TU COM :

BLAZHKO RR LYRAE

IN A BINARY SYSTEM??

3d European Conference for Amateur Variable Star Observers

Hamburg - 2016/09/17

Pierre de Ponthière

www.dppobservatory.net

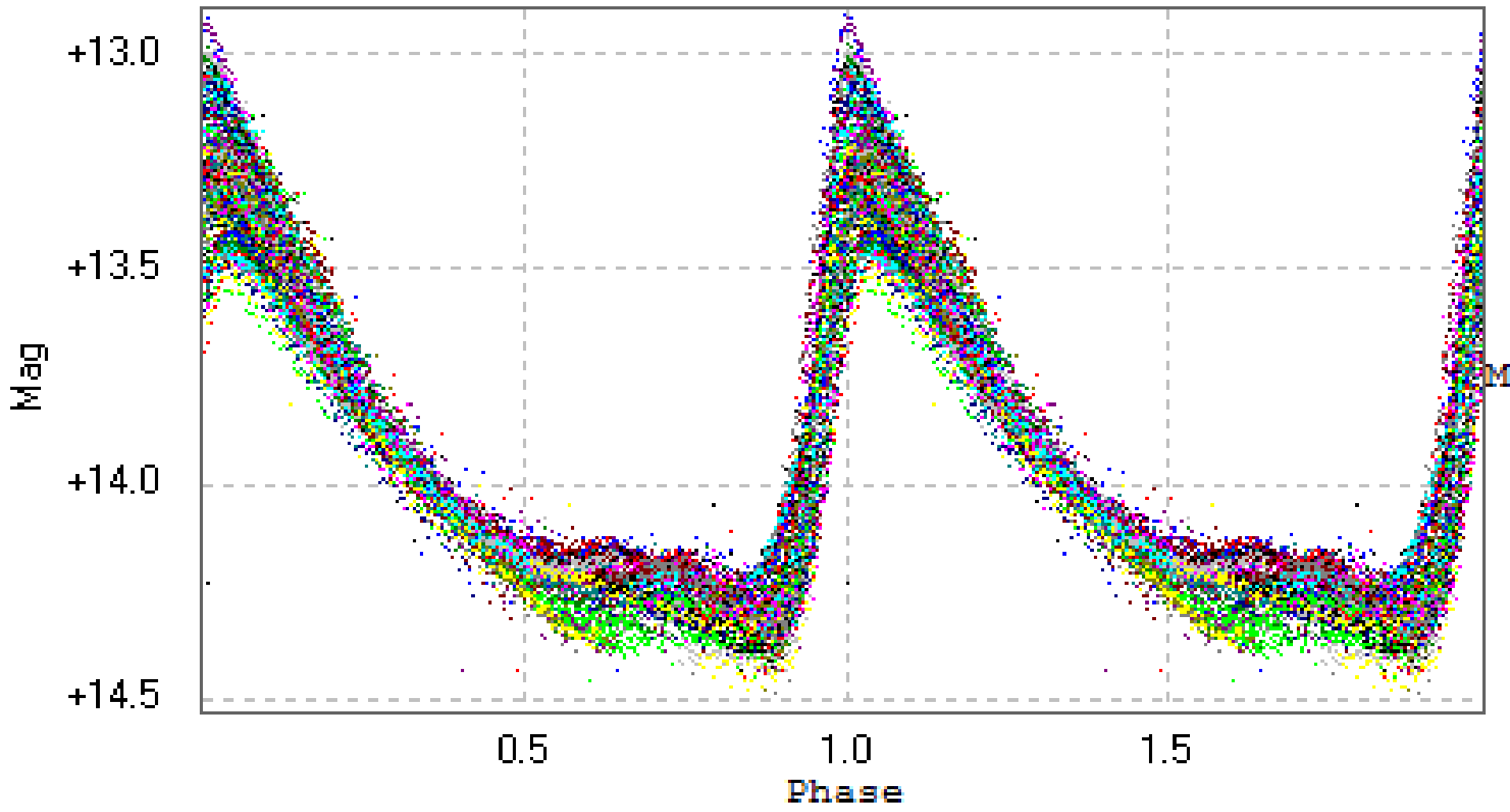
TU Com observations

- A group of AAVSO observers
  - Josch Hambsch : New Mexico and Belgium
  - Ken Menzies : Massachusetts
  - Richard Sabo : Montana
  - Pierre de Ponthiere : New Mexico and Belgium
- 150 nights with a time span of 6.5 years
- 23 577 light curve data points

TU Com main features

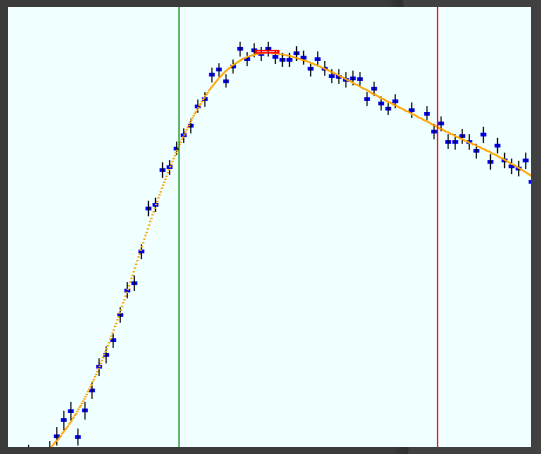
- RR Lyrae (RRab)
  - Pulsating period 0.4618665 day
- Blazhko effect
  - Periods 43.6 and 45.5 days
  - Maxima amplitude
  - Epoch of maxima (O-C)
- Long period
  - 1676 days
  - only (O-C) is affected
  - ➔Probably in a binary system

Folded light curve on the pulsation period



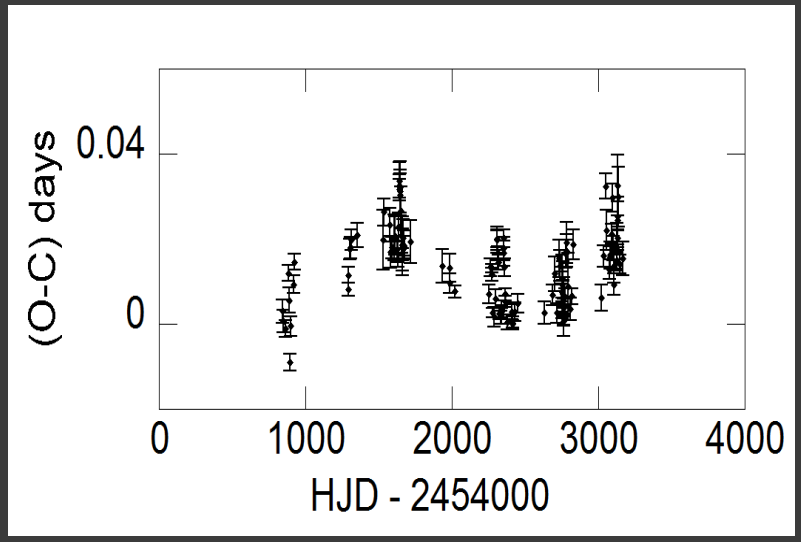
Light curve maxima analysis

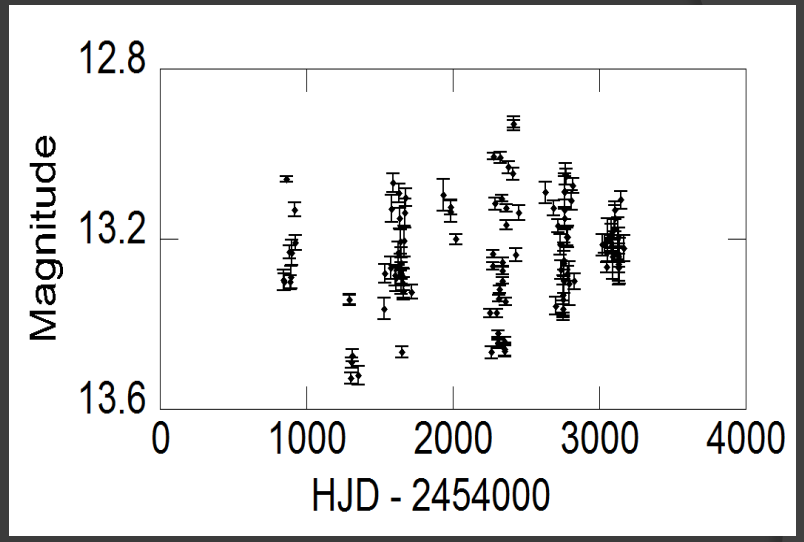
- Times and magnitudes of maxima are measured by curve fitting with a spline (Reinsch algorithm)



- 124 pulsation maxima recorded
  - $(O\text{-}C) = t_{obs} - (t_0 + n\, P_{pulsation})$
  - Magnitude at maximum
- Linear regression of the (O-C) values
  - Pulsation period of 0.4618665 day

(O-C) and Magnitude at Maximum





- Blazhko effect (45 days) on (O-C) and MagMax
- Periodic modulation (1676 days) of (O-C) is not apparent in the Magnitude diagram

Spectral analysis of Maxima

- Period04 : (O-C)
  - Blazhko period 45.28 d
  - Long period 1635 d
- Period04 : M_{max}
  - Blazhko period 43.37 d
  - Blazhko period 45.36 d
  - The long period is not apparent

Long period a sign of binary system

- Light-travel time effect in a binary system
  ➔
  variation in O-C
  and not in
  Magnitude at maximum

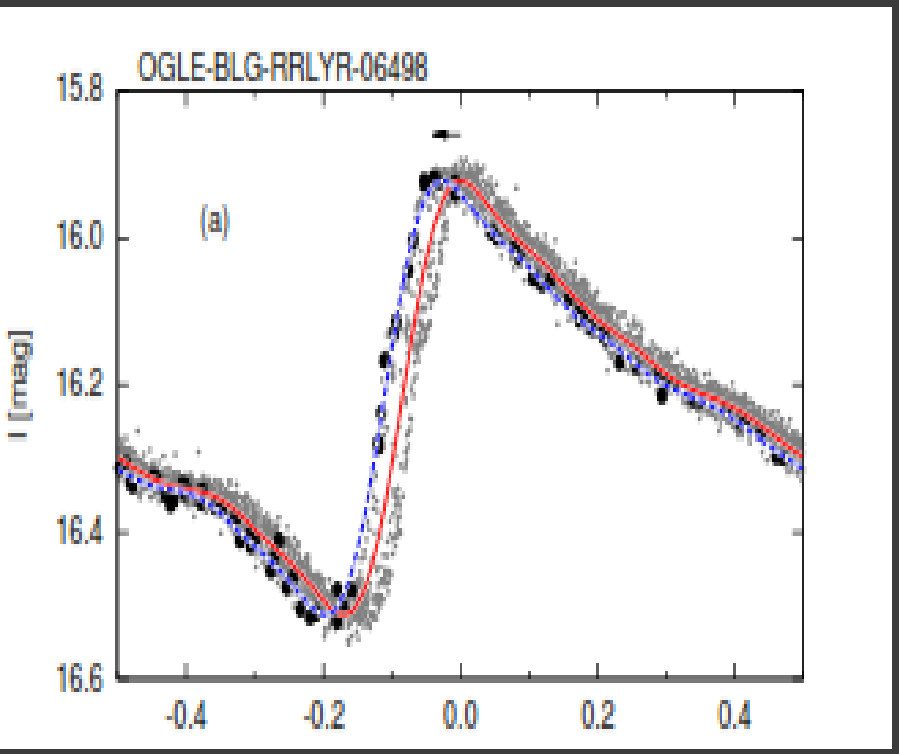
Very few detected RR Lyrae in binary system

- Last century TU UMa was the only one.
- Today, 12 in galactic bulge and some others as potential in the galactic field.
- All those RR Lyrae in binary systems are not affected by Blazhko effect.
- Why?
  - Blazhko RR Lyrae are generally eliminated during the investigation.

How to detect binary systems

- Eclipses
- Radial velocity (spectrometry)
- Light-travel time effect on the orbit ➔ O-C
  - O-C of the maxima
    - needs a large number of recorded data
  - O-C Hertzsprung's method
    - derive O-C from a light-curve template
    - not applicable to Blazhko star

O - C Hertzsprung's method



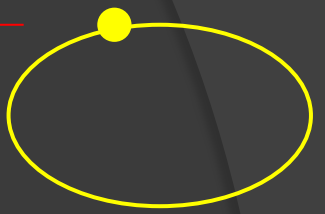
- derive a Light Curve template
- each data point has an (O-C)
- applicable to sparse Light Curve sampling
- but not for Blazhko RR Lyrae

G. Hajdu et al.

Orbital parameter estimation

- light-travel time equation

  maxima are seen as ticks of a clock moving around the mass center



$$\tau = \frac{(a_{RRL} \sin i)}{c} \frac{(1 - e^2)}{(1+e \cos \nu)} \sin(\nu+\omega)+\tau_0$$

τ : light-travel time
a_{RRL} : semi-major axis
i : orbit inclination
e : orbit eccentricity
ν : true anomaly
ω : periastron longitude

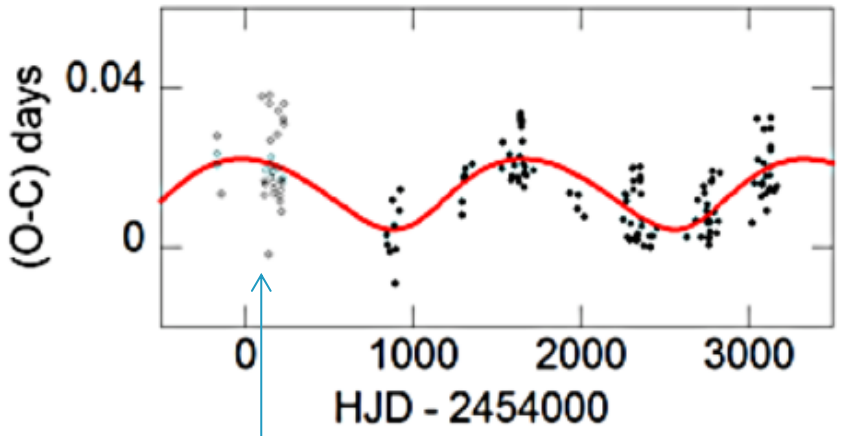
- minimize residuals r = (O-C) – τ

  with Levenberg-Marquart algorithm (improved Gauss-Newton method)

- Blazhko effect seen as a noise added to light-travel time.

Orbital parameter estimation

$a_{RRL} \sin i / c = 0.00893$ d (1.55 AU)
$P_{orb} = 1{,}676$ d = 4.59 years
$e = 0.22$
$\omega = -0.978$ rad
$T_{peri} = 2455006$ HJD
$\tau_0 = 0.0117$ d



- Radial velocity 10 km/s

WASP data

Secondary star mass estimation

- Assuming 0.7 M⊙ for the RR Lyrae

Table 7. Secondary mass and semi-major axes of the two stars for different orbital inclinations.

Orbital Inclination (degrees)	*Secondary Mass ($M_\odot$)*	a_{RRL} *(AU)*	a_s *(AU)*
90	0.70	1.55	1.54
80	0.72	1.57	1.53
70	0.77	1.65	1.50
60	0.87	1.78	1.44
50	1.07	2.02	1.32
40	1.45	2.40	1.16
30	2.36	3.09	0.92
20	5.56	4.52	0.57
10	34.84	8.90	0.18

derived from Kepler's third law

- Secondary star probably more evolved as its mass is higher than RR Lyrae mass

  (both stars formed at same epoch and have same metallicity)

Conclusions

- To confirm TU Com binary system, spectroscopic radial velocity measurement would be required.
- A challenge as the radial velocity is low (10km/s)
  - and impacted by pulsation and motion of the atmospheric layers of the RR Lyrae.
- If confirmed, TU Com will be the first detected RR Lyrae with Blazhko effect in a binary system

References

- de Ponthière, P. *et al*, 2016 TU Comae Berenices: Blazhko RR Lyrae Star in a Potential Binary System
  J. Amer. Assoc. Var. Star Obs, **44**, 18

- Hajdu, G. *et al,* 2015 New RR Lyrae variables in binary systems.
  MNRAS **449**, L113

- Hilditch, R. W. 2001, An Introduction to Close Binary Stars,
  Cambridge Univ. Press, Cambridge.