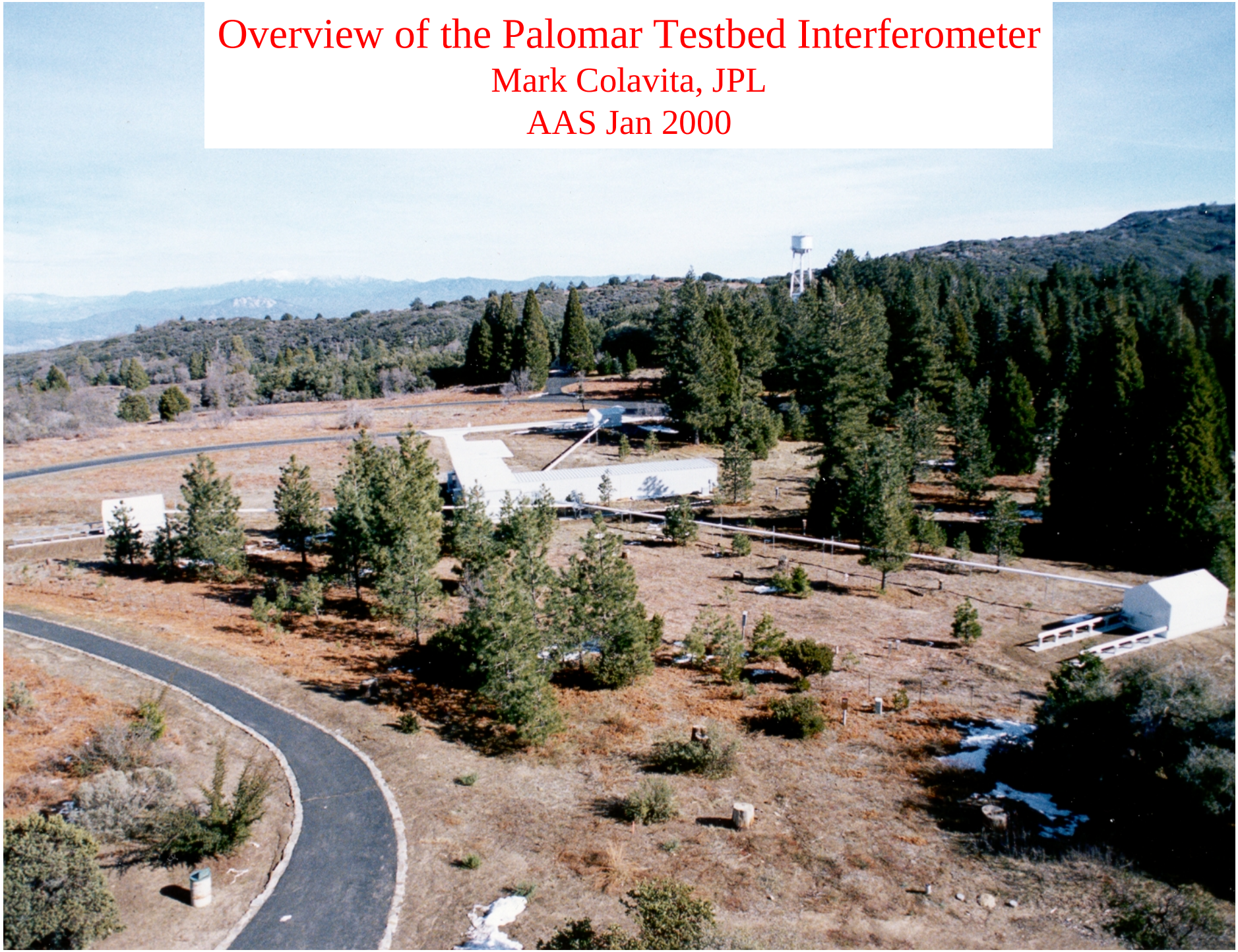
Overview of the Palomar Testbed Interferometer

Mark Colavita, JPL

AAS Jan 2000



Members of the PTI Collaboration

Name	Affiliation	Primary PTI Interests
R. L. Akeson	Caltech	Young Stellar Objects Differential Phase
R. Bambery	JPL	
A. F. Boden	Caltech	Spectroscopic Binaries Astrometry
M. M. Colavita	JPL	Astrometry
M. J. Creech-Eakman	JPL/Caltech	Mira Variable Stars Young Stellar Objects Mid-IR Instruments and Detector Technology
P. J. Dumont	JPL	Astrometry
C. D. Koresko	Caltech	RS CVn Stars
M. Kuchner	Caltech	Cepheid Variables
S. R. Kulkarni	Caltech	Science Program Coordination
B. Lane	Caltech/JPL	Main Sequence Stars Instrumentation
P. Lawson	JPL	Astrometry Instrumentation
R. Linfield	Caltech	Atmospheric Studies
M. Shao	JPL	
M. Swain	JPL	Differential Phase
R.R. Thompson	JPL/University of Wyoming	Evolved Stars Stellar Angular Diameters
G. T. van Belle	JPL	Evolved Stars Stellar Angular Diameters
D. Van Buren	Caltech	
G. Vasisht	JPL	
J. K. Wallace	JPL	Instrumentation
F. P. Wilkin	Caltech/IPAC	Young Stellar Objects Astrometry

Instrument Description

- NASA funded, tech dev. for Keck and other interferometers
- 2-way system, 110 m max baseline
- 40 cm collecting apertures
- Active broadband fringe tracking at K (2-2.4 μm) or H (1.5-1.8 μm)
- Spectrometer resolution of R = 25 – 50
- Angle tracking at R + I (0.7 – 1.0 μm)
- Dual-star capability for narrow-angle astrometry

More detail:
ApJ 510, 505 (1999)

New for 99

  - Routine H-band capability
  - Selectable coherent integration times
    - » 10, 20 ms for fringe tracking
    - » 50, 100, 250 ms for phase referencing
  - Phase referencing with pathlength feedforward
  - Narrow-angle baseline monitoring
  - Automated pipeline reduction, archiving, reporting
  - New observation planning tools
- Bad stuff
  - Mid-season recoating necessary ☹

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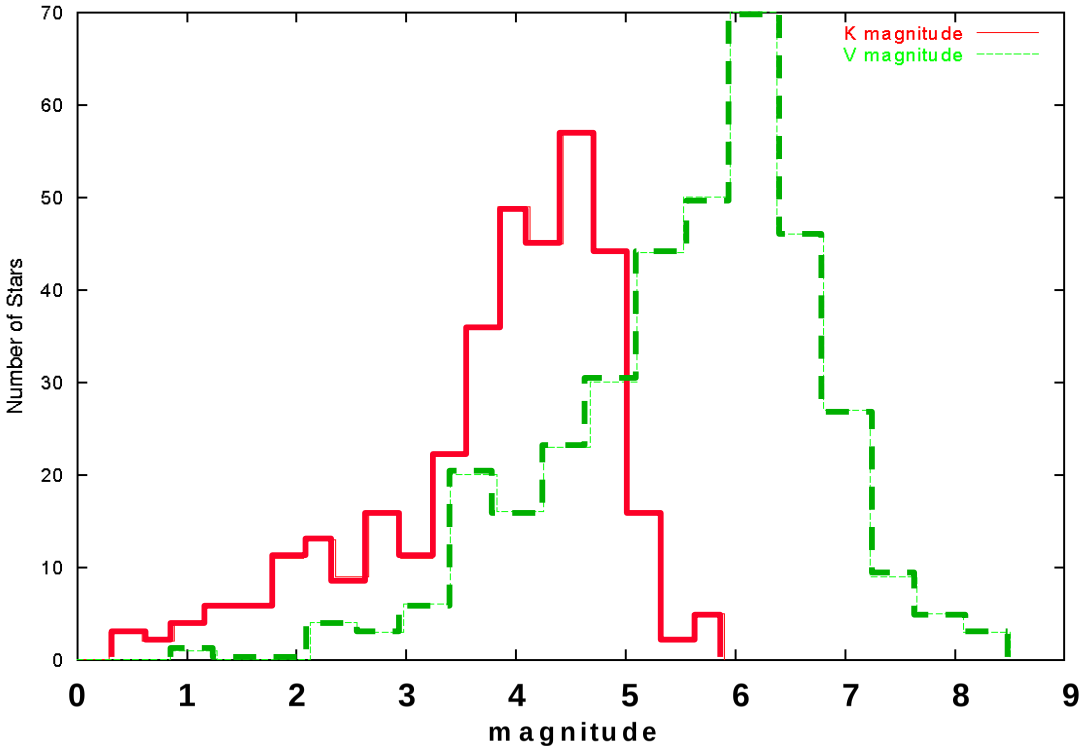
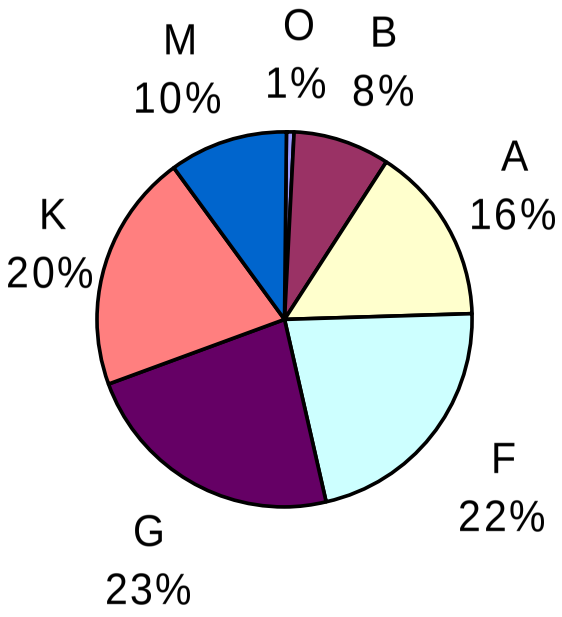
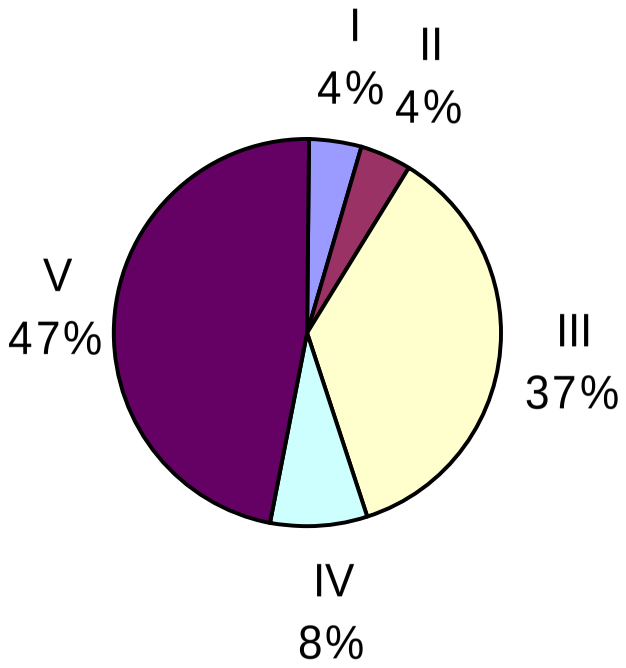
Observing Stats 1999 Partial (Feb28-Nov21)

- Up 204 of 267 possible nights
  - 161 single star
  - 28 dual-star
  - 15 engineering
- 8600 scans on 547 separate targets
  - (1 scan = 130 sec of fringe tracking data + calibrations)
- Highest-throughput night: 122 scans
- Efficiency (fraction time tracking fringe + calibrations): 40%

Observing Stats 1999 partial

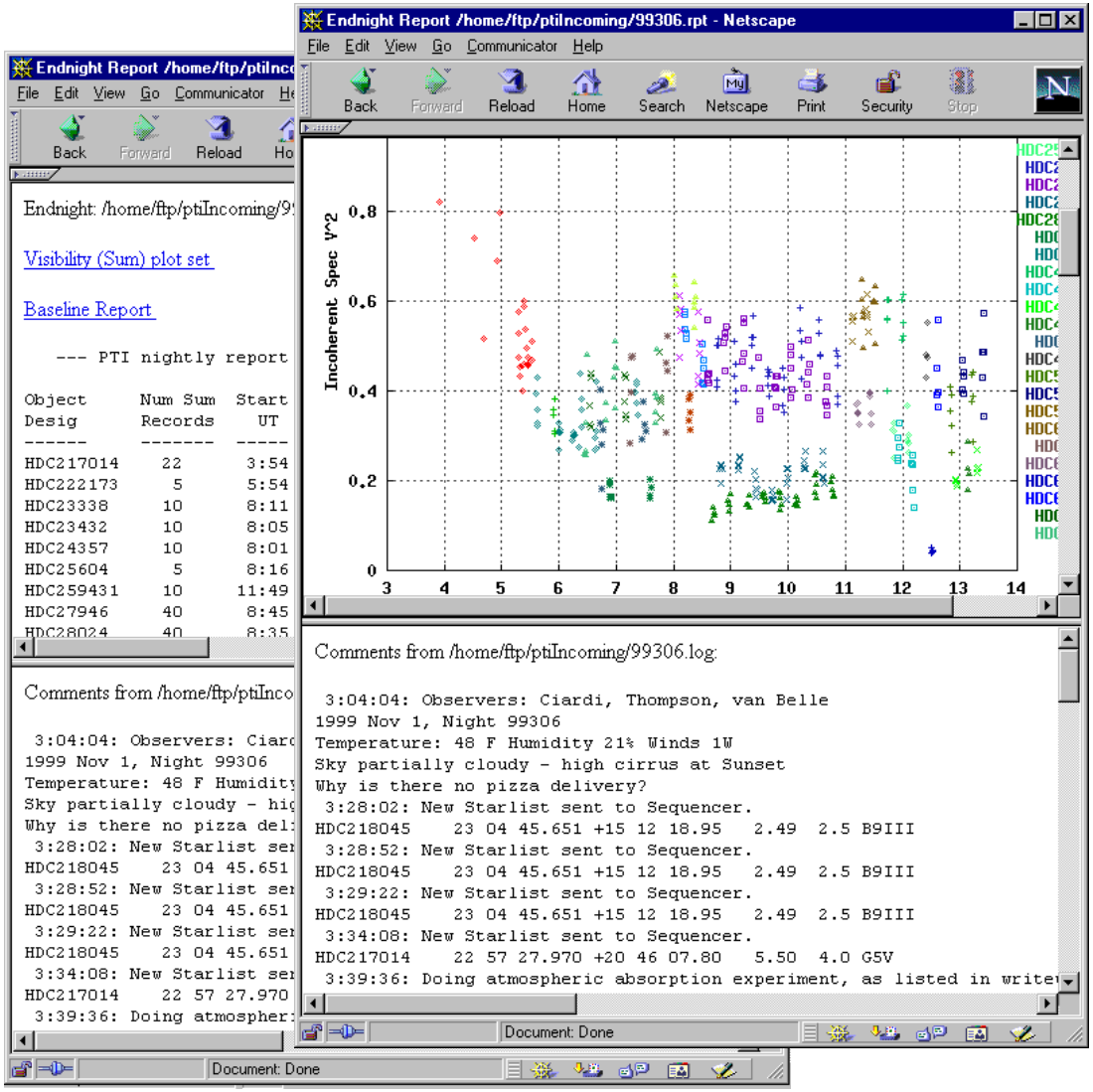






Automated Level-1 reductions

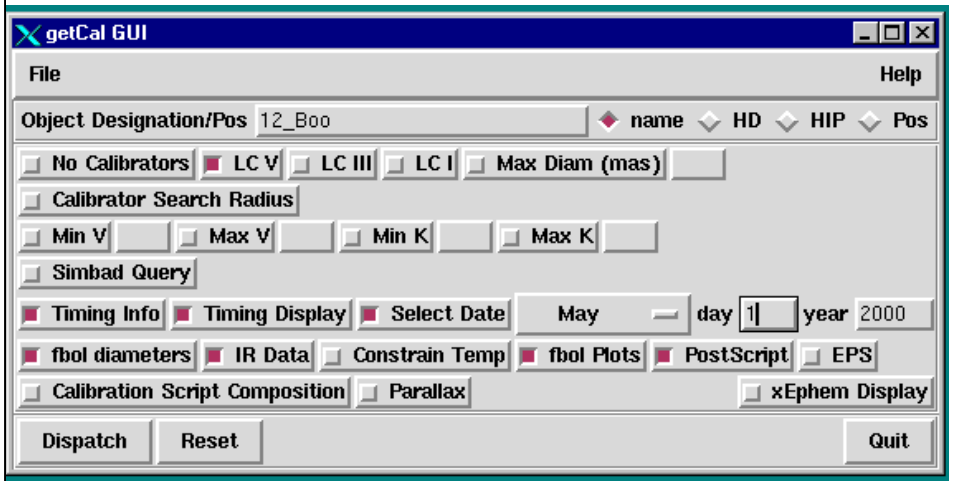
- Scripts automate end-of-night reductions
  - Level -1 reductions
    - » Calibrated visibilities
    - » 25 sec visibility points
  - Baseline model
  - Email report to collaborators
  - Web access to nightly summary, log
  - CD burns of level-0 data

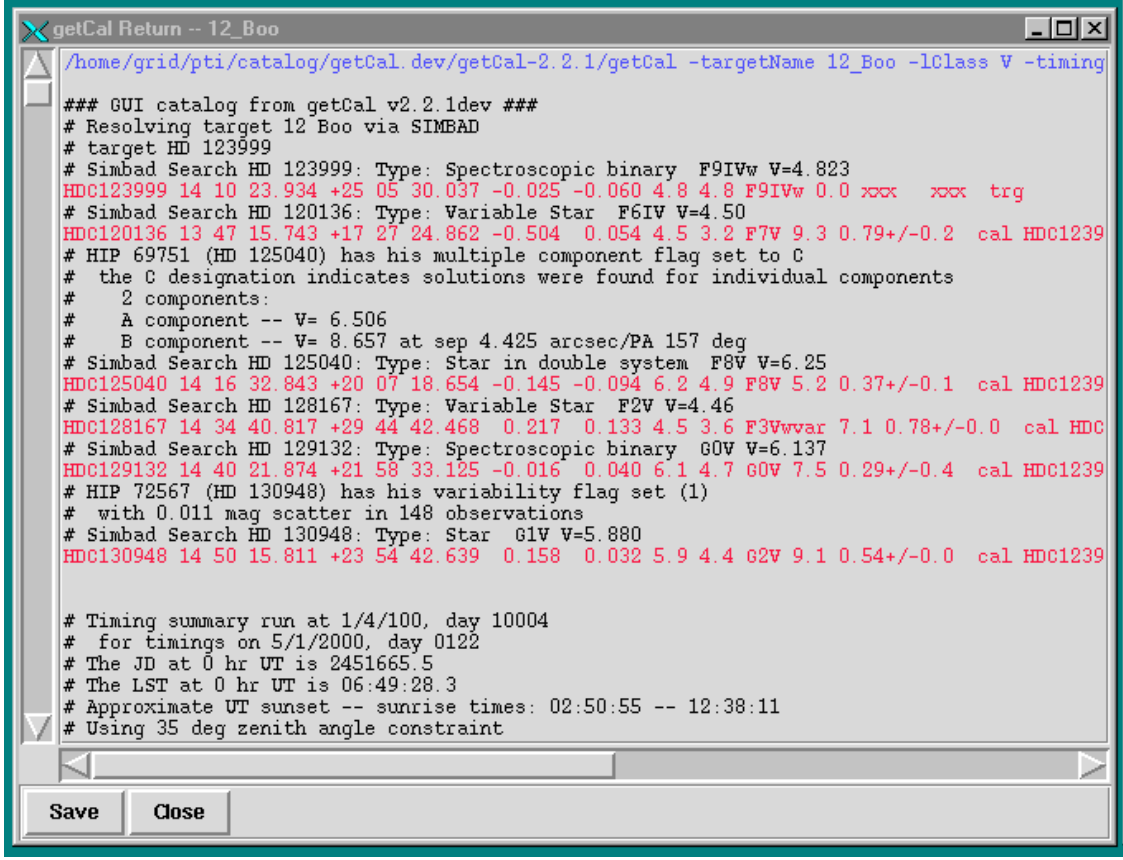


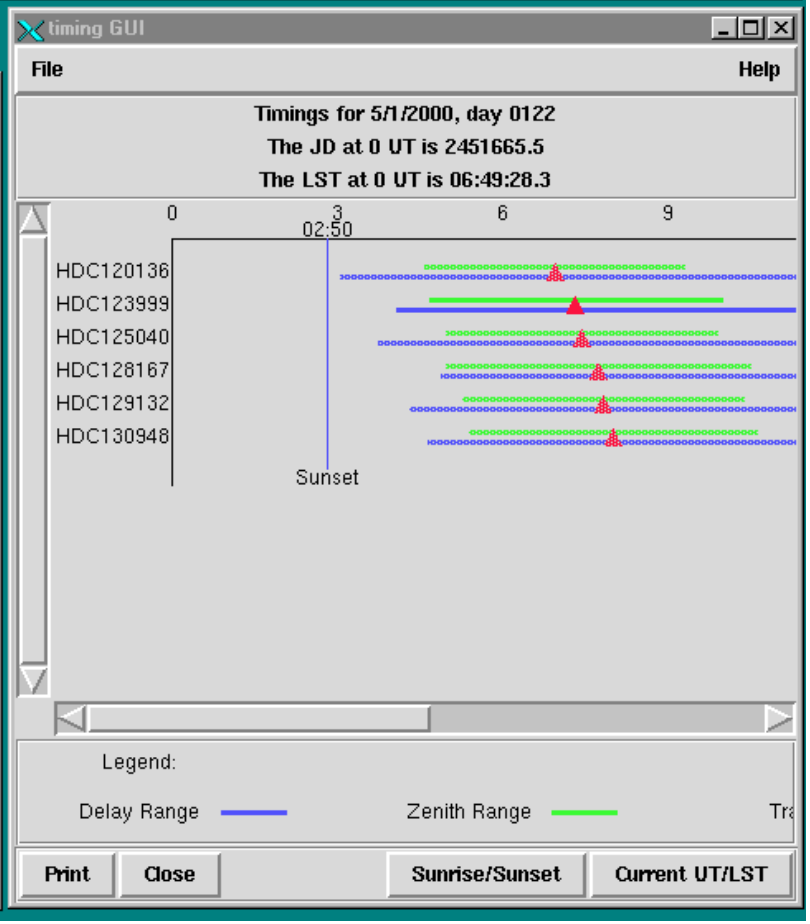
Automated Calibrator Selection

- Physical Parameter Estimation (T_{eff}, diameter)
- Database query (Hipparcos, Simbad)

- Timing/Delay Range Calculations
- Real-Time Target Availability GUI







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Diameters

- Parameter space
  - λ/D = 4.1 mas (K), 3.0 mas (H)
- Calibration, calibration, calibration = single mode fiber, careful scan calibration, lots of science calibrators
- Posters

[45.01] Linear Diameters and Effective Temperatures of Carbon Stars (van Belle et al.)

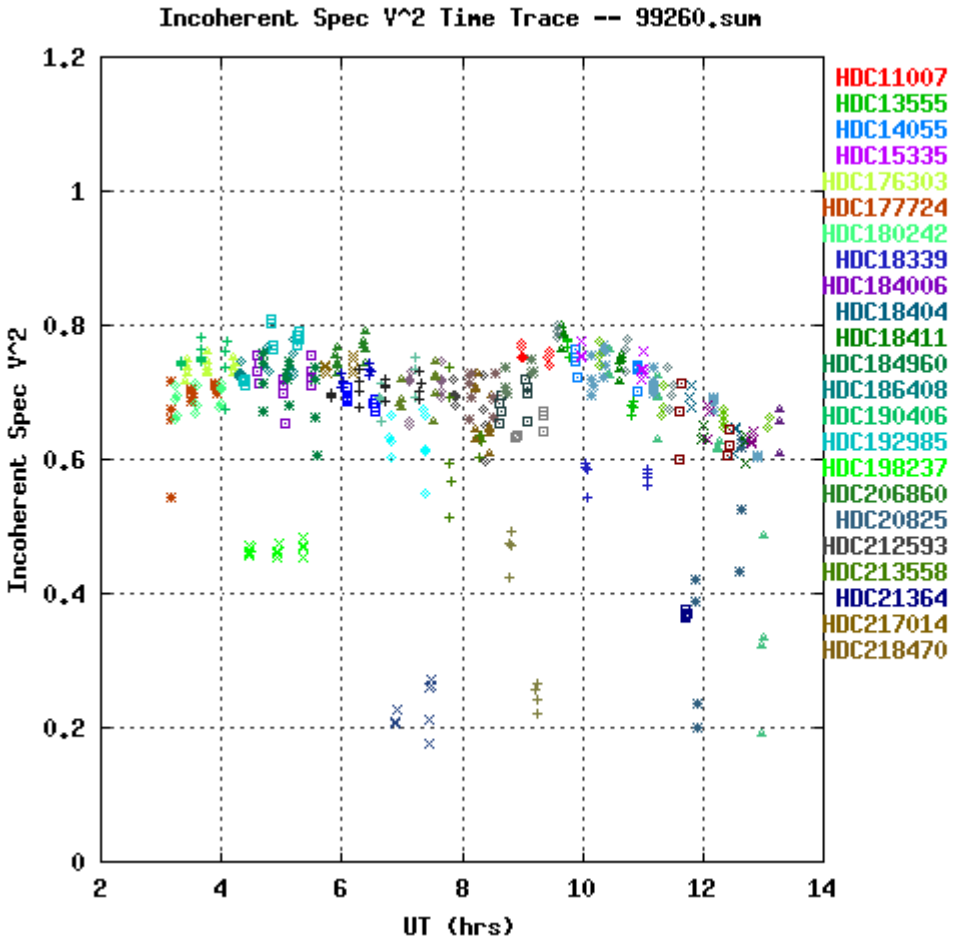
[45.02] Periodic changes in the K-band spectral angular diameters of Mira Variables at PTI (Thompson et al.)

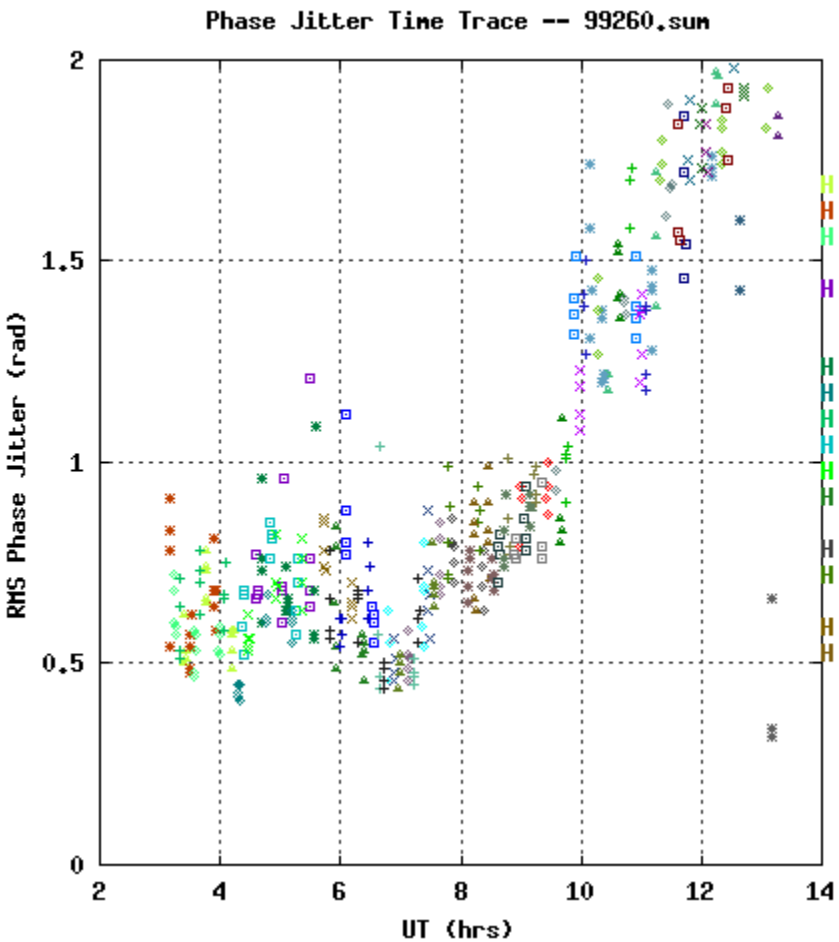
[49.05] Near-Infrared Observations of Circumstellar Material Around Young Stars on the Sub-AU Scale (Ciardi et al.)

[75.02] Measuring Cepheid Angular Sizes Directly using PTI (Kuchner et al.)

[75.05] Pulsational Modes of Mira Variables Examined through IR Interferometry (M.J. Creech-Eakman et al.)

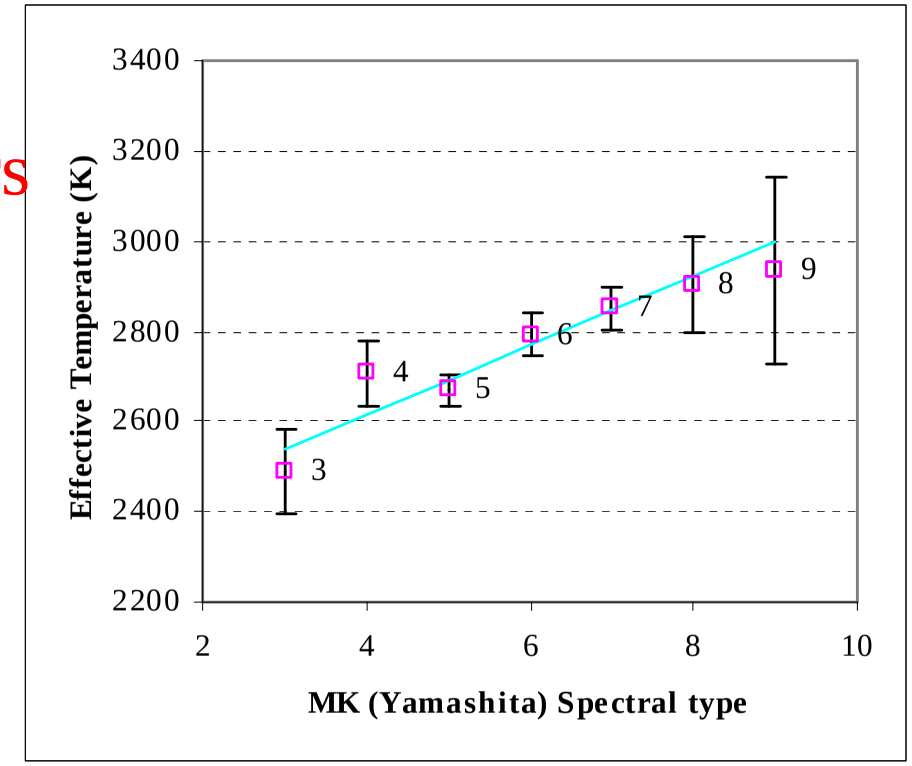
Visibility and Seeing Data (25 sec points)





Linear Radii and Effective Temperatures of Carbon Stars

- As a function of MK spectral class as determined by Yamashita (1972, 1975)
- Temperature increase towards "later" spectral types
  - First noted by Tsuji (1981a,b) and indicated previously (Dyck *et al.* 1996)
  - T = 76×C + 2310 K
- Consistent with presence of M-S bands as indicated by Dominy (1985) (linked to SiC_2)

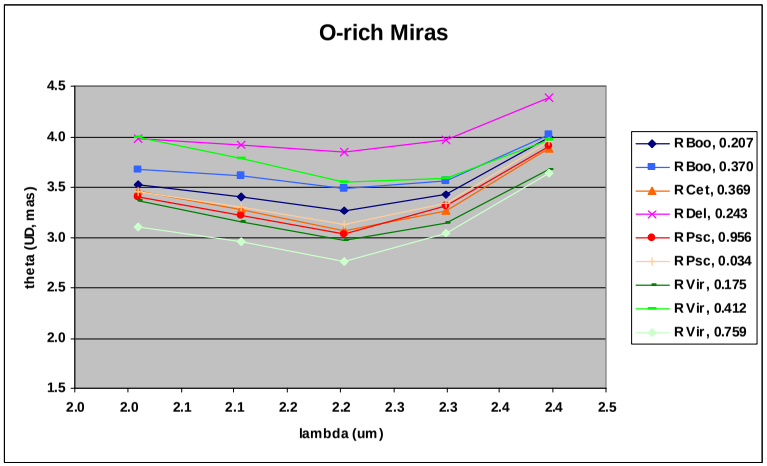


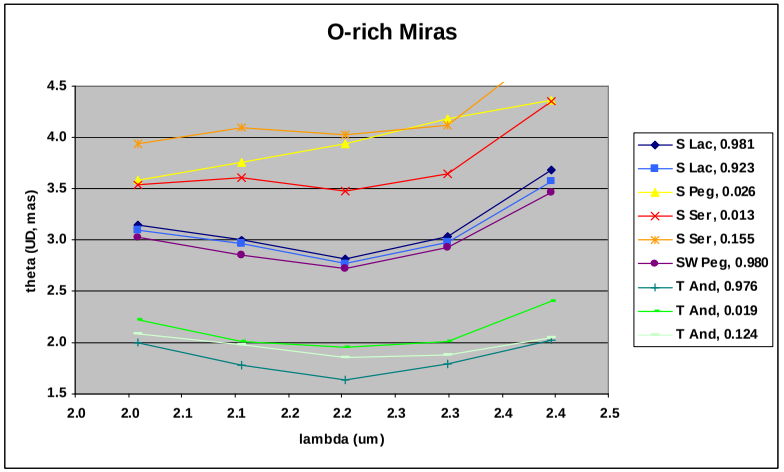
Class	N	T (K)	σ_T	Std. Dev.
C3	1	2491	94	
C4	3	2706	73	183
C5	14	2669	33	217
C6	9	2794	45	370
C7	9	2850	46	152
C8	2	2906	106	174
C9	1	2936	209	

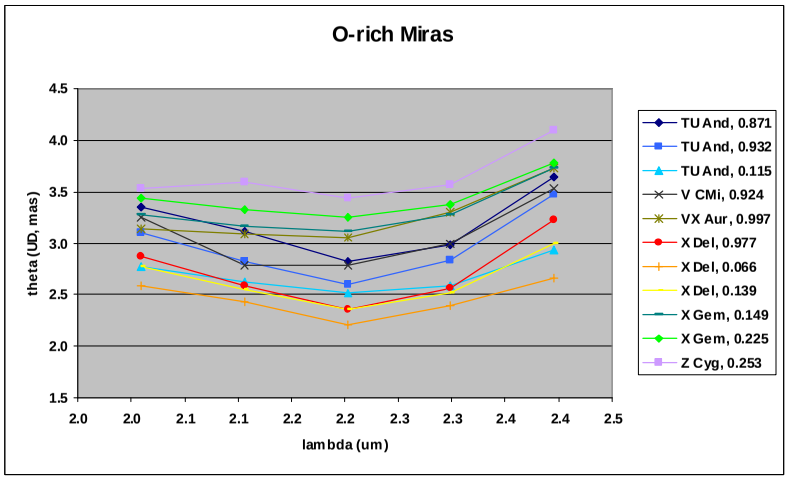
The PTI Mira data set

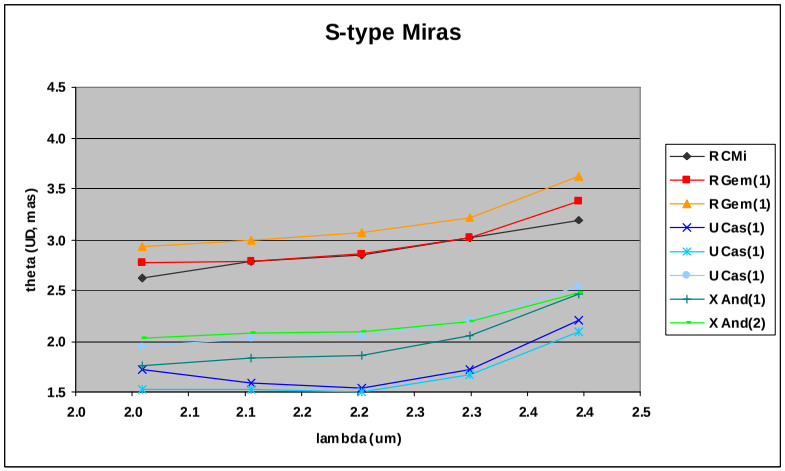
92 spectral observations, binned by phase

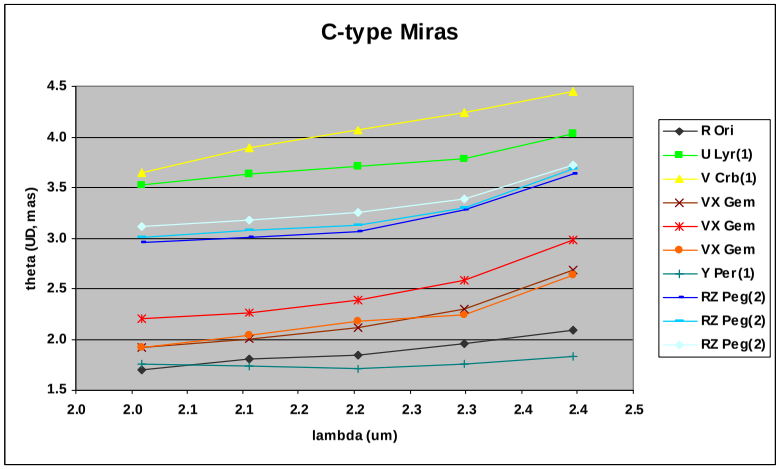
	P < 325d	P > 325d
M-type	10	6
C-type (R, N)	1	5
S-type	1	3











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Binary Stars

- Parameter space
  - 2 - 100 mas, $\Delta K < 3.5$
- Global solutions, inclusion of raw RV data in integrated fit
- Posters

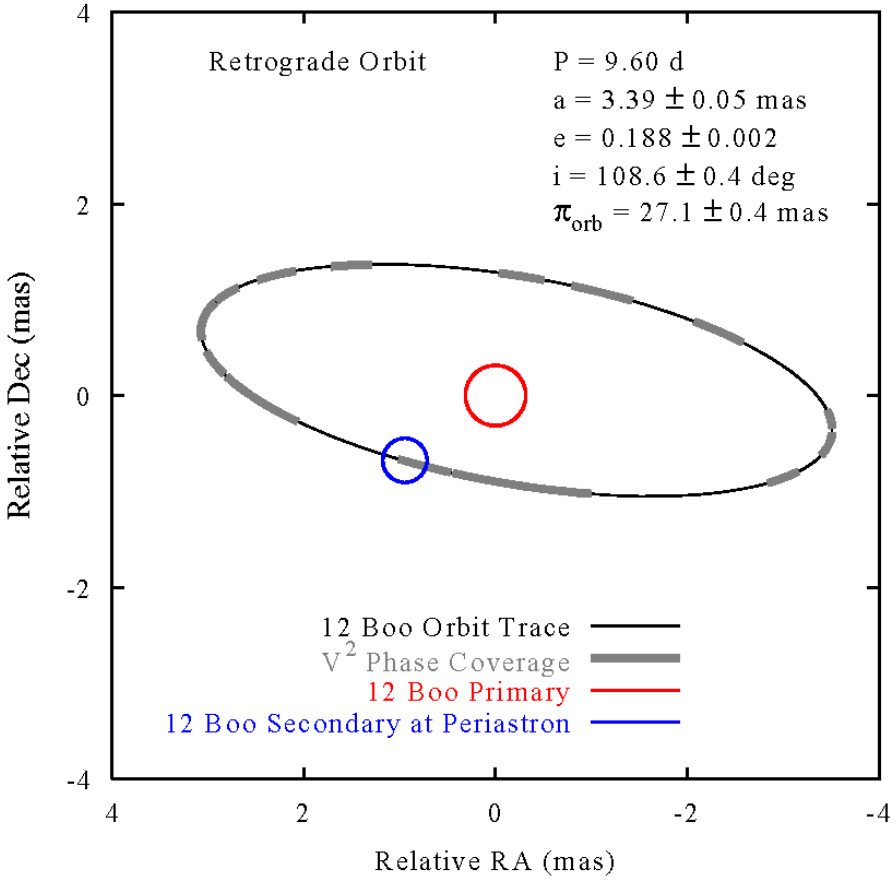
[113.01] Spectroscopic Binary Star Studies with PTI (Boden et al.)

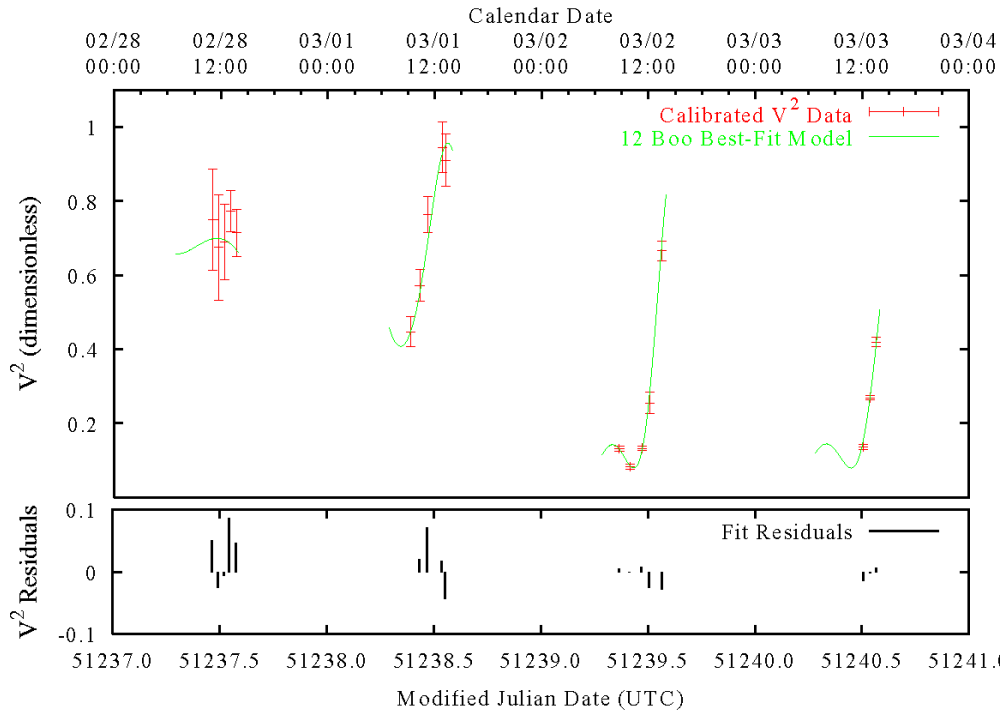
[113.02] K-Band Orbit Determination for Massive Binaries with PTI (Bambery et al.)

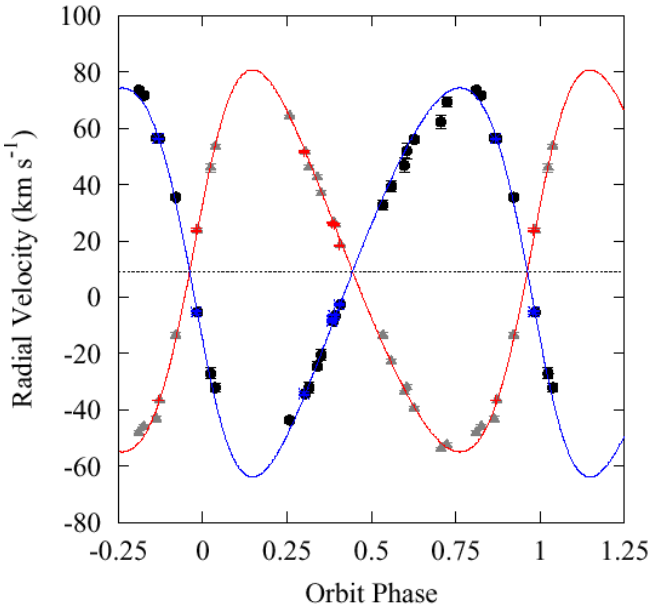
[late] The Visual Orbit of the Chromospherically-Active Binary Star HR 8170 (Koresko et al.)

[late] The Visual Orbit of Atlas and the Distance to the Pleiades (Pan et al.)

12 Boo Analysis







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Astrometry and technology

- Posters

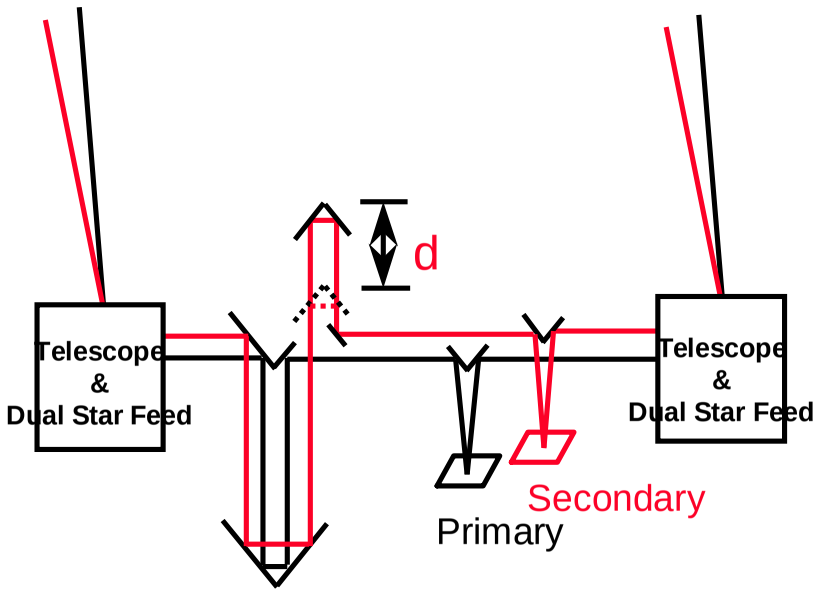
[87.14] Differential Astrometry of the 61 Cygni System with PTI (Shao et al.)

[87.12] Phase Referenced Stellar Interferometry at PTI (Lane et al.)

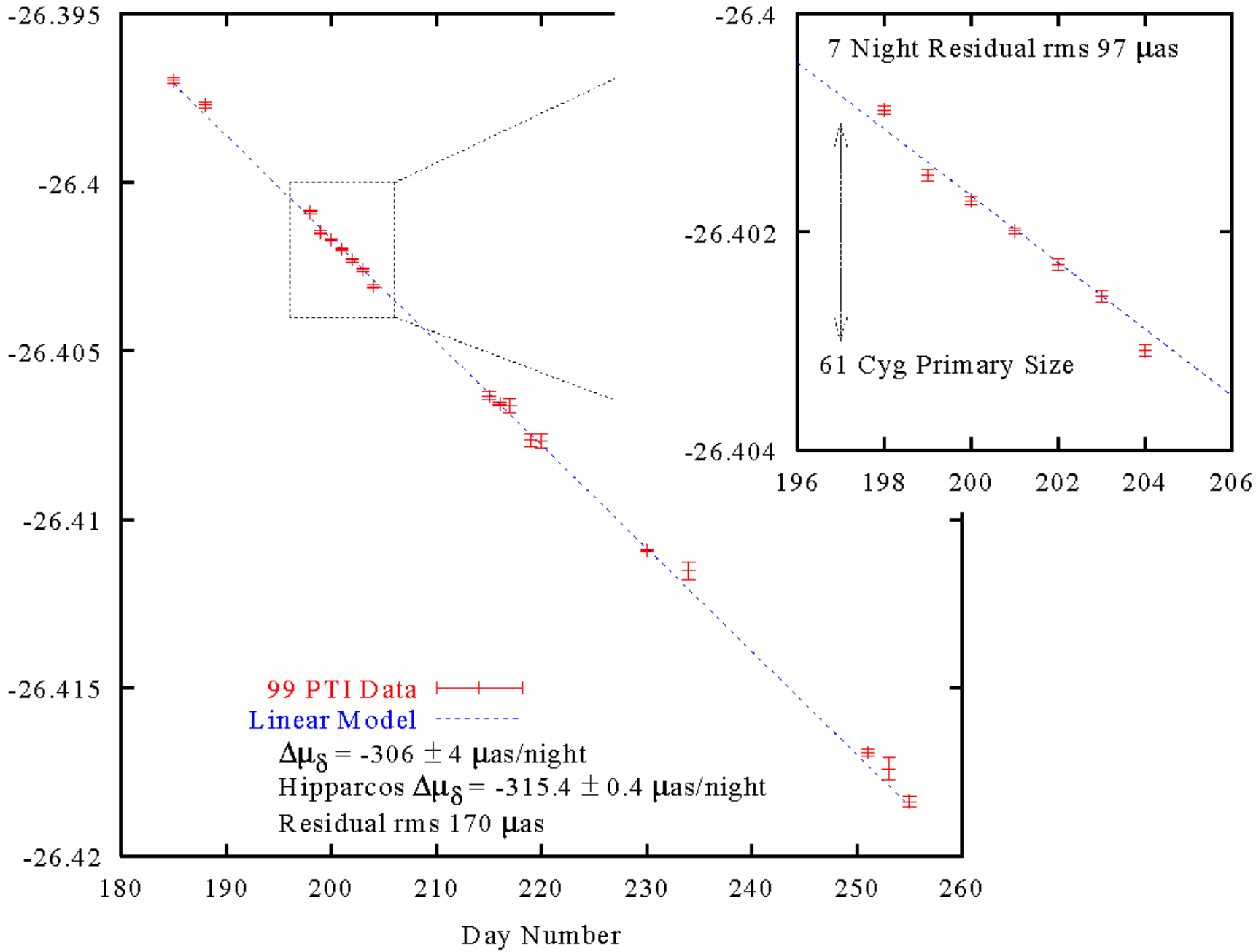
[92.02] Atmospheric Fluctuation Measurements with PTI (Linfield et al.)

Narrow-angle astrometry with PTI

- With a long-baseline interferometer, accuracies <100 uas are possible with differential measurements over small fields
- Approach
  - Dual-star feed to separate out target star from astrometric reference
  - Dual beam combiners to allow simultaneous measurements
    - » One beam combiner tracks target star
    - » Second beam combiner switches between stars
  - Laser metrology to control systematic errors



61 Cyg Astrometry



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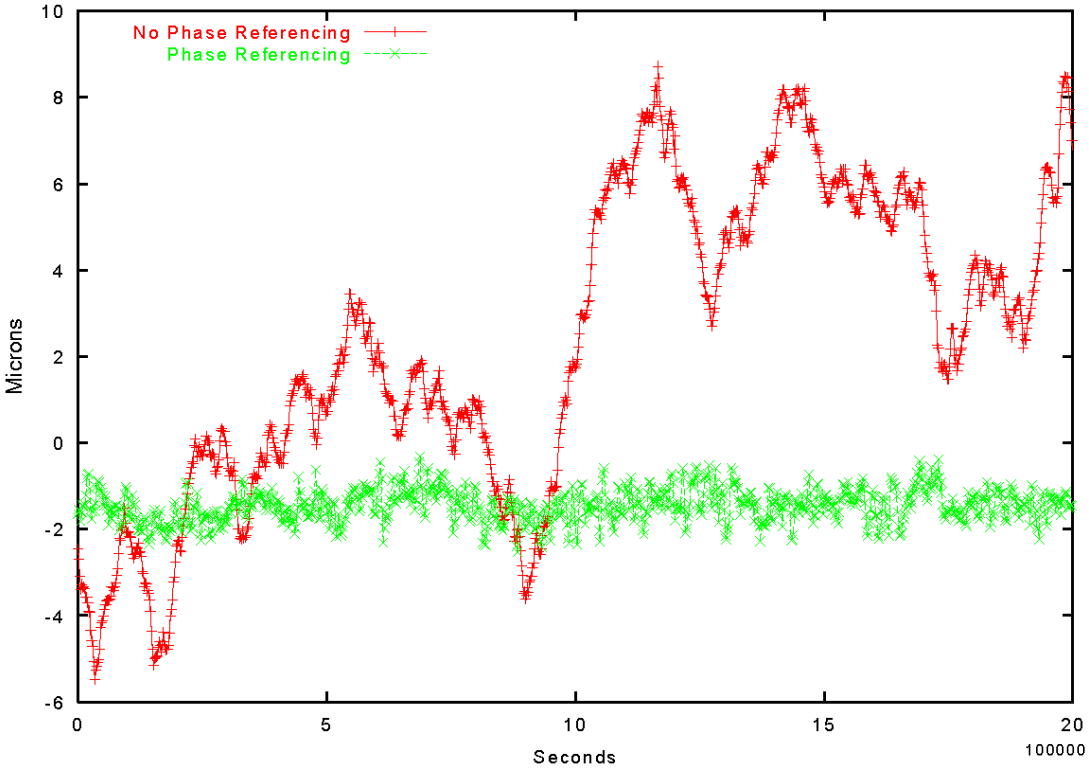
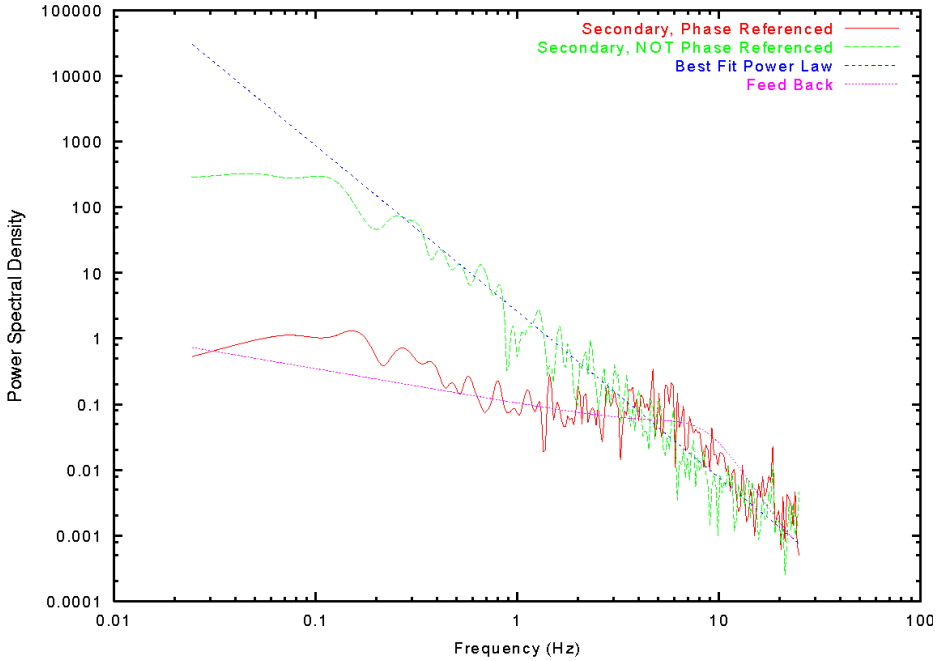
Phase referencing with PTI

- Analogous to adaptive optics on a large telescope
- Approach
  - Fringe track on a bright star within the isoplanatic patch of the target star
  - Use as a probe of the atmospheric effects on the target star
  - Correct using optical delay lines by
    - » Feedback same signal to both stars' delay lines
    - » or... Feedforward signal to secondary star's delay line
- Advantage
  - Allows longer integration times that would ordinarily be possible

Phase referencing with PTI





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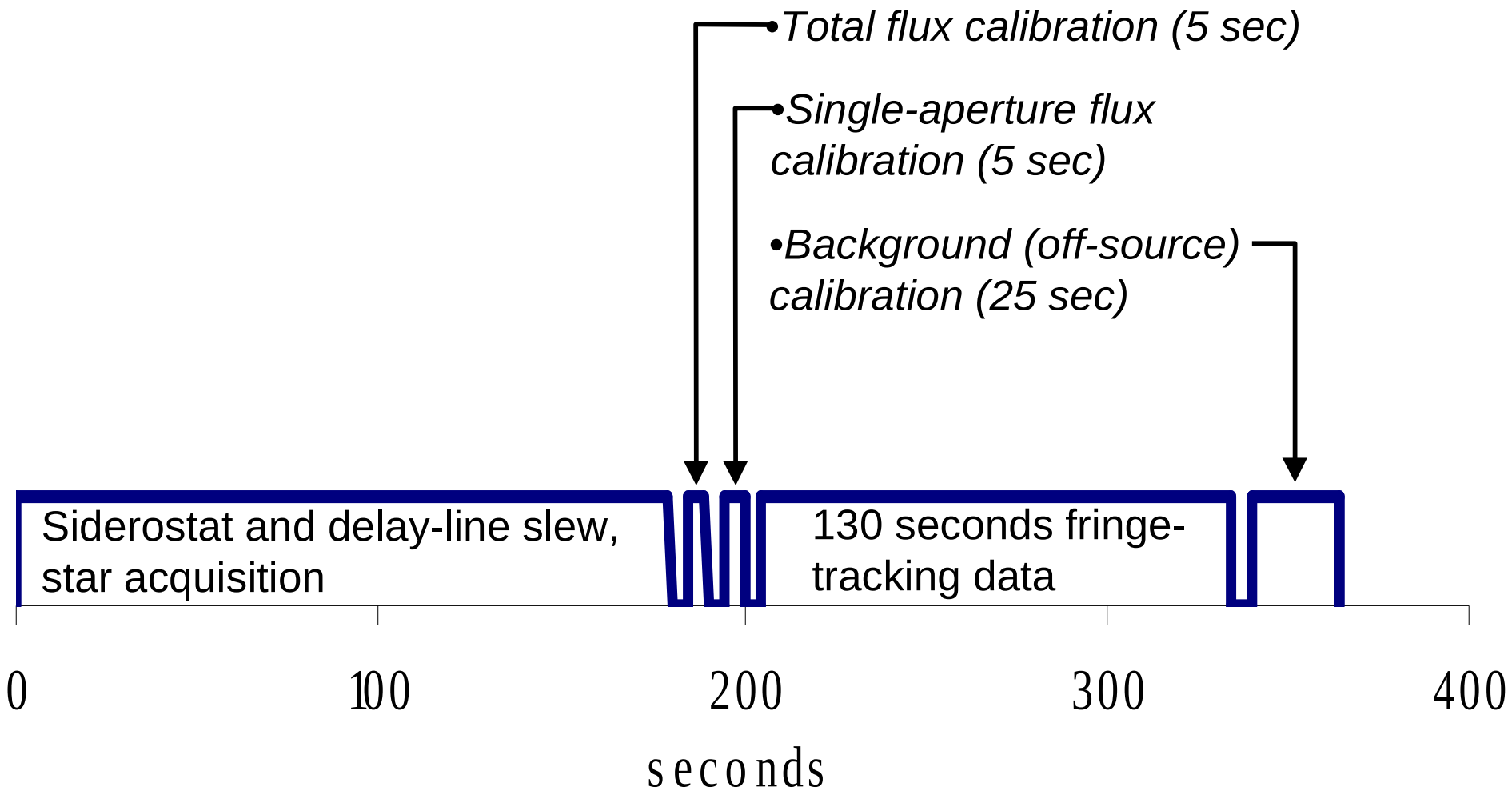
Next Year

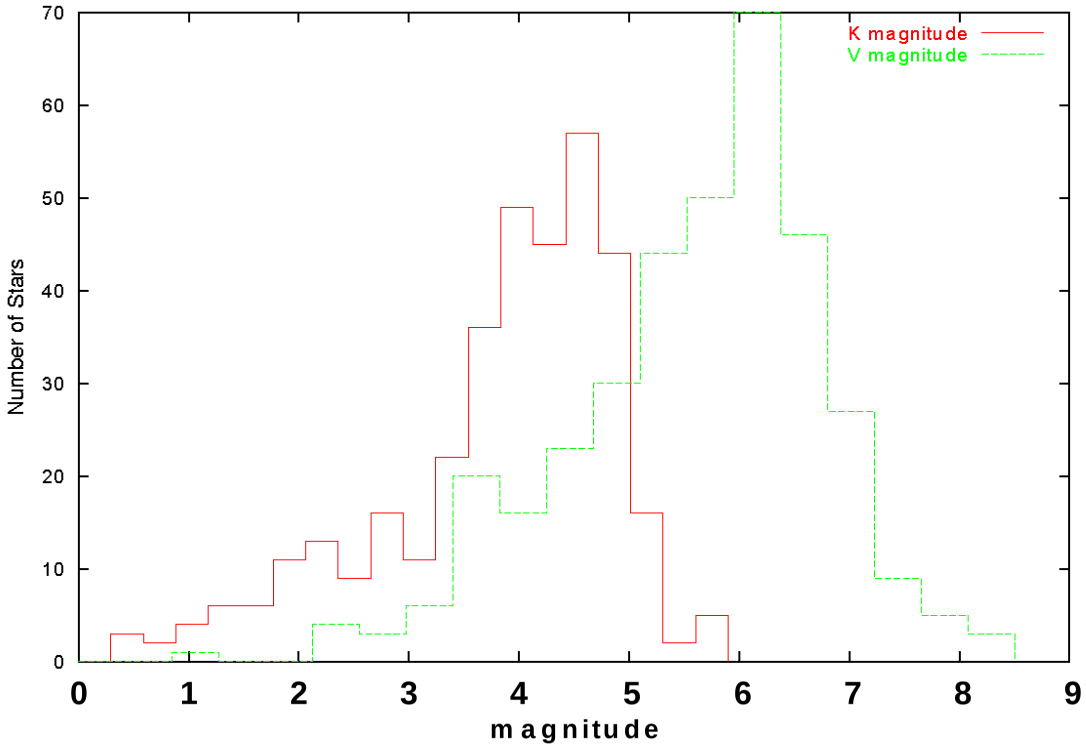
- Observations using N-W baseline
- New fringe-tracker camera, better spectral capabilities
- Continued science and engineering observations

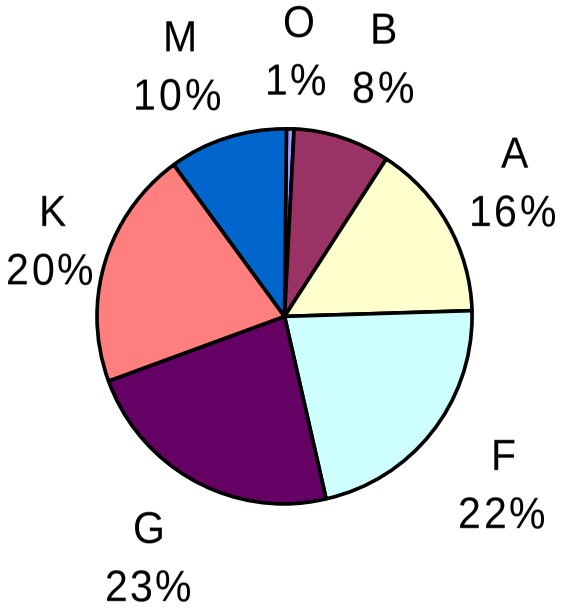
- References and publications
  - http://huey.jpl.nasa.gov/palomar

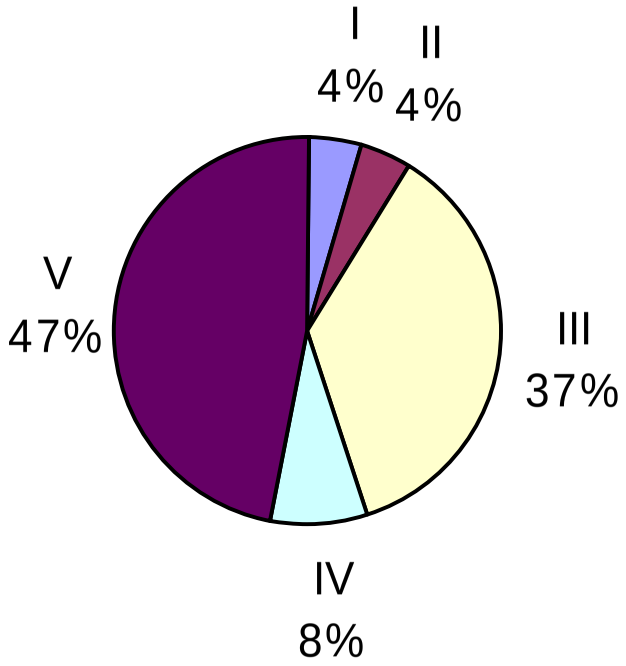
A “Scan”


•Total flux calibration (5 sec)
•Single-aperture flux calibration (5 sec)
•Background (off-source) calibration (25 sec)
Siderostat and delay-line slew, star acquisition
130 seconds fringe-tracking data
0
100
200
300
400
seconds

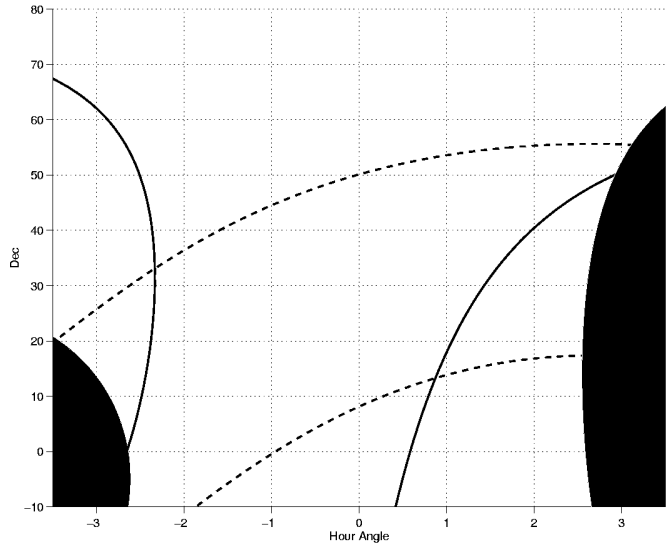
Observing Stats 1999 partial

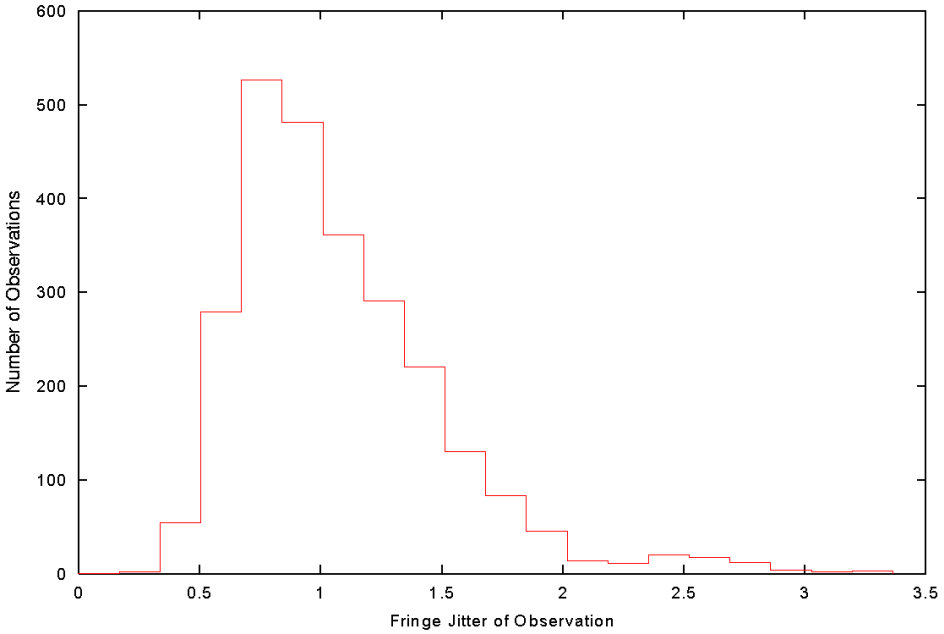


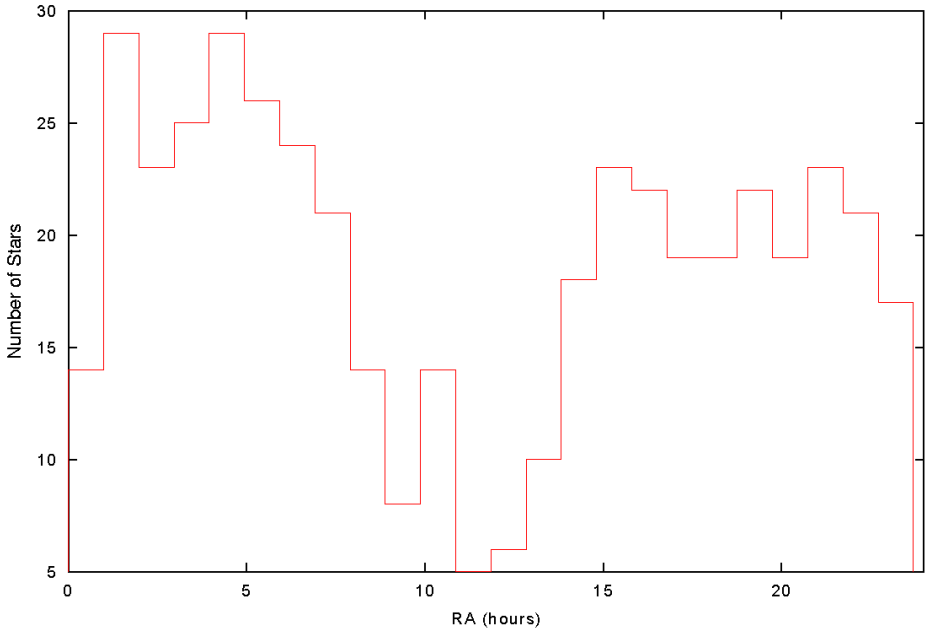


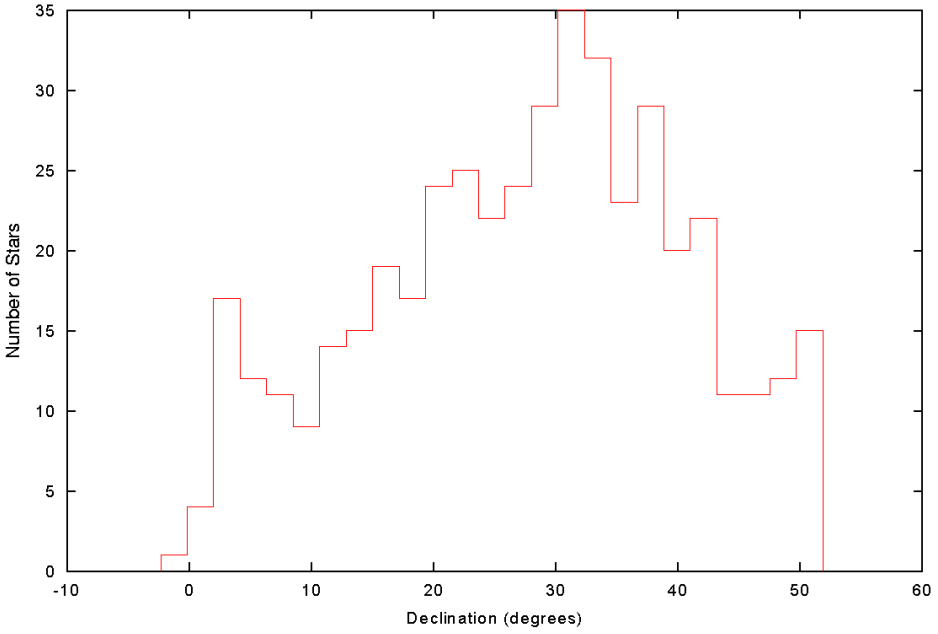


More Observing Stats









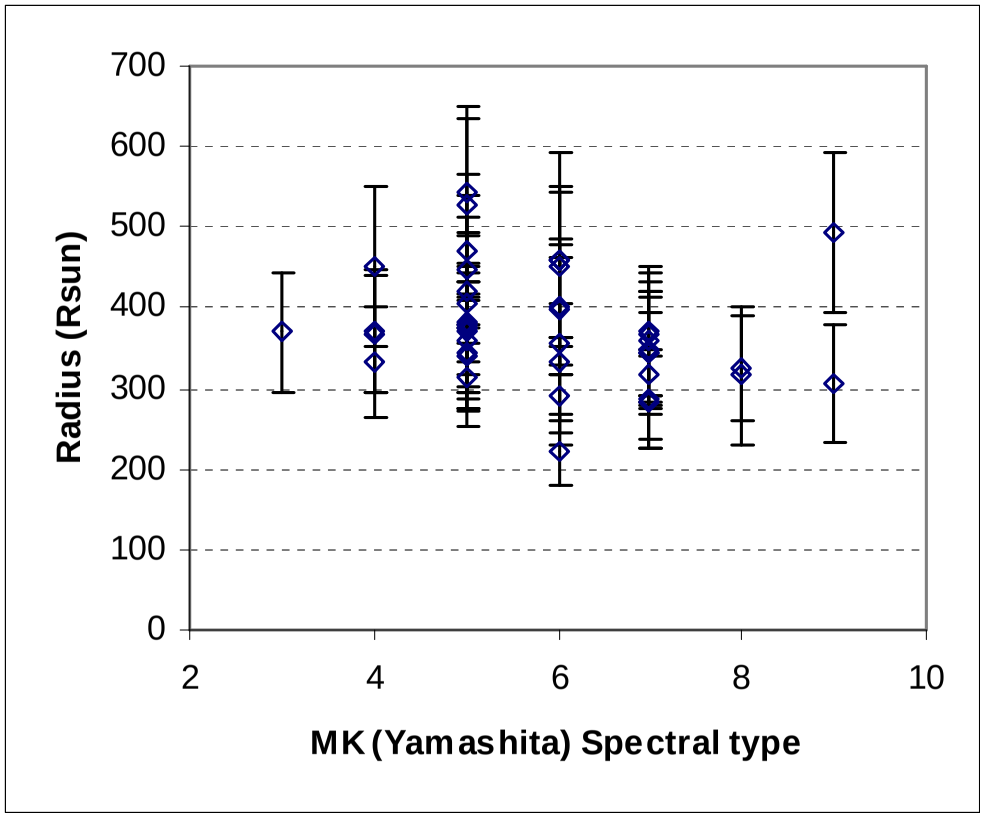
Linear Radii and Effective Temperatures of Carbon Stars

Gerard T. van Belle. Jet Propulsion Lab
Robert R. Thompson, Jet Propulsion Lab/University of Wyoming

We report new interferometric angular diameter observations of 32 carbon stars as measured with the Palomar Testbed Interferometer (PTI). Combining these with previously published diameters for 22 other carbon stars, primarily found in the Infrared-Optical Telescope Array (IOTA) investigation of Dyck, van Belle & Benson (1996), we are able to compute effective temperatures and linear radii for 52 stars. Consistent with the previous IOTA investigation of these objects, the average temperature of entire sample is roughly 2700K; we also demonstrate effective temperatures appear to increase towards "later" spectral types. Using the distance estimates to these objects as found in Claussen *et al.* (1987) the mean radius for the entire carbon star sample is estimated to be 350±70 $R_{\odot}$. As such, these stars appear quite similar in effective temperature and radius to oxygen-rich Mira variables (van Belle *et al.* 1997). We note that the linear size of our observed sample as indicated by Hipparcos parallaxes appears to be systematically smaller by a factor of two. We expect this to be an artifact of the satellite observations and stellar surface morphology rather than a phenomenon intrinsic to the spatial distribution of the observed carbon stars.

Linear Sizes of Carbon Stars

- Average size of 350±70 $R_{\odot}$
- Apparent radius decrease towards “later” spectral types is not statistically significant
- Sizes and temperatures consistent with those of oxygen-rich Miras (van Belle *et al.* 1997)

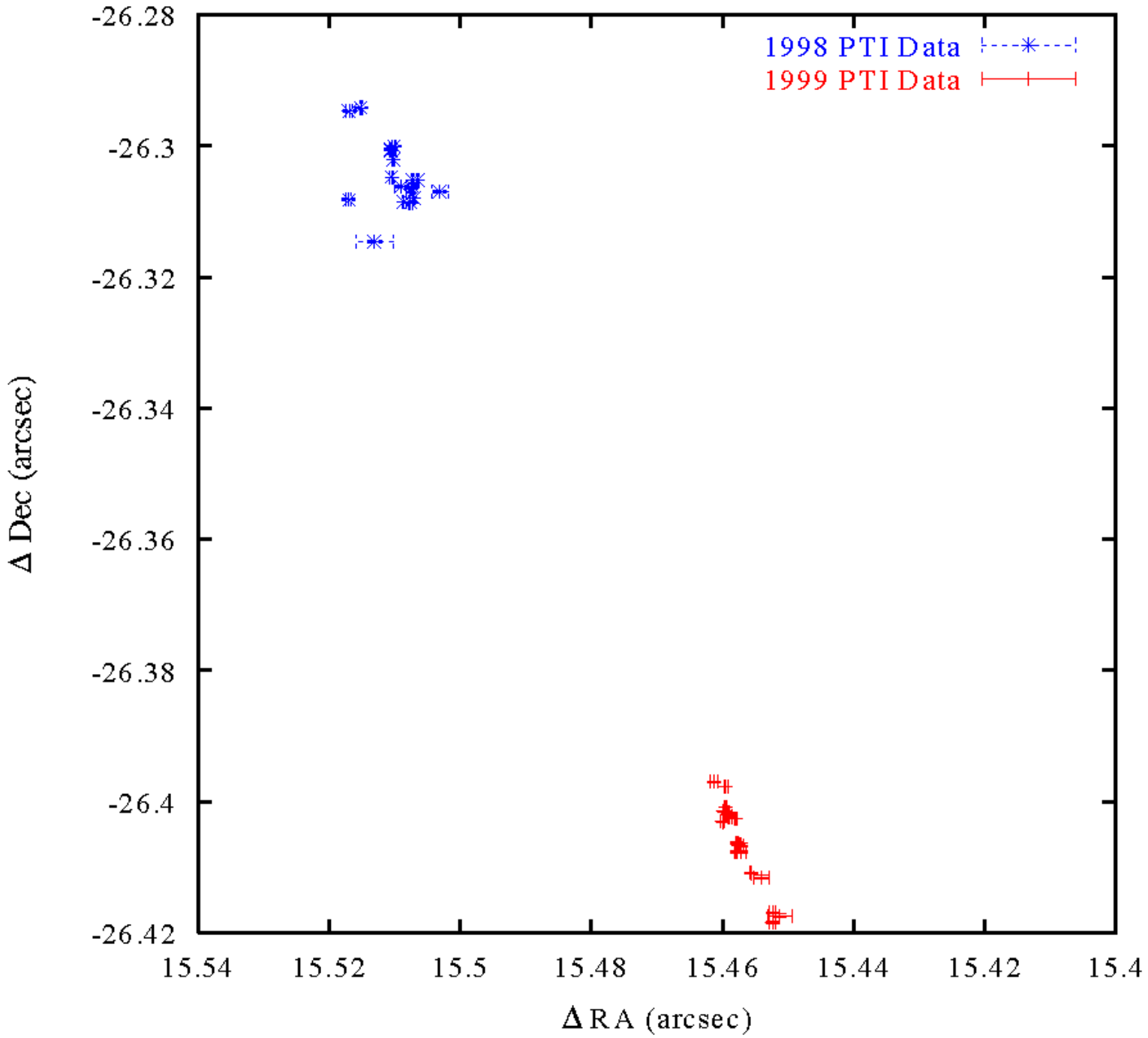
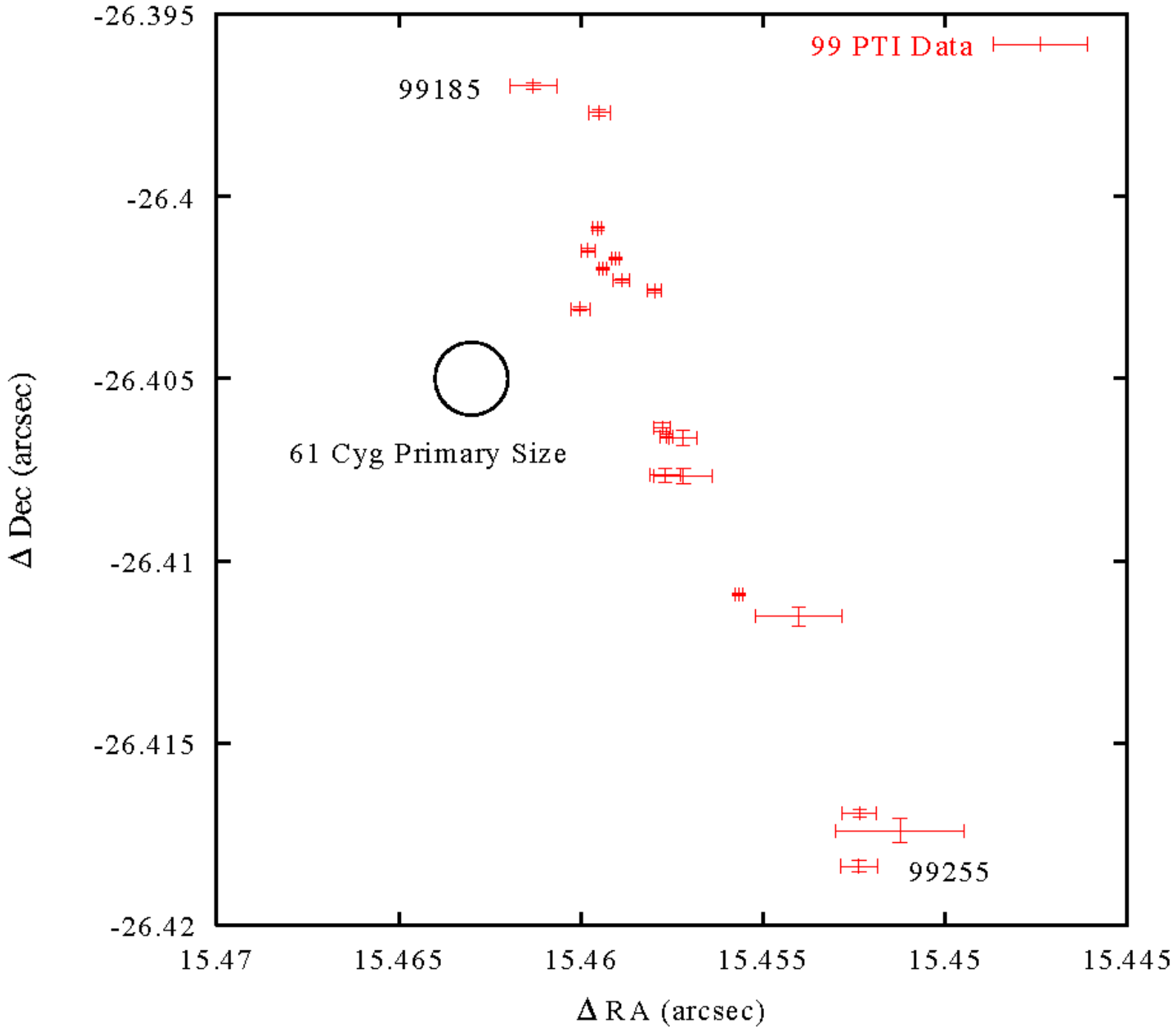


The Visual Orbit and Evolutionary State of 12 Bootes

A.F. Boden, M.J. Creech-Eakman, D. Queloz

We report on the determination of the visual orbit of the double-lined spectroscopic binary system 12 Bootes with data obtained by the Palomar Testbed Interferometer in 1998 and 1999. 12 Boo is a nearly equal-mass double-lined binary system whose spectroscopic orbit is well known. We have estimated the visual orbit of 12 Boo from our interferometric visibility data fit both separately and in conjunction with archival radial velocity data. Our 12 Boo orbit is in good agreement with the spectroscopic results, and the physical parameters implied by a combined fit to our visibility data and radial velocity data from CORAVEL result in precise component masses. In particular, the orbital parallax of the system is determined to be 27.09 ± 0.41 mas, and masses of the two components are determined to be 1.435 ± 0.023 M_O and 1.409 ± 0.020 $M_{O,}$ respectively. Somewhat remarkably, even though the two components are nearly equal mass, the system exhibits a significant brightness difference between the components in the near infrared(0.6K) and visible. We attribute this brightness difference to evolutionary differences between the two components in their transition between main sequence and giant evolutionary phases, and based on theoretical isochrones we can estimate a system age. Further, because the atmospheres of the two components are becoming more convective, we project the system components are currently at or near synchronous rotation, and the system orbit is in the process of circularizing.

61 Cyg Astrometry



61 Cyg Astrometry