Observational results on exoplanets

January 18, 2007

Radial velocity results Foreword

- Distinguish candidates and confirmed planets, e.g.:
  - transit detections require RV confirmation (contamination, mass measurement)
  - RV detections have minimum masses m_p.sin i
  - mass-luminosity uncertainties (direct detection)
- Complicated sensitivity space:
  - bias (sample selection:
    spectral type, Z, companionship, distance,…)
  - detection efficiencies=
    f(method, instrument, time baseline,
    mass, semi-major axis, eccentricity, age, Z, inclinaison,…)

HARPS Guaranteed Time Observations

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In compliance with the GTO policies, we here present the GTO proposals of the HARPS consortium.

NO.	PI	TITLE
1	M. Mayor	Searching for very low mass planets
2	M. Mayor	Better distributions of orbital elements
3	M. Mayor	Planets around very-low mass stars
4	M. Mayor	Stellar metallicity and the formation of giant planets (metal deficient stars)
5	M. Mayor	Stellar metallicity and the formation of giant planets (searching for planets in visual binaries and possible chemical anomalies)

Send comments to <visas@eso.org>
Last update: 28 August 2006

m_p.sin i

- Probability that the inclinaison be larger than θ:

$$p(\theta < i < 90°) = \cos(\theta)$$

- *Median* planet mass is 1.155 x(m_p.sin i)
- *Average* planet mass is π/2 x(m_p.sin i)
- Uncertainty of stellar mass propagates to the planet mass

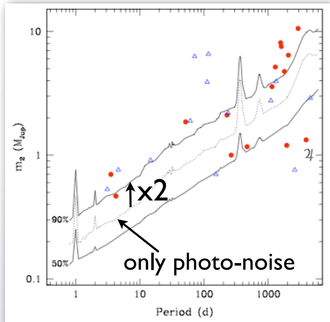
Confidence that

$$m_p \sin i \leq m_p < F \times m_p \sin i$$

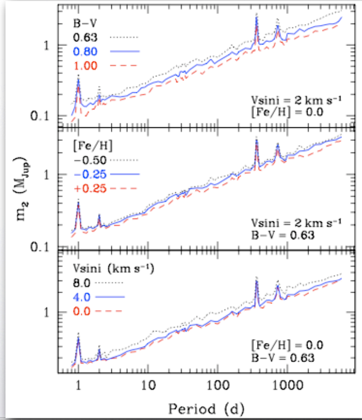
Confidence	F
50%	$1.155 = \frac{1}{\sin(\cos^{-1}(50\%))}$
90%	2.294
95%	3.203
99%	7.088
99.9%	22.366

Detection efficiency

ELODIE survey



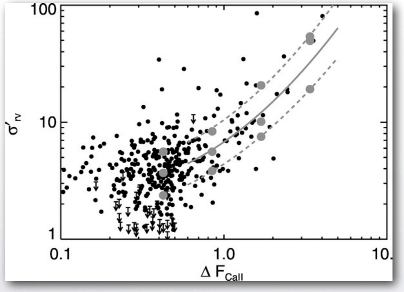
Simulation paper:
Cumming (2004) *MNRAS* **354** 1165

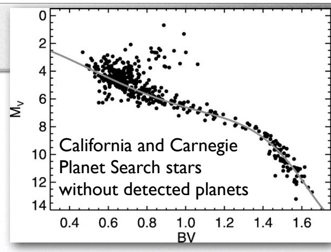


Naef et al. (2005) *Cool Stars #13*

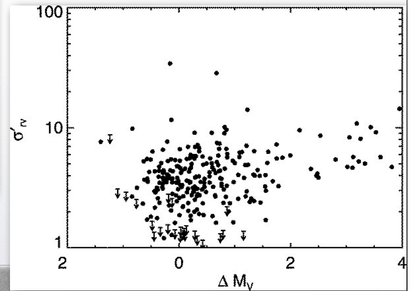
RV limitations

Activity related jitter:





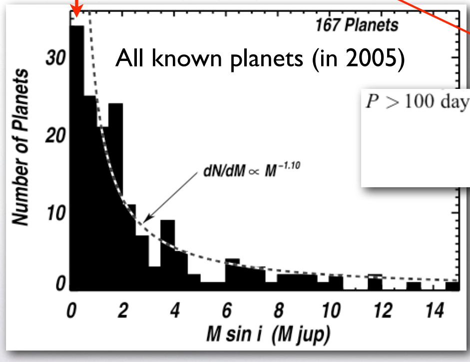
Evolution jitter:



Wright (2005) *PASP* **117** 657

Mass distribution

Incomplete!
(<0.5M_{jup}), depending on orbital period

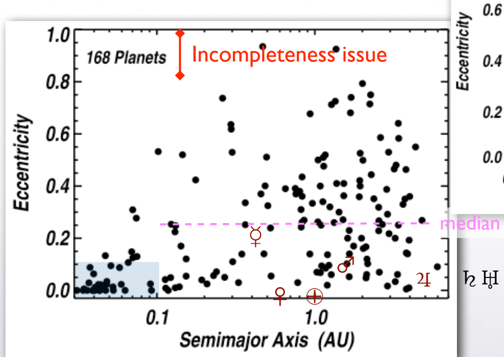


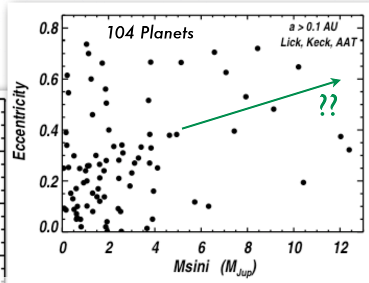
$P > 100$ days is well fitted with a broken power law:

$$dN/dM \propto \begin{cases} M^{-1.2}, & M < 0.6M_J, \\ M^{-1.9}, & M > 0.6M_J. \end{cases}$$

Butler et al. (2006) *ApJ* **646** 505 — Cumming et al. (unpubl.)

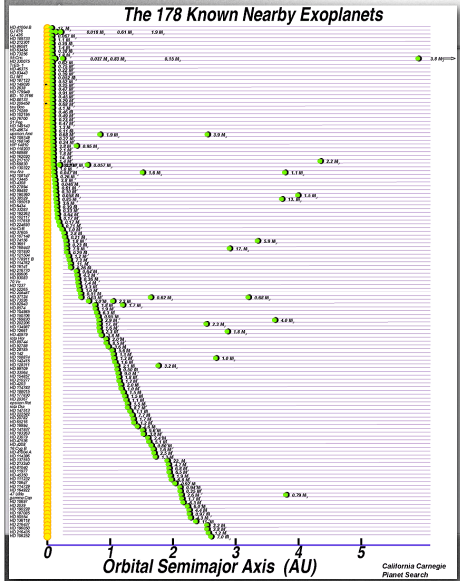
Eccentricity distribution





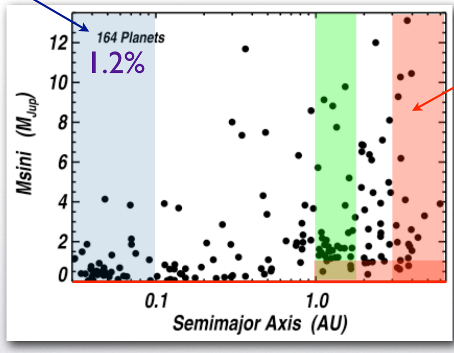
from Butler et al. (2006) *ApJ* **646** 505 — Marcy et al. (2005) *P.Th.Ph.Suppl.* **158**

Semi-major axis



Semi-major axis

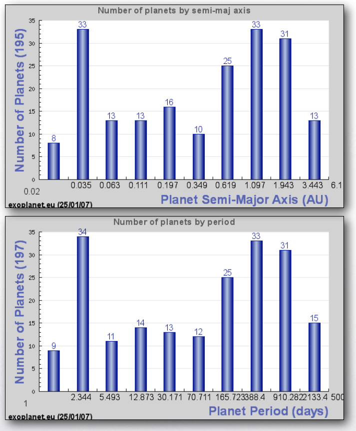
very complete!

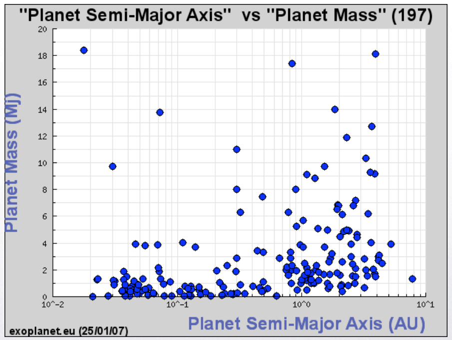


Incomplete!
> ~ 3AU<==>P>~5a
or
>~1AU and M_p<1M_{Jup}
or
M_p<0.1M_{Jup}

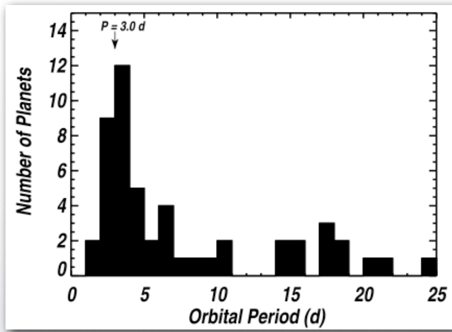
Butler et al. (2006) *ApJ* **646** 505

from exoplanet.eu



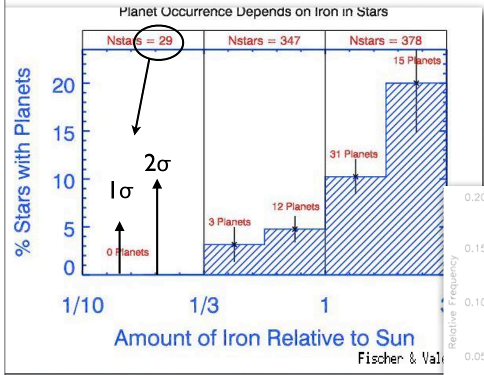


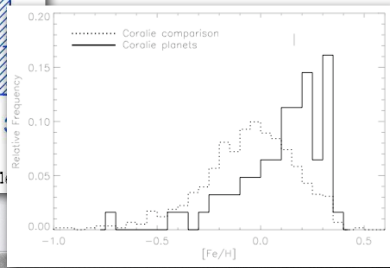
Close-in planets



from Butler et al. (2006) *ApJ* **646** 505

Host star metallicity

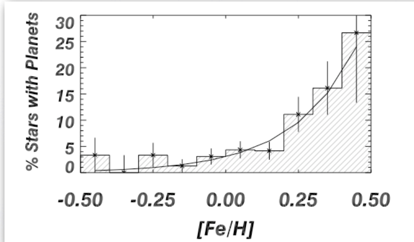




From Fischer & Valenti (??)

Ecuvillon et al., 2007, *A&A* **461** 171

Host star metallicity



$$\mathcal{P}(\text{planet}) = 0.03 \times \left(\frac{(N_{Fe}/N_H)}{(N_{Fe}/N_H)_\odot}\right)^2$$

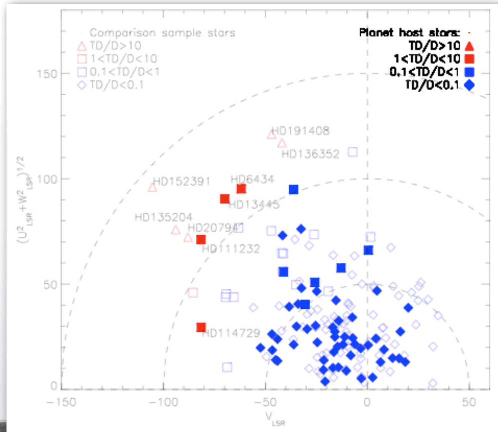
- High-metallicity stars create planets more easily

or

- stars that have created planets experienced metallicity increase

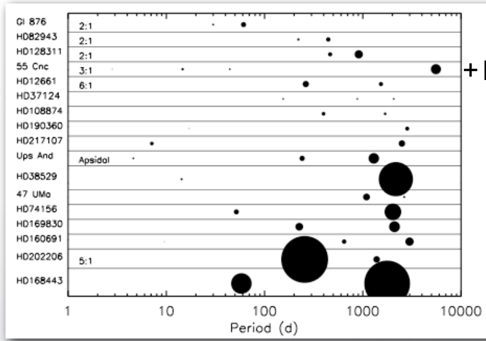
Fischer & Valenti, 2005, *ApJ* **622** 1102

Velocity distribution



Ecuvillon et al., 2007, *A&A* **461** 171

Multi-planet systems



+1

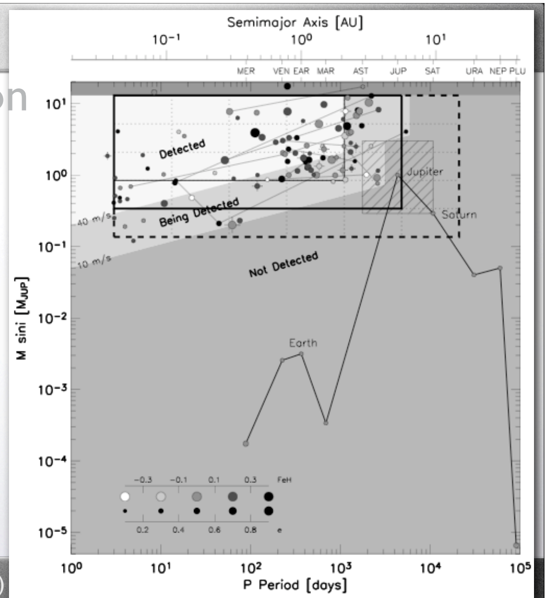
Marcy et al. (2005) *P.Th.Ph.Suppl.* **158**

Frequency

- ELODIE survey (18 planets):
  Naef et al. (2005) *Cool Stars #13*

$$f = 0.7 \pm 0.5\% \text{ for } P < 5\,\text{d}$$
$$f = 4.0 \pm 1.1\% \text{ for } P < 1500\,\text{d}$$
$$f = 7.3 \pm 1.5\% \text{ for } P < 3900\,\text{d}$$

Reservation

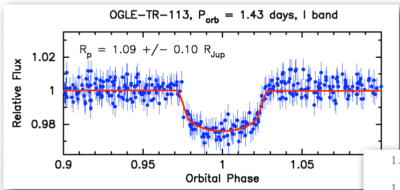


Lineweather & Grether (2003)

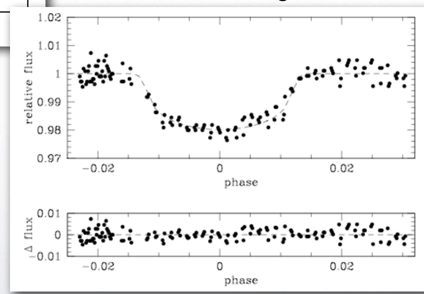
Transit results

	V	M/Msun	Type	Rp/RJup	Mp/MJup	P (days)	a (AU)
Originally detecte							
HD209458b	7.7	-	G0V	1.32	0.69	3.5	0.045
HD149026b	8.2	1.3	G0IV	0.72	0.36	2.9	0.042
HD189733b	7.7		K1-K2	1.15	1.15	2.2	0.0313
OGLE Survey (Te	I	M/Msun	Type	Rp/RJup	Mp/MJup	P (days)	a (AU)
OGLE-TR-56b	16.6	1.04	G	1.23	1.45	1.2	0.0225
OGLE-TR-111b	15.5	0.82	G or K	1.00	0.53	4.0	0.047
OGLE-TR-113b	14.4	0.77	K	1.08	1.35	1.4	0.0229
OGLE-TR-132b	15.7	1.35	F	1.13	1.19	1.6	0.0306
OGLE-TR-10b	14.9	1.2	G or K	1.16	0.54	3.1	00416
Trans-Atlantic Ex	V	M/Msun	Type	Rp/RJup	Mp/MJup	P (days)	a (AU)
TrES-1	11.8	-	K0V	1.08	0.75	3.0	0.0393
TrES-2	11.4	1.08	G0V	1.24	1.28	2.5	0.0367
XO Project XO-1	11.3	1	G1V	1.18	0.9	3.9	0.048
HATNet Project HAT-P-1b	10.4	1.12	G04	1.36	0.53	4.46	0.055
Superwasp Project WASP-1	11.9	1.15	F7V	1.93	0.89	2.51	0.038
WASP-2	11.8	0.79	K1V	0.95	0.88	2.15	0.030
SWEEPS Project SWEEPS-4	18.8	1.24	-	0.81	<3.8	4.2	0.055
SWEEPS-11	19.8	1.1	-	1.13	9.7	1.79	0.03

From Afonso

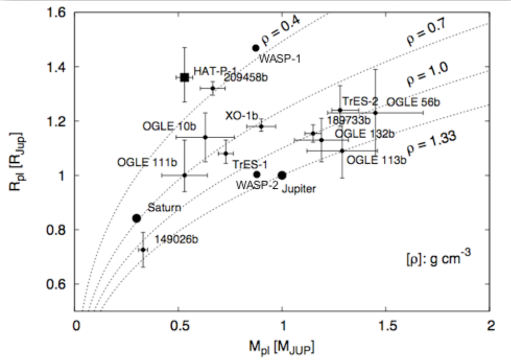


OGLE-TR-111b using VIMOS



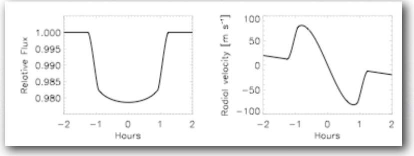
Minniti et al. (2007) astro-ph/0701356

Planetary Radius

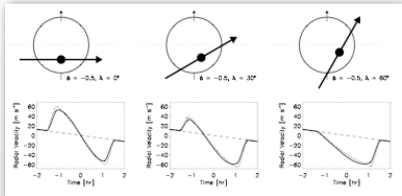


Bakos (2006)

Rossiter-McLaughlin (1924) effect



- Constrains the stellar spin–rotational plan angle (in all 4 cases: aligned)
- Offer transit confirmation



Winn (2007) astro-ph/0612754

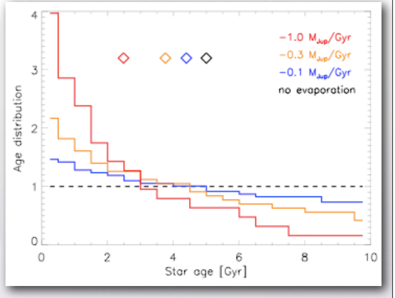
Planetary atmosphere

- Atmosphere - STIS data, increase in transit depth of (2.320.57) x10^{-4} in a passband centered on the sodium resonance doublet (589 nm) -> absorption from atomic sodium in the planetary atmosphere
  - Charbonneau et al. 2002
- Exosphere - STIS data in UV, detection of atomic hydrogen absorption of 15% in the stellar Lyman line during transit -> atmospheric escape of hydrogen
  - Vidal-Madjar et al. 2003

Very hot Jupiter host age distribution

- Very close planets are suspected to evaporate => life-time?

Star	age_{CaII} 2 − σ lower lim.	age_{Li}	age other	Ref. other
TrES-1	>1.1	>0.6	2.5 ± 1	1
OGLE-TR-10	>1.1	–		
OGLE-TR-56	>2	–	3 ± 1	2
OGLE-TR-111	>1.1	>0.6		
OGLE-TR-113	>0.7	>0.6		
OGLE-TR-132	–	–		
HD149026	–	–	2 ± 0.8	3
HD189733	>0.5	>0.6		
HD209458	>2	–	4.5	4



Melo et al., 2006, *A&A* **460** 251

Comparison RV-transit

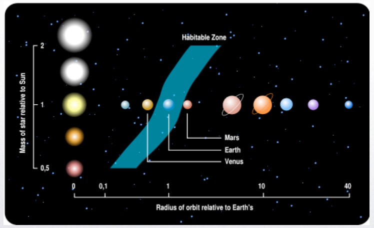
	RV	Transit
hot Jupiters: *P*=2–4d	19 (+3transits)	8(+3RVs)
very hot Jups: *P*<2d	3, *P*=1.3–2d	3, *P*=1.2–2d
sensitivity	$\propto K \propto M_p \sin i . P^{-1/3}$	$\propto P^{-5/3}$
completeness	$M_p \sin i > 0.2 M_{Jup}$ and $P < 10$d	eff(2d) = 2 x eff(3d)

RV: exoplanet.eu & transits: http://obswww.unige.ch/~pont/TRANSITS.htm

Next lecture

Monday, January 29 → Models of planetary atmosphere and structure; habitable zone

Monday, February 5: conclusion and prospects



- Bibliography:
  - Marley et al.: atmosphere (PPV) astro-ph/0602468
  - Chyba, ARAA 2005: astrobiology