Activity, rotation and stellar ages using Kepler

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HELAS VI / SOHO 28 / SPACEINN

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Long time ago...

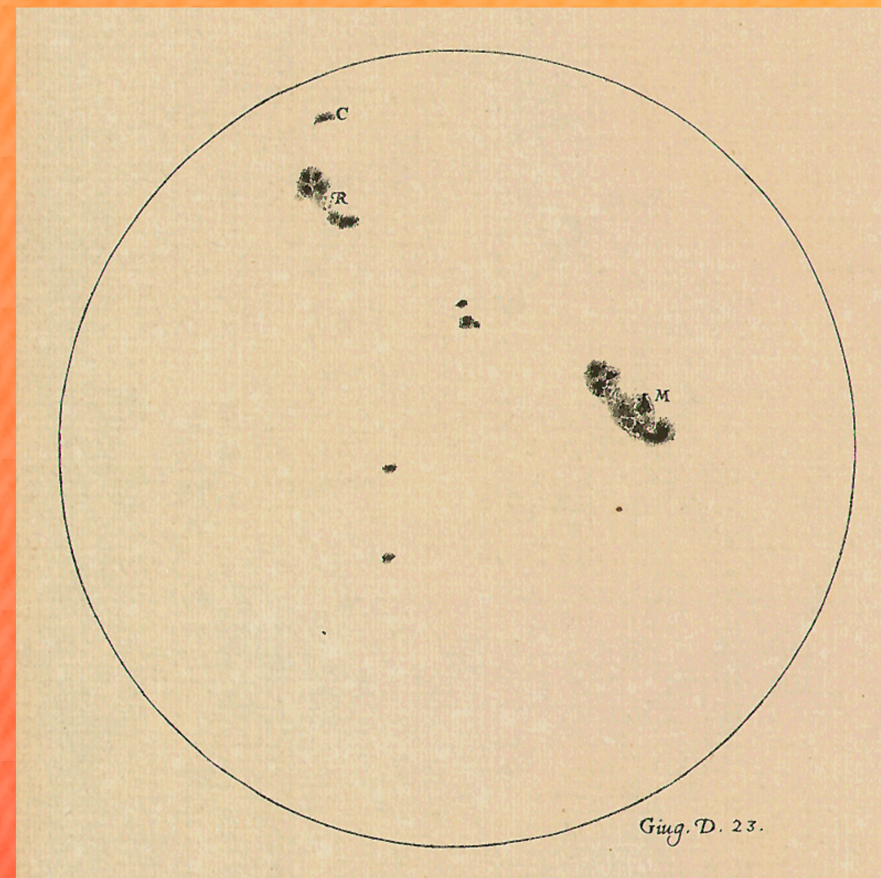
- Telescope invented

  ~ 1608
- Galilei discovered dark spots on the Sun
- Many others followed:

  - T. Harriot

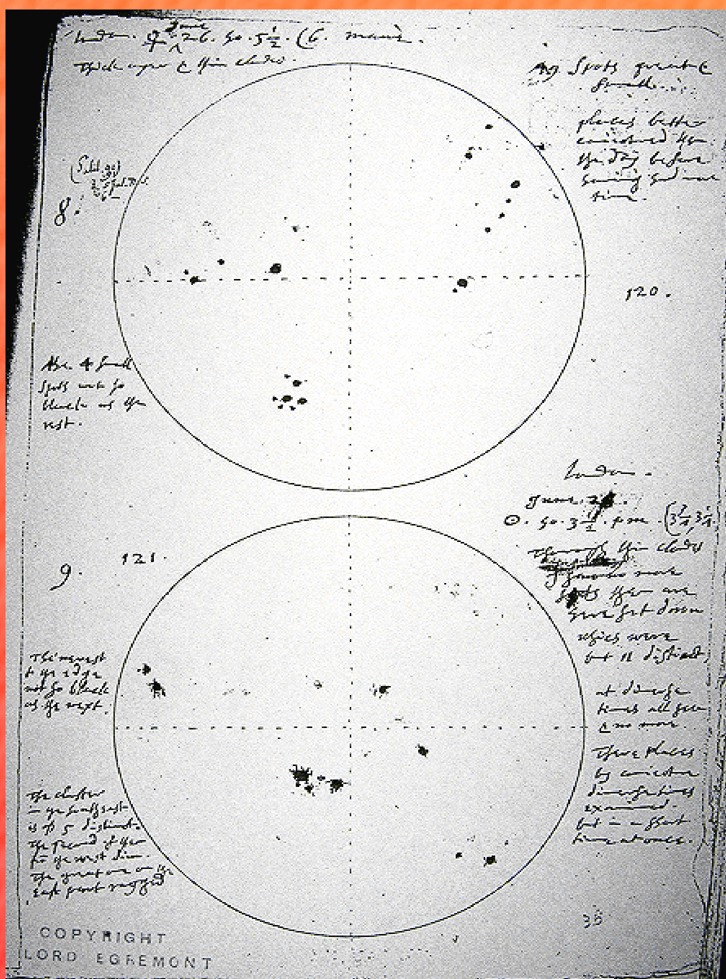
  - J. & D. Fabricius

  - C. Scheiner...

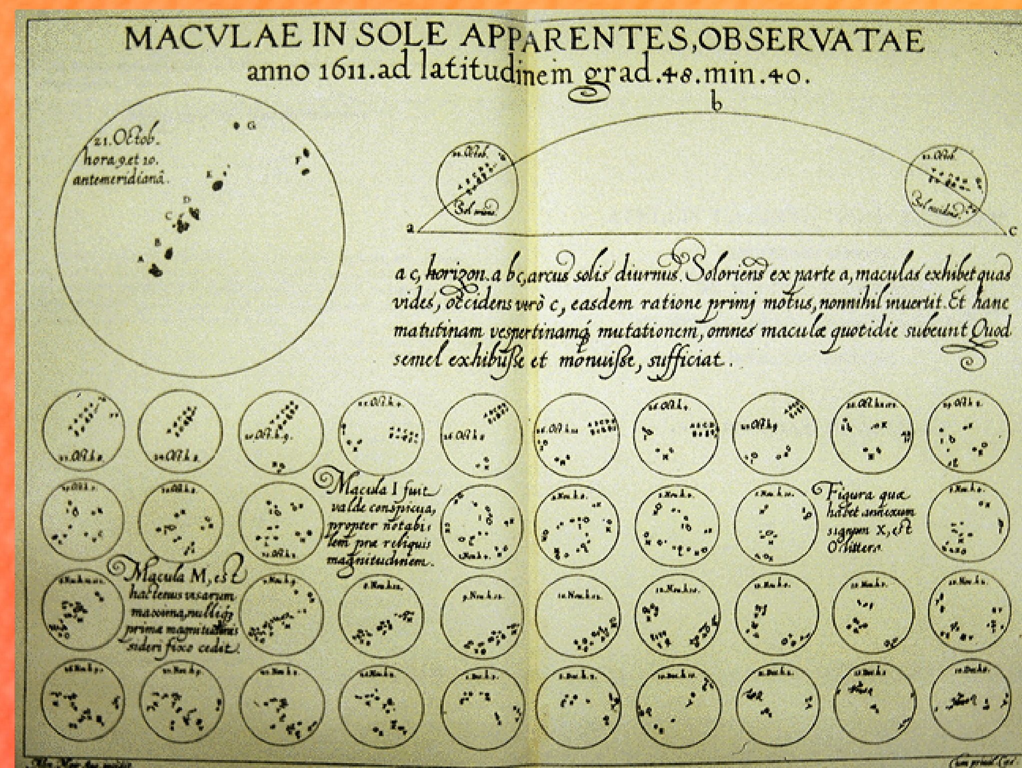


Sun spot observations

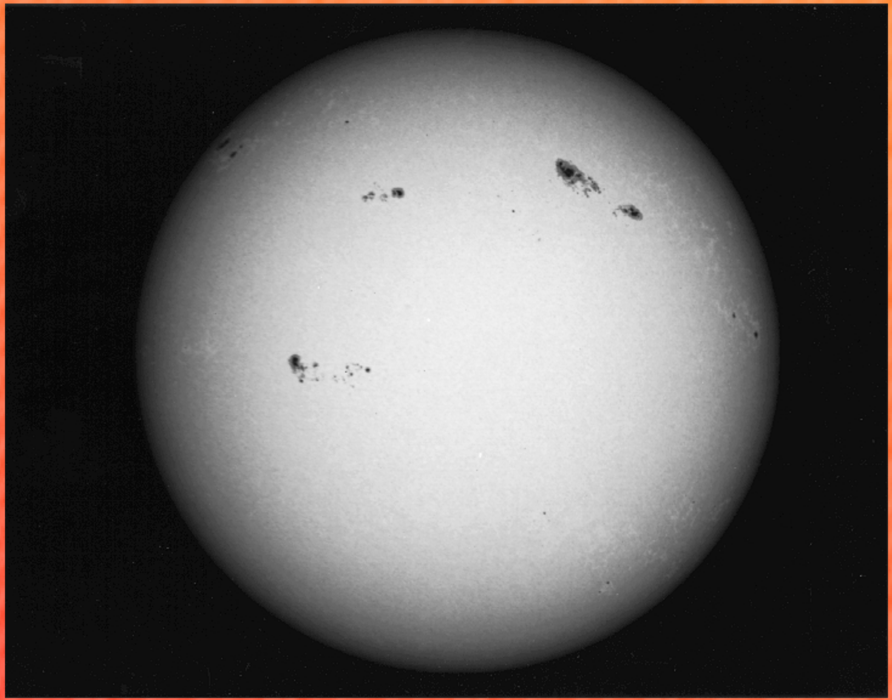
Thomas Harriot

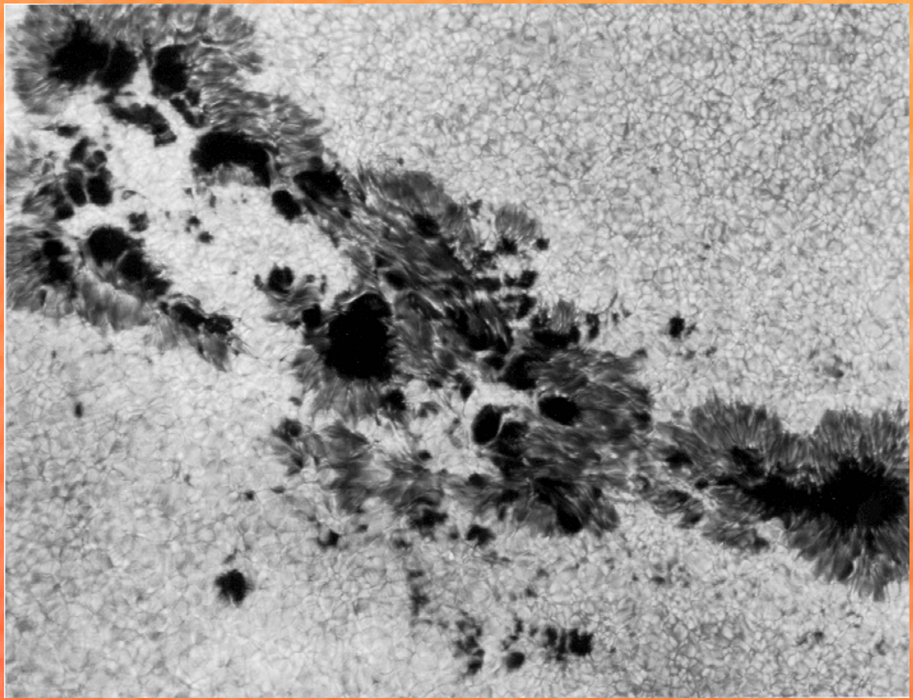


Christoph Scheiner



Sun spots today
(as seen by SOHO)





From the Sun to the stars

- Problem: Cannot resolve spots on distant stars
- But: Star spots cause (periodic) variability in stellar lightcurves
- High-precision lightcurves from space telescopes: MOST, CoRoT, Kepler, (PLATO)

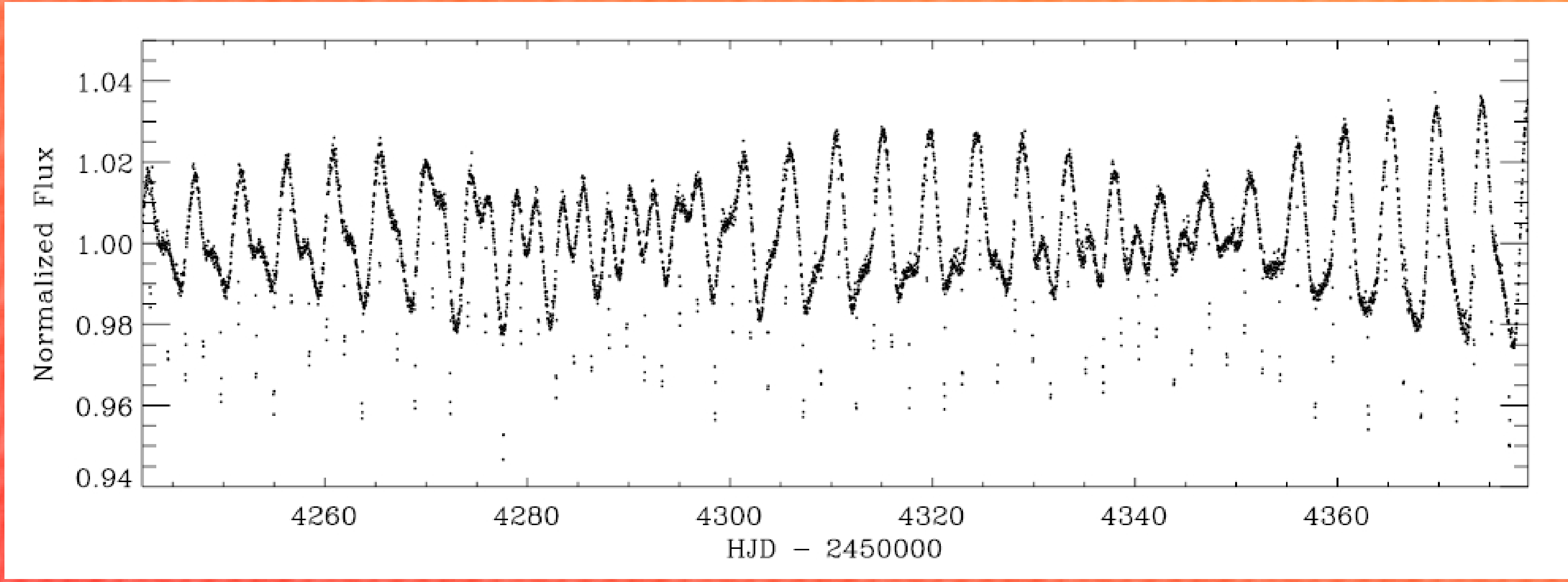
Star spots today

- CoRoT-2 light curve: periodic variability due to star spots

  → achieve stellar rotation periods!

- Beat-shape: More than only one rotation period!

  → Differential Rotation (DR)



Stellar rotation & Chromospheric activity

- Spotted star

  → (strong) magnetic fields

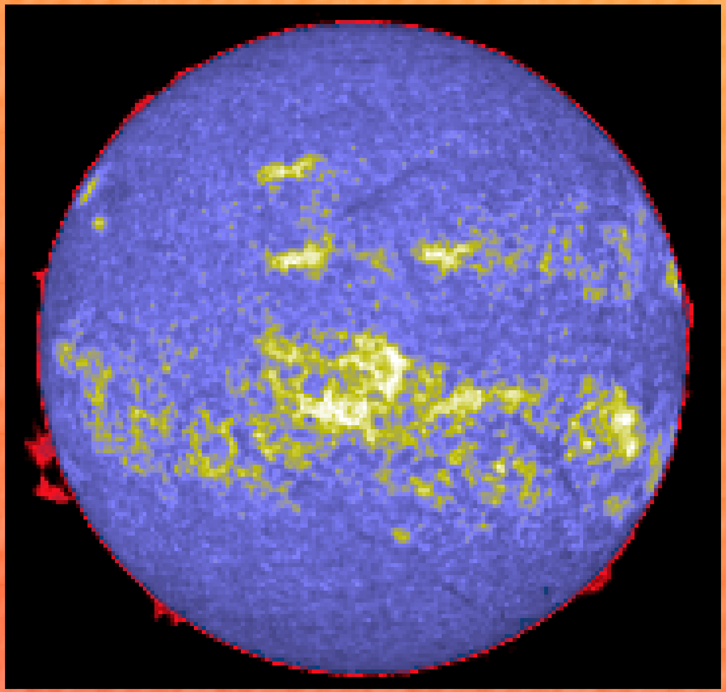
  → Magnetic field heats the chromosphere

  → chromospheric emission

- Mount Wilson H-K project (1980): Measured rotation periods & chrom. activity

  → Use CaII H & K as rotation indicator

Solar chromosphere



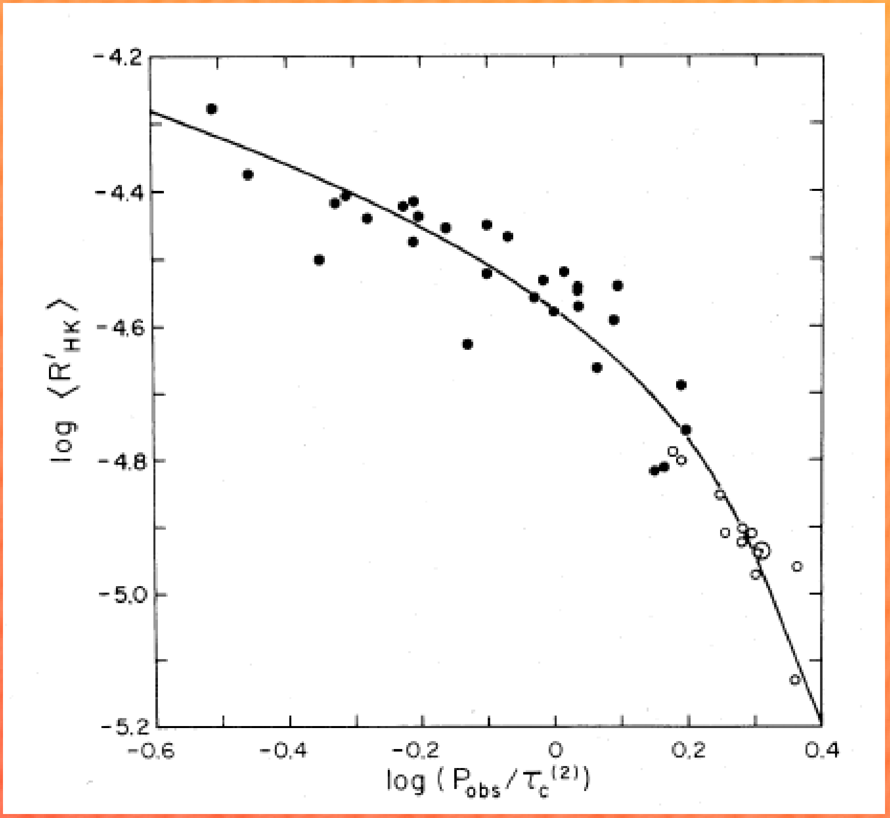
Activity-rotation relation

- Activity indicator R'_{HK} vs. Rossby number P/τ (rotation period over convective turnover time) for Mount Wilson stars
- Symbols:

  closed = young stars

  open = old stars
- Activity increases towards fast rotators!

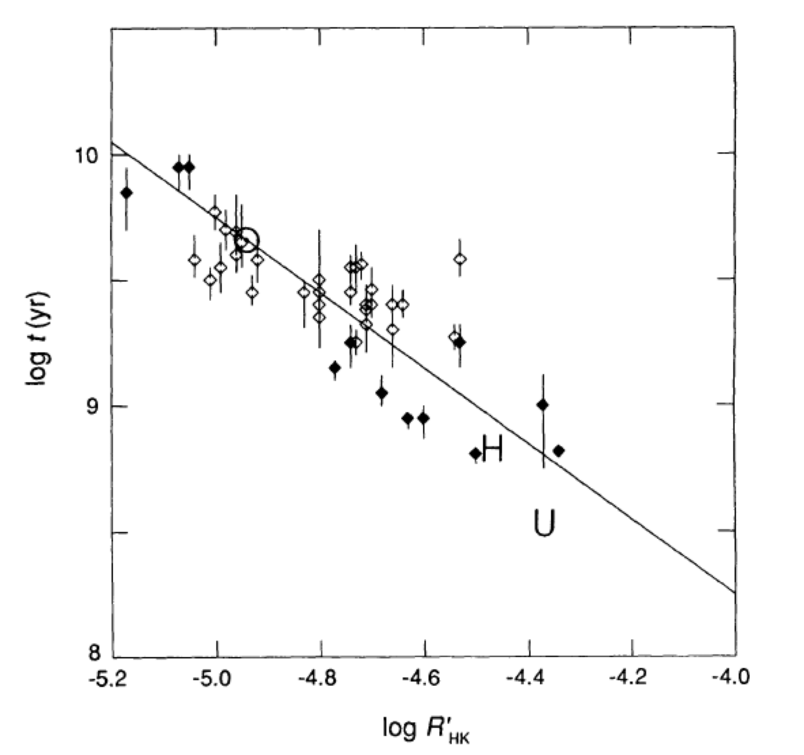
Noyes (1984)



Activity-age relation

- Stellar age t vs. activity index R'_{HK} for visual binaries, single F stars & open clusters
- Activity decreases with stellar age!

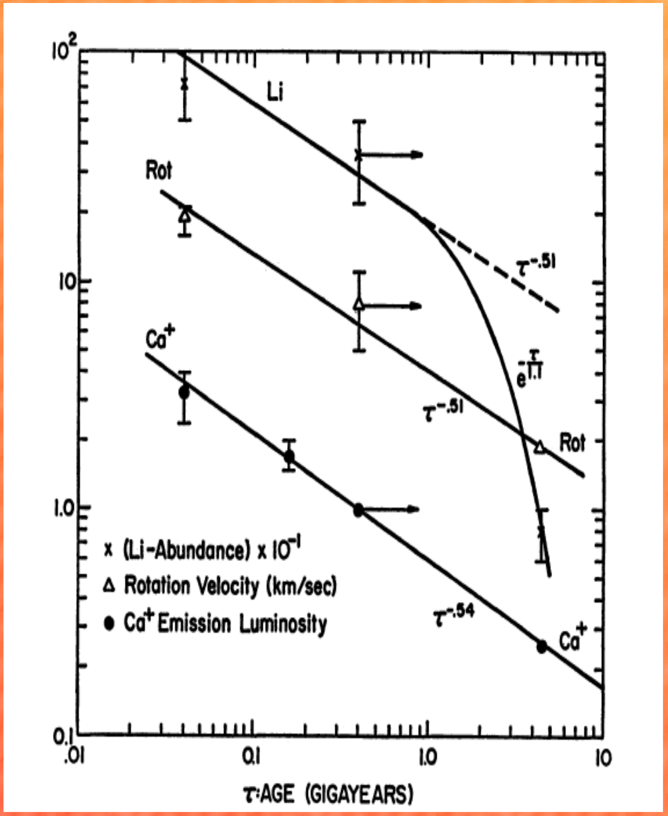
Soderblom, Duncan & Johnson (1991)



Activity-rotation-age relation

- Skumanich (1972) showed relation between activity indicator (CaII), age τ (Li), and rotation rate *v sin i*
- All trends ~ $\tau^{-1/2}$

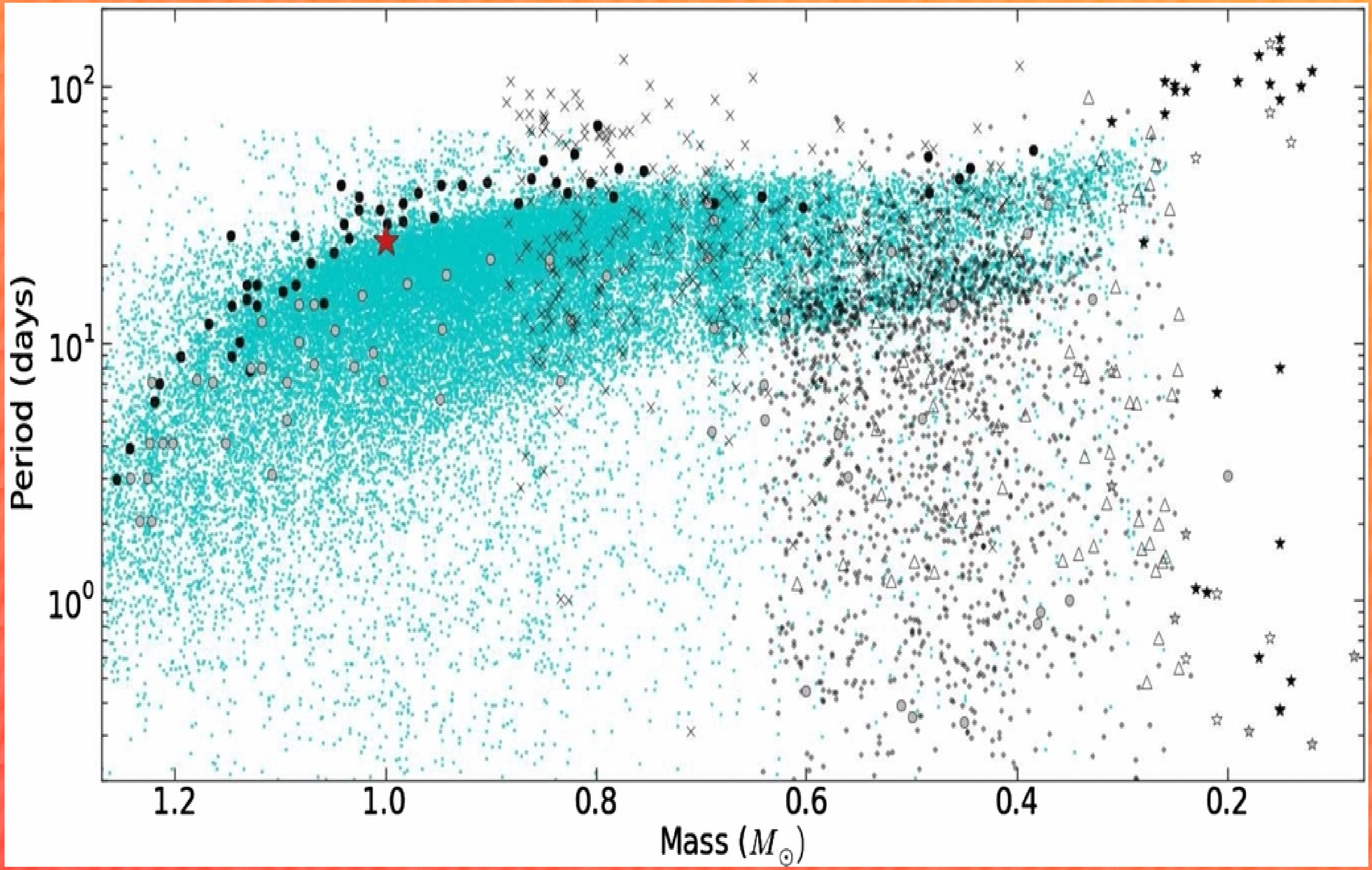
Skumanich (1972):



What can *Kepler* do?

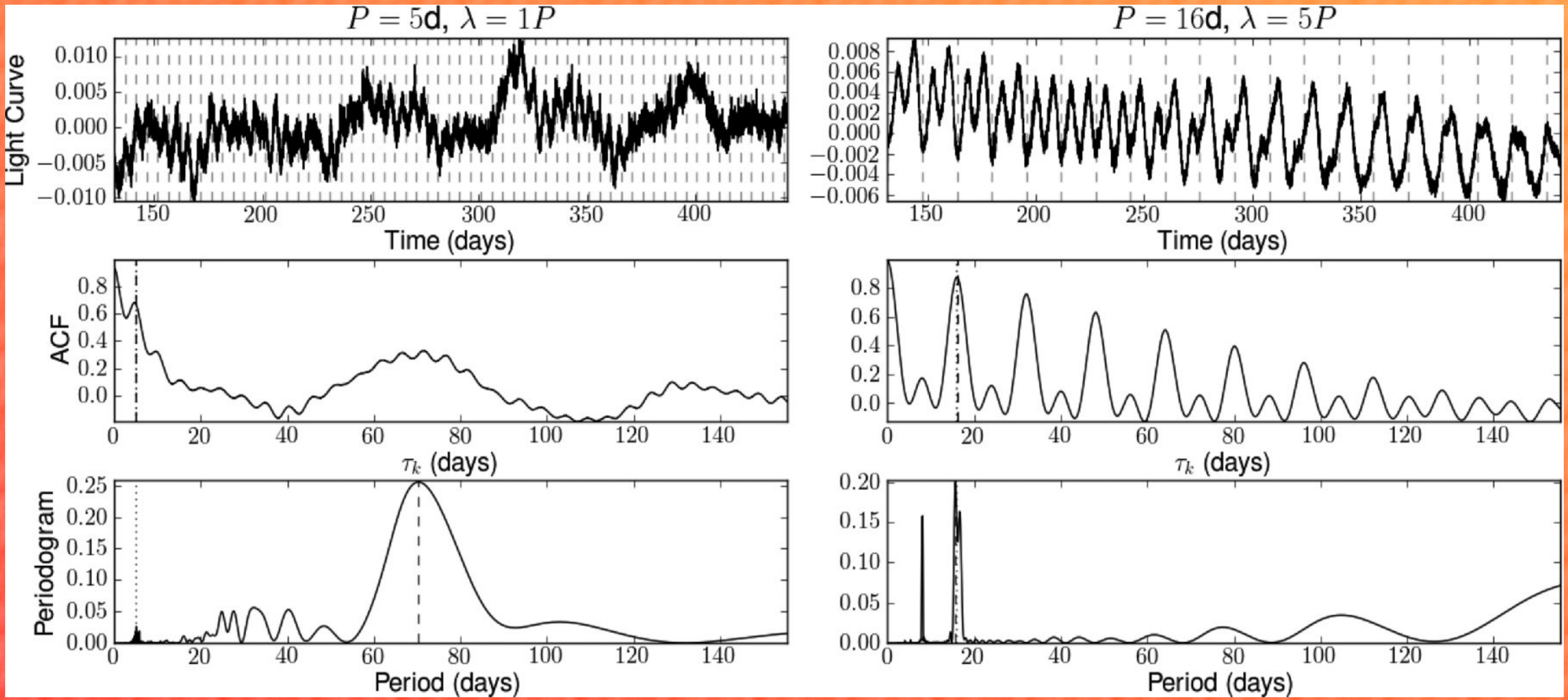
Kepler: Rotation periods!

McQuillan et al. (2014)

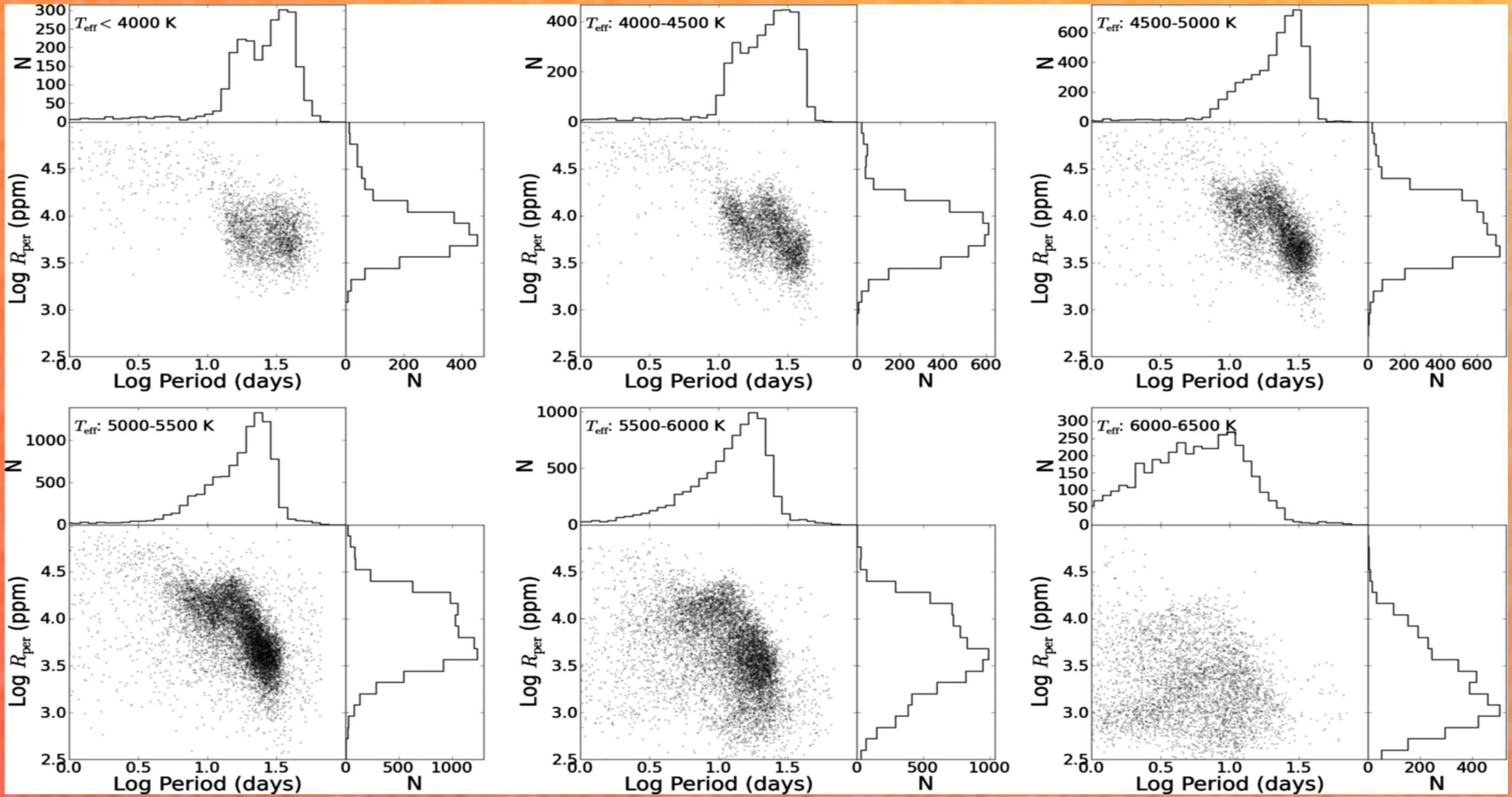


How to measure periods?

- Auto-correlation function (ACF)
- Lomb-Scargle periodogram



Kepler: activity?



- Difficult: Only lightcurves, no spectra!

→ variability amplitude R_{per}, but no chromospheric activity measure R'_{HK}

Measured rotation periods with Kepler (so far...)

- McQuillan et al. (2013a): 1570 (M dwarfs)
- Nielsen et al. (2013): 12.151 stars
- McQuillan et al. (2013b): 737 (KOIs)
- Walkowicz & Basri (2013): 950 (KOIs)
- Reinhold et al. (2013): 24.124 stars
- McQuillan et al. (2014): 34.030 stars!!!

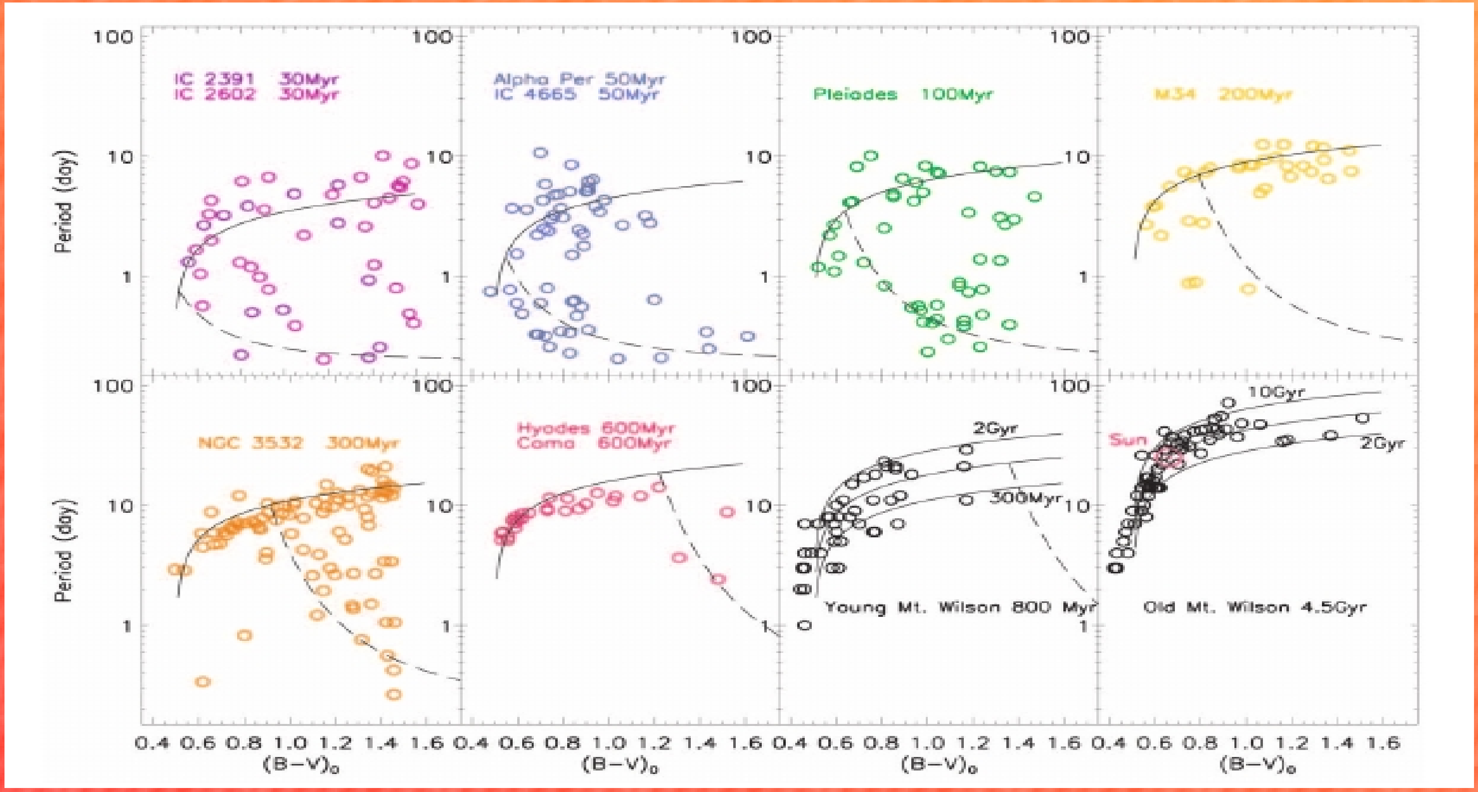
How can we use these periods?

Gyrochronology: Infer stellar ages from rotation periods & color (mass)!

- Stars spin down due to stellar winds (rotational braking)

  → color-period & color-age dependence

S. Barnes (2003, 2007)

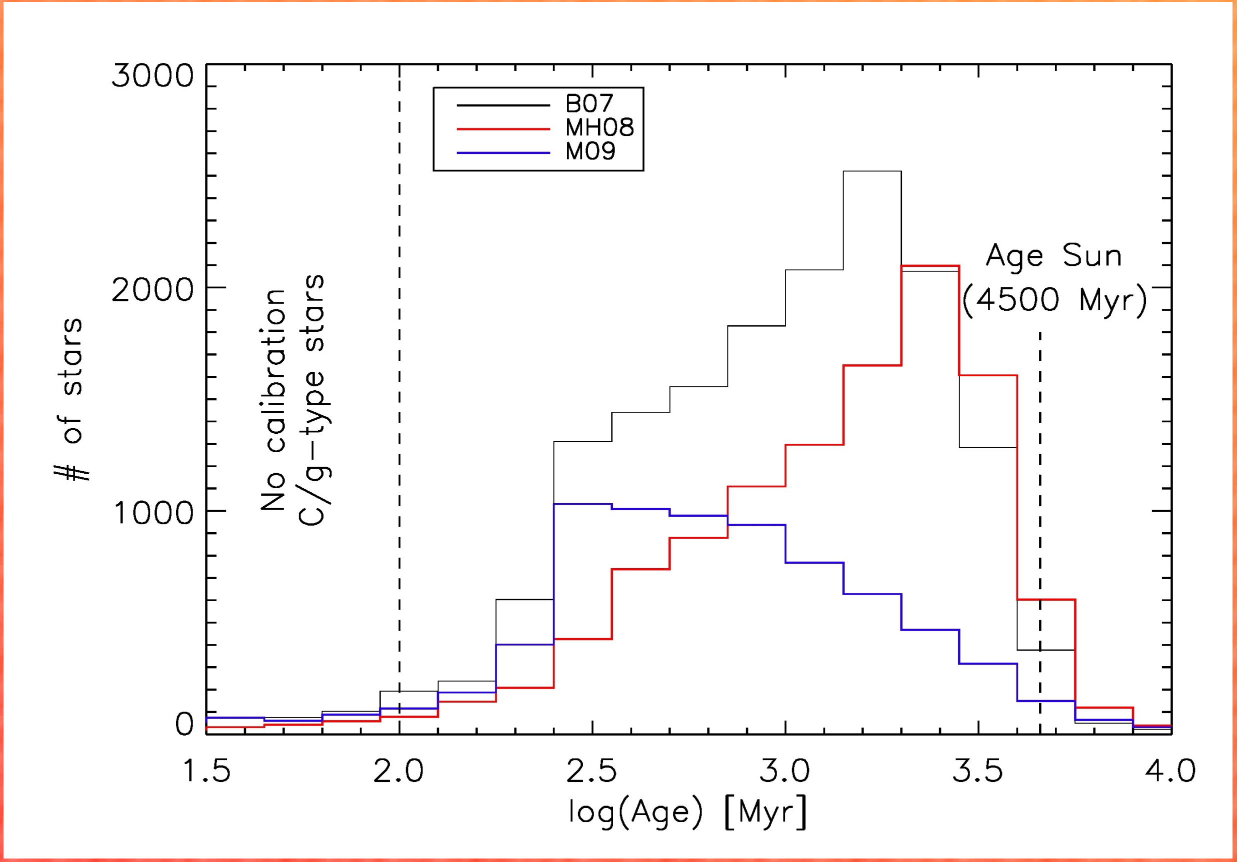


Problems...

- Calibration mostly for young FGK stars
- Old stars: The Sun (age known); ages for Mount Wilson stars from activity-age relations
- Error sources:
  - Different color & period ranges used for calibration
  - Differential rotation $\rightarrow P \pm \Delta P$
  - Stars are born with initial range of rotation periods P_0
  - Kepler: No B-V colors (g-r colors used instead)

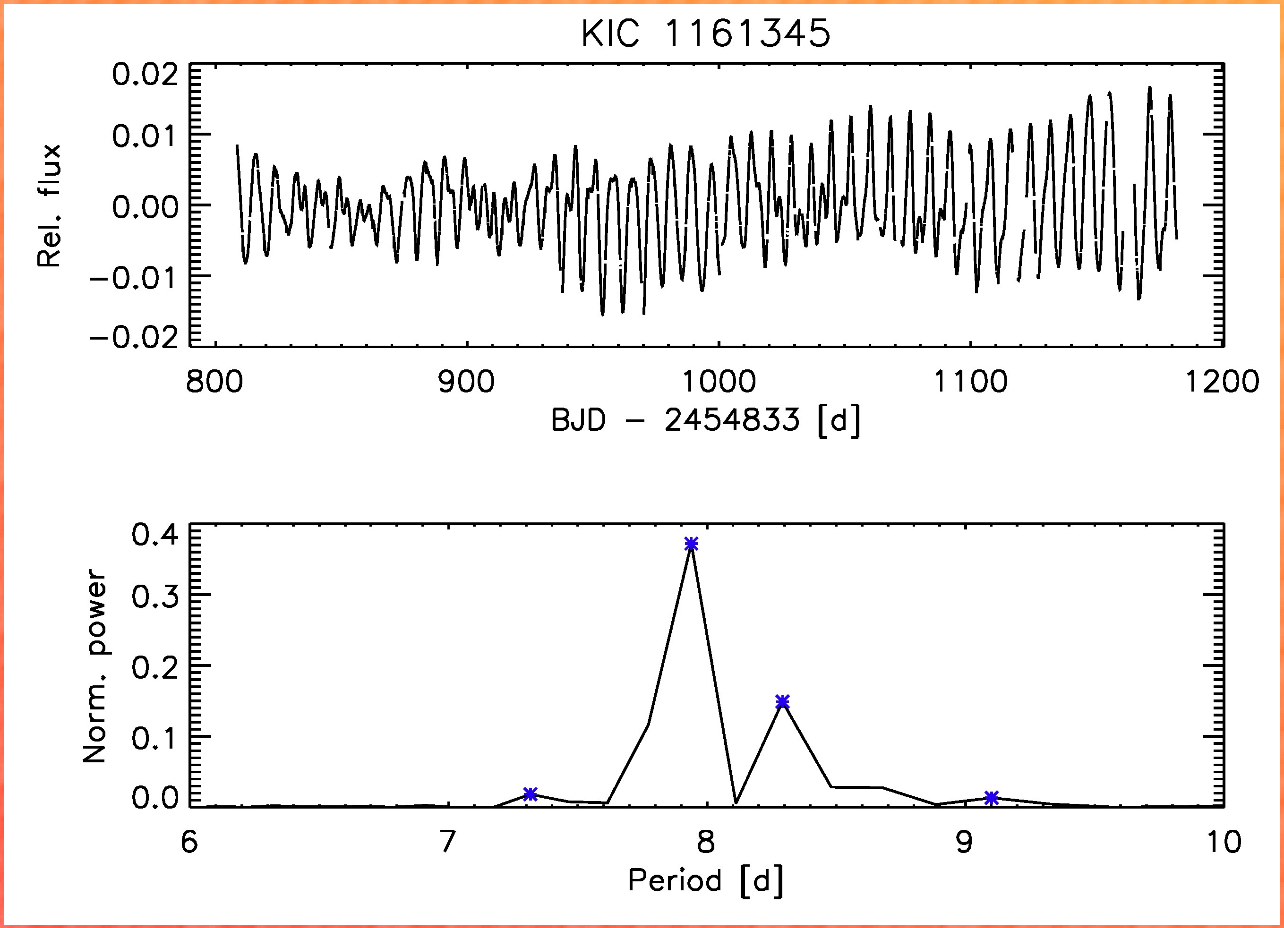
Gyro ages

- Sample of ~16,000 stellar rotation periods
- Different relations: Only valid for certain color & period range → stars missing!

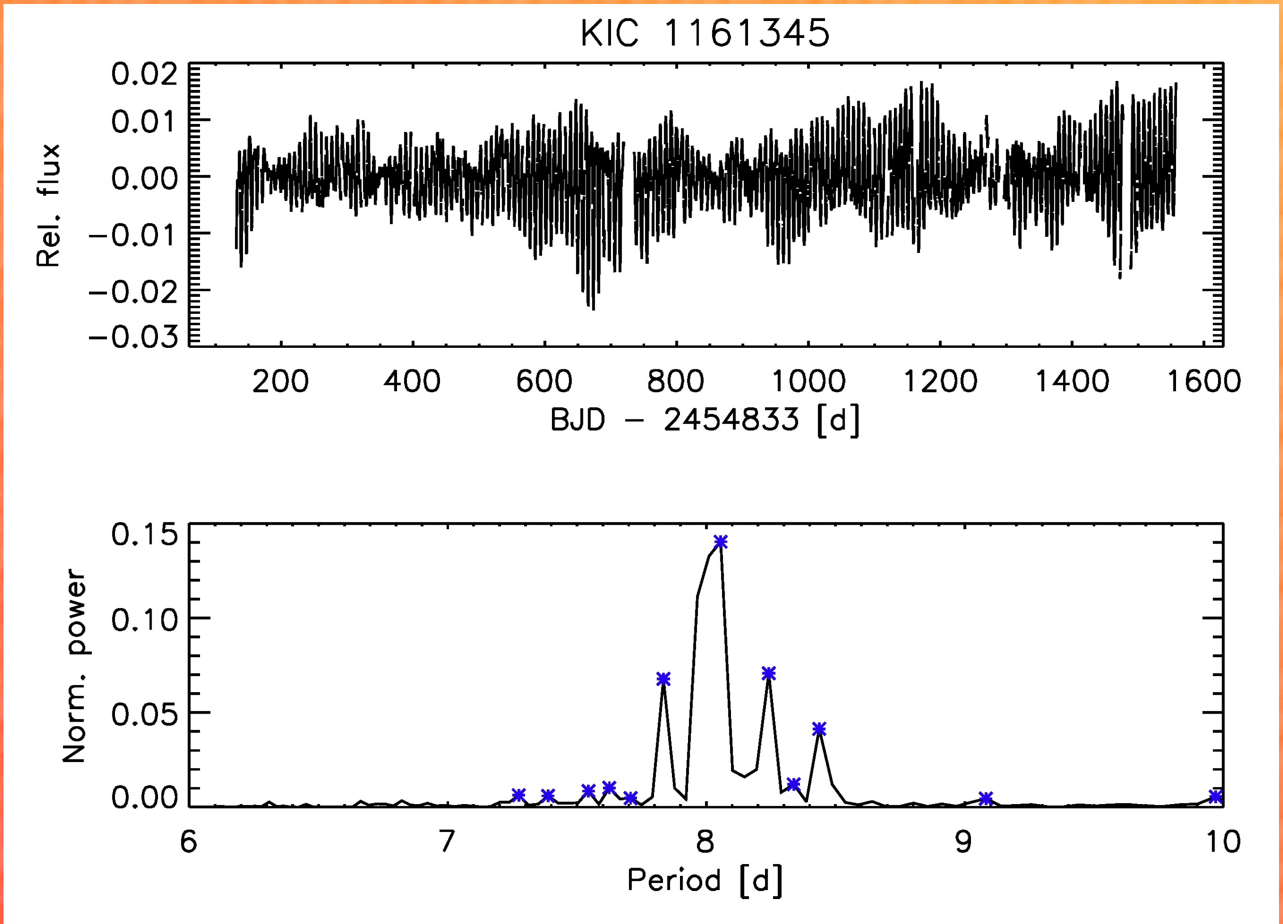


Differential rotation

Measure differential rotation with Lomb-Scargle periodogram

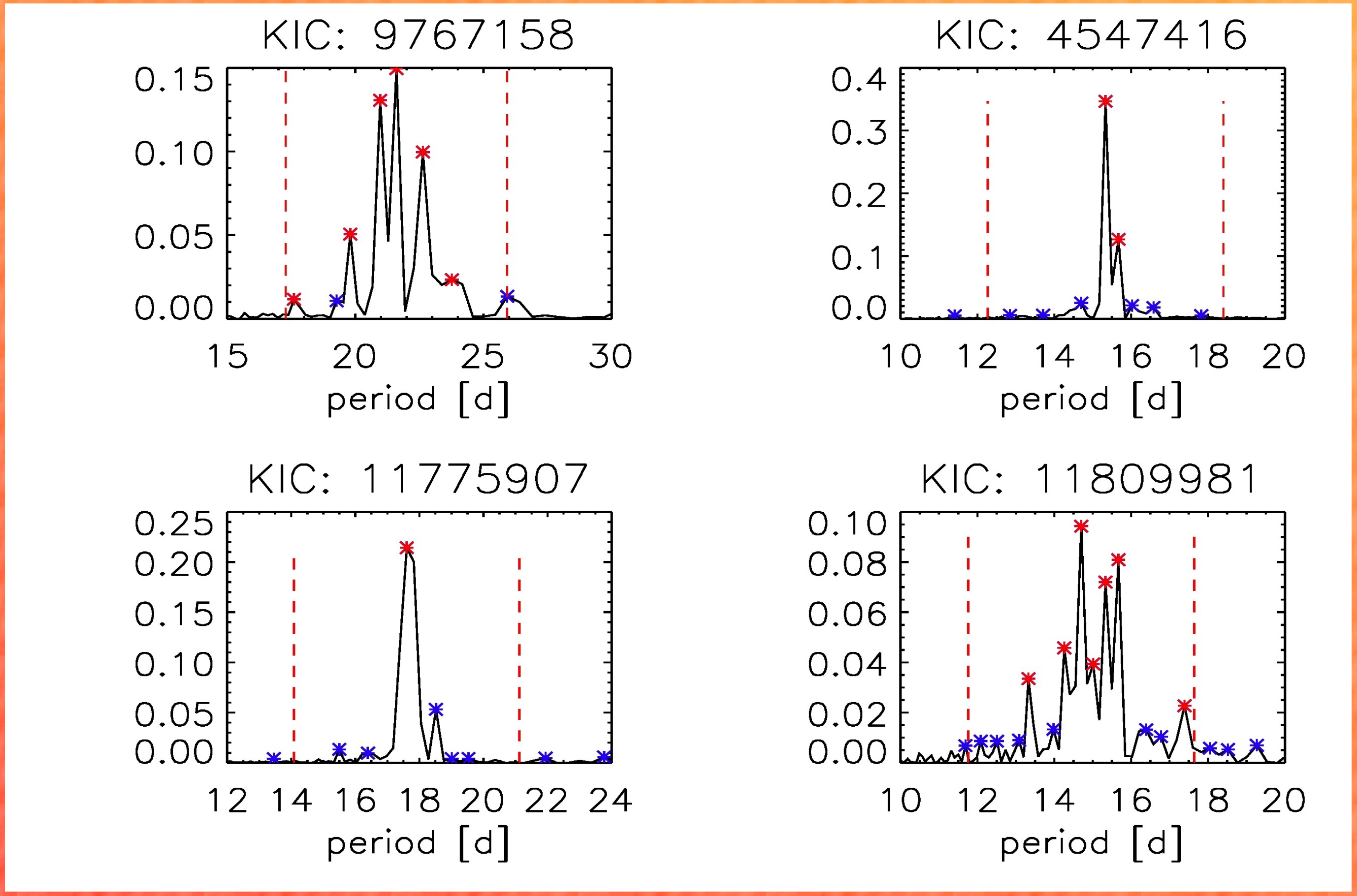


Difficult: Same star but full lightcurve...



→ More than one period due to differential rotation, spot evolution, ...

Significant peaks?



→ Differential rotation or spot evolution?

Conclusions

- Activity: Relations between chromospheric activity, stellar age, and rotation period well established

  → Kepler: no direct relation between amplitude and period (or age)

- Rotation: (Mean) rotation periods well known for thousands of stars!

- Ages: Gyrochronology provides reliable ages for young-mid age field stars

  → Problem: old stars (age > 2 Gyr)

- Differential Rotation: Difficult to distinguish from spot evolution; additional periods induce errors in gyro ages!