Spots, Eclipses, and Pulsation: The Interplay of Photometry and Optical Interferometric Imaging

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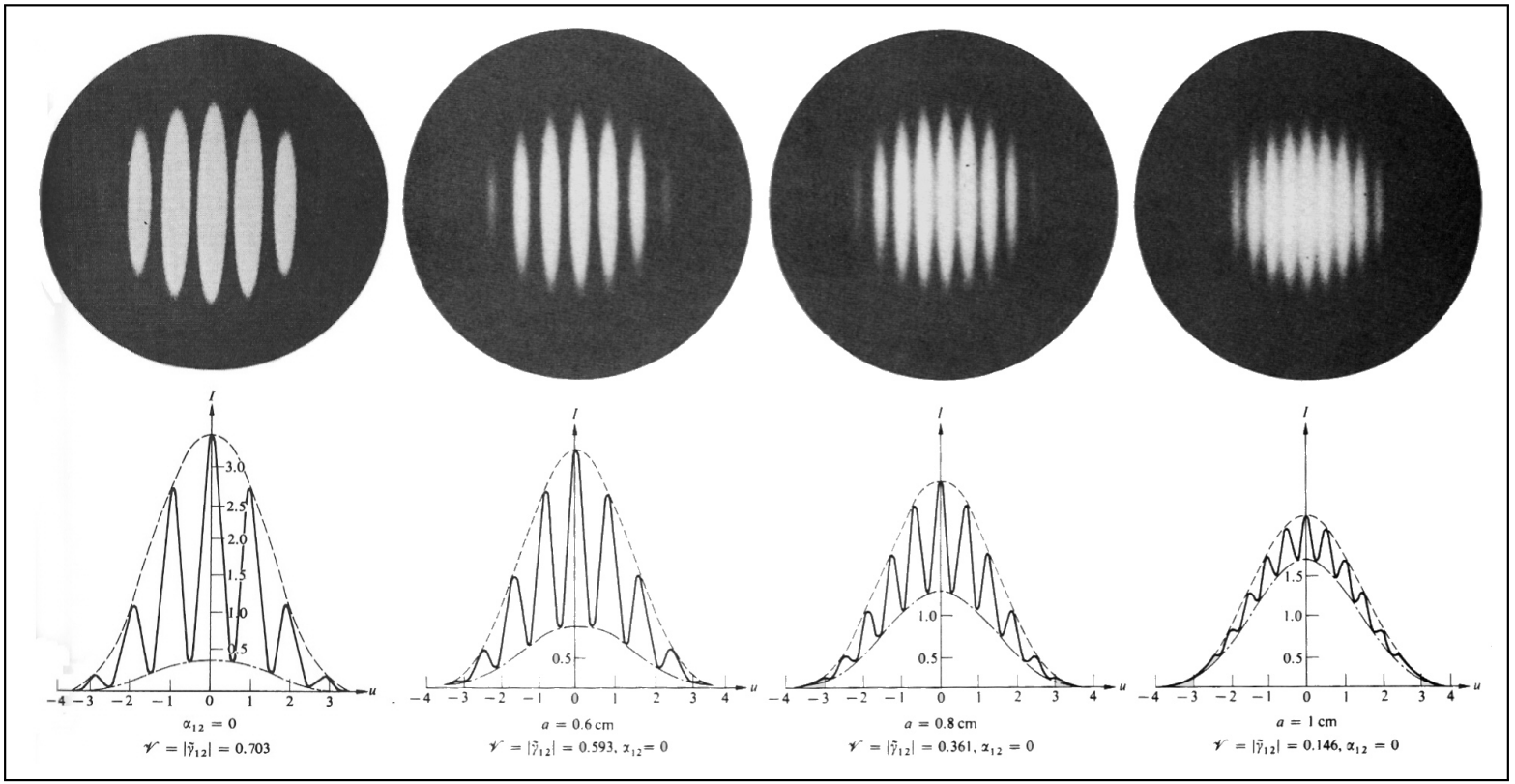
Outline

1. Intro to Interferometric Imaging
   - Interferometric Observables
   - Image Reconstruction
2. Photometry and Interferometry
   - Spots
   - Eclipses
   - Radial / Non-Radial Pulsation
   - Novae
3. Conclusion

Visibility



Fringes as seen by an Interferometer (Hecht, 2002)

$$V = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$$

Closure Phase

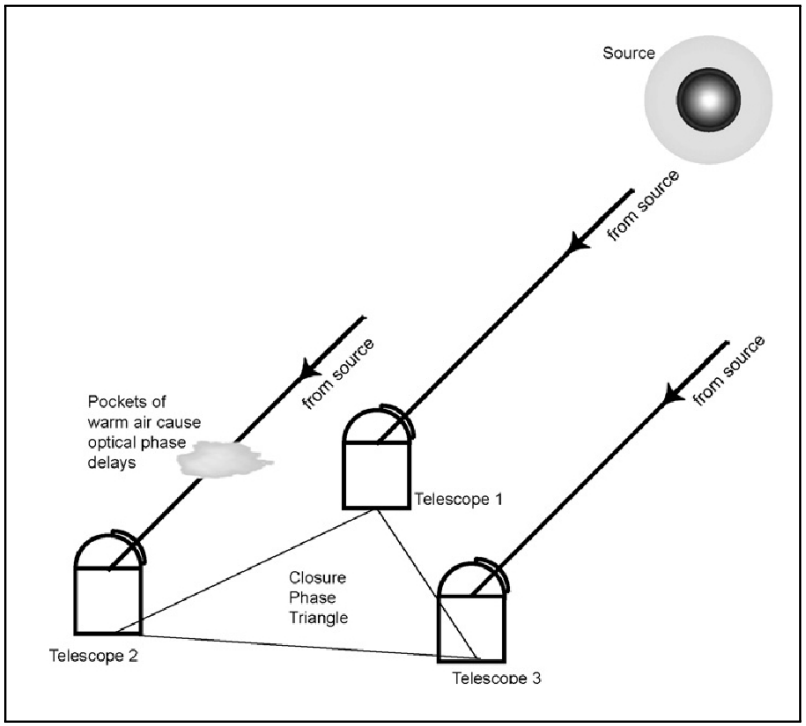


Image Credit: John D. Monnier, 2007

$$\begin{aligned}\Phi_{ijk} &= \phi_{ij} + (\phi_{jk} + \phi_{atm}) \\ &\quad +(\phi_{ki} - \phi_{atm}) \\ &= \phi_{ij} + \phi_{jk} + \phi_{ki}\end{aligned}$$

Generic Image Interferometric Reconstruction

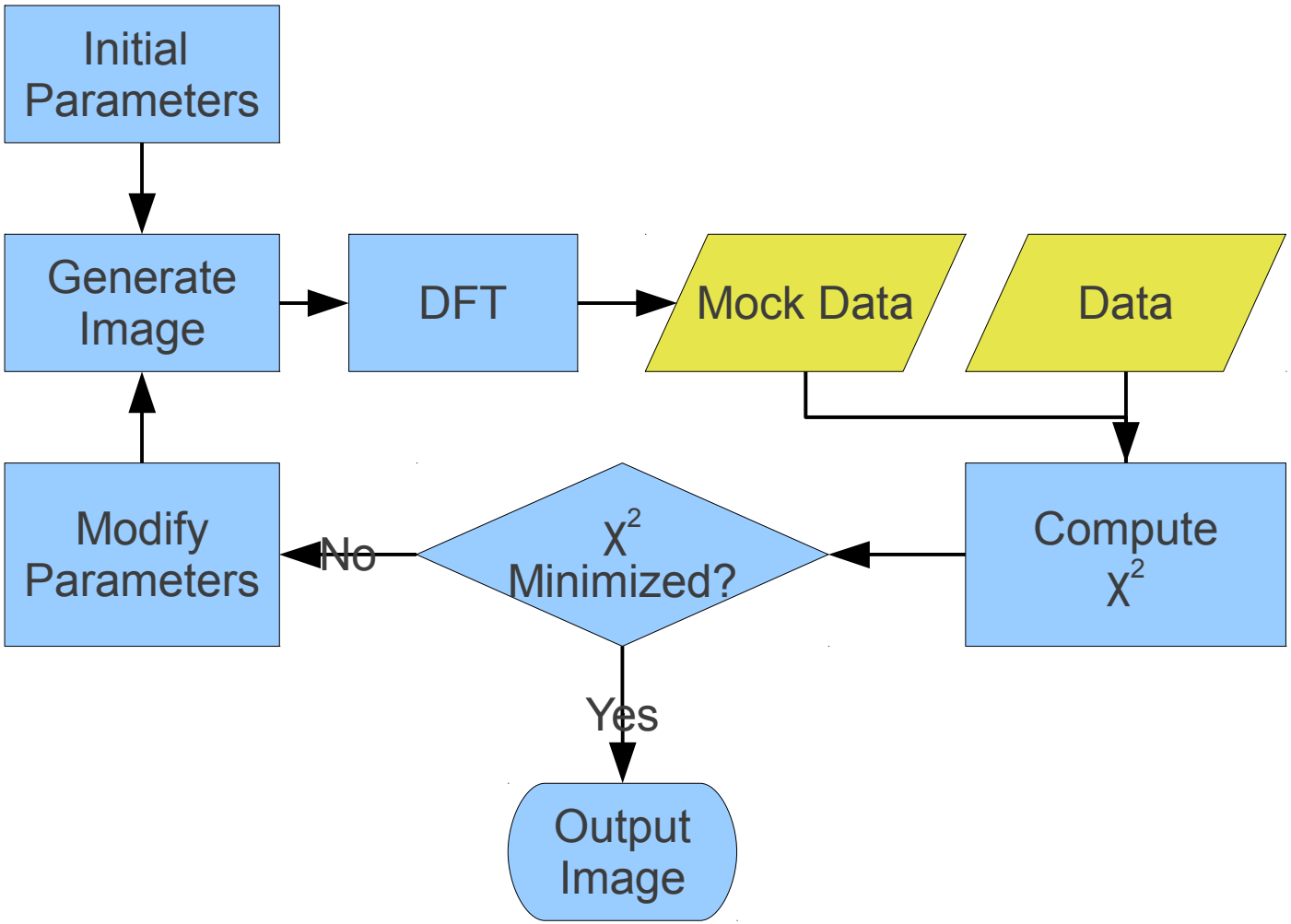


Image Reconstruction Programs

BSMEM

BiSpectrum Maximum Entropy Method

Buscher (1994)

- Baysian Approach
- Maximizes Gull-Skillings Entropy
- Uses non-linear conjugated gradient

MACIM

MArkov Chain Imager

Ireland (2006)

- Markov Chain Approach
- Samples posterior prob. dist. using simulated annealing and parallel tempering.
- Uses "average" statistics for the final image

Other methods: WISARD, MIRA, RPR, CLEAN. See "Interferometric Imaging Beauty Contest" papers

All images in this talk are (essentially) model-independent!

Needed: Accurate Photometry

At the very least interferometry needs photometry for:

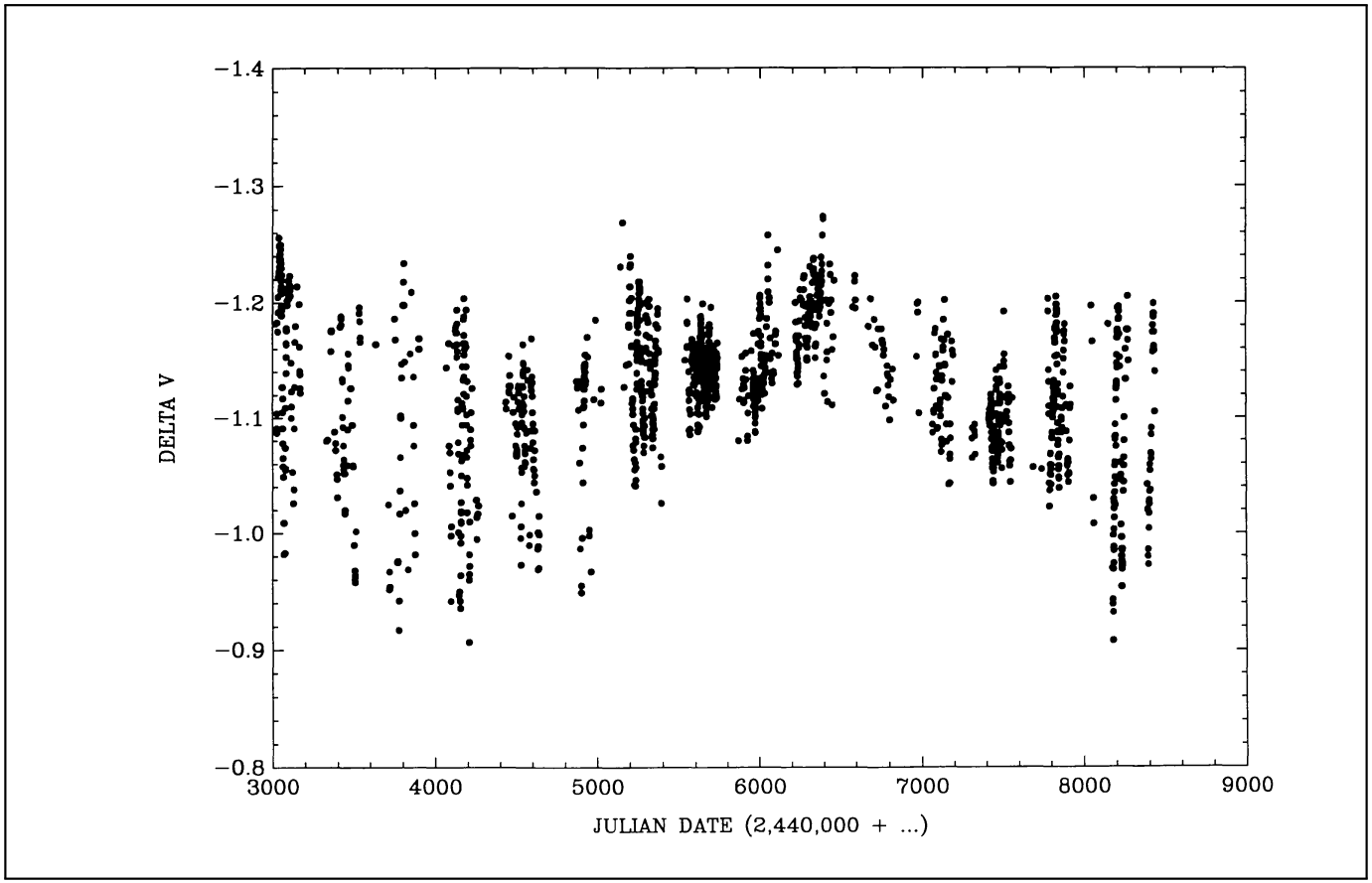
- Interesting Target Selection
- Calibrator Diameters (via. spectrophotometric SED fitting)

λ Andromeda Overview

- Known Variable since 1933 (Calder, 1938)
- SB1 (G8III) with period 20.52 days
- Classification: RS CVn
- Photometric period of 54.2 days (3.69-3.97 V-band)

λ Andromeda Photometry

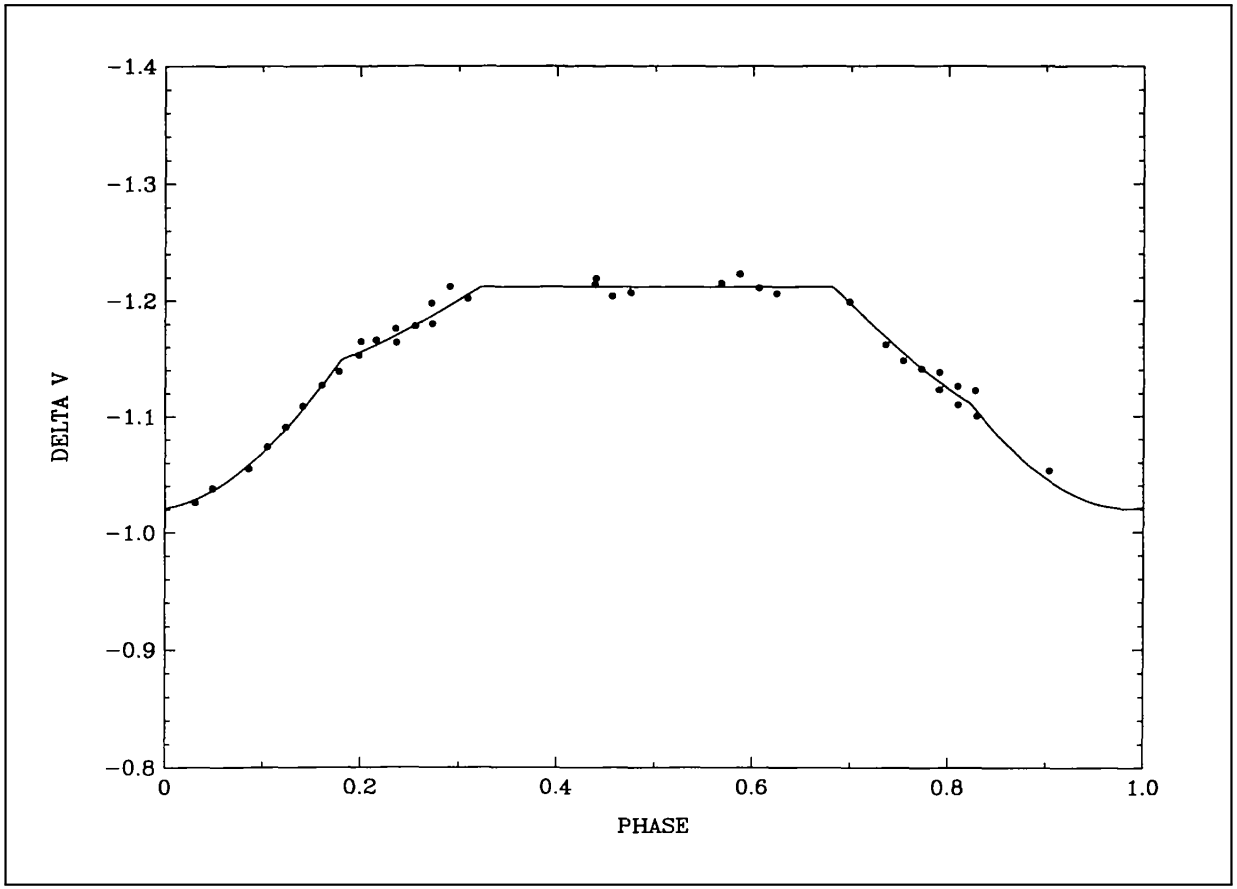
V-band photometry



Henry et. al 1995

λ Andromeda Photometry

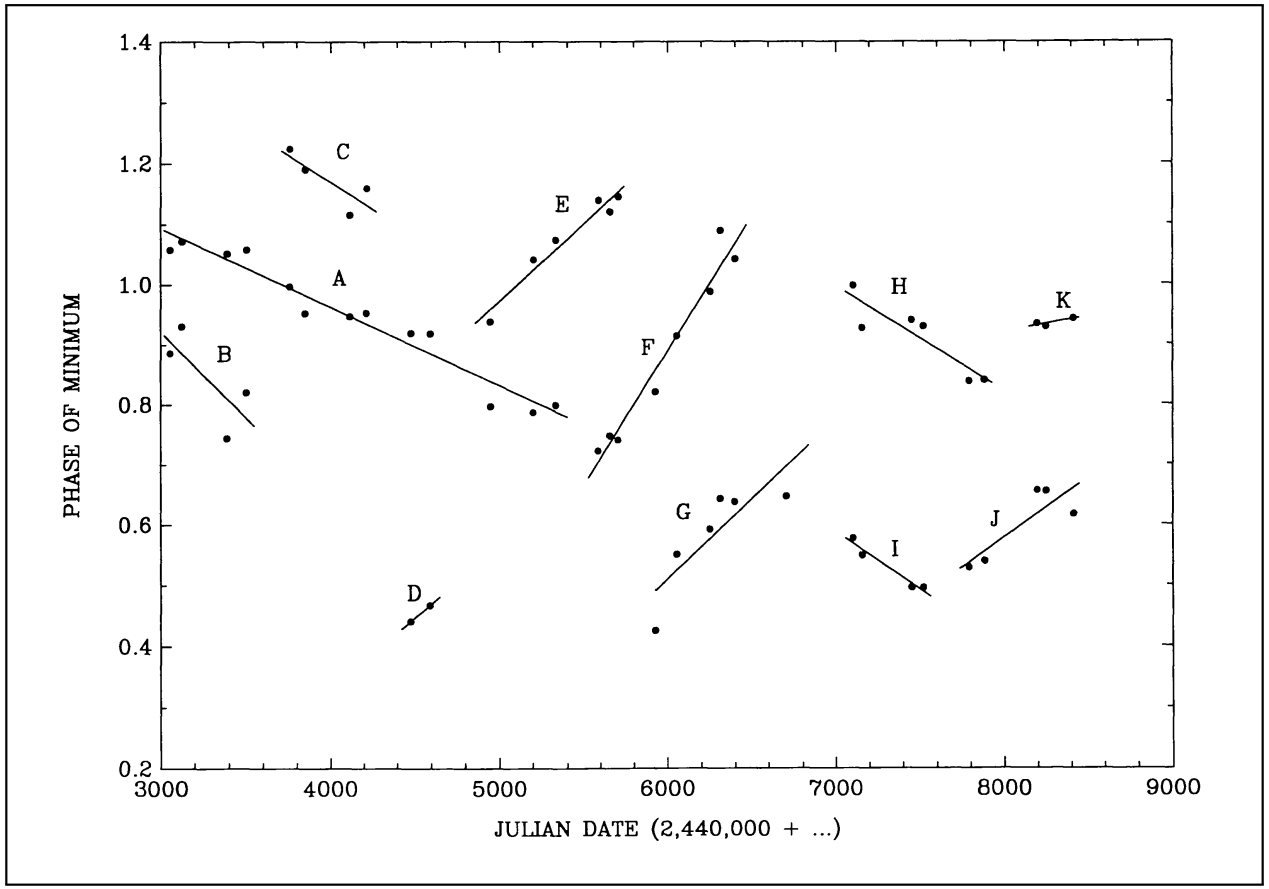
Two Spot Model



Henry et. al 1995

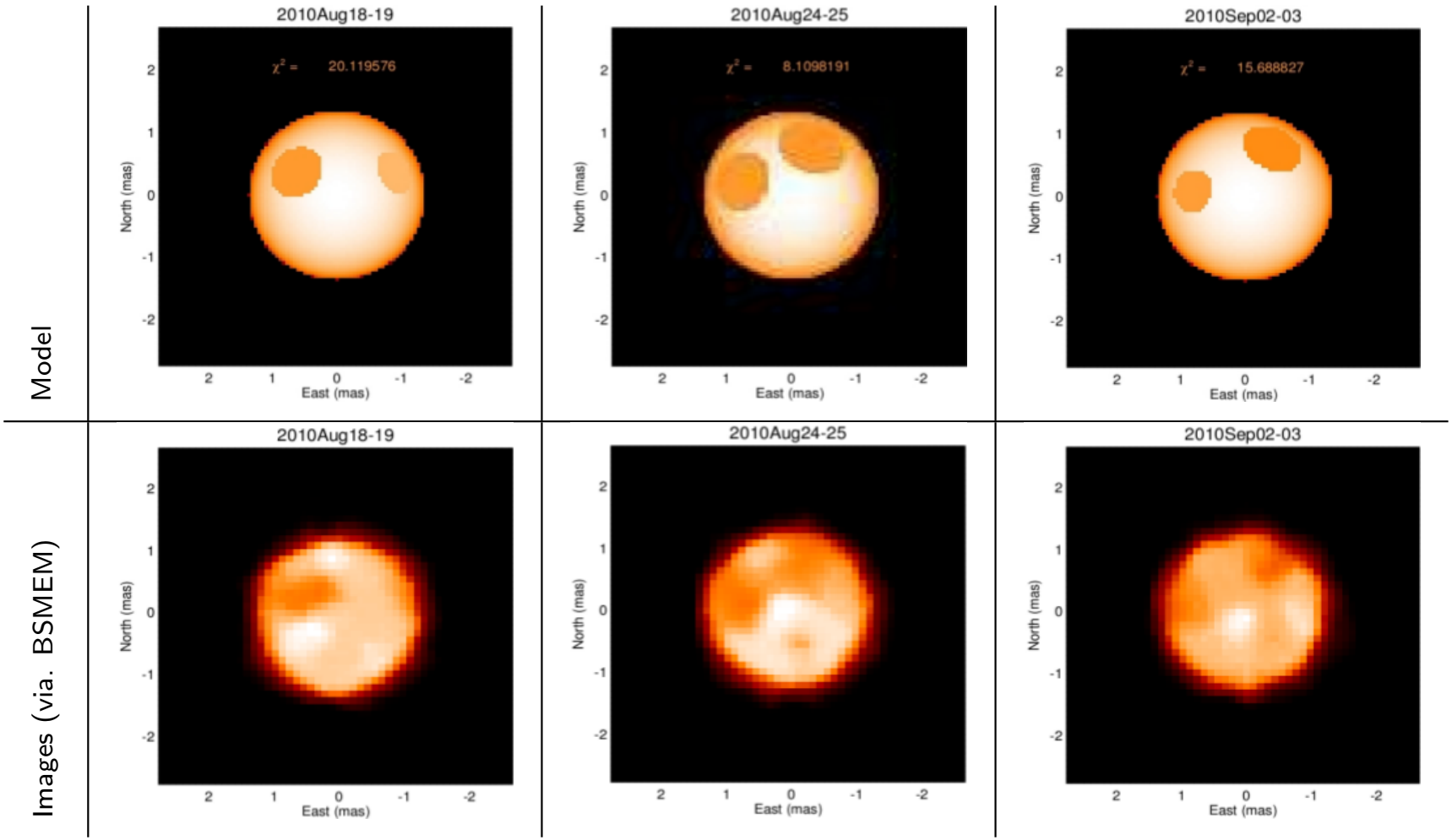
λ Andromeda Photometry

Spot Migration



Henry et. al 1995

Interferometric Work

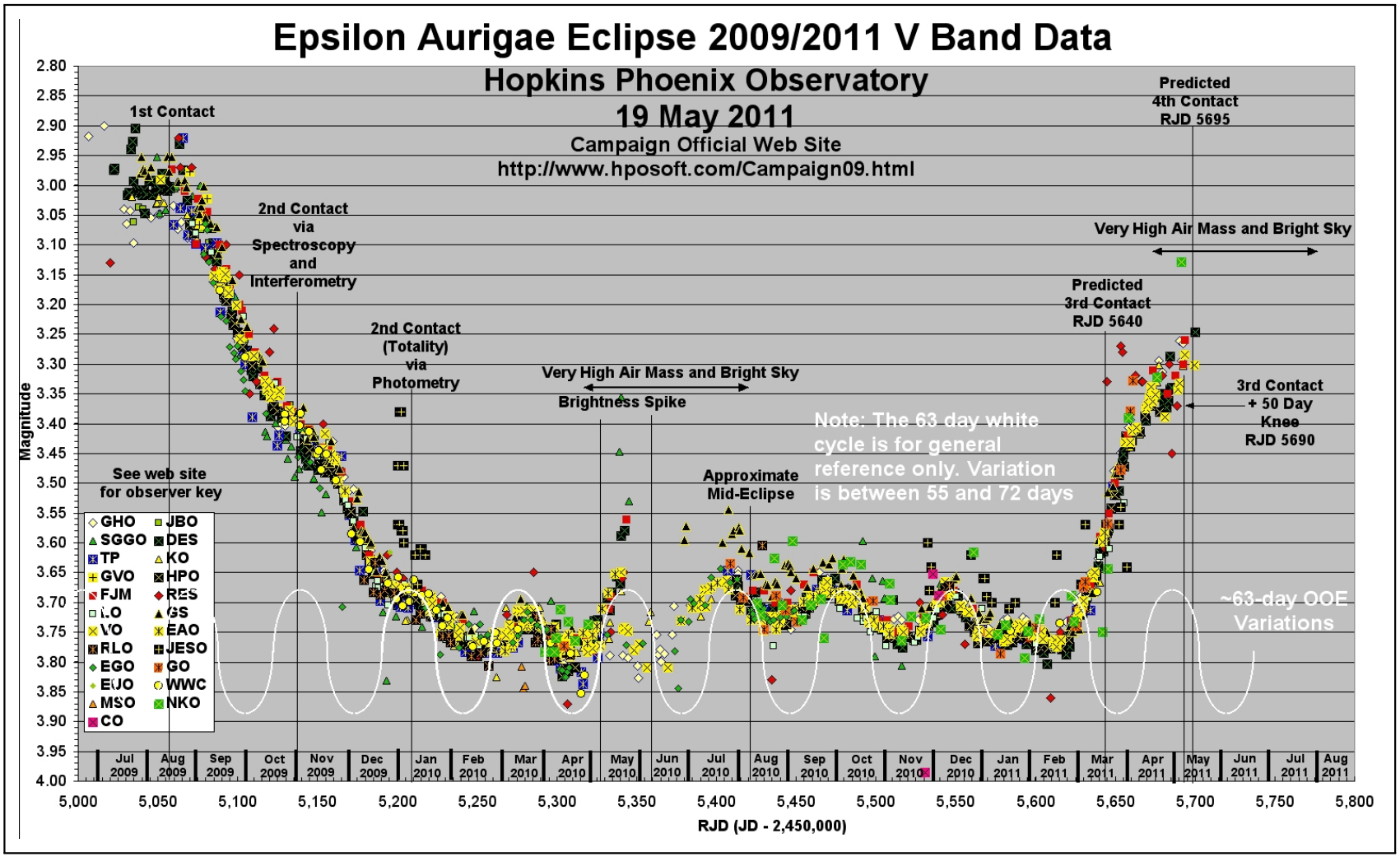


Parametric Modeling and Imaging of λ And. (Parks et. al 2011)

ϵ Aurigae Overview

- 27.1-year eclipsing binary
- Single Line
- Eclipses are anomalously long
- "Discovered" in 1821

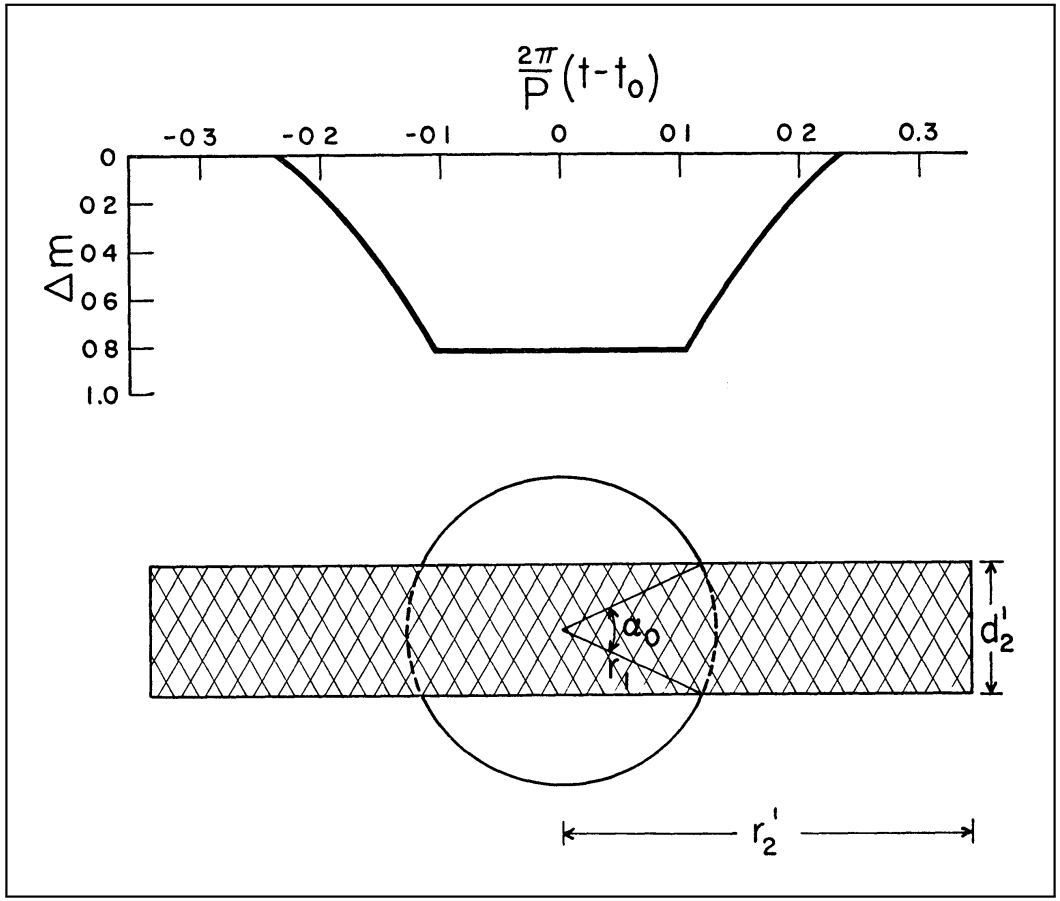
ϵ Aurigae Photometry



2009-2011 Eclipse light curve. Courtesy of ϵ Aur Campaign. Hopkins et. al 2009-2011

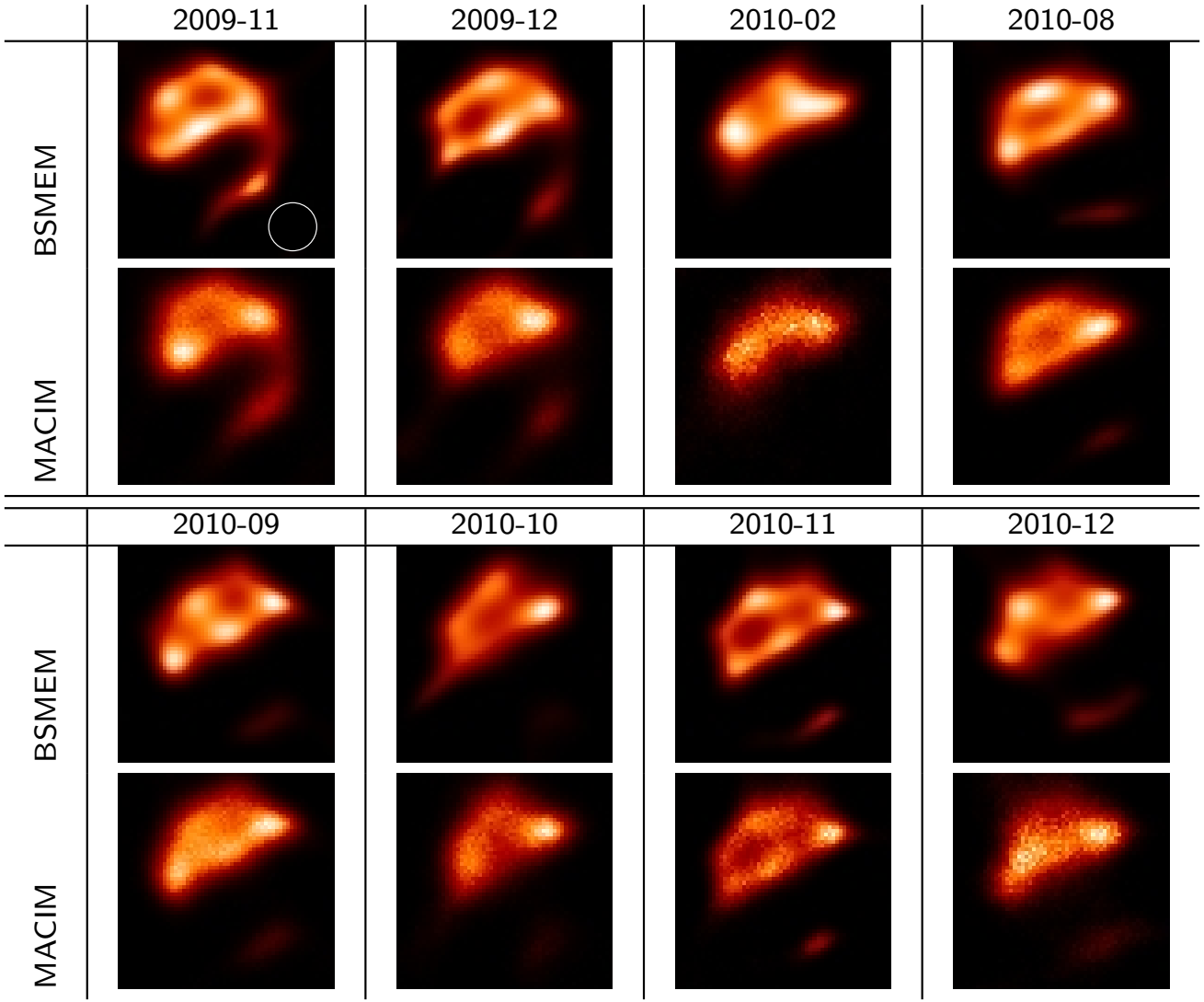
ϵ Aurigae Photometry

Explaining the Photometry



ϵ Aur Model. Huang (1965)

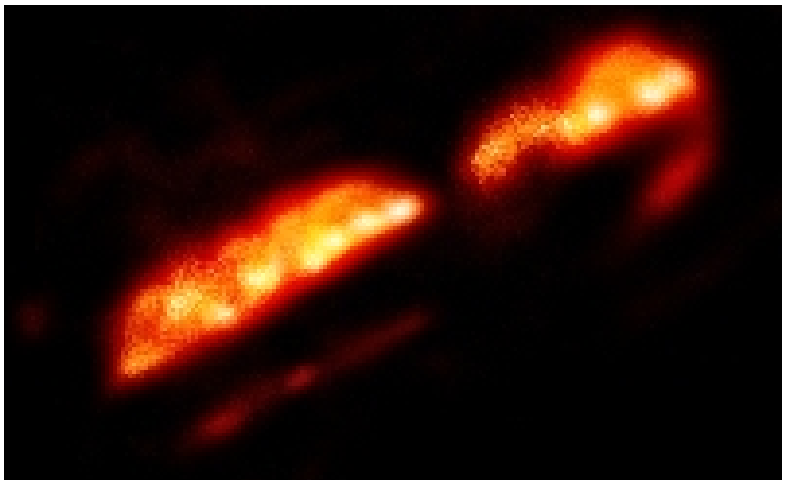
Eight of 13 Epochs

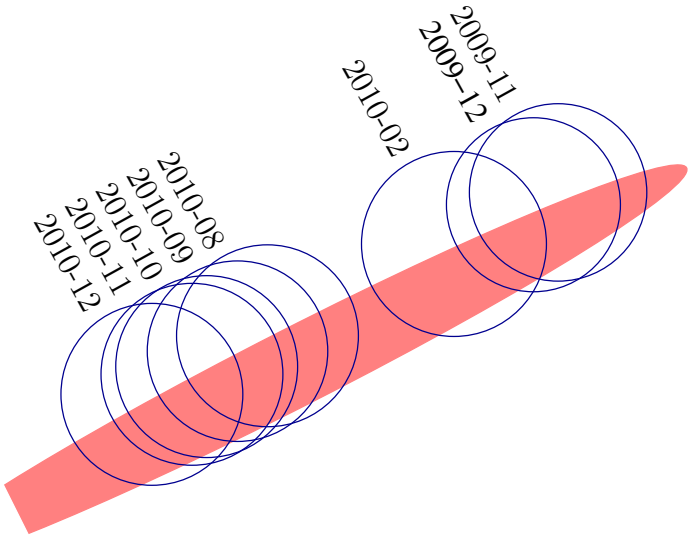


CHARA Observations of ϵ Auriage Kloppenborg et. al 2010, 2011

Interferometric Images

CHARA Observations of ϵ Auriage Kloppenborg et. al 2010, 2011





A View of the eclipsing Object

- Eight CHARA epochs anchor appearance
- Interpolate shape using UBVRIJHK photometry
- Establish ingress/egress velocity

Additional info. on ϵ Aur:

- 230.04 - Spectroscopic Monitoring
- **230.05** - ϵ Aur Orbit
- 225.04 - Discovered He 10830A Absorption In The Mid-eclipse Disk
- 225.05 - Monte Carlo Sim. of Disk

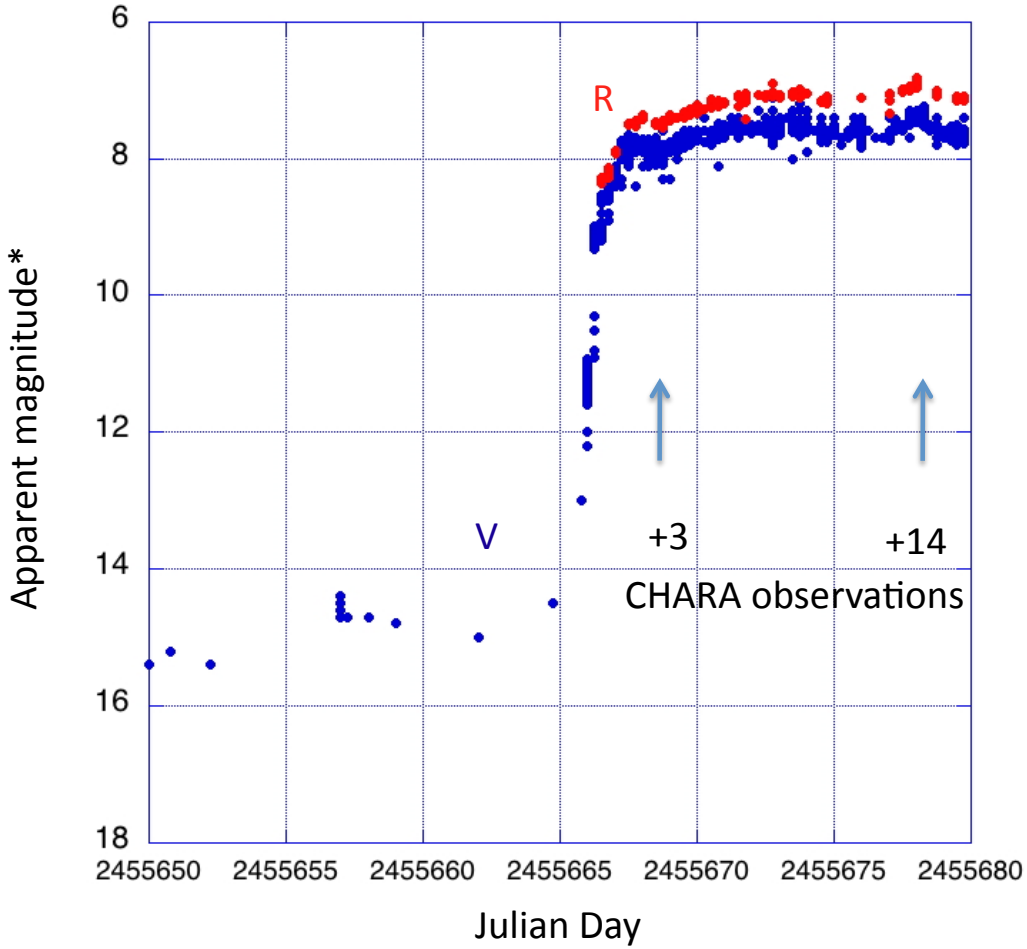
T Pyx

- Discovered in 1913 by Henrietta Leavitt
- Recurrent Novae (mass transfer onto white dwarf)
- Prototype for recurrent novae
- Latest eruption spotted by Michael Linnolt (AAVSO Notice 436)
- "Soon to be Type Ia Supernovae?" - Astronomy News

Past Eruptions

- 1890
  ... 12 years
- 1902
  ... 18 years
- 1920
  ... 24 years
- 1944
  ... 22 years
- 1966
  ... 45 years
- 2011

T Pyx Photometry



T Pyx (2011)

Graphic courtesy of Steve Ridgeway (NOAO), data from AAVSO. 20,000 measurements in 14 days!

T Pyx Interferometry

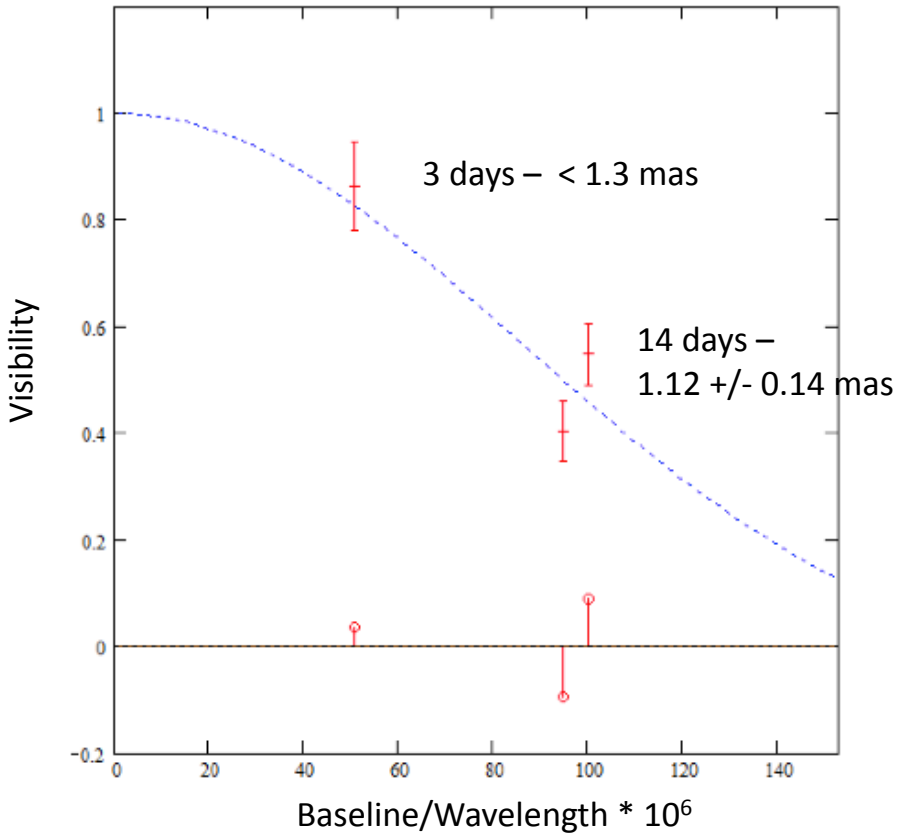
Mt. Wilson Today, Credit: Georgia State University

Observers:

- Chris Farrington
- Tabetha Boyajian
- Fabien Baron
- Gail Schaefer

Reductions:

- Theo ten Brummelaar
- Hal McAlister



Plot: Theo/Hal and Steve Ridgeway (NOAO)

Conclusions

- Accurate JHK photometry needed by interferometrists
- Photometry helps choose targets for interferometers
- Photometry and Interferometry can yield better solutions for:
  - Spots
  - Eclipses
  - Pulsation (radial/non-radial)
  - Novae
- Further pro-am and inter-field collaboration is encouraged