

PHASES

The Palomar High-precision Astrometric Search for Exoplanet Systems

A Search for Planets in Binary Star Systems

Matthew W. Muterspaugh¹

Benjamin F. Lane² B. F. Burke² Maciej Konacki¹³

S. R. Kulkarni⁴ M. M. Colavita⁵ M. Shao⁵

¹Division of Geological & Planetary Sciences, Caltech

²Kavli Institute for Astrophysics and Space Research, MIT

³Nicolaus Copernicus Astronomical Center, Polish Academy of Sciences

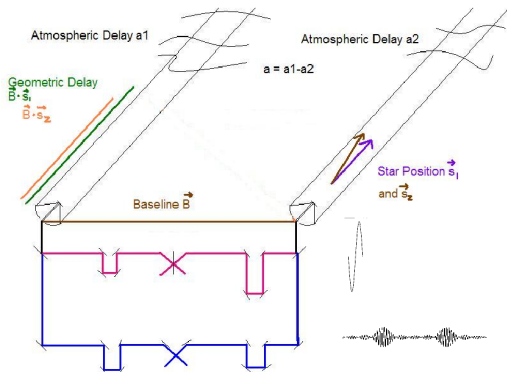
⁴Division of Physics, Mathematics, and Astronomy, Caltech

⁵Jet Propulsion Laboratory

<http://stuff.mit.edu/~matthew1/thesis/thesis.html>



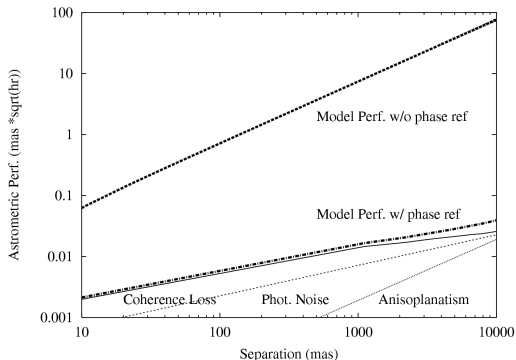
Phase-Referencing



- ▶ Fast tracking (10ms) determines $a(t)$.
- ▶ Second detector stabilized, slowly scans the two stars.

Differential Astrometry: Theoretical Precision

$$\delta D = \delta \vec{s} \cdot \vec{B} - \delta d - \delta a$$



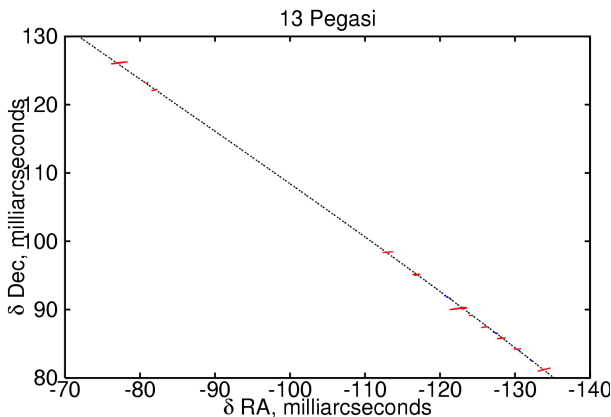
- ▶ Baseline \vec{B} measured by wide-angle astrometry.
- ▶ Internal delay d measured by laser interferometer.
- ▶ $\delta a(t, \vec{s})$ nonzero due to two terms:
 1. Anisoplanatism: $\delta \vec{s} > 30$ arcsec.
 2. Coherence Loss: Temporal turbulence variations.

13 Pegasi

F2IV

33 pc, P=29y

- ▶ Median minor axis error: $16.4 \mu\text{as}$
- ▶ Average relative precision: $\frac{16}{160000} = 10^{-4}$
- ▶ Slope consistent with speckle orbit.



δ Equulei

F7V+F7V

$P = 5.7058 \pm 0.0003$ years

$d = 18.39 \pm 0.05$ parsecs

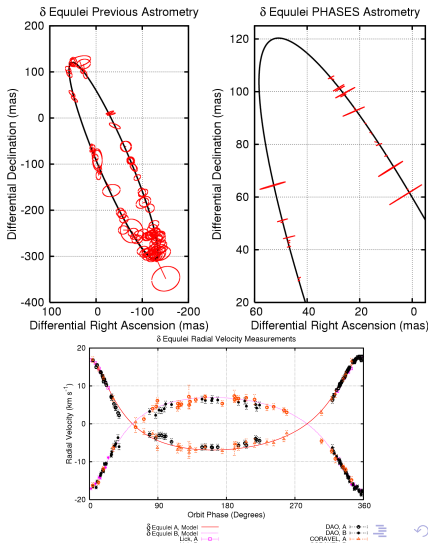
$V = 4.99$, $K = 3.27$

Each $1.19 \pm 0.01 M_{\odot}$

Age 2.2 ± 0.6 Gyr

$M_p \geq 11.5 \left(\frac{P}{\text{month}}\right)^{-\frac{2}{3}}$ Jupiter Masses

astro-ph/0507585



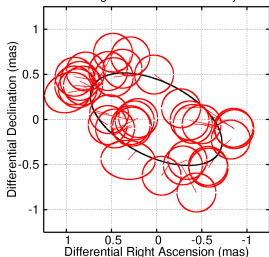
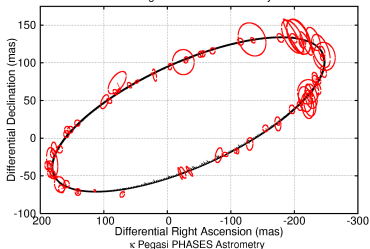
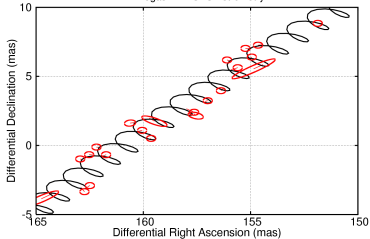
κ PegasiA: F5 IV, $1.54 M_{\odot}$ Ba: F5 IV, $1.67 M_{\odot}$ Bb: $0.82 M_{\odot}$

A-B Period: 11.6 years

Ba-Bb Period: 5.97 days

Mutual Inclination: 43.8 degrees

astro-ph/0509406

 κ Pegasi PHASES Astrometry κ Pegasi Previous Astrometry κ Pegasi PHASES Astrometry

V819 Herculis

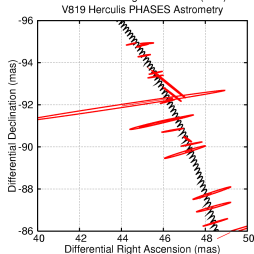
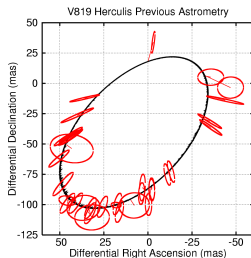
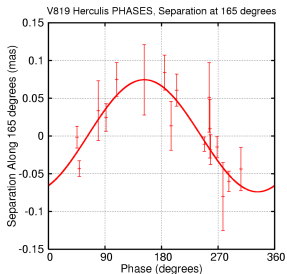
A-B Period: 5.5 years

Ba-Bb Period: 2.23 days

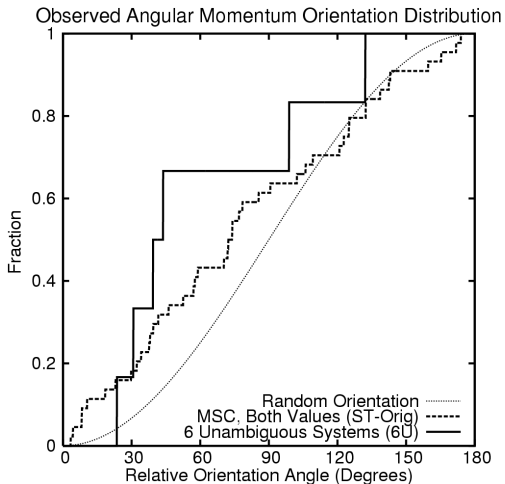
Ba-Bb shows eclipses

Mutual Inclination: 23.6 degrees

[astro-ph/0509855](https://arxiv.org/abs/astro-ph/0509855)



Mutual Inclinations

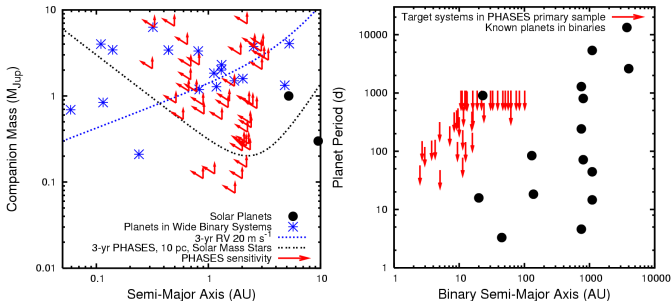


Future Work

≈ 50 systems observable with *current* setup.

- ▶ Within view of PTI (dec $\approx +10$ to $+50$)
- ▶ $K < 4.5$
- ▶ Astrometry for $\Delta K < 1.5$. Direct detections at $\Delta K < 5$
- ▶ Separation less than 1 arcsecond
- ▶ Average $M_{\text{pl},\text{min}} = 0.7M_{\text{J}}$. ($3\sigma = 30\mu\text{as}$)
- ▶ 36 systems: $M_{\text{pl},\text{min}} < 1M_{\text{J}}$
- ▶ 17 systems: Maximum stable $P_{\text{pl}} < 2\text{y}$.

Conclusions



- ▶ Astrometry of sub-arcsecond binaries demonstrated at precisions $< 10^{-4}$.
- ▶ Astrometry detects faint companions to binary systems.
- ▶ A survey of sub-arcsecond binaries will search for planets around stars inaccessible to other methods.