

The orbital eccentricity–radius relation for planets orbiting M dwarfs

Sheila Saguear

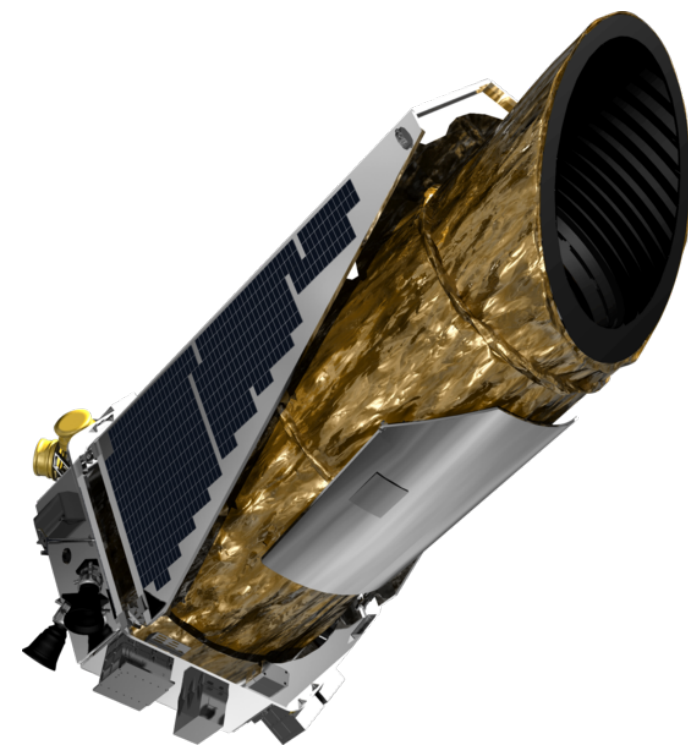
PhD Candidate @ the University of Florida

Advisor: Sarah Ballard

In collaboration with Gregory Gilbert, Mariangel Alborno and Christopher Lam

Exoplanet demographics

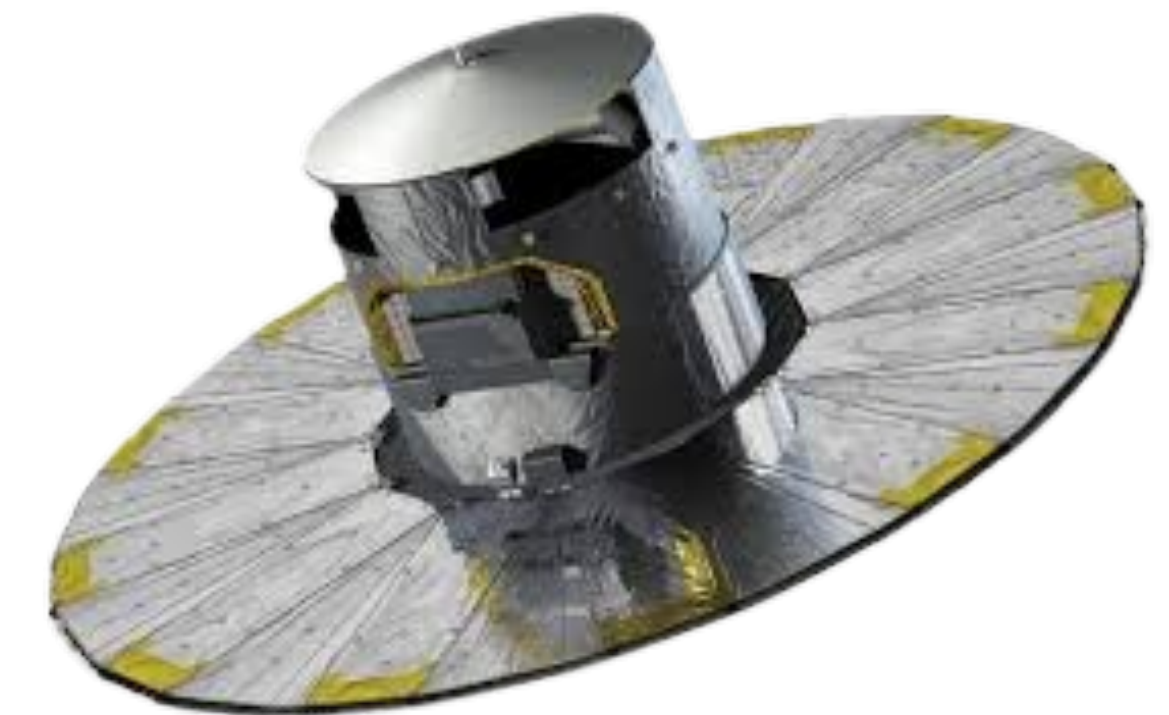
There is a LOT of exoplanet data.



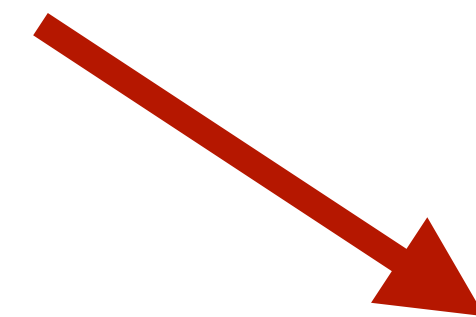
Kepler/K2



TESS



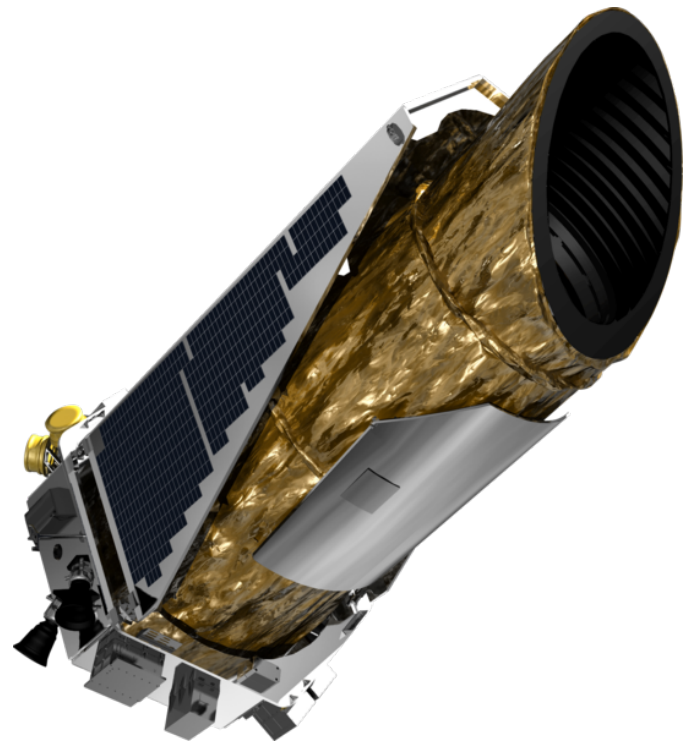
Gaia



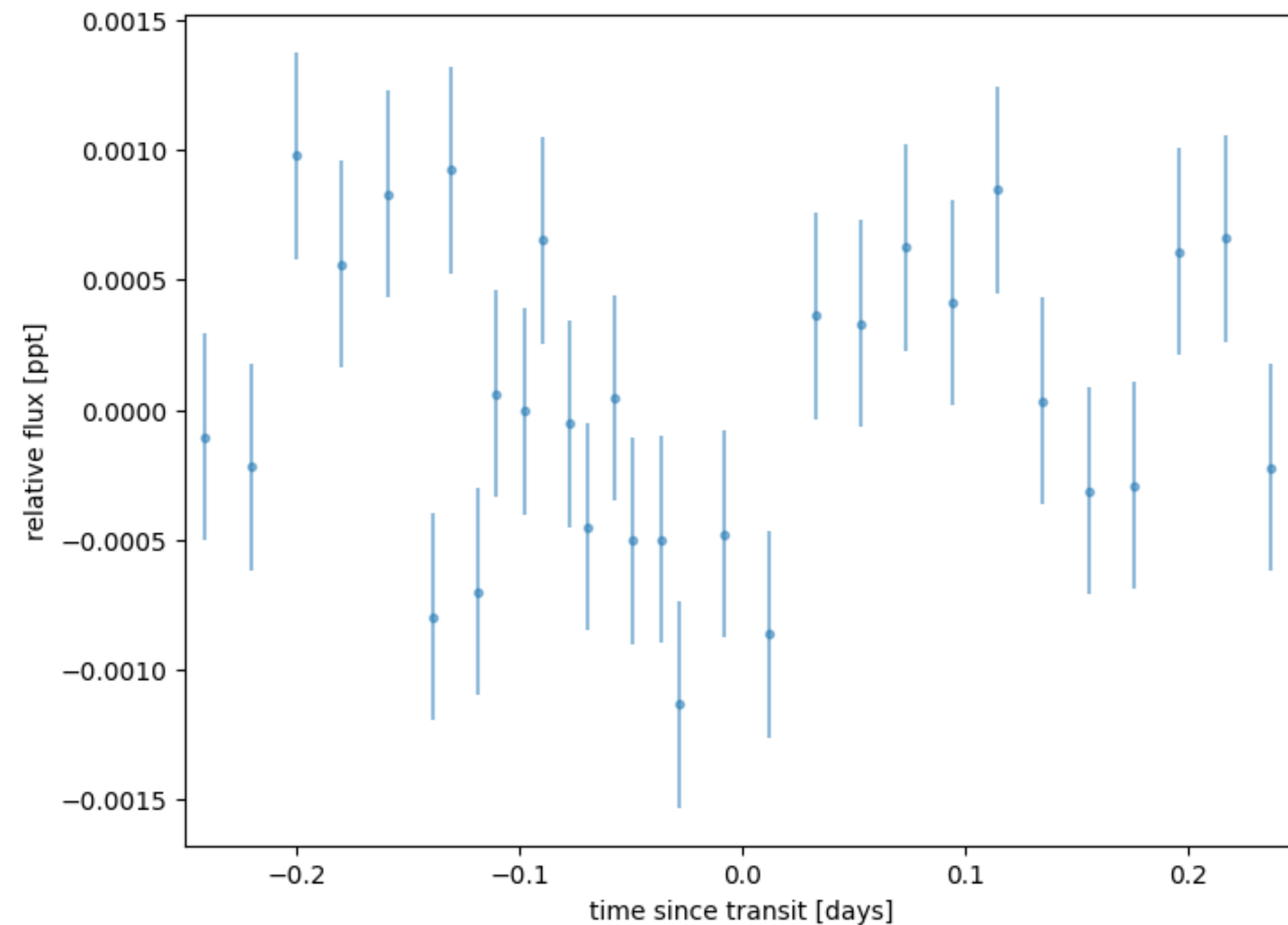
stellar parameters, kinematic measurements, and
thousands upon thousands of transit light curves

Exoplanet demographics

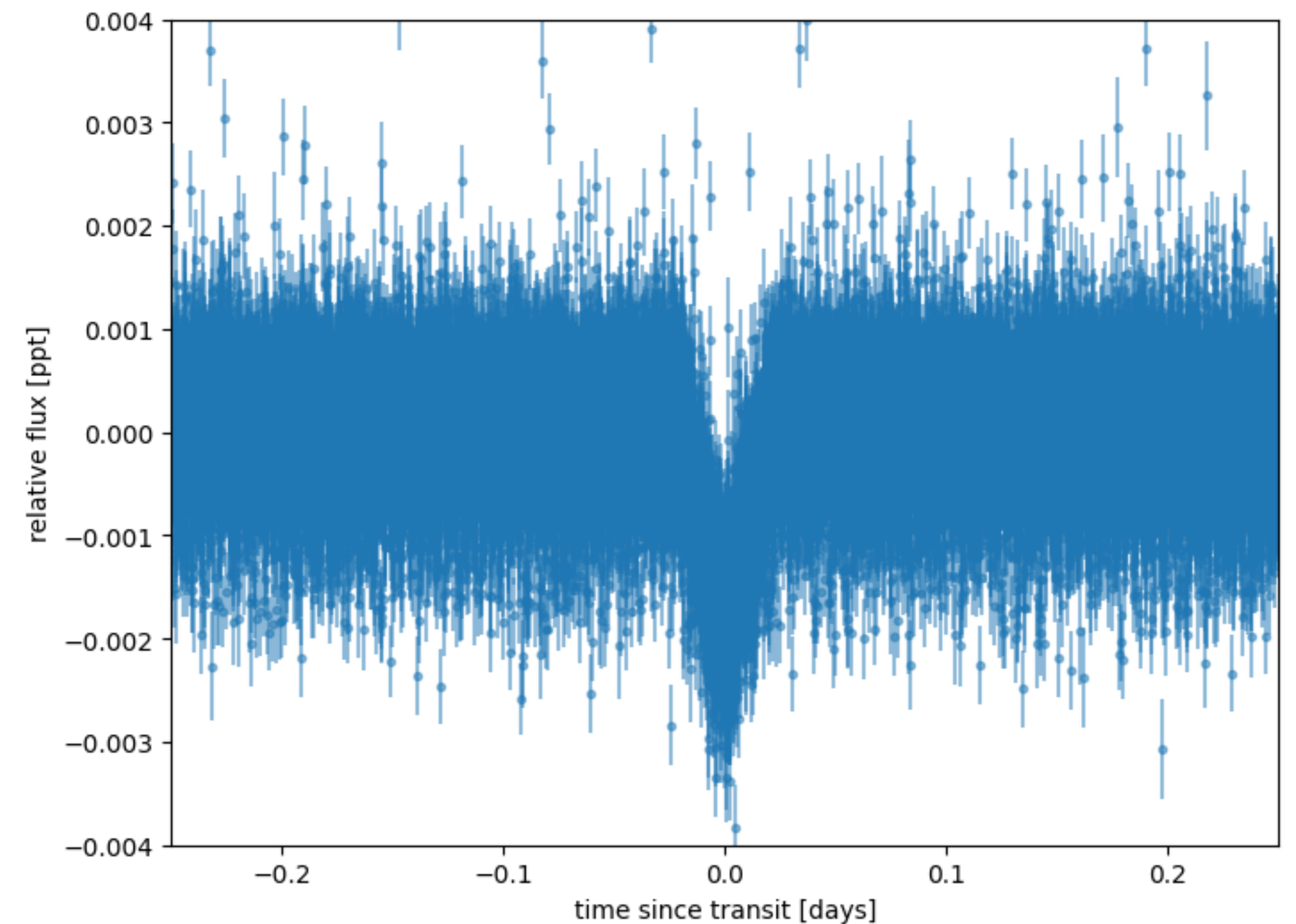
However, the precision of these data varies...



One transit of Kepler-42b

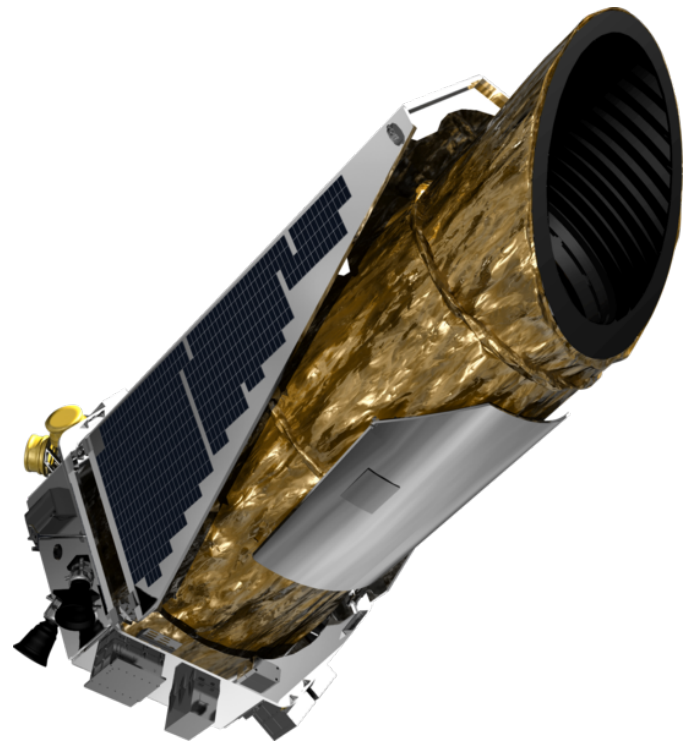


Combined transits of Kepler-42b over several years



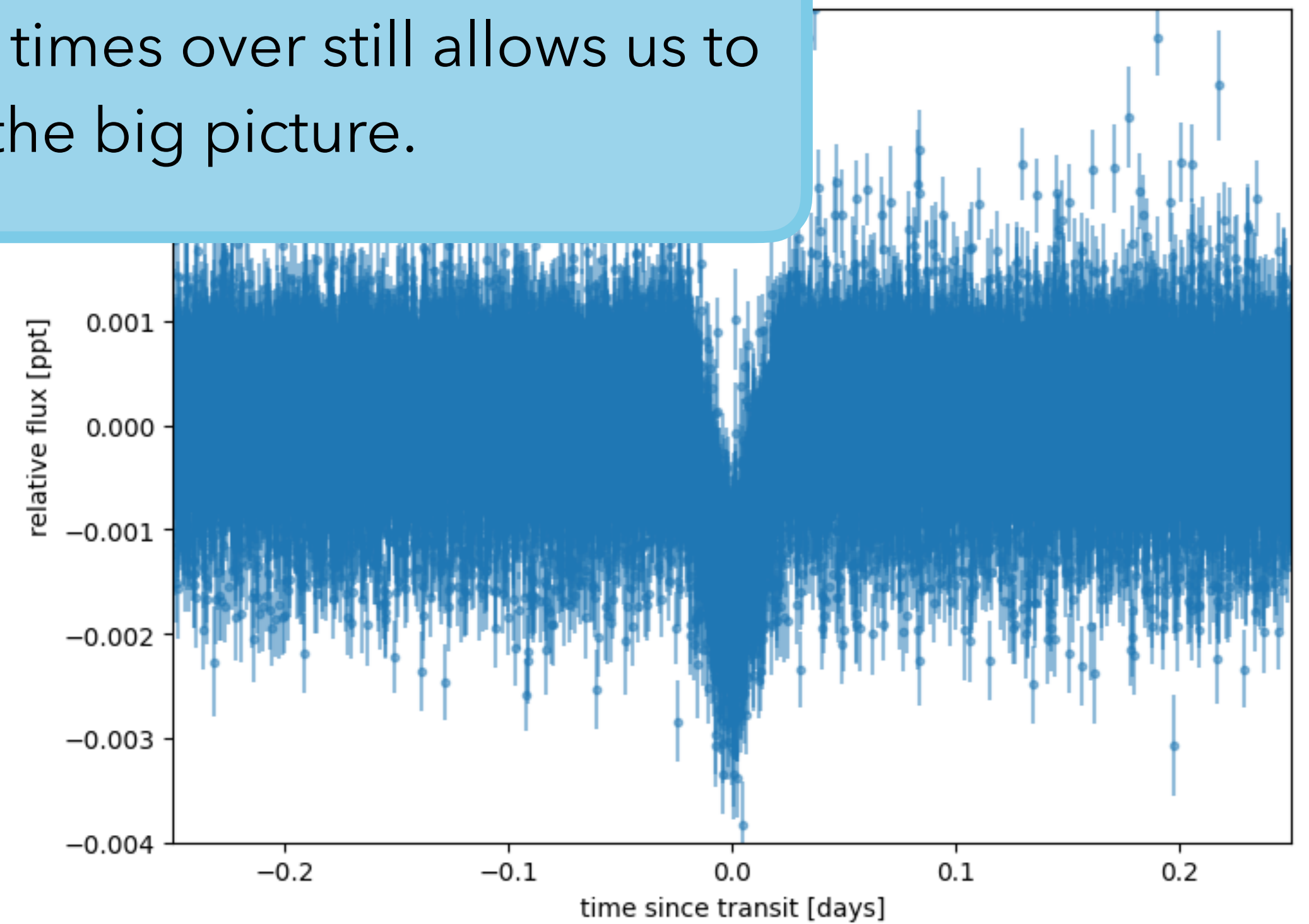
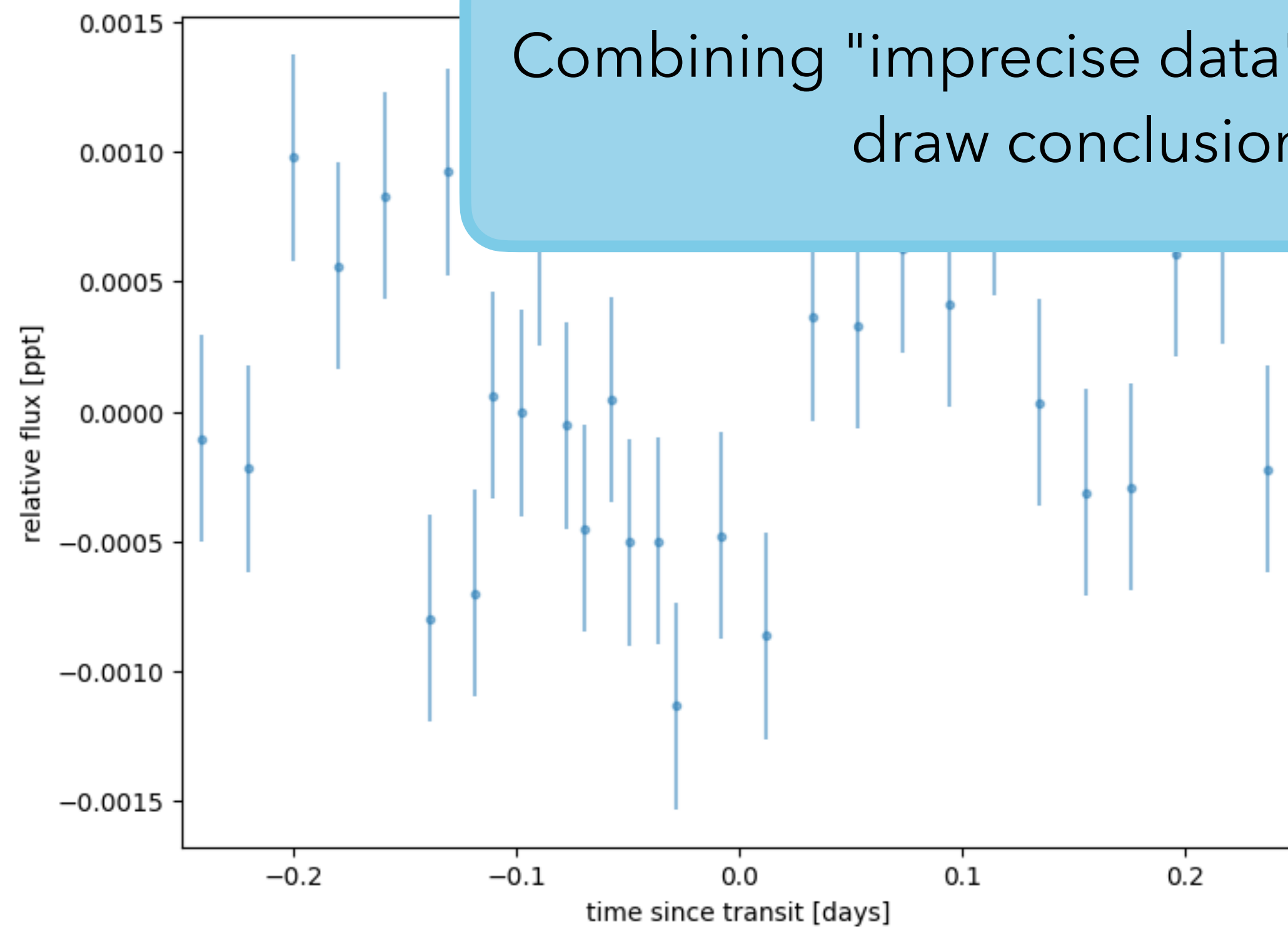
Exoplanet demographics

However, the precision of these data varies...

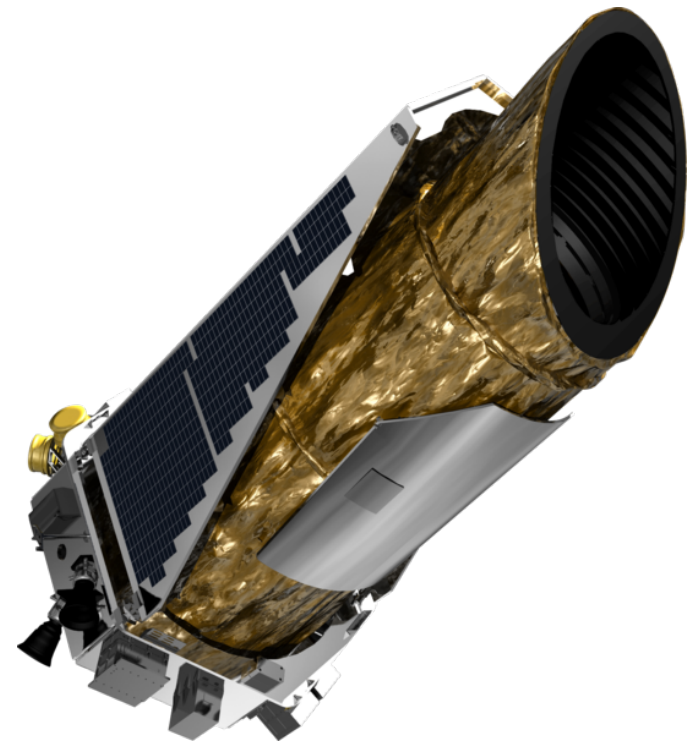


Orbit of Kepler-11b over several years

Combining "imprecise data" enough times over still allows us to draw conclusions about the big picture.

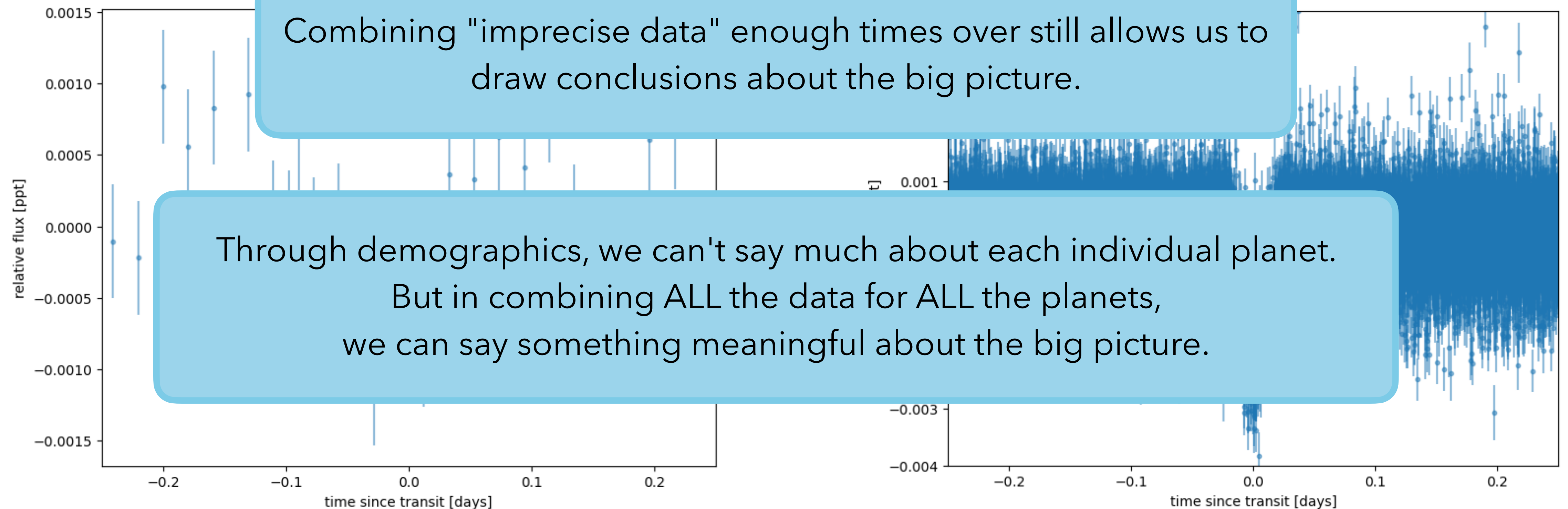


Exoplanet demographics



However, the precision of these data varies...

Orbit of Kepler-11b over several years



Combining "imprecise data" enough times over still allows us to draw conclusions about the big picture.

Through demographics, we can't say much about each individual planet. But in combining ALL the data for ALL the planets, we can say something meaningful about the big picture.

The orbital eccentricity distribution for M dwarf planets

We are interested in understanding the orbital dynamics of planets around small stars (M dwarfs) from a demographic perspective.

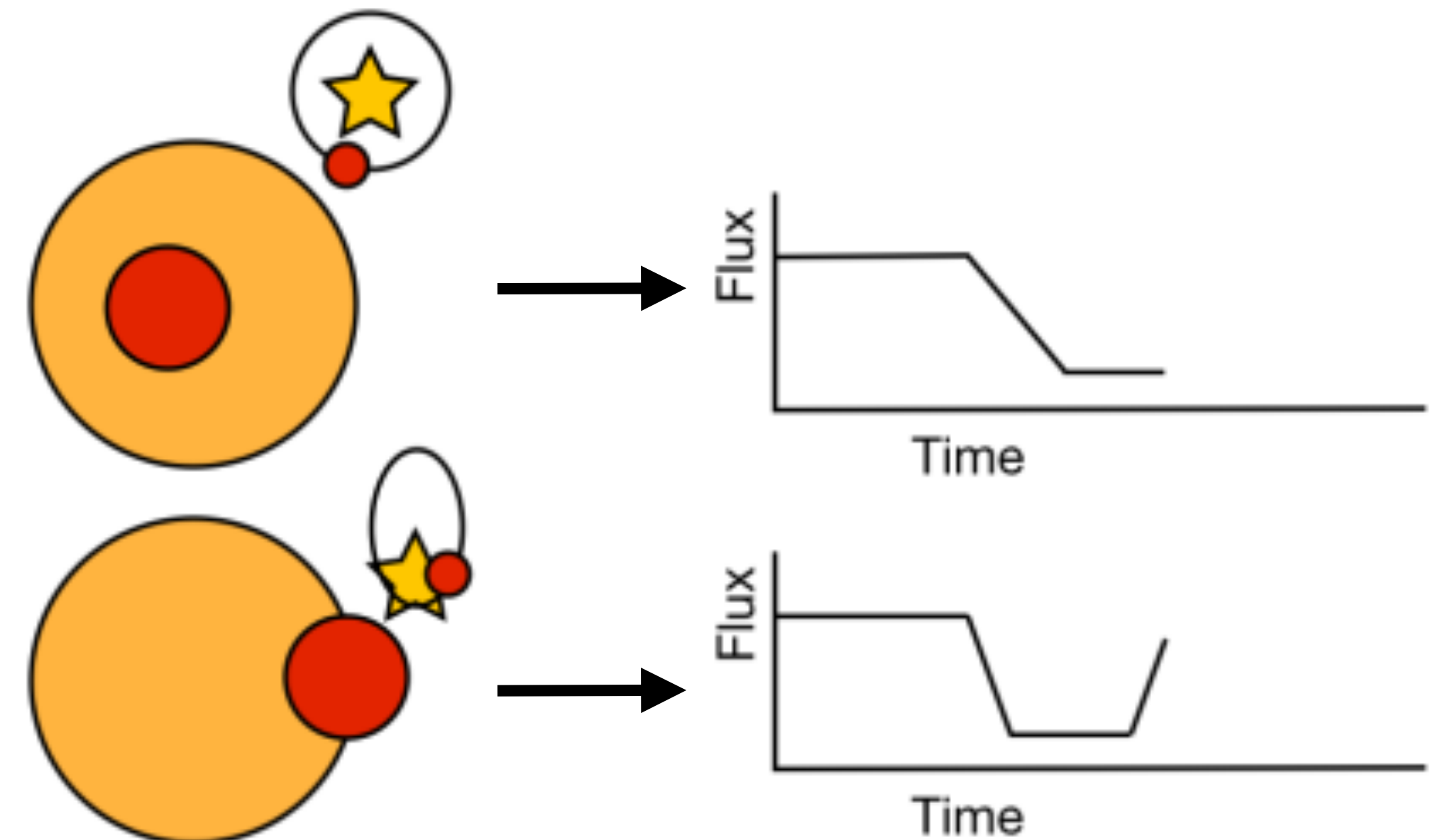
The problem: Transit light curves are abundant, but not well-suited for drawing out precise dynamical information.

We take advantage of the abundance of data by combining individual, **imprecise** dynamical measurements to come to a demographic conclusion.

The orbital eccentricity distribution for M dwarf planets

We can indirectly measure eccentricities by measuring the velocity of the transiting planet via the transit duration. (Dawson & Johnson 2012)

Measuring eccentricity from photometry: the “Photoeccentric Effect”



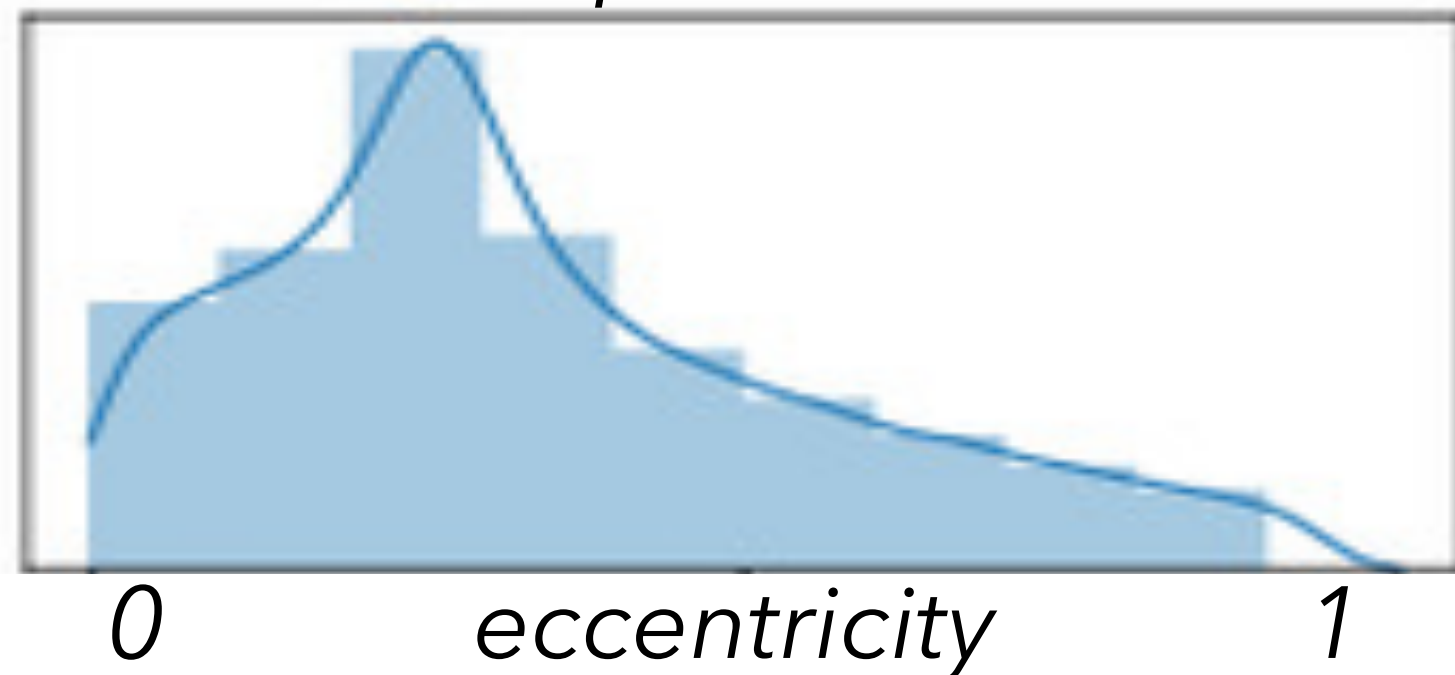
Credit: Rebecca Dawson

The orbital eccentricity distribution for M dwarf planets

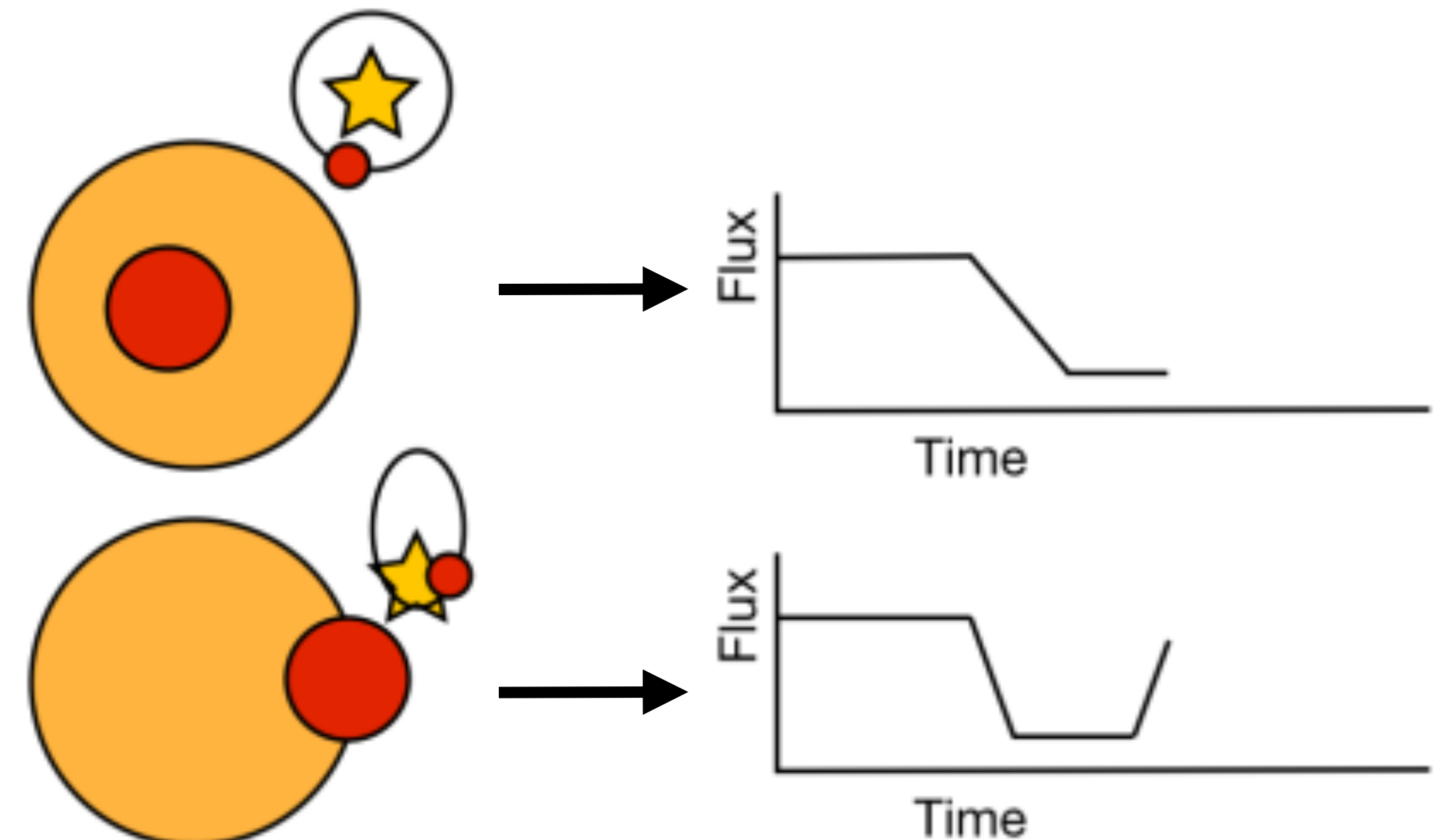
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The "photoeccentric effect" gives us poorly constrained individual eccentricity posteriors, but a lot of them.

Sagear & Ballard 23 Kepler-42b



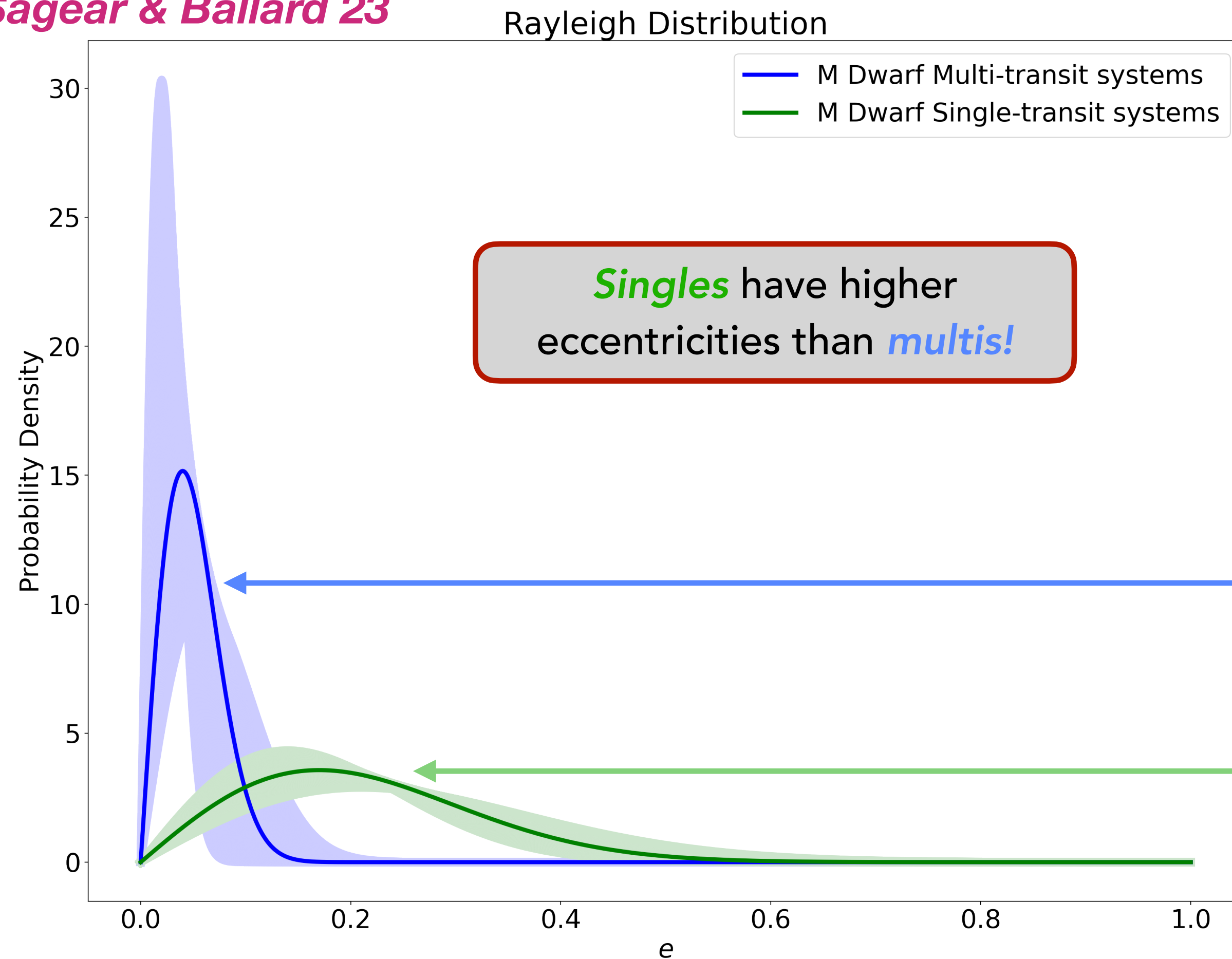
Measuring eccentricity from photometry: the "Photoeccentric Effect"



Credit: Rebecca Dawson

The orbital eccentricity distribution for M dwarf planets

Sagear & Ballard 23



Singles and *Multis* could have formed and evolved differently.

Singles may be victims of planet-planet scattering or other orbital perturbations.

Eccentricity distribution for multi-transit systems

Eccentricity distribution for single-transit systems

The eccentricity–radius relation for M dwarf planets

How do planetary cores and atmospheres evolve?

How do planets interact with their neighbors?

The eccentricity–radius relation for M dwarf planets

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How do planets interact with their neighbors?

Different late-stage planet evolution mechanisms may imprint differently on eccentricities.

For example...

- *Giant impacts* may excite eccentricity
- *Disk-driven migration, inelastic mergers* may quench eccentricity
- Mass-loss driven by stellar luminosity (e.g. *photoevaporation*) may preserve eccentricity at birth

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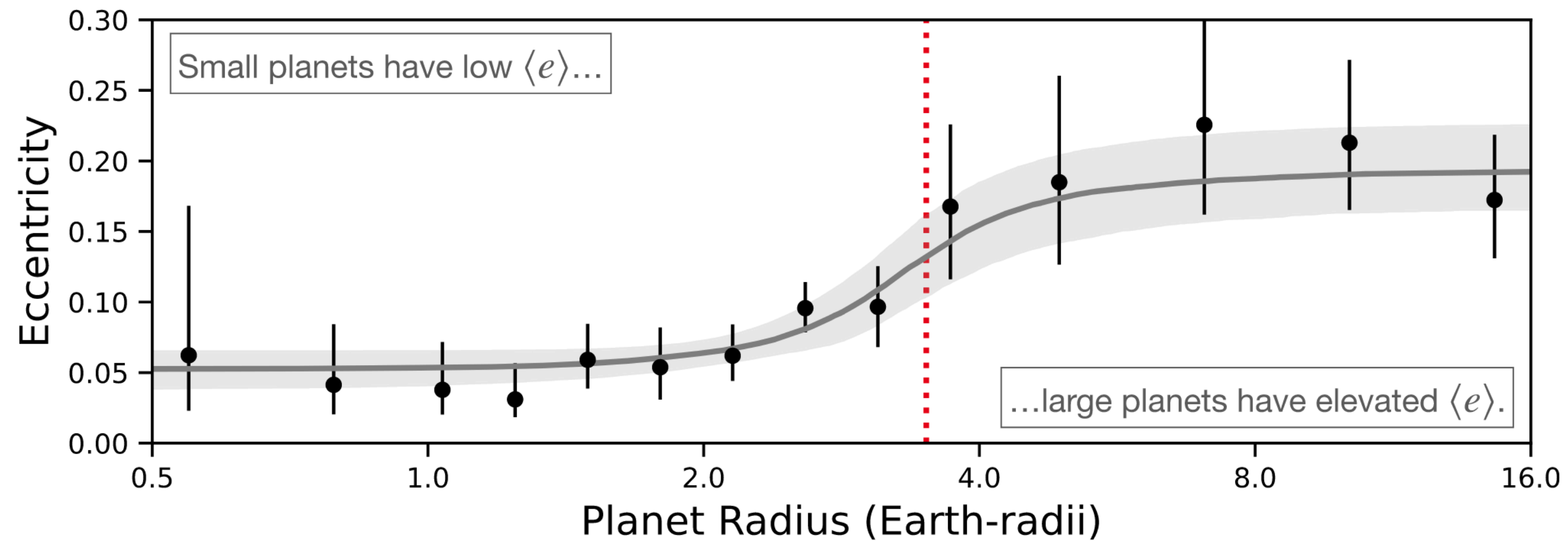
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*Which late-stage evolution mechanisms are dominant for **M dwarf planets**?*

We investigate this by looking at the eccentricity—planet radius relation.

The eccentricity–radius relation for M dwarf planets

Gilbert+ 25: Large planets orbiting *Sun-like stars* have elevated orbital eccentricities.



What about planets around M dwarfs?

The eccentricity–radius relation for M dwarf planets

Kepler transit light curves

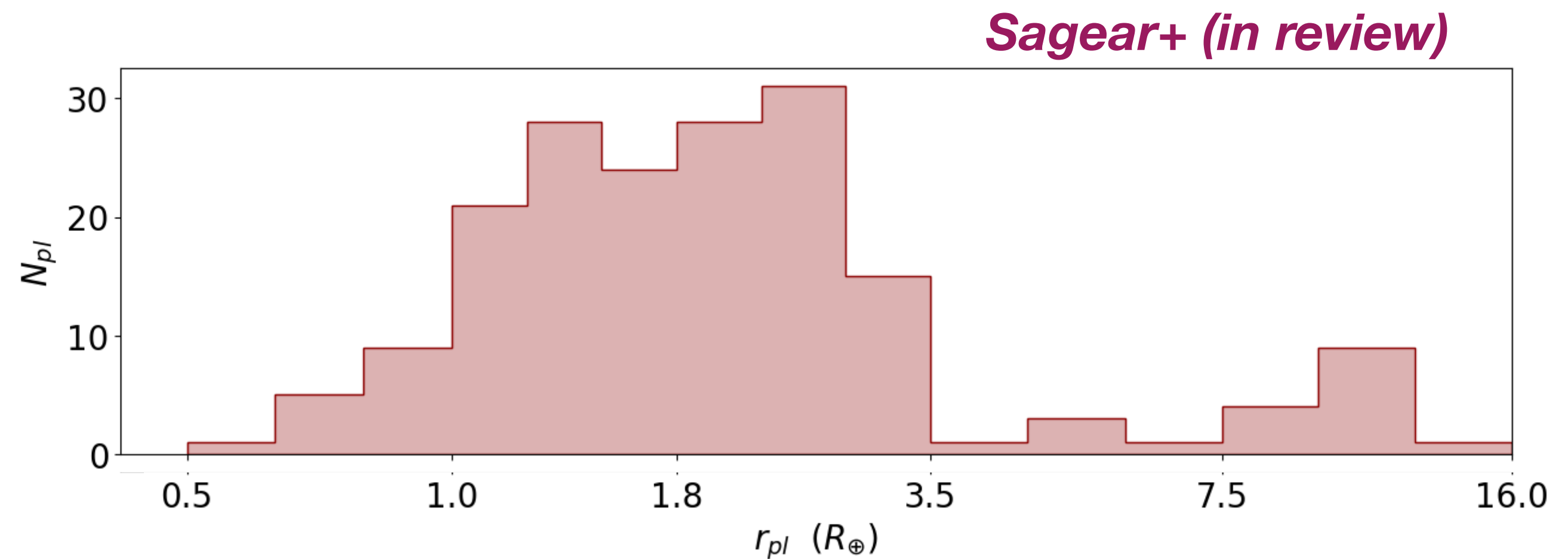
+ *TESS transit light curves*

The eccentricity–radius relation for M dwarf planets

Kepler transit light curves

+ *TESS* transit light curves

**Large planets orbiting M
dwarfs are rare...**



The eccentricity–radius relation for M dwarf planets

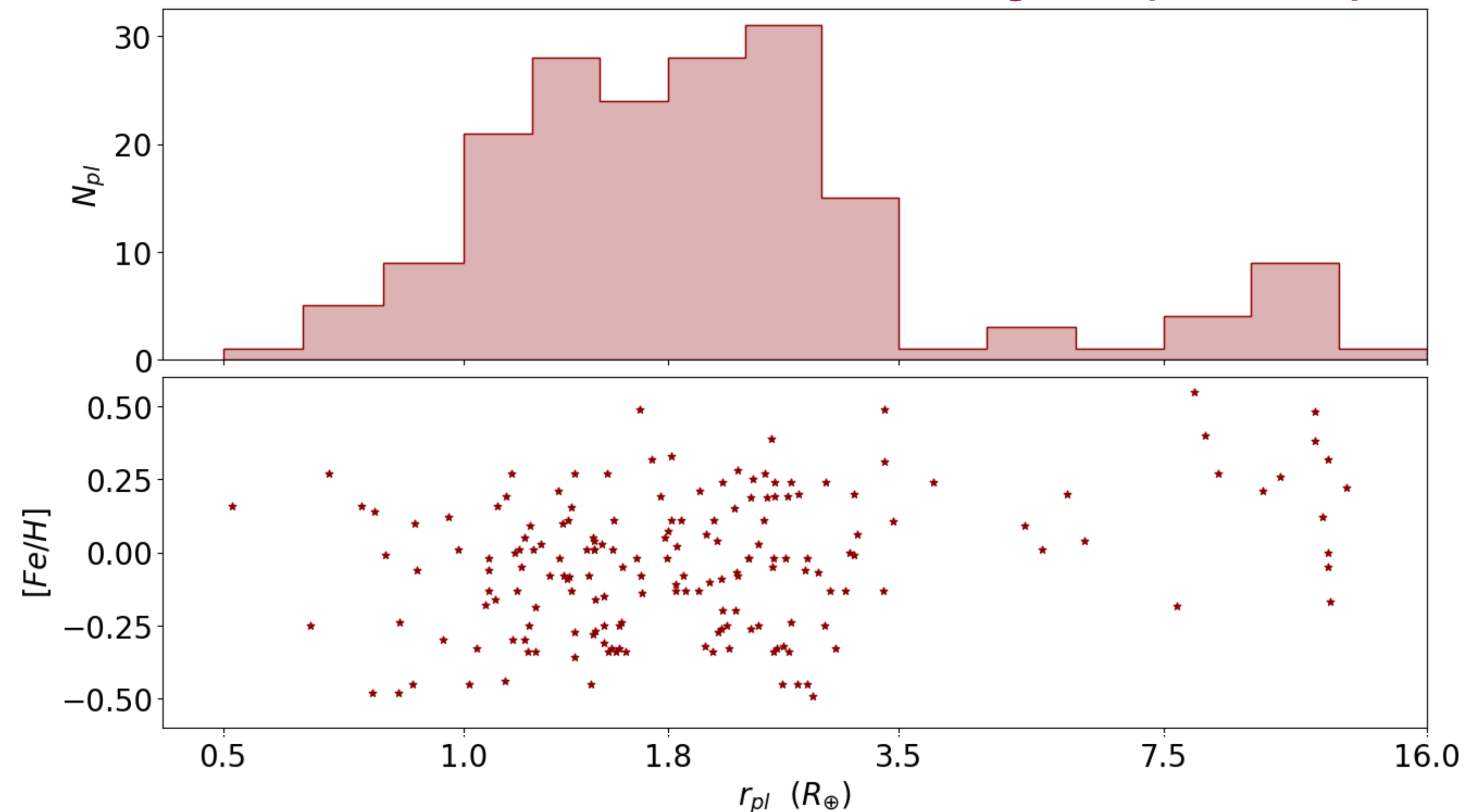
Kepler transit light curves

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Large planets orbiting M dwarfs are rare...

And require higher stellar metallicities.

Sagear+ (in review)



The eccentricity–radius relation for M dwarf planets

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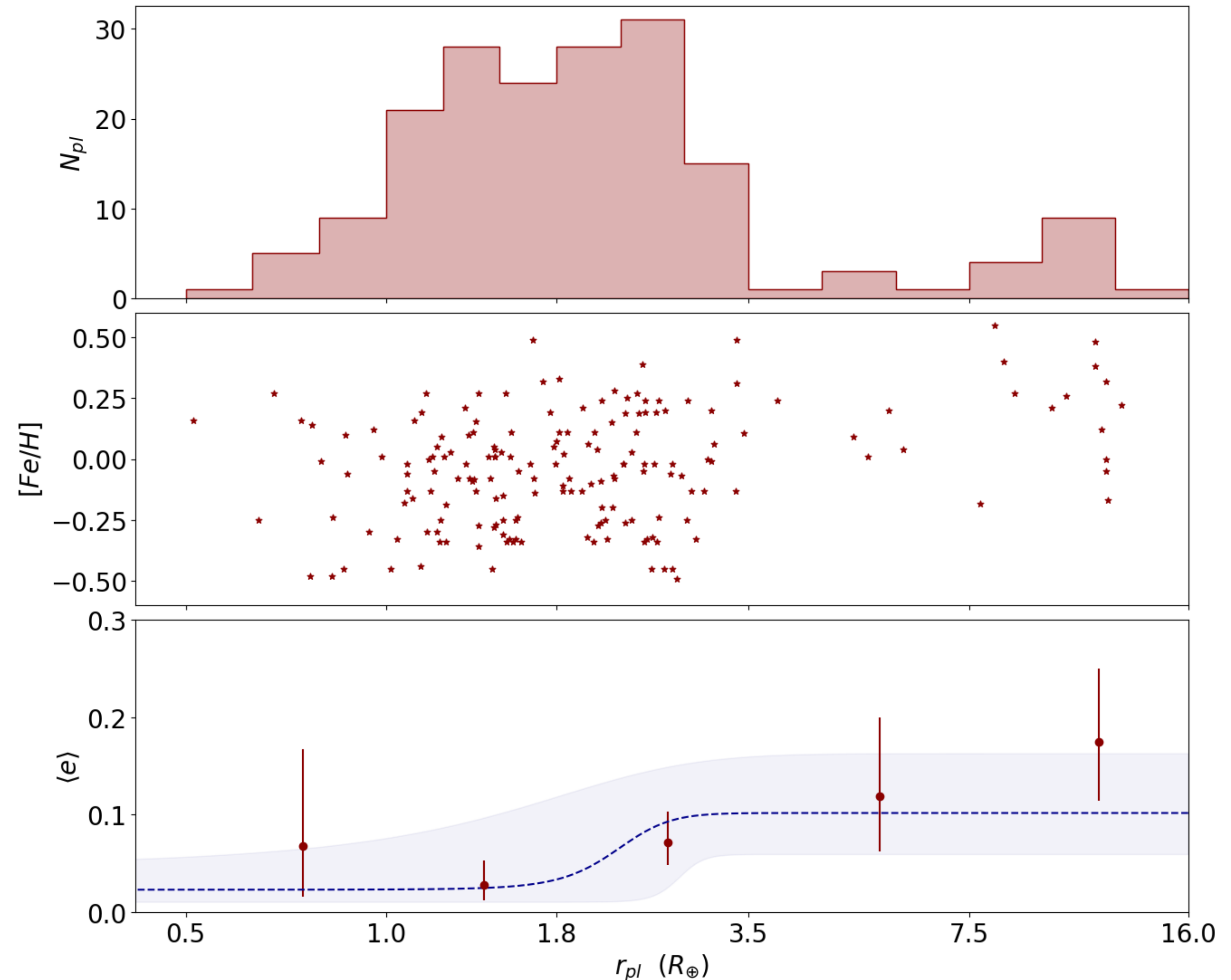
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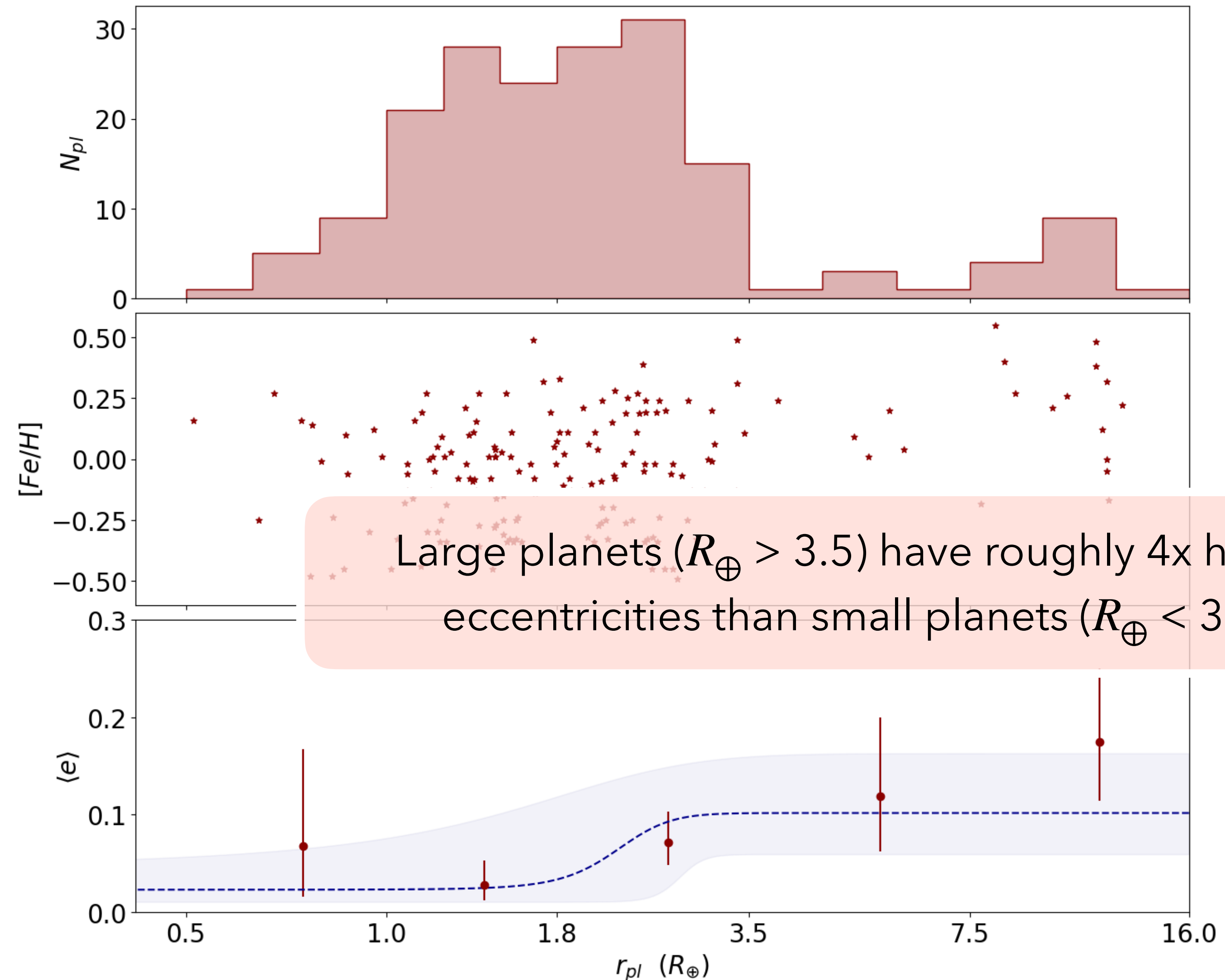
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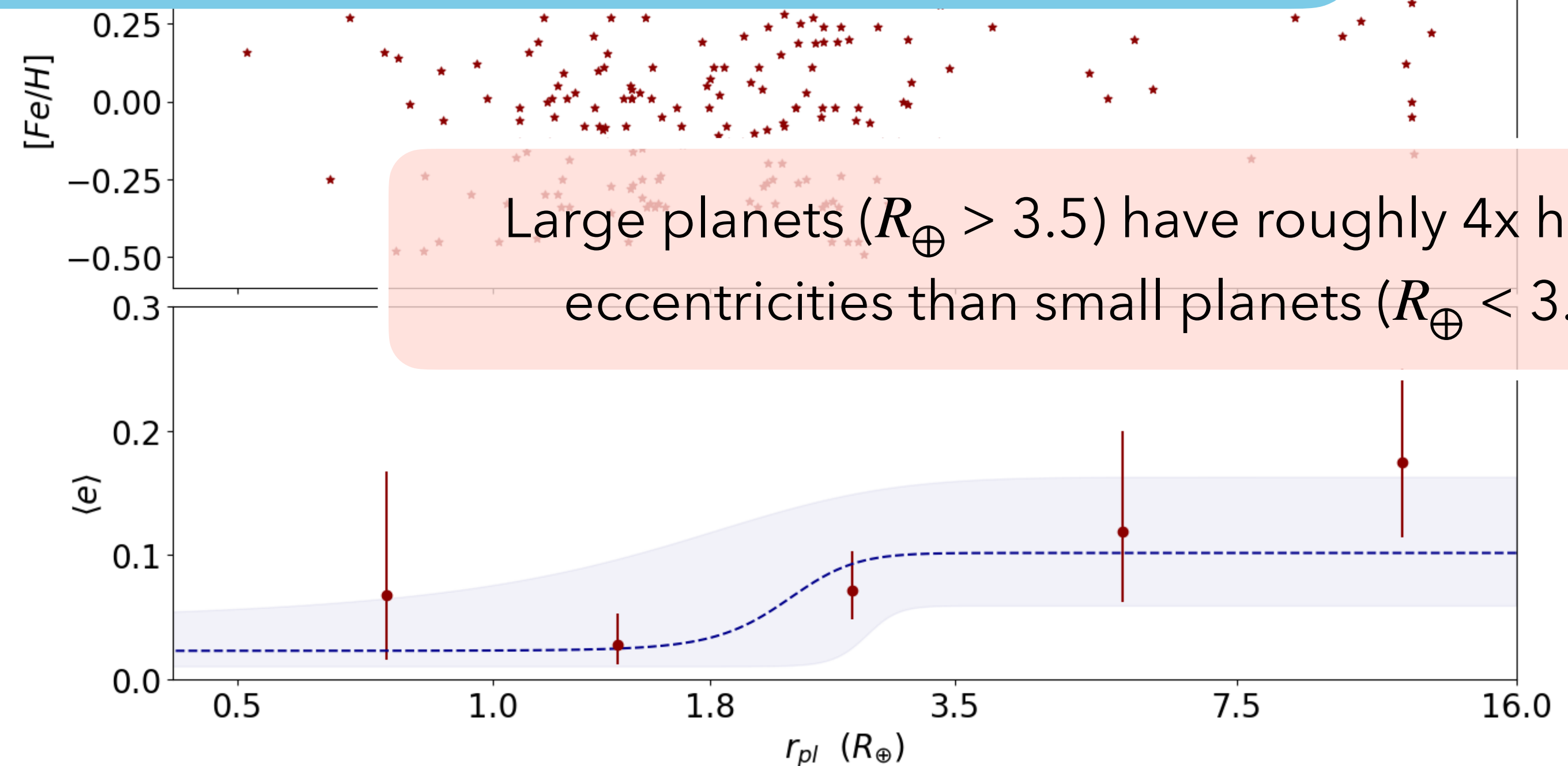
The eccentricity–radius relation for M dwarf planets

Sagear+ (in review)

There is a "break" in the eccentricity–radius relation at $\sim 3.5 R_{\oplus}$ for planets orbiting both **FGK stars** and **M stars**, suggesting two distinct evolutionary pathways for small and large planets.

And require higher stellar metallicities.

They also exhibit higher orbital eccentricities.



Large planets ($R_{\oplus} > 3.5$) have roughly 4x higher eccentricities than small planets ($R_{\oplus} < 3.5$).

The eccentricity–radius relation for M dwarf planets

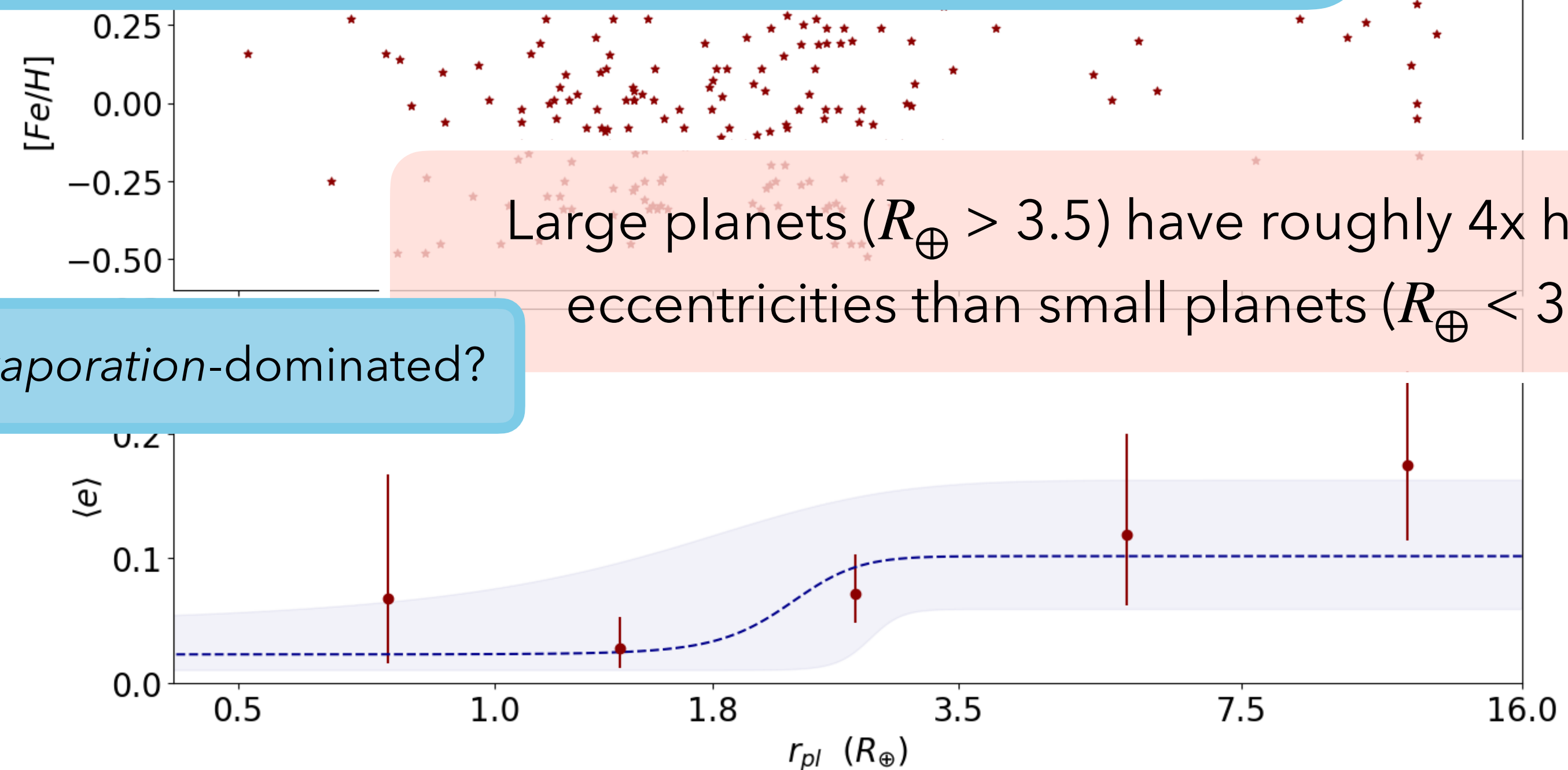
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Photoevaporation-dominated?

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Sagear+ (in review)

Kepler transit light

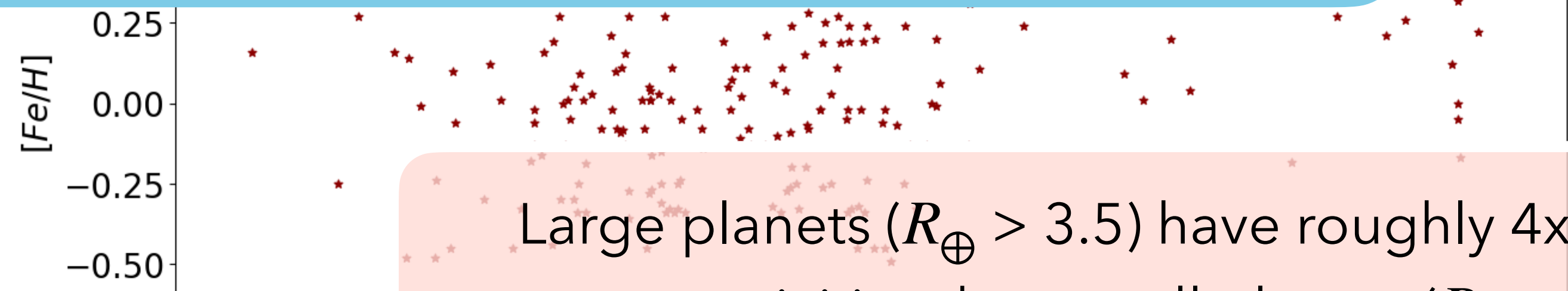
+ TESS tra

Large pla

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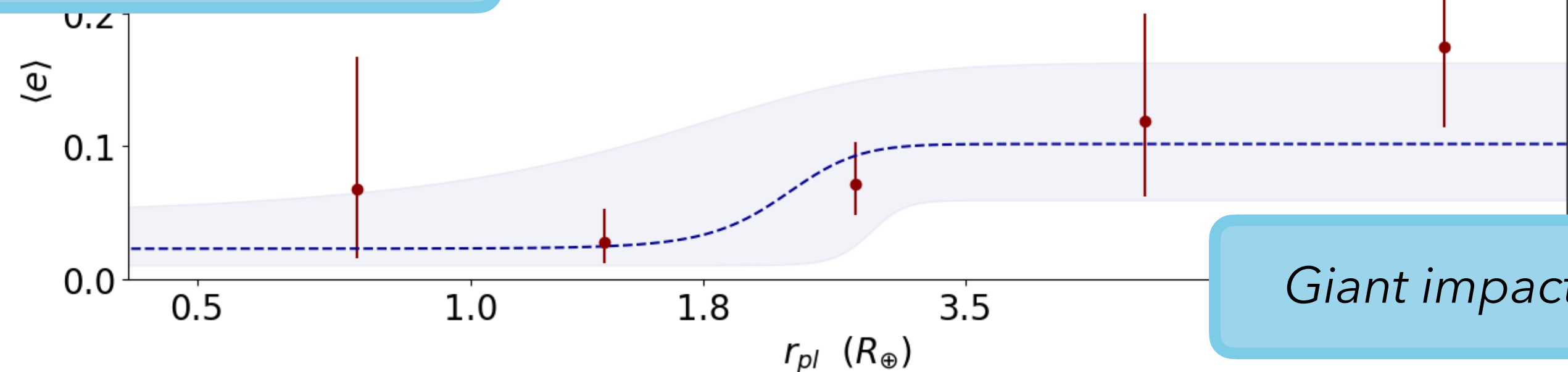
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Giant impact-dominated?

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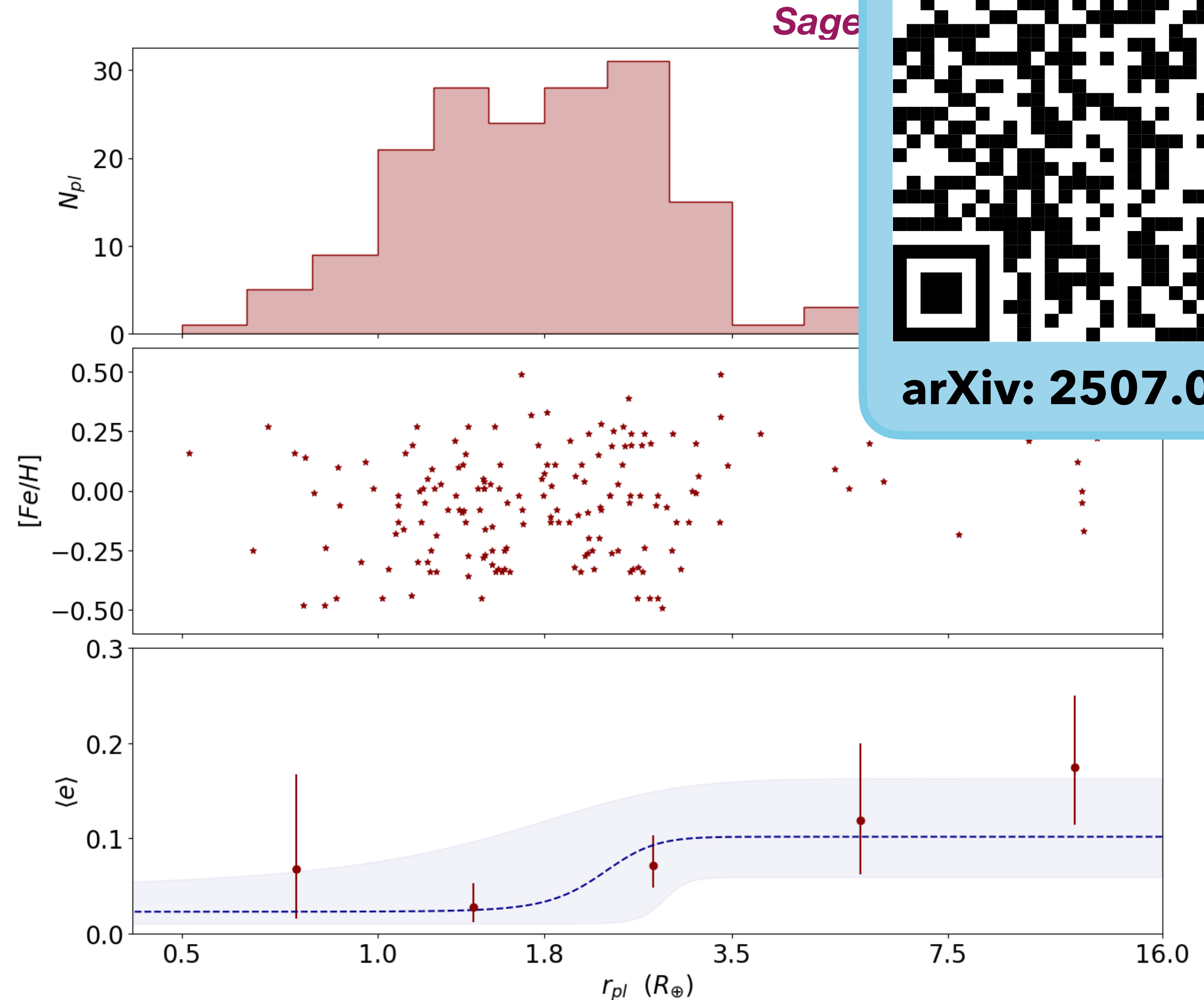
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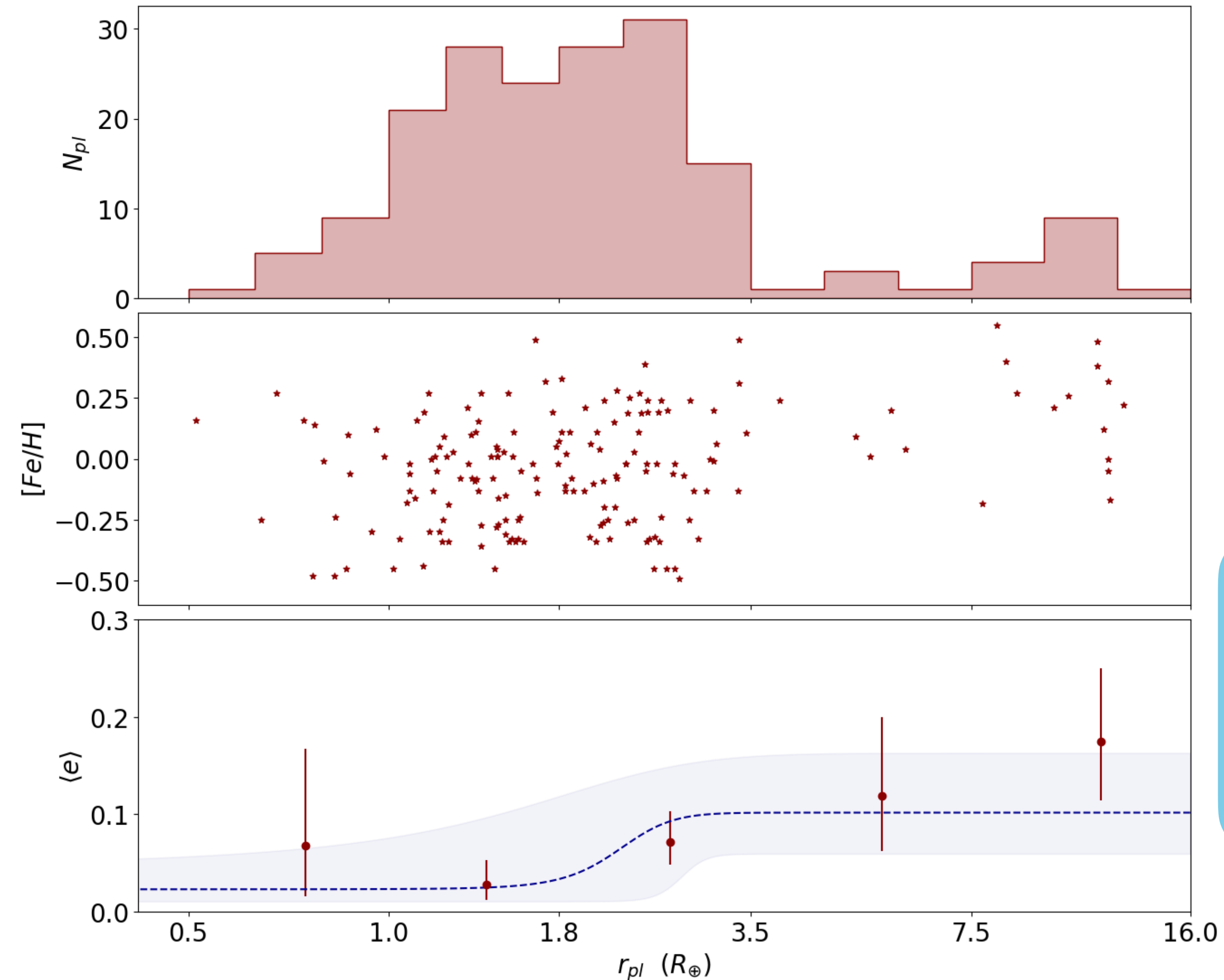
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arXiv: 2507.07169

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