Resolved Disk Observations of Cool Mira Variables

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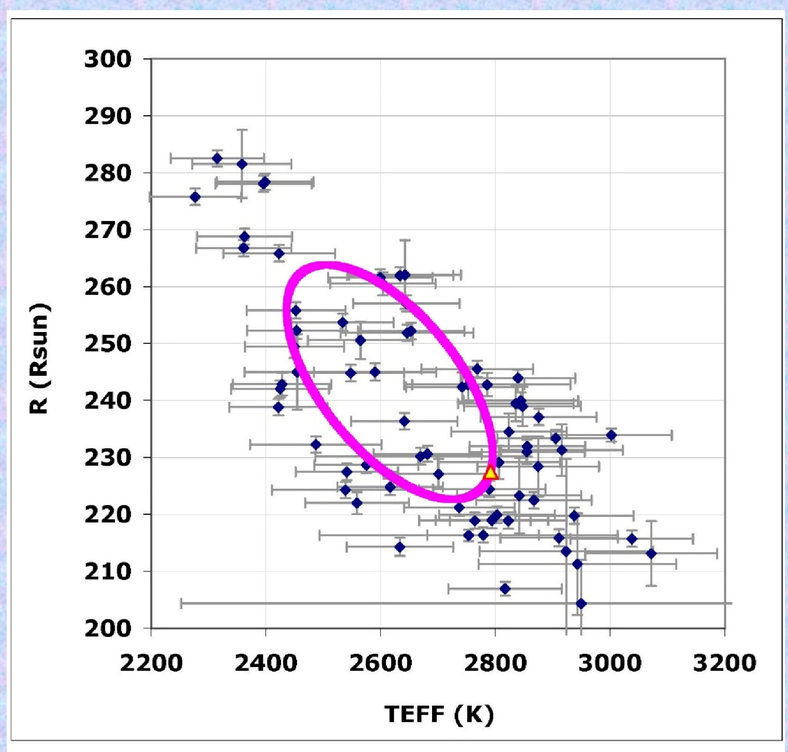
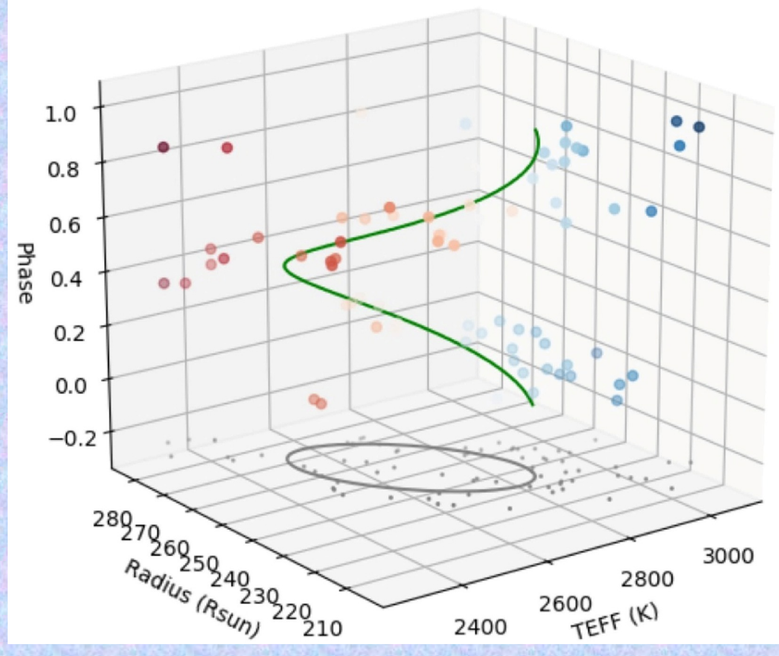
ABSTRACT

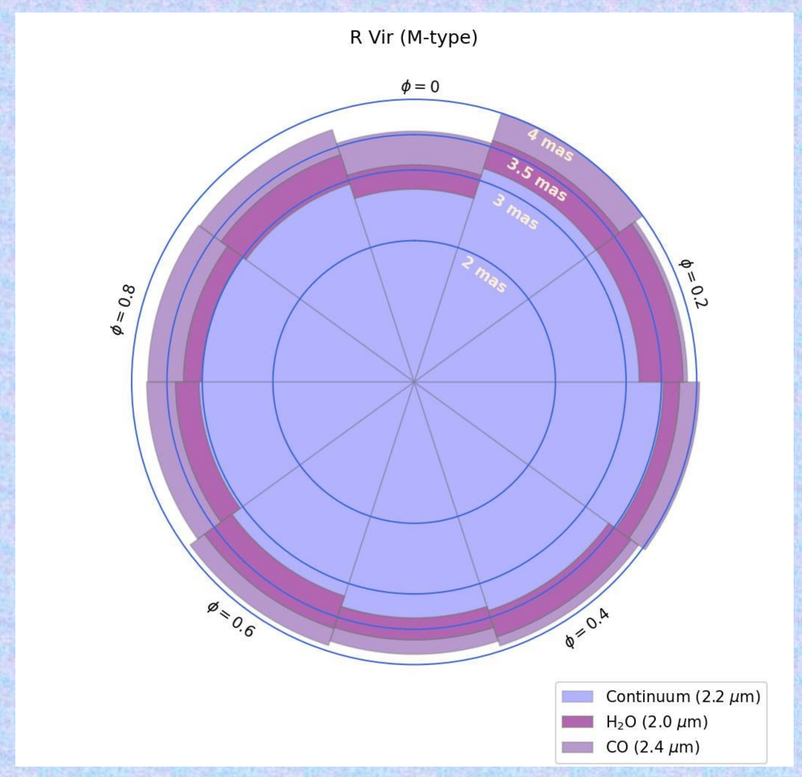
Mira variables are among the largest stars in the menagerie of cool stars. These 1-2 $M_\odot$ stars exhibit dramatic year-long variations with $\Delta V > 3$, the result of stellar pulsations that drive mass loss at 10^{-5} to 10^{-7} $M_\odot$/yr rates. We have been monitoring a select set of ~100 of these stars over the past two decades with optical interferometry, Spitzer, SOFIA, and other facilities to provide unique insights into the dynamical physics and chemistry of these evolved stars. The V-band, K-band, angular size, and effective temperature variation amplitudes and periodicity have been characterized by chemical sub-type: oxygen-rich, intermediate, and carbon-rich. Overall angular size variations are roughly 10-20%, with 150-300K excursions about 2600K average temperatures, with individual stars having up to 100 distinct epochs of size measurements. This mix of observations is being combined into a **Mira Reference Set**, a laboratory to a wealth of different experiments on Miras.

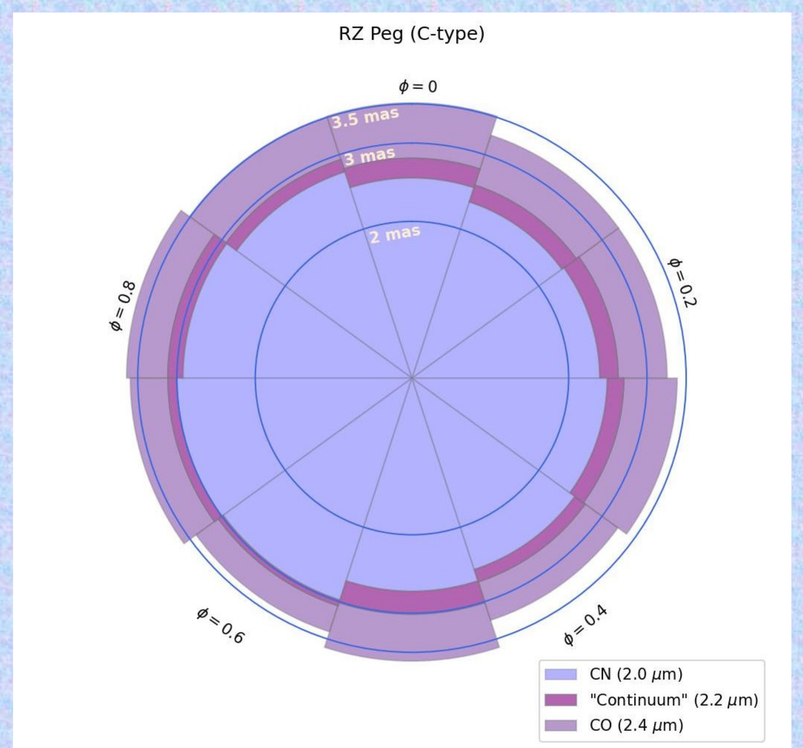




Radius and Temperature versus Phase

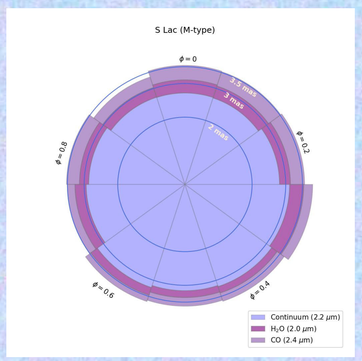
An example of the PTI broad-band archival data for the Mira variable R Boo from 1999 to 2008. (Upper) Time-dependent values for R and TEFF (blue points) have been fit (red line) as a function of period derived from visible AAVSO data; the yellow triangle denotes the zerophase point. (Lower) The same data but with the third dimension (phase) revealed, showing the 'corkscrew' behavior of these stars in R-T - phase space. Data points are color-coded now for temperature. The orientation angle of the ellipse is suspected to be related to the pulsation mode, and will be explored during this study.

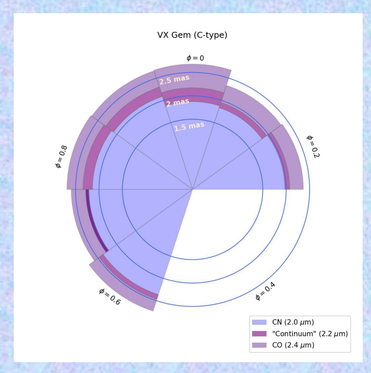


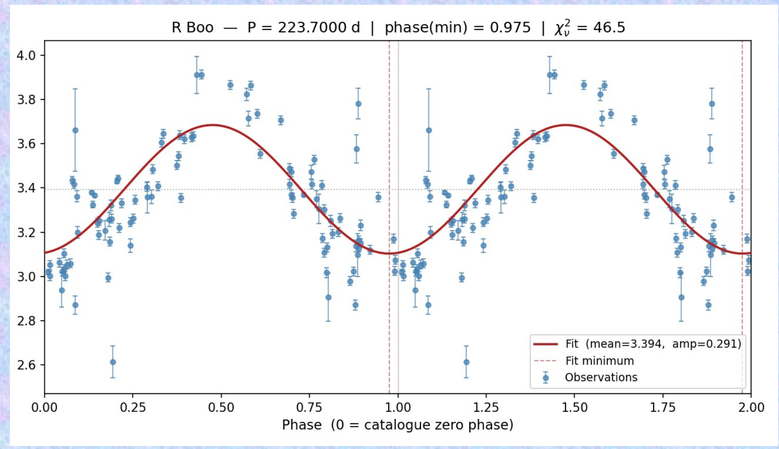


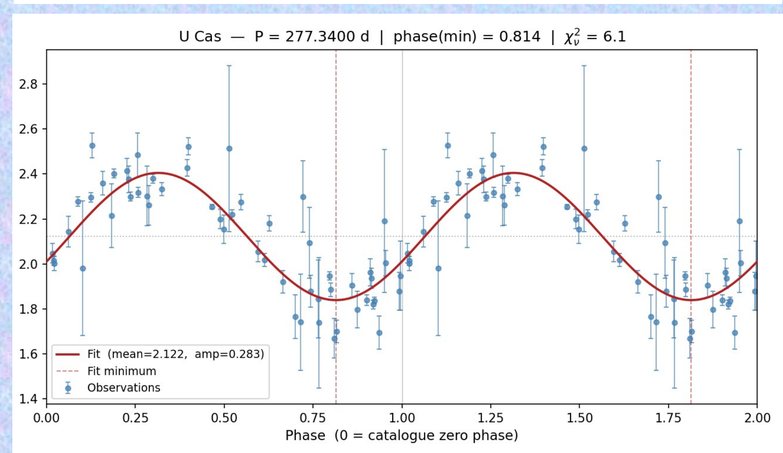
Stellar Layers versus Phase

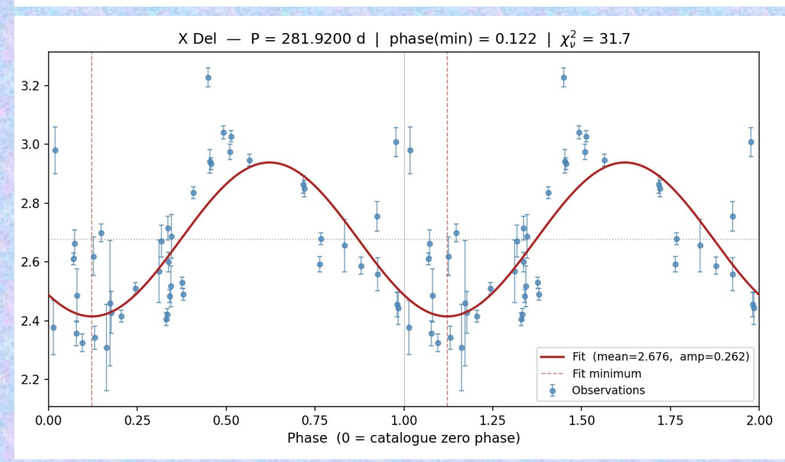
The M-type Mira R Vir (top) and the C-type Mira RZ Peg (above), showing the time evolution of angular size throughout a star's phase. Additionally, the M-type S Lac (below left) and C-type VX Gem (below right) are shown.











Angular Size versus Phase

Plots of the broad-band angular size for R Boo, U Cas, and X Del

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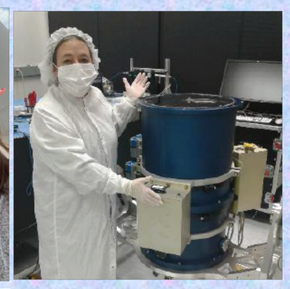

Michelle Creech-Eakman

The Palomar Testbed Interferometer

A 109-meter baseline optical interferometer

- Operations: H, K-band
- Resolution: 1 – 4.5 mas
- Sensitivity: K< 5, V<12
- Operations: 1996-2008

Notable catalog of achievements

- First direct detections of Cepheid pulsations (Lane et al 2000 Nature 407 485)
- Resolution of the Pleiades distance controversy (Pan, Shao, & Kulkarni 2004 Nature 427 396)
- First direct measurement of rotational oblateness in rapid rotator Altair (van Belle et al 2001 ApJ 559 1155)
- Dual-star wide-angle astrometry at the 100uas level (Shao et al AAS 195 8714)
- Narrow-angle astrometry at the 10uas level and detection of planetary-mass objects (Muterspaugh et al 2010 AJ 140 1657)
- Giant star linear sizes and temperatures (van Belle et al 2021 ApJ 922 163)
- Supergiant linear sizes and temperatures (van Belle et al 2009 394 1925)
- Carbon star sizes & oblateness (van Belle et al 2013 ApJ 775 45)
- First M-dwarf diameters (Lane, Boden, & Kulkarni 2001 ApJ 551 L81)
- Detection of T Tauri star excited inner dust rims (Akeson et al 2000 ApJ 543 313)

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