ESPRESSO characterizes the small transiting exoplanet population with extreme precision radial velocities

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With Baptiste Lavie, François Bouchy, Christophe Lovis, and the ESPRESSO GTO consortium

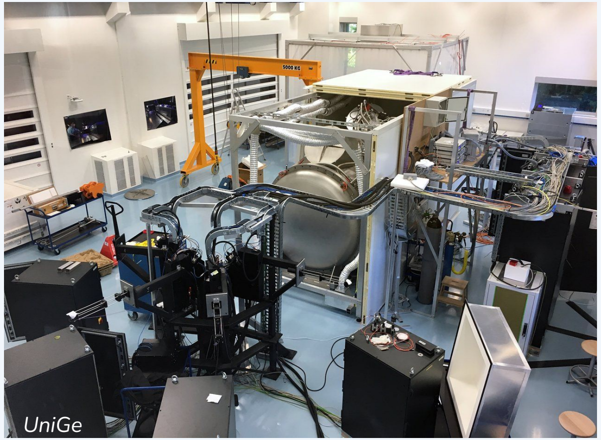
Observatoire de Genève Fondé en 1772 · PlanetS · Fonds national suisse · IPAG · UGA Université Grenoble Alpes · McMaster University

Outline

- The ESPRESSO transiting planet follow-up
- Rocky to volatile-rich transition
- Planetary mass vs stellar metallicity
- Protoplanetary disk mass vs planet mass
- Observing strategy
- Stellar activity

Transit follow-up with ESPRESSO

- Echelle SPectrograph for Rocky Exoplanets and Stable Spectroscopic Observations
- Very Large Telescope, Chile
- Ultra-stable, high-SN, extremely precise RVs and activity indicators
- Part of the ESPRESSO Guaranteed Time Observations
  - ESPRESSO GTO: 273 UT nights over periods 102-111 (2018-2023)
  - Working Group 3: small transiting candidates follow-up



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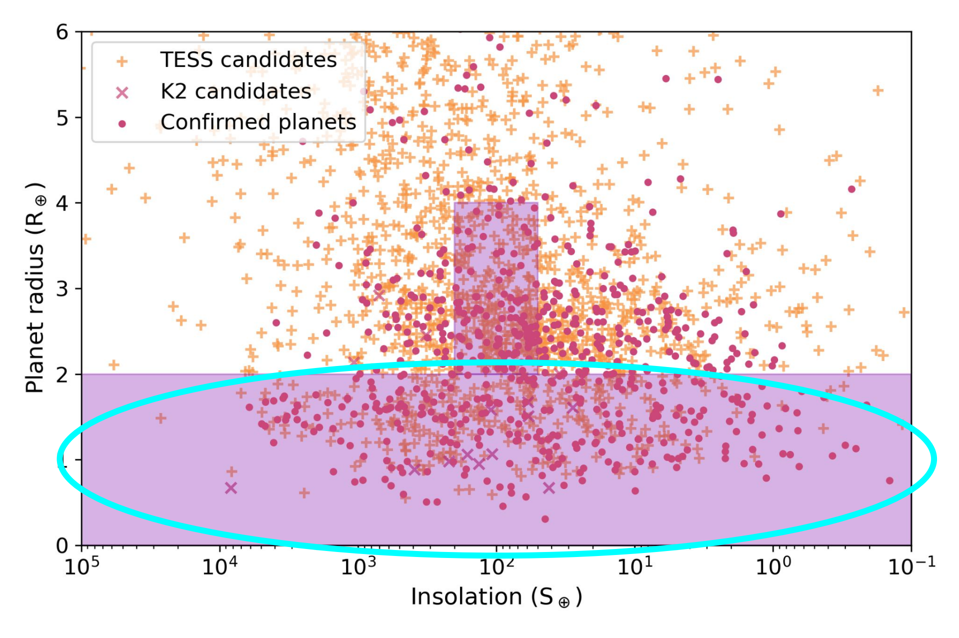
Sample selection

Two main objectives:

- ❖ Characterize the smallest candidates with Rp ≲ 2 $R_\oplus$



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- ❖ Probe the rocky-to-gaseous transition for candidates with:
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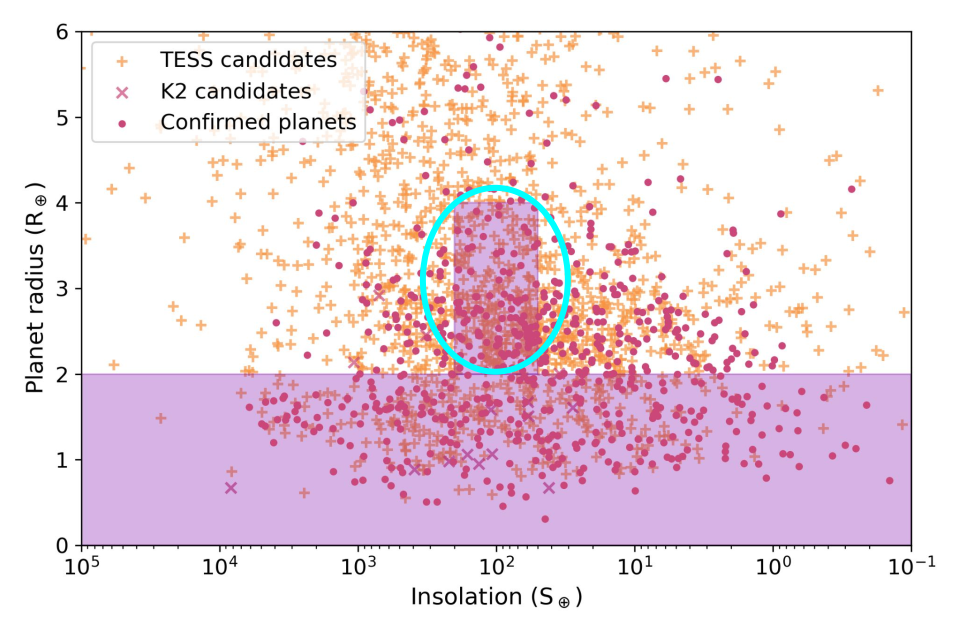
  - ➢ $50\ S_\oplus \lesssim S_p \lesssim 200\ S_\oplus$



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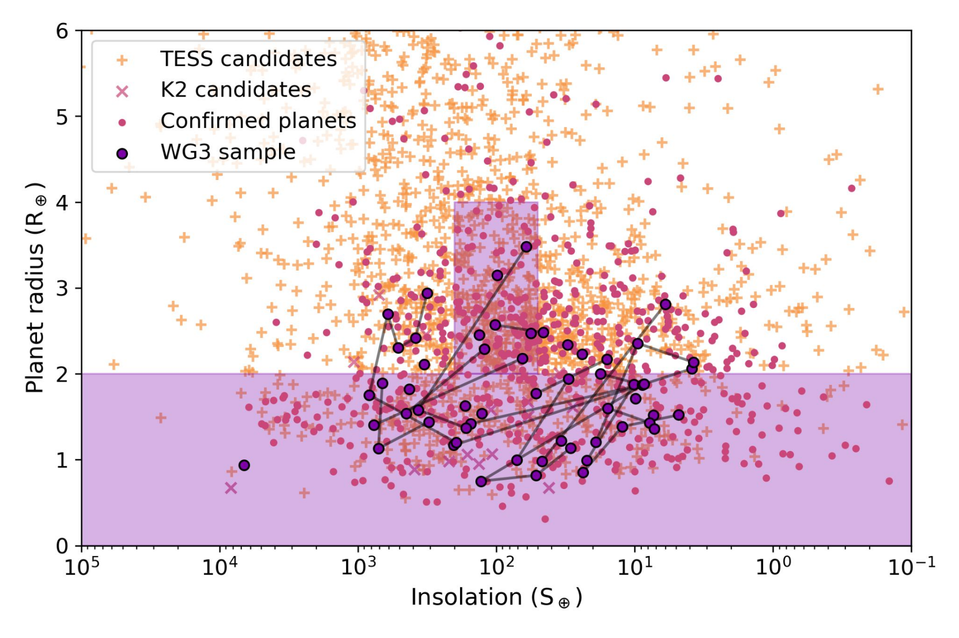
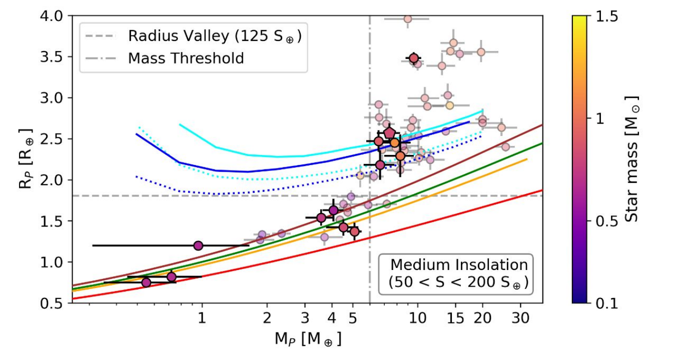
  - ➢ 50 $S_\oplus \lesssim S_p \lesssim 200 S_\oplus$
- ❖ 65 planets in 30 systems characterized



Rocky-to-volatile?

- $50\ S_\oplus \lesssim S_p \lesssim 200\ S_\oplus$ insolation regime:
  - Possible transition threshold at ~ 6 $M_\oplus$



Solid points: ESPRESSO WG3
Transparent: PlanetS catalogue
(Parc et al. 2024)

Rocky-to-volatile?

❖ High-insolation:

➢ Population overlap : Irradiation + host star

➢ Low-mass volatile-rich planets orbit low-mass stars

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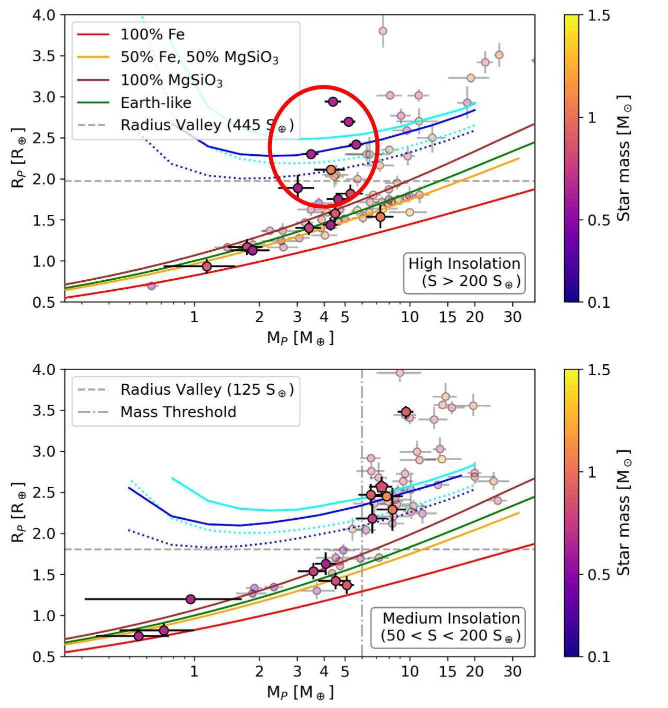

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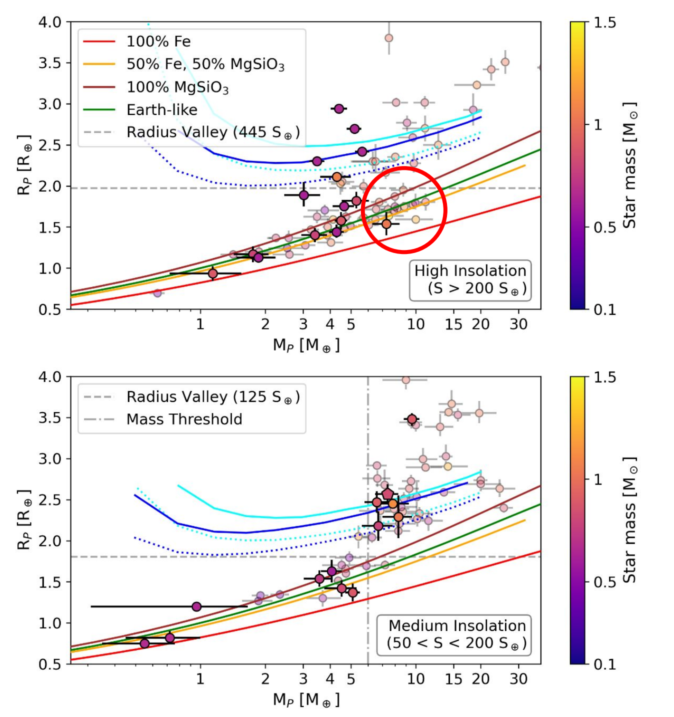

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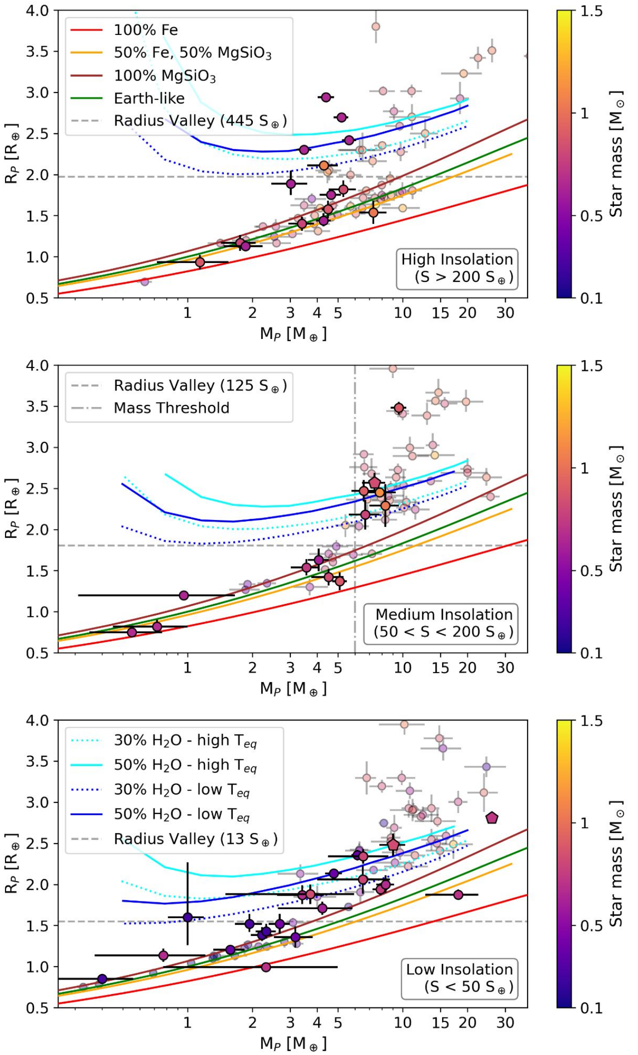
❖ Low-insolation:

➢ No clear threshold

➢ Host star effect: 50% hosted by M dwarfs



Planet mass and stellar metallicity

- Strong giant planet occurrence - metallicity correlation, weak small planet occurrence - metallicity correlation
  - Large planets require more solids
- Does small planets' mass correlate with stellar metallicity?

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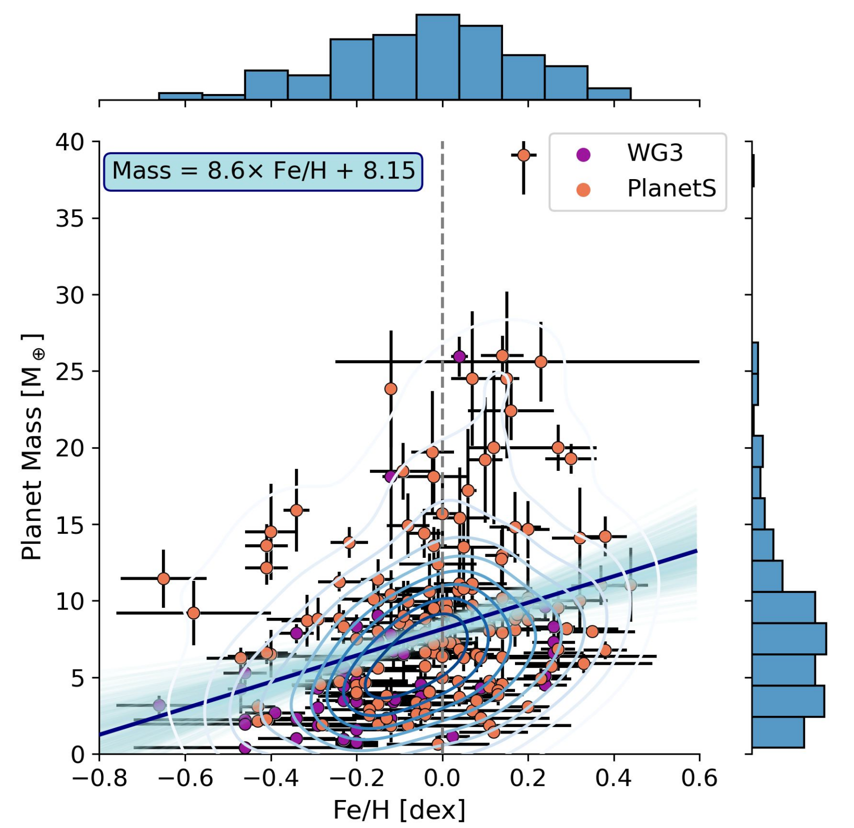
  - ➢ Large planets require more solids
- ❖ Does small planets' mass correlate with stellar metallicity?
  - ➢ Yes!
- ❖ Lack of planets at low metallicities
- ❖ Drop-off at high metallicities
  - ➢ Inhibited by giant planets

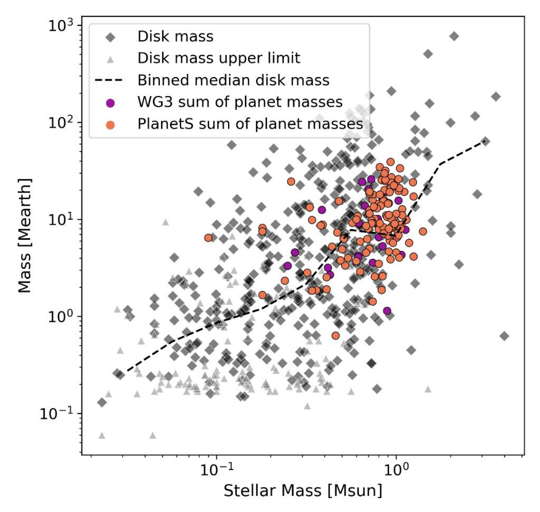


Protoplanetary disks

❖ How do planet masses compare to disk masses?

➢ Planet masses: WG3, Parc. et al (2024)

➢ Class II disk masses: Manara et al. (2023)



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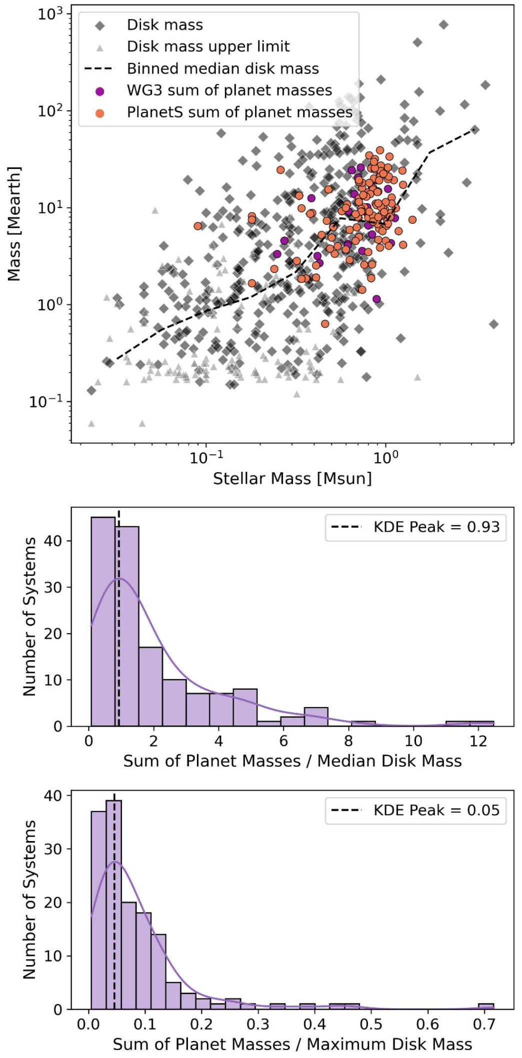
➢ ~5% of maximum disk mass



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- Sum of planet masses:
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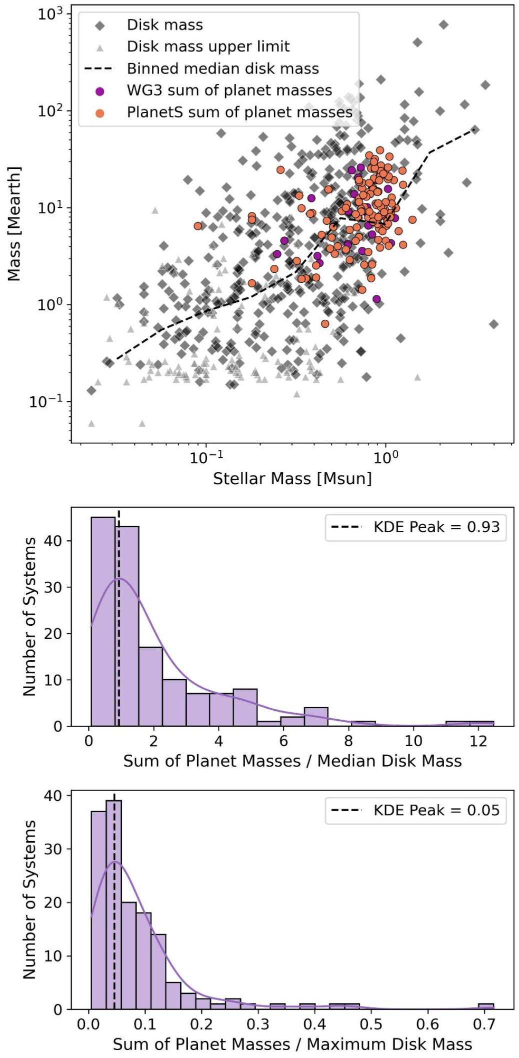
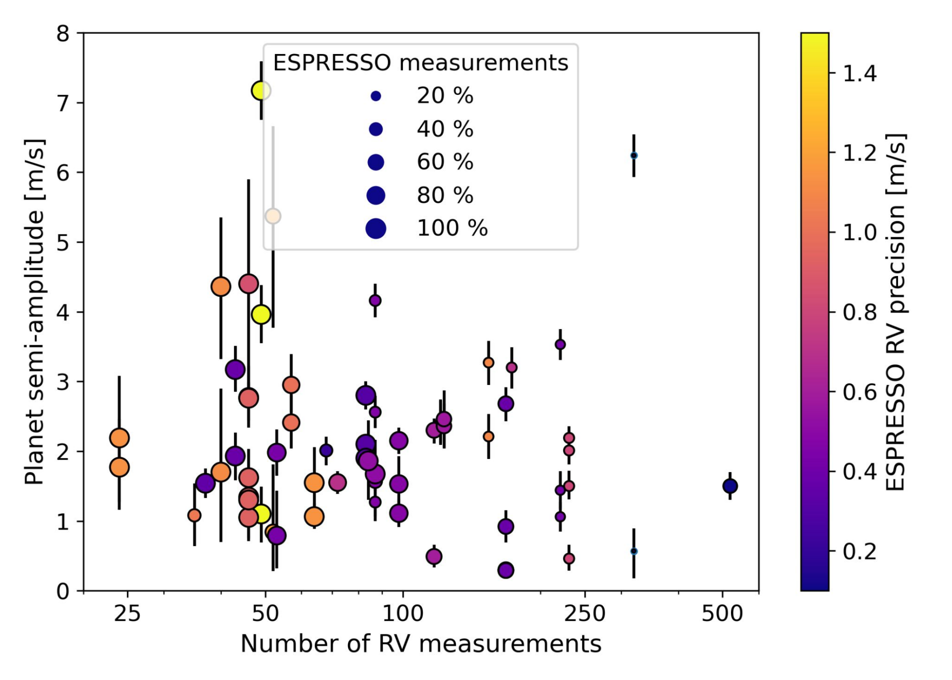
  - ~5% of maximum disk mass
- Planets must form:
  - With high efficiency
  - In massive disks
  - Earlier in the disk's lifetime



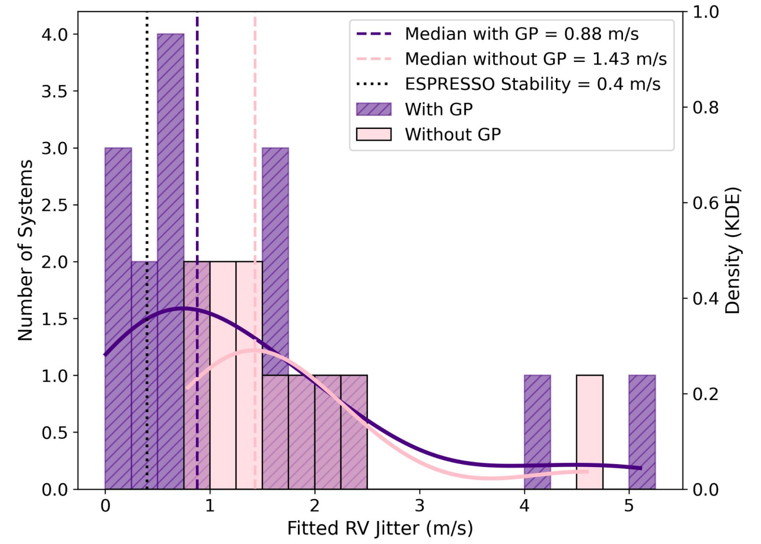
Observing strategy impact

- ❖ Non-uniform, prioritized by:
  - ➢ Emerging RV signals
  - ➢ RV precision
  - ➢ Activity level
- ❖ 50-100 points needed for sub-m/s
- ❖ Collaboration with other surveys vital for large datasets!



Stellar activity impact

- Stellar activity modelling
  - 18/30 systems have GP modelling
  - Adding a GP decreases the residual RV jitter
    - With GP, median RV jitter ~ 88 cm/s → well above ESPRESSO's 40 cm/s long-term precision
    - Significant RV variation remains unaccounted for



Conclusions

- The ESPRESSO transit follow-up has precisely characterised a wide range of planets
- A potential threshold mass between rocky and volatile-rich planets
- More metal-rich stars host more massive planets
- Planetary masses are comparable to the median disk masses
  - Formation implications
- Impact of the observing strategy can inform future surveys
- Stellar activity still impacts the RVs, despite GP modelling
- Paper on arXiv last month: https://arxiv.org/abs/2605.27002