

TU COM :

BLAZHKO RR LYRAE

IN A BINARY SYSTEM??

3^d European Conference for Amateur
Variable Star Observers

Hamburg - 2016/09/17

Pierre de Ponthière

www.dppobservatory.net

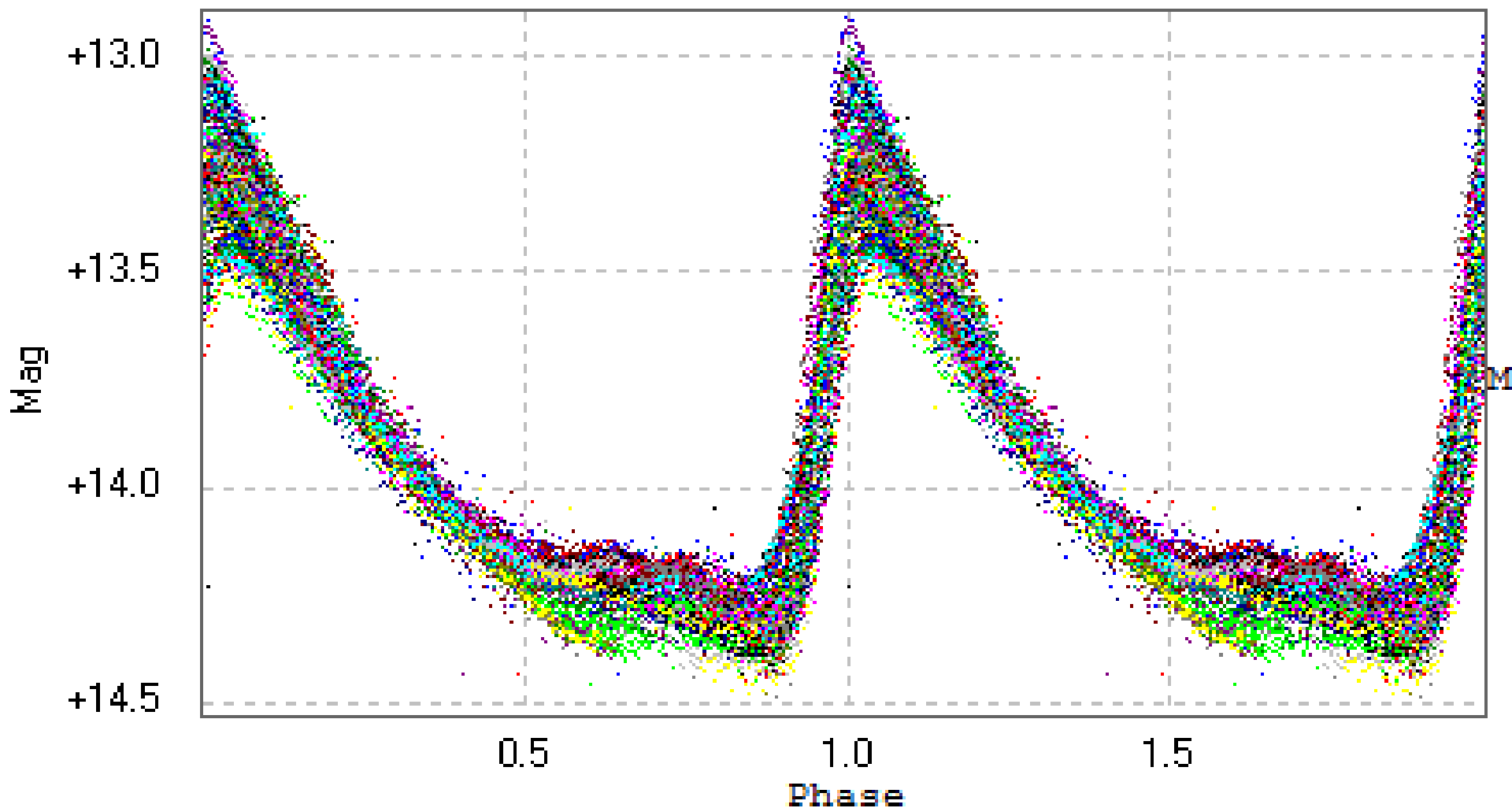
TU Com observations

- ⦿ A group of AAVSO observers
 - Josch Hamsch : 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

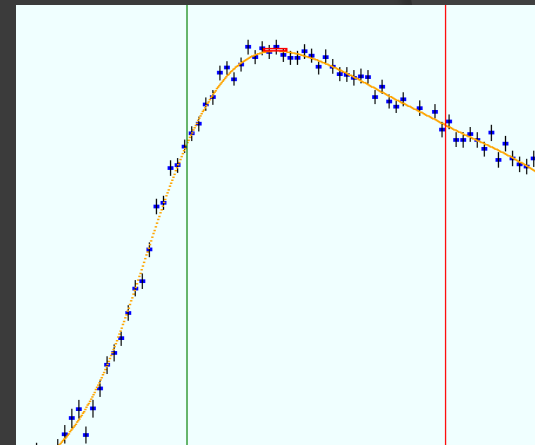
- ⊙ RR Lyrae (RRab)
 - Pulsating period 0.4618665 day
- ⊙ Blazhko effect
 - Periods 43.6 and 45.5 days
 - Maxima amplitude
 - Epoch of maxima (O-C)
- ⊙ Long period
 - 1676 days
 - only (O-C) is affected
 - → Probably in a **binary system**

Folded light curve on the pulsation period

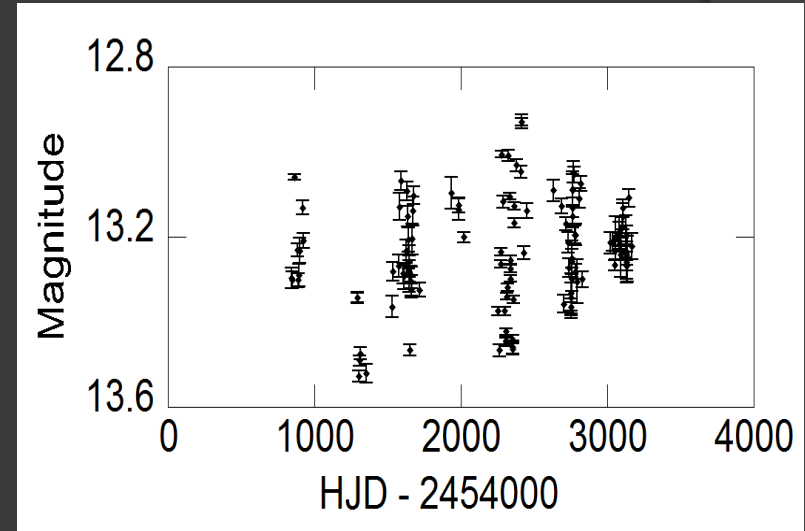
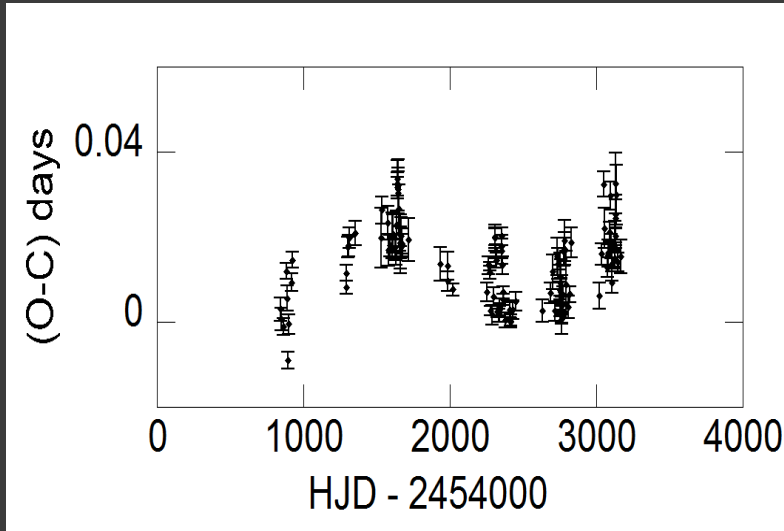


Light curve maxima analysis

- ⦿ Times and magnitudes of maxima are measured by curve fitting with a spline (Reinsch algorithm)
- ⦿ 124 pulsation maxima recorded
 - $(O-C) = t_{\text{obs}} - (t_0 + n P_{\text{pulsation}})$
 - 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

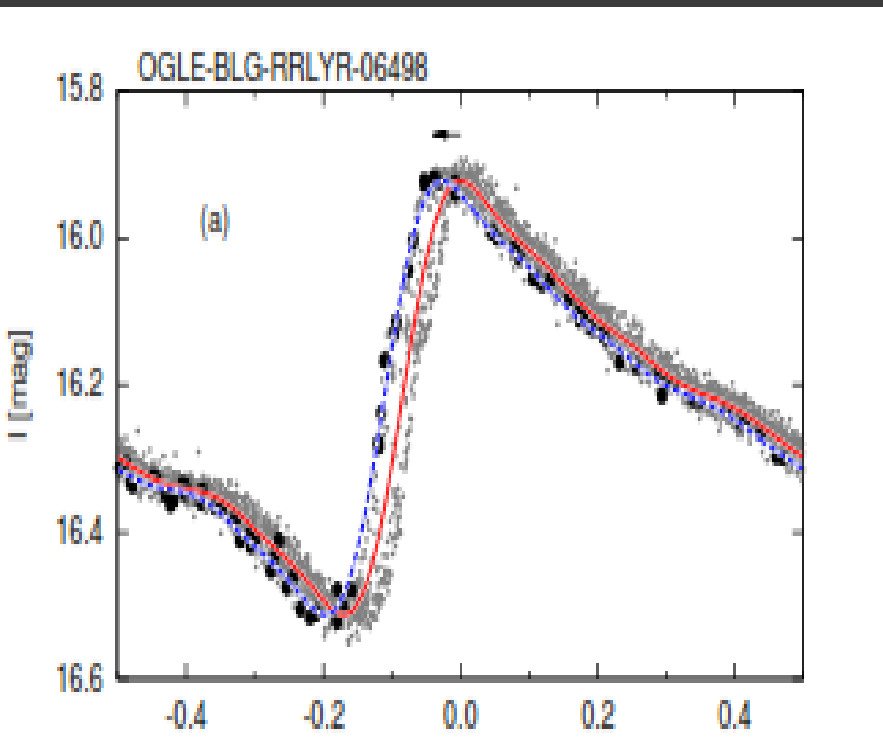
Very few detected RR Lyrae in binary system

- ⦿ 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

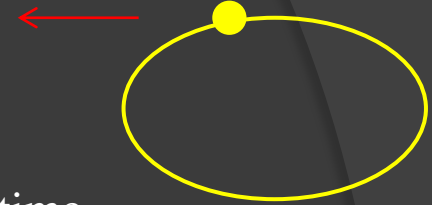
- light-travel time equation

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

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

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

observer



- minimize residuals $r = (O-C) - \tau$

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

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

Orbital parameter estimation

$$a_{\text{RRL}} \sin i / c = 0.00893 \text{ d (1.55 AU)}$$

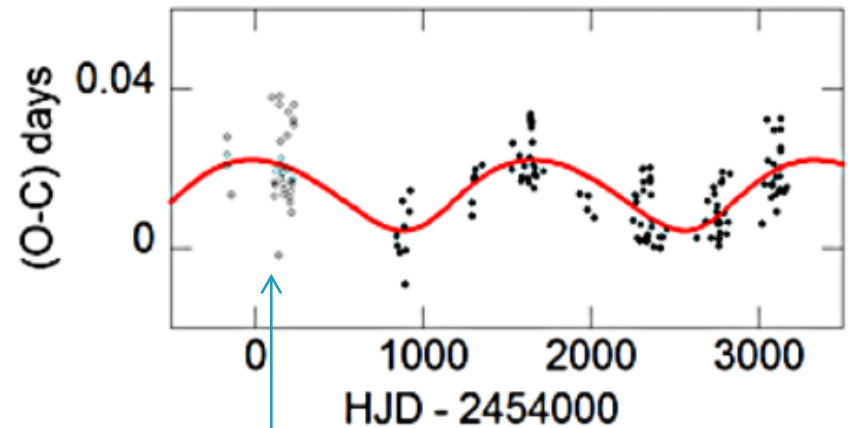
$$P_{\text{orb}} = 1,676 \text{ d} = 4.59 \text{ years}$$

$$e = 0.22$$

$$\omega = -0.978 \text{ rad}$$

$$T_{\text{peri}} = 2455006 \text{ HJD}$$

$$\tau_0 = 0.0117 \text{ d}$$



- Radial velocity 10 km/s

WASP data

Secondary star mass estimation

- Assuming $0.7 M_{\odot}$ for the RR Lyrae

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

<i>Orbital Inclination (degrees)</i>	<i>Secondary Mass (M_{\odot})</i>	<i>a_{RRL} (AU)</i>	<i>a_s (AU)</i>
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

- ① To confirm TU Com binary system, spectroscopic radial velocity measurement would be required.
- ① A challenge as the radial velocity is low (10km/s) and impacted by pulsation and motion of the atmospheric layers of the RR Lyrae.
- ① 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.