ExoPAG Report

APS Meeting, Washington DC

October 20, 2011

James Kasting, ExoPAG Chair

ExoPAG activities since July APS meeting

- Made further progress on defining science goals/requirements for a future UV/optical flagship exoplanet direct characterization mission
  - Charley Noecker/Tom Greene co-chair this Study Analysis Group, with logistical help from Marie Levine at JPL
  - 2 telecons held
  - Temporary hiatus as Noecker moves to new organization
  - Slowing down is not a problem, as the Imaging Performance Study that was to commence this Fall has been postponed due to budget problems

Concerns

- As Mike Devirian pointed out yesterday, we are worried about maintaining continuity in exoplanet exploration
  - Whether or not a flagship exoplanet mission is conceivable for the next (2020-2030) decade is currently unclear
  - A growing community of young astronomers interested in exoplanets needs access to new data
  - Some things can be done from the ground, but many tasks (e.g., transit spectroscopy, precision astrometry, direct imaging of terrestrial planets) need to be done from space

- Now, the good news: Exoplanets are being found all over the place $\Rightarrow$

Astronomy & Astrophysics manuscript no. HARPS stat
September 13, 2011

The HARPS search for southern extra-solar planets

XXXIV. Occurrence, mass distribution and orbital properties of super-Earths and Neptune-mass planets*

M. Mayor[1], M. Marmier[1], C. Lovis[1], S. Udry[1], D. Ségransan[1], F. Pepe[1], W. Benz[2], J.-L. Bertaux[3], F. Bouchy[4], X. Dumusque[1], G. LoCurto[5], C. Mordasini[6], D. Queloz[1], and N.C. Santos[7,8]

- 822 stars monitored for 8 years
- More than 50% of solar-type stars harbor at least one planet of any mass and with period up to 100 days
- The mass distribution of Super-Earths and Neptune-mass planets (SEN) is strongly increasing between 30 and 15 $M_\oplus$ and is independent of stellar metallicity
- At the opposite, the occurence rate of gaseous giant planets is growing with the logarithm of the period, and is strongly increasing with the host-star metallicity

Table 1. Occurrence frequency of stars with at least one planet in the defined region

Mass limits	Period limit	Planetary rate based on published planets	Planetary rate including candidates	Comments
$> 50\ M_\oplus$	< 10 years	13.9 ± 1.7 %	13.9 ± 1.7 %	Gaseous giant planets
$> 100\ M_\oplus$	< 10 years	9.7 ± 1.3 %	9.7 ± 1.3 %	Gaseous giant planets
$> 50\ M_\oplus$	< 11 days	0.89 ± 0.36 %	0.89 ± 0.36 %	Hot gaseous giant planets
Any masses	< 10 years	65.2 ± 6.6 %	75.1 ± 7.4 %	All "detectable" planets with $P < 10$ years
Any masses	< 100 days	50.6 ± 7.4 %	57.1 ± 8.0 %	At least 1 planet with $P < 100$ days
Any masses	< 100 days	68.0 ± 11.7 %	68.9 ± 11.6 %	F and G stars only
Any masses	< 100 days	41.1 ± 11.4 %	52.7 ± 13.2 %	K stars only
$< 30\ M_\oplus$	< 100 days	47.9 ± 8.5 %	54.1 ± 9.1 %	Super-Earths and Neptune-mass planets on tight orbits
$< 30\ M_\oplus$	< 50 days	38.8 ± 7.1 %	45.0 ± 7.8 %	As defined in Lovis et al. (2009)

- Almost 70% of F and G stars have a planet with a period of <100 days
- K stars are a little lower—only 40-50% have an observed planet

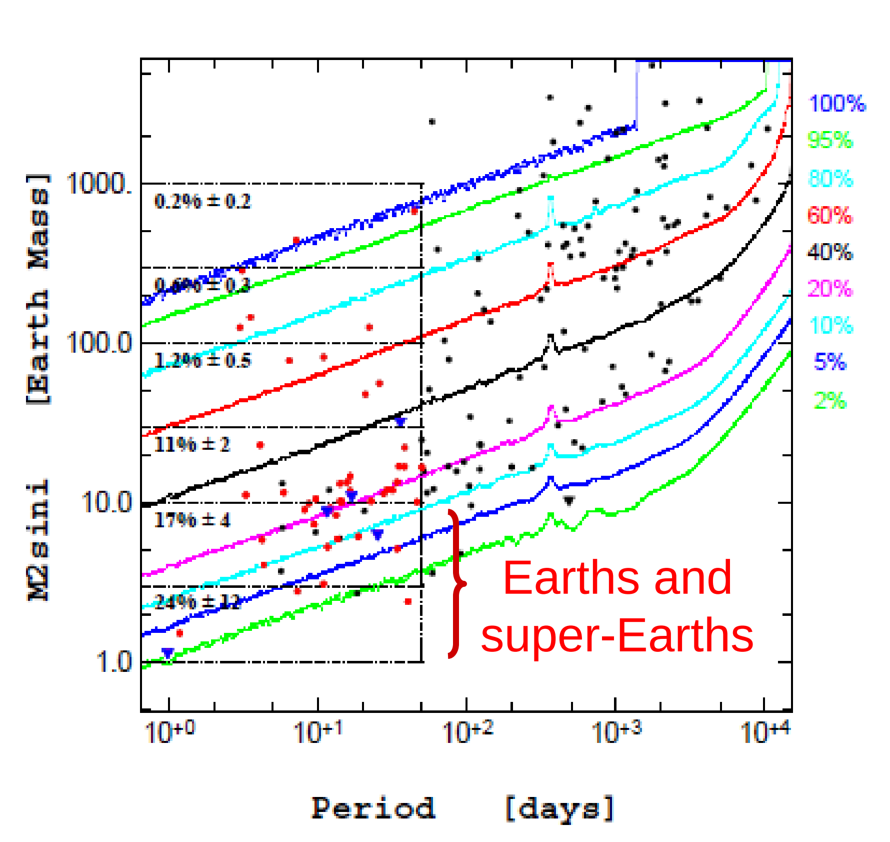
Table 2. Detected planets with periods <50 days (comparison with Howard et al. η_{Earth} survey)

Mass range	HARPS & CORALIE survey				η Earth survey			
	Nb of planets			Planetary rate	Nb of planets			Planetary rate
$M_\oplus$	N_1	N_2	N_3	[%]	N_1	N_2	N_3	[%]
3-10	19	2	48.5	16.6 ± 4.4	5	3	10.2	11.8 ± 4.3
10-30	25	1	20.6	11.1 ± 2.4	4	1	4.6	6.5 ± 3.0
30-100	5	1	4.6	1.17 ± 0.52	2			1.6 ± 1.2
100-300	4	0	0.8	0.58 ± 0.29	2			1.6 ± 1.2
300-1000	2	0	0	0.24 ± 0.17	2			1.6 ± 1.2

- N_1 = number of detected planets
- N_2 = number of planet candidates
- N_3 = estimated number of planets
- Planetary frequency is significantly larger than found in the previous η_{Earth} survey, probably due to lower detection limits (down to 0.5 m/s for HARPS)

Fig. 9. Occurrence rate of short-period planets (<50 days)

- When extrapolated to lower masses, the estimated number of planets is even higher
- Some 41% (!) of observed stars have a planet with a mass less than 10 $M_{\oplus}$ (hence, rocky) and with a period <50 days



Planets with periods <100 days

- There are two distinct populations of exoplanets: those with masses <30 $M_{\oplus}$ and those with masses >50 $M_{\oplus}$
- These results make it clear that rocky, terrestrial planets are abundant

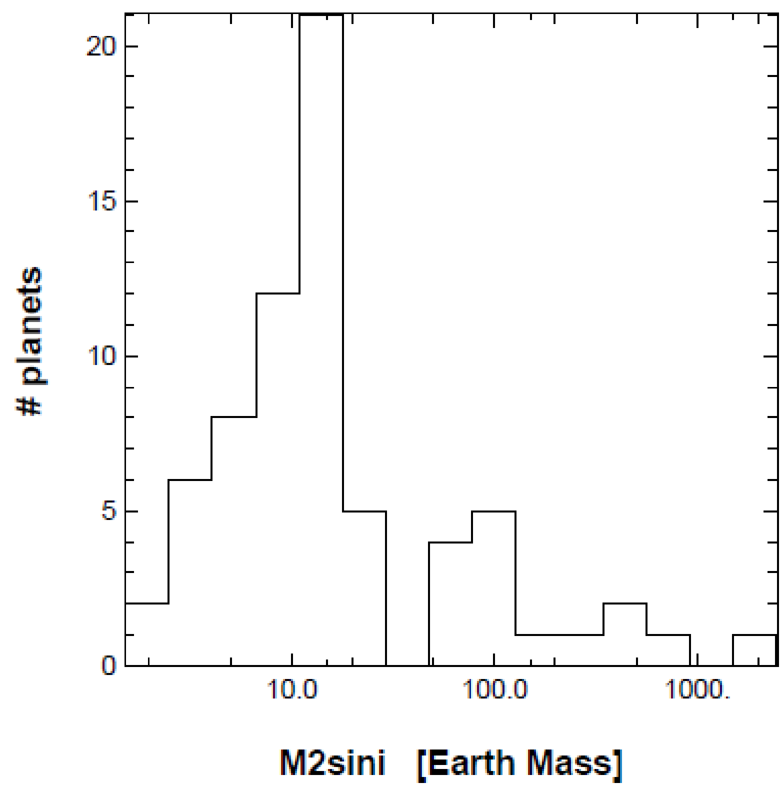
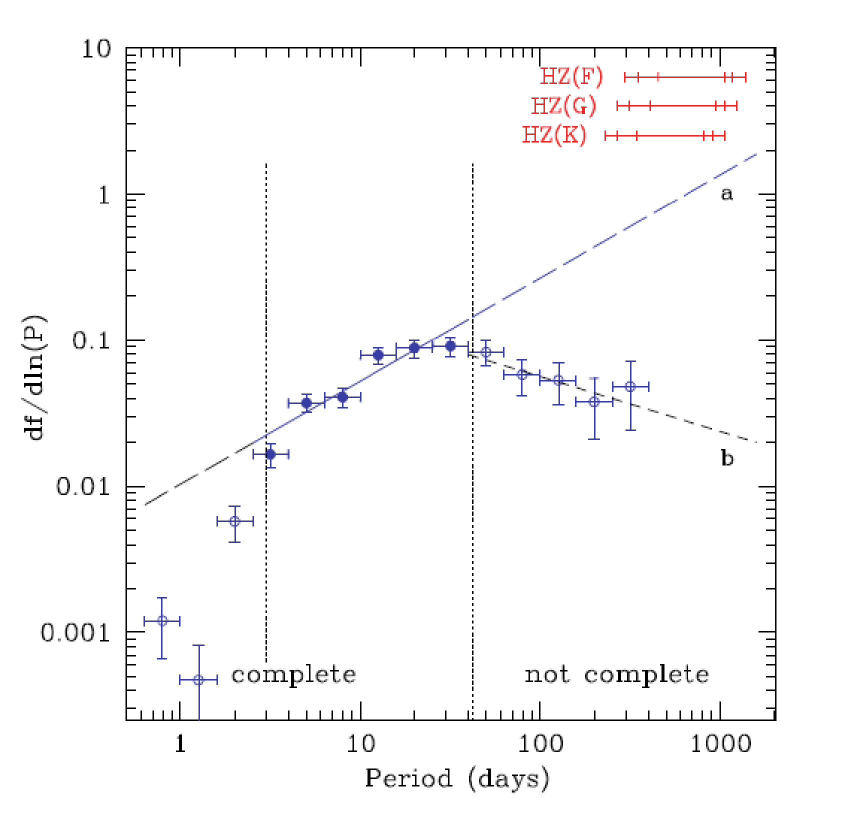


Fig. 11. Same as Fig. 10 but for planets with periods smaller than 100 days. We see the dominance of low-mass planet with short orbital periods.

η_{Earth} from Kepler

- Two different estimates of η_{Earth} have now been published based on the Feb. (2011) Kepler data release
- Cantanzarite and Shao (Ap. J., in press) estimate 1-3%
- Traub (diagram at right) estimates 34±14%
  - The difference has to do with whether one assumes that the data are complete for orbital periods >42 d. (They obviously are *not,* so Traub's estimate is arguably better.)
- It is a no-brainer to conclude that we need to see a longer Kepler dataset!



W. Traub, Ap. J., in press

Conclusions

- Exoplanets are abundant
- η_{Earth} is likely to be high (we will know better in another two years)
- NASA may have made a mistake by canceling SIM, because we're not likely to find the nearby Earths using radial velocity (the stars themselves are too noisy)
- That said, we can do a direct imaging (TPF) mission anyway because there are lots of targets. We probably will only need a 4-m mirror for this same reason, so the mission need not be terribly large and expensive. Such a mission should be a high NASA priority!