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PTI/KI's Greatest Hits

JPL/CIT Interferometry Mafia

(Reported by A. Boden)

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Outline

- The Interferometers
- The People
- The Process
- The Hits
- The Full List
- Mystery Guest…
- Postscript

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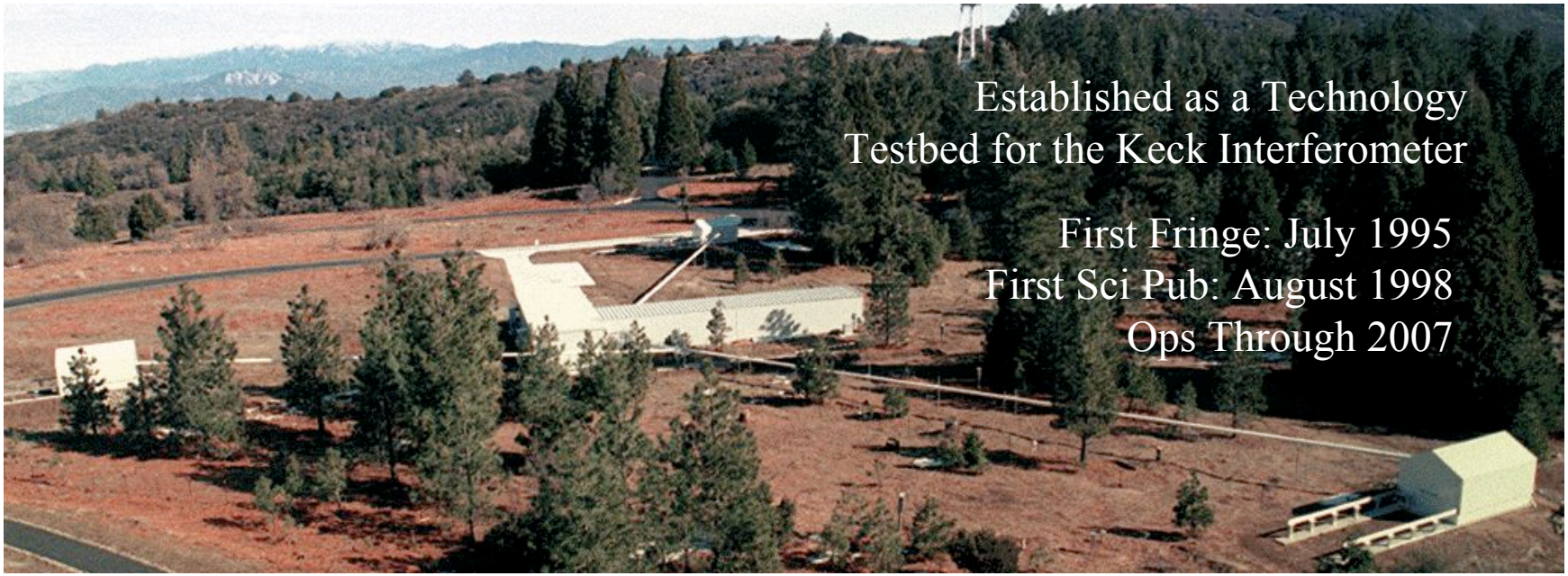
Photogenic Testbed Interferometer

Credit: National Geographic

Palomar Testbed Interferometer (PTI)



- PTI is a Near-IR (K & H-band) single-baseline interferometer
  - Direct (homodyne) combination
  - NS, NW, and SW baselines
  - NICMOS array combiner
  - Point Src Limiting Mag K ~ 6.7
  - Scientific Limiting Mag K ~ 6.1
  - 40 peer-reviewed papers
- Single and Dual-Beam Interferometry:
  - Normalized visibility (V^2) measurement => modelling (simple morphology like one or two stars)
  - Simultaneous fringe tracking on two nearby stars => differential astrometry

http://pti.jpl.nasa.gov

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Keck Interferometer (Mauna Kea, HI)

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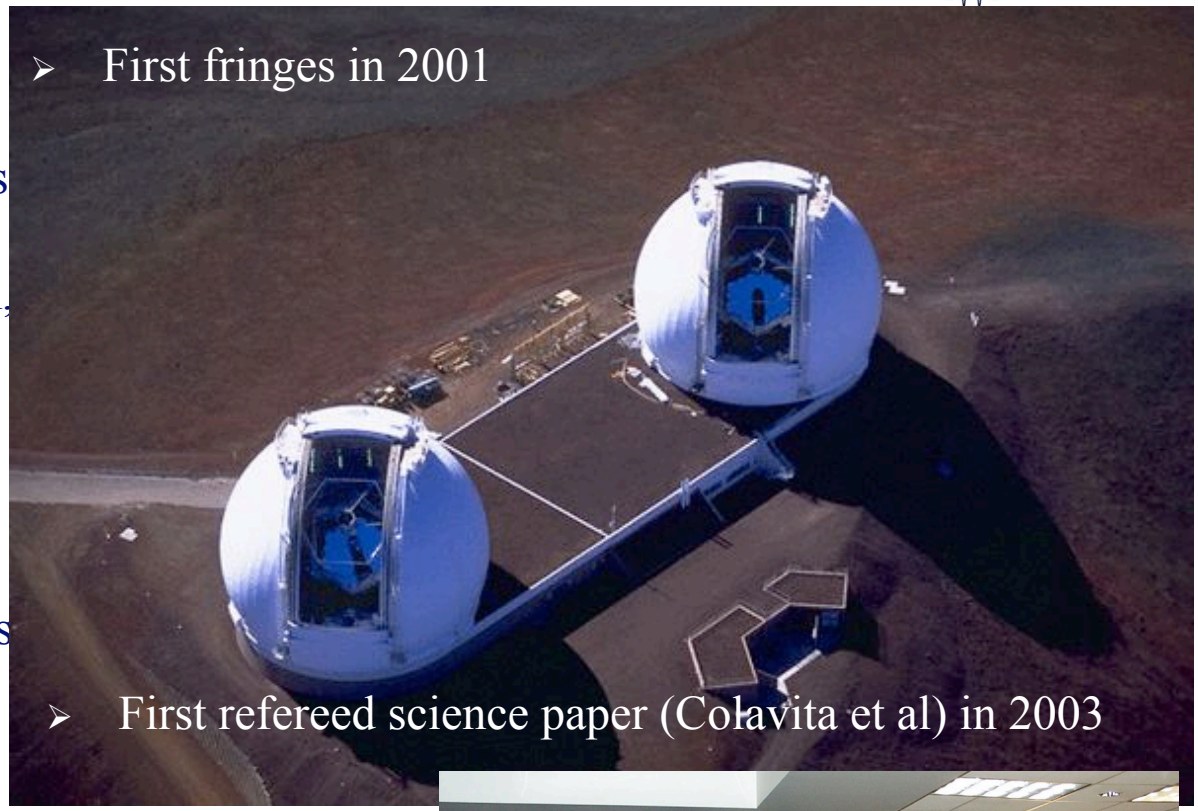
- Keck Interferometer at Mauna Kea, HI
- Links the two 10m-Kecks on an 85-m baseline
- H & K-band combination, J-band angle tracking; V^2 amplitude science
- 10 μm nulling (and (hopefully V^2)
- In development: astrometric measurements using the two Kecks
- Developed by JPL, WMKO, and MSC
- Operations through WMKO and MSC
- Nine (9) peer-review papers



First Fringe Crew: Vashisht, Akeson, Colavita, Kendrick, van Belle,Ligon Wizinowich, Swain, Booth

planetquest.jpl.nasa.gov/keck/Keck_index.cfm

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The People

Key KI Contributions:

Mark Colavita

Peter Wizinowich

Mike Shao

Andrew Booth

John Gathright

Paul Swanson

Jim Kelley

The PTI Collaboration is:

R. Akeson (MSC)
R. Bambery (JPL)
A. Boden (MSC)
M. Colavita (JPL)
M. Creech-Eakman (JPL/NMT)
J. Eisner (CIT/UCB)
S. Kulkarni (CIT)
B. Lane (CIT/MIT)
P. Lawson (JPL)
C. Koresko (MSC)
M. Mutterspaugh (MIT/UCB)
K. Rykoski (CIT)
M. Shao (JPL)
M. Swain (JPL)
R. Thompson (JPL)
G. van Belle (MSC)

The Process

- On 24 October SteveR invited me to give a "lunch" talk summarizing the science contributions from PTI and KI
- It's clear that my selections for PTI and KI science contributions might not be totally objective (e.g. might have lots of Keplerian ellipses on the slides!)
- On 26 Oct I "invited" a (non-scientific) cross-section of Pasadena (and non-Pasadena)-based scientists to opine on the most important PTI & KI science contributions
- I received five (5) responses, which I have incorporated with my own selections (without bias) to define the consensus "Top-10" list I'll share with you now…

Process (2 of 2)

- I do harbor some concern I received relatively few (six total) responses, and that the selections may not be completely "fair and balanced" – for instance one response was:
  - *NGC 4151, KI, Swain et al 2003*
  - FU Ori, PTI, Malbet et al 1998
  - YSO's, PTI, Akeson et al 2000
  - HD 98800 B, KI, Boden et al 2005
  - *Cepheids, PTI, Lane et al 2000*
  - *Altair, PTI, van Belle et al 2001*
  - *HD 9939, PTI, Boden et al 2006*
  - T Taus, Akeson et al 2002
  - T Taus, Eisner et al 2005
  - Herbigs, PTI Eisner et al 2004

60% of selections are YSO-related!!!

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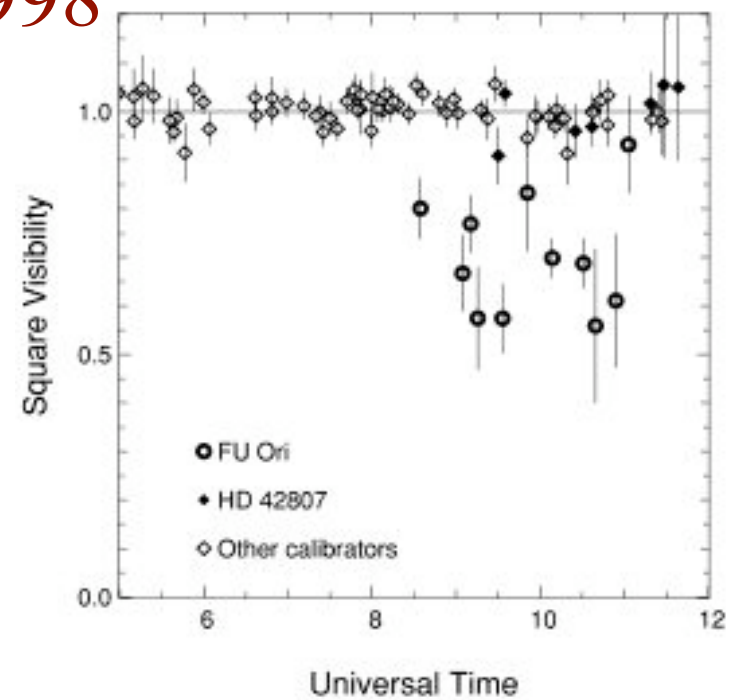
The Hits

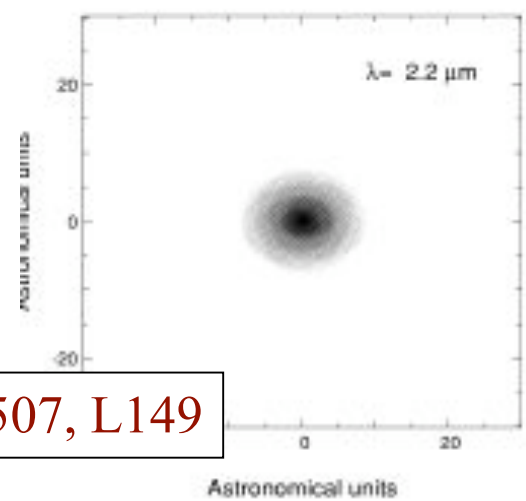
- So, just in from the home office in Pasadena, CA are the (consensus) Top-10 PTI/KI Science Hits…

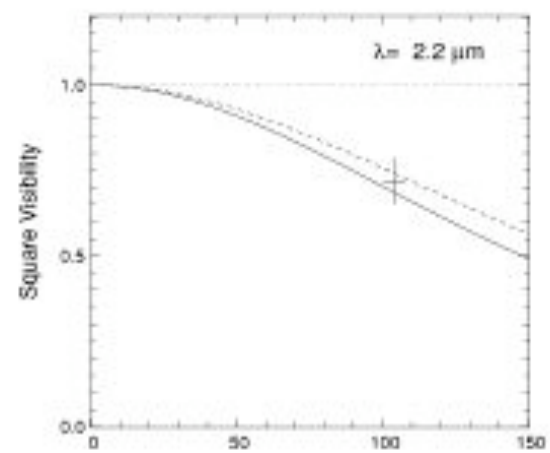
10: FU Ori/Malbet et al 1998

- Malbet et al 1998 published the first ever long-baseline observations of a YSO – FU Orionis
- FU Ori is the prototype of a class of aperiodic variables thought to have episodes of high accretion
- Results:
  - FU Ori resolved to PTI
  - Resolution consistent with near pole-on accretion disk model
- Follow-on work with IOTA & PTI (e.g. Malbet 2005)



Disk Model & Visibility Observable





Baseline (m)

Malbet et al 1998 ApJ 507, L149

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9: M-Dwarf Diameters/Lane et al 2001

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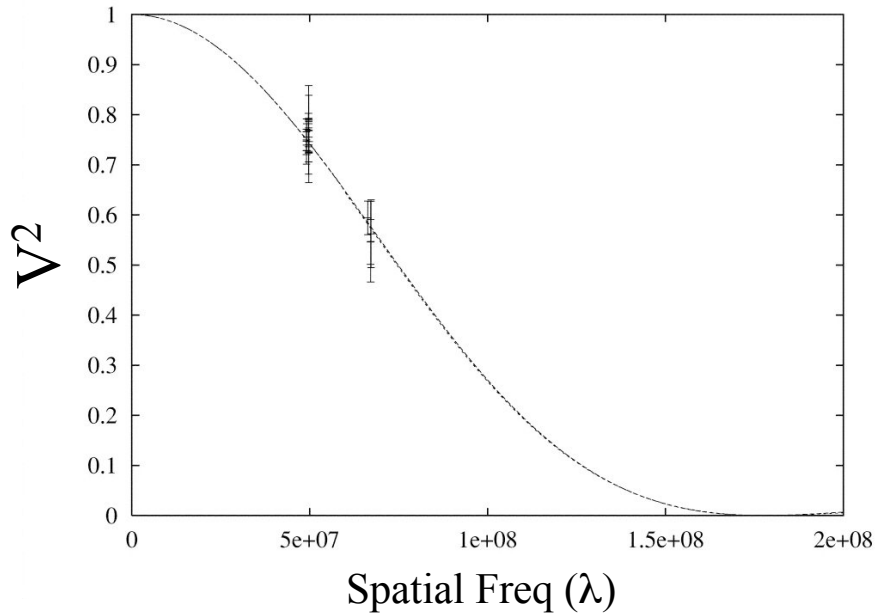
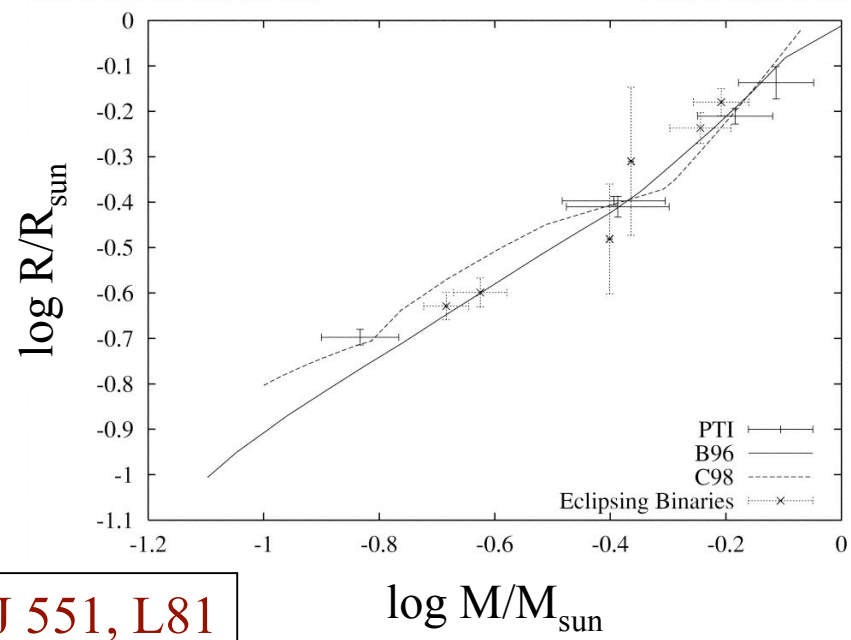
- Few observational constraints on dwarf diameters, and M-dwarf diameters in particular
- Signs there are "problems" with M-dwarf diameters; diameters are larger than predicted (e.g. EB YY Gem, Torres & Rivas 2002)
- Lane et al measured five KM dwarf diameters in *K* & *H* bands (50-80 Mλ spFreq)
- Measurements reinforced growing body of evidence of issues in M-dwarf sector
- Possible issues with low-T opacities and/or M-dwarf equations of state
- Additional work with VLTI & CHARA

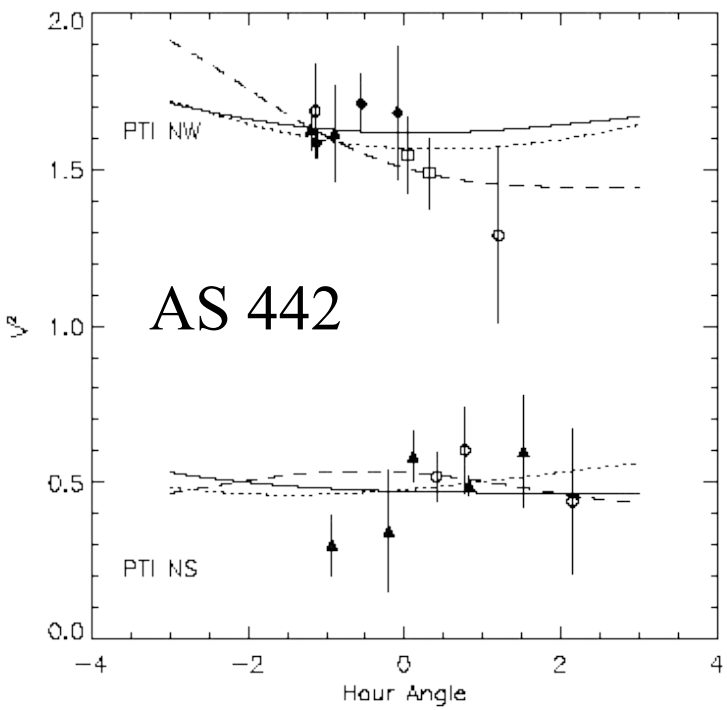


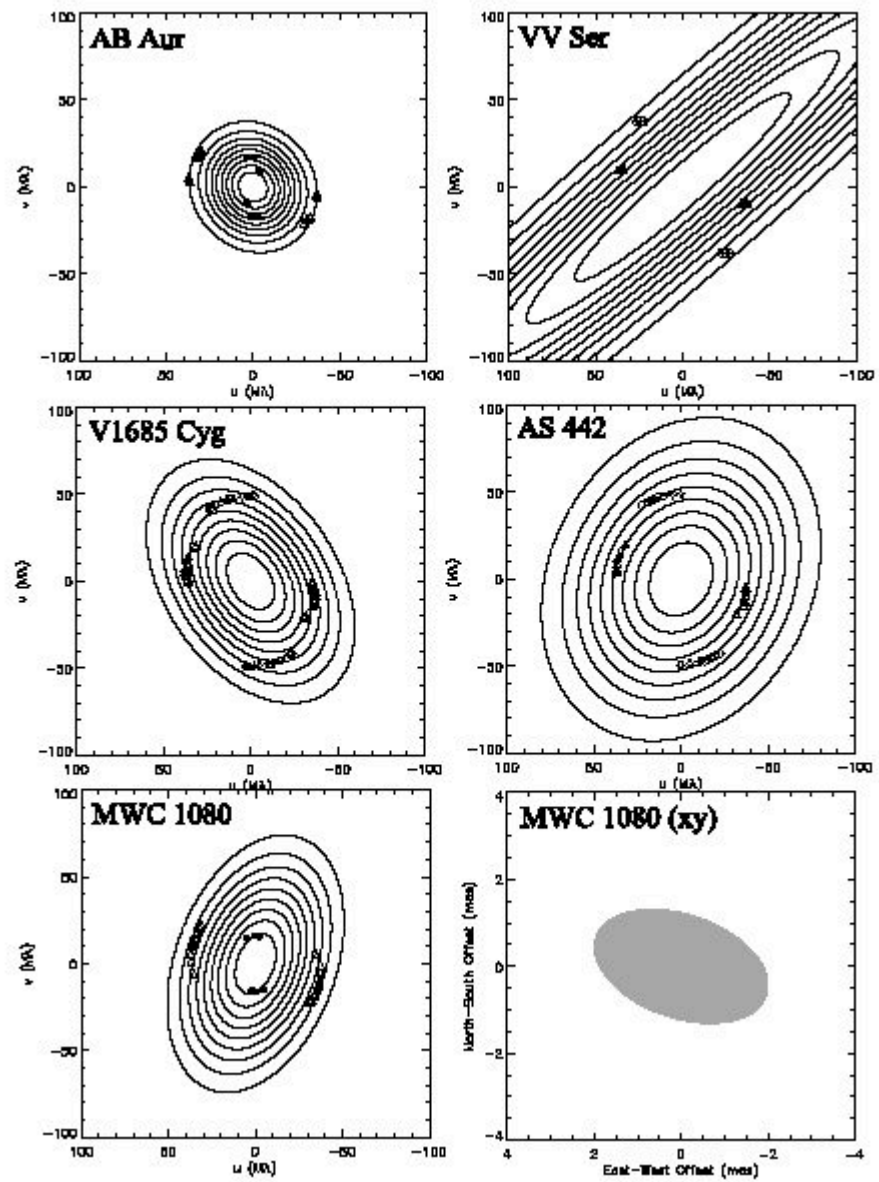


Lane, Boden, & Kulkarni 2001 ApJ 551, L81

8: Herbigs/Eisner et al 2004

- IOTA & PTI pioneered near-infrared resolution of YSO Circumstellar Material
- Eisner et al 2003 & 2004 Study of Herbig Ae/Be stars
- Results suggested structural differences between early & late-type Herbig inner disks





Eisner et al 2004, ApJ 613, 1049

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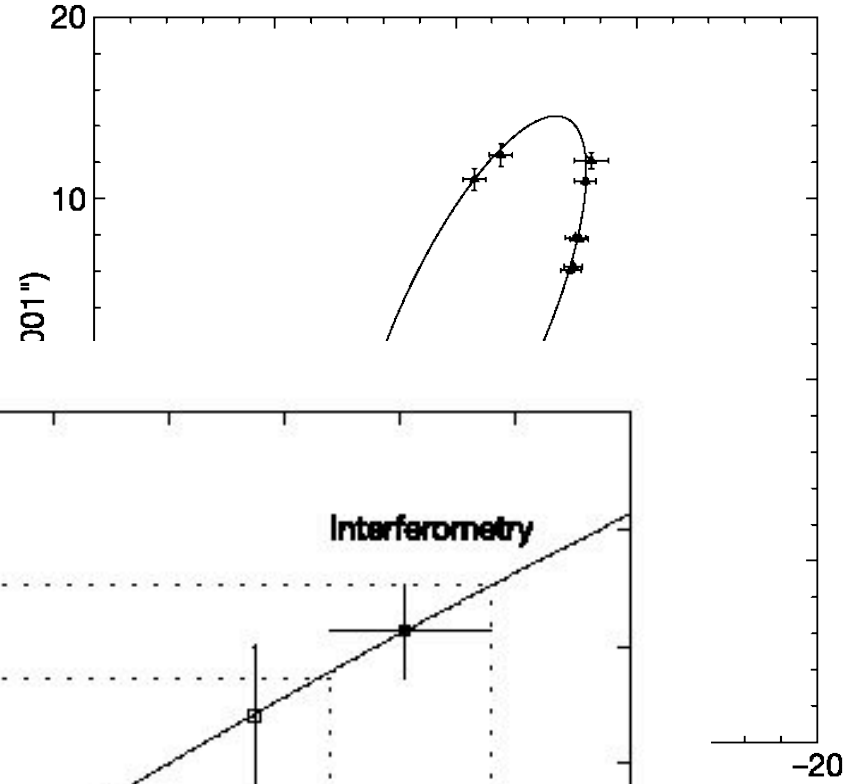
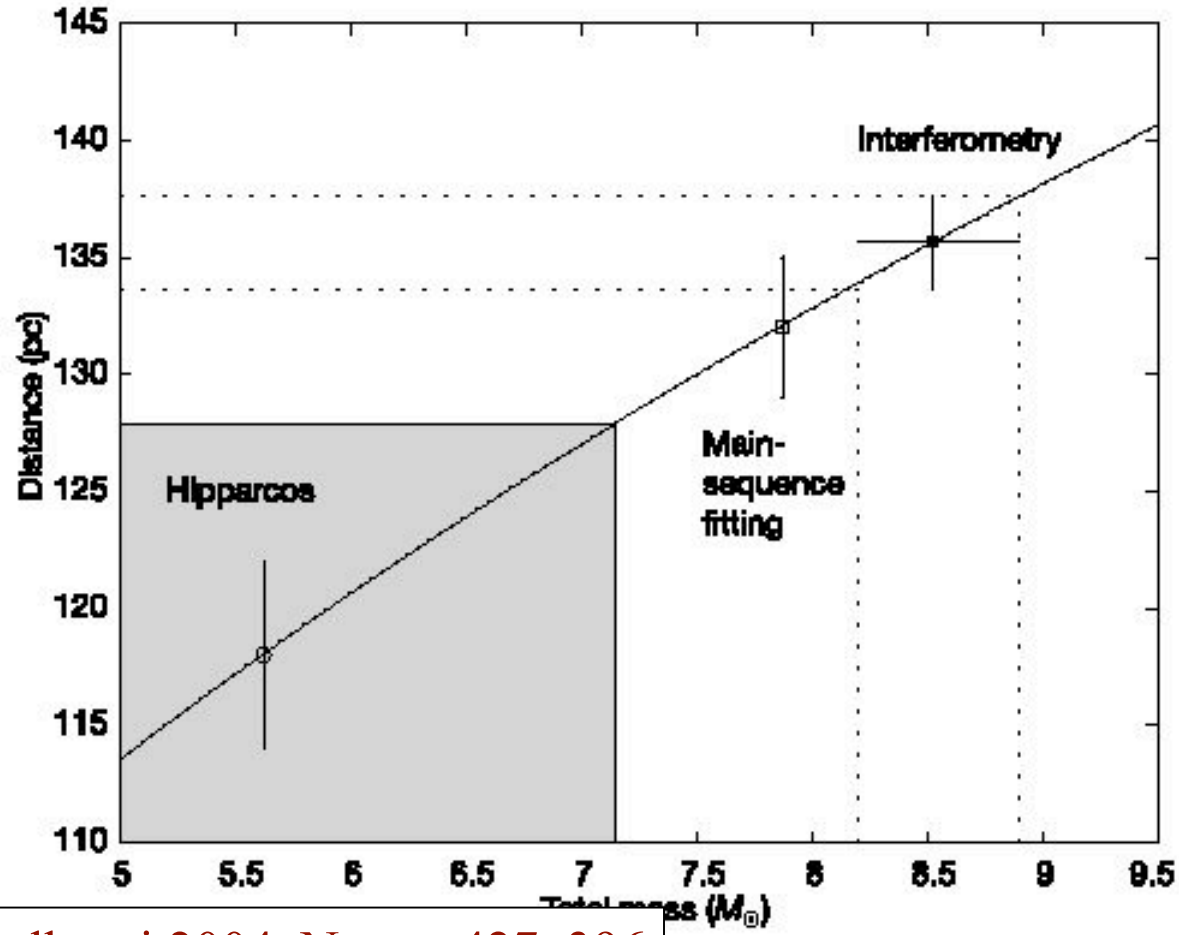
7: Atlas/Pleiades/Pan et a

- Controversy between "conventional" and Hipparcos estimates of
- Atlas visual estimate yie
- Result stron "convention
- (Additional reinforces A al 2004, Soc





Pan, Shao, & Kulkarni 2004, Nature 427, 396

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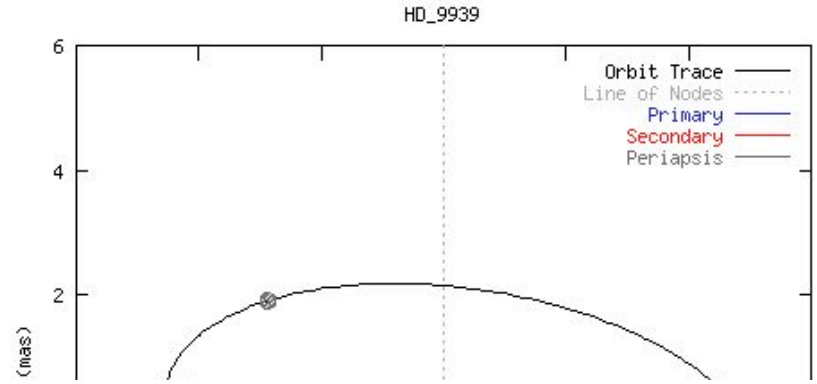
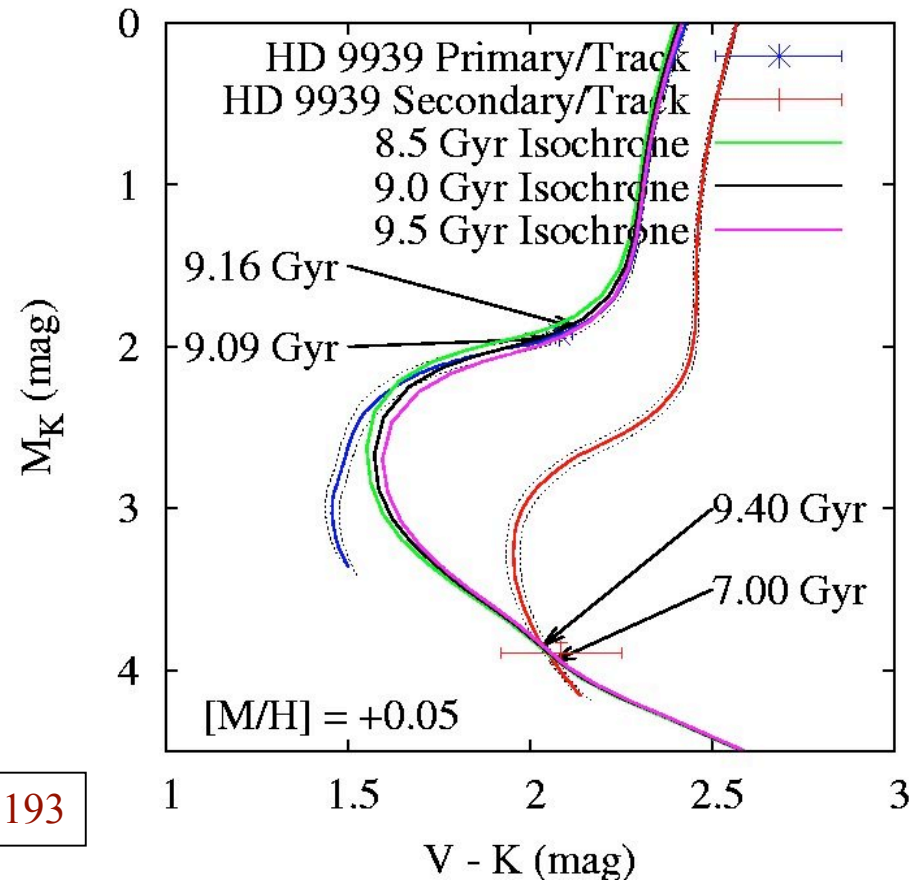
6: HD 9939/Boden et al 2006

- HD 9939 Selected as part of High-Proper Motion Sample (Carney & Latham 1987++)
- System abundance is not sub-solar (as previously thought), but solar (or even higher)…
- Primary in Hertzsprung gap – very *precise* age estimate 9.1 +/- 0.25 Gyr (thick disk)
- Kinematics suggest formation ~ 7.5 kpc from GC
- Solar abundance star formation 7.5 kpc from GC 9 Gyr ago!!!
- Anecdotally establishes that spread in disk age/metallicity relation is REAL!
- Supports 'local nucleation' model of disk metallicity enhancement





Boden, Torres, & Latham 2006 ApJ 644, 1193

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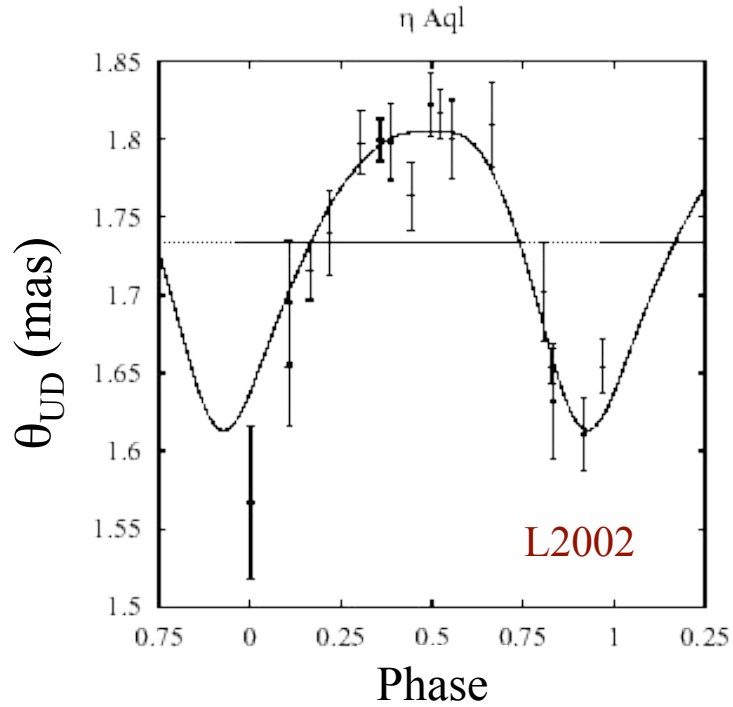
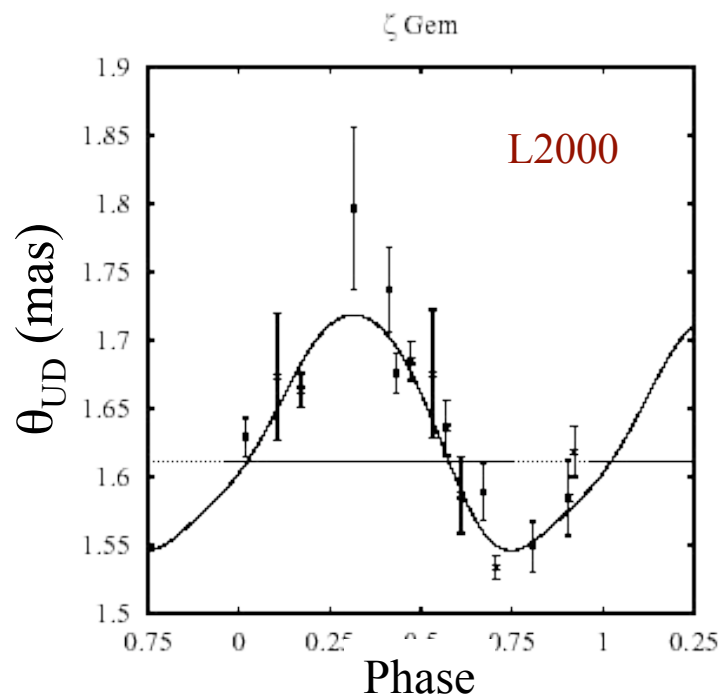
5: Cepheid Pulsations /Lane et al 2000

- PTI made the first detection of Cepheid angular pulsations (Lane et al 2000)
- Lane et al 2002 Cepheid modeling combined PTI and NPOI data





Lane et al 2000, Nature 407, 485

Lane et al 2002, ApJ 573, 330

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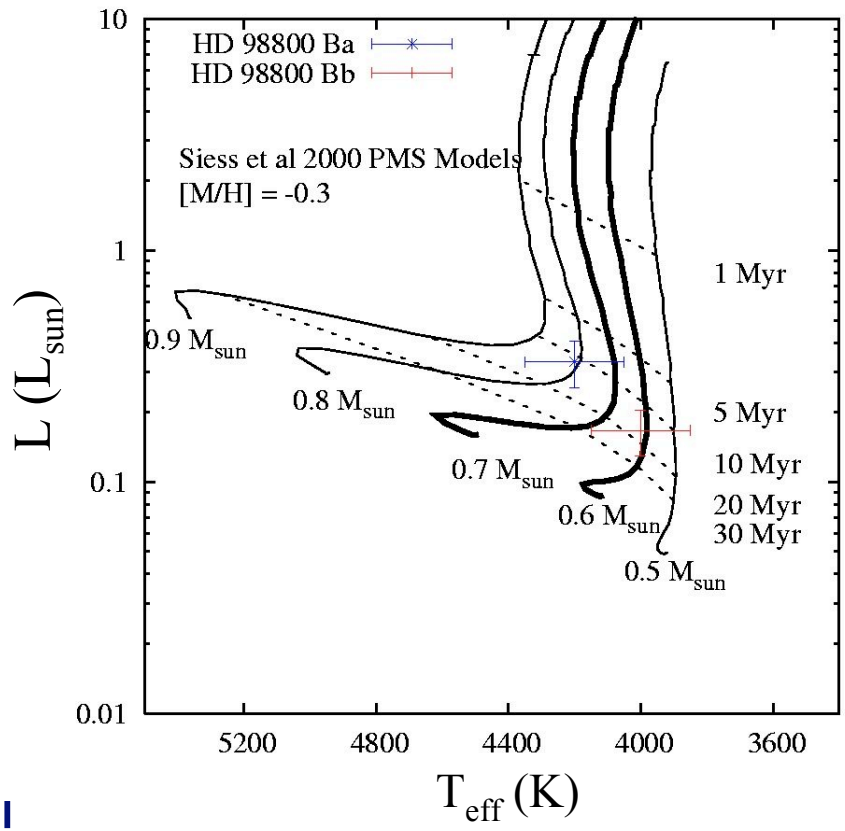
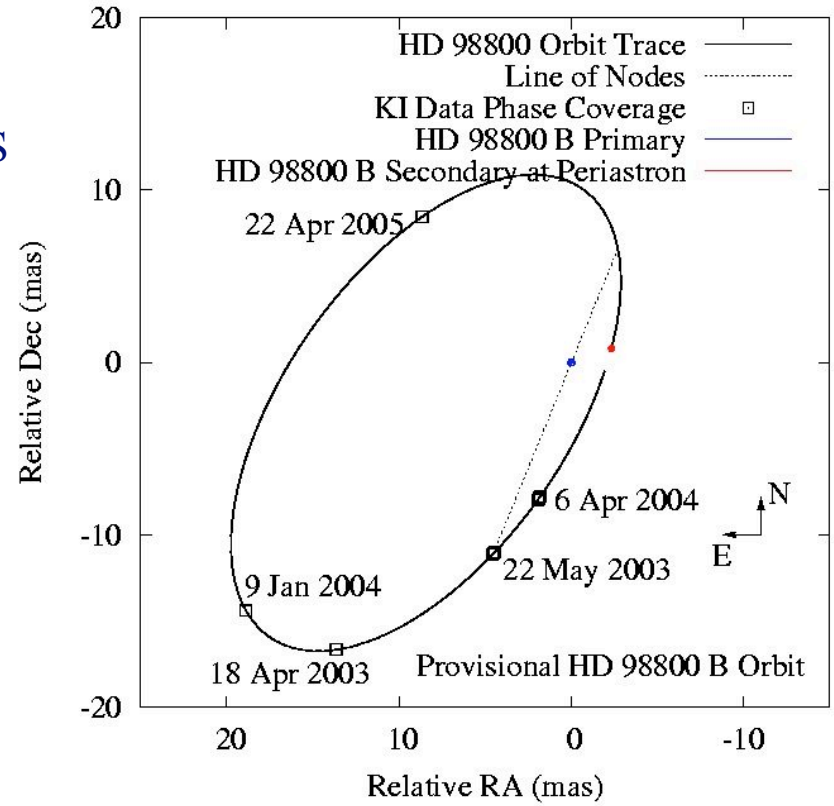
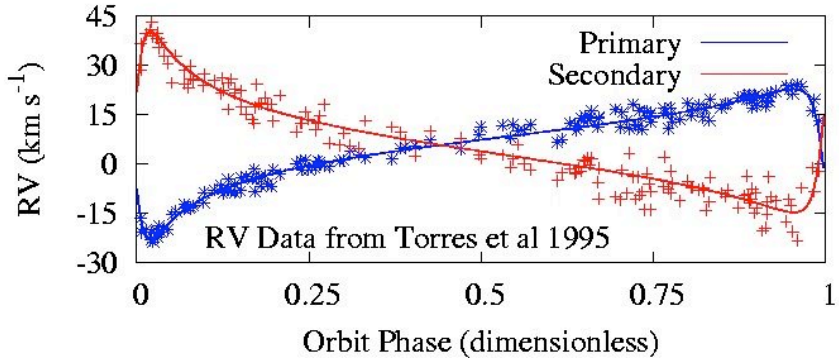
4: HD 98800 B/Boden et al 2005

Boden et al 2005, ApJ 635, 442

- HD 98800: PMS quad system, B an SB2 with 315d period & mid-IR excess
- Physical orbit from KI V^2, HST FGS, & RV data; dynamical masses of two low-mass PMS components
- Suggestion that HD 98800 (& TW Hya stars) have sub-solar metallicity







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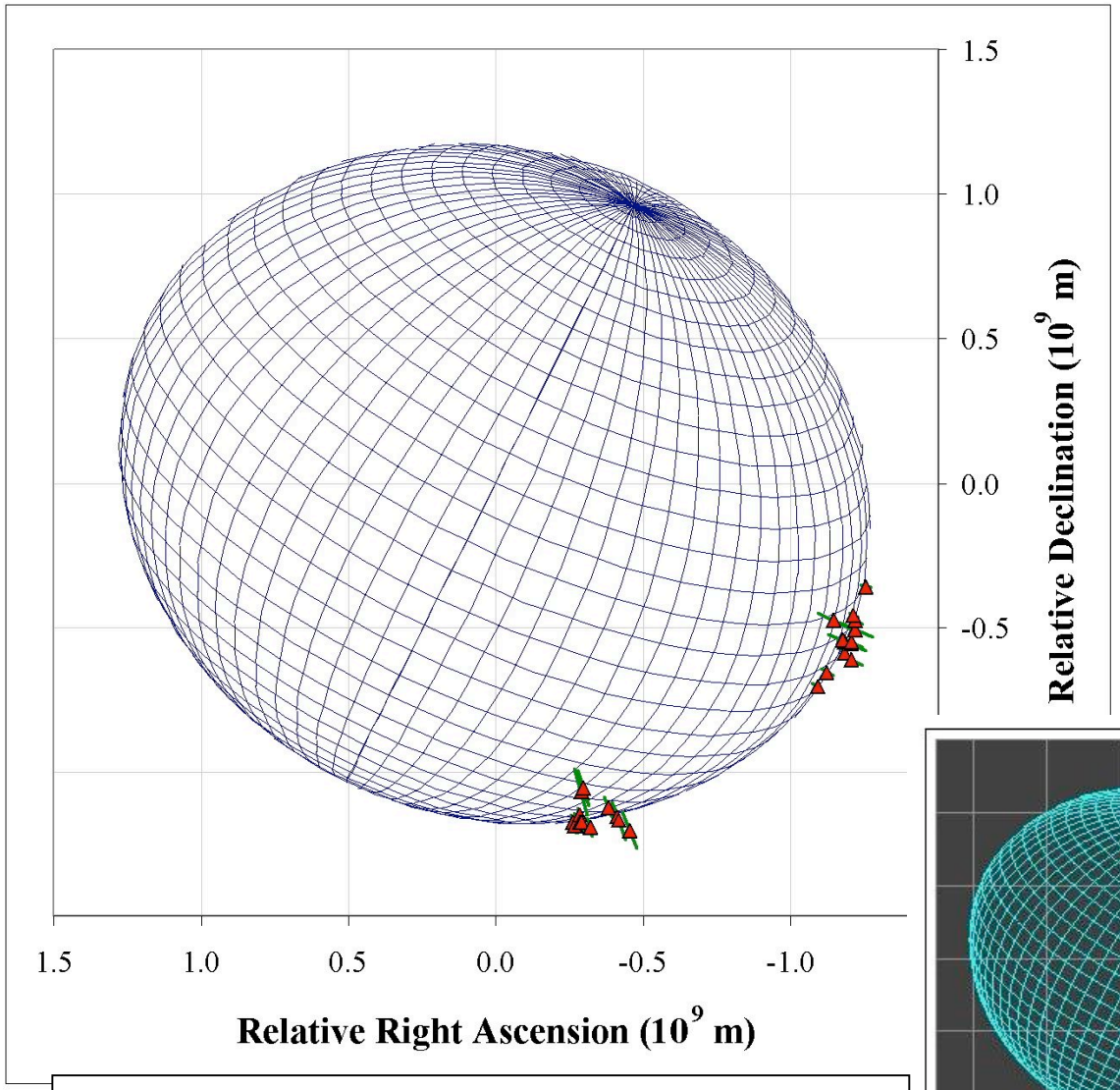
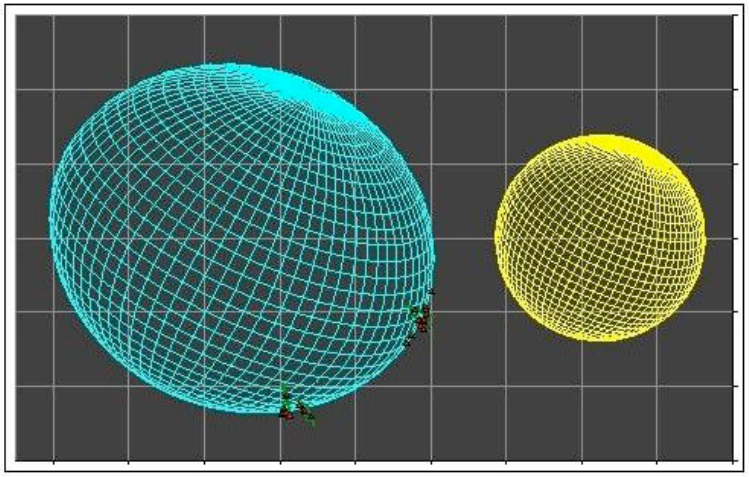
3: Altair/van Belle et al 2001



First *Direct* Measurement of Rotational Oblateness in Rapid Rotator Altair (HD 187642)

Apparent Axial Ratio:
86 +/- 3 %

v sin i ~ 240 km/s – matches well with spectroscopic determination



van Belle et al 2001, ApJ 559, 1155
and Peterson et al 2006, ApJ 636, 1087

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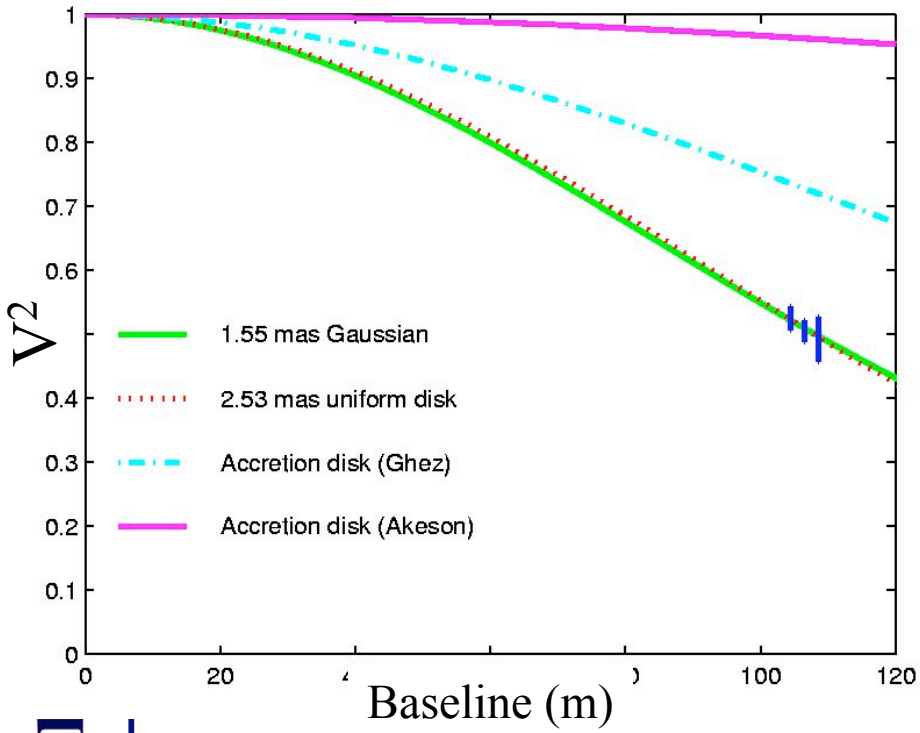
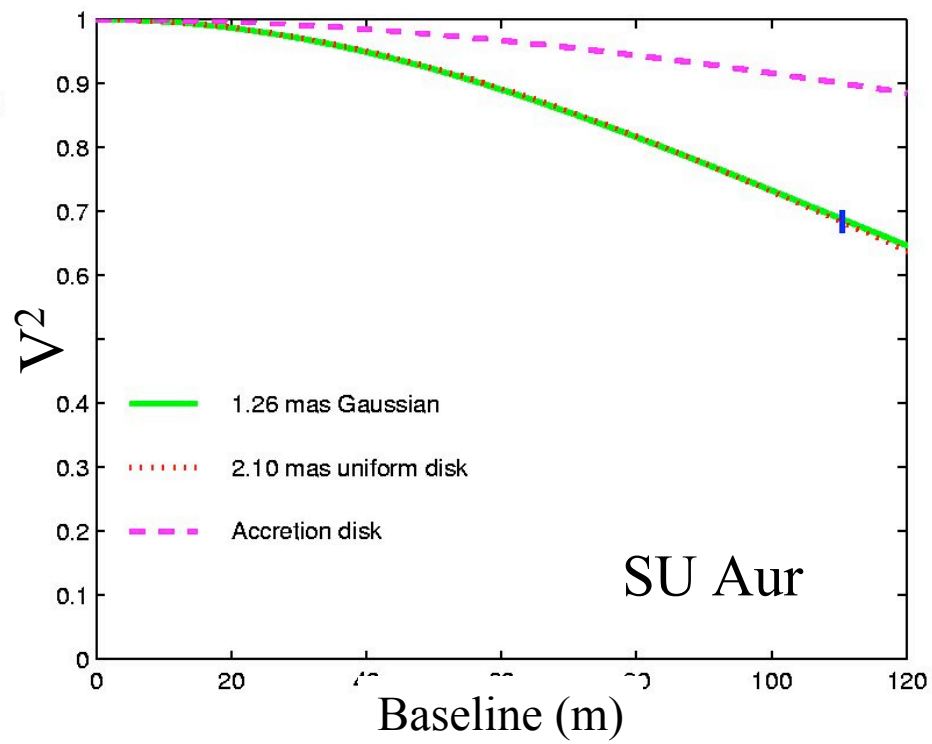
2: T Tauri Studies/Akeson et al 2000…



- Near-IR measurements of YSO circumstellar material
- Objects consistently more resolved than expected
- *Led to a new class of models with "excited" inner dust rims* (Natta et al 2001, Tuthill et al 2001)*!!!*

T Tau N Models:
Ghez 1991: SED Modeling
Akeson 1998: mm Emission

Akeson et al 2000, ApJ 543, 313
Akeson et al 2002, ApJ 566, 1124
Akeson et al 2005, ApJ 622, 440
Millan-Gabet et al 1998
Monnier & Millan Gabet 2003



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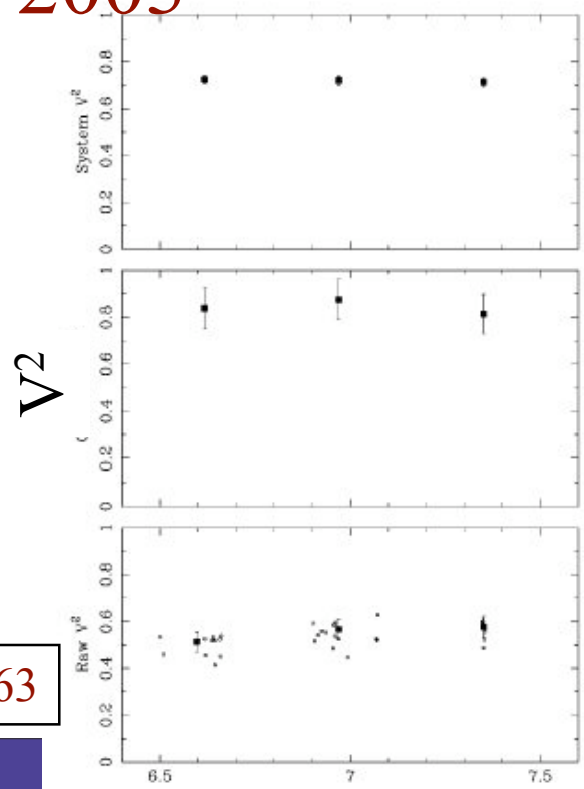
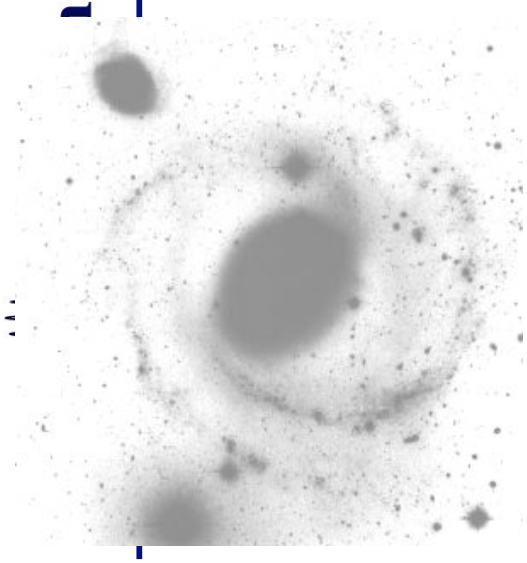
1: NGC 4151/Swain et al 2003

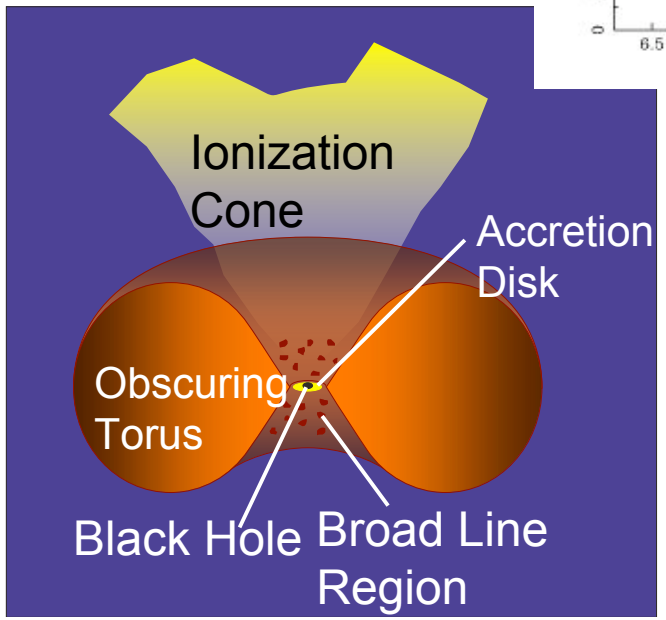
- First extra-galactic source detected with optical/IR interferometry
- Measured 2 micron emission to be very compact ≤ 0.1 pc.
- *The measurements rule out models in which the majority of the K-band nuclear emission is produced on scales larger than 0.1 pc for this P.A.*
- Results interpreted as 2 μm light originating from thermal gas (dust possible).

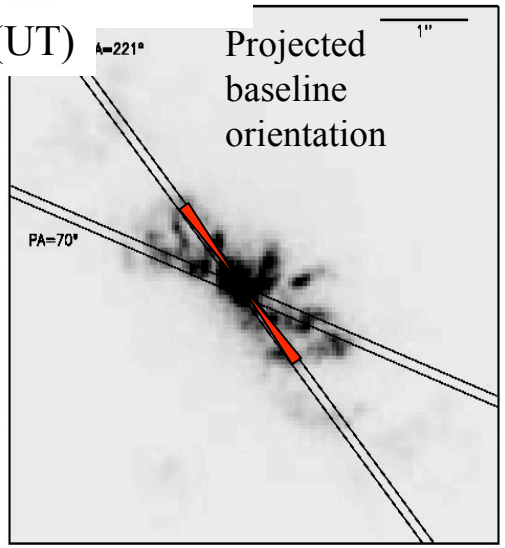
Swain et al 2004, ApJ 596, L163



21 May 2003
$V^2 = 0.84 \pm 0.064$
$81.8 \leq b \leq 83.6$ m
$39.3 \leq$ P.A. $\leq 33.9°$







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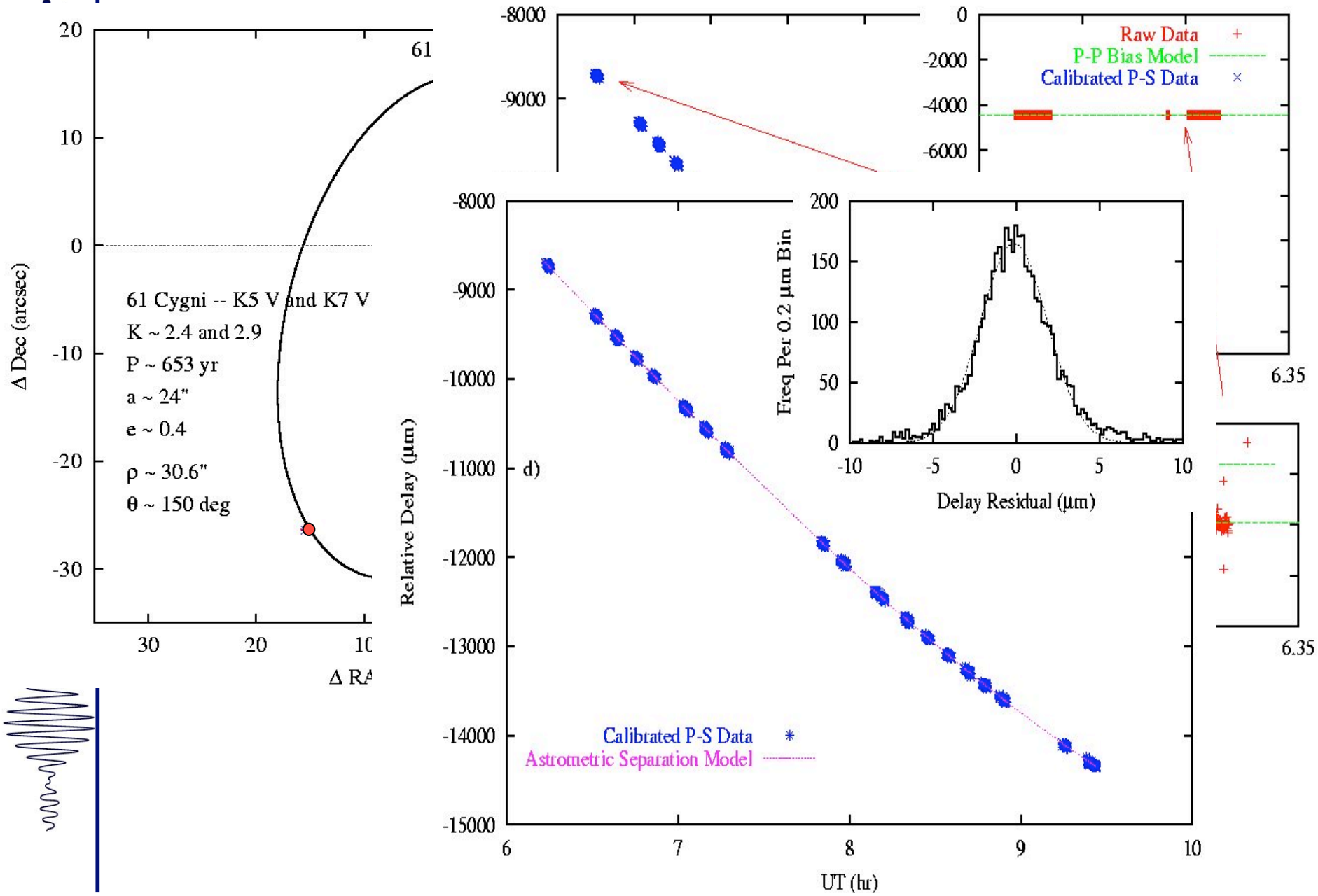
The Full List (Top 15)

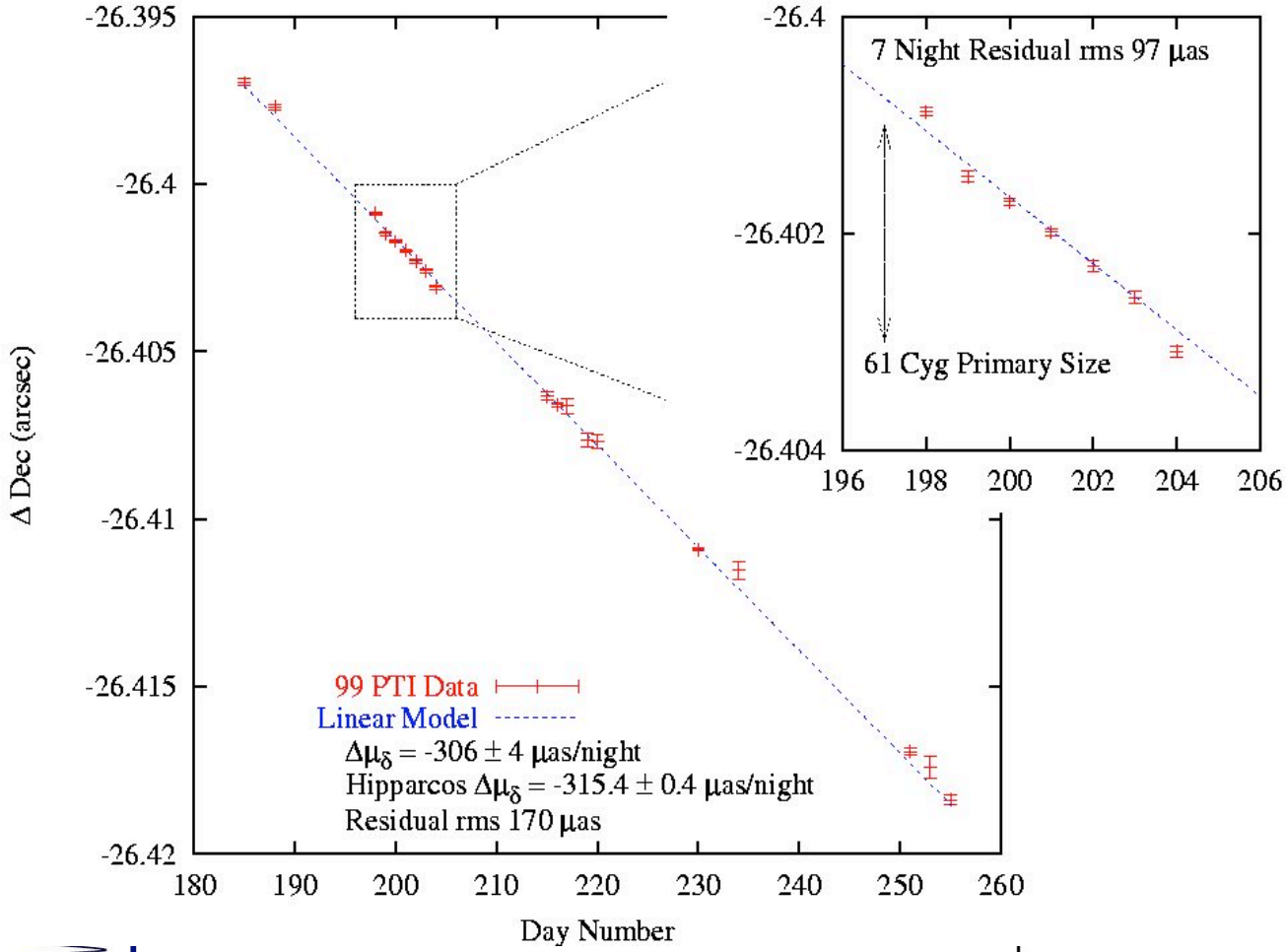
- NGC 4151/Swain et al 2003
- T Tauri Studes/Akeson et al 2000
- Altair/van Belle et al 2001
- HD 98800 B/Boden et al 2005
- Zeta Gem/Cepheids/Lane et al 2001
- HD 9939/Boden et al 2006
- Atlas/Pan et al 2001
- Herbigs/Eisner et al 2004
- M-Dwarf Diameters/Lane et al 2001
- FU Ori/Malbet et al 1998

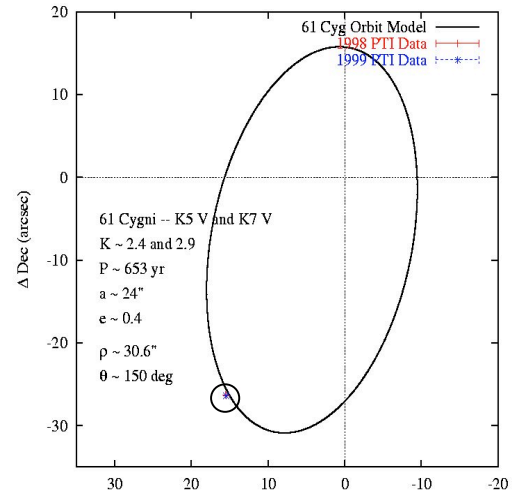
- HD 195987/Torres et al 2002
- Giants/Teff/van Belle et al 1999
- R Tri/Thompson et al 2002
- Kappa Peg/Mutterspaugh et al 2006
- Mystery Guest…

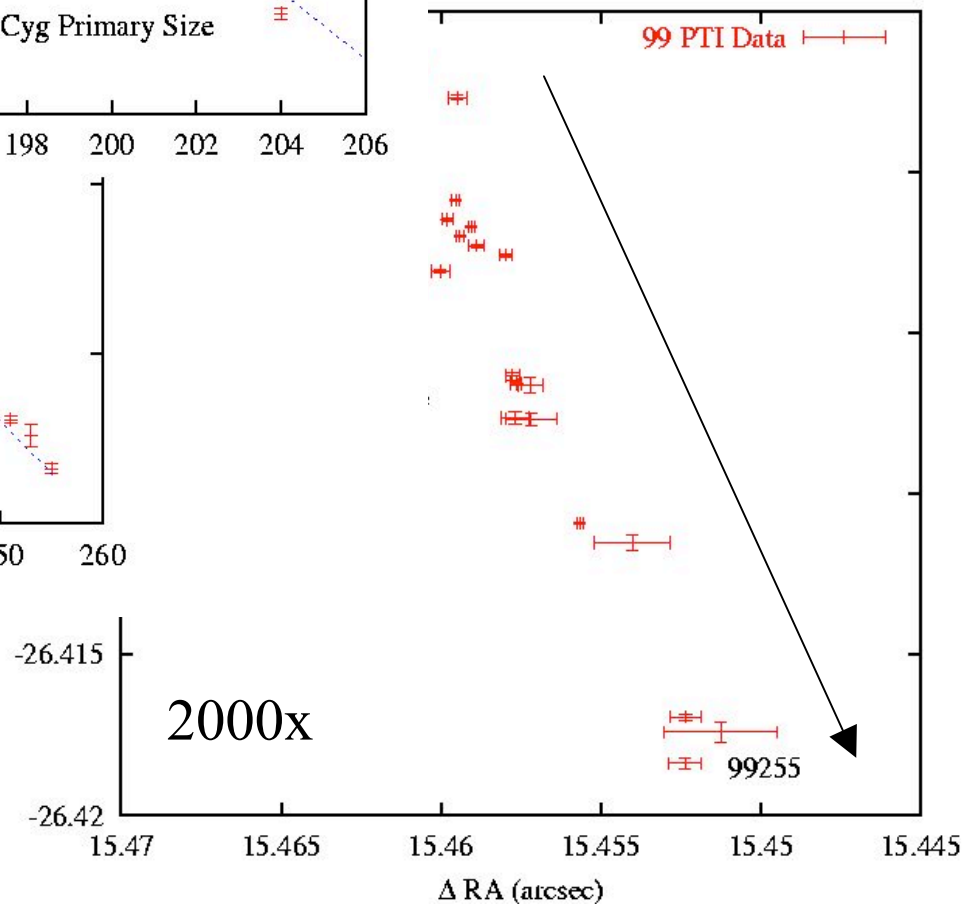
Mystery Guest: PTI Astrometry 61Cygni



PTI Astrometry on 61 Cyg (2)







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Postscript: My Personal Acknowledgements for PTI & KI

PTI:

- M. Colavita, M. Shao
- G. van Belle
- K. Rykoski
- R. Akeson, M. Creech-Eakman
- R. Thompson
- SIM Project & TPF Foundation Science Program
- *PTI Collaboration*

KI:

- M. Colavita, M. Shao
- P. Wizinowich
- J. Gathright
- P. Swanson
- *J. Kelley*
- A. Sargent & C. Beichman
- External KI Shared-Risk Teams (Danchi, Kulkarni Monnier, Traub)

- NASA
- JPL
- Caltech & Palomar Observatory