Oscillating double-lined binaries as test cases for understanding stellar evolution

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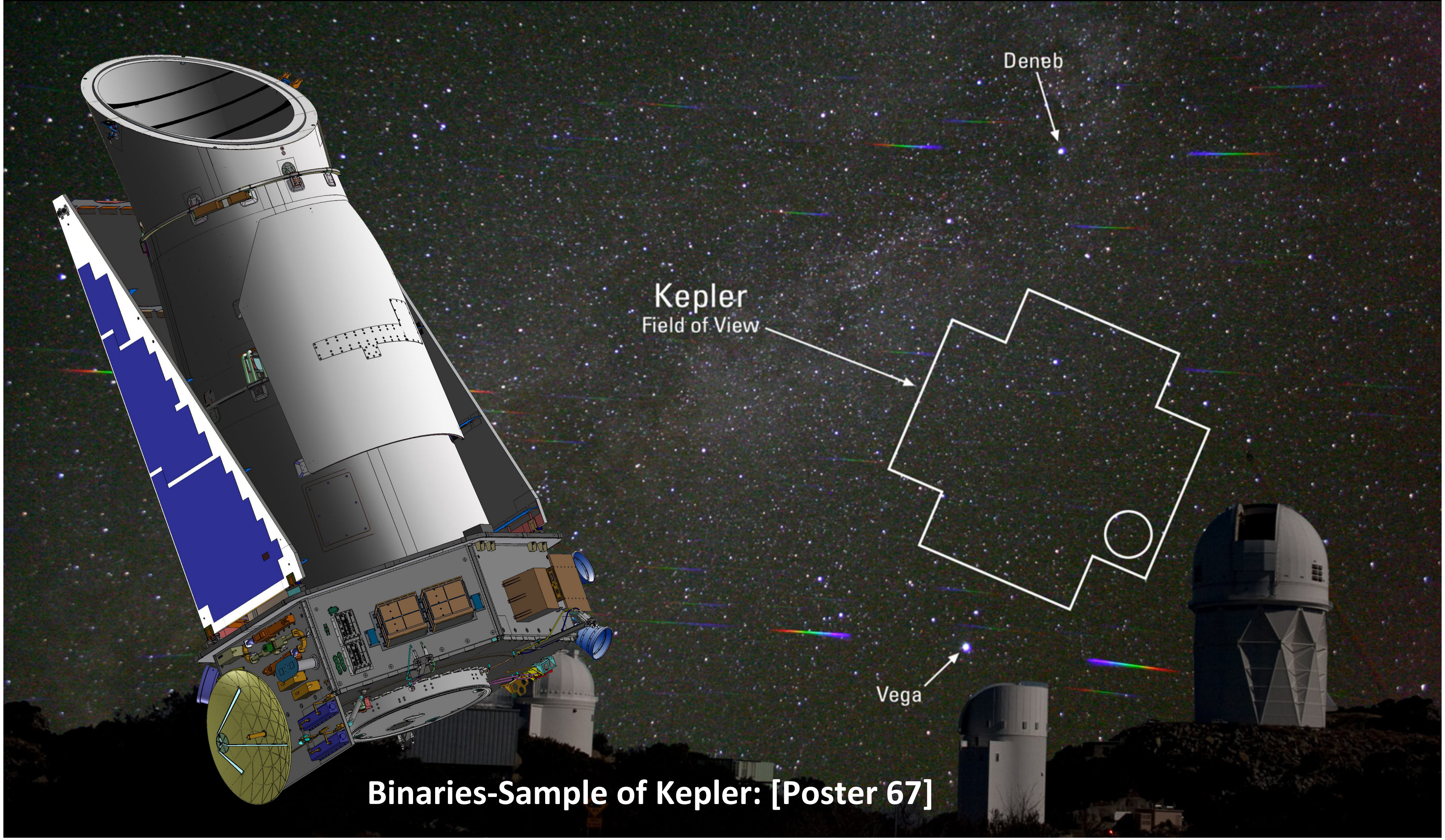
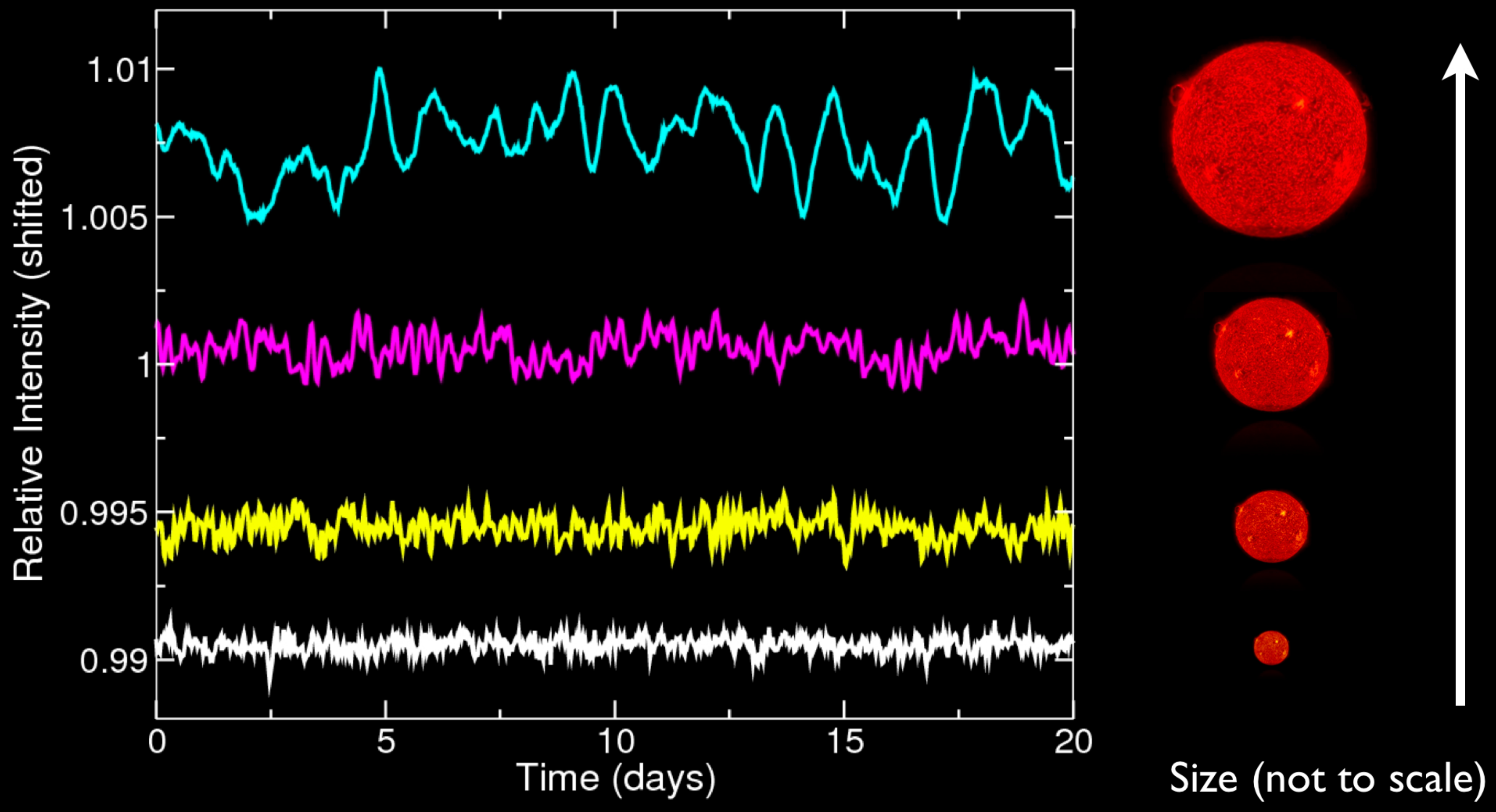
And the authors of
Beck, Kallinger, Pavlovski et al. (A&A, submittd)

The golden age of Asteroseismology : NASA *Kepler* Mission



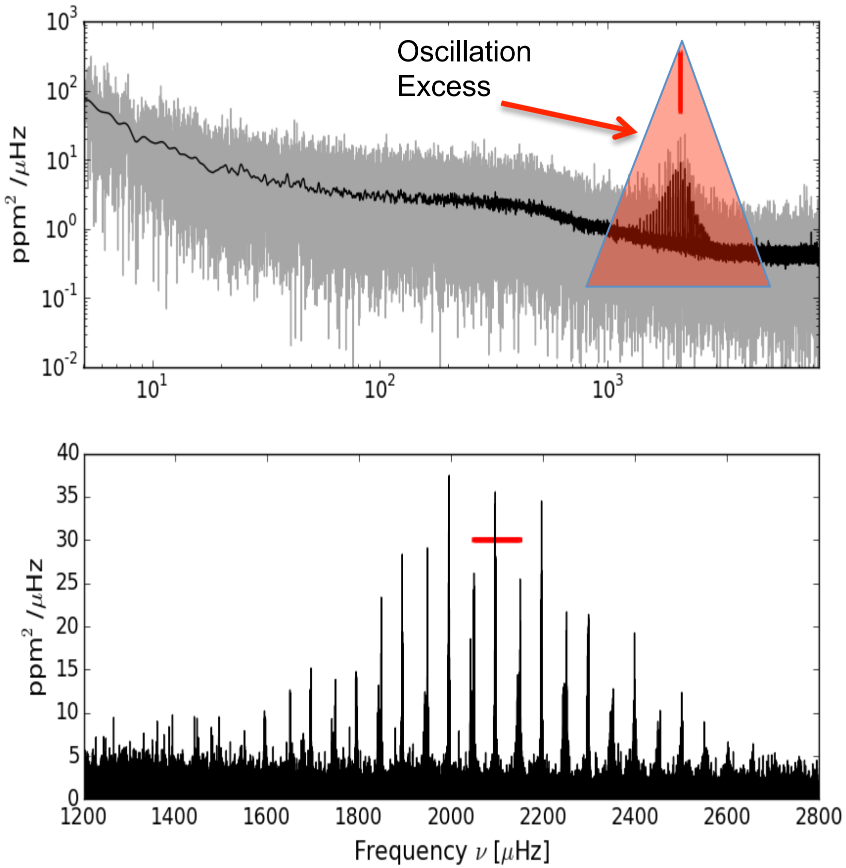
Binaries-Sample of Kepler: [Poster 67]

Its all about density …



Courtesy of Daniel Huber

Solar-like oscillations in Binaries



Stochastic Oscillations

- Excited by convection
- Amplitudes: ~100 ppm
- Typical signature in frequency spectrum
  - → Mass, radius (Kjeldsen & Bedding 1995)
  - → Detailed stellar structure & dynamics

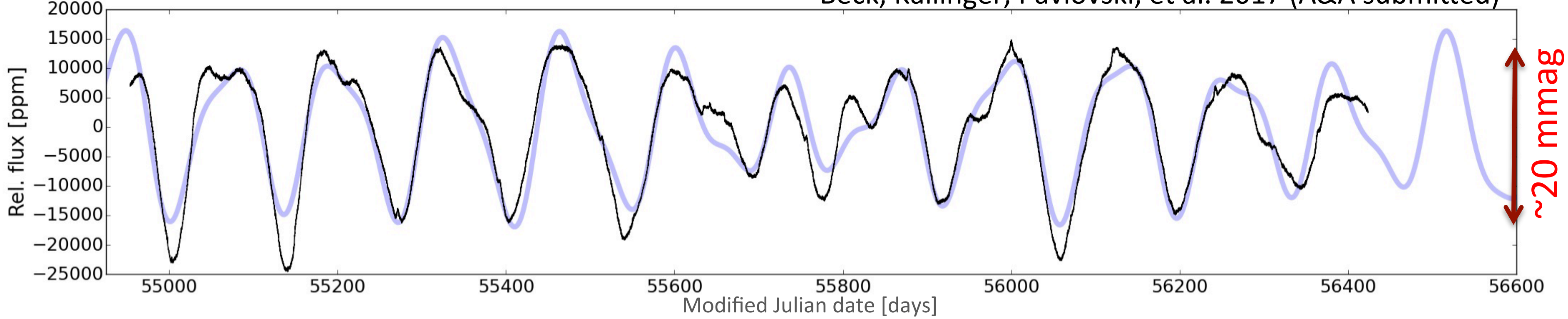
Binaries

- PB1: Single oscillating component
  - One well-constrained component
  - 20 eclipsing & 20 Tidally interacting
  - → 7 eSB2: calibration of Scaling Relations (Gaulme+ 2016, ApJ, 832, 121)
- PB2: Both components oscillating
  - Many rewarding constraints
  - Only few solar-like PB2 studied (e.g. White+ 2017, Davis+ 2014)

- **RGB: KIC9163796: Beck+ (this work)**

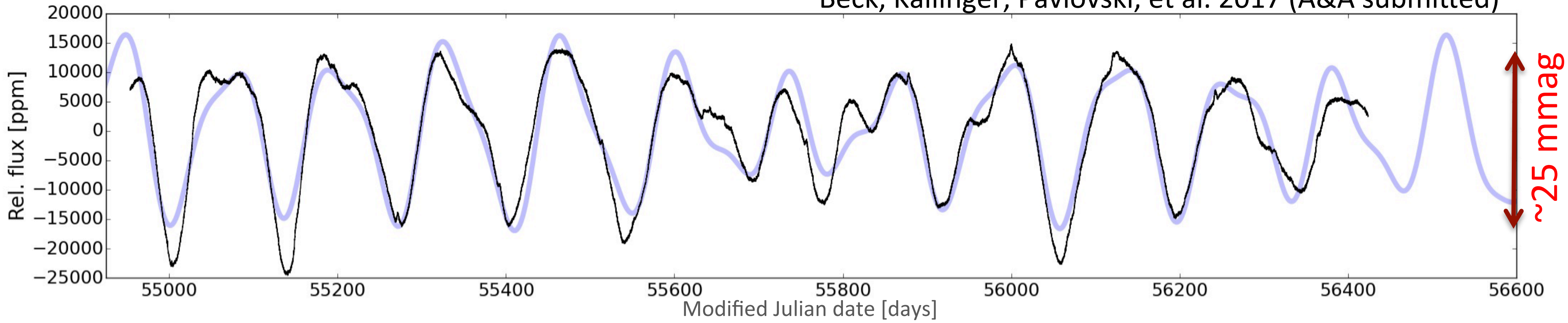
KIC 9163796: Asterix & Obelix

Beck, Kallinger, Pavlovski, et al. 2017 (A&A submitted)

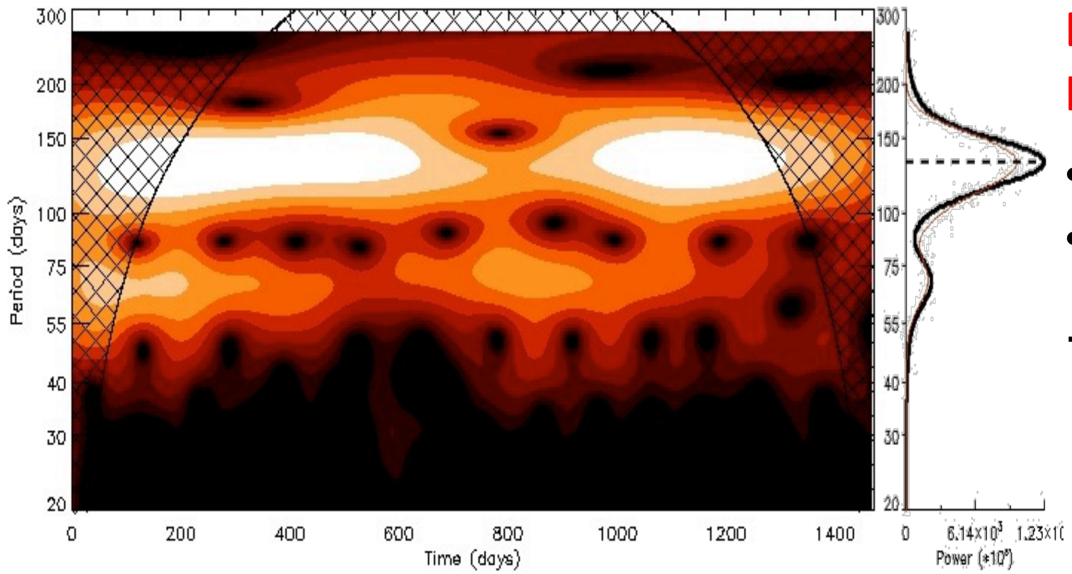


The light curve

Beck, Kallinger, Pavlovski, et al. 2017 (A&A submitted)



Surface rotation: 130 days



Dominant Period: ~130 days

High chromospheric activity

- Periodic minima
- Variable maxima

→ Variable Active regions

The light curve

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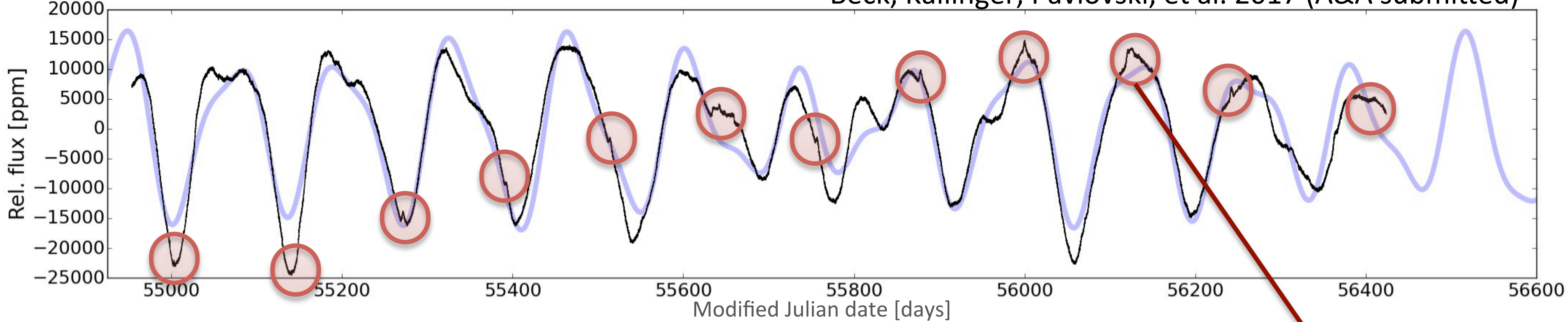

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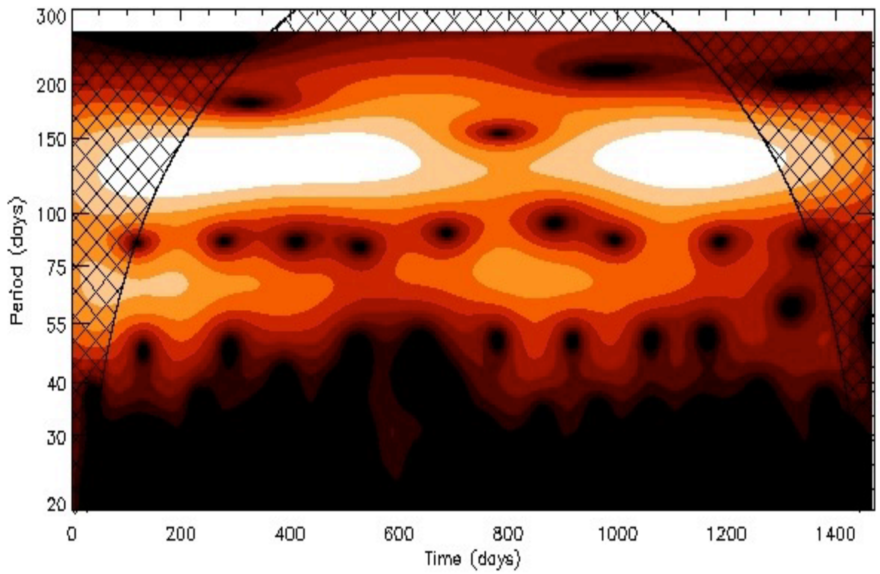
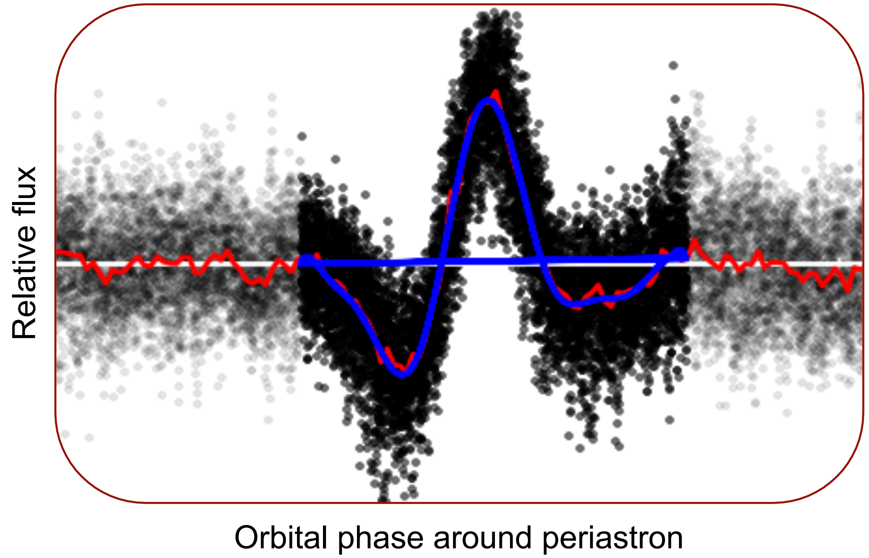
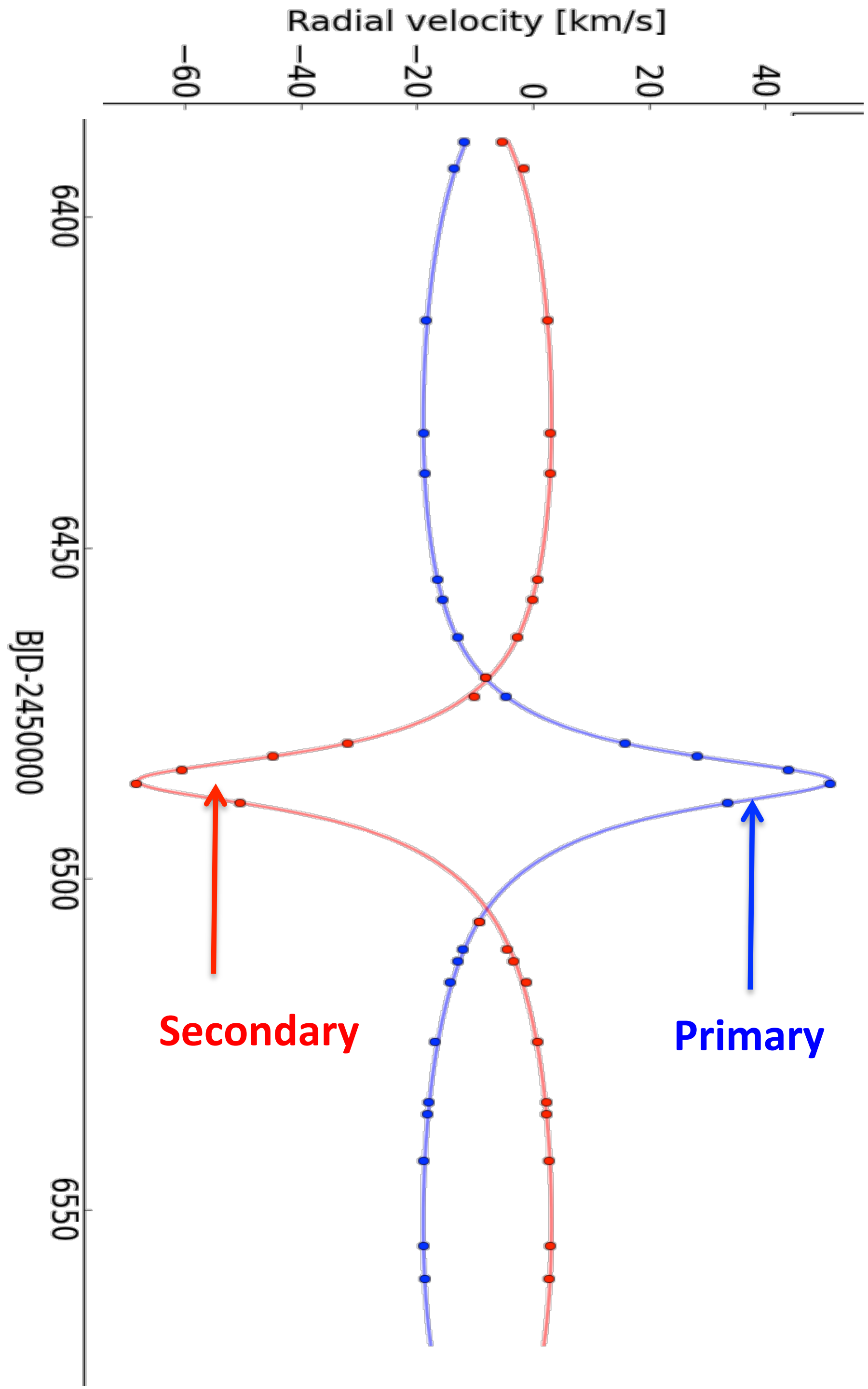


Orbital period: 120 days



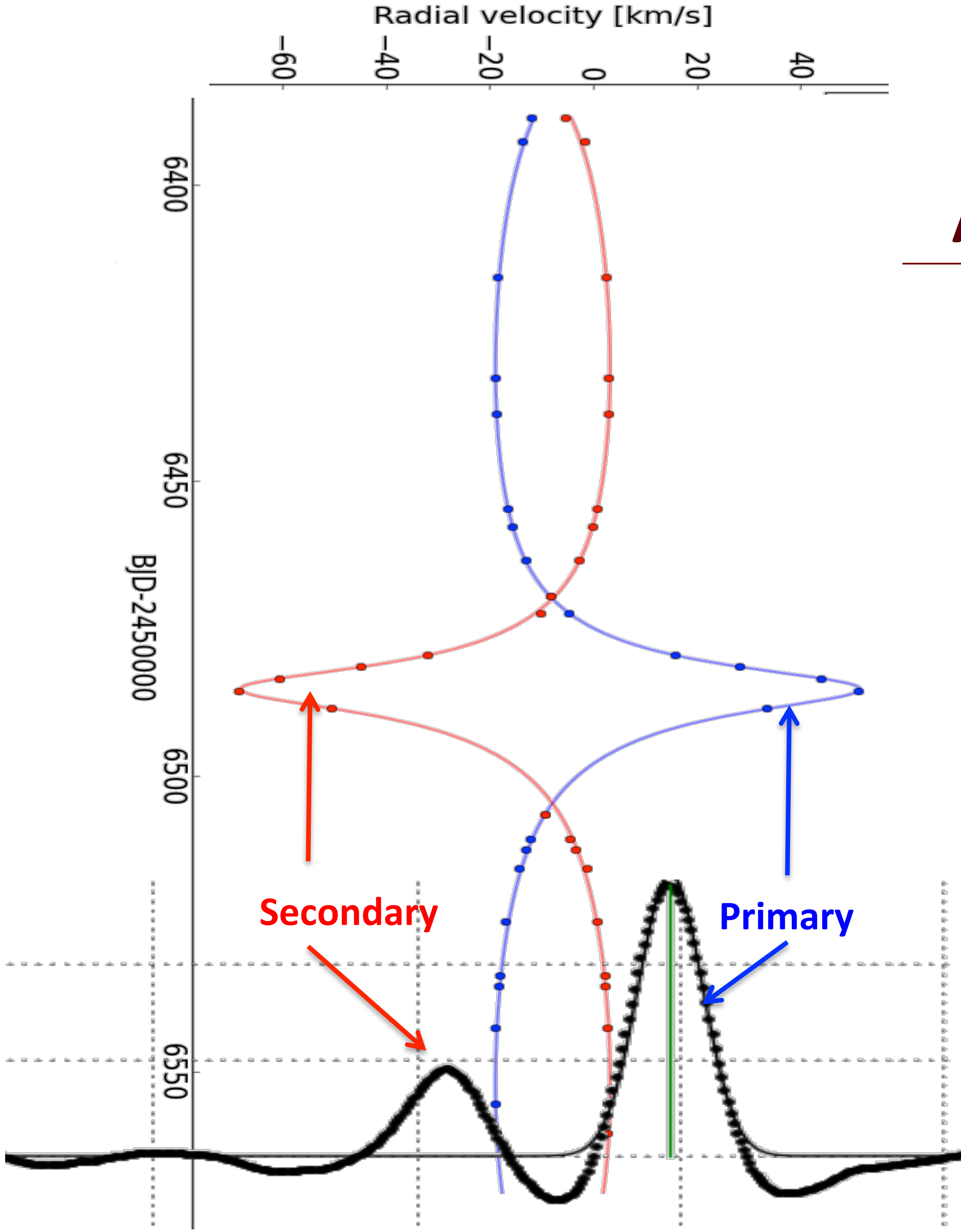


An SB2 binary

- Orbital period 120.3 days
- Eccentricity = 0.7
  - A sin i = 122Ro (~25 R_{RG})
  - Min: ~7 R_{RG}
- Ill constrained inclination

- Mass ratio from radial velocity amplitudes:

  M_1/M_2 = 1.014±0.01



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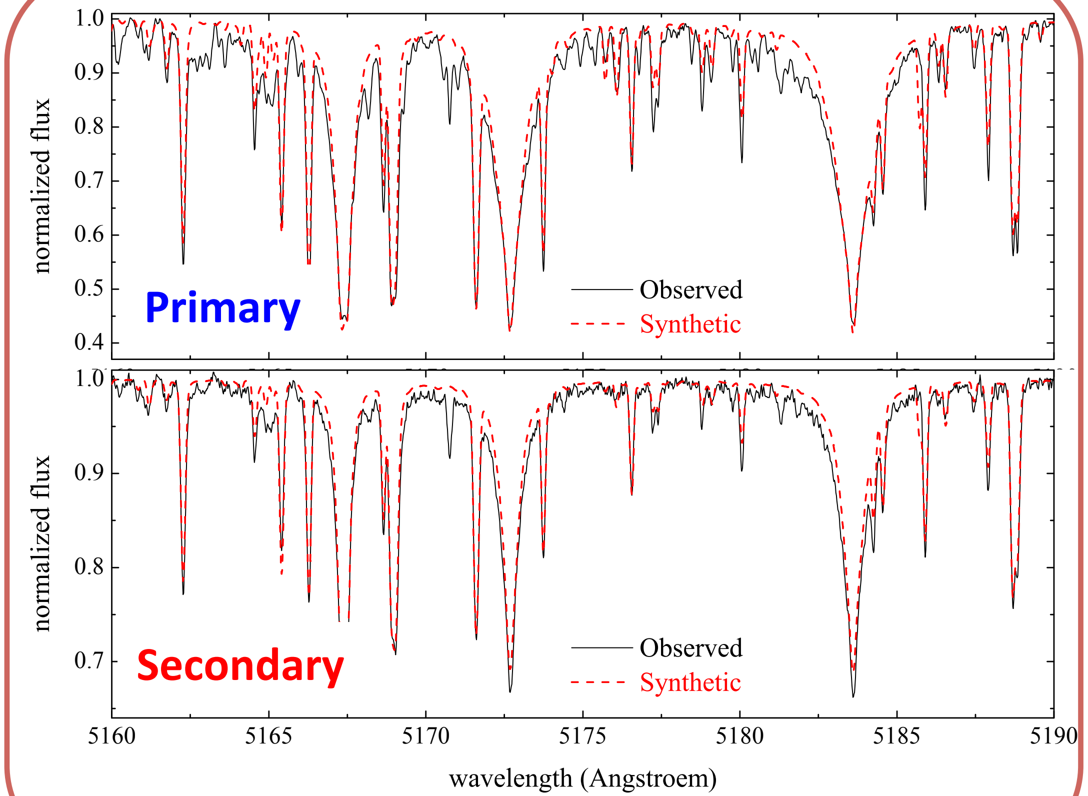
- Very different line profiles

Spectral Disentangling



Isolate and renormalize Components

- Functional: $F_2/F_1 < 1\%$
  (FDBinary, Ilijic+ 2004, ASPC 318, 111)
- SB2 fit confirms the SB1 solution

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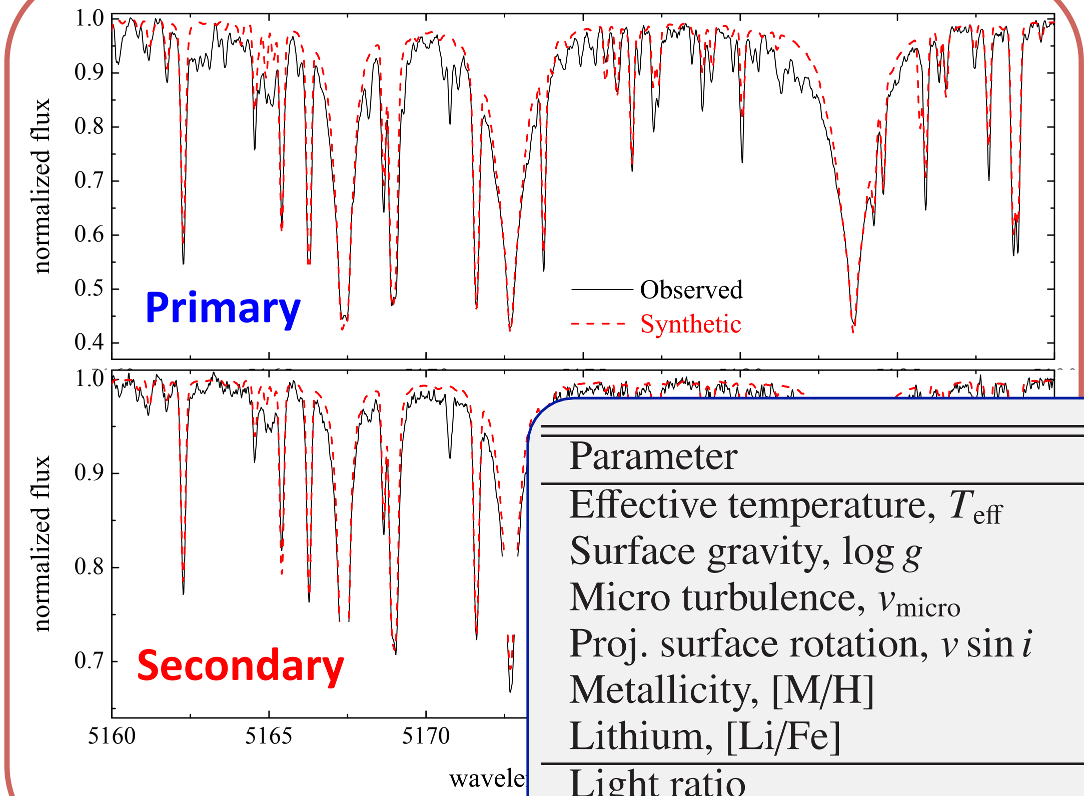

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- GSSP (Tkachenko+ 2012& ref therein
  - Consistent result
  - Lithium differs by 1.2 dex

Parameter	Unit	Primary	Secondary
Effective temperature, T_{eff}	[K]	5020±100	5650±70
Surface gravity, log g	[dex]	3.14±0.2	3.48±0.3
Micro turbulence, v_{micro}	[km/s]	1.2±0.3	1.43±0.2
Proj. surface rotation, $v \sin i$	[km/s]	4.7±0.5	5.0±0.5
Metallicity, [M/H]	[dex]	-0.37±0.1	-0.38±0.1
Lithium, [Li/Fe]	[dex]	1.31±0.008	2.55±0.07
Light ratio	[%]	63±3	37±2
Difference, Δmag_V	[mag]	0.58±0.08	
Apparent magnitude	[mag]	10.32±0.04	10.90±0.09

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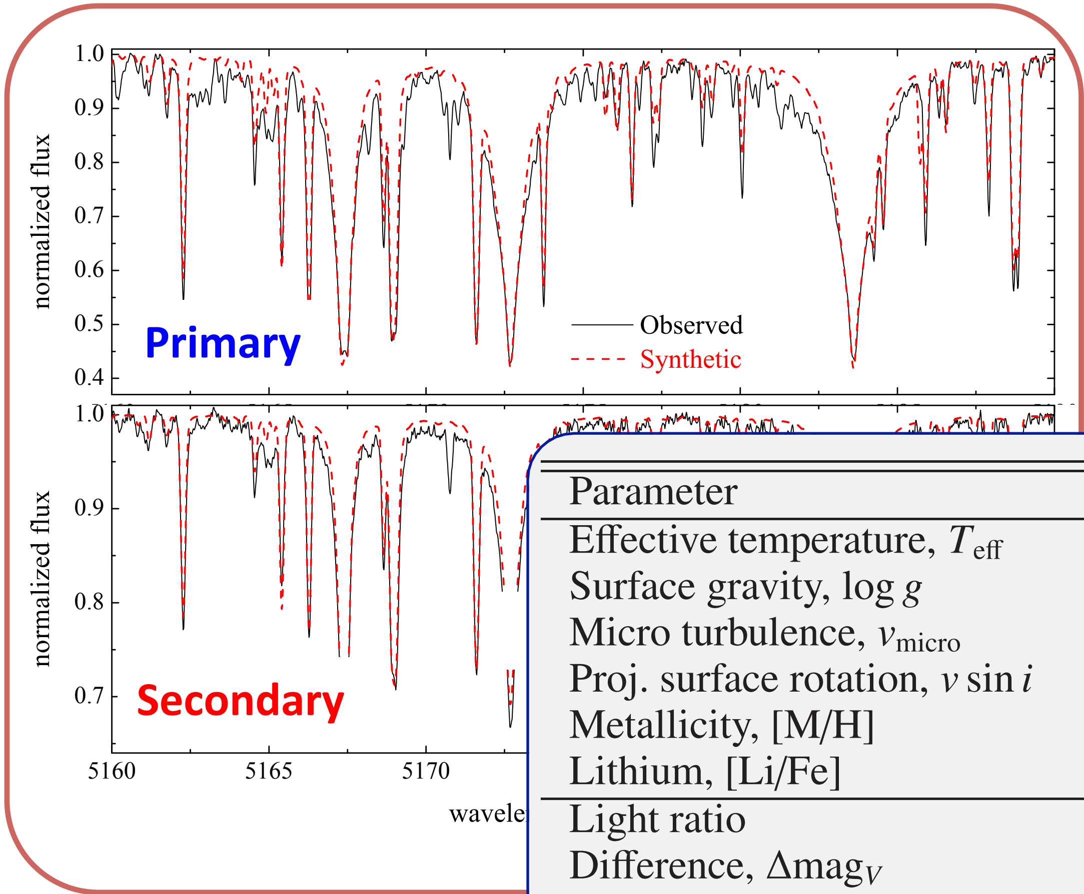

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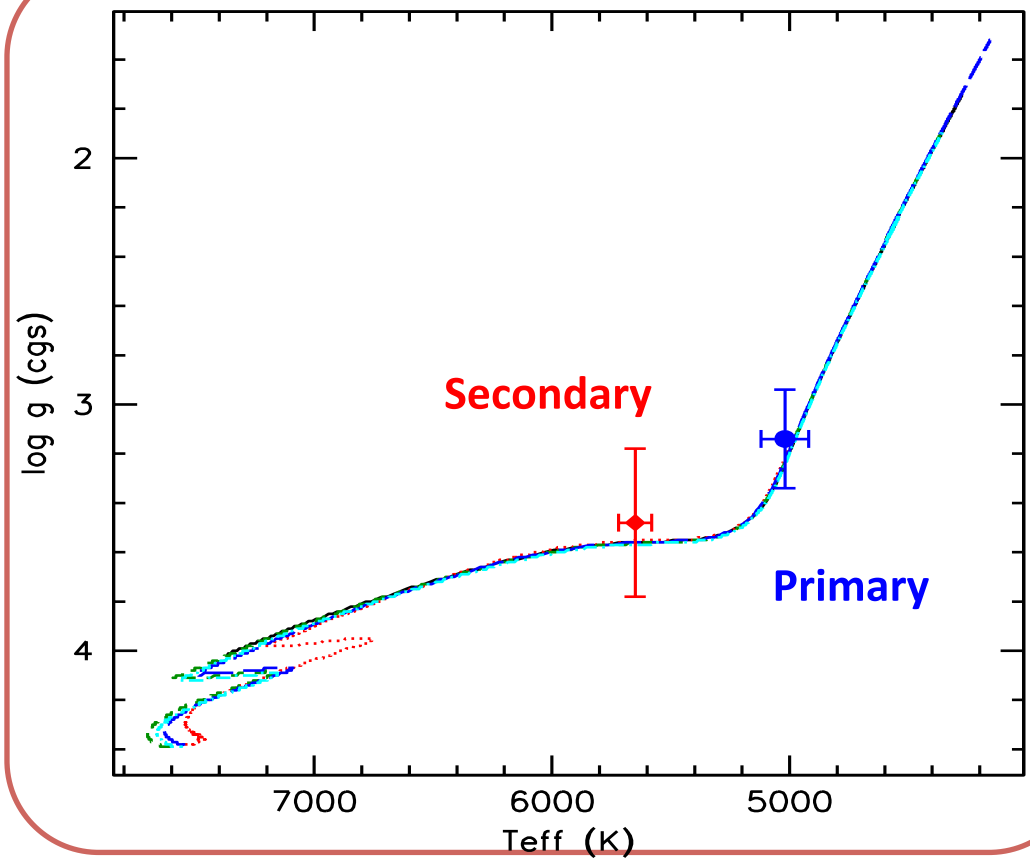

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- Two low-luminosity red giants
- Position compatible with solar-like oscillations

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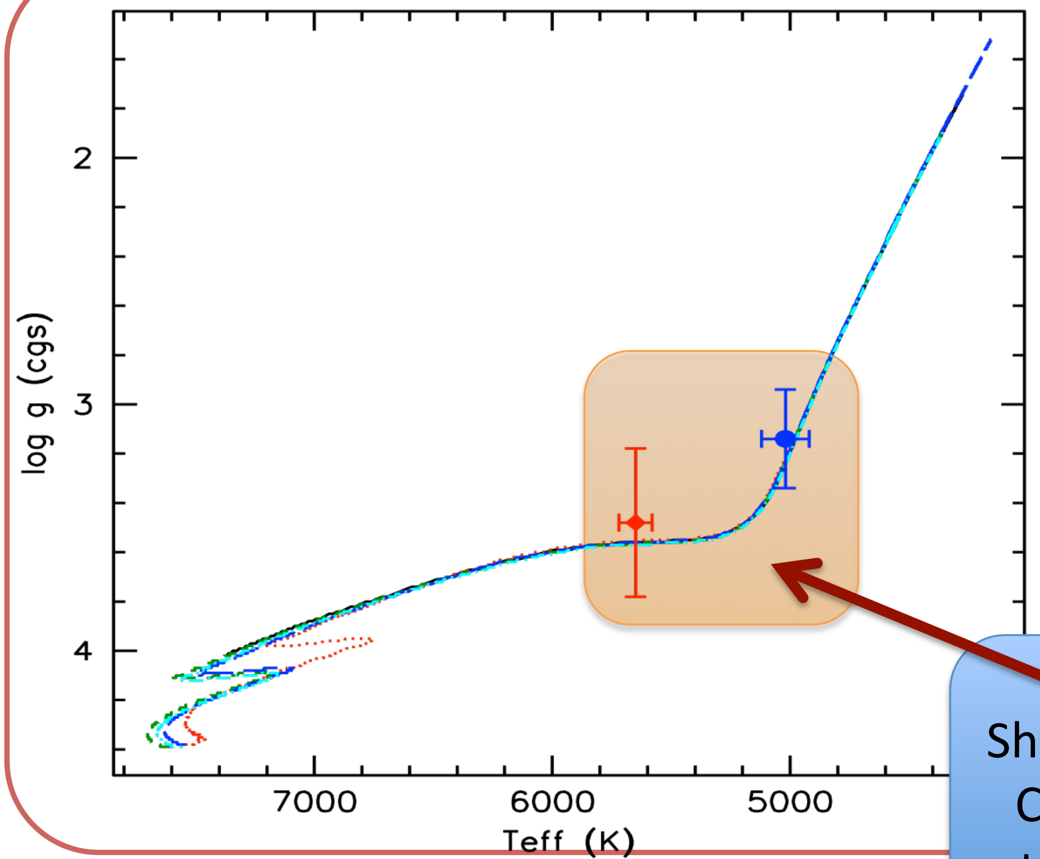

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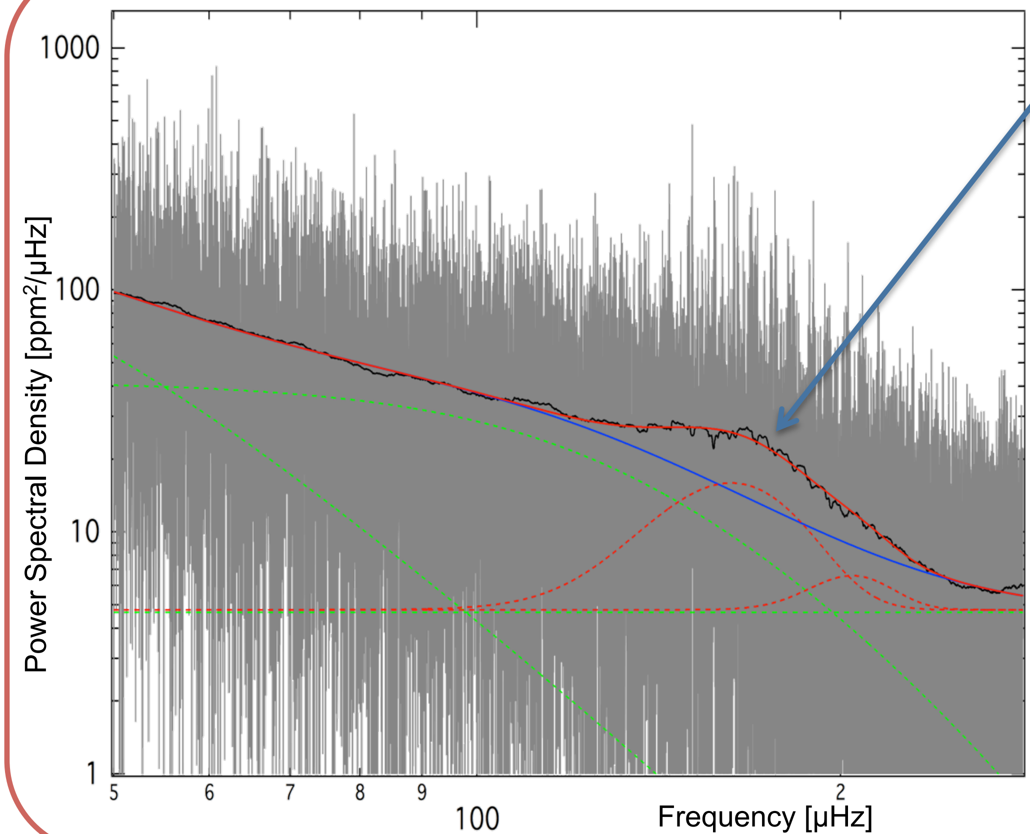
First Dredge-Up Event:
Short lived phase in stellar evol.
Convective envelope reaches
the maximum penetration in
mass coordinates

Global Seismology



Primary power excess

ν_{max}= 163μHz, Δν=12.8μHz

→Mass: 1.39M_o ; Radius: 5.35R_o

- Noisy spectrum
  - Photometric dillution
  - Stellar activity

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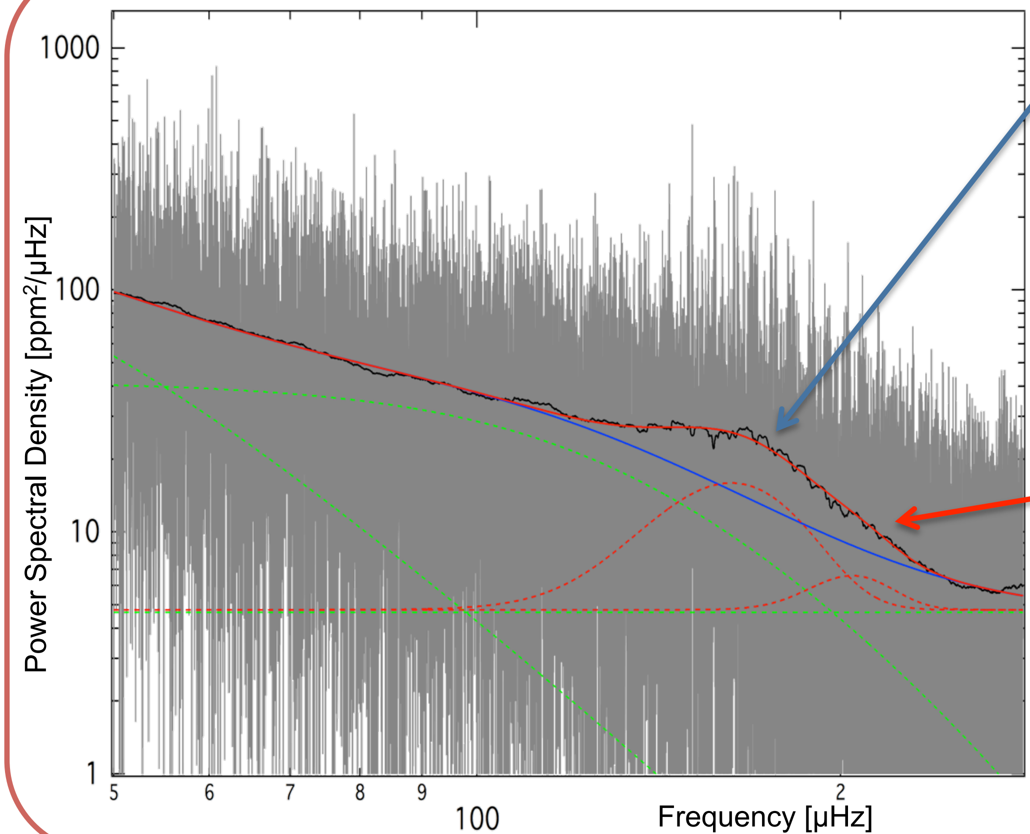

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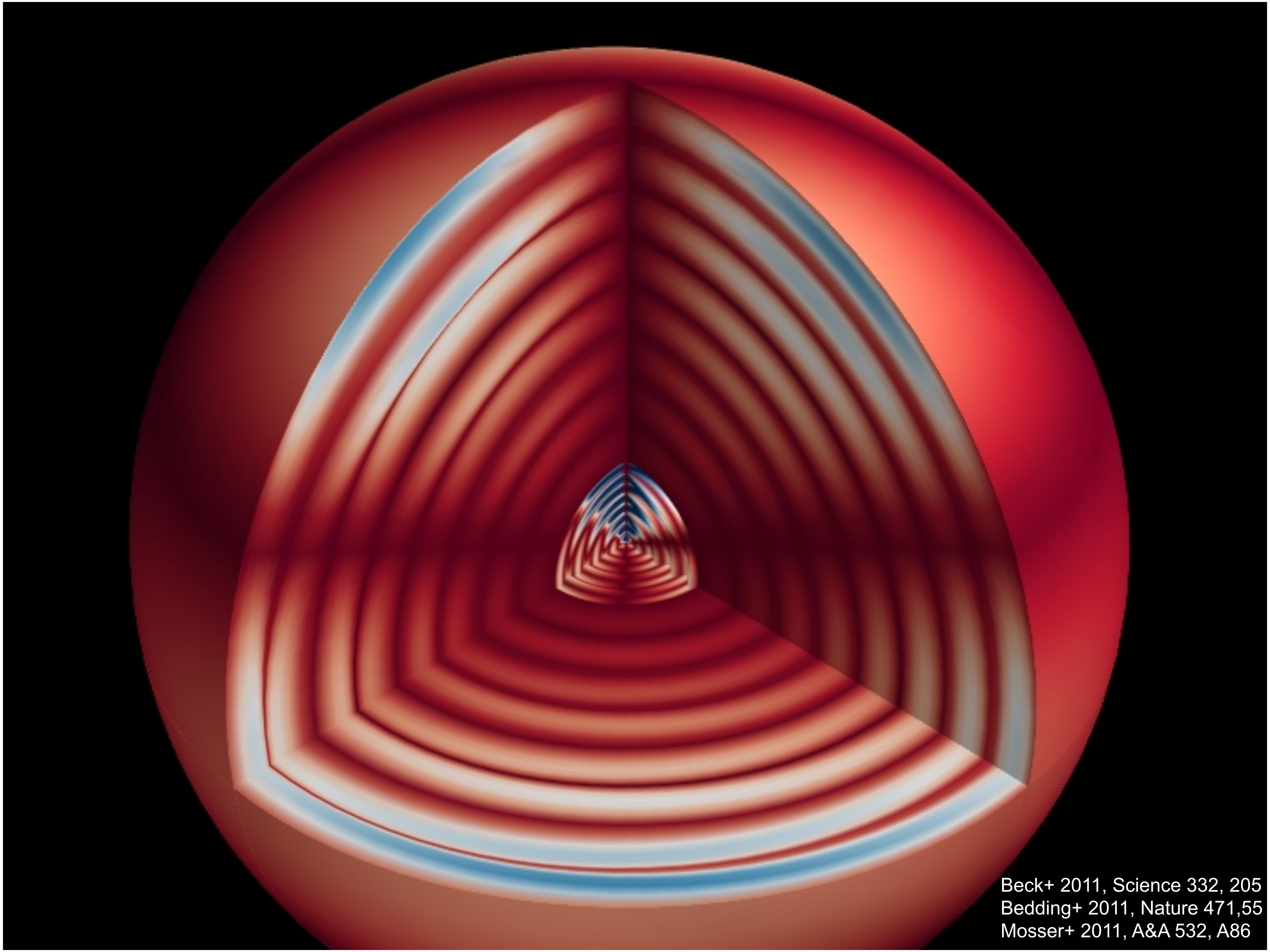
Secondary power excess

ν_{max}: 214±10μHz, (corr: 352μHz)

- Reflected super-Nyquits ν_{max}

→ Scaled: 410 ±50μHz
agreement within 1.2σ

→ NASA Tess or ESA Plato missions

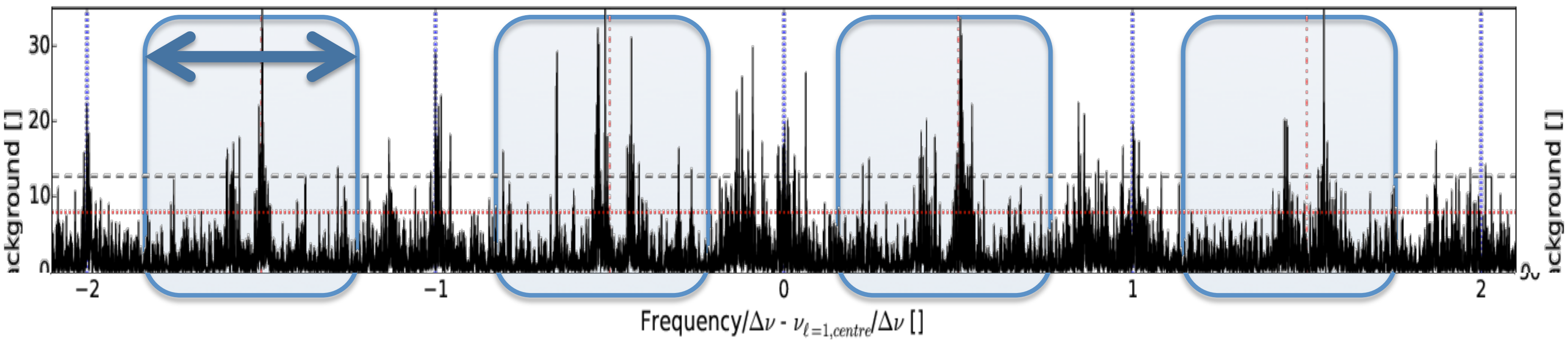

Beck+ 2011, Science 332, 205
Bedding+ 2011, Nature 471,55
Mosser+ 2011, A&A 532, A86

Internal Structure & Dynamics

Dipole mode forest

Rotational splitting:
δf_{max} = 0.24μHz

Period spacing
$\Delta\Pi_1$ = 80 sec



Evolutionary state

Period Spacing: $\Delta\Pi_1$=80”

→ Hydrogen-shell burning / RGB

(for method: Mosser+ 2015, A&A 584, 50 + Refs)

Mass: 1.39M_o Radius: 5.35R_o

Rotational Gradient

Core/Envelope : 6.9±1.5 (seism)

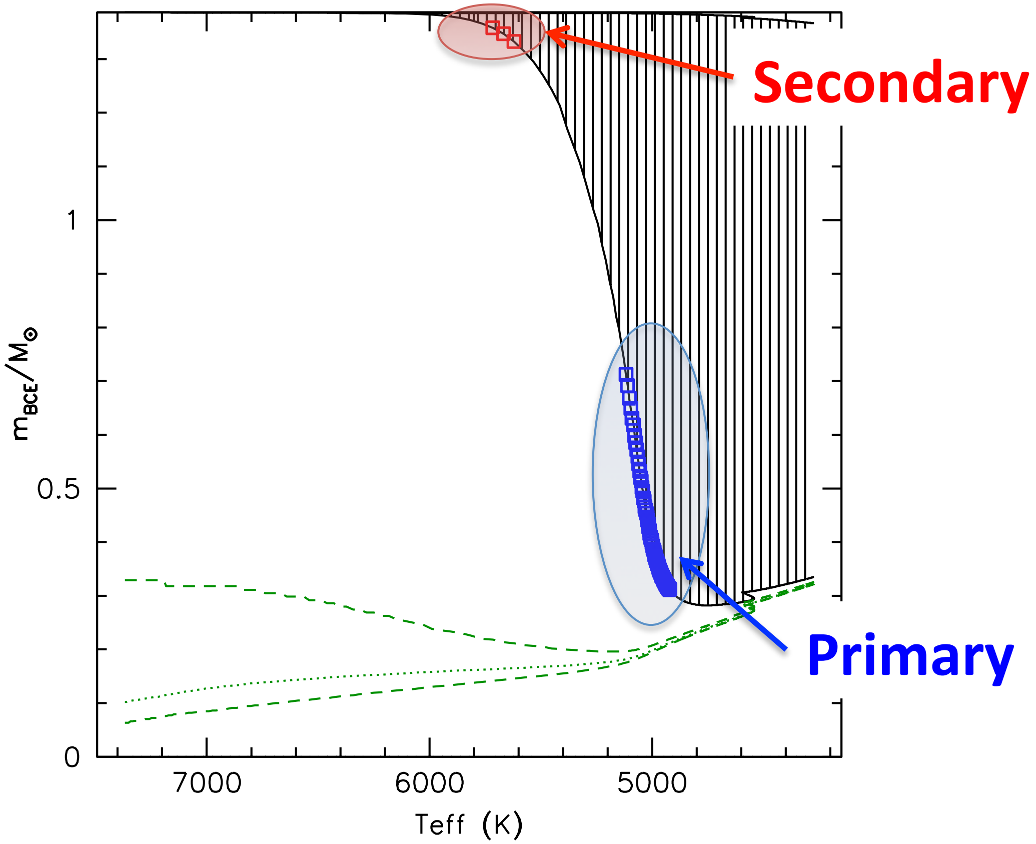
Core/Surface : 6.3±1 (phot)

→ Flatter than average: 10-30x

→ **Quasi rigid-rotation in Conv. Env.**

Simplifies math for tides [poster 65]

Kippenhahn & Lithium

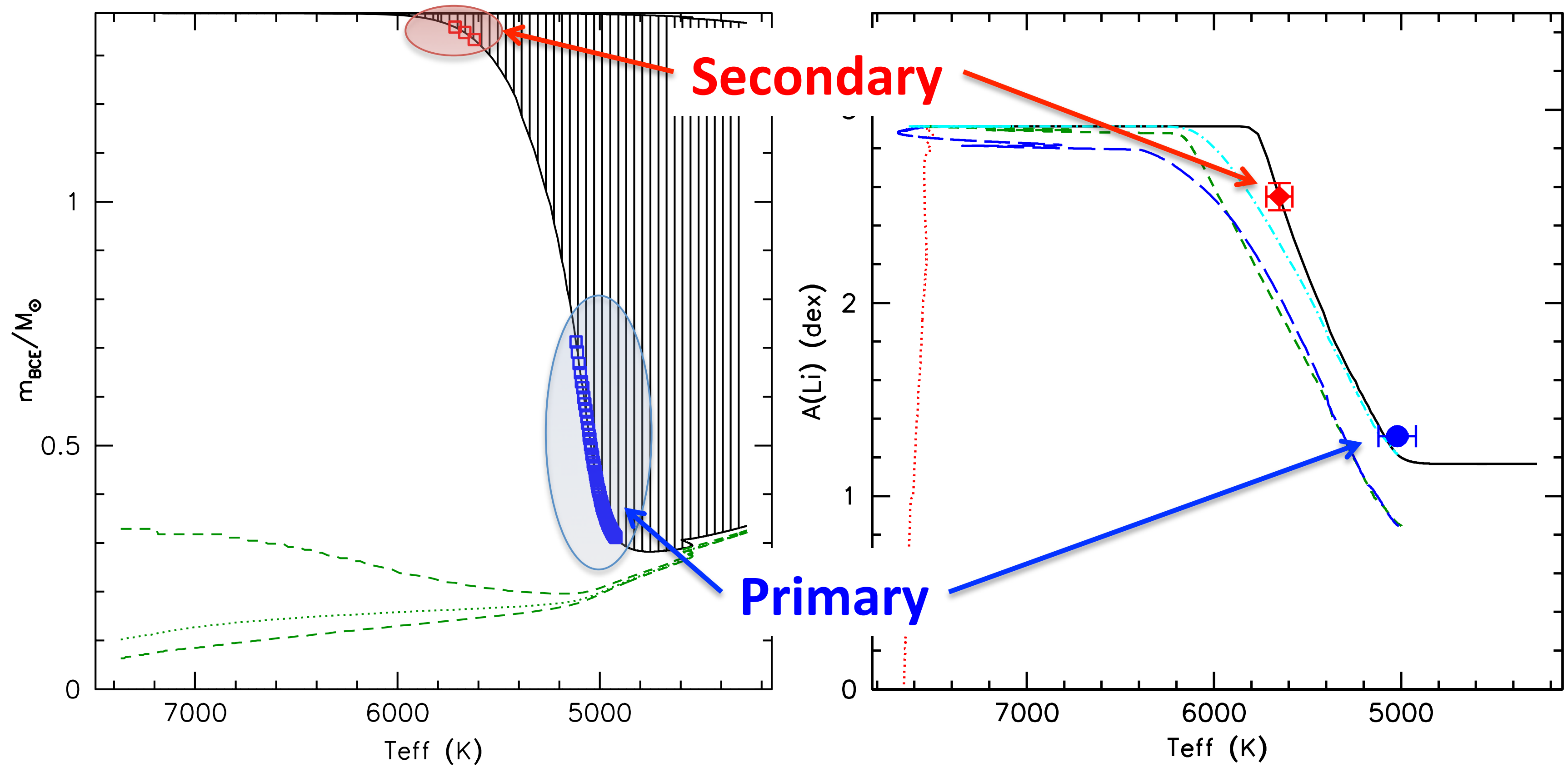


Modelling constraints

- Very well constrained primary
- Both stars have same
  - Age
  - Initial metallicity
  - Distance
- The only (main) difference is the mass

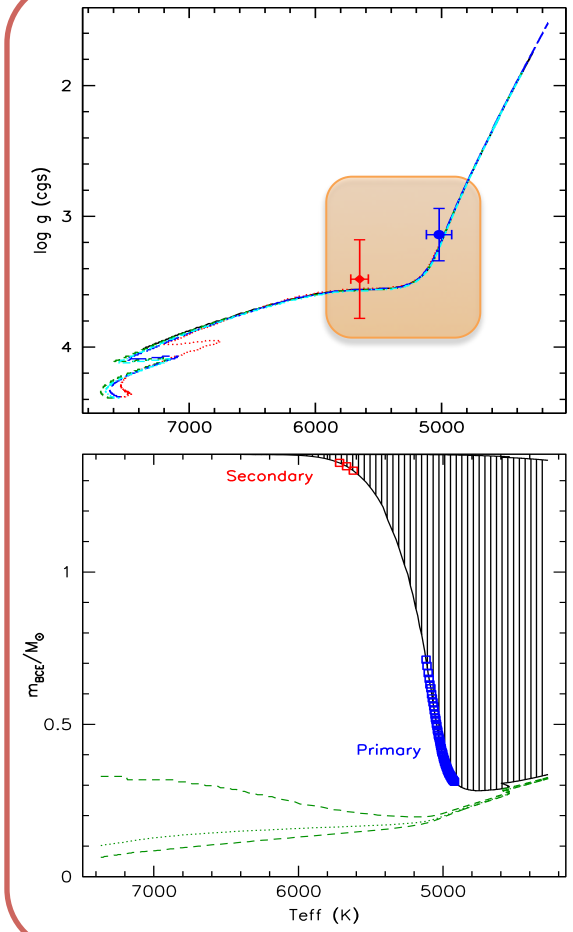
Result for a model from a mass grid around the mass from SR, calculated with with STAREVOL

Kippenhahn & Lithium



Result for a model from a mass grid around the mass from SR, calculated with with STAREVOL
Collaboration with Stephane Mathis & Ana Palacios

Summary



- KIC9163796: eccentric, double-lined and seismic binary.
- Challenging analysis & big rewards, more to come
- Secondary Oscilllations could be caught : TESS & Plato
- **Evolutionary state: framing the dredge-up event**
- **Rotation:**
  - Surface rotation not synchronized,
  - flat gradient (7 times)
  - Quasi-rigid rotation in envelope
- **Lithium:**
  - Difference of 1.2 dex
  - Is compatible with rigid rotation history

This binary in a striking example of how strong ~1% of difference in mass effects the stellar evolution

Oscillating double-lined binaries as test cases for understanding Lithium surface abundancy

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