The stellar spin-axes within the eclipsing binary system V1143 Cyg.

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Stellar Rotation axes: Why care?

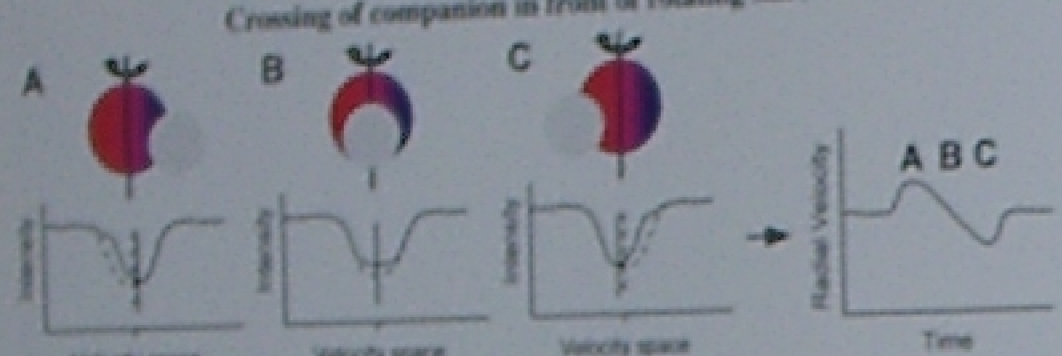
The orientation of stellar rotation axes relative to the orbital spin axes might shed new light on questions of:

- Binary/planetary system formation
- Binary/planetary system evolution

How: Rossiter-McLaughlin effect

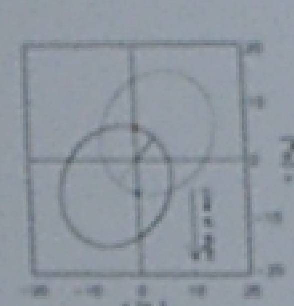
- First discovered: β Lyrae (Rossiter 1924) and Algol (McLaughlin 1924)
- Recently the effect has been observed for transiting planets (e.g. Queloz 2000)

Crossing of companion in front of rotating star:



→ Light integrated over part of the disk
→ Radial velocity anomaly
→ Function of the orientation of the rotation axis
⇒ **spatially resolved information on the stellar surface scales**

What: Binary system V1143 Cyg



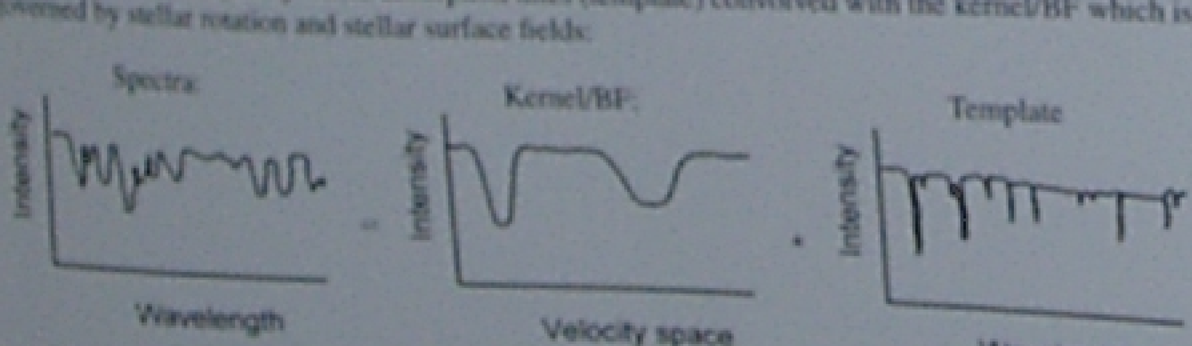
- Well studied double lined system with two F5V stars (e.g. Andersen et al. (1987) Gimenez et al. (1985))
- Bright (V_{mag} = 5.9)
- Period = 7.64 days
- High eccentricity (e = 0.54)
- Measured apsidal motion does not fully agree with the expected apsidal motion

Observations at the Lick Observatory

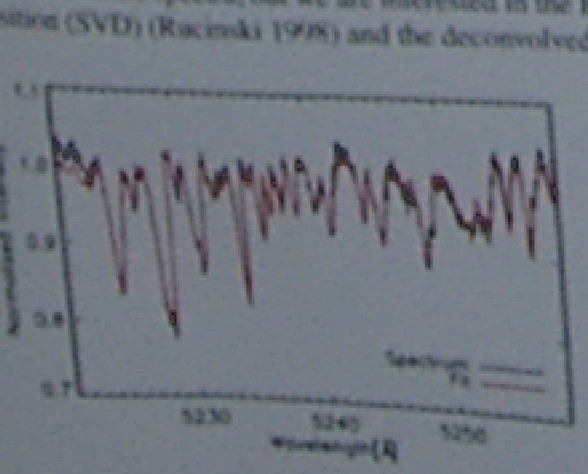
- 0.6 m CAT telescope & Hamilton spectrograph
- Primary eclipse (≈ 4 hours) 9 observations
- Secondary eclipse (≈ 8 hours) 11 observations
- Out of eclipse 26 observations

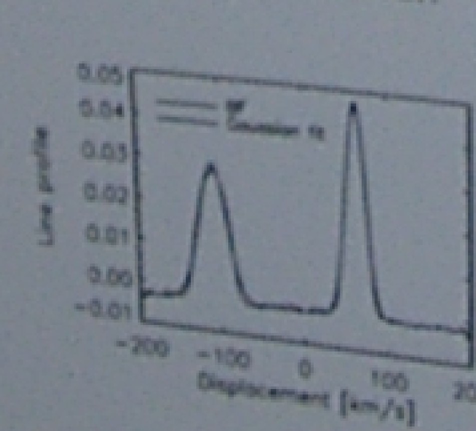
Broadening function (BF)

Stellar spectra are shaped by stellar absorption lines (template) convolved with the kernel/BF which is governed by stellar rotation and stellar surface fields:



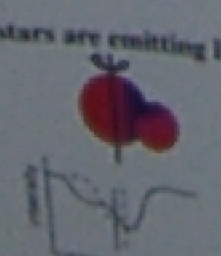
We obtained the spectra, but we are interested in the BF. Therefore we use the Singular Value Decomposition (SVD) (Racinski 1998) and the deconvolved spectrum of HD222368 to obtain the BF.





Challenge: Too much light

Both stars are emitting light:



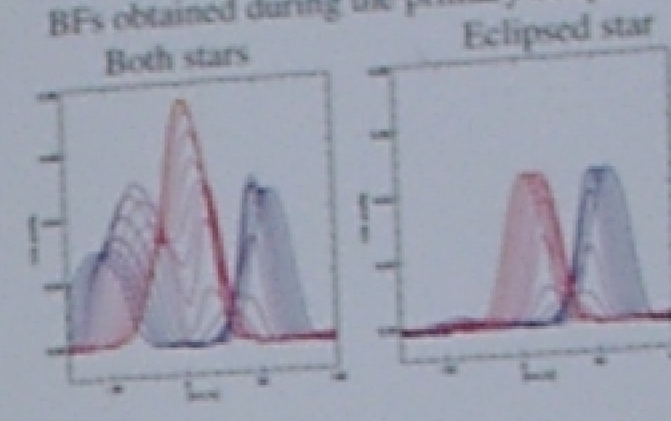
2 methods

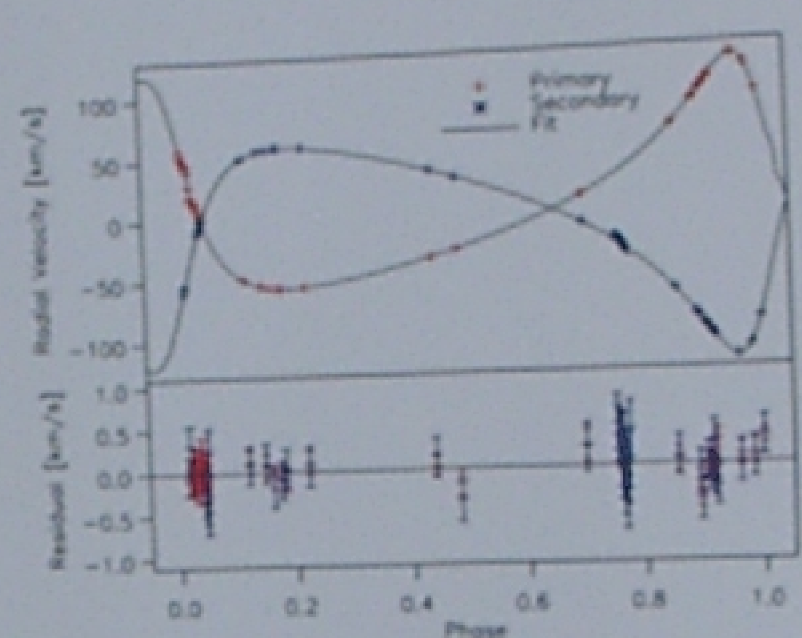
1. Influence of the foreground star is subtracted: **"center"** is used.
2. The profile of **both** stars are used: **"shape"** is used

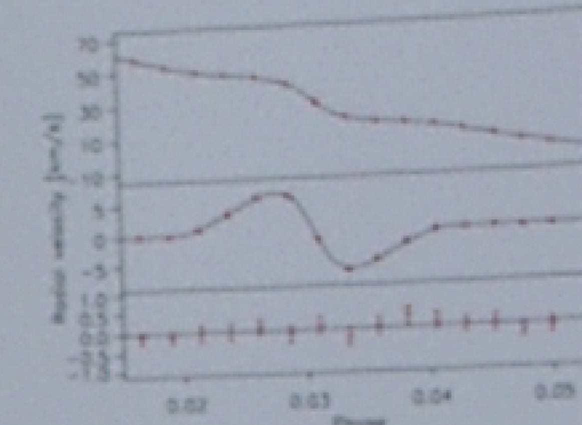
Method 1: Center

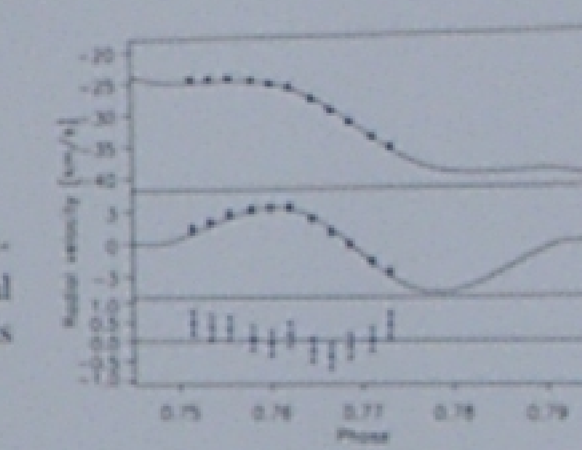
1. Obtain orbital parameter from out of eclipse data
2. Extract spectra of components using tomography (William et al. , 1991)
3. Subtract spectra of foreground star
4. Calculation of BF of the eclipsed star
5. Now the RM effect can be calculated

BFs obtained during the primary eclipse.





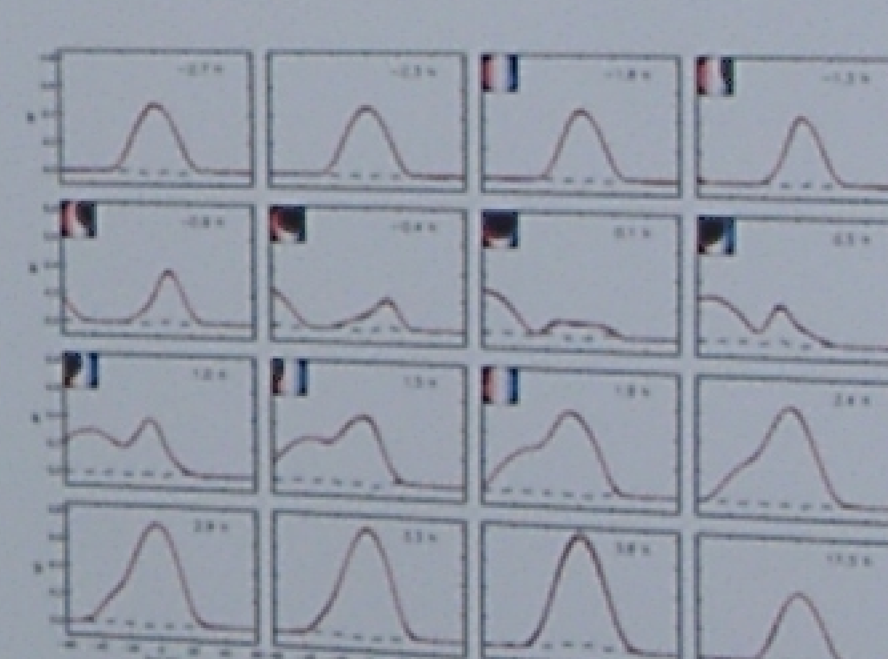


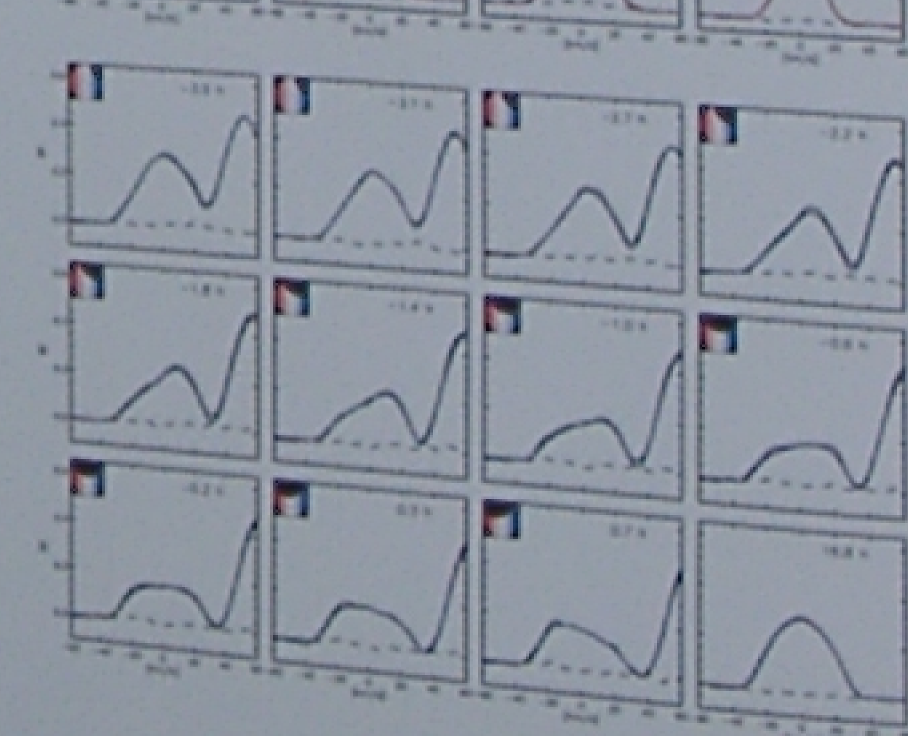


The radial velocity measurements of the primary and secondary components of V1143 Cyg along with the orbital solution are plotted against orbital phase. The two panels on the right show the a zoom in into the two eclipses.

Method 2: Shape

1. Simulation of BFs of **both** stars due to:
   - Orbital movement
   - Stellar rotation
   - Linear limb darkening
   - Macro-turbulence
   - (Size of components)
   - (Differential rotation)
2. χ^2 fit of all 46 Observations





The upper 4x4 panels show the BFs obtained during primary eclipse and the 4x3 bottom panels show the BFs obtained during the secondary eclipse. The black lines represent the obtained BF and the colored lines the best fits, while the dash lines represent the difference between the two. All panels are centered in the radial velocity space on the eclipsed star.

Results

Parameter	Method 1: Center Orbit	Method 1: Center Joint fit	Method 2: Shape	Andersen et al.(1987) † Gimenez et al. (1985) *
T_0 [JD-2400000]	53536.130±0.002	53536.131±0.002	53536.1317±0.0006	
K_p [km/s]	88.1±0.04	88.1±0.1	88.01±0.05	88.2±0.2†
K_s [km/s]	90.1±0.08	90.1±0.2	89.9±0.1	91.1±0.4†
e	0.538±0.001	0.538±0.001	0.5378±0.0003	0.540±0.003†
ω [°]	49.1±0.2	49.1±0.2	49.27±0.05	49.31±0.06*
$a \sin i$ [$R_\odot$]	22.67±0.03	22.67±0.03	22.64±0.02	22.78±0.08†
γ [km/s]	−16.8±0.3	−16.8±0.3	−16.8±0.3	−16.5±0.7†
$v \sin i_p$ [km/s]		16.9±1.0	19.6±0.1	18±2†
$v \sin i_s$ [km/s]		28.0±5.0	28.2±0.1	27±3†
ζ_{RT} P [km/s]			3.4±0.1	
ζ_{RT} S [km/s]			3.3±0.1	
β_p [°] ‡		**0.5±4.0**	**0.3±1.5**	
β_s [°] ‡		**−3.9±4.0**	**−1.2±1.6**	

‡ β indicates the angle between the projected stellar rotation axes and the orbital spin axis.

Conclusions

- Two methods to obtain the projection of the rotation axes in a double lined binary system
- Spin axes in V1143 Cyg are aligned with the orbital spin
  → expected apsidal motion is unchanged
- Methods can be used in other systems (e.g. DI Herculis)