Refinement of Near Earth Asteroids' orbital elements via simulateous measurements by two observers

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Found & Lost

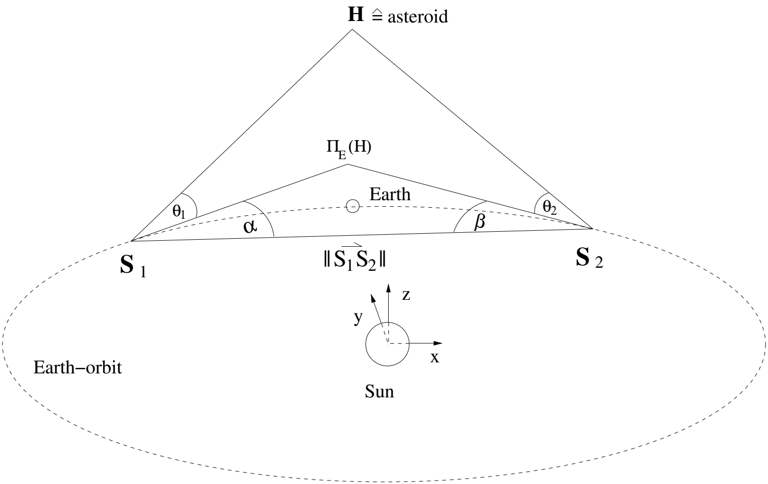
- Detection of PHAs with $H \approx 21$ on regular basis
- Main Problem: Very Short Arc (VSA) observations
  e.g. Milani & Gronchi (2009), Gronchi et. al. (2010)
- Potentially Hazardours Asteroids (PHAs) 2011:

% of total population	data arc
11 %	$< 10d$
24 %	$\leq 20d$
55 %	$< 40d$

(IAU Minor Planet Center, 26.09.2011)

Method

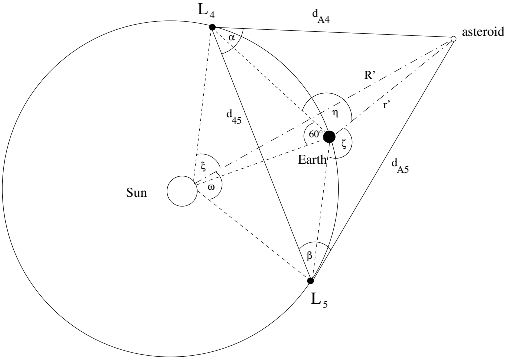
Gain NEO's orbital elements via triangulation by **two observers**



History

Gromaczkiewicz (2006):

- relies heavily on fixed, trigonometric relations
- 7 (!) trigonometric funcitons in denominators
- observers restricted to the ecliptic



History

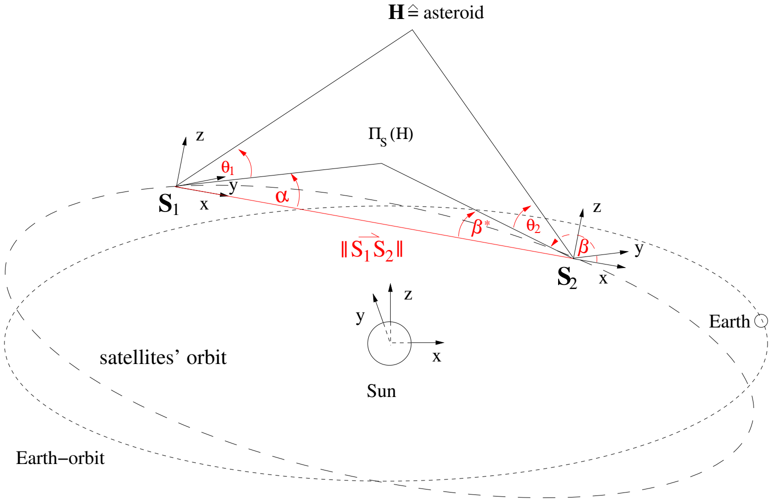
Gromaczkiewicz (2006):

- relies heavily on fixed, trigonometric relations
- 7 (!) trigonometric funcitons in denominators
- observers restricted to the ecliptic plain

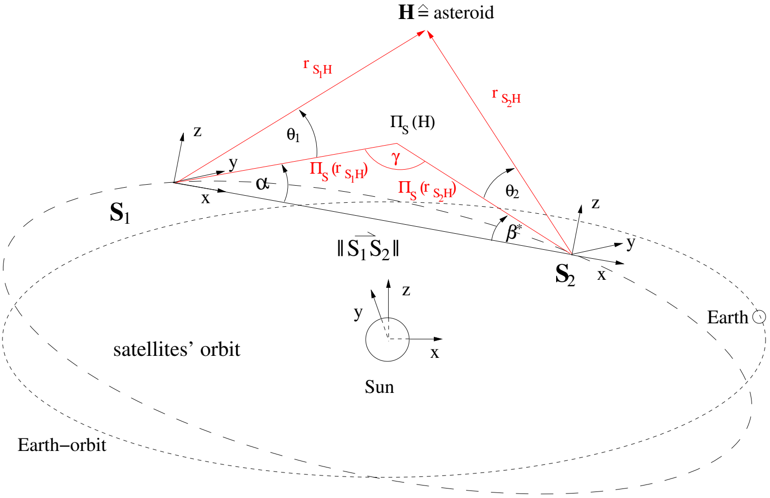
Goals:

- eliminate 'trigonometric denominators'
- eliminate observer positioning restrictions
- determine method-performance

Asteroid Positioning I



Asteroid Positioning II



Velocity Interpolation

- linear interpolation from two observations:

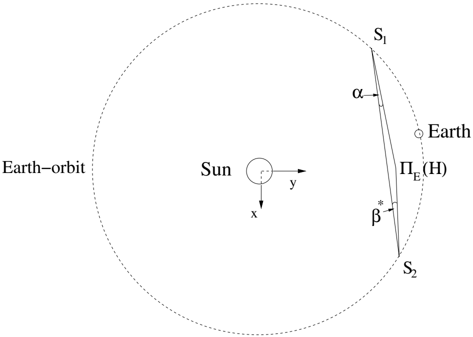
$$\vec{v}_{t_1} = \frac{\vec{H}_{t_2} - \vec{H}_{t_1}}{\Delta t} + O(\Delta t)$$

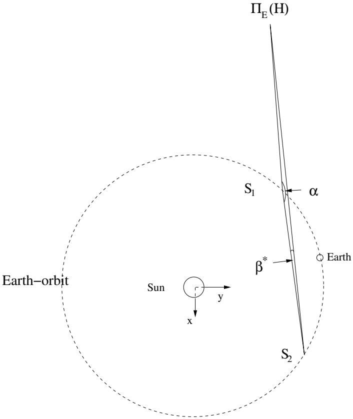
- stirling interpolation from three observations:

$$\vec{v}_{t_1} = \frac{\vec{H}_{t_2} - \vec{H}_{t_0}}{2\Delta t} + O((\Delta t)^2)$$

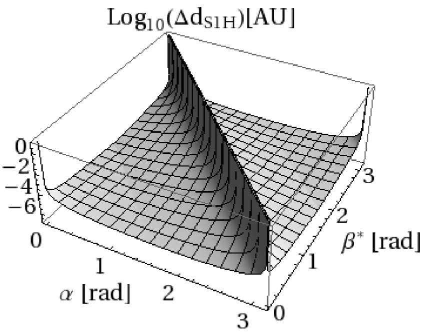
$$\{ \vec{H}, \vec{v} \} \rightarrow \{ a, e, i, \omega, \Omega, M \}$$

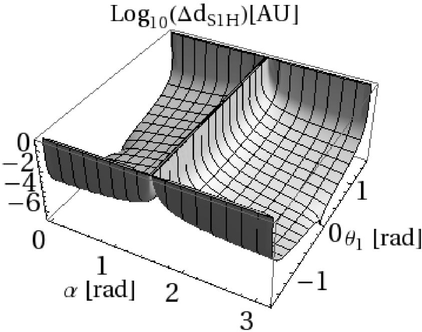
Unfavorable Configurations





Error Propagation





	α [^{o}]	$\beta*$ [^{o}]	θ_1 [^{o}]	$d_{S_1S_2}$ [AU]	$\Delta\alpha$ ["]	$\Delta\beta*$ ["]	$\Delta\theta_1$ ["]	$\Delta d_{S_1S_2}$ [AU]
l	0 to π	0 to π	fixed $\pi/4$	1	1	1	1	10^{-7}
r	0 to π	fixed $\pi/2$	-$\pi/2$ to $\pi/2$	1	1	1	1	10^{-7}

Applicability

Down to a minimum baseline, the method is **robust against observer positioning**, as well as NEO positioning, except for 'unfavorable configurations'

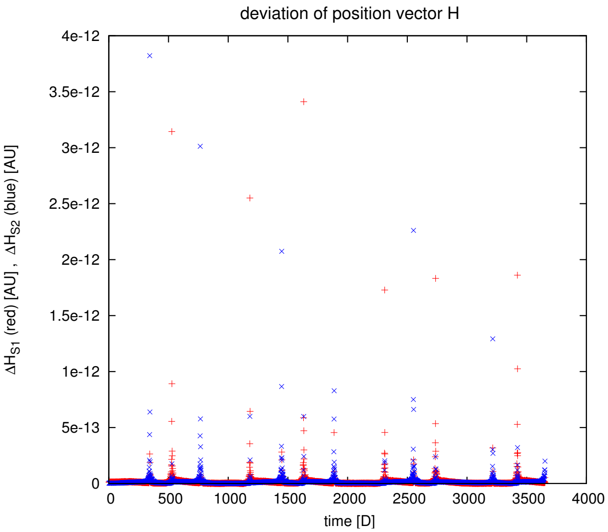
$$\Delta_{min} = 2d \cdot tan(\Delta\alpha)$$

d	α	Δ_{min}
1 AU	2"	2901 km
36000 km	2"	0.69 km

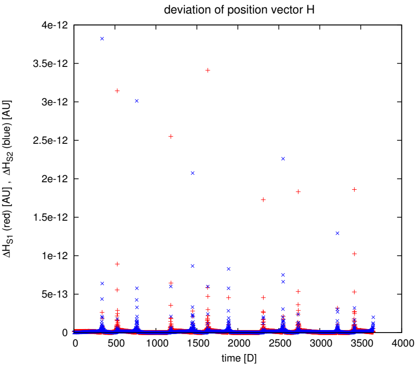
Simulation

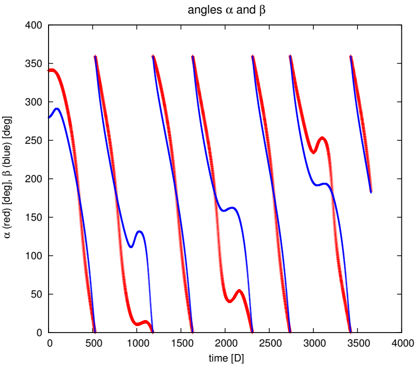
- numerical interation:
  Sun + 8 planets + NEA + 2 Observing Satellites
- ficticous NEA ($a = 2\ AU$, $e = 0.5$, $i = 30^o$, $\omega, \Omega, M = 0$)
- satellites positioned at L_4 and L_5 (Sun-Earth)
- integrator: Lie-Series (Eggl & Dvorak, 2010)

Ideal Measurement Positioning Error

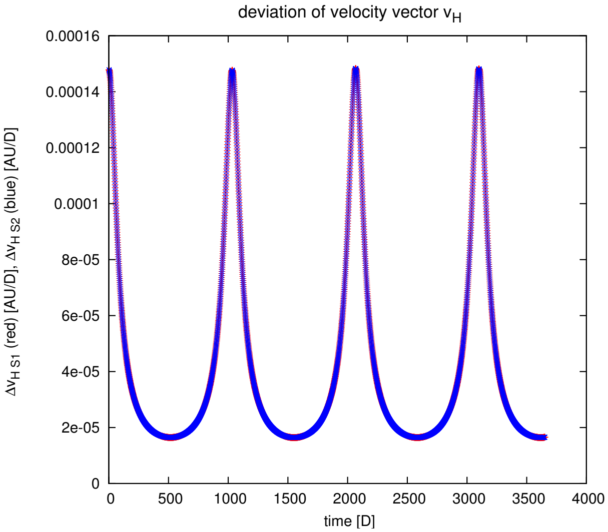


Ideal Measurement Positioning Error

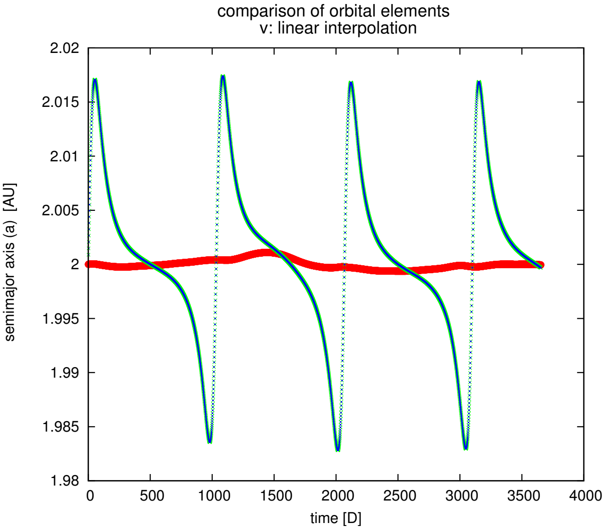


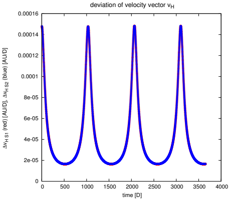


Ideal Measurement Velocity from 2 Observations

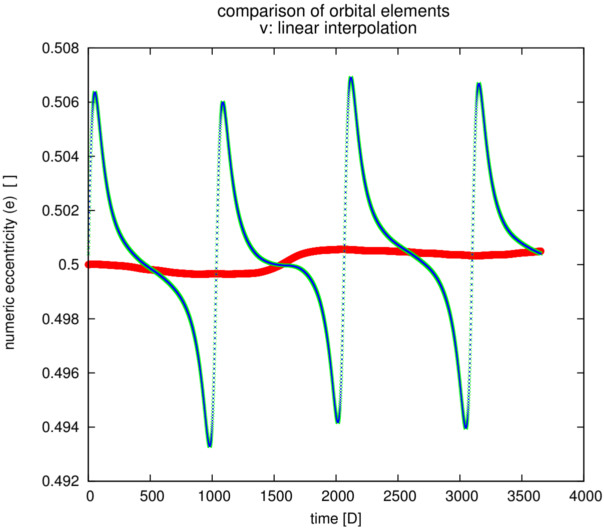


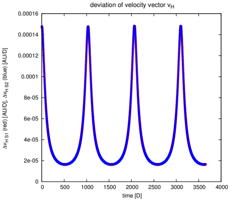
Ideal Measurement - Semimajor Axis



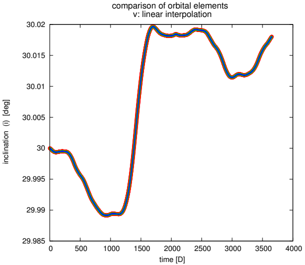


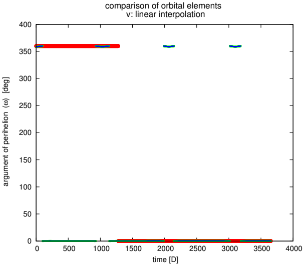
Ideal Measurement - Eccentricity

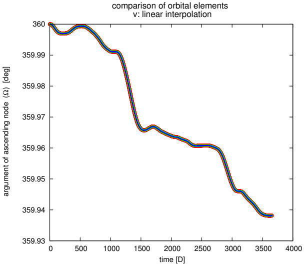


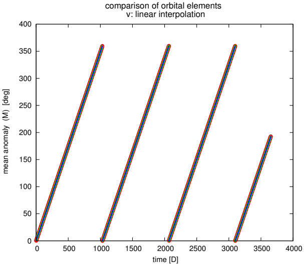


Ideal Measurement - Positioning Orbital Elements









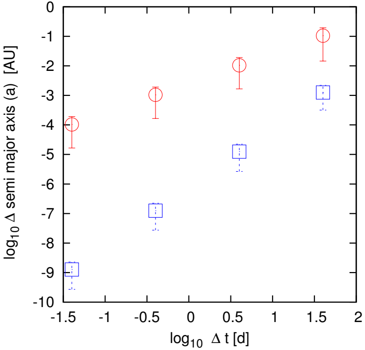
Try something real!

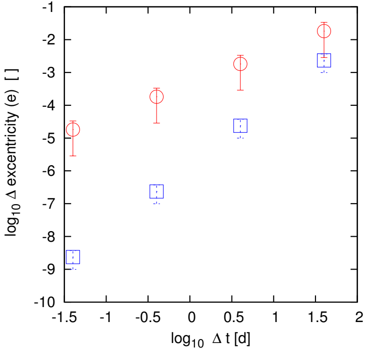
2007 JY2

a [AU]	e []	i [^{o}]	$\omega[^o]$	$\Omega[^o]$	M[^{o}]
2.19956074	0.68806235	1.5955816	105.080281	225.738210	329.8208272
σ_a [AU]	σ_e []	σ_i [^{o}]	$\sigma_\omega[^o]$	$\sigma_\Omega[^o]$	$\sigma_M[^o]$
0.0031225	0.0005391	0.0016273	0.0037194	0.00049895	0.69888

78 observations spanning a data arc of **31 days** (JPL, 2011)

Ideal Measurement Statistics

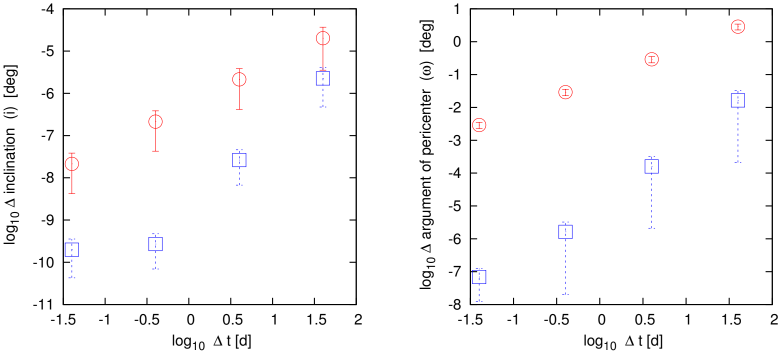




measurement intervals: 1h, 0.4d, 4d, 40d

two (○) and three (□) observations

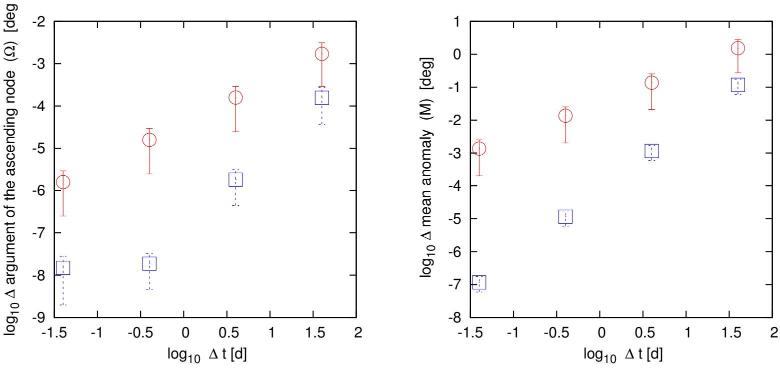
Ideal Measurement Statistics



measurement intervals: 1h, 0.4d, 4d, 40d

two (○) and three (□) observations

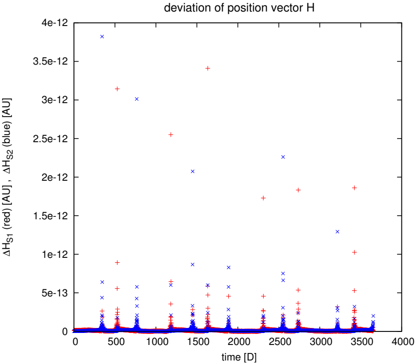
Ideal Measurement Statistics

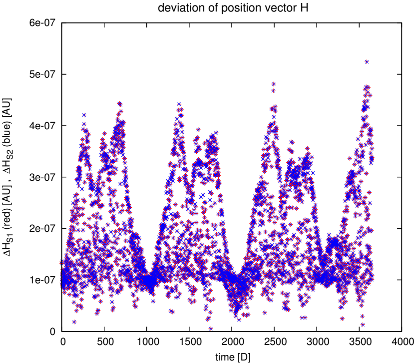


measurement intervals: 1h, 0.4d, 4d, 40d

two (◯) and three (□) observations

+ Angular Measurement Uncertainties





Uncertainties & Scenarios

Uncertainties:

- Angular measurements (diffraction, seeing)
- Observer positioning errors
- Finite light travel time

Three scenarios:

2 satellites (1m optical)	○
2 satellites (30cm optical)	□
1 satellite (1m optical) + 1 earthbound (2" seeing)	*

2007 JY2

a [AU]	e []	i [^{o}]	$\omega[^o]$	$\Omega[^o]$	M[^{o}]
2.19956074	0.68806235	1.5955816	105.080281	225.738210	329.8208272
σ_a [AU]	σ_e []	σ_i [^{o}]	$\sigma_\omega[^o]$	$\sigma_\Omega[^o]$	$\sigma_M[^o]$
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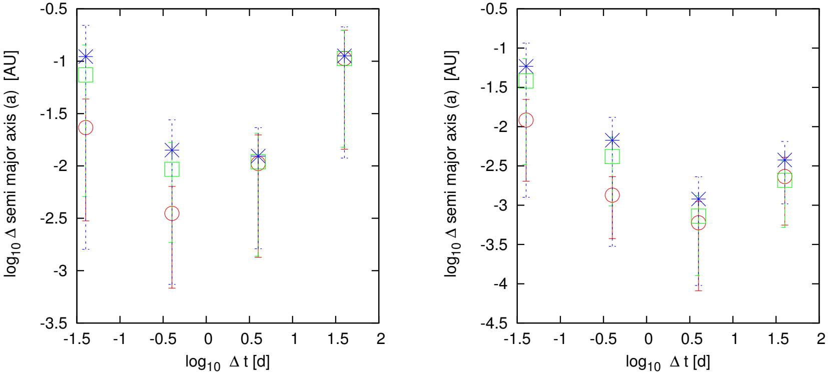
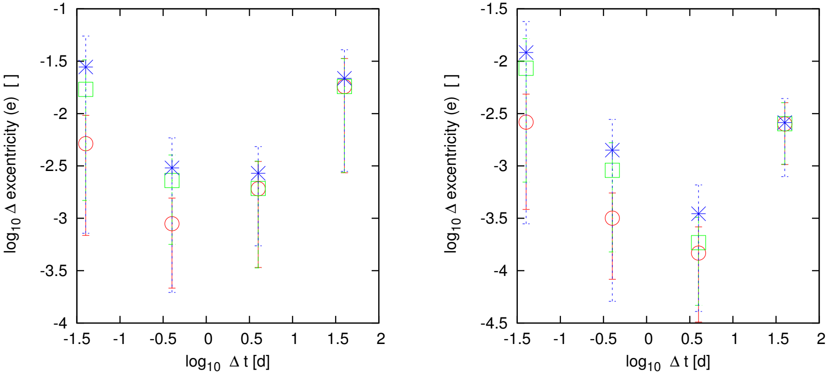
Statistical Results, 2007 JY2, a



two observations three observations

◯ 2 sats (1m), □ 2 sats (30cm), ∗ 1 sat + 1 earthbound

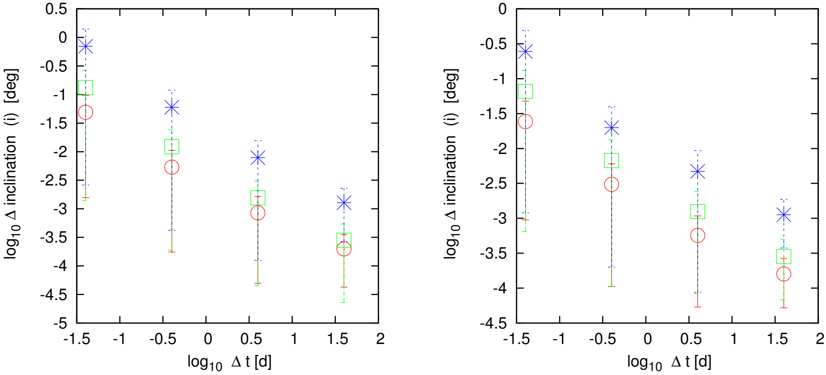
Statistical Results, 2007 JY2, e



two observations three observations

◯ 2 sats (1m), □ 2 sats (30cm), $*$ 1 sat + 1 earthbound

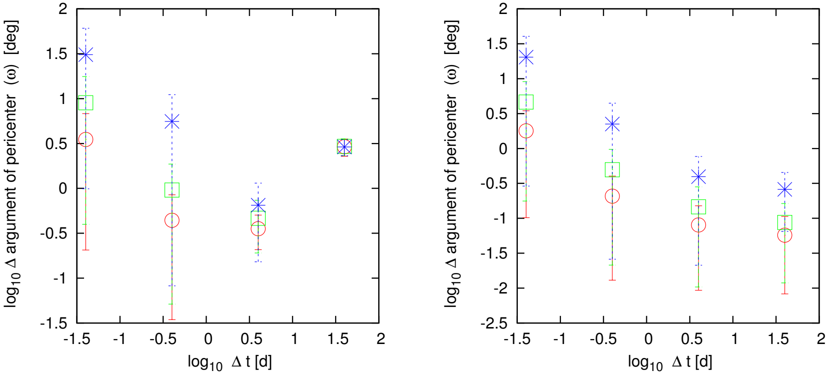
Statistical Results, 2007 JY2, i



two observations three observations

○ 2 sats (1m), □ 2 sats (30cm), $*$ 1 sat + 1 earthbound

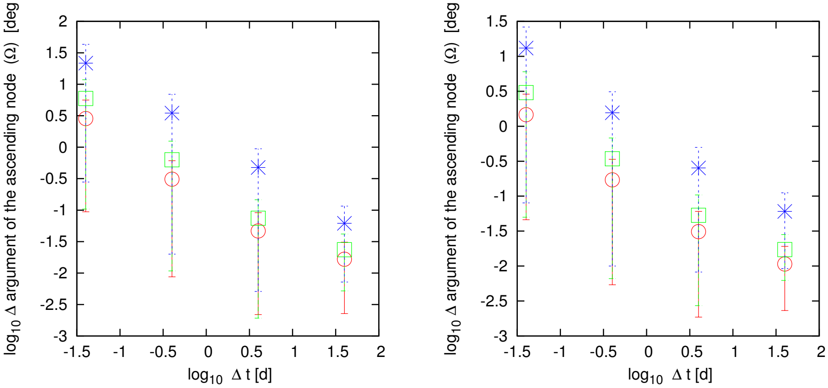
Statistical Results, 2007 JY2, ω



two observations three observations

○ 2 sats (1m), □ 2 sats (30cm), ∗ 1 sat + 1 earthbound

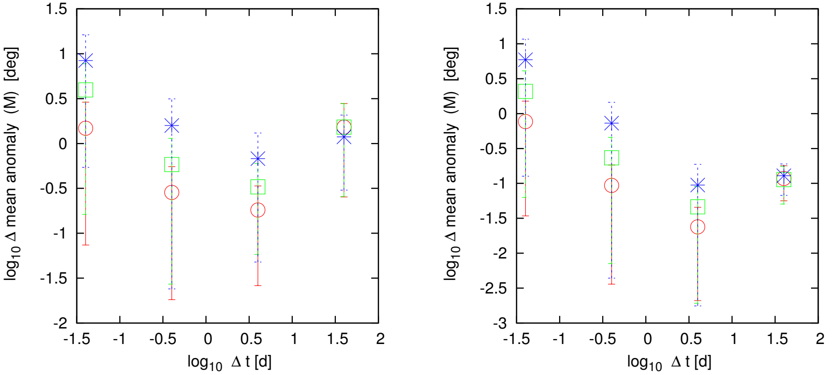
Statistical Results, 2007 JY2, Ω



two observations three observations

○ 2 sats (1m), □ 2 sats (30cm), ∗ 1 sat + 1 earthbound

Statistical Results, 2007 JY2, M



two observations three observations

○ 2 sats (1m), □ 2 sats (30cm), $*$ 1 sat + 1 earthbound

Summary & Conclusion

- Method for **quick follow-up refinement** of orbital elements
- Only 2 trigonometric functions in denominators left causing 'unfavorable configurations'
- 'Realistic' measurement scenarios (e.g. 2007 JY2) produce comparable results to JPL with **two observations only**
- Improvements via more precise measurements and/or combination with classical approaches

Thank you for your attention!

References:

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