MULTIPLE SYSTEMS

WITH

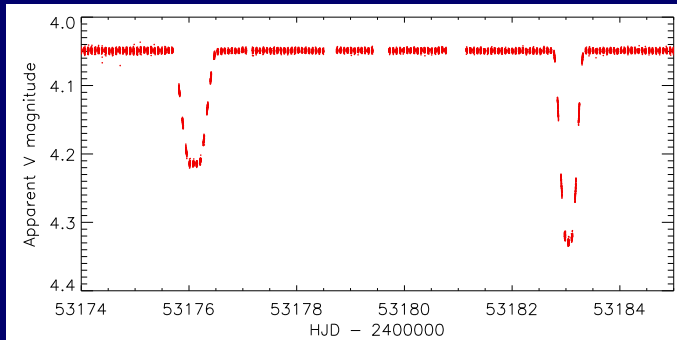# Kepler

and

CoRoT

John Southworth

Keele University, UK

Eclipsing binaries and space missions

- Study of eclipsing binaries is a mature field

- Eclipses proposed for β Persei by John Goodricke in 1783

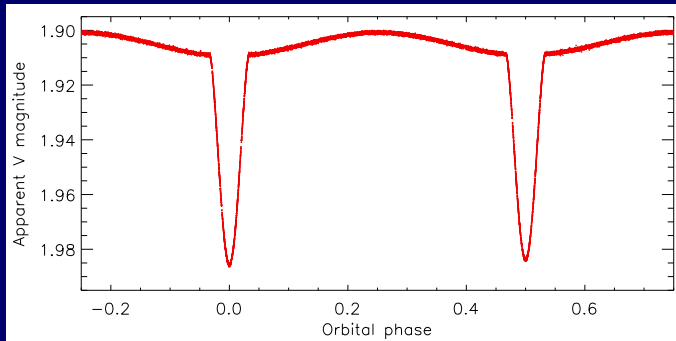- Stebbins (1911ApJ....34..112S): first measurement of mass and radius

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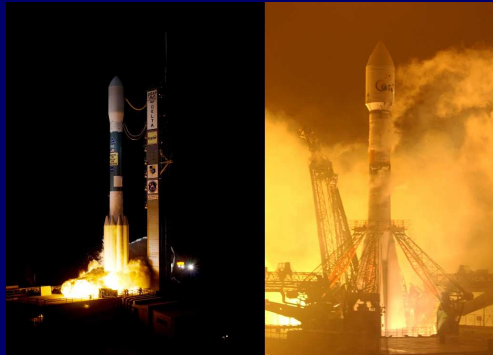 - ψ Centauri: $V = 4.0$ Bruntt et al. (2006A+A...456..651B)

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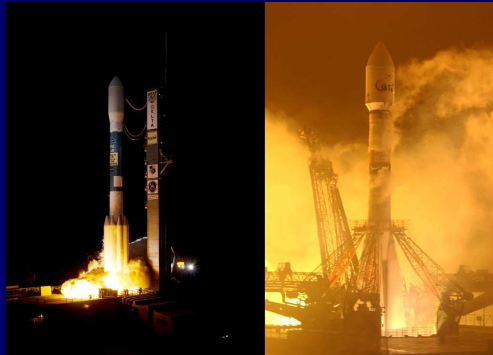   - β Aurigae: $V = 1.9$ Southworth et al. (2007A+A...467.1215S)

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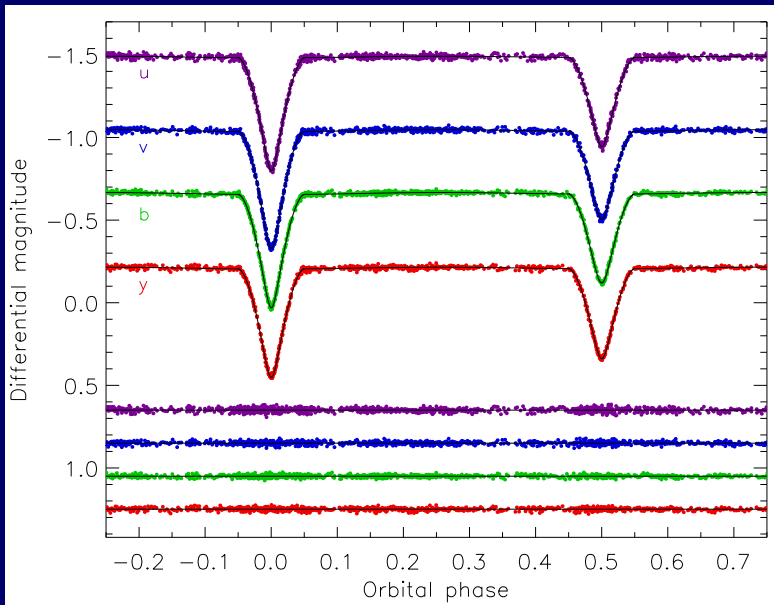
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- 2009: *Kepler*
  - Any search for transiting planets will get eclipsing binaries too
  - CoRoT and *Kepler* did this on a large scale
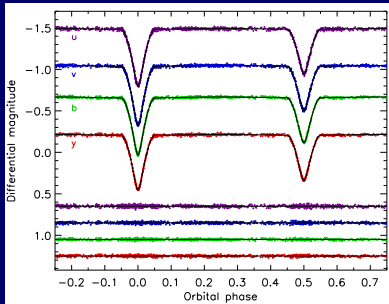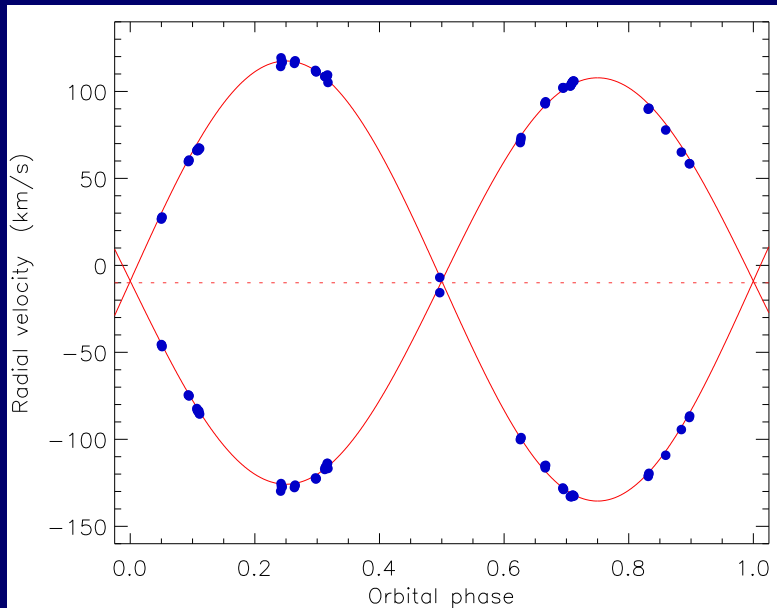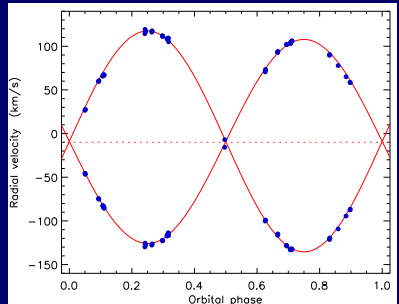 - Need large-scale response

The importance of eclipsing binaries

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- Light curve analysis gives: $\frac{R_1}{a}$ $\frac{R_2}{a}$ inclination i $e\cos\omega$

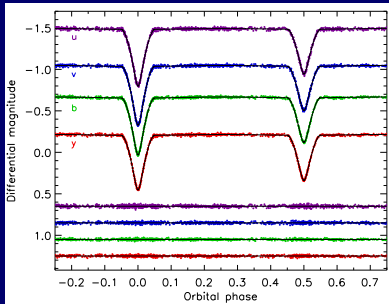WW Aurigae (Southworth et al., 2005MNRAS.363..529S)
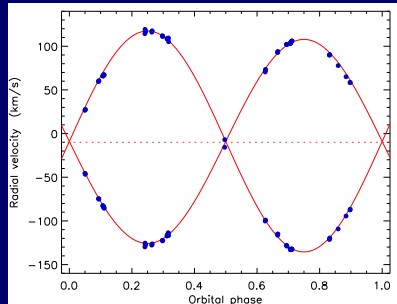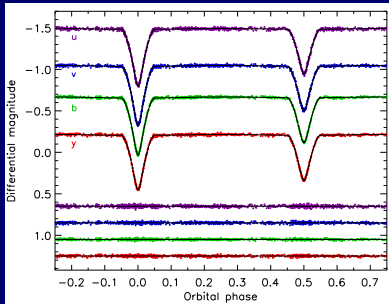
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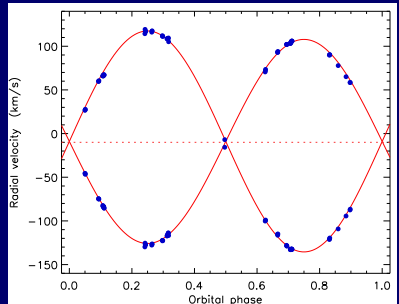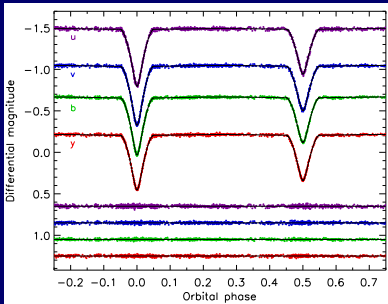- Combine: masses to 1% radii to 1% $\log g$ to $0.01 \, \text{dex}$
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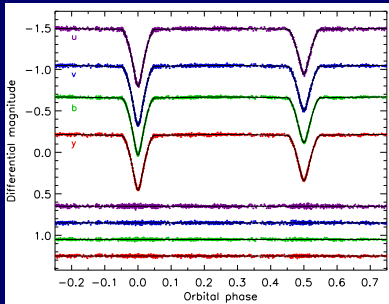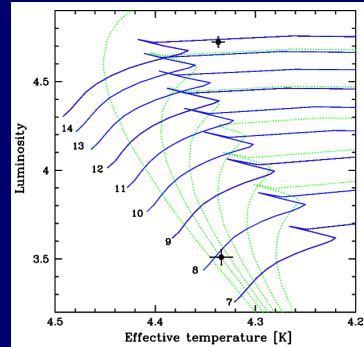

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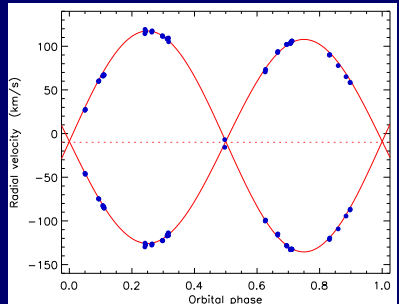
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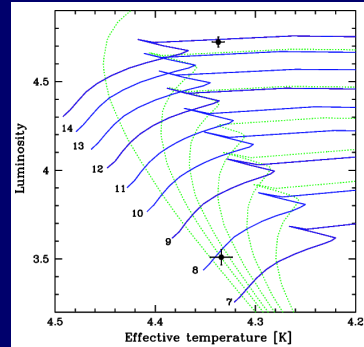
Uses of eclipsing systems

- Test theoretical stellar models
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- Apsidal-motion test of stellar structure
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- Test model atmospheres via limb darkening
  (see Howarth, 2011MNRAS.418.1165H)

Components of V380 Cygni:
$M_1 = 13.13 \pm 0.24\,\mathrm{M}_\odot$
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Figure taken from Pavlovski
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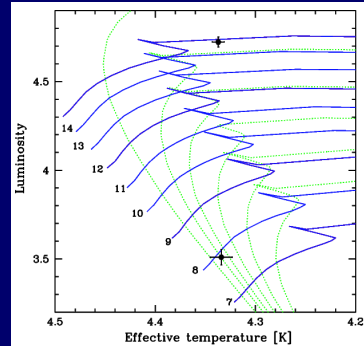# Uses of eclipsing systems

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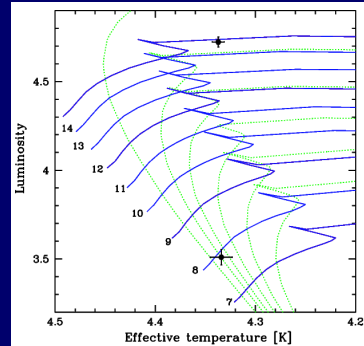 (e.g. Albrecht et al., 2009Natur.461..373A)

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- Direct distance indicators
  (e.g. Graczyk et al., 2014ApJ...780...59G)
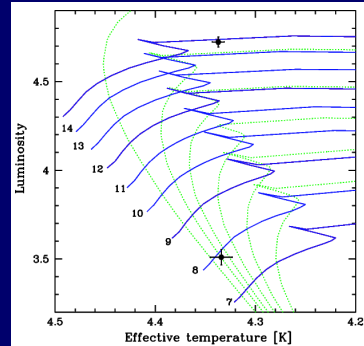
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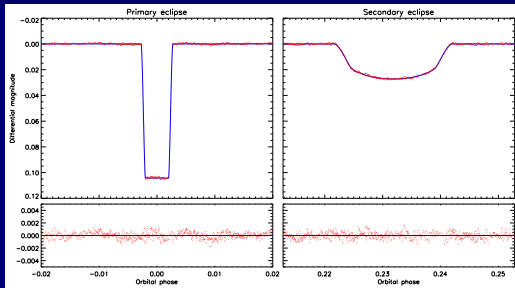et al. (2009MNRAS.400..791P).

Red giants in EBs

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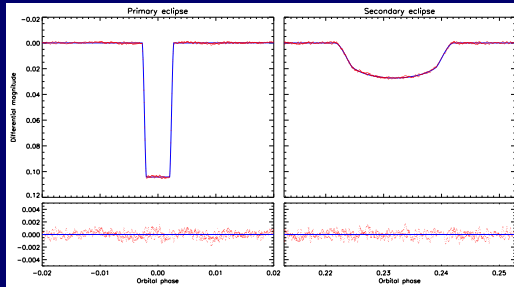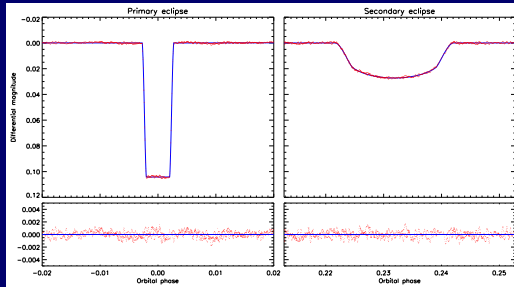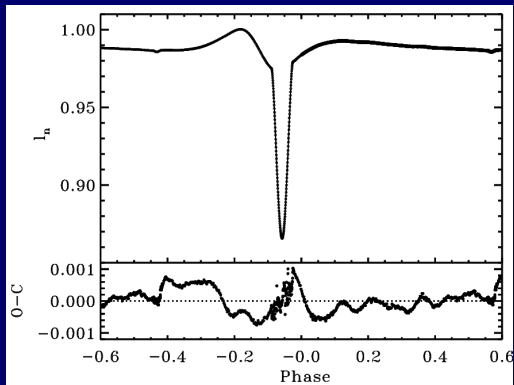 - Pulsating red giant in EB
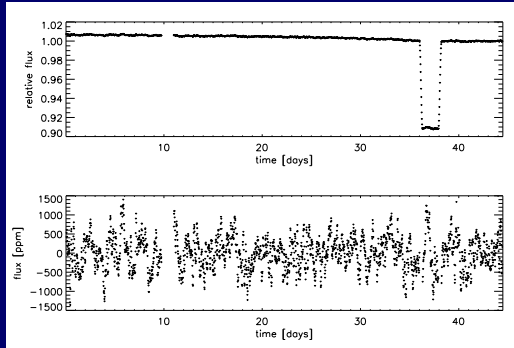
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Tidally-induced pulsations

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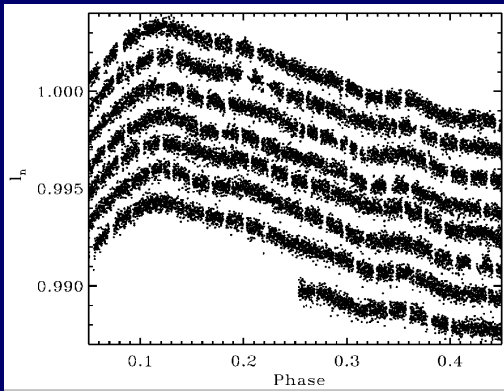
Very low mass stars in EBs

- KOI-126 (Carter et al. 2011Sci...331..562C)
  - Triply eclipsing G star with two $0.2\,M_\odot$ stars
  - Periods: $33.9\,d$, $1.8\,d$
  - Masses to 1%, radii to 0.5%
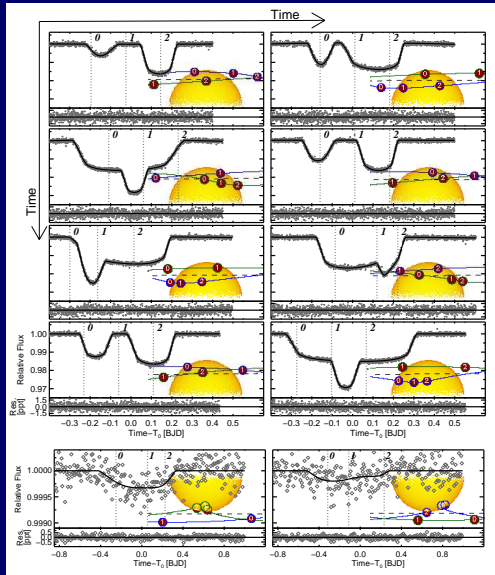
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  - Masses to 1%, radii to 0.5%
- Model discrepancy: low-mass stars are bigger than theoretical models predict
  - Probable cause: tidal effects cause magnetic activity
  - Solution: study long-period EBs
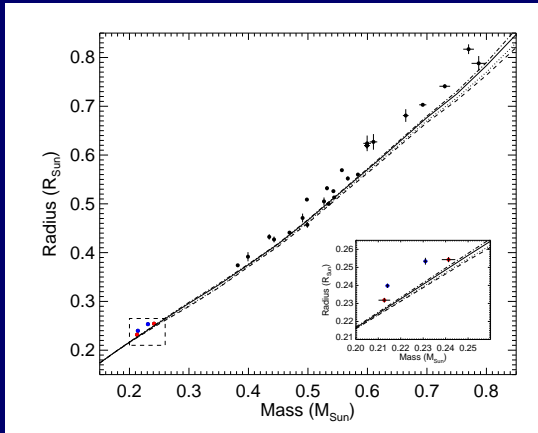
Pre-main-sequence stars in EBs
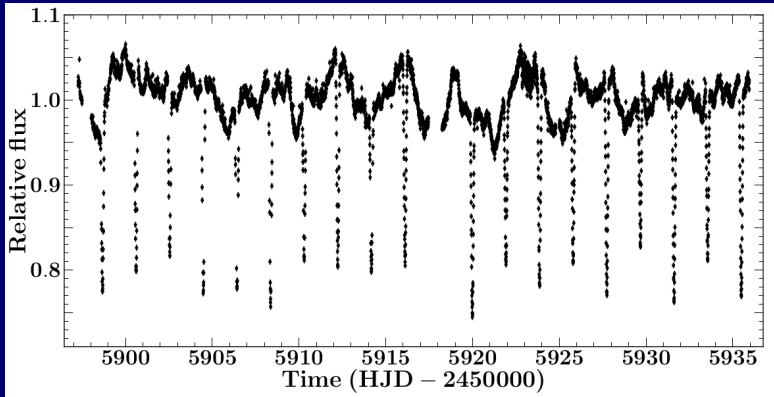
- CoRoT 223992193 (Gillen et al. 2014A+A...562A..50G)
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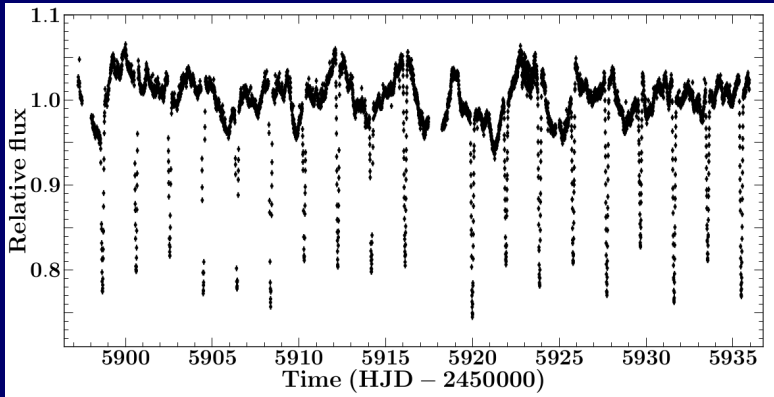
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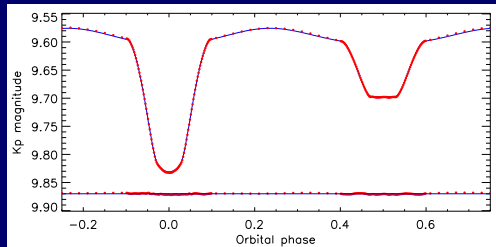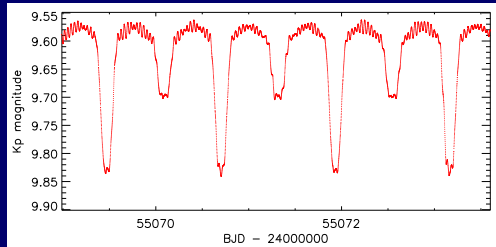 - Observed by CoRoT in 2008 and 2011/12
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δ Scuti stars in EBs

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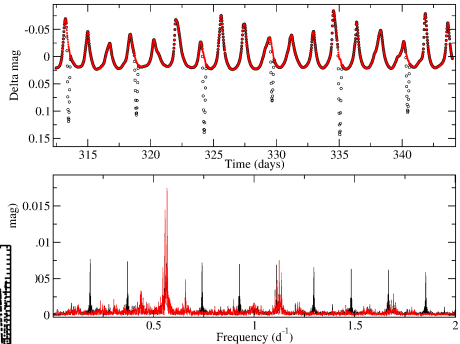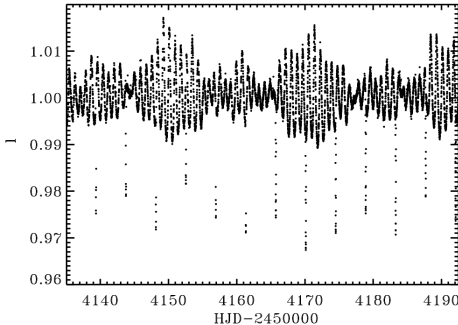 - Doppler beaming needed to fit light curve
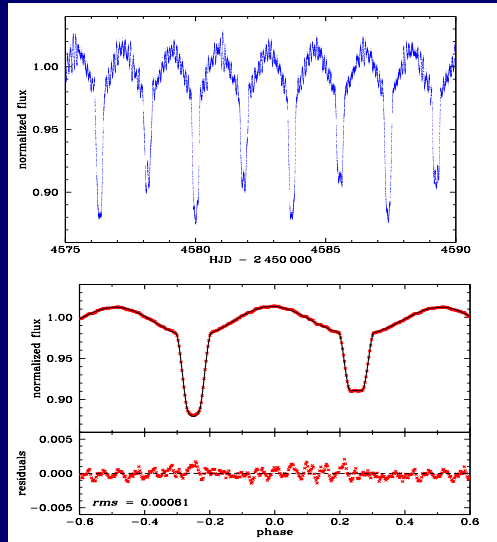
γ Doradus stars in EBs

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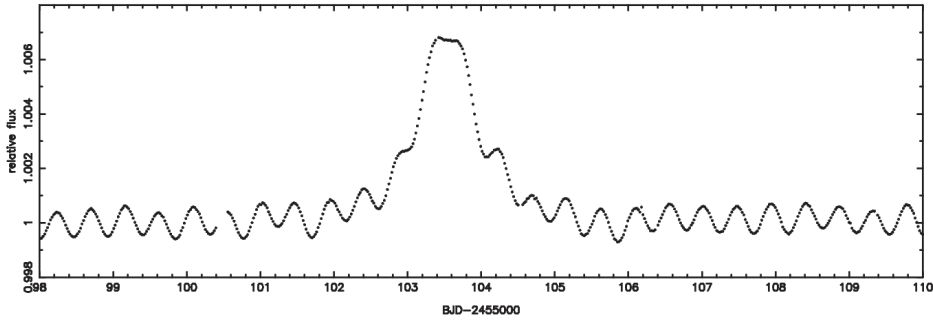 - Pulsations show amplitude variability
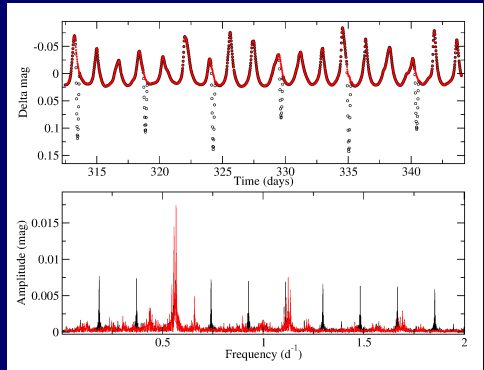
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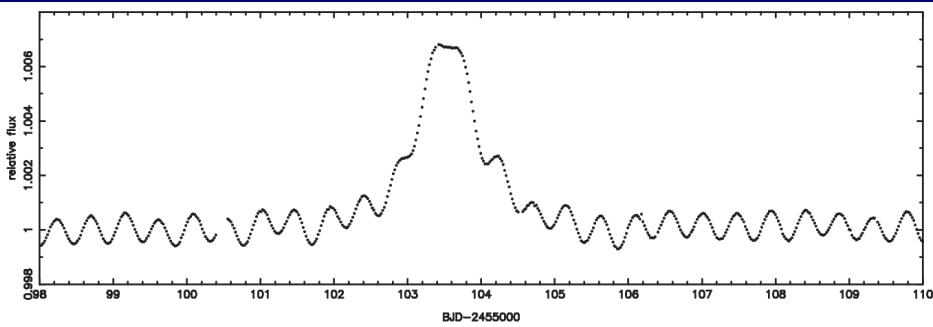 - Pulsations show amplitude variability

- CoRoT 102918586 (Maceroni et al., 2013A+A...552A..60M)
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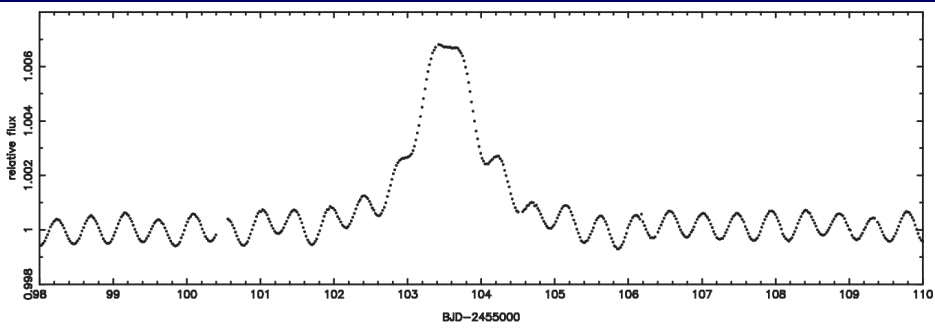 - Pulsations consistent with $\ell = 1$ g-modes

Heartbeat stars

- KOI-54 (Welsh et al. 2011ApJS..197....4W)
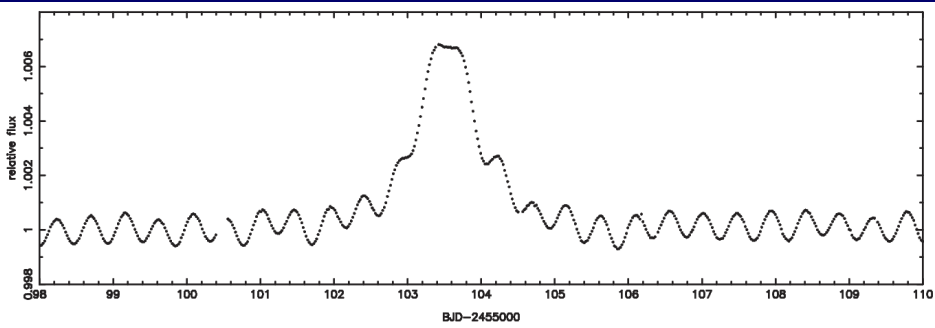 - 42 d period binary with very eccentric orbit ($e = 0.83$) and no eclipses

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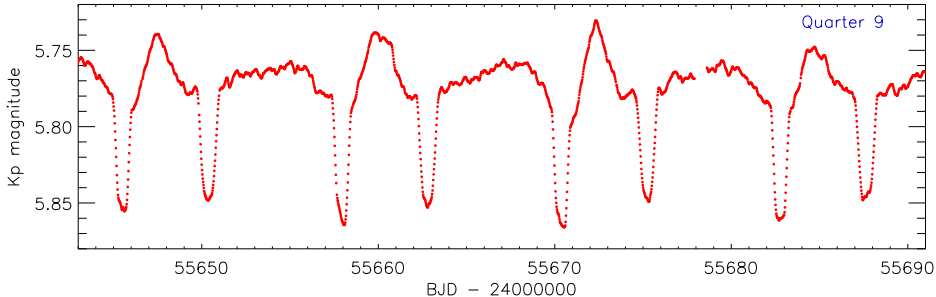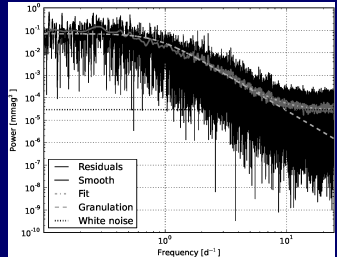- See talk by Kelly Hambleton

Stochastic oscillations in EBs

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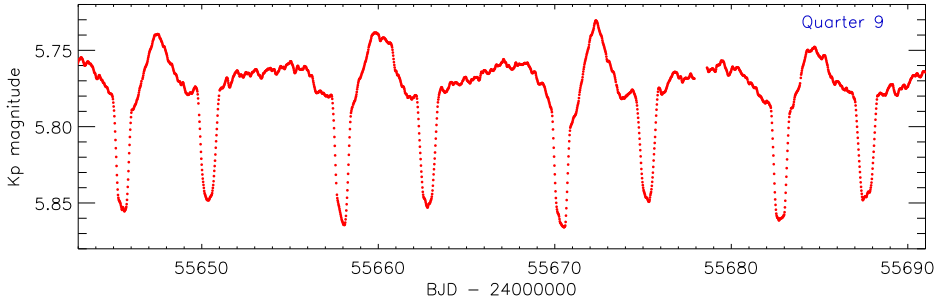
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    data after removing binarity effects

Stochastic oscillations in EBs

- V380 Cygni = KIC 5385723
  (Tkachenko et al. 2014MNRAS.438.3093T)
  - Well-known 12.4 d eccentric EB
  - Spectral type: B1.5 II-III + B2 V
  - Granulation signal detected in *Kepler*
    data after removing binarity effects
- Late-type dwarfs are more problematic
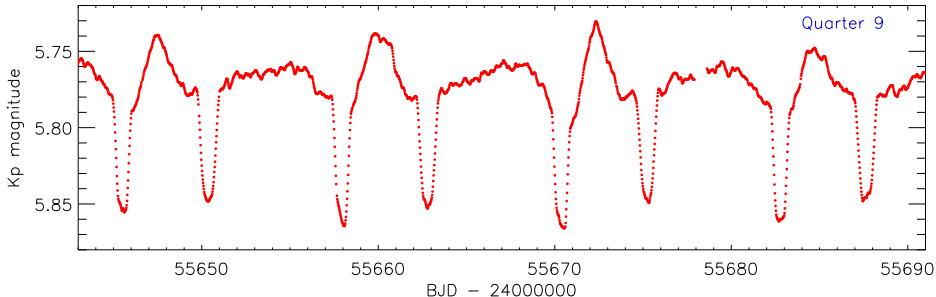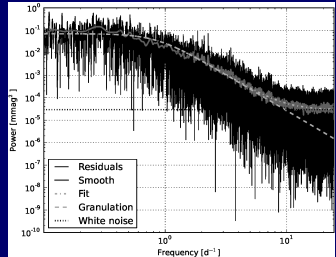
Circumbinary planets

- 8 known transiting circumbinary planets, all orbiting EBs
  - Kepler-16 first, then Kepler- 34, 35, 38, 47b, 47c, 64, 413
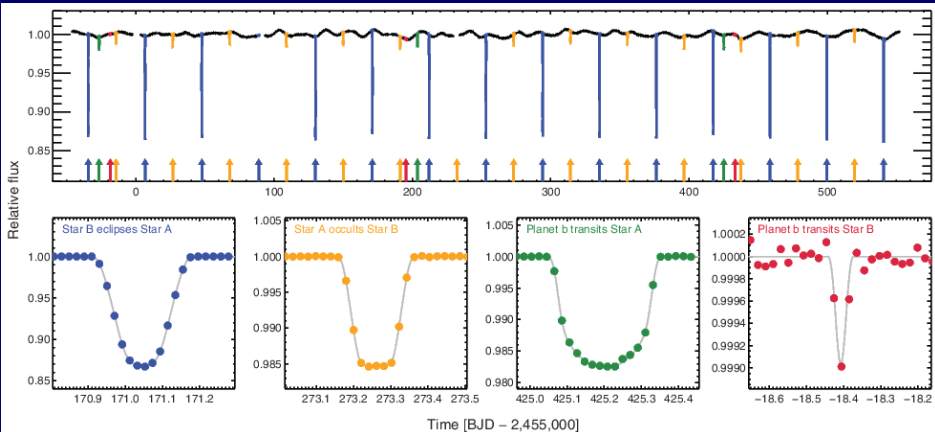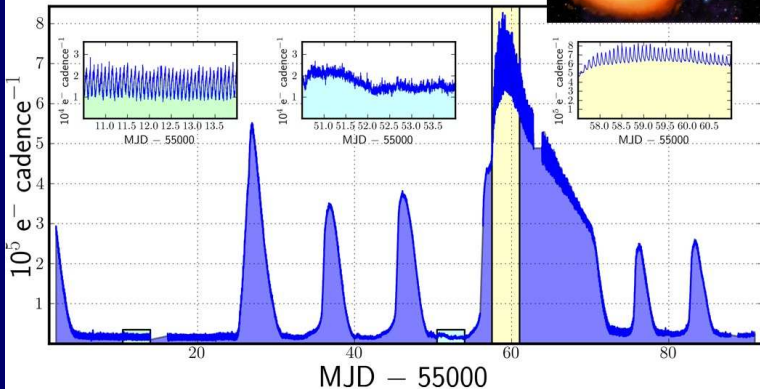
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  - Exquisite measurements of masses and radii of the host stars
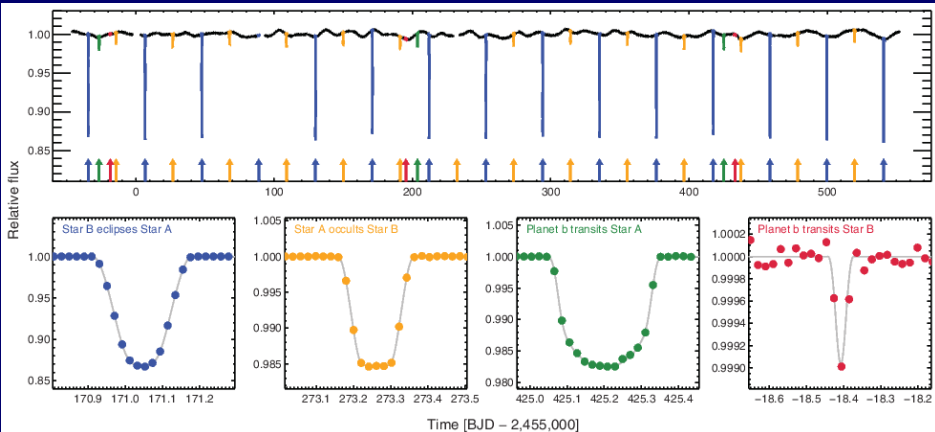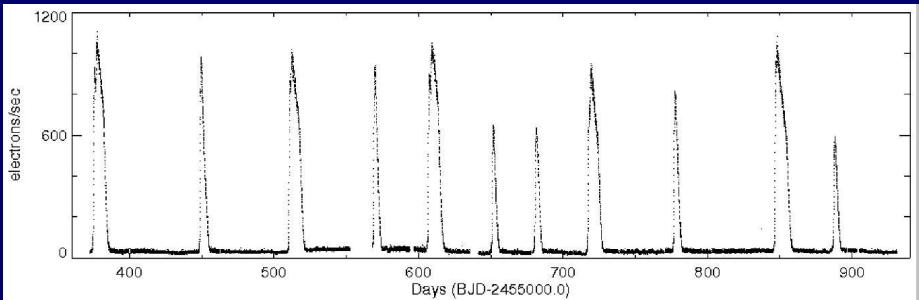
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  - CoRoT light curve shows fast oscillations
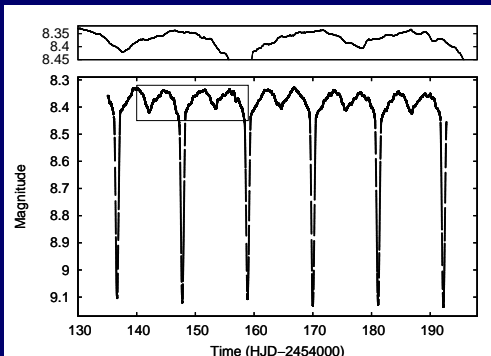
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- KPD 1946+4340 (Bloemen et al., 2011MNRAS.410.1787B)
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  - Doppler beaming and gravitational lensing
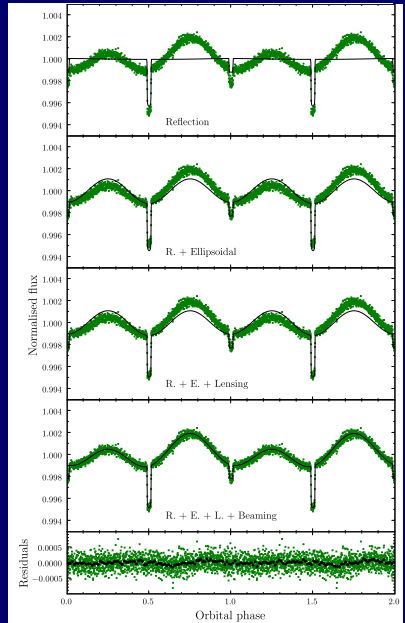
Near future

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  - *Kepler* EB catalogue contains 2640 objects
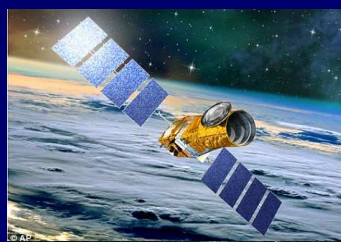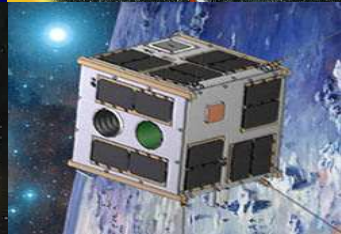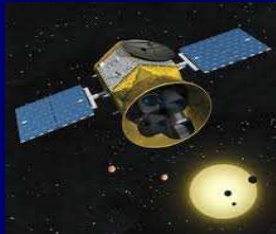 - CoRoT obtained >163 000 light curves

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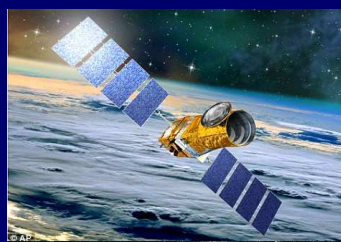- *Kepler* K2 mission now funded

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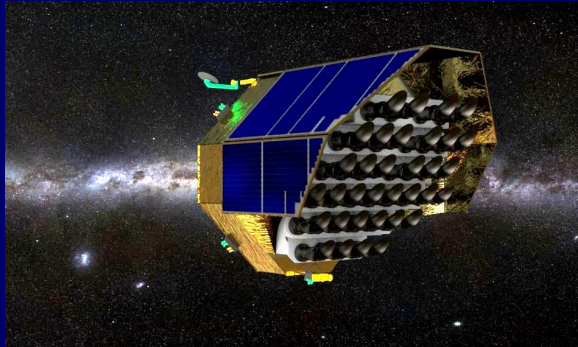 - – Trigonometric distances to 10^9 stars
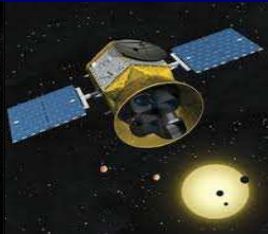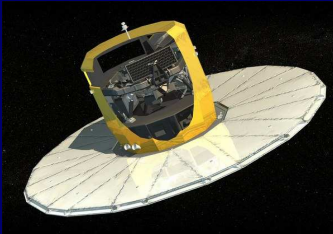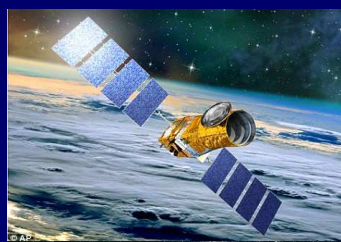
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- Likely science areas:
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    - low-mass stars
    - pulsations in EBs
    - calibration of
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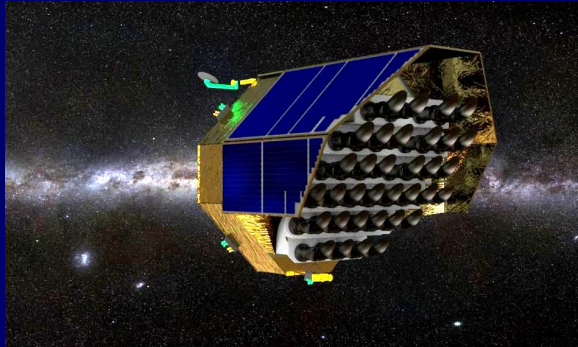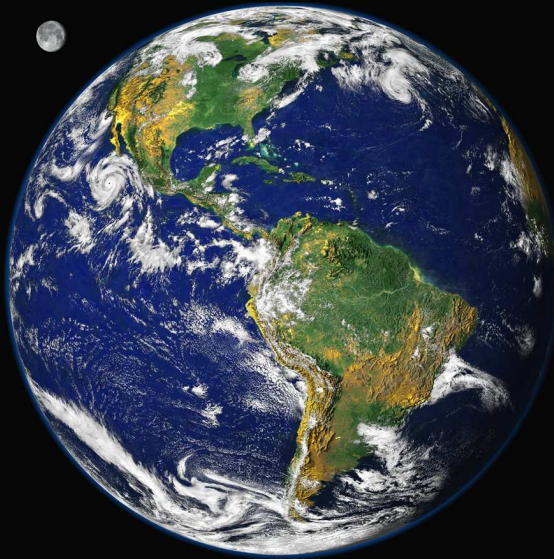
John Southworth, Astrophysics Group, Keele University