

Orbits of Binaries from MC inversion

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Workshop: Orbiting couple – Pas de Deux
– Paris, France –

“Is this orbit really necessary”

- OK, but what about not having one,
 - ▶ but a bundle of orbits? (the carpet story)
 - ▶ what is the information or inference you can have?
- problem of
 - ▶ indeterminacy
 - ▶ initial orbit
 - ▶ confidence region
 - ▶ constraining some parameter
 - ▶ predicting past/future position

Sparse+scarce data

- ① resolved pairs at LT with AO systems or HST
 - ▶ relative position (x,y) or polar coord.
 - ▶ $\sigma \approx 10\text{--}100\text{mas}$
- ① less than 10 points spread over several (many) orbital periods
 - ▶ $P \approx \text{weeks-month}$; $\text{arc} \approx 2\text{--}10 \text{ years}$

Method

- ① linearisation, gradient
- ① GLS + Lampton (1976) χ^2 mapping
- ① Trial & Error sampling
 - ▶ brute force : sample the 7+ dimension in a grid
 - ▶ statorbit: use semi-analytical
 - ▶ genetic approach: sample the best (DPAC impl.)
 - ▶ MCMC: chain to the most probable solution

Method

$$(t_k - t_i) - \frac{\Delta_{ik}}{c^*} = \frac{1}{n} [(E_k - E_i) - \sin(E_k - E_i)],$$

- ① Thiele Innes (van der Bos), inversion

- ▶ 3 relative positions (x_i, y_i) (i=1..3)

- ▶ + (C or P) \Rightarrow Keplerian orbit (if it exists)

- ①
$$\begin{aligned} x &= AX + FY && (X, Y = f(e, E, c, t)) \\ y &= BX + GY && (A, B, F, G \leftrightarrow a, n, e, I, \omega, \Omega, T) \\ z &= CX + HY && \leftarrow \text{parallax} \end{aligned}$$

- ① We have -slightly- more than 3 points

- ① Observations are given with error bars

- ① Monte Carlo, forward problem

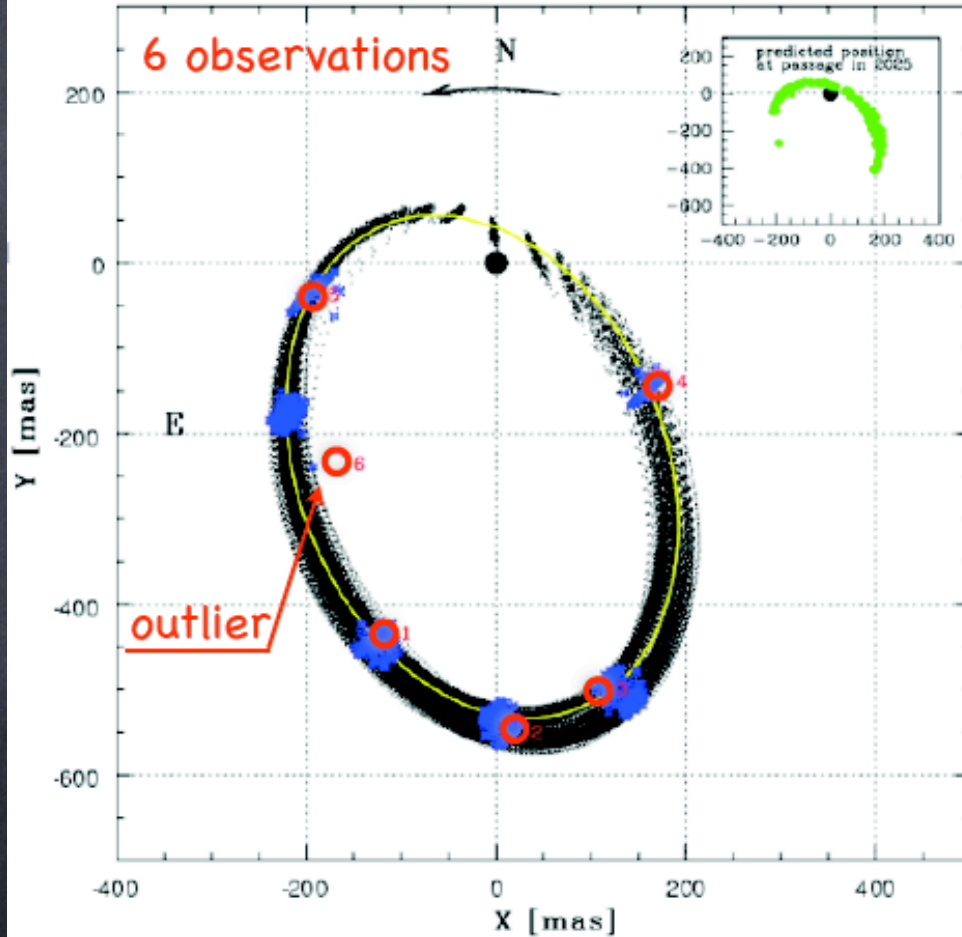
Method

- Sampling the orbital parameter space, \mathcal{P}
parallelised code
- semi-forward problem: test vs. any quantity
from orbit propagation and measure

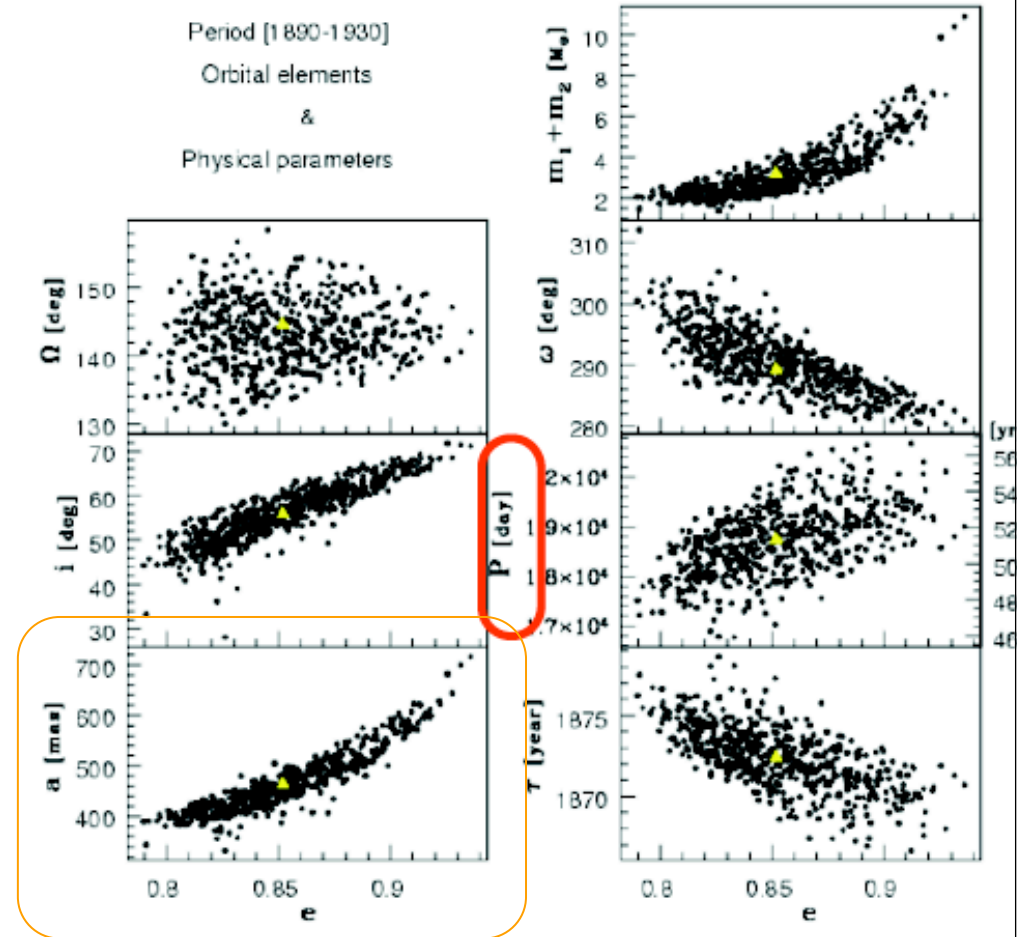
Binary star

(R. Aitken 1964)

Apparent Orbit of 24 Aquarii



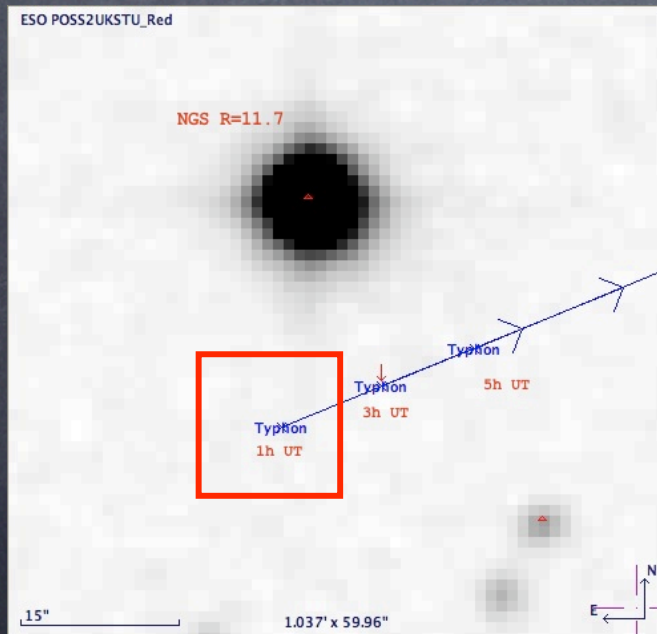
Visual binary 24 Aquarii



Asteroids

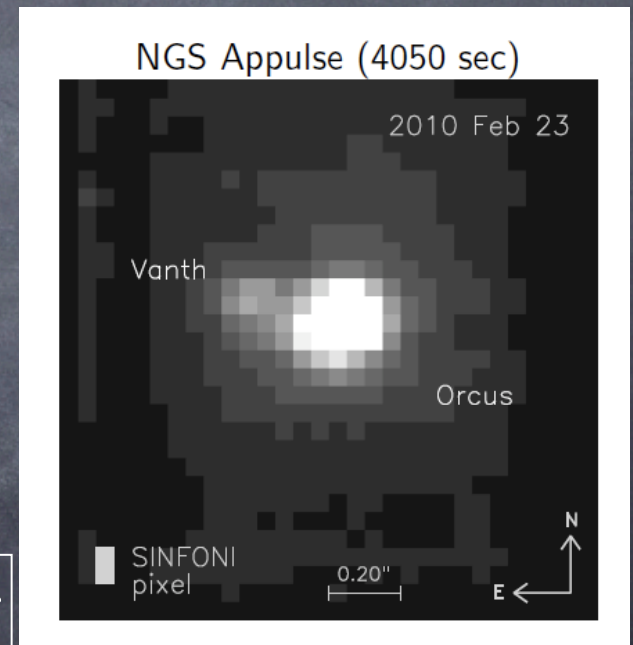


ESO/VLT



appulse

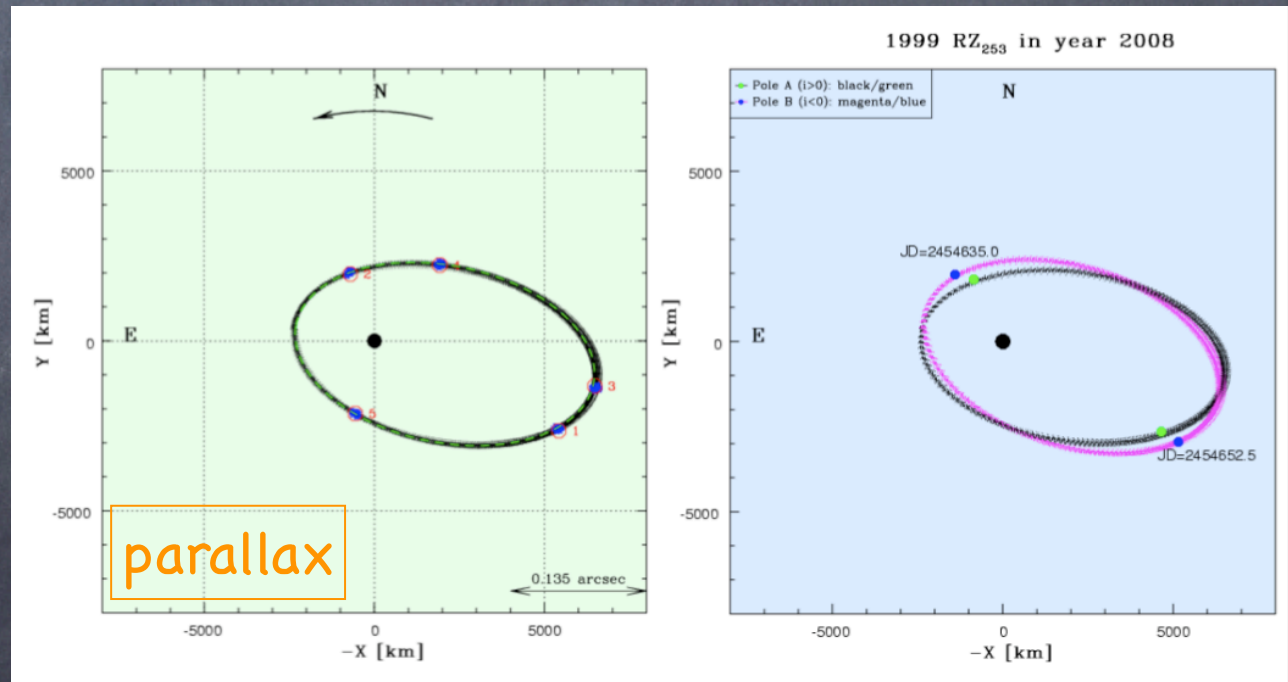
spectro-imageur



Asteroids

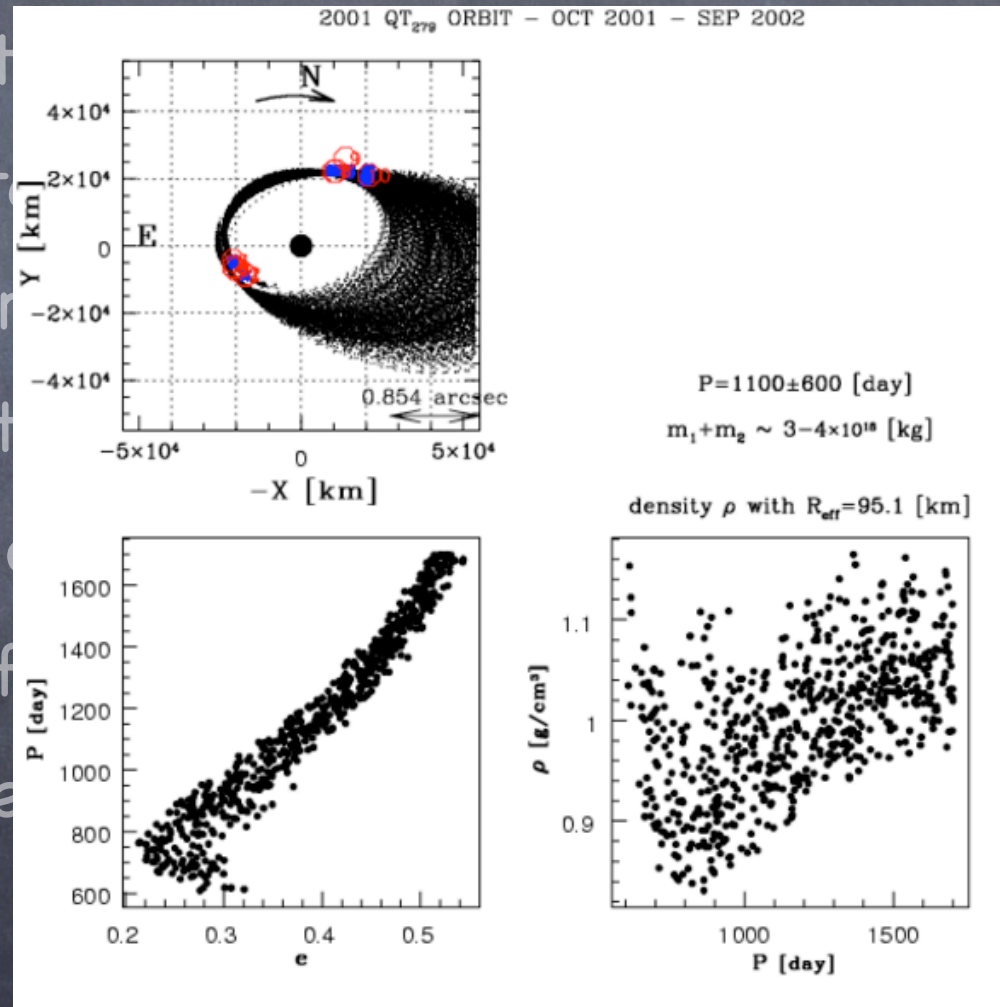
Note:

- ▶ varying geoc^{entric} distance
- ▶ parallax, helioc. orbital period
- ▶ bias from J_2
- ▶ Keplerian orbits
- ▶ verify non detection



Asteroids

- look for acceptable solutions region
- check predicitions
- compare orbits
- get mass estimates
- number densities
- LS value, model
- no refined pdf
- Is this confidence



Asteroids

- look for acceptable solutions region & rejection
 - ▶ check predictions
 - ▶ compare orbital pole to spin pole
 - ▶ get mass estimation
- number density, no mapping
 - ▶ LS value, mode, ...
 - ▶ no refined pdf, or probable value → LS
- Is this confidence region really necessary?

Long period

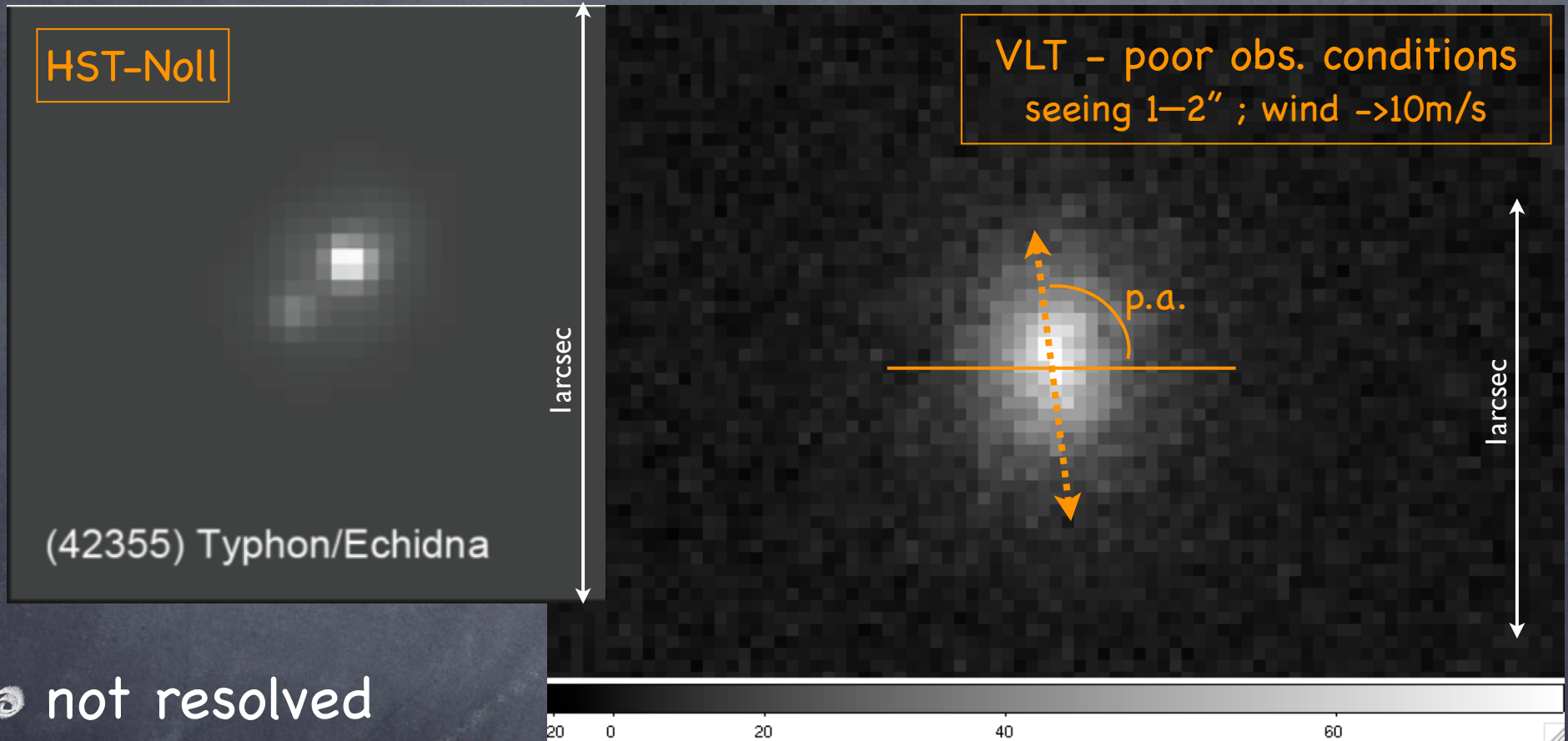
- Unbound orbits
- Explore $e > 1$
- Universal variables (Viñuales et al. 1995, Danby book)

$$\boxed{E} \quad (t_k - t_i) - \frac{\Delta_{ik}}{c^*} = \frac{1}{n} [(E_k - E_i) - \sin(E_k - E_i)] ,$$

$$\boxed{H} \quad (t_k - t_i) - \frac{\Delta_{ik}}{c^*} = \frac{1}{\nu} [\sinh(F_k - F_i) - (F_k - F_i)] ,$$

$$\boxed{U} \quad (t_k - t_i) - \frac{\Delta_{ik}}{c^*} = \mu \nu_3 (s_k - s_i; h) ,$$

1D astrometry

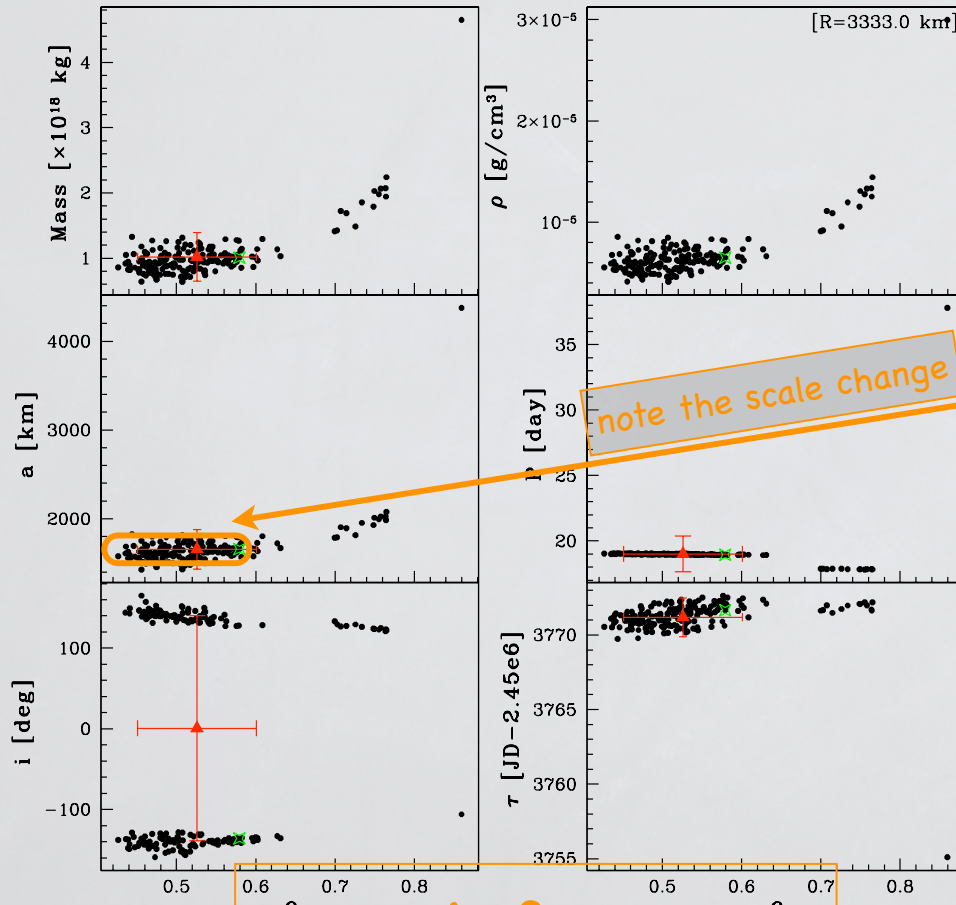


- not resolved
- 1D = (~~ρ~~ , θ) position angle, no separation
- can poor obs be useful?

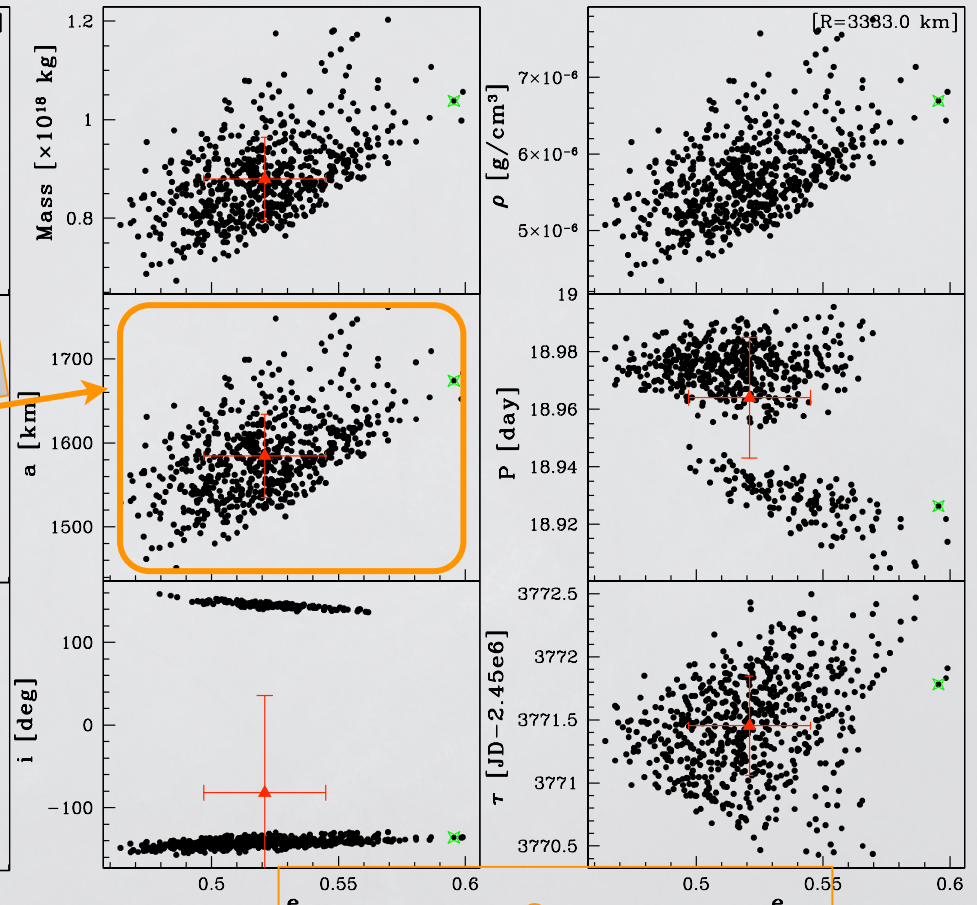
1D-astrometry

(42355) TYPHON - FEB-DEC '06

(42355) TYPHON - JAN/FEB '06



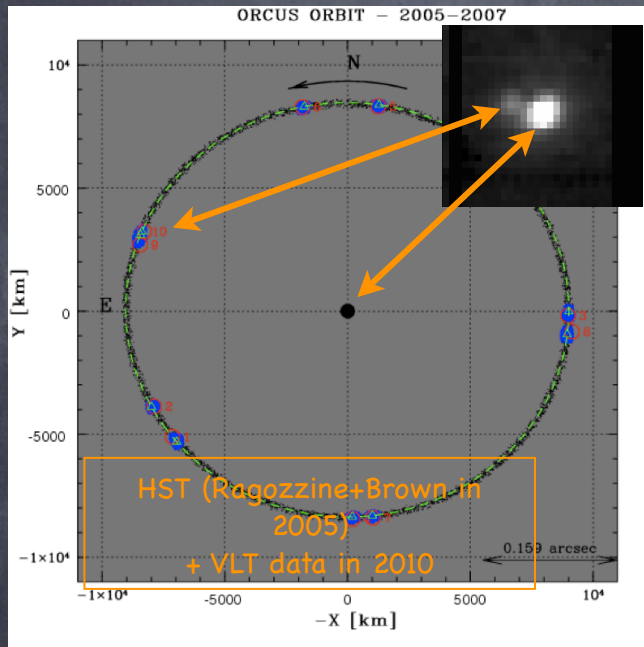
before
data from Grundy et al. 2008



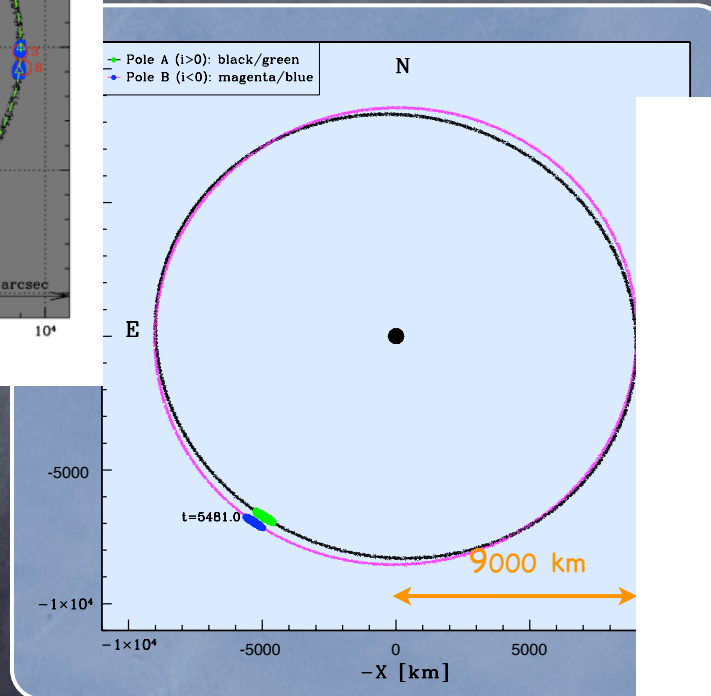
after
same + 1D data

Stellar occultation

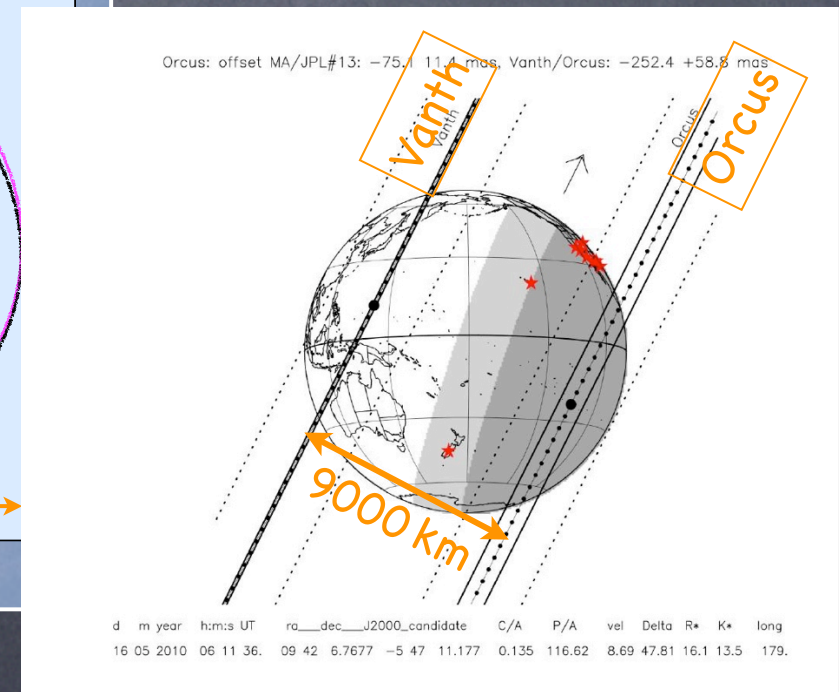
- large separation
- small offset barycenter primary



orbite

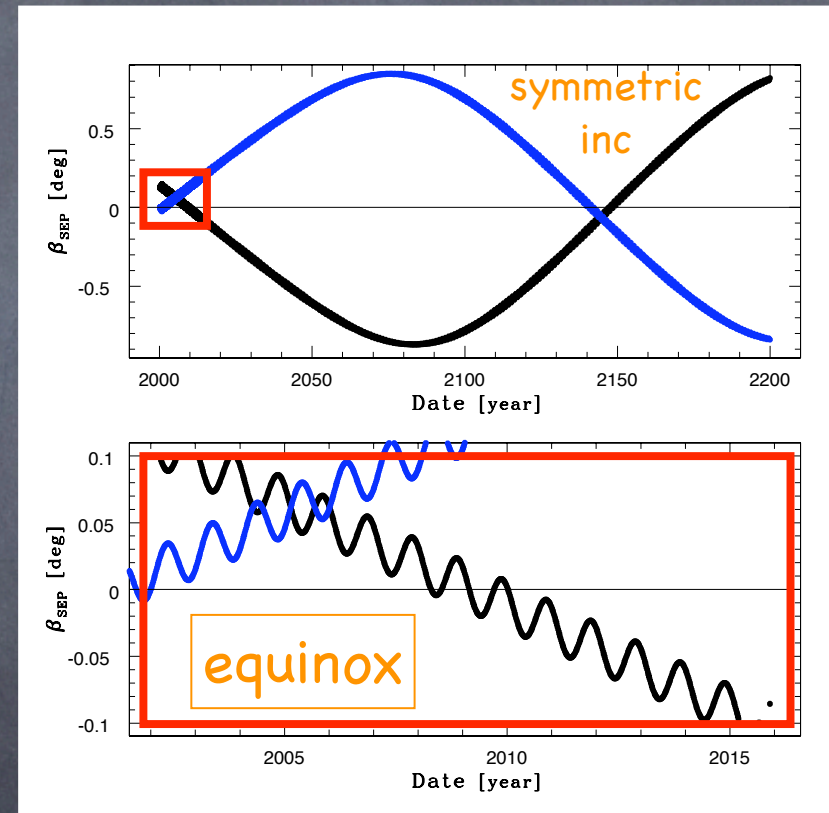


occultation

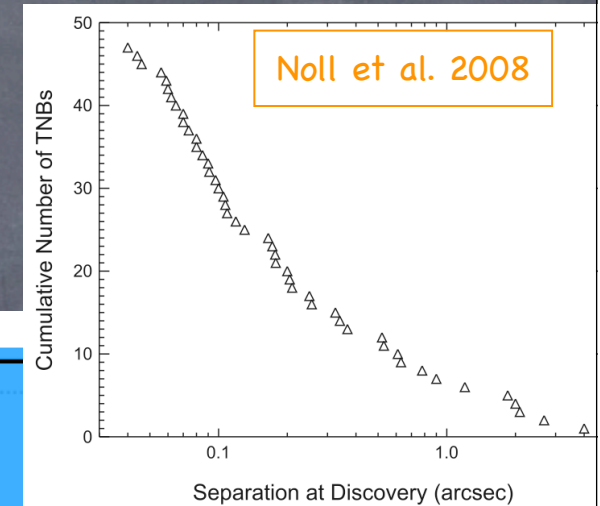
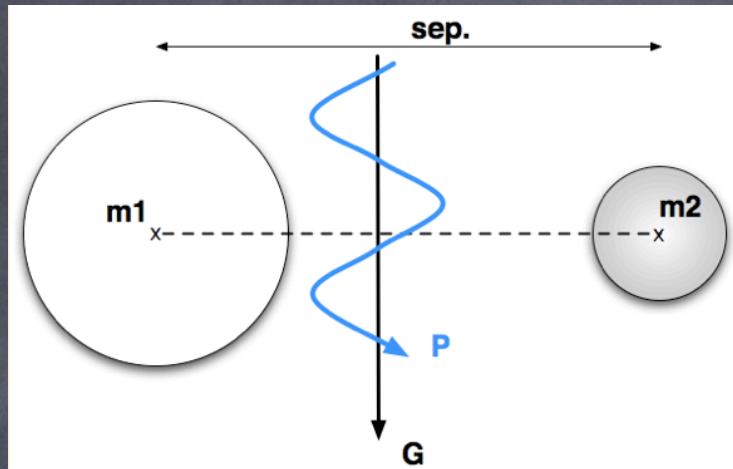


Mutual events

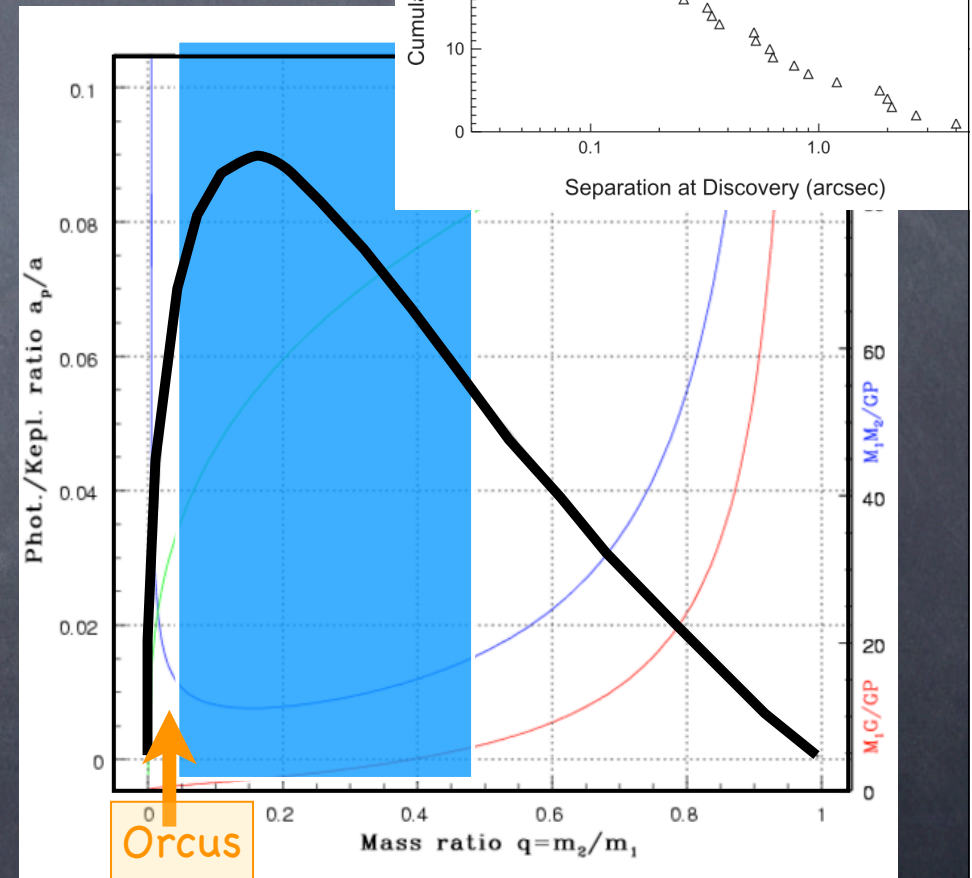
- 2 seasons per helioc period...
- equinox season last long for TNOs
- need correct pole



Astrometric binaries



- photometric vs. keplerian orbit
 - ▶ $\alpha/a = (\beta - f)$
- peak at $q \approx 0.15$
- combine to resolved 2D obs.
- Orcus/Vanth test case



Next

• To be done

- ▶ full pdf, a priori knowledge, MLE, use with stability
- ▶ precessing orbits (dA/dt , dB/dt , ...)
- ▶ mass ratio fitting (astrometric + resolved)

• Use of Gaia

- ▶ direct: mass determination + close encounter
- ▶ combine gb + space data (60 obs. over 5 years)
- ▶ indirect: mass-ratio for absolute position
- ▶ indirect: astrometric binaries for small TNB separation, possibly MBBs

Tonight

- ▶ David Latham surprise suitcase ≈18^h here
- ▶ social dinner 20^h M°Alesia

Google restaurant le moulin vert Paris, 34b rue des plantes

Itinéraire Mes adresses

77 Avenue Denfert-Rochereau, Paris

restaurant le moulin vert Paris

Ajouter une destination - Afficher les options

ITINÉRAIRE

Le calcul d'itinéraires piétons est en bêta.
Faites attention – Cet itinéraire n'est peut-être pas complètement aménagé pour les piétons.

Itinéraires possibles

Rue Mouton-Duvernet	1,4 km, 18 minutes
Av. du Général Leclerc	1,4 km, 18 minutes
Rue Froidevaux et Rue Gassendi	1,4 km, 18 minutes

Itinéraire à pied vers Au Moulin Vert

77 Avenue Denfert-Rochereau
75014 Paris

1. Prendre la direction sud-ouest sur Av. Denfert-Rochereau
2. Tourner à droite pour rester sur Av. Denfert-Rochereau
3. Prendre complètement à gauche sur Av. Denfert-Rochereau/Av. du Général Leclerc
Continuer de suivre Av. du Général Leclerc

Next

- presentations put on the web:
 - ▶ USB key or send by mail to hestro or fred arenou
- proceedings
 - ▶ 4 pages or 6 pages (cf. template)
doc, pdf, or latex (if you bring the wine next time)
 - ▶ deadline Dec. 31 (ok, make it January 1st)
- outcome
 - ▶ conclusive remarks (D. Queloz):
 - not enough data? put cumulative distribution instead of histogram
 - planets are like mushrooms
 - ▶ discussion - interactions?
 - ▶ another meeting? IAU, other topic, ... ?
 - ▶ ménage à trois ? (A. Quirrenbach)

Q & A

- Thiele Innes convergence problem if points not well spaced
- parallactic effect from Earth orbit on 1999QW₃₂₂ should be taken into account