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The SOAPS project: Spin-Orbit Alignment of Planetary Systems from Kepler

Francesca Faedi

Yilen Gomez Maqueo Chew and Don Pollacco (Warwick), Luca Fossati (Uni-Bonn), Amy McQuillan and Suzanne Aigrain (Oxford), Leslie Hebb (Washington), Bill Chapling (Birmingham)

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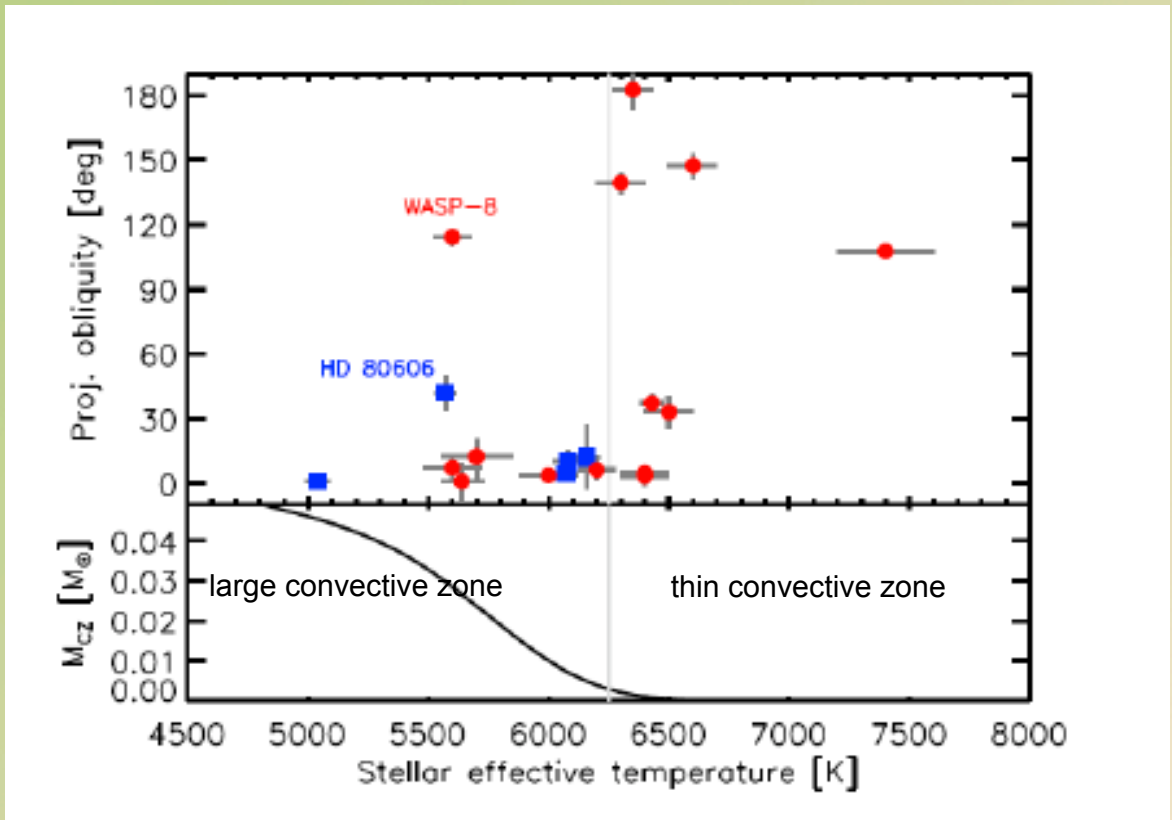
Spin-Orbit alignment … why ?

- **Planetary formation and migration mechanisms**
- **Only possible for transiting planets**



Winn et al. 2010 ApJ, 718L, 145

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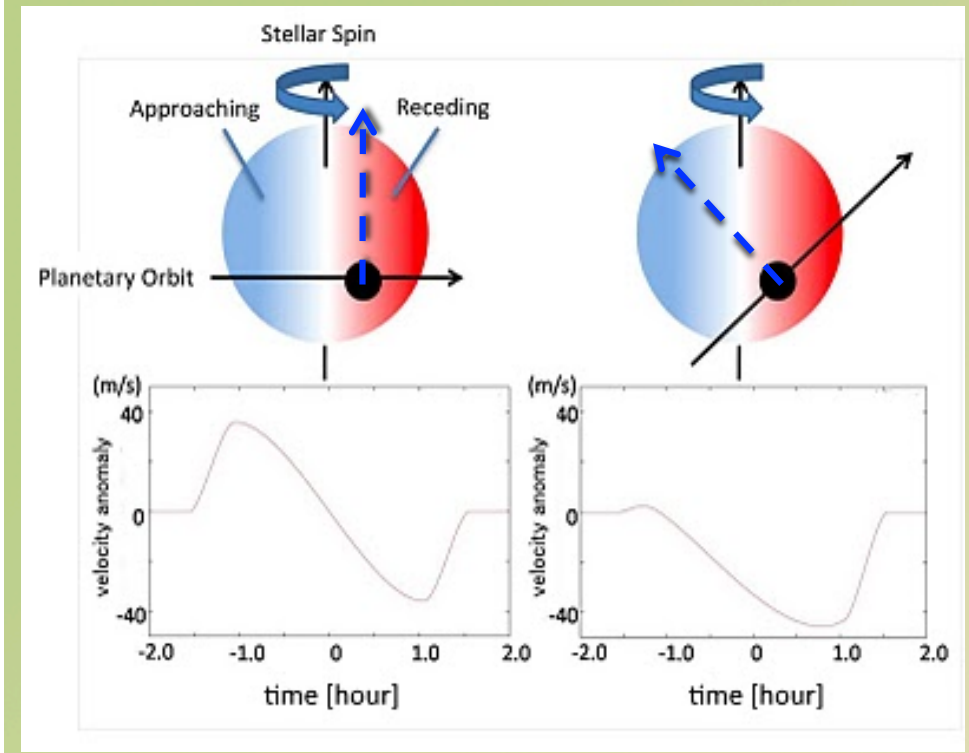
Measurement of exoplanets Spin-Orbit alignment

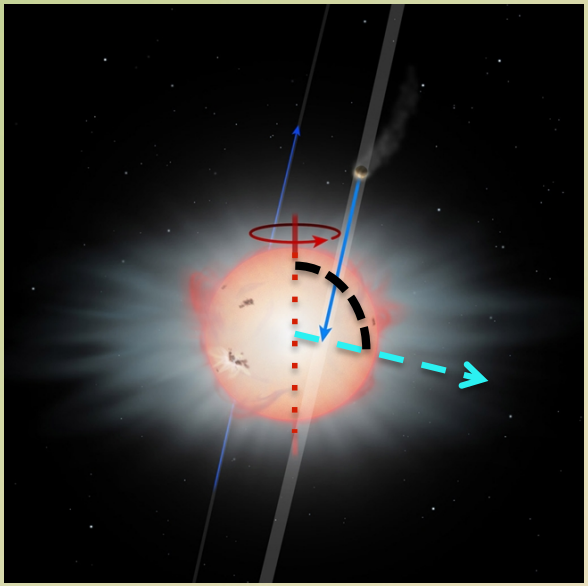
The RM effect:

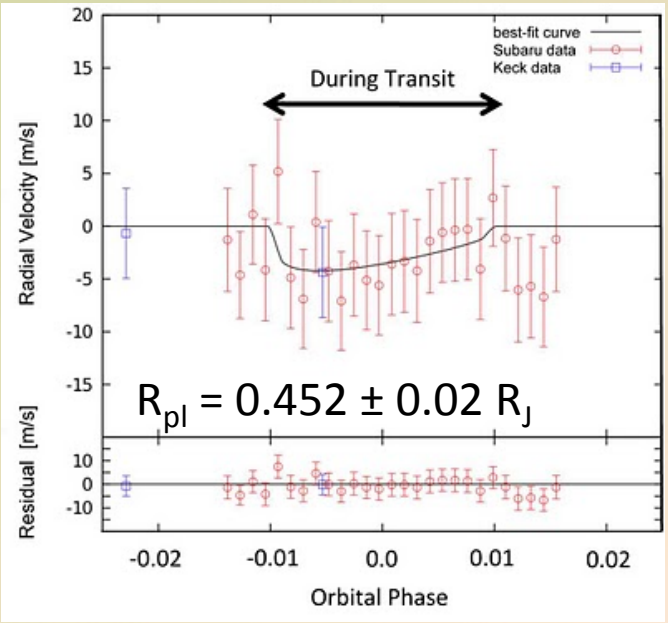
- proportional to the R_{pl}, *vsini* and *stellar brightness* (short T_{exp})



$\lambda \approx 106° - 97°$

HAT-P-11b





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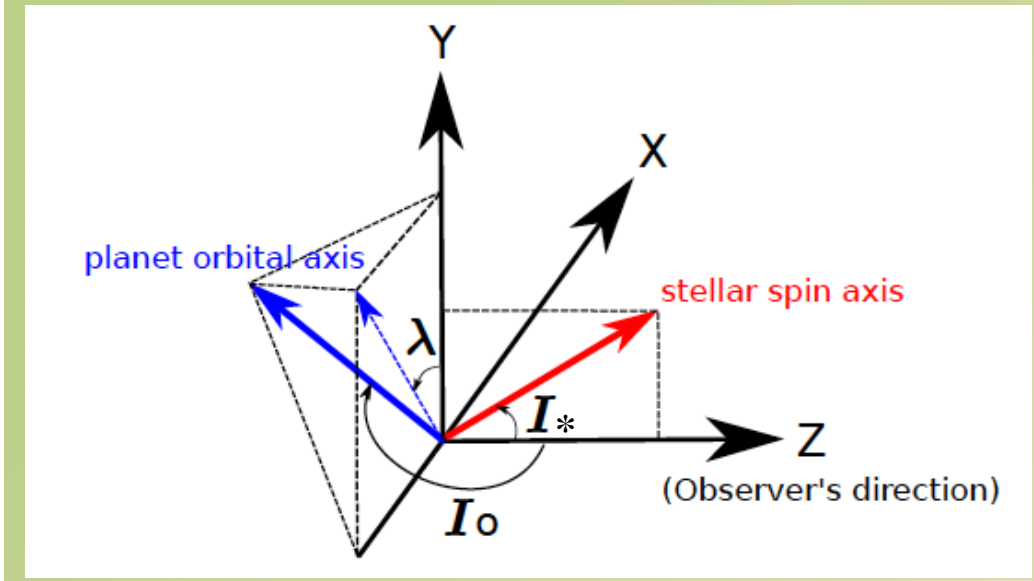
Kepler systems:
- small R_{pl}
- orbiting faint stars
- slow rotators

RM measurements impossible!!

……

But for stars with measured P_{rot} …..

$$\cos\psi = \sin I_* \cos\lambda \sin I_o + \cos I_* \cos I_o$$



$$\sin I_* = \frac{P_{rot}\, v \sin I_*}{2\pi R_*}$$

LCs; spectra; spectra

See also Hirano et al. 2012, ApJ, 756, 66H

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The SOAPS sample

Targets selected from Borucki et al. 2012, ApJ, 736, 19

- SpT 5500< Teff < 7100K
- V_{mag} < 14.5
- With measured P_{rot} from LCs
- Different planetary structures

~ 70 targets

- Slow rotators, Subaru/HDS
  R=160,000, S/N ~ 20 - 30
- Fast rotators CFHT/ESPaDOnS
  R=80,000 S/N ~ 20 - 30

- Variability analysis from McQuillan et al 2012, A&A 539A, 137

No Kepler PDC:
long term and low amplitude signals could be affected
PDC could add high freq. noise

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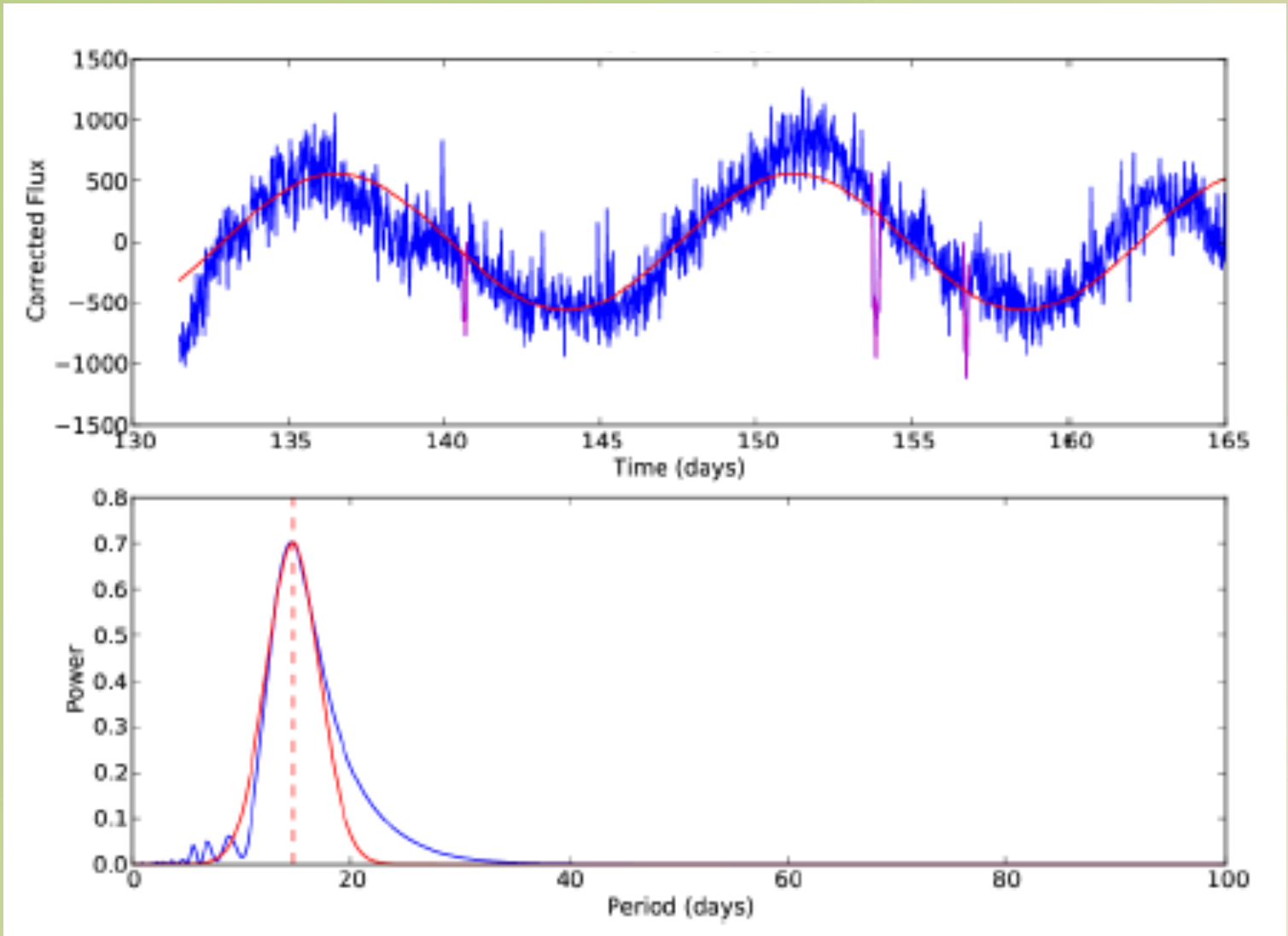

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Data reduction and analysis: Subaru sample – slow rotators

- Standard IRAF data reduction

- **LSD analysis + FT of the LSD profile** (LSD profile with S/N>400)

→ $v\sin I_s$ < 3km/s: asymmetries from line natural broadenings

- Method:
Sampling of the LSD profile important
independent from macroturbulence

- **Sources of error:**
a) Sampling of the LSD profile
b) Uncertainty on the RV
c) Normalisation of the LSD profile (dominant error and independent of S/N)

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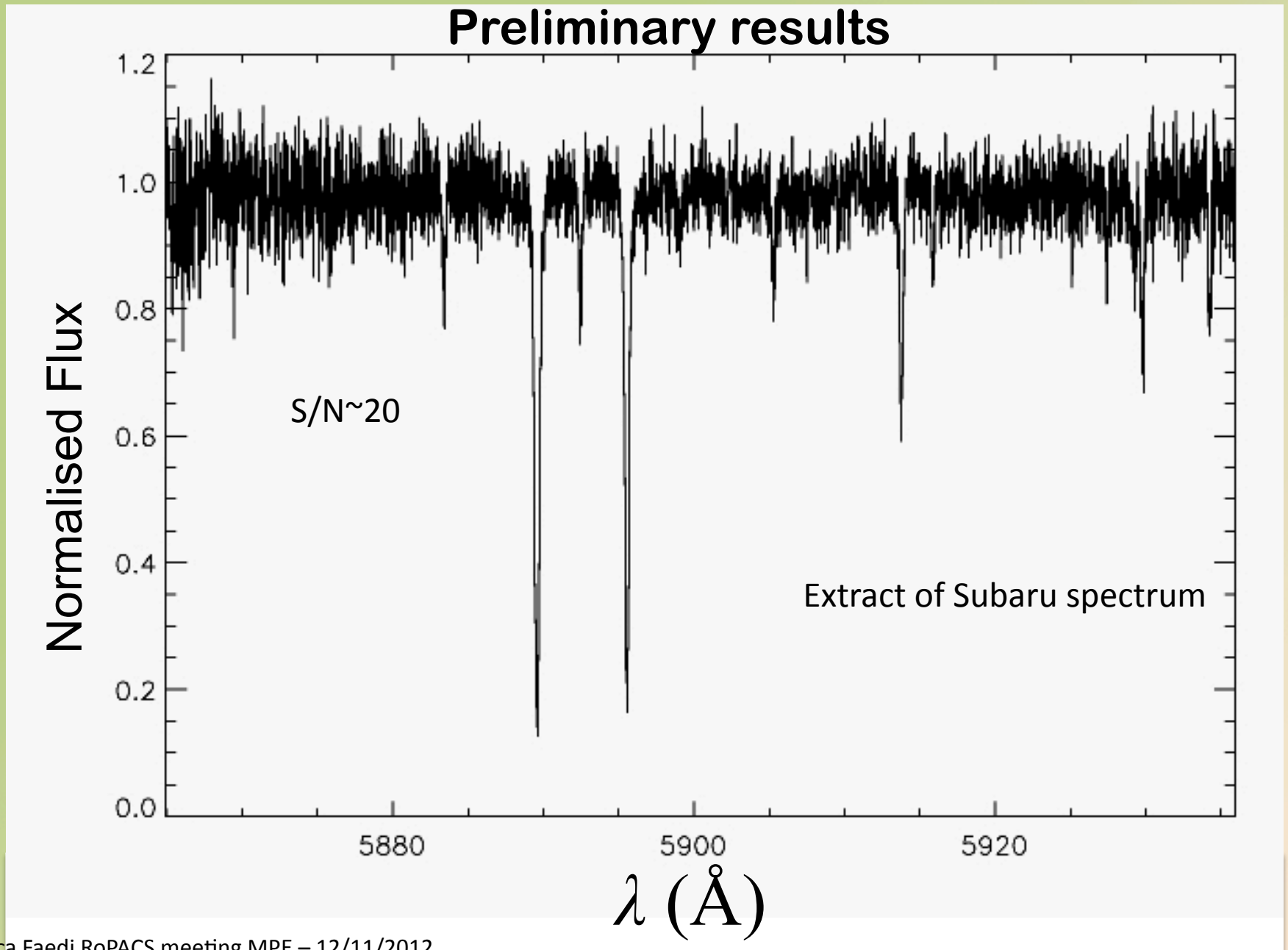
Preliminary results



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Preliminary results

KIC $v\sin I_*$ = 29.35 km/s

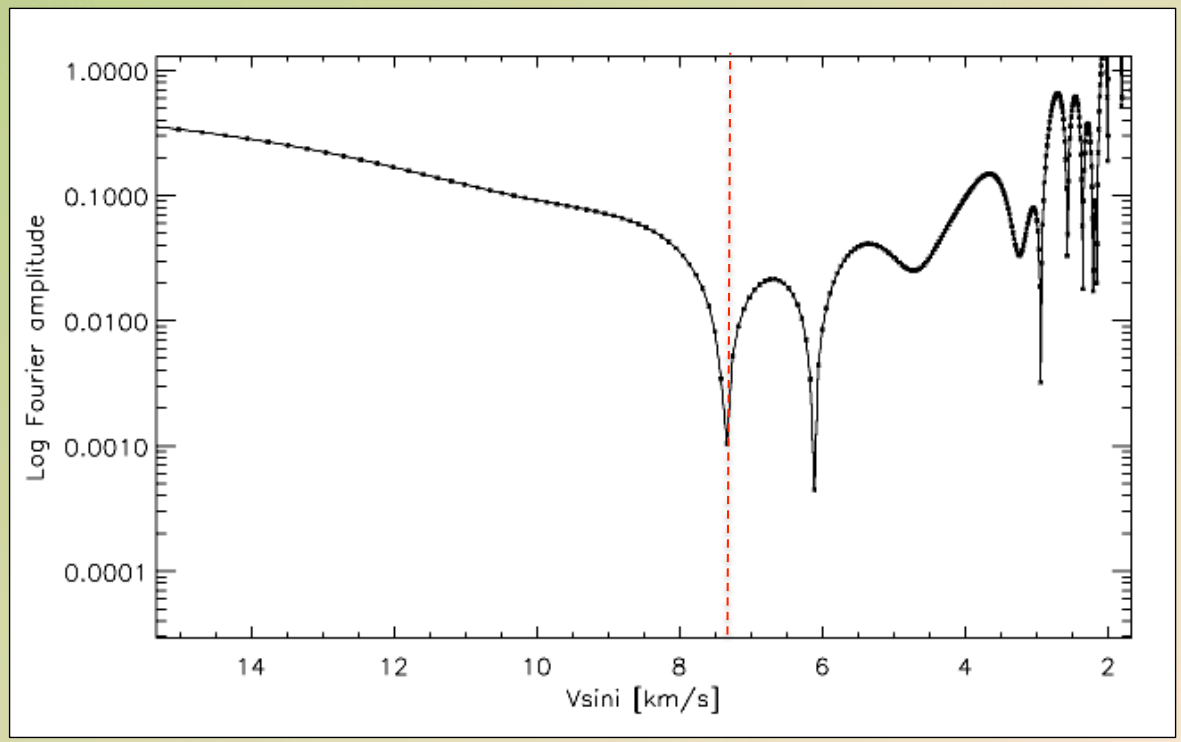
We obtain:

$$\sin I_* = 0.27 \pm 0.08$$

possibly small I_s and thus
large Spin-Orbit misalignment

Host star F6, T_{eff} ~ 6130K
with a SuperEarth

$v\sin I_*$ = 7.2±0.15 km/s



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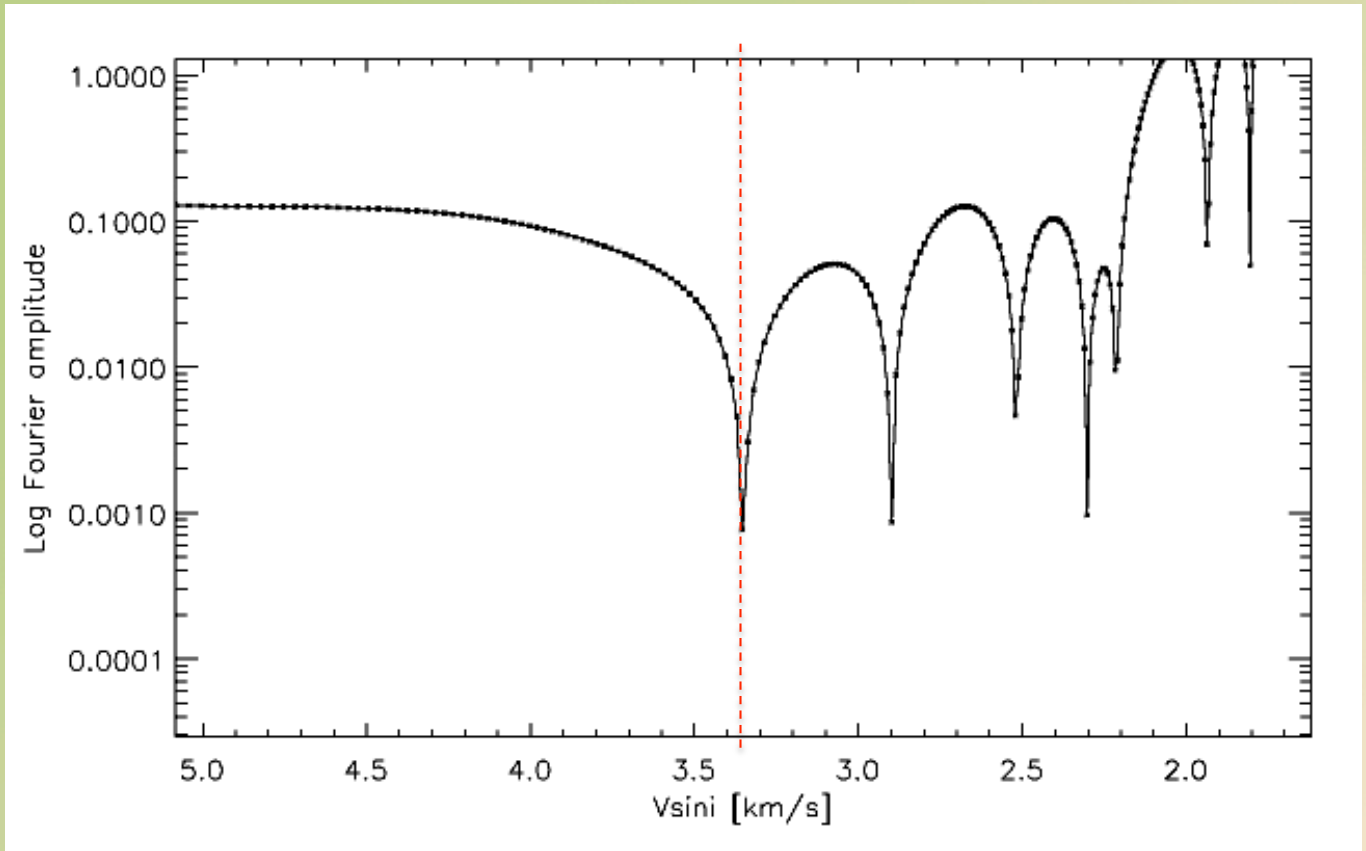
Preliminary results

Host star G,
T_{eff} = 5627K

Multiple system with SuperEarths



$$\sin I_* \sim 1.0 \pm 0.1$$

I_* ~ 90°

$v \sin I_*$ = 3.35±0.1 km/s

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Conclusions

- We have about 30 objects + standard stars from Subaru/HDS
- about 30 fast rotating objects from CFHT/ESPaDOnS

…… analysis is ongoing!

- P_{rot} analysis only from Kepler Q1 data

our sample will increase with the new Kepler release Batalha et al, 2012 arXiv1202.5852B