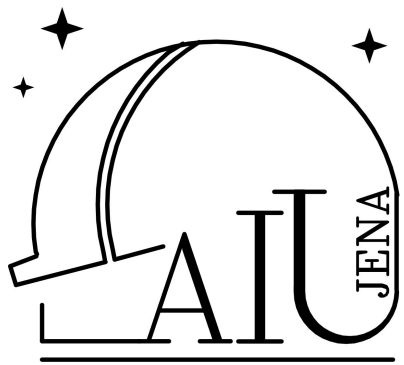
Astrometric search for extrasolar planets

Tristan Röll

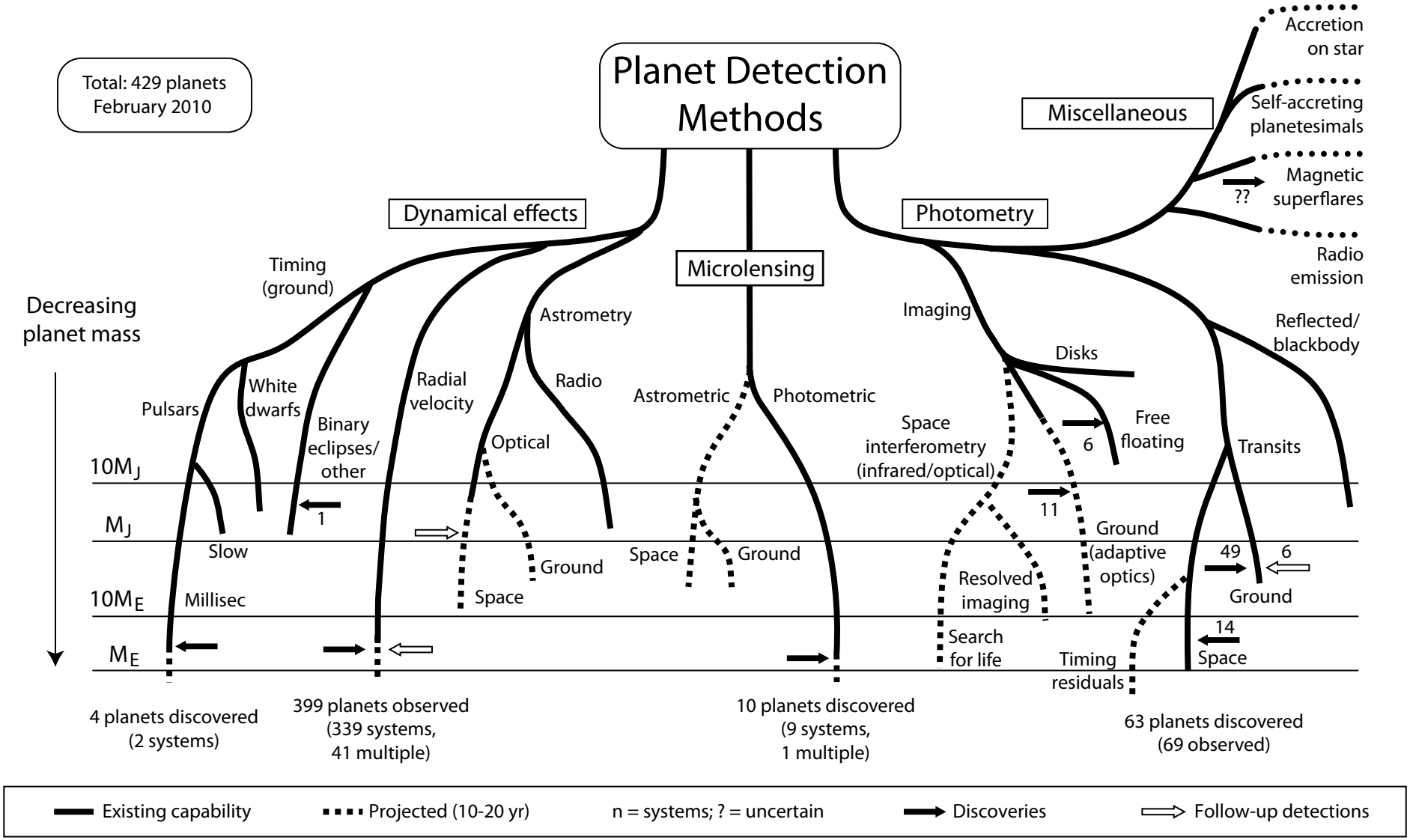
Ralph Neuhäuser, Andreas Seifahrt, Guillermo Torres,
Rainer Köhler, Jacob Bean

Astrophysikalisches Institut und Universitäts - Sternwarte Jena

Young Planetary Systems Workshop,
Jena 2010

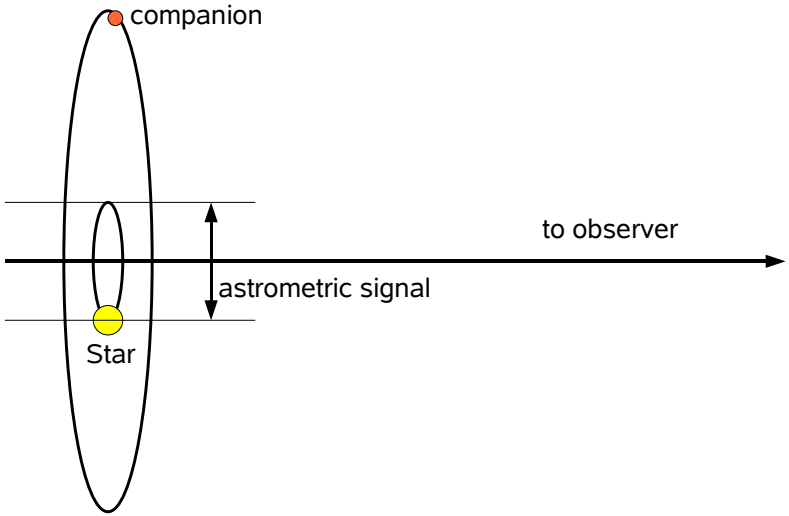


Exoplanet Detection - Methods



(diagram by M. Perryman)

Astrometric Signal



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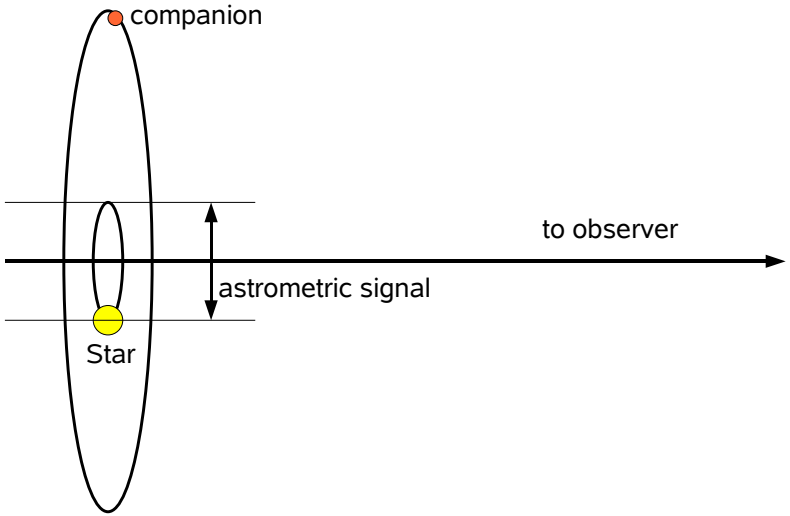

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Astrometric Signal (circular orbit)

$$\Theta\,[\mathrm{mas}] = 2 \times a_{\mathrm{wobble}}\,[\mathrm{mas}] = 1.91 \times \frac{a_{\mathrm{comp}}}{[\mathrm{AU}]}\,\frac{[\mathrm{pc}]}{\mathrm{d}}\,\frac{M_{\mathrm{comp}}}{[M_{\mathrm{J}}]}\,\frac{[M_{\odot}]}{M_{\mathrm{star}}}$$

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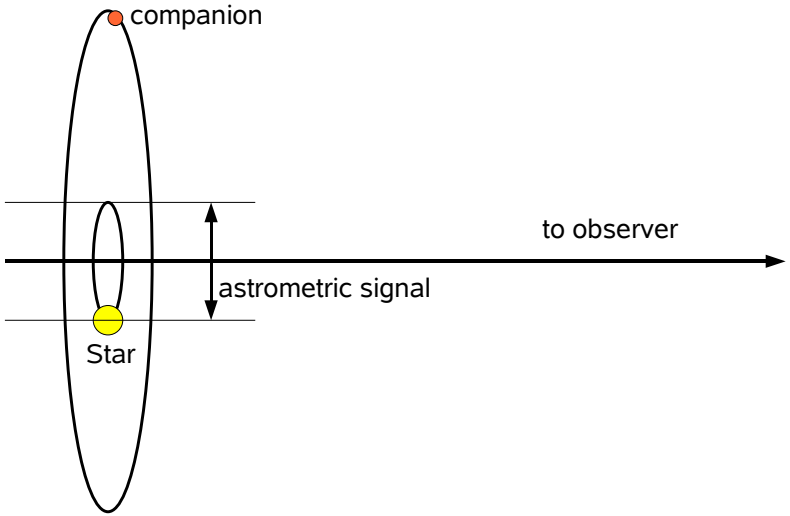

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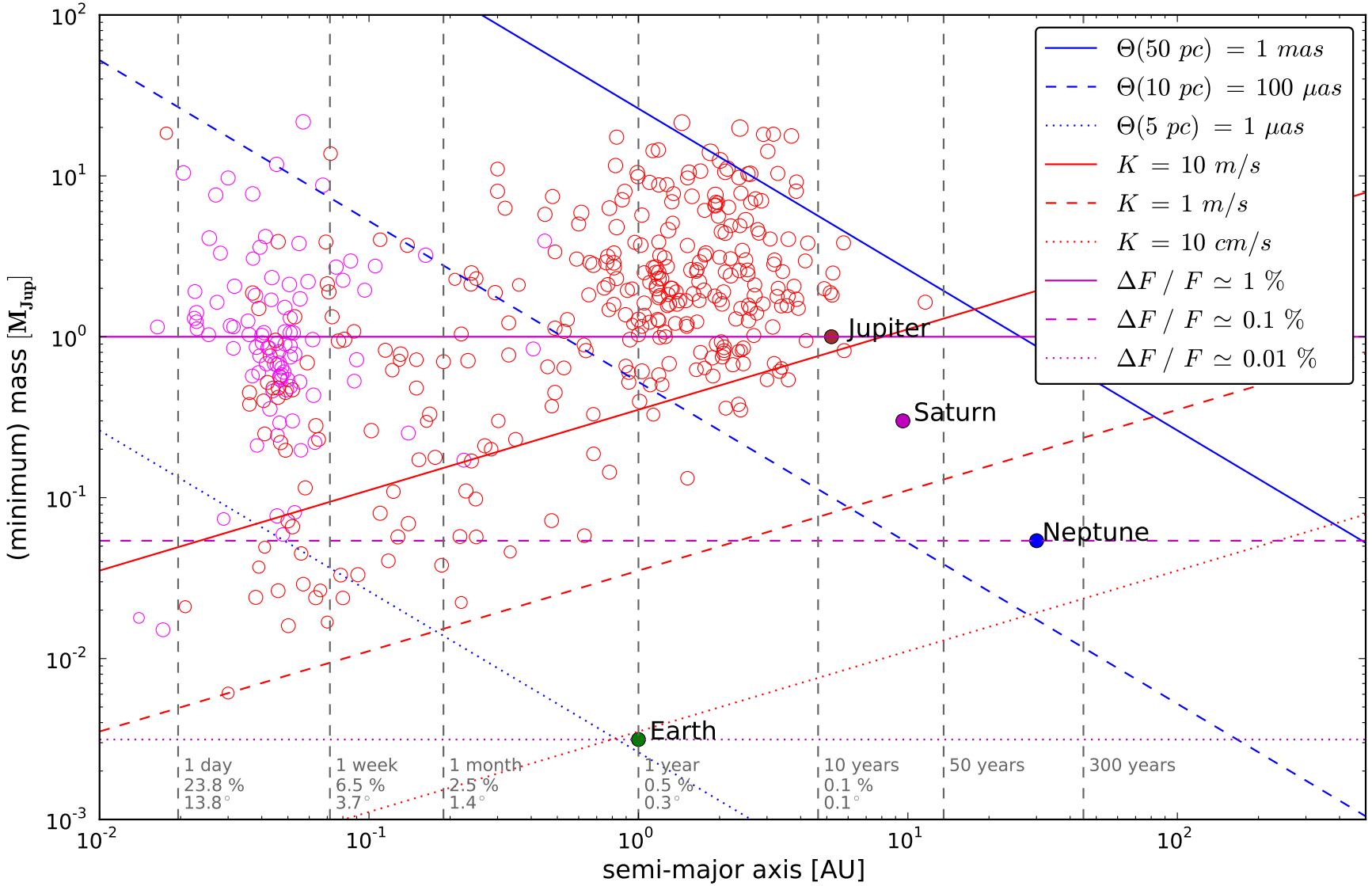
Example

Jupiter with Sun seen from 5 pc / 100 pc : $\Theta = 2\,\mathrm{mas}\ / 0.1\,\mathrm{mas}$

Earth with Sun seen from 5 pc: $\Theta = 1.2\,\mu\mathrm{as}$

Exoplanet Detection - Sensitivity



(data from exoplanet.eu)

First Detection of an Astrometric Companion

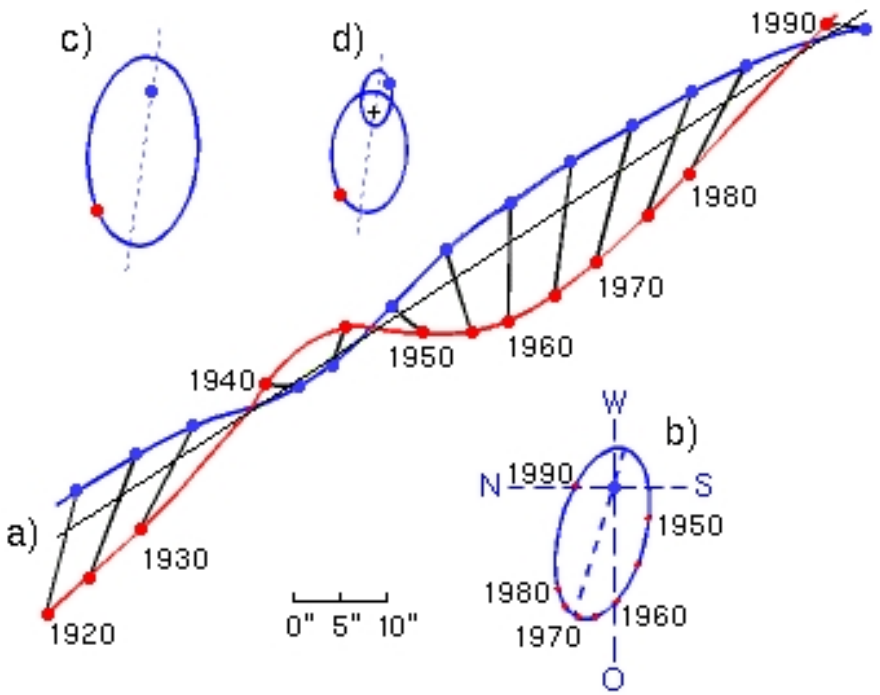
Friedrich Wilhelm Bessel (1784-1846)

1844

periodic perturbation in the proper motions of Sirius and Procyon

Conclusion

existence of unseen companion orbiting the star



Sirius A, Sirius B

Peter van de Kamp

ASTRONOMICAL JOURNAL VOLUME 74, NUMBER 2 MARCH 1969

Parallax, Proper Motion, Acceleration, and Orbital Motion of Barnard's Star

PETER VAN DE KAMP
Sproul Observatory, Swarthmore College, Swarthmore, Pennsylvania
(Received 31 December 1968)

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- Sproul refractor (diameter: 61 cm, focal length: 10.9 m)
- never confirmed by other groups (Gatewood et al., 1973)
- detection of systematic errors (Hershey, 1973)

Spaced based Astrometry

Hubble Space Telescope (launch: 1990)

Currently the only telescope, which already delivers successful applications of astrometry regarding exoplanets.

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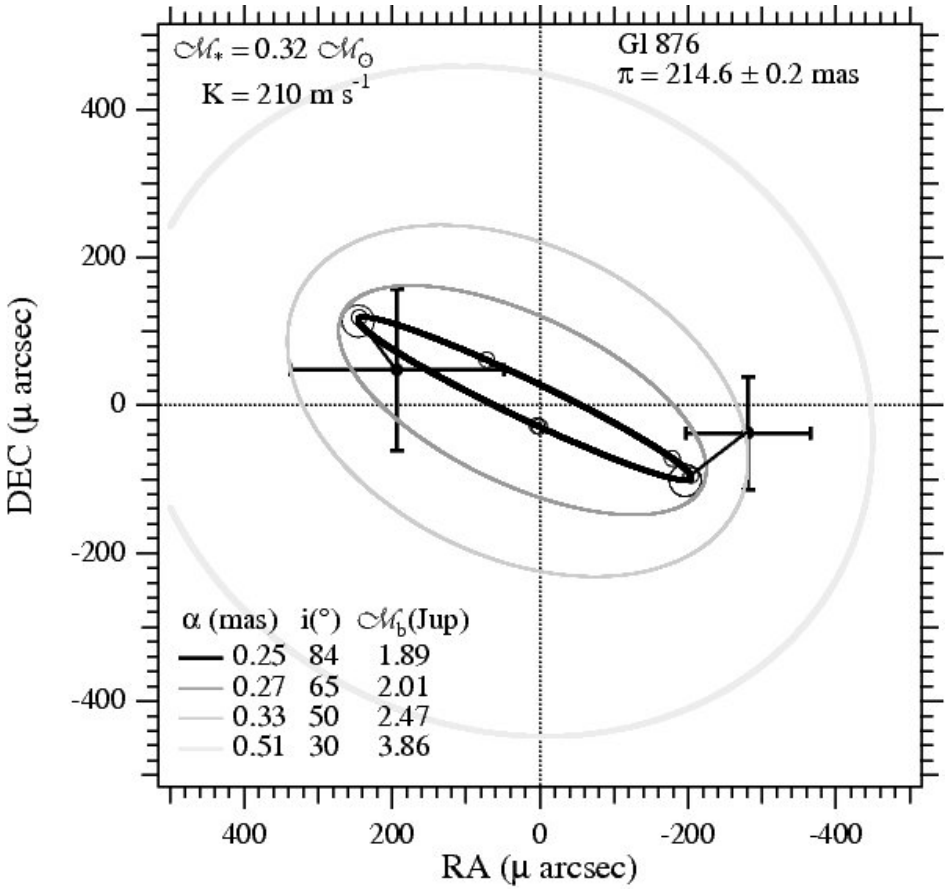

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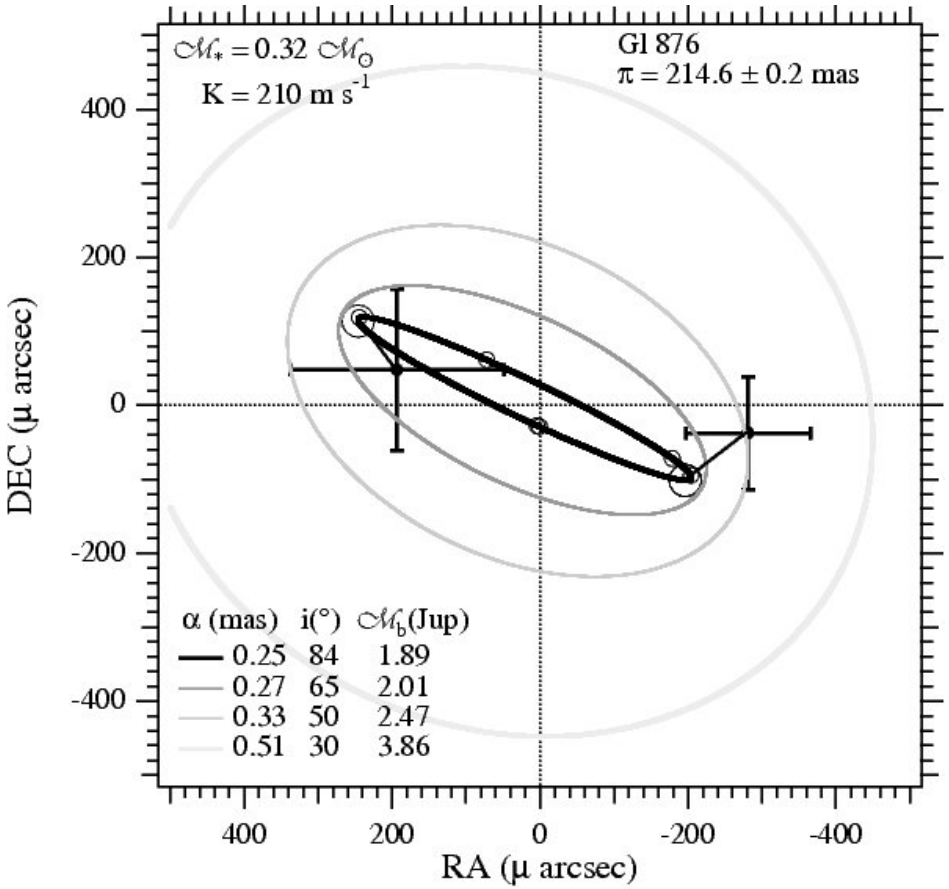

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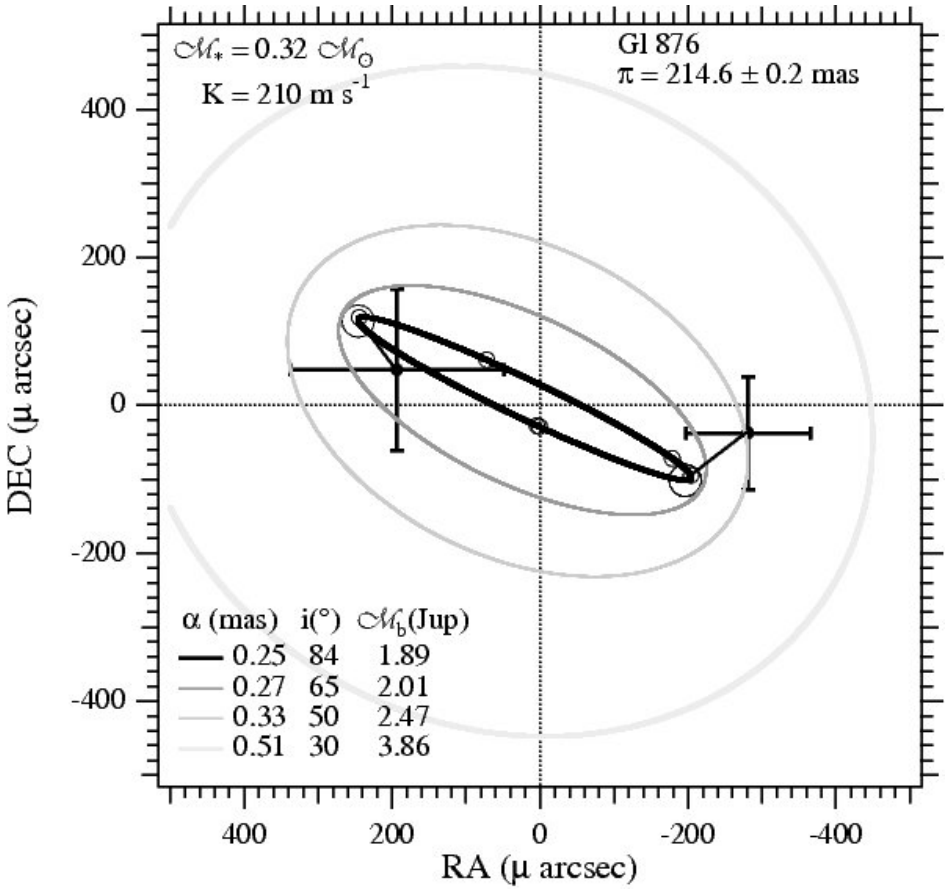

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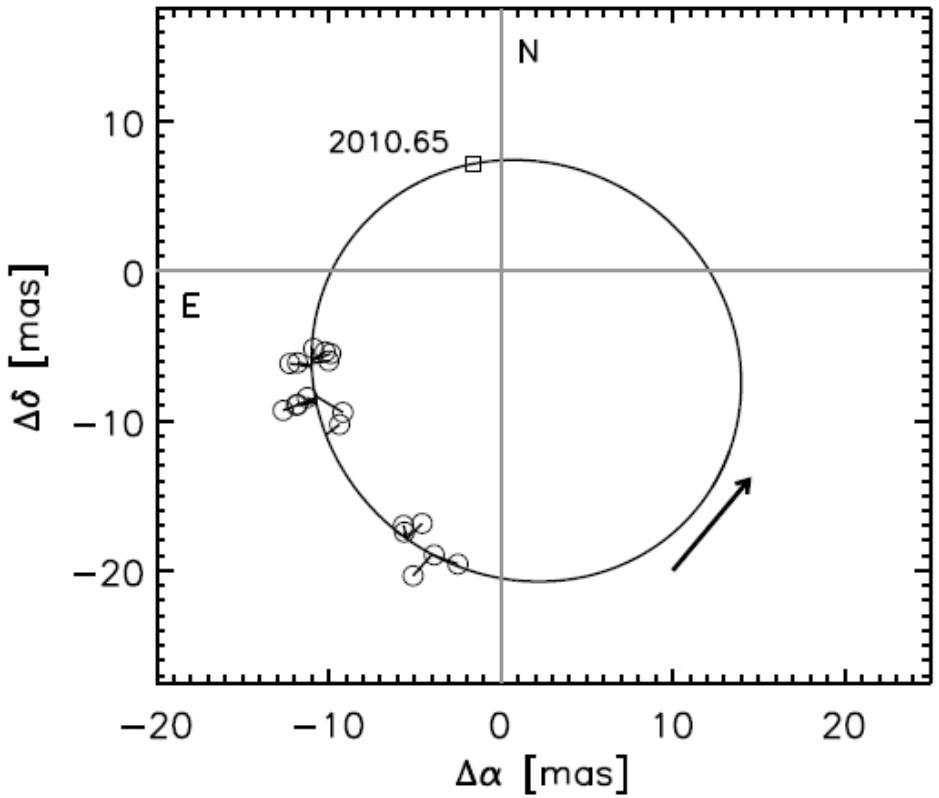
Spaced based Astrometry



HD 33636 b

RV planet candidate with

$$M \sin i = 9.3\, M_J$$

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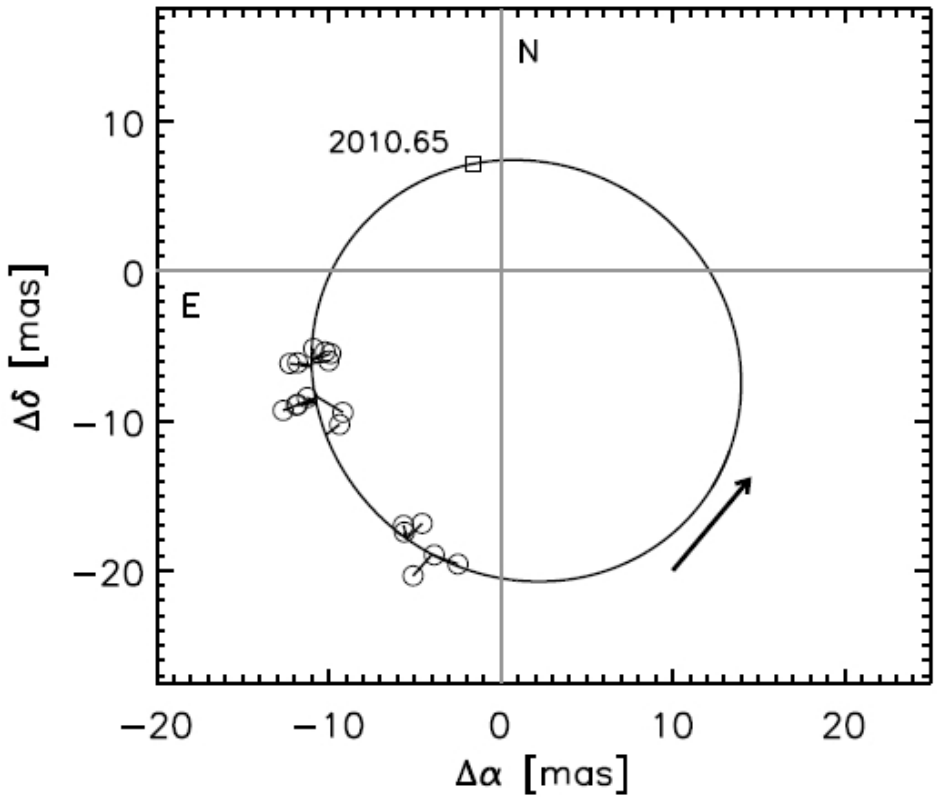

HD 33636 b

RV planet candidate with $\mathrm{M} \sin \mathrm{i} = 9.3\,\mathrm{M_J}$

Bean et al. 2007

determined with astrometry a true mass of $M_{true} = 142 \pm 11\,M_J$

Astrometric Exoplanet Search at the AIU Jena

Targets

nearby stellar multiple systems (distance < 100 pc)

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Calibration

old globular cluster (47Tuc and M15)

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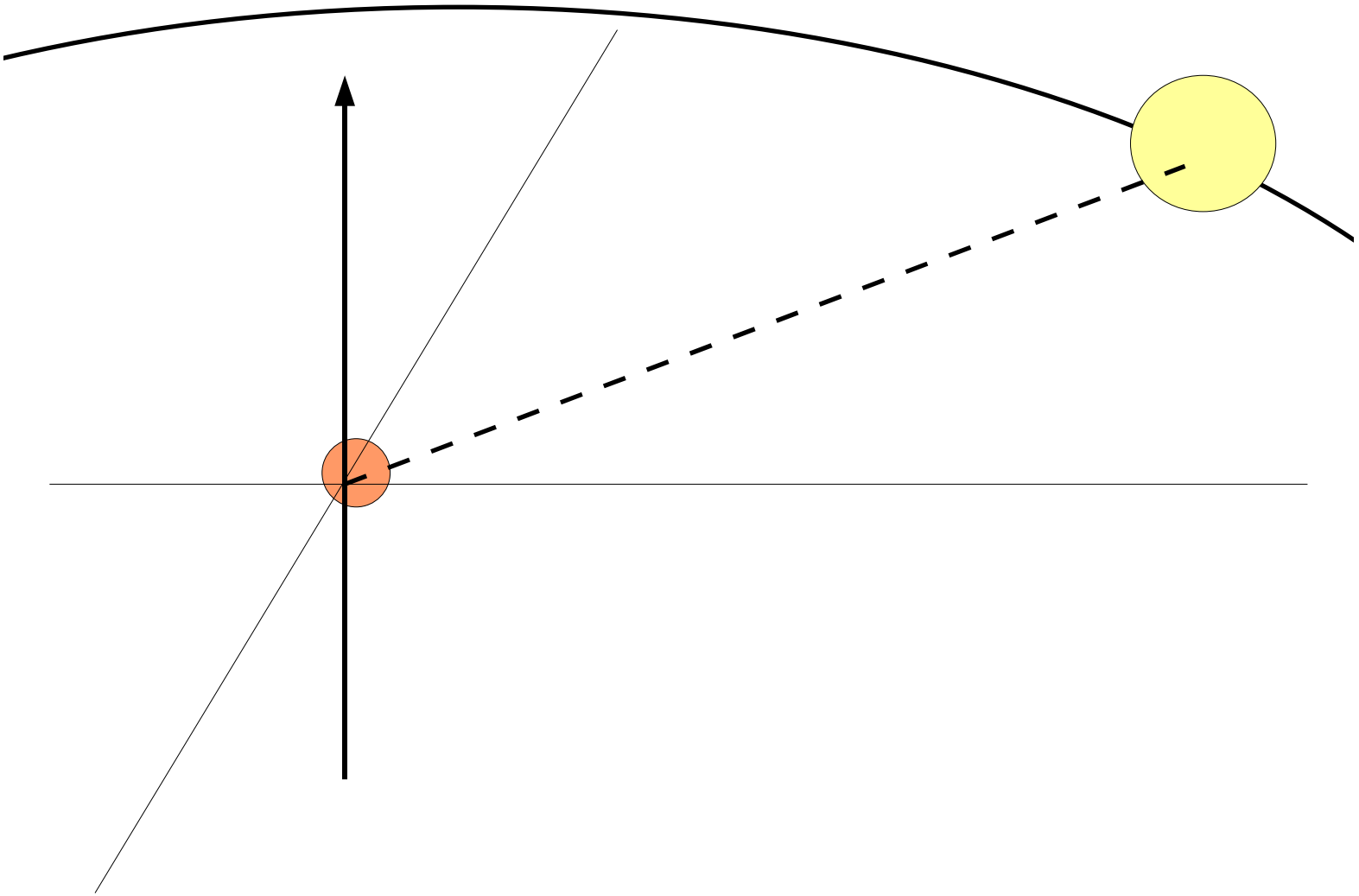

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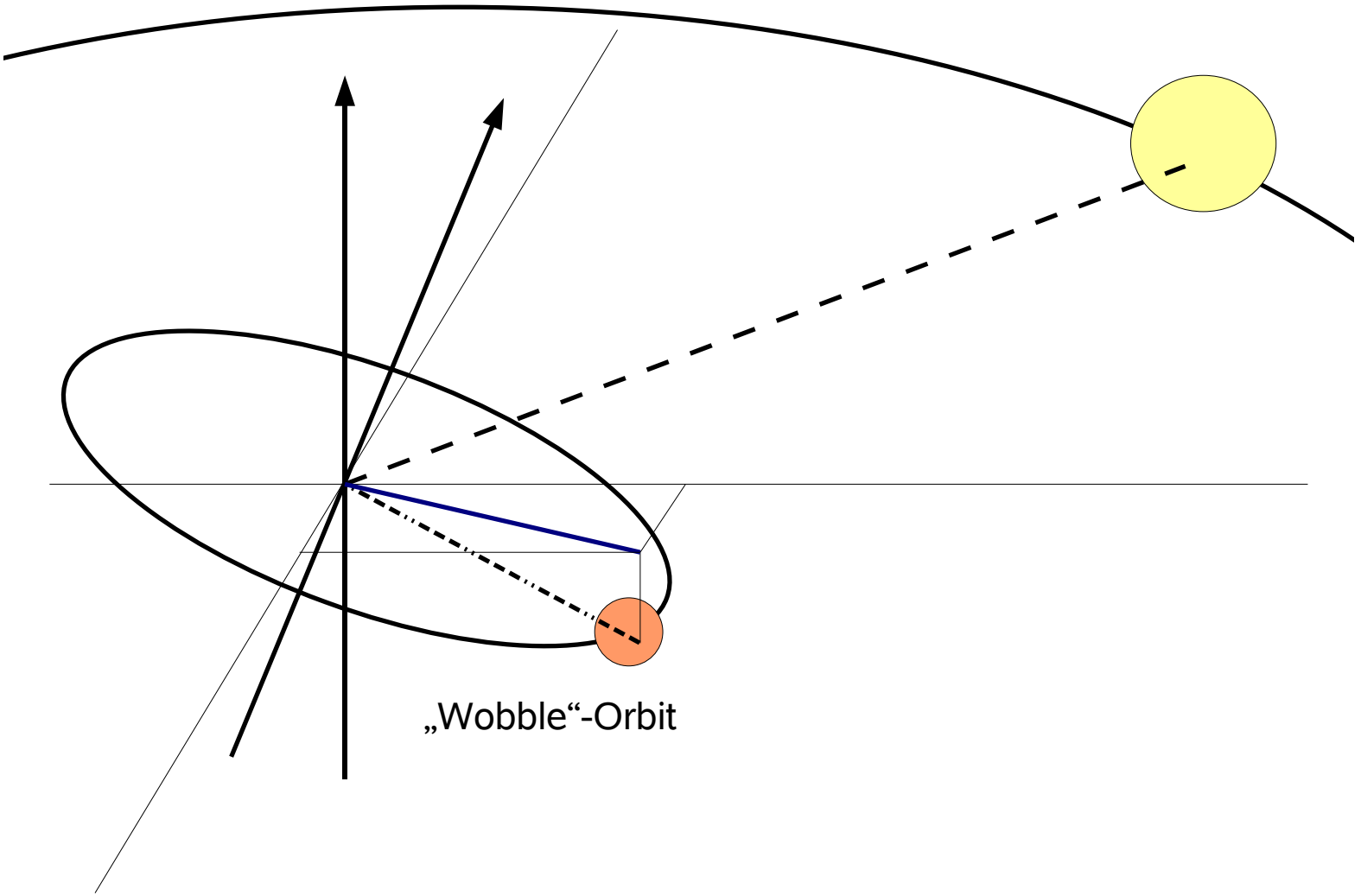

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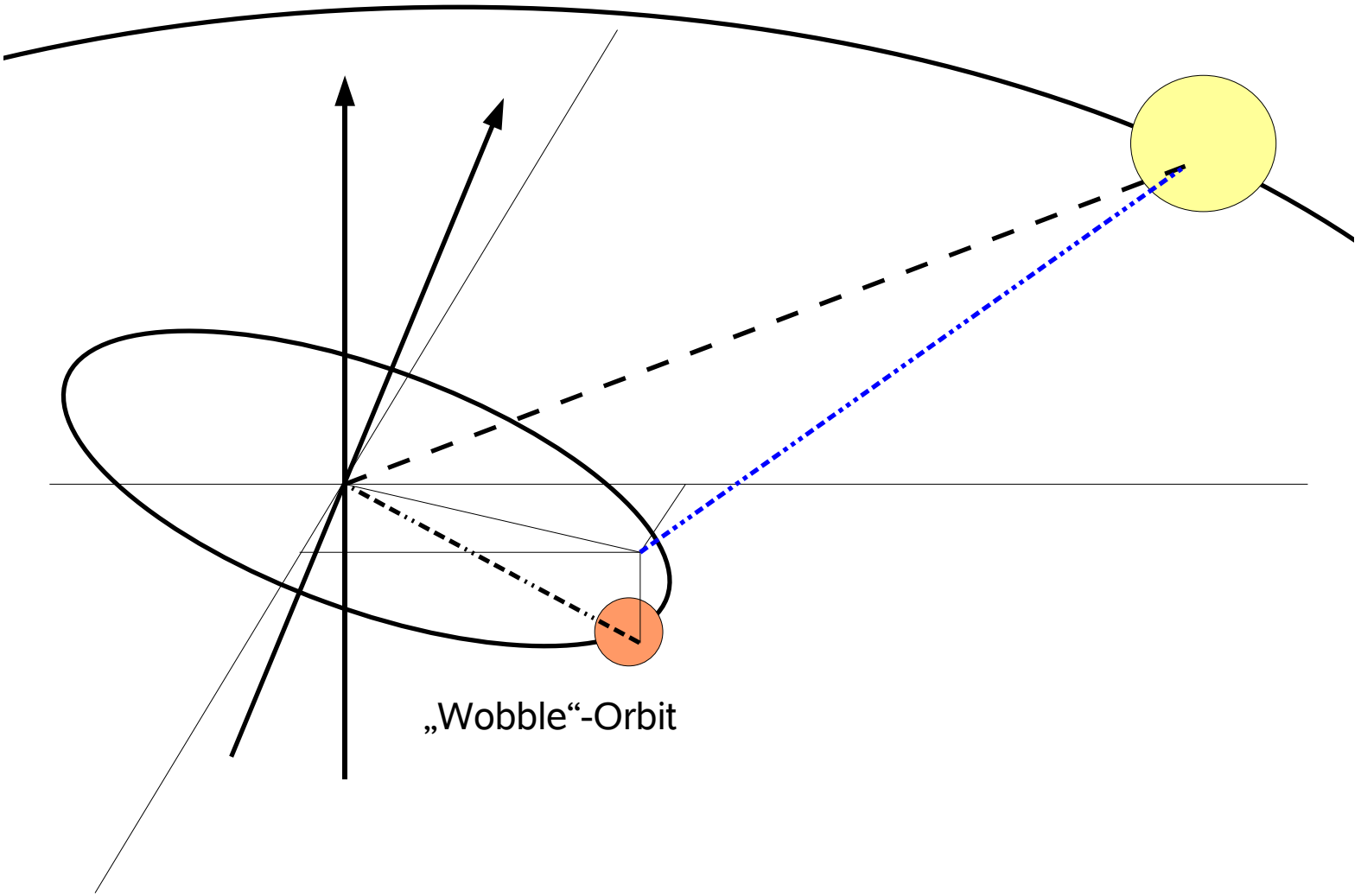

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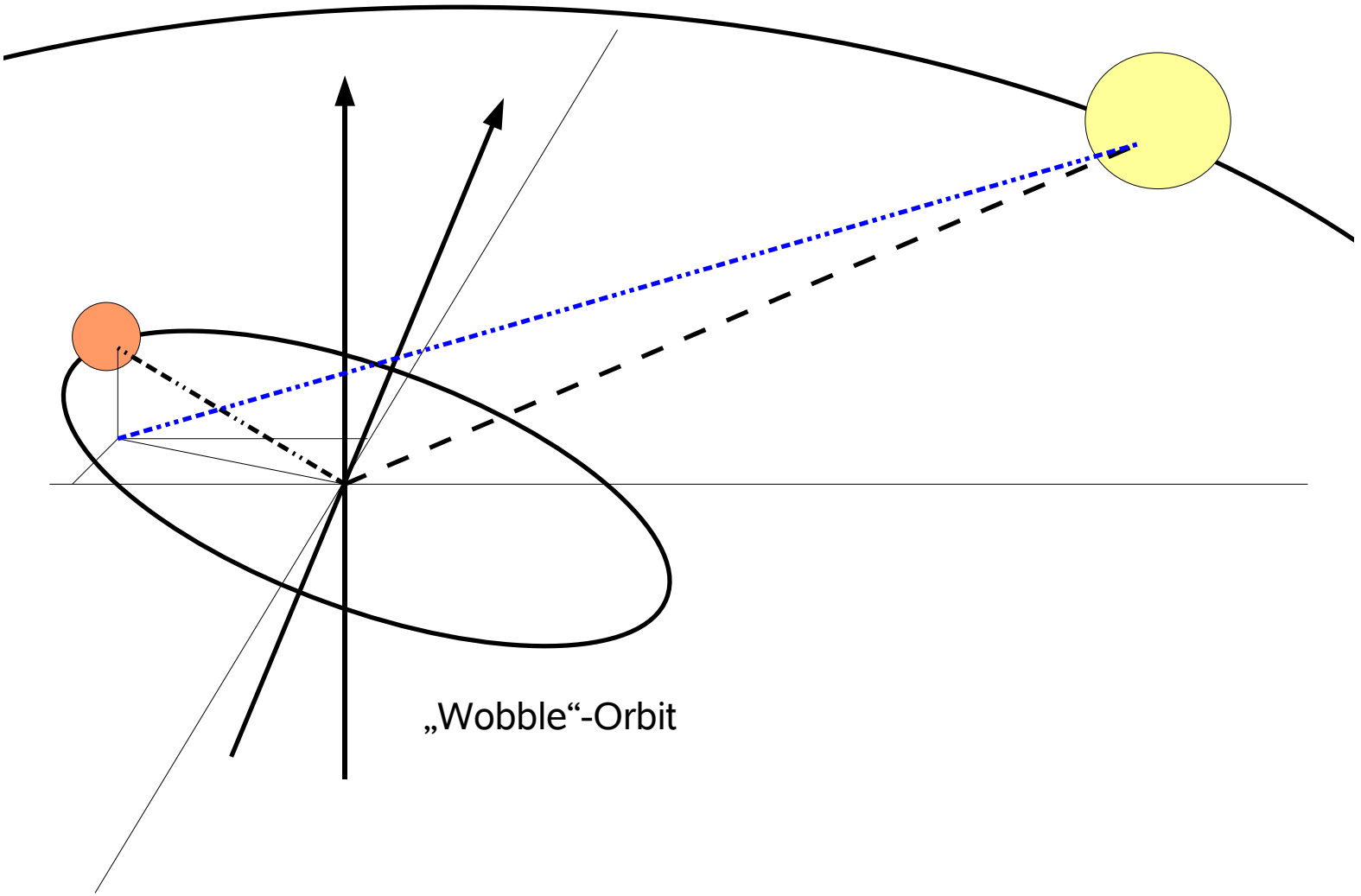
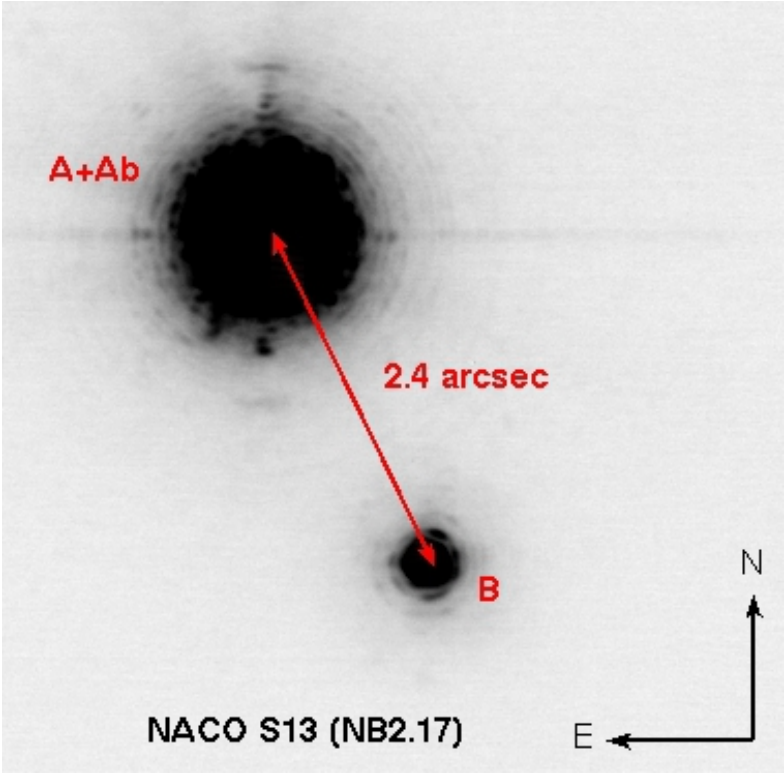


First Target System: HD 19994 A&B



RV planet candidate HD 19994 Ab
Mayor et al. (2004)

$$P_{pl} \simeq 535\,\text{days}$$

$$a_{pl} \simeq 1.4\,\text{AU}$$

$$m \sin i \simeq 1.7\,M_{Jup}$$

$P_{binary} \geq 1400$ years

distance $\simeq 22.6$ pc

$M_A \simeq 1.34\,M_\odot, \quad M_B \simeq 0.4\,M_\odot$

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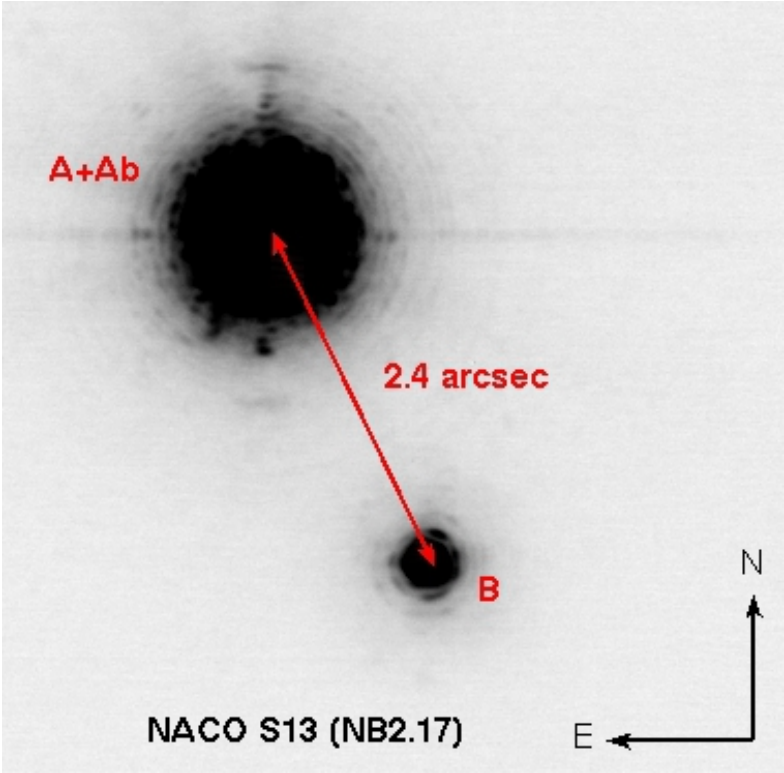

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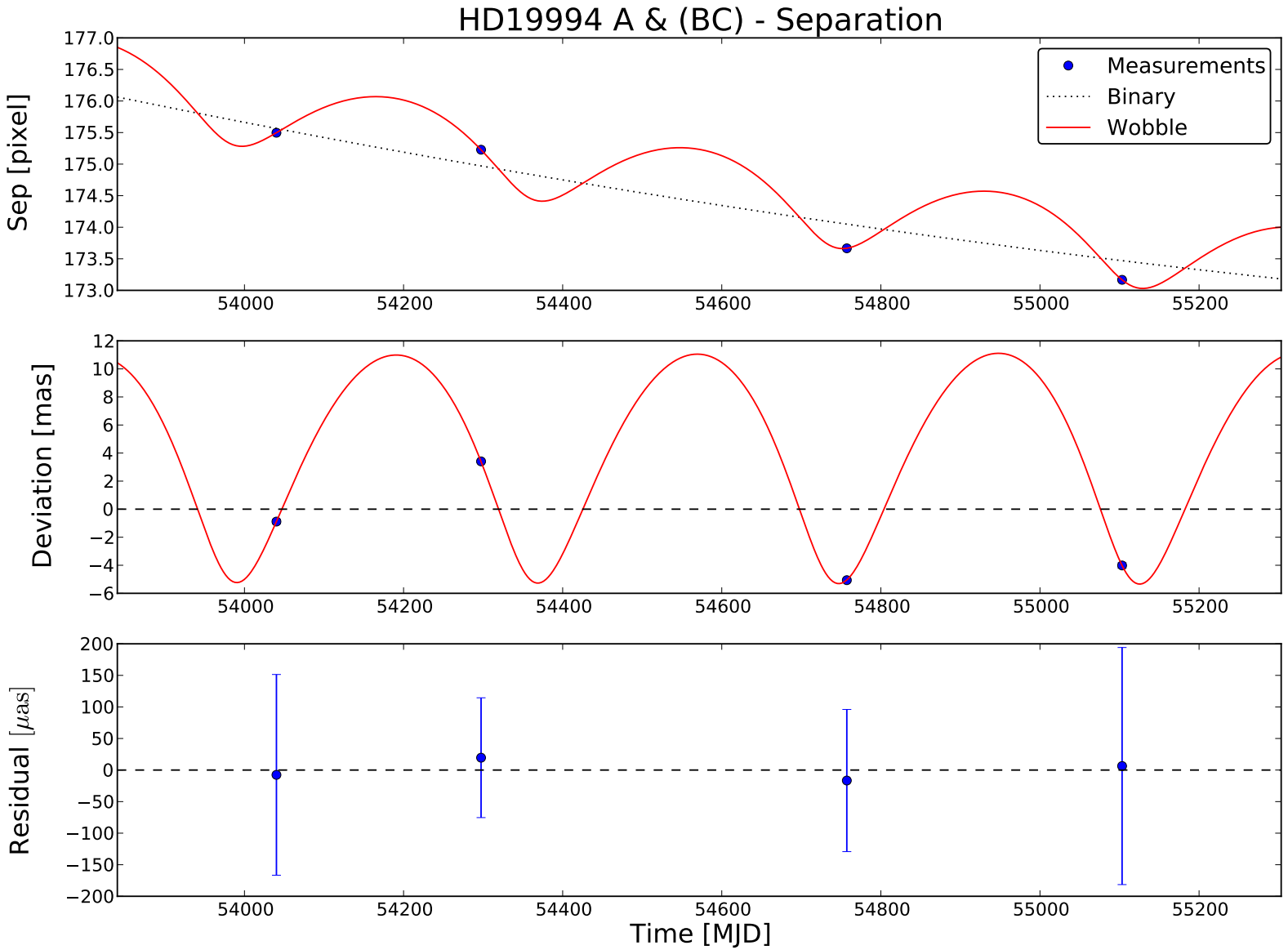
Expected Astrometric Signal:

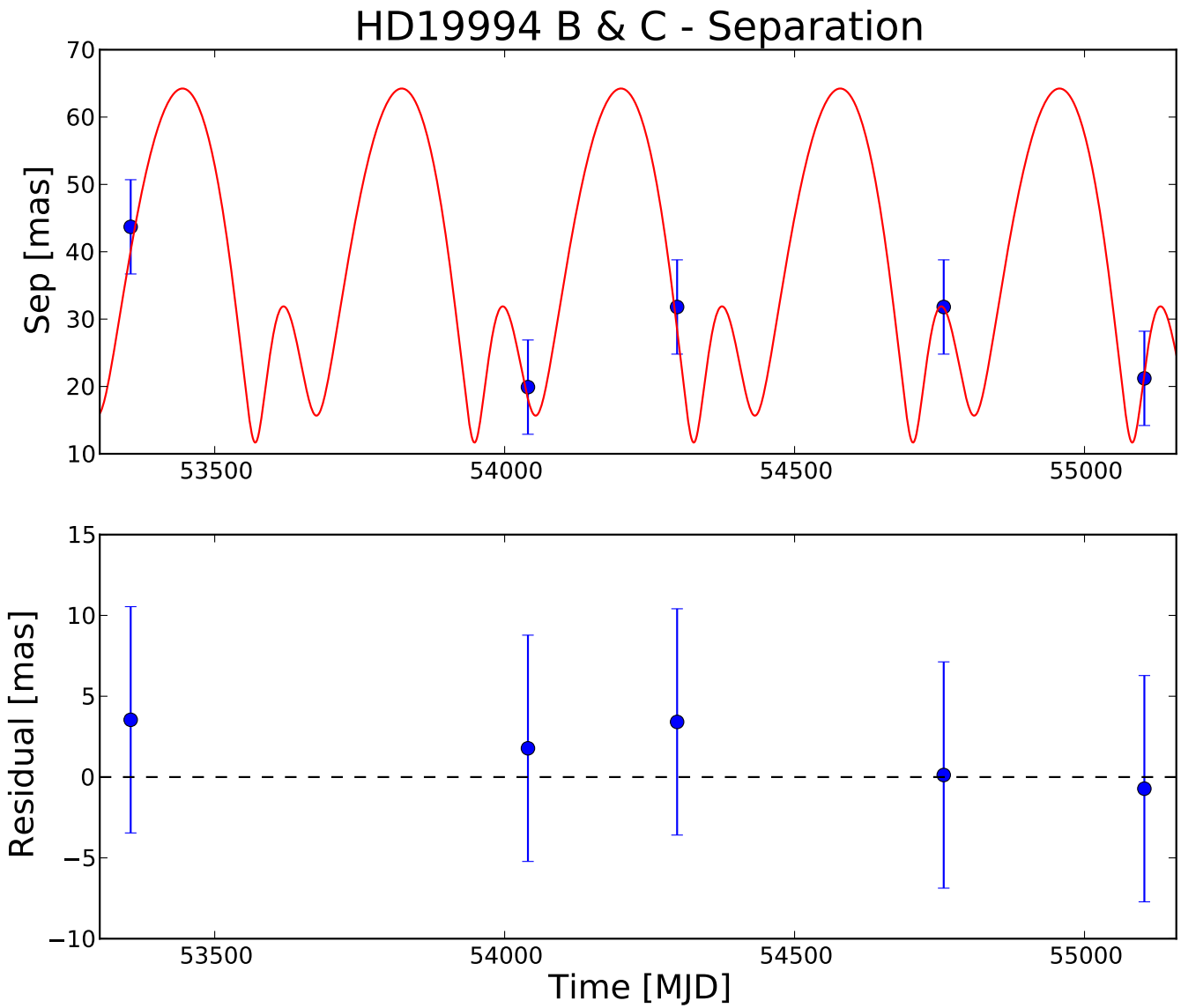
$$\Theta(i = 90^\circ) \simeq 150\,\mu\text{as}$$

$$\Theta(13\,M_{Jup}) \simeq 1.2 \text{ mas}$$

HD 19994 A&B - Astrometric measurements

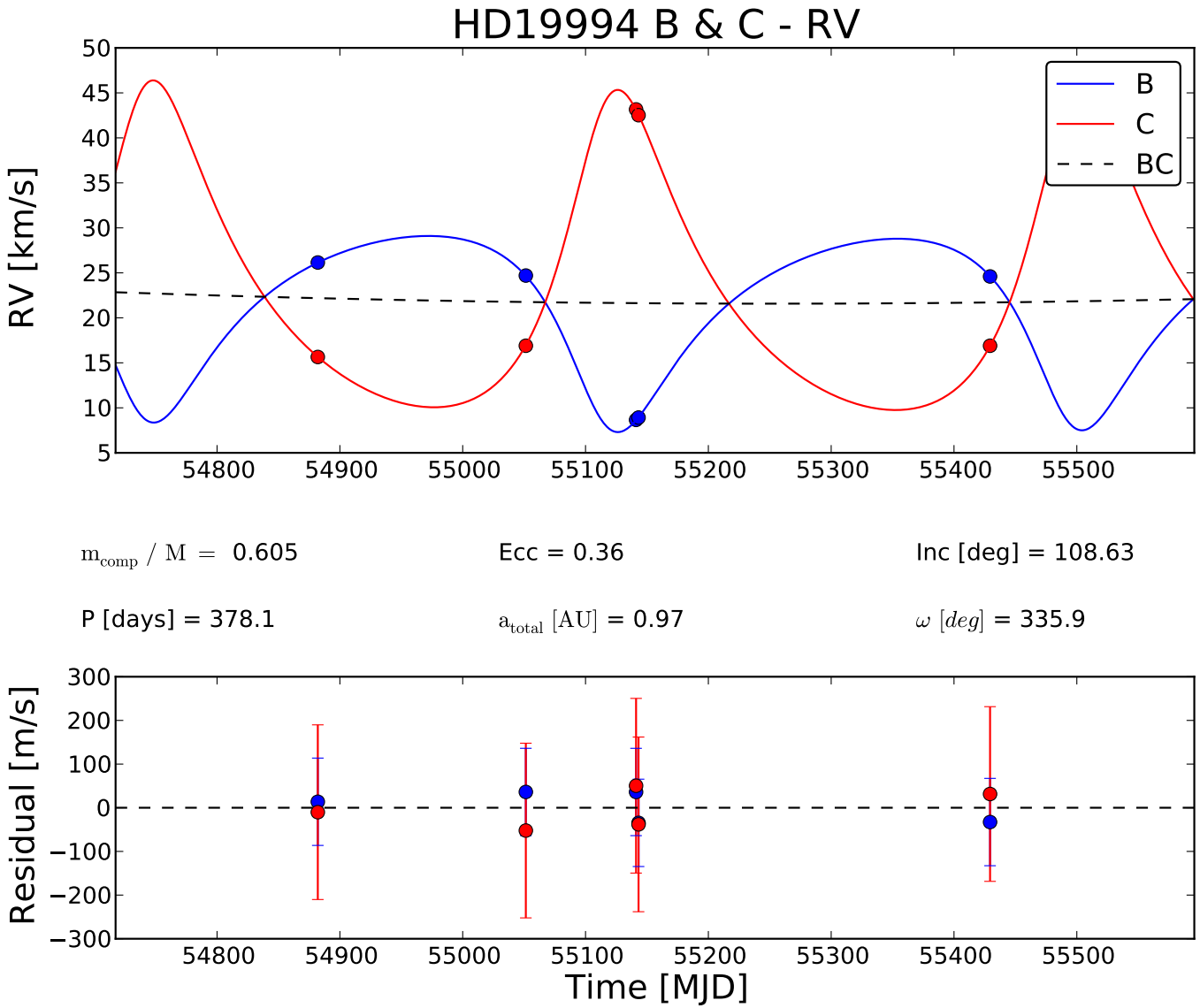


HD 19994 B&C - Speckle Interferometry



(speckle interferometry program written by Rainer Köhler)

HD 19994 B&C - Radial Velocity (CRIRES, VLT)



(radial velocity data by Andreas Seifahrt and Jacob Bean)

HD 19994 B - Wobble Orbit

$$
\begin{aligned}
\mathrm{P\,[days]} &= 378.07^{+0.64}_{-0.60} \\
\mathrm{m_C\,[M_\odot]} &= 0.326 \pm 0.012 \\
\mathrm{M_B\,[M_\odot]} &= 0.54 \pm 0.014 \\
\mathrm{Inc\,[deg]} &= 108.58^{+0.54}_{-0.51} \\
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\end{aligned}
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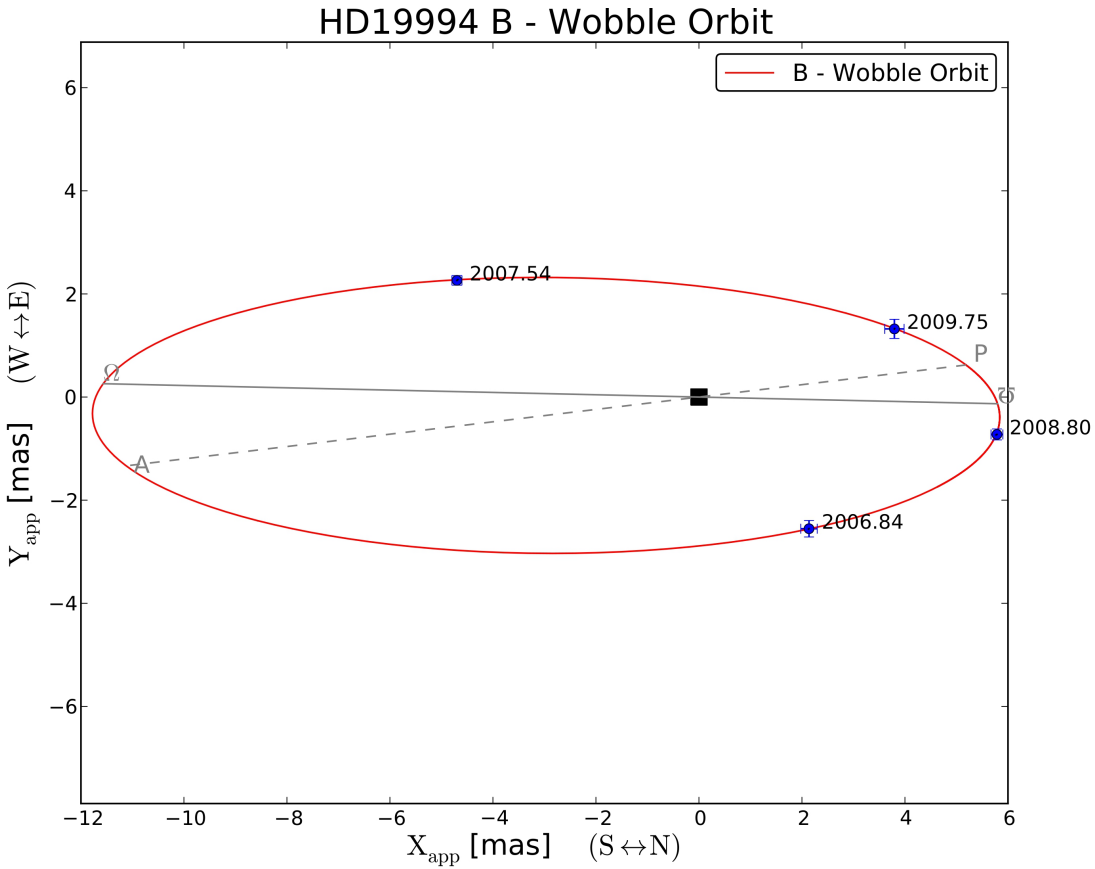

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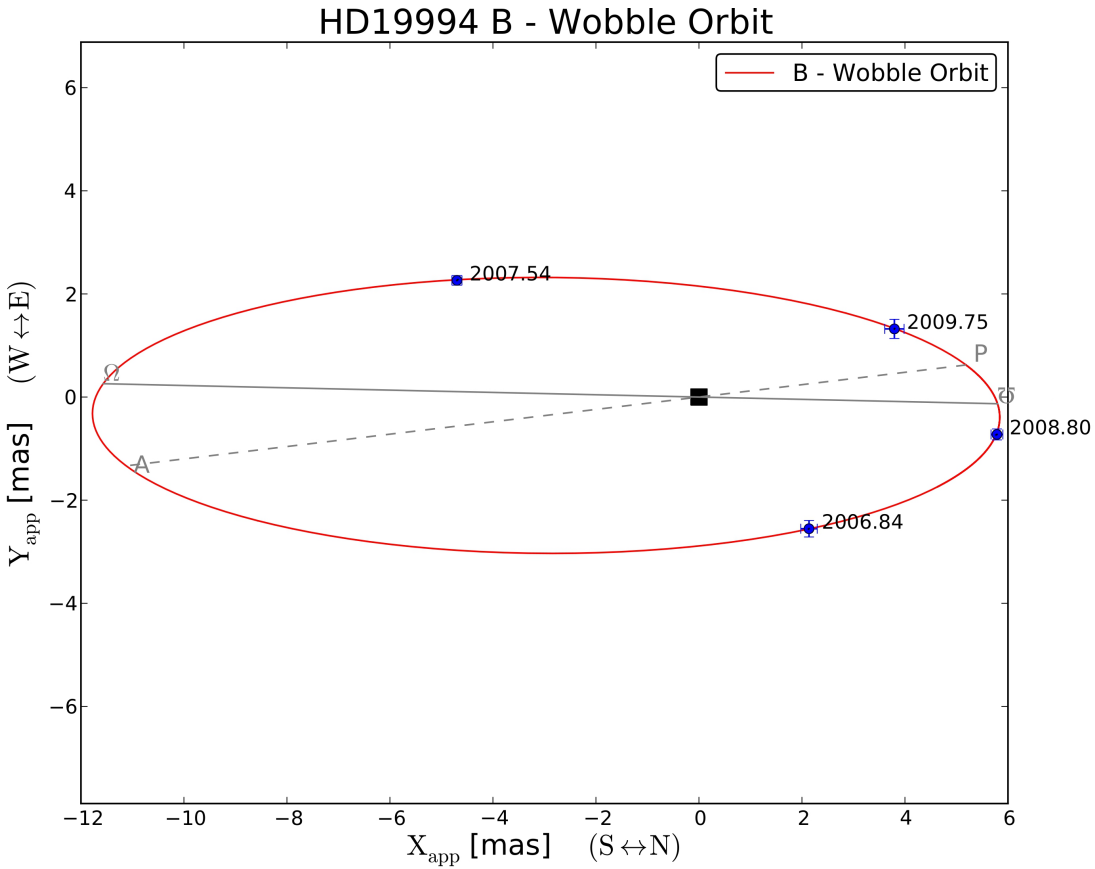
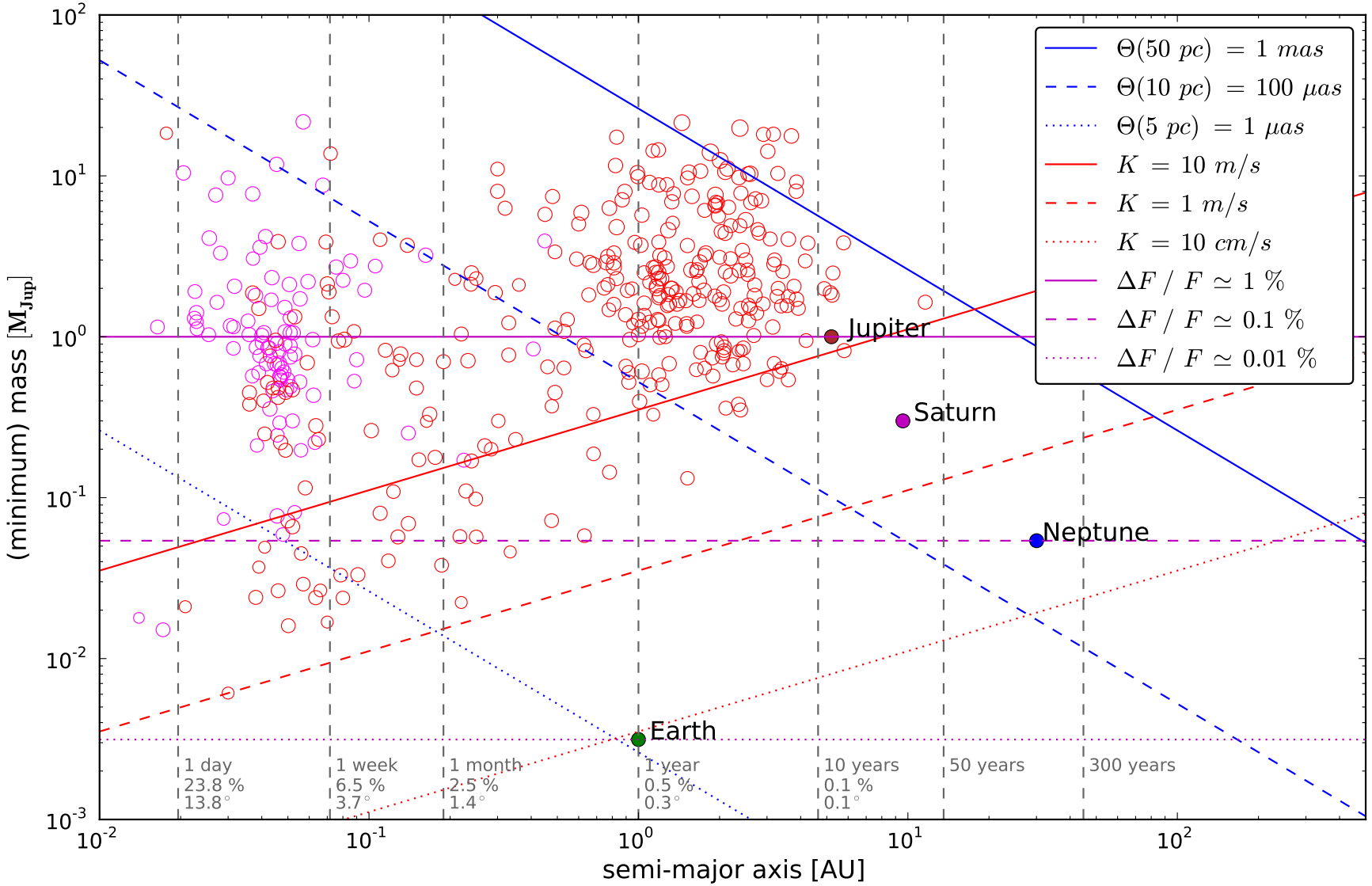


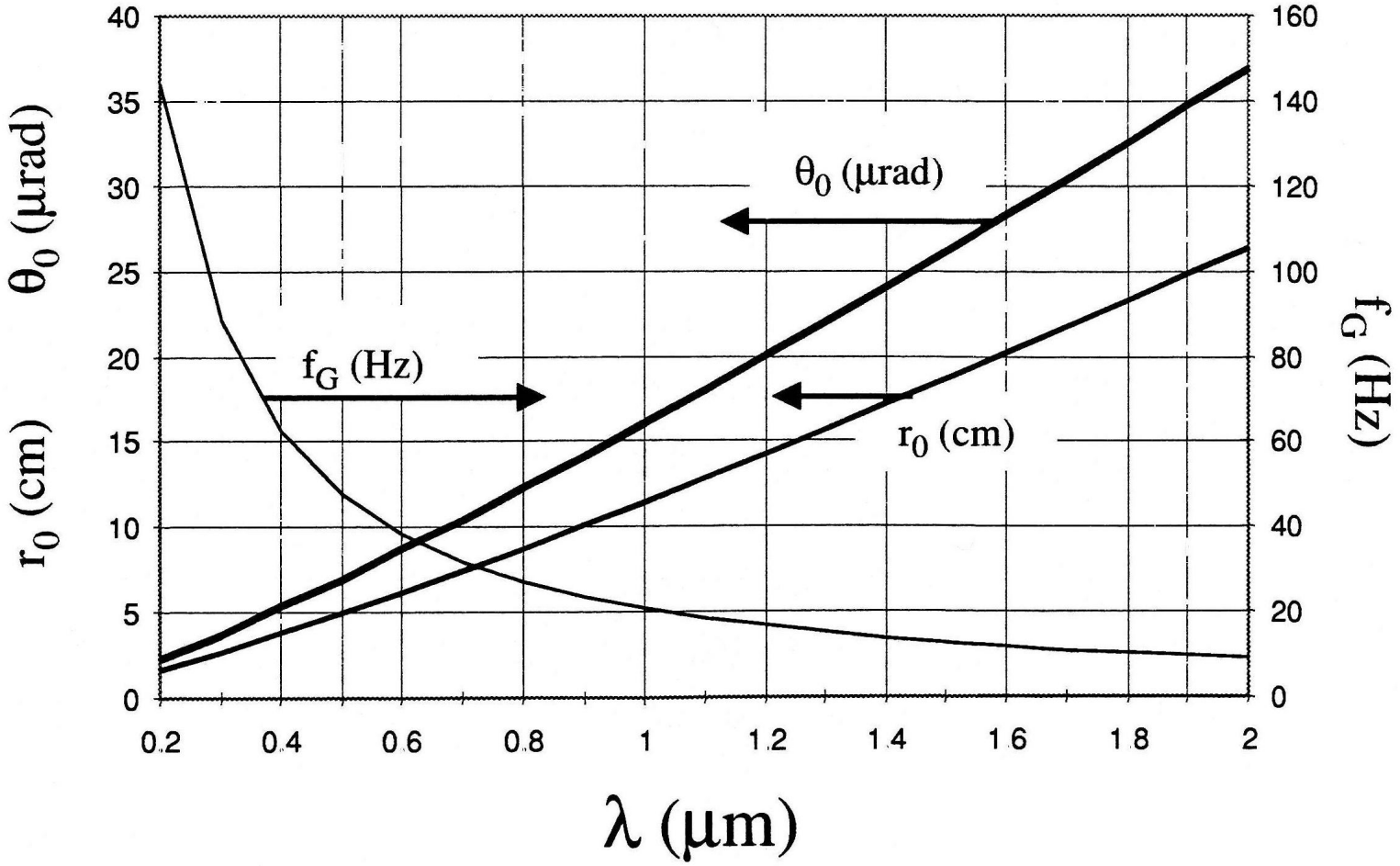
HD 19994 is a triple system, harboring one exoplanet

Exoplanet Detection - Sensitivity



(data from exoplanet.eu)

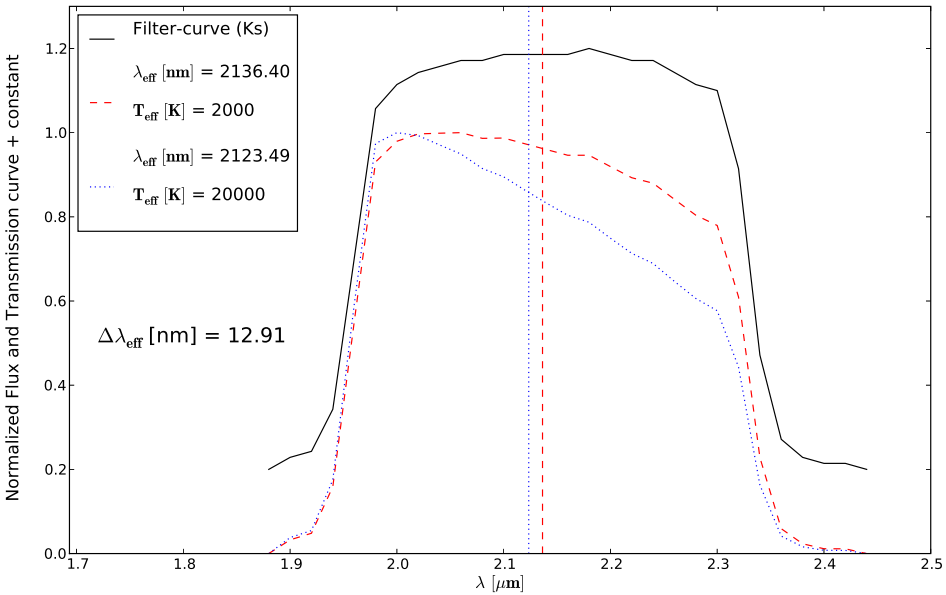
Earth's Atmospheric Turbulence's



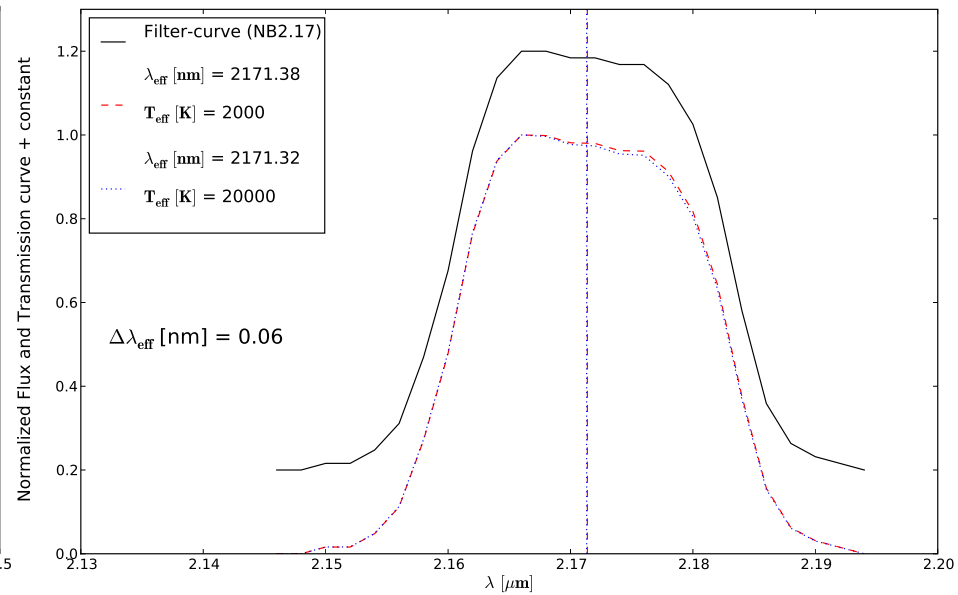
(by Tyson: "Introduction to Adaptive Optics")

Filter Transmission Curves

ESO Ks Filter

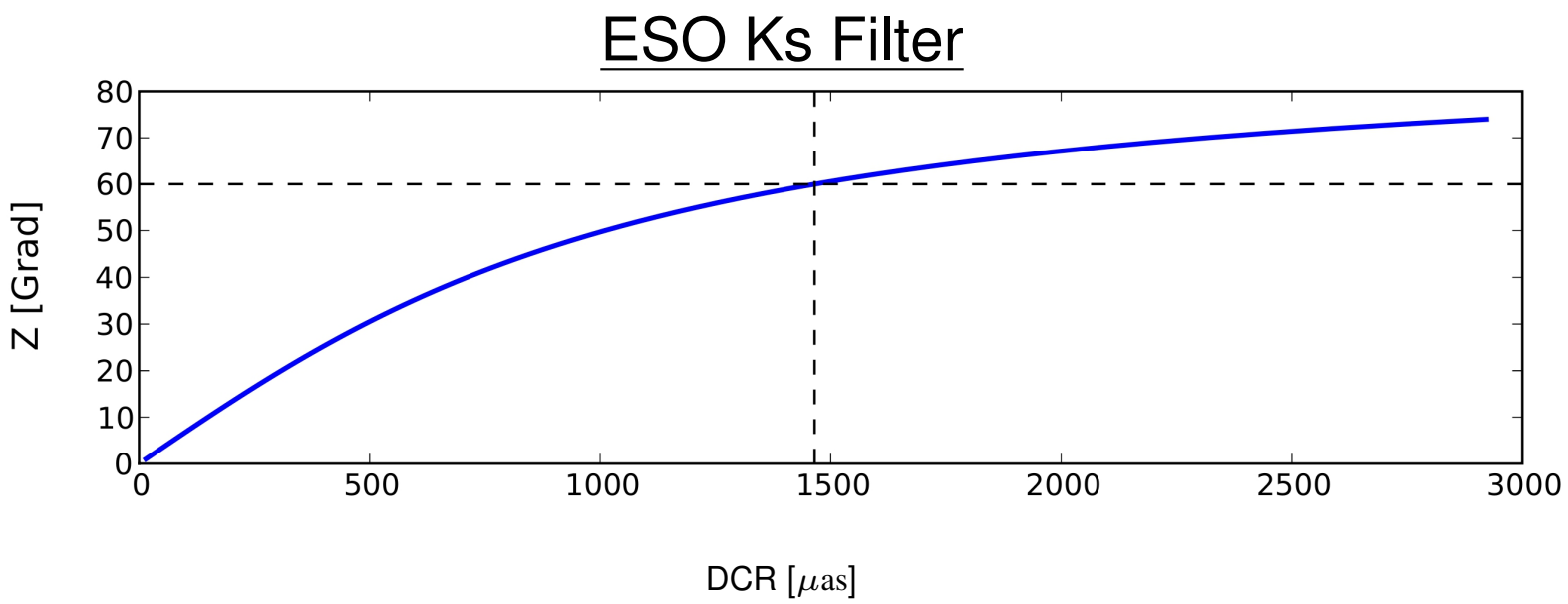


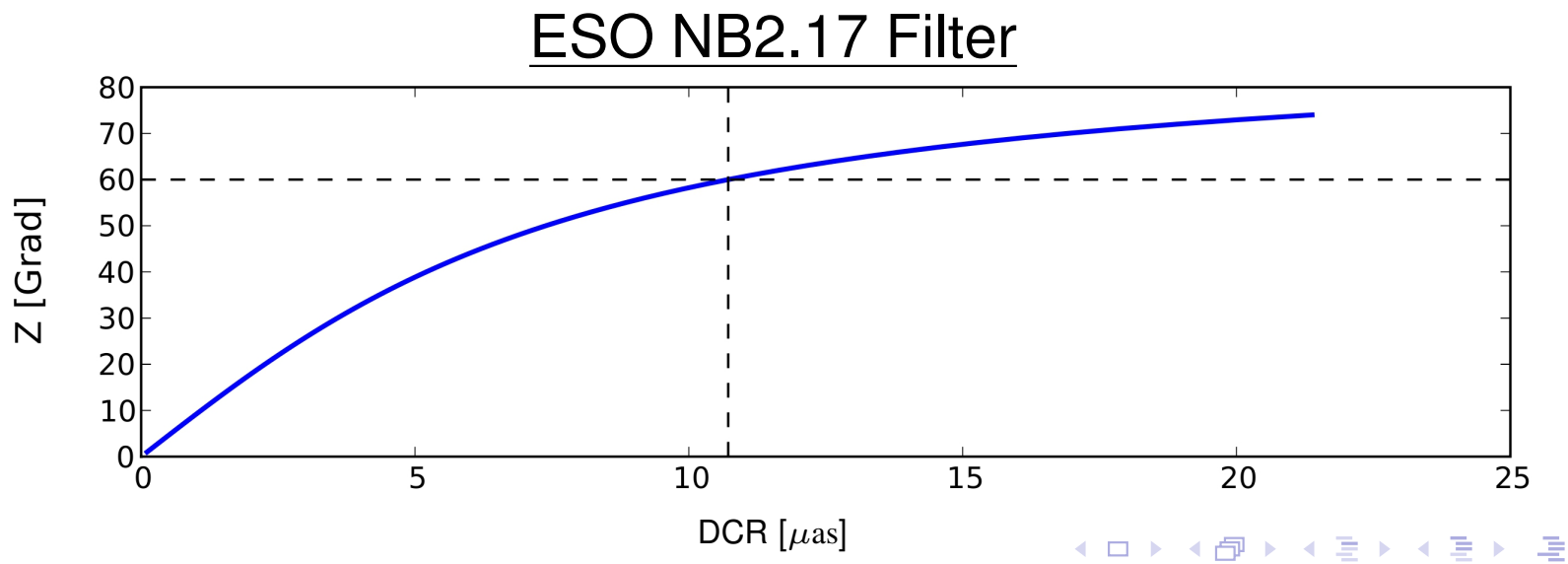
ESO NB2.17 Filter



Extreme case: Two blackbodies with $T_{\rm eff} = 2000\,{\rm K}$ and $T_{\rm eff} = 20000\,{\rm K}$

Differential Chromatic Refraction





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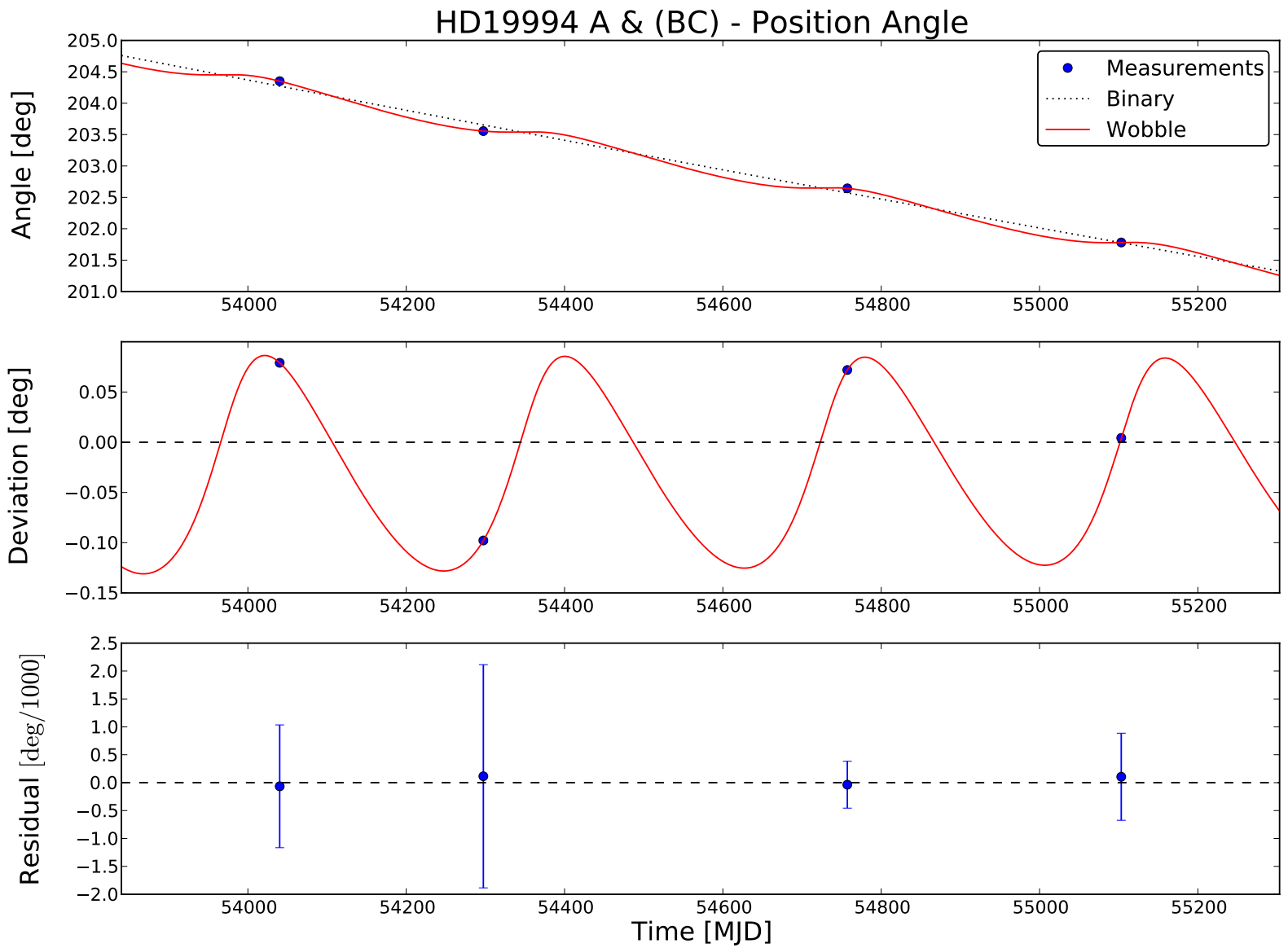

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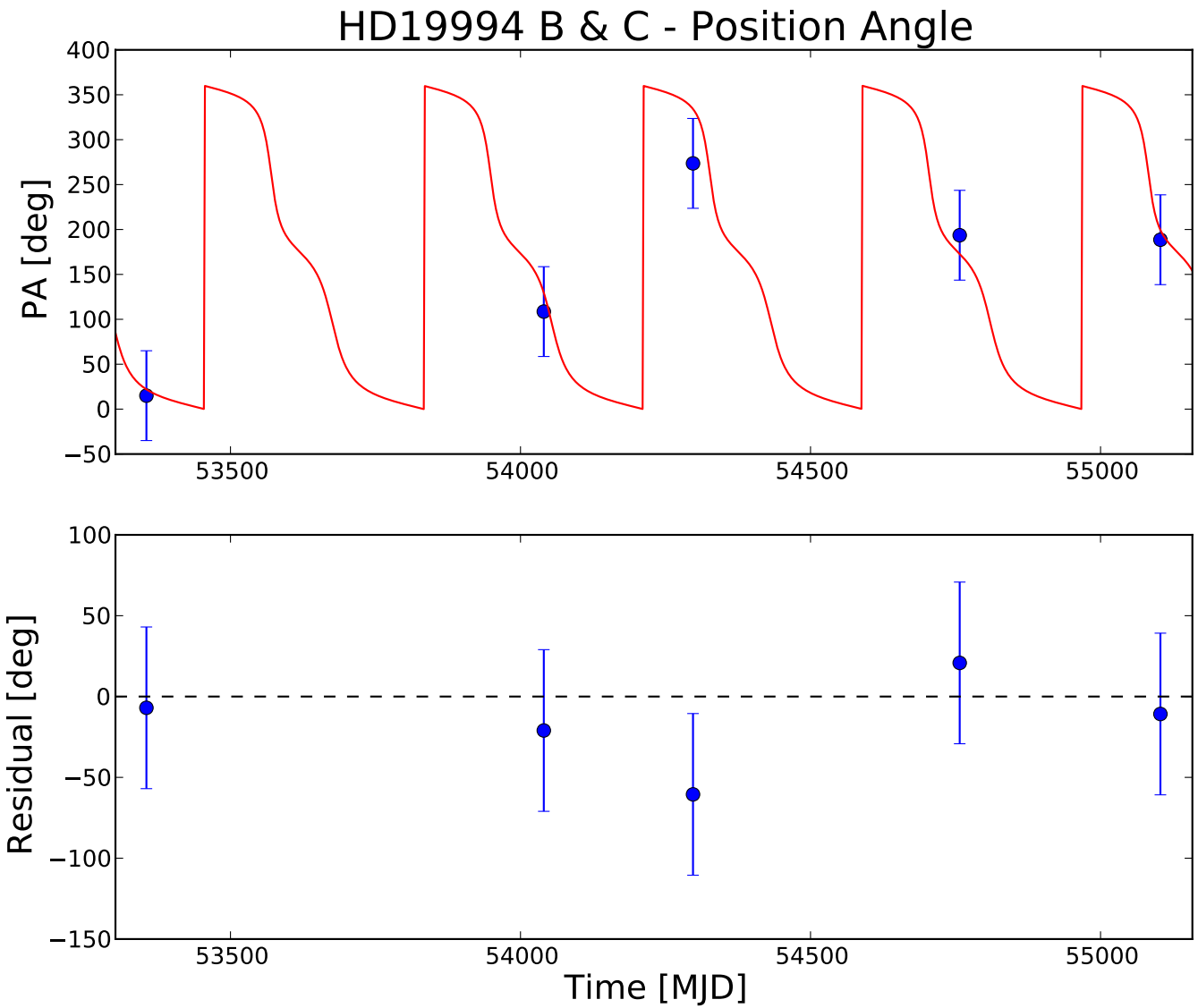

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