Stellar Occultations

From observation to results

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Sso Observational methods

Astrometry	Measure of positions on the celestial sphere w.r.t stars: orbits, dynamics	Since 1800
(Spectro) Photometry	Measure of the intensity of the received light: spin, period, size, shape, satellite, ...	Since 1800 → 1950, UBV filter, G. Kuiper
Closed approach	Direct measurement of the mass Estimation of the size and density	1802, C. F. Gauss
Polarimetry	Study of the surface, taxonomic class Measure of albedo, size	First measure: 1934, B. Lyot → 1968, Icarus & Flora, T. Gehrels and J. Veverka
Stellar occultations	Direct measurement of the size Estimation of the profile, shape, astrometry, satellite, ...	First successful obs.: 1958 → Juno (P. Bjorklund and S. Muller, Sweden)
Radar observation	Physical and chimical properties, albedo, size, shape, spin, ...	First app.: 1968, Icarus
Interferometry	Direct measurement of the size	1970, A. Labeyrie
Radiometry	Measure of the diameter (IR) and albedo (10 – 20 μm)	1970, Vesta, D. Allen
Adaptive optic	Estimation of the size, shape, spin, satellite, ...	Since 1990
Space probes	In situ study	Since 1990

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Stellar occultations science

Direct measurement of the physical size of Sso, without any hypothesis about its nature

- Modeling the profile (large scale, non-convexity)
- Modeling the geometric shape (sphere, triaxial ellipsoid, complex shape)
- Astrometry and size/shape of asteroid satellites

Stellar occultations 1958 - 2008

- Number of occultations observed with success: 1417
- Number of chords used to fit asteroid sizes: 3161

  → Mean number of (positive) chords per event: 2.2
- Max. number of (positive) chords for an occultation:

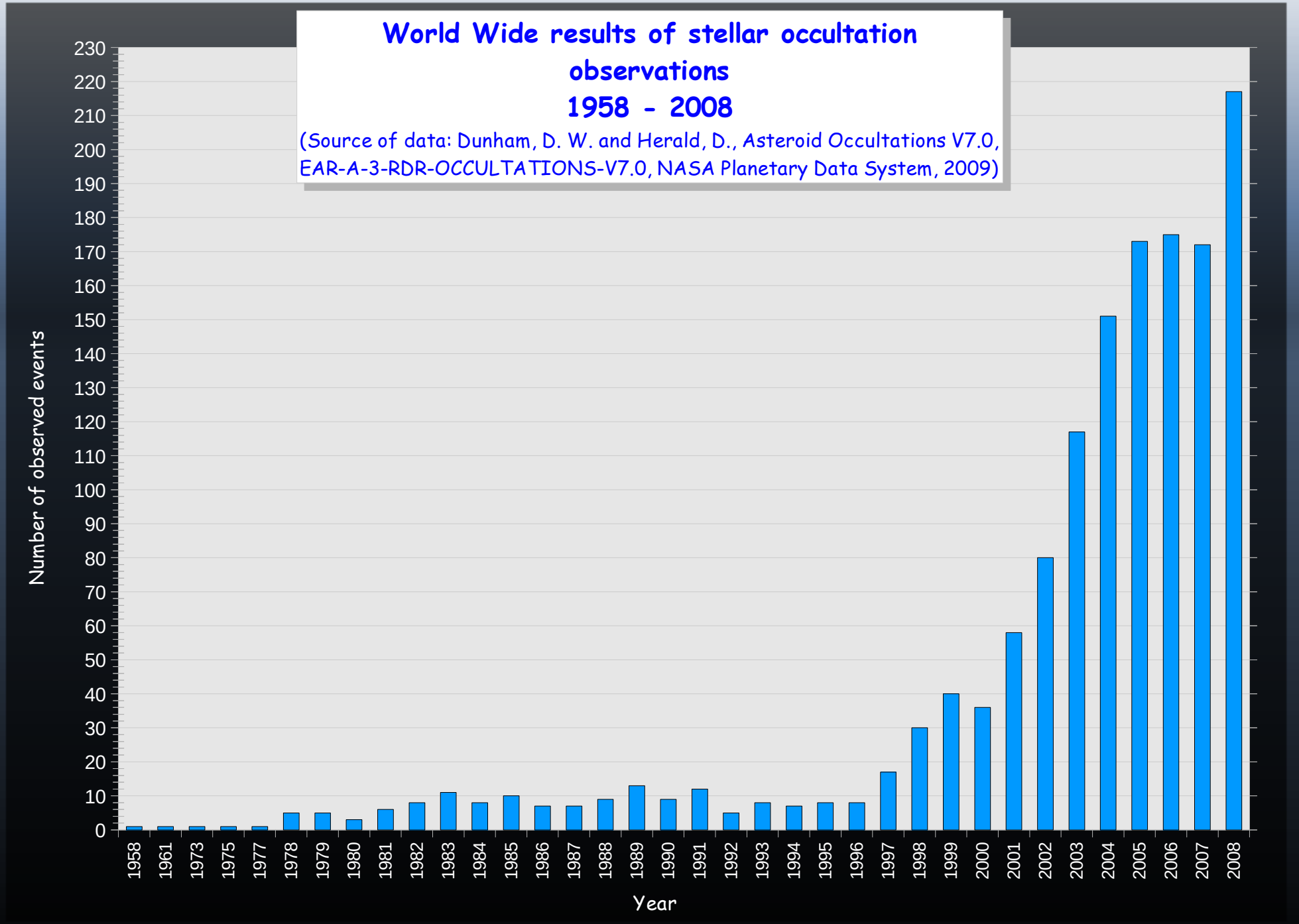
  133 (2) Pallas vs 1 Vulpeculae (1983)

  135 (420) Bertholda vs TYC 5757-00353-1 (2003)

Source of data: Dunham, D. W. and Herald, D., Asteroid Occultations V7.0, NASA Planetary Data System, 2009

Stellar occultations 1958 - 2008

- Events observed …
  - With 1 chord: 47%
  - With 1 or 2 chords: 62%
  - With 1, 2 or 3 chords: 72%
  - With more than 5 chords: 21%
  - With more than 10 chords: 8%


World Wide results of stellar occultation observations
1958 - 2008
(Source of data: Dunham, D. W. and Herald, D., Asteroid Occultations V7.0, EAR-A-3-RDR-OCCULTATIONS-V7.0, NASA Planetary Data System, 2009)
Number of observed events
0
10
20
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40
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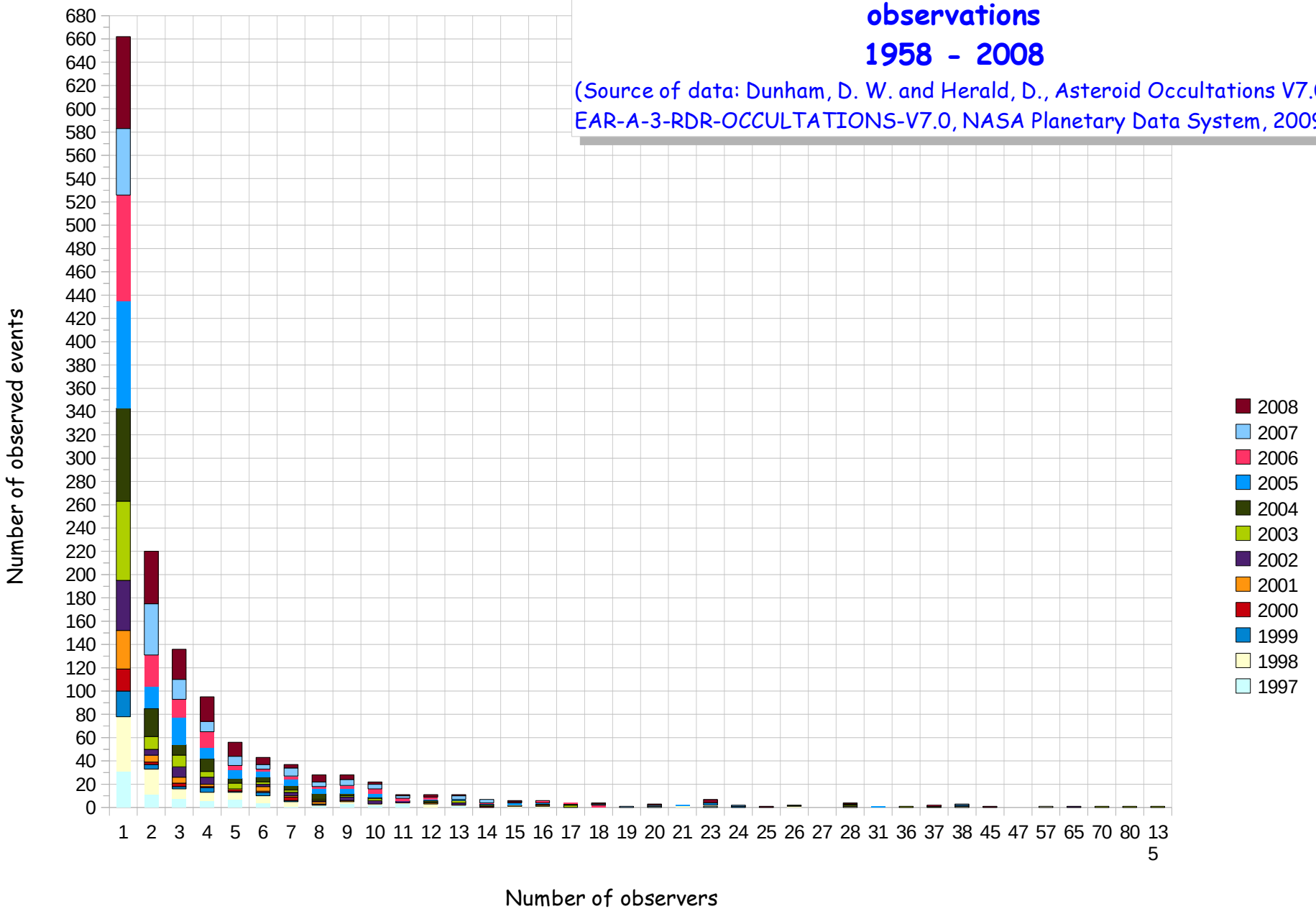

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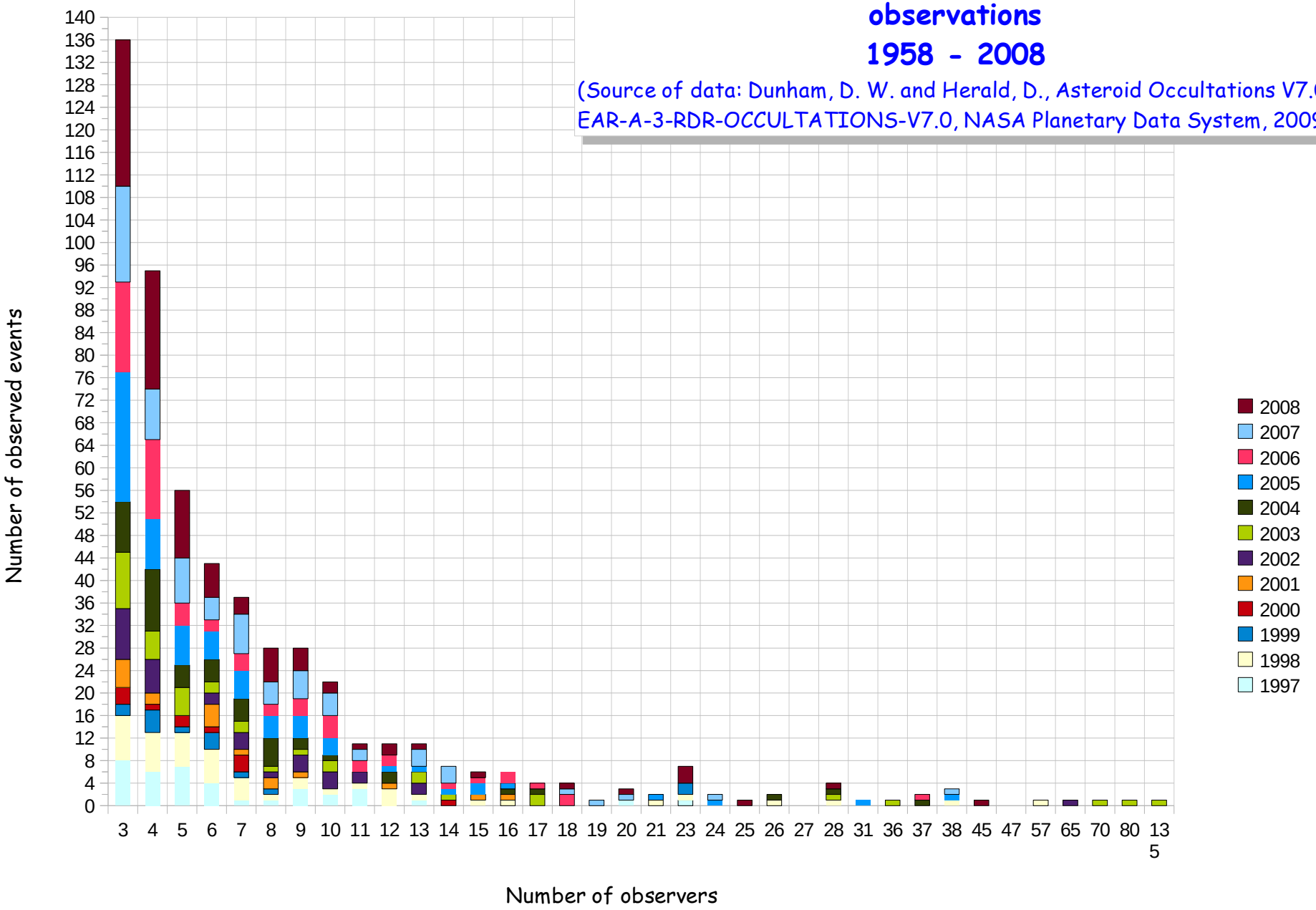

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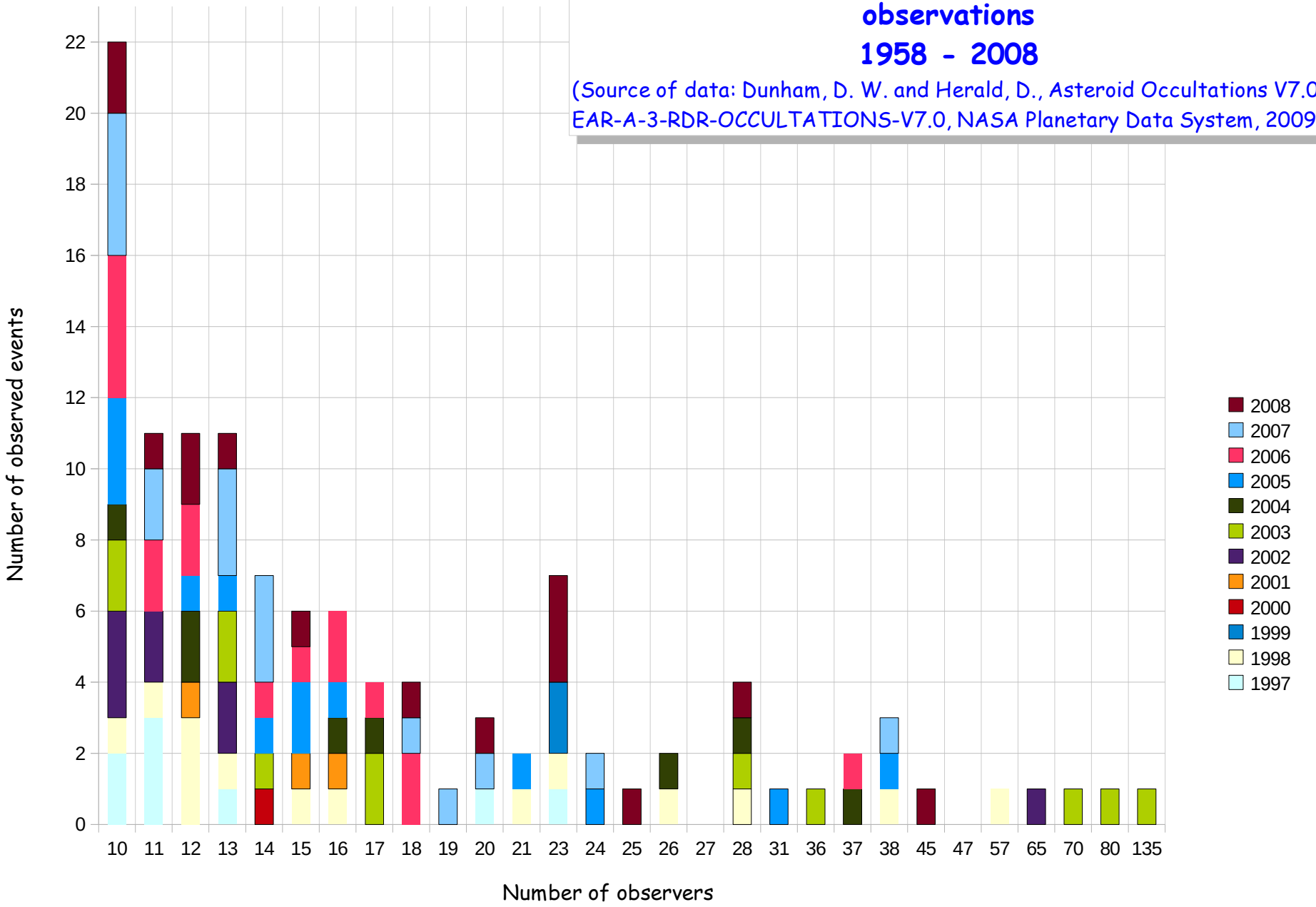

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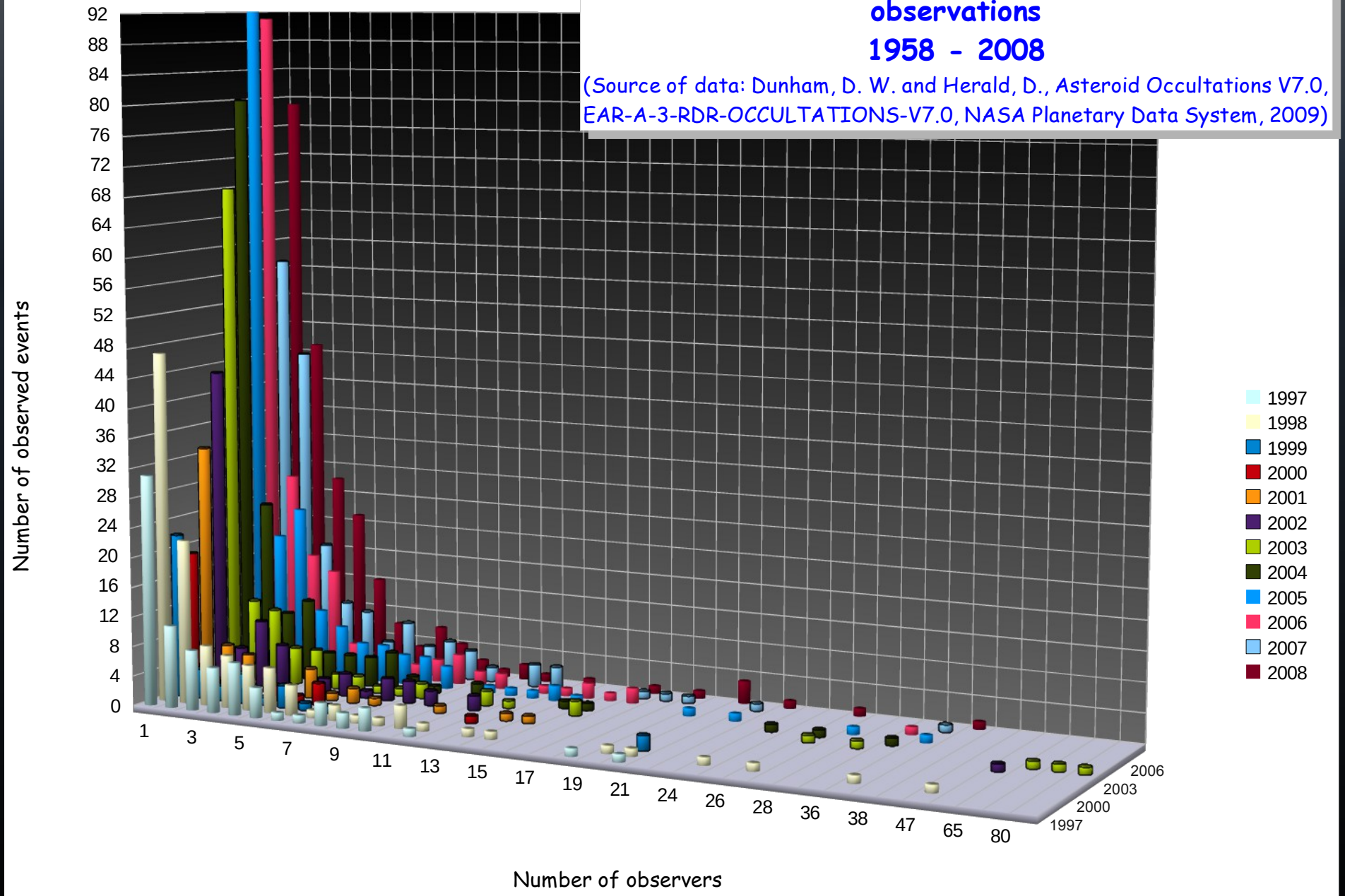


From observation...

- Dating of the DISAPPEARANCE and REAPPEARANCE of the star as seen by the observer (visual, photo-electric) from its geographic location
  → from few tenth to tens of seconds

- Dating of any secondary event (blink, double event, etc.)

- Accurate determination of the geographic coordinates of the observer (GPS)

- Accurate determination of the measurement uncertainties:
  - Time synchronization, calibration
  - Personnal equation

Observational parameters

- Hour of disappearance + uncertainty
- Hour of reappearance + uncertainty
- Geographic coordinates
- Comments

... to results ...

- Collection and publication of observational reports
  → ensured by networks (IOTA, EAON, Euraster, …)
  → newsletters, email, very few per-reviewed papers, PDS

- Reduction and (pre)analysis of data:
  - Computation of chords → one hypothesis = apparent Sso velocity)
    - Mostly done by the curators of data
    - Very few per-reviewed papers (after 1990's)

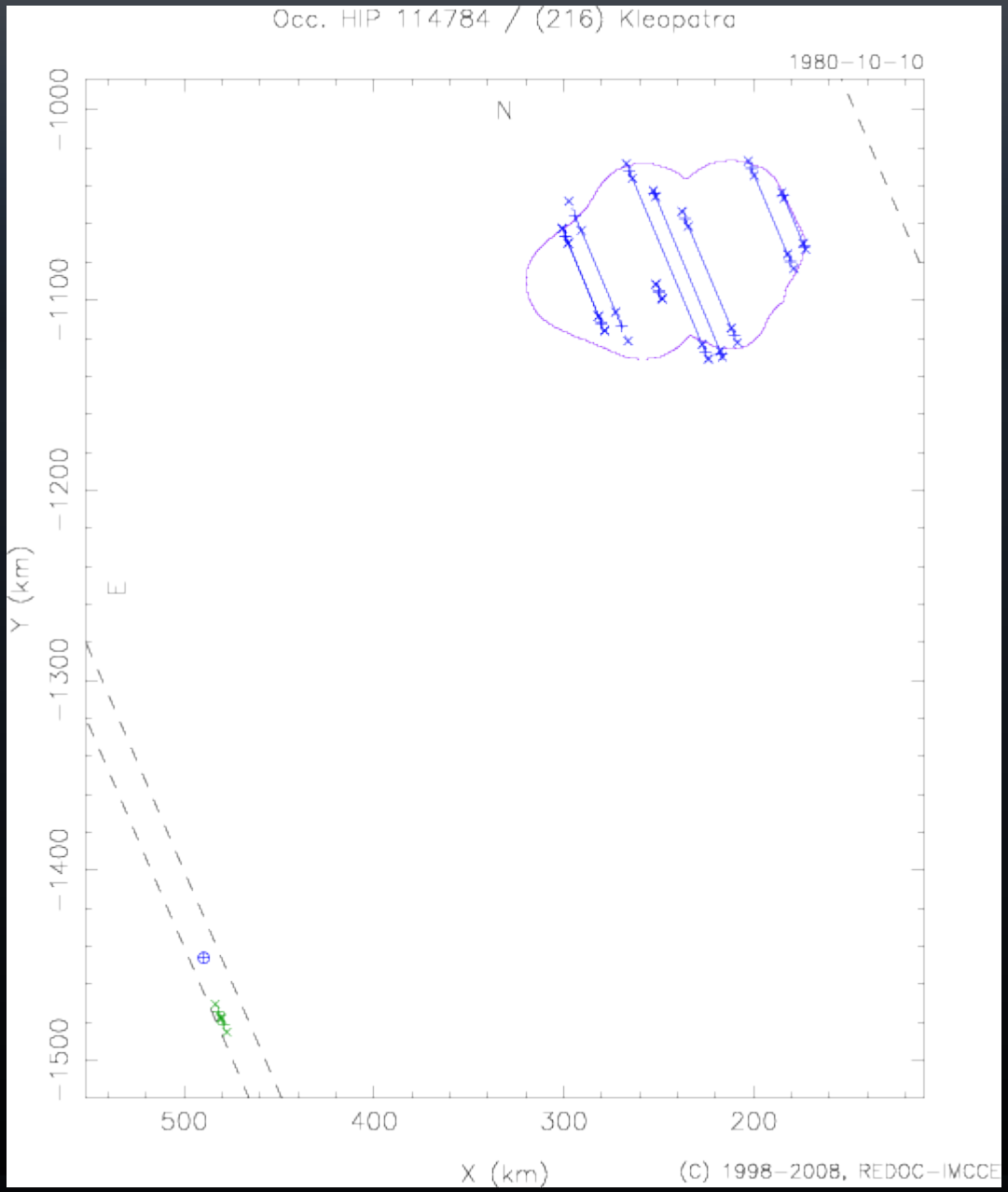
  - Fitting of the profile → first order size and shape
    - Mostly done by the curators of data
    - Published in the case of a particular study

  - Astrometry of the Sso → first order determination
    - Mostly done by the curators of data
    - Very few per-reviewed papers (after 1990's)

... and science

- Scientific analysis of data:
  - Fit of the profile → accurate size and shape of a section
    - Almost nobody (published in the case of particular studies)
  - Combination of sections → 3D size and shape
    - Almost nobody (published in the case of particular studies)
  - Astrometry of the Sso → accurate astrometric position
    - Almost nobody (published in the case of particular studies)

(216) Kleopatra vs HIP 114784 - 1980/10/10



(Descamps et al., 2010)

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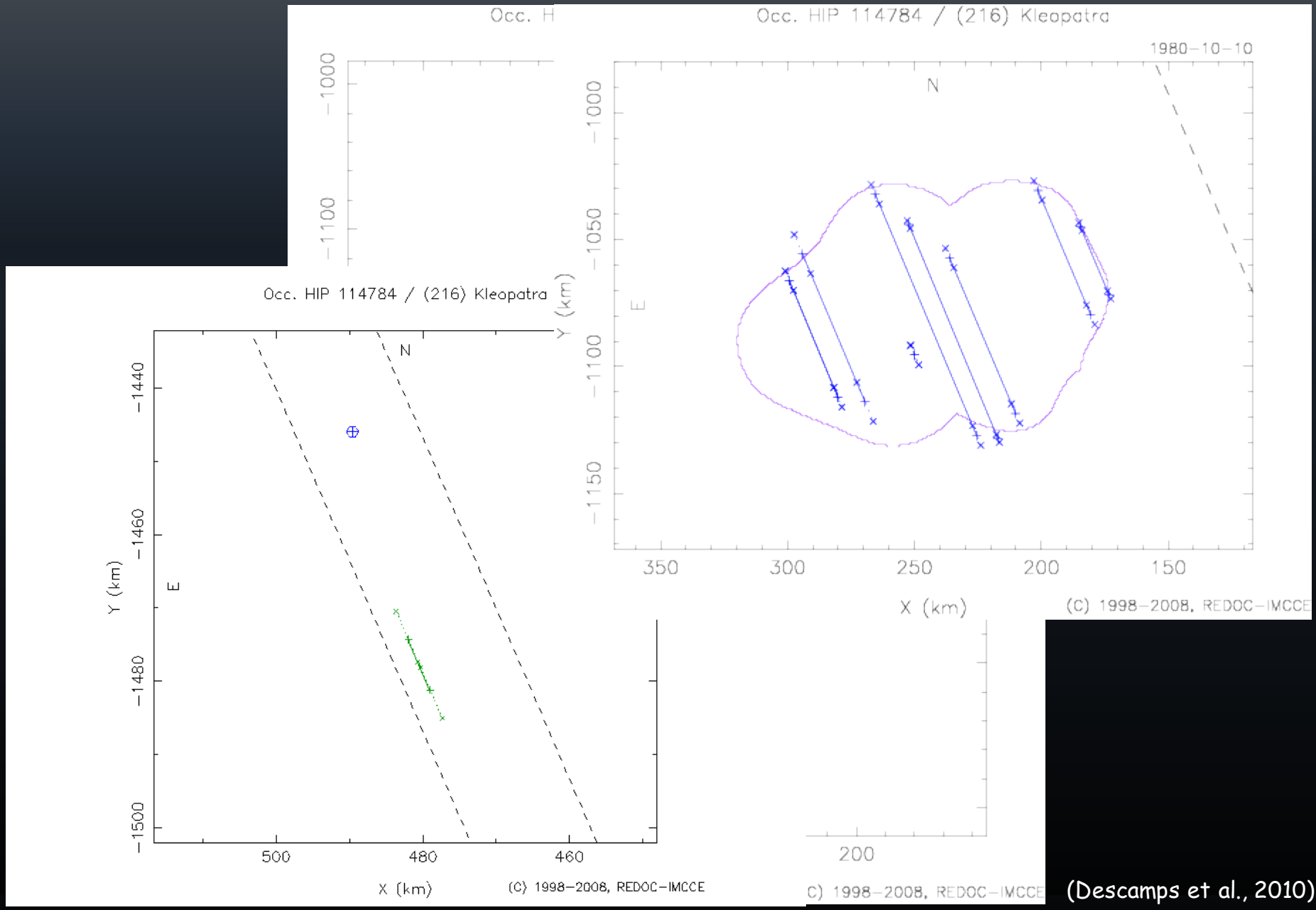
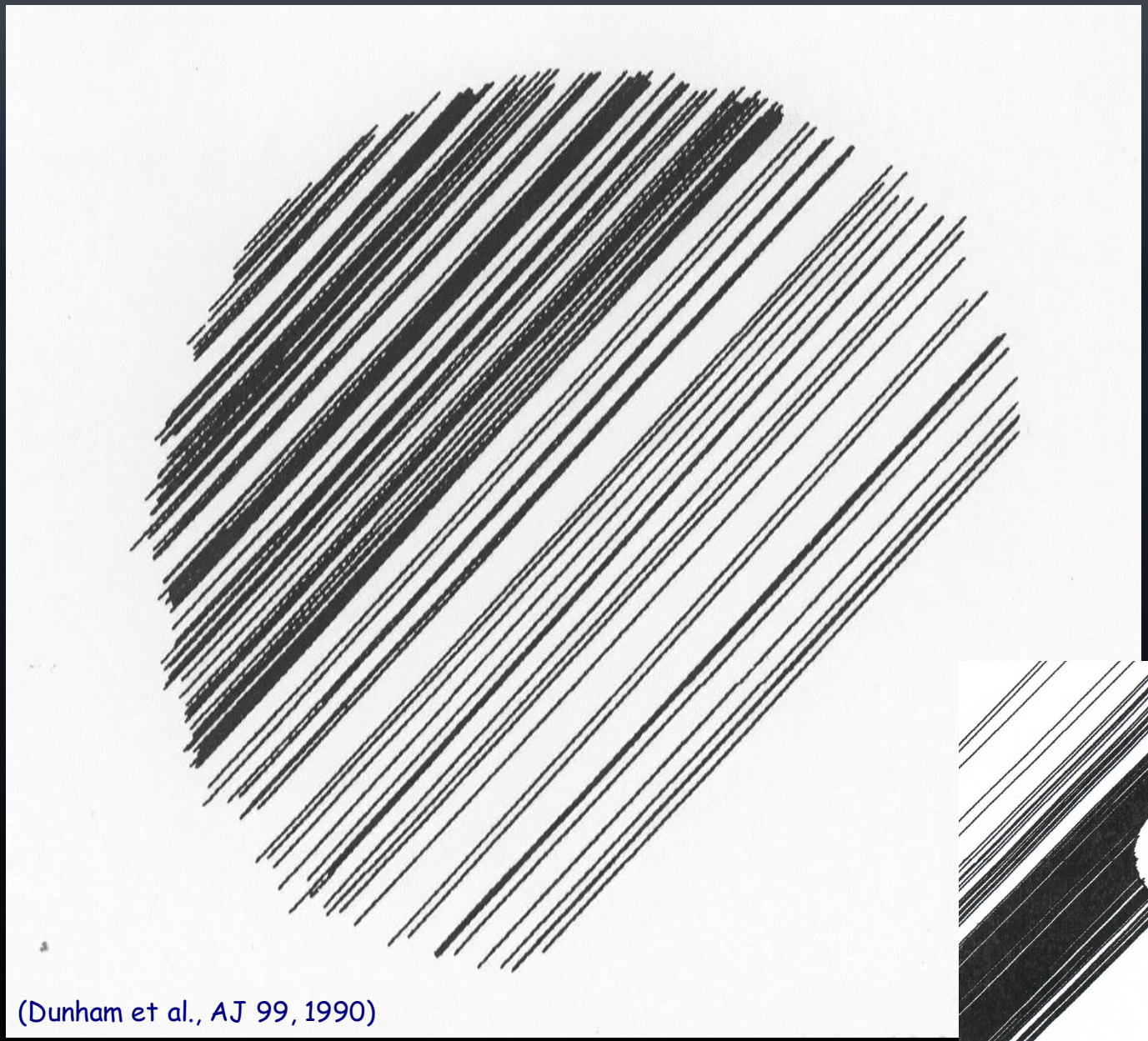


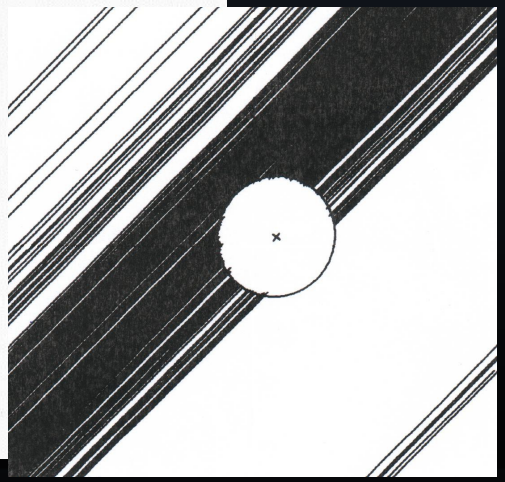
(Descamps et al., 2010)

(2) Pallas vs 1 Vulpeculae - 1983/05/29

135 positive + 111 negative observations

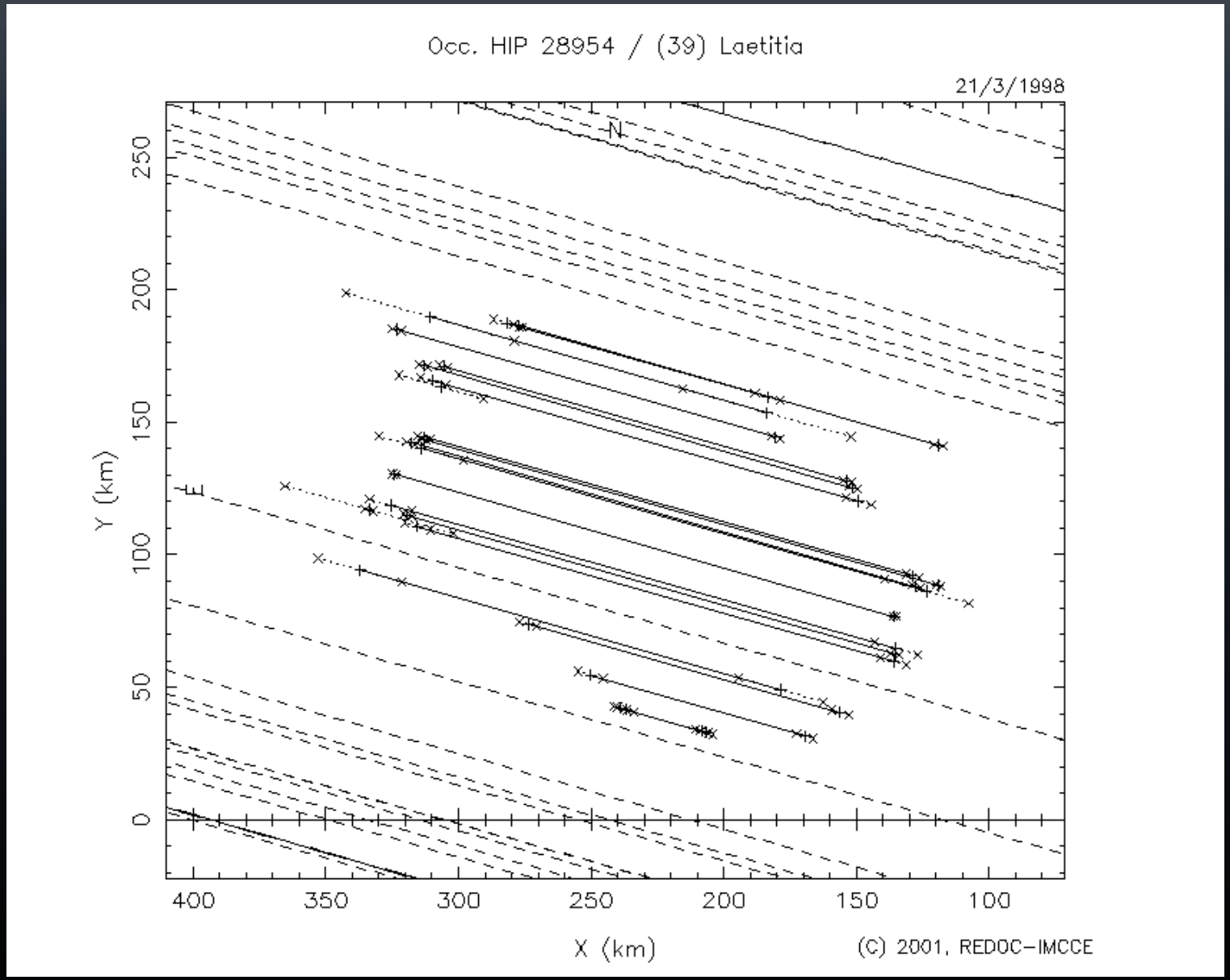


(Dunham et al., AJ 99, 1990)



(39) Laetitia vs Gliese 227 - 1998/03/21

22 positive + 34 negative observations



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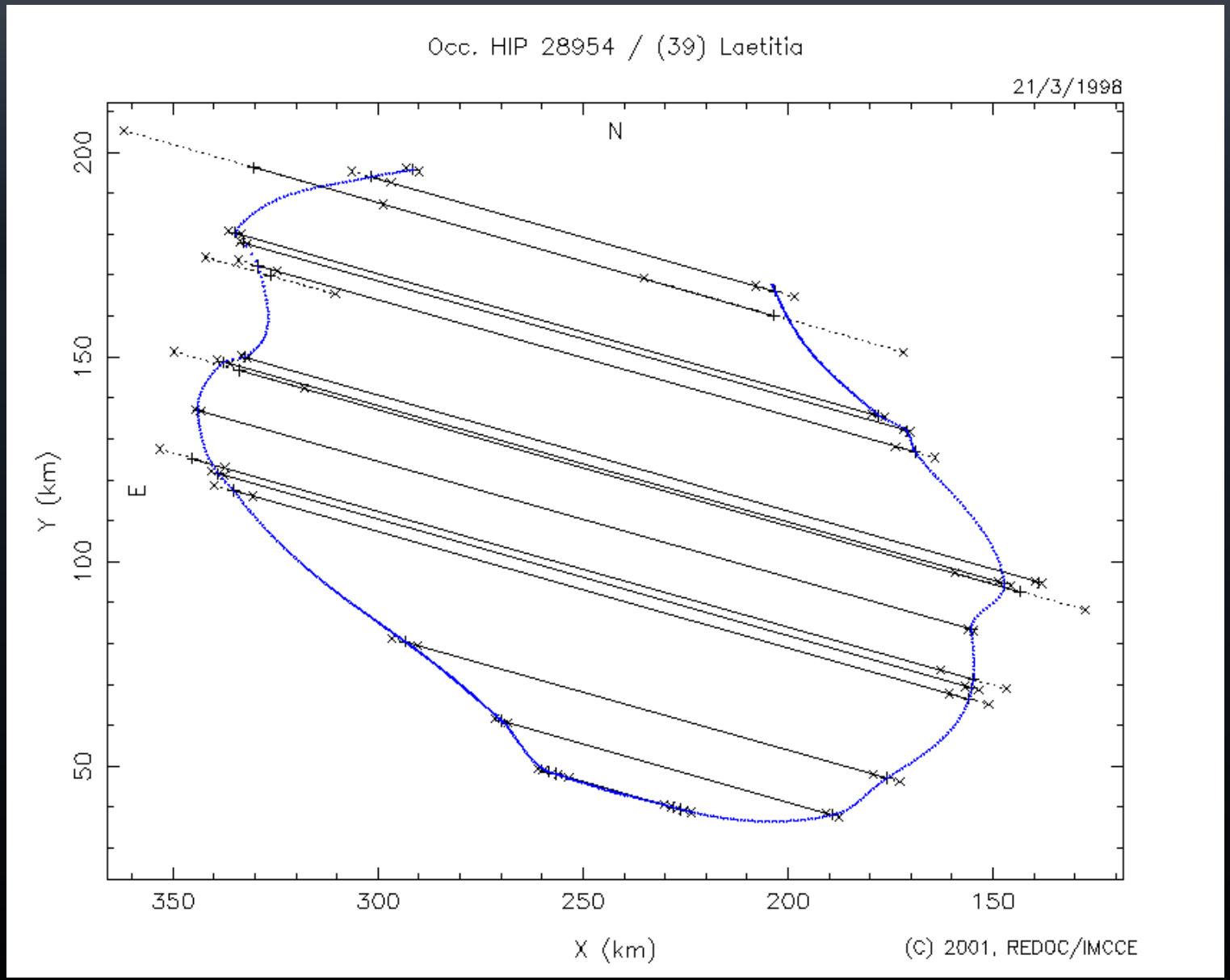
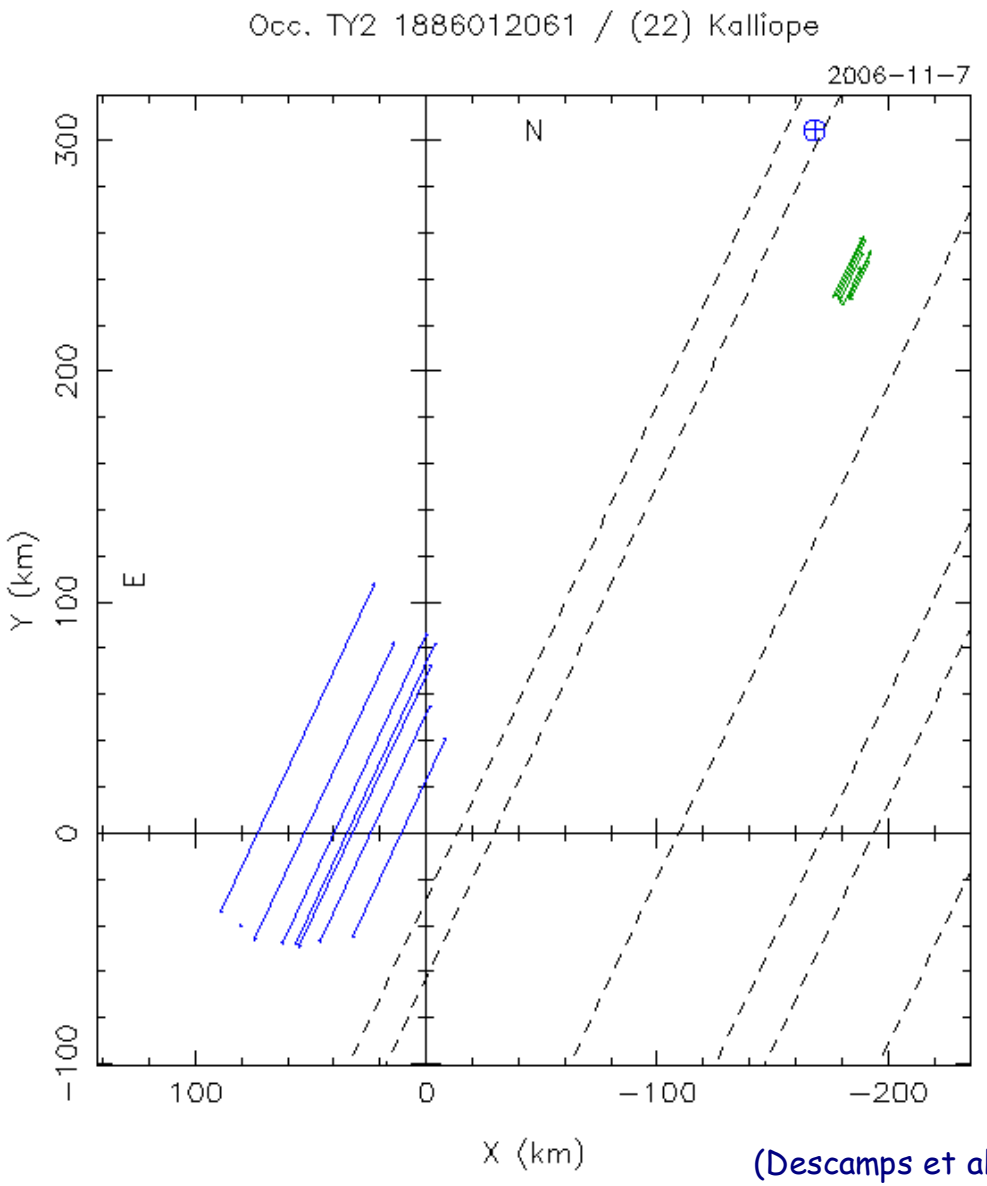
Modeling the profile

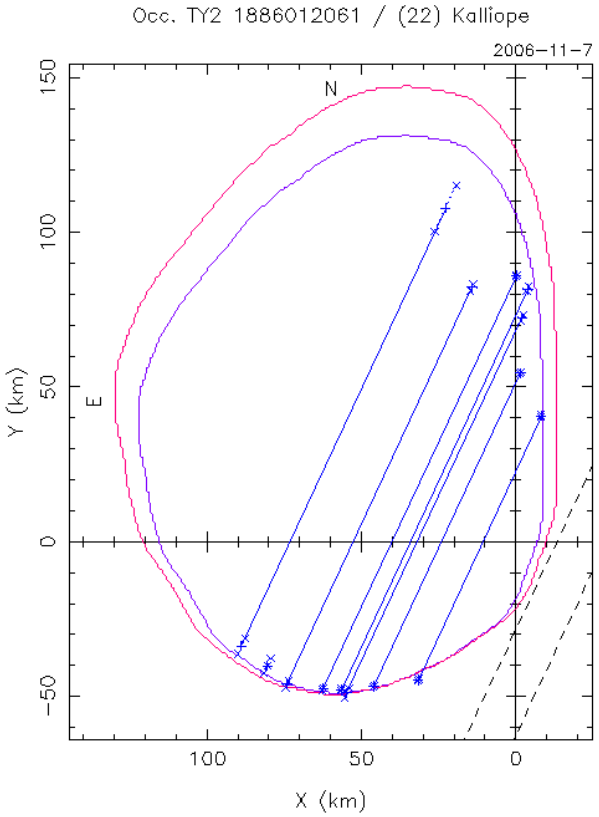


(22) Kalliope vs TY2 1886012061 - 2006/11/07

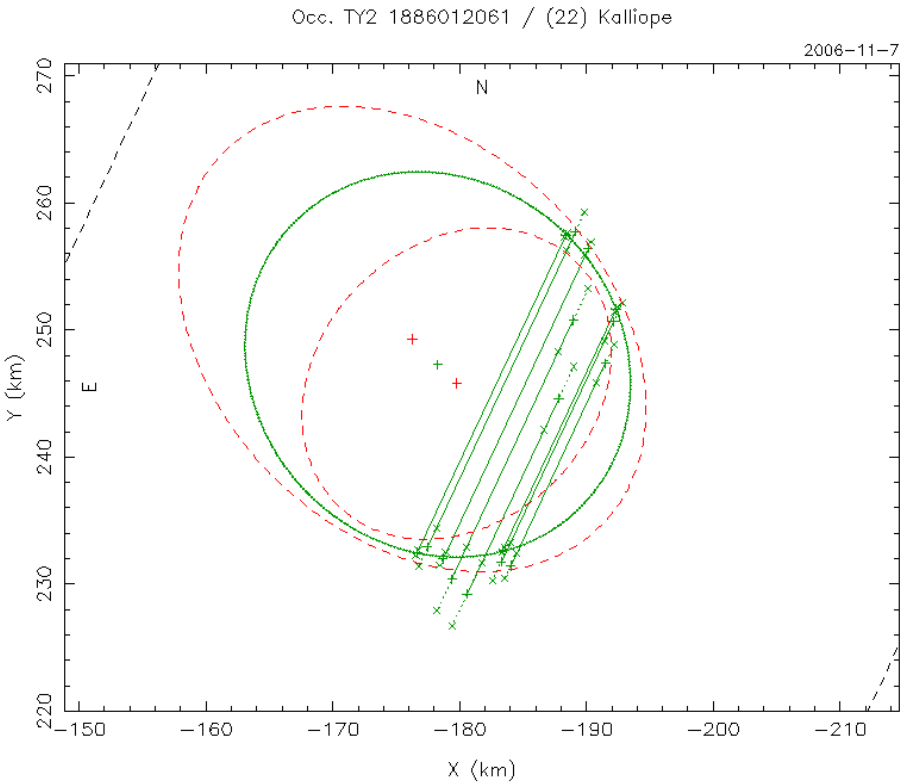


(Descamps et al., Icarus 196, 2008)

(22) Kalliope vs TY2 1886012061 - 2006/11/07



Linus' shape



Kalliope's shape

(Descamps et al., Icarus 196, 2008)

Useful complementary data

- Photometry
  - Orientation of the body at the time of occultation
  - More constraints to fit the profile
- Astrometry
  - Minimum distance between the asteroid and the star
  - Contribution to the improvement of the orbit

Main issues to be solved

- Observational strategy
  - Priorities in the choice of the events
    - x Too much predictions vs useful results
    - √ Dedicated campaigns are usually well followed
  - Mobilization of observers, and geographical distribution
    - x Not each days...
    - √ Effectiveness is no longer in doubt

Main issues to be solved

- Publication of observational data
  - Collection of reports
    - x Depends on the goodwill of few people
    - √ Almost all results are published
  - Format of the data
    - x Many not really ready-to-use formats (IOTA, EAON, Euraster, PDS, ...)
    - √ PDS4 is coming...

=> A common data model is needed as well as a recognized international service of publication

Main issues to be solved

- Improvement of dating methods
  - Accuracy of technics
    - x Human factor! Difficult to calibrate it
    - √ Easy access to accurate time and timing
  - Accuracy of chords
    - x Need to trust observers
    - √ Only a large number of observations allows the cross-matching of event times (cf. Dunham et al. paper reporting Pallas vs 1 Vulpeculae event)