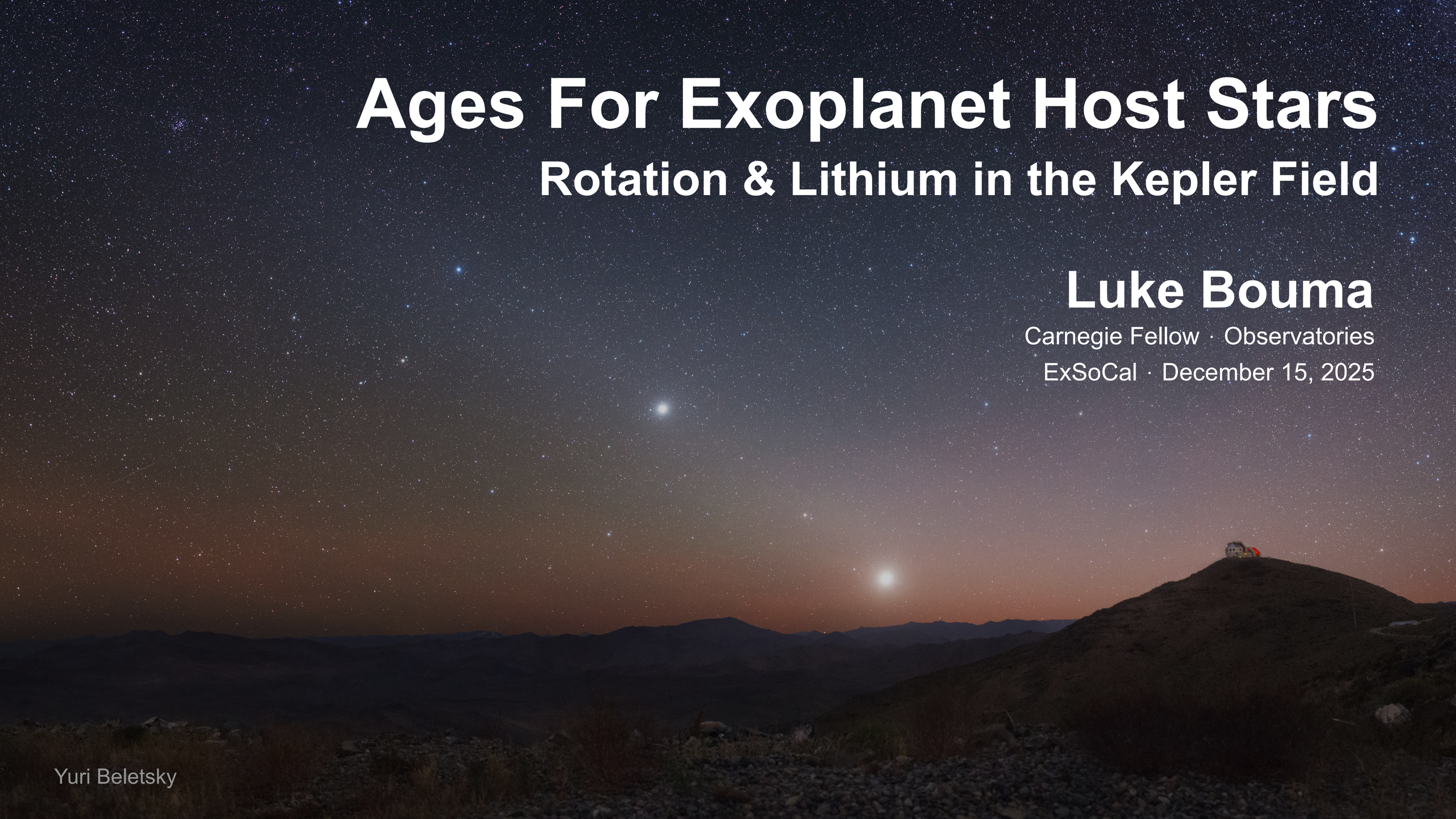
Ages For Exoplanet Host Stars

Rotation & Lithium in the Kepler Field

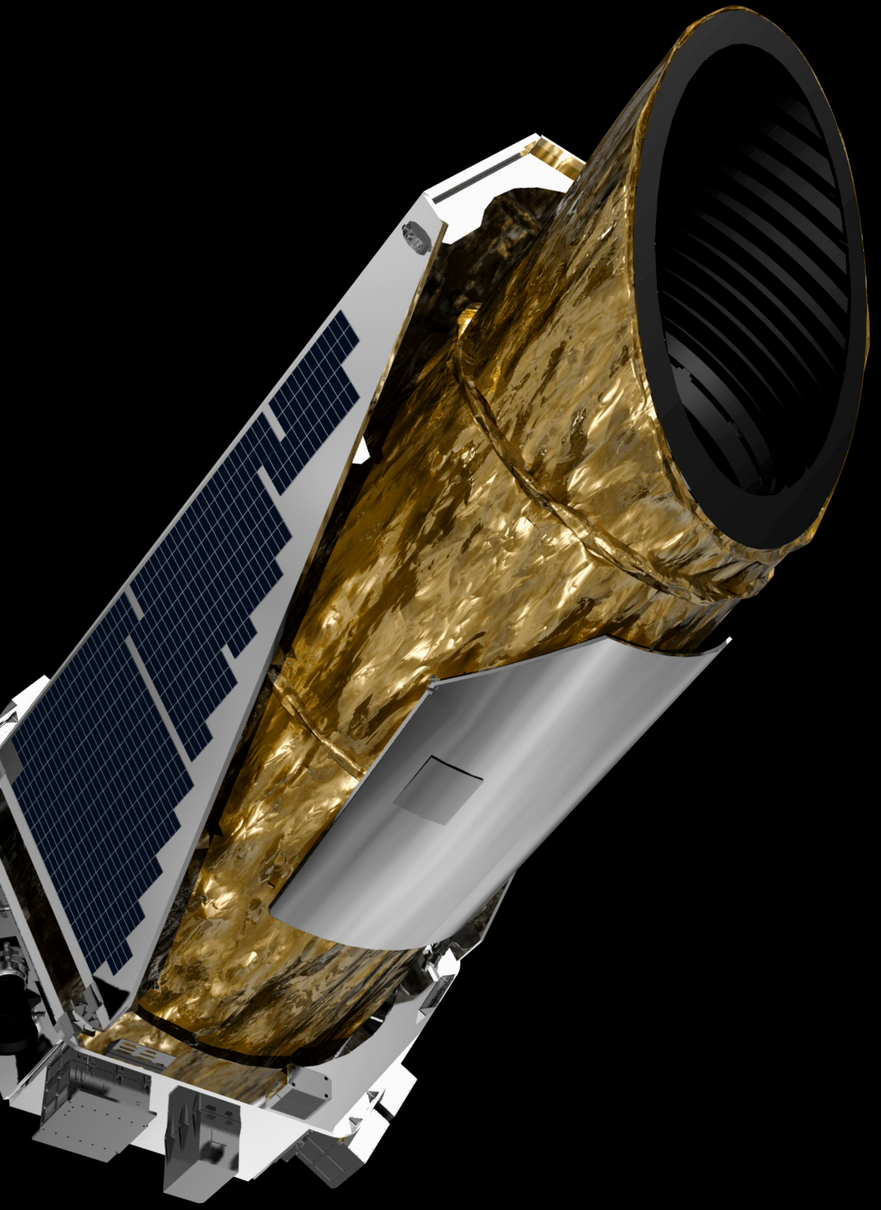
Luke Bouma

Carnegie Fellow · Observatories

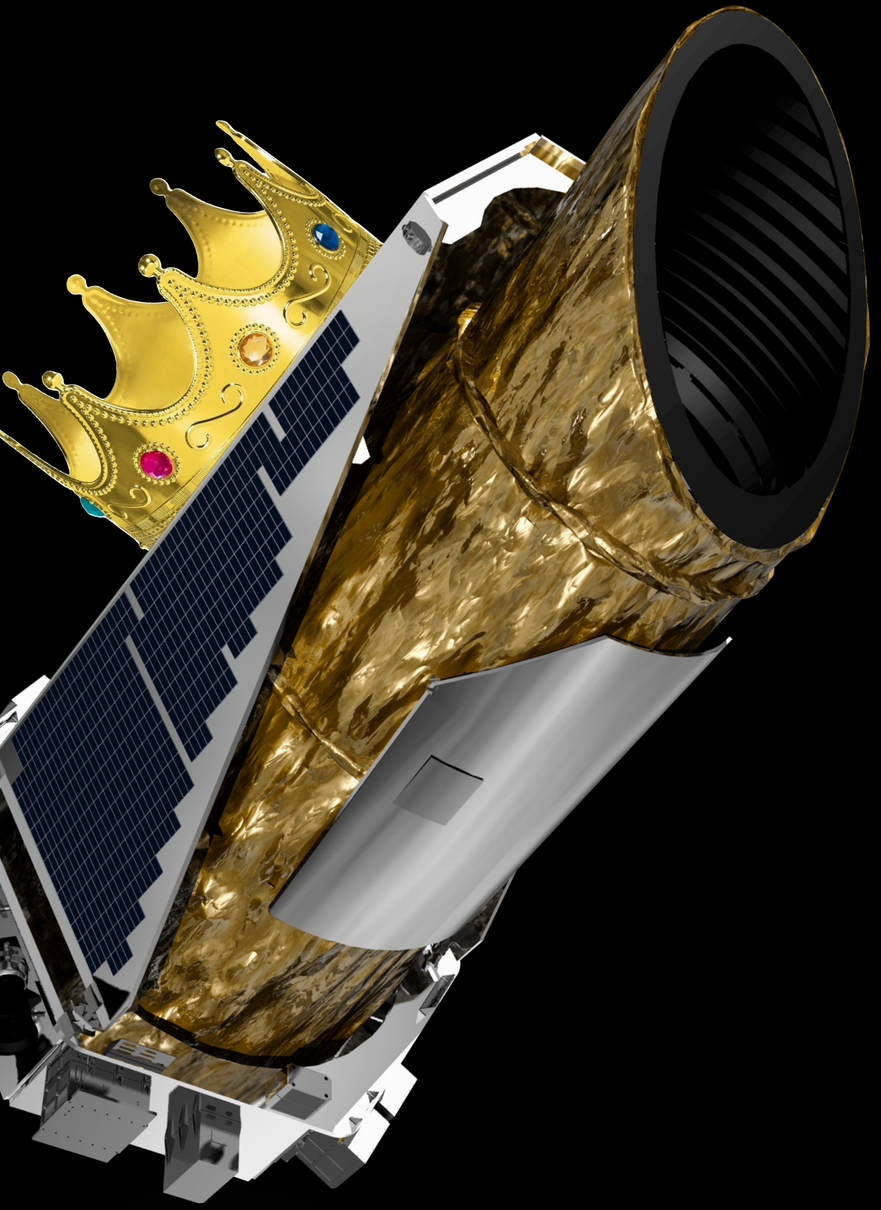
ExSoCal · December 15, 2025



Yuri Beletsky



NASA, NASA Exoplanet Archive
NASA/Tim Pyle



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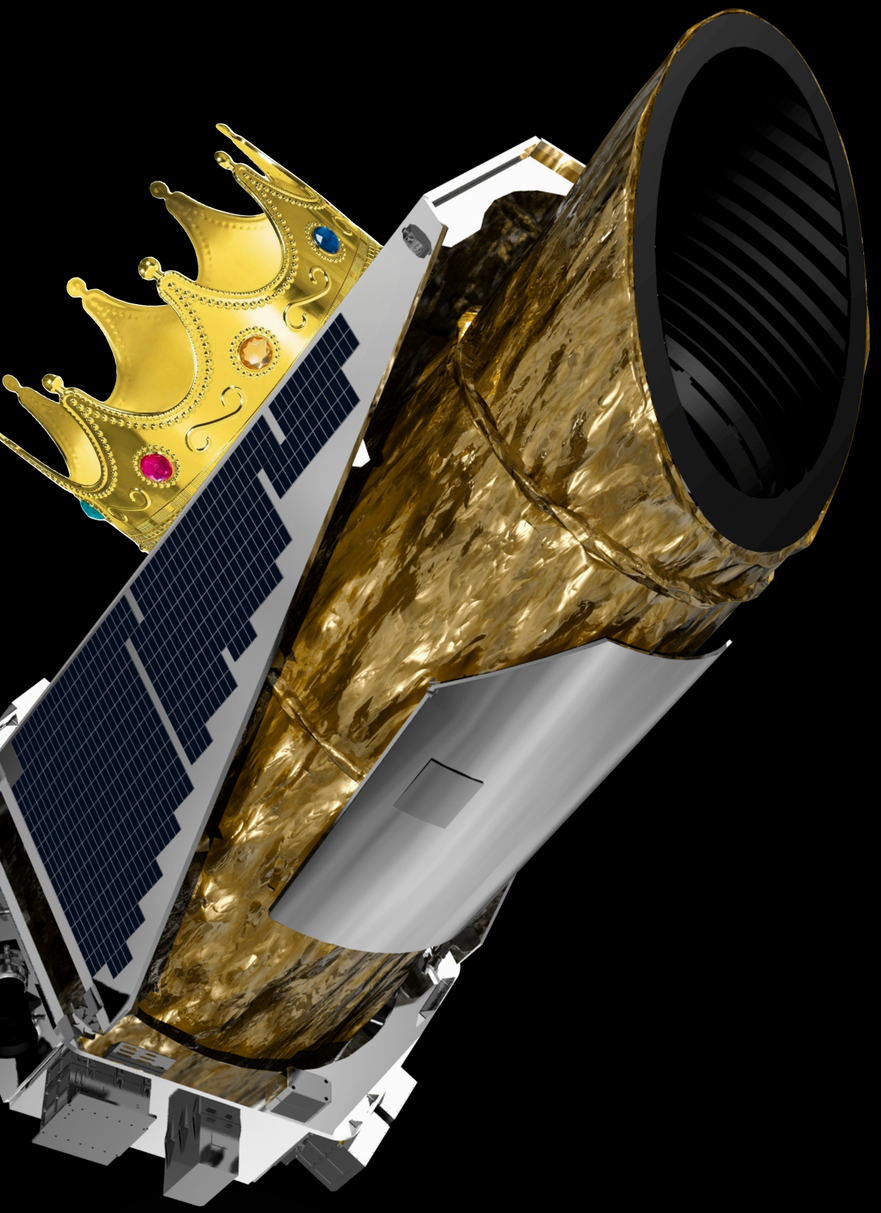
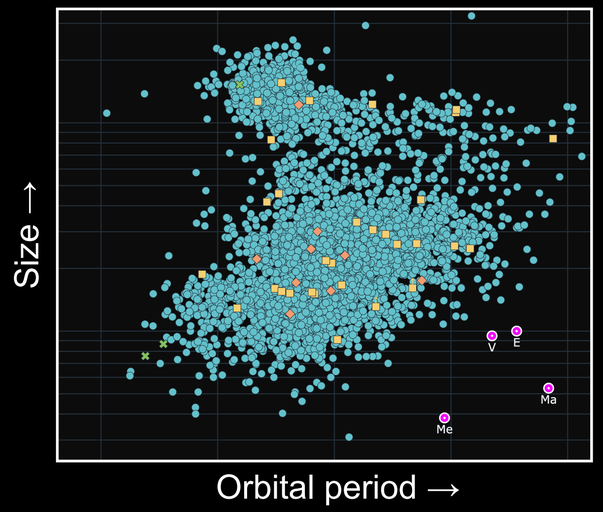


Most exoplanets



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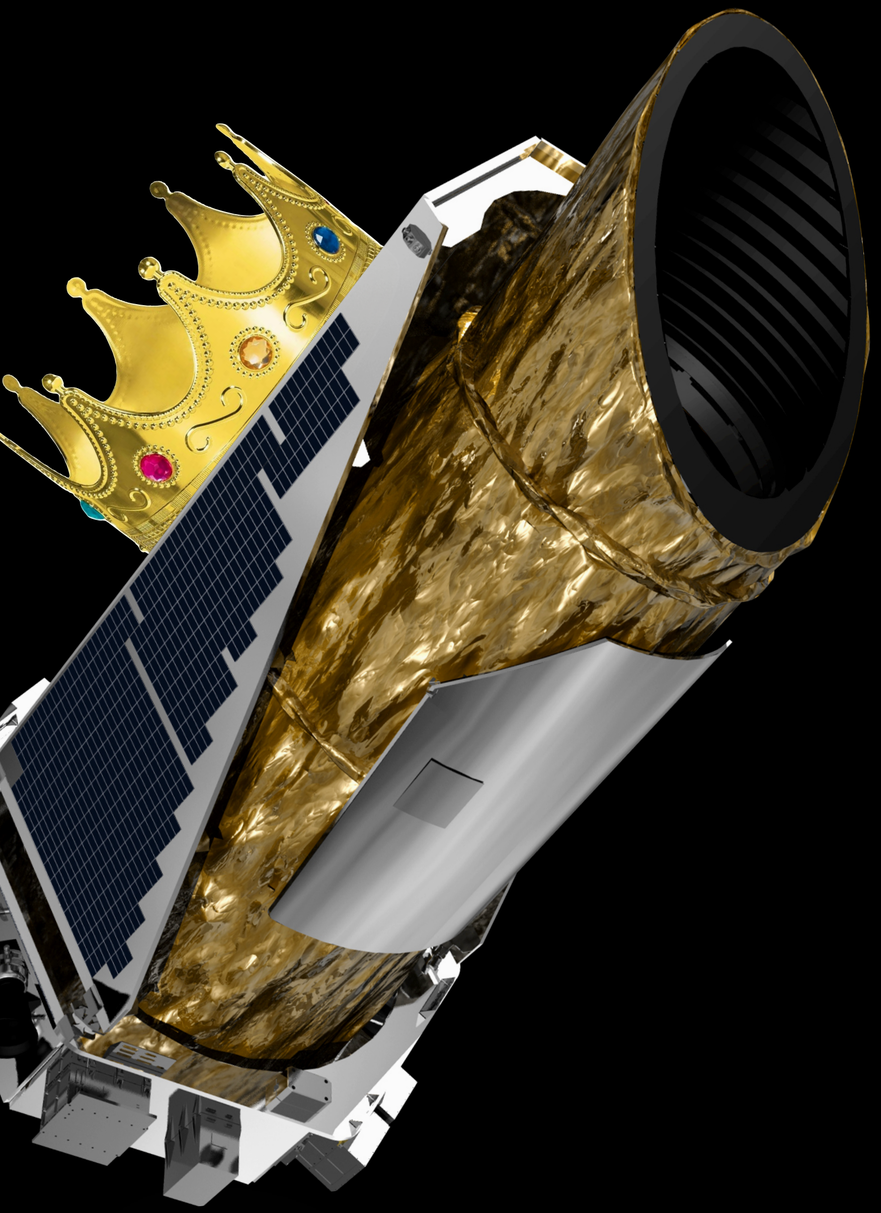

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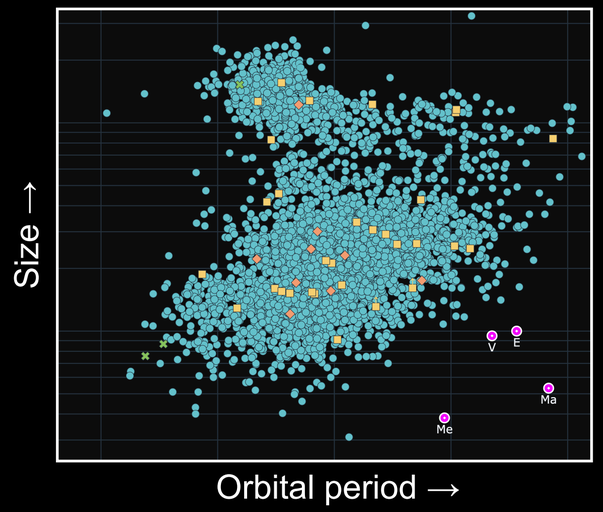
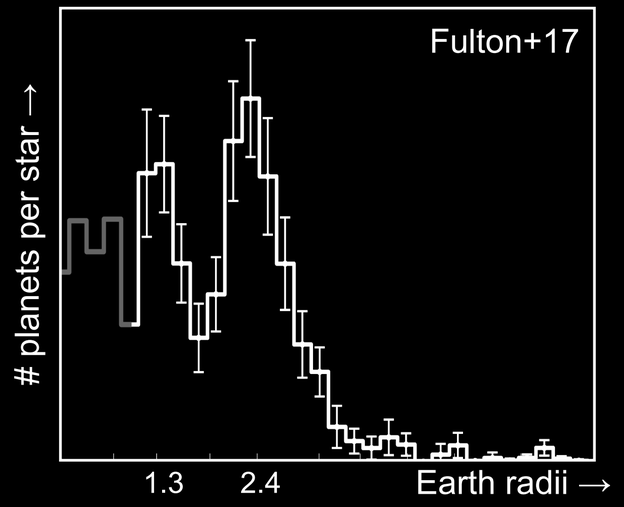


Radius valley



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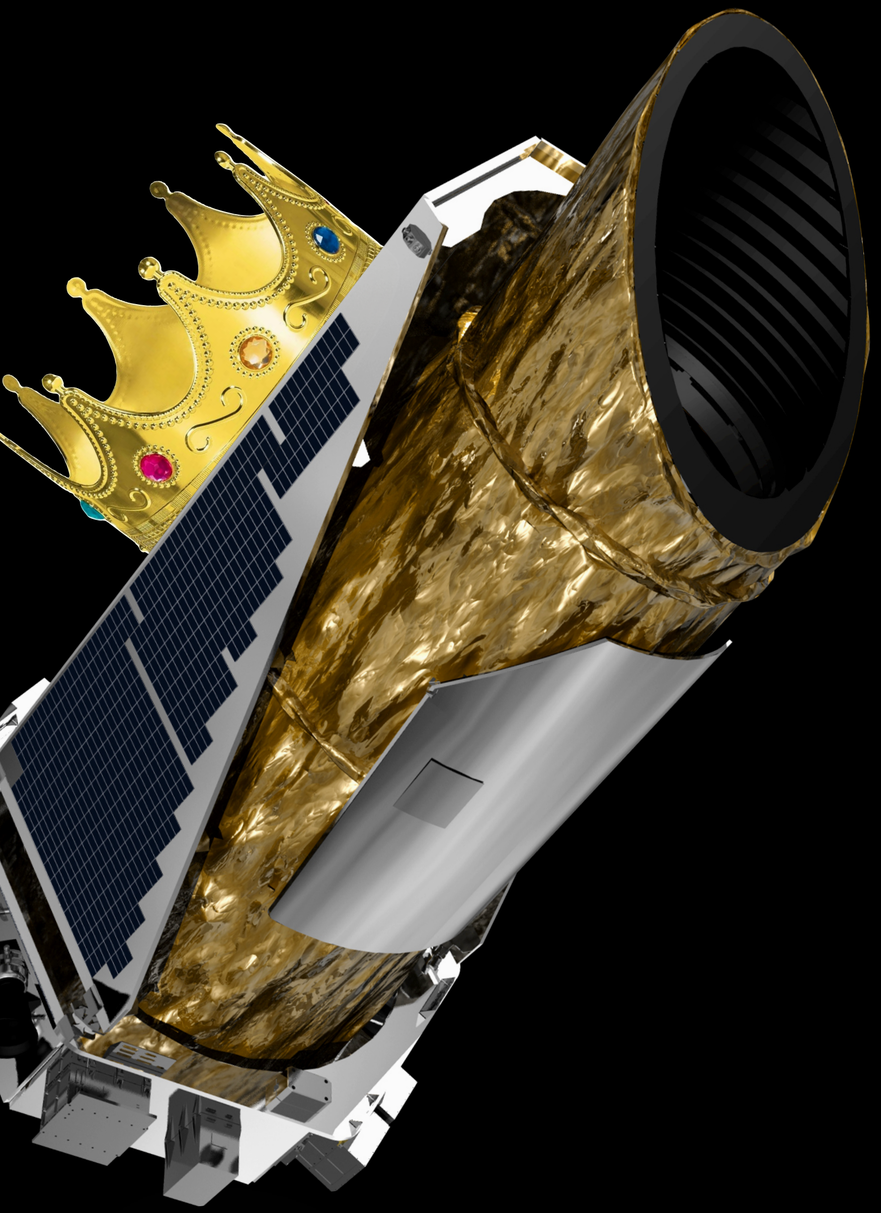

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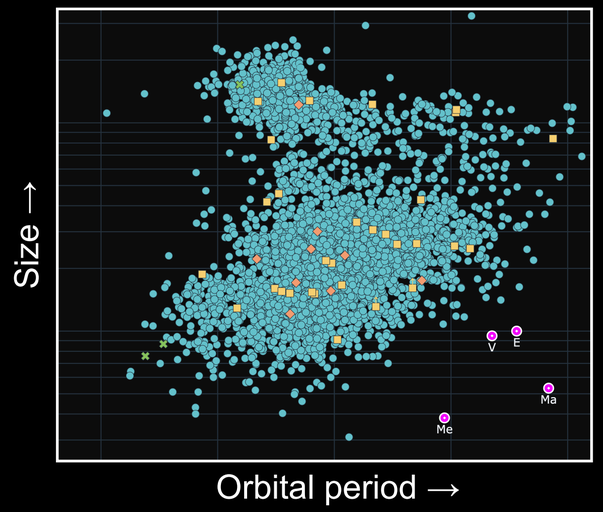

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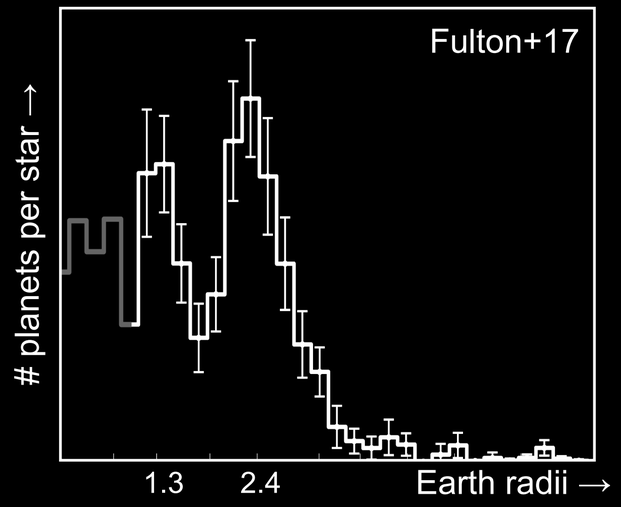
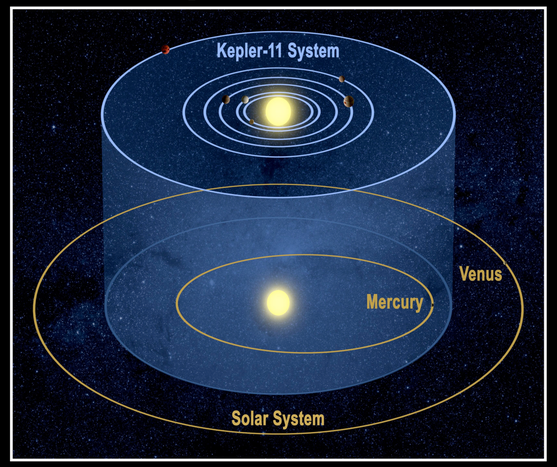
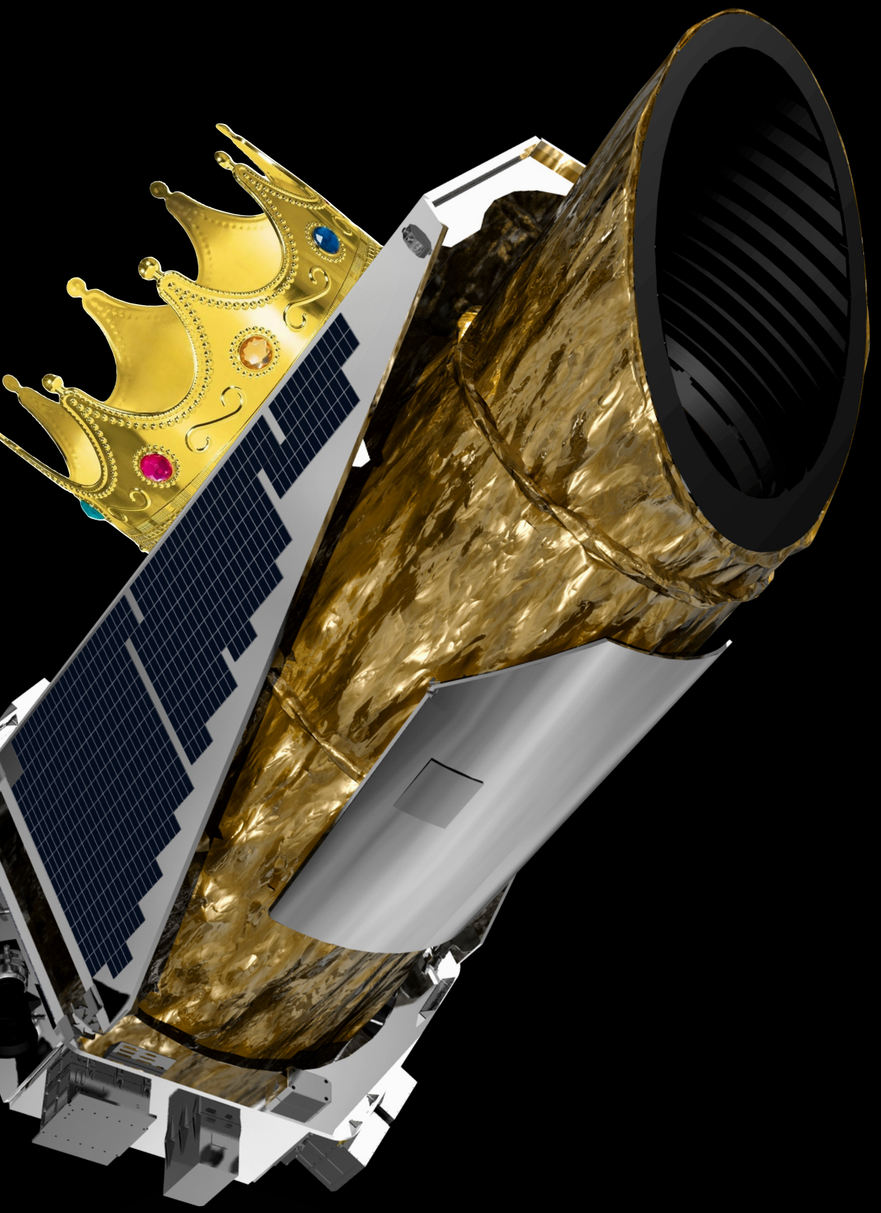


Compact multis





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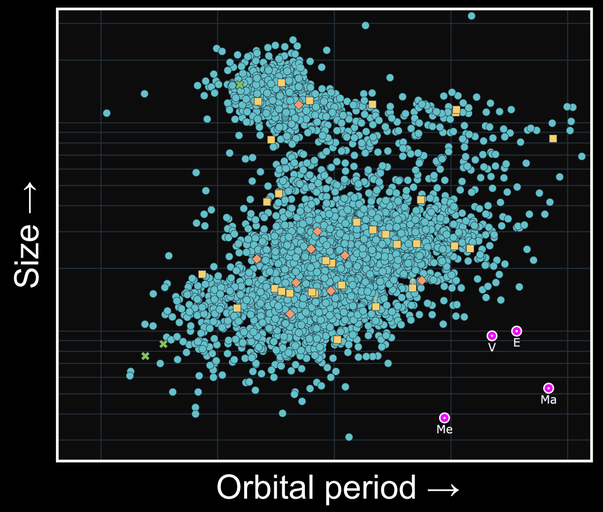

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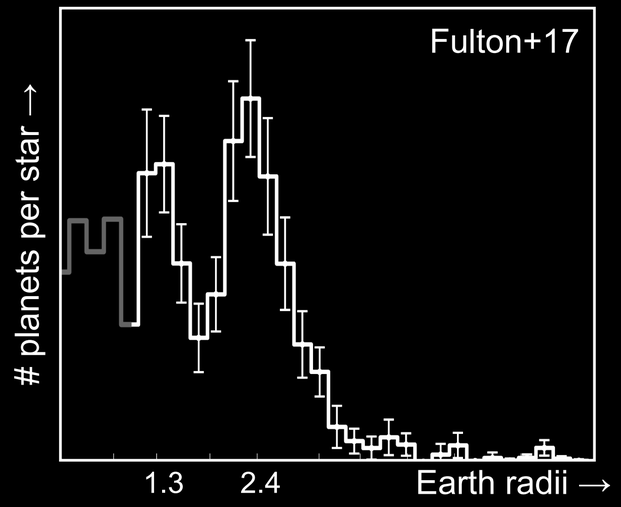

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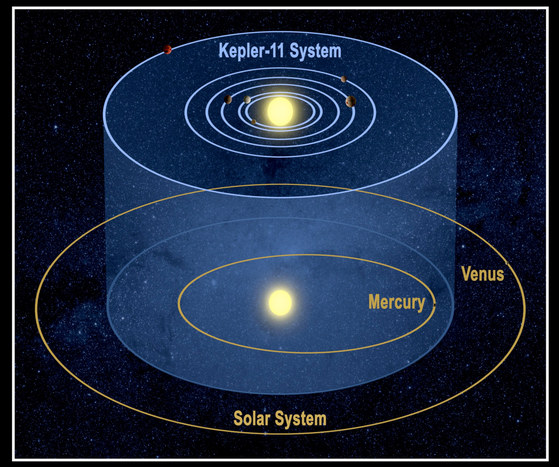

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Where are Kepler’s missing young planets?

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5,000 planets. t/Gyr ~ U[0,10]

Age distribution:
Binney+00, Nordstrom+04

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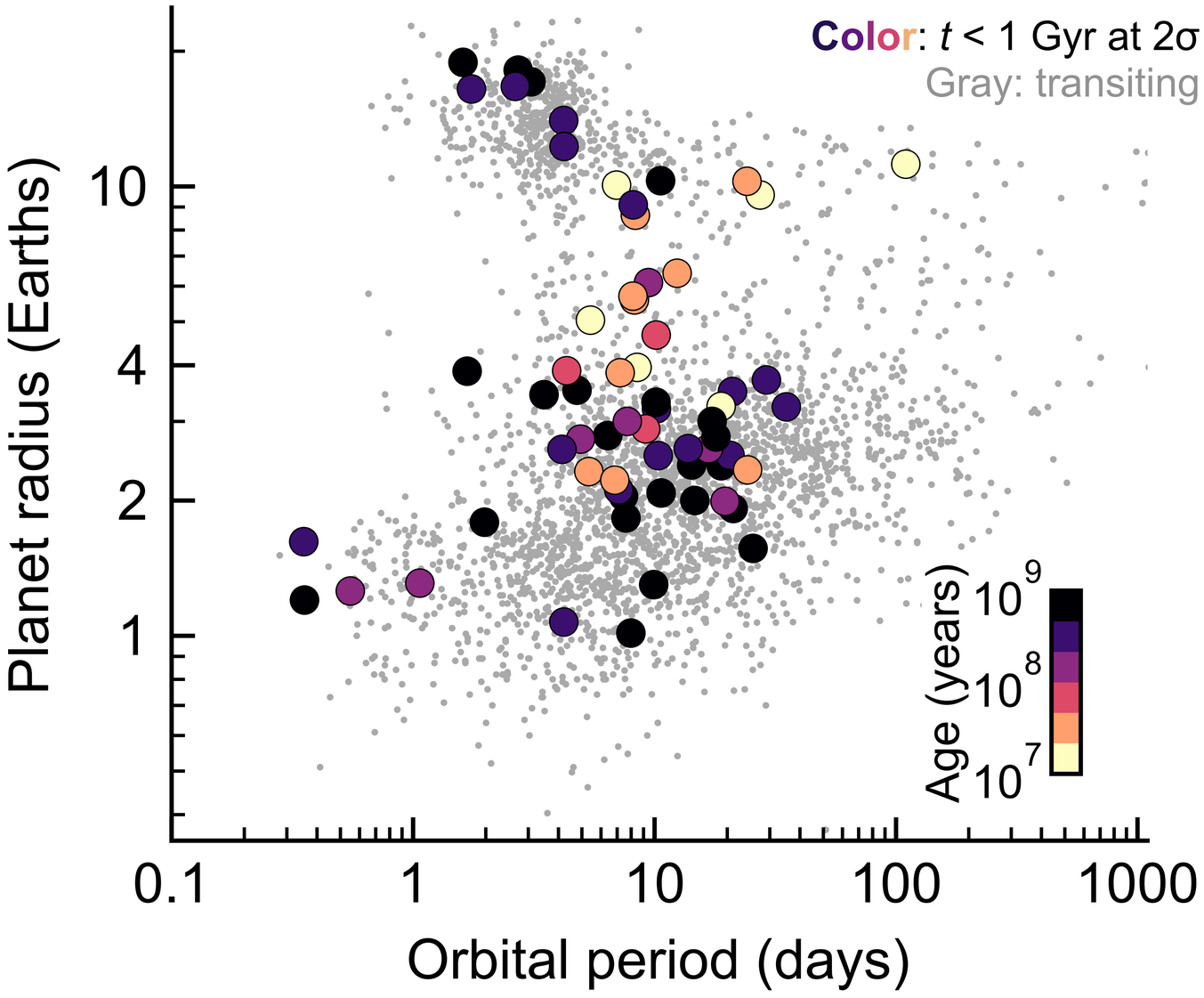
Where are Kepler's missing young planets?

5,000 planets. t/Gyr ~ U[0,10] ⇒ Expect 500 sub-gigayear planets. 50 observed!



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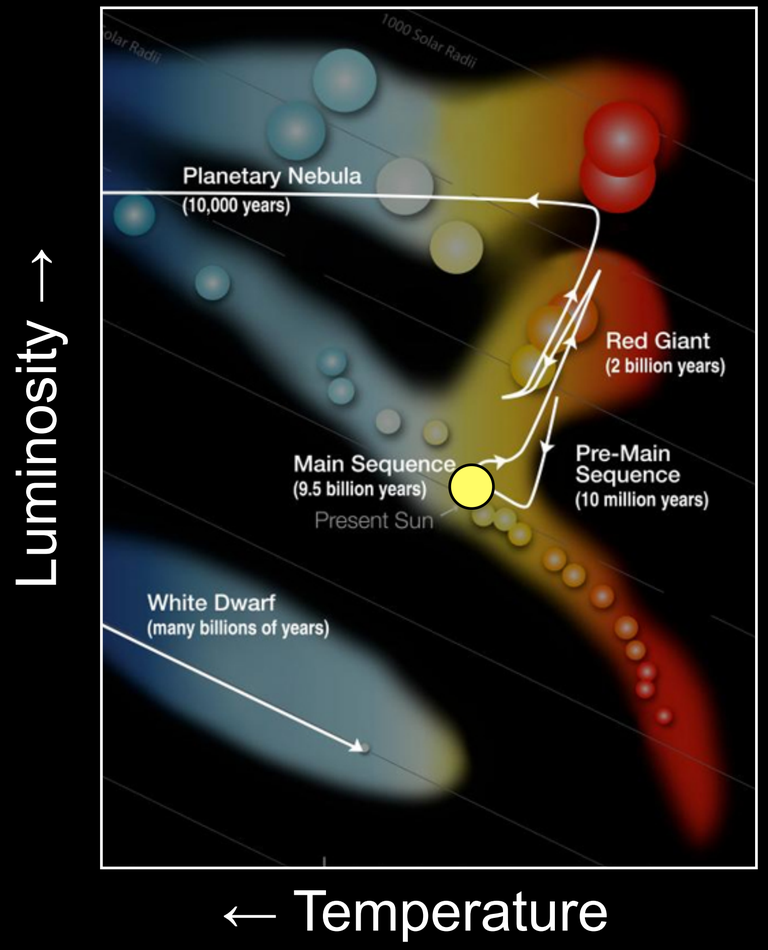
LGB from
NASA Exoplanet Archive

Sun-like stars spend gigayears on main seq.



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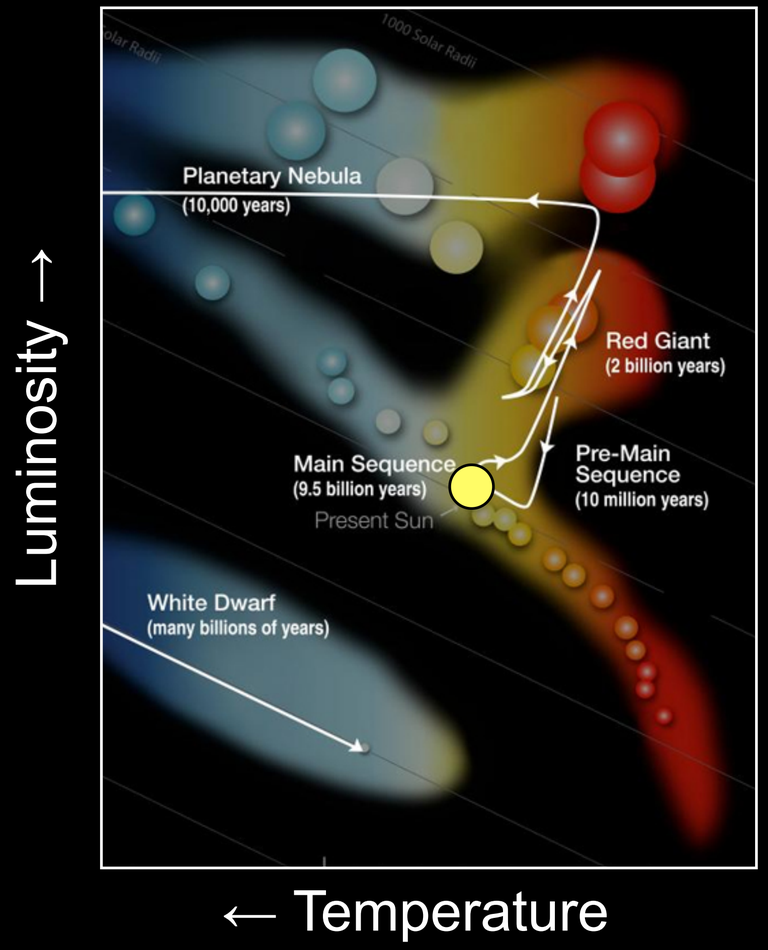
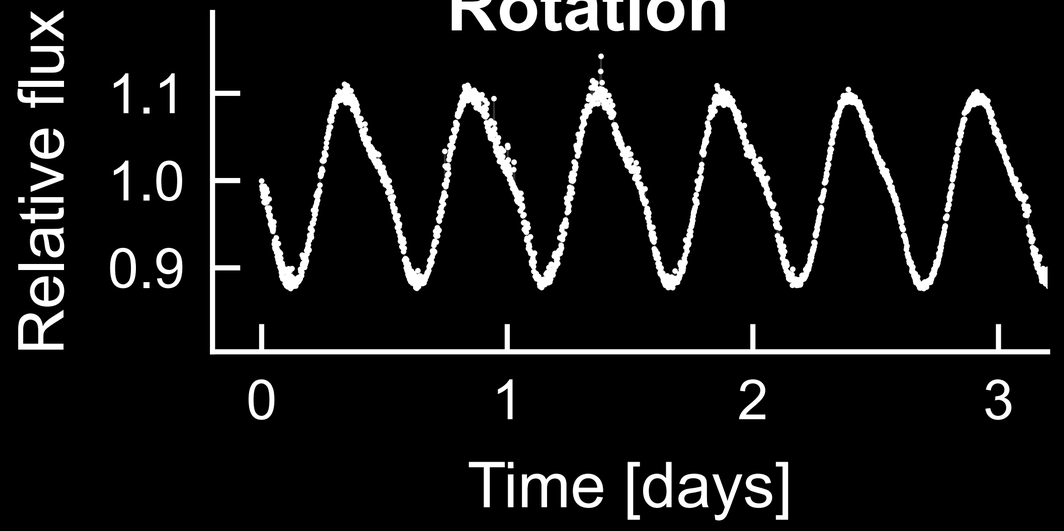


Rotation



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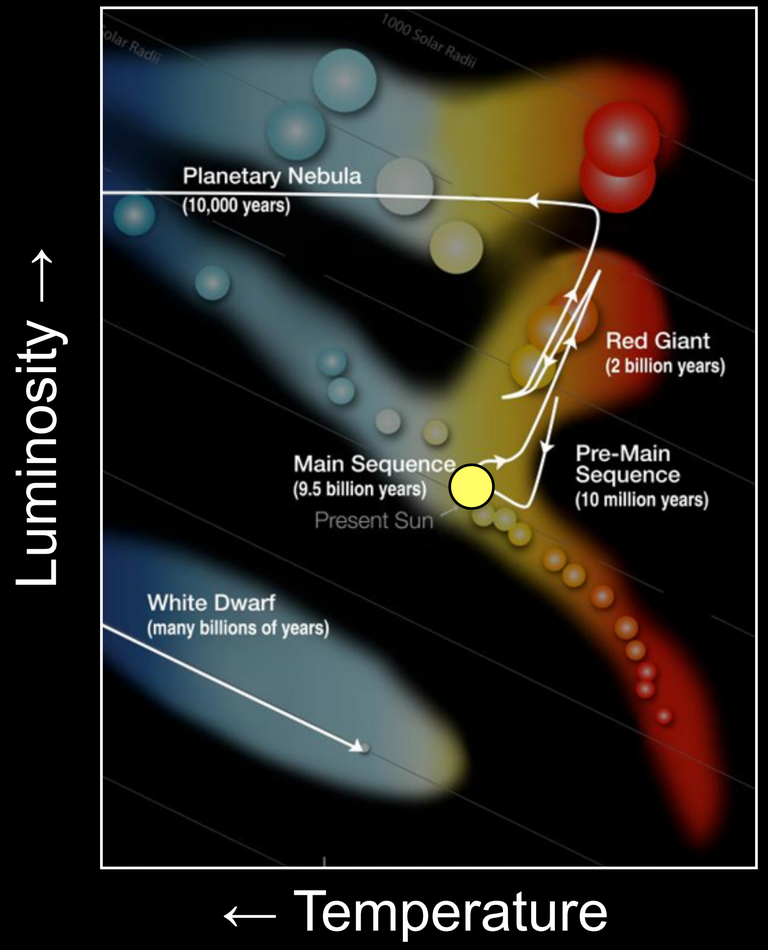

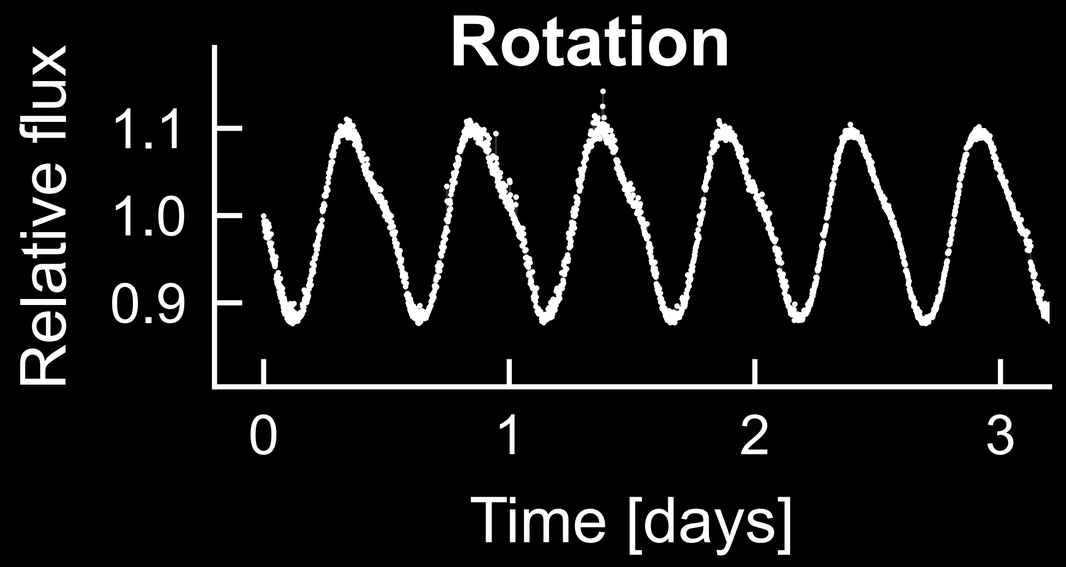

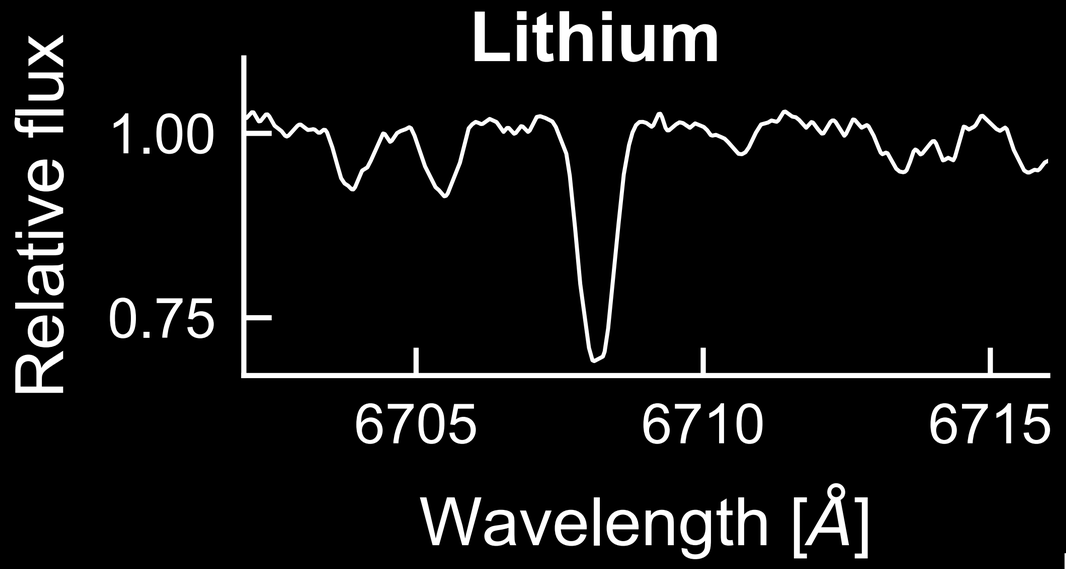

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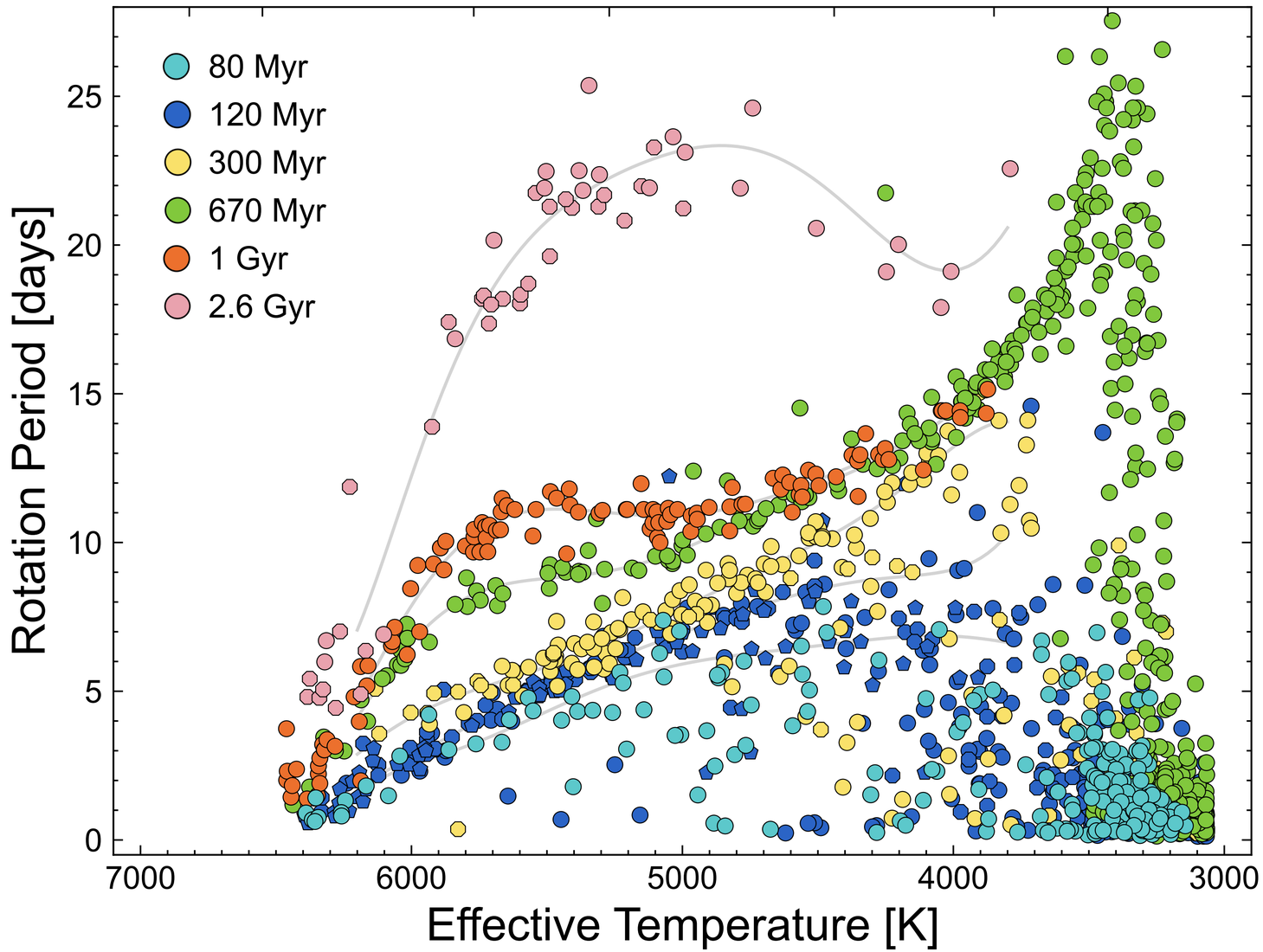
Stellar ages: open clusters anchor rotational ages for field stars



α Per: Boyle & Bouma 23, Pleiades: Rebull+16, Blanco-1: Gillen+20, Psc-Eri: Curtis+19b, NGC-3532: Fritzewski+19
Group-X: Messina+22, Praesepe: Rampalli+21, NGC-6811: Curtis+19a, NGC-6819: Meibom+15, Ruprecht-147: Curtis+20

Binaries are removed;
Fit from 3800 to 6200 K

Bouma+23

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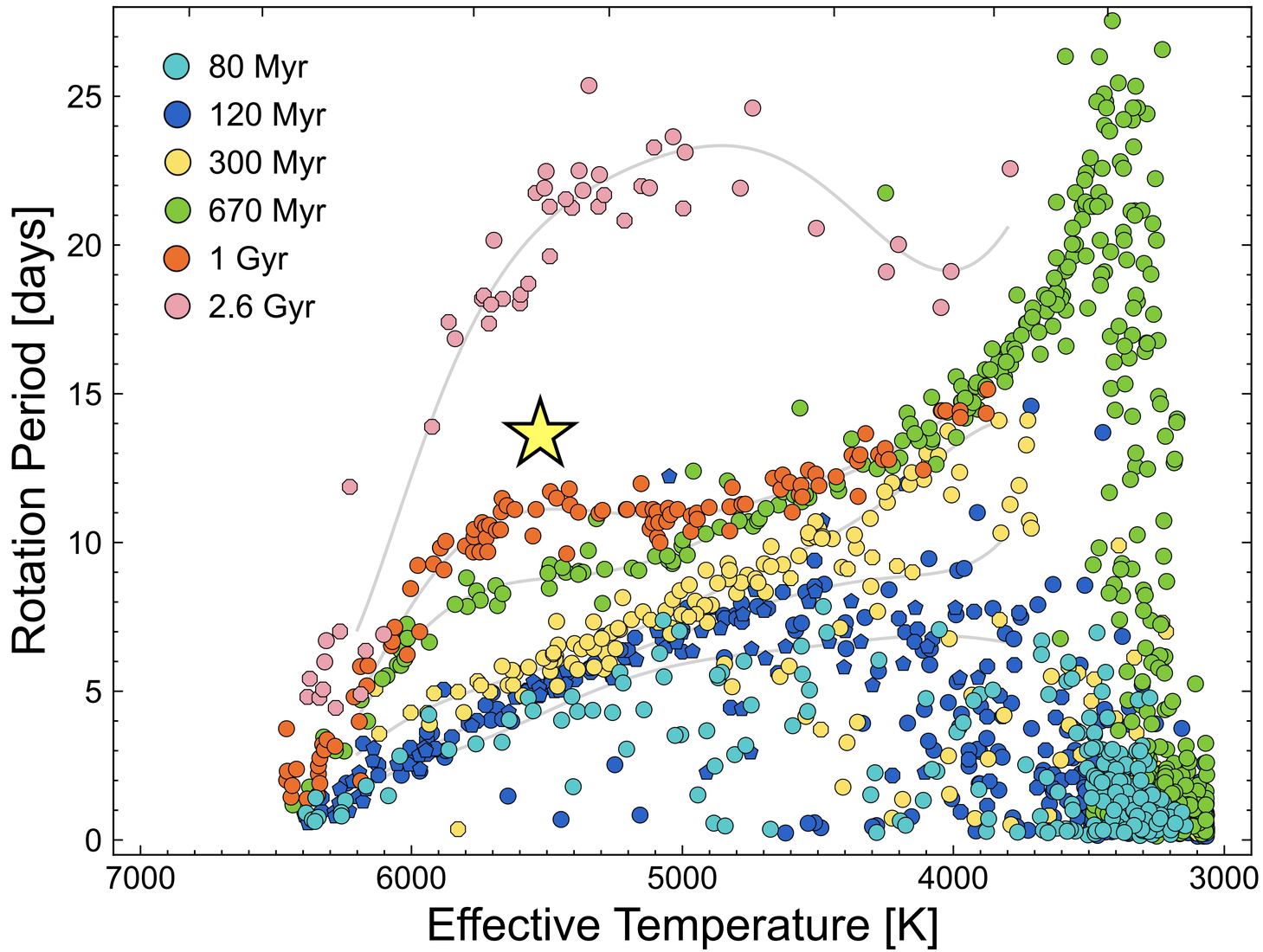

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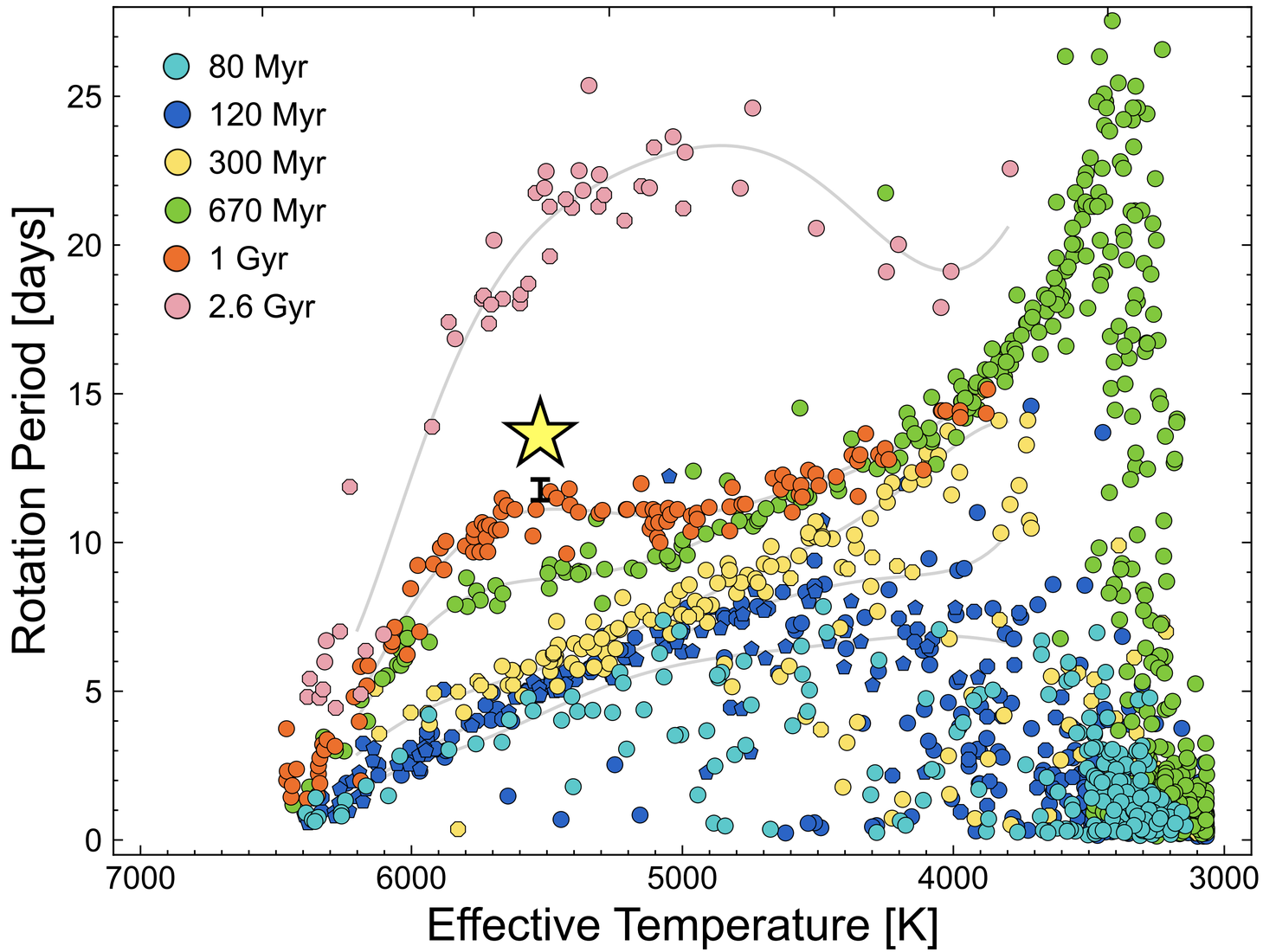

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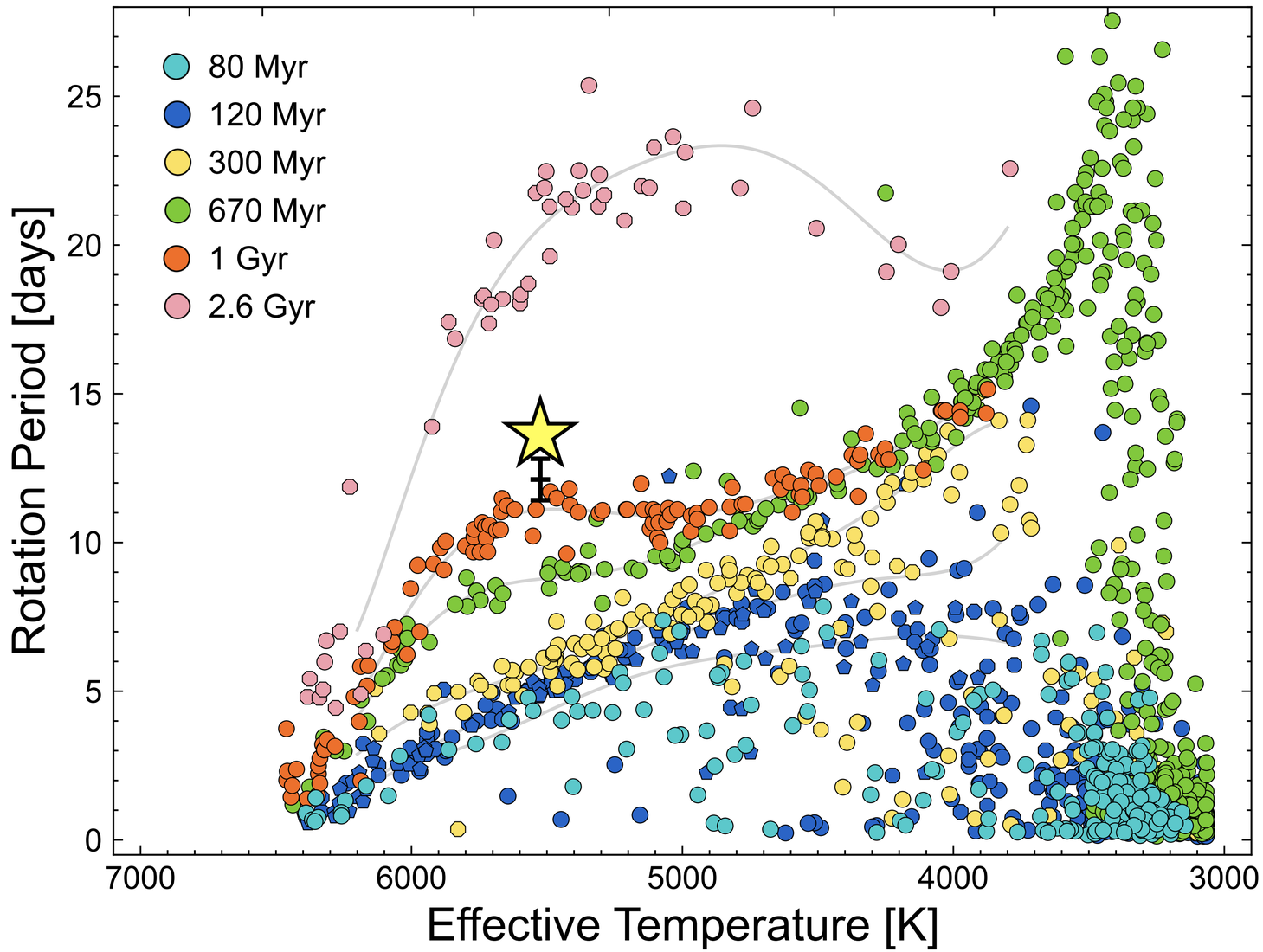

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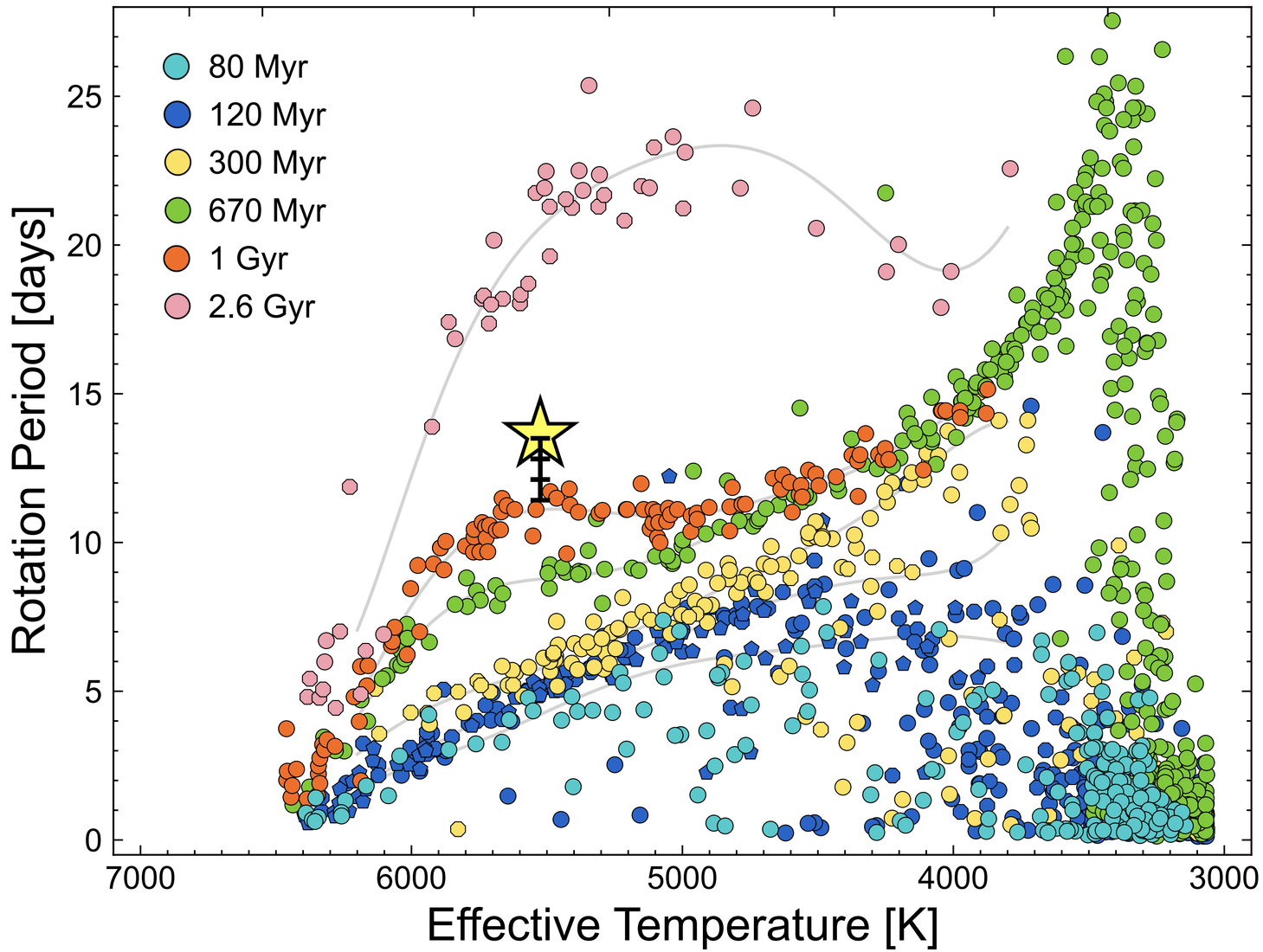

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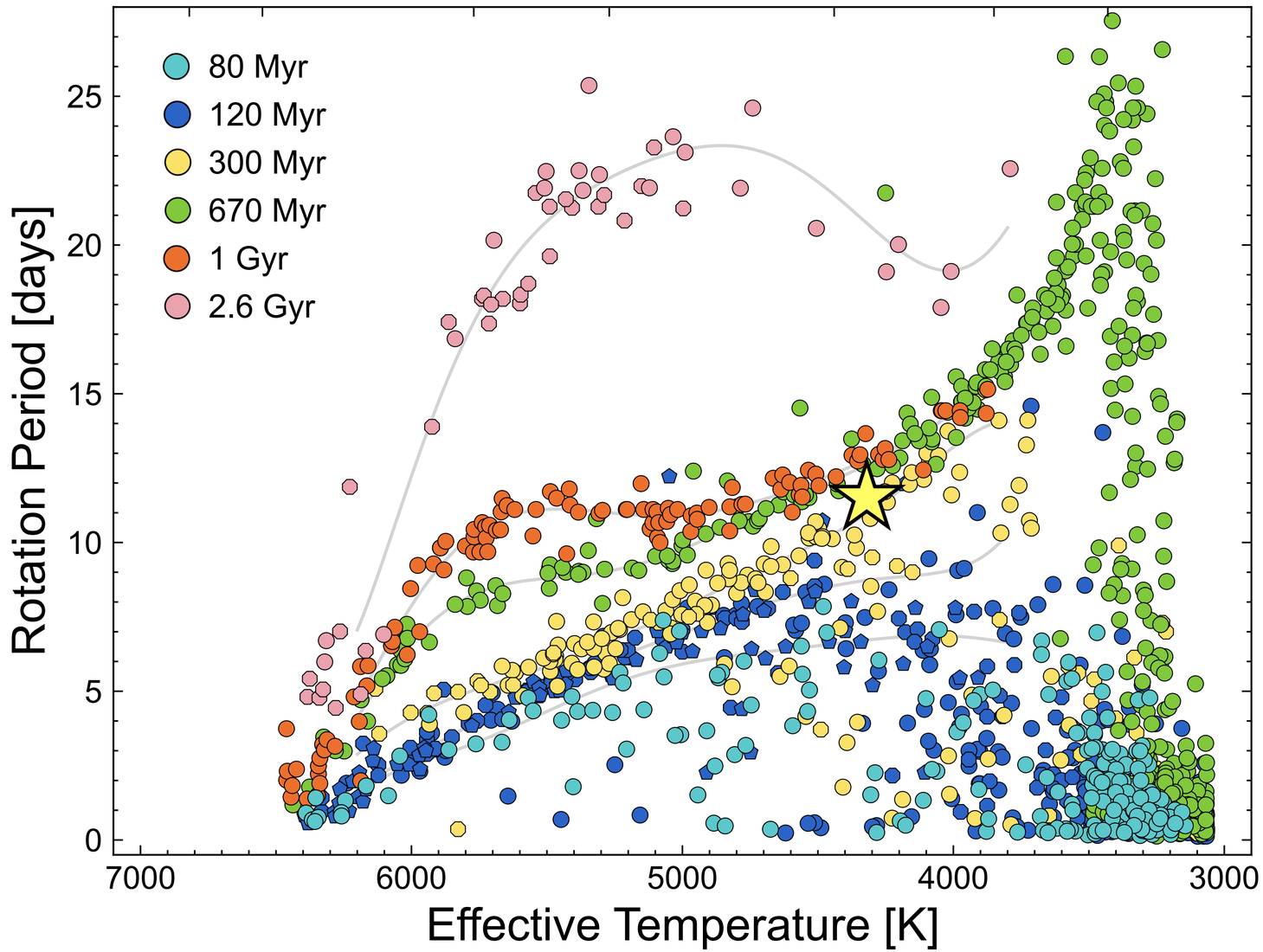

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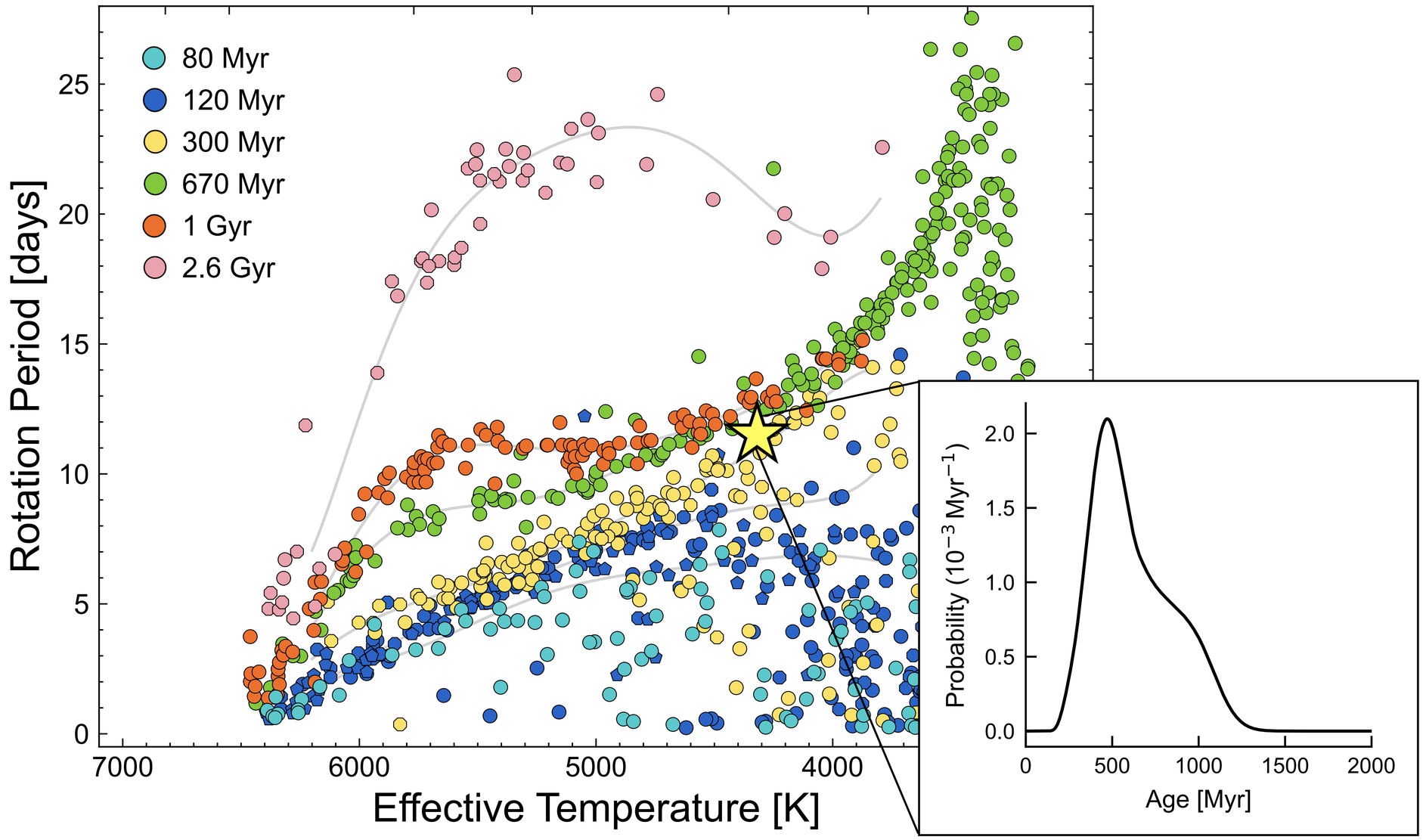

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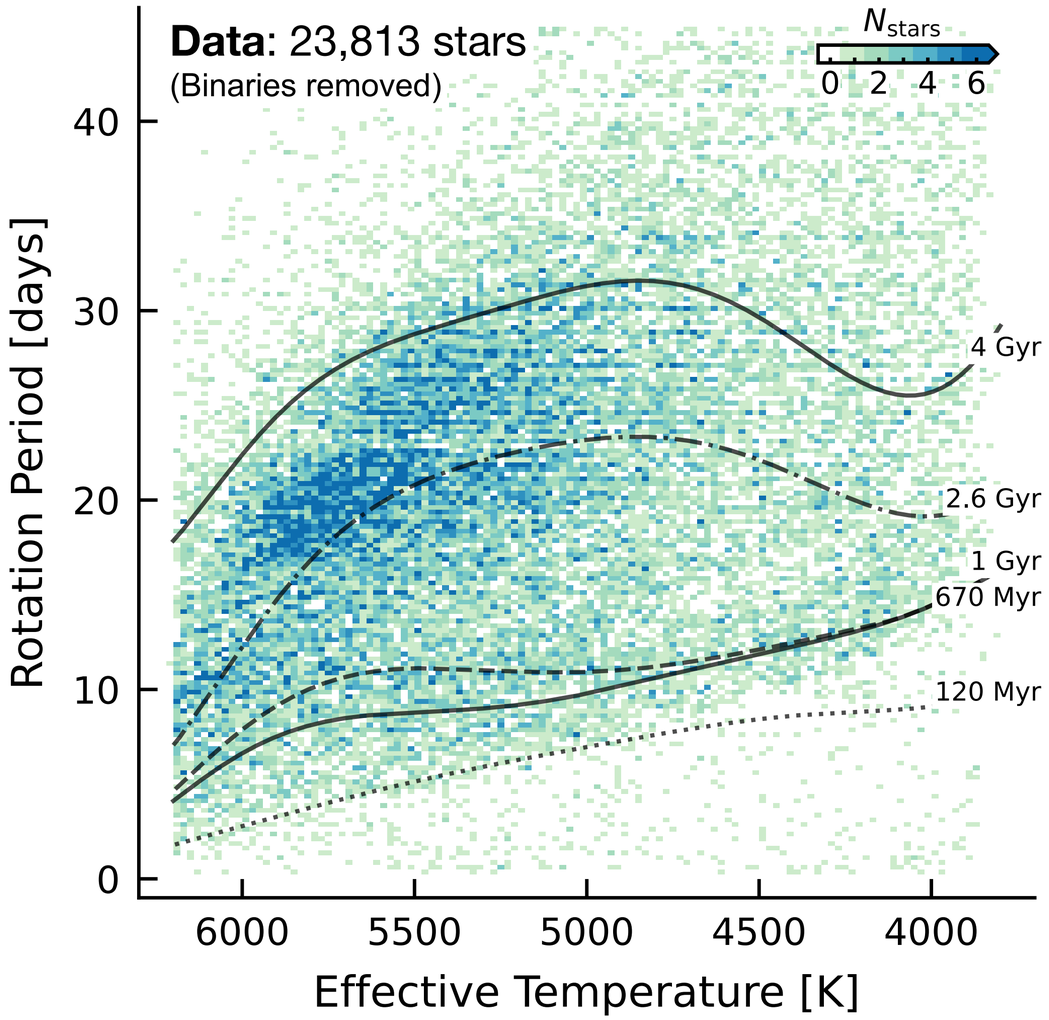
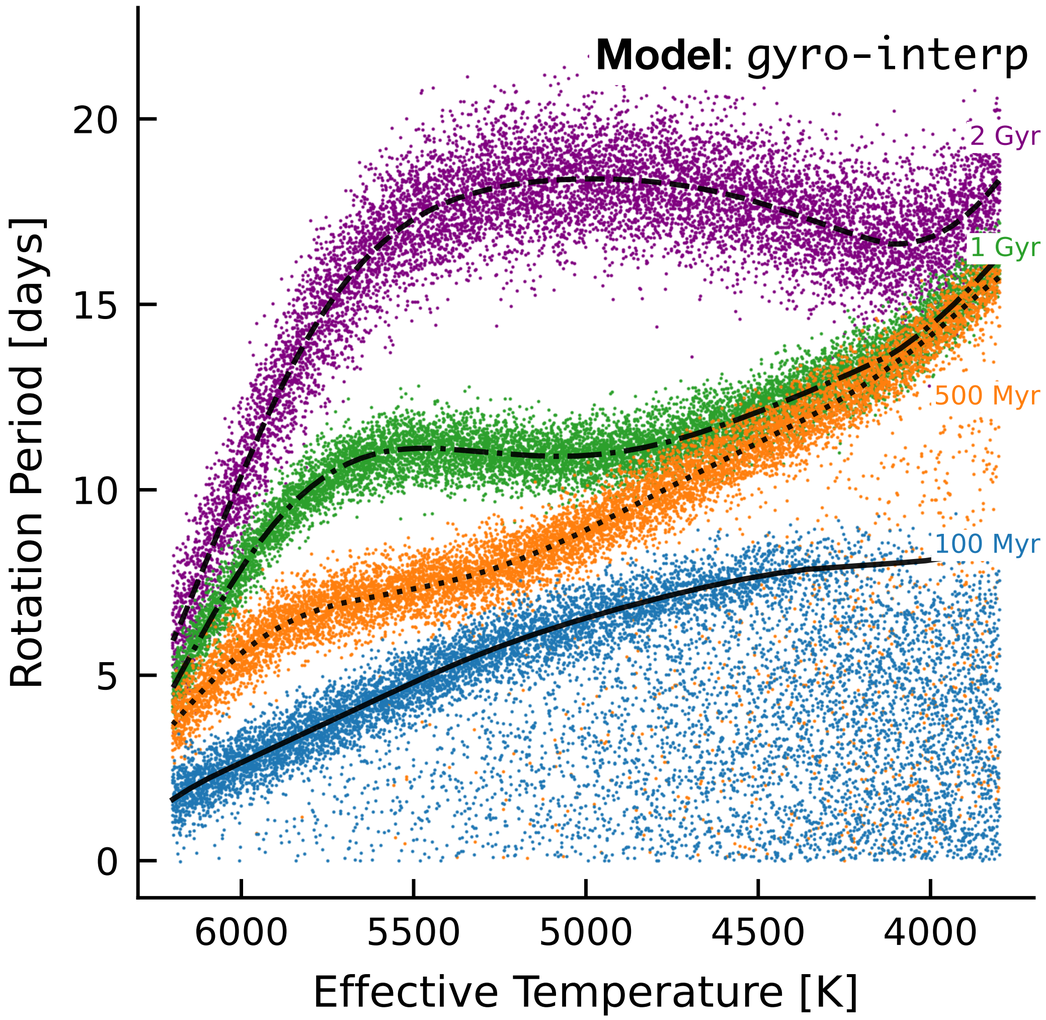
```
pip install gyro-interp
```

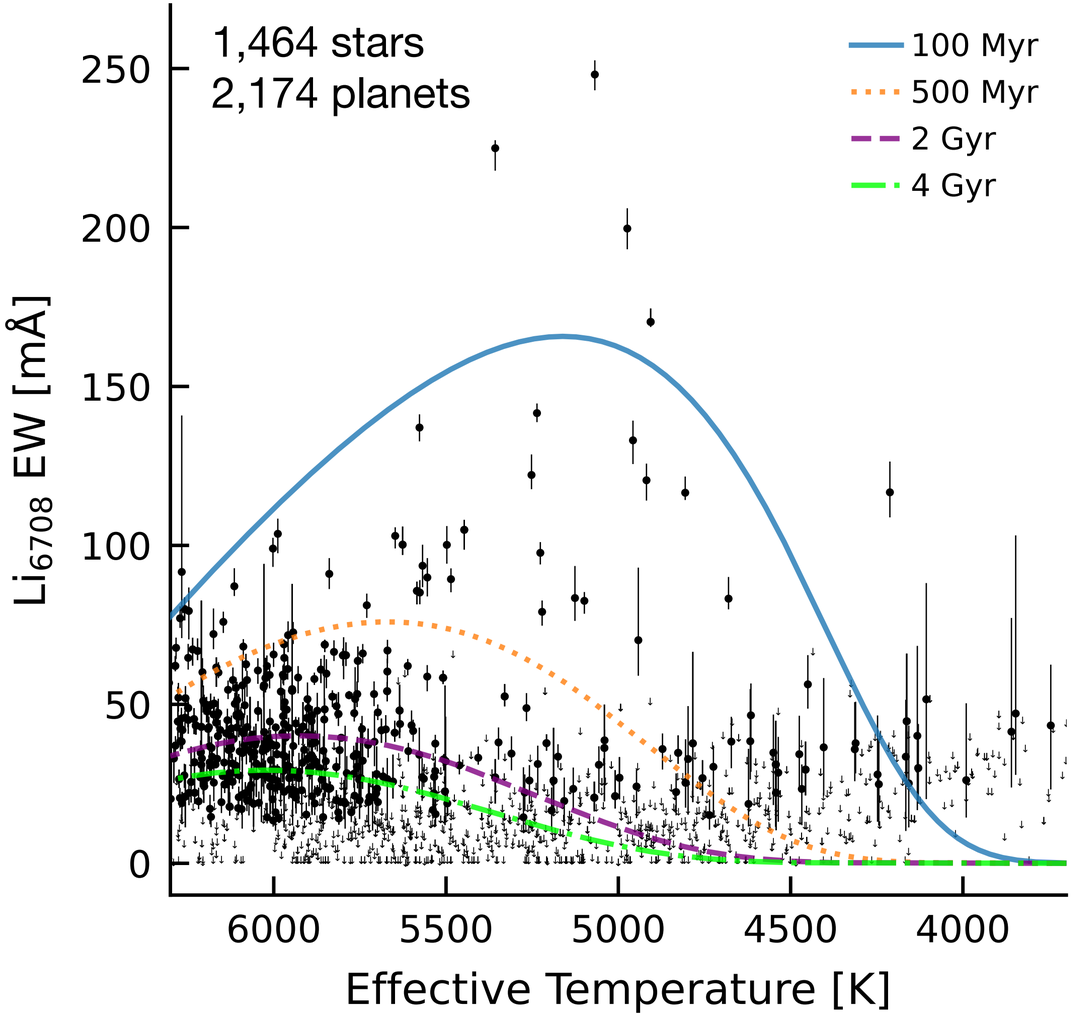
Kepler detected rotation for ≈one in three of its stars

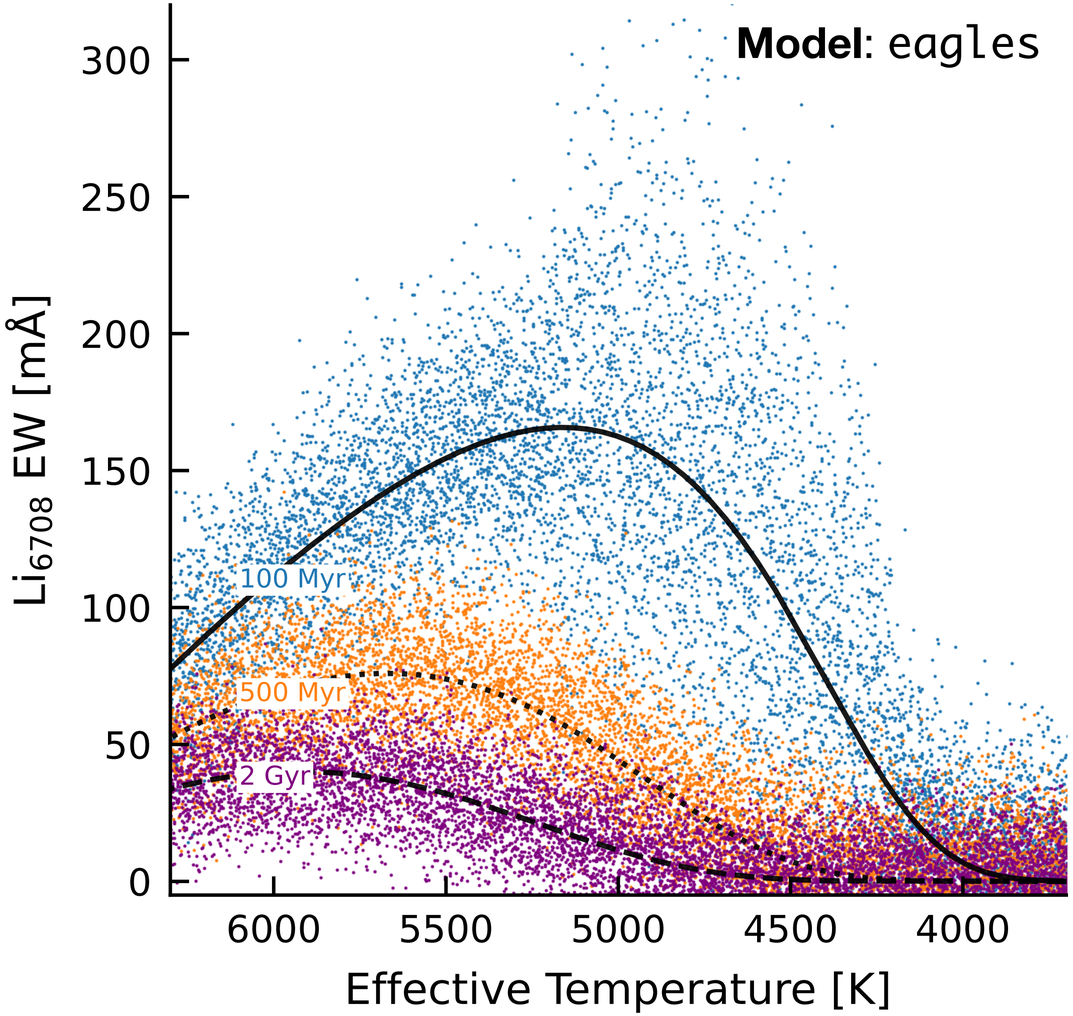




P_{rot}: McQuillan+14, Mazeh+15, Santos+19, Santos+21. T_{eff}: Berger+20

Lithium in Keck/HIRES spectra of KOIs provides independent ages

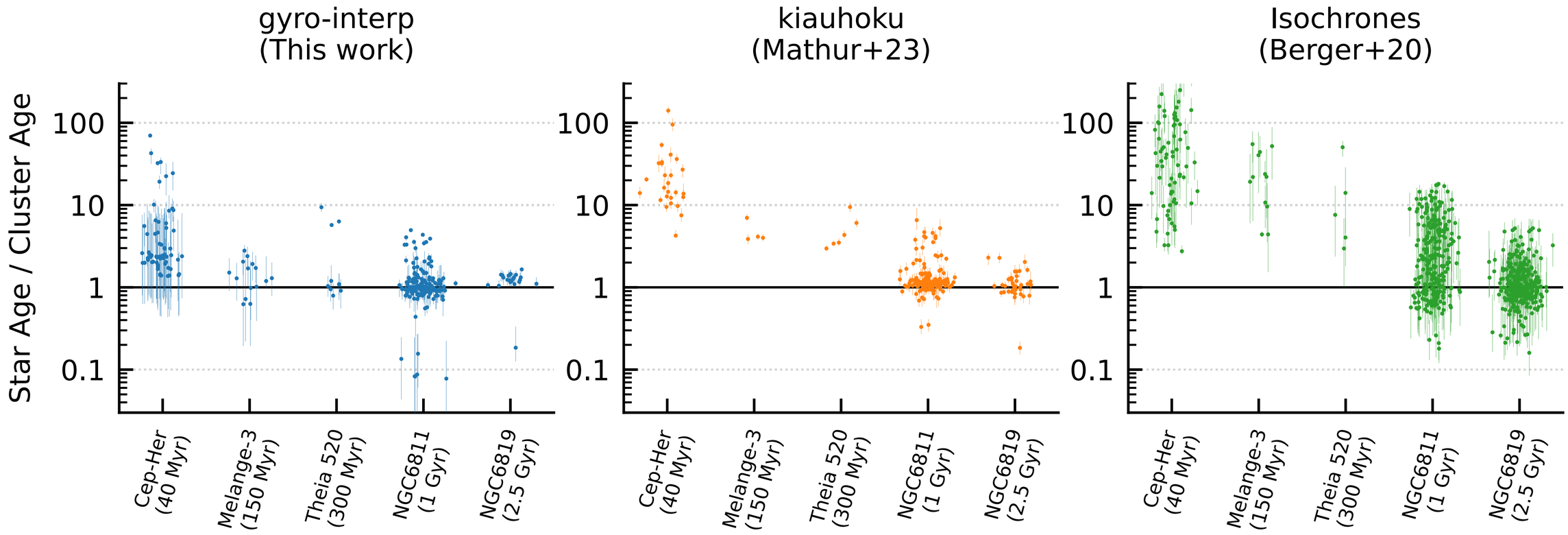




Model: **Jeffries+23**, Weaver+24

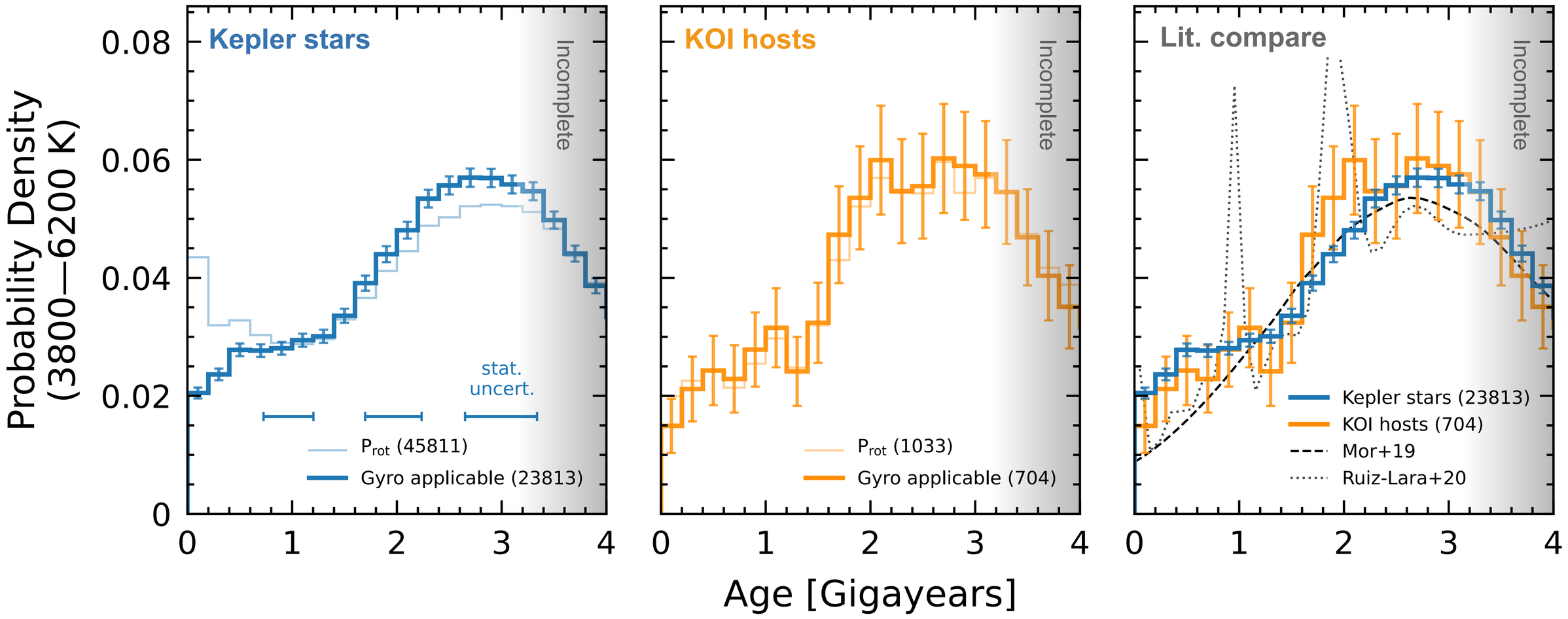
Li: Fulton+17, Johnson+17, Petigura+17, Berger+18, Bouma+24

Kepler's open clusters provide extra verification



Bouma+24

Young Kepler stars 3-5x more rare than their 3 Gyr counterparts



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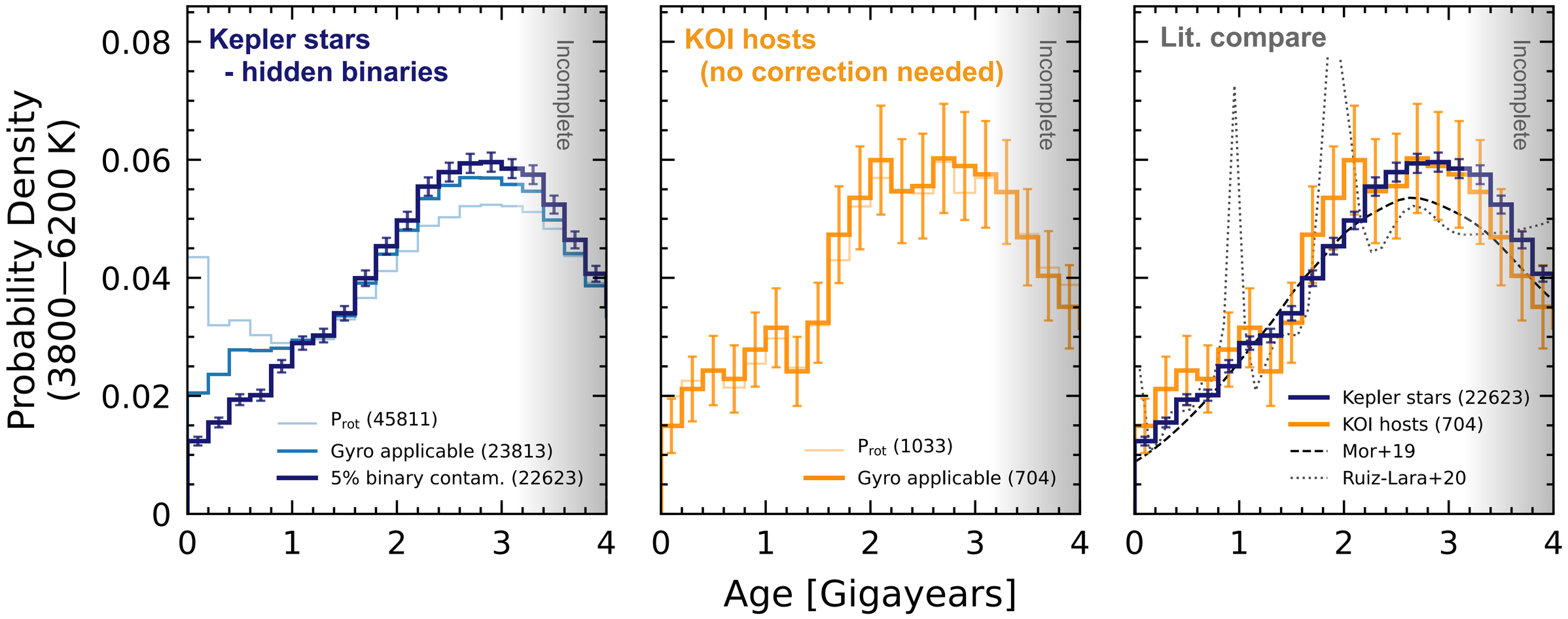

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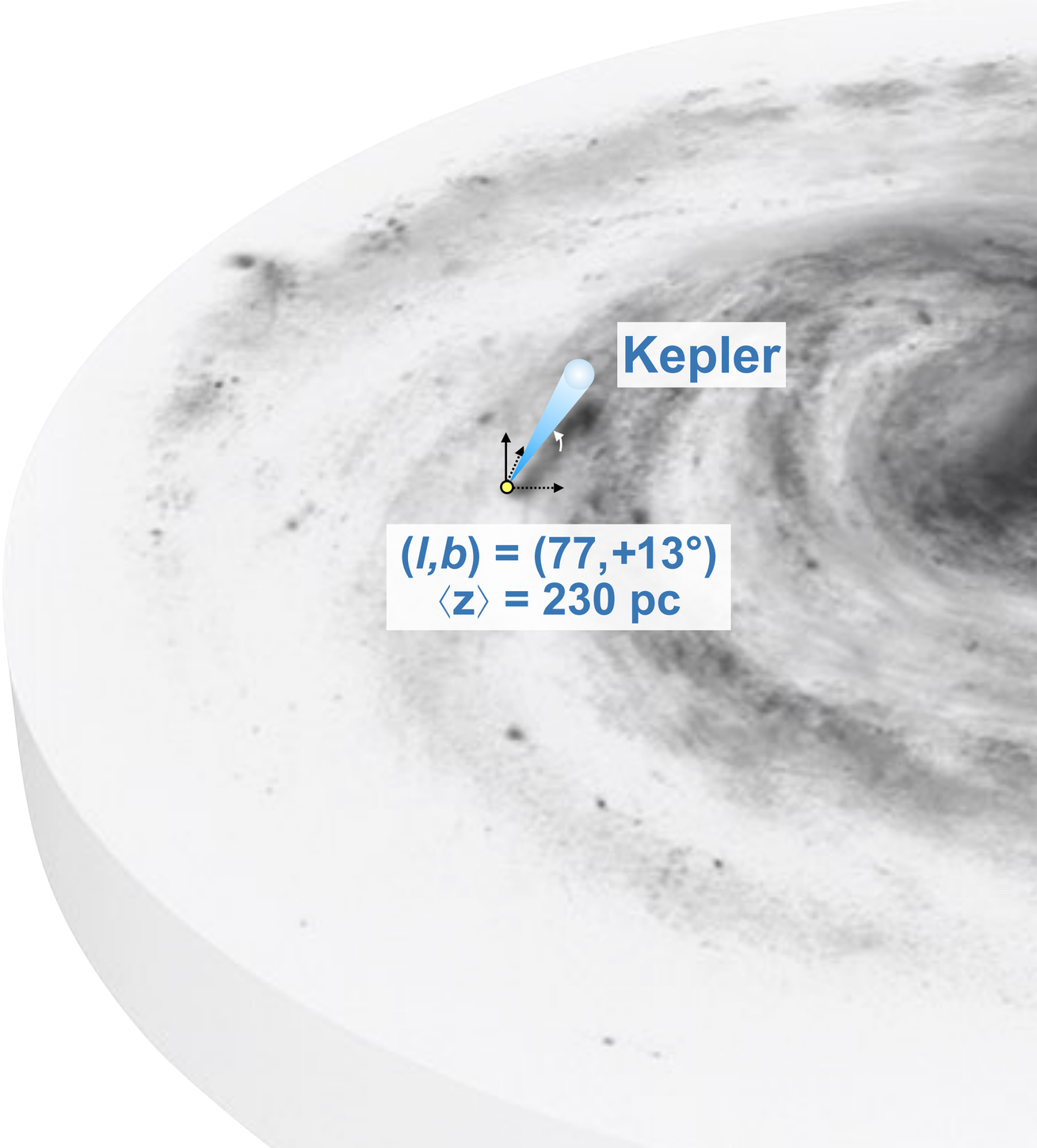
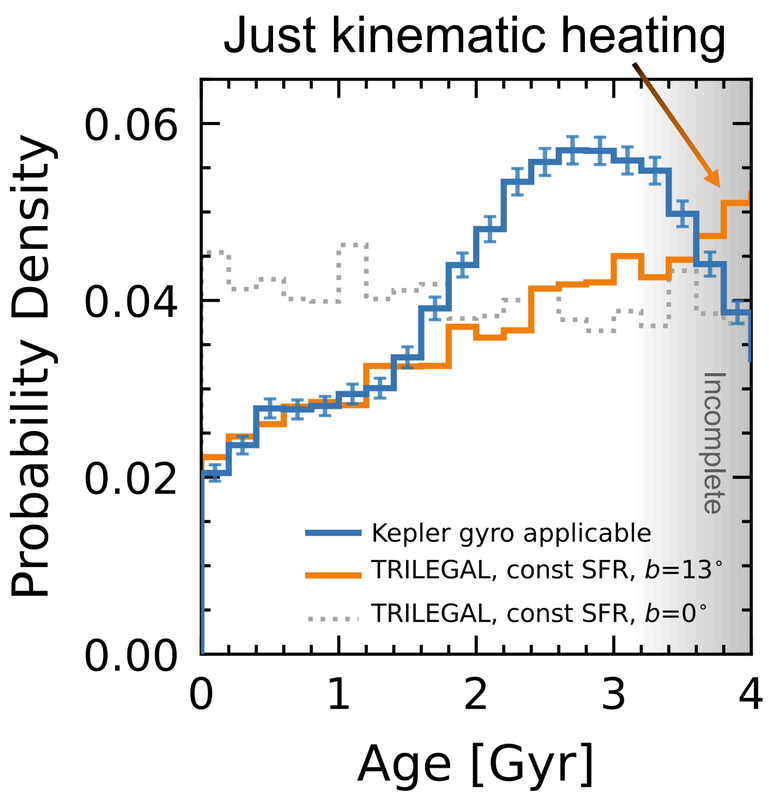
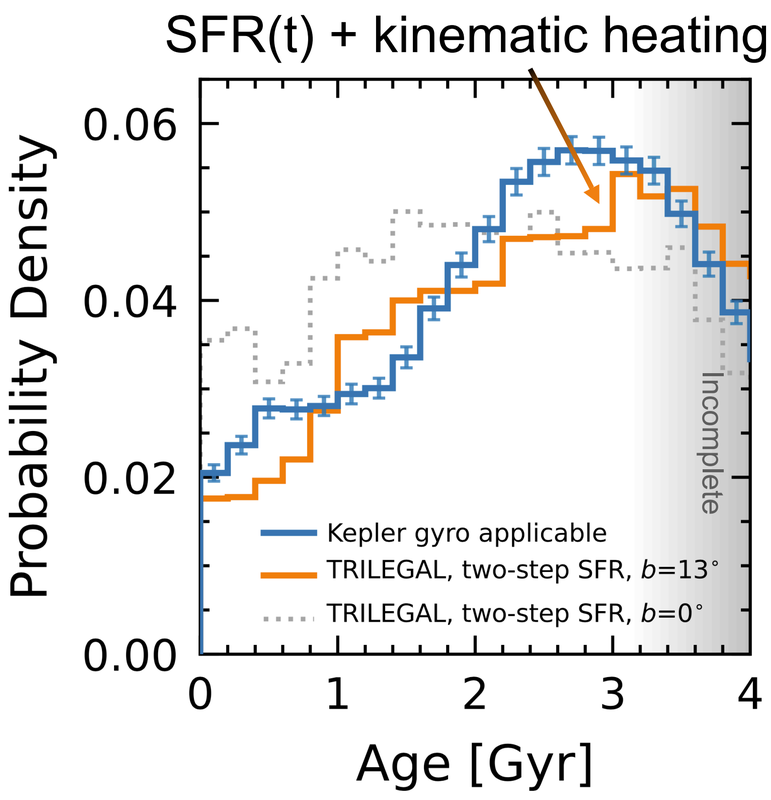
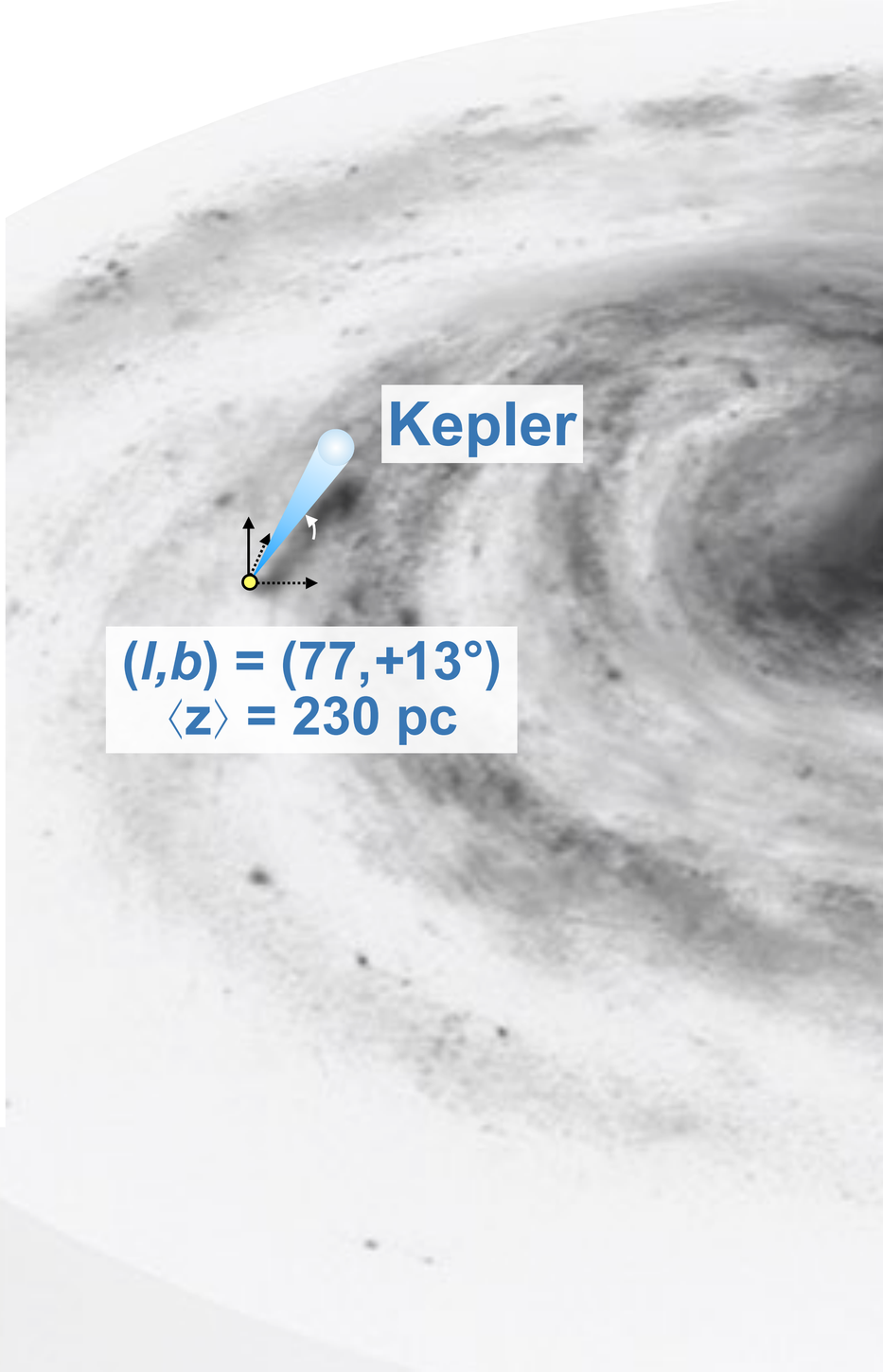

Kepler
(l,b) = (77,+13°)
⟨z⟩ = 230 pc

Kepler's age distribution is a product of both kinematic heating & star formation history

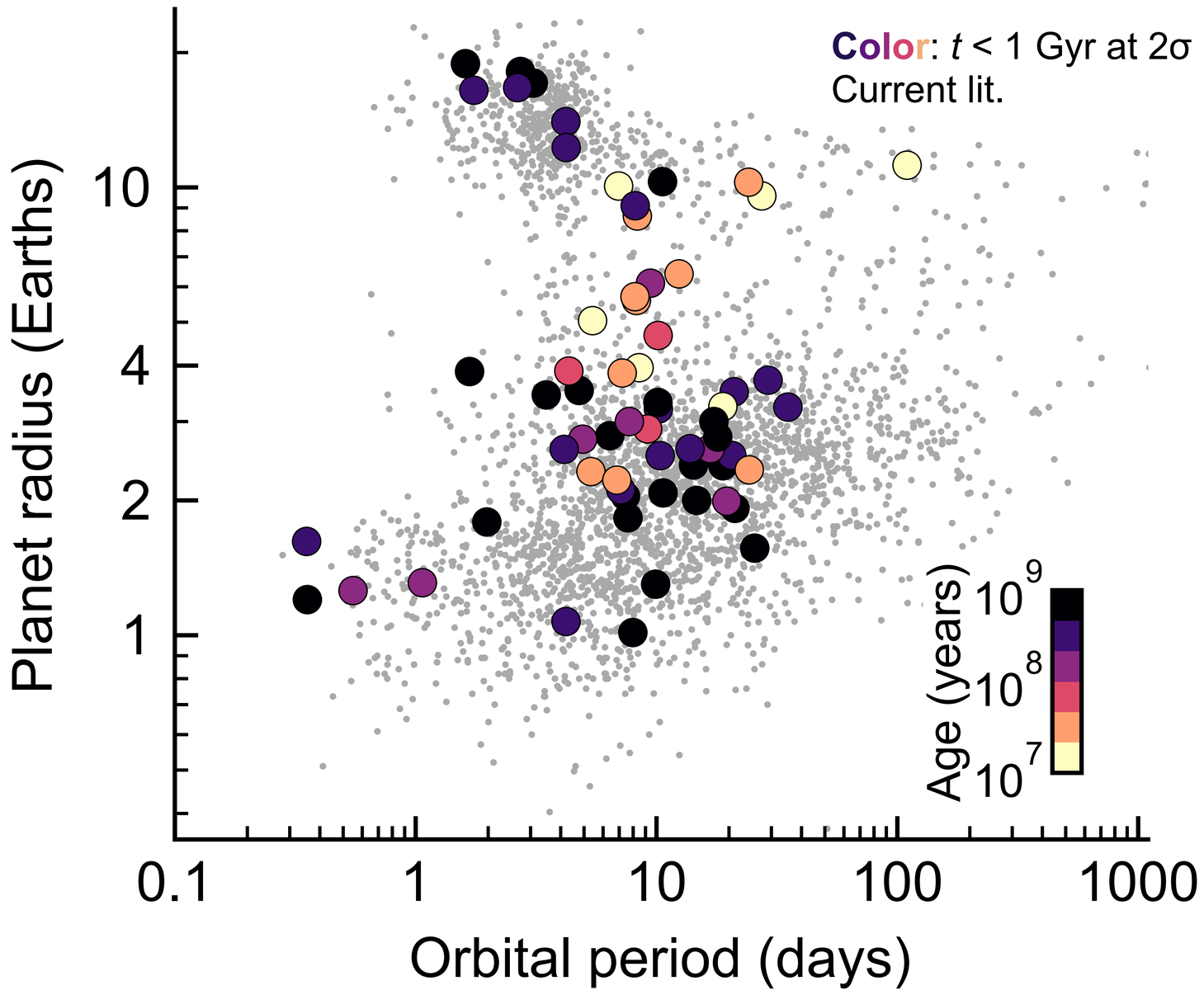






Bouma+24

Field ages offer 2-3x expansion for demographics at 0.1-1 Gyr



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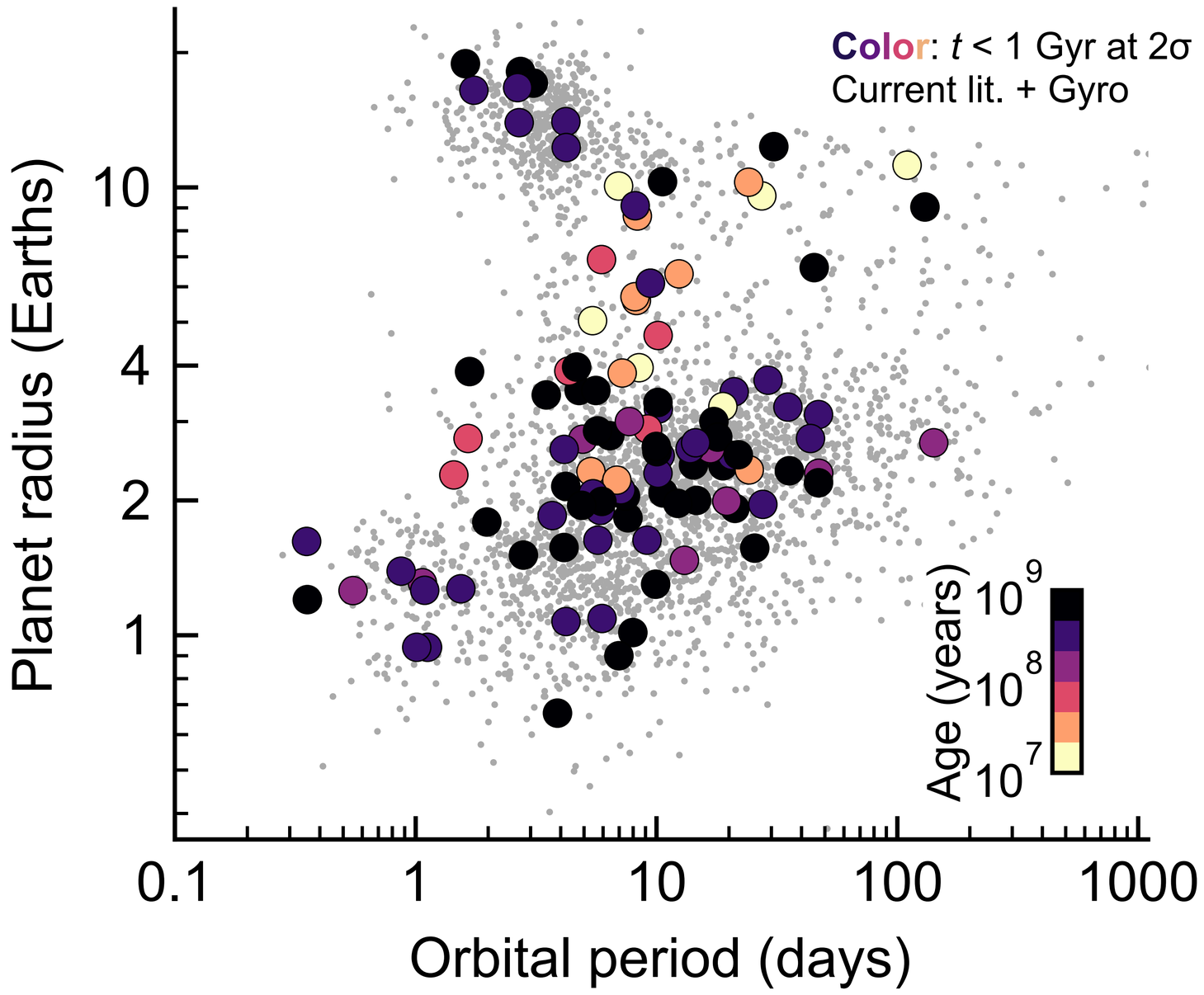


Bouma+24

Yuri Beletsky

Precision limit for rotational & lithium ages set by **intrinsic scatter** in open cluster distributions.

- Rotation: ***gyro-interp*** (**Bouma+23**)
- Lithium: *eagles* (Jeffries+23, Weaver+24)
- Calibrated for: single FGK stars at < 4 Gyr near solar metallicity

Youngest Kepler stars **3-5x rarer** than stars 3 Gyr old.

- Age distribution product of both **kinematic heating** and **declining SFR**
- Unresolved binaries main source of uncertainty

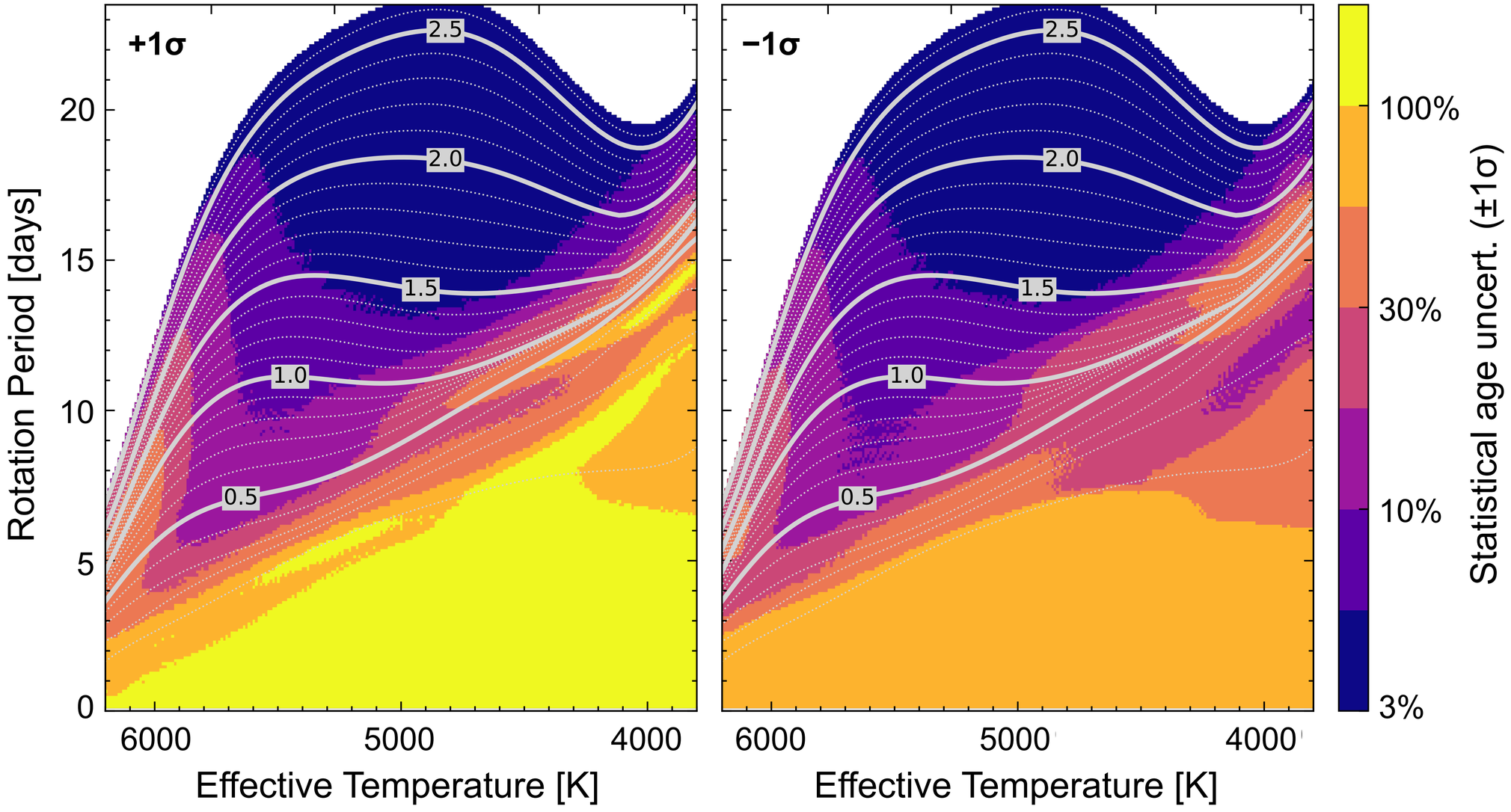
Kepler's missing young planets **no longer missing**.

- 10x discrepancy now < 2x, due to **declining d*N*/d*t*** and **new rotational ages**
- N=109 Kepler planets with t < 1 Gyr: useful for demographics (**Bouma+24**)
- TESS, PLATO, Roman, & Rubin will open new stellar populations, young & old

Luke Bouma
lbouma@carnegiescience.edu

bonus

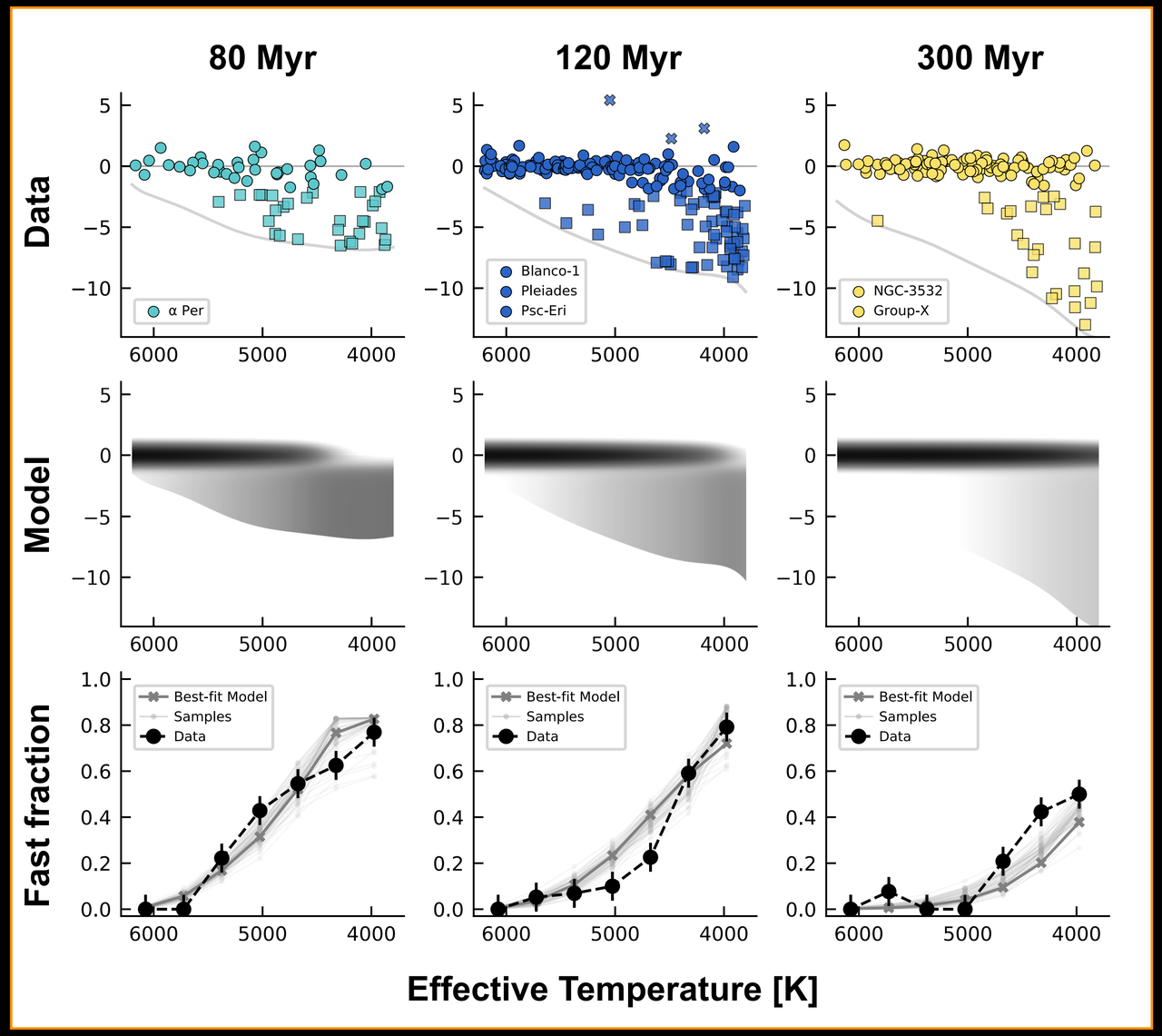
How precise are gyro ages?



1) Interpolates between clusters
0.08 - 4 Gyr, FGK (3800-6200 K)

2) Fits the scatter
Normal + trailing uniform distribution
Let uniform distribution converge with ZAMS

3) Calculates $p(t \mid P_{\mathrm{rot}}, T_{\mathrm{eff}})$ by marginalizing over scatter



Bouma+2023

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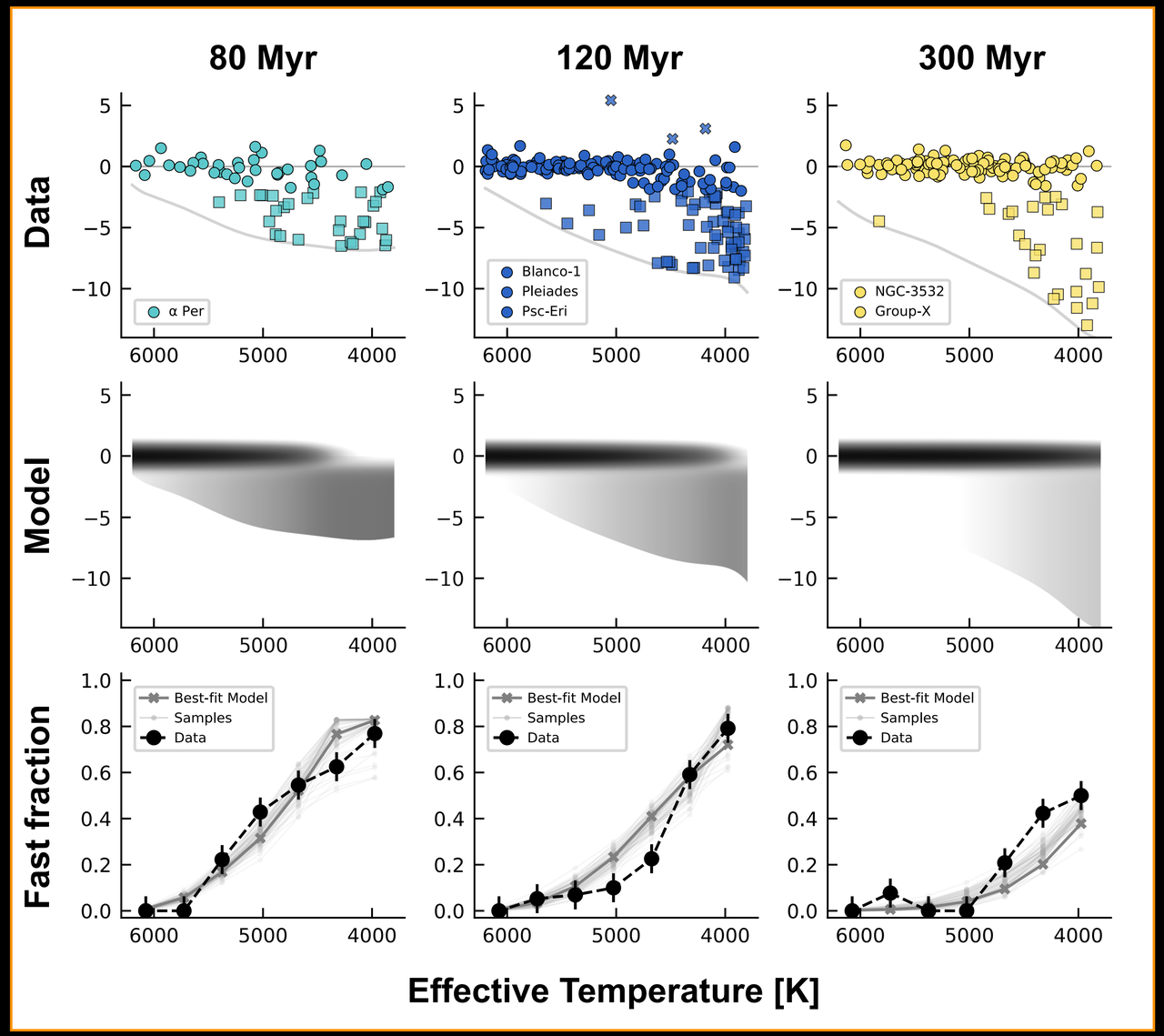
3) Calculates $p(t \mid P_{\rm rot}, T_{\rm eff})$ by marginalizing over scatter

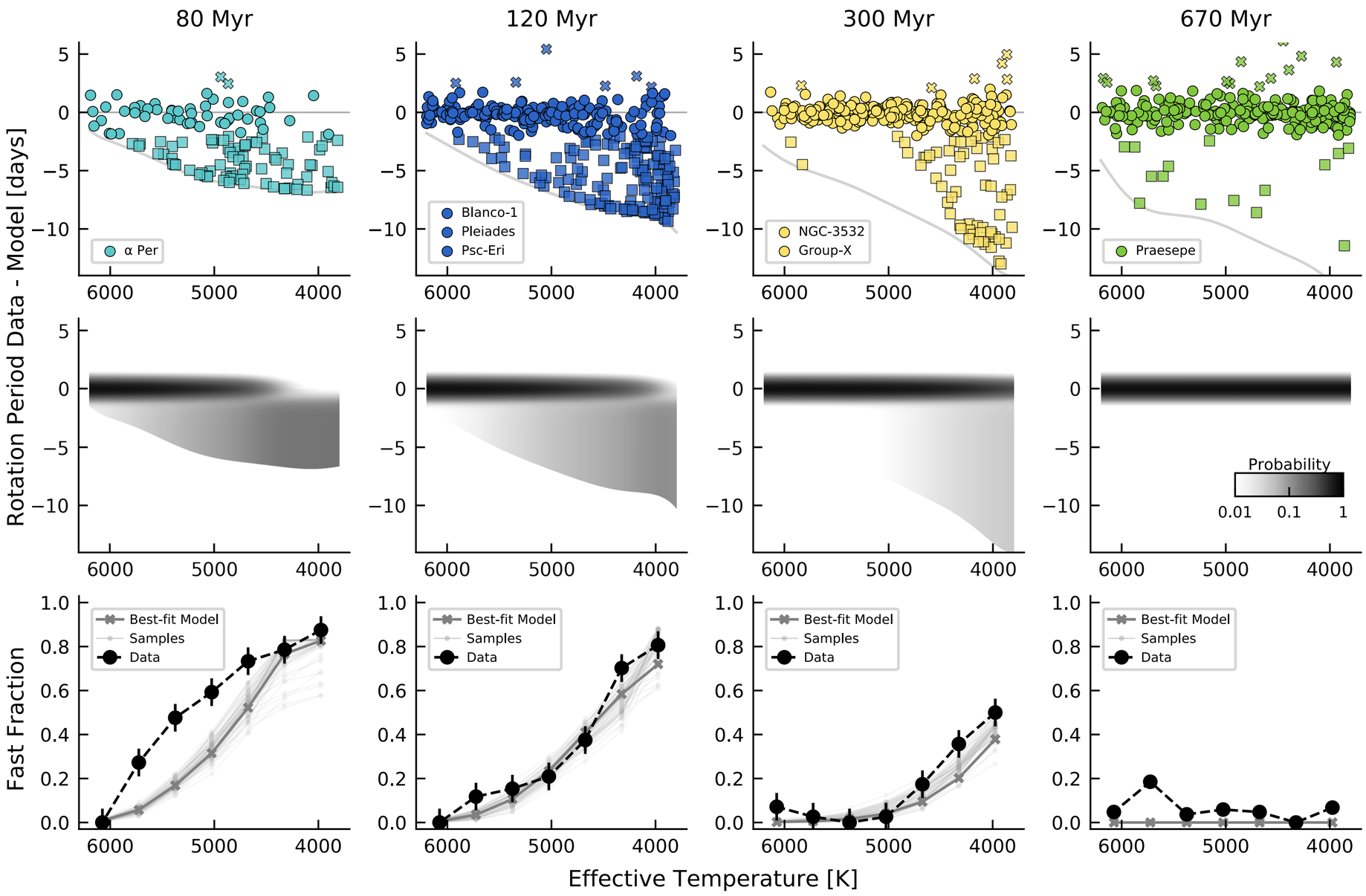
- Reproduces <4 Gyr spin-down
  With the evolving fast fraction!
  With stalled spin-down!
- $P_{\rm rot}, T_{\rm eff} \not\Rightarrow$ unique age
  Range of ages dictated by scatter in data

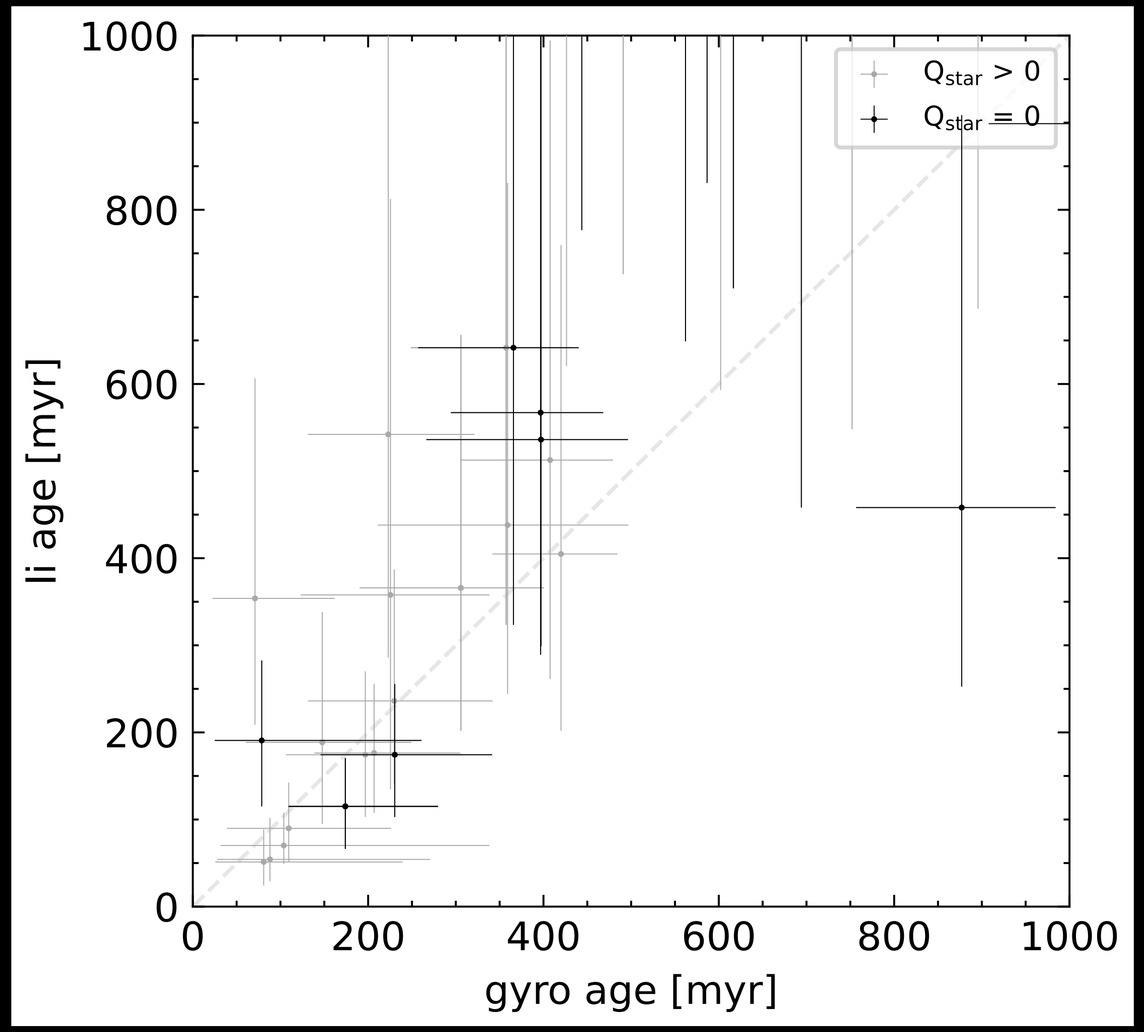
```
pip install gyro-interp
```

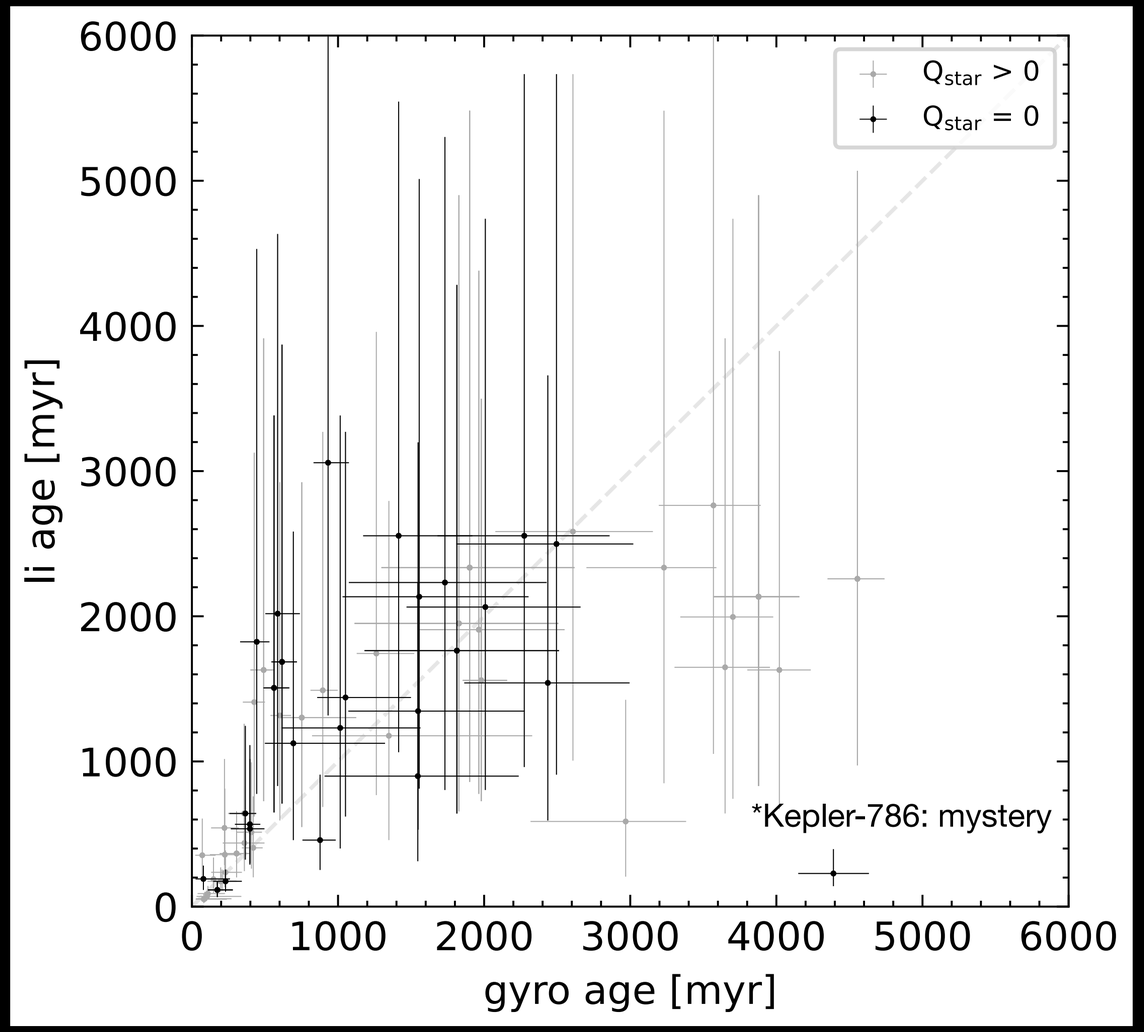


Bouma+2023

How do unresolved binaries affect gyro ages?







gyro-interp (Prot) vs. eagles (Li) age scale comparison

They mostly* agree, but not many stars overlap!

Bouma+24 suppl.

How good is $P_{rot} \sim t^{1/2}$?