The first low-mass, pre-main sequence eclipsing binary with evidence of a circumbinary disk

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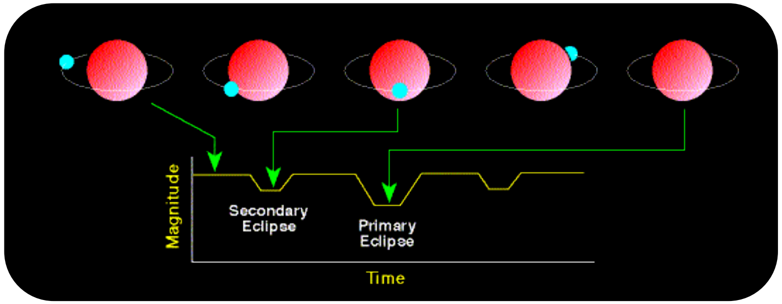
10th July 2014

CoRoT3 - KASC7: The Space Photometry Revolution

Credit: NASA

Eclipsing Binaries – why are they important?



Credit: cartage.org

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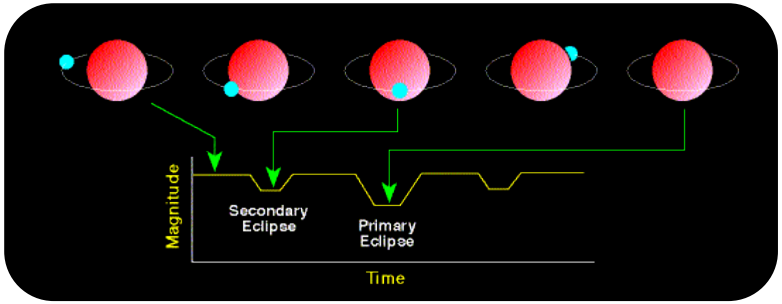

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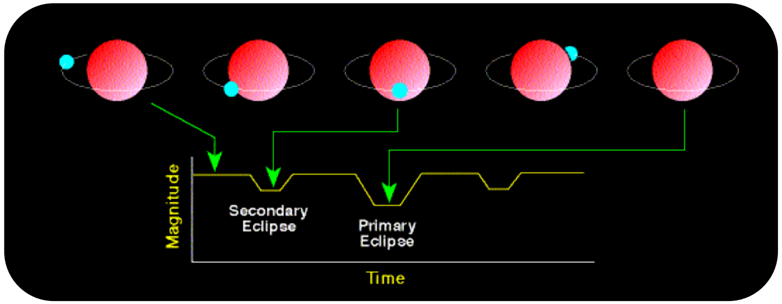

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  - From photometry and spectroscopy:
    - Masses
    - Radii
    - Luminosities

    + coevality and shared metallicity

    - **Constrain models of stellar evolution**

      (e.g. Andersen 1991; Torres et al. 2010)

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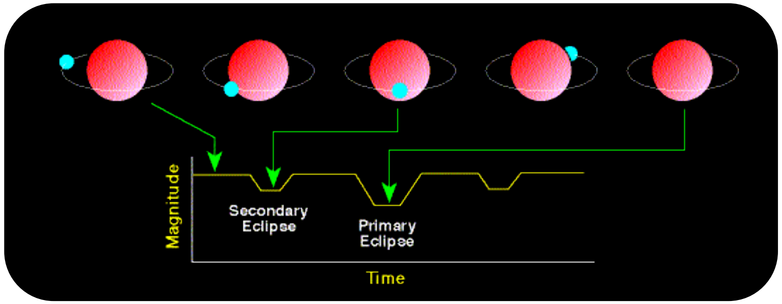

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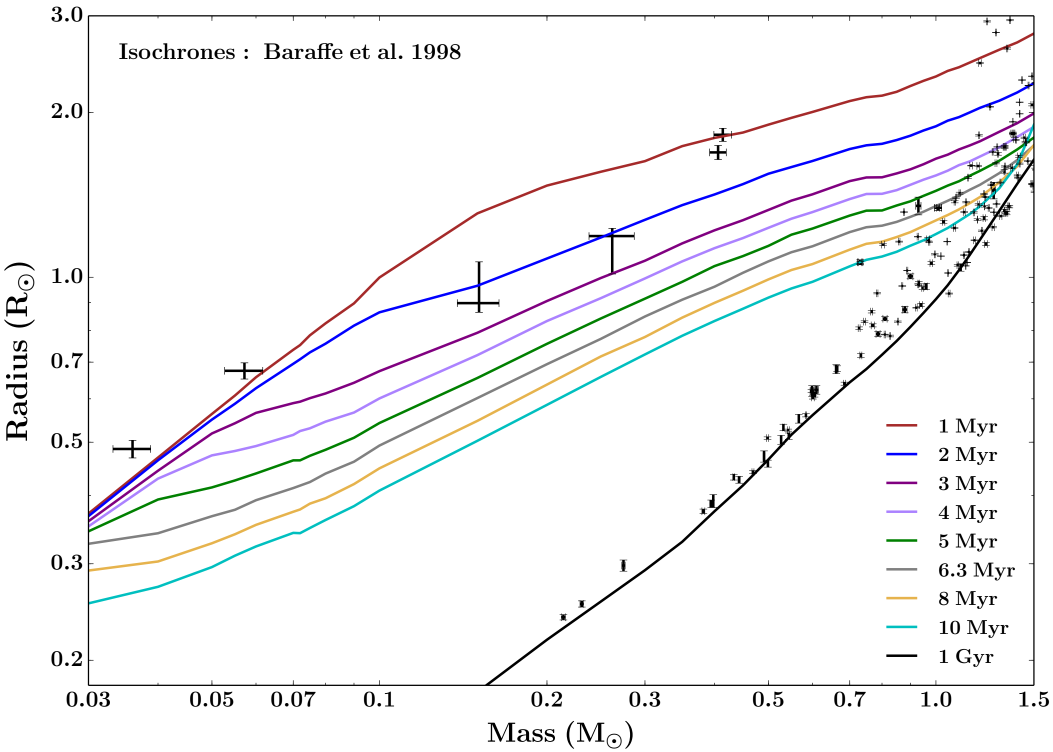

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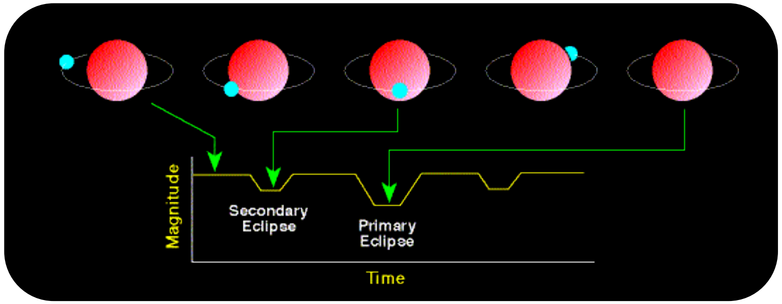

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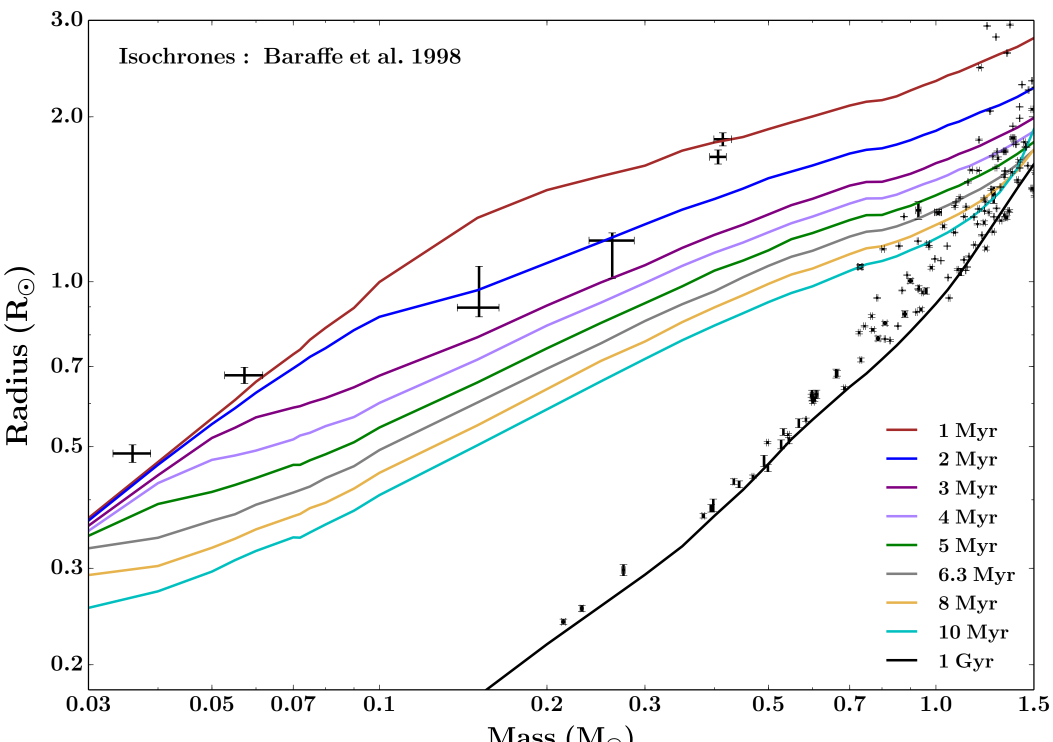

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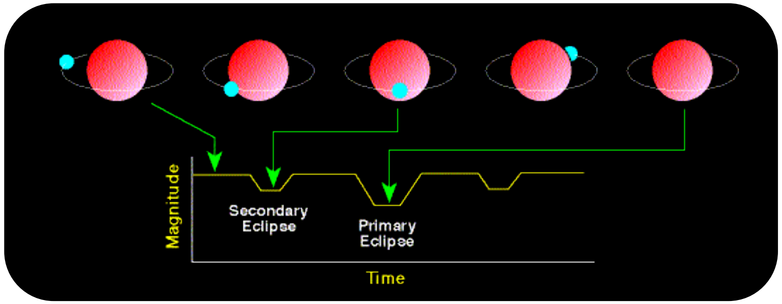

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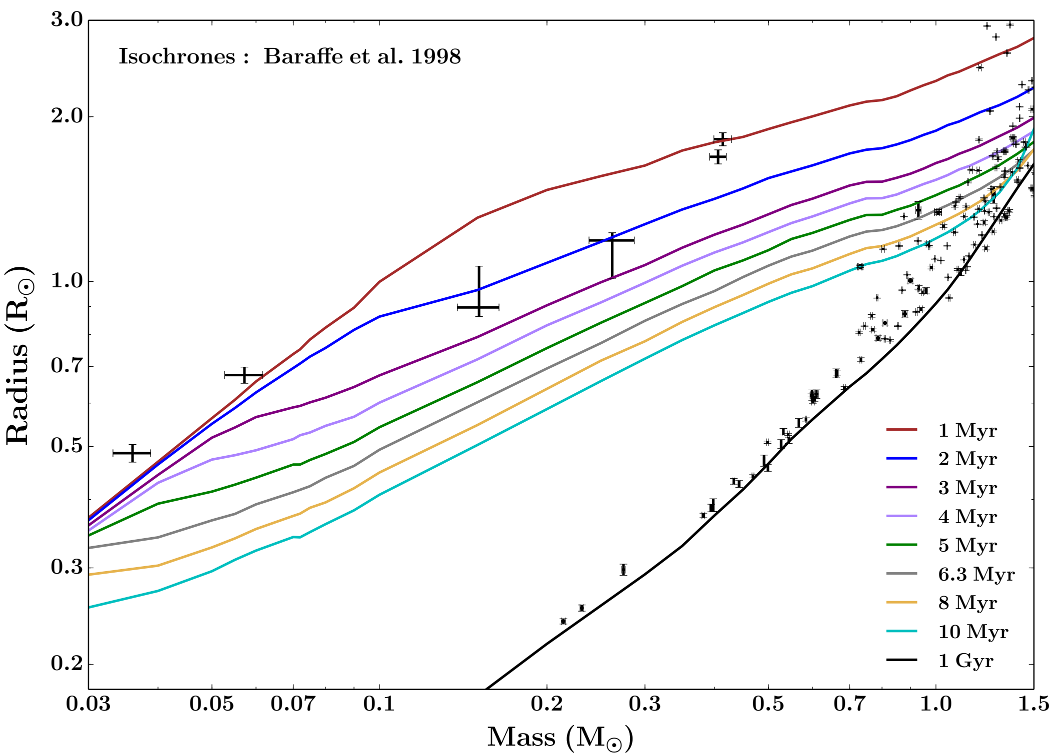

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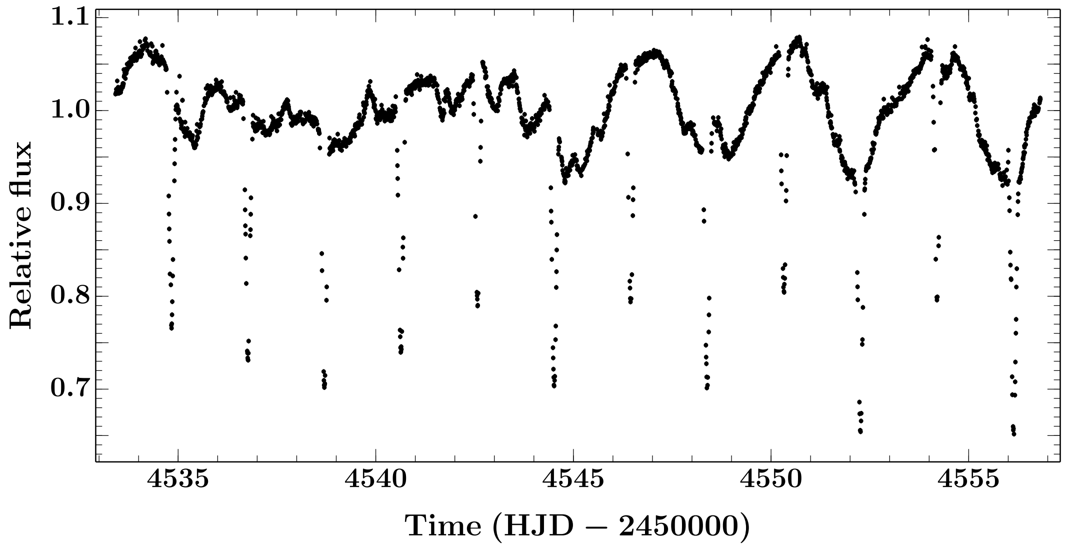
  - Desire for a set of coeval PMS EBs
    - led CoRoT to observe NGC 2264 (3 Myr)

The 2008 light curve



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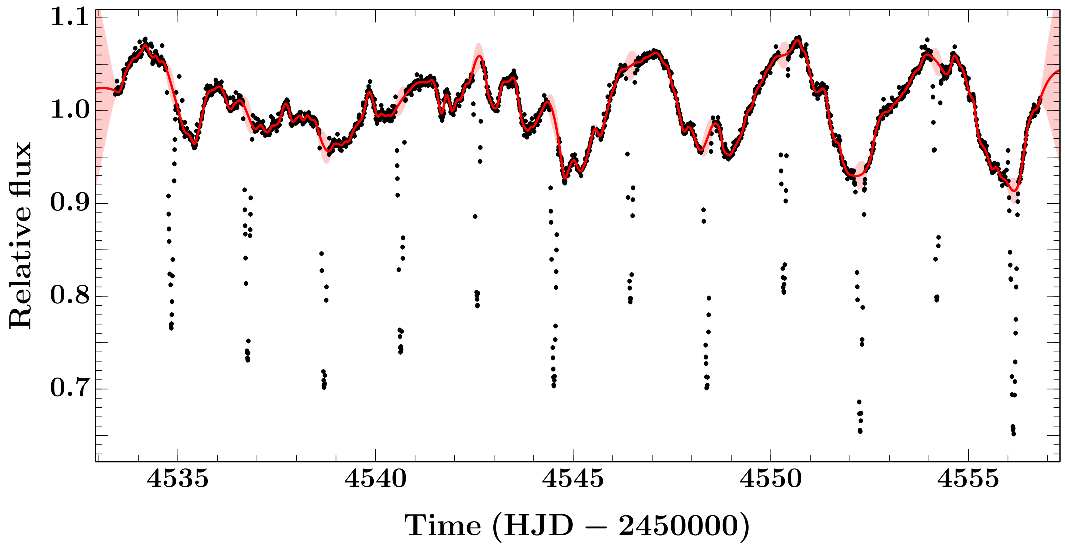

- Gaussian Process (GP)
  - model the LC by parameterising the covariance between flux measurements

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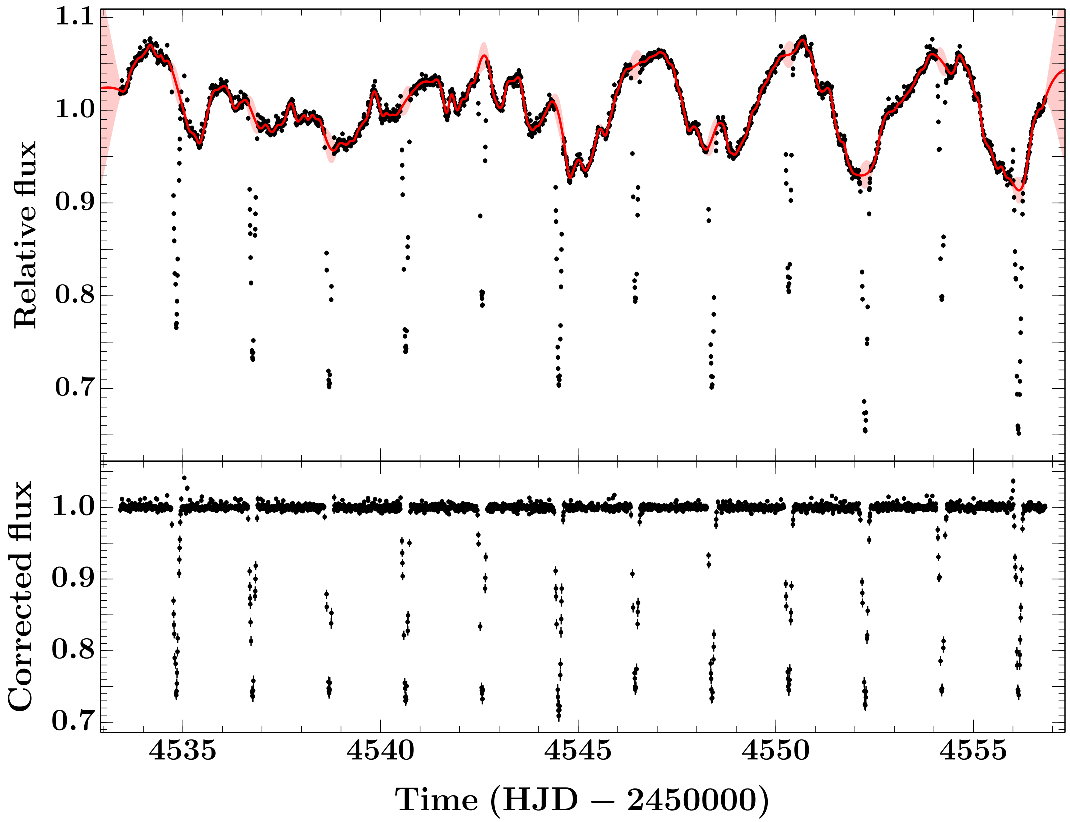

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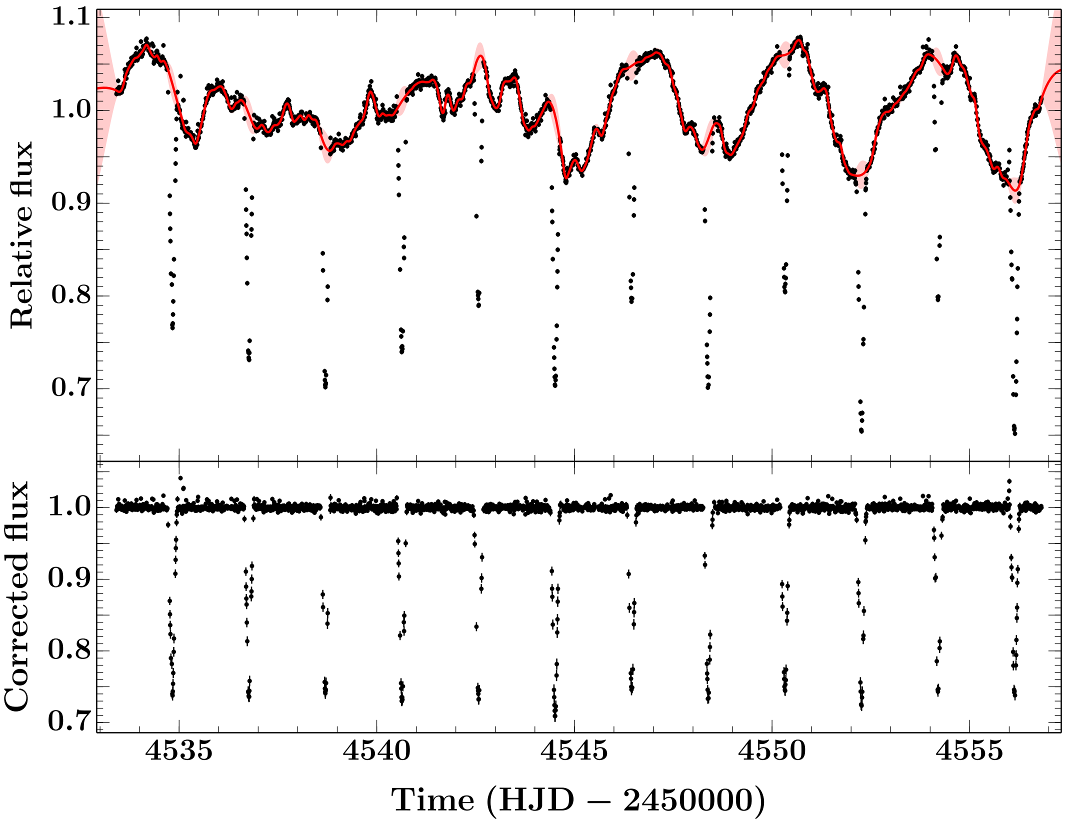

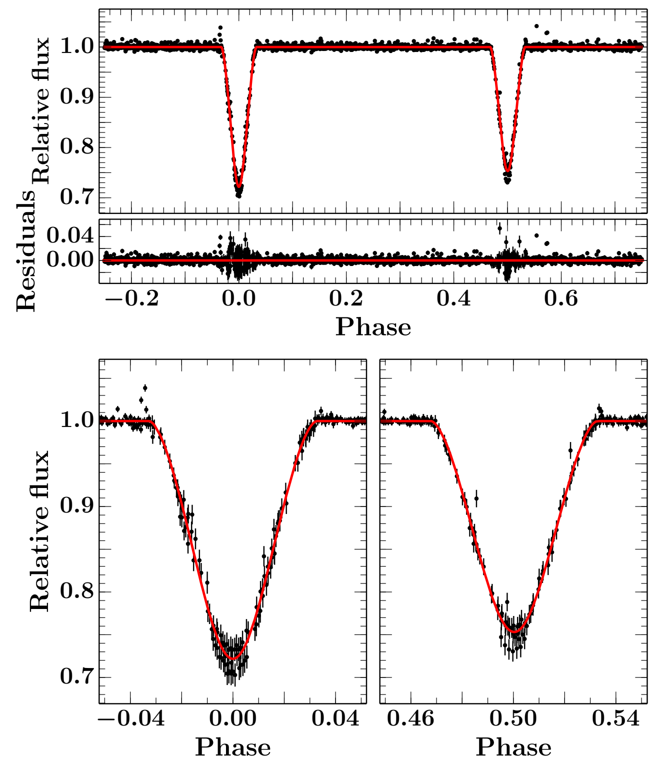

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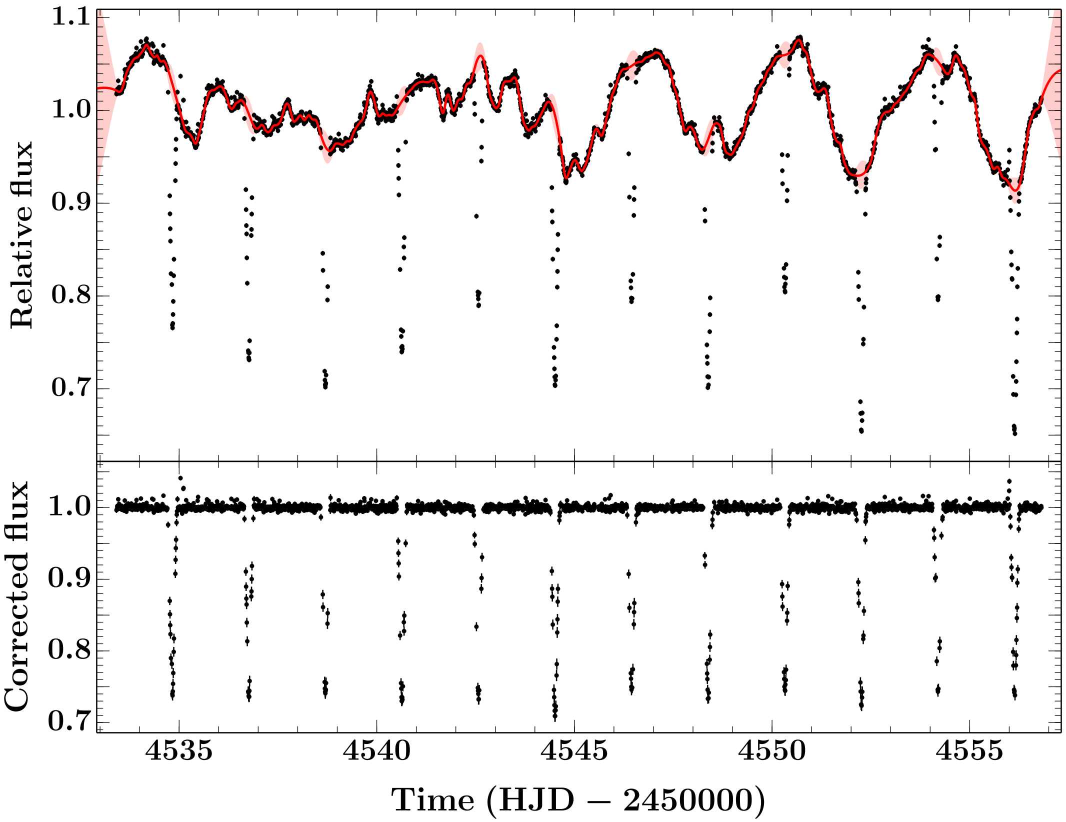

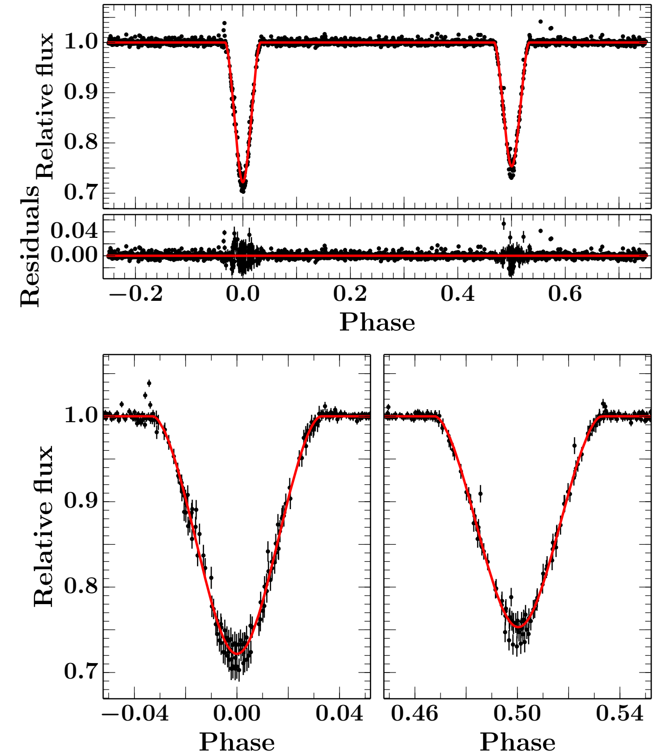

Parameter	Value
SB_{sec}/SB_{pri}	$0.871^{+0.037}_{-0.035}$
$(R_{pri}+R_{sec})/a$	$0.2198^{+0.0017}_{-0.0018}$
R_{sec}/R_{pri}	$0.854^{+0.058}_{-0.061}$
i (°)	$85.09\ ^{+0.16}_{-0.11}$
P (days)	3.8745746 ± 0.0000014
$e\cos\omega$	$0.00050^{+0.00029}_{-0.00028}$
$e\sin\omega$	$-0.0049^{+0.0077}_{-0.0075}$

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Instrument	Resolution	λ range (Å)	No. of spectra
Spectral Type			
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RVs			
VLT / FLAMES	R $\sim$ 17 000	$\sim$6440 – 6820	15
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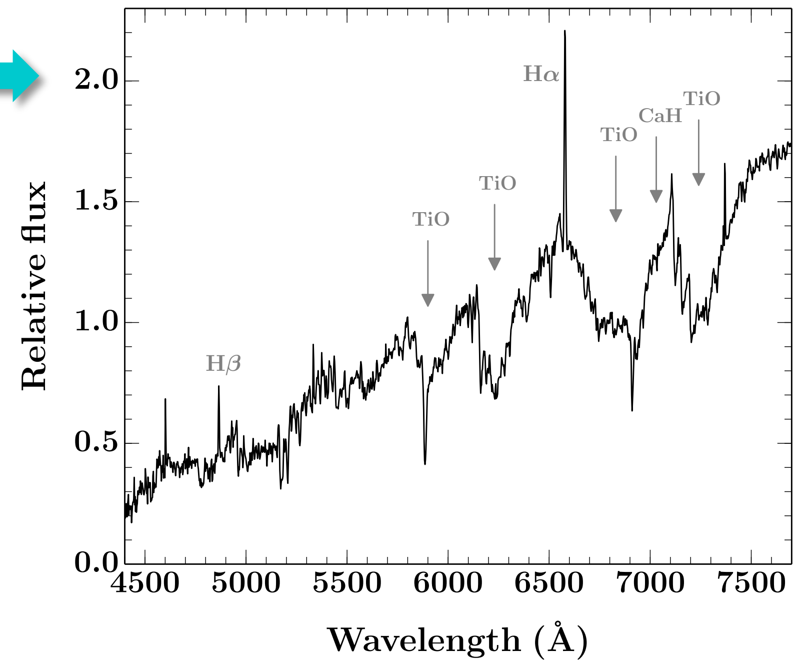

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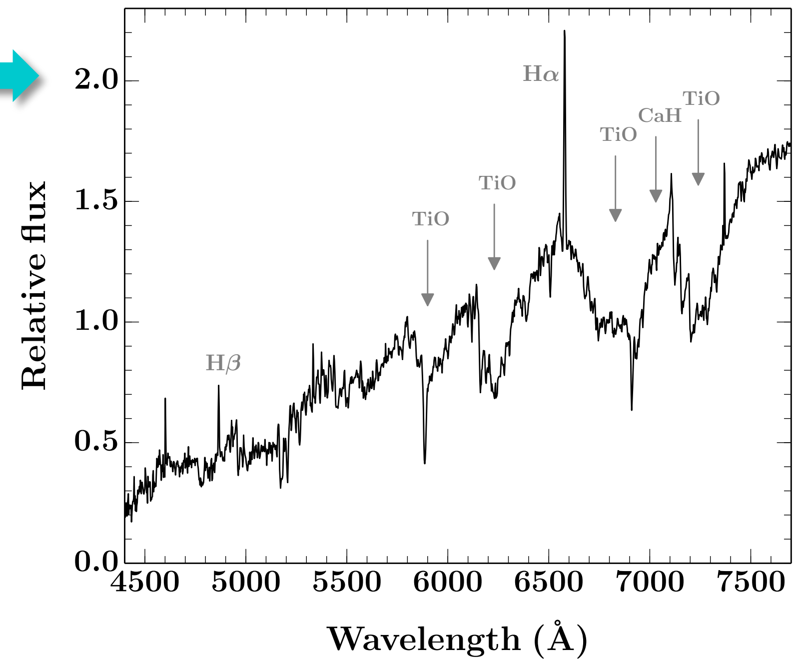

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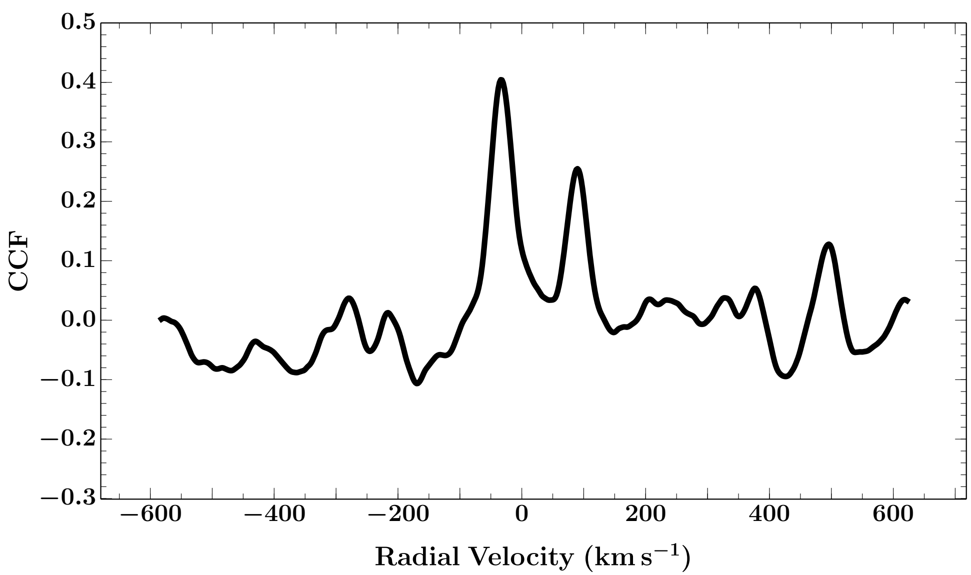

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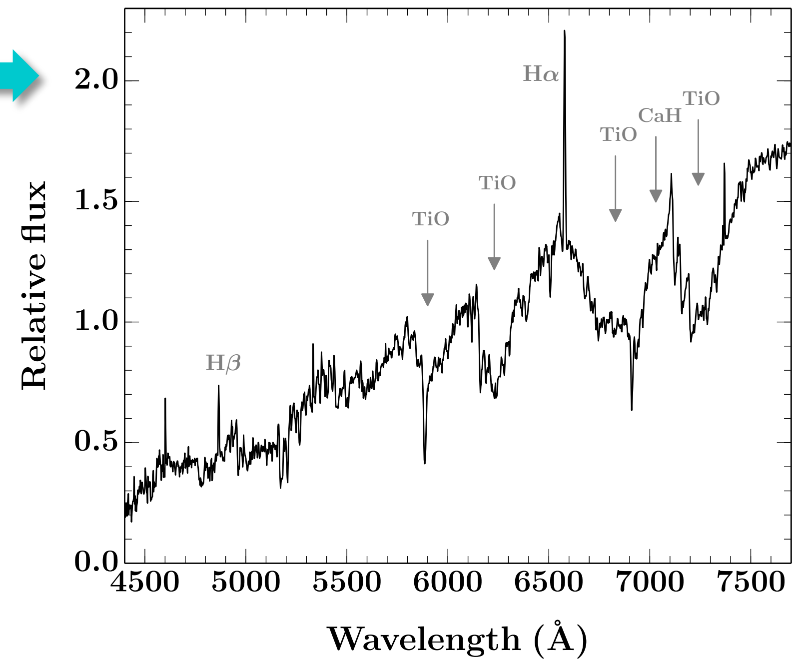

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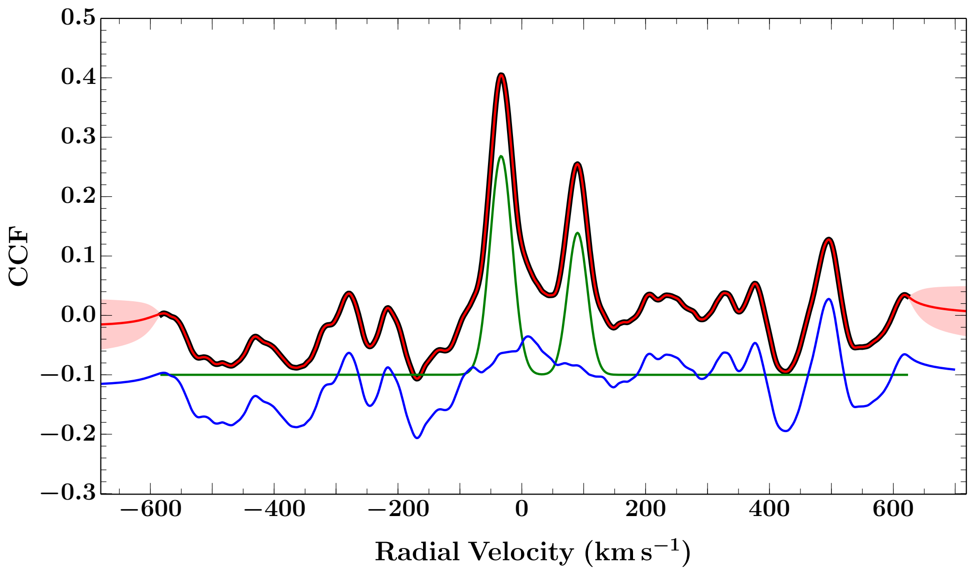


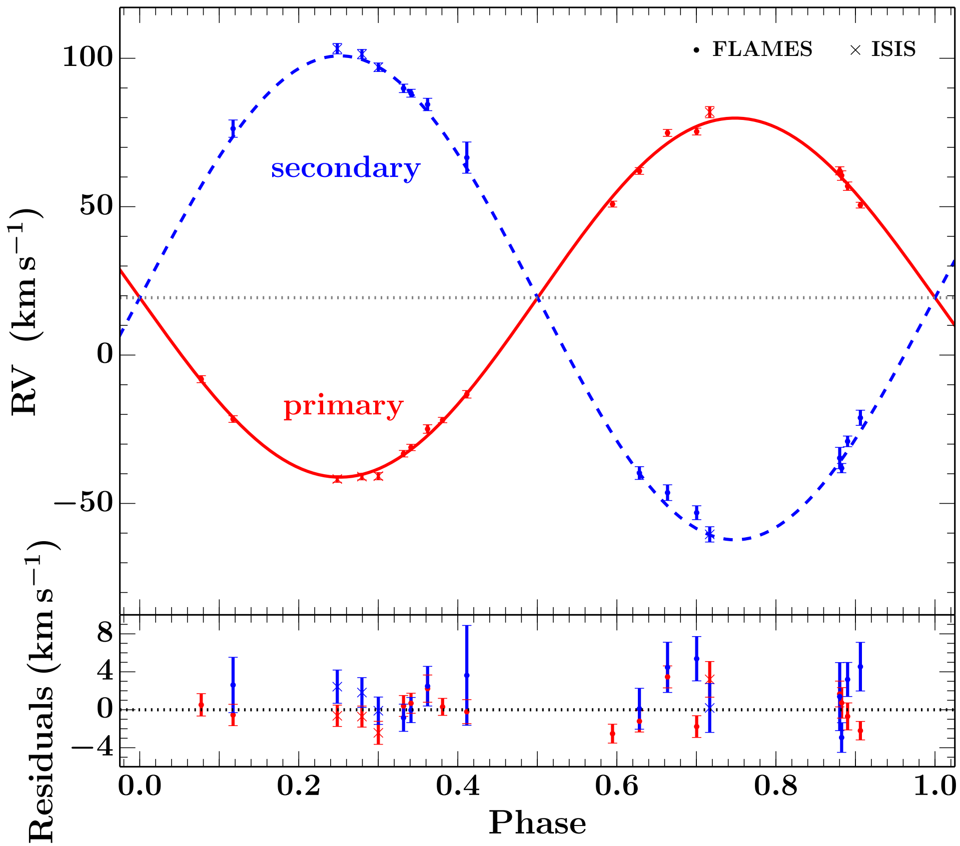
- CCF modelled as:

  2 Gaussians

  +

  stochastic noise (GP)

Radial Velocities



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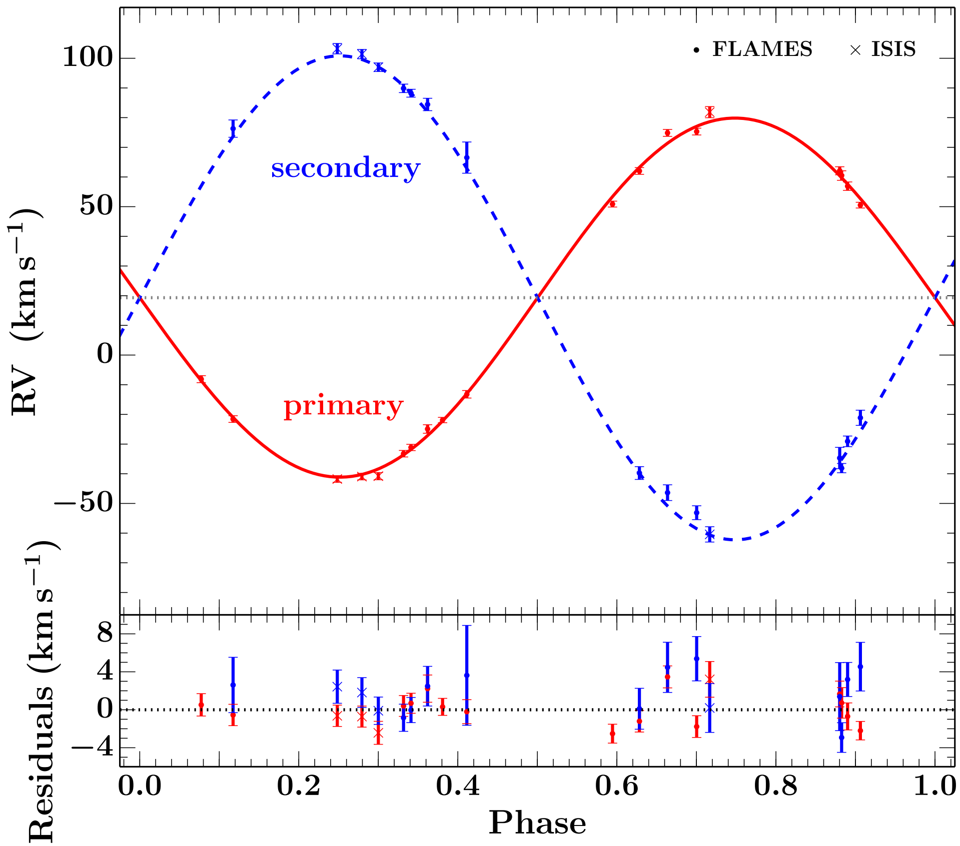

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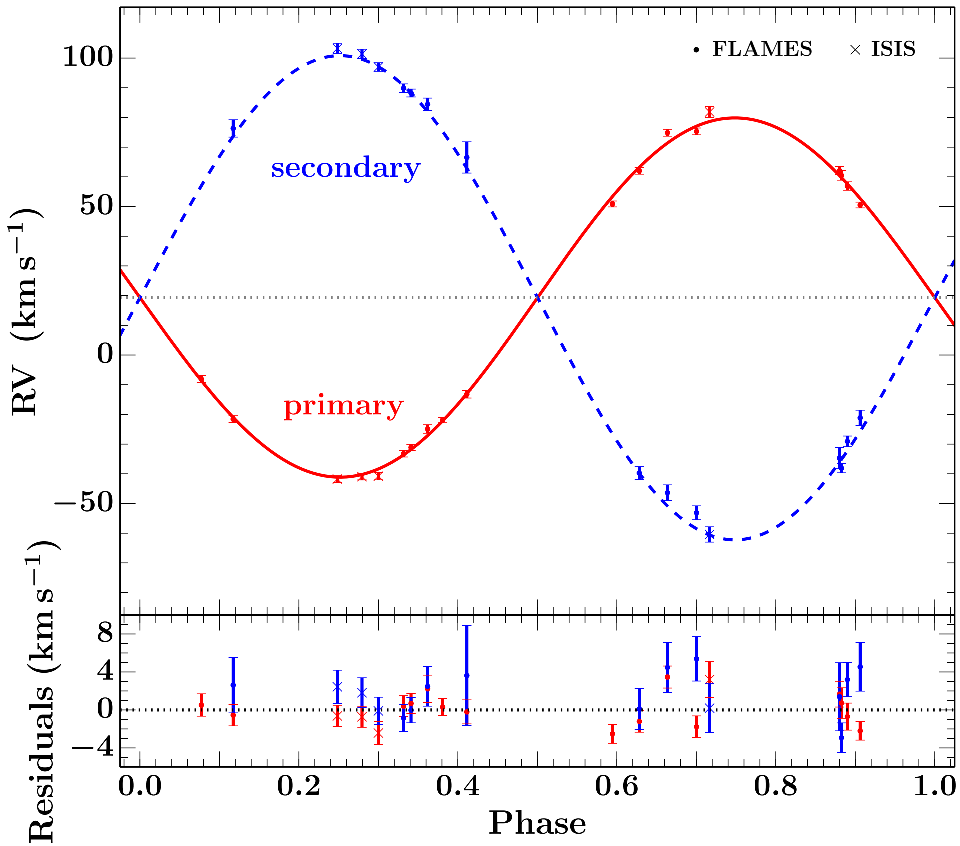

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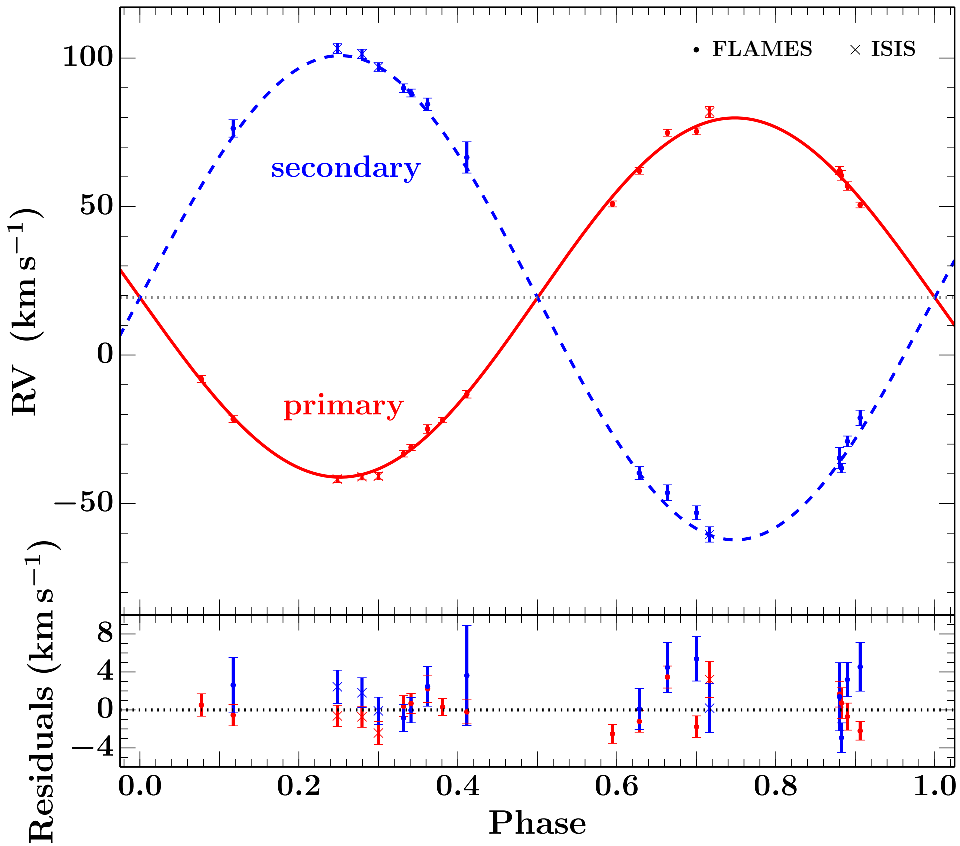

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Hα in emission

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Presence of lithium

- strong evidence for cluster membership

Deriving masses and radii

- Combining LC and RV information
  - RVs + i from LC:
    Mass and semi-major axis
  - Semi-major axis + LC info:
    Radii

Parameter	Primary	Secondary	
Mass	$0.668^{+0.012}_{-0.011}$	$0.4953^{+0.0073}_{-0.0072}$	$M_\odot$
Radius	$1.295^{+0.040}_{-0.037}$	$1.107^{+0.044}_{-0.050}$	$R_\odot$
Semi-major axis	10.921 ± 0.056		$R_\odot$

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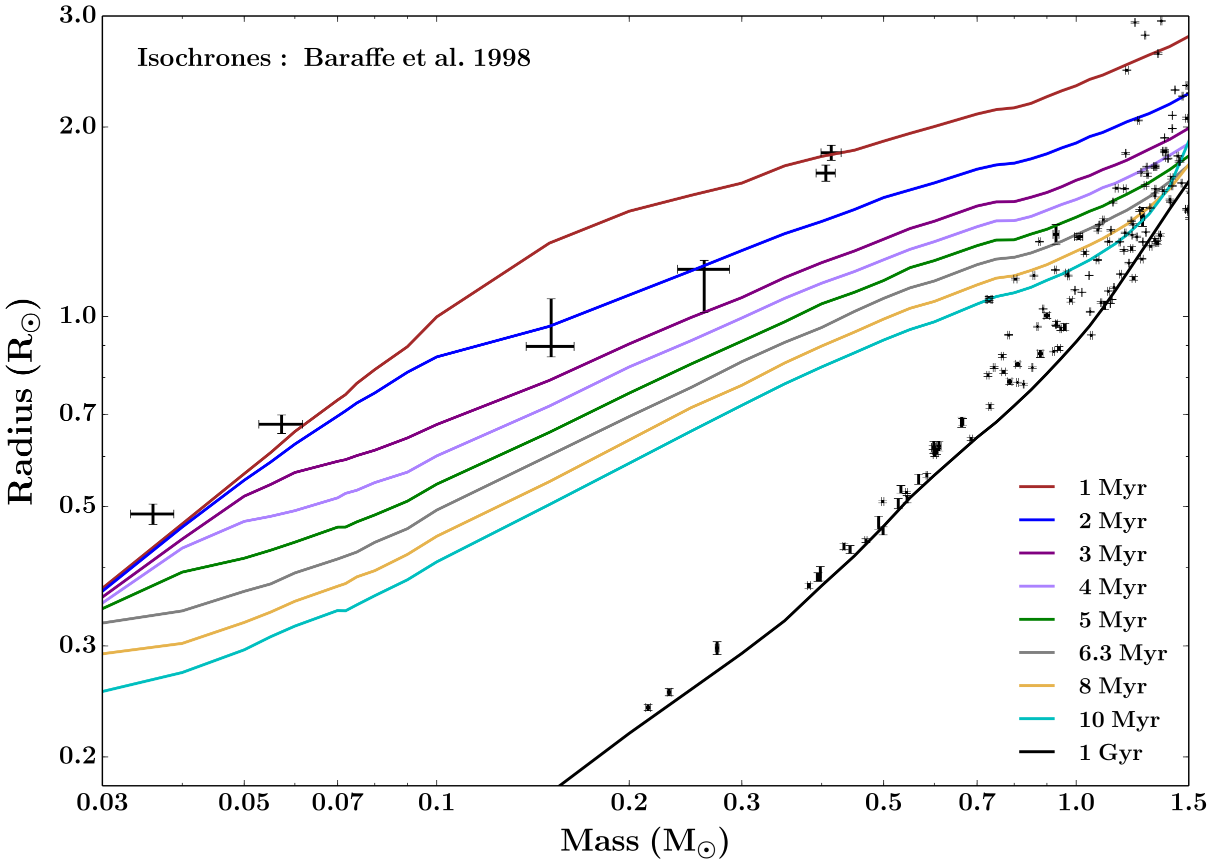

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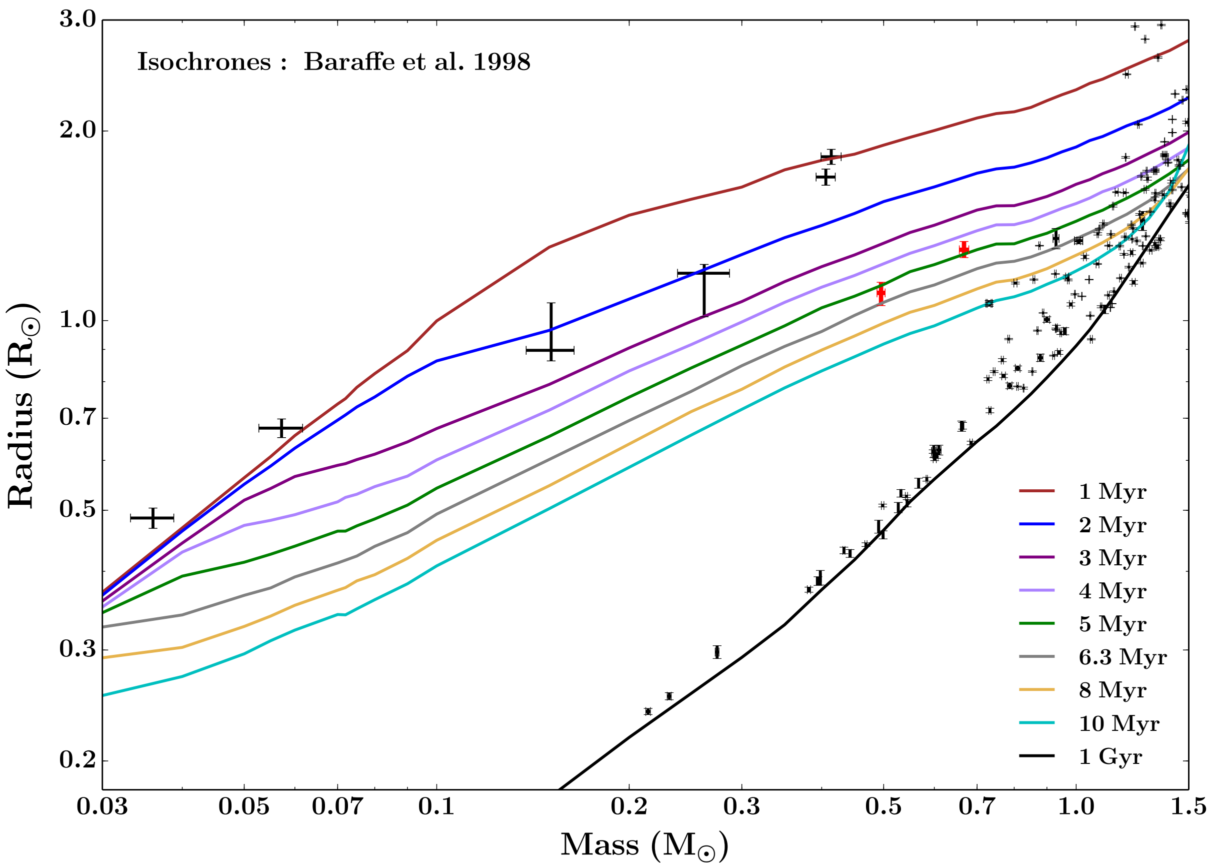
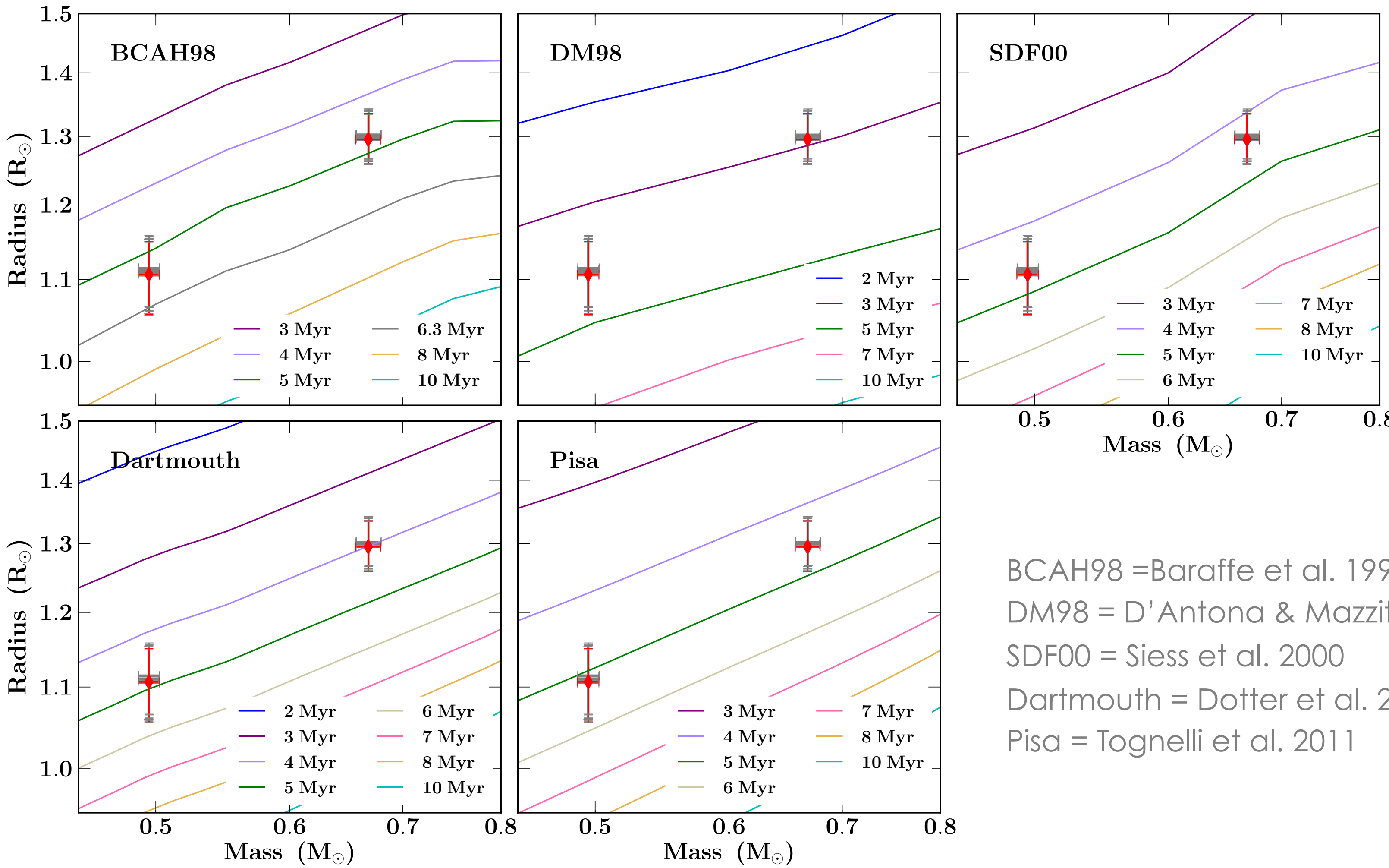


Comparing to different sets of isochrones



BCAH98 =Baraffe et al. 1998

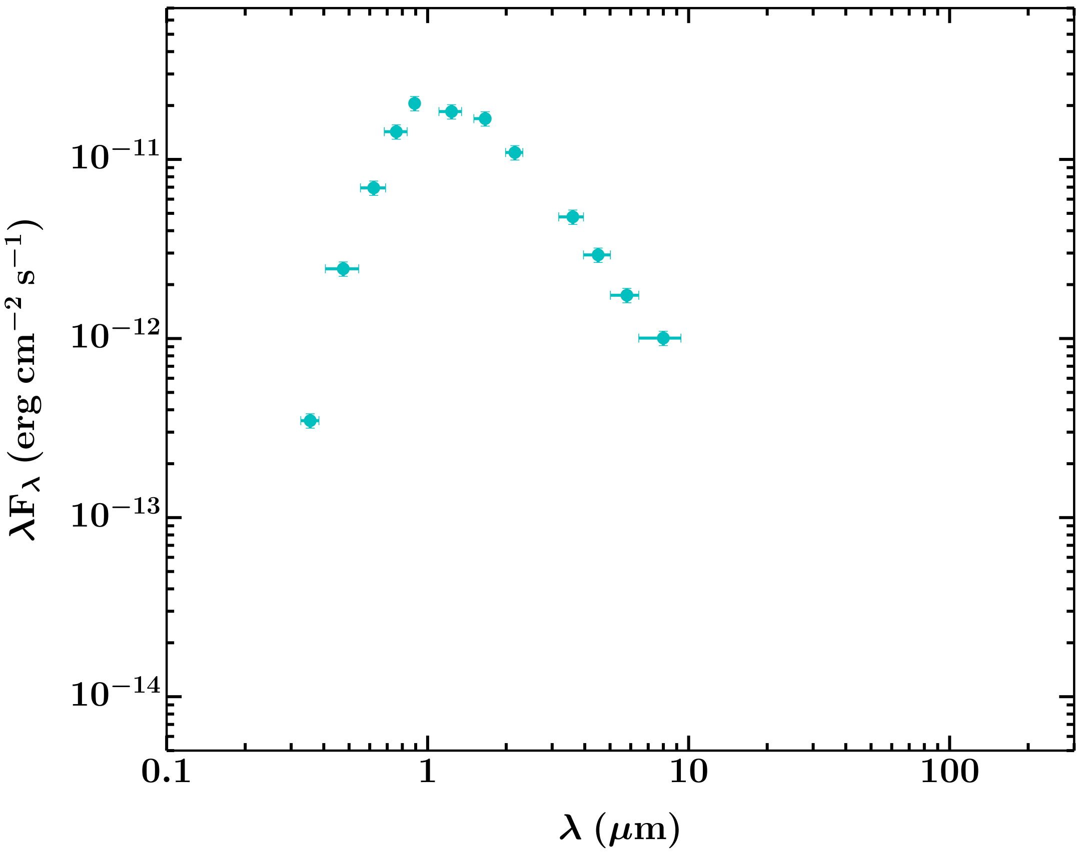
DM98 = D'Antona & Mazzitelli 1998

SDF00 = Siess et al. 2000

Dartmouth = Dotter et al. 2008

Pisa = Tognelli et al. 2011

The SED



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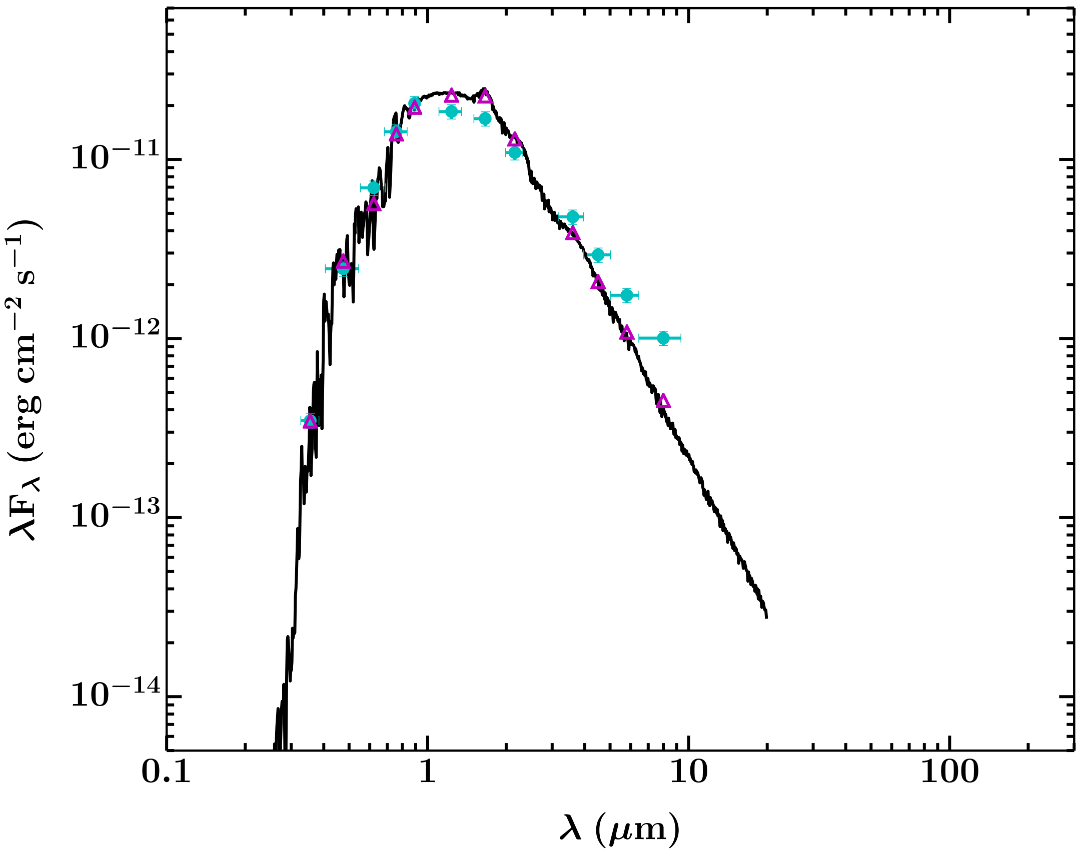

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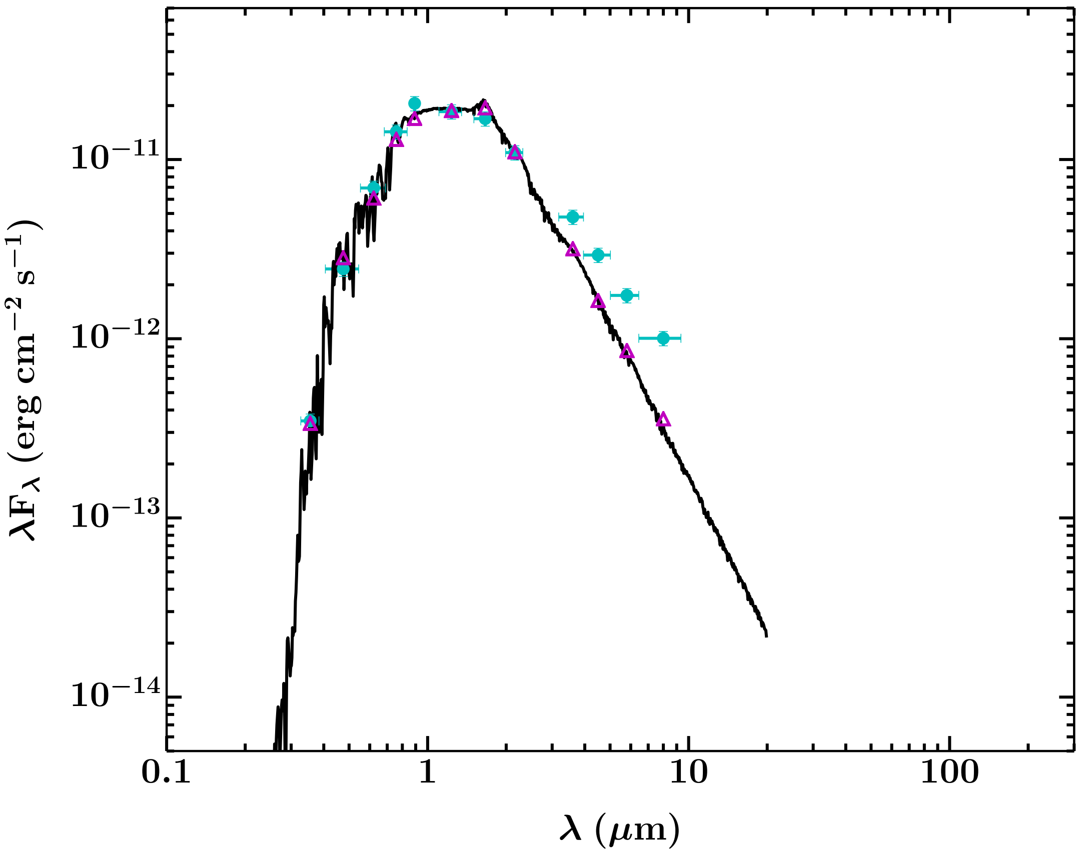

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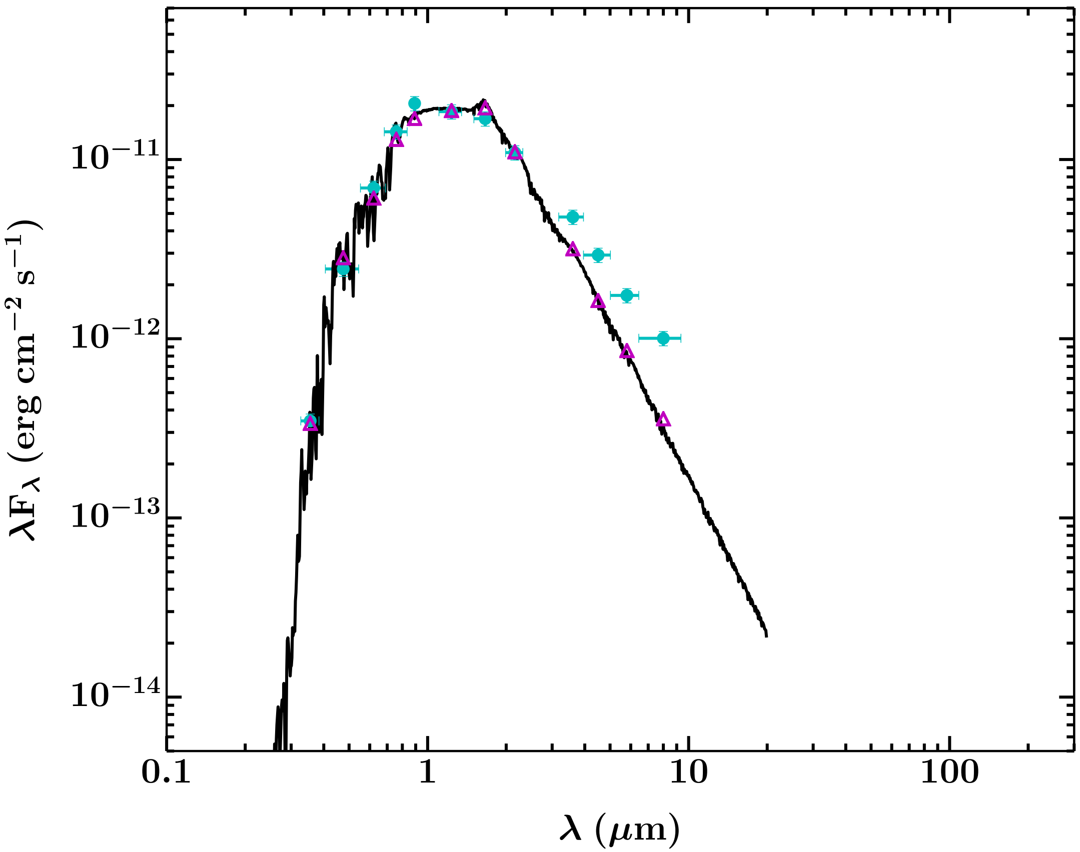

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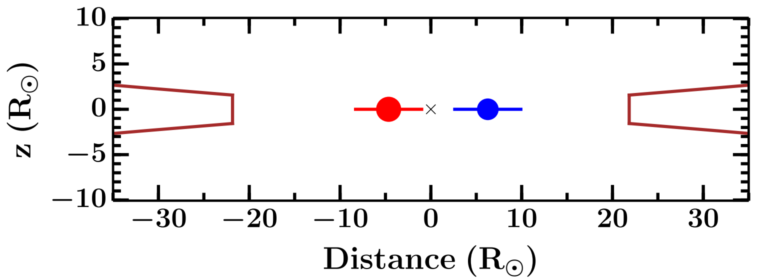

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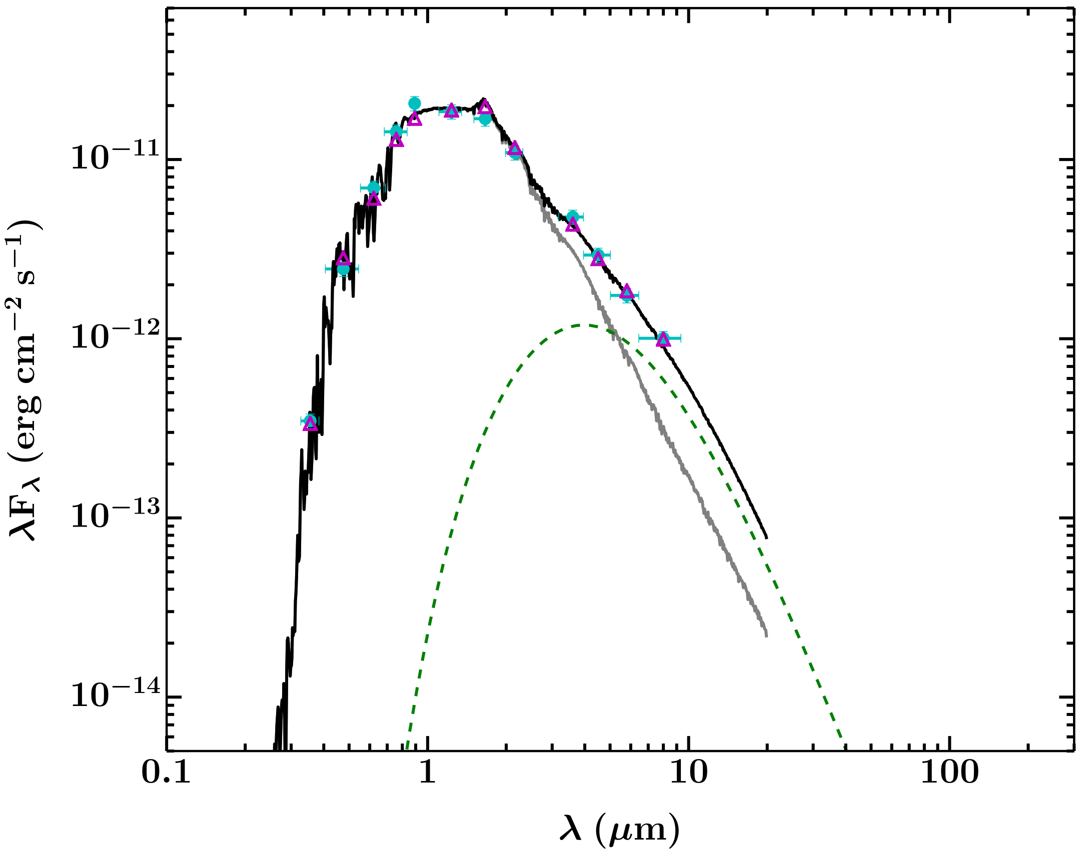

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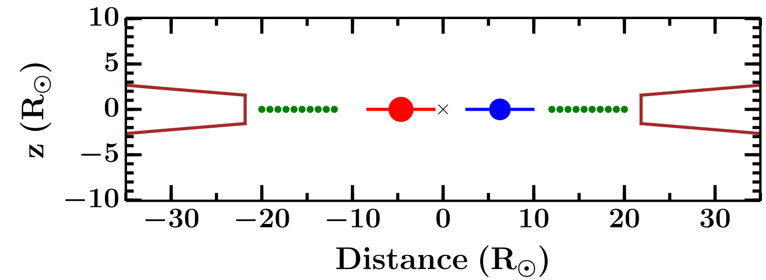

- Attribute excess to circum-binary material
  - Dust emission from the central cavity of a circumbinary disk

    (e.g. Jensen & Mathieu 1997)

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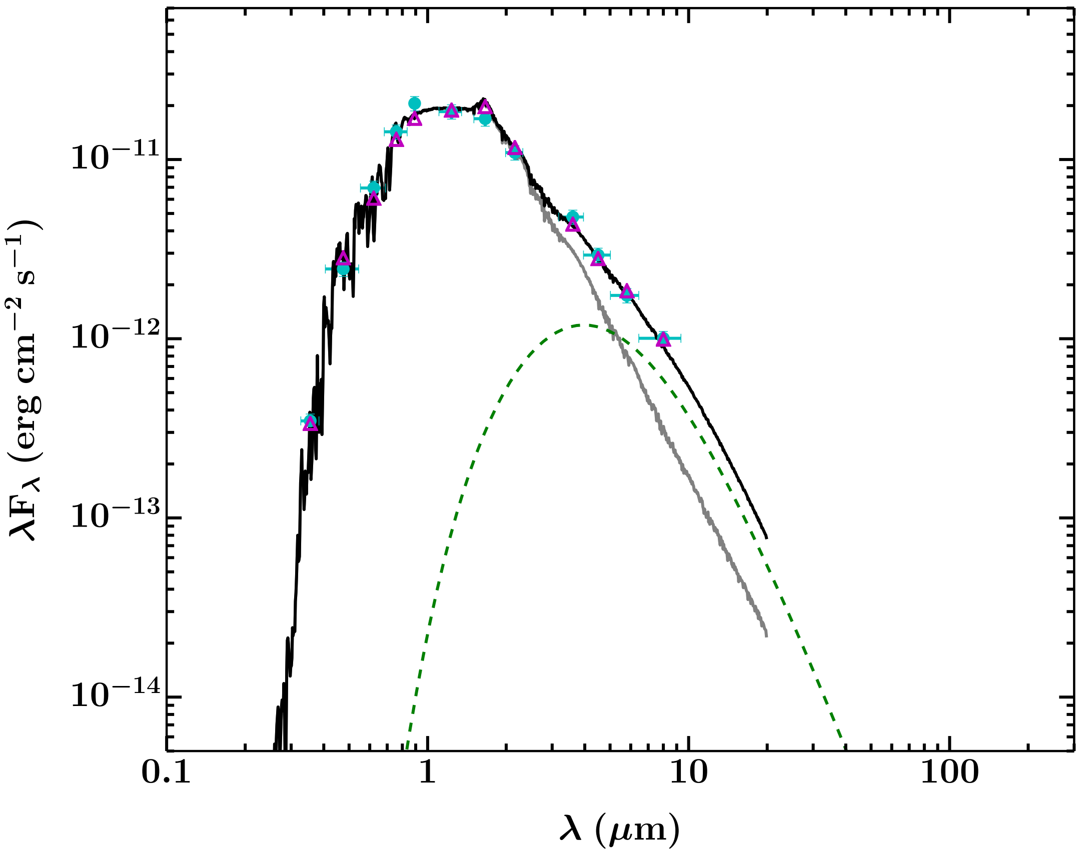

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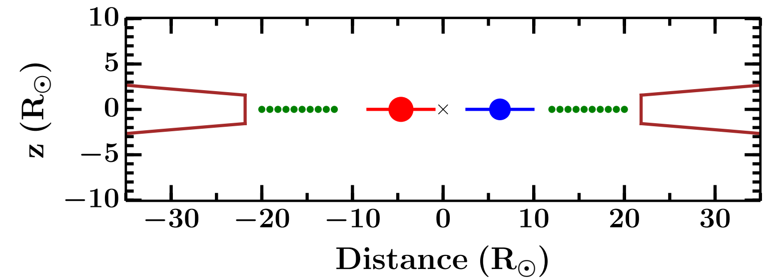

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  - 1×10^{-13} M$_\odot$
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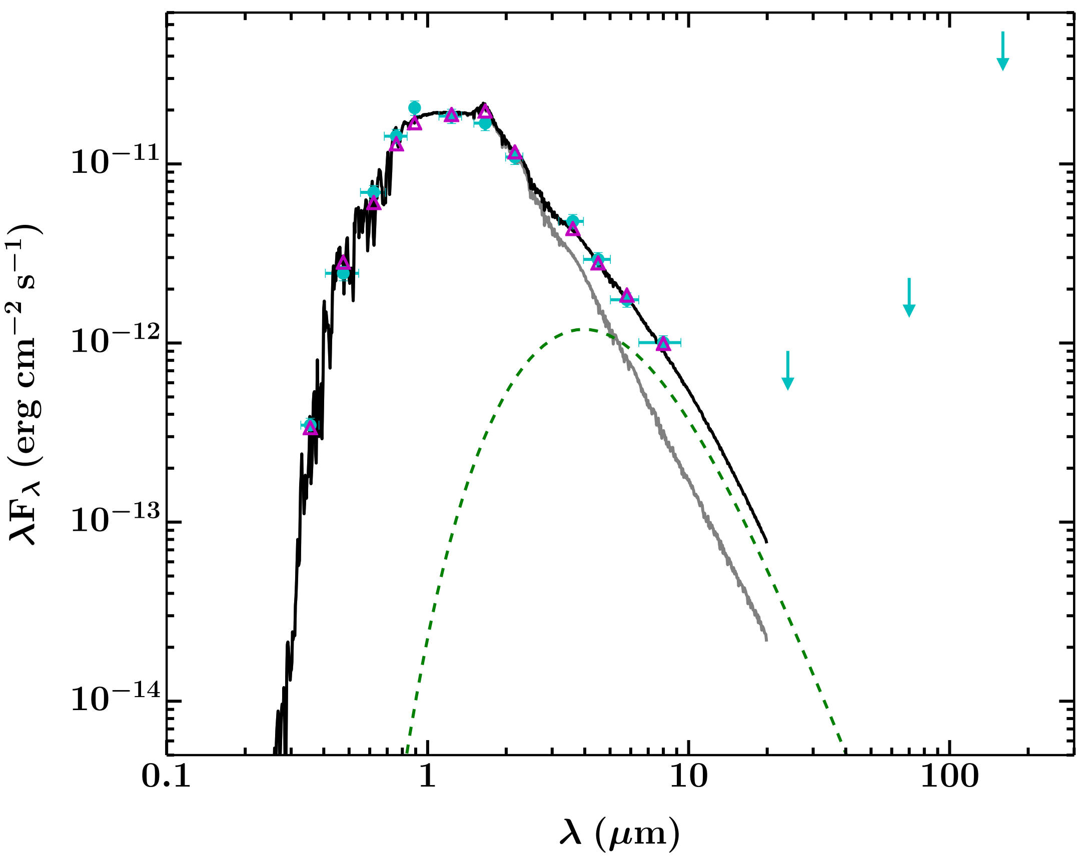

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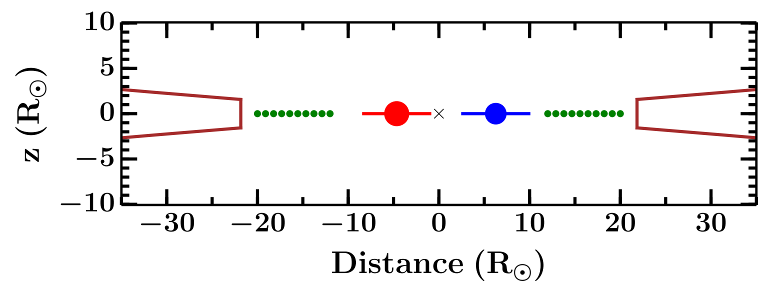

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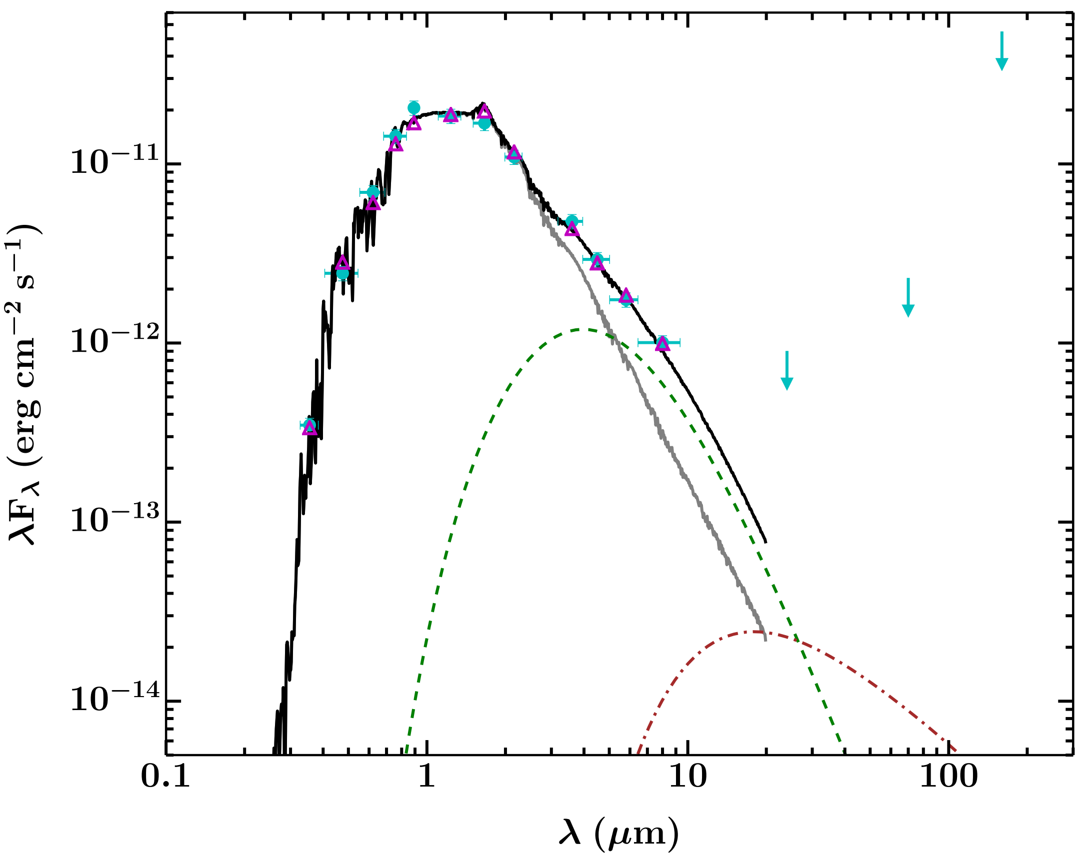

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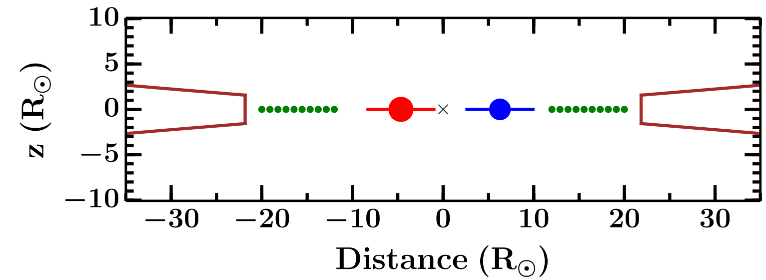

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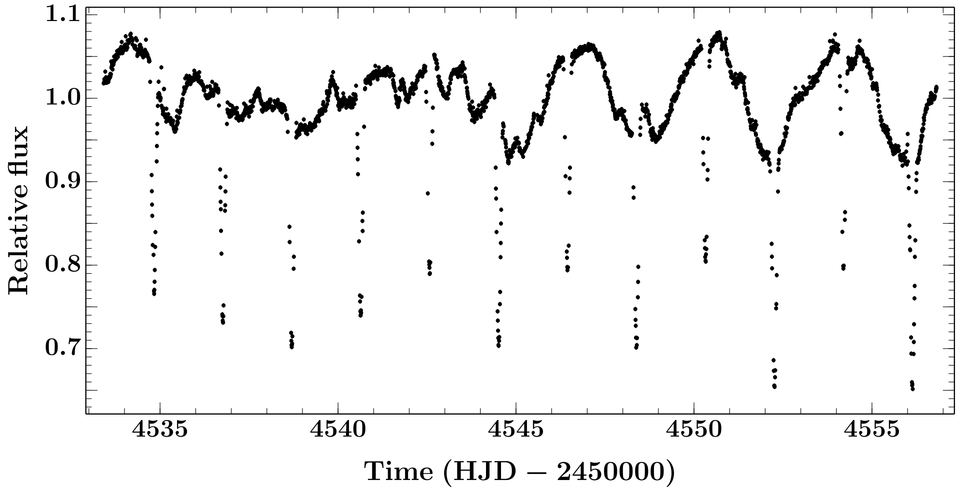
- Very low mass of dust required
  - 1 x 10^{-13} $M_\odot$
  - Accretion streams from a circumbinary disk?
    (e.g. Shi et al. 2012)

The 2008 light curve revisited



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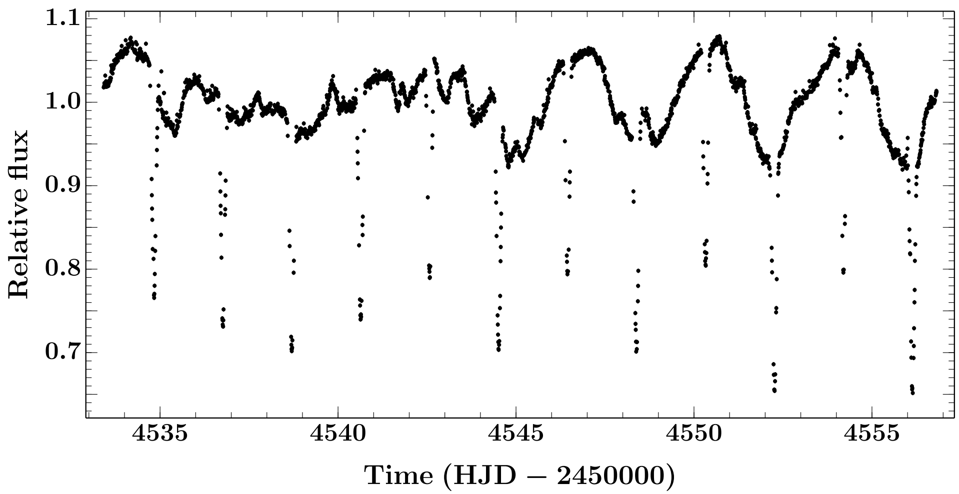

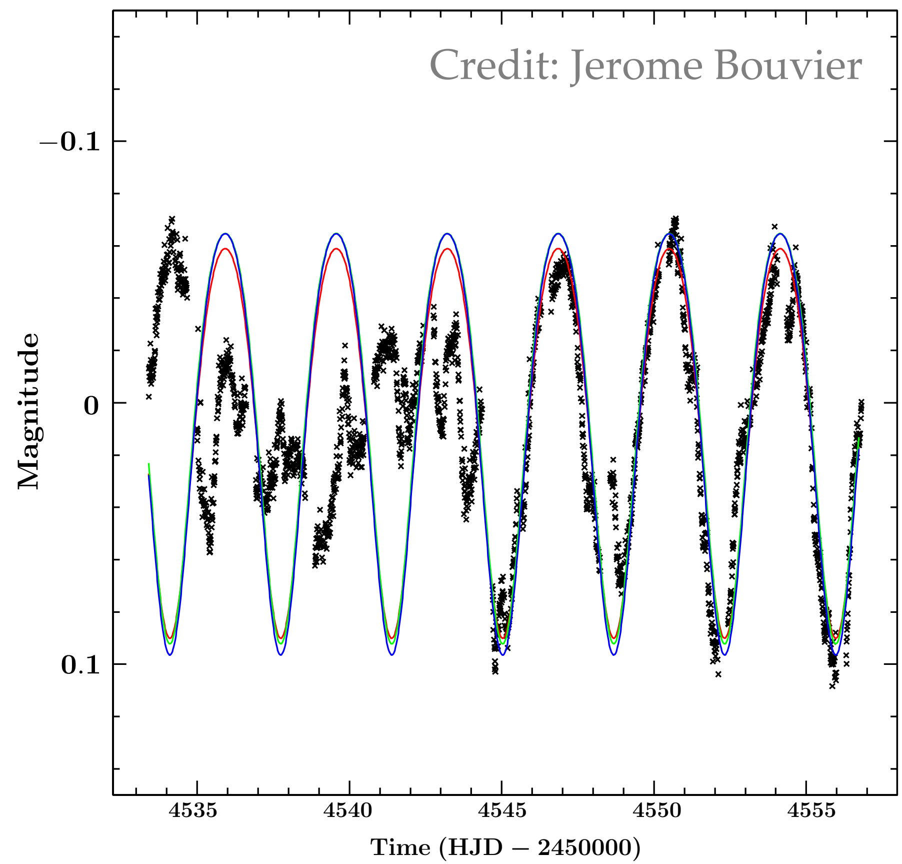

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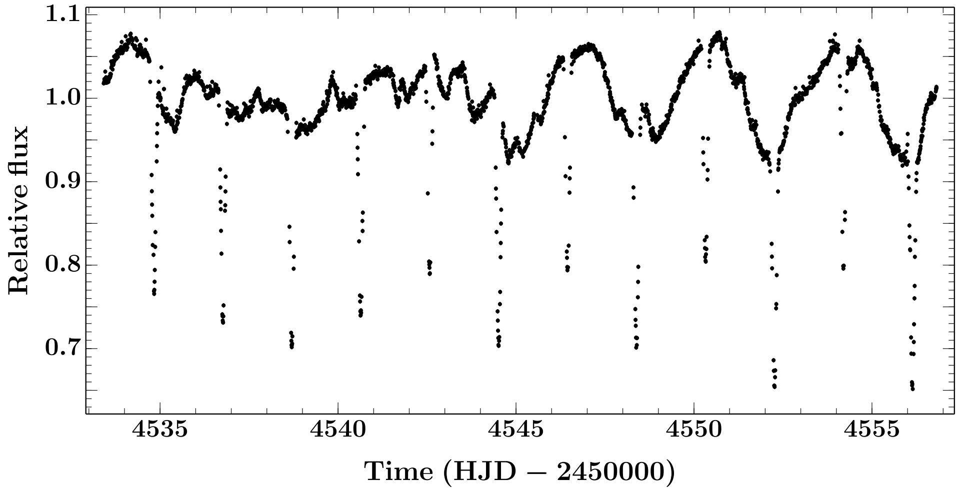

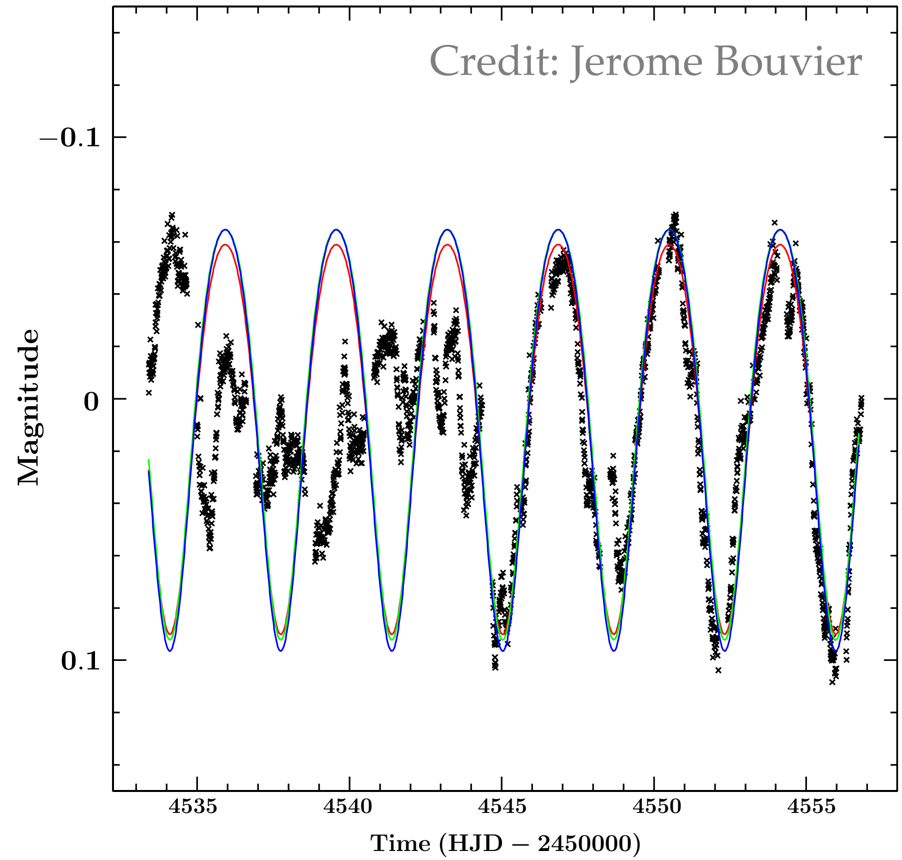

- Large spot on primary (~20% of stellar surface)
  - Can reproduce the large scale structure in 2nd half of LC

    BUT

    need rapid spot evolution

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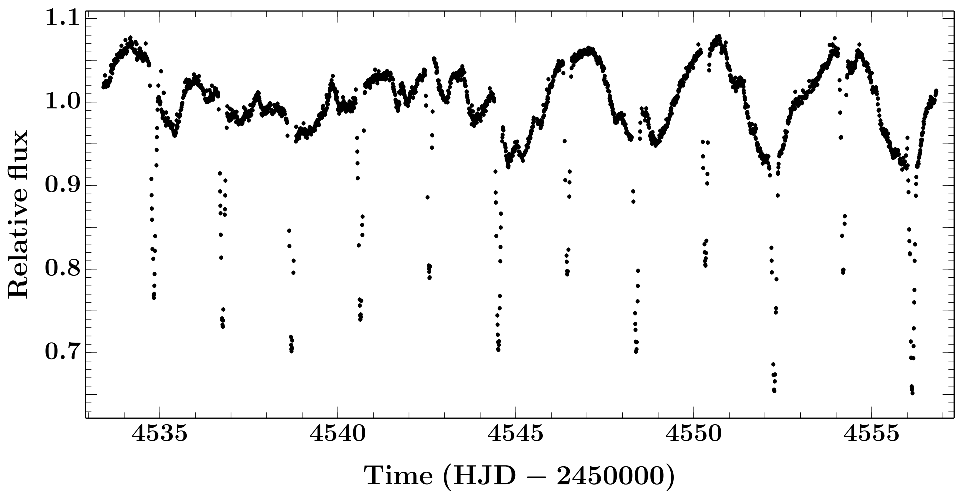

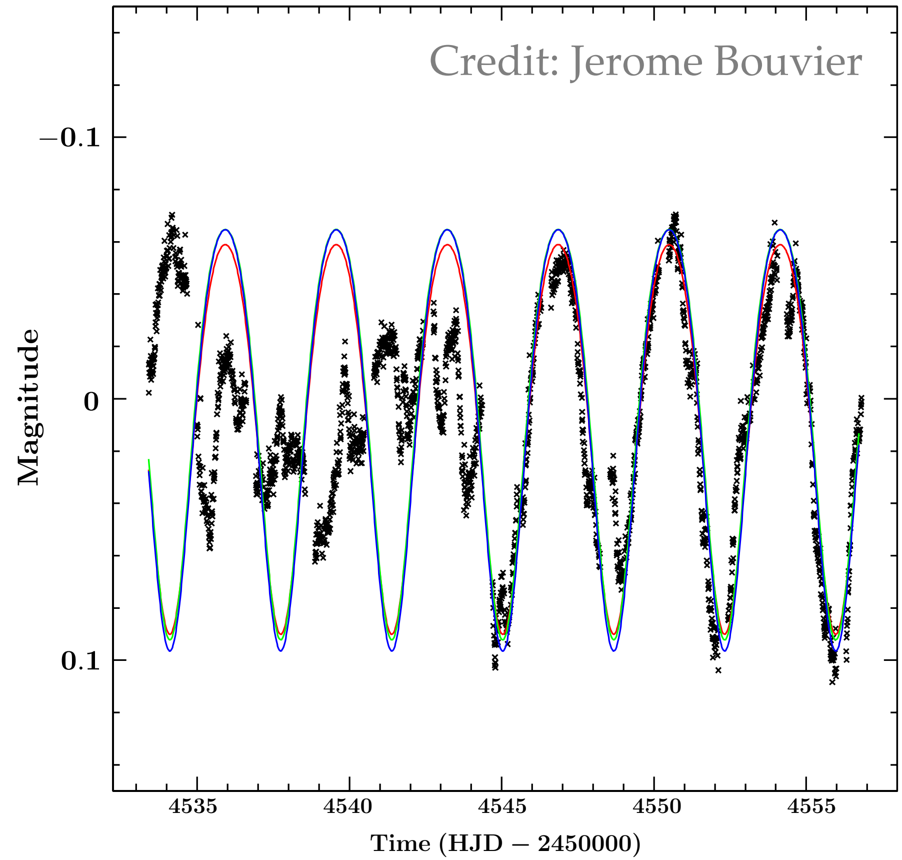

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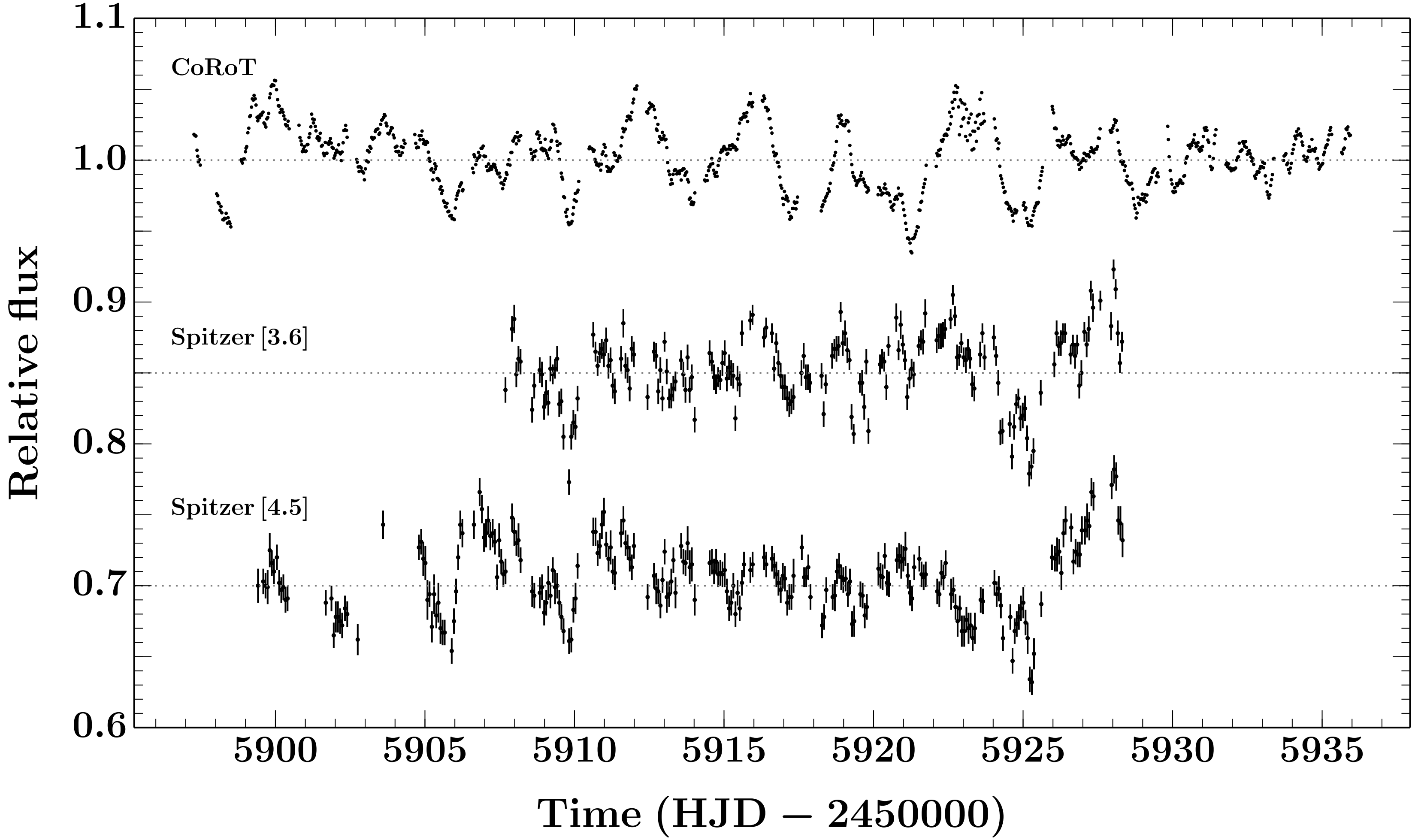
- Variability due to:
  - ➢ Occultation of star(s) by material at the inner edge, or in the central cavity, of the circumbinary disk???

The 2011/2012 OOE LCs



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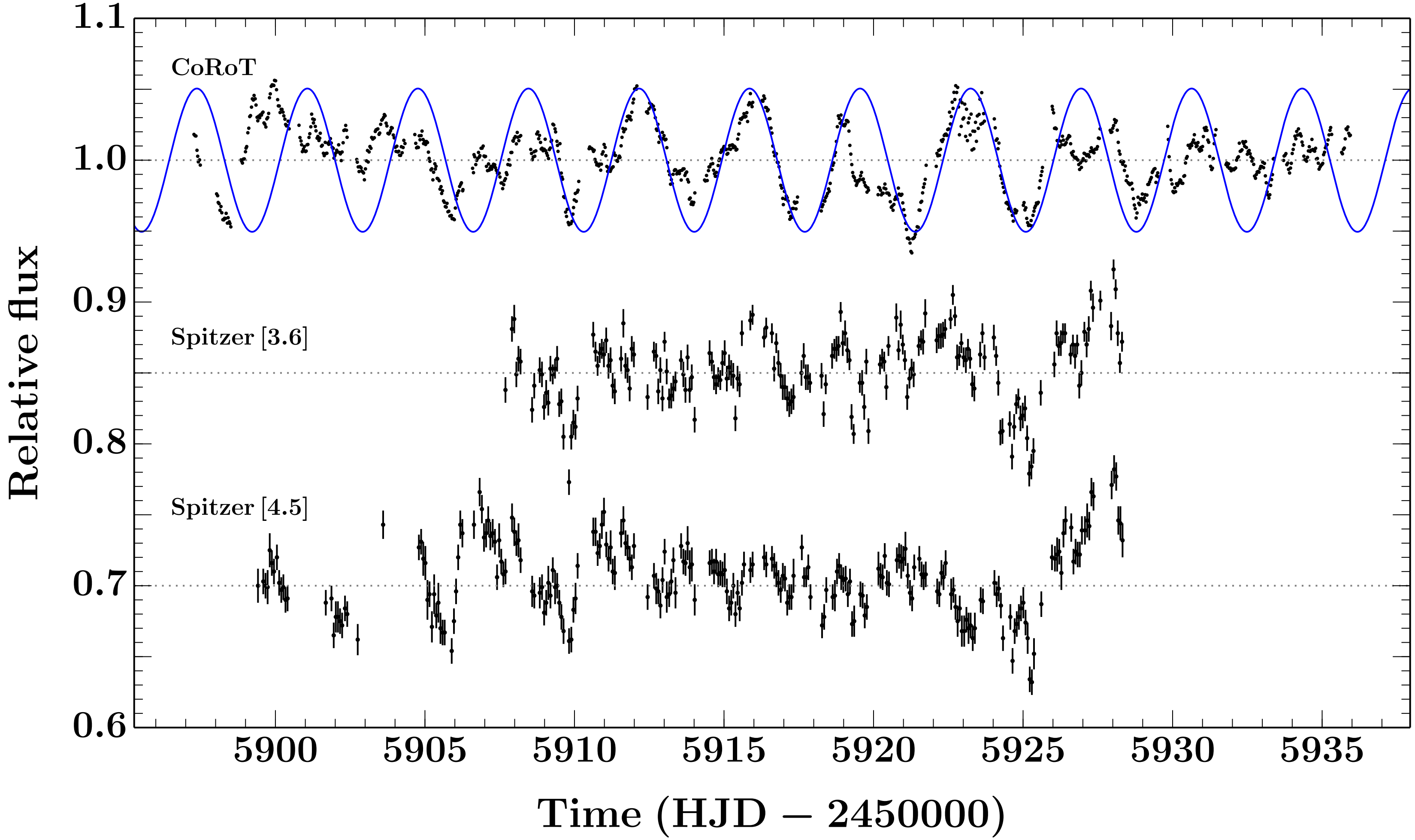

Cold spot = 3000K, ~15% of stellar surface

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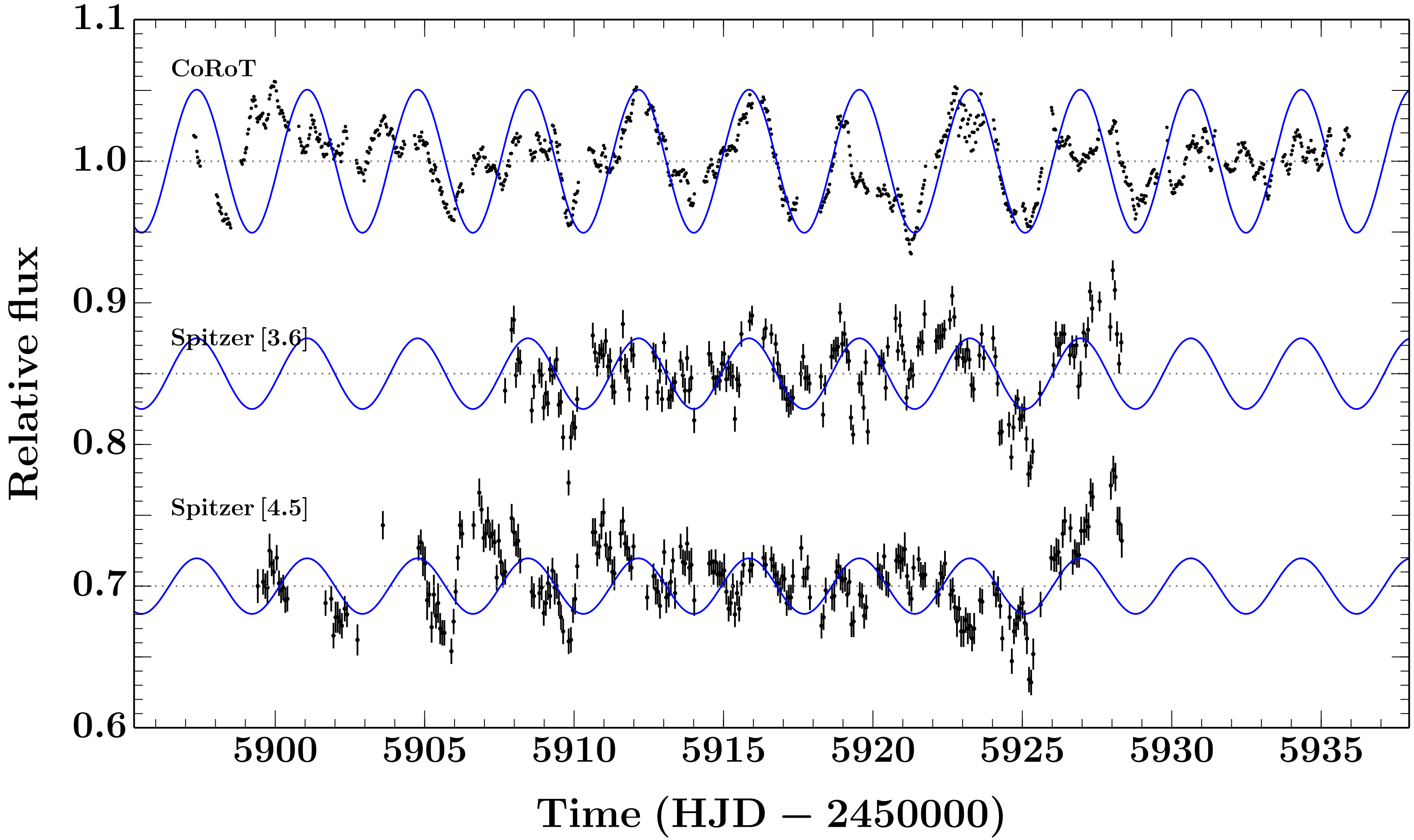

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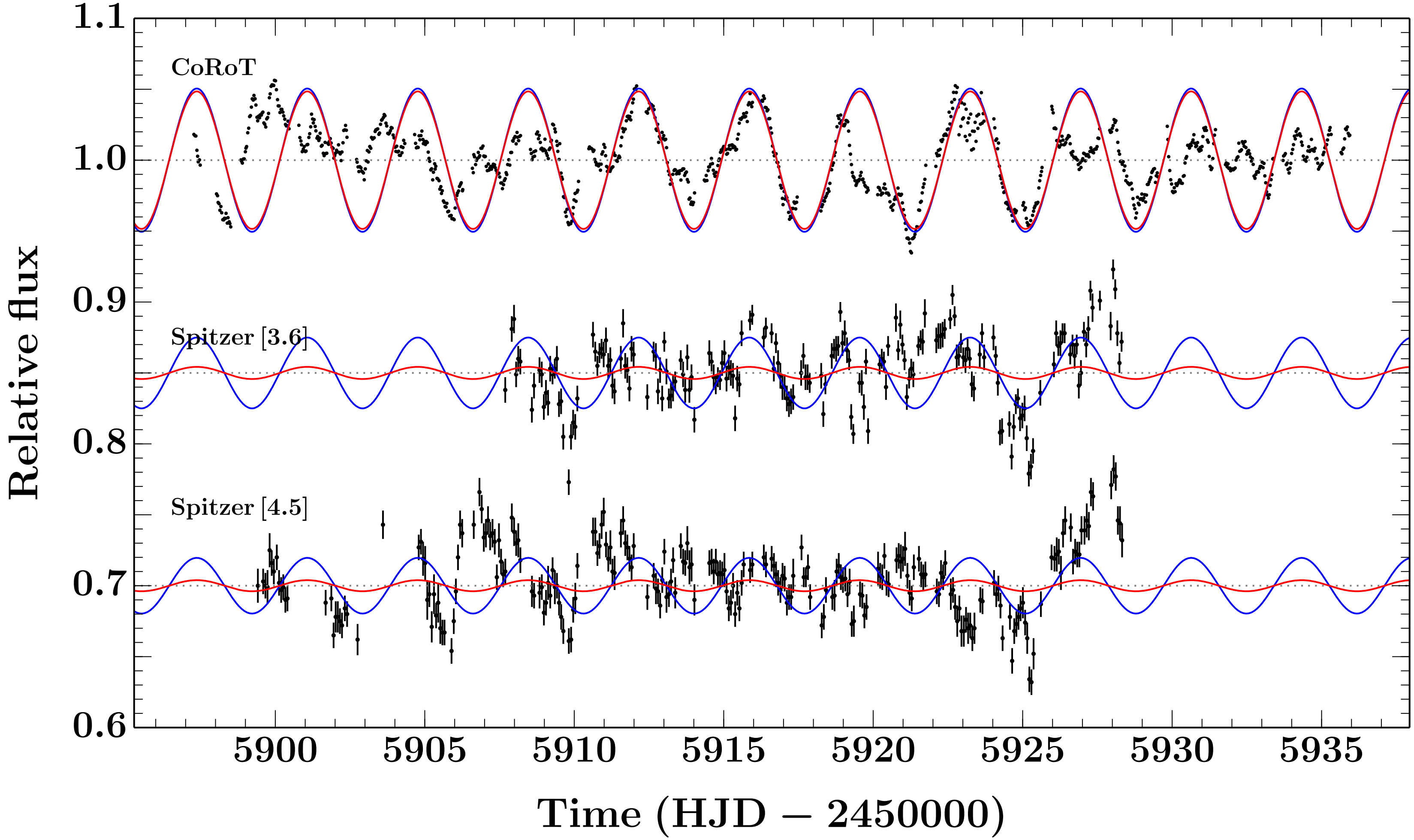

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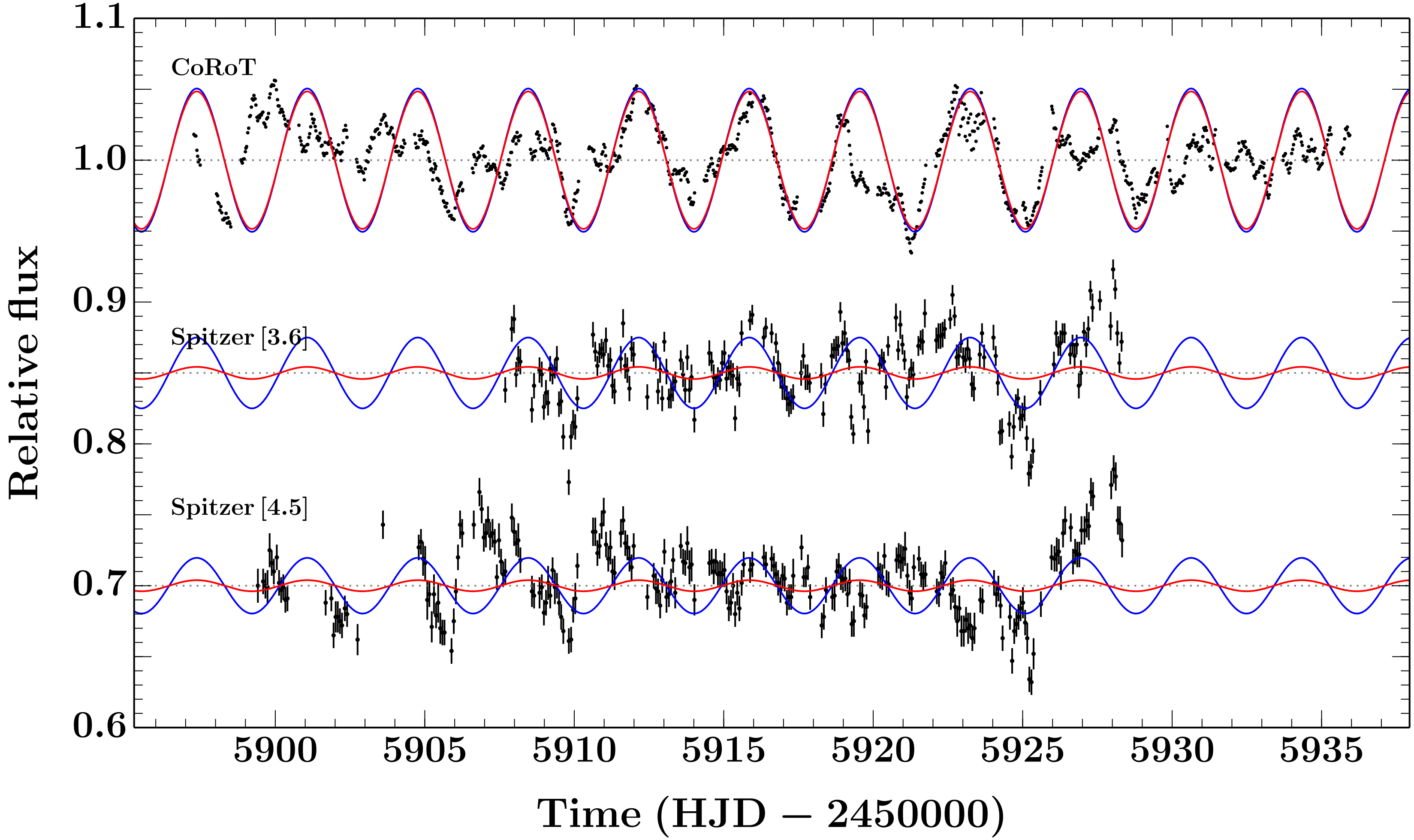

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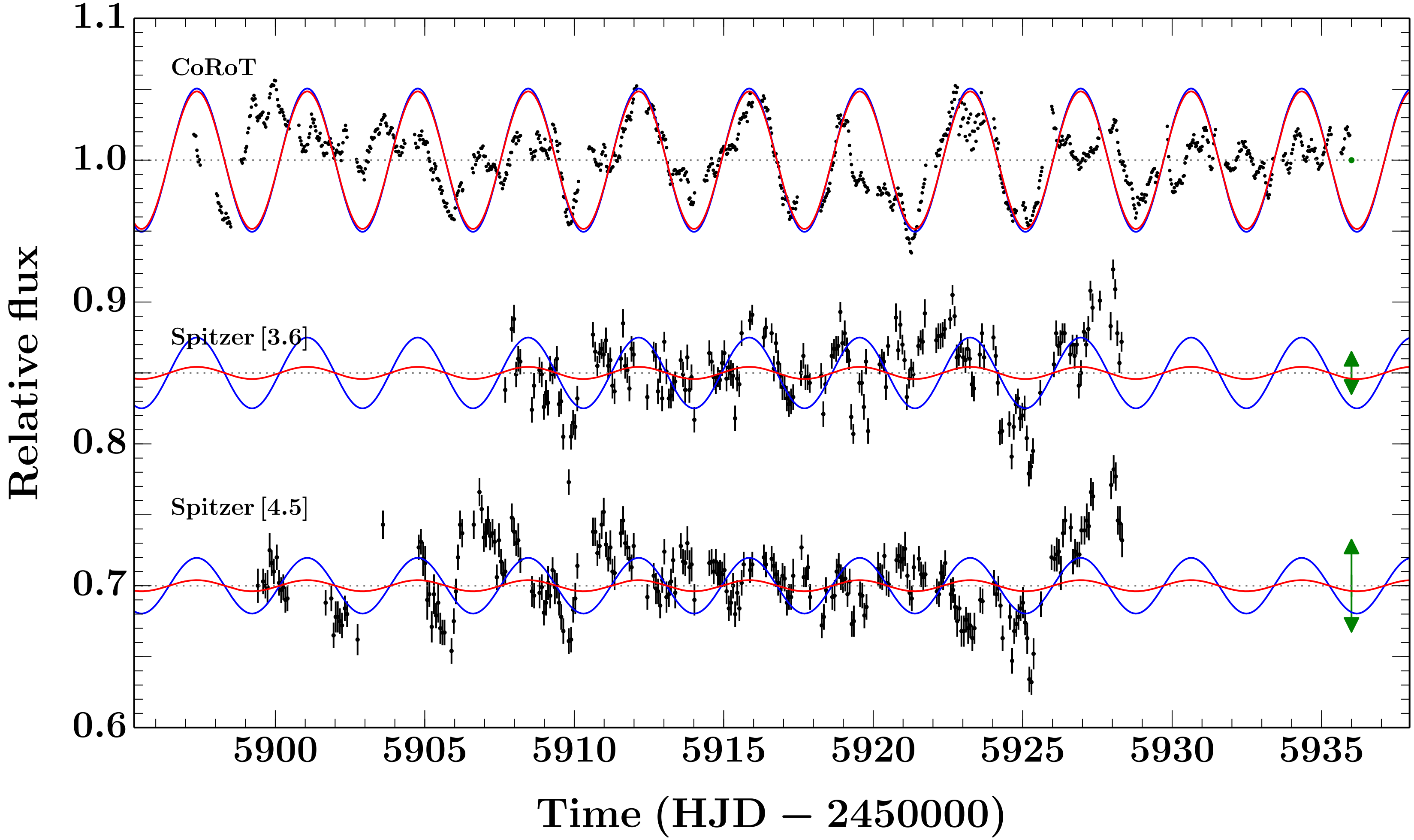

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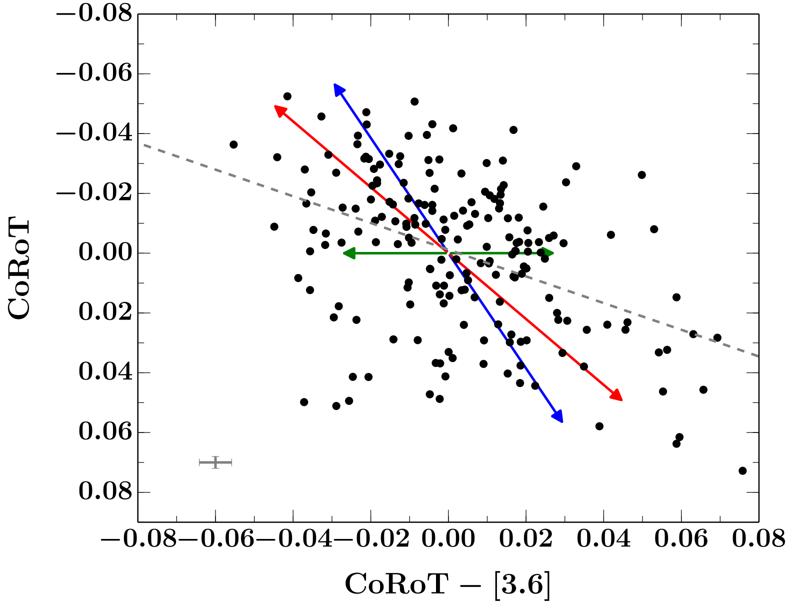
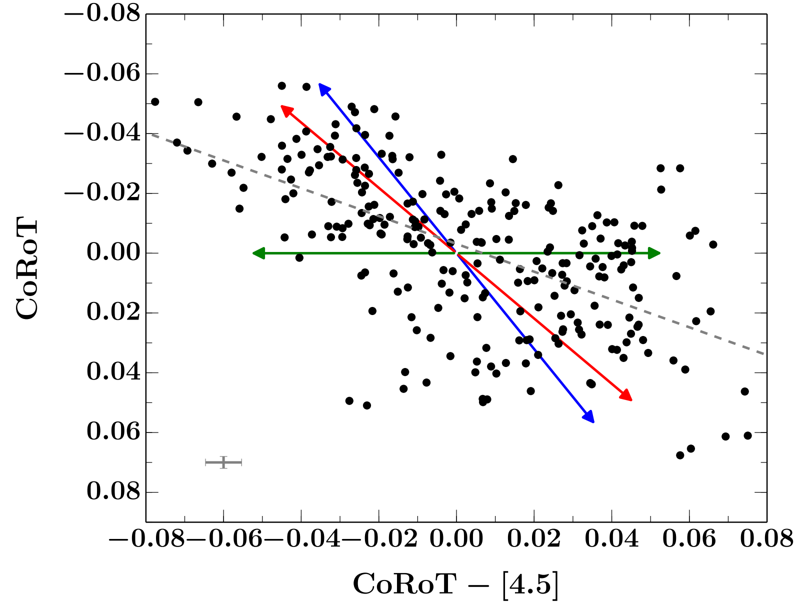
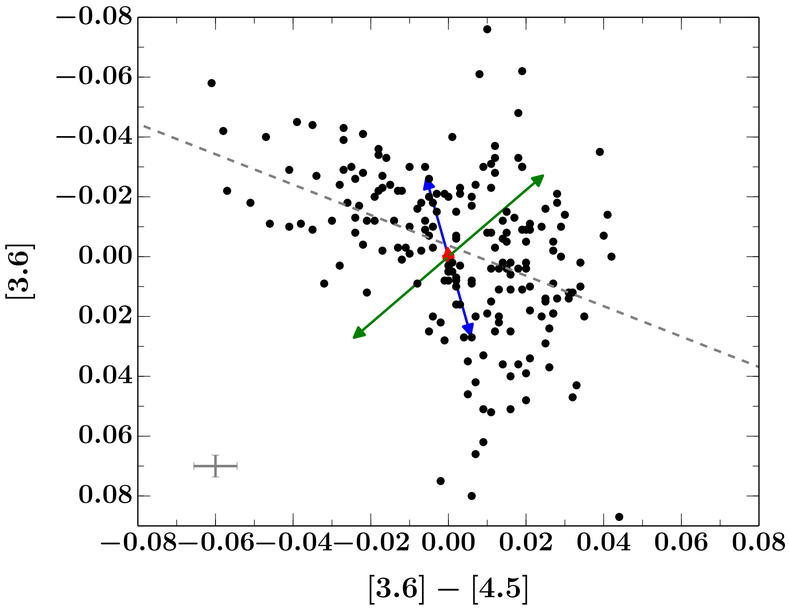
Dust emission = ~1200K, ~10^{-14} $M_\odot$

Colour-magnitude plots







Cold spot
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Hot spot
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/ Dust obscuration

Dust emission
- 10^{-14} $M_{\odot}$

Conclusions

- Unique, low-mass PMS EB
  - Solved fundamental parameters
    - Using Gaussian process regression methods
    - Constrains sparsely populated region of the mass-radius plane
  - Evidence for circumbinary material
    - Emission from hot dust in the central cavity of a circumbinary disk

See Gillen et al. A&A 562 A50

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  - Will observe SFRs and young clusters of various ages

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Thank You