

# V402 LAC, A MYSTERIOUS ECLIPSING BINARY

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Eclipsing binary (EB) systems showing double lines in their spectra are excellent sources of knowledge about structure and evolution of stars. The analysis of photometric and spectroscopic data in such double systems provides very accurate values for the absolute properties of both stars, as well as clues about their internal structure, their formation process and the possible existence of other bodies altering their motion.

V402 Lac is a V=6.7 mag binary system with two B9 type stars at a distance of 240 pc from the Sun, classified as an Algol-type EB since Hipparcos observations. In our work we are using light curves and radial velocity data in order to obtain the parameters of the binary system through an analysis with the Wilson-Devinney (WD) code. The first results, using independently the two types of data, show a clear discrepancy in some orbital parameters, which is also reproduced by new observations. Our study also revealed the existence of apsidal movement in the system, and all the times of minima are being used in order to characterize it through an O-C diagram.

We are dealing with a very interesting EB with no solution for the moment. The photometric observations scheduled for late 2010 can be decisive to solve the orbit of the system and then be able to obtain accurate values of the physical properties of the stars.

## Eclipsing Binary stars

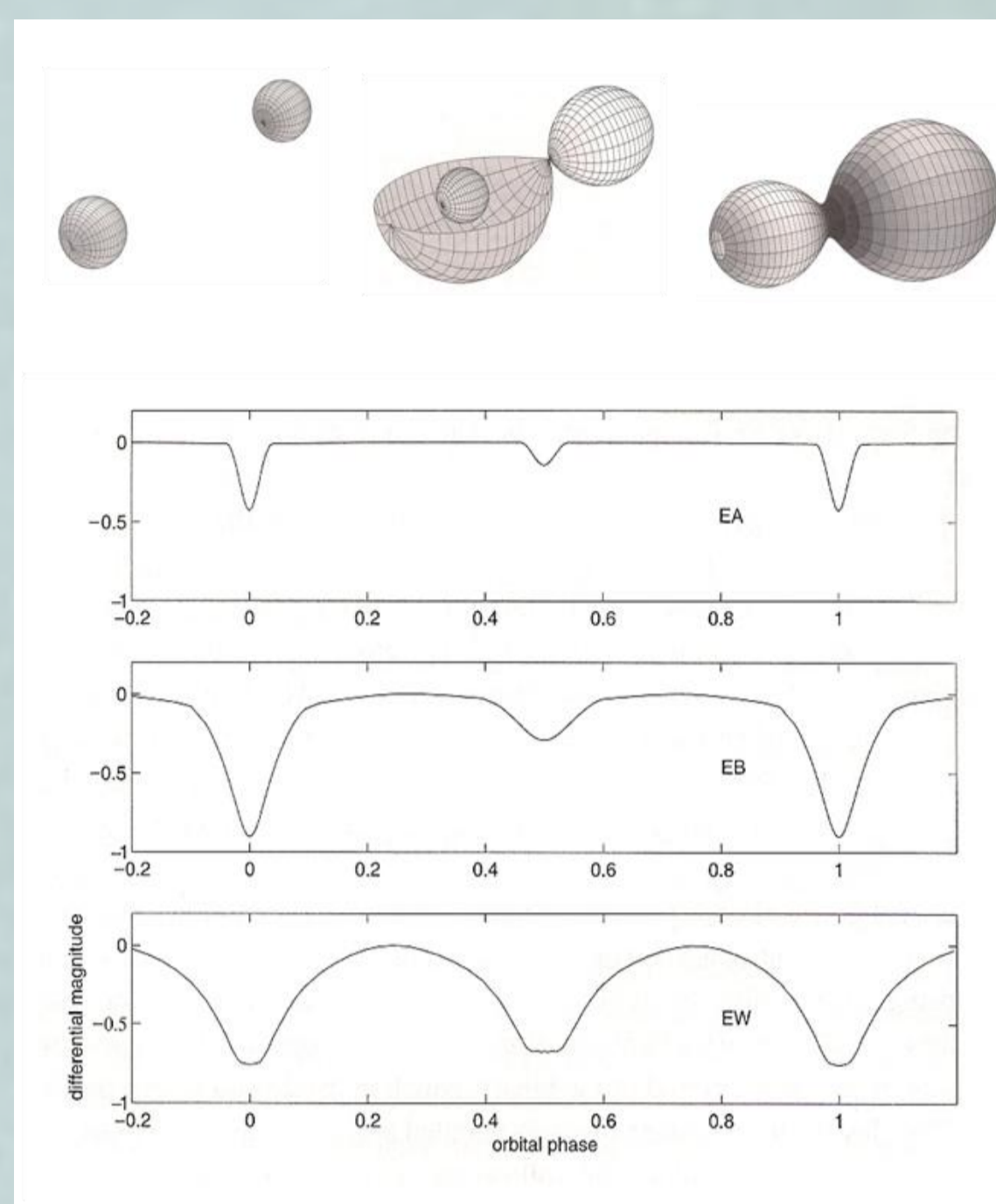
If the orbital plane is near our vision sight, binary stars can show periodic eclipses observable as overall decreases in brightness.

The shape of the light curve of an EB depends on some properties of the system, such as orbit parameters and relative radius, luminosities and temperatures of the stars.

If there are also available radial velocity measurements from spectroscopy, then a deeper analysis is possible and most of the physical parameters can be calculated.

This combination of photometry and spectroscopy is the only way to obtain direct measurements of masses and sizes of the stars, without any calibration, and with uncertainties under 5%, allowing a critical test of stellar models.

From radius and temperature determinations, distances to double lined Ebs can be derived. In the last decade, extragalactic Ebs have been used to determine extragalactic distances (LMC, Guinan et al 1998; M31, Ribas et al 2005; Vilardell et al., 2006, among others).



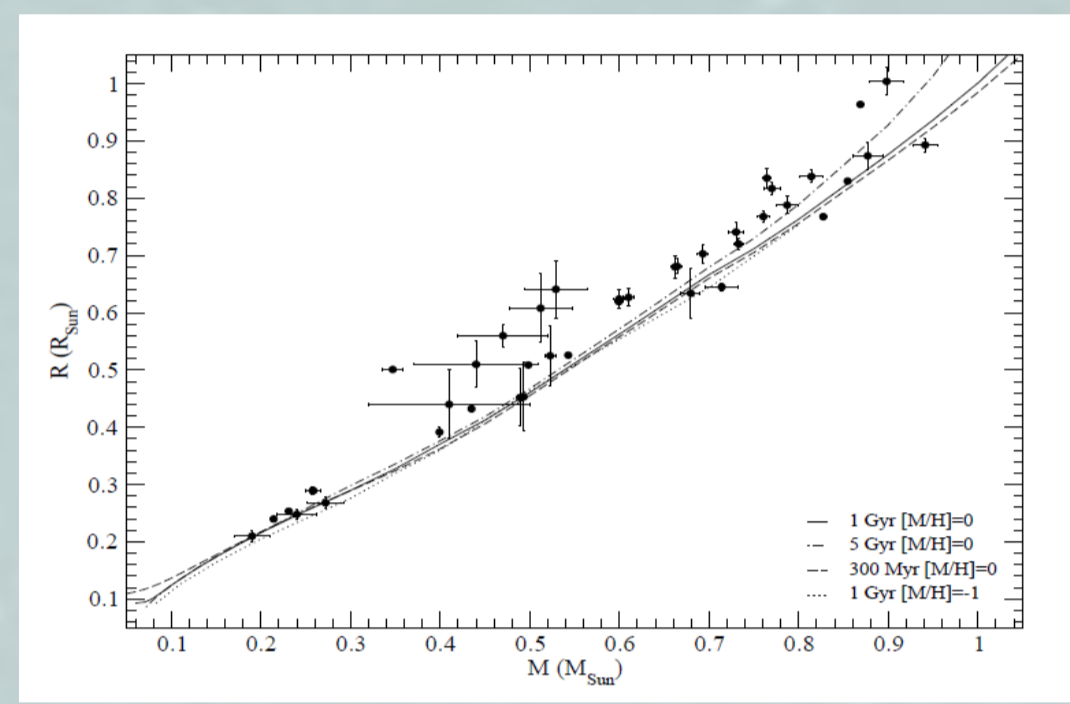
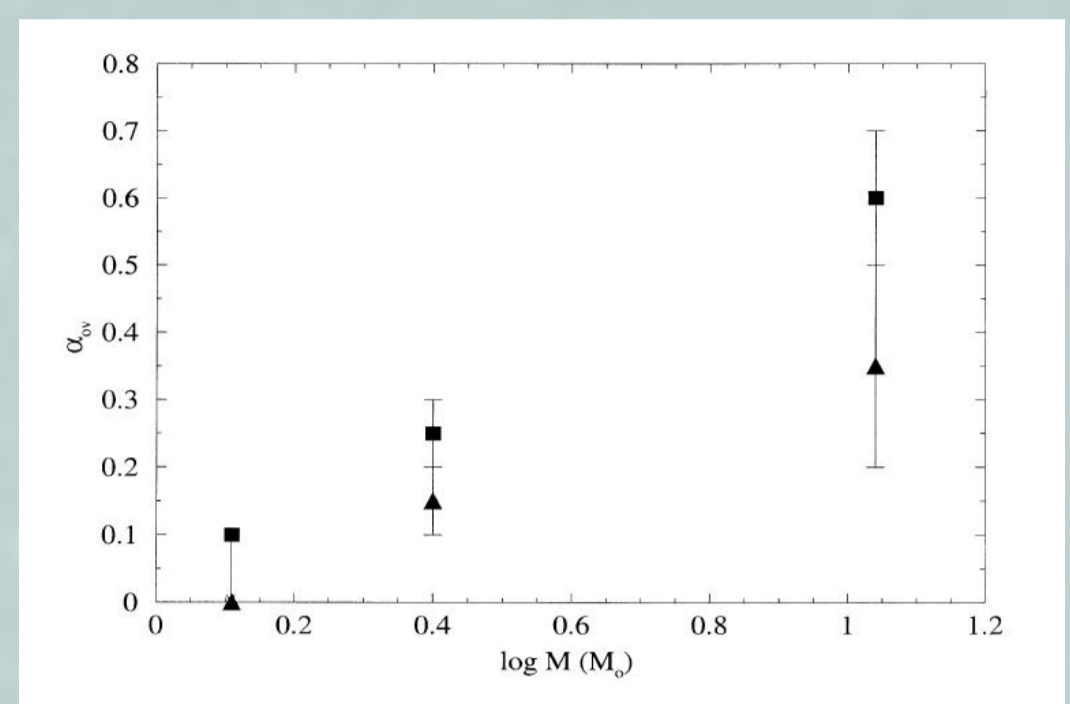
Types of eclipsing binaries: separated (EA), semi-separated (EB) and contact (EW).

## Stellar structure and evolutionary models

Accurate values for the physical properties of stars are essential to test stellar models.

For high-mass stars, there is not yet a theory that correctly describes convection in their nucleus and the importance of the overshooting, which could be a decisive parameter to determine their life time in the main sequence, and which shows a clear dependence with stellar mass (Ribas et al., 2000).

For low-mass stars, stellar models are still deficient in predicting fundamental properties such as radius and effective temperature. Morales et al. (2010) showed that the magnetic activity can be the explanation, although a larger sample of objects with accurate measured properties is required in order to firmly establish conclusions.



Comparison between stellar models and direct measurements obtained for a sample of low-mass stars in EB.

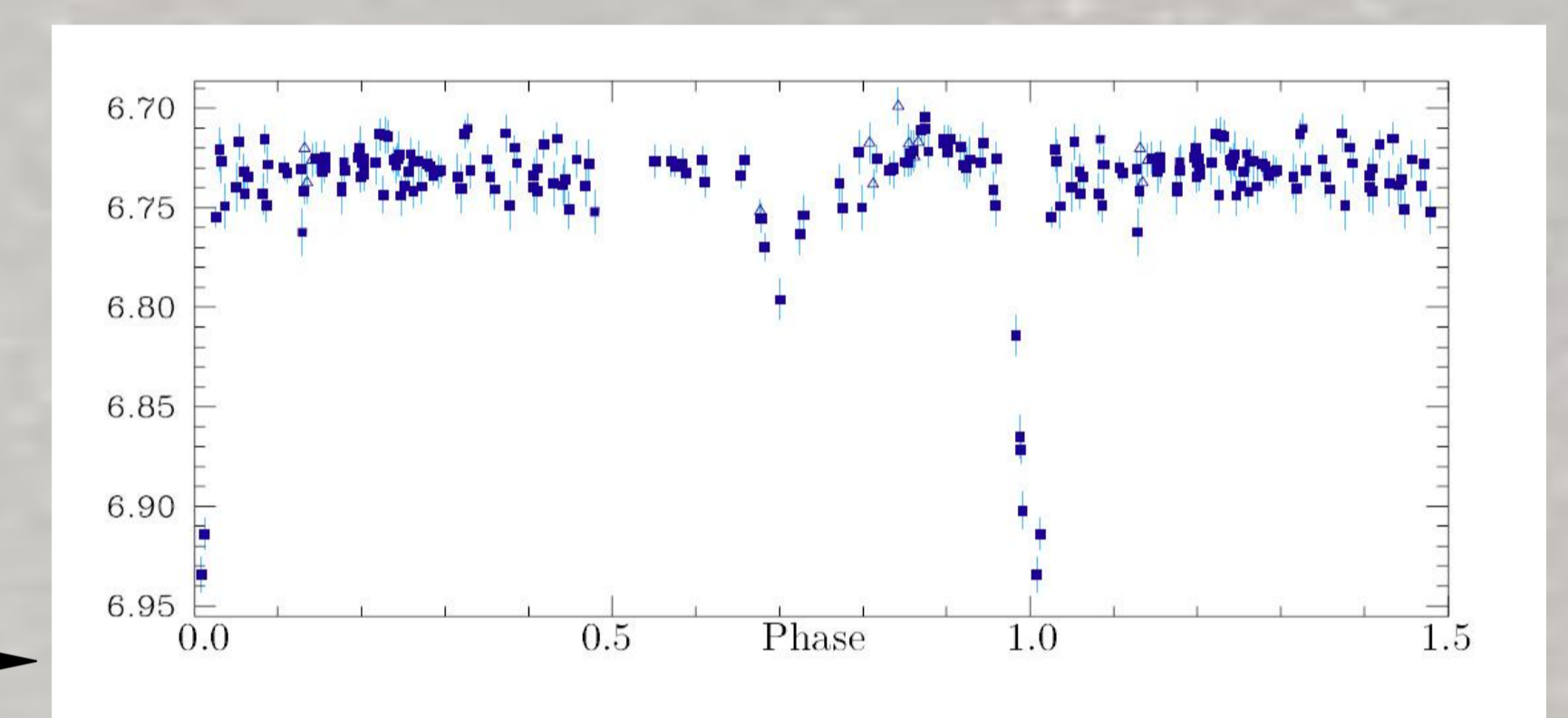
## V402 Lac

$\alpha = 22^{\text{h}} 09^{\text{m}} 15^{\text{s}}$ ,  $\delta = +44^{\circ} 50' 47''$ , V=6.73, B=6.69

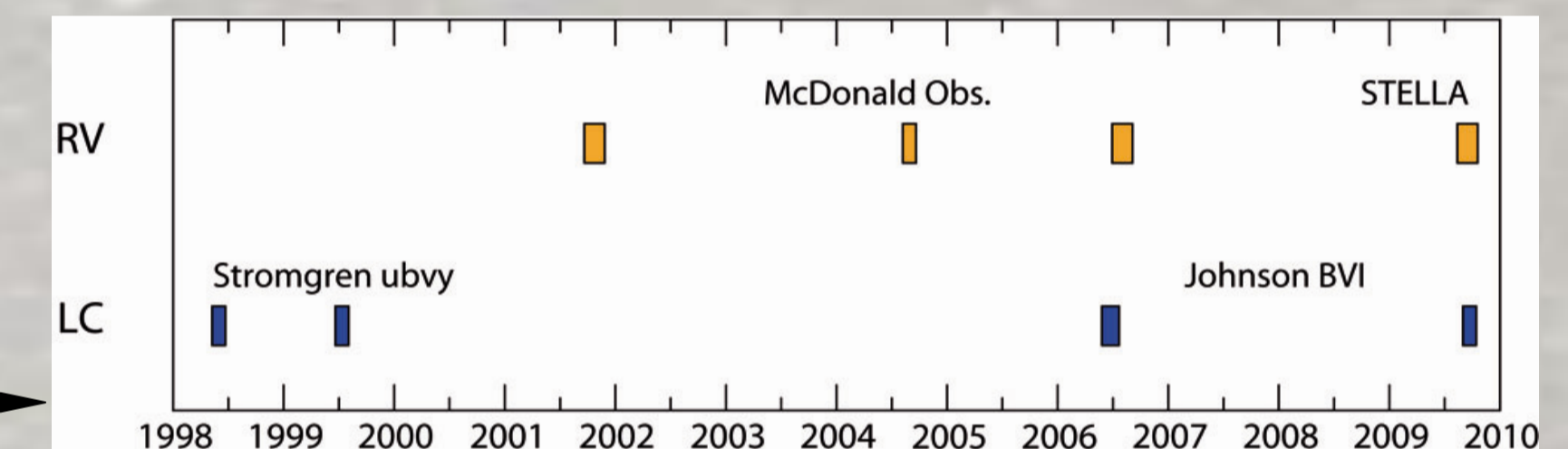
**Previous works:** Eggen (1963) discusses the possible physical relation between several components in the field of V402Lac. From the Hipparcos light curve (right), V402Lac was first classified as a detached EB. Some recent papers present photometric times of minima (Hegedus et al. 2003, Bulut & Demircan 2003) and a parameter analysis with EBOP (Bulut & Demircan 2008).

**New data:** Our group has obtained photometric and spectroscopic data from several observatories in the past 12 years. The goal is to make a comprehensive study using a large number of accurate data, both radial velocities and light curves in several filters, to solve the orbit of the system and to derive physical properties of the stars.

Hipparcos light curve

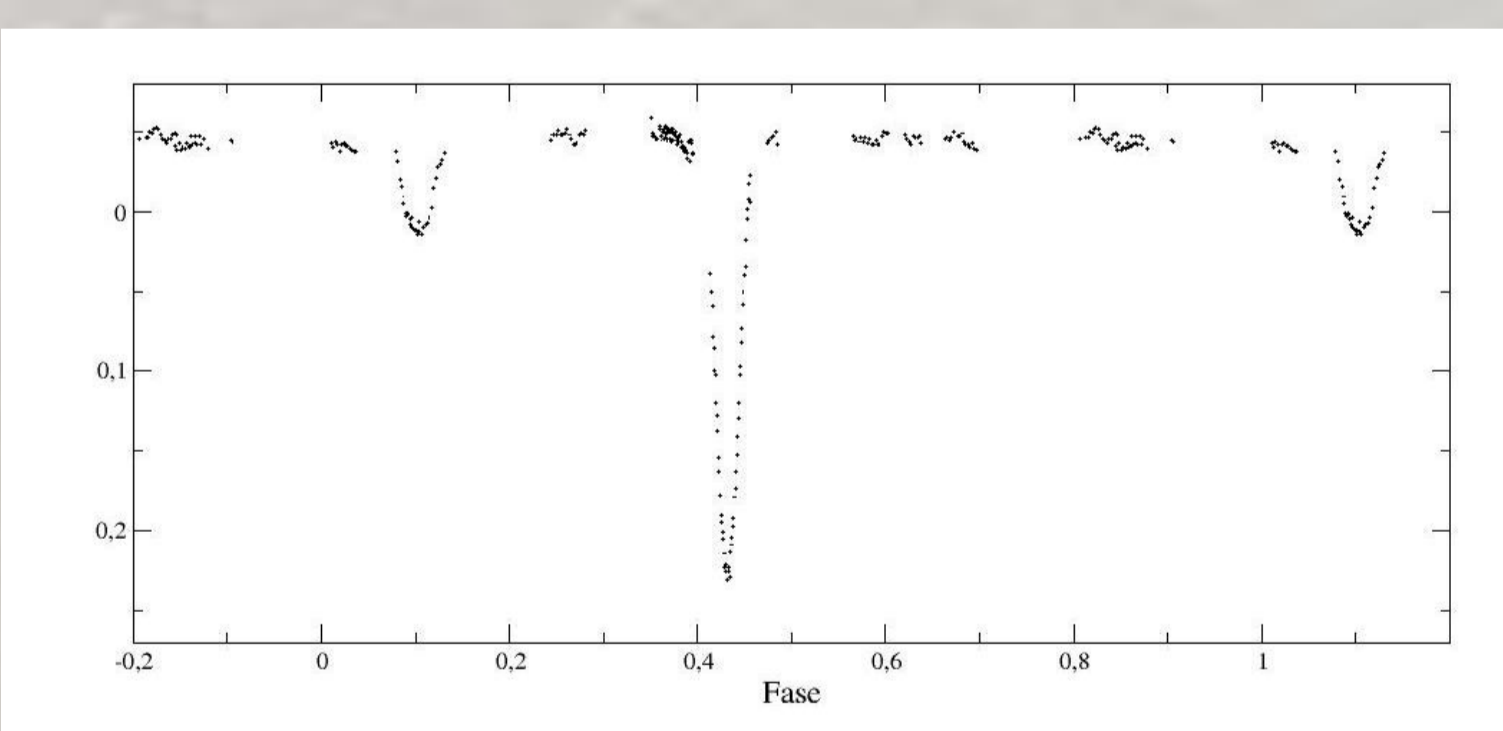


Times of new data acquisition: light curves (LC) in blue and radial velocities (RV) in orange.

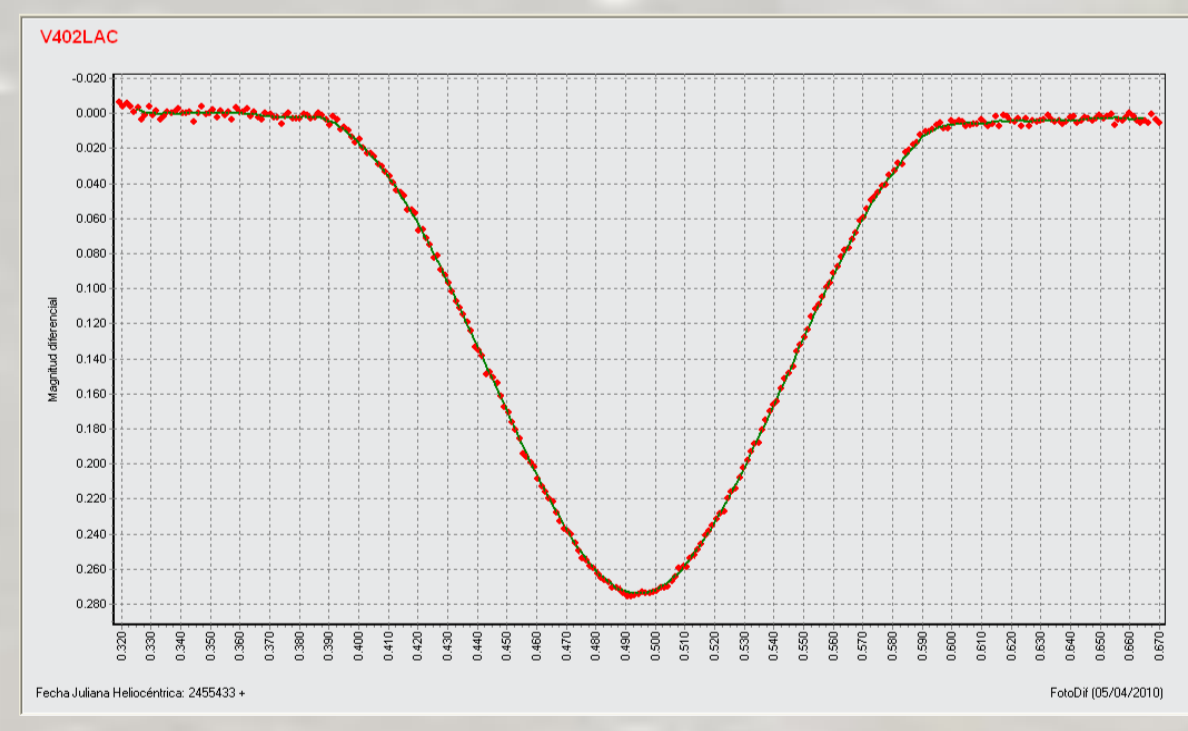


13' x 13' field centered on V402 Lac (POSSII).

Apart from the Hipparcos light curve, the rest of the photometry was acquired for this work. The Strömgren photometry was taken with the 0.90m telescope at OSN, simultaneously in uvby with a four-channel photometer. For Johnson photometry, CCD observations were carried out at several observatories, applying a defocus in order to increase exposure times and avoid the effects of scintillation.



Light curve in Johnson B filter from Obs. Esteve Duran.



Primary minimum photometry in Johnson B filter (R. Naves, Obs. Montcabrer)

## Photometry

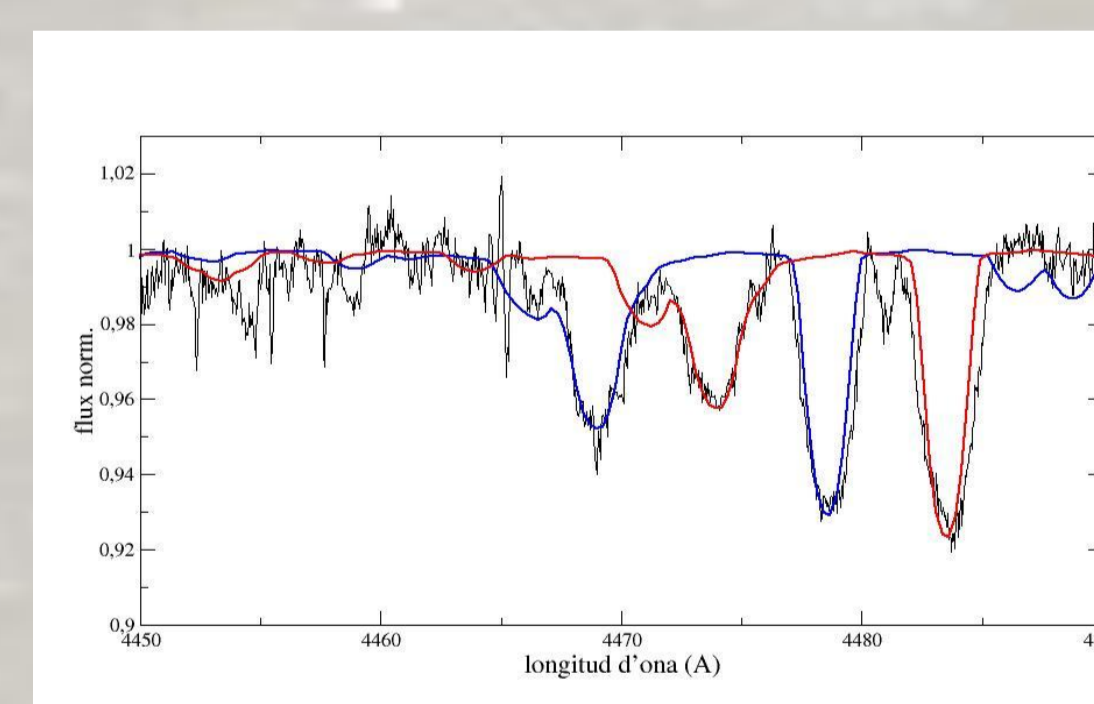
Hipparcos (1990 - 1992) — 156 measur.  
 Johnson BVI.  
 Obs. Esteve Duran (2006) — 250 measur.  
 Obs. Planes de Son (2009) — 330 measur.  
 Obs. Montcabrer (2009) — 150 measur.  
 Strömgren uvby.  
 Obs. Sierra Nevada (1998 - 1999) — 300 measur.

## Spectroscopy

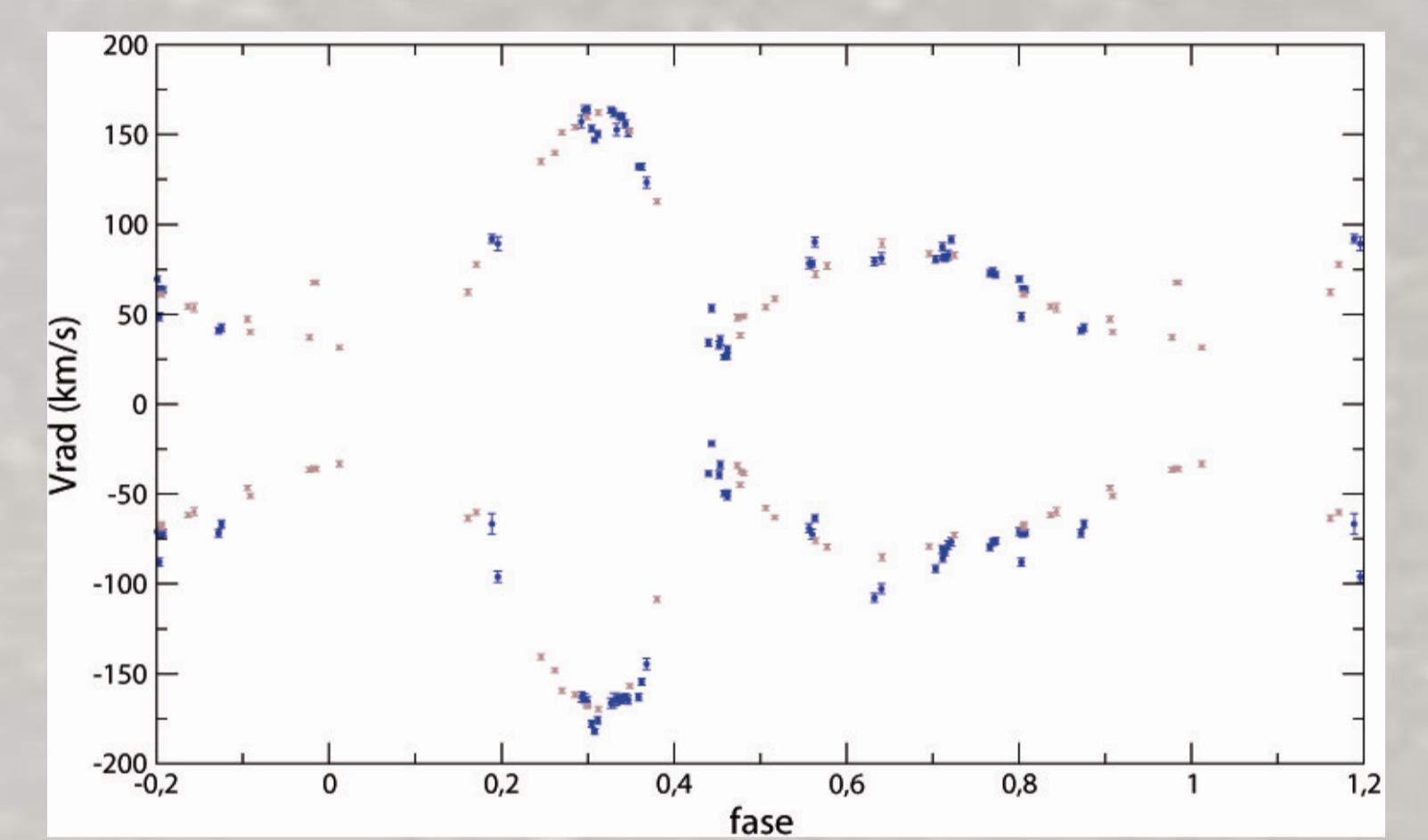
McDonald Obs. (2001 - 2006) — 31 measur.  
 Obs. STELLA (2009) — 45 measur.

Echelle spectra were reduced and several spectral regions were selected for radial velocity obtention.

A library of synthetic spectra was made from Kurucz atmosphere models and the two best spectra were chosen by visual comparison. Those were used for cross-correlation with TODCOR.

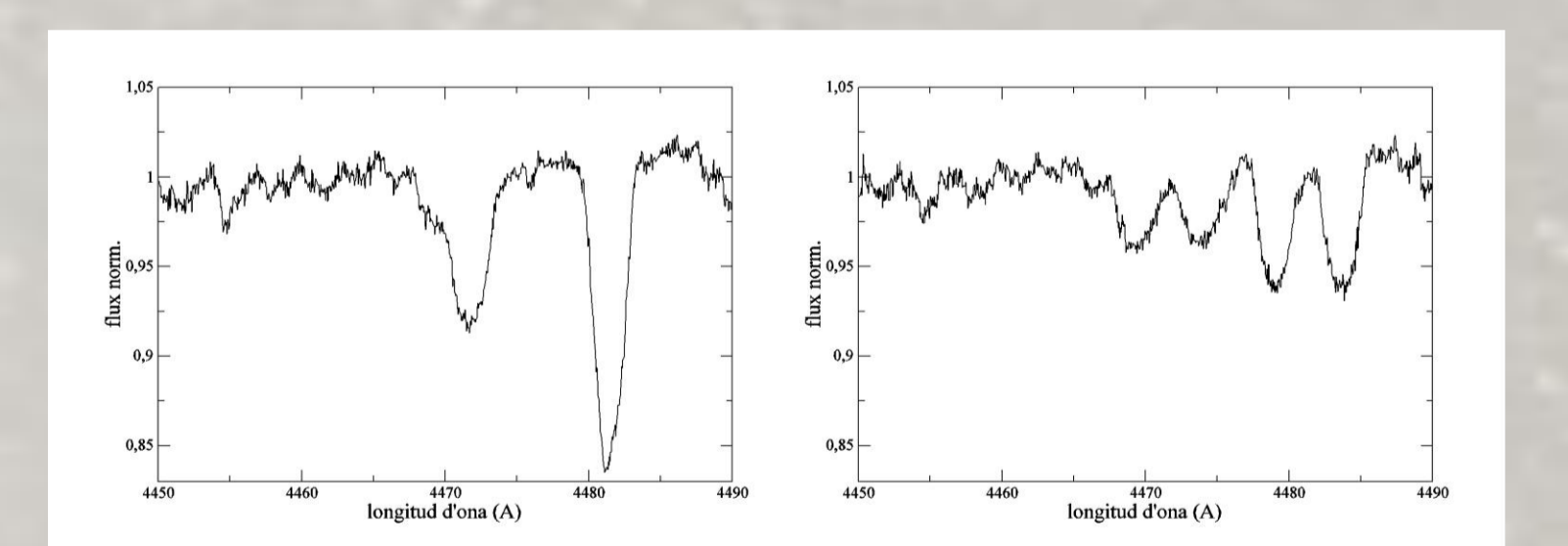


Observed spectra (black) with two superimposed synthetic spectra (blue & red).



Radial velocity curve, (McDonald Obs. measurements in brown and STELLA ones in blue).

The phase-folded radial velocity curve including all 76 points shows that both sets of measurements are consistent.



Spectral range containing He-Mg lines, used for radial velocity obtention with TODCOR.

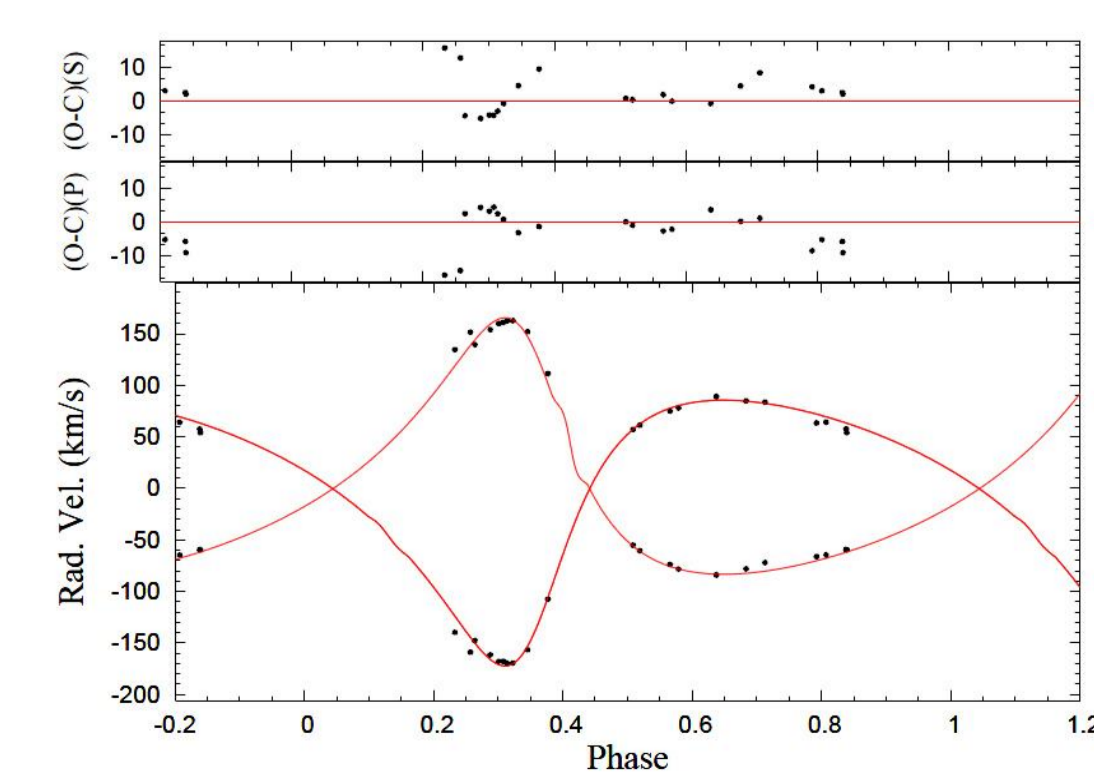
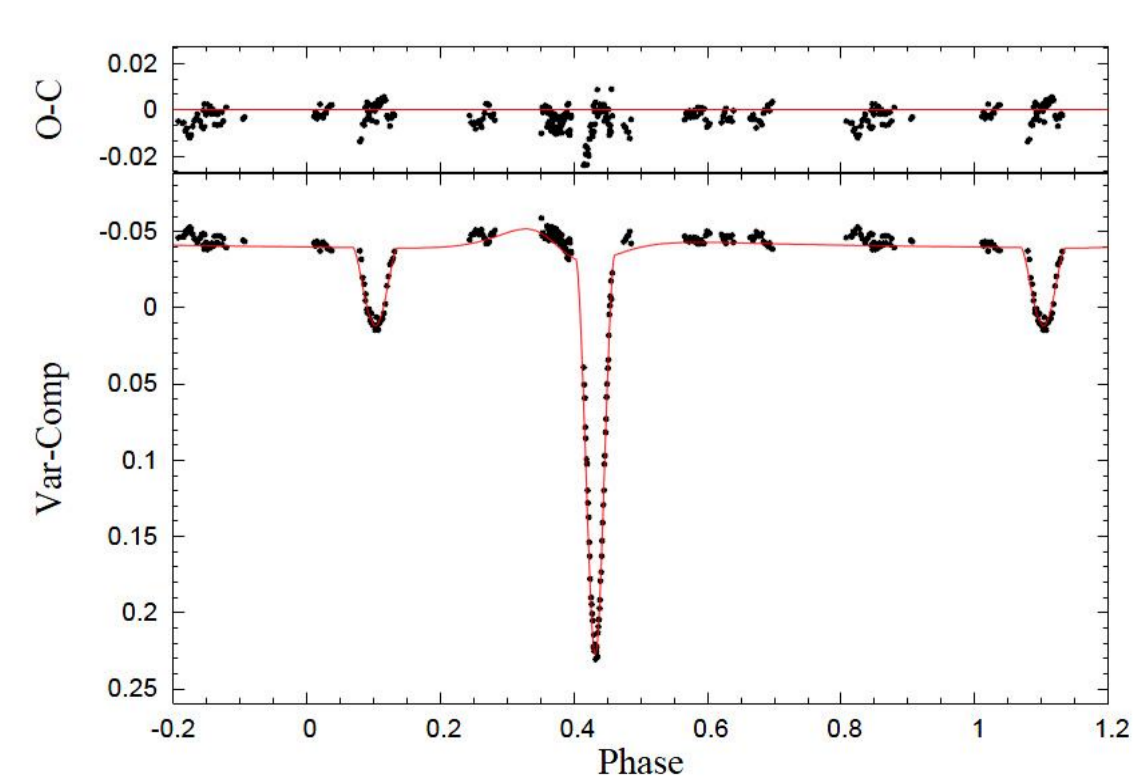
## Data Analysis

Parameter fitting using Wilson-Devinney code was done separately for light curves and radial velocity data.

The analysis has shown that we are dealing with a system of detached star of masses around  $2.9 M_{\odot}$  and  $3.1 M_{\odot}$  and temperatures around 11500 K. However, some of the orbital parameters still remain inconsistent between the two types of data. This problem has no solution for the moment.

Paràmetre	Valor
$P$	$3.7820448 \pm 0.0000011$ dies
$t_0$	$2455117.9323 \pm 0.0009$ (HJD)
$e$	$0.3619 \pm 0.0014$
$\omega_{inicial}$	$227.7 \pm 0.3^{\circ}$
$d\omega/dt$	$0.00244 \pm 0.00006$ $^{\circ}$ /dia
$i$	$79.60 \pm 0.02^{\circ}$
$T_1$	11250 K (fixada)
$T_2$	$11748 \pm 62$ K

Paràmetre	Valor
$P$	$3.781985 \pm 0.000015$ dies
$t_0$	$2455117.89802 \pm 0.008$ (HJD)
$e$	$0.448 \pm 0.007$
$\omega_{inicial}$	$224.9 \pm 1.3^{\circ}$
$m_2/m_1$	$0.969 \pm 0.015$
$a$	$17.60 \pm 0.15 R_{\odot}$
$V_0$	$-0.018 \pm 0.008$ km/s



## Conclusions & Future Work

-V402 Lac analysis is showing an intriguing discrepancy between light curve and radial velocity results, so there is not a satisfactory solution yet and it represents a very interesting object for further study. The case of DI Her (Albrecht et al 2009) could give us some clues.

-Apsidal motion analysis from times of minima has shown short-time variations. Photometric data are being taken during second-half of 2010 from several observatories for a study through an O-C diagram.

-The study of eclipsing binaries like V402 Lac is suitable for collaboration projects between professional and amateur astronomers.

## Related papers

Albrecht S., Reert S., Snellen I.A.G., Winn J.N., Sep. 2009, Nature, 461, 373  
 Bulut I., Demircan O., 2003, Information Bulletin on Variable Stars, 5476, 1  
 Bulut I., Demircan O., 2008, New Astronomy, 13, 252  
 Egen O.J., 1963, AJ, 68, 483  
 Guinan E.F., Fitzpatrick E.L., Dewarf L.E., et al., 1998, ApJ, 509, L21  
 Hegedus I., Borkovits T., Biro I.B., et al., 2003, Information Bulletin on Variable Stars, 5372, 1  
 Morales J.C., Gallardo J., Ribas I., Jordi C., Baraffe I., Chabrier G., 2010, ApJ, 708, 502  
 Ribas I., Jordi C., Giménez A., 2000, MNRAS, 318, L55  
 Vilardell F., Ribas I., Jordi C., 2006, A&A, 459, 321

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