

The Eclipsing Binary LV Her – A Photometric Study

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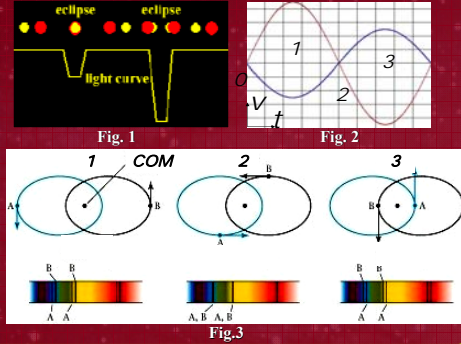
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Introduction to Eclipsing Binary

- Binary stars are numerous (frequency > 50%)
- Classifications:
 - Visual, Astrometric (Wide Binary)
 - Spectroscopic, Eclipsing (~10⁹ in our galaxy) (Close)
- Photometric study of eclipsing binaries provides the only way to directly and accurately determine the absolute dimensions of stars (mass, r, L, g and M_{abs}).
- Using our method, these results (with 1% accuracy) can be tested against stellar evolutionary model.
- Light curve: Fig.1 • Radial velocity curve (Fig. 2, 3)



Objective – LV Herculis

- Historical Account on LV Her - Period (days)

2.634	Zessewitch	'44
5.2674	Zessewitch	'54
9.218	Popper	'96
18.1312	Torres	'00
18.43593	Torres	'01

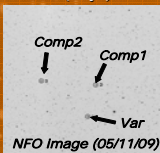


Fig. 4 The Measure Pattern. The "Var" (variable) star is LV Her. The telescope was unable to resolve two components due to ~1000 light-year distance. The apparent visual magnitude of ~11 (very dim) also requires telescope for observing power.

- Algol type



- Color indices: Hilditch&Hill (1975)
- Spectral analysis: Popper, Torres
- Two similar components in mass and temperature
- Mass-1M_⊙, Spectral class-F9, T~6000K (Sun: 5800K)
- Late main sequence
- Relatively long period for close binary
- High eccentricity (~0.6)
- use results to test the theoretical prediction: Y2 Isochrones (Yonsei-Yale, latest version 2005)
 - > α-element (O, Ne, Si, Mg, S, Ti, Ca) enhanced
 - > convective core overshoot
 - > interpolator in Fortran; enable plotting program such as SM to visualize and refine results

Methodology – EBOP

- Photometric data:
 - Telescope: URSA (UArk. campus), 10" CCD
 - Observing period: Feb 2001 to May 2009
 - ~7K data (5% bad points)
 - Processing data: Multimeasure (Lacy)
- Light Curve: differential magnitude vs. phase (Fig. 5)

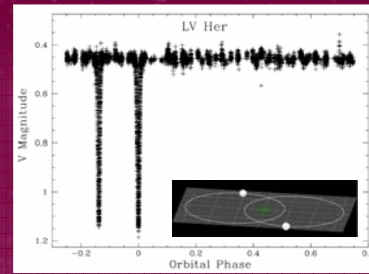


Fig.5 Primary eclipse is defined to be at phase 0, secondary eclipse due to high eccentricity is around -0.14 (0.5 for circular orbit). Period is determined to be 18.43595 days. (Dates of Minima, Lacy)

- Spectroscopic data (Torres, priv.comm.)

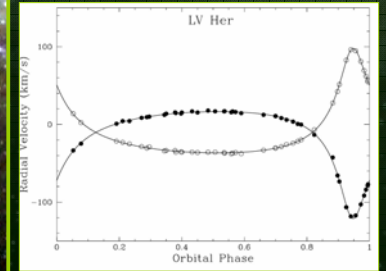


Fig.6 Radial Velocity Curve. Fitting (GLSPL) shows low system (absolute) velocity (~10km/s), implies LV Her is population I star with high metallicity (~3%). Fitting also gives e = 0.6150 ± 0.0021, ω = -7.86° ± 0.42

- Light curve fitting (EBOP, Nelson, Davis & Etzel)
 - > faster than Wilson-Devinney code
 - > method from Binnendijk (1960)
 - > other parameters used in the fitting:
 - gravitational darkening Coeff. (Claret)
 - longitude of periastron ω
 - mass ratio: (semiamplitude of prim.)/(semiamplitude of sec.)
 - use e and ω from radial velocity fit as initial value

Methodology – Temperature (with reddening)

- The first attempt: Strömgren color indices confirmed by spectral type (Popper), between F8 and G0; Prim: 6014K Sec: 5995K ± 91
- Motivation for the second attempt – using color directly
 - > Spectral type is independent of interstellar reddening.
 - > Hilditch&Hill's Strömgren color only has one data point.
 - > The first attempted comparison with Y2 Isochrones did not show satisfying result (σT is too large). (See Result section.)
 - > Previous obtained values are useful:
 - ❖ log g (independent of T)
 - ❖ temp. diff. from secondary surface brightness parameter
- Implement 3 recent surveys: 2MASS, TYCHO, TASS.
 - > Goal: to "guess" a reddening factor that matches all the measured color to Kurucz's model atmosphere table (with overshoot) ('95)
 - > Main techniques:
 - ❖ reddening relation (Lebofsky)
 - ❖ color transformation (Johnson BVR1JHK, Strömgren, Tycho)
 - ❖ interpolate to determine temperature
- Result: Prim: 6215 K Sec: 6195K ± 25

Absolute Dimensions

- Orbit information (spectroscopic fitting)

Parameter	Value	σ
R1/a	0.0355	0.0004
R2/a	0.0332	0.0004
R2/R1	0.9354	0.0236
Inclination	89.5697	0.0370
Oblateness	0.0001	0.0001
e	0.6142	0.0001
Ω (deg)	-9.2169	0.1729



- Absolute dimensions (To 1% accuracy)

Parameters	Prim.	σ	Sec.	σ
Mass (M _⊙)	1.191	0.015	1.165	0.011
Radius (R _⊙)	1.388	0.018	1.298	0.018
Log L	0.414	0.013	0.350	0.014
Abs. Mag. (M)	3.84	0.08	4.01	0.08

- Distance: 1 218 light-year (5.2% error)
- > M = m + 5 - 5 log [d/pc] (M = 10.90)

- Binary Stars (Lacy) (simulation of light curve using above results agrees with observed light curve)

Results and Conclusion

- Y2 Isochrones, if correct, should predict the same age for both stars
- First attempt

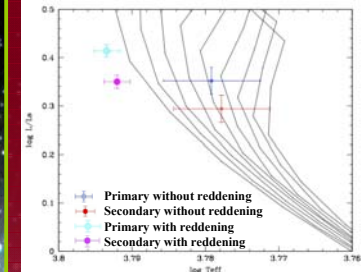


Fig.6 The positions of the stars on the H-R diagram before and after interstellar reddening is considered. The tracks (isochrones) from right to left are of 4.52, 4.32, 4.12, 3.92, 3.72, 3.52, 3.32, 3.12, 2.92 billion years.

- Second attempt: after the effect of reddening is considered, the stars' intrinsic colors are bluer – they are hotter by about 200K. This makes a big difference on LV Her's age from what was previously around 3.72 Ga.

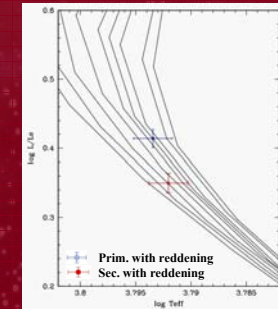


Fig.7 The tracks from right to left are of 2.87, 2.82, 2.72, 2.67, 2.62, 2.52, 2.42, 2.32, 2.22 billion years, with primary on the 2.67Ga isochrone, and secondary on the 2.42Ga isochrone.

- > Within the uncertainties of the observed color indices, Y2 isochrones' prediction on the two stars' ages overlap, therefore we are unable to reject this theory.

Future Work & Acknowledgement

- Test our results against other stellar evolutionary tracks, such as the Victoria-Regina Stellar Models (2006), Chiosi (2000), YREC Isochrones (2000) and Stauffer (2007).
- I'm thankful for the photometric data and knowledge from my adviser Dr. Claud Lacy. Dr. G. Torres from CFA provided us the spectroscopic data. Dr. Julia Kennefick and Daniel Kennefick have helped me on SM and PHOEBE.

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