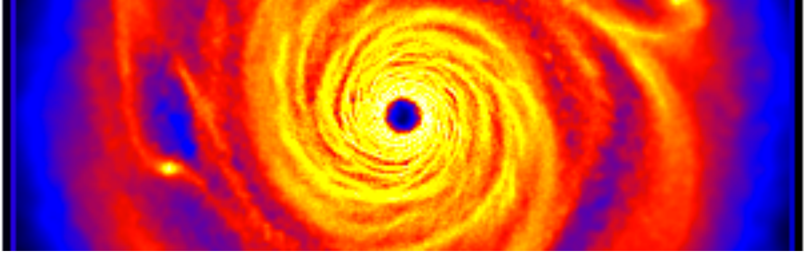


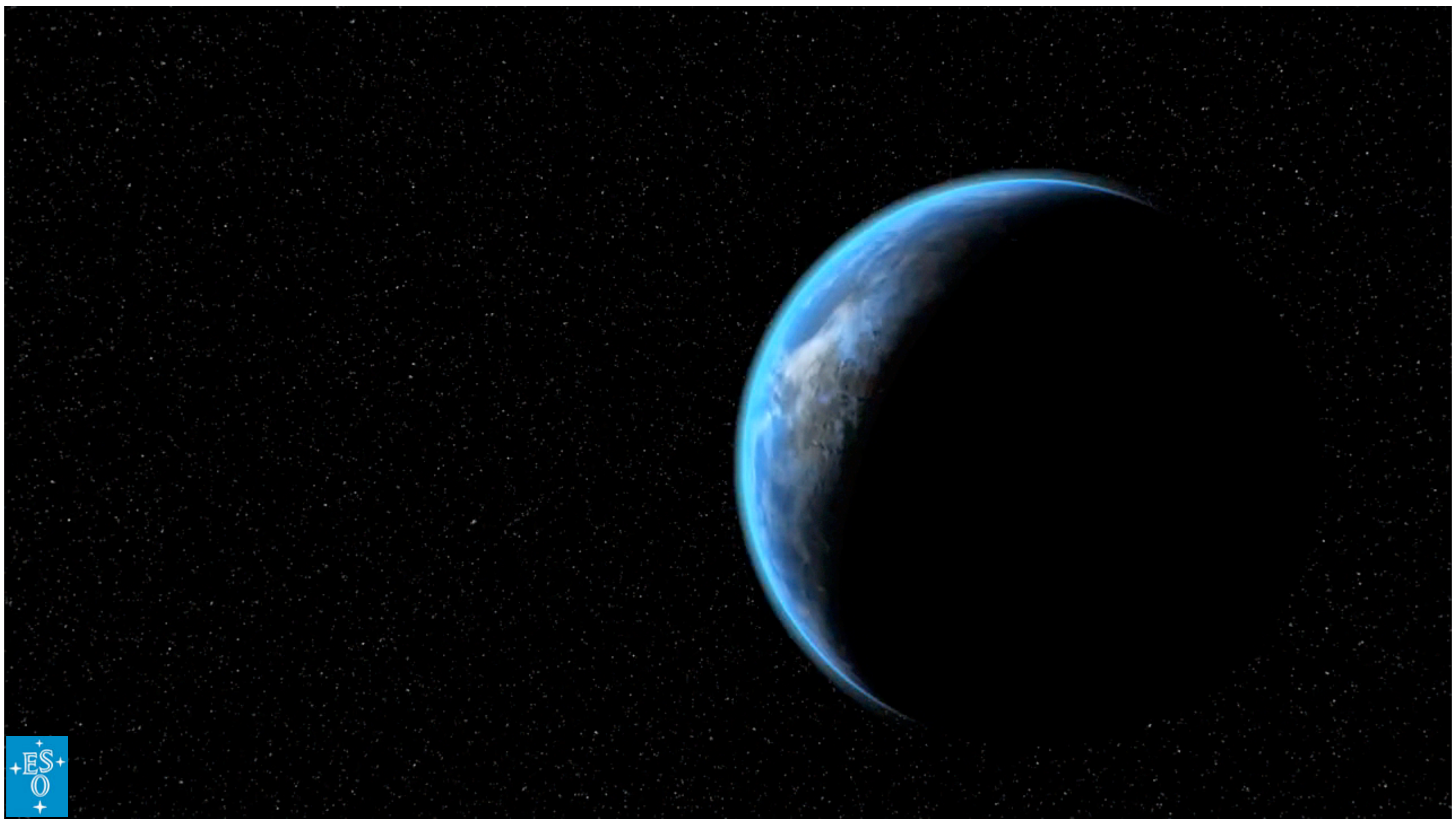
1st ITA - MPIA/Heidelberg - IPAG Colloquium

"Signs of planetary formation and evolution"

8-9 Oct 2012 Grenoble (France)

SEARCH FOR PLANETS ORBITING M DWARFS

STATUS AND PROSPECTS



IPAG
Institut de Planétologie et d'Astrophysique de Grenoble

cnrs
dépasser les frontières

Université Joseph Fourier
Grenoble 1
Sciences. Technologie. Santé

M-DWARF FRIENDS @IPAG :

X. BONFILS, X. DELFOSSE, T. FORVEILLE, C. PERRIER, V. NEVES

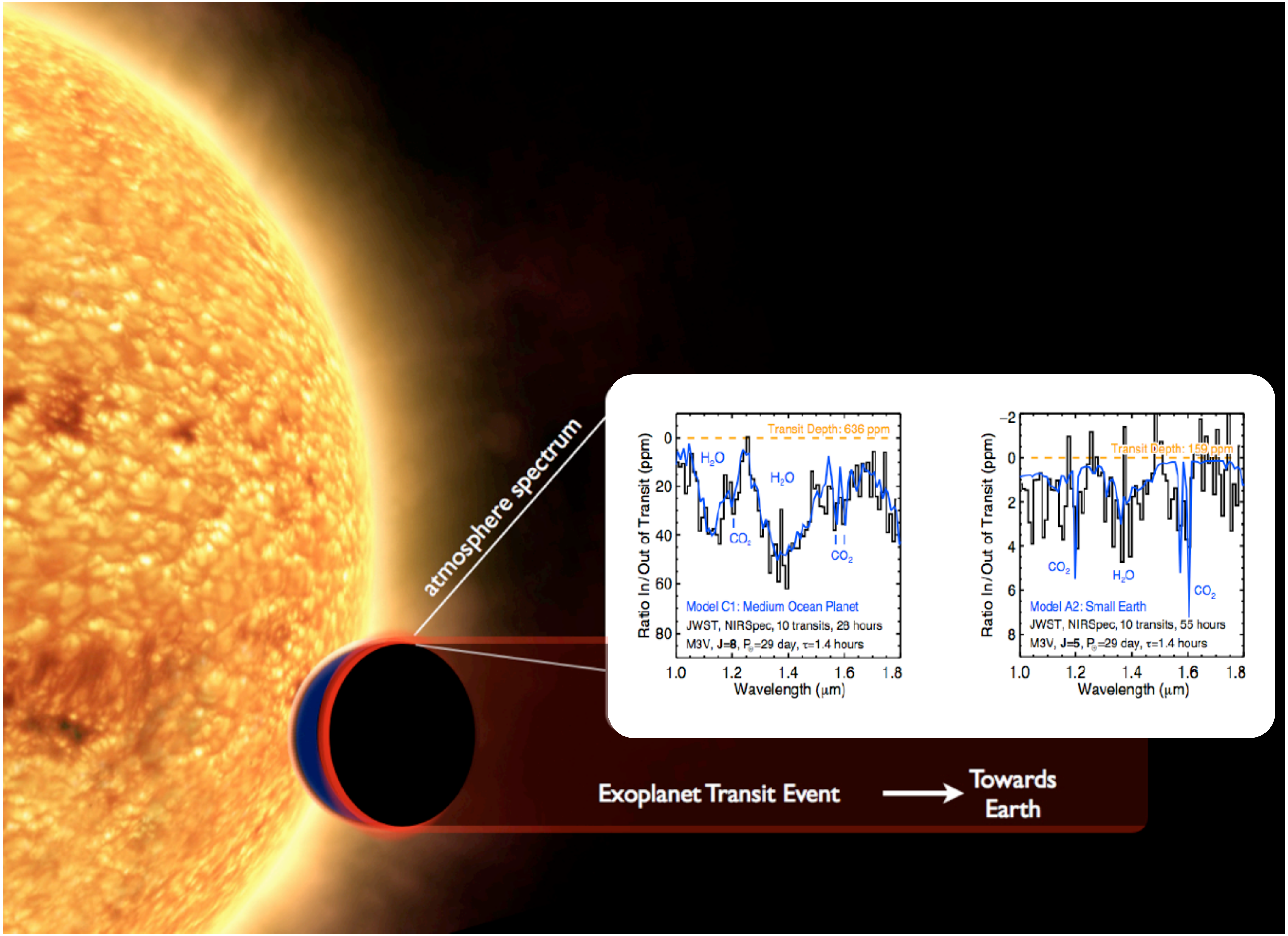
WHAT DO EXOPLANET SEARCHES WANT ?

- UNDERSTAND PLANET FORMATION,
- PLANET PHYSICO-CHEMISTRY, AND
- ORIGIN OF LIFE

PRACTICALLY :

- MANY (DIVERSE) PLANETS
- HABITABLE EARTH-LIKE PLANETS

The shortest route to an exo-Life laboratory ?



OUTLINE

1. STATUS OF DISCOVERIES
   FOR M-DWARF PLANETS

2. OCCURRENCE OF PLANETS

3. SO… HOW MANY TARGETS ?

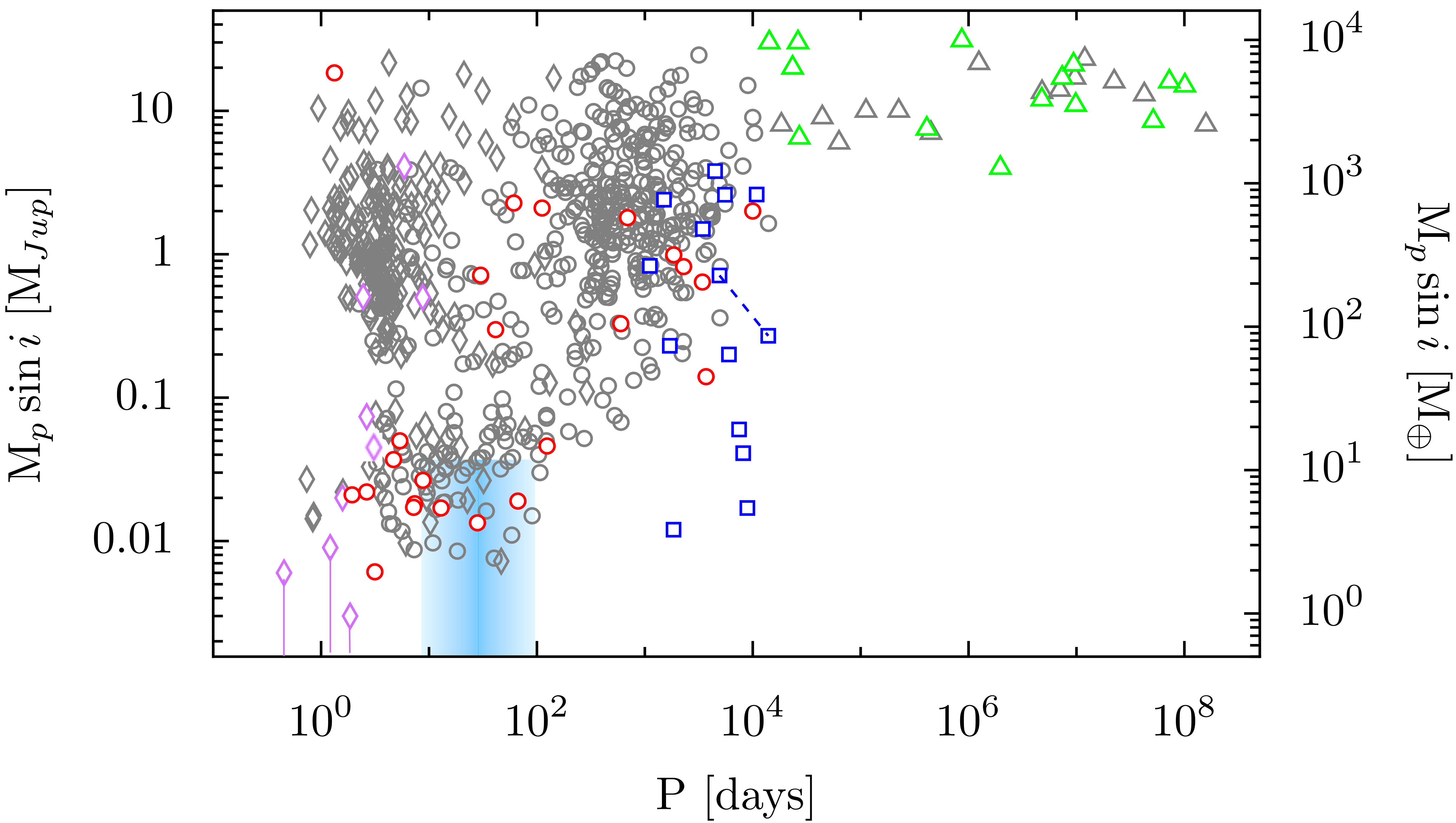
4. OK… BUT HOW ? (= capability)

Status

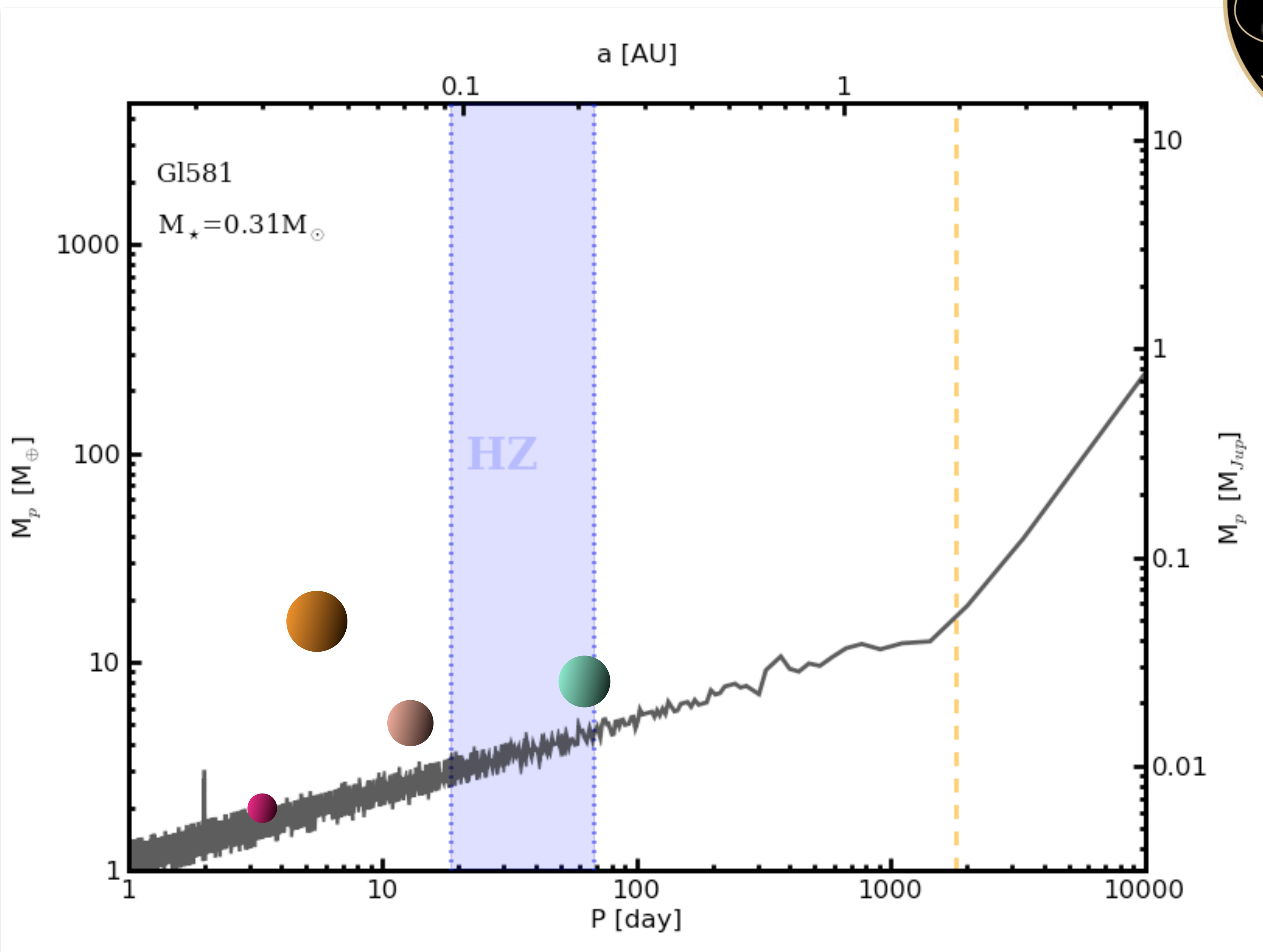
- *diversity*
- *structure*

➡ *statistical information*

bias / need non-detection



OCCURRENCE OF M-DWARF PLANETS FROM HARPS



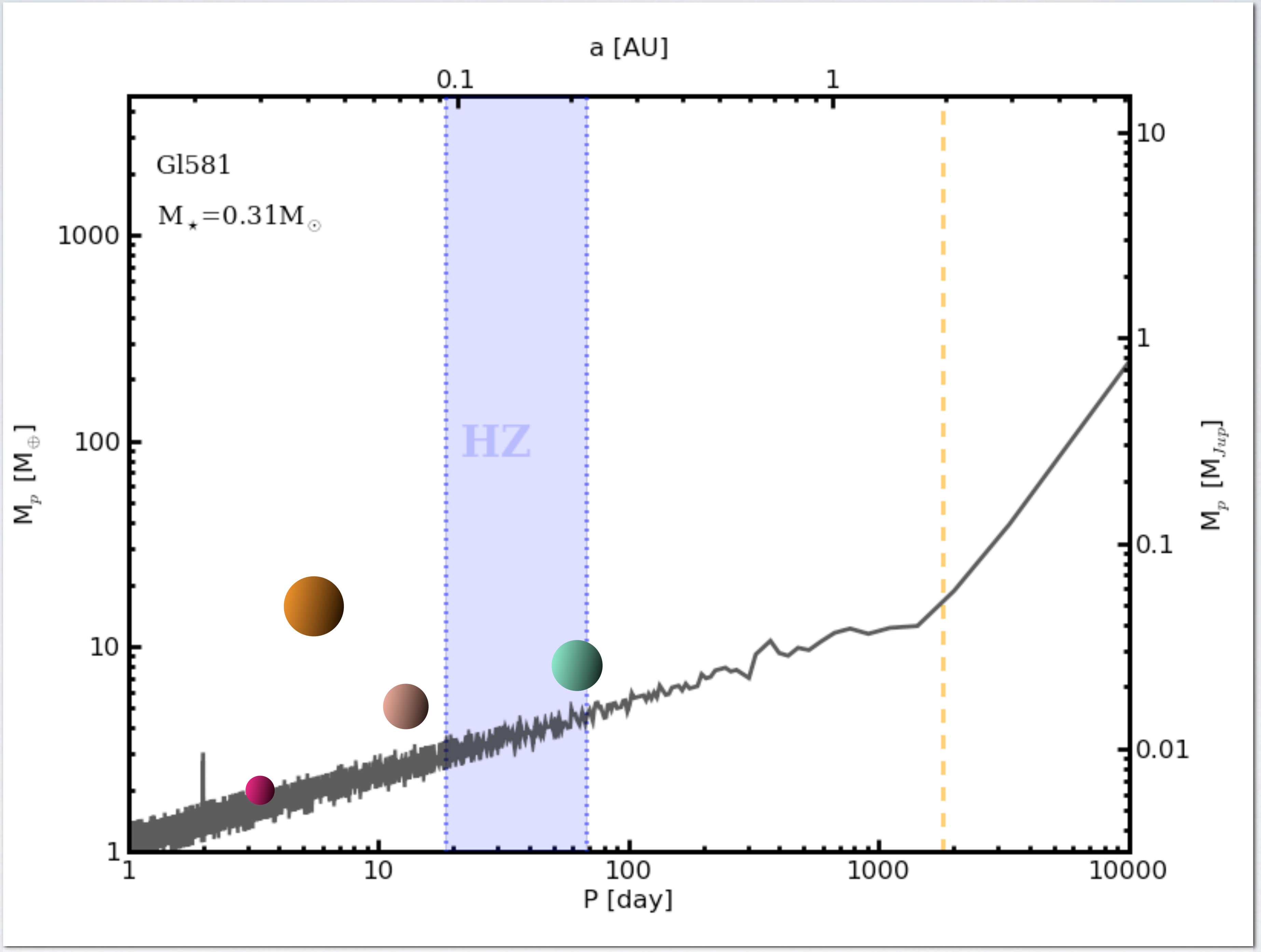
Planetary Search HARPS

http://obswww.unige.ch

IPAG
Institut de Planétologie et d'Astrophysique de Grenoble

Centro de Astrofísica da Universidade do Porto

ULg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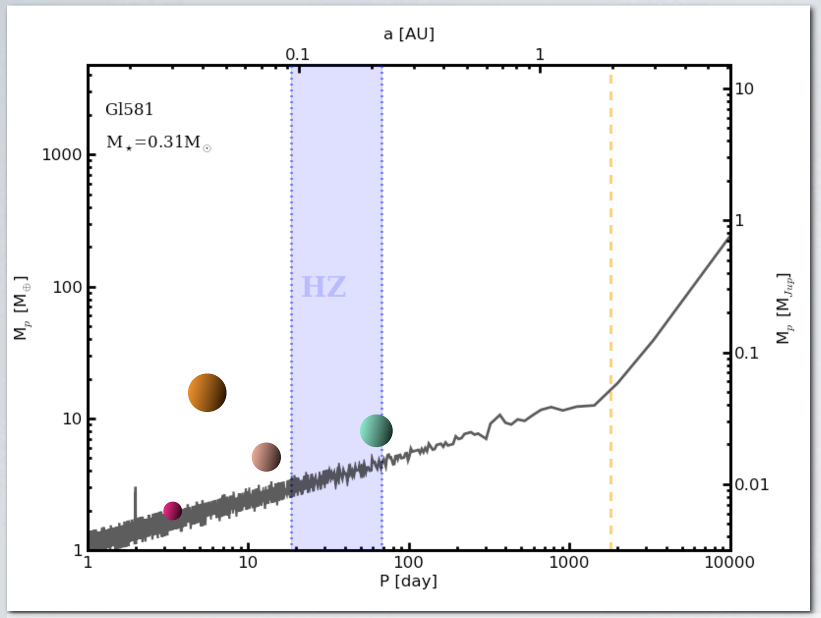
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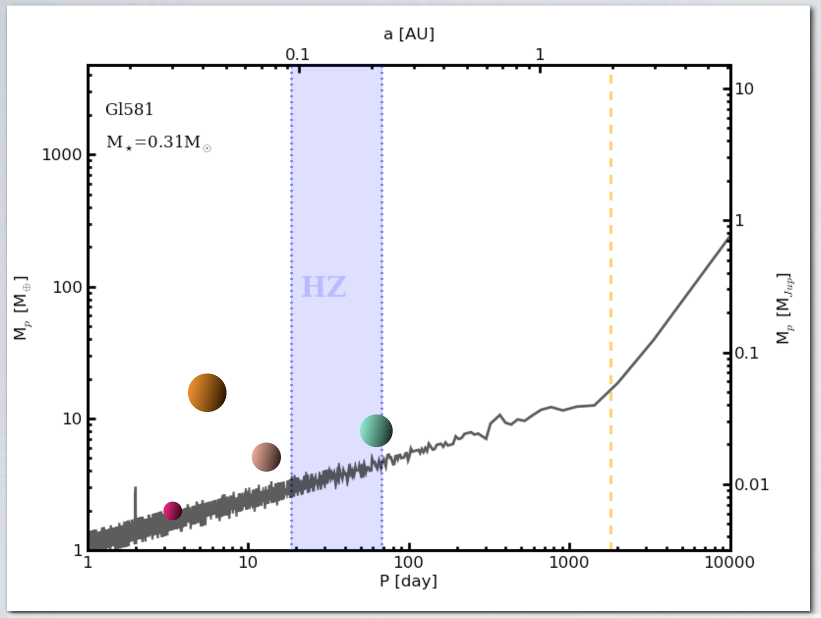

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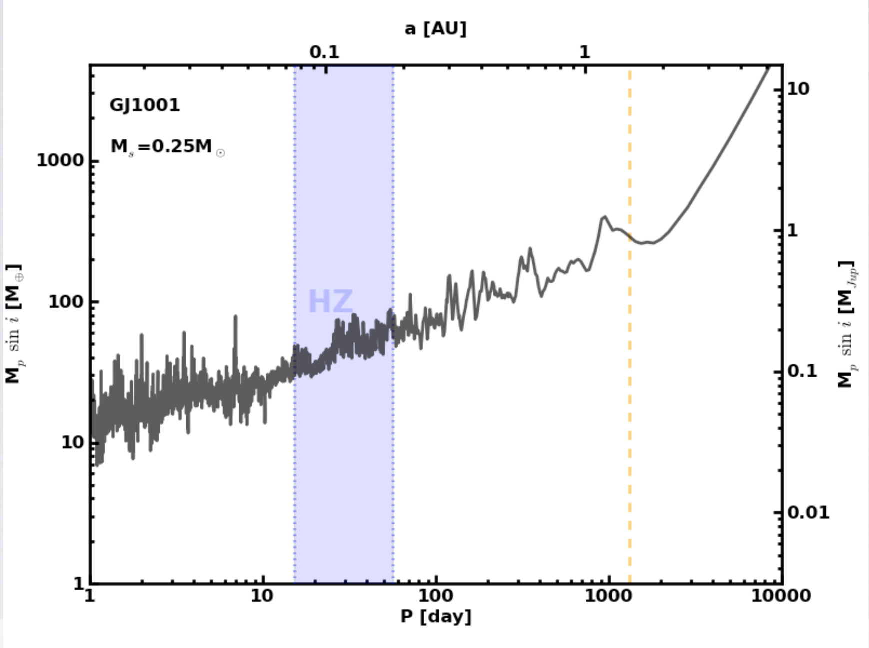

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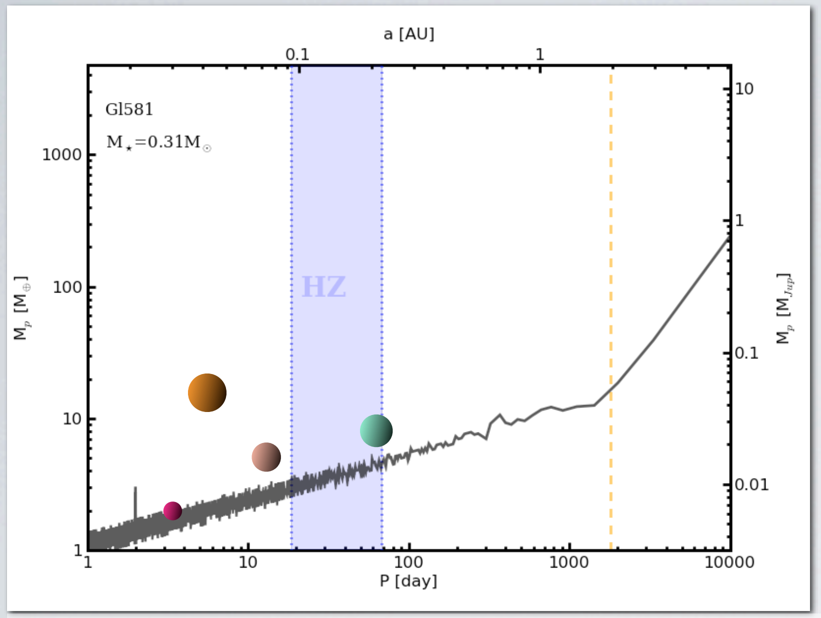

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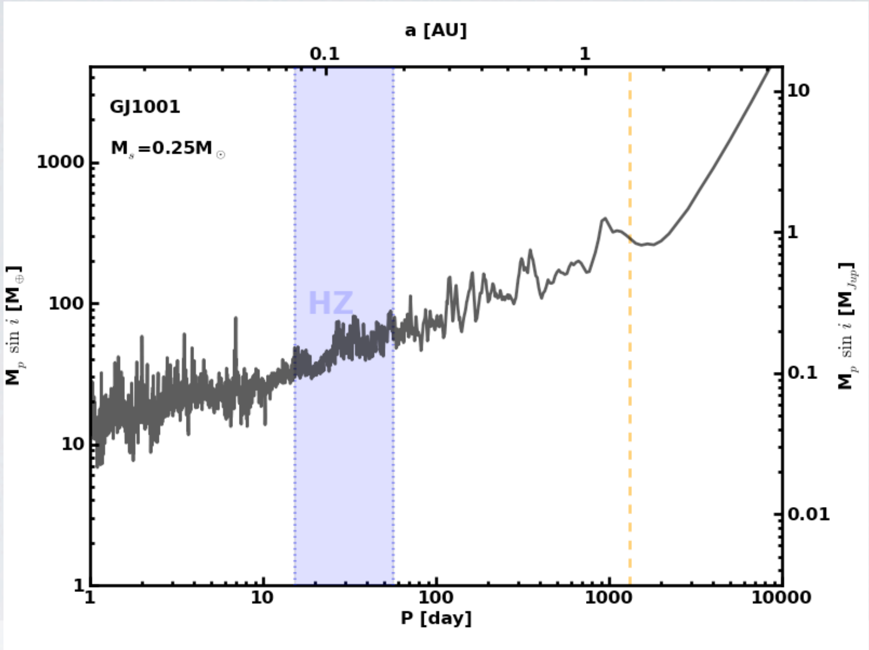

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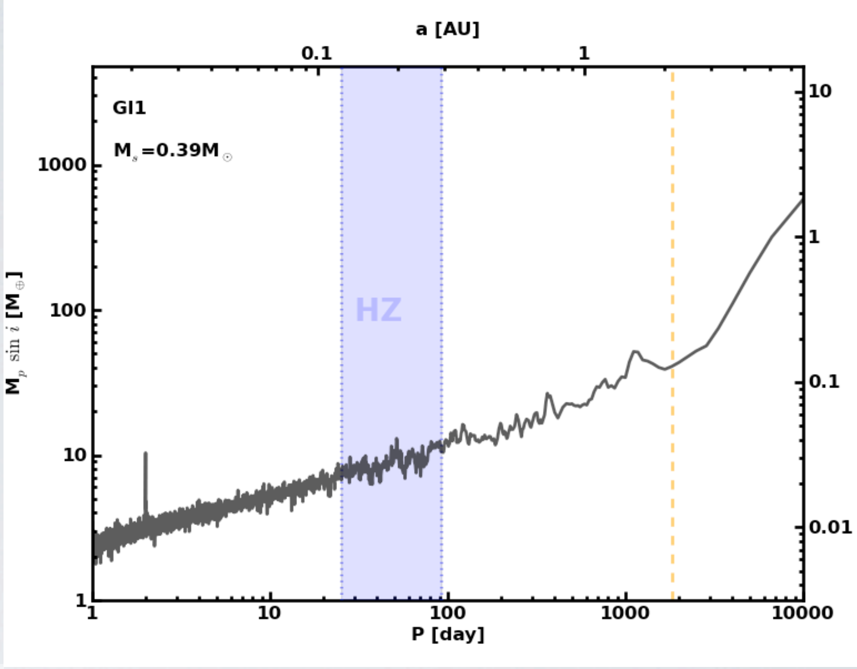

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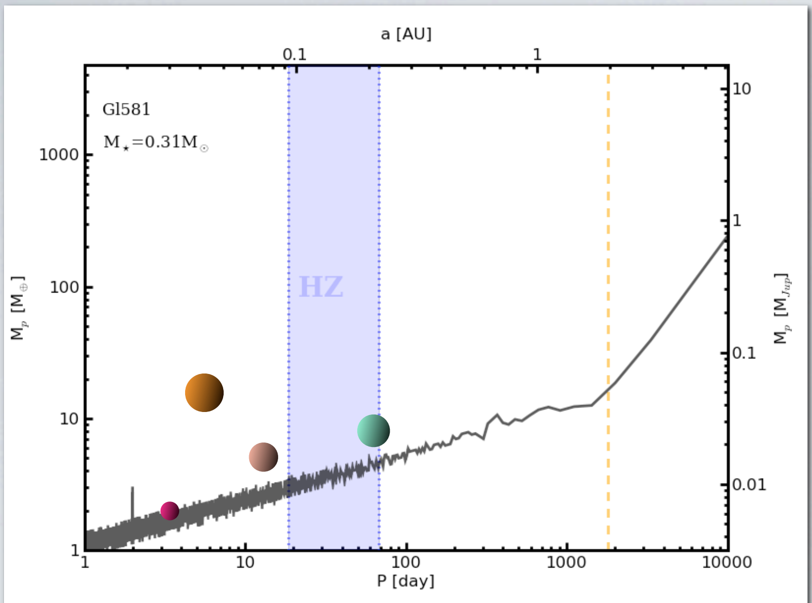
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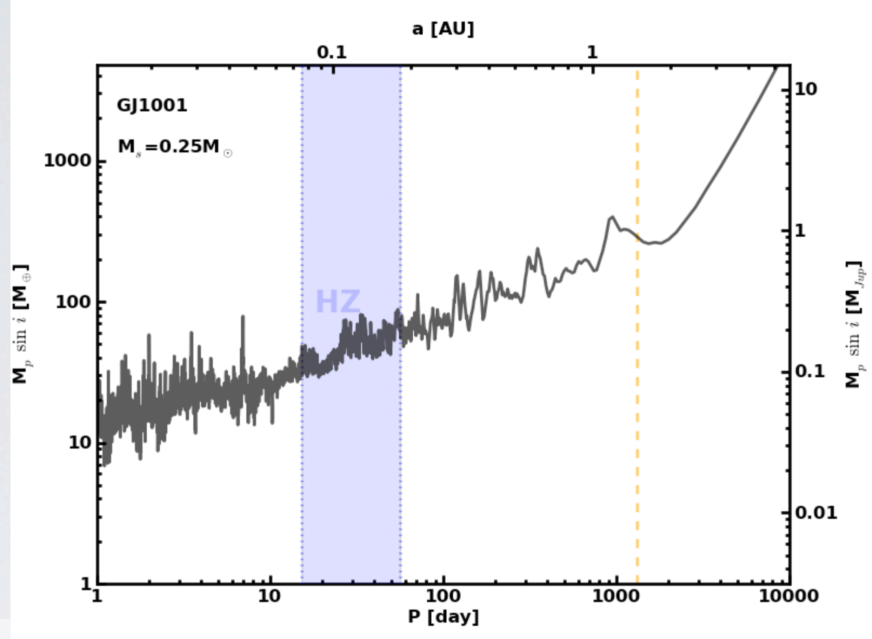
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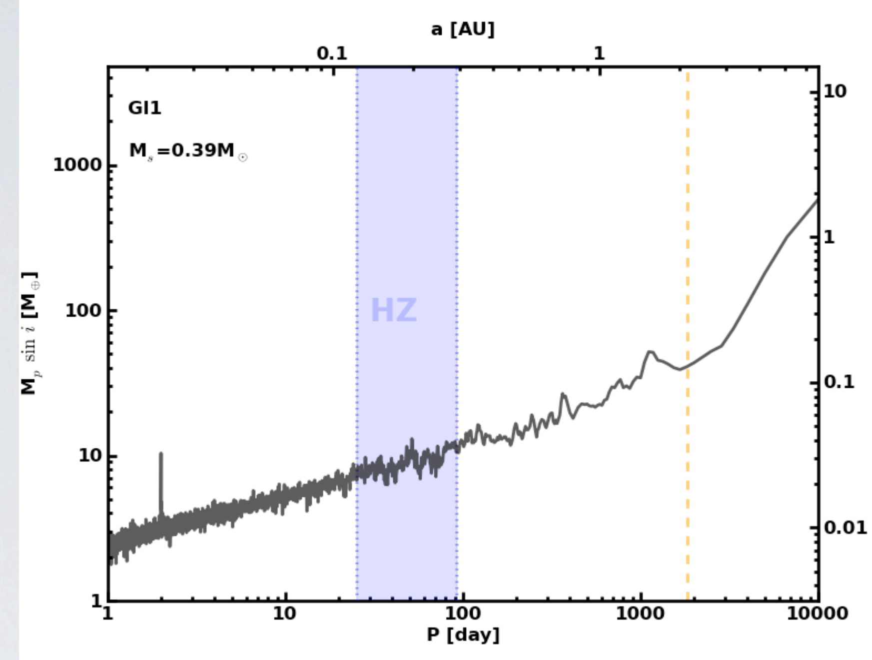
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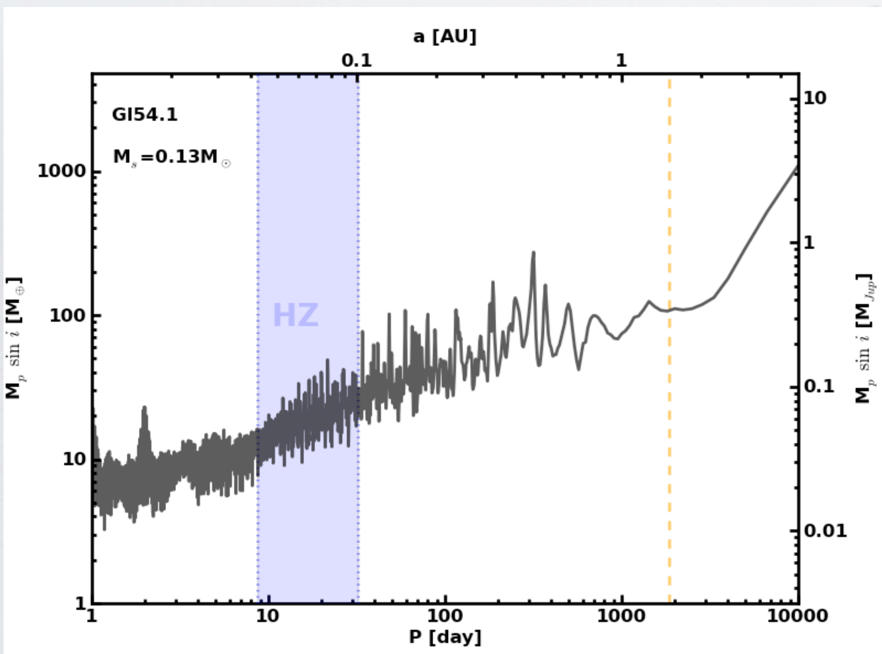
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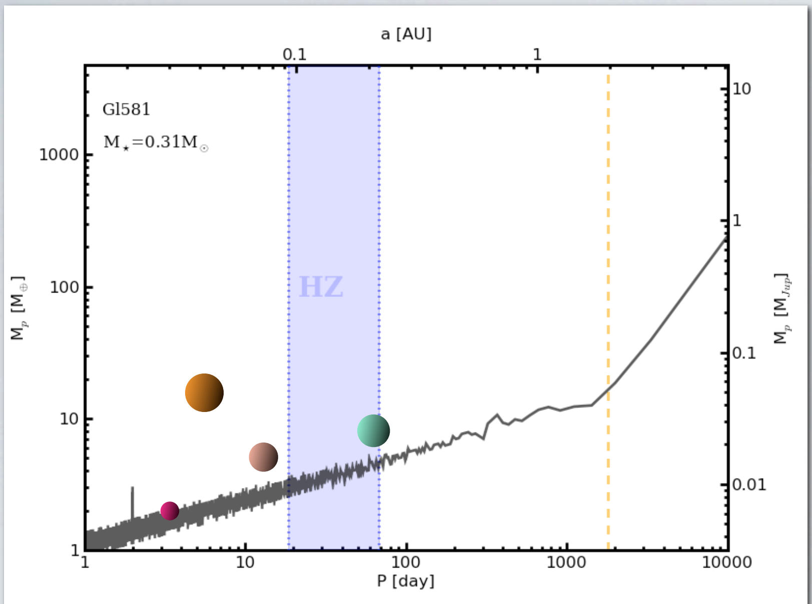
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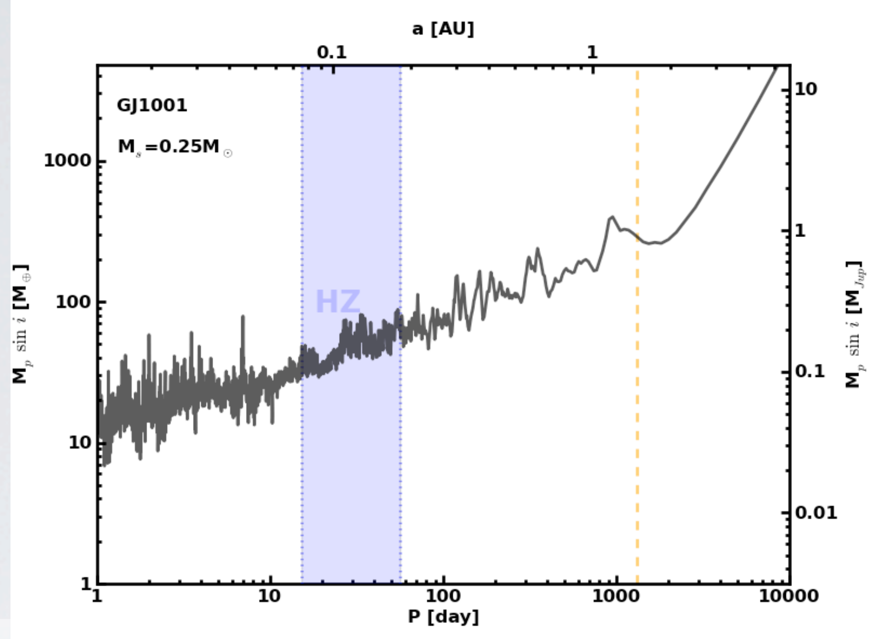
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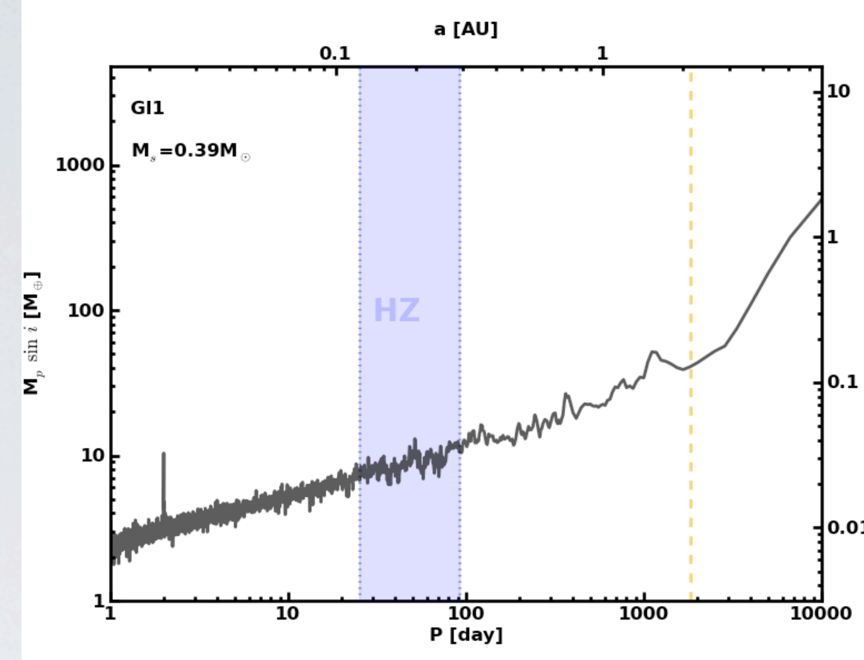
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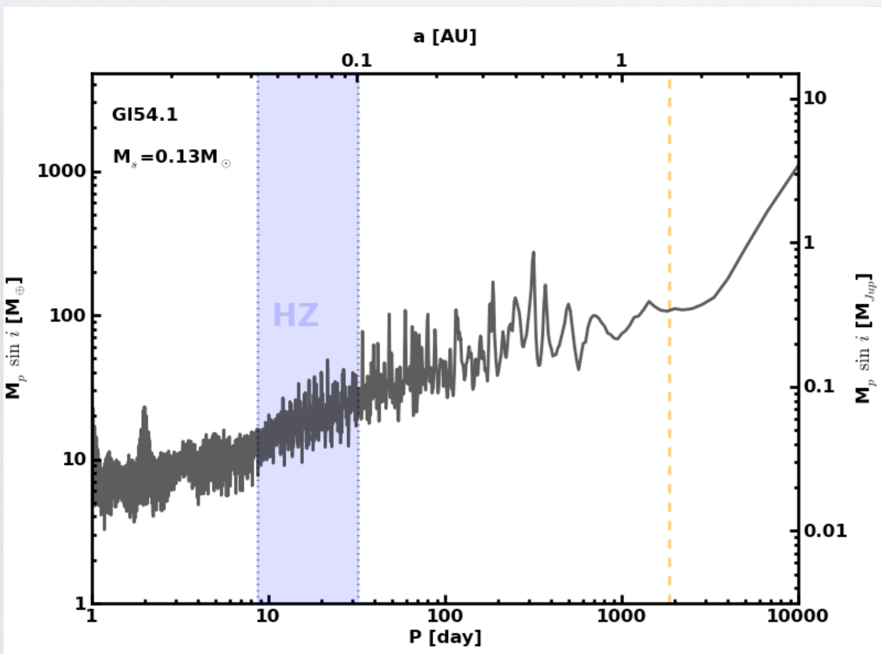
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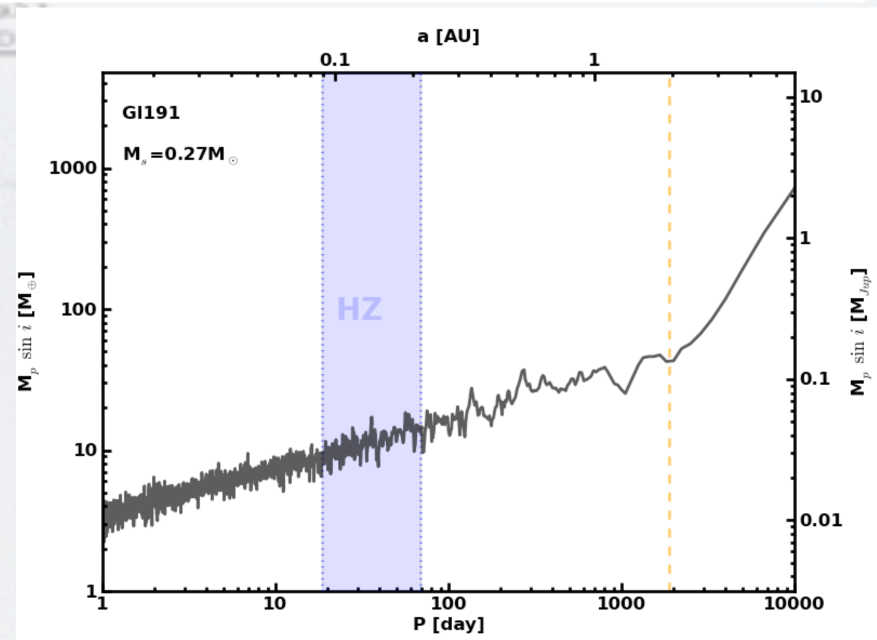
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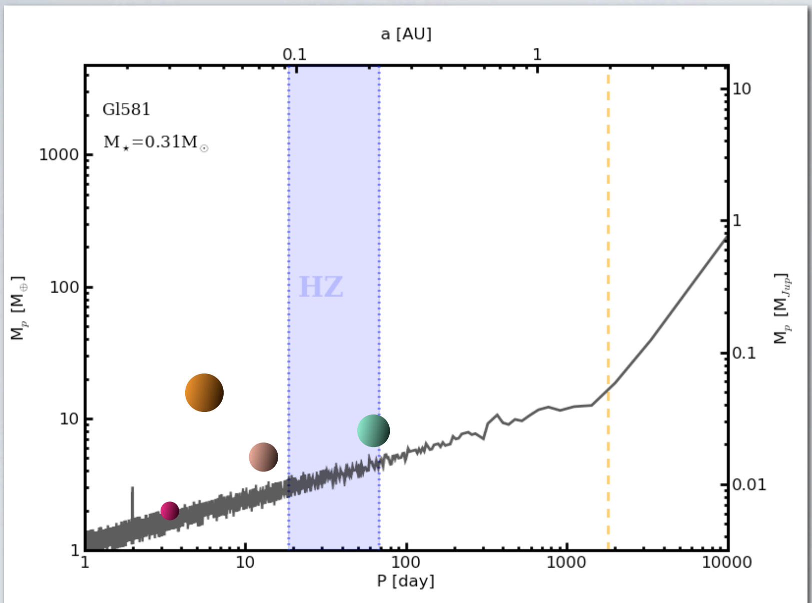
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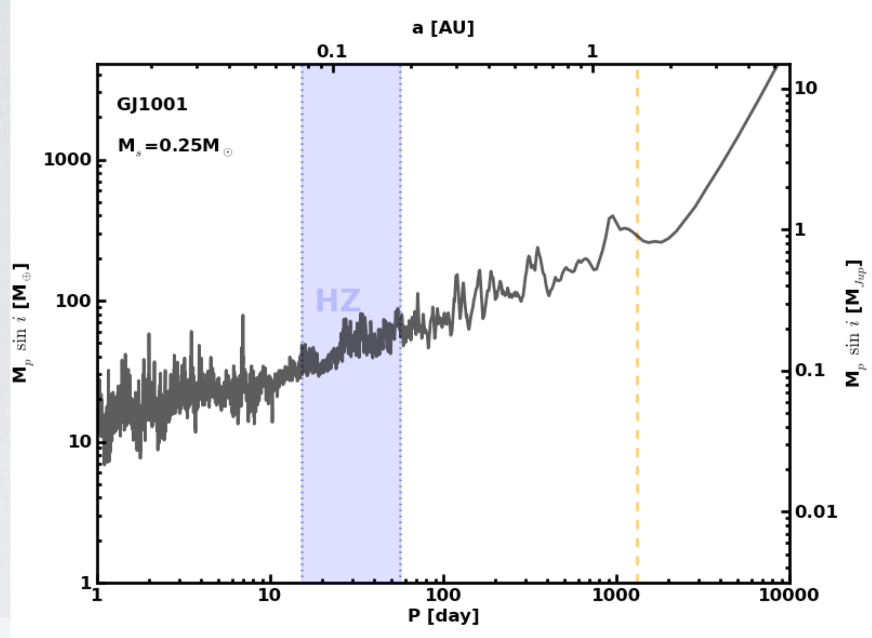
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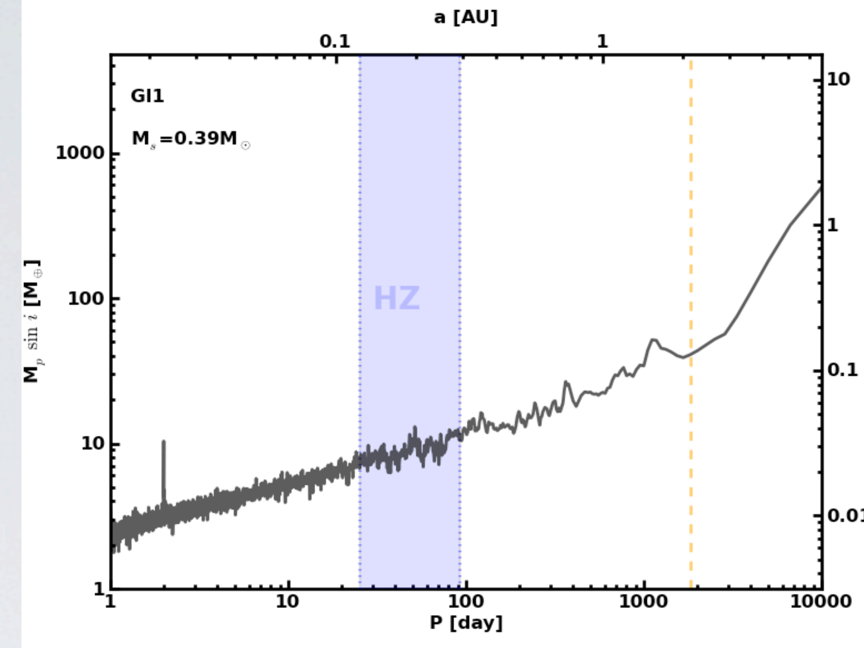
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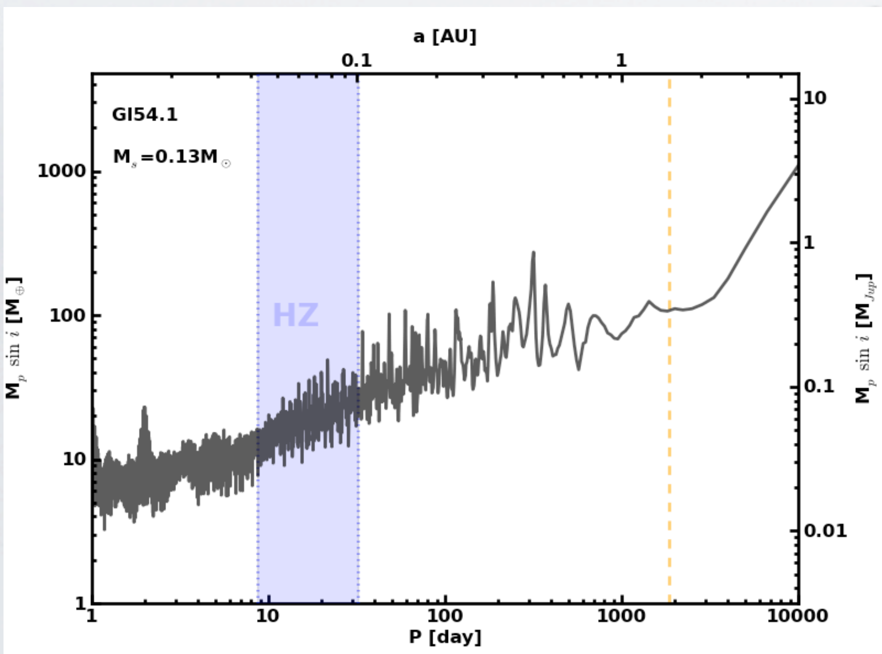
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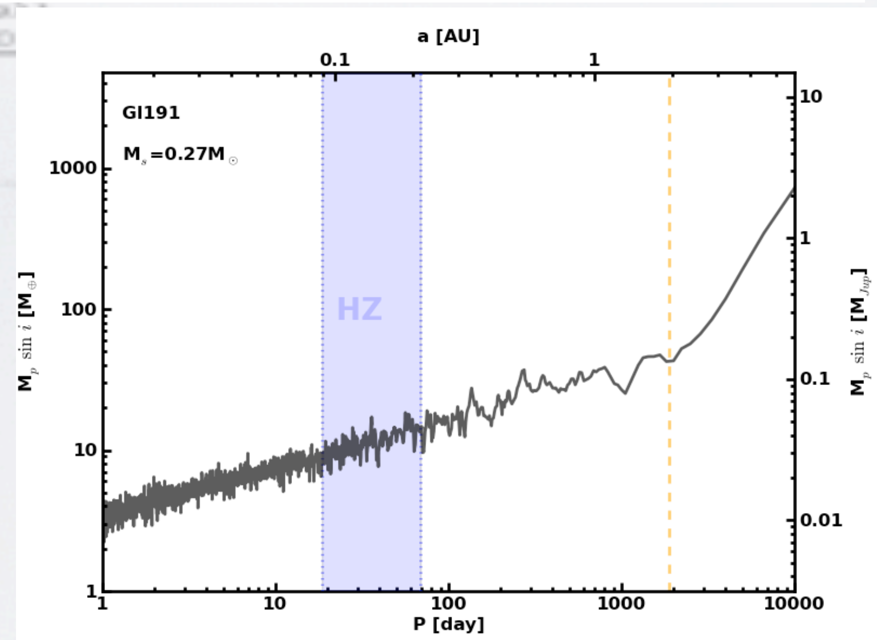
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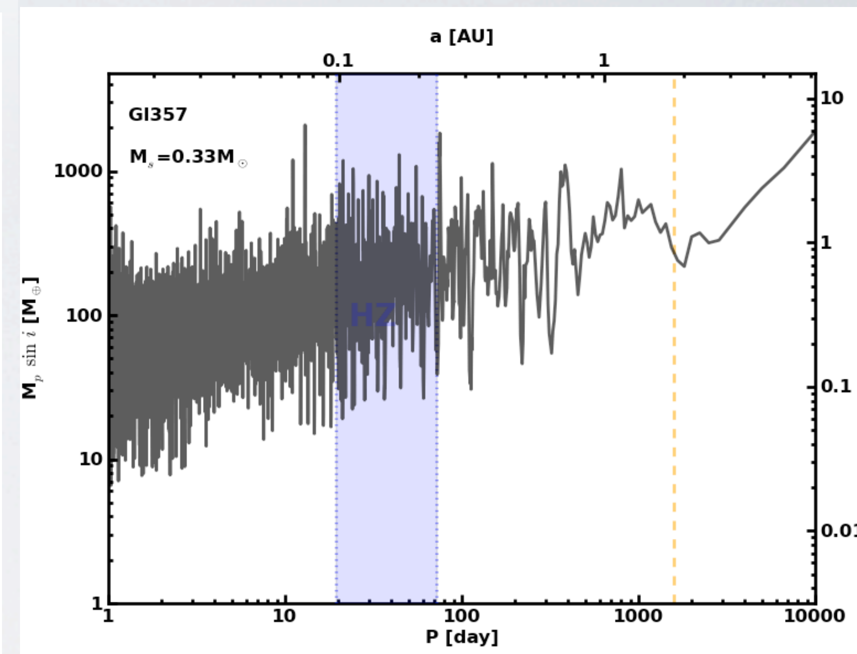
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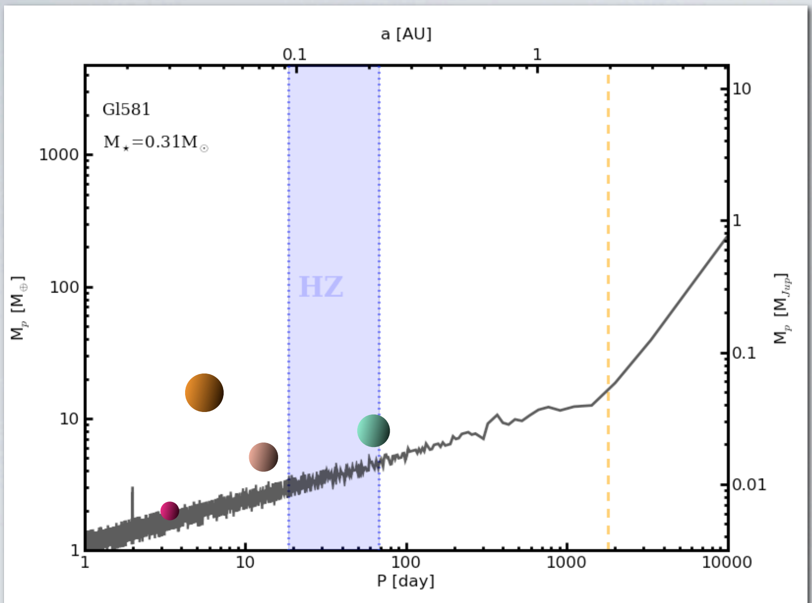
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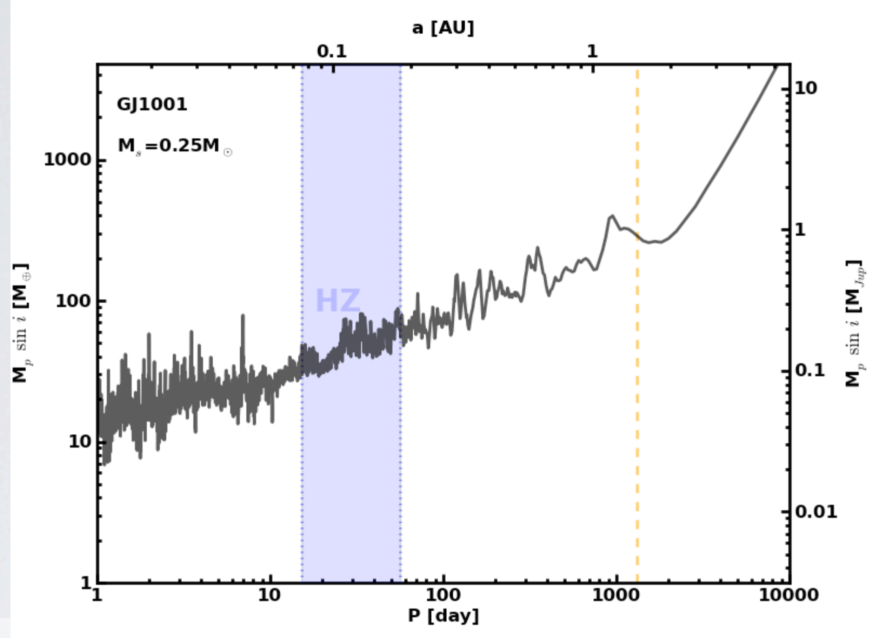
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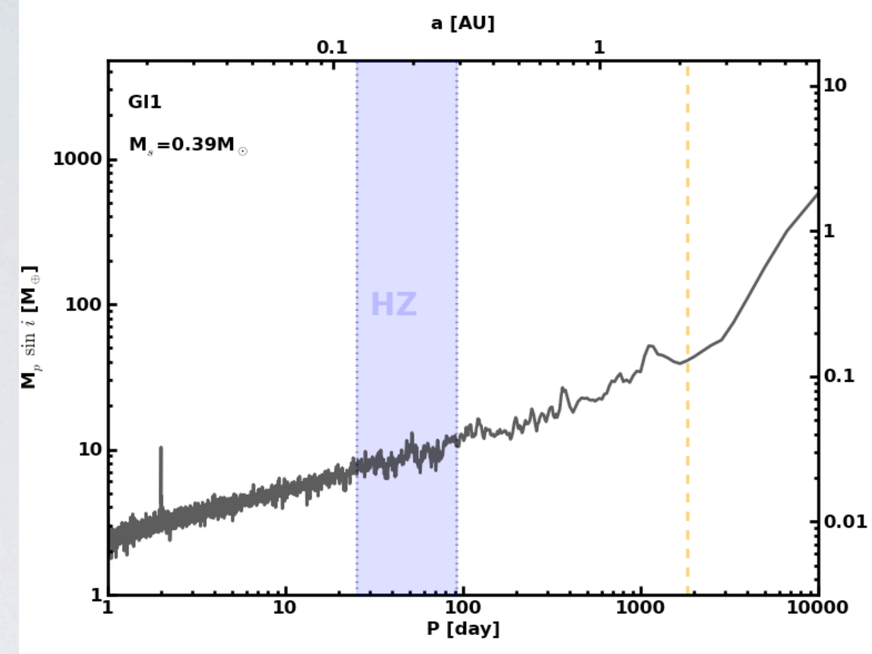
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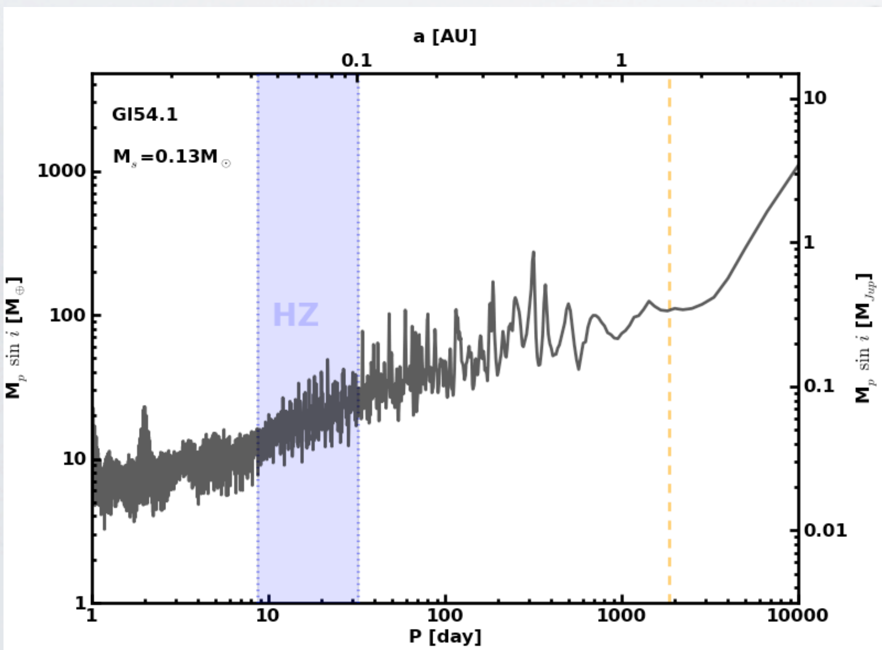
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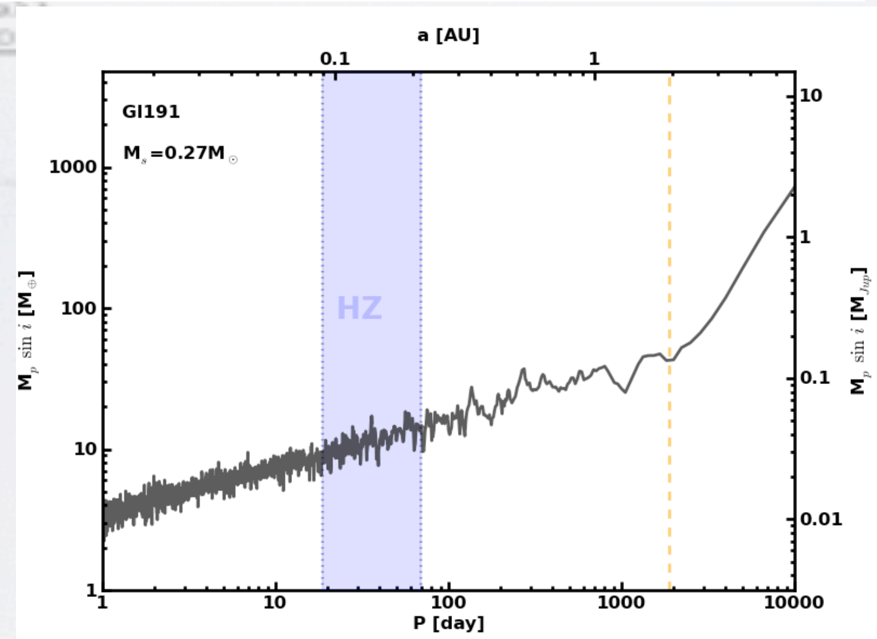
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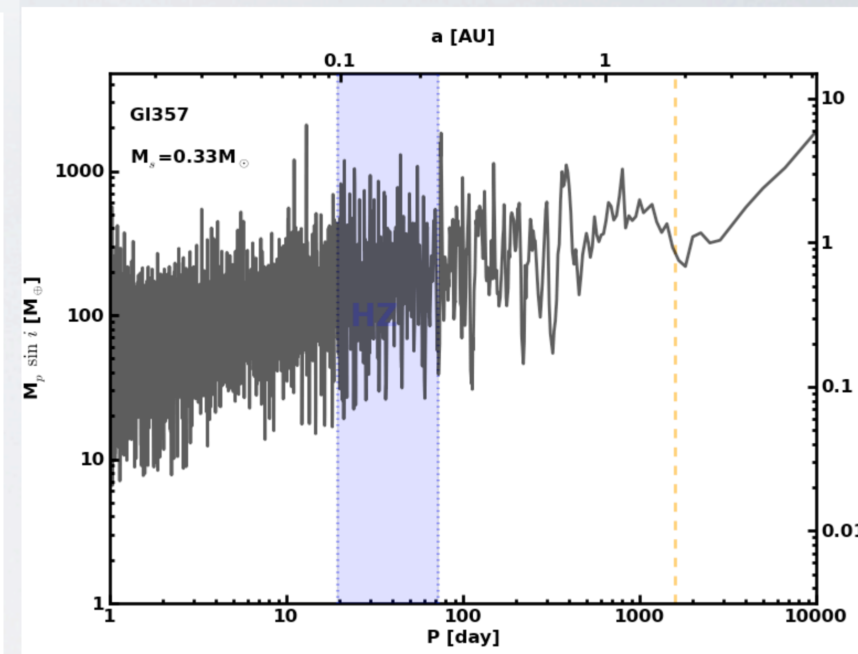
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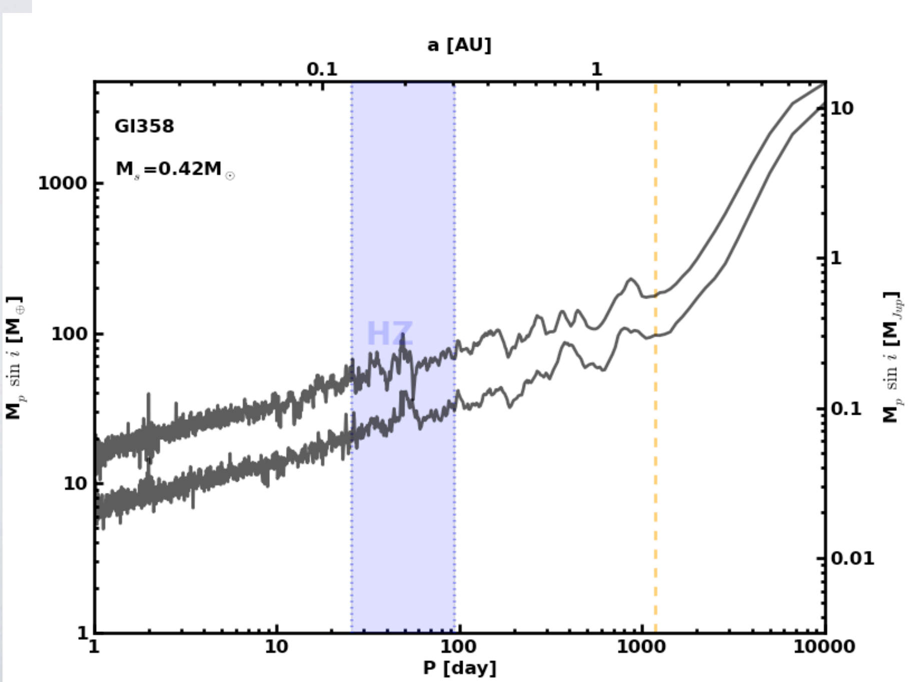
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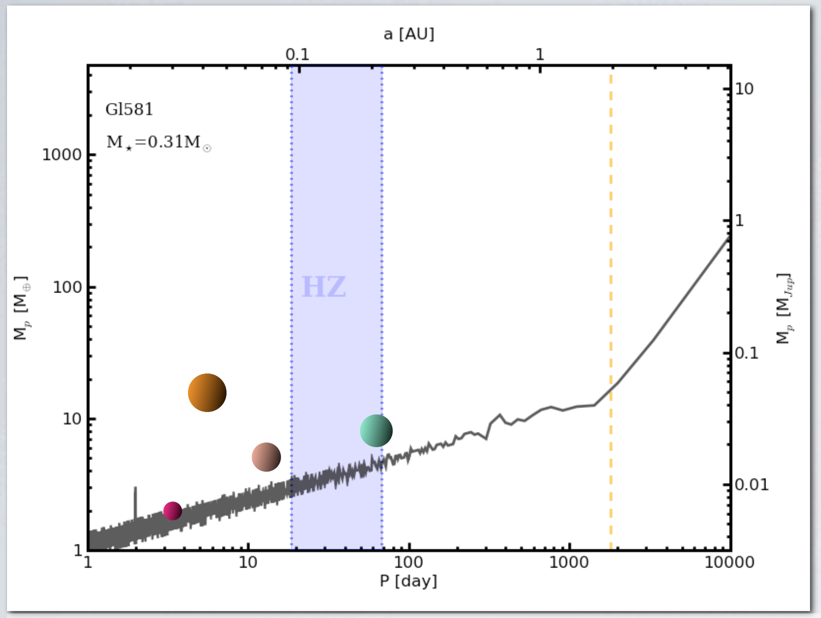
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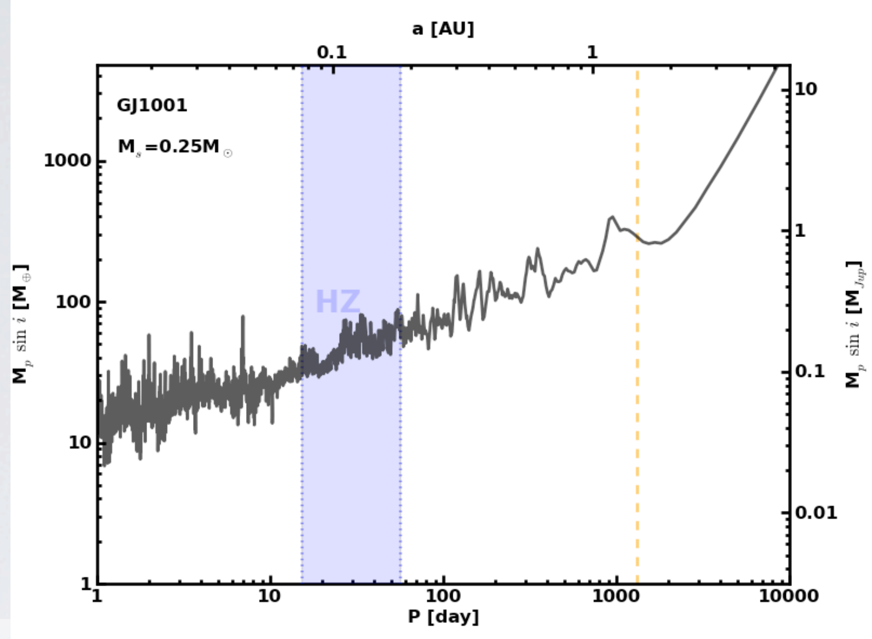
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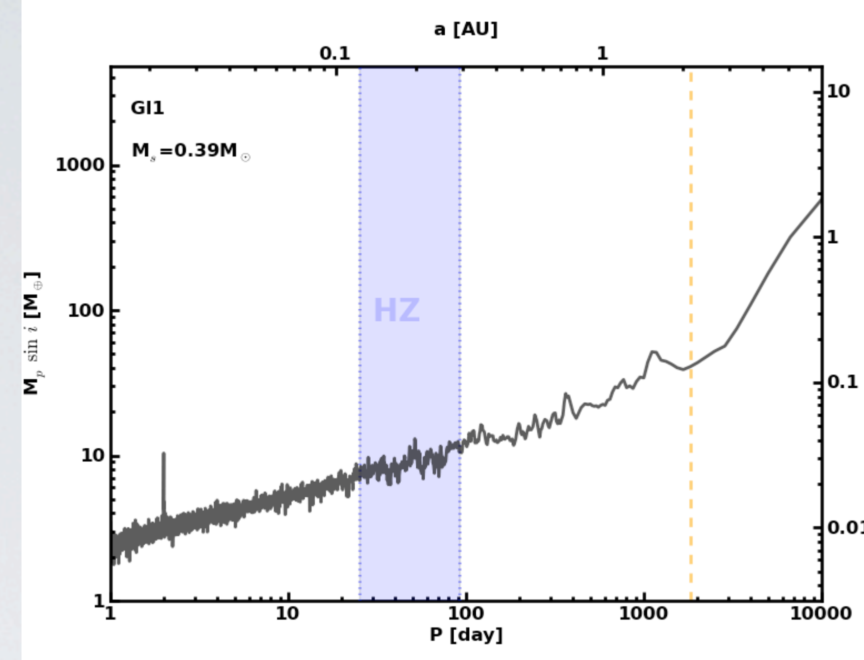
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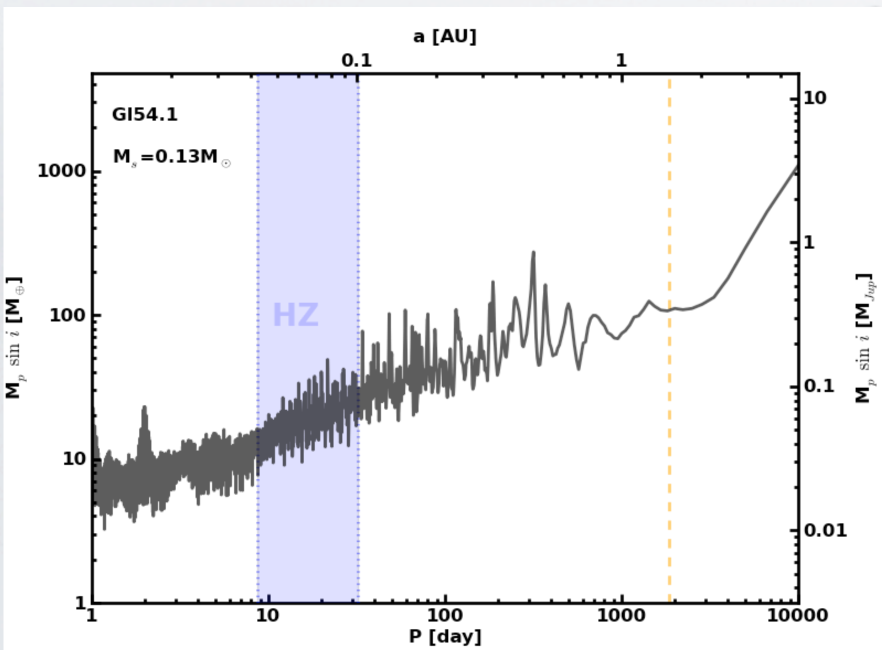
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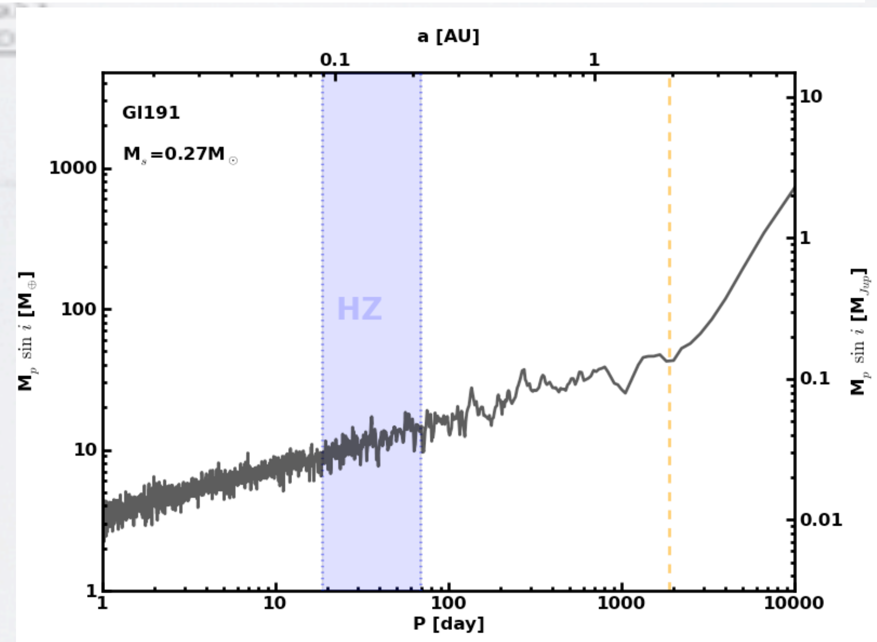
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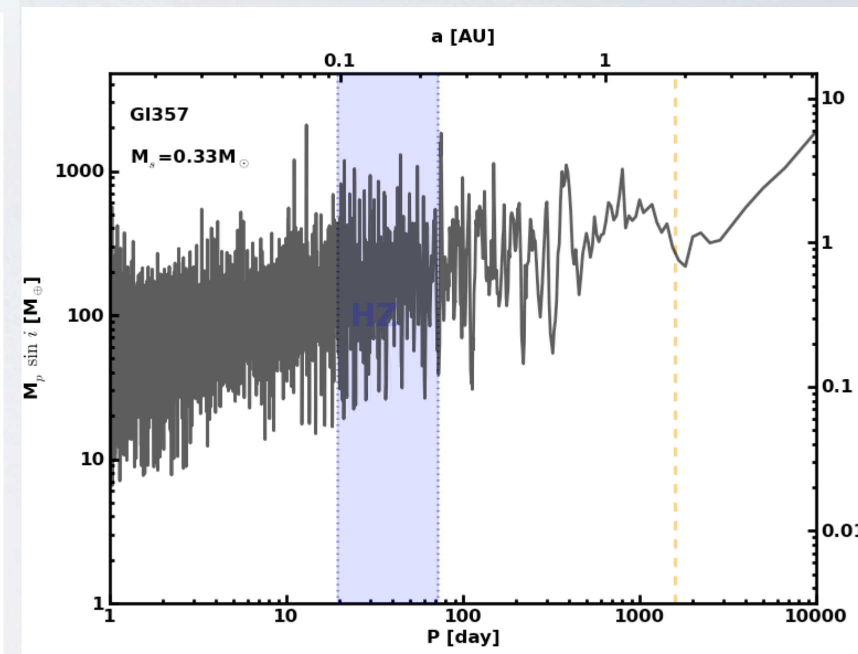
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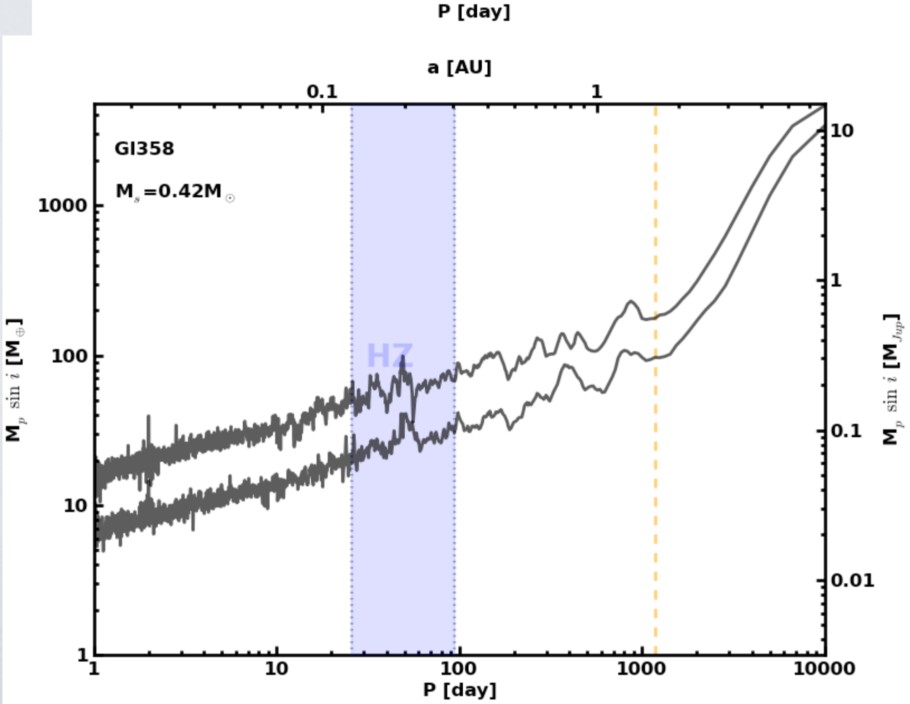
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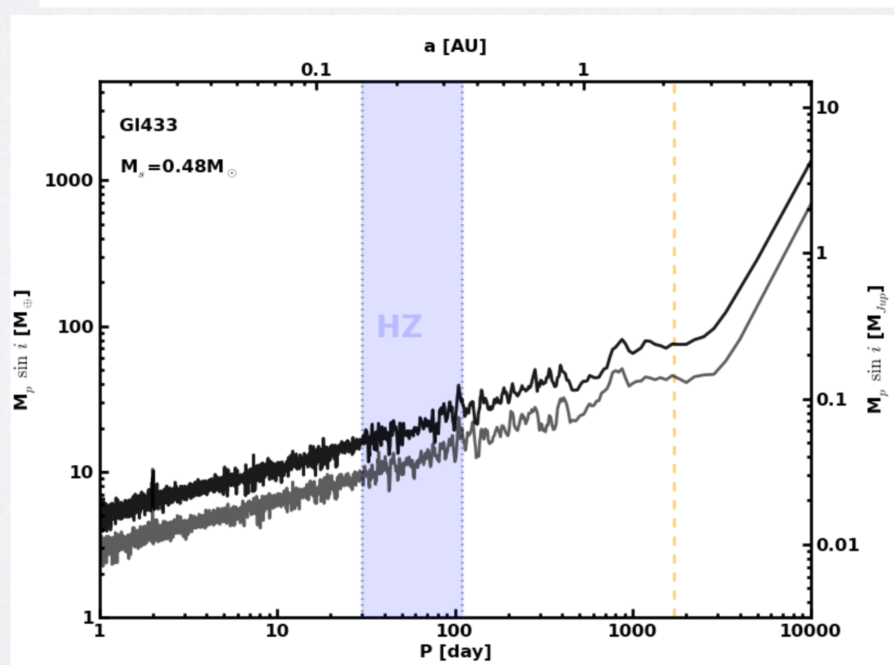
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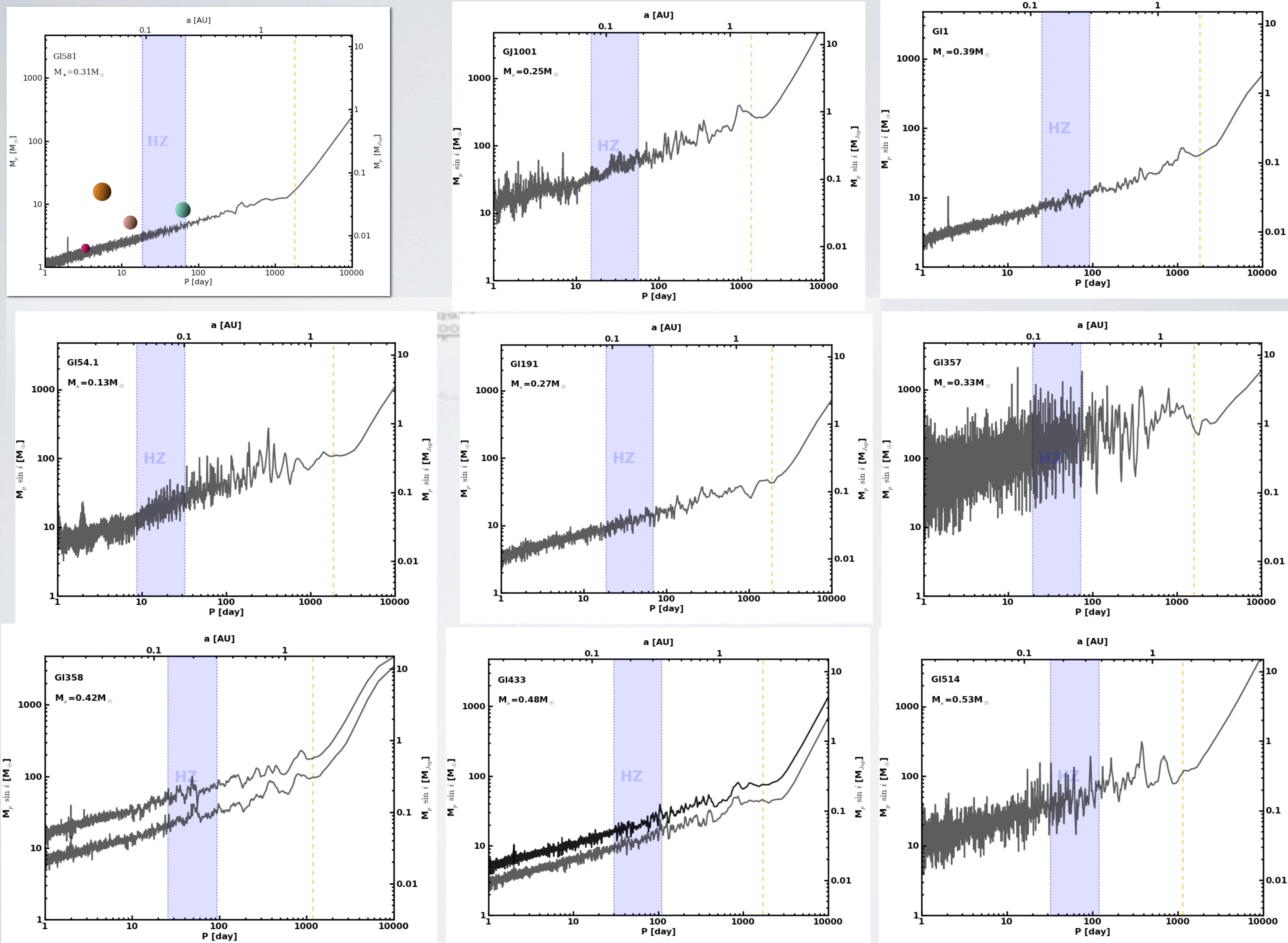
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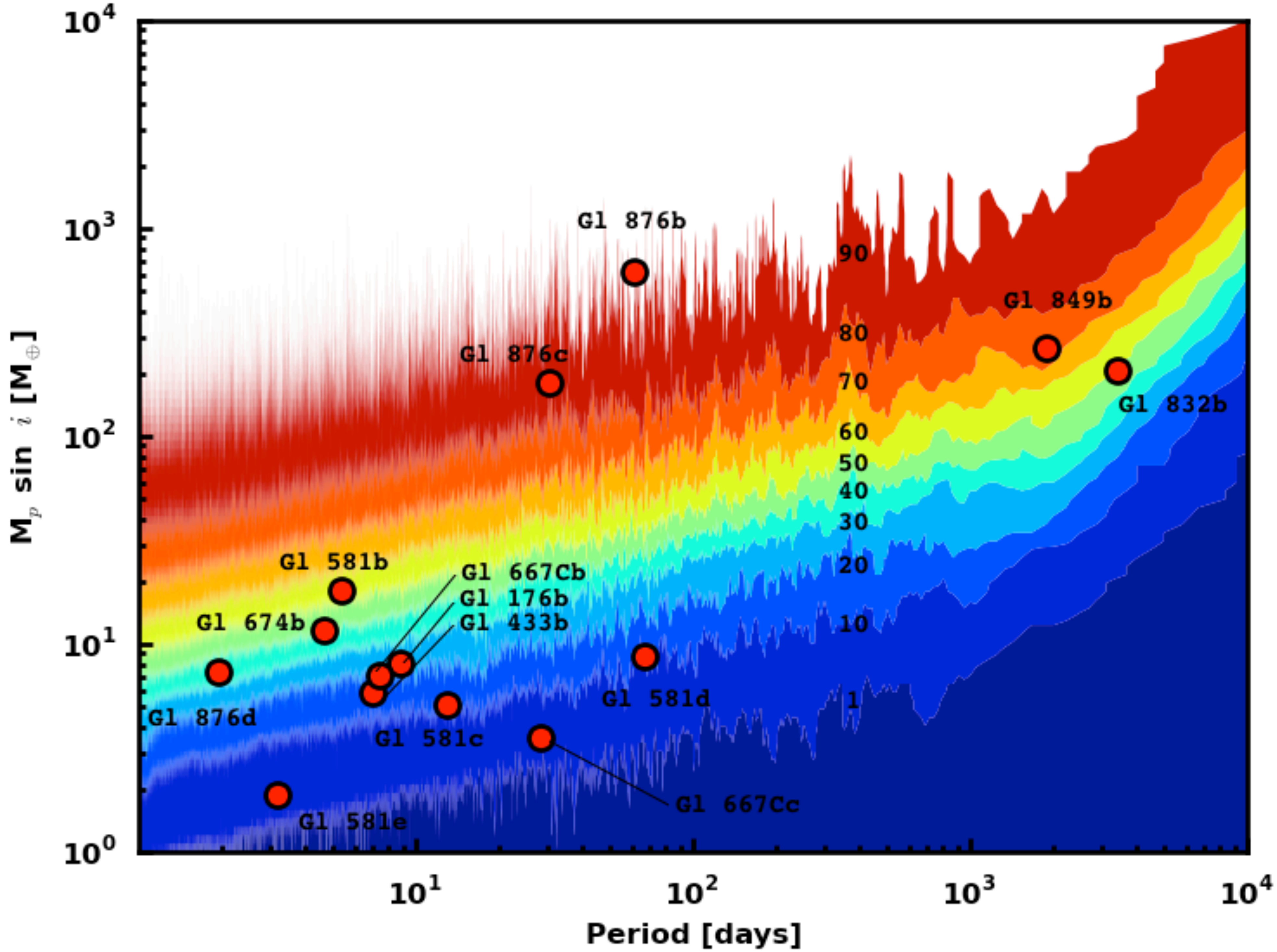
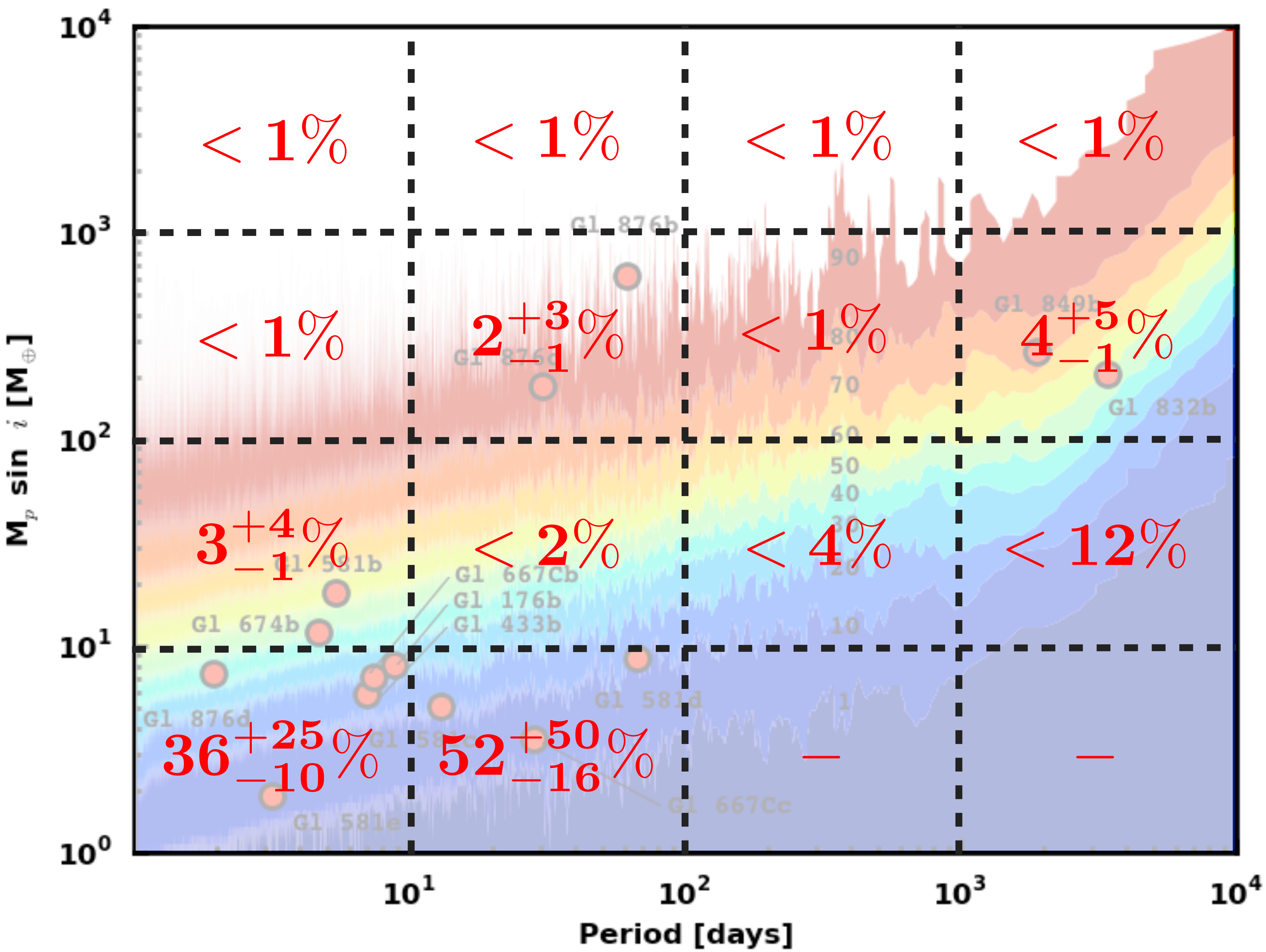


Bonfils et al. (2012, A&A in press)
astro-ph/1111.5019B



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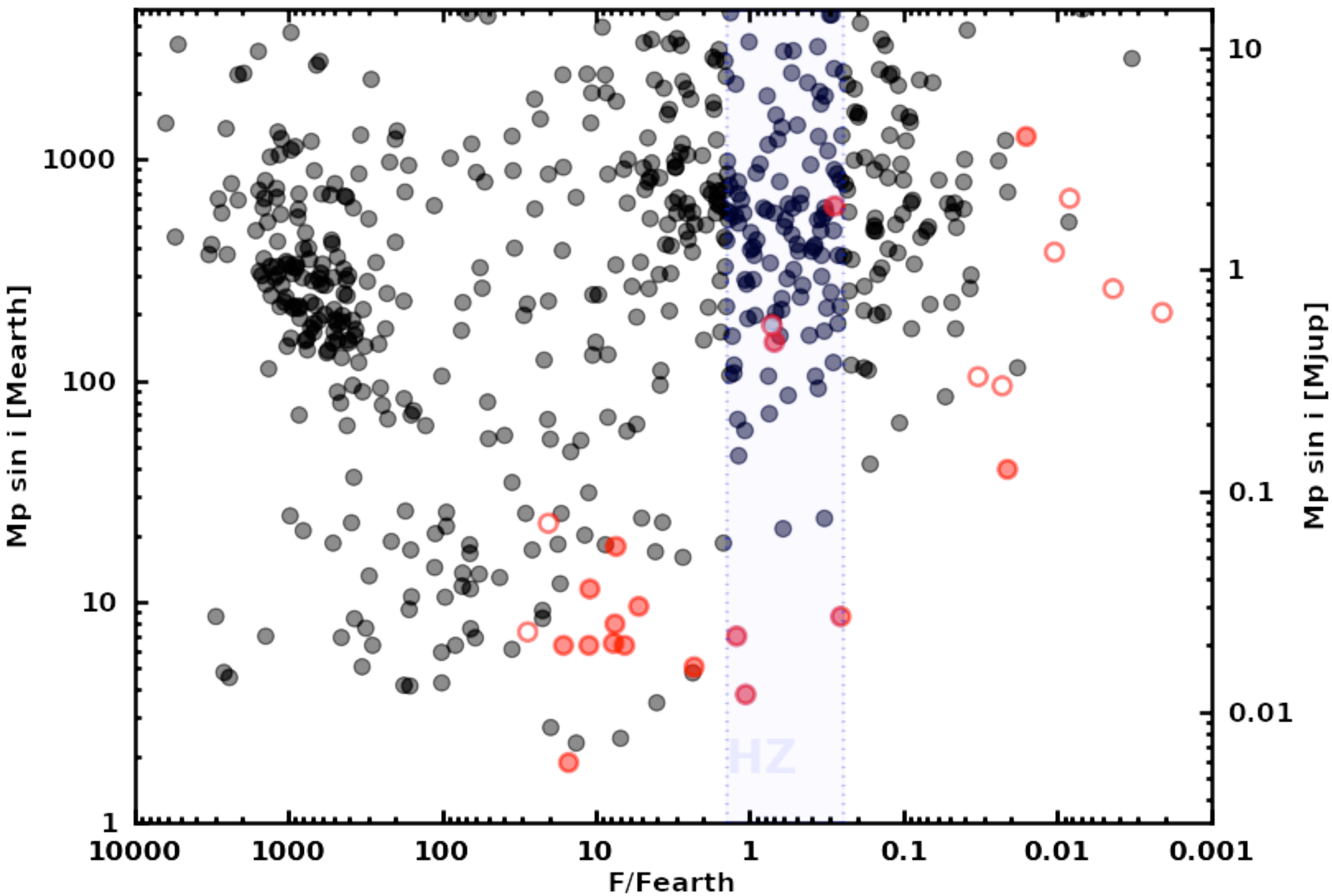
(a direct measure)



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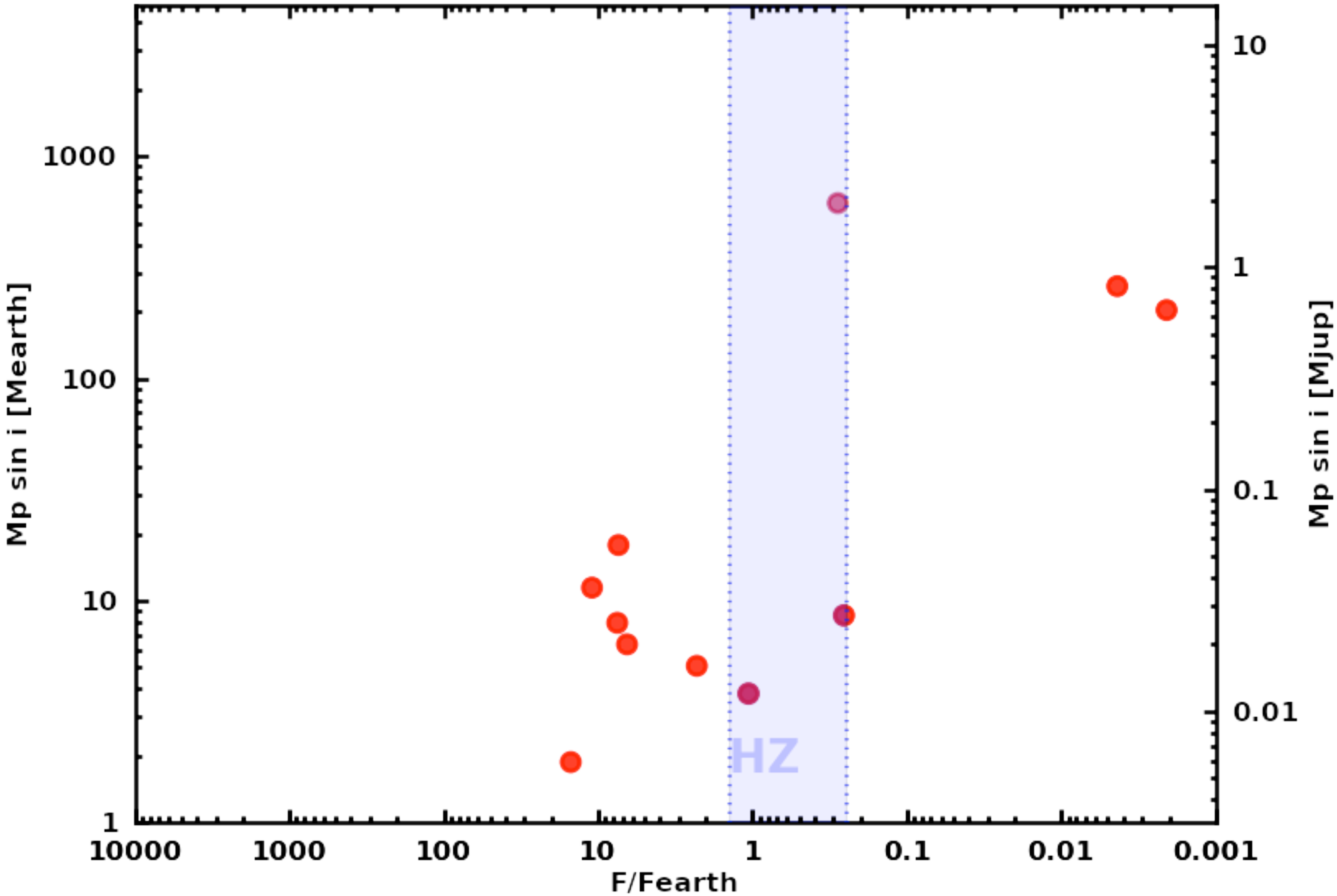
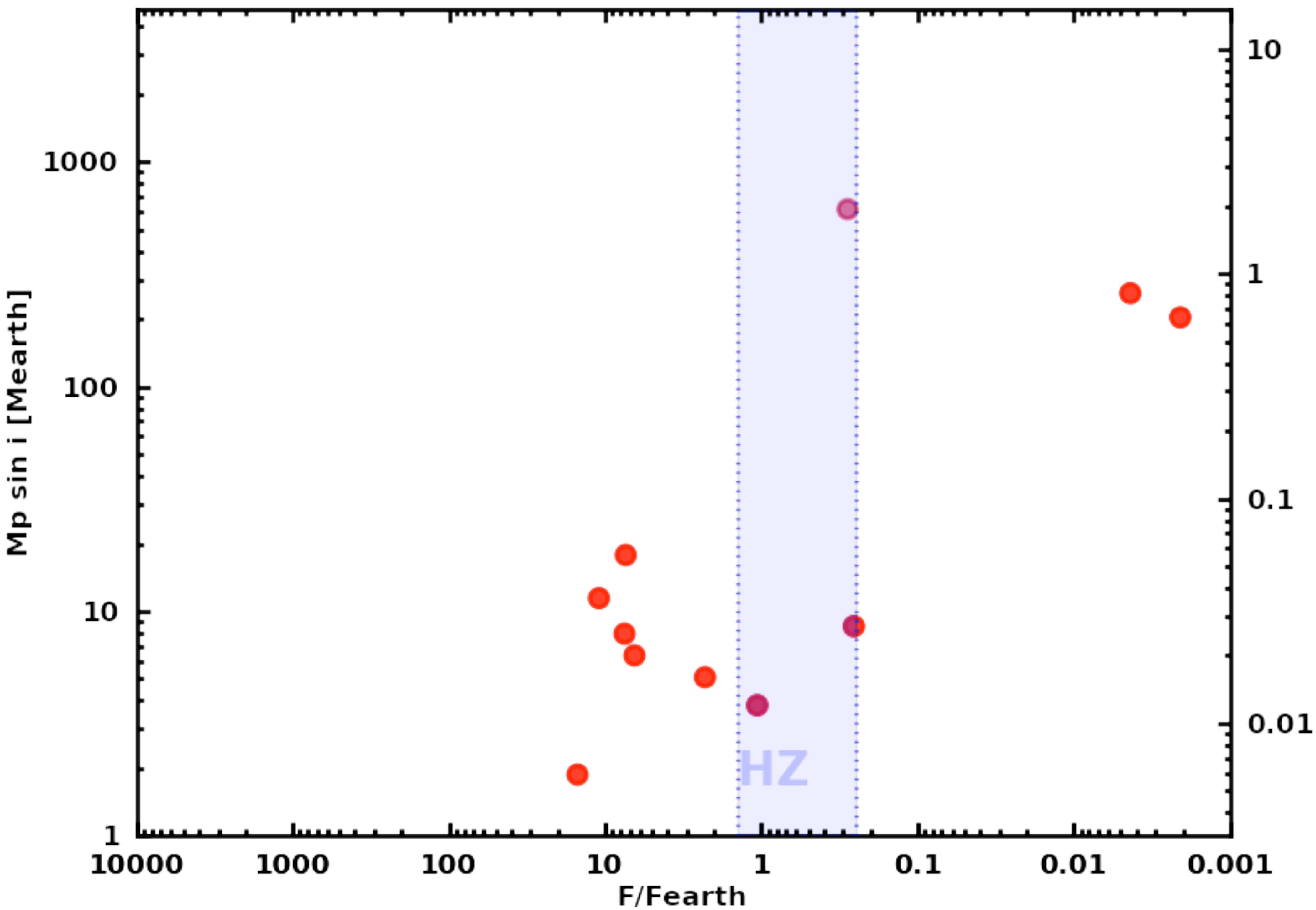


Bonfils et al. (2012, A&A in press)
astro-ph/1111.5019B

$$\eta_{\oplus} = 0.41^{+0.54}_{-0.13}$$

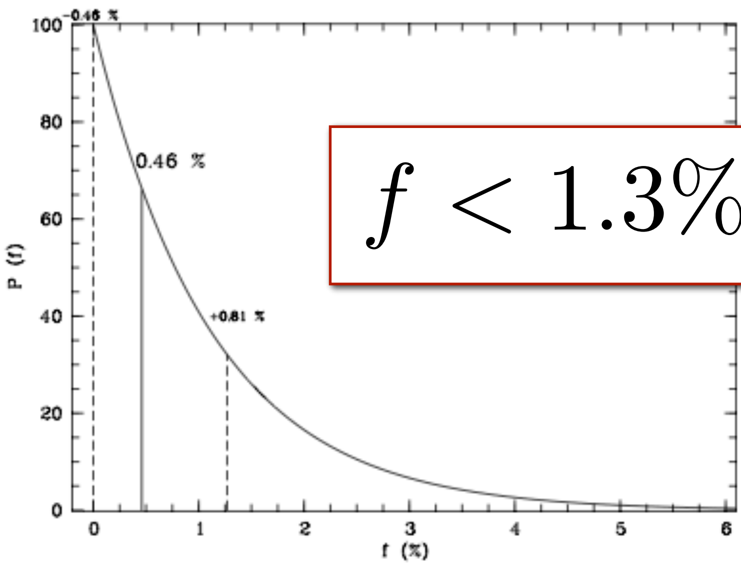
(a direct measure)



Bonfils et al. (2012, A&A in press)
astro-ph/1111.5019B

follow-up on previous radial-velocity results *(mostly for giant planets)*

Endl et al. (2006, AJ 649, 436)



$$f < 1.3\% (1\ \sigma)$$

FIG. 2.—Probability function $P(f)$ for the true companion frequency f based on all our M dwarf data (HET, VLT, HJS, and Keck: $N = 89$ stars) and $d = 0$ detections. We find $f = 0.46^{+0.81}_{-0.46}$ percent. The dashed lines delimit the area of 68% integrated probability (≈1 σ Gaussian error).

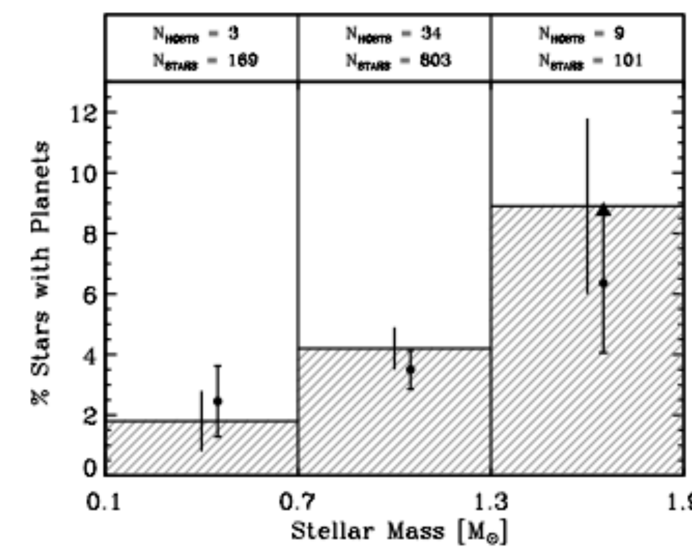
Butler et al. (2006, AJ 649, 436)

$$f = 1.8 \pm 1.2\% \ (> 0.4\ \mathrm{M_{Jup}}; < 2.5\mathrm{AU})$$

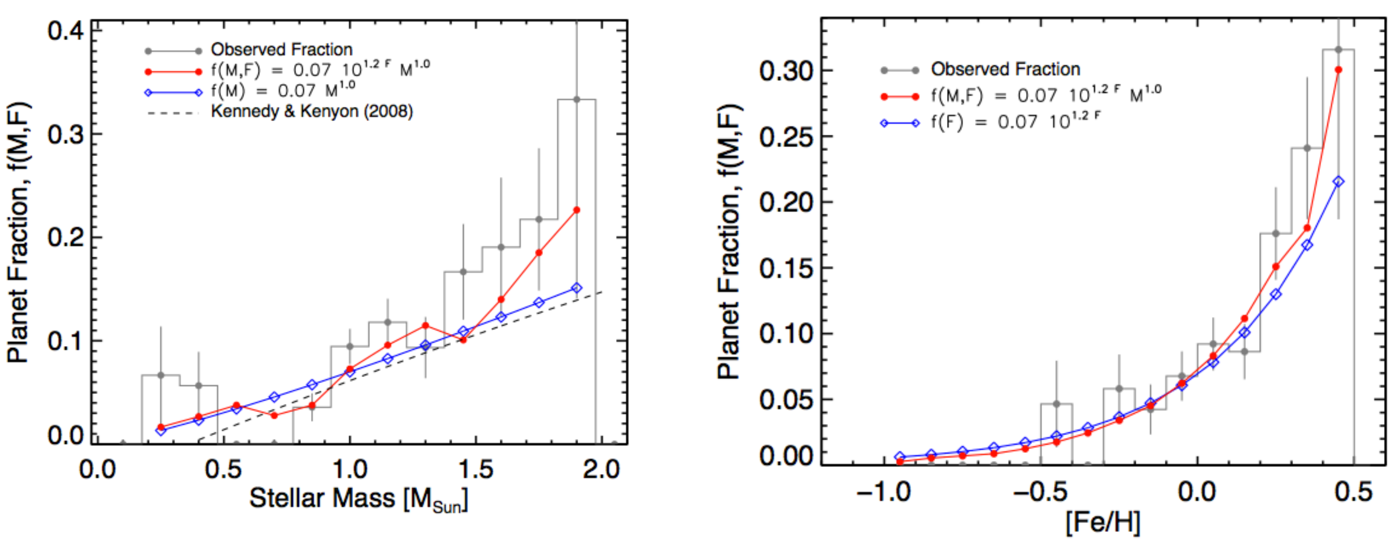
Cumming et al. (2008, PASP 120, 531)

> 1 Mjup are x5-10 times under abundant compared to Sun-like stars
f~1% (<5.4% @ 2-sigma)

Johnson et al. (2007, AJ 670, 833)



Johnson et al. (2010, PASP)



Bonfils et al. (2007, A&A 474, 293)

$f_{\mathrm{hot\ Nept.}} > f_{\mathrm{hot\ Jup}}$ (> 97% probability)

$$f(M_\star, [Fe/H]) = 0.07 \pm 0.01 \times (M_\star/M_\odot)^{1.0\pm0.3} \times 10^{1.2\pm0.2[Fe/H]}$$

photometry (transit)

- *Kepler results*
- *Mearth*

The Astrophysical Journal, 736:19 (22pp), 2011 July 20 Borucki et al.

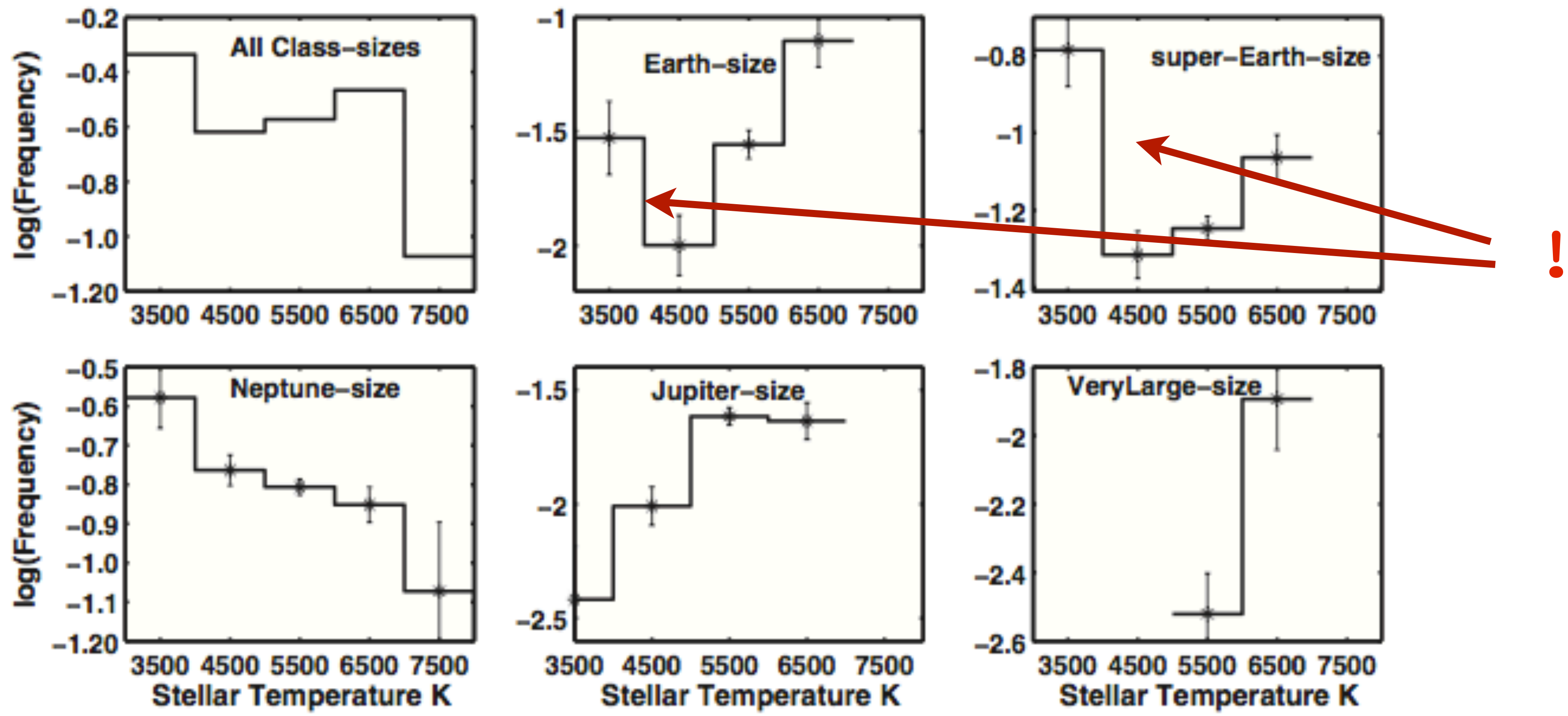


Figure 15. Logarithm of the intrinsic frequencies as a function of stellar effective temperature after implementing the sensitivity corrections described in Section 4. The bins along the *x*-axis span 3000–4000 K, 4000–5000 K, 5000–6000 K, and 6000–7000 K, with each bin labeled by the central value.

```
small mass planets much more
abundant around (early-)M dwarfs
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Howard et al. (2011, Sci 330, 653)

$$f = 0.30 \pm 0.08$$

Gaidos et al. (2012, AJ 753, 90)

$$f = 0.36 \pm 0.08$$

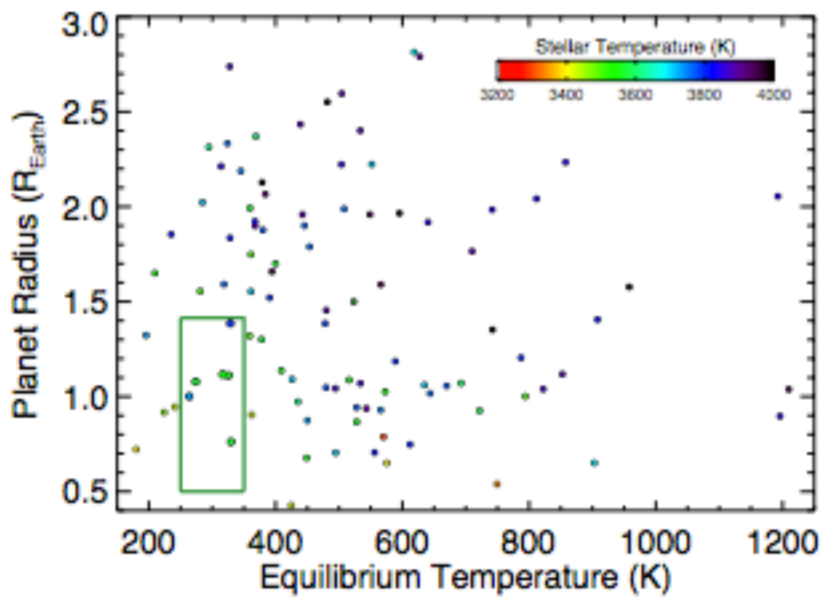
$$(3600 < T_{eff} < 4100 \text{ K};\ \ P < 50 \text{ d};\ \ 2 < R_p < 32 \text{ R}_\oplus)$$

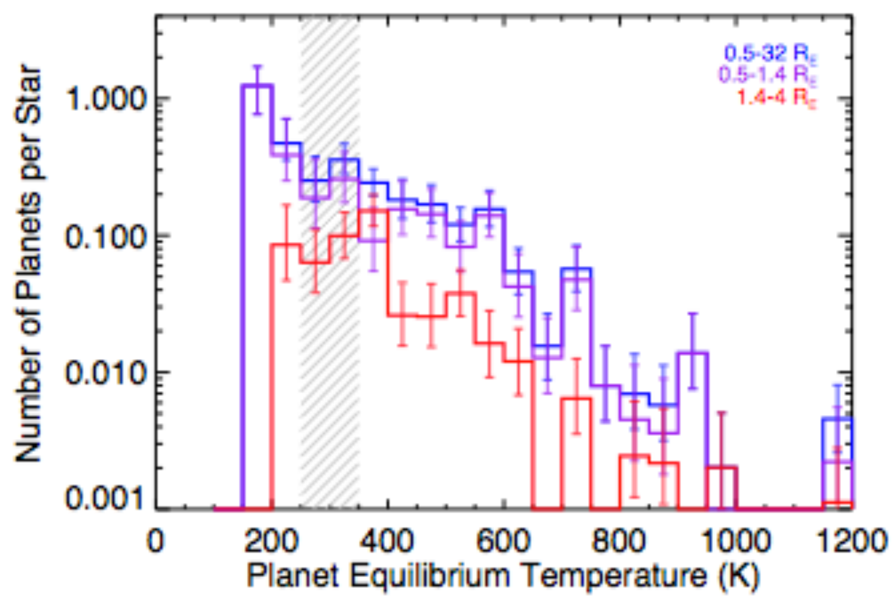
photometry (transit)

- *Kepler results*
- *Mearth*

The Occurrence Rate of Habitable Planets Around M Dwarfs from Kepler

Courtney Dressing[1,*] & David Charbonneau[1]
[1]Harvard-Smithsonian Center for Astrophysics, *cdressing@cfa.harvard.edu



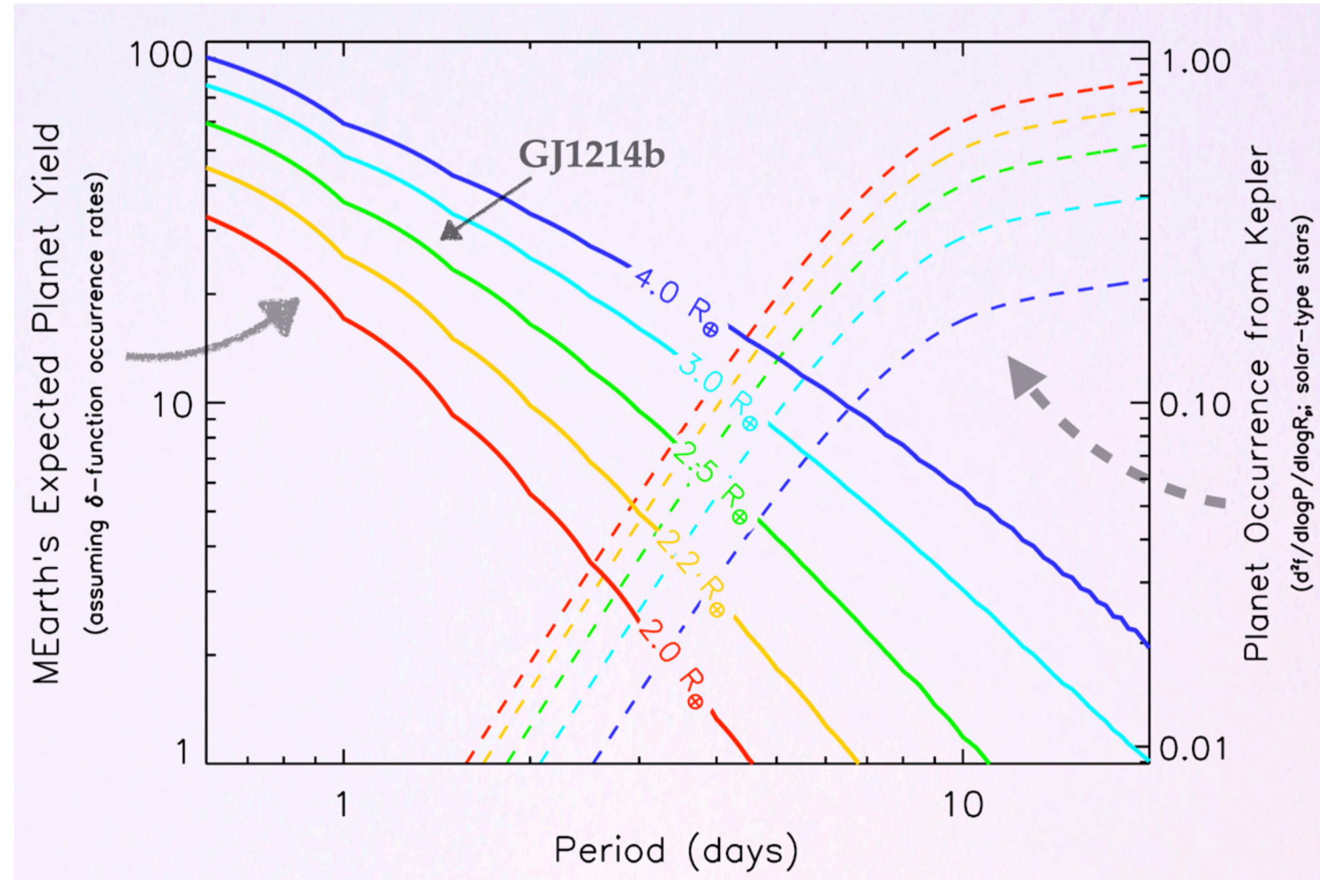


$f \sim 0.4$ habitable pl. / star

Dressing et al.

MEarth and the occurrence rate of warm super-Earths and Neptunes orbiting mid-to-late M dwarfs

Zachory K. Berta[1], Jonathan Irwin[1], David Charbonneau[1], Christopher Burke[2], Emilio Falco[3]



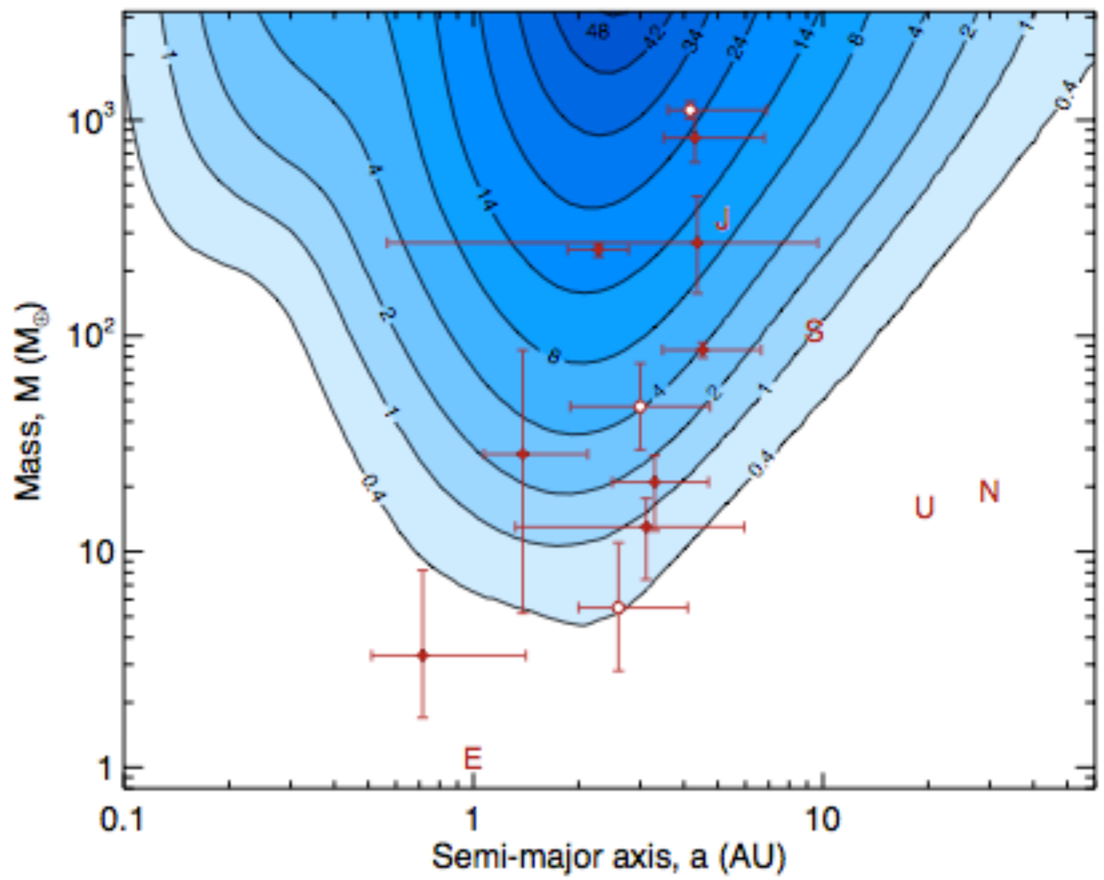
Berta et al.

$$f = 0.22^{+0.52}_{-0.06}$$

$$2 - 4\ \mathrm{R}_\oplus ; P < 10\ \mathrm{d}$$

μ-lensing

- *Gould et al. (2010, ApJ 720, 1013)*
- *Cassan et al. (2011...)*



$$0.5 < a < 10\ AU$$

$$f = 19^{+6}_{-9}\% \qquad 0.3 < M_p < 10\ \mathrm{M_{Jup}}$$

$$f = 55^{+22}_{-29}\% \qquad 10 < M_p < 30\ \mathrm{M}_\oplus$$

$$f = 62^{+35}_{-37}\% \qquad 5 < M_p < 10\ \mathrm{M}_\oplus$$

HOW MANY TARGETS ?

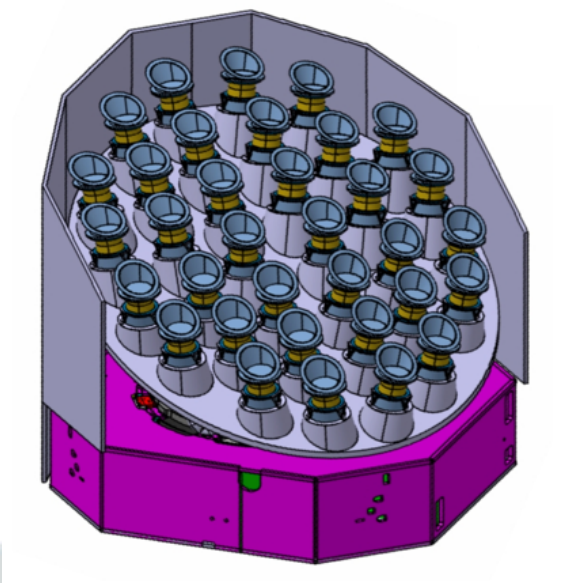
- consistent picture emerging from HARPS, Kepler, Mearth and μ-lensing surveys
  - occurence of $1 - 10\ \mathrm{M}_{\oplus}$: $f \sim 30 - 50\%/\mathrm{dlog}P$
  - ~40% habitable planets
- one can use the statistical results to estimate :
  - the number of planets for a given survey
  - the number of targets required to significantly *refined* or *change* the number

  e.g. RV surveys put <1% on hot-Jupiter occurrence

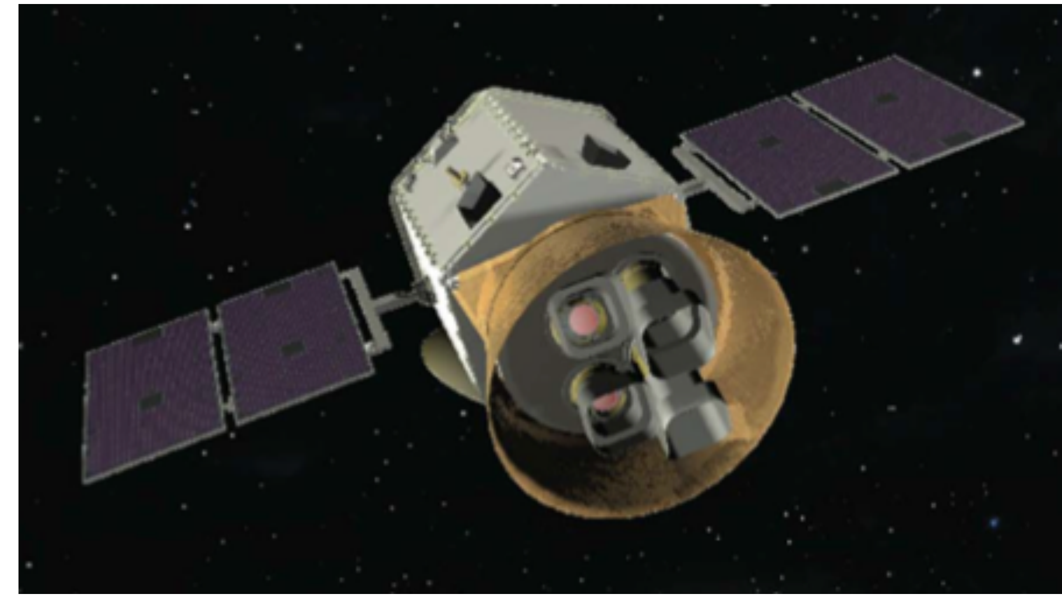
  Kepler found one (KOI-254b, Johnson et al. 2012)

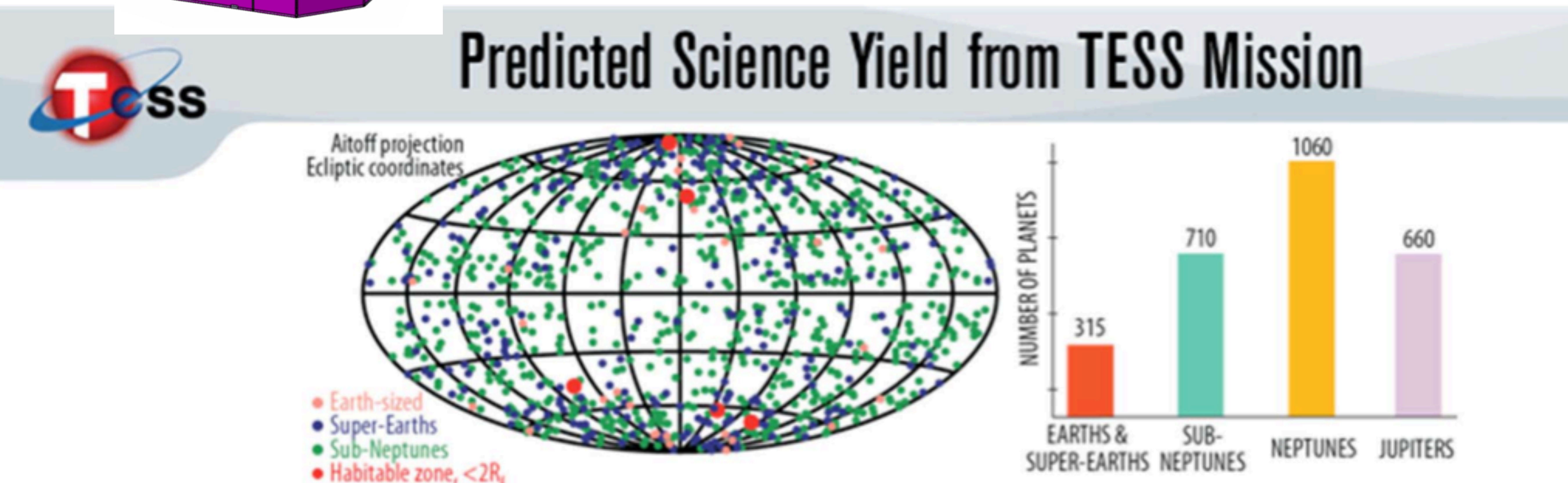
  $O(15)$ M dwarfs to refine/change RV results
- for $P_{tr} \sim 2\%$ one need $O(100)$ M dwarfs to expect one habitable transiting planets

HOW ?



PLATO / TESS





TESS vs. PLATO :

- more M-dwarf planets for TESS,
- more (habitable) Earth-size transiting GK stars for PLATO

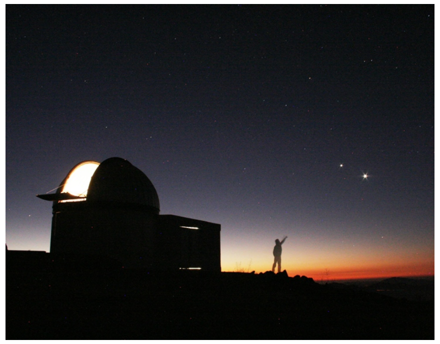
Waiting for TESS / PLATO...

MEARTH

TRAPPIST - UCDTS

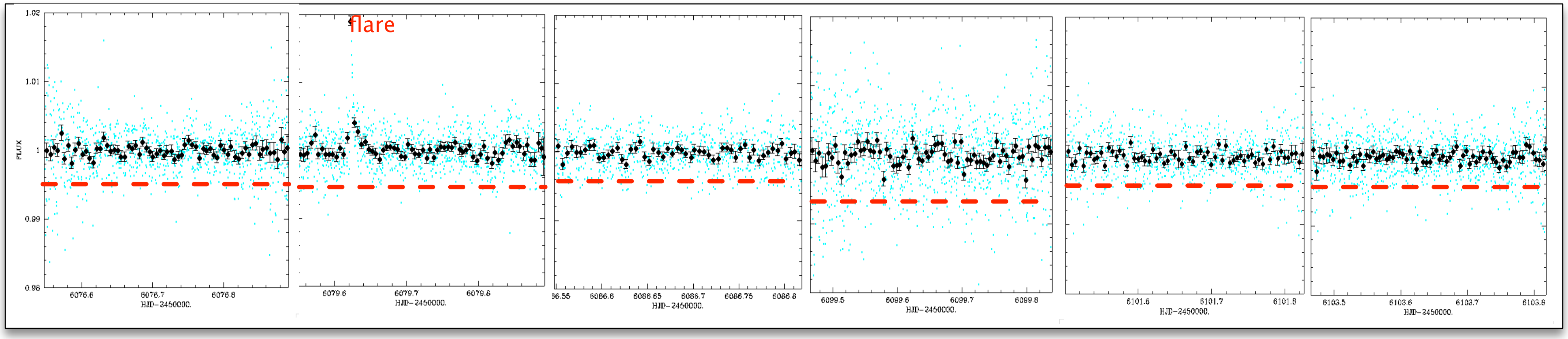
UltraCool Dwarfs Transit Survey

M6--L0



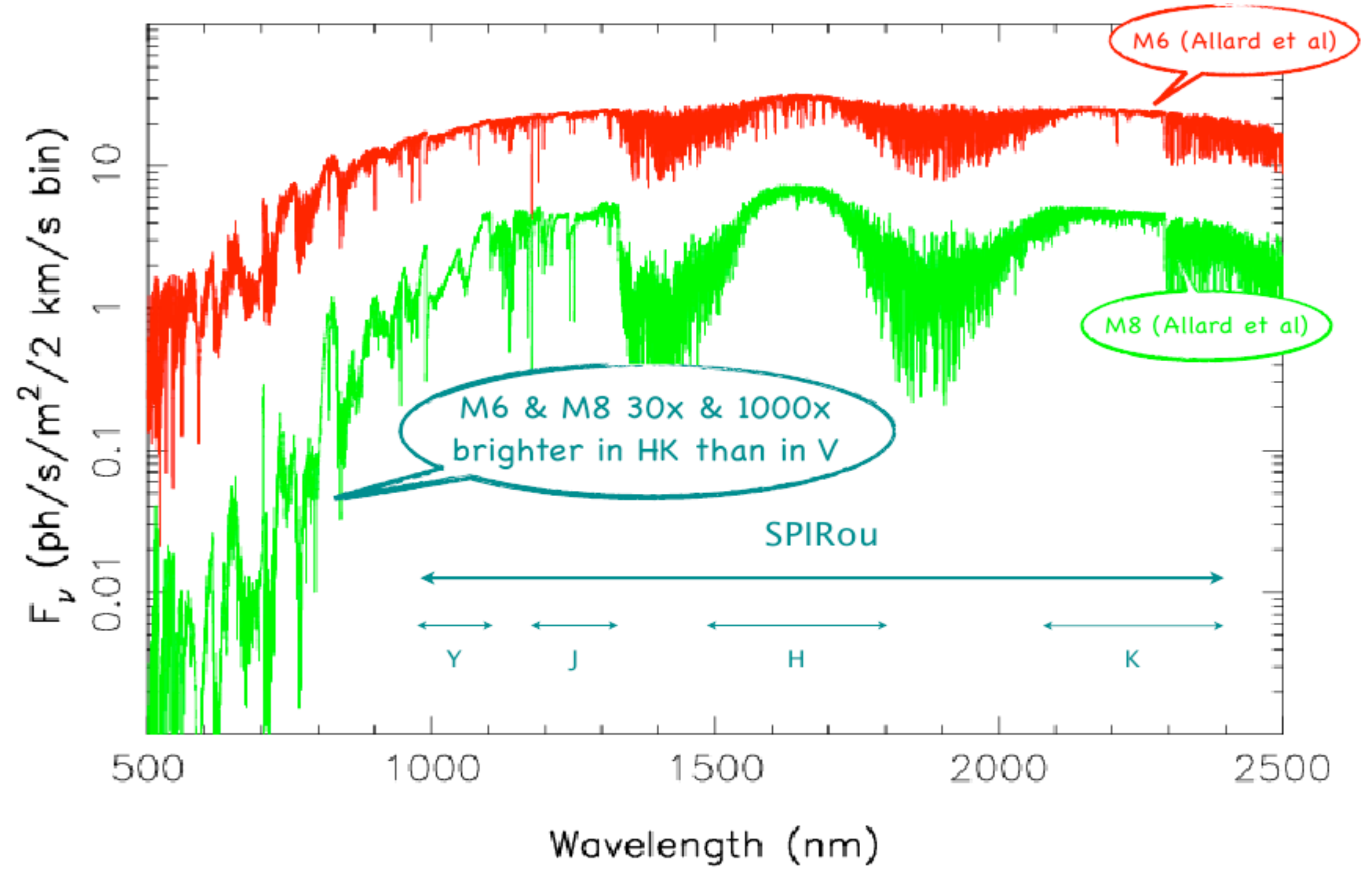
PI: Michaël Gillon (University of Liège, Belgium)
michael.gillon@ulg.ac.be

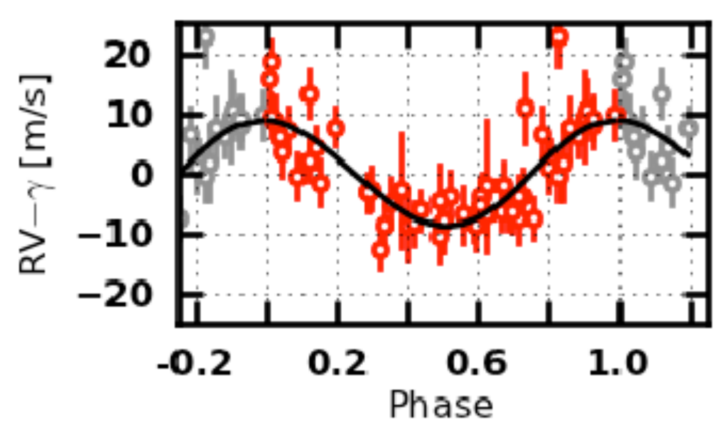
UCDTS-41, M7V, V=16.6, J=9.8, M~0.09$M_\odot$, R~0.12 $R_\odot$, Teff~2660K, HZ from 4.3 to 7.4d

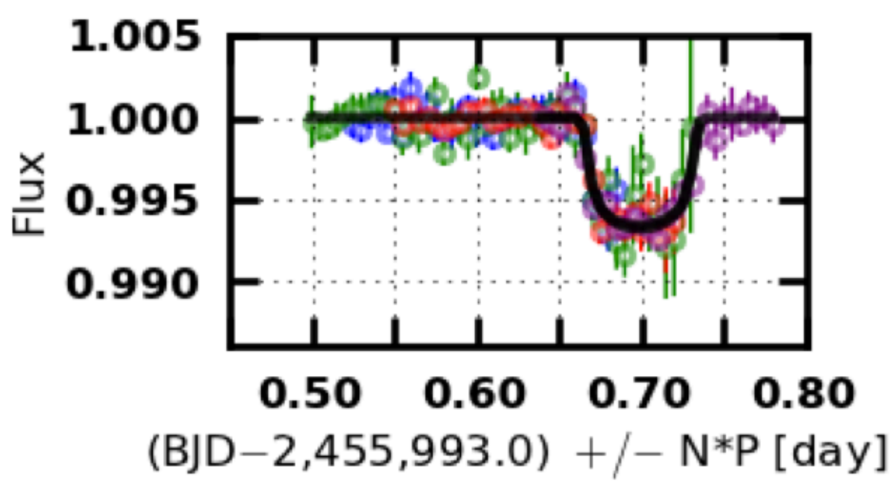


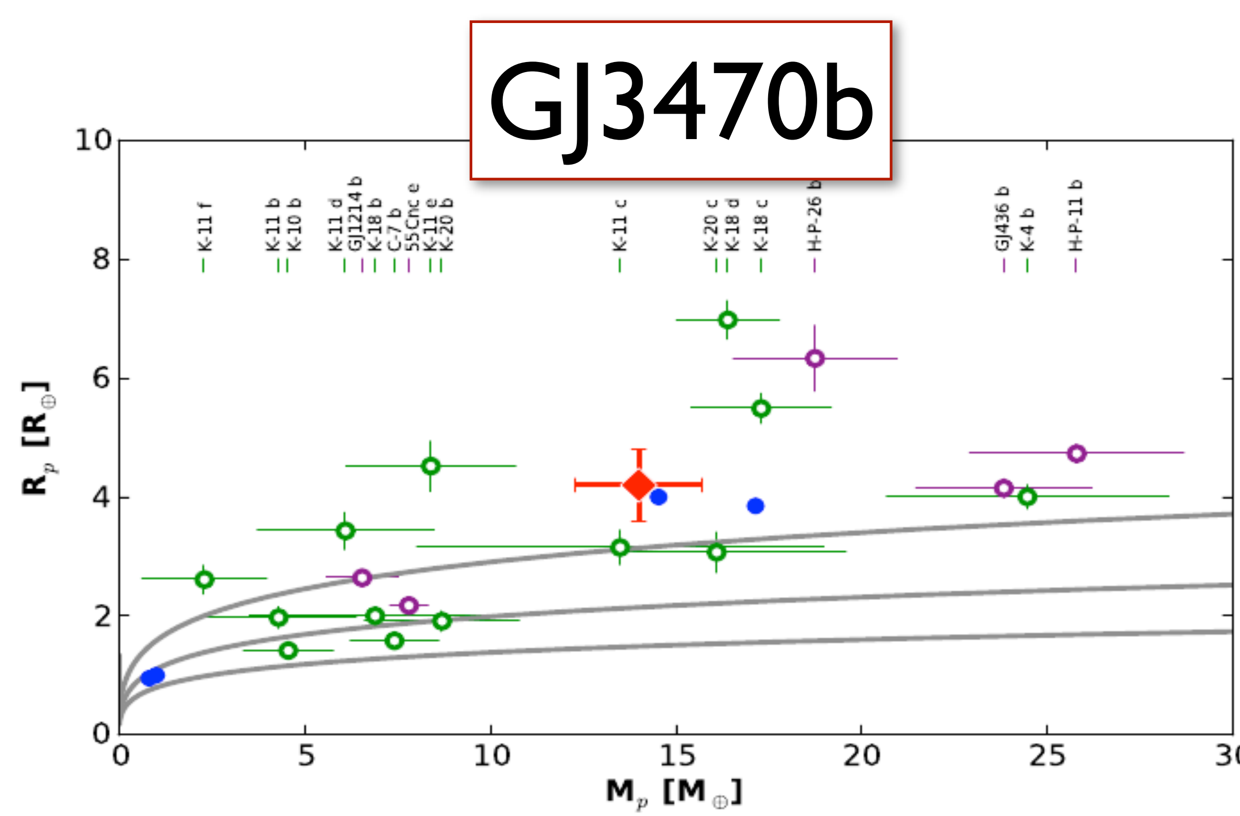
<5σ-threshold> = 0.9R_{earth} $P_{detection,in}$=3% $P_{detection,HZ}$=0.6%

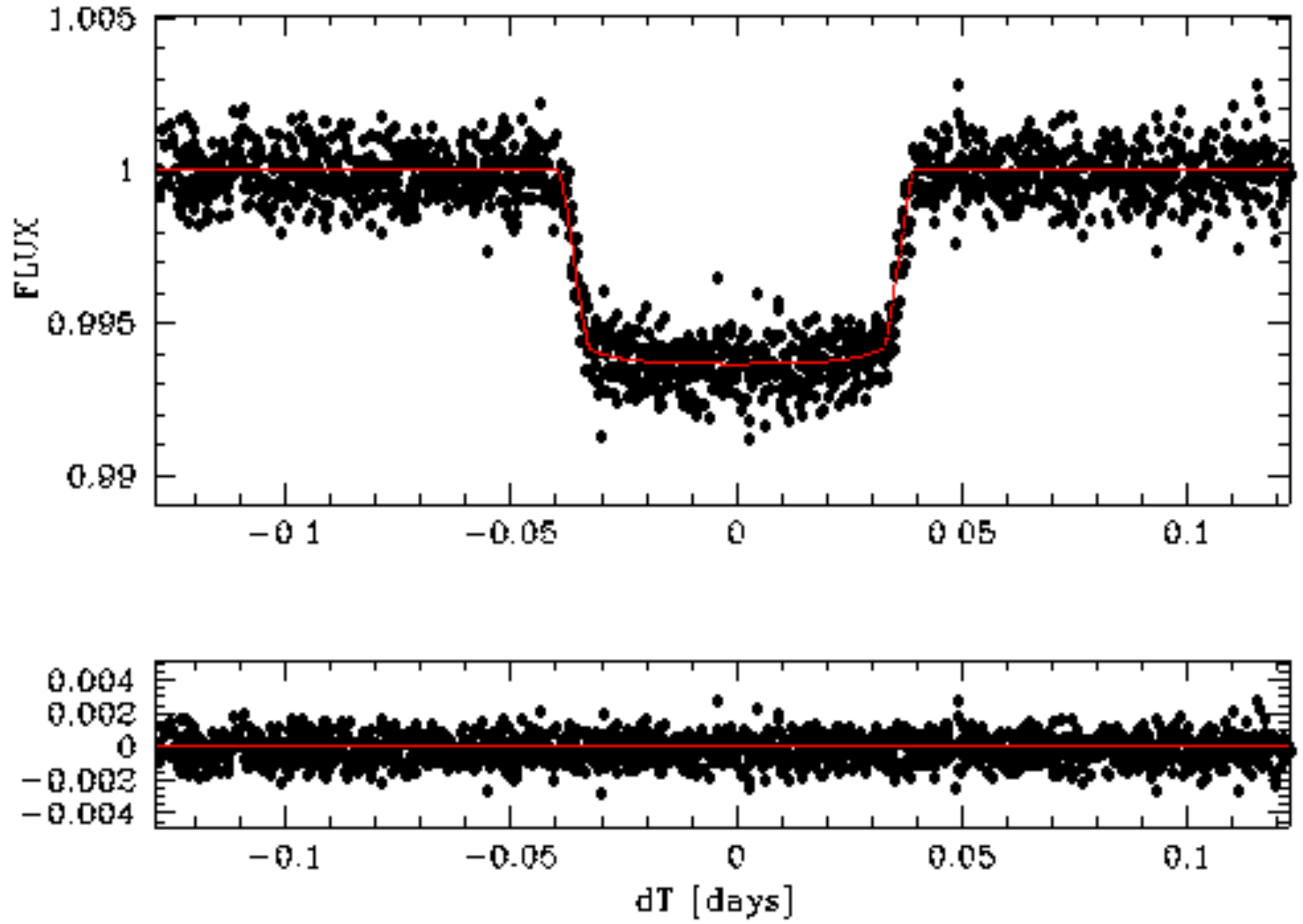
Waiting for TESS / PLATO...



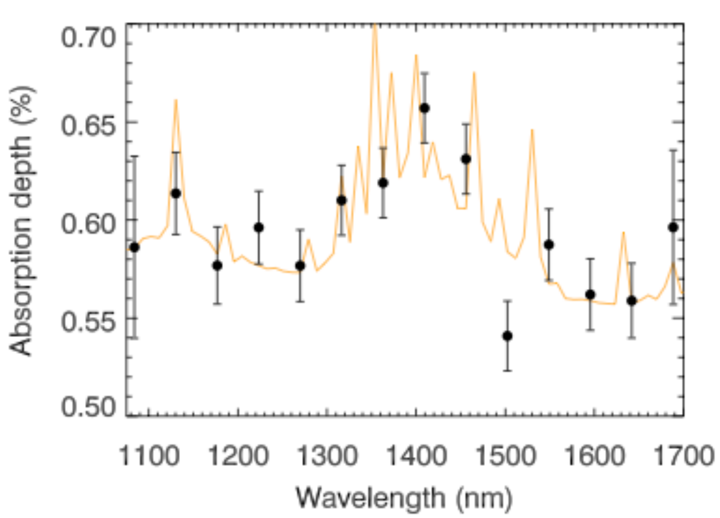




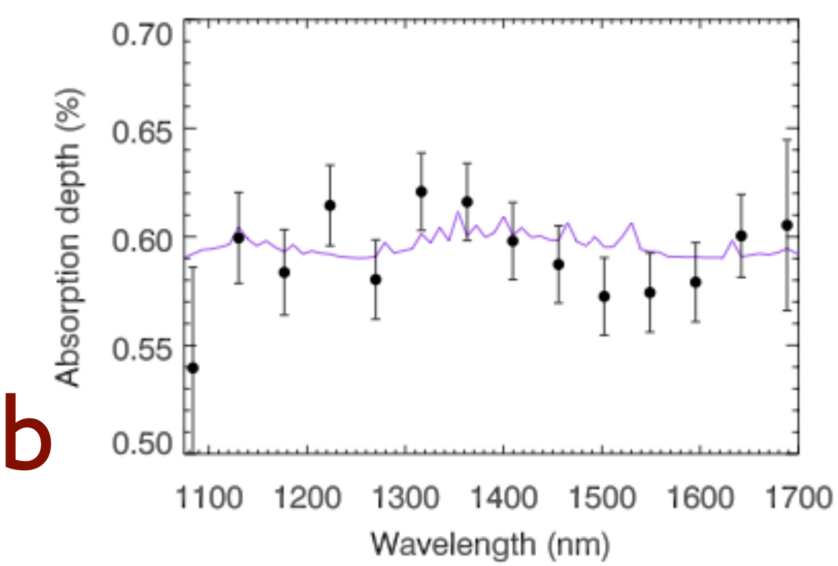




Demory et al.



GJ3470b



13064 - **David Ehrenreich**

Investigating the nature of GJ 3470b, the missing link between super-Earths and Neptunes

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HOW ?

- space-borne transit survey (PLATO, TESS)
- ground based MEarth-like photometry (APACHE, TRAPPIST, ...)
- IR-spectro (SPIRou, CARMENES) coupled to photometric follow-up