Planets of binary and multiple star systems

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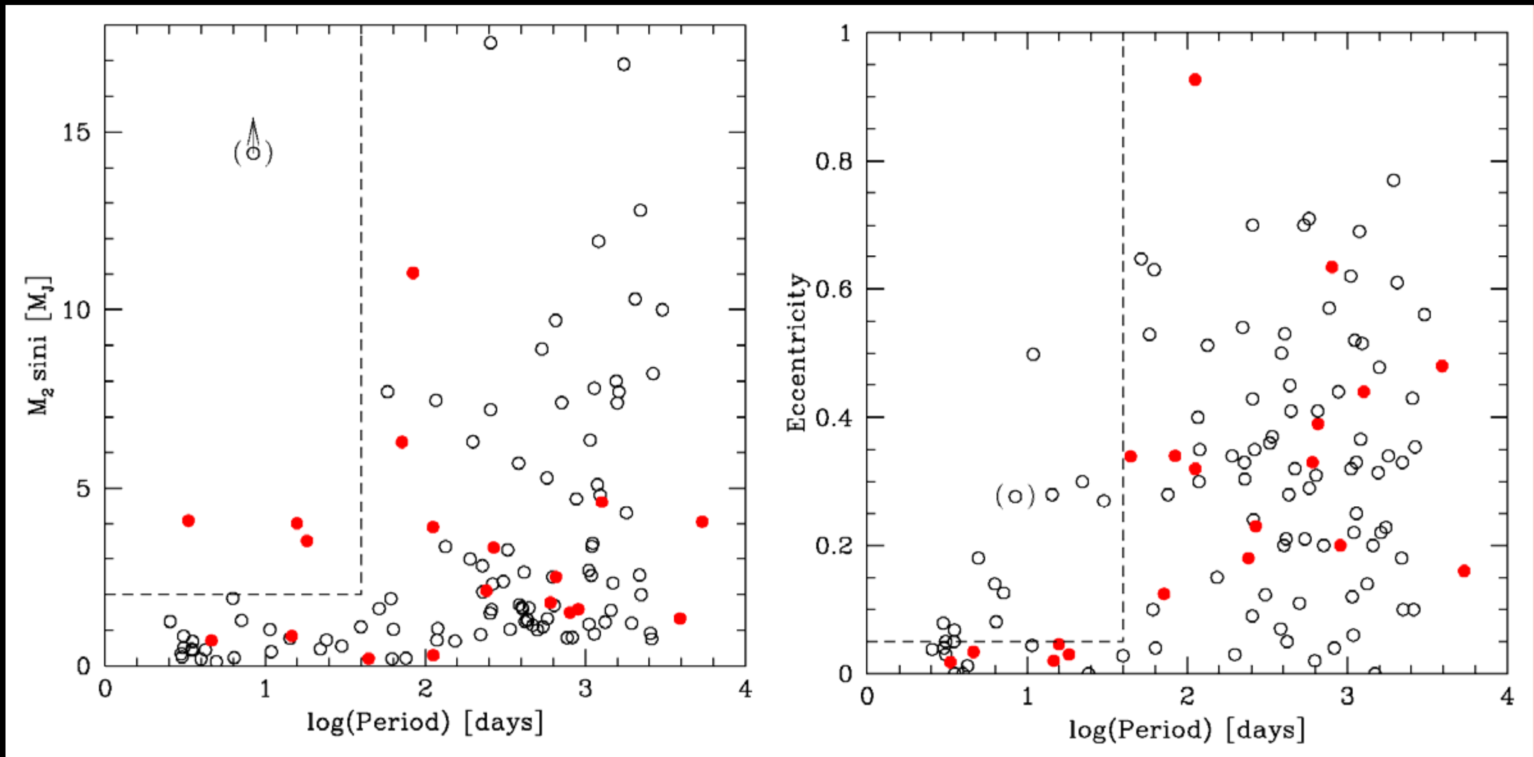
Reading

1. Muterspaugh, Konacki, Lane & Pfahl, **“Observational Techniques for Detecting Planets in Binary Systems”**, 2007, astro-ph/**0705.3072**

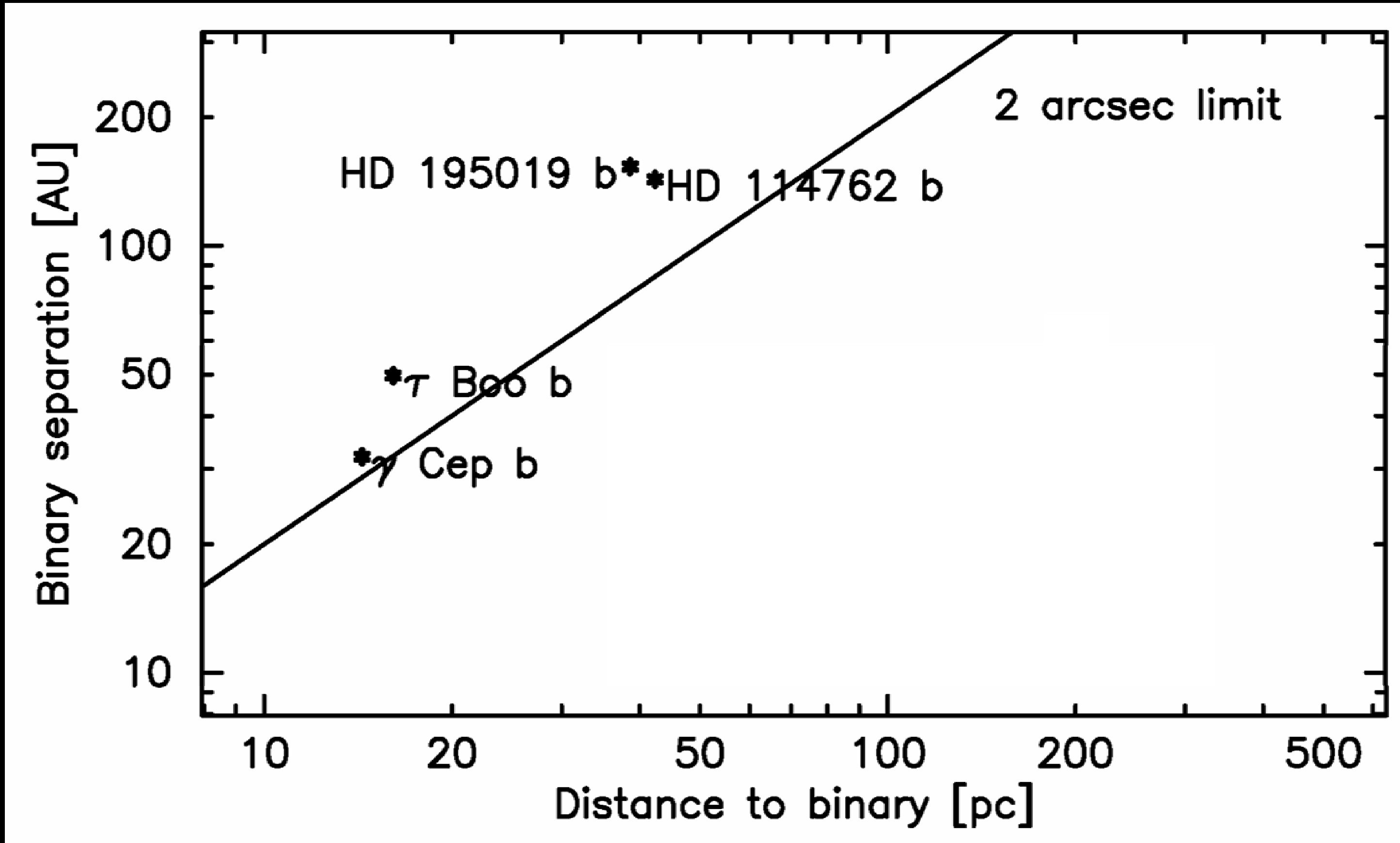
2. Eggenberger & Udry,”Probing the Impact of Stellar Duplicity on Planet Occurrence with Spectroscopic and Imaging Observations”, 2007, astro-ph/0705.3173

Both to appear in the book "Planets in Binary Star Systems," ed. Nader Haghighipour (Springer publishing company)

Planets in multiple star systems



Eggenberger et al, A&A, 2004



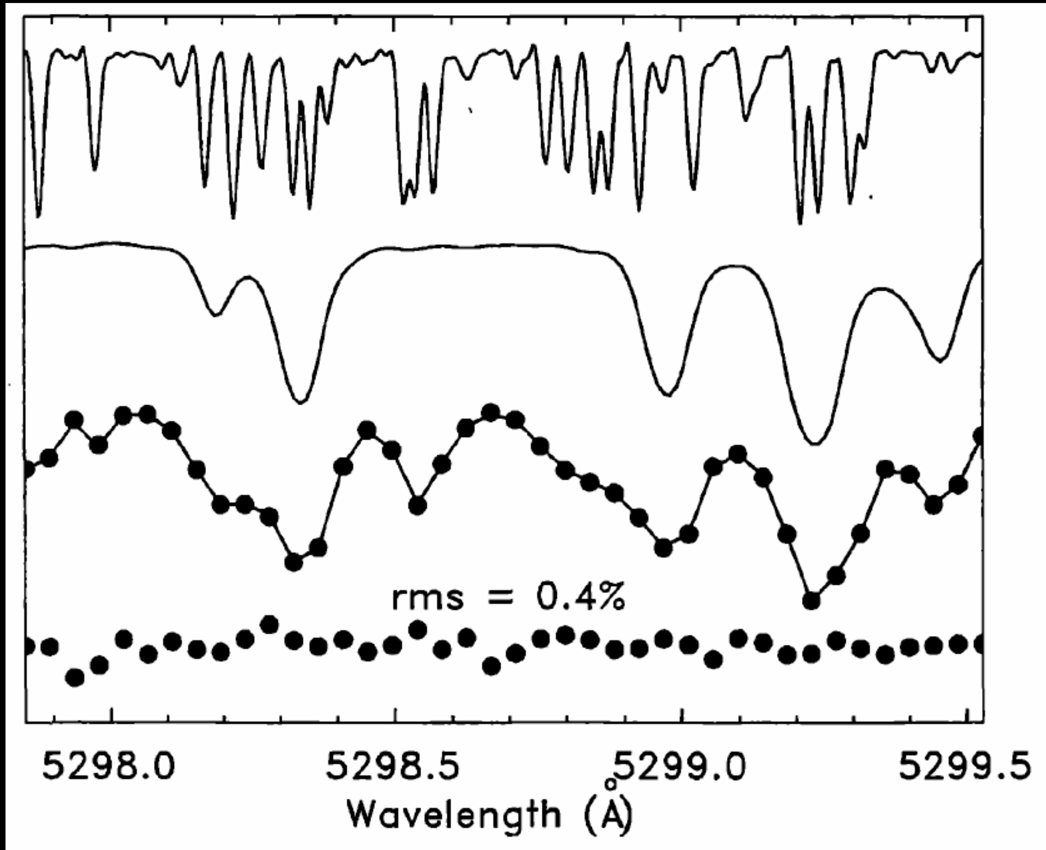
Apparent separations

Preliminary results from the imaging su

1. 42 planets belong to stars from binary and multiple stellar systems

2. The occurrence of planets is reduced in binaries with separations smaller than 120 AU

Eggenberger & Udry, 2007, astro-ph/0705.3173



Iodine transmission fun

Template stellar spectr

Stellar spectrum observ
through the iodine cell

Marcy & Butler, 1992

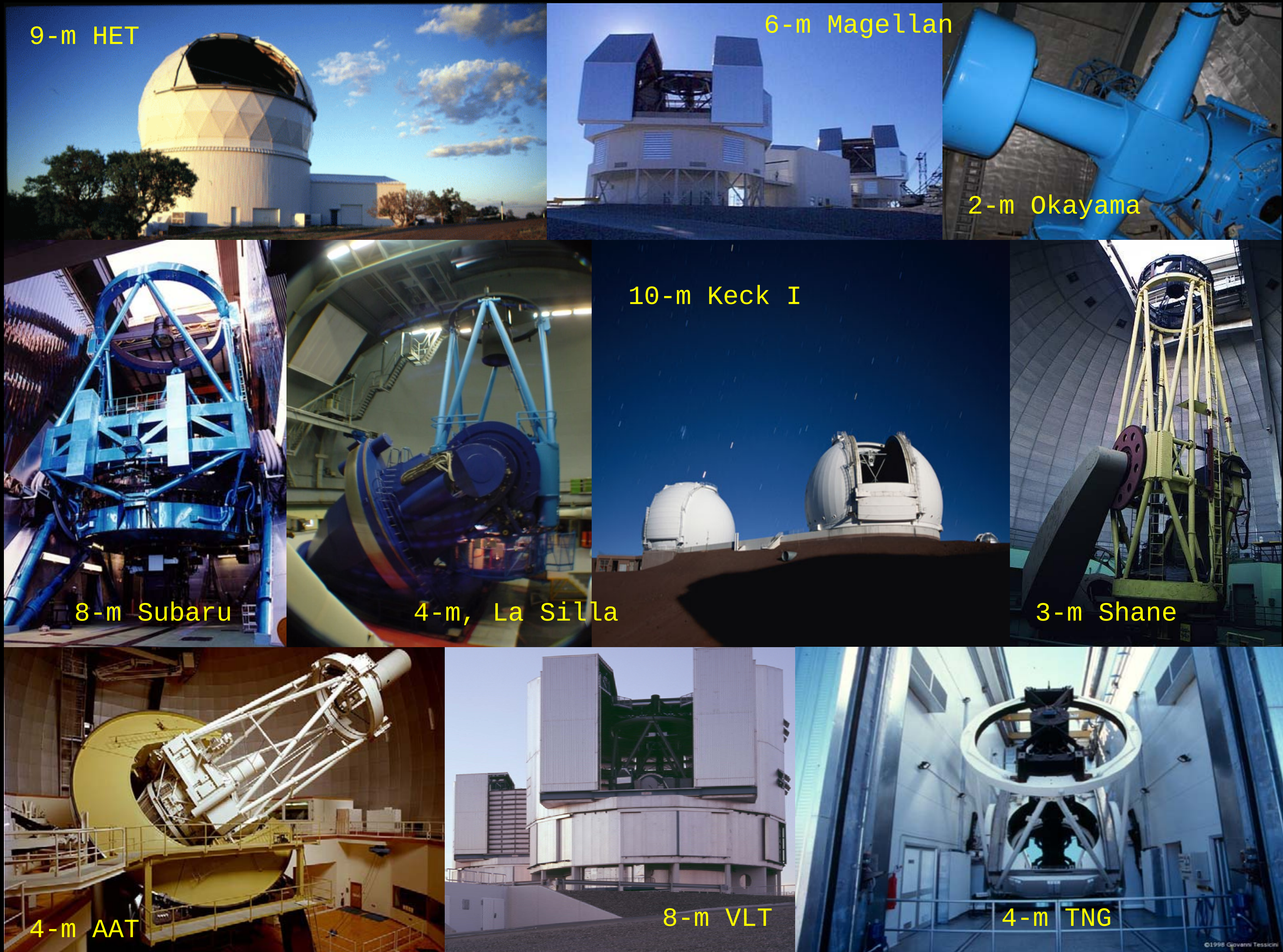
$$I_{obs}(\lambda) = [I_s(\lambda + \Delta\lambda_s)\, T_{I_2}(\lambda + \Delta\lambda_{I_2})] \otimes PSF$$

Precision velocities of binaries:

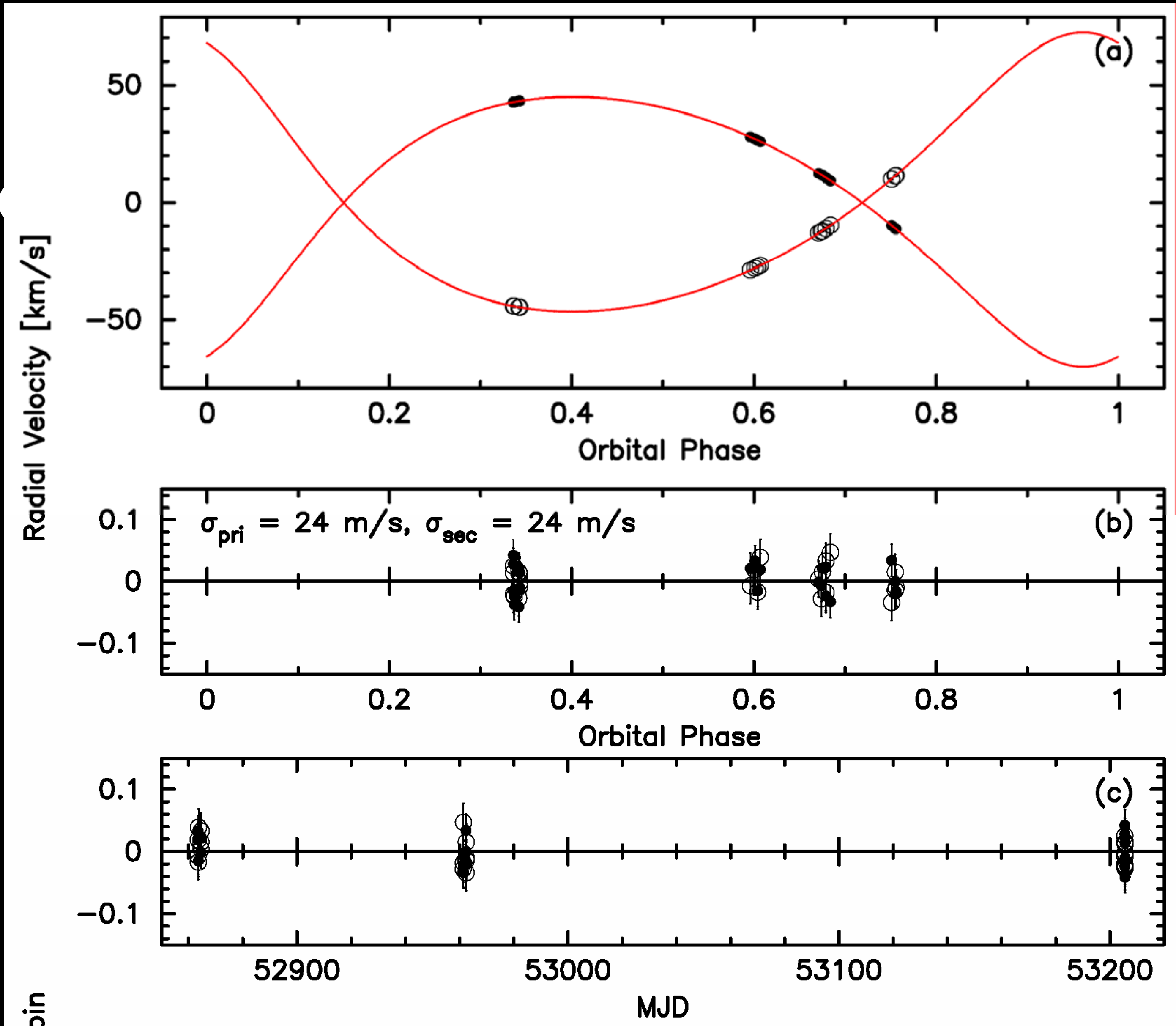
take a template stellar spectrum each t
a spectrum with the cell is taken

$$I_{obs}(\lambda) = [I_s(\lambda + \Delta\lambda_s)\, T_{I_2}(\lambda + \Delta\lambda_{I_2})] \otimes PSF$$

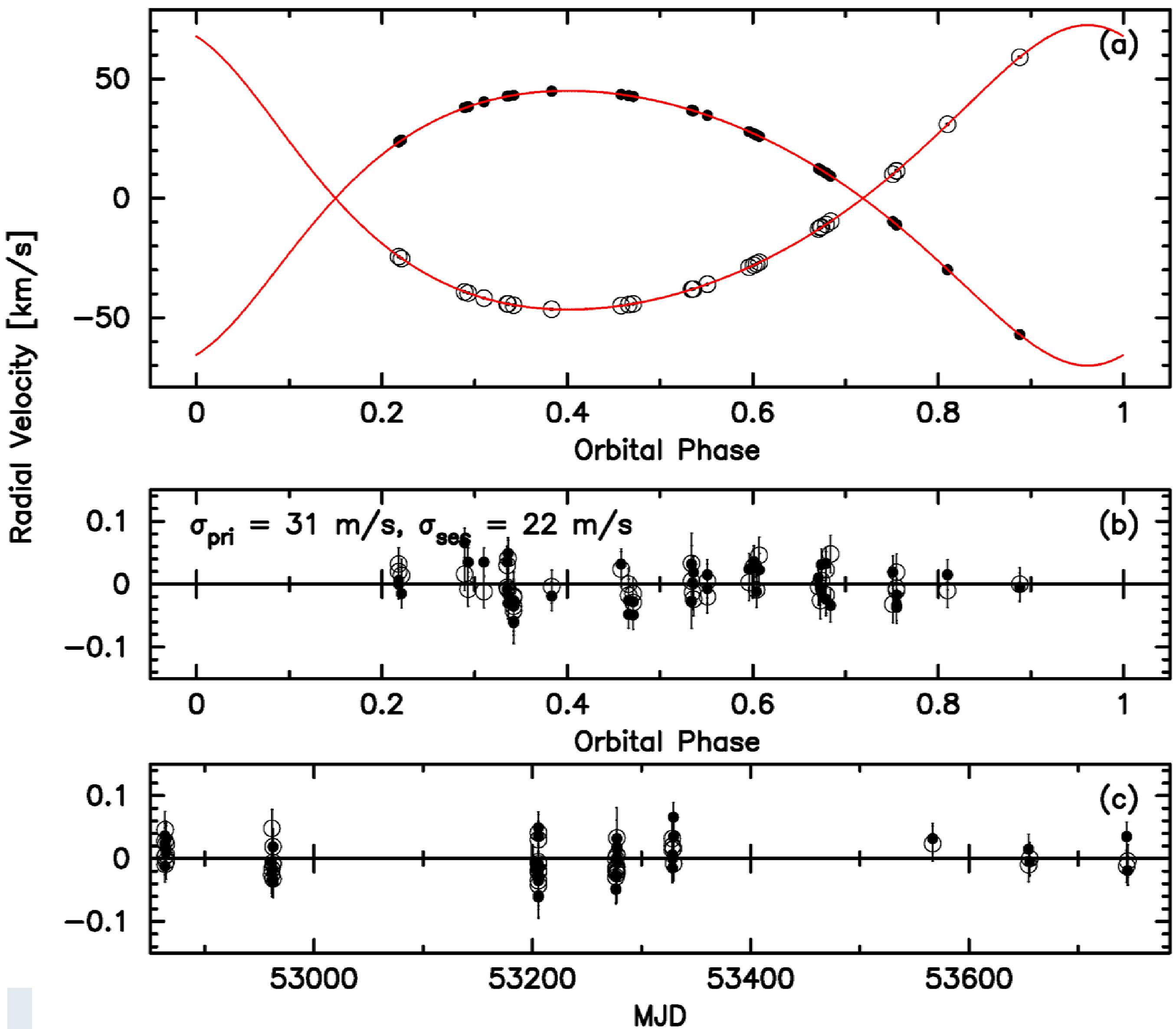
$$I^{\star,i}_{obs}(\lambda) = [I^i_{obs}(\lambda) \otimes^{-1} PSF^i]/T_{I_2}(\lambda)$$


9-m HET
6-m Magellan
2-m Okayama
10-m Keck I
8-m Subaru
4-m, La Silla
3-m Shane
4-m AAT
8-m VLT
4-m TNG

HD 4676
(64 Psc)
P = 13.8 d
F8V+F8V



Konacki, 2005, ApJ



Radial Velocity [km/s]
(a)
50
0
−50
0
0.2
0.4
0.6
0.8
1
Orbital Phase
(b)
σ_{pri} = 31 m/s, σ_{sec} = 22 m/s
0.1
0
−0.1
0
0.2
0.4
0.6
0.8
1
Orbital Phase
(c)
0.1
0
−0.1
53000
53200
53400
53600
MJD

Table 1. Best-fit Orbital Parameters for HD 4676[a]

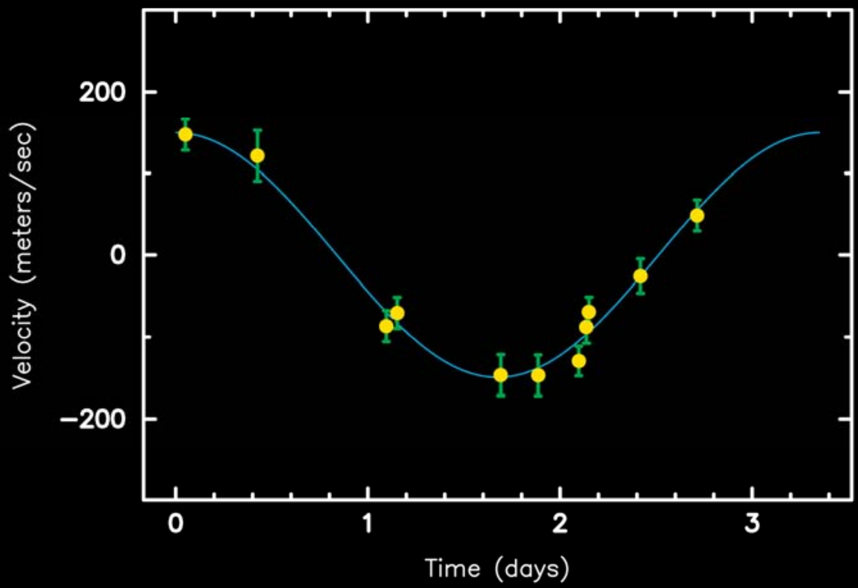
Parameter	HD 4676
Apparent semi-major axis, $\hat{a}$ (mas)	6.545 ± 0.0133
Period, P (d)	$13.8244906 \pm 4.3\times10^{-5}$
Time of periastron, T_p (MJD)	50905.9746 ± 0.0067
Eccentricity, e	0.23657 ± 0.00063
Longitude of the periastron, ω (deg)	203.057 ± 0.073
Longitude of the ascending node, Ω (deg)	207.41 ± 0.65
Inclination, i (deg)	73.92 ± 0.80
Magnitude difference (K band, *assumed*), ΔK .	*0.11*
Velocity amplitude of the primary, K_1 (km/s) .	57.552 ± 0.037
Velocity amplitude of the secondary, K_2 (km/s)	59.557 ± 0.038
Reduced χ^2, χ^2/DOF	1.18

Table 2. Physical Parameters for HD 4676[a]

Parameter	Primary	Secondary
Semi-major axis, $a_{1,2}$ (AU)	$0.073953 \pm 4.8\times10^{-5}$	$0.076529 \pm 5.0\times10^{-5}$
Mass, M ($M_\odot$)	1.210 ± 0.014	1.169 ± 0.014
Parallax, κ (mas)	43.496 ± 0.089	
Distance, d (pc)	22.991 ± 0.047	
Spectral type	F8V	F8V

Masses accurate to 1.2%

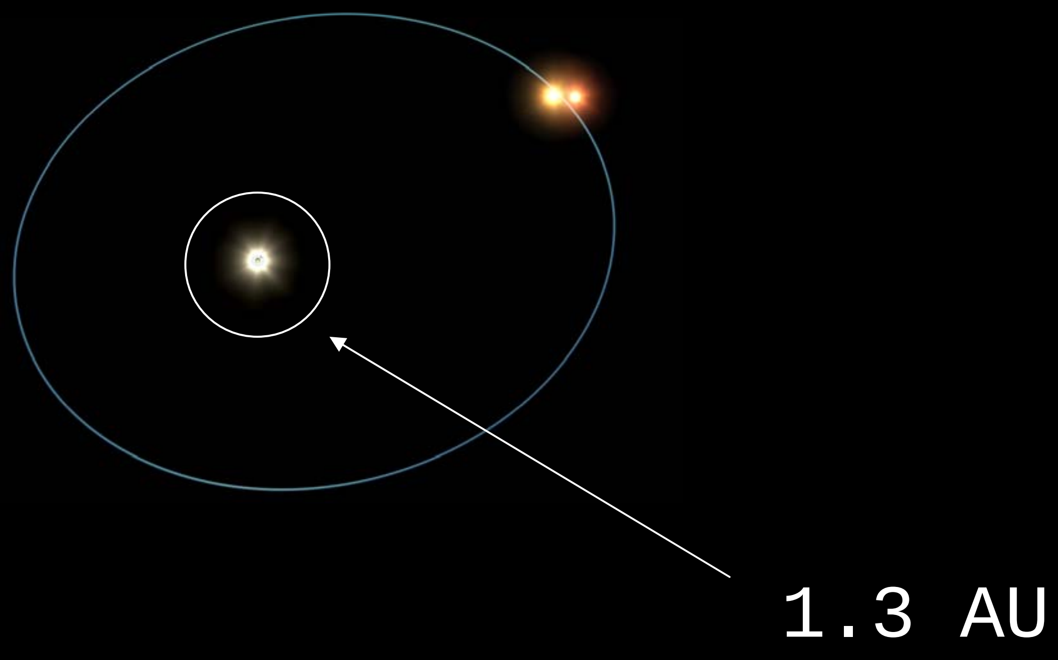
ndidate planet in a close triple-star syste
HD 188753??



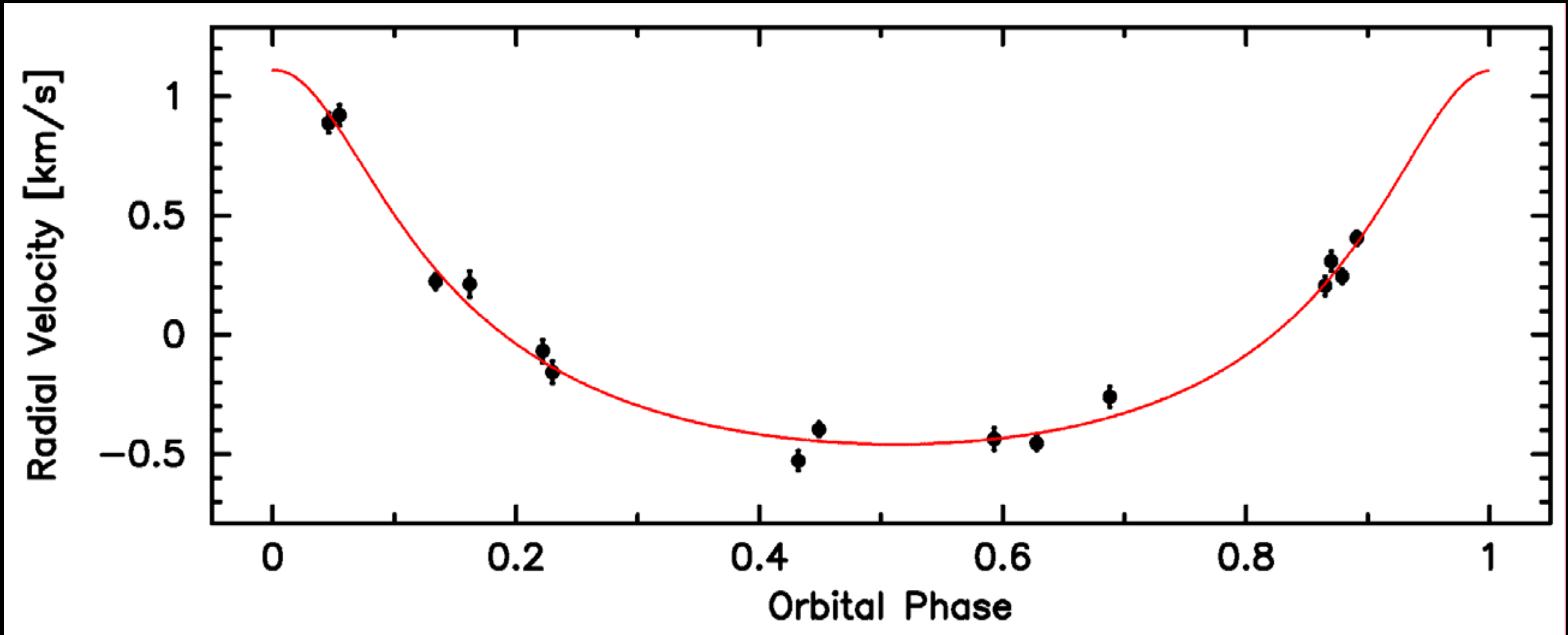
Incorrect orbital solution?: P_{orb} = 3.348 days, M

Konacki, 2005, Nature
See also Eggenberger et al, 2007, astro-ph/0702574

A putative protoplanetary disk in the HD 188753 system



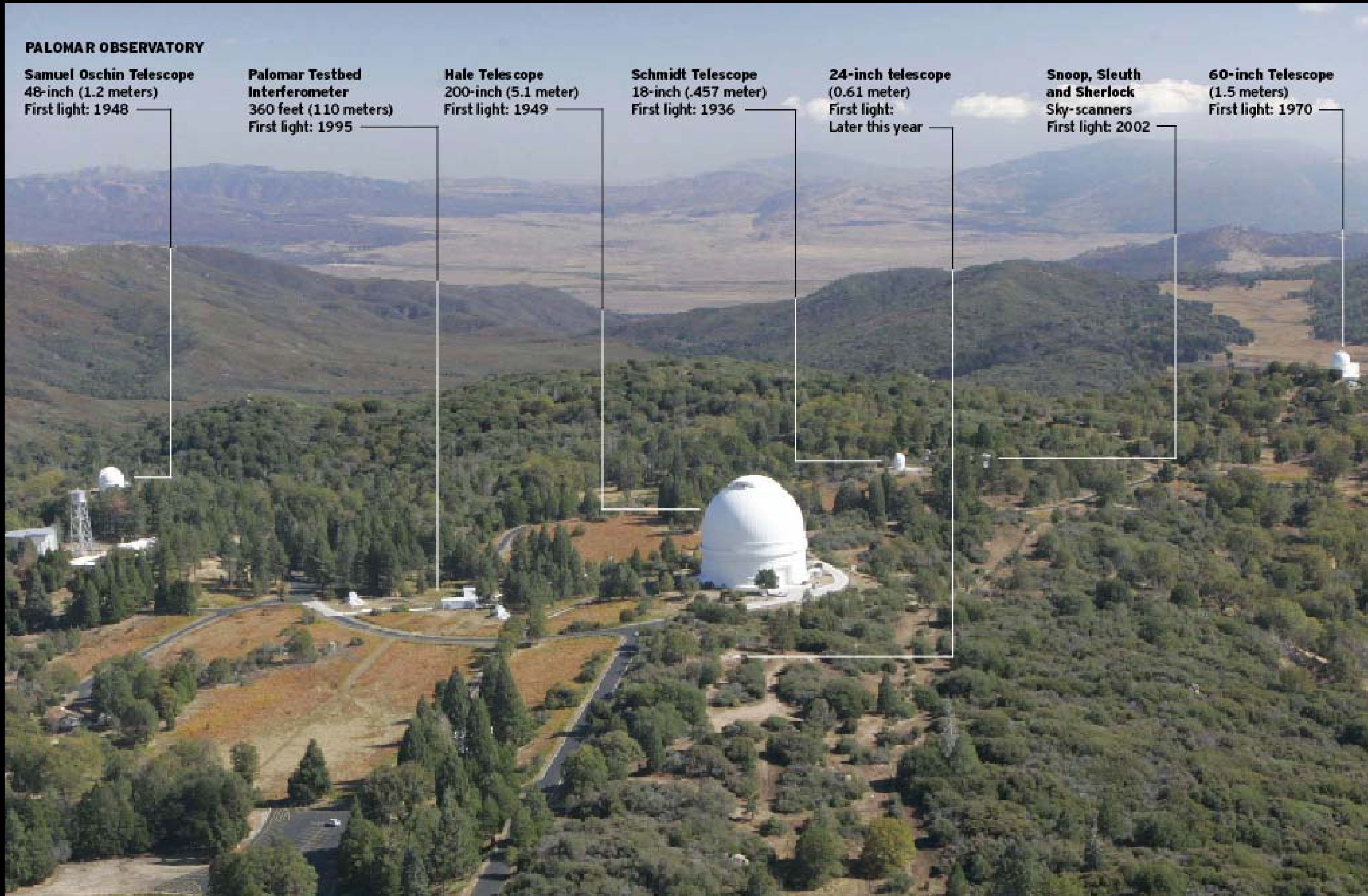
Another candidate planet in a triple sta



Palomar Testbed Interferometer (PTI)

NS 110 m, NW 86 m, SW 87 m

K (2.2 μm), H (1.6 μm)


PALOMAR OBSERVATORY
Samuel Oschin Telescope
48-inch (1.2 meters)
First light: 1948
Palomar Testbed Interferometer
360 feet (110 meters)
First light: 1995
Hale Telescope
200-inch (5.1 meter)
First light: 1949
Schmidt Telescope
18-inch (.457 meter)
First light: 1936
24-inch telescope
(0.61 meter)
First light:
Later this year
Snoop, Sleuth and Sherlock
Sky-scanners
First light: 2002
60-inch Telescope
(1.5 meters)
First light: 1970

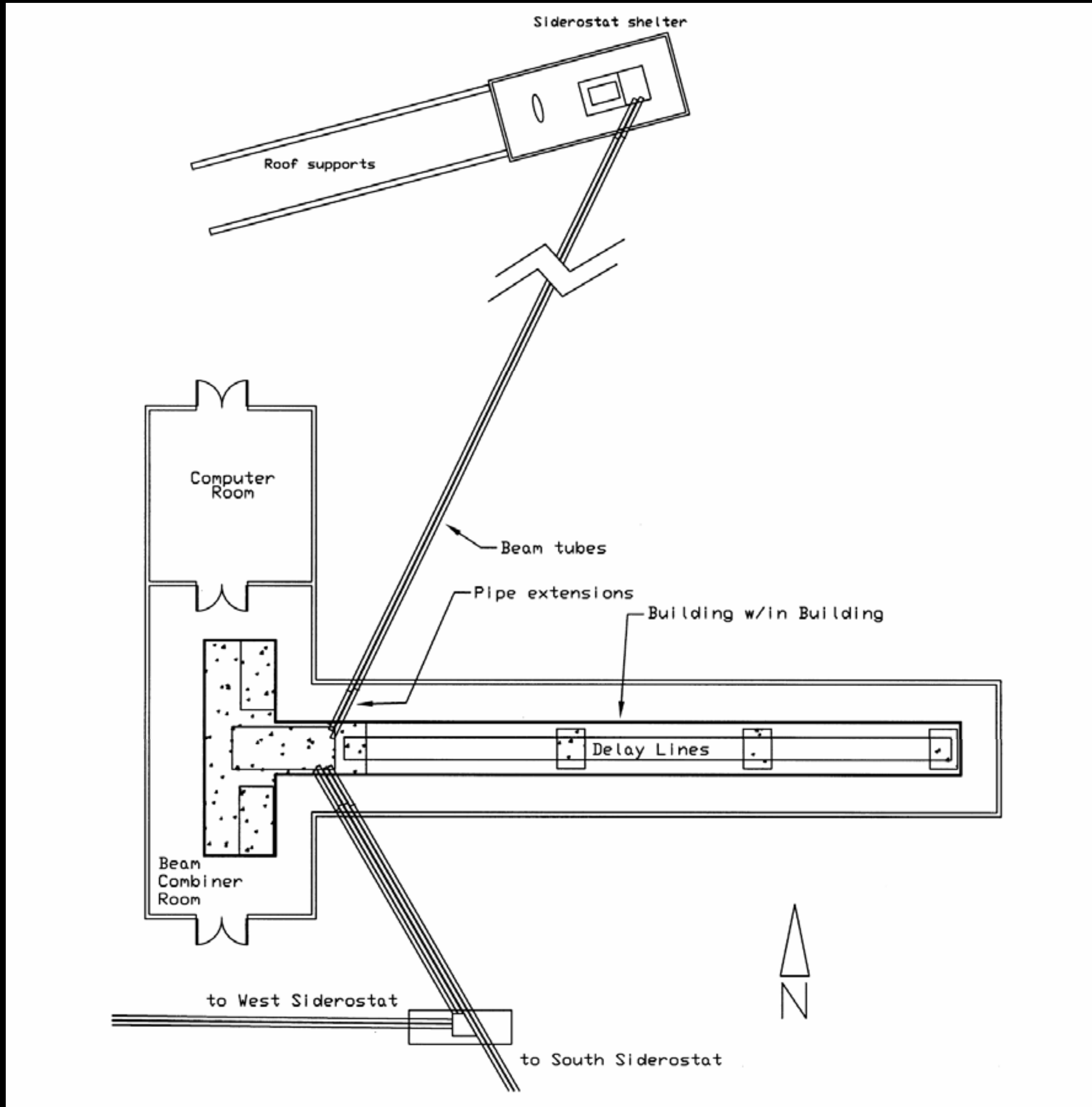

Energy Shield


Energy
Atlas Energy Products
Shield

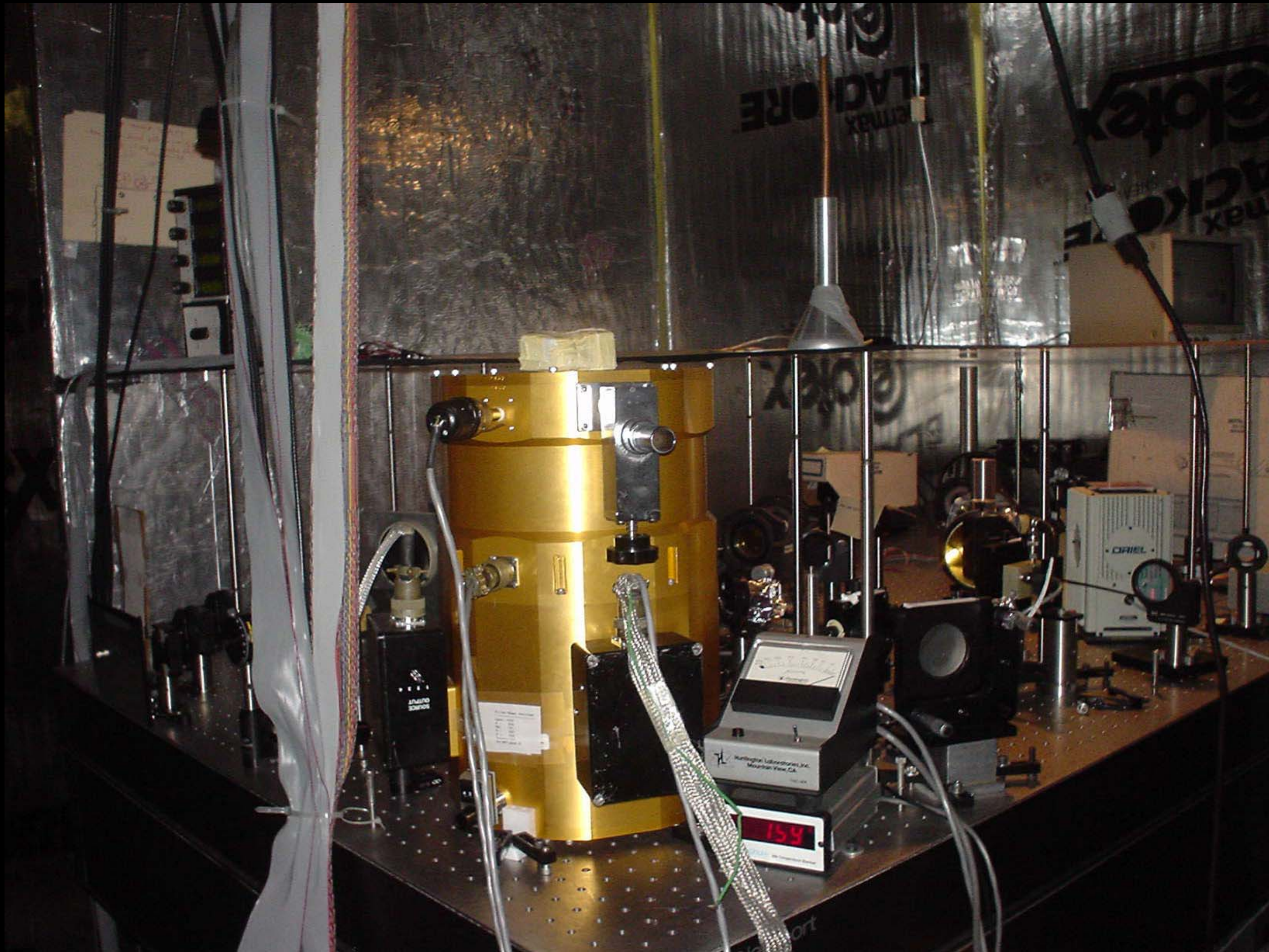

Energy Shield
Atlas Energy Products

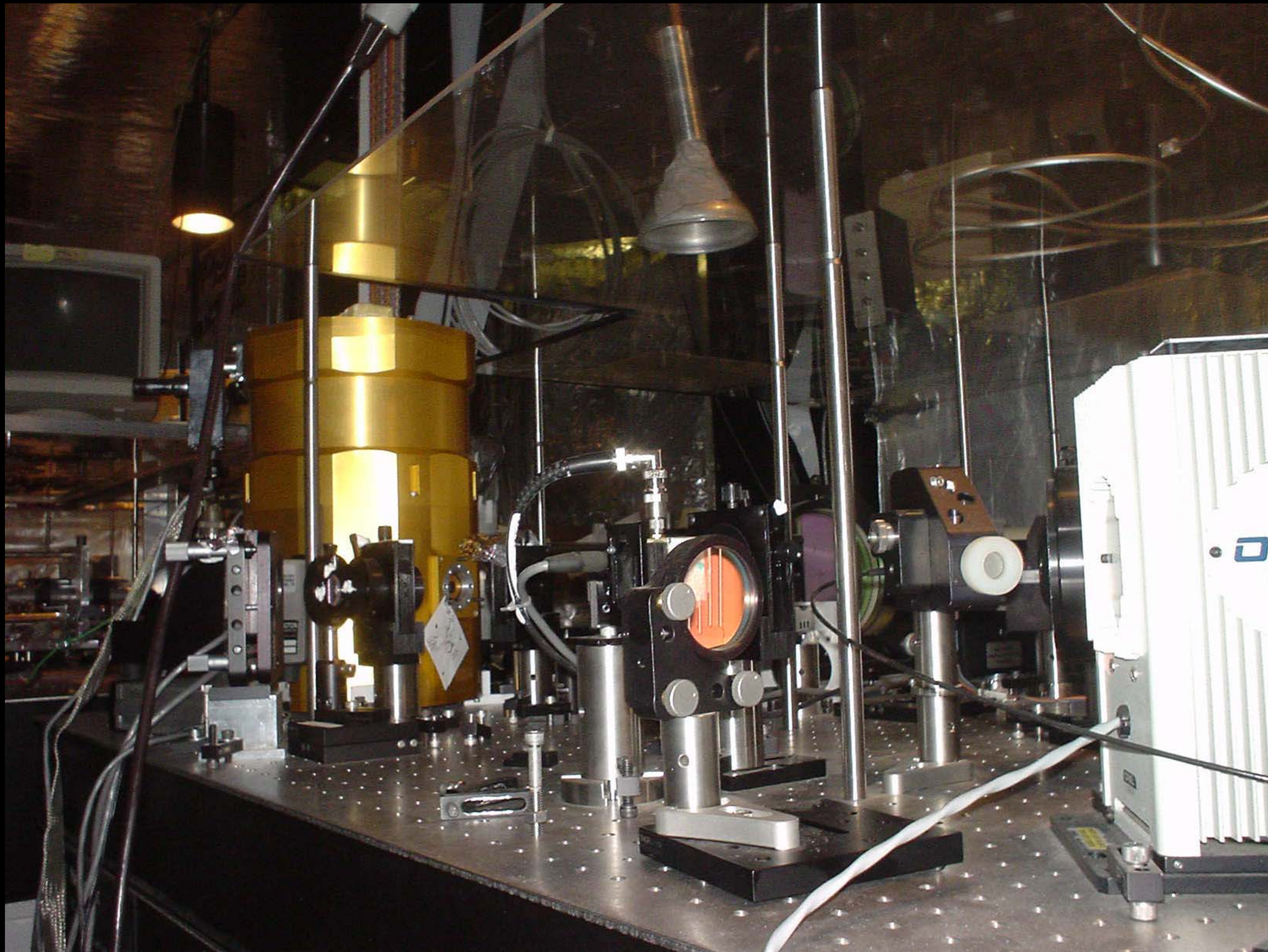

Atlas Energy Products



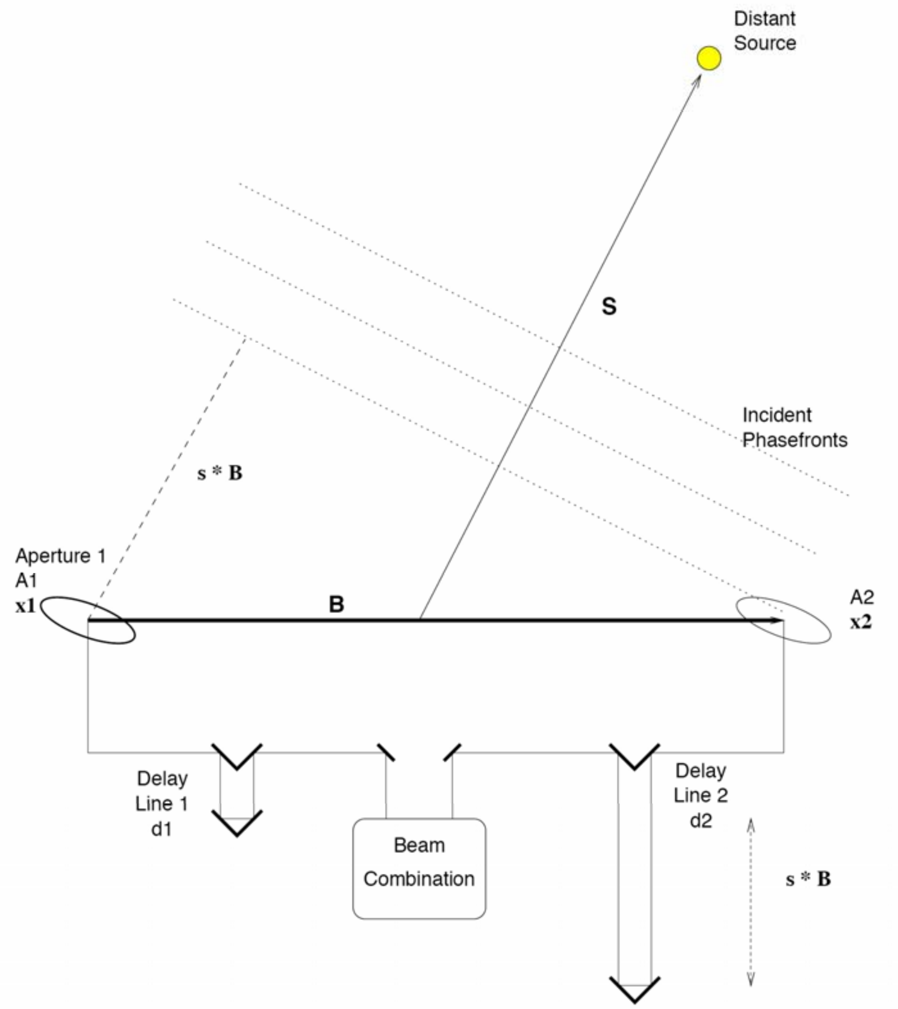
Siderostat shelter
Roof supports
Computer Room
Beam tubes
Pipe extensions
Building w/in Building
Delay Lines
Beam Combiner Room
N
to West Siderostat
to South Siderostat


ORIEL
Huntington Laboratories, Inc.
Mountain View, CA
159




LE GRAND BLEU

$$P = 2AF(1 + \cos(2\pi(\vec{s} \bullet \vec{B} + d_1 - d_2) / \lambda))$$



$$P = 2AF(1 + \cos(2\pi D / \lambda))$$

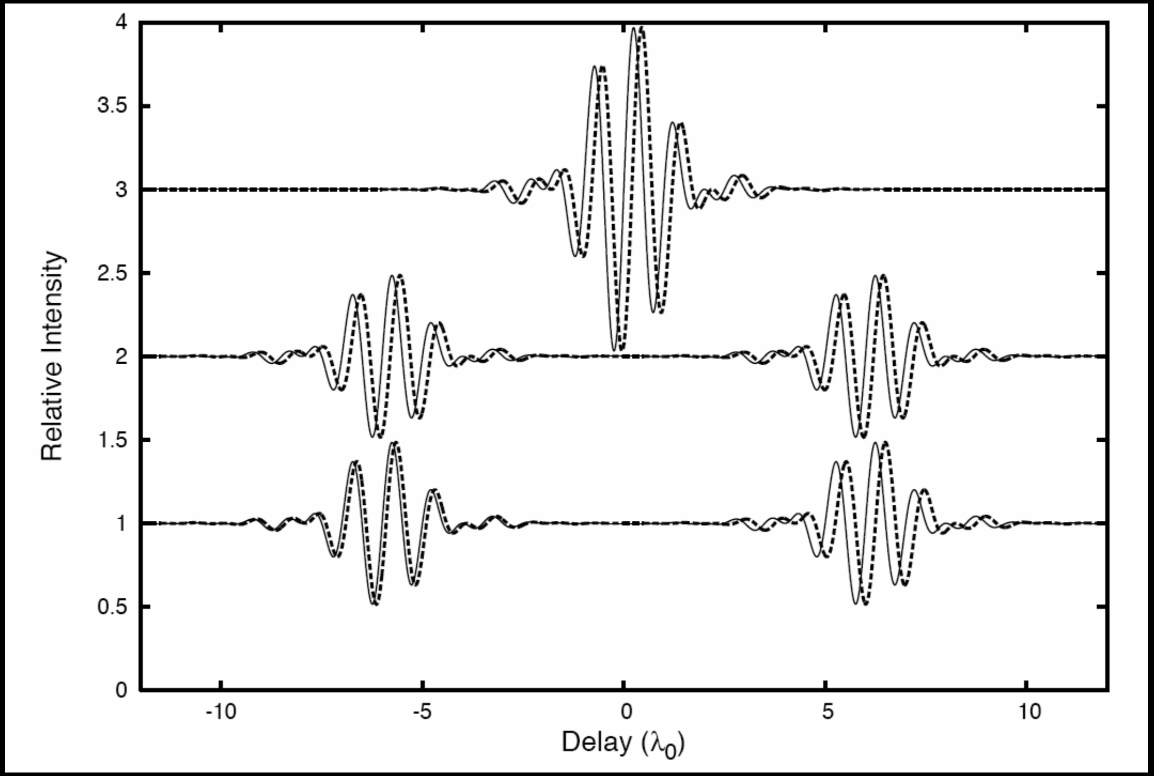
PHASES
The Palomar High-precision Search for Exoplanet Systems

Matthew W. Muterspaugh (Berkeley),
Benjamin F. Lane (MIT),
Maciej Konacki, B. F. Burke, M. M. Colavita, S. R. Kulkarni, M. Sha

The sample:

Binary stars brighter than K = 4.5 mag
~40 binaries observed so far
Current time-span: 3.5 years
Precision: ~10 micro arcseconds over one night
~30 micro arcseconds long term

PHASES



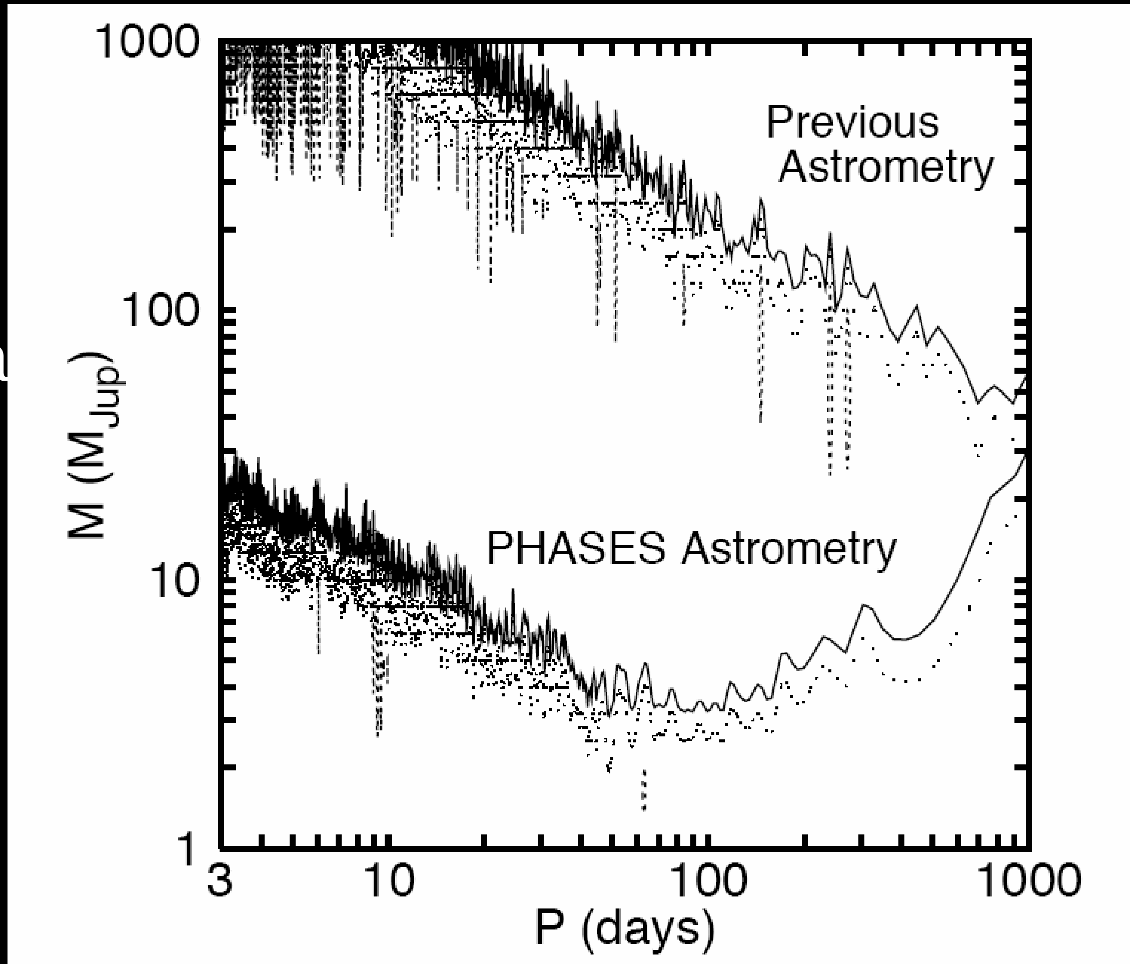
$$d = \boldsymbol{B} \cdot \boldsymbol{S}$$

Lane, B.F. & Muterspaugh, M. W., 2004, ApJ

PHASES

HD202275

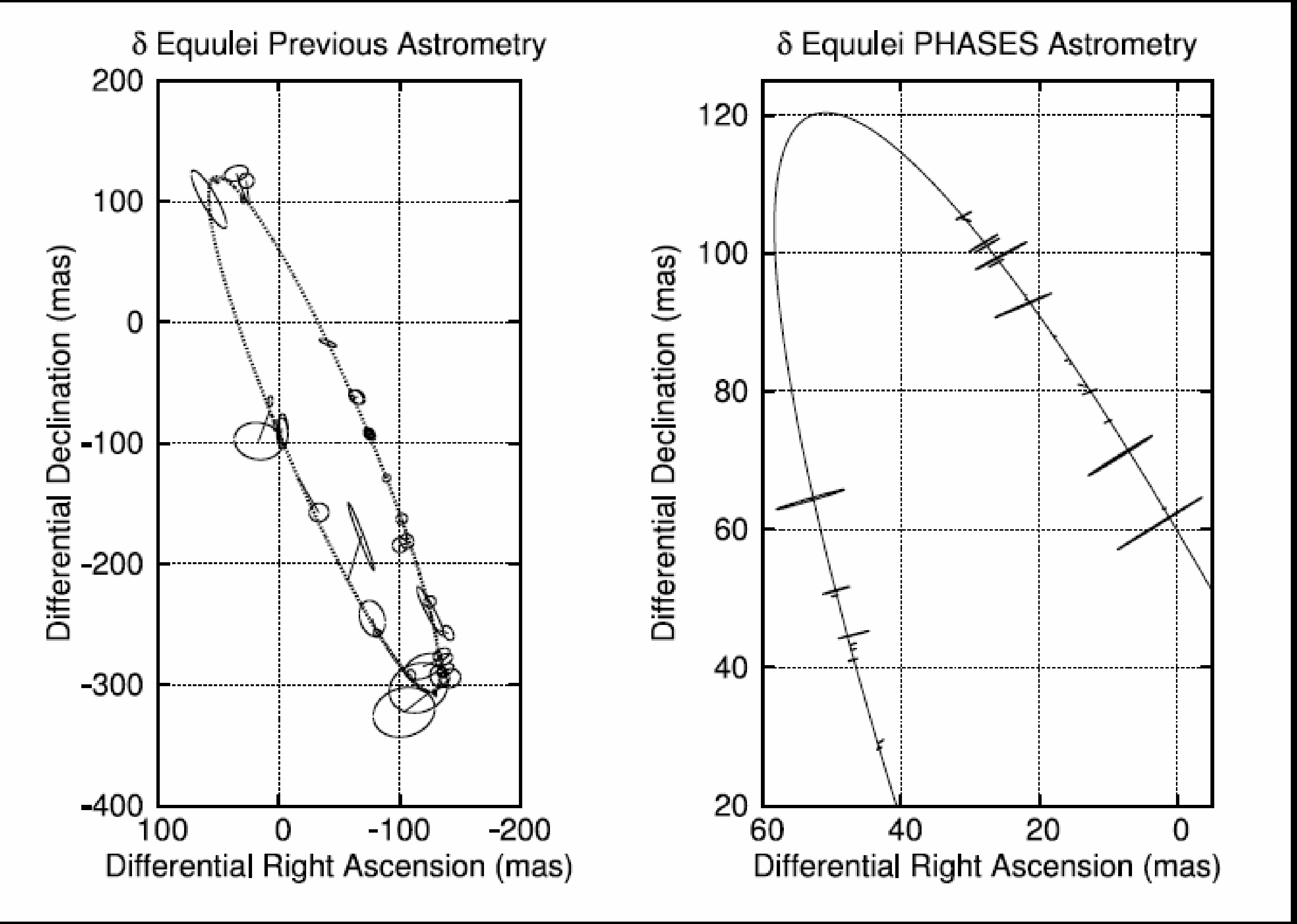
38 measurements
Time-span 760 da
RMS ~30 muas



Muterspaugh, M. W. et al, 2006, ApJ

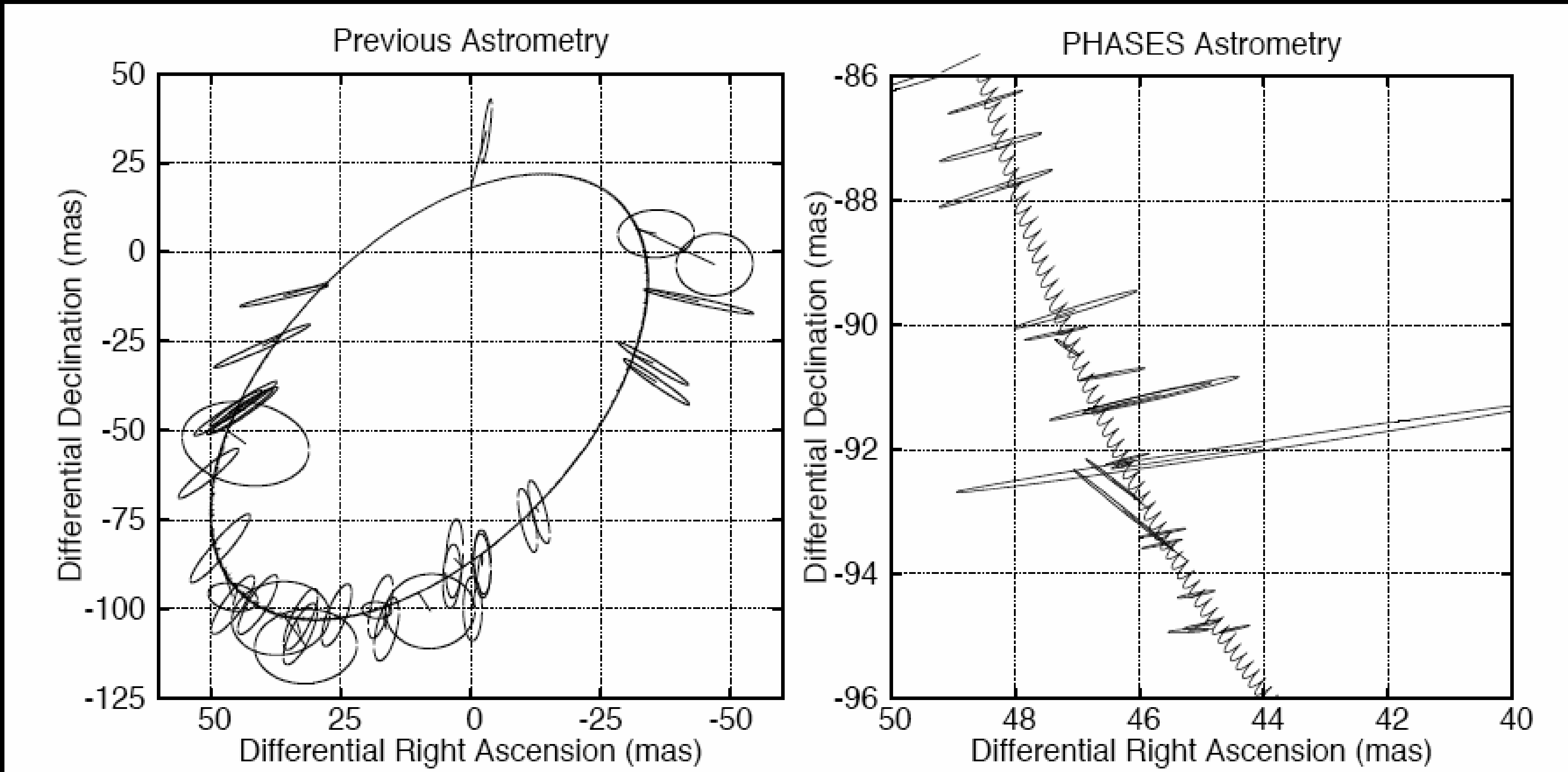
PHASES

HD202275:
a binary



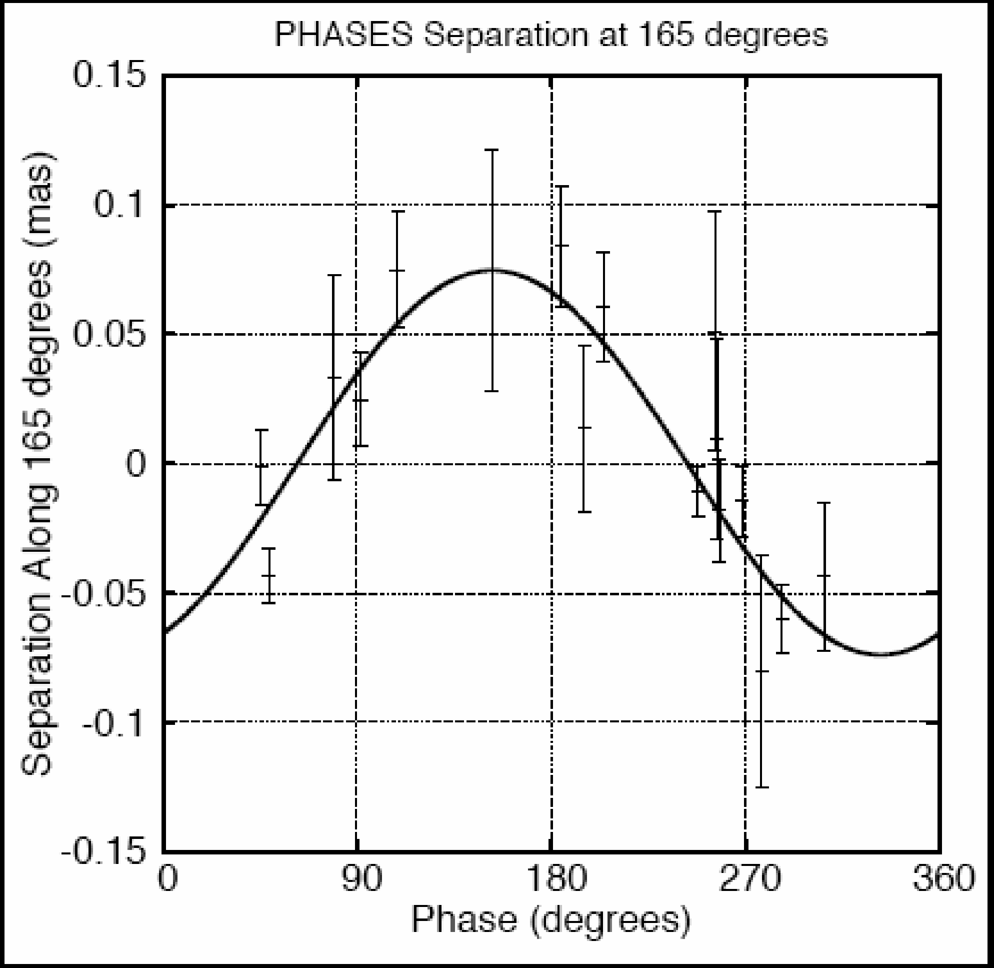
Muterspaugh, Lane, Konacki et al, 2005, AJ

PHASES V819 Herculis: a triple system 2019 days + 2.2 days



Muterspaugh, Lane, Konacki et al, 2006, A&A

PHASES



Muterspaugh, Lane, Konacki et al, 2006, A&A

PHASES

Table 6
Known Mutual Inclinations

Star	Mutual Inclination (degrees)	Reference
V819 Her	23.6 ± 4.9	This paper
κ Peg	43.8 ± 3.0	[Muterspaugh et al., 2005]
η Vir	30.8 ± 1.3	[Hummel et al., 2003]
ϵ Hya	39.4	[Heintz, 1996]
ξ UMa	132.1	[Heintz, 1996]
Algol	98.8 ± 4.9	[Lestrade et al., 1993] [Pan et al., 1993]

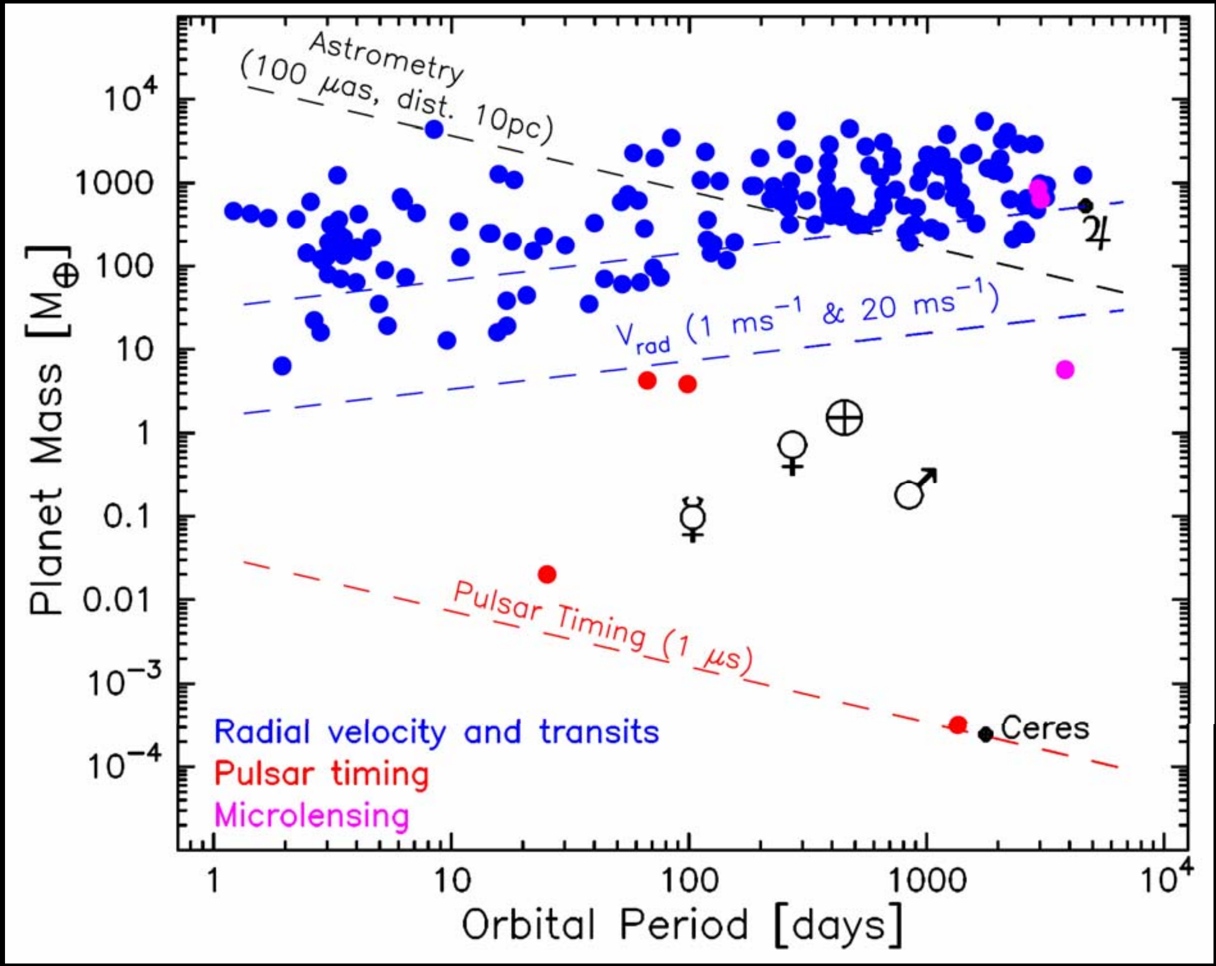
Table 6. Unambiguously known mutual inclinations of triple systems. The value for Algol is determined using the measurement precisions and values of Pan et al. [1993] for all but the A-B nodal position angle of 52 ± 5 degrees from Lestrade et al. [1993]

Muterspaugh, Lane, Konacki et al, 2006, A&A

Adaptive optics

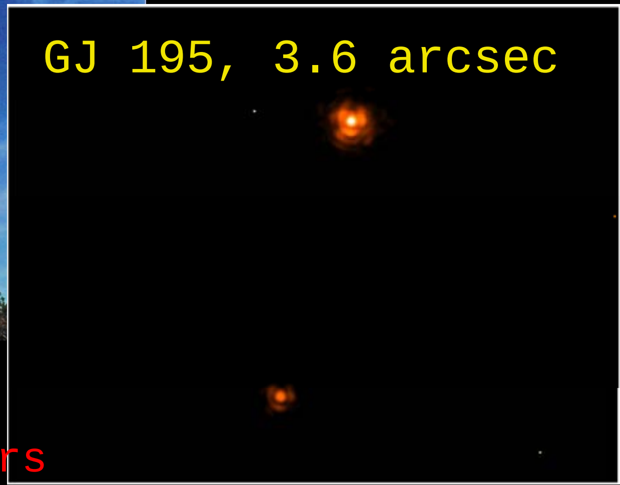
Ben R. Oppenheimer, American Museum of Natural History
http://lyot.org/background/adaptive_optics.html

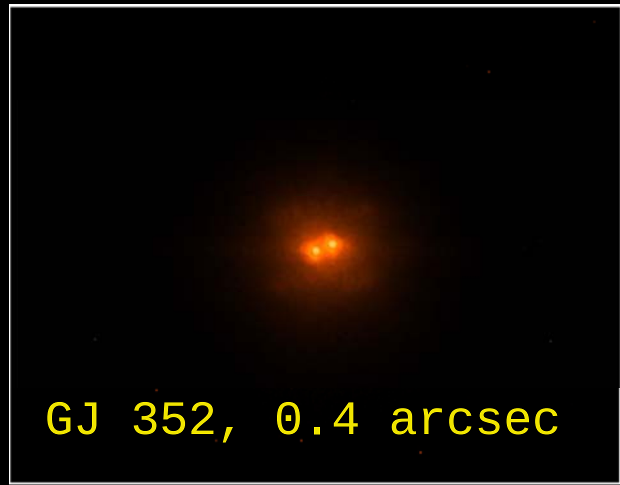
Astrometry with Adaptive Optics

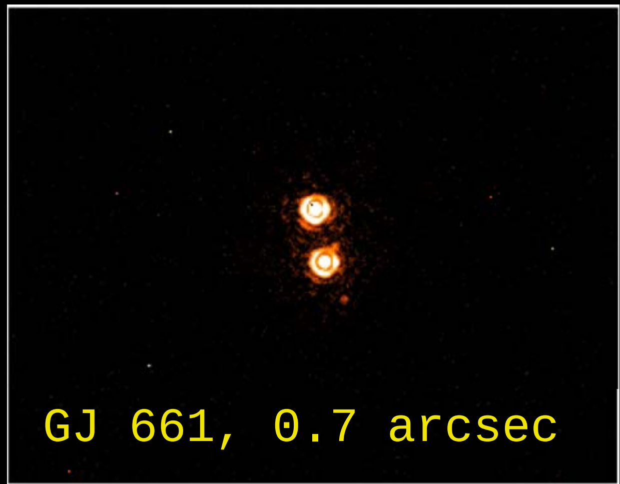


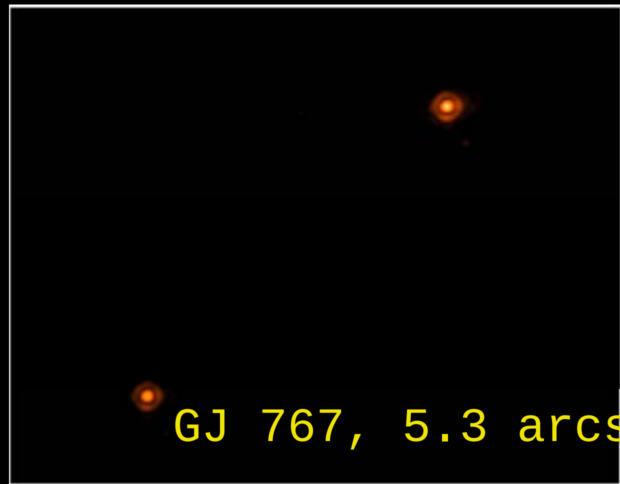
Precise astrometry with adaptive opti

Palomar 200 inch
Data time span: ~2 yrs









Collaborators: K. Helminiak, S. Kulkarni
Look for a preprint on astro-ph this Fall