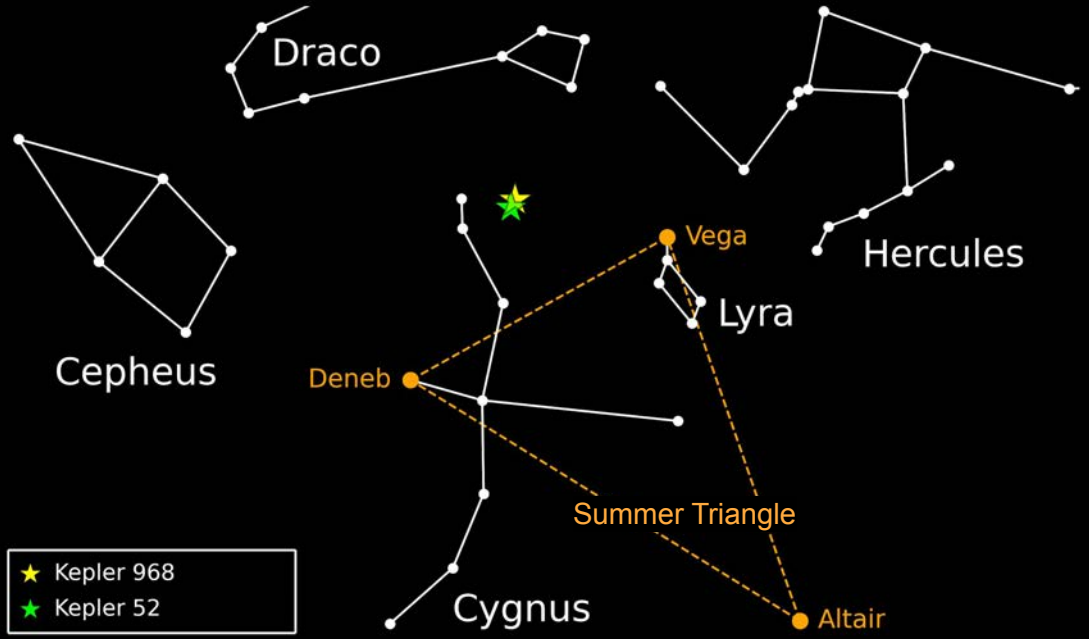
How Two Old and Unrelated Exoplanetary Systems Turned Out to Be 400-Million-Year-Old Siblings



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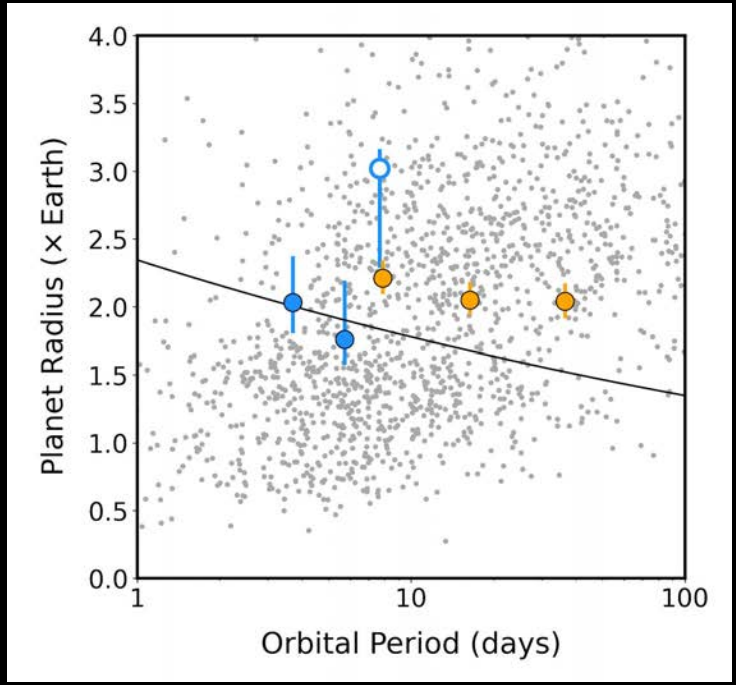
Kepler 52 and Kepler 968: two stars, six planets*

- Already known to harbor three exoplanets each
  - All about twice the size of Earth
  - All orbit their stars between 4 and 36 days
- Kepler 52 and Kepler 968 are K dwarf stars
  - Masses and radii ~ 60-70% of the Sun
  - Luminosity ~10-15% of the Sun
- Planet properties (e.g., sizes) evolve over first billion years. Why? We need precise ages to see.

How old are these planets?



Gray points: CKS planets (Petigura et al. 2020)
Kepler 52 b, c, d
Kepler 968 b-c, KOI 1833.02

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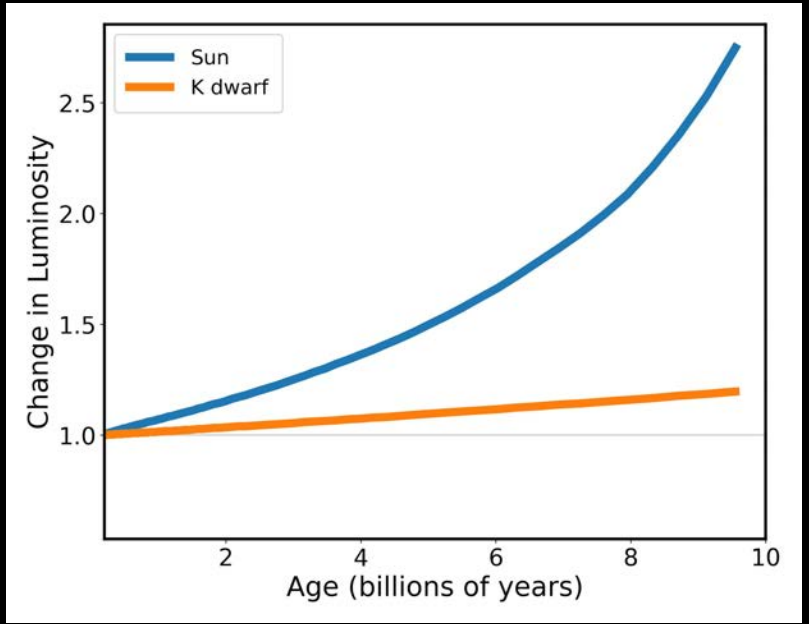
K dwarfs evolve too gradually for traditional age-dating

- They evolve too gradually for traditional age-dating
  - Latest calculation using *Gaia* places them at 3-16 billion years (Berger et al. 2020).
- This affects 20%, up to 50%, of *Kepler* exoplanets
- Problem is exacerbated for young stars and planets
  - <1 billion years
- What can we do?
  - Associate stars with their birth clusters



Models are from PARSEC (Bressan et al. 2012) with solar composition, and are shown relative to the luminosity at 200 million years

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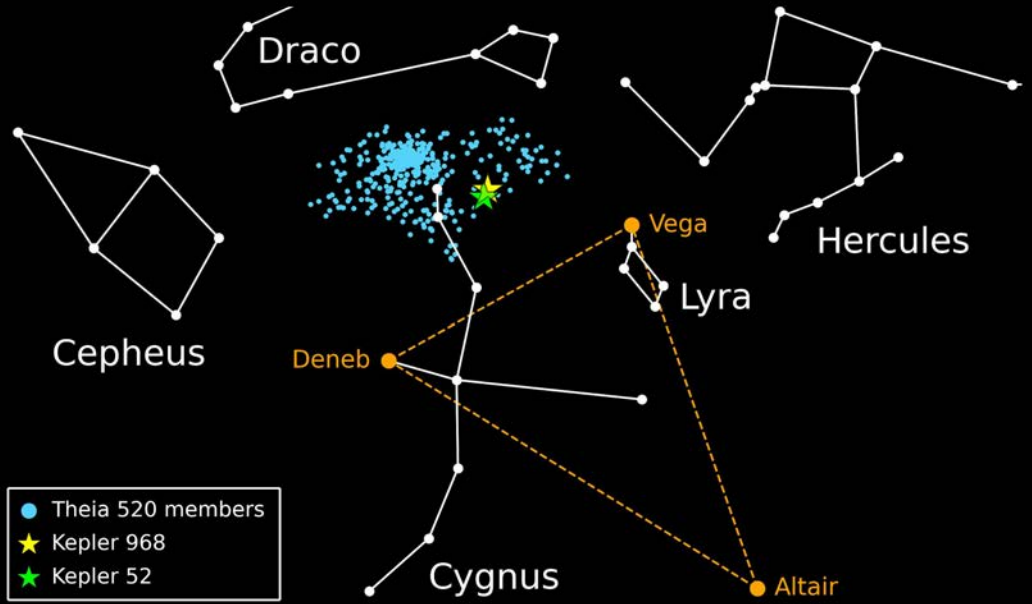
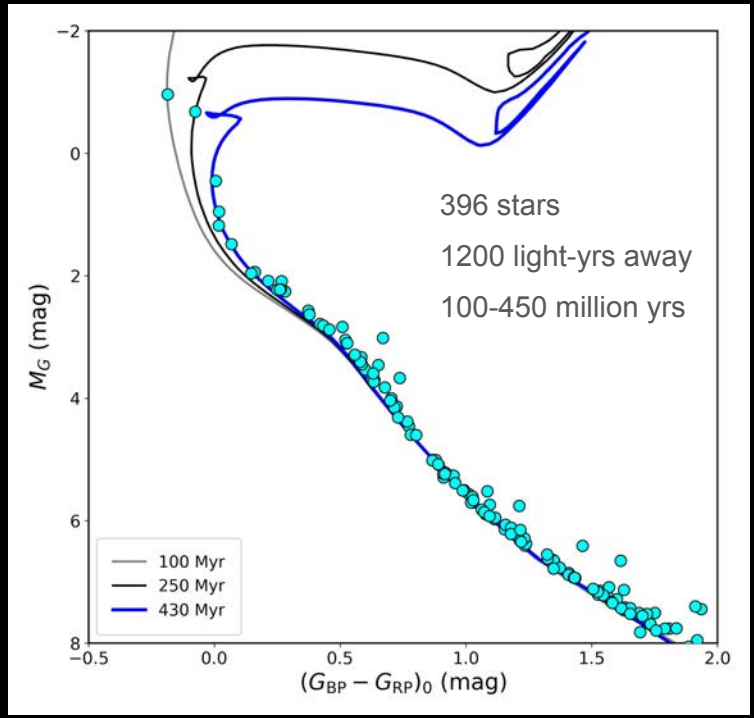
Kepler 52 and Kepler 968 are members of the newly discovered group, Theia 520

Is Theia 520 a real cluster?





(bright) Luminosity (faint)

(hot) Surface temperature (cool)

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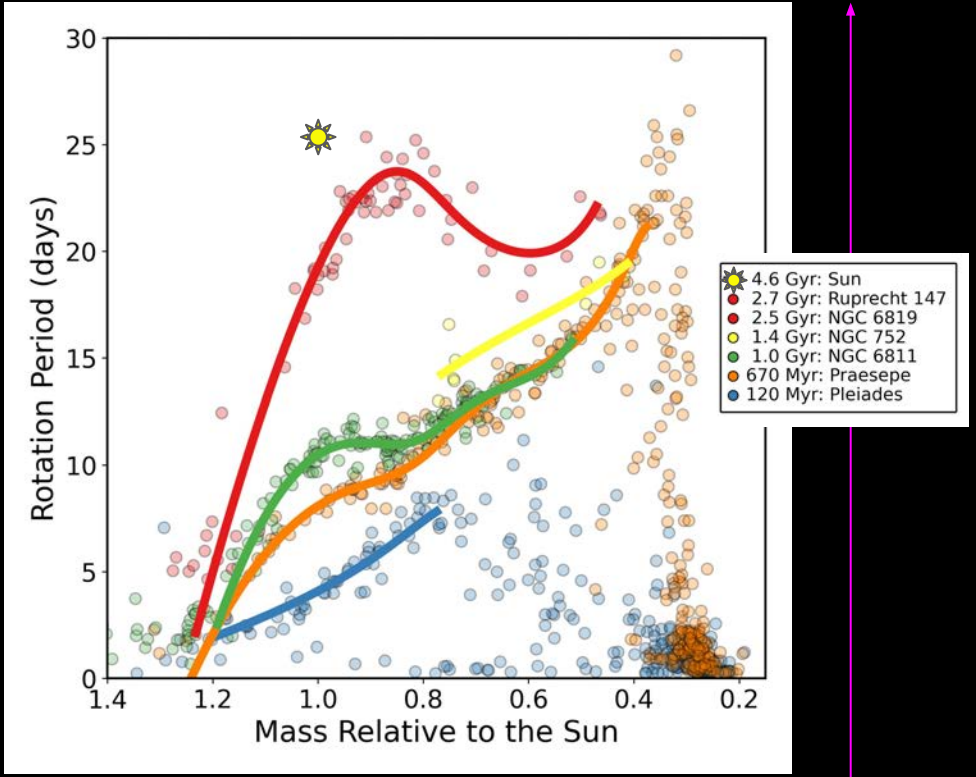
Telling Time with Spinning Stars



Age

Star clusters older than
100 million years
trace out tight sequences in
mass versus *rotation*

As the stars slow down over time,
the sequences move upward in
this diagram

What about Theia 520?

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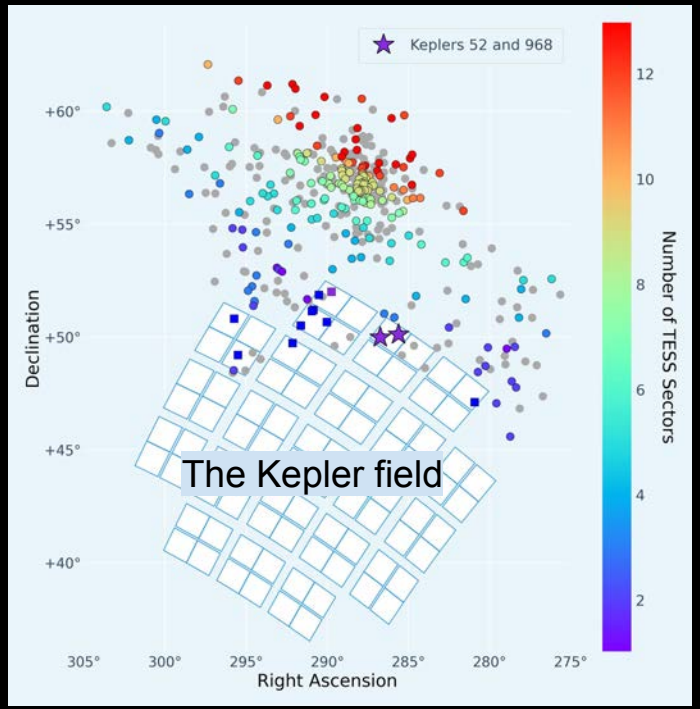
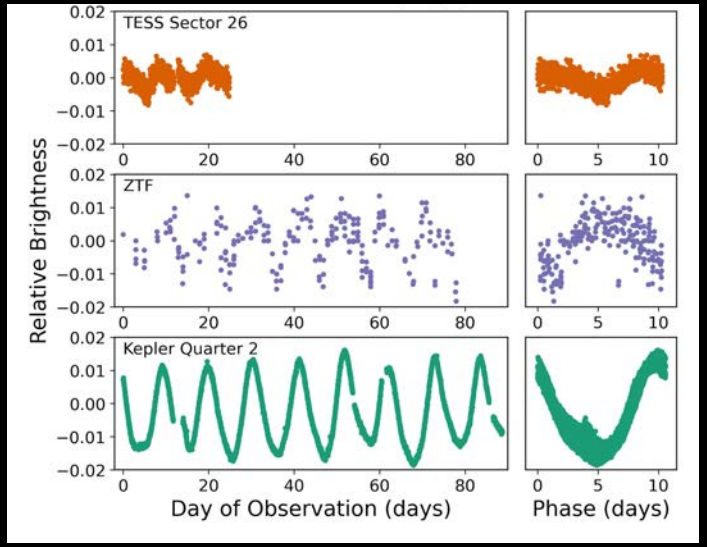
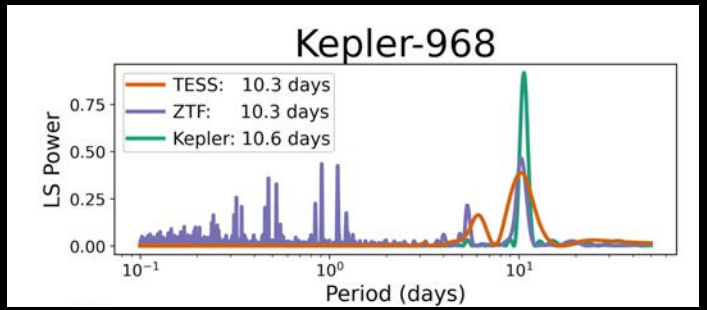
Adapted from Curtis et al. (2020)

Measuring how fast stars spin from space and California







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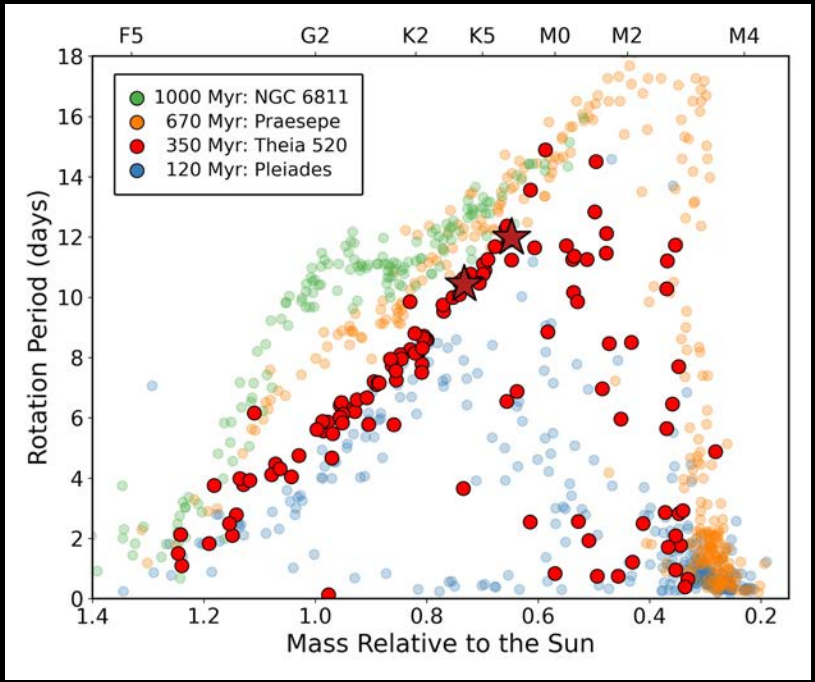
Theia 520 is real and it is 350 million years old



- Measured periods for 130 stars
- Tight sequence proves stars are same age
- Periods for Kepler 52 and Kepler 968 support their membership and youth
- Rotation age is 350 ± 50 million years, from comparison with benchmark clusters

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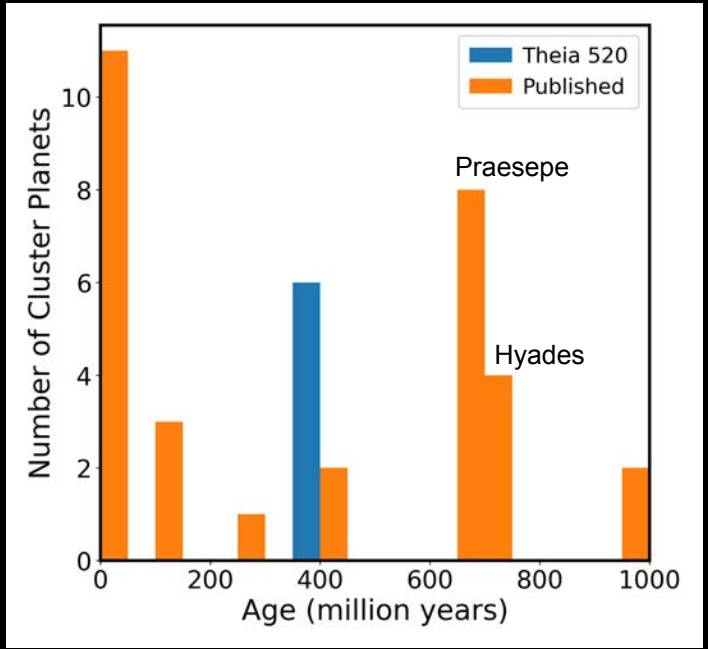
Six young exoplanets join the small, growing list of cluster planets



- 29 transiting exoplanets in clusters <1 billion years are published so far
- Theia 520 adds 6 to the list
- Doubles the sample between 100-500 million years

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Astrometry & Photometry

All data were already available online!

Time Series Imaging

Spectroscopy

Conclusions and Looking Forward

- Theia 520 is about 400 million years old
  - 130 rotation periods measured from TESS, ZTF, and Kepler
  - Tight slowly rotating sequence confirms Theia 520 is a real cluster
  - 350 Myr determined by rotation comparison with benchmark clusters
  - 430 Myr from the Hertzsprung-Russell Diagram
- Kepler 52 and Kepler 968 add 6 planets to the list of 29 young cluster planets (<1 Gyr)
  - Kepler 52 has three validated planets
  - Kepler 968 has two validated planets and one candidate planet
- All data required were already available online!
  - Gaia, Kepler, TESS, ZTF, Keck, LAMOST, APOGEE
- Just the beginning
  - Thousands of other groups newly identified with *Gaia*
  - Stellar rotation can confirm their common origin and constrain the ages of these groups

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