The HARPS low-precision, volume limited sample

Planet detection statistics from the ongoing survey after 8 years of data taking

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ESO, Bern, Geneva Obs., LAM

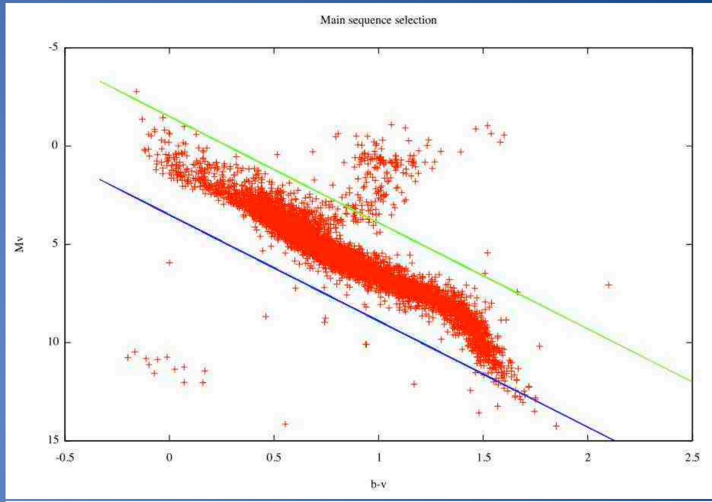
HARPS GTO programs

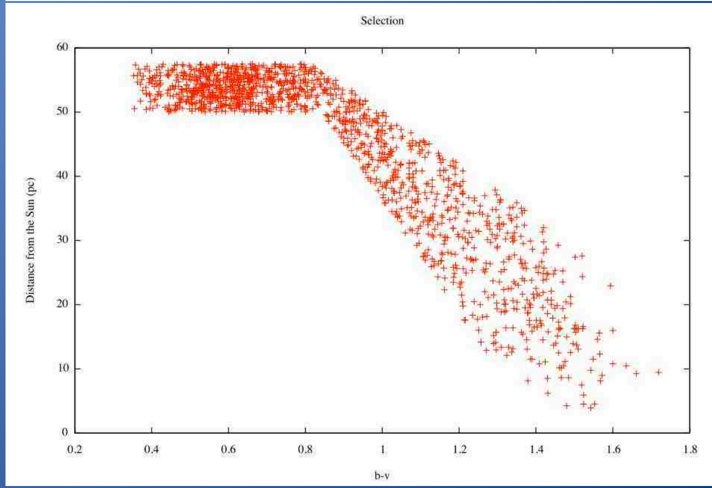
- Low mass planets search (~450 stars)
- **Volume limited sample** (~850 stars)
- Planets around low mass stars (~100 stars)
- Planets around metal poor stars (~100 stars)

Observations of the volume limited sample continued after the end of the HARPS GTO program via normal observing proposals to the ESO OPC.

The sample selection

- HIPPARCOS catalog
- F2-M0 spectral types
- Main sequence stars
- Declination < 0
- 50 pc < dist. < 57.5 pc
- Complement to the CORALIE sample

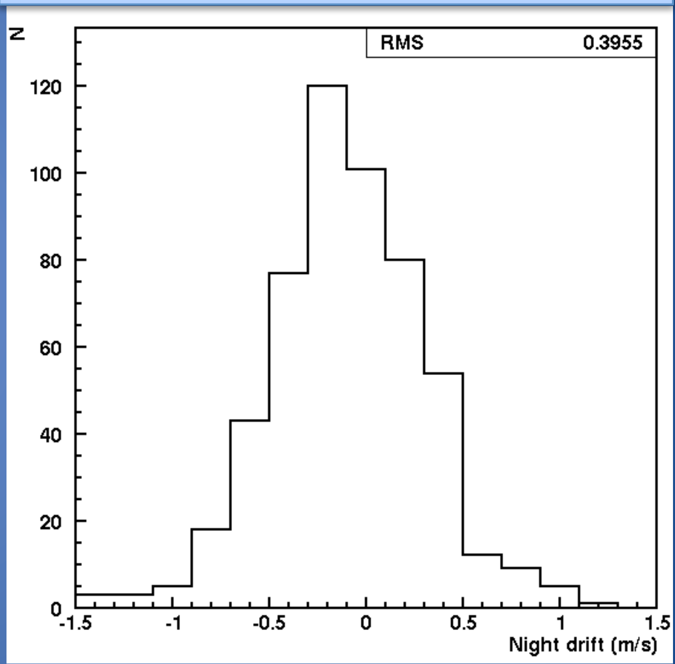




Observing strategy

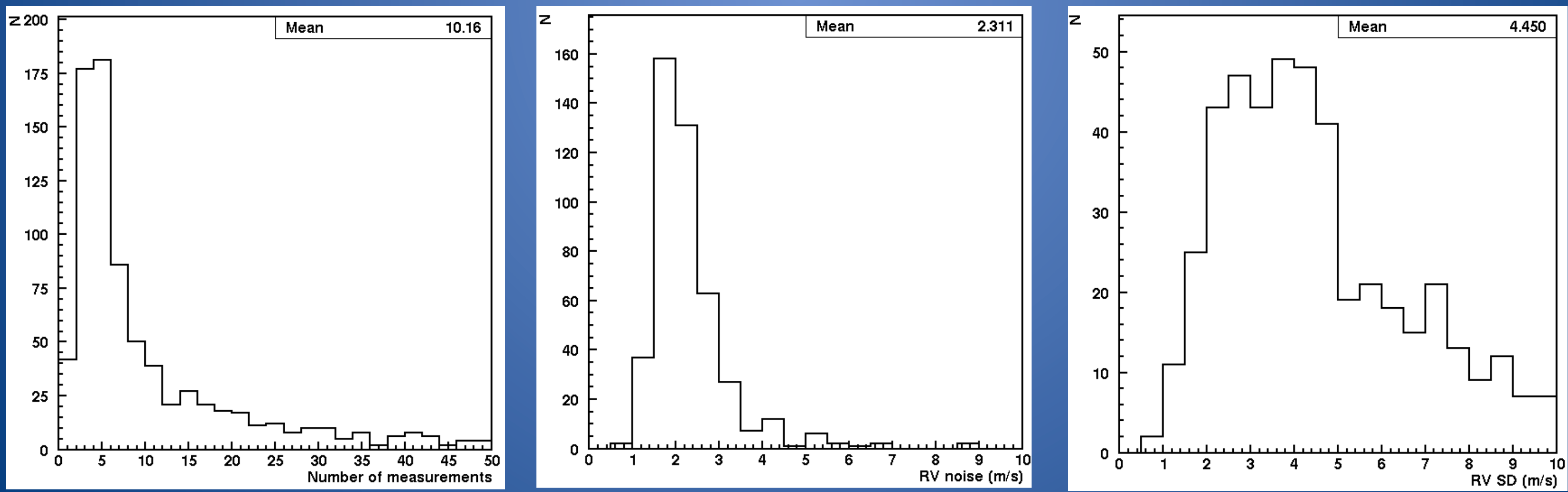
- Limit to 2-3m/s RV precision
- S/N ~ 40 (@ 550nm)
- No simult. Th-Ar reference
  - Night drift is low:
    - drift<0.5m/s : 83%
    - drift<1.0m/s : 98%
- Single exposures
- Telescope time ~8'/exp.
- Follow up if RV varying over 5m/s

Instrumental stability over one night

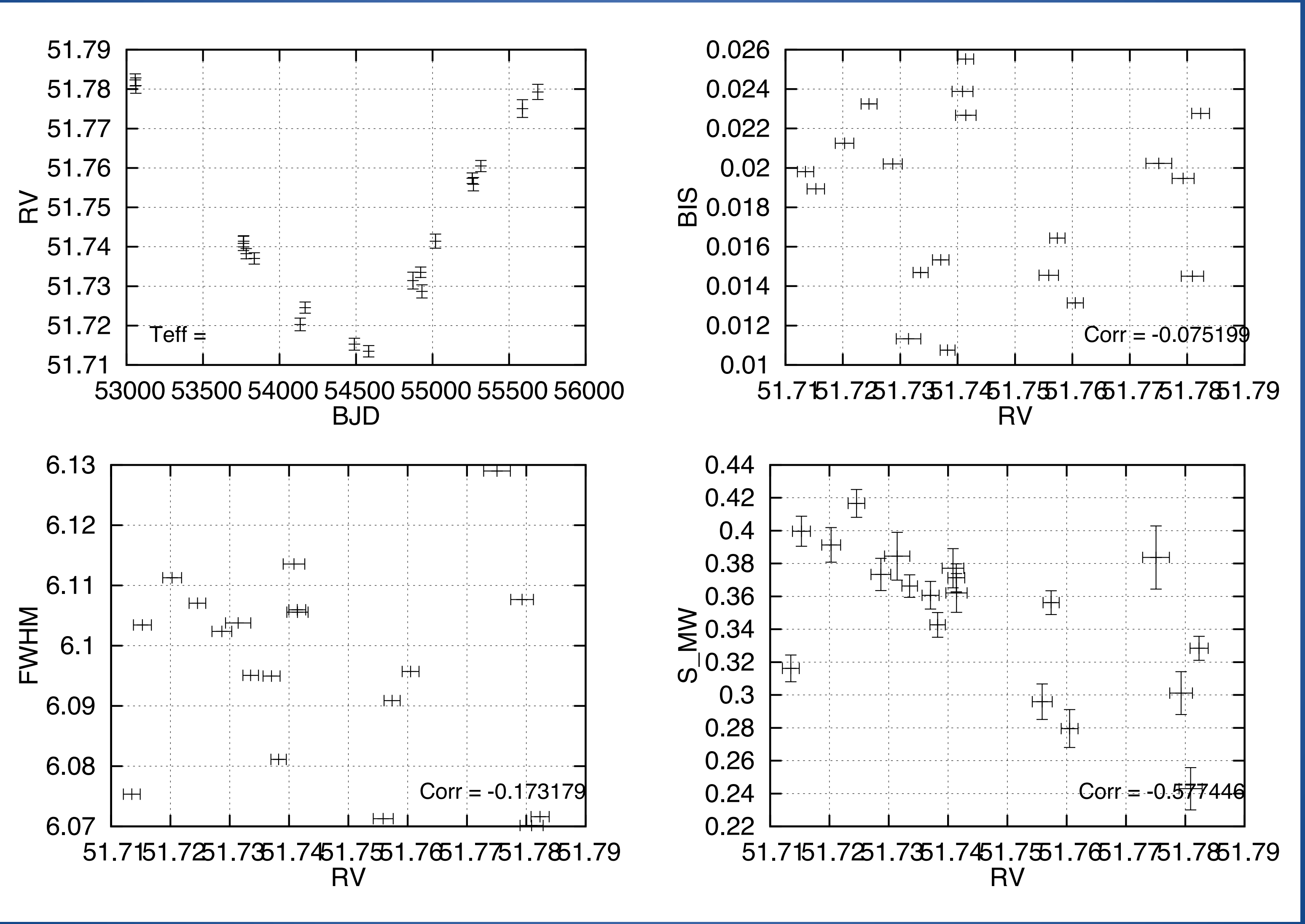


Measurements statistics

- 10 measurements per target on average
- <RV variations> > 2 * <RV noise>

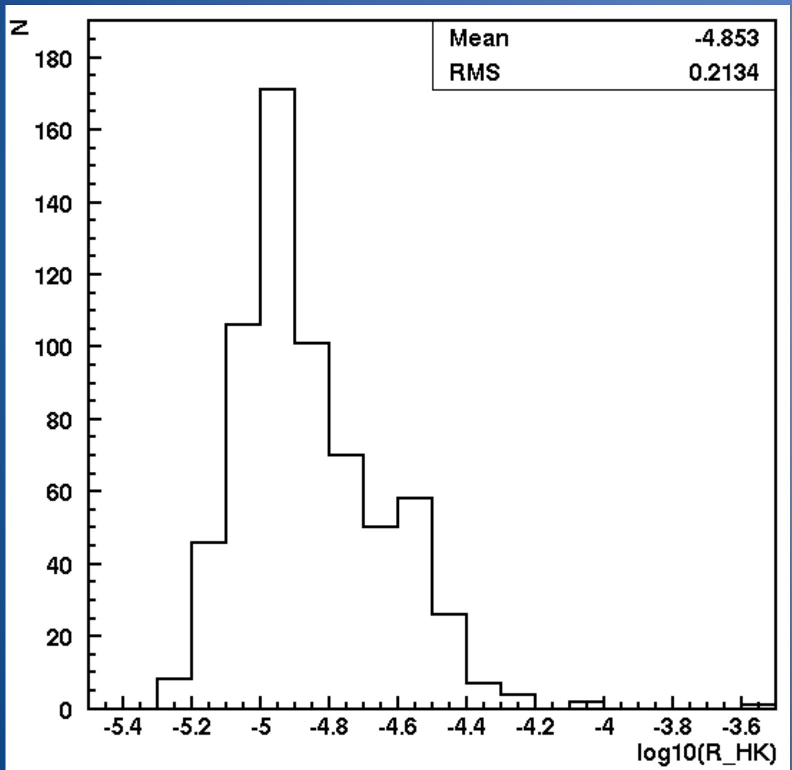


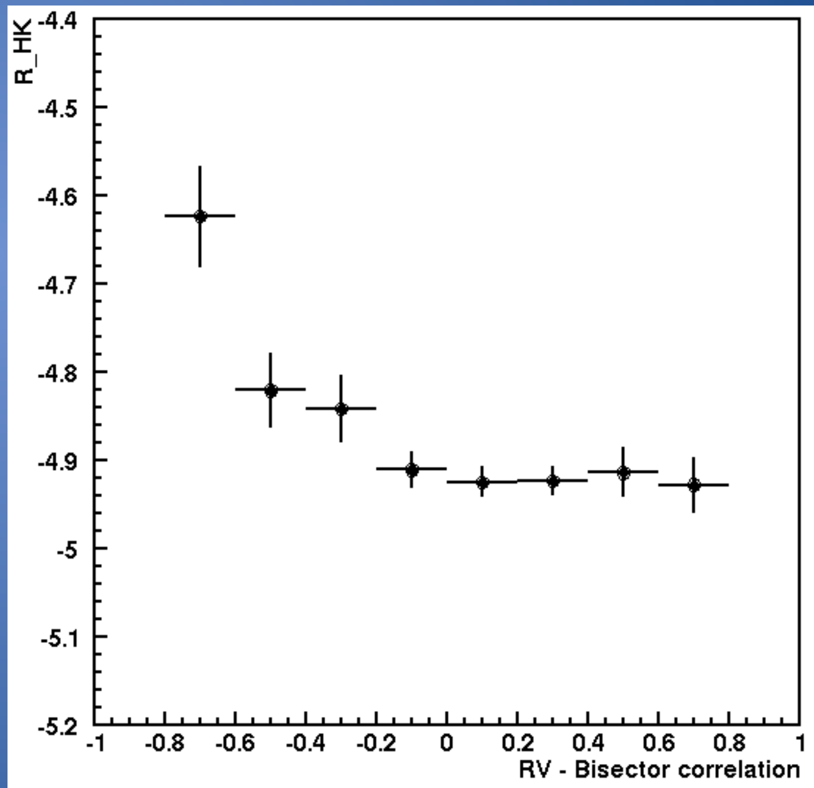
Origin of the signals



Origin of the signals

Correlation RV – bisector (Queloz et al. 2001, A&A)



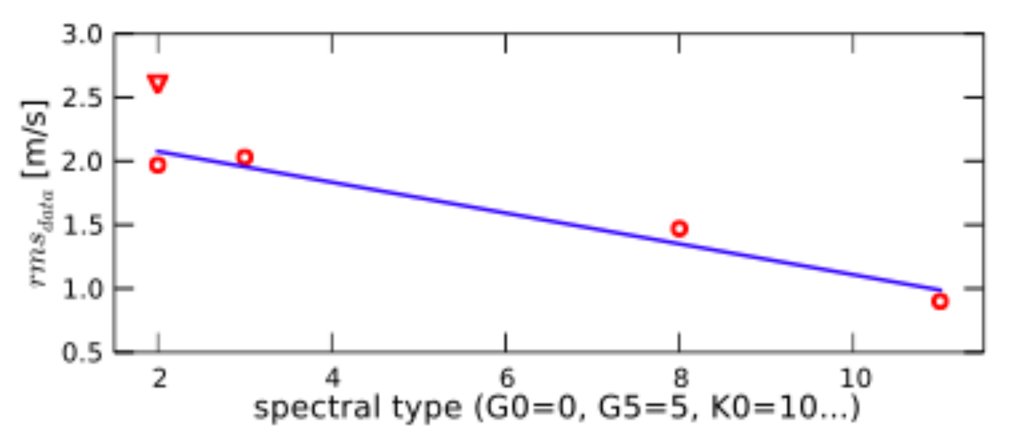


Origin of the signals

- Study the variation of the CCF parameter (BIS, FWHM) and the activity index with RV

- Define the origin of the signal as "stellar" when a clear correlation is detected
  - CAVEAT: absence of correlation does not mean that the signal is "keplerian" (Santos 2004).

- Stellar oscillations and granulation effects are more relevant for earlier spectral types.



Dumusque, X. (A&A 2011)

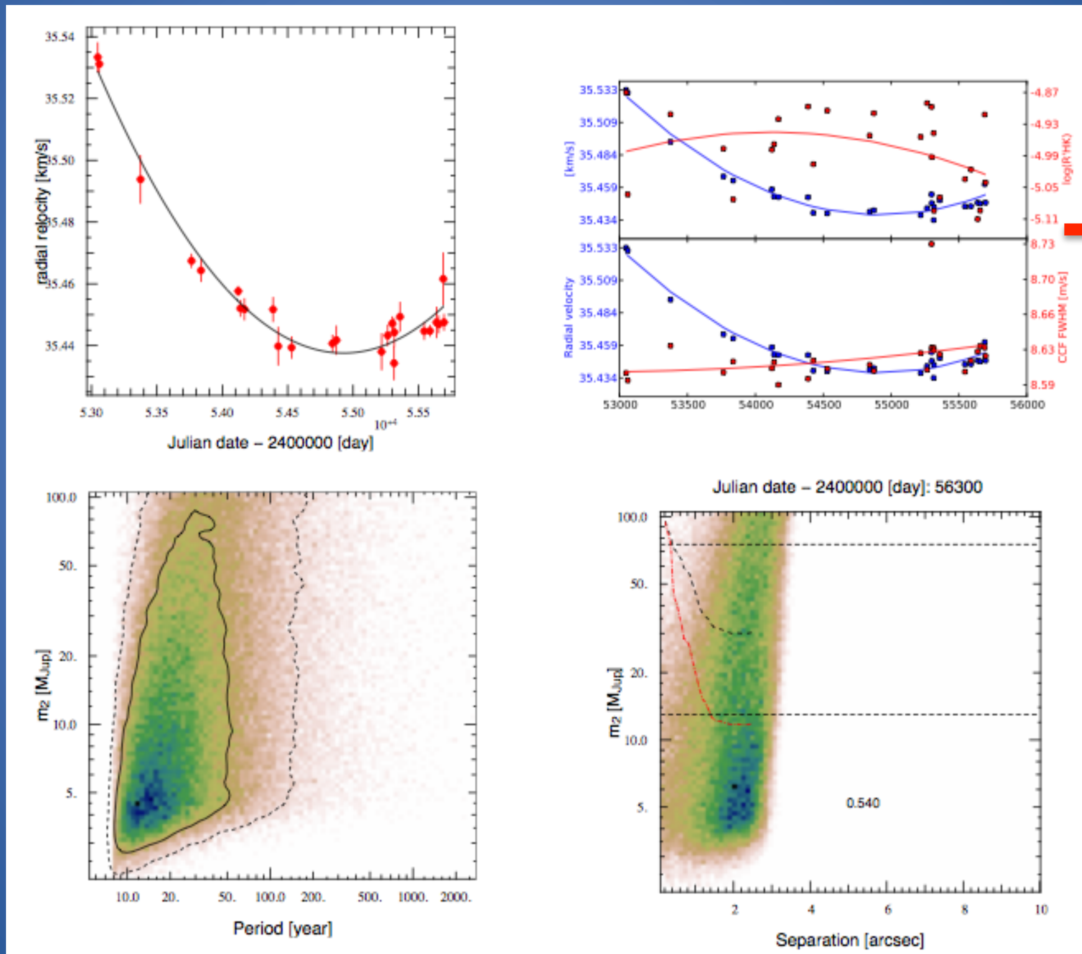
Origin of the signals

Stars with > 5 data points : 472

- Long period drifts => 111 ~ 24%
- Confirmed orbits : 47
  - Brown dwarfs => 2 (a<5AU)
  - Planets => 45
    - in multiple systems 11 => 24%
    - Neptune mass planets: 3 (P<10d)
    - Super-Earth: 1
    - Jupiter mass planets: 41
- Stars (RV correlates with BIS, FWHM, R_{HK}) => 60 ~ 13%

Drifts / incomplete orbits

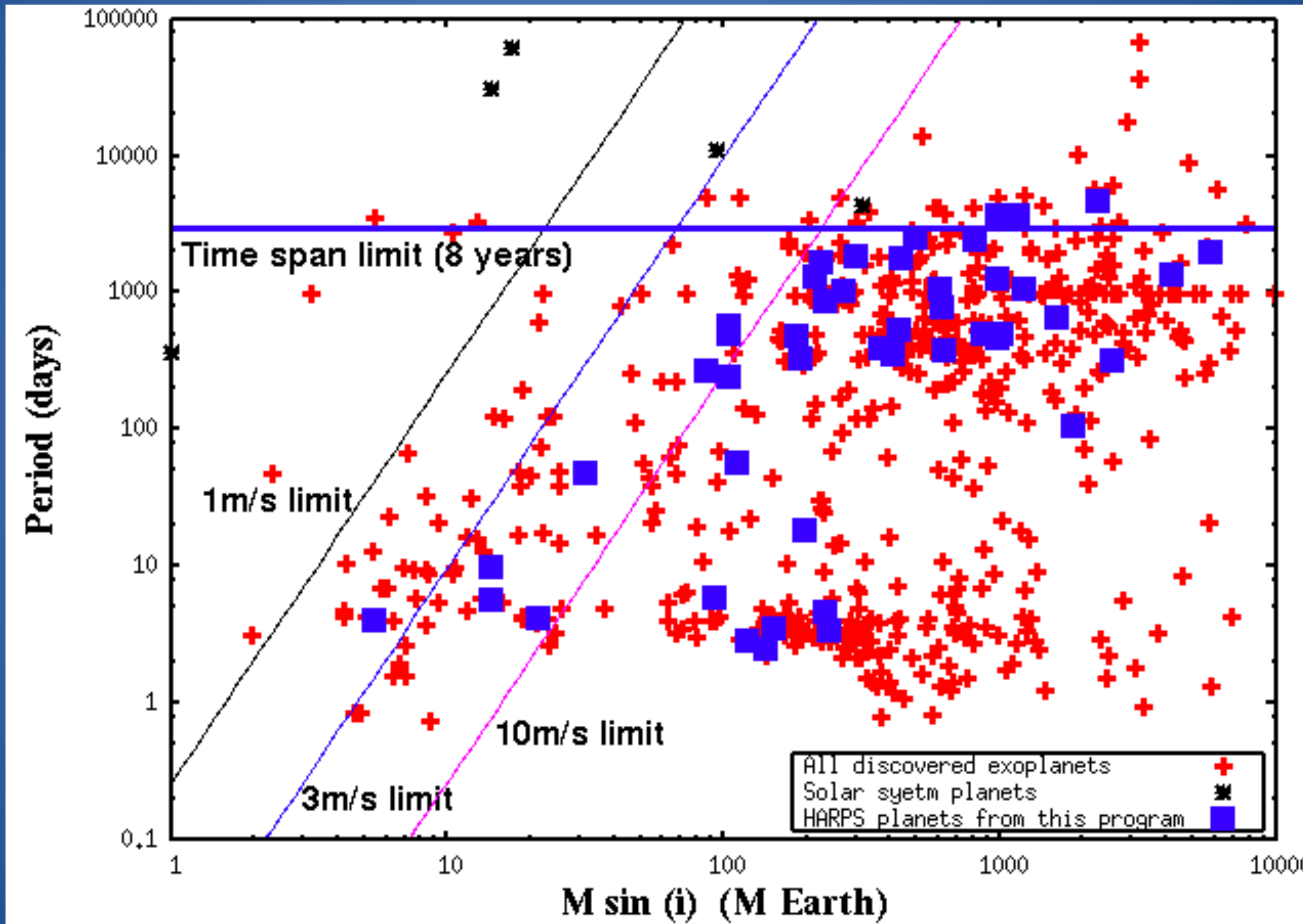
- Keep monitoring with low frequency
- Prepare candidates for direct imaging survey



Check activity & magnetic cycles

Janis Hagelberg
(see also his poster at this workshop)

The M-P plane



Time span limit (8 years)
1m/s limit
3m/s limit
10m/s limit
All discovered exoplanets
Solar syetm planets
HARPS planets from this program
Period (days)
M sin (i) (M Earth)
100000
10000
1000
100
10
1
0.1
1
10
100
1000
10000

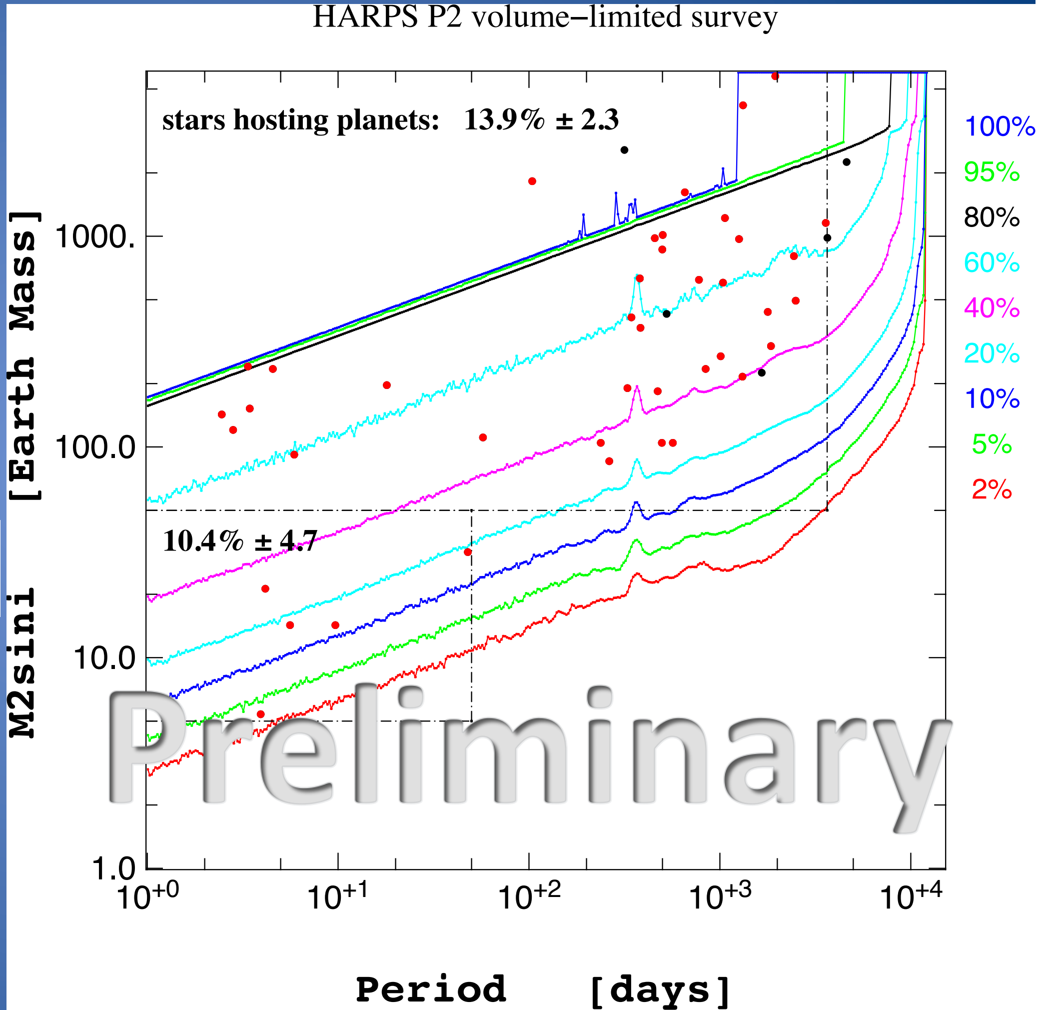
Planet occurence rates
- preliminary -

P<10 years
M>50 M_{Earth}

13.9% ± 2.3%

P<50 days
5<M<50 M_{Earth}

10.4% ± 4.7%



Maxime Marmier

Planet occurence rates - comparison

This work - preliminary

P<10 years, $M>50\ M_{Earth}$	**13.9% ± 2.3%**
P<50 days, $5<M<50\ M_{Earth}$	**10.4% ± 4.7%** **Incomplete !**

Mayor et al., 2011

P<10 years, $M>50\ M_{Earth}$	**13.9% ± 1.7%**
P<50 days, $5<M<50\ M_{Earth}$	**20.2% ± 3.7%**

Mayor et al., 2011

P<50 days, $3<M<30\ M_{Earth}$	**27.7% ± 4.4%**

η Earth, Howard et al., 2010

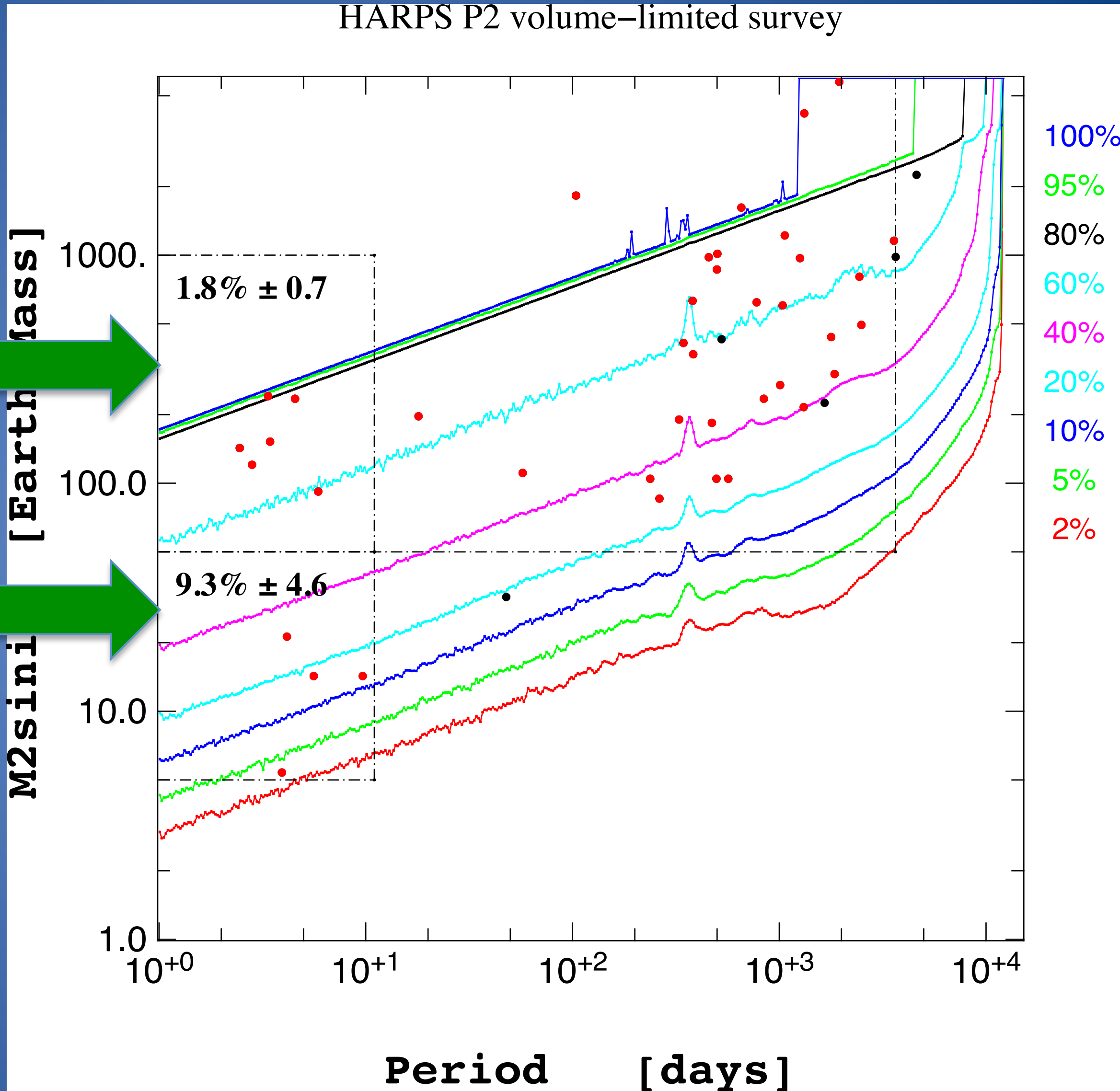
P<50 days, $3<M<30\ M_{Earth}$	**18.3% ± 4.3%**

The 'hotties'

a< 0.1AU
(P<11d)

Hot Jupiters

Hot Neptunes

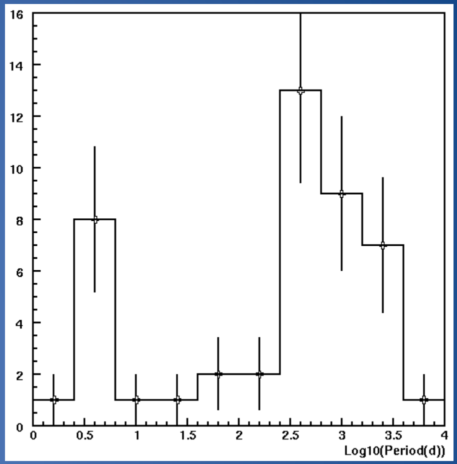


Maxime Marmier

Distribution of the orbital elements

- Bimodal period distribution

  peaks at P ~ 4d – 400d



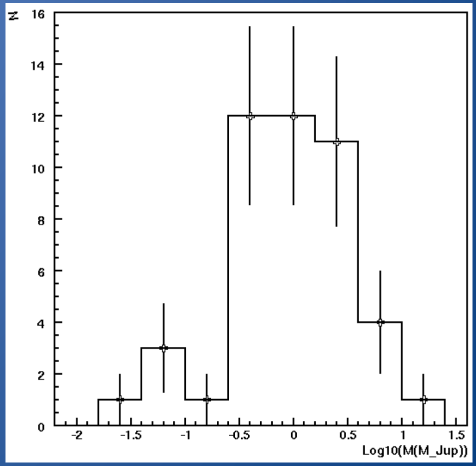
- Bimodal mass distribution

  peaks at ~ $1M_{Nept}$ and $1\ M_{Jup}$

  Evidence of the peak at low mass

  is only marginal

  Sensitivity very low in this mass range



Multiple planetary systems

11 planets are found in 5 multiple systems:

~ 24% of the planets of this program.

Very similar to the global statistics.

Planets seem to exhibit lower mass when they are in multiple systems (could be observational bias !):

	All planets	This program
All systems	$3.0 \pm 0.2\ M_{Jup}$	$1.9 \pm 0.4\ M_{Jup}$
Multiple systems	$2.5 \pm 0.3\ M_{Jup}$	$1.2 \pm 0.6\ M_{Jup}$

Multiple planetary systems

HD125612
4 d
502 d
4613 d

HD215497
4 d
567 d

HDXXXX
6 d
526 d

BD-082823
6 d
238 d

No obvious mean motion resonances

HD113538
263 d
1657 d

Eccentricity

Unconstrained a	All planets	This program
All systems	0.21 ± 0.01	0.27 ± 0.03
Multiple systems	0.21 ± 0.01	0.34 ± 0.06

- In this program we detect significantly high eccentricities (?)

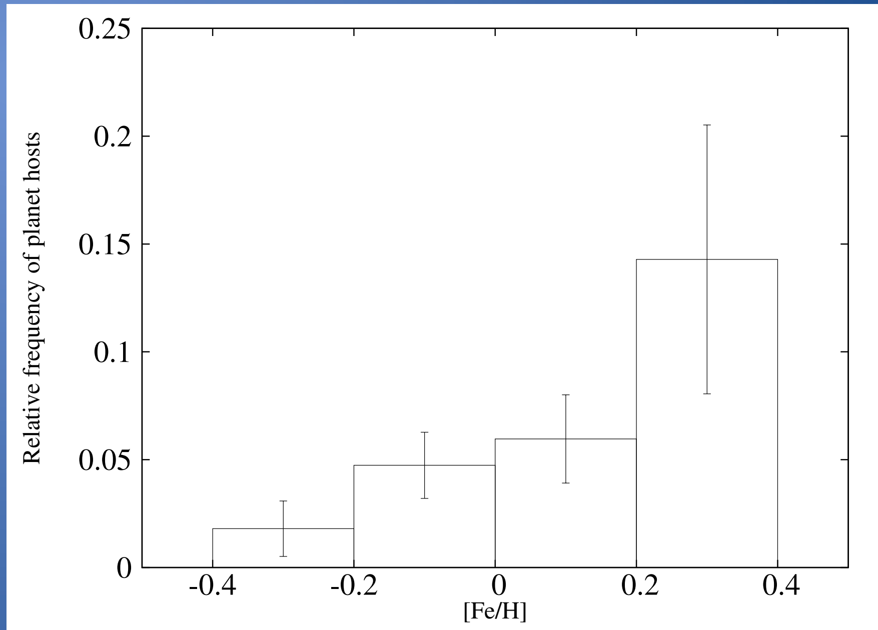
a<0.1	All planets	This program
All systems	0.07 ± 0.01	0.07 ± 0.03
Multiple systems	0.15 ± 0.02	0.16 ± 0.04

- Multiple systems in close-in orbits can sustain higher eccentricity

Work in progress...

Metallicity distribution

- Planet host stars are preferentially metal-rich
- ~ 1/3 hosts have [Fe/H]<=0
- ~ 2/3 hosts have [Fe/H]>0



See also the work of S. Sousa, A&A 2011

Conclusions

- Jupiter occurrence rates is of 13.9% ± 2.3%, in perfect agreement with the high precision survey (Mayor 2011)
- Hot Jupiters (a<0.1AU) occurence rate: 1.8% ± 0.7%
- Hot Neptunes occurrence rate: 9.3% ± 4.6%

- Period distribution is bimodal (peaks at 4d and 400d)
- Mass distribution is bimodal (peaks at ~ 1 Neptune and 1 Jupiter mass)
- (Giant) Planet host stars are metal rich (2/3 have [Fe/H] > 0)

- We measure eccentricities higher than average => work in progress

- Multiple planets frequency is of ~ 24%
- Planets in multiple systems have a lower mass (close to a factor 2 less)
- No mean motion resonances detected
- Close in planets in multiple systems have higher eccentricity than single planet systems