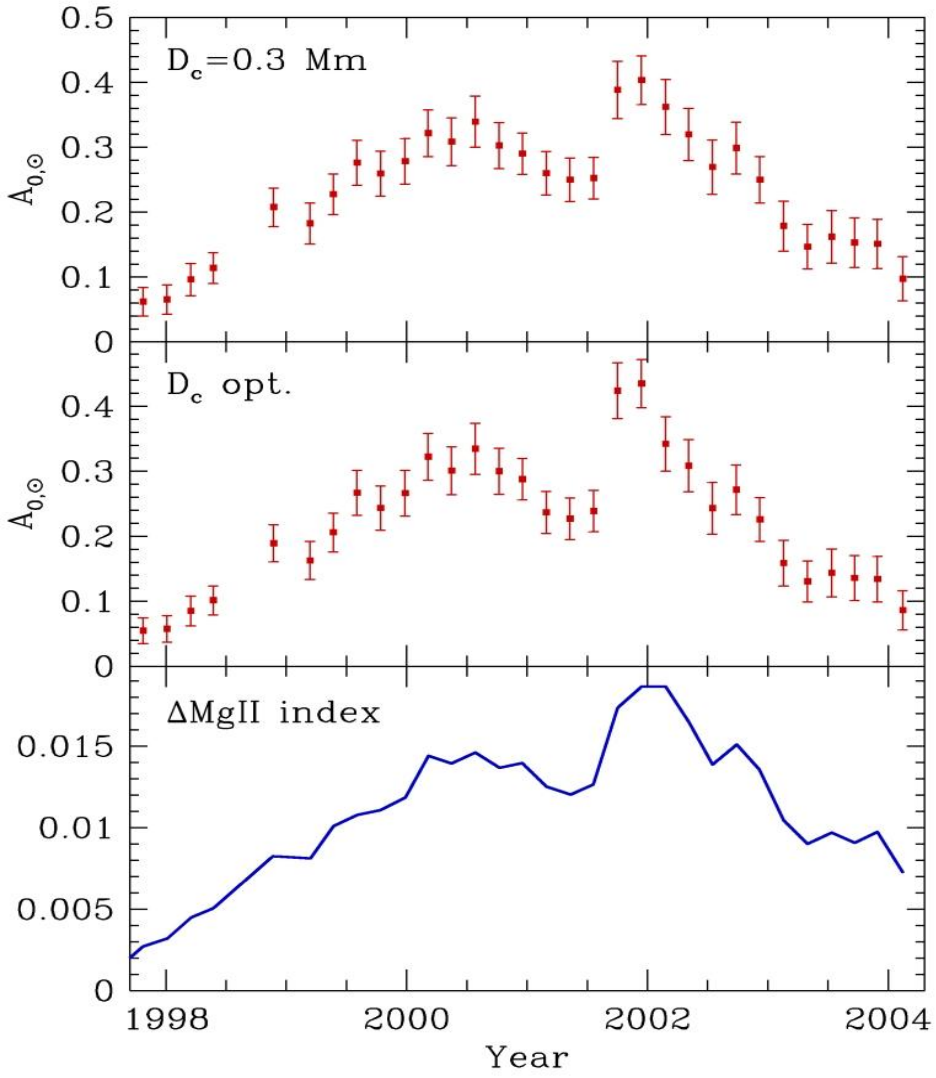
- Solar p-mode shifts first detected in 1990, depend on frequency and degree
- Even the lowest degree solar p-modes are shifted by the magnetic cycle
- Unique constraints on the mechanism could come from asteroseismology

Theoretical interpretation



- Magnetic perturbations modify the near-surface propagation speed
- Also leads to decreased convective velocity and change in temperature
- Distinct behavior for solar f-modes and p-modes confirms these sources

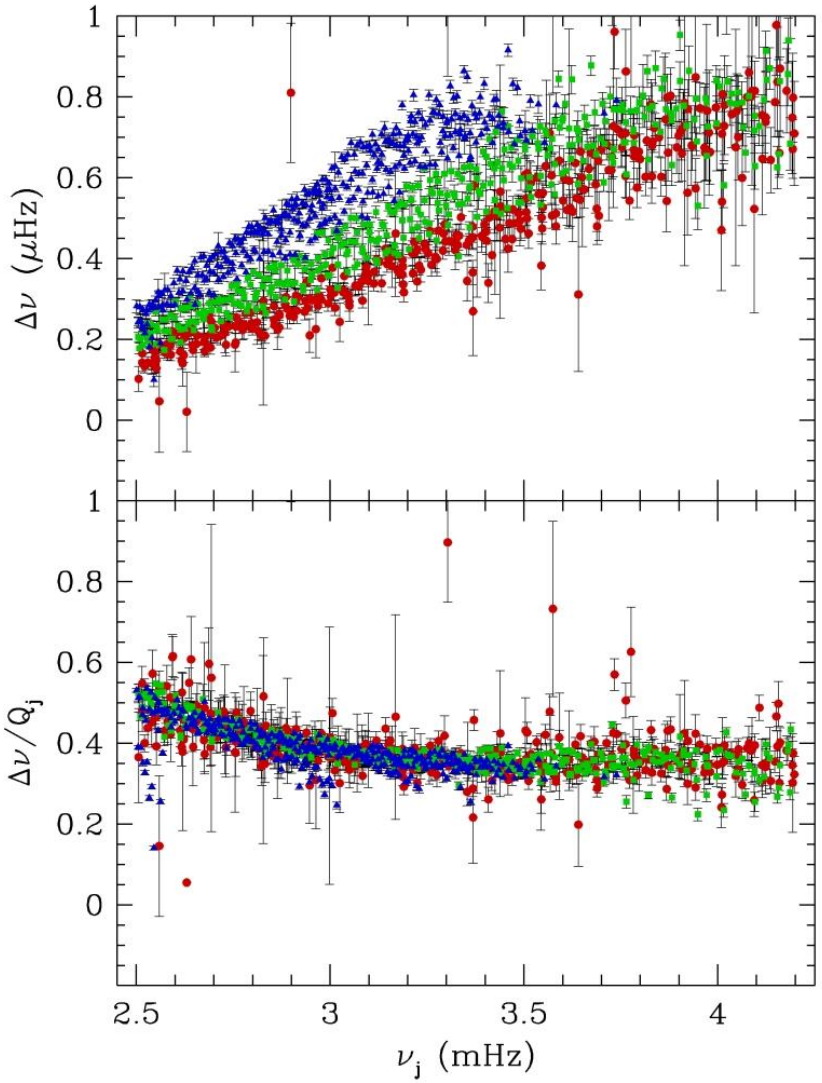
Scaling from the Sun



- Parameterize shifts with $\Delta\nu \sim A_0\ (R / M)\ Q_j(D_c)$ and fit the MDI p-mode data
- A_0 ~ activity level, while the depth of the source $D_c \sim H_p \sim L^{1/4}\ R^{3/2} / M$
- A_0 captures most of the variation if depth fixed at D_c = 0.3 Mm for the Sun

Metcalfe et al. (2007)

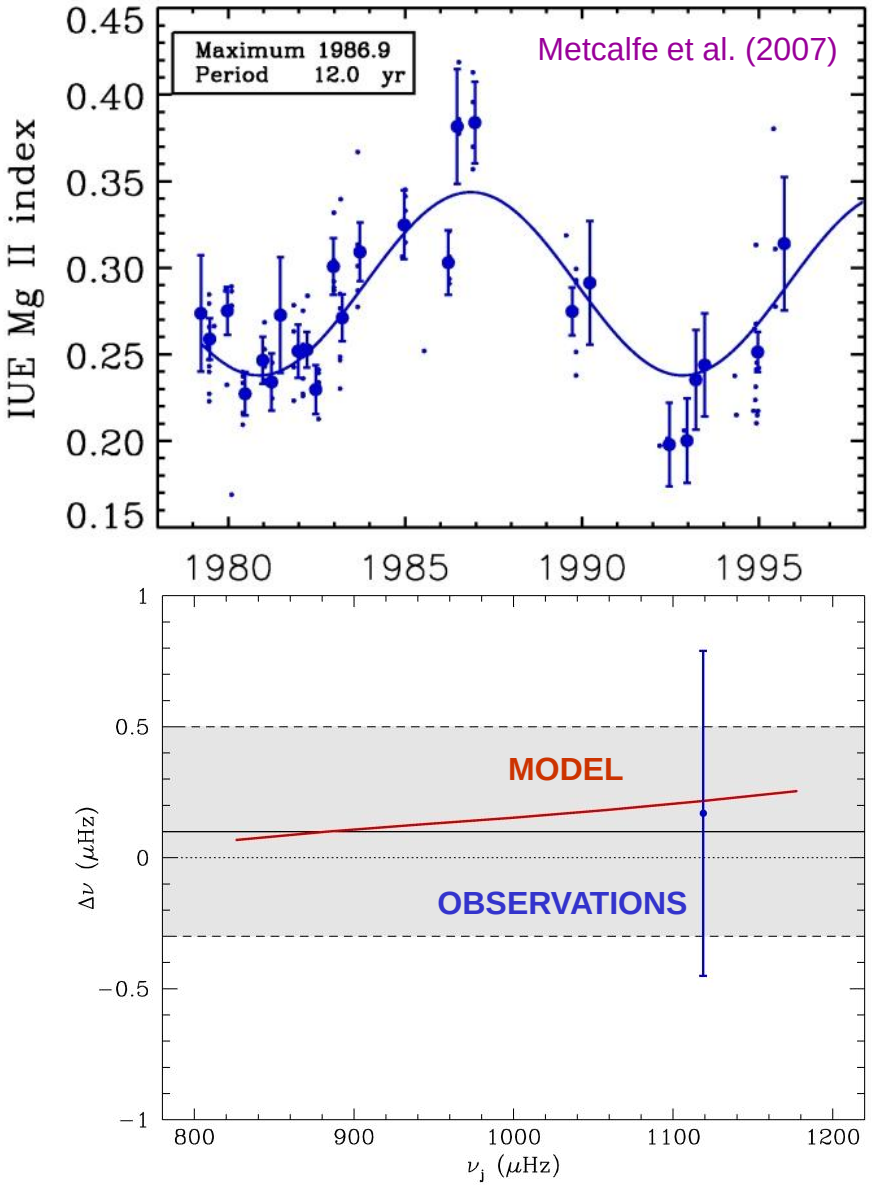
Cycle-induced frequency shifts



- Solar p-mode shifts show spread with degree and frequency dependence
- Normalizing shifts by our parametrization removes most of the dependencies
- Kepler will document similar shifts in hundreds of solar-type stars

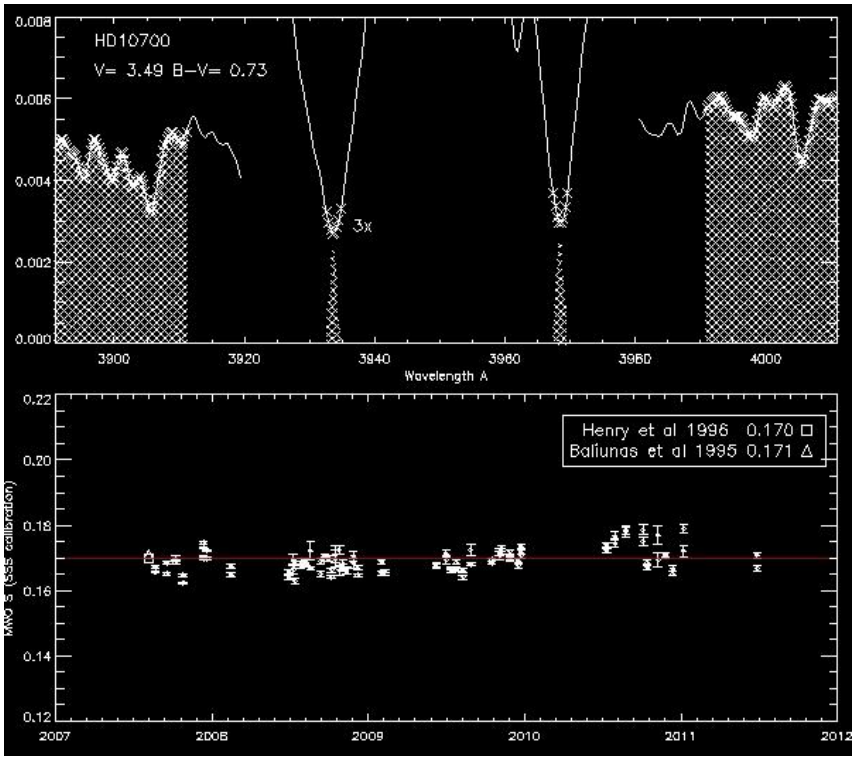
Metcalfe et al. (2007)

HD 2151 (β Hydri)



- Reanalysis of archival IUE data, including more recent observations
- Asteroseismic data from 2000 (just past maximum) and 2005 (near minimum)
- Mean shift: 0.1 ± 0.4 μHz, individual n=18 frequency shift: 0.17 ± 0.62 μHz

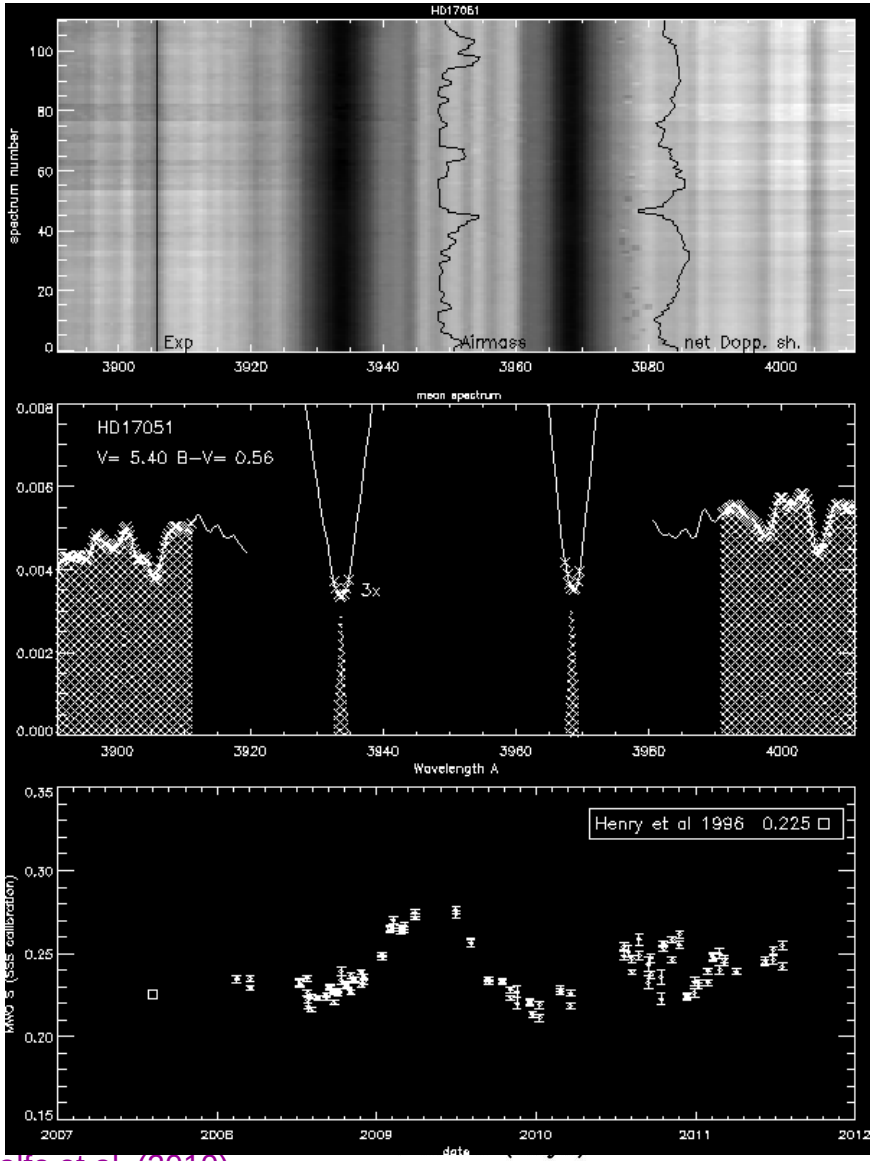
Southern HK project



- Small telescopes at CTIO run by SMARTS partners: Yale, GSU, STScI, et al.
- Service observing 2-3x per month using RC Spec with R ~ 2500 at Ca HK
- Monitor bright southern asteroseismic targets for stellar activity variations

Metcalfe et al. (2009, arXiv:0909.5464)

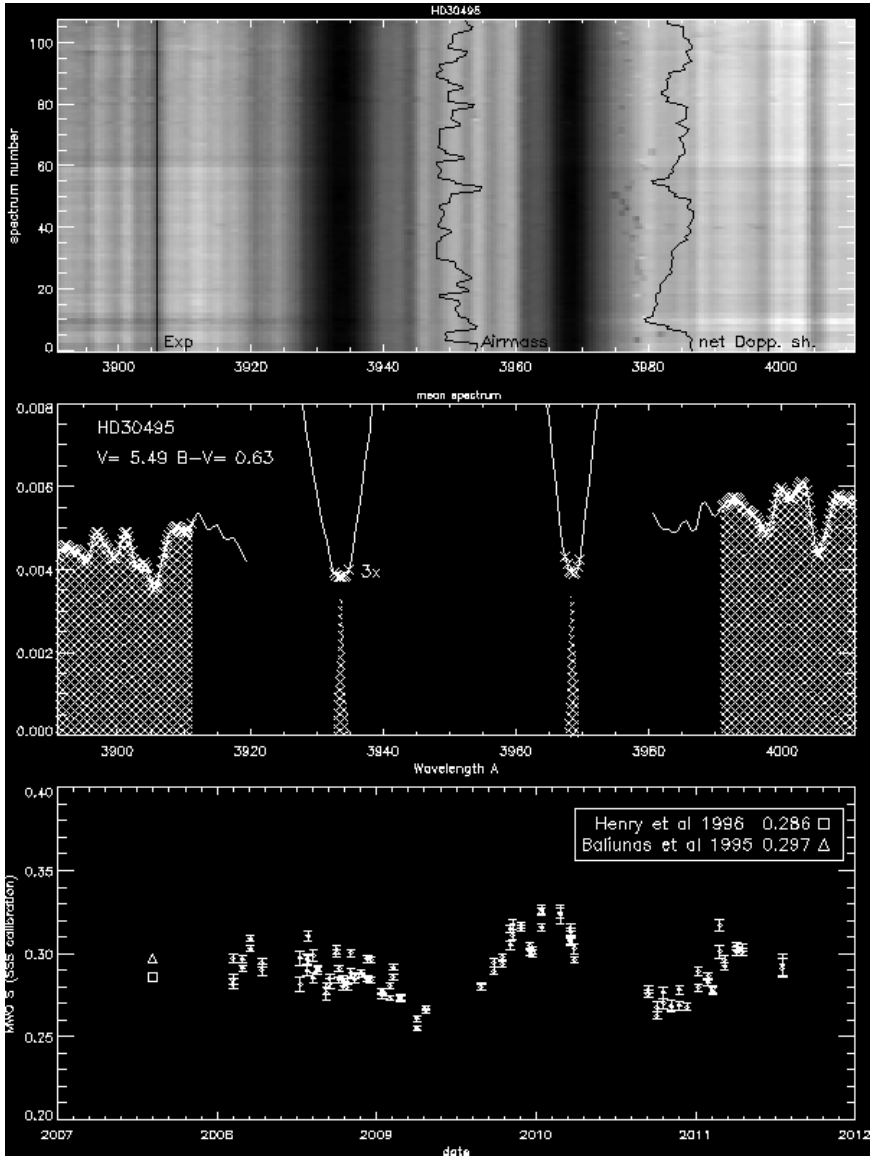
HD 17051 (ι Hor)



- Shortest measured stellar activity cycle in a solar-type star: 1.6 years
- Sampling permits some indication of the rotation rate: ~3x solar (8.5 days)
- Asteroseismology in 2007 (near maximum), repeat at minimum in late 2013?

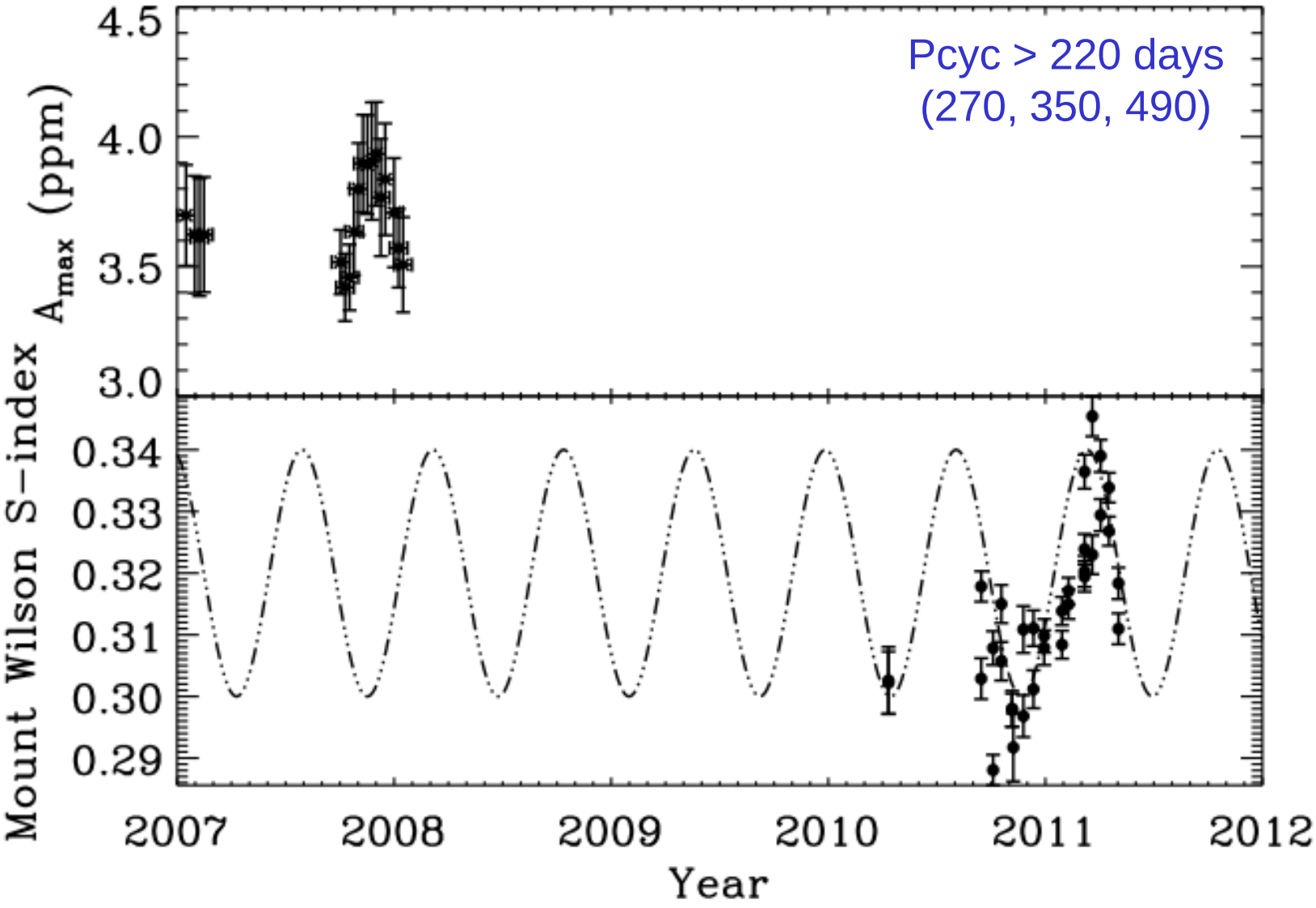
Metcalfe et al. (2010)

Short activity cycles

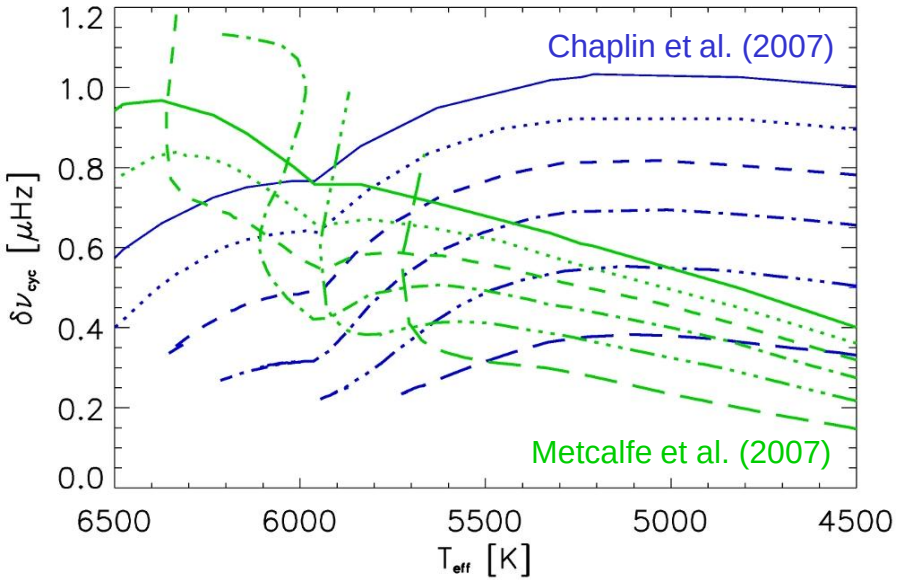


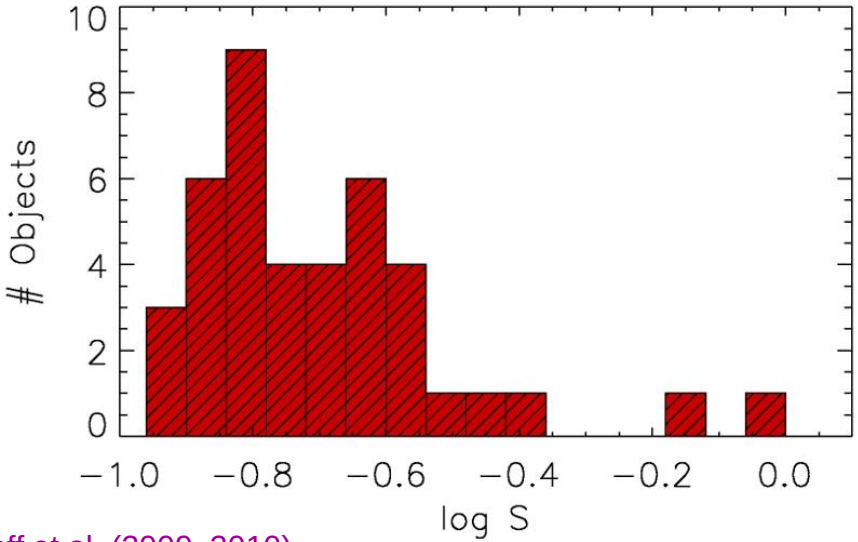
- Confirm ~2.5 year cycle in HD 76151 from Mount Wilson survey
- Cycle in HD 22049 (ε Eri) may be shorter than the ~5 year MWO result
- Irregular short period variations in HD 30495, as in Mount Wilson

CoRoT: HD 49933



Kepler: the NOT sample





- Two proposed scalings for frequency shifts as a function of spectral type
- HD 49933 shows larger than solar shifts, supports Dziembowski scaling
- Several dozen Kepler targets being monitored in Ca HK from NOT

Karoff et al. (2009, 2010)

Future prospects

- Satellite missions will extend the calibration of dynamo models to many unique sets of physical conditions and to different evolutionary phases.

- Must be coupled with long-term ground-based monitoring of stellar activity cycles from Ca HK surveys (Lowell, SMARTS, CASLEO).

- We will eventually move beyond scaling from solar data, and use the new observations as independent tests of dynamo models.