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

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

Method

- linearisation, gradient
- GLS + Lampton (1976) chi^2 mapping
- 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

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

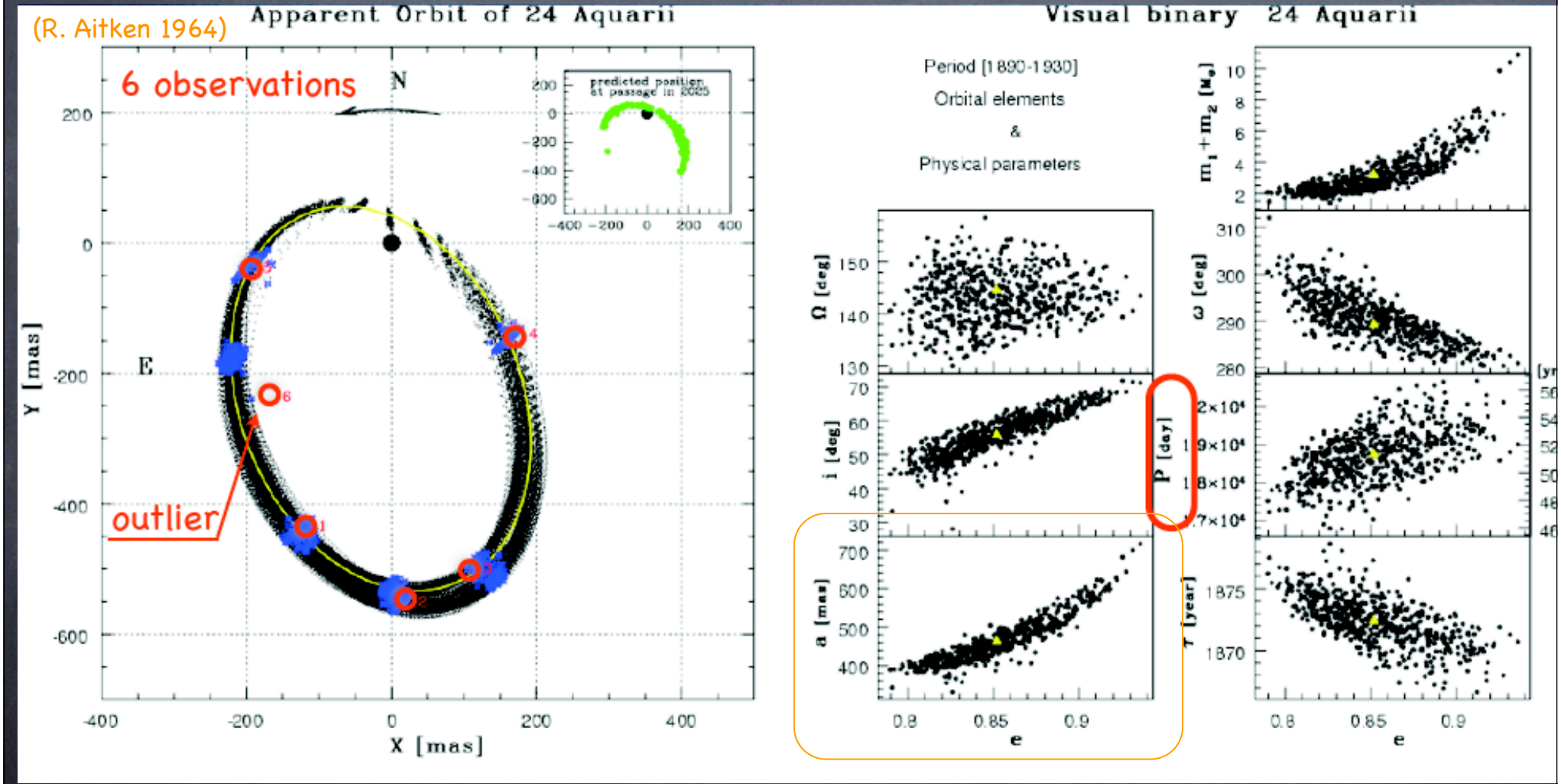
- Thiele Innes (van der Bos), inversion
  - 3 relative positions (x_i, y_i) (i=1..3)
  - + (C or P) => Keplerian orbit (if it exists)
- x = AX+FY
  y = BX+GY
  z = CX+HY <-- parallax
  (X,Y = f (e,E,c,t))
  (A,B,F,G <-> a,n,e,I,ω,Ω,T)
- We have -slightly- more than 3 points
- Observations are given with error bars
- Monte Carlo, forward problem

Method

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

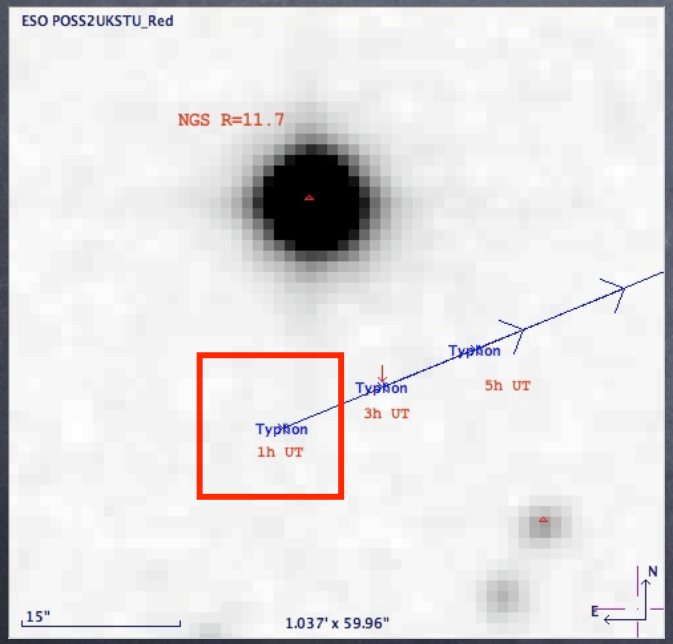
Binary star

(R. Aitken 1964)

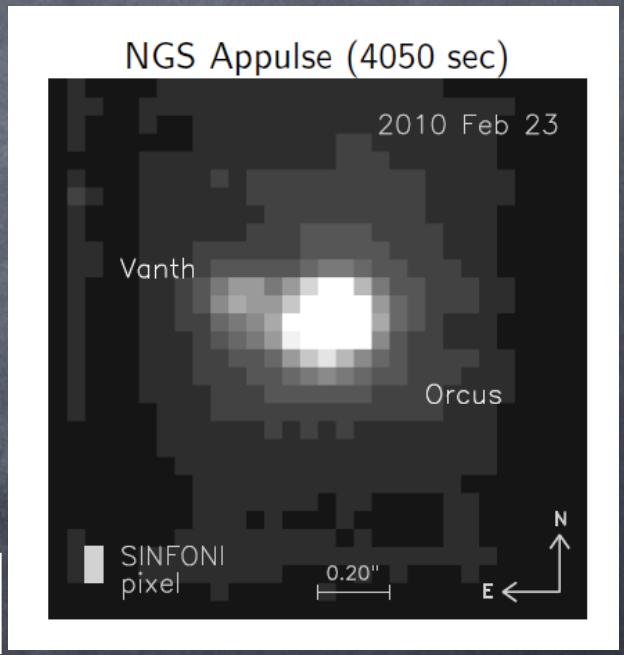


Asteroids

ESO/VLT



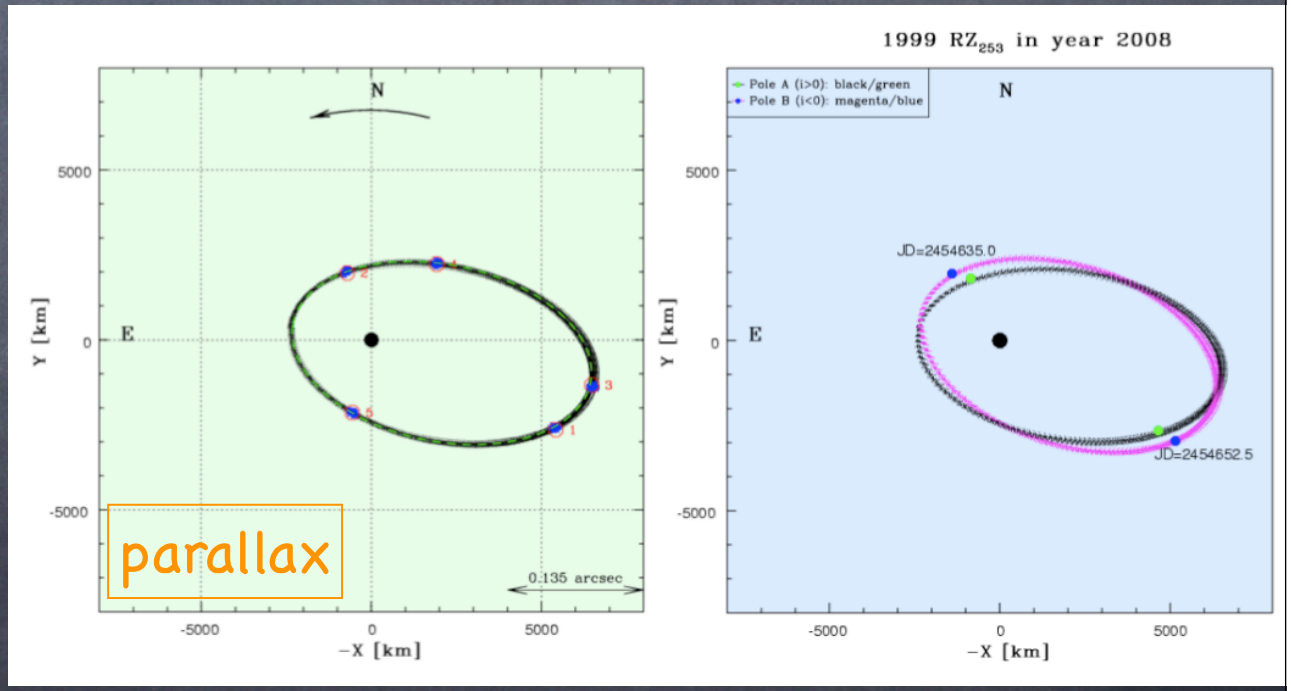
appulse



spectro-imageur

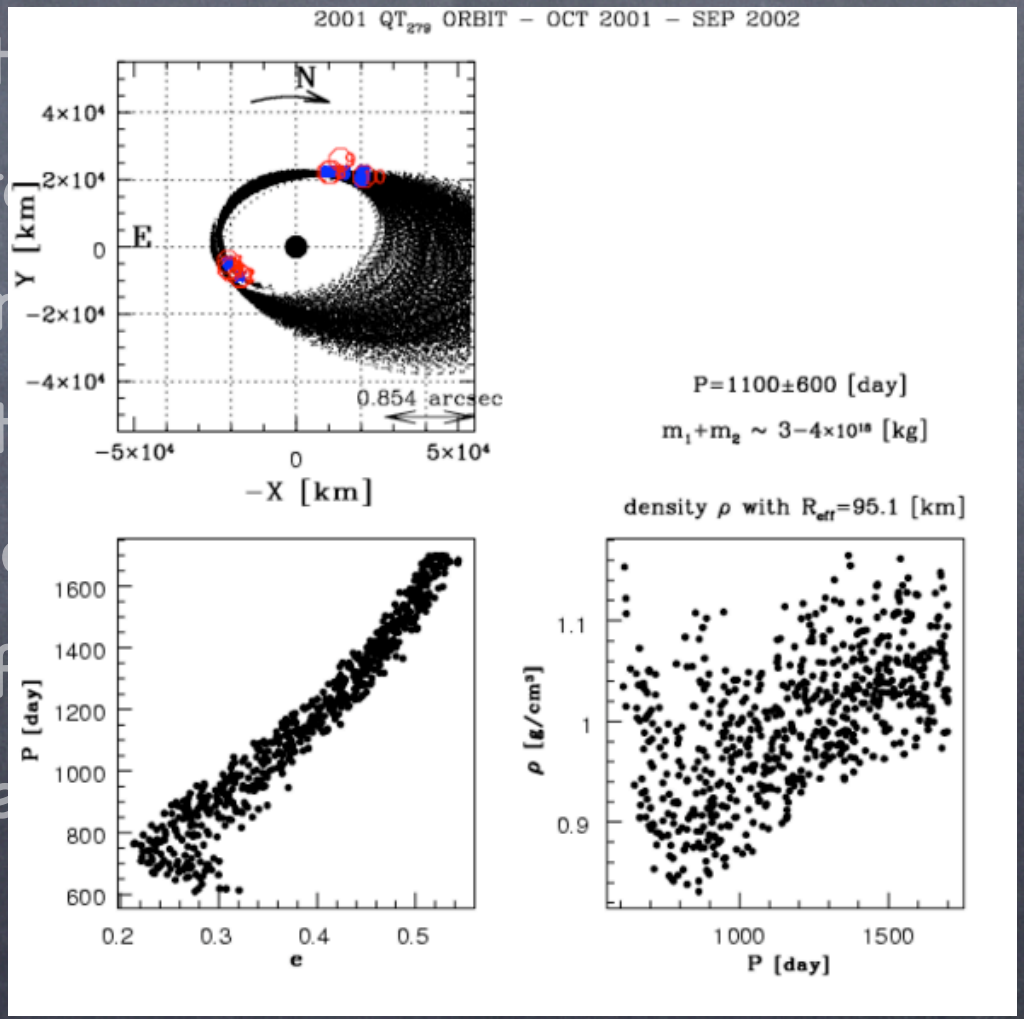
Asteroids

- Note:
  - varying geoc^{entric} distance
  - parallax, helioc. orbital period
  - bias from J_2
  - Keplerian orbits
  - verify non detec^{tion}



Asteroids

- look for acceptable solutions region
- check predicit
- compare orbit
- get mass estir
- number densit
- LS value, mod
- no refined pdf
- Is this confide



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

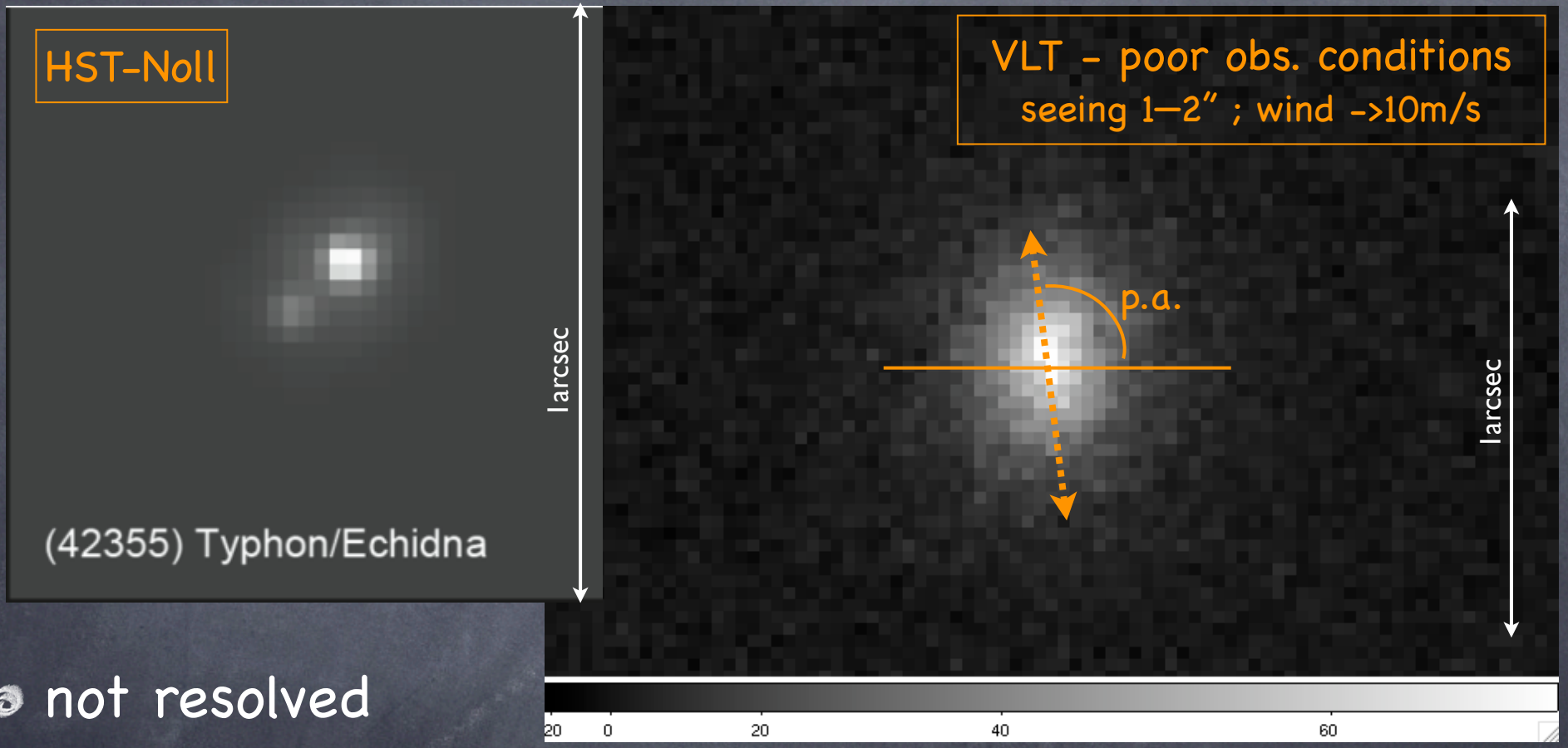
E $$(t_k - t_i) - \frac{\Delta_{ik}}{c^*} = \frac{1}{n}\left[(E_k - E_i) - \sin(E_k - E_i)\right],$$

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

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

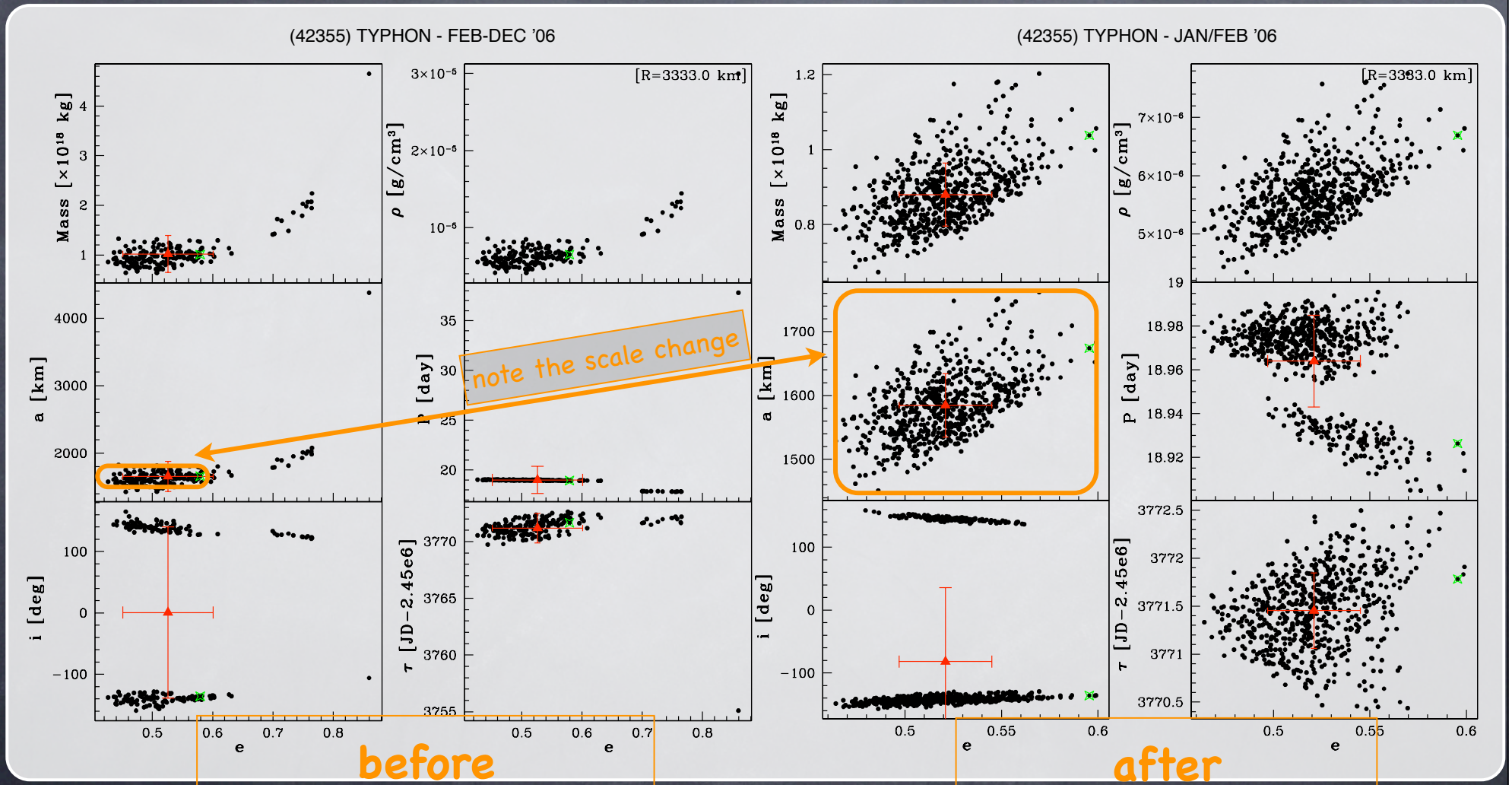
- Unbound orbits
- Explore e>1
- Universal variables (Viñuales et al. 1995, Danby book)

1D astrometry



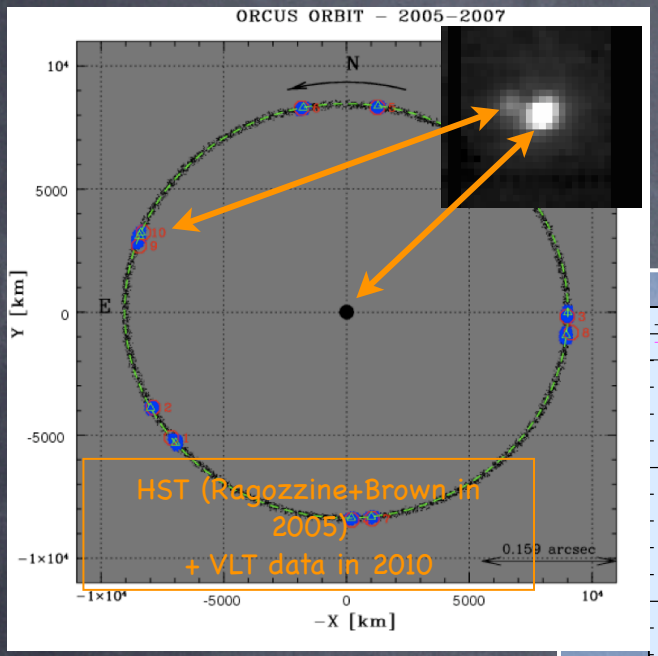
- not resolved
- 1D = (~~ρ~~,θ) position angle, no separation
- can poor obs be useful?

1D-astrometry

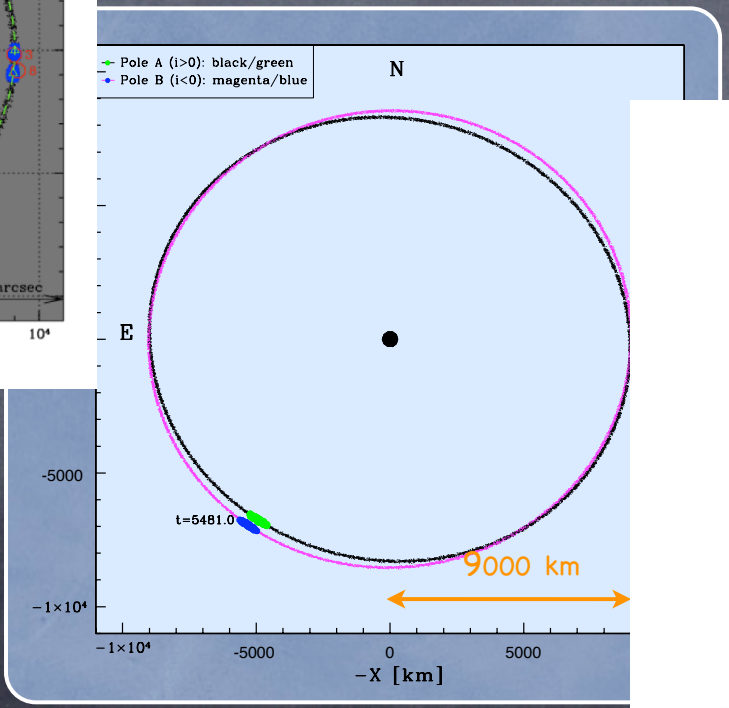


Stellar occultation

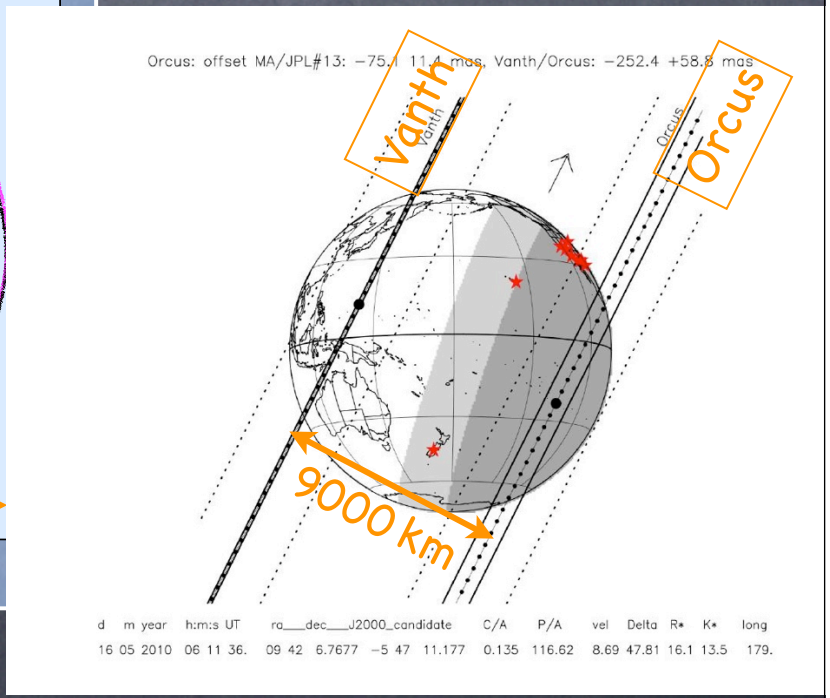
- large separation
- small offset barycenter primary



orbite

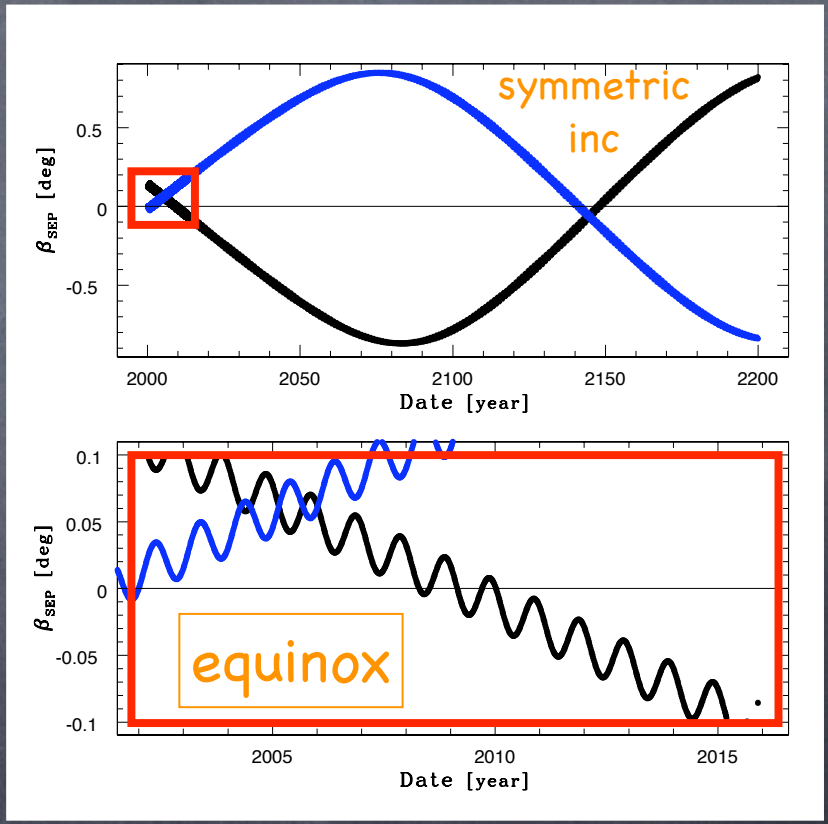


occultation

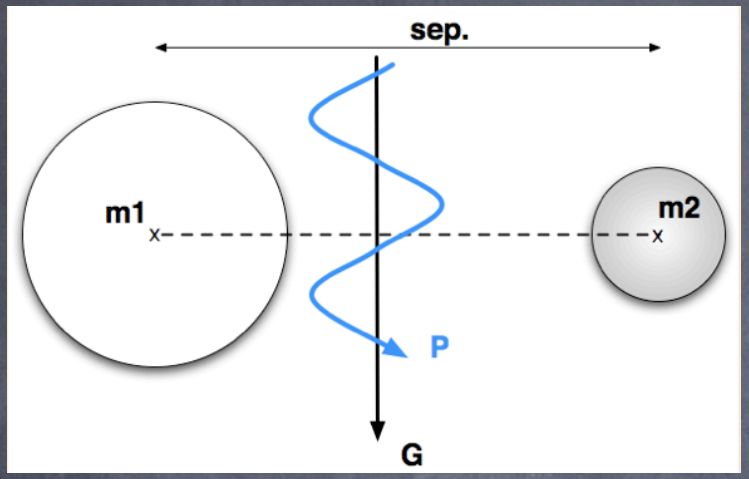


Mutual events

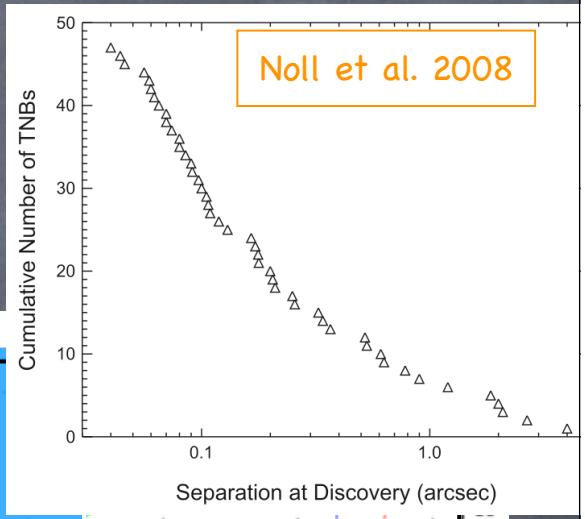
- 2 seasons per helioc period...
- equinox season last long for TNOs
- need correct pole

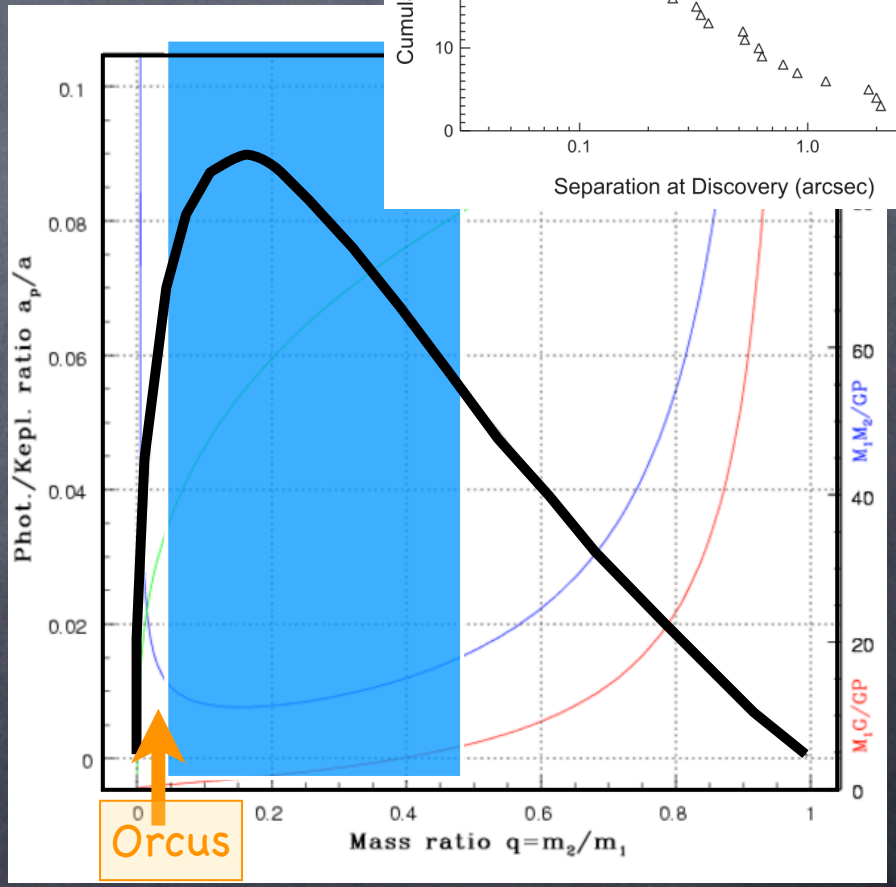


Astrometric binaries



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

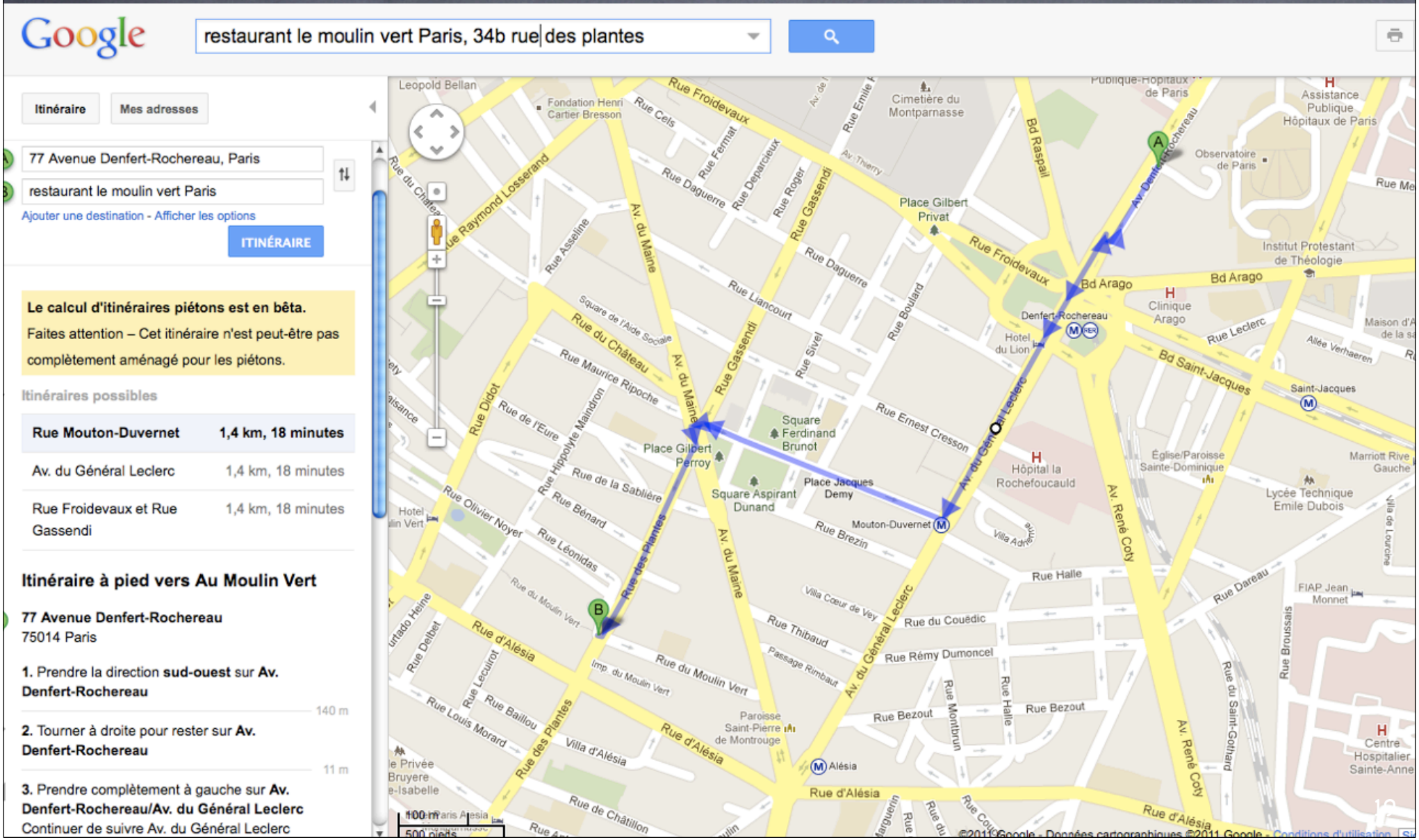




Next

- Tobe 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 5years)
  - indirect: mass-ratio for absolute position
  - indirect: astrometric binaries for small TNB separation, possibly MBBs

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



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 $1999QW_{322}$ should be taken into account