Planets and Stellar Activity:

Hide and Seek

in the CoRoT-7 system

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600 YEARS
1413 – 2013

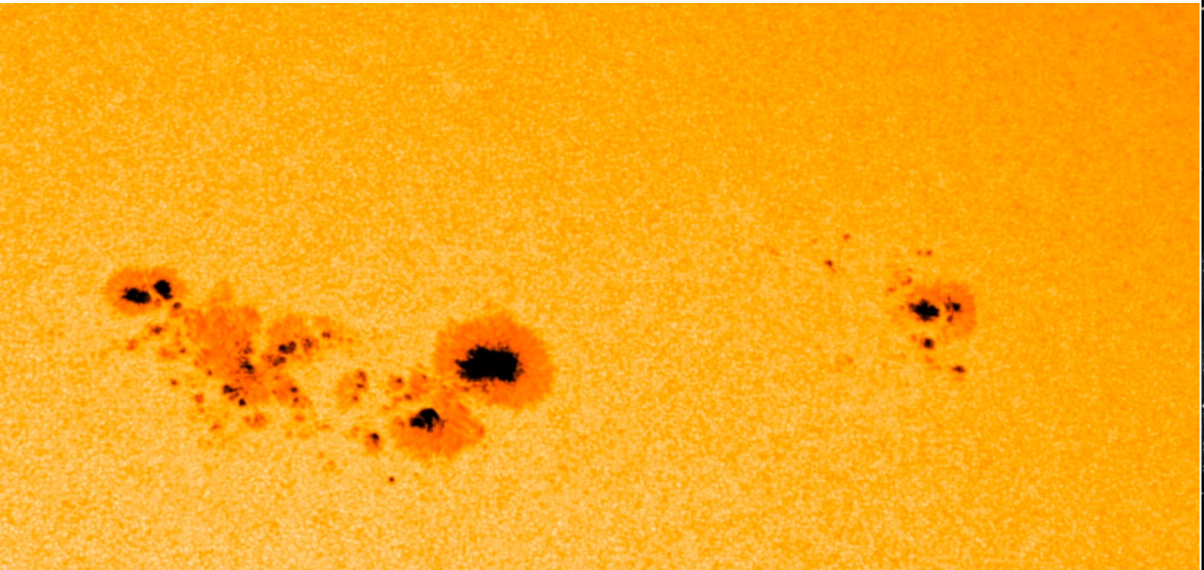
Introduction

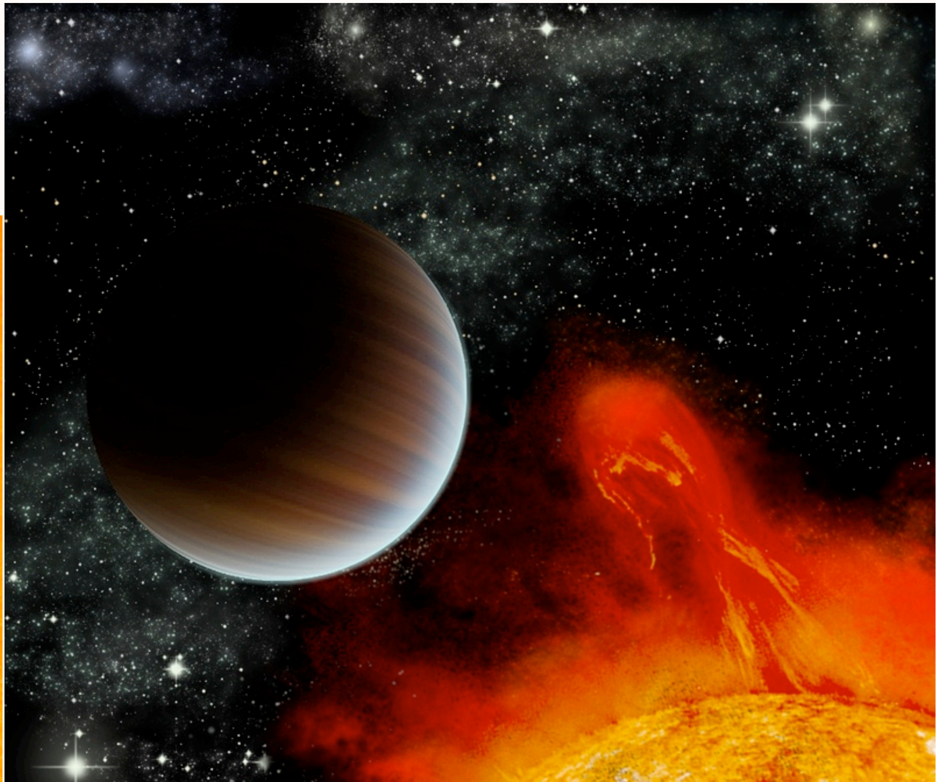
- Radial velocity (RV) method: Super-Earths ($>10M_\oplus$) hidden in stellar activity "noise":

  $1M_\oplus$ planet orbiting a typical dwarf star at 10 pc:
  - $\Delta RV_{planet} \approx 0.1$ m/s
  - $\Delta RV_{activity} \approx 0.5$ m/s (Makarov et al. 2009)

- Use lightcurve ⇒ model RV

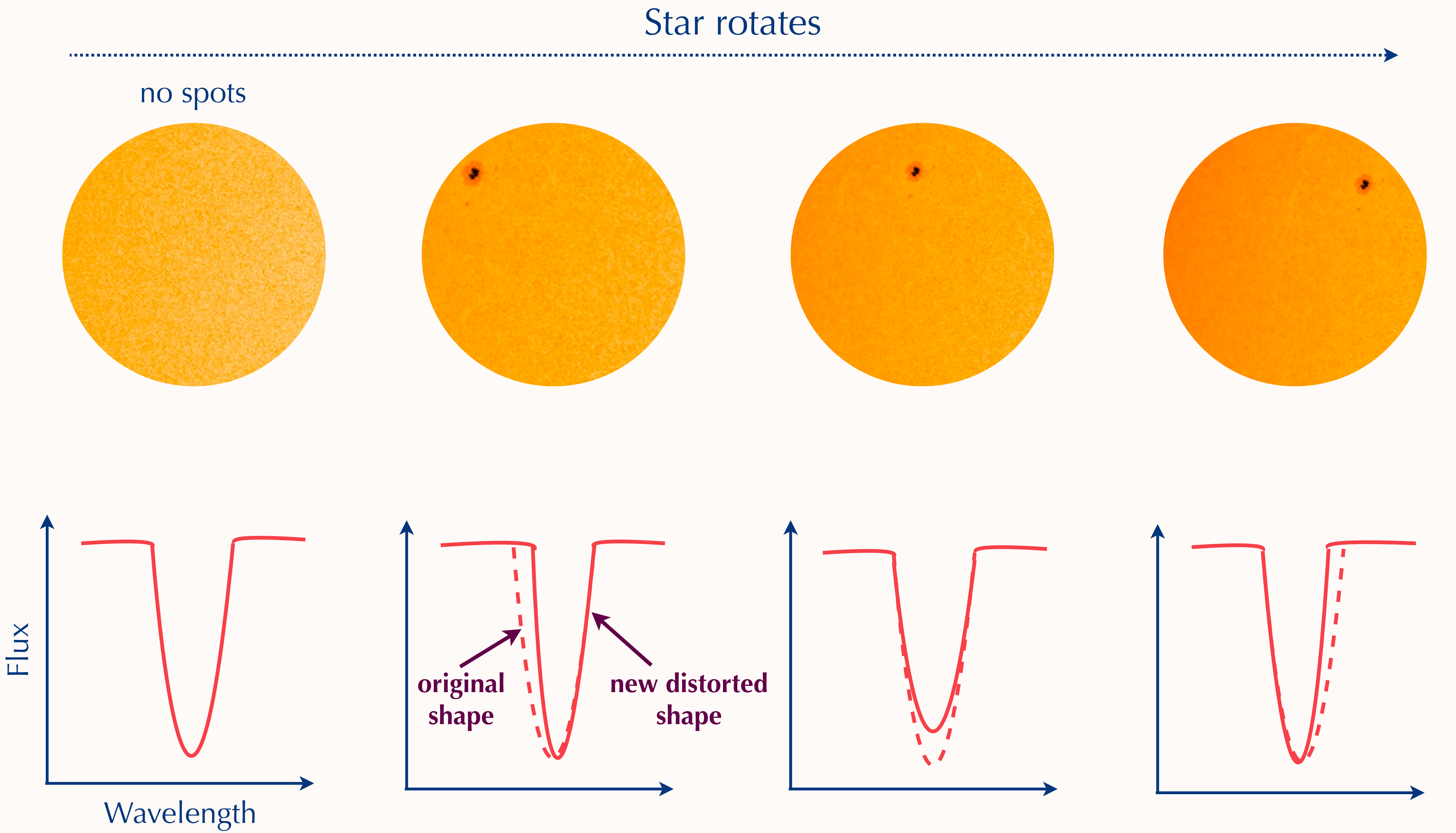
- Apply to CoRoT-7 system





How do spots affect radial velocity?

I. Stellar rotation



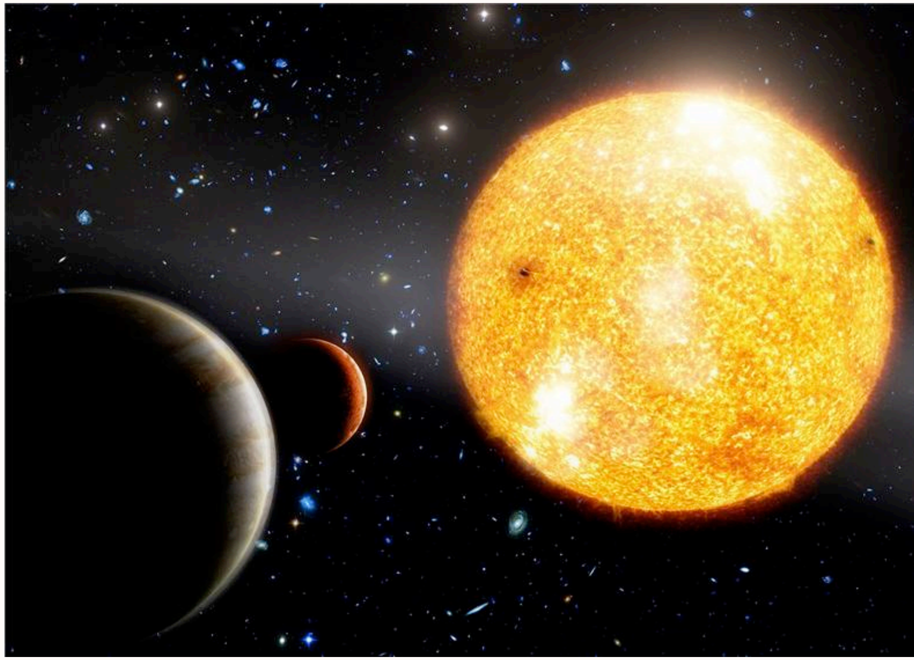
Shape of the spectral lines changes

How do spots affect radial velocity?

II. Suppression of convective blueshift

Dopplergram of the Sun (SDO)

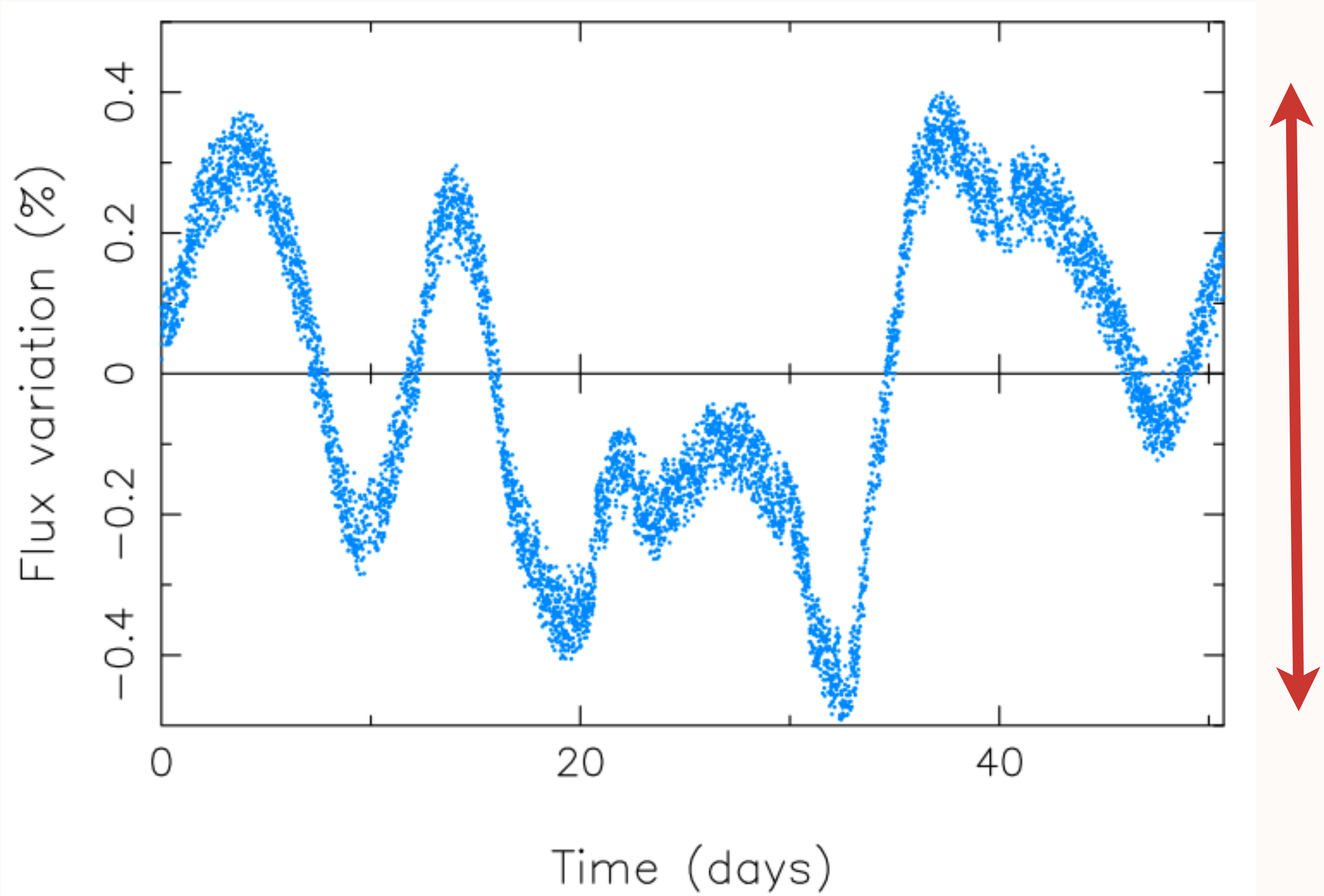
CoRoT-7



- G9, V=11.7
- CoRoT observations in 2009
  Léger et al. 2009: CoRoT-7b
  "first Super-Earth with a measured radius"
- HARPS campaign (2009)
  Queloz et al. 2009: CoRoT-7c
- Hatzes et al. 2010: CoRoT-7d
- **Many analyses, no agreement**
  (Bruntt et al. 2010, Lanza et al. 2010, Pont et al. 2010, Boisse et al. 2010, Ferraz-Mello et al. 2011, Hatzes et al. 2011)
- **Jan. 2012 –** New observations: CoRoT photometry & HARPS RV
  → Can do a new analysis!

CoRoT-7 off-transit lightcurve

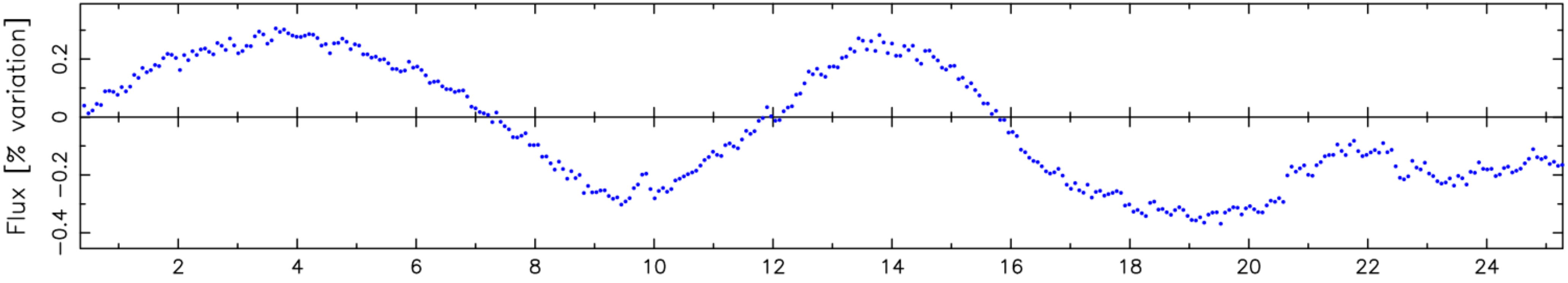
Up to 1% variation



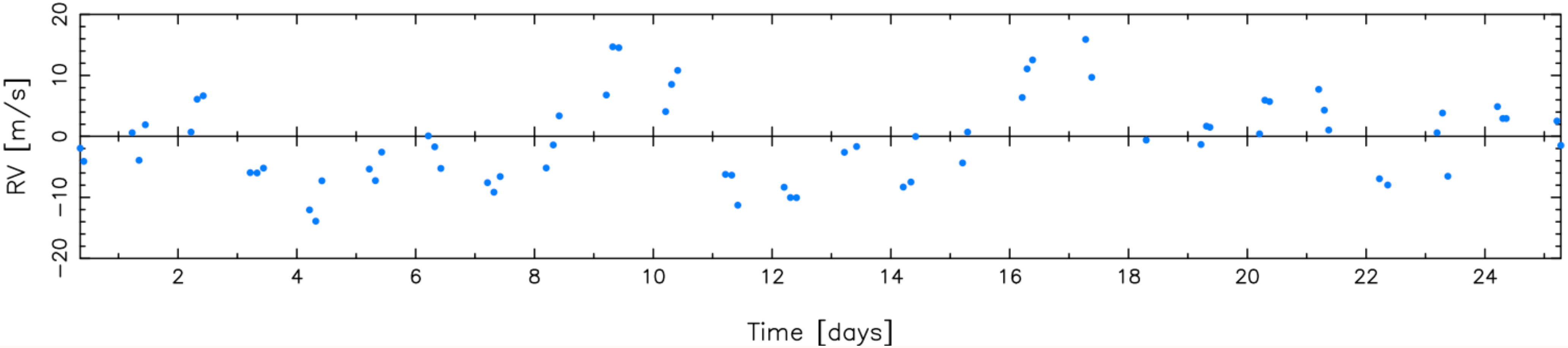
CoRoT Jan. 2012 data, Barros et al. (in prep)

Simultaneous photometry & RV

lightcurve (binned in blocks of 0.07 days)

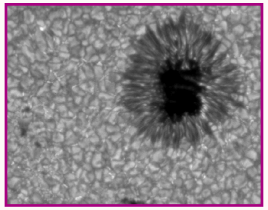


RV data



Modelling stellar RV variations

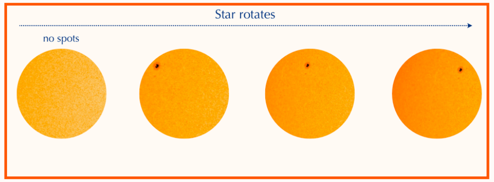
Model RV variations based on variations in the lightcurve (Aigrain et al. 2011)



suppression of convective blueshift

$$\Delta RV_{activity} = A\, \Delta RV_{rot}(t,\psi_0) + B\, \Delta RV_{conv}(t,\psi_0)$$

rotation of stellar disk

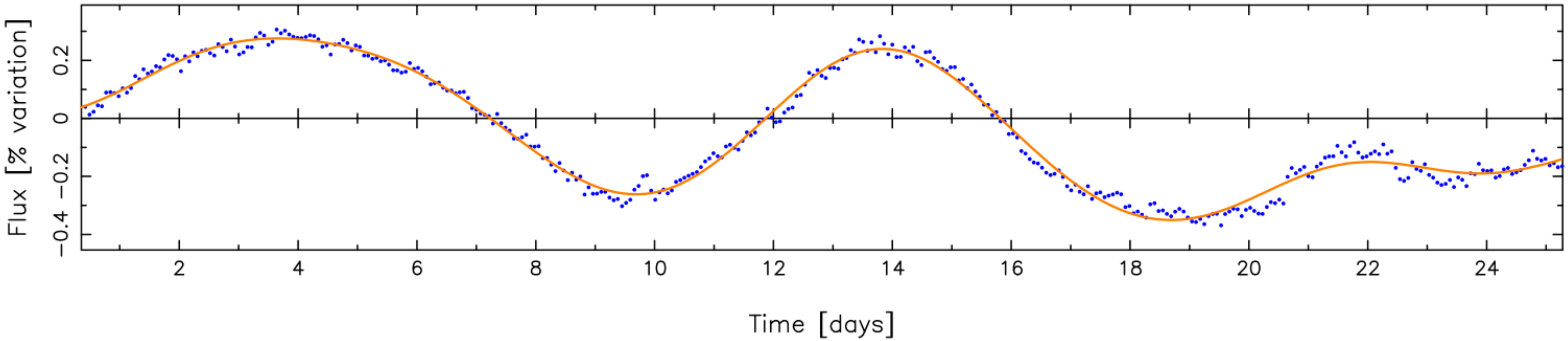


A, B constants

ψ_0 = unspotted flux level

$$\Delta RV_{activity} \propto F \,.\, dF/dt$$

lightcurve & fit



Total RV model

$$\begin{aligned}RV_{\mathbf{total}} = \quad & A\ \Delta RV_{\mathbf{rot}}\ (t,\psi_0)\ + B\ \Delta RV_{\mathbf{conv}}\ (t,\psi_0) \\ & + \textit{planet b}\ (K_b,\ e_b,\ \omega_b) \\ & + \textit{planet c}\ (K_c,\ e_c,\ \omega_c,\ P_c,\ T_{peri\_c}) \\ & + \textit{planet d}\ (K_d,\ e_d,\ \omega_d,\ P_d,\ T_{peri\_d}) \\ & + RV_0\end{aligned}$$

1. **Least squares optimization** ⇒ Obtain rough guesses for parameters

2. **Monte Carlo Markov chain (MCMC)**

RV models out of MCMC

Data

Suppression of convective blueshift

Stellar rotation

CoRoT-7 b

CoRoT-7 c

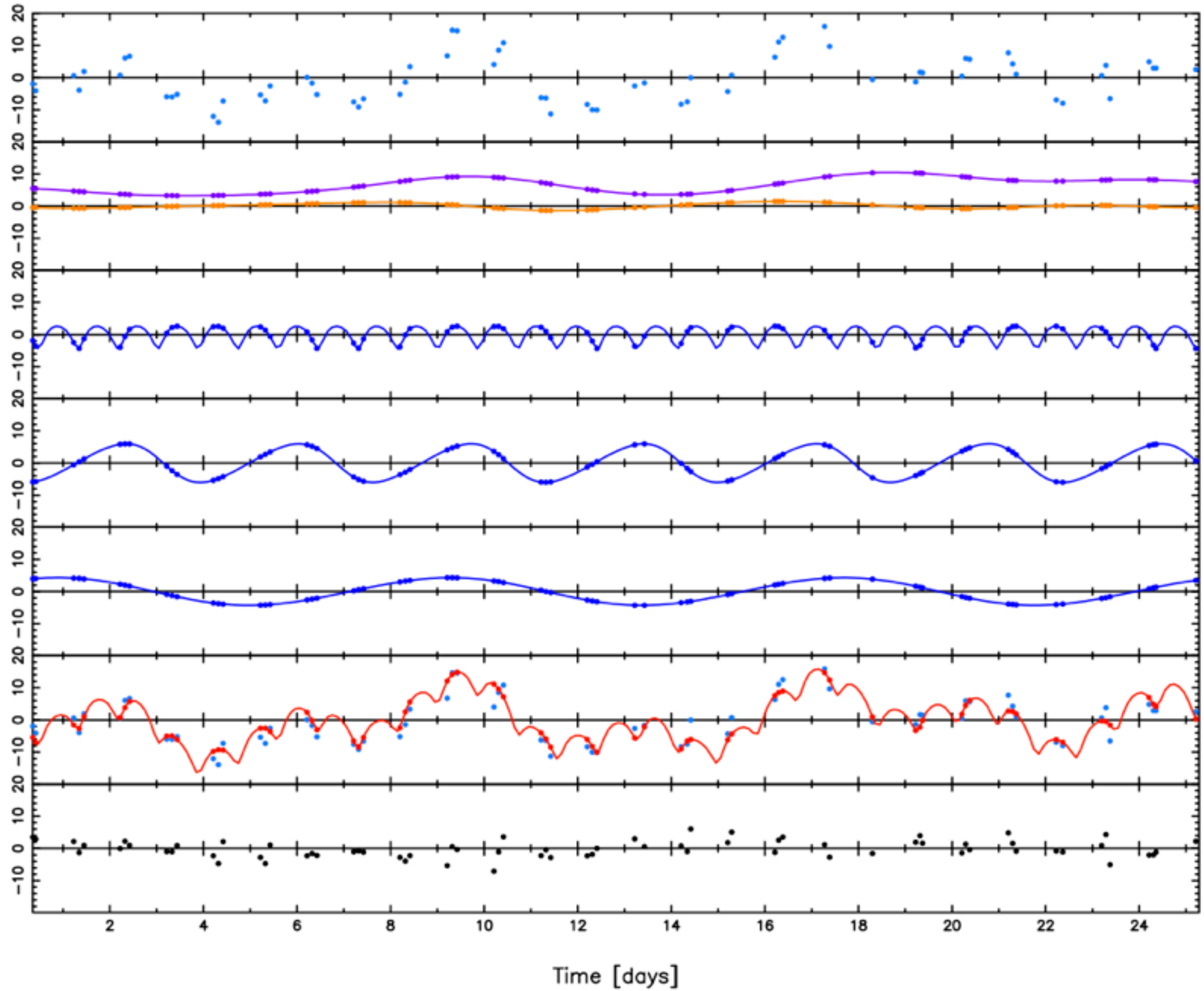
CoRoT-7 d

Data

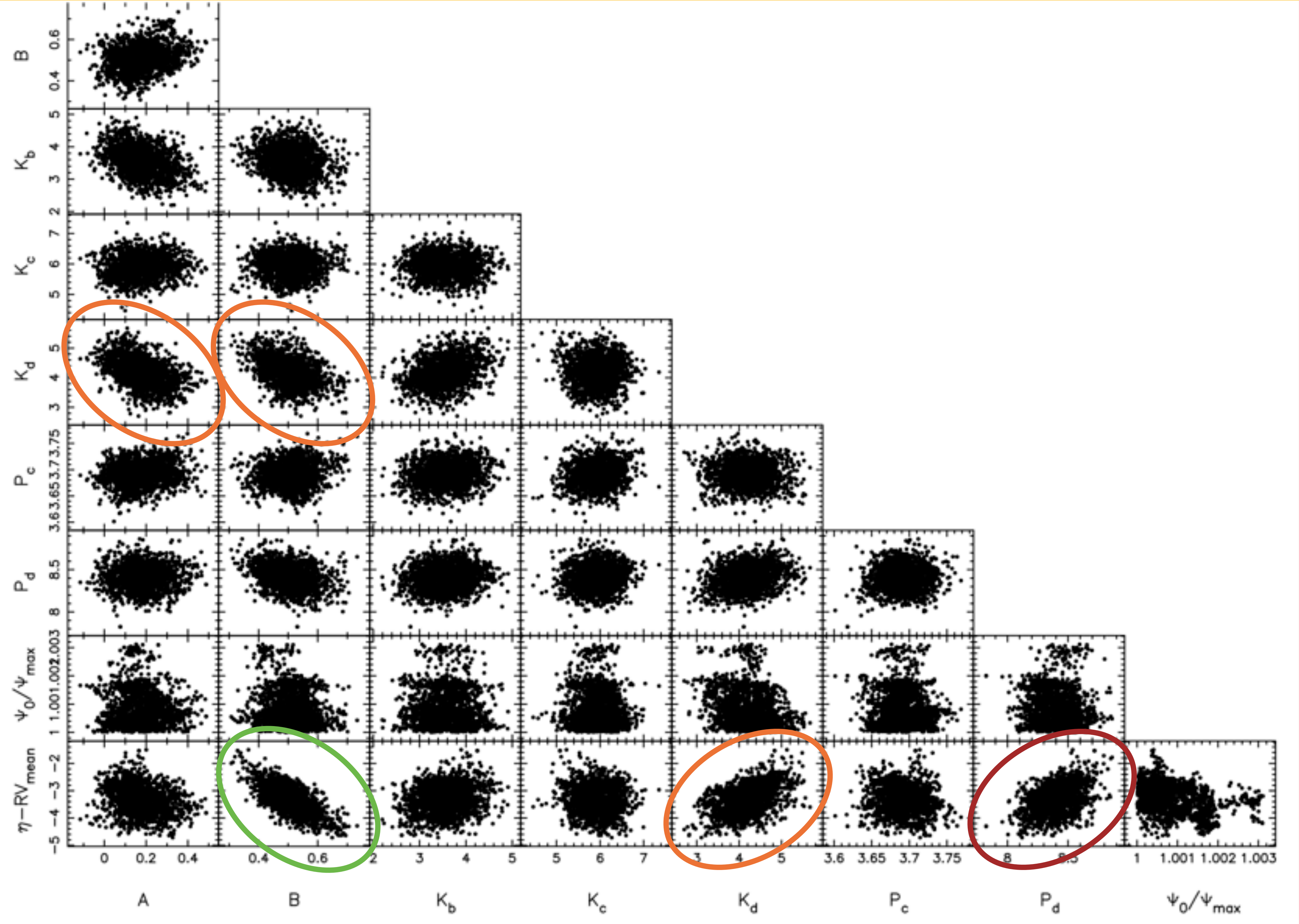
Total model

Residuals

RV [m/s]



Phase plots for MCMC solution



Activity indicators

RV CoRoT-7 d

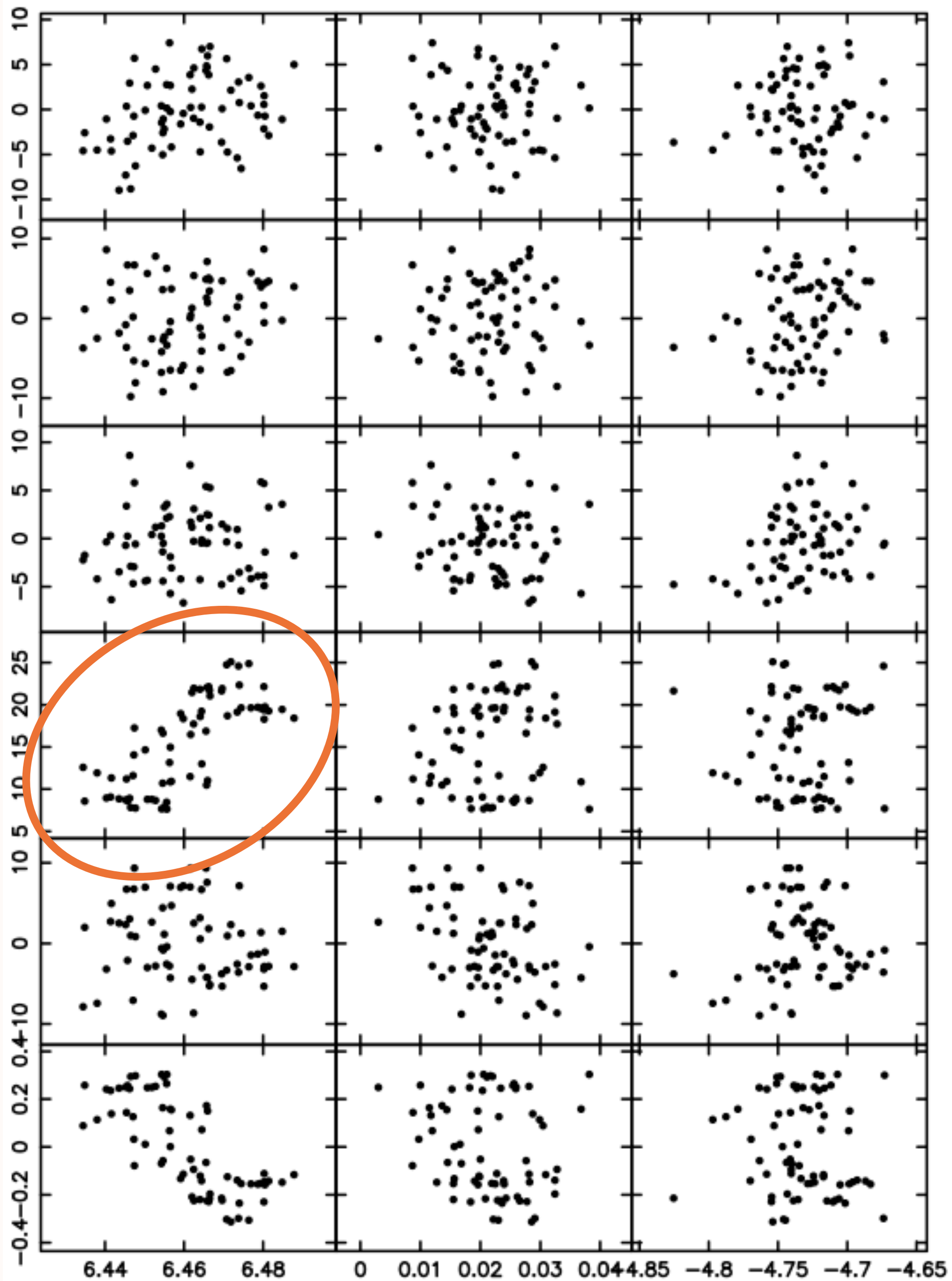
RV CoRoT-7 b

RV CoRoT-7 c

RV suppression of convective blueshift

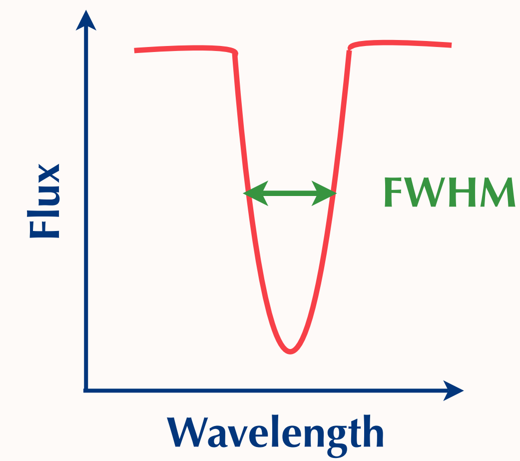
RV stellar rotation

Flux

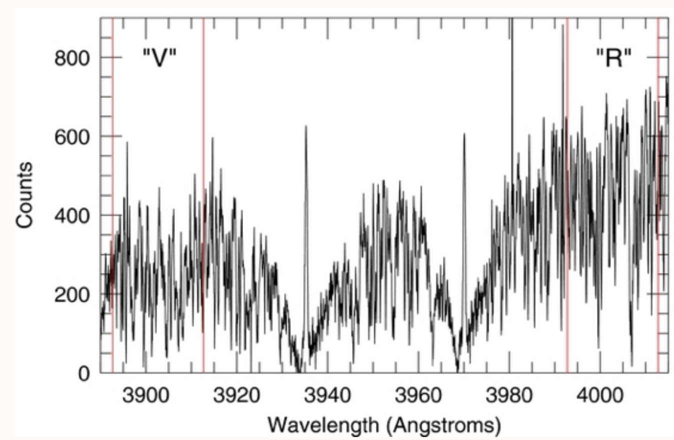


FWHM | Bisector span | R'_{HK}

Cross-correlation function

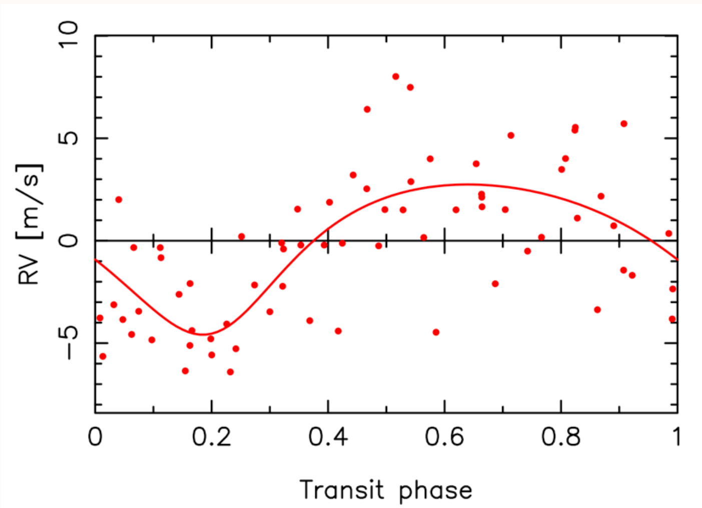


Ca H&K lines

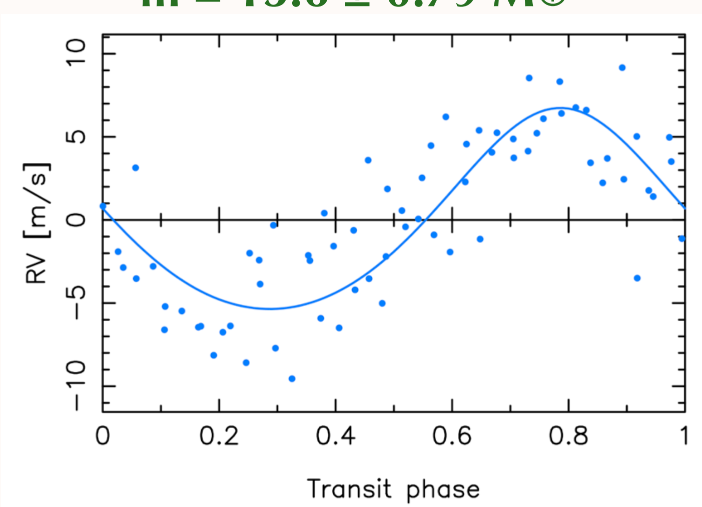


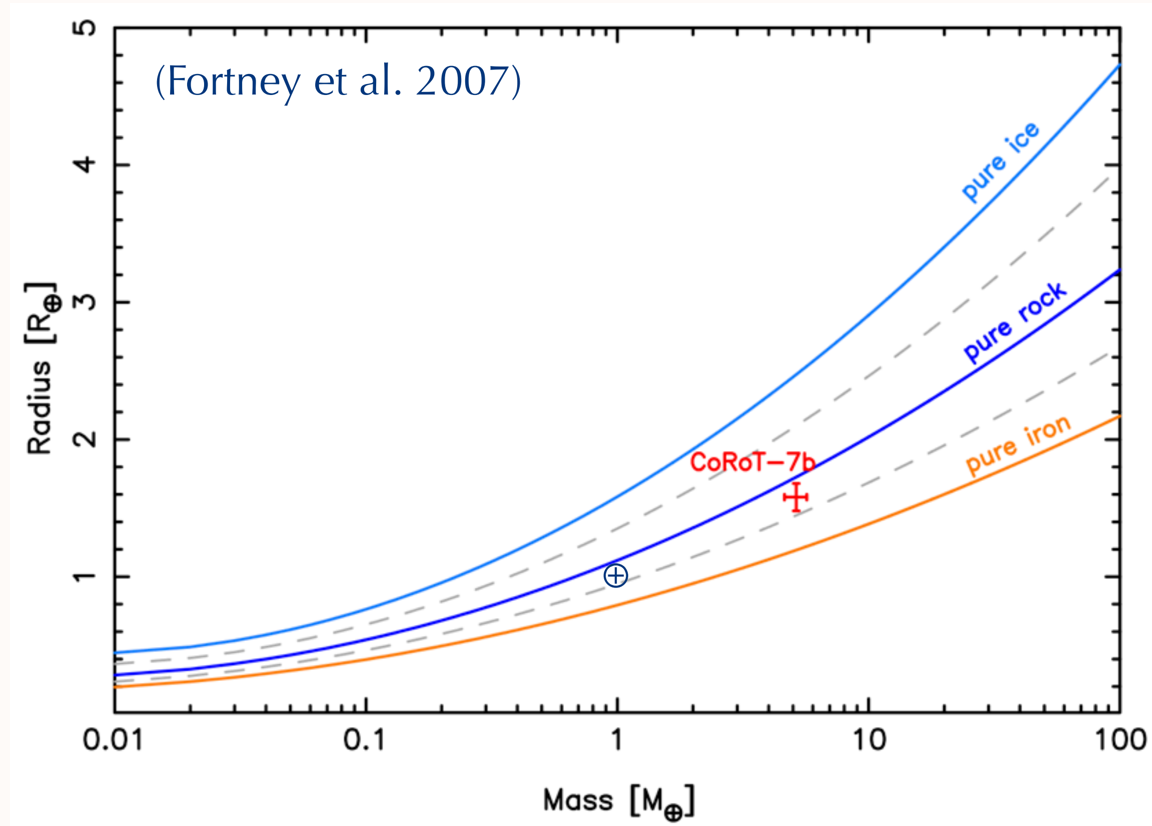
Planets

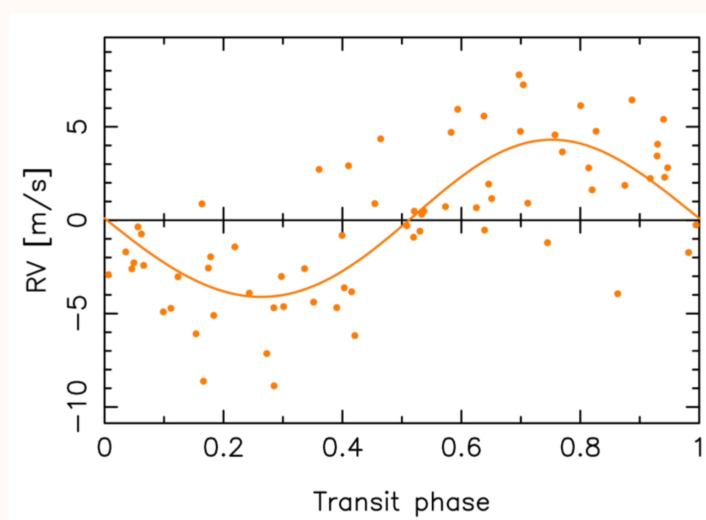
CoRoT-7 b
m = 5.12 ± 0.65 M⊕



CoRoT-7 c
P = 3.70 ± 0.02 days
m = 13.6 ± 0.79 M⊕







CoRoT-7 d
P = 8.44 ± 0.16 days
m = 13.1 ± 1.76 M⊕

Conclusions

- CoRoT-7b is rocky with iron core
- Also detect 2 sub-Neptune mass planets with P = 3.69 and P = 8.44 days
- In CoRoT-7, suppression of convective blueshift dominates strongly
- See Haywood et. al (in prep.) and Lanza et al. (in prep.)