Giant Exoplanets around M dwarf Stars (GEMS)

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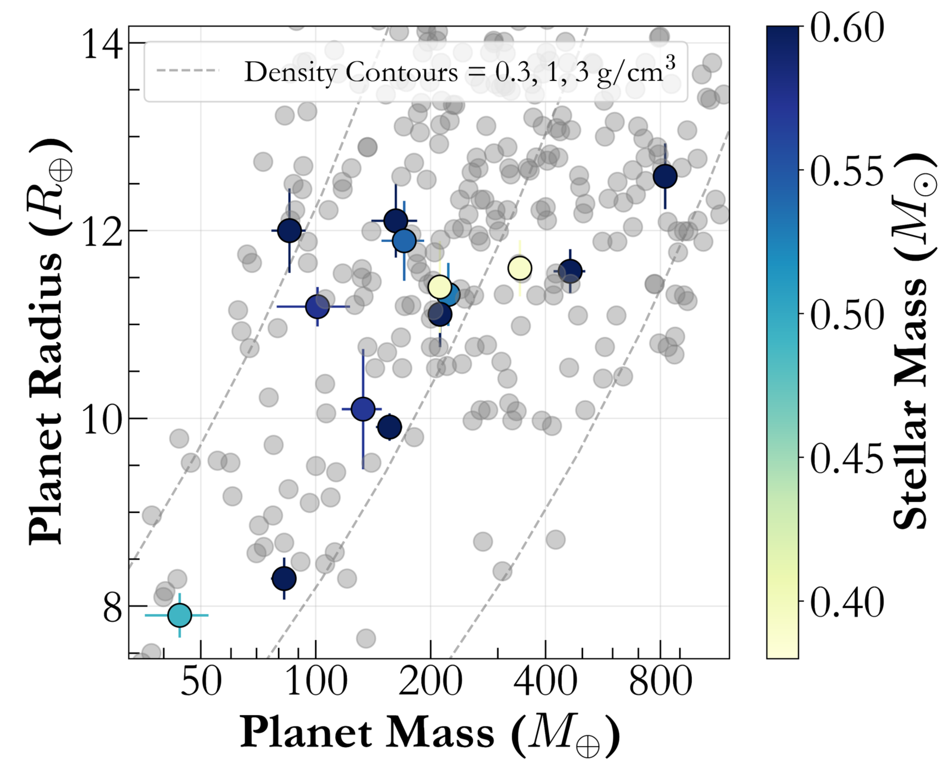
Introduction

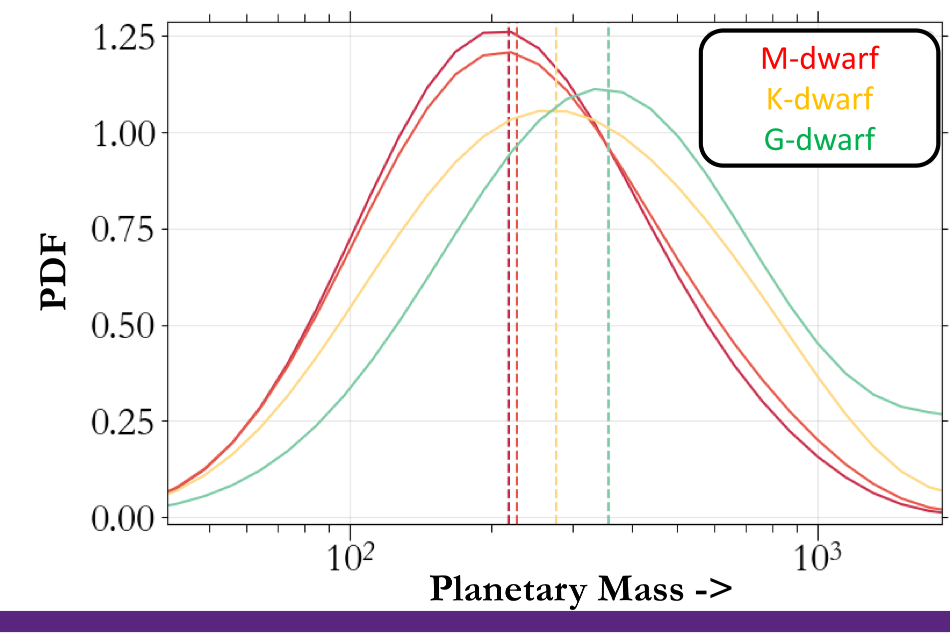
NASA's Transiting Exoplanet Survey Satellite (TESS) is starting to transform our understanding of transiting Giant Exoplanets around M-dwarf Stars (GEMS).

- All-sky survey
- Observing millions of M-dwarfs (including bright ones conducive for additional follow-up)

Currently about 15 confirmed GEMS spanning 80 to 800 Mearth (2.5 MJ) and periods 1.6 to 30 days (Johnson et al. 2012, Hartman et al. 2015, Cañas et al. 2020, 2022, 2023, Kanodia et al. 2022, 2023, Jordan et al. 2022, Hobson et al. 2023, Delamer et al. in prep., Han et al., in prep.)



Using nonparametric multi-variate density estimation (MRExo; Kanodia et al. 2019, in prep.) we see **tentative hints that the M-dwarf Jupiters tend to be lower in mass than those around GK stars.**



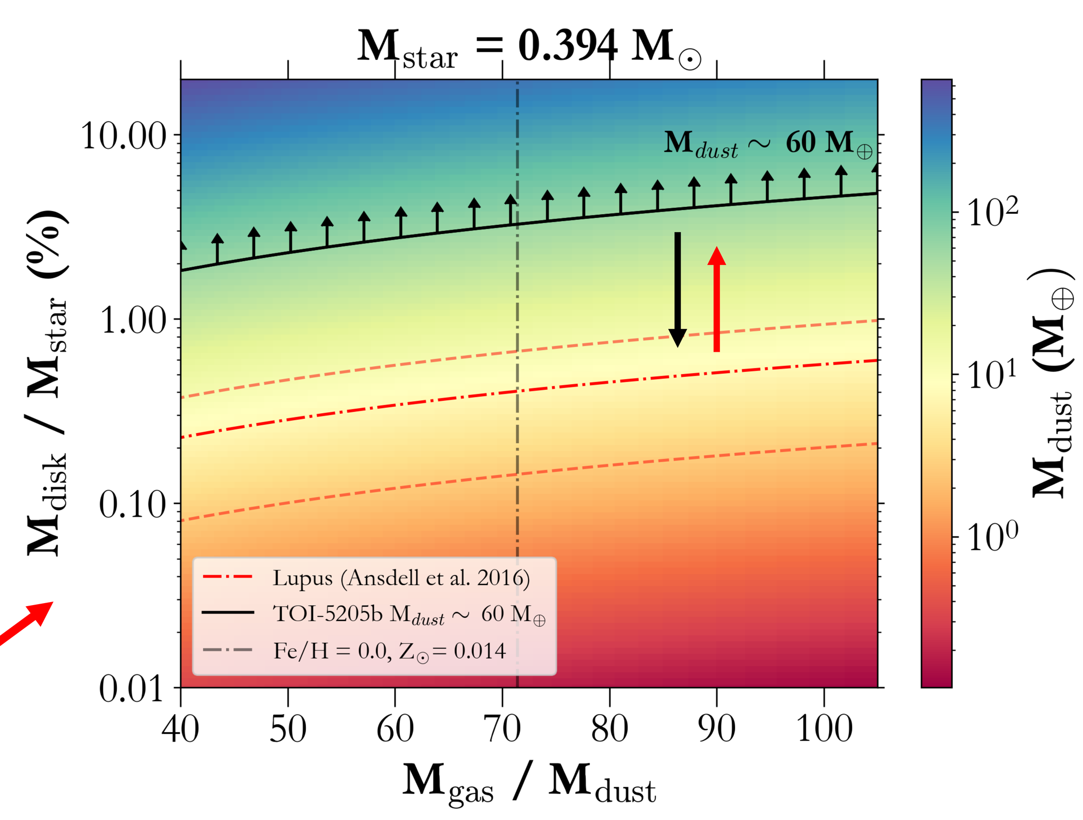
Challenge to Planet Formation

Starting to find transiting Jupiters (TOI-5205 b and TOI-3235 b) around mid-M dwarfs M4V. Interior models predict metal-rich interiors for these short-period Jupiters (Thorngren et al. 2016) with **heavy-element content of about 60 Mearth.**

ALMA observations for **Class 2 disks suggest median disk dust masses of about 10 Mearth** for solar-metallicity mid-M dwarf disks.

Planet formation cannot be 60/10, i.e., 600% efficient! Most efficient pebble-accretion models suggest 10% efficiency.

600/10 ≈ 60x discrepancy !!!



Potential solutions:

- Earlier onset of planet formation --- Class 0 and 1 disks --- would enhance available dust masses by 10x (Mulders et al. 2021, Tychoniec et al. 2020).
- Underestimation of disk dust masses (Liu et al. 2022).
- Gravitational Instability as a formation pathway (Boss et al. 2006).
- Less metal-rich planetary interiors.

Need more planets to compare to enable estimating occurrence rates.

Compare occurrence rates to protoplanetary disk dust mass posteriors.

Giant Exoplanets around M-dwarf Stars Survey

$R_p > 8\ R_\oplus$

* - Estimated

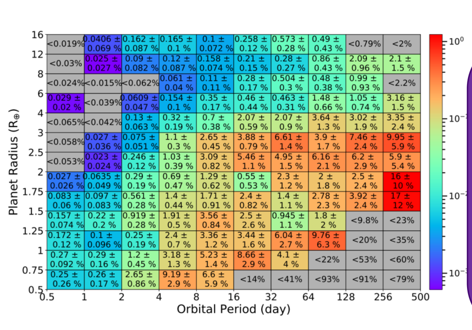
1,000,000 M dwarfs (J < 14)

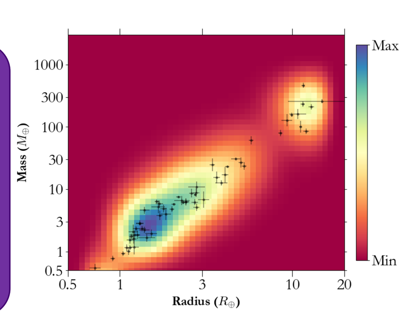
- ~ 100* Astrophysical False Positives → Brown Dwarfs; Eclipsing Binaries
- ~ 100* Transiting Planets — Occurrence Rate* (0.2%) x Transit Probability* (5%)

Keck Planet Finder · HPF · NEID · PFS · MAROON-X

> 40* Transiting Gas Giants w/ RV Masses

- Connection to Disks (ALMA)
- Atmospheric Characterization (Webb Space Telescope, Ariel)
- Occurrence Rates
  - Dependence on St. Mass
  - Dependence on St. Metallicity
  - Dependence on Period
- MRExo: Pl. Mass + Pl. Radius + Insolation + Stellar Mass + Fe/H





Conclusion

What we will have at the end of the GEMS survey?

1. About 100 validated transiting giant planets around M-dwarfs.
2. 40 transiting giants with mass measurements (3x current sample).
3. Occurrence rates for these planets as a function of stellar and orbital properties.
4. Comparison with FGK gas giants using multi-dimensional MRExo framework.
5. In time for astrometric detections from GAIA DR4 and ARIEL.

Open Questions to be addressed

1. Reliable M-dwarf disk (especially structured ones) dust mass estimates (accounting for varying opacity, disk structure, UV environment)
2. Robust M-dwarf metallicity estimation.
3. Better estimates of bulk-composition of these planets. Perhaps utilizing information about their atmospheric composition (Müller and Helled 2021, 2022).

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