hamburger sternwarte

Rossiter-McLaughlin-Effect in α CrB

J. Schmitt

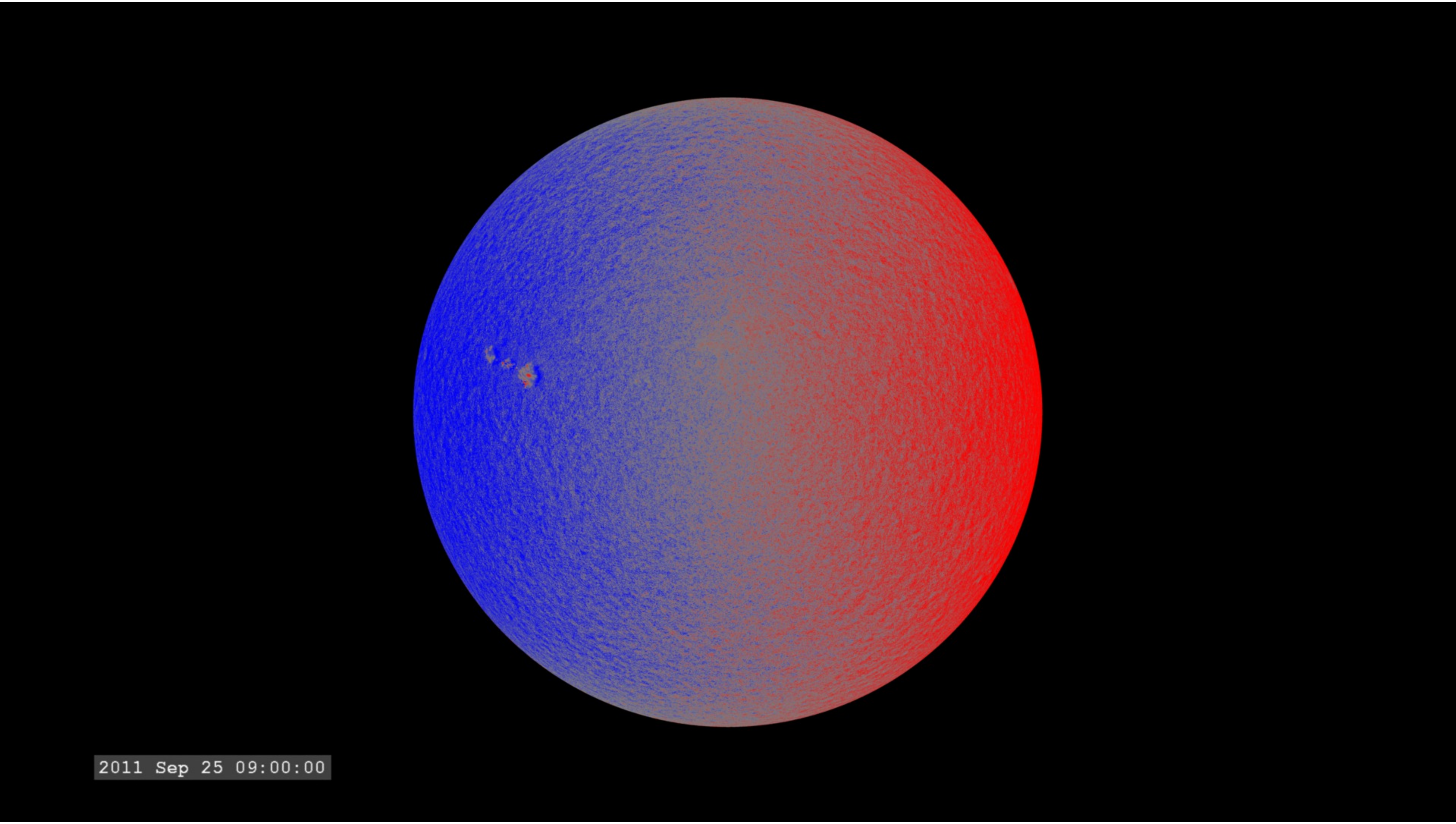
Email: jschmitt@hs.uni-hamburg.de

Internet: http://www.hs.uni-hamburg.de

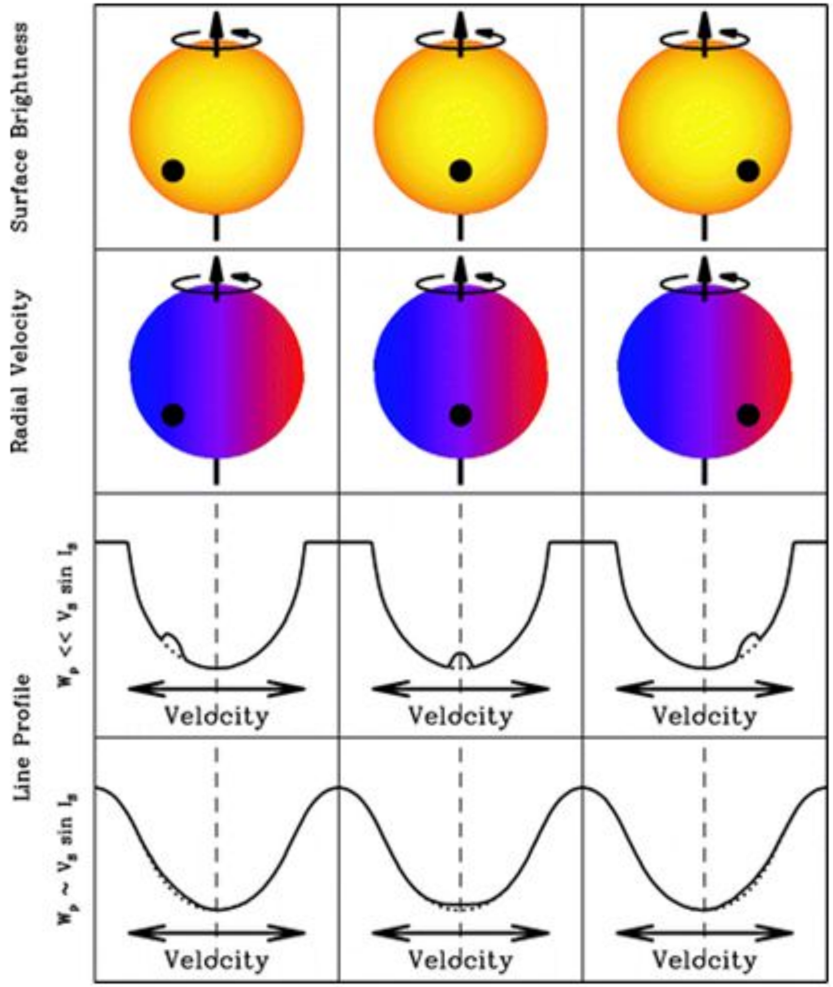
Topics:

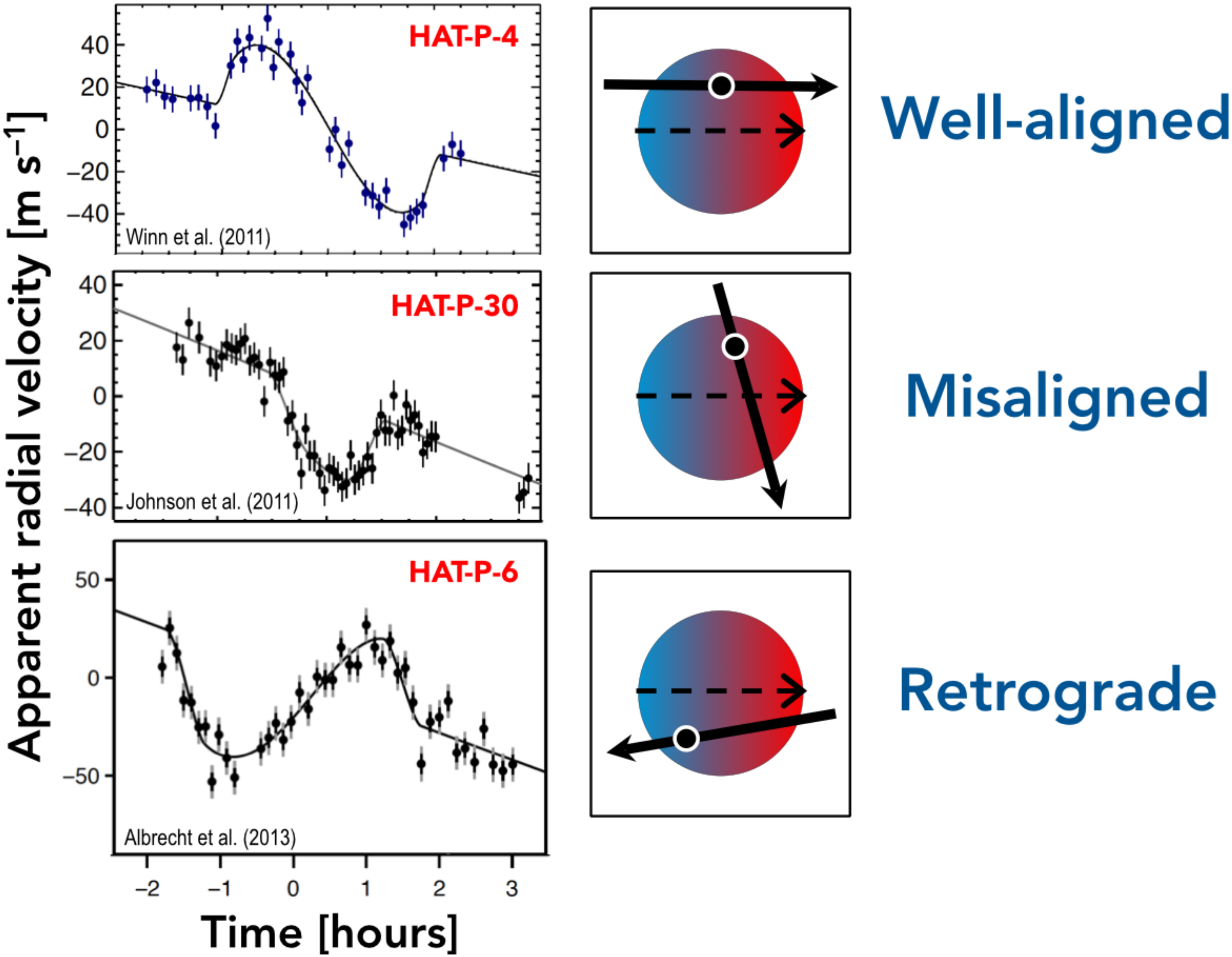
- The Rossiter-McLaughlin-Effect
- What is the RMcL-Effect used for ?
- RMcL-Effect in α CrB
- Conclusions

MDI Dopplergram of Sun



The Rossiter-McLaughlin Effect or „Rotation Effect“

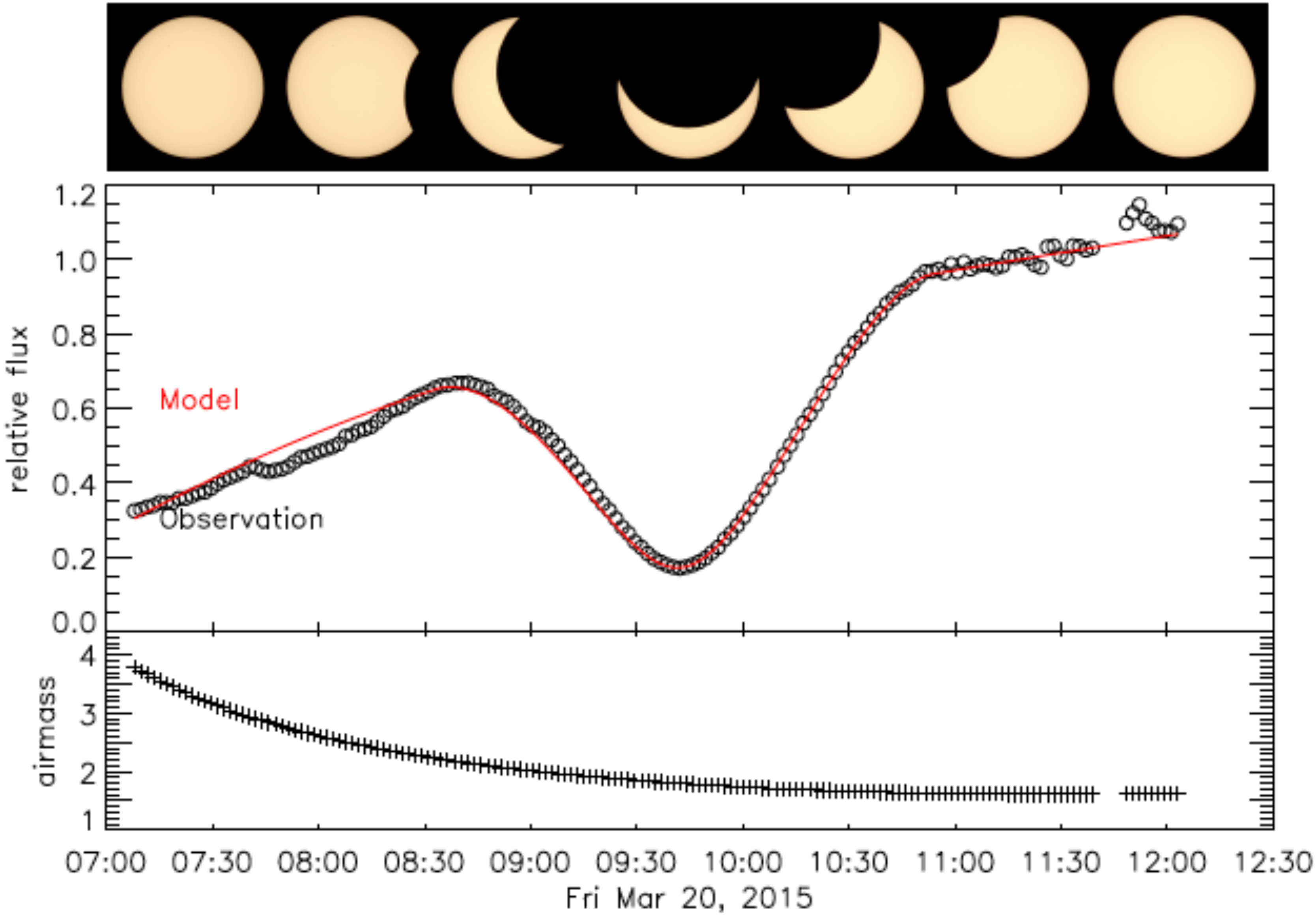




HAT-P-4
Winn et al. (2011)
HAT-P-30
Johnson et al. (2011)
HAT-P-6
Albrecht et al. (2013)
Apparent radial velocity [m s^{-1}]
Time [hours]
Well-aligned
Misaligned
Retrograde

A really big planet ....

Reiners et al. (2016)



Reiners et al. (2016)

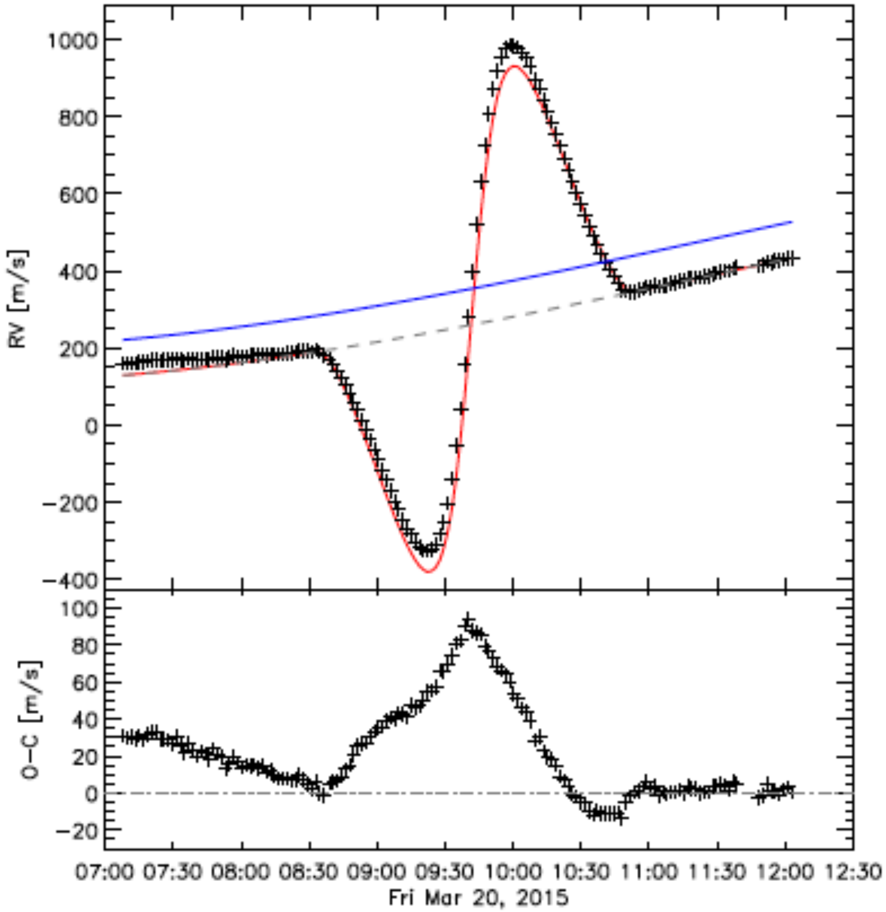


Fig. 5. Observations of solar RVs during the eclipse together with the standard line model 1. *Top panel*: black plus symbols show our solar RV observations. The red line shows results from our model corrected for an offset so that they match observations after the end of the eclipse (see text). The gray dashed line shows the eclipse-free model (only barycentric motion). The blue line shows barycentric motion from JPL's ephemeris. *Bottom panel*: residuals between observations and model (black symbols minus red curve in top panel).

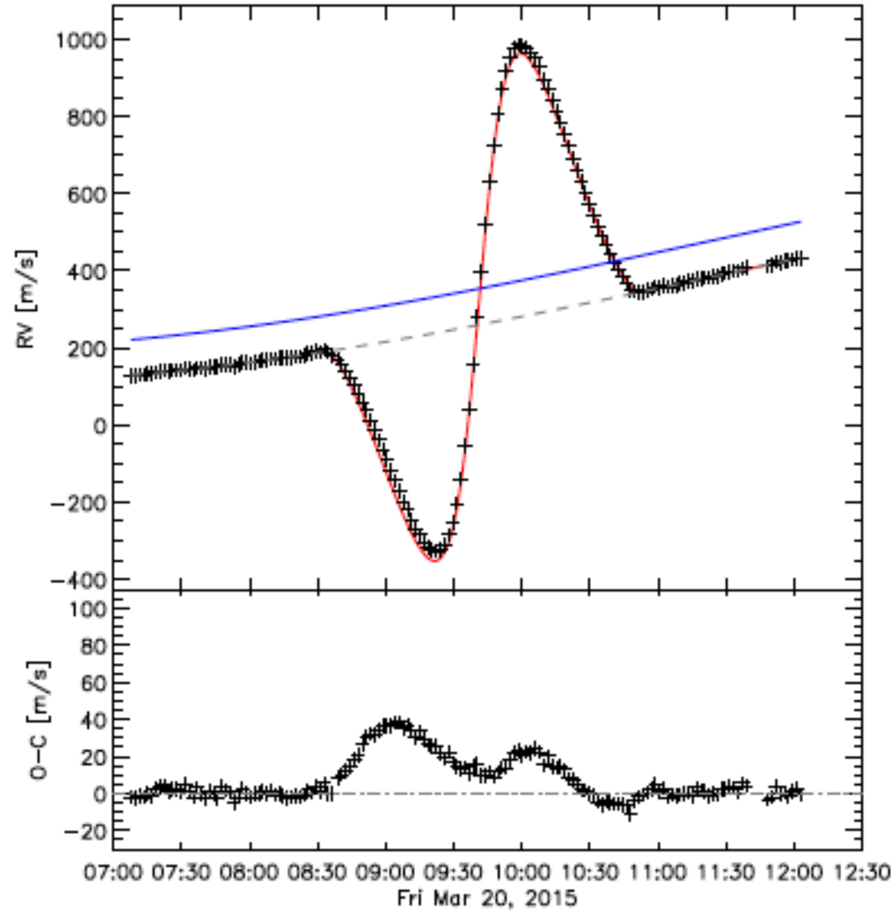


Fig. 6. Observations of solar RVs during the eclipse together with results from model 1 including convective blueshift. Lines and symbols are the same as in Fig. 5. Here, the model velocities (red line) match the solar observations without any offset.

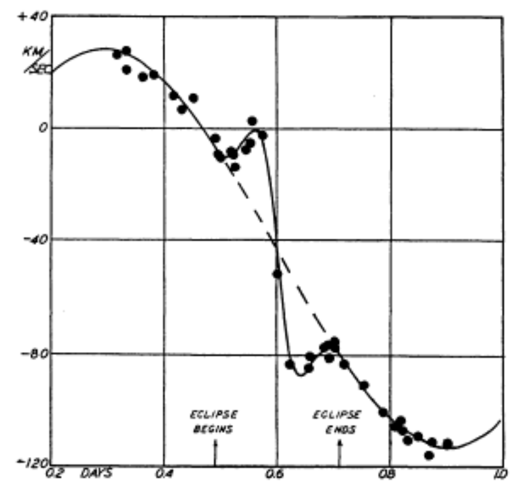
We therefore suspect that the source of the RV "noise" in our observations of the Sun as a star is in fact solar granulation.

Petrie (1938)

„Rotation“-Effect in RZ Cas

mid-eclipse there is an excess of rotational motion of approach, hence the measured velocities are more negative than pure orbital motion would predict and they fall below the curve.

The interest and importance of this "rotation effect" lie in the result that, upon certain assumptions, we may from it secure the size of the star being eclipsed. Having this dimension we may then, by combining photometric and spectroscopic data, secure the masses and densities of the stars and the absolute dimensions of the



ROTATION-EFFECT UPON RADIAL VELOCITIES IN RZ CASSIOPIAE

Fig. 1.

system. These data are of great importance since they are available for only a very few stars and are necessary to our understanding of stellar structure and evolution. In the case of an eclipsing binary showing only one spectrum an investigation of the rotation effect is, at present, the only means of securing the dimensions.

The rotational deviation from orbital motion gives us the equatorial velocity of rotation of the eclipsed star and finally its size, but in this study we require the calculation of a quantity called the "rotation-factor". This is a mean value of the rotational velocity, in the line of sight, in terms of the equatorial velocity,

THE APSIDAL MOTION OF THE ECCENTRIC ECLIPSING BINARY DI HERCULIS—AN APPARENT DISCREPANCY WITH GENERAL RELATIVITY

EDWARD F. GUINAN[a] AND FRANK P. MALONEY[a]

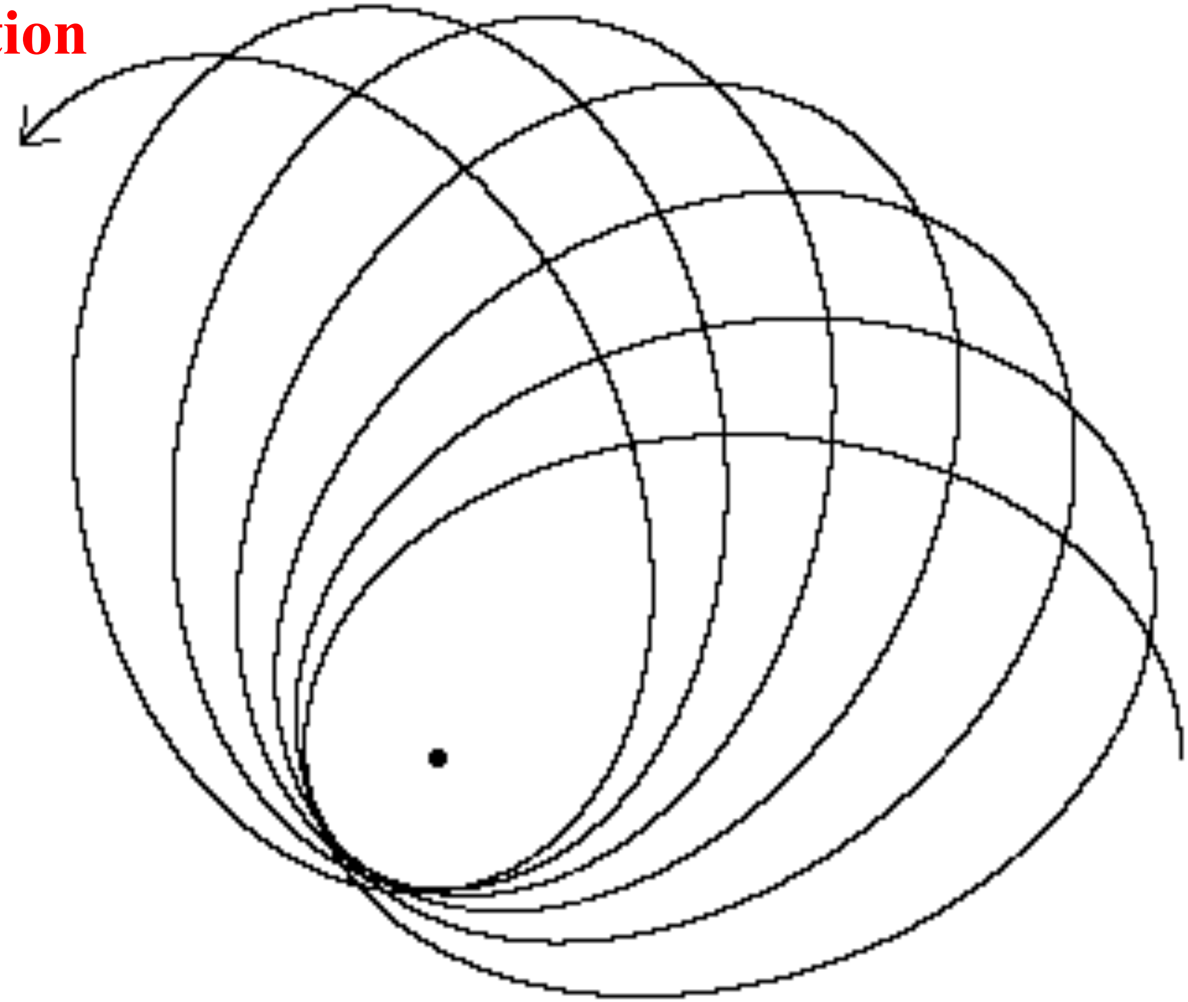
Department of Astronomy and Astrophysics, Villanova University, Villanova, Pennsylvania 19085

Received 10 December 1984; revised 2 April 1985

ABSTRACT

In 1959, Rudkjøbing called attention to the 8th magnitude, eccentric eclipsing binary DI Herculis as an important test case for studying relativistic apsidal motion, since the theoretical relativistic apsidal motion is greater than that expected from the classical effects (i.e., from the tidal and rotational deformation of the stellar components). Excellent determinations of the orbital and stellar parameters of the system have been made by Popper (1982) from the combined analysis of the system's radial-velocity data and *UBV* light curves of Martynov and Khaliullin (1980), which permit the theoretical relativistic and classical components of the apsidal motion to be determined with reasonable certainty: $\dot{\omega}_{\rm GR}^{\rm theor} = 2\overset{\circ}{.}34/100$ yr and $\dot{\omega}_{\rm CL}^{\rm theor} = 1\overset{\circ}{.}93/100$ yr. Least-squares solutions of the timings of primary and secondary minima, extending over an 84-yr interval, and including eclipse timings obtained as recently as 1984, yield a small advance of periastron $\dot{\omega}^{\rm obs} = 0\overset{\circ}{.}65/100$ yr $\pm\, 0\overset{\circ}{.}18/100$ yr. The observed advance of the periastron is about one-seventh the theoretical value of $\dot{\omega}_{\rm GR+CL}^{\rm theor} = 4\overset{\circ}{.}27/100$ yr that is expected from the combined relativistic and classical effects, and results in a discrepancy of $-3\overset{\circ}{.}62/100$ yr, a value which has a magnitude of $\sim 20\,\sigma$. Classical mechanisms that can possibly explain this apparent discrepancy are discussed, along with the possibility that there may be problems with general relativity.

Apsidal motion



Can be due to GR
Tidal deformation
Rotational flattening ....

The whole truth is here .... (Shakura 1985)

$$\frac{d\omega}{dt} = \left(\frac{d\omega}{dt}\right)_E + \bar{\omega} 15 f(e)\left[k_1 r_1^5 \frac{M_2}{M_1} + k_2 r_2^5 \frac{M_1}{M_2}\right]$$

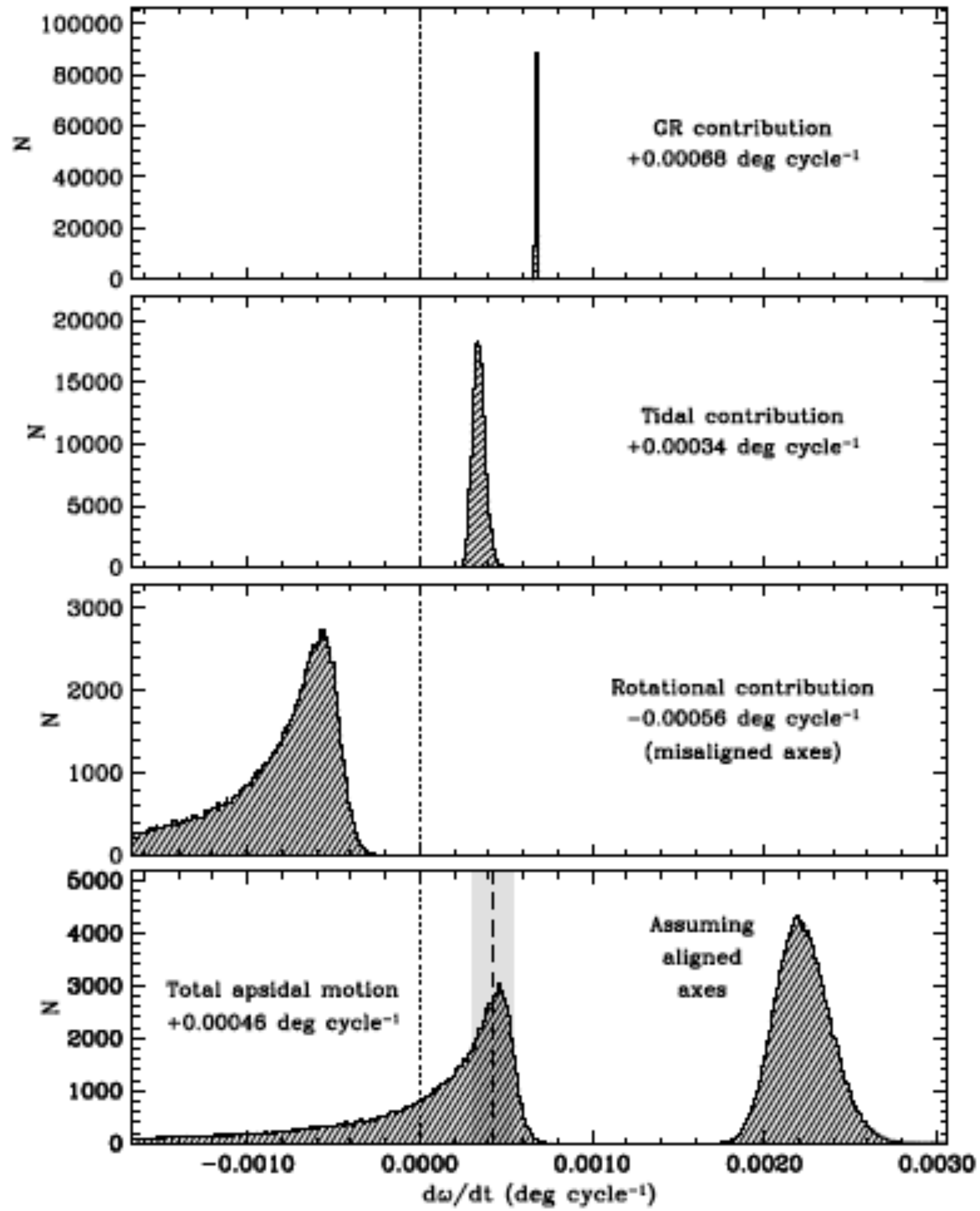
$$- \frac{\bar{\omega}}{\sin^2 i\,(1-e^2)^2}\left\{k_1 r_1^5 \left(\frac{\omega_1}{\bar{\omega}}\right)^2 \left(1+\frac{M_2}{M_1}\right)\right.$$

$$\times \left[\cos\alpha_1 (\cos\alpha_1 - \cos\beta_1 \cos i) + \frac{1}{2}\sin^2 i\,(1-5\cos^2\alpha_1)\right]$$

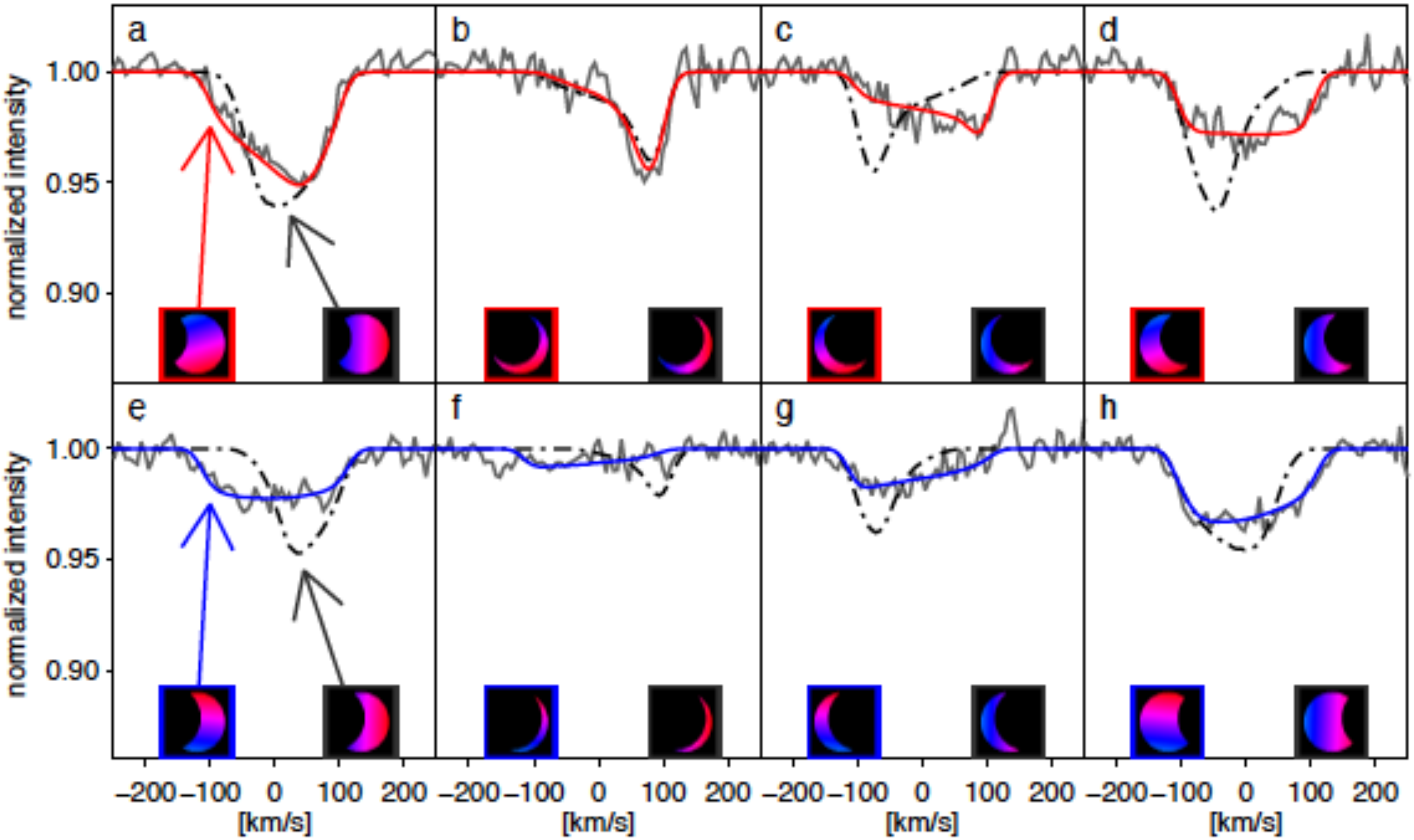
$$+ k_2 r_2^5 \left(\frac{\omega_2}{\bar{\omega}}\right)^2 \left(1+\frac{M_1}{M_2}\right)\left[\cos\alpha_2 (\cos\alpha_2 - \cos\beta_2 \cos i)\right.$$

$$\left.\left. + \frac{1}{2}\sin^2 i\,(1-5\cos^2\alpha_2)\right]\right\};$$

Claret et al. (2010)



Albrecht et al. (2009)



Coming to α CrB

PUBLICATIONS OF THE OBSERVATORY

OF THE UNIVERSITY OF MICHIGAN

VOLUME V, NO. 7.

PUBLISHED FROM THE LAWTON FUND.

THE ORBIT AND ROTATION EFFECT OF ALPHA CORONAE BOREALIS.

By Dean B. McLaughlin.

Properties of α CrB

Eclipsing binary

two line systems visible

K_1 = 99 km/sec, K_2 = 35.5 km/sec, ε = 0.37,

P = 17.3599 days, i = 88°

RMcL-effect expected in both components

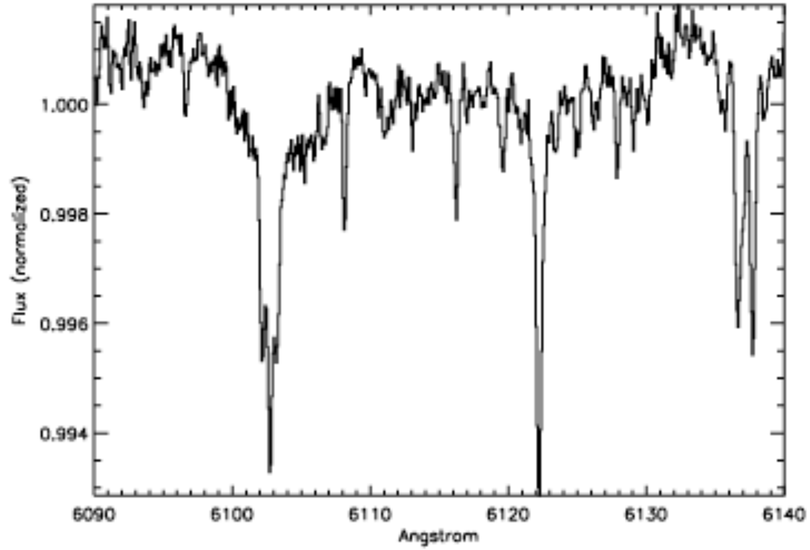
$M_1/M_2 = 2.79$

$M_{total} = 3.5\ M_\odot$

$M_2 = 0.92\ M_\odot$

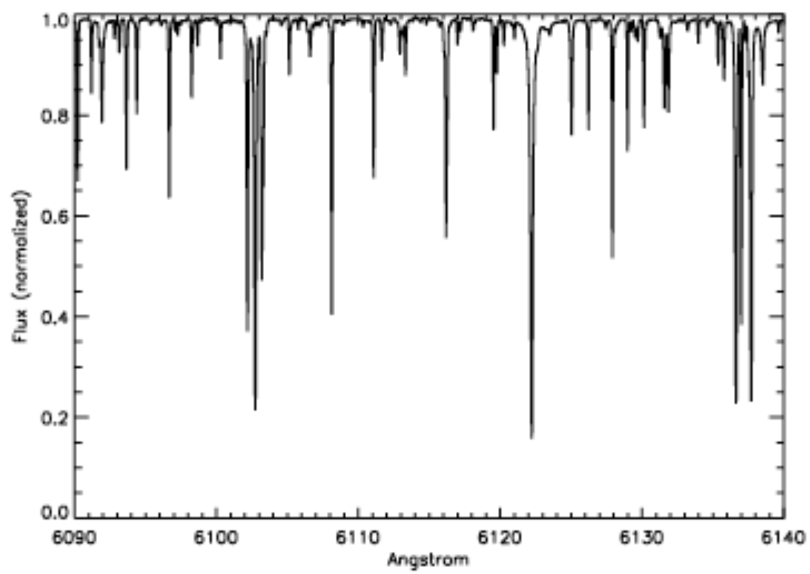
$M_1 = 2.58\ M_\odot$

Schmitt et al. (2016)



α CrB (TIGRE)

Fig. 1. Coadded TIGRE spectrum of α CrB in the spectral region 6090–6140 Å. The sharp lines are all due to the secondary component; cf., Fig. 2 and discussion in text.



Sun (Liege)

Fig. 2. High-resolution solar spectrum in the spectral region 6090–6140 Å taken from Delbouille et al. (1990) and Delbouille & Roland (1995); see text for discussion.

Schmitt et al. (2016)

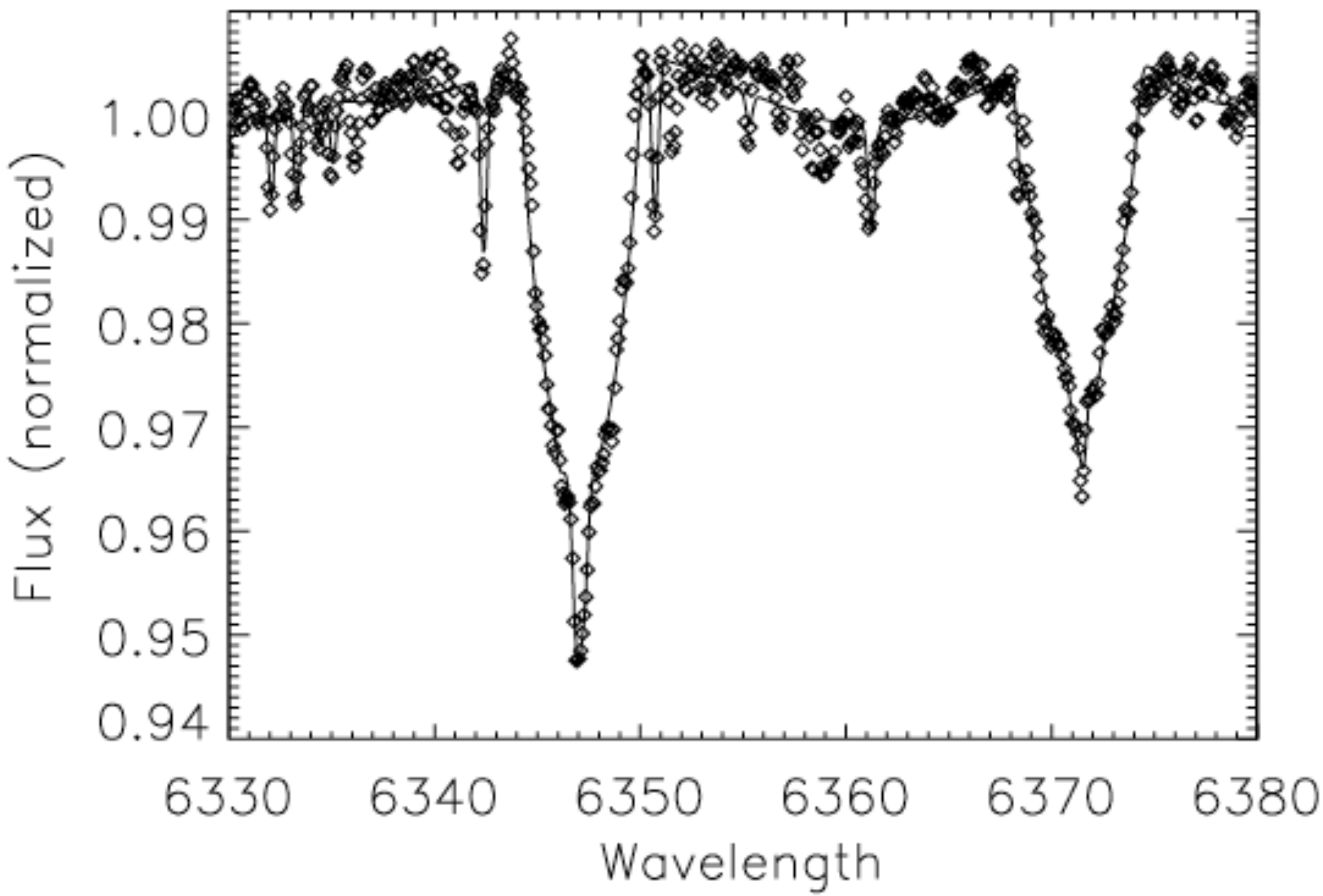
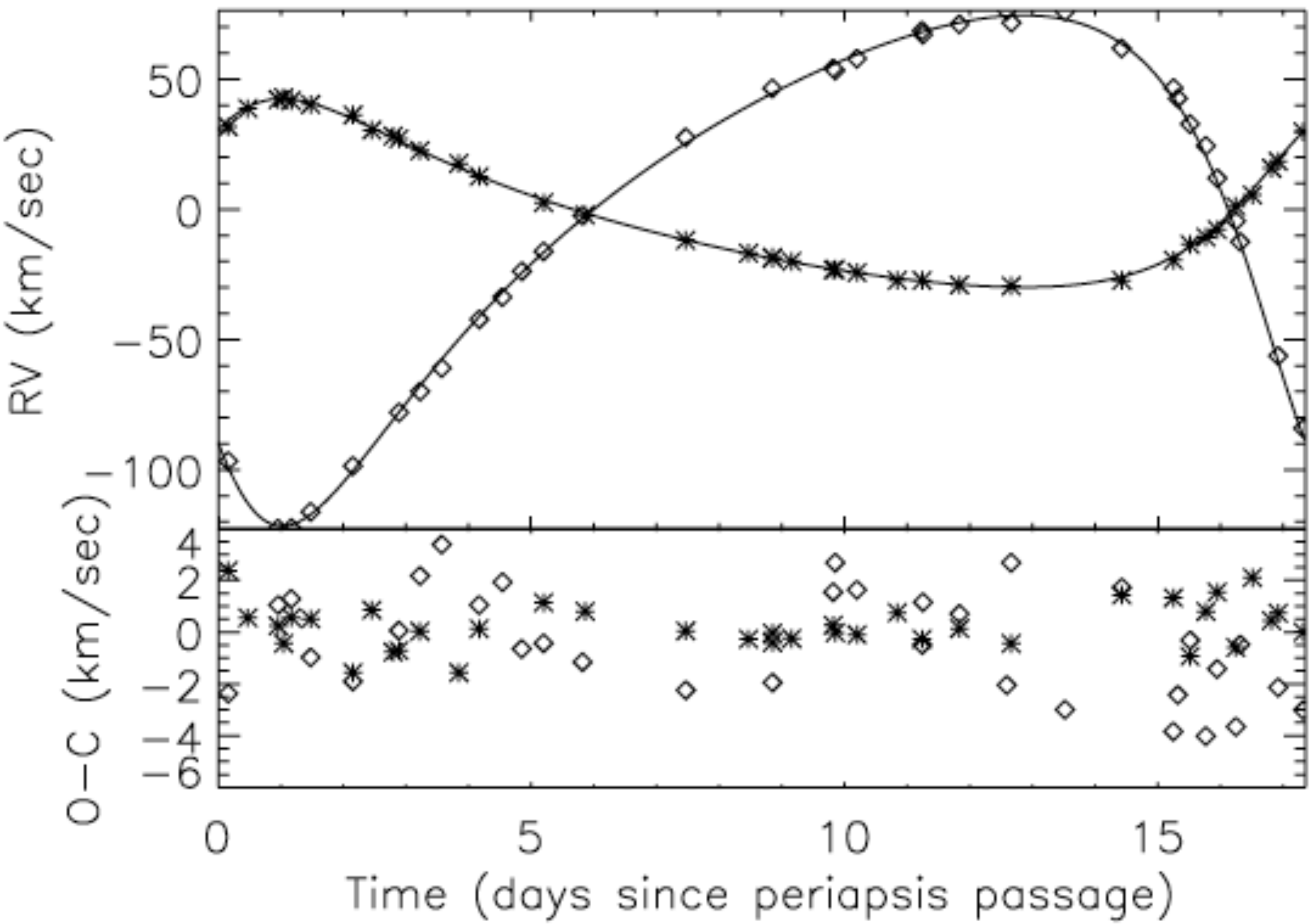


Fig. 3. TIGRE spectrum of α CrB in the spectral range 6330–6380 Å together with model fit; the sharp lines are telluric, the two broad lines are produced by Si II; see text for details.

Schmitt et al. (2016)



McLaughlin (1934)

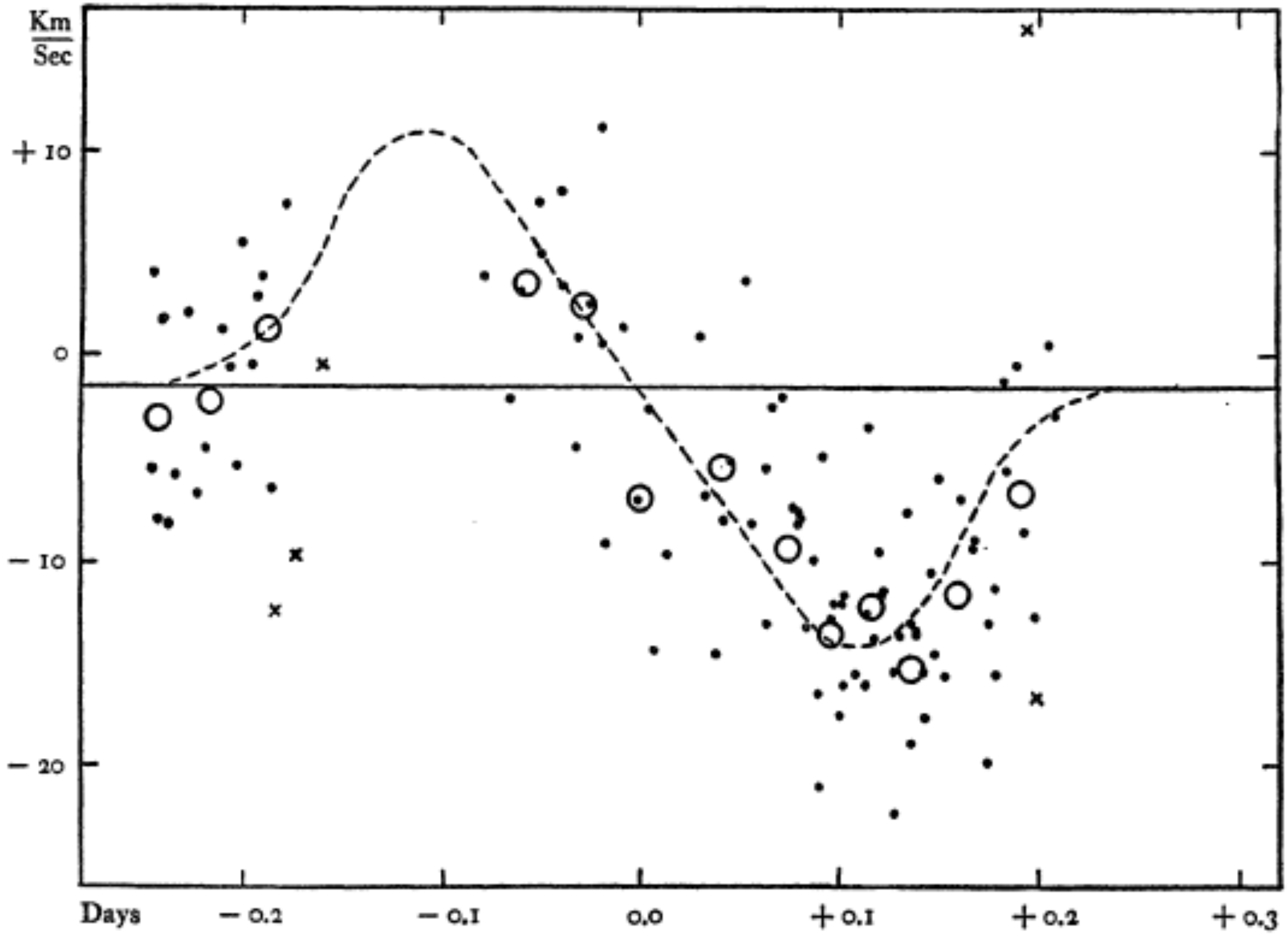


FIGURE 2. Rotation effect of Alpha Coronae Borealis. Dots are single plate velocities; crosses, very poor velocities; circles, normal places; dashed curve, computed rotation effect, assuming amplitude of 25 km/sec., with zero at − 1.5.

Strategy:

(1) Rossiter-McLaughlin effect of primary with TIGRE

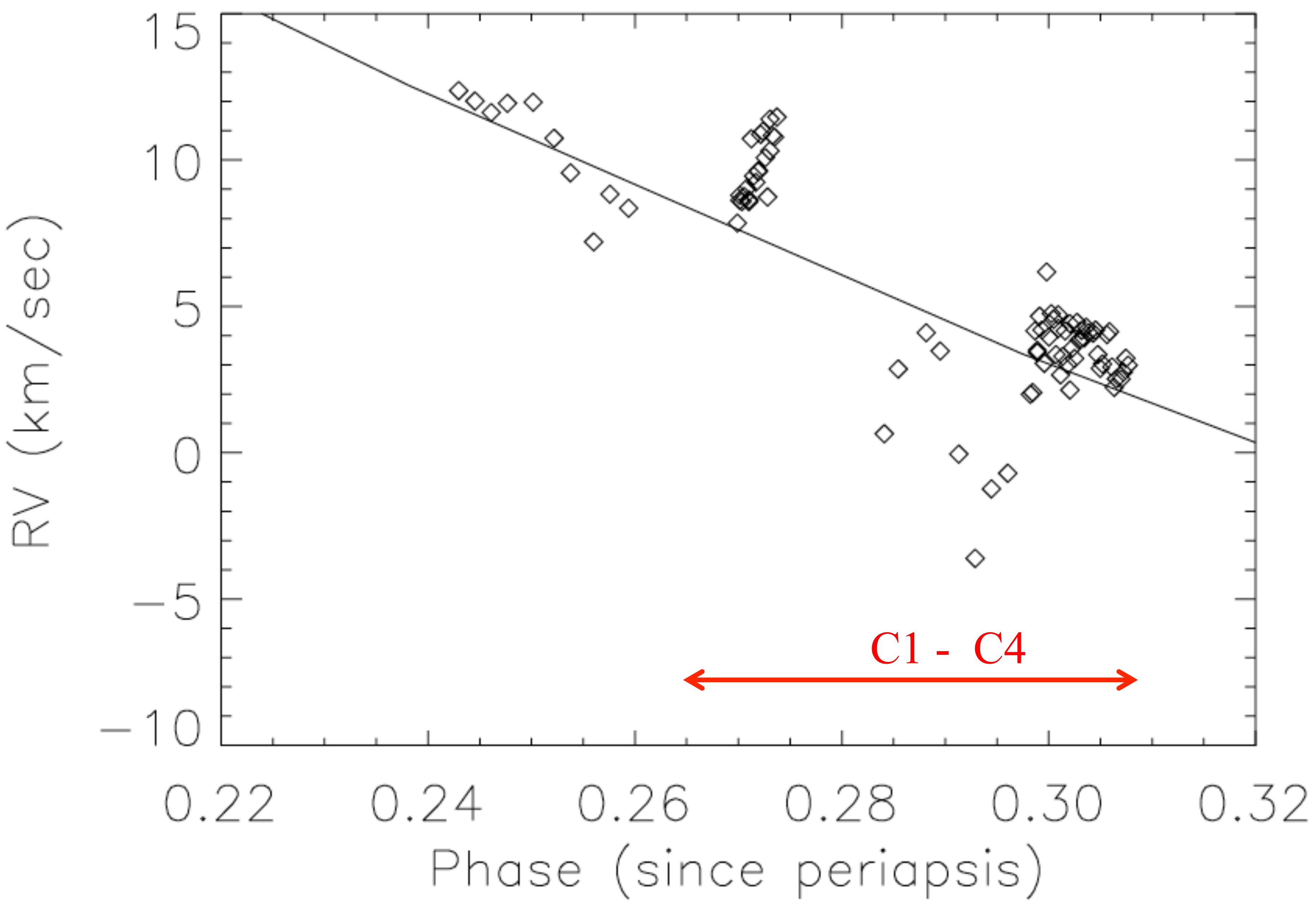
(2) Rossiter-McLaughlin effect of secondary with CARMENES

Difficulties:

(1) α CrB A is rapid rotator

(2) C1-C4 lasts 19 hours (primary)

(3) C1-C4 lasts 8 hours (secondary)



15
10
5
0
−5
−10
RV (km/sec)
C1 - C4
0.22
0.24
0.26
0.28
0.30
0.32
Phase (since periapsis)

Conclusions:

- Rossiter-McLaughlin effect in α CrB can be measured
- Project ongoing − needs more eclipes for proper modeling

The End !