Massive Star Diameters Measured with CHARA/PAVO

PhD update for Noel Richardson (GSU)

Presented by Douglas Gies

Purpose of the project

- Few O- or B-type stars have accurate OLBI diameters.
  Exceptions: Intensity Interferometer results from Hanbury Brown et al. 1974;
  Regulus – McAlister et al. 2005;
  Achernar – Domiciano de Souza et al. 2003
- Diameter measurements allow us to determine effective temperatures of the stars
- For nearby B stars, we have reliable parallaxes, so we can obtain radii and luminosities
- For other targets, especially O stars, we may need to wait for SIM for a good parallax

Why PAVO?

- We get several spectral channels that can all be calibrated individually. This leads to multiple points on a visibility curve for each observation (faster estimates of diameters).
- Three baselines simultaneously provide
  - 1 closure phase
  - Better constraints on variations of size versus position angle for the rapid rotators

PAVO Targets: Orion Supergiants and Mass Loss

- PAVO and Classic programs on Orion supergiants
- Comparison of sizes will help determine mass loss rates

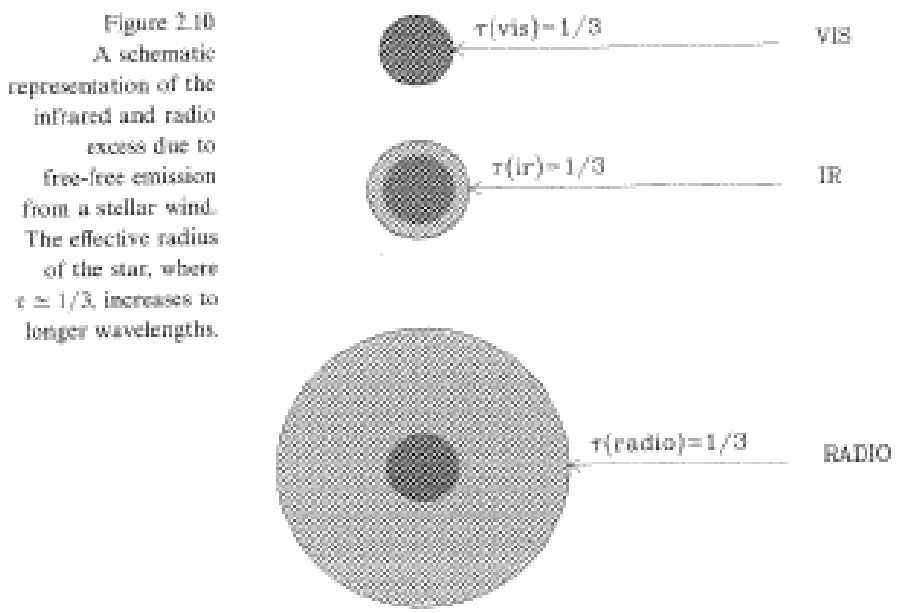


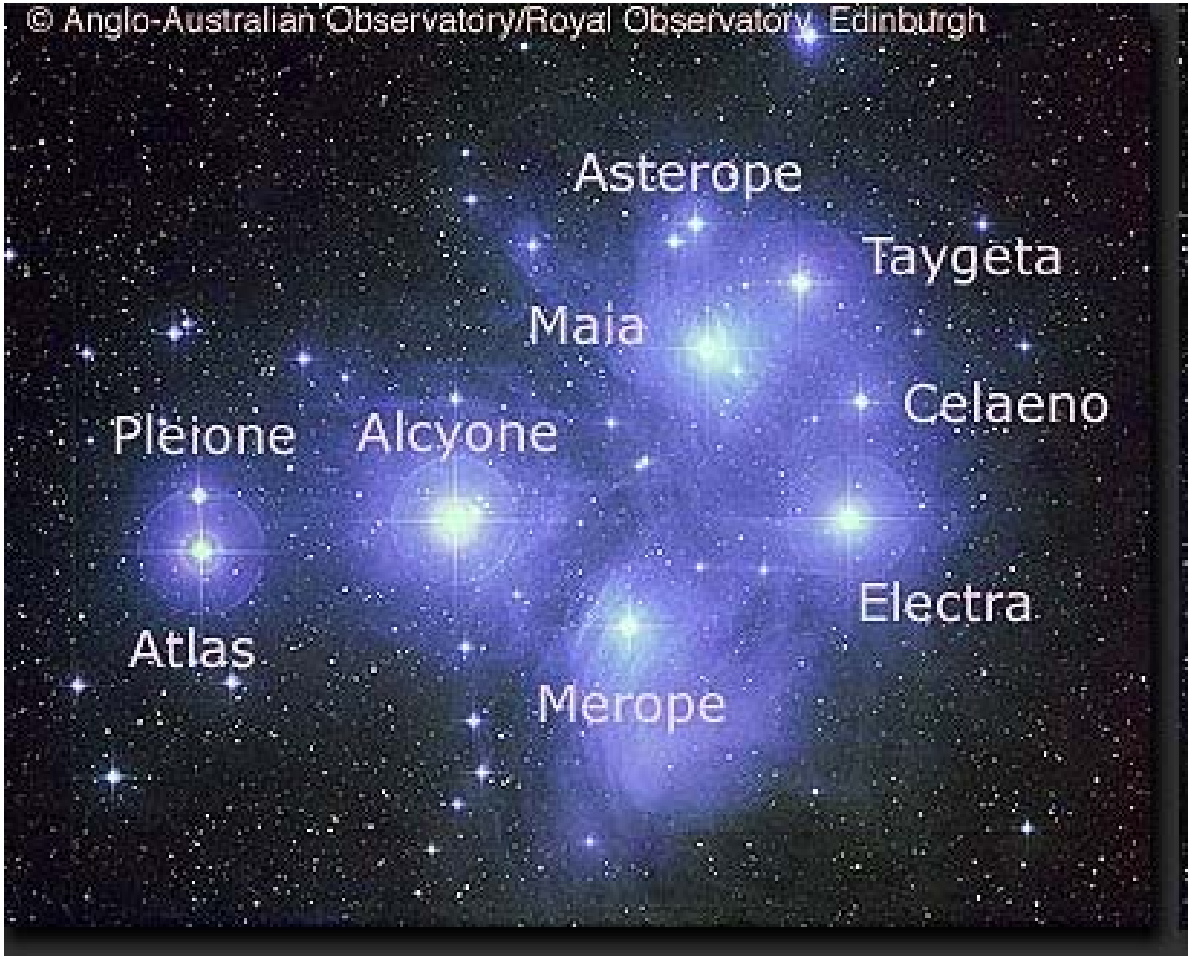
Figure 2.10
A schematic representation of the infrared and radio excess due to free-free emission from a stellar wind. The effective radius of the star, where $\tau \simeq 1/3$, increases to longer wavelengths.

Figure from Lamers & Cassinelli (1999)

PAVO Targets: Rapidly Rotating Be Stars

- *R*-band (except H alpha) is mainly free from disk contributions (possible electron scattering from inner disk) allowing measurements of the gravitational distortion of the star itself
- Will help determine how close Be stars are to critical rotation

PAVO Targets: Pleiades



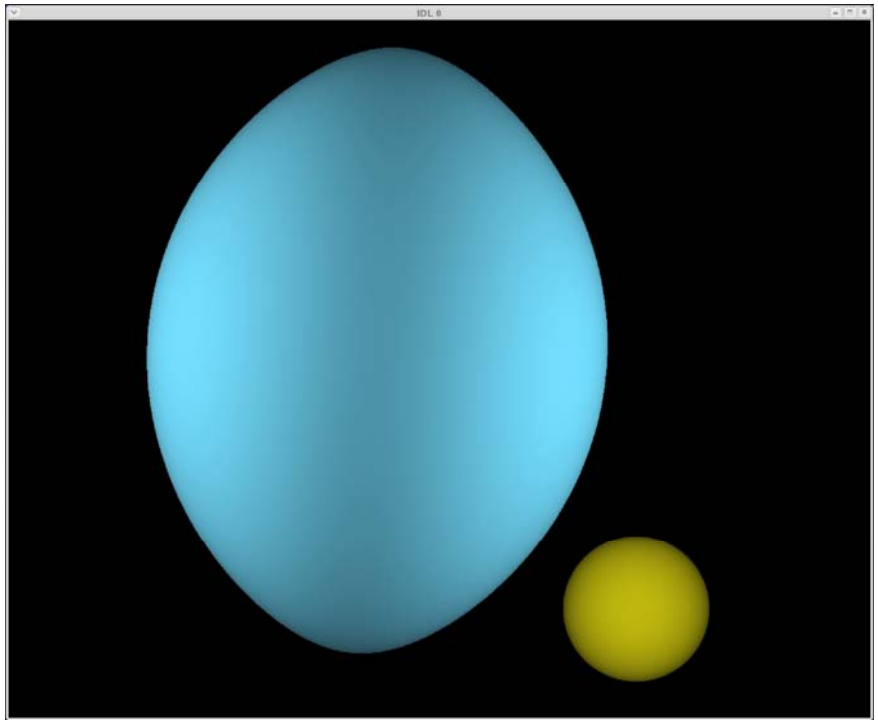
Status of the data

- CLASSIC runs -
  - Of Noel's 3 programs with CLASSIC, all three had bad weather.
    - 2 runs in consecutive winters for supergiants in K' band
    - 1 run for B star diameters last spring
- PAVO -
  - One run last fall
  - Data reduction underway
  - Collected data on 11 stars
    - Pleiades diameters, Orion supergiants, 15 Mon (mainly multiplicity), and Beta CMi (Be star)

Analysis

- Many O and B stars are rapid rotators and/or binaries
  - Take into effect rotational distortion and gravity darkening
  - Create a model star image that depends on position angle, inclination, gravity darkening, and companions

Regulus (B7 V)



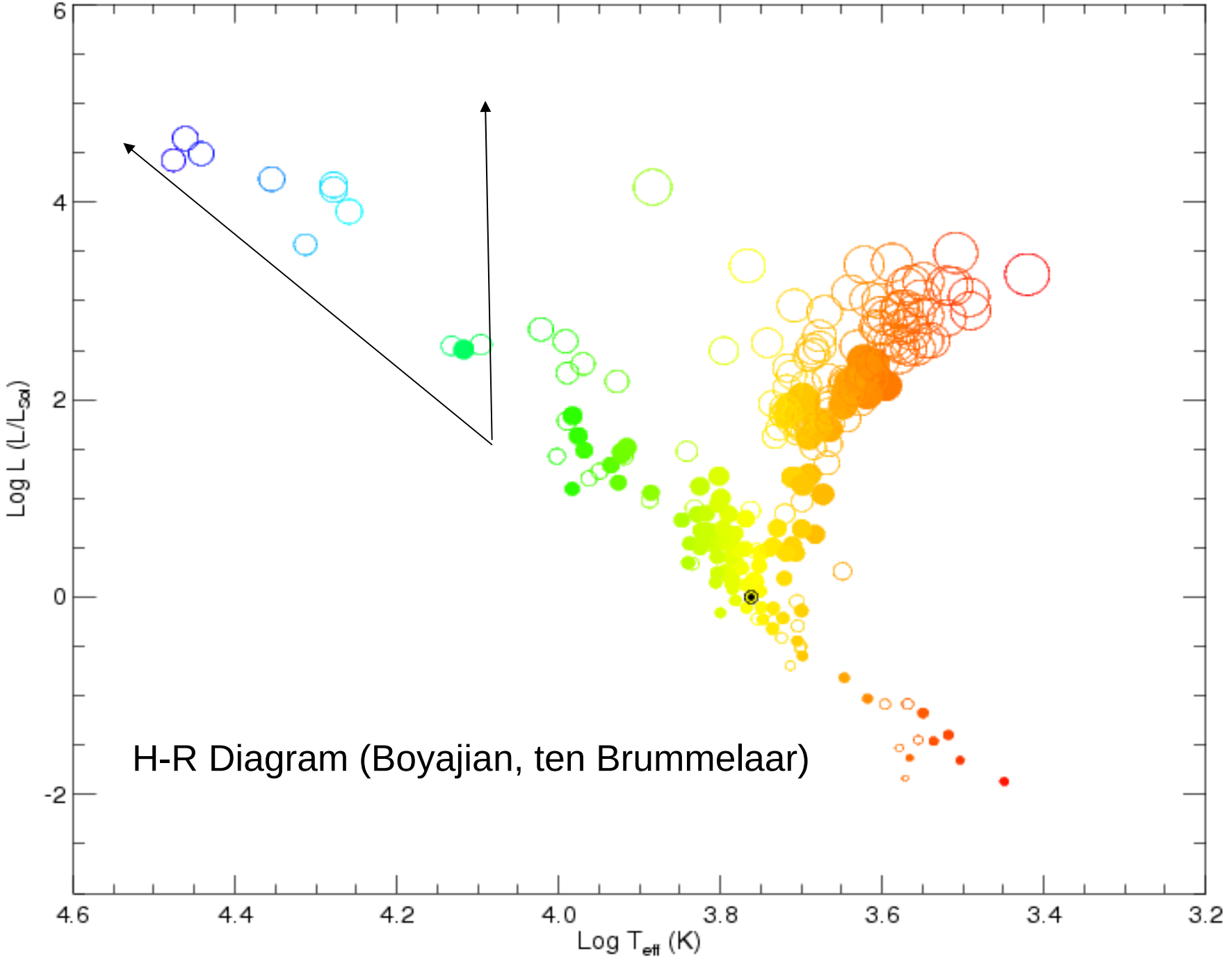
McAlister et al. 2005

Targets

- Have data (Fall 2008)
  - HD 23302 (B6 IIIe)
  - HD 23338 (B6 V)
  - HD 23408 (B8 III)
  - HD 23480 (B6 IV)
  - HD 23630 (B7 III)
  - HD 23850 (B8 III)
  - HD 37128 (B0 Ia)
  - HD 37742 (O9.7 Ib)
  - HD 38771 (B0.5 Ia)
  - HD 47839 (O7 V – multiplicity)
  - HD 58715 (B8 Ve)
- Need data (Spring 2009)
  - HD 109387 (B6 IIIe)
  - HD 120315 (B3 V)
  - HD 135742 (B8 V)
  - HD 147394 (B5 IV)
  - **HD 149757 (O9.5 Vnn)**
  - HD 155763 (B6 III)
  - HD 160762 (B3 V)
  - HD 176437 (B9 III)
  - HD 177756 (B9 Vn)
  - HD 186882 (B9.5 III)
  - HD 196867 (B9 V)
  - HD 205021 (B2 III)

Fall 2009

- Get final data needed for this portion of the dissertation; goal of additional 5 O stars and 20 B stars
- Construct upper H-R diagram from data.
  - Will rely on cluster distances for several stars, rather than parallax


6
4
2
0
-2
Log L (L/L$_{sol}$)
4.6
4.4
4.2
4.0
3.8
3.6
3.4
3.2
Log T$_{eff}$ (K)
H-R Diagram (Boyajian, ten Brummelaar)

Other CHARA-related projects

- P Cygni spectroscopy
- Zeta Tau and Gamma Cas spectroscopy
- Spectral Energy Distributions

Luminous Blue Variable P Cygni

- Peter Tuthill & Theo ten Brummelaar: CHARA Classic experiment produced unexpected results
  - Is envelope larger than thought?
  - Or, is the IR excess causing the continuum to appear larger than expected?
  - Or, is the variability causing the unusual results?
- Noel has more than 10 years of high resolution echelle spectroscopy of P Cyg (H-alpha) taken at Ritter Observatory
- Long term study of the variability

P Cyg

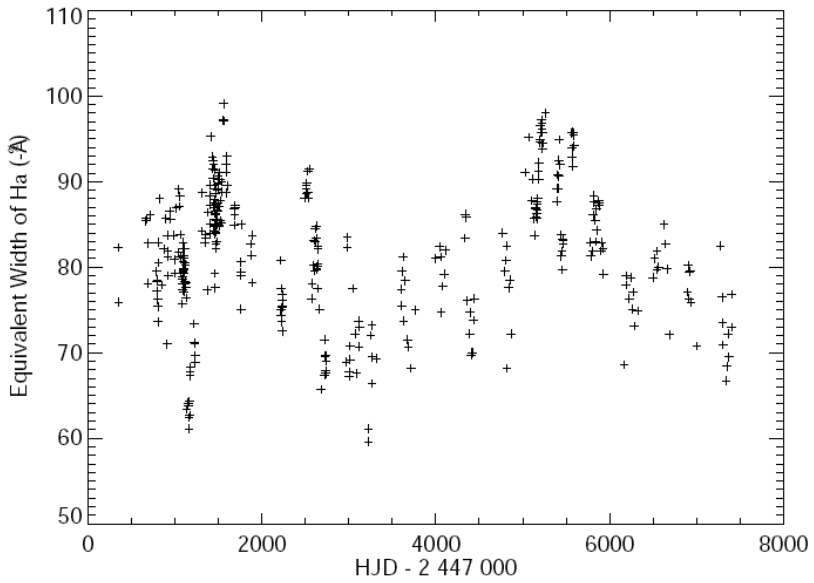
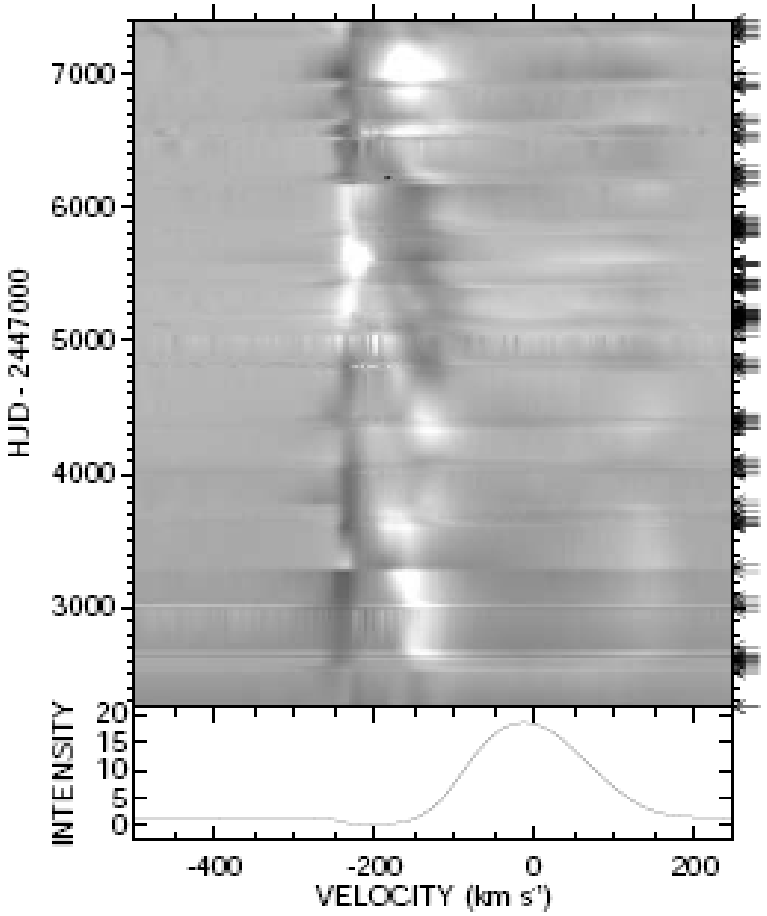


Fig. 1.— The measured equivalent widths of the Hα profile of P Cygni between 1988 and 2007.

- H-alpha equivalent width variations
- Long term trend is called a "short S Doradus phase"
- Not wildly variable during CHARA observations

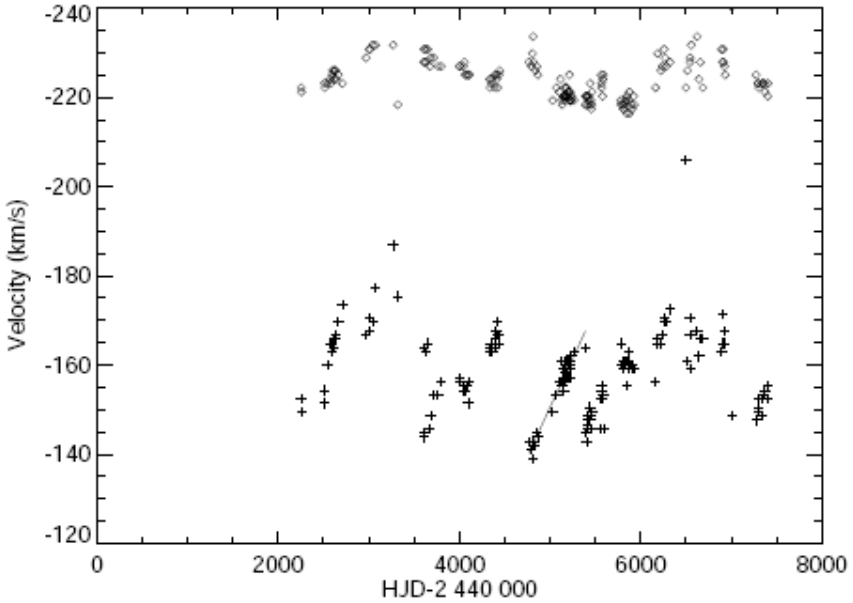
A Structured Wind

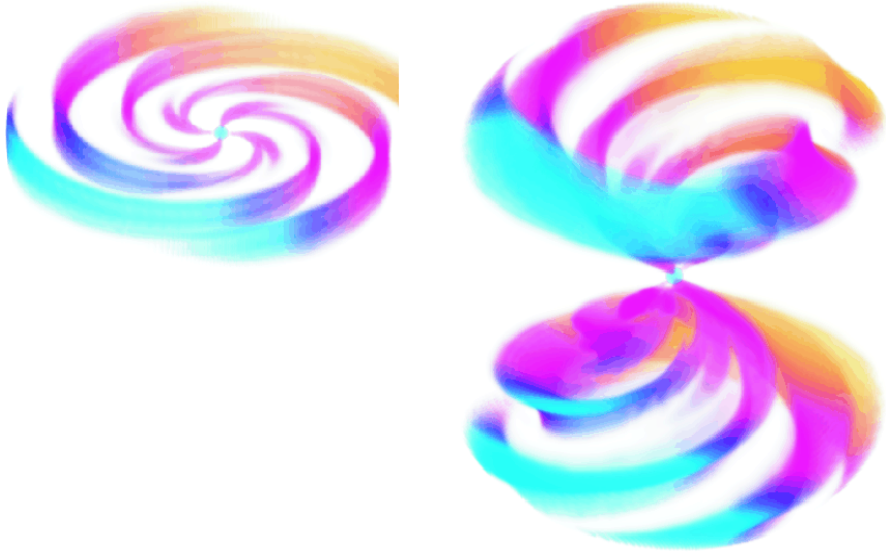


- Dynamical spectrum: grayscale depiction of each spectrum divided by average spectrum
- Main features are 'DACs' (Discrete Absorption Components)

Discrete Absorption Components

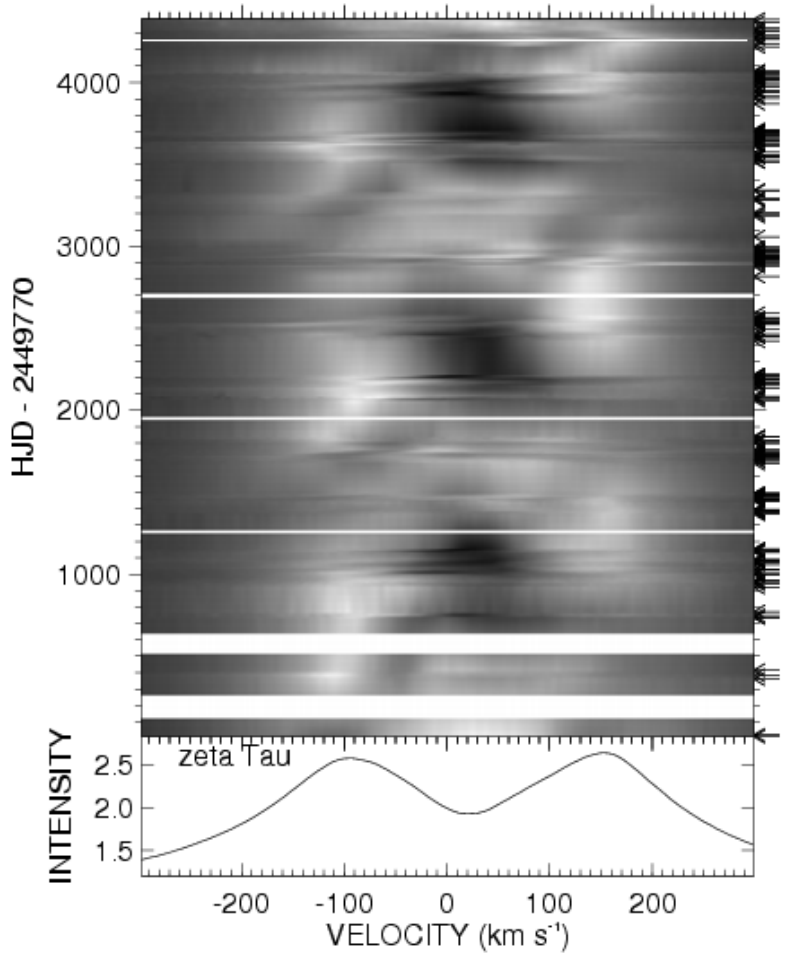
- Moving features probably formed in a Co-Rotating Interaction region
- May have interferometric signal



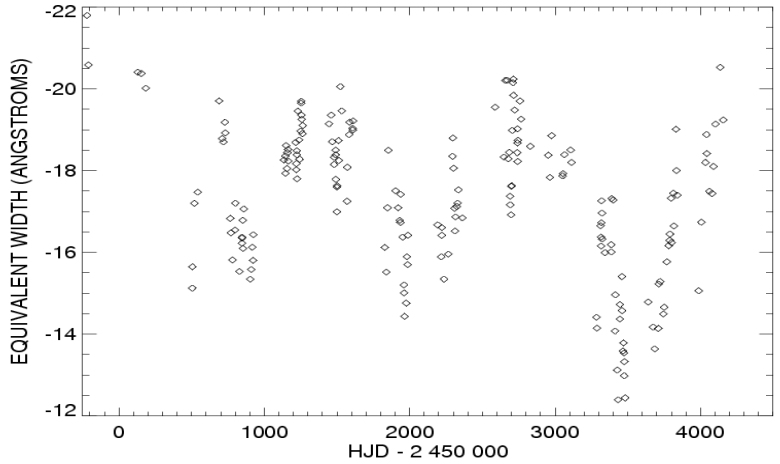


Dessart (2004)

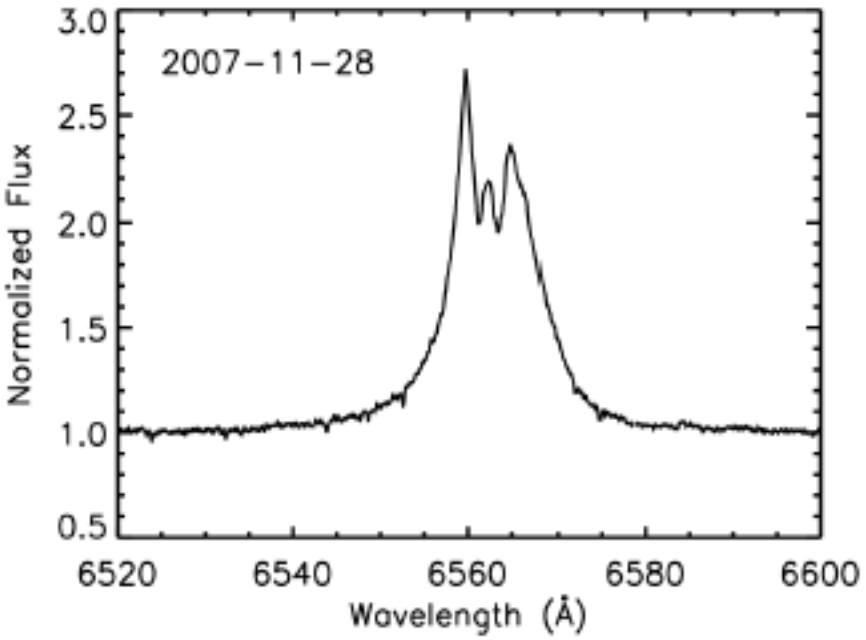
Be Star Zeta Tau

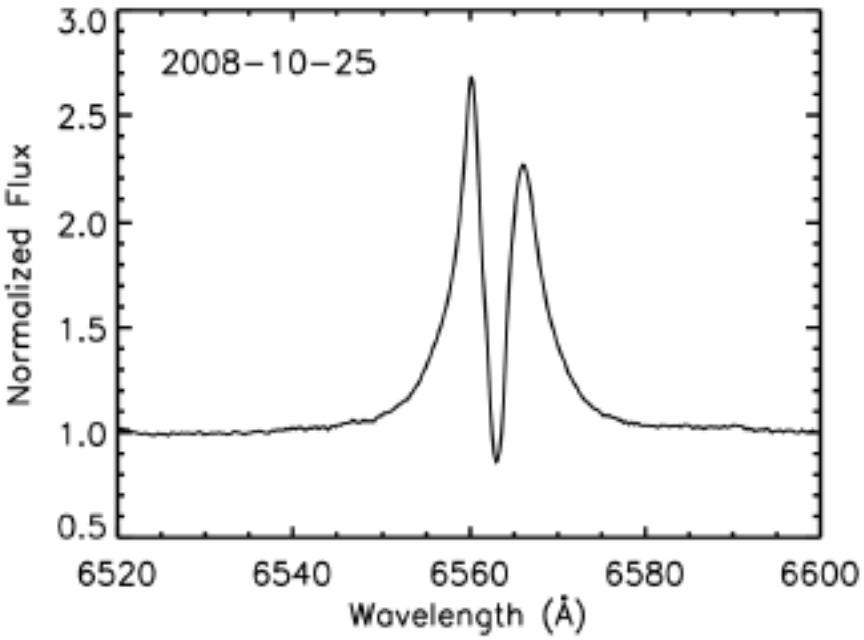


- Long term spectroscopy to compare to MIRC observations
- H-alpha (Ritter Obs.)

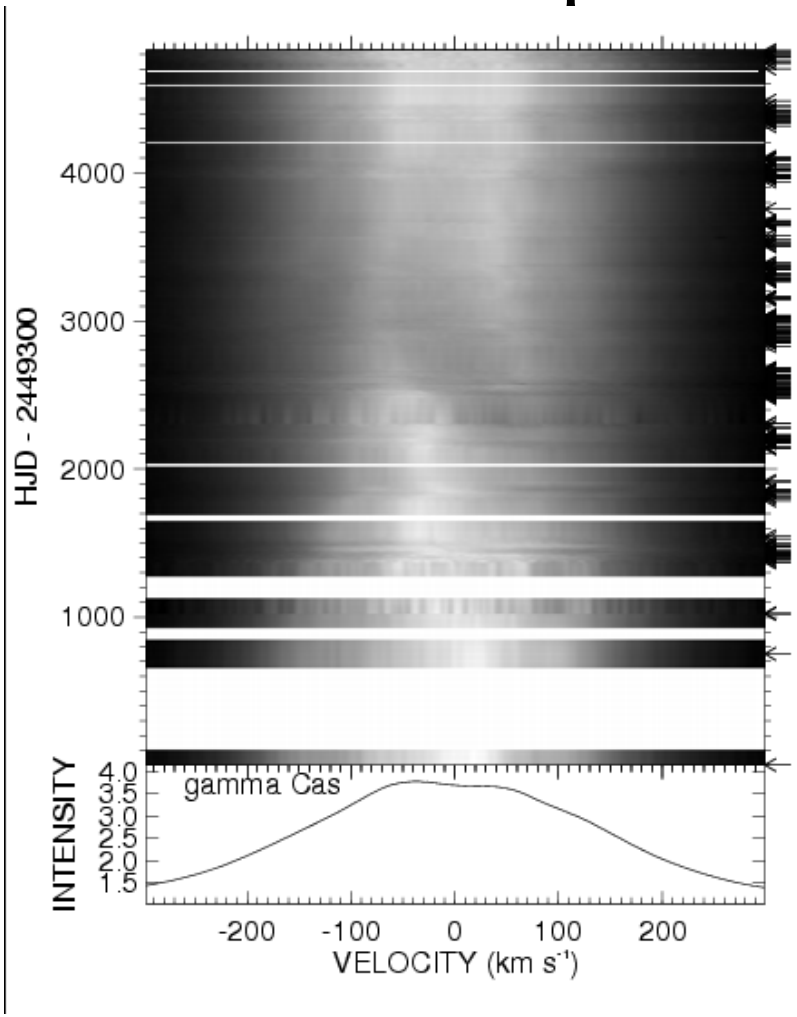


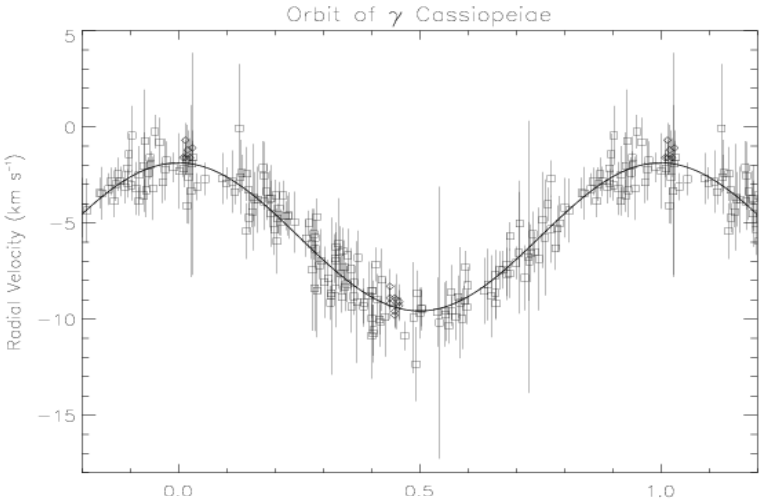
Zeta Tau at dates of MIRC observations: change in disk appearance

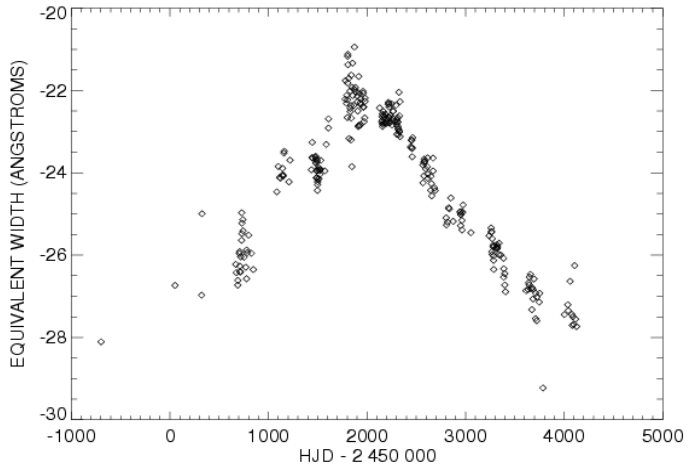




Be Star Gamma Cas: H-alpha variations and Orbit







Spectral Energy Distributions of Hot Stars

- All of the PAVO targets will have comparative SED fits
- For many of the Be stars in Yamina's program as well as the hot supergiants, Noel has collected contemporaneous optical (KPNO Coude Feed) and NIR (Lowell - Mimir plus IRTF) spectrophotometry
  - Data reduction in progress (optical is done; Noel is at Boston University doing the NIR data this week)
  - Will construct SEDs and determine the amount of IR light coming from the disk. This will better constrain the Be star models developed to fit the CHARA observations.