CoRoT Seismology of a Sun-like planet-host star

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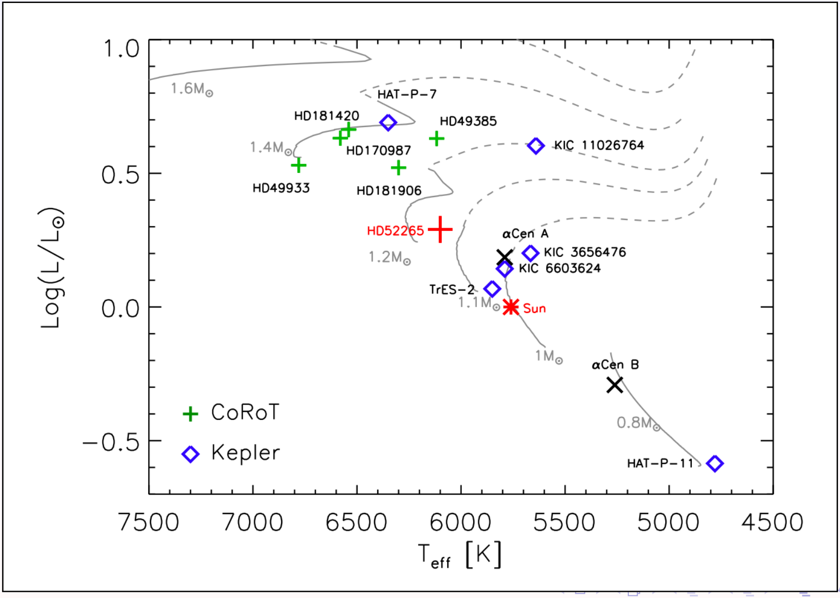
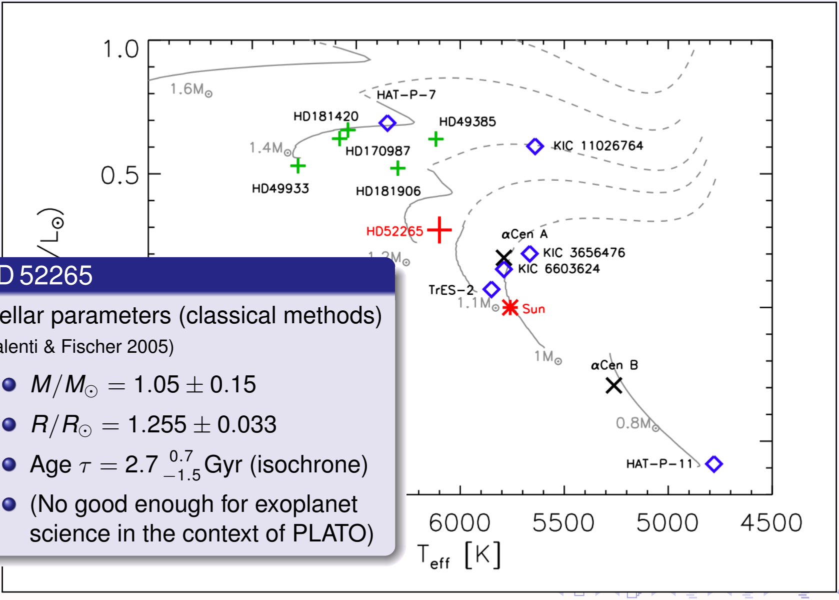
HD 52265: G0V planet host



HD 52265: G0V planet host



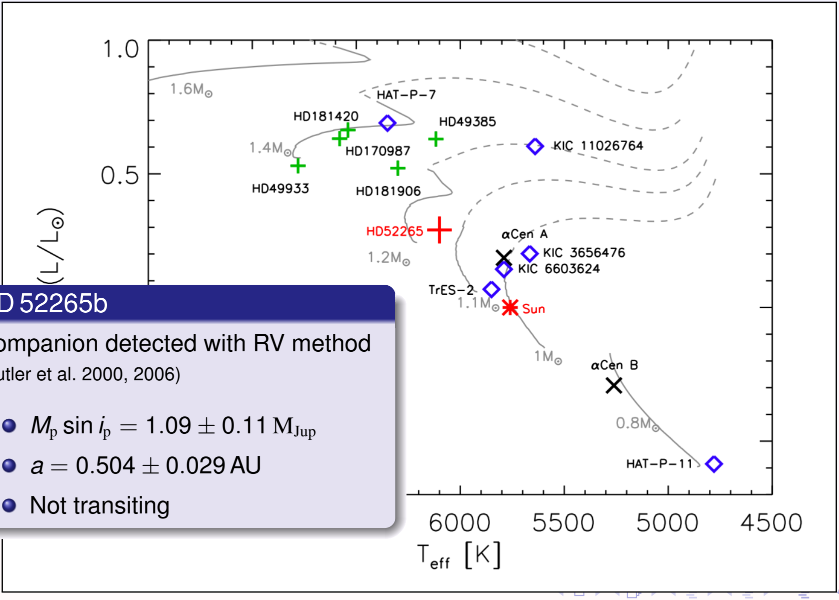
HD 52265

Stellar parameters (classical methods)

(Valenti & Fischer 2005)

- $M/M_{\odot} = 1.05 \pm 0.15$
- $R/R_{\odot} = 1.255 \pm 0.033$
- Age $\tau = 2.7\ ^{0.7}_{-1.5}$ Gyr (isochrone)
- (No good enough for exoplanet science in the context of PLATO)

HD 52265: G0V planet host

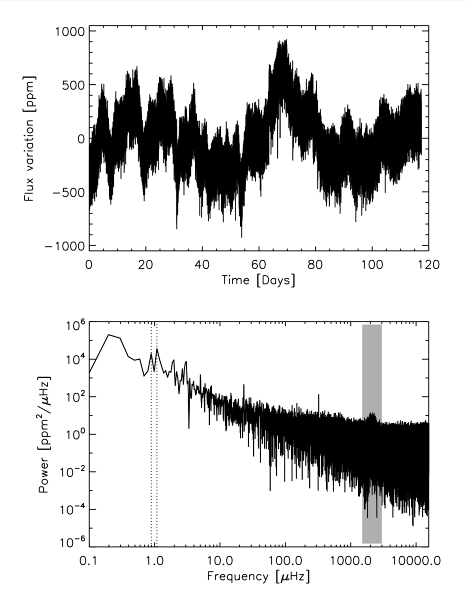


HD 52265b

Companion detected with RV method (Butler et al. 2000, 2006)

- $M_\mathrm{p} \sin i_\mathrm{p} = 1.09 \pm 0.11\ \mathrm{M_{Jup}}$
- $a = 0.504 \pm 0.029$ AU
- Not transiting

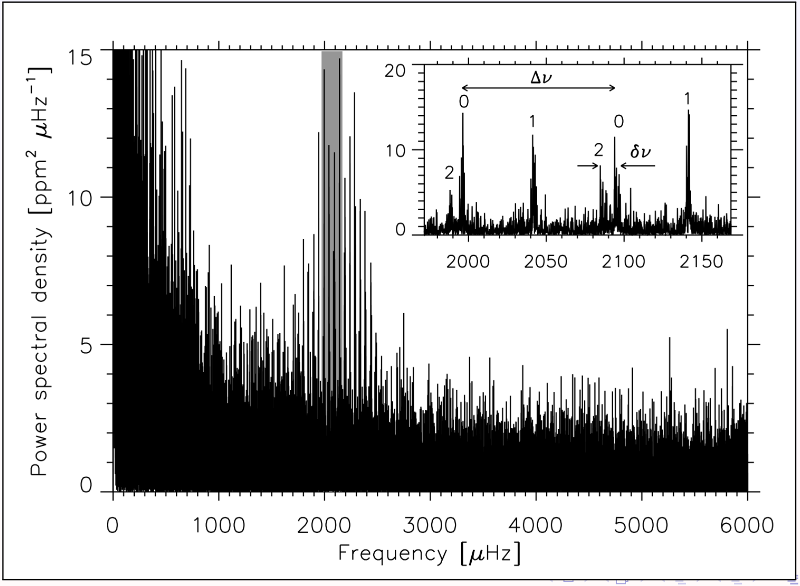
CoRoT observation of HD 52265



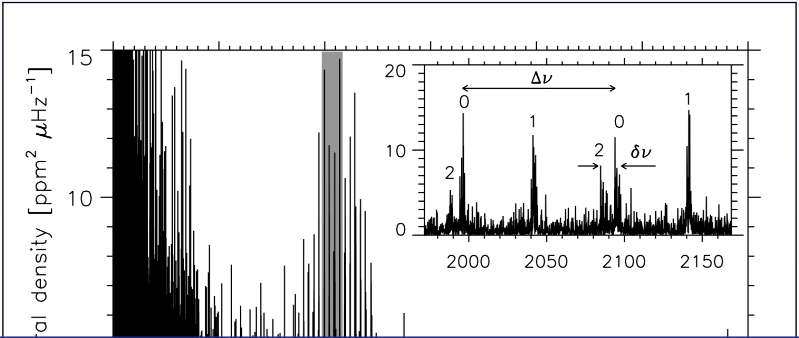
CoRoT Long Seismo Run

- November 2008 – March 2009
- $T = 117$ days,
  freq. res. $1/T = 0.1\ \mu$Hz
- Sampling $dt = 32$ sec,
  Nyquist-freq. $1/(2dt) = 15.6$ mHz
- Modulation of the lightcurve due to rotation of starspots
- *Signature of surface rotation:*
  $\nu \sim 1\mu$Hz ($P_{\rm rot} \approx 11$ days)
- Low-degree p modes at $\nu \sim 2$ mHz

HD 52265: Oscillation power spectrum



HD 52265: Oscillation power spectrum



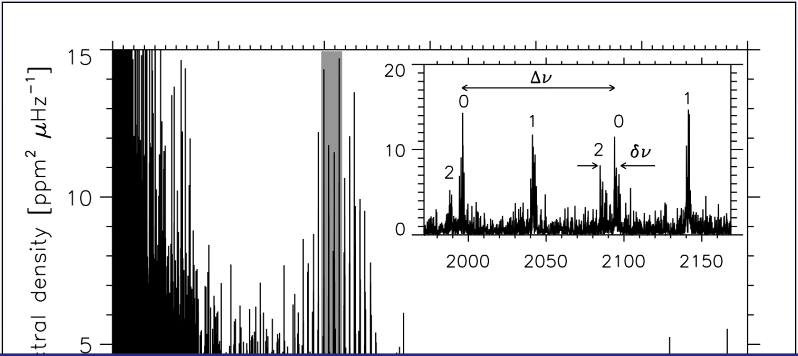
Large separation

$$\Delta\nu \simeq \nu_{n+1,\ell} - \nu_{n\ell}$$

$$\Delta\nu = \left(2\int_0^R \frac{dr}{c}\right)^{-1} \propto (\bar{\rho})^{1/2}$$

- valid for $n >> \ell$
- travel time through a stellar diameter

HD 52265: Oscillation power spectrum



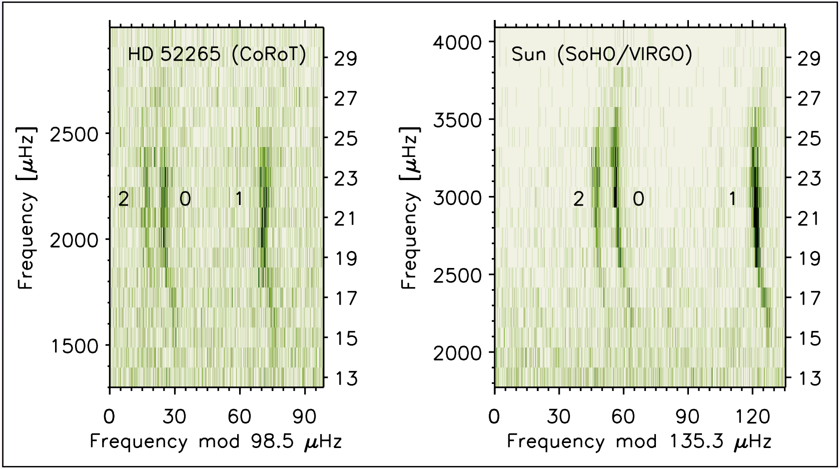
Small separation

$$\delta\nu_{n\ell} = \nu_{n\ell} - \nu_{n-1,\ell+2}$$

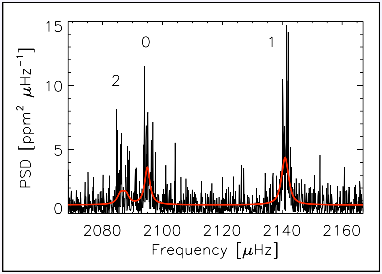
$$\delta\nu_{n\ell} = -(4\ell+6)\frac{\Delta\nu}{4\pi^2\nu_{n\ell}}\int_0^R \frac{dc}{dr}\frac{dr}{r}$$

- valid for $n >> \ell$
- $\delta\nu$ sensitive to the Hydrogen content in the core ($\rightarrow$ age)

HD 52265: Echelle spectrum



Global fit of HD 52265 power spectrum



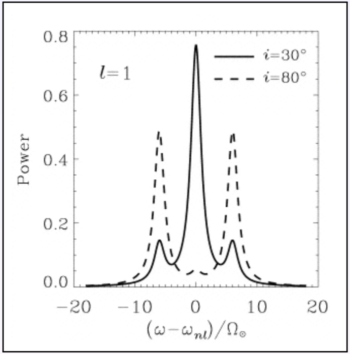
Measurement of mode frequencies

- Global fit of the power spectrum
  $\longrightarrow$ fit of all modes simultaneously
- Effect of rotation on mode freq.
- Fit of Lorentzian line profiles
- Maximum likelihood estimation

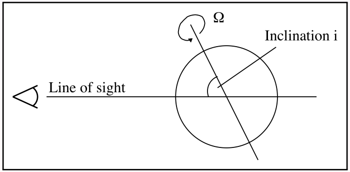
Validation (T. Stahn):

- Monte Carlo simulation and fits of synthetic power spectra
- Tests using 13 years of VIRGO solar data

Effect of rotation on oscillations



from Gizon & Solanki (2003)



Rotation

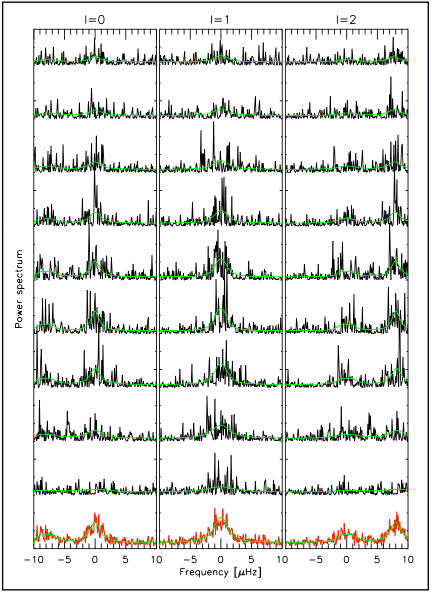
- Splitting of azimuthal components of a multiplet due to **rotation**
- Assumption: rigid body rotation

$$\nu_{n\ell m} = \nu_{n\ell 0} + m\Omega/2\pi$$

Inclination angle of rotation axis

- The visibility of the azimuthal components depends on the **inclination angle** of the rotation axis with respect to the line of sight

HD 52265: Results of global fit



Number of modes:

- $n = 17 - 25$ (9 consecutive ns)
- $\ell \leq 2$, $|m| \leq \ell$
- 84 mode frequencies
- Polynomial dependence of frequencies with n at fixed ℓ.

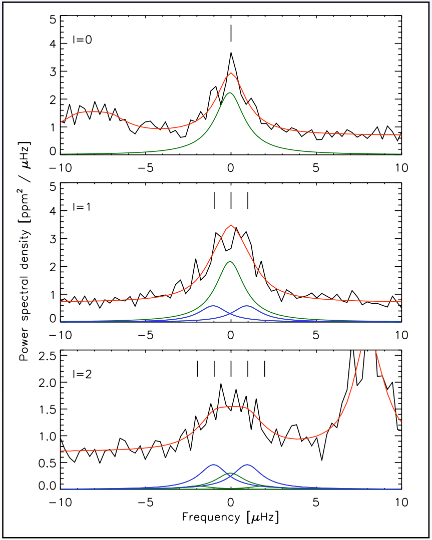
Large/small separation

- $\langle \Delta\nu \rangle = 98.56 \pm 0.13\,\mu$Hz
- $\langle \delta\nu \rangle = 8.08 \pm 0.16\,\mu$Hz

Rotation

- $\Omega/2\pi = 0.98\,^{+0.21}_{-0.27}\,\mu$Hz
- $i = 36^\circ\,^{+13^\circ}_{-10^\circ}$

HD 52265: Results of global fit



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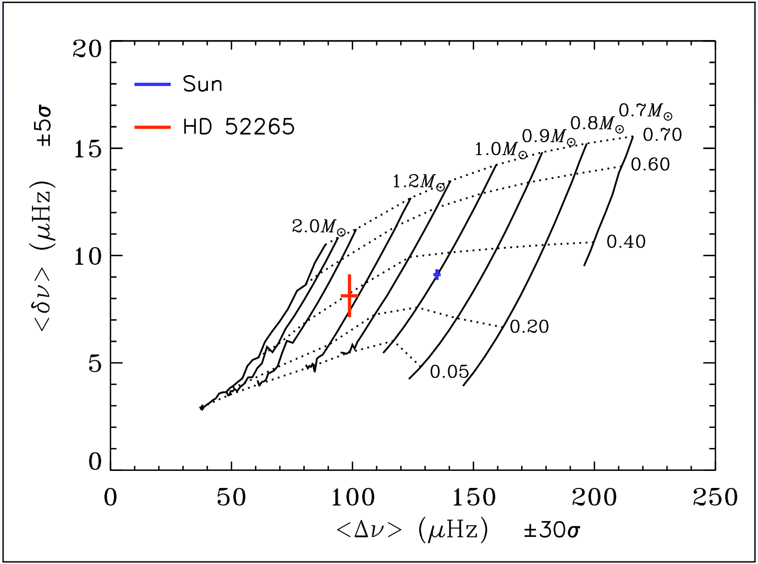
Interpretation of $\Delta\nu$ and $\delta\nu$



asteroseismic HRD courtesy of Christensen-Dalsgaard

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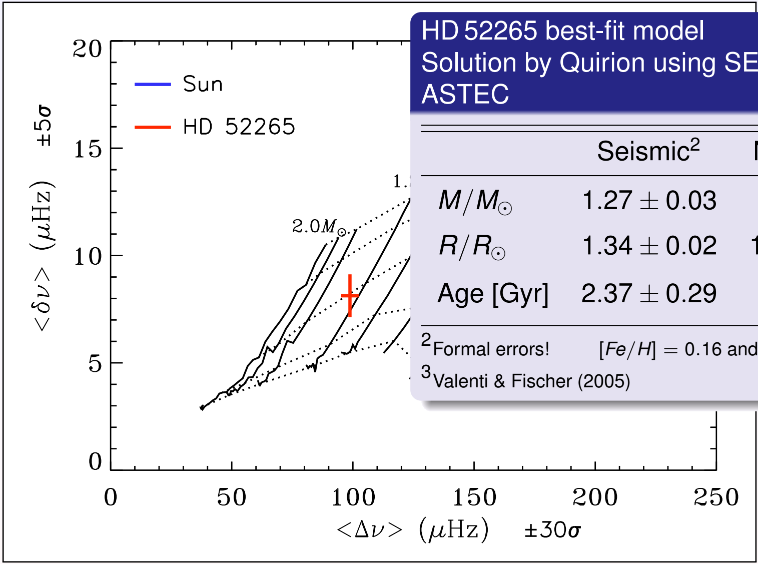


HD 52265 best-fit model
Solution by Quirion using SEEK and ASTEC

	Seismic[2]	Non-seismic[3]
$M/M_\odot$	1.27 ± 0.03	1.05 ± 0.15
$R/R_\odot$	1.34 ± 0.02	1.255 ± 0.033
Age [Gyr]	2.37 ± 0.29	$2.7^{+0.7}_{-1.5}$

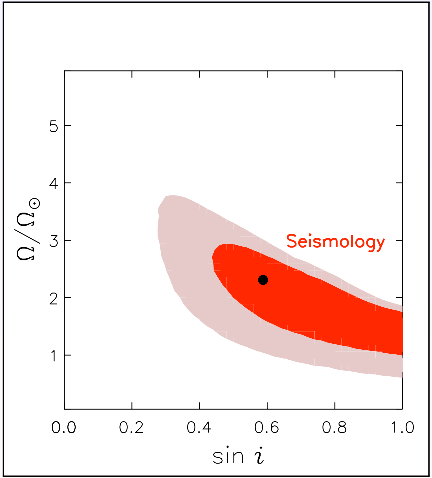
[2] Formal errors! $[Fe/H] = 0.16$ and $Y_{\rm init} = 0.26$

[3] Valenti & Fischer (2005)

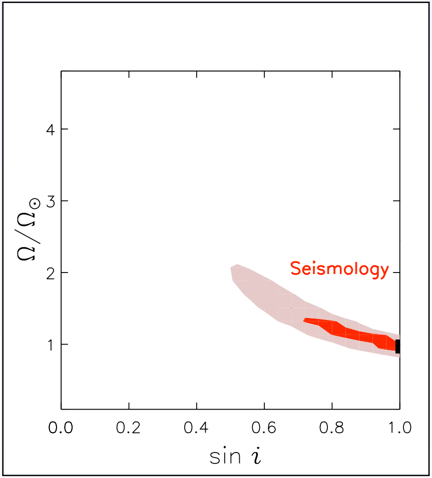
asteroseismic HRD courtesy of Christensen-Dalsgaard

Rotation of HD 52265 and the Sun

HD 52265

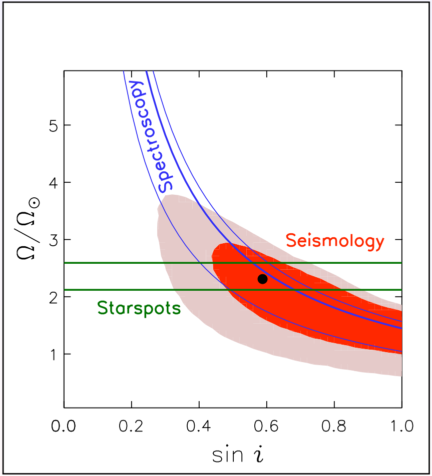


Sun



Rotation of HD 52265

HD 52265

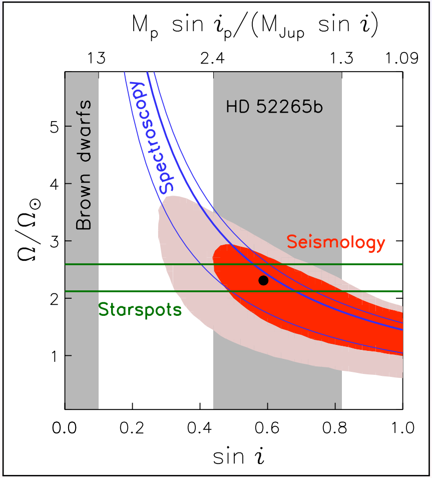


Remarkable consistency

- Asteroseismology
  $\rightarrow 0.71\ \mu\text{Hz} \leq \Omega/2\pi \leq 1.19\ \mu\text{Hz}$
  $\rightarrow i > 27^\circ$
- Starspot rotation
  $\rightarrow \Omega/2\pi = 0.91\ \mu\text{Hz}$, $\Omega/2\pi = 1.07\ \mu\text{Hz}$
- Spectroscopy
  $\Omega \sin i = v \sin i / R$
  $\rightarrow v \sin i = 3.6^{+0.3}_{-1.0}$ km/s (Narval@Lyot)
  $\rightarrow R$ from seismology
- Eight independent seismic analyses

Constraint on the mass of HD 52265b

HD 52265



The mass of HD 52265b

Radial velocity measurements

(Butler et al. 2006)

- $M_p \sin i_p = (1.09 \pm 0.11)\,\mathrm{M_{Jup}}$

Asteroseismology

- Assumption: $i = i_p$
- $M_p < 2.4\,\mathrm{M_{Jupiter}} < M_{BD,min}$

$\Rightarrow$ This work suggests that HD 52265b is a planet (unlike Hipparcos intermediate astrometry!)

Seismology + starspots

- $1.3 \leq M/\mathrm{M_{Jupiter}} \leq 2.4$

Summary

1. First unambiguous seismic measurement of rotation in a solar-type star (error $\sim$ 25%)
2. Seismic constraint on inclination angle (error $\sim 12^\circ$)
3. Consistency between spectroscopic $v \sin i$, starspot rotation, spot modeling
4. Formal errors on mass and radius of about 2%
5. Formal error on age of 5% of MS lifetime

Next steps

1. Physics/systematics: Effects of varying metallicity, Helium abundance, diffusion, etc, on estimation of seismic parameters? Talk by S. Vauclair
2. Repeat analysis for star with planetary transit! (cf. PLATO)
3. To constrain M_p, R_p, and age.
4. To constrain *true* spin-orbit angle (using seismic $\sin i$, i_p from transit, and Rossiter projected spin-orbit angle)?