Digitizations in the GAIA framework

The NAROO project
New **A**strometric **R**eduction of **O**ld **O**bservations

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The NAROO project

A new project

- Development of a numerisation facility :
  - photographic plate processings
  - photographic plate analyzes

Which data ?

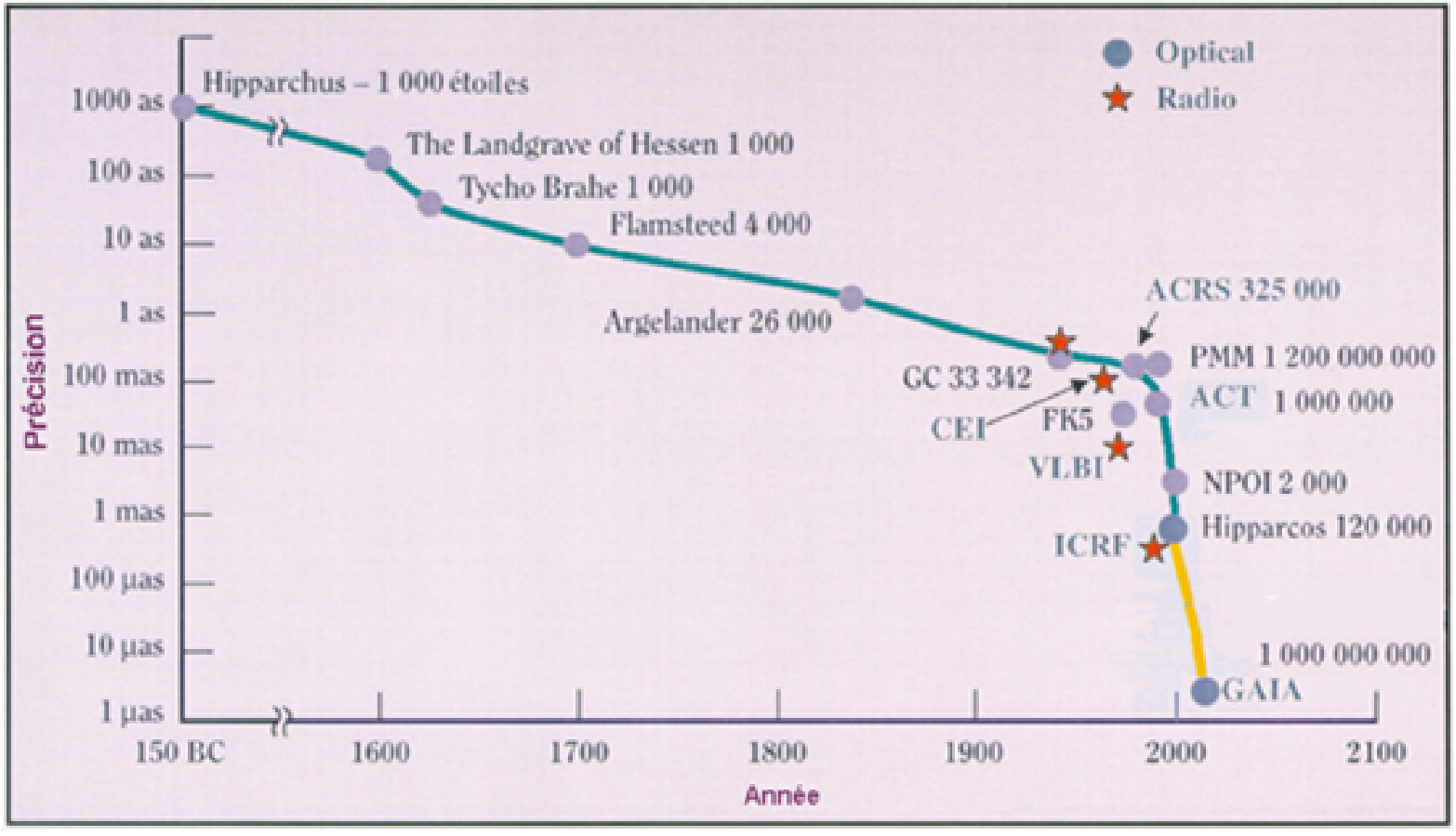
The priority is science !

- Processing of photographic plates mainly for astrometric purposes
- Scientific use for astrometry, celestial mechanics and dynamics
- Gap with concurrent projects : archiving and saving

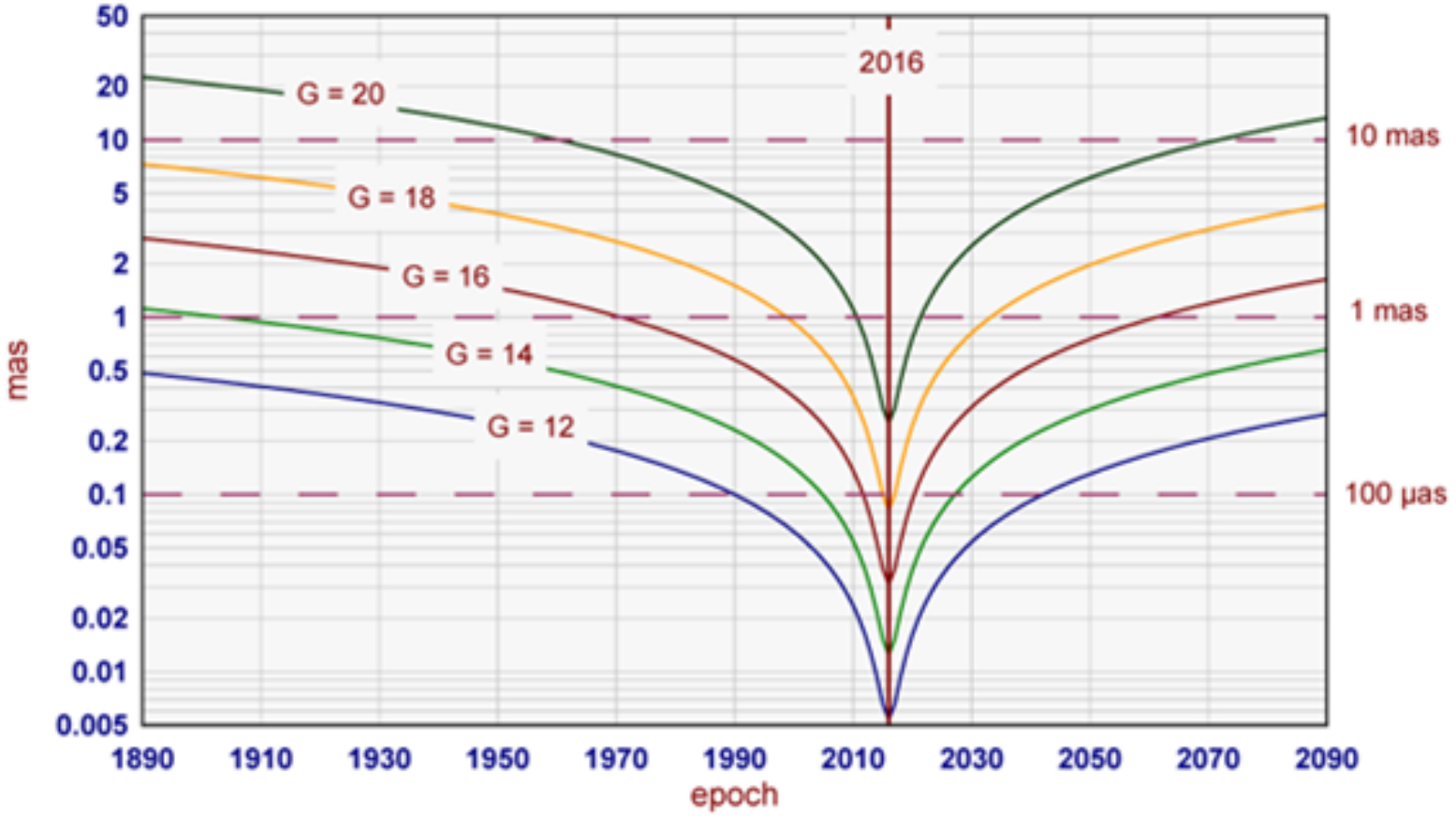
Context

- Interest growing in old observations
- Various projects for different goals :
  - science
  - archiving
  - saving
- Expertise of IMCCE - Paris Observatory and IPSA in astrometry, photometry and spectroscopy
  - reduction of data asked by the U.S. Naval Observatory (Washington DC)
  - reduction of data in european projects
- Increasing of the current catalog accuracies
- The future arrival of the GAIA catalog

Astrometric accuracy



Observe in the past with GAIA



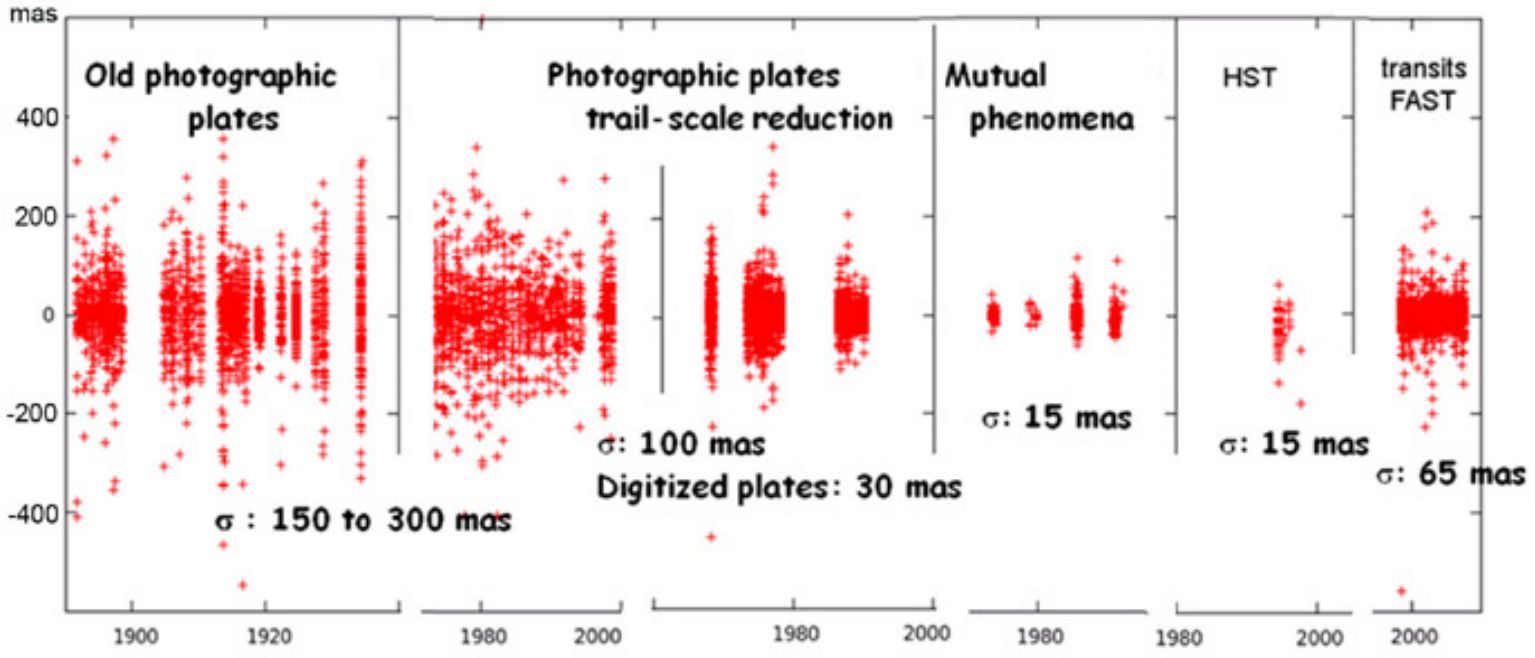
Positional accuracy of the GAIA catalog.

Astronomy

Scientific goals

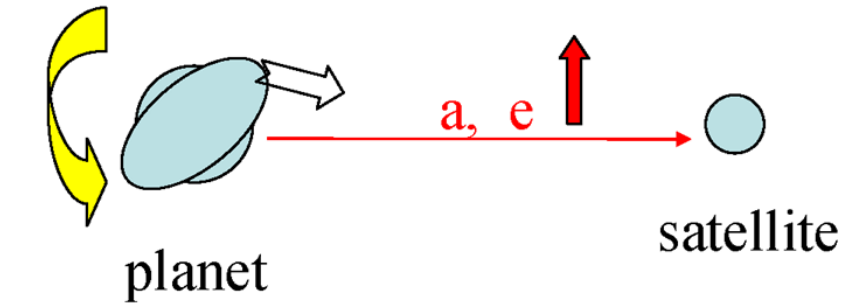
- Analysis of the cumulative effects in time for which the old observations are necessary (dynamics)
- Detection of original informations with old plates (objects that were not detected with the manual analysis)
- Reach an order of magnitude in terms of accuracy comparing with “classical” reductions
  - machine technical performances
  - development of new and suitable reduction softwares
  - introduction of “neglected” effects
  - use of new star catalogs : UCAC2, UCAC4, GAIA, ...

Astrometric observation accuracies



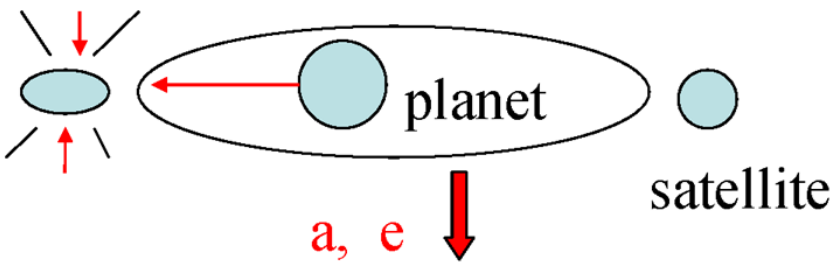
Measurement of longitude drifts in satellite motions with astrometry.

The example of dissipations in icy moons



Tides from satellite to planet

↳ Satellite escapes

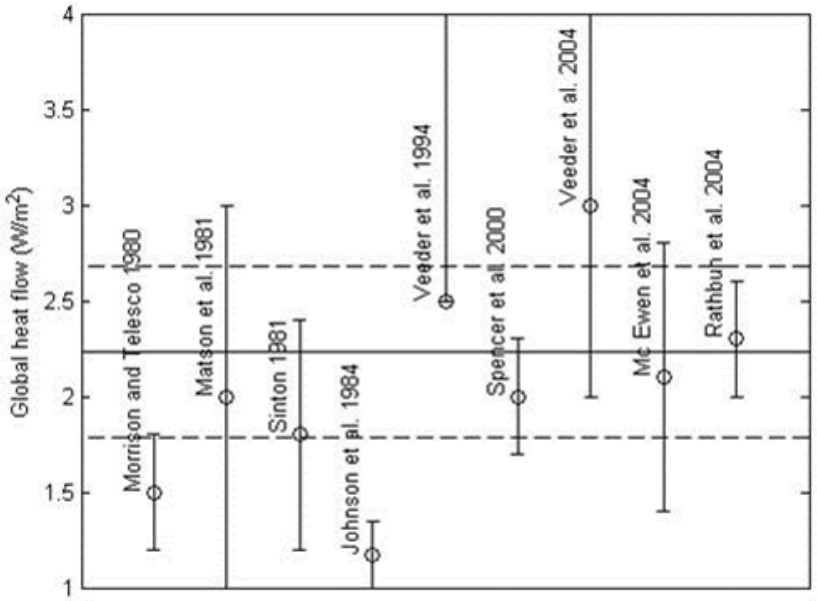


Tides from planet to satellite

↳ Satellite falls

Measurement of longitude drifts in satellite motions with astrometry.

The example of surface flows vs internal heat

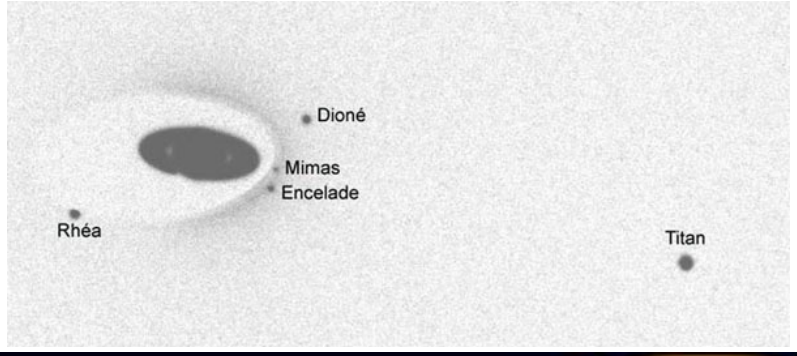


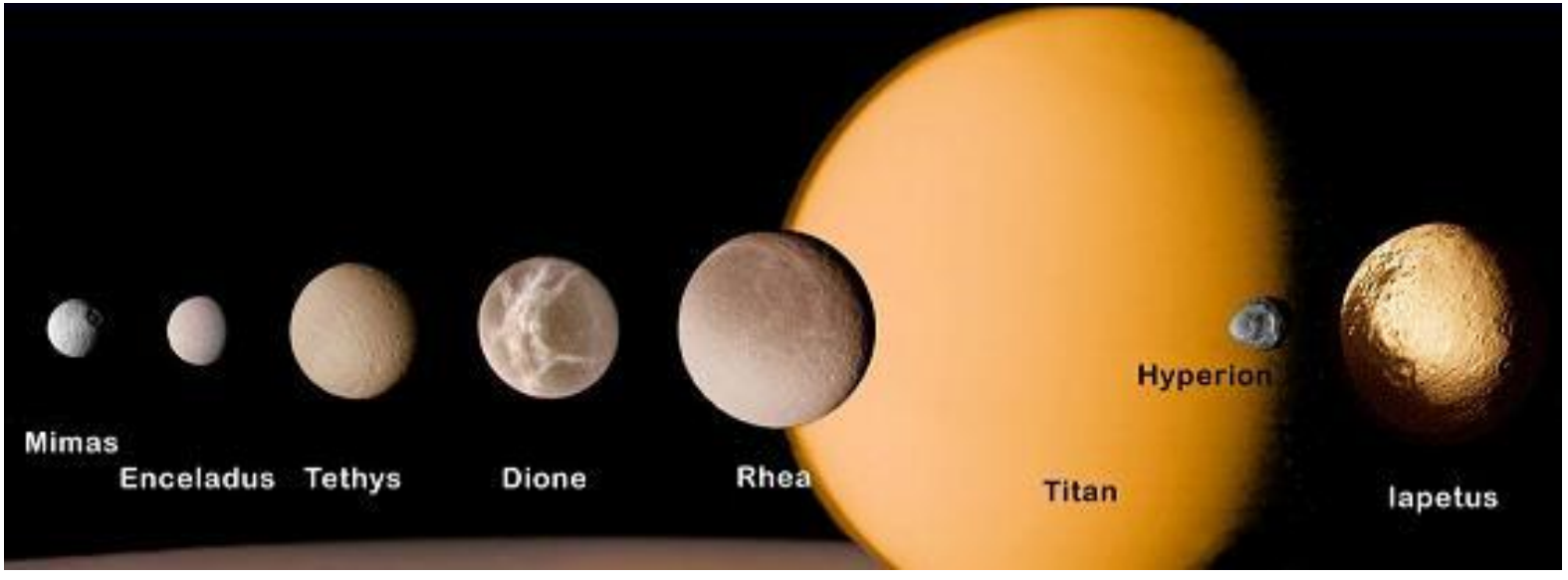
Flows calculated with astrometric observations and dynamical models.

There is a concordance between the observed surface flow and this calculated with astrometric observations and the complete dynamical model including the tidal effects.

Io is in thermal equilibrium !

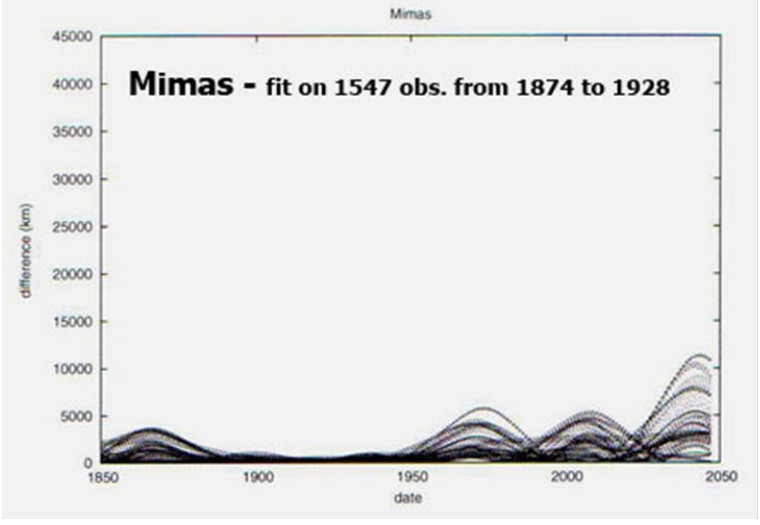
The example of the Saturnian moon formations

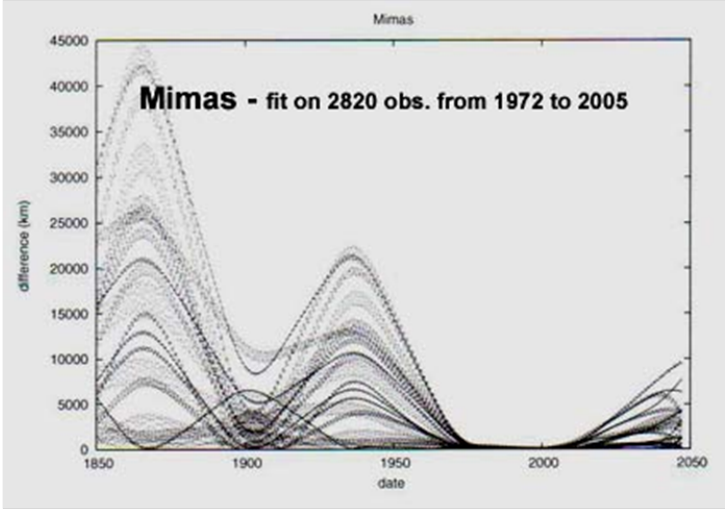




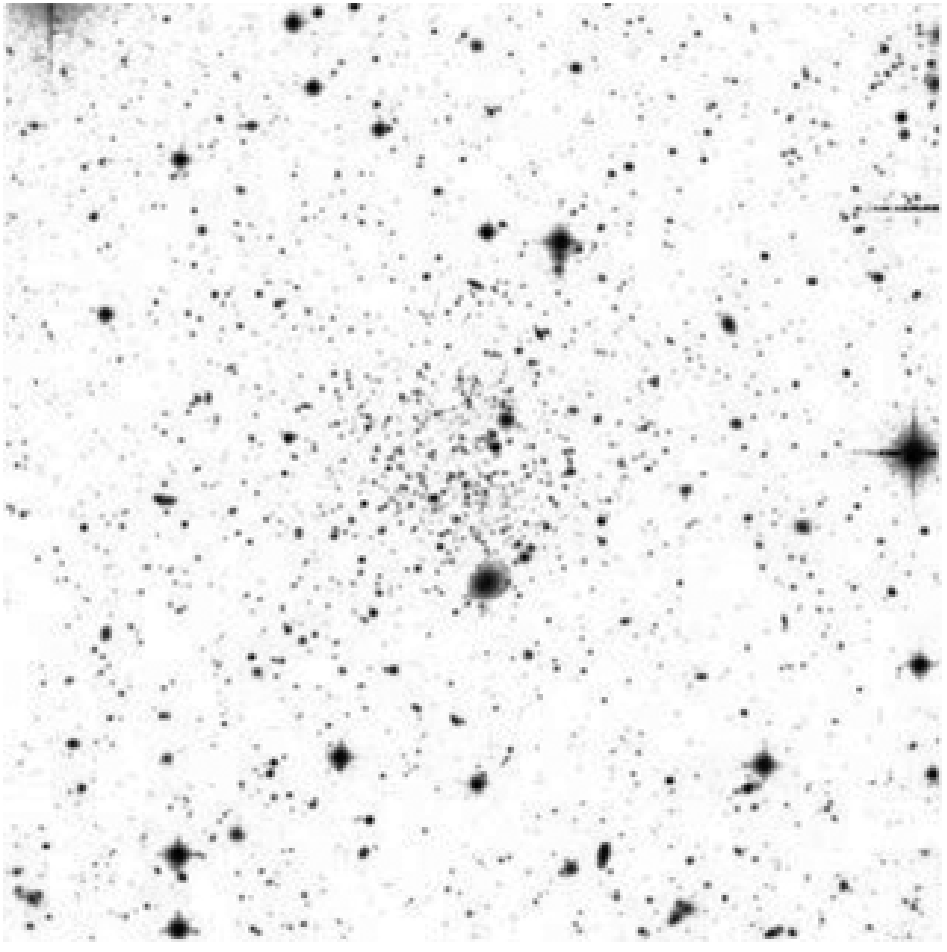
The example of the spatial missions

- The ephemerides are only valuable over their fitting periods
- Even if the accuracy is ordinary, if the fitting period is over a long time span the extrapolation will be better

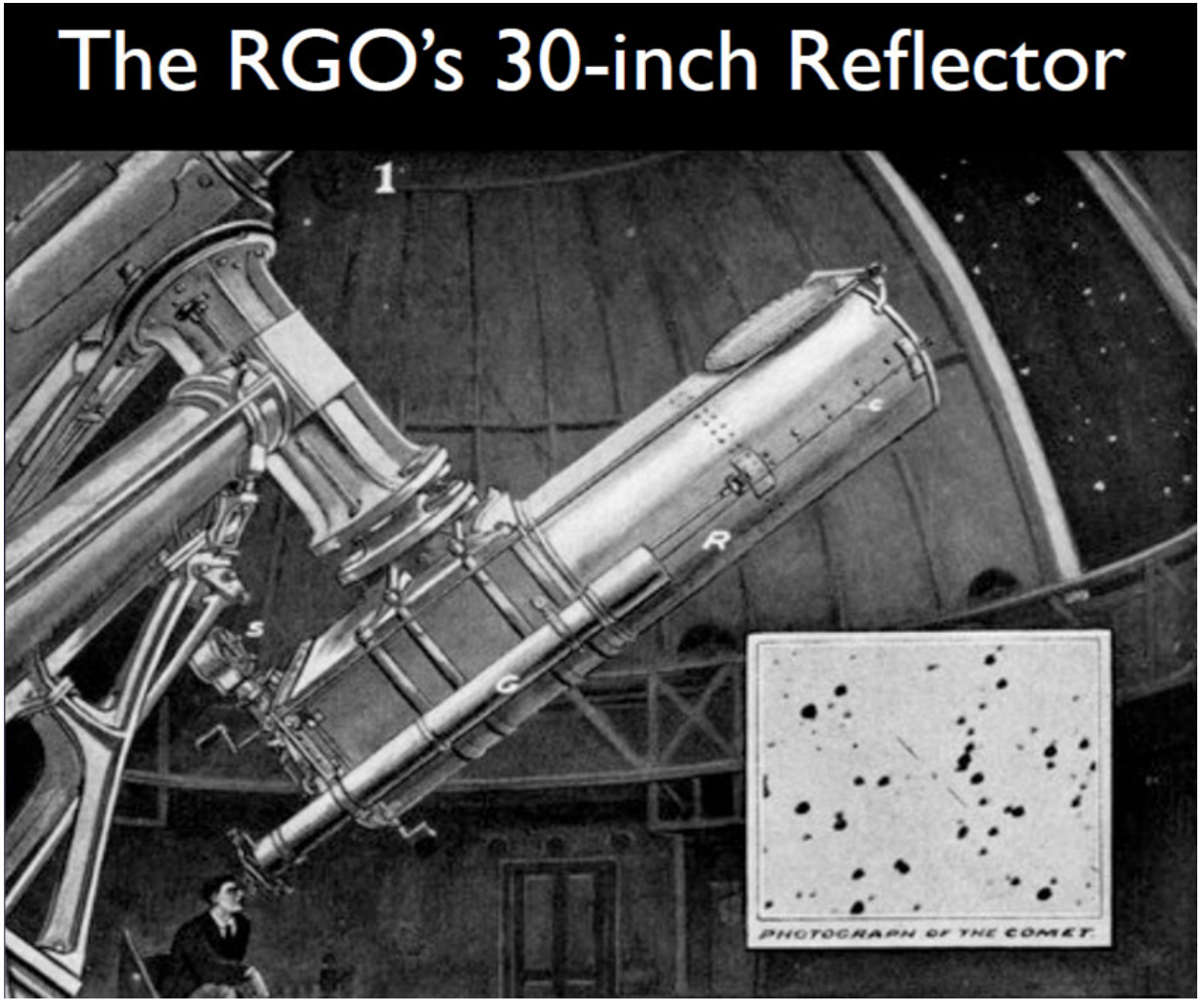




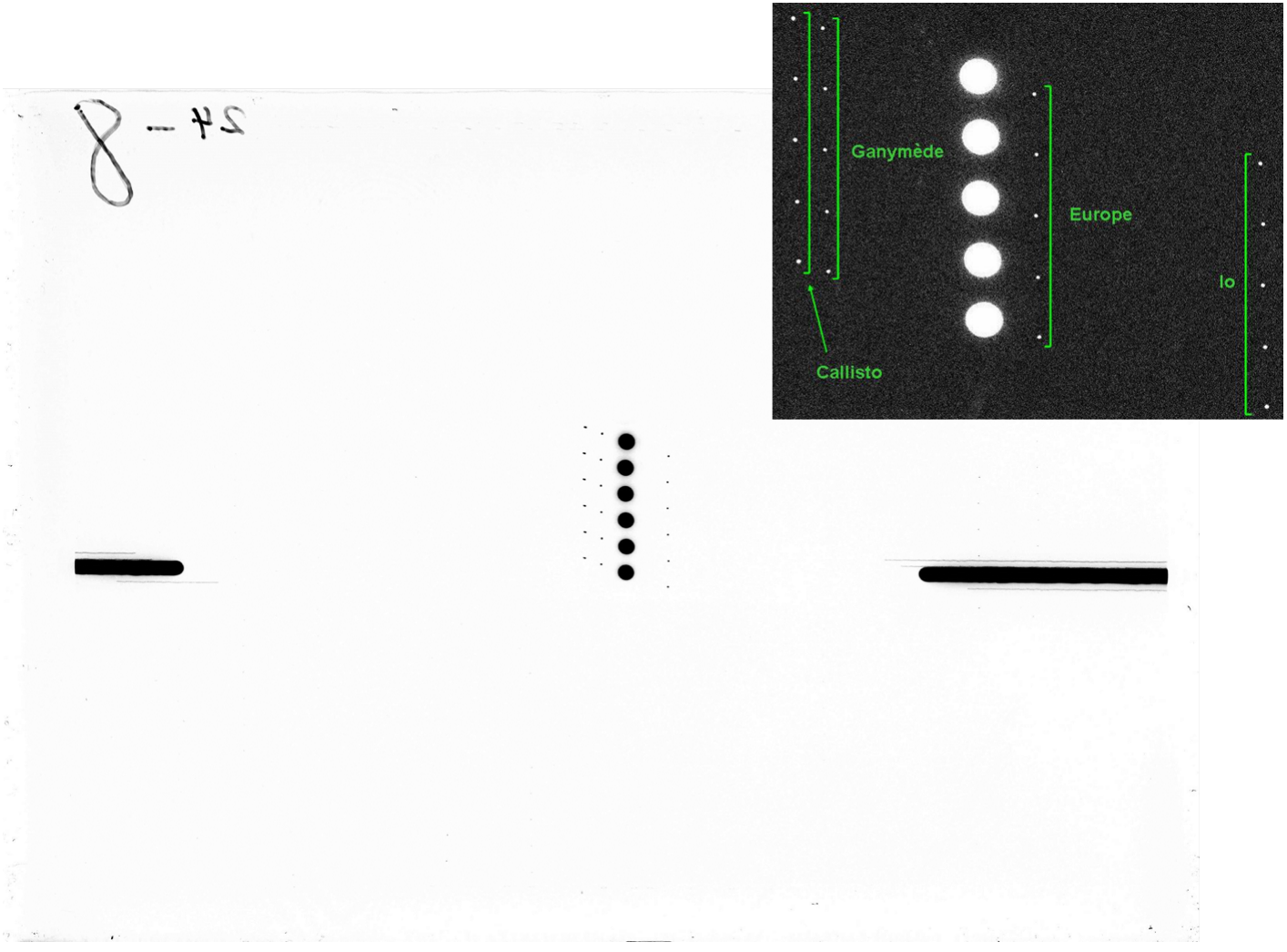
Pre-discoveries of asteroids (TNO's, ...)



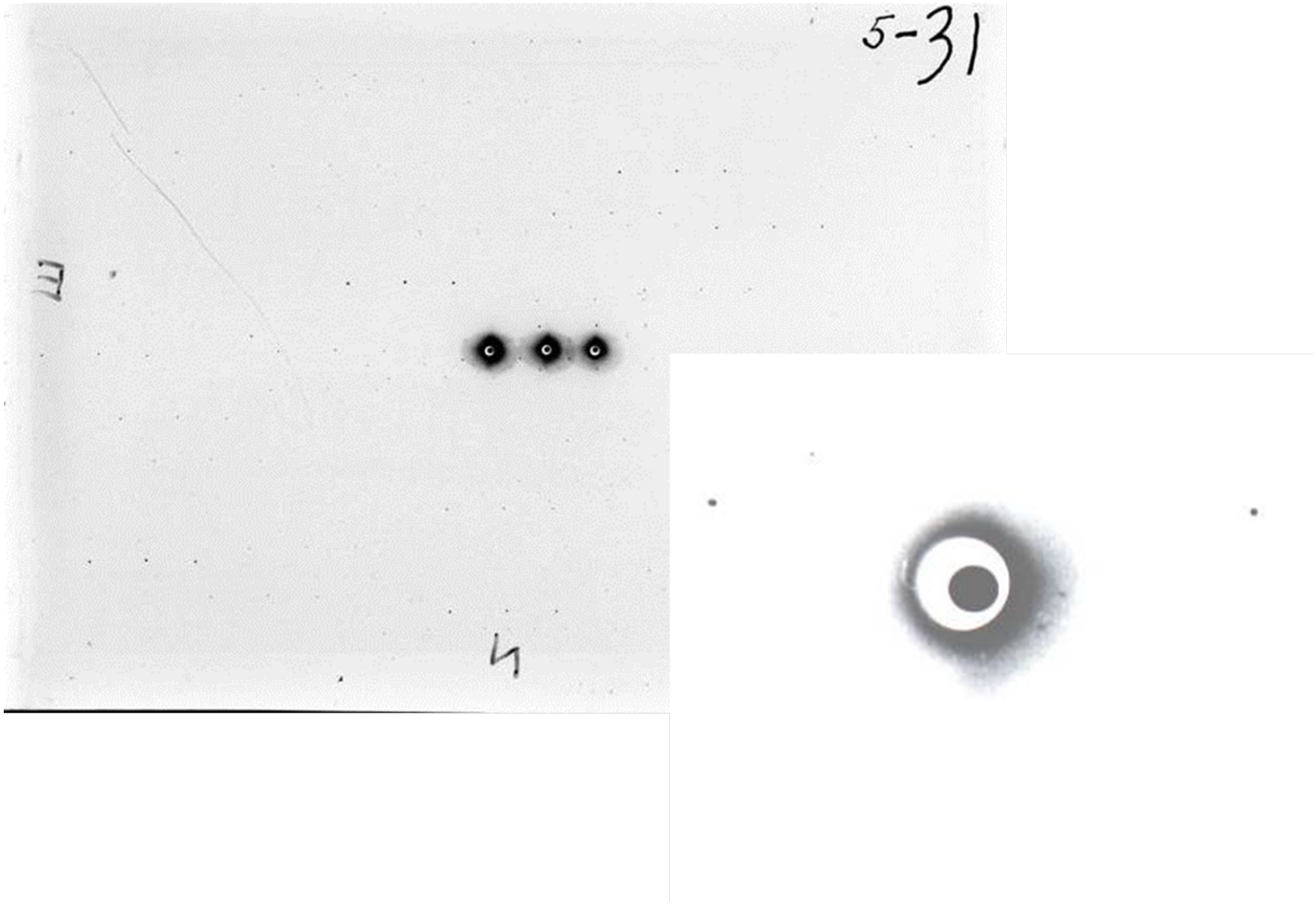
Comets



The Galilean moons



The martian satellites



NAROO workshop

- 45 participants coming from 16 institutes : IMCCE, IPSA, IAP, ROB, Pulkovo, Nikolaev, JPL, QMUL, USNO, Shanghai, ...
- 30 communications
- 11 observatories and institutes intended to go further in the partnership

Overview and results

Technical meanings

- Development of a sub-micrometric numerisation facility :
  - location Paris Observatory
  - international pruposes
- Installation of a sub-micrometric digitizer

- Choice of astrometry vs photometry
- Choice of high precision vs speed
- Optimization of the digitization criteria : spatial resolution, accuracy, dynamics

- Partnerships :
  - Other institutes with equivalent needs
  - Observations outside the Solar System (evolutive phenomena)
  - Non-astronomical plates (heritage)

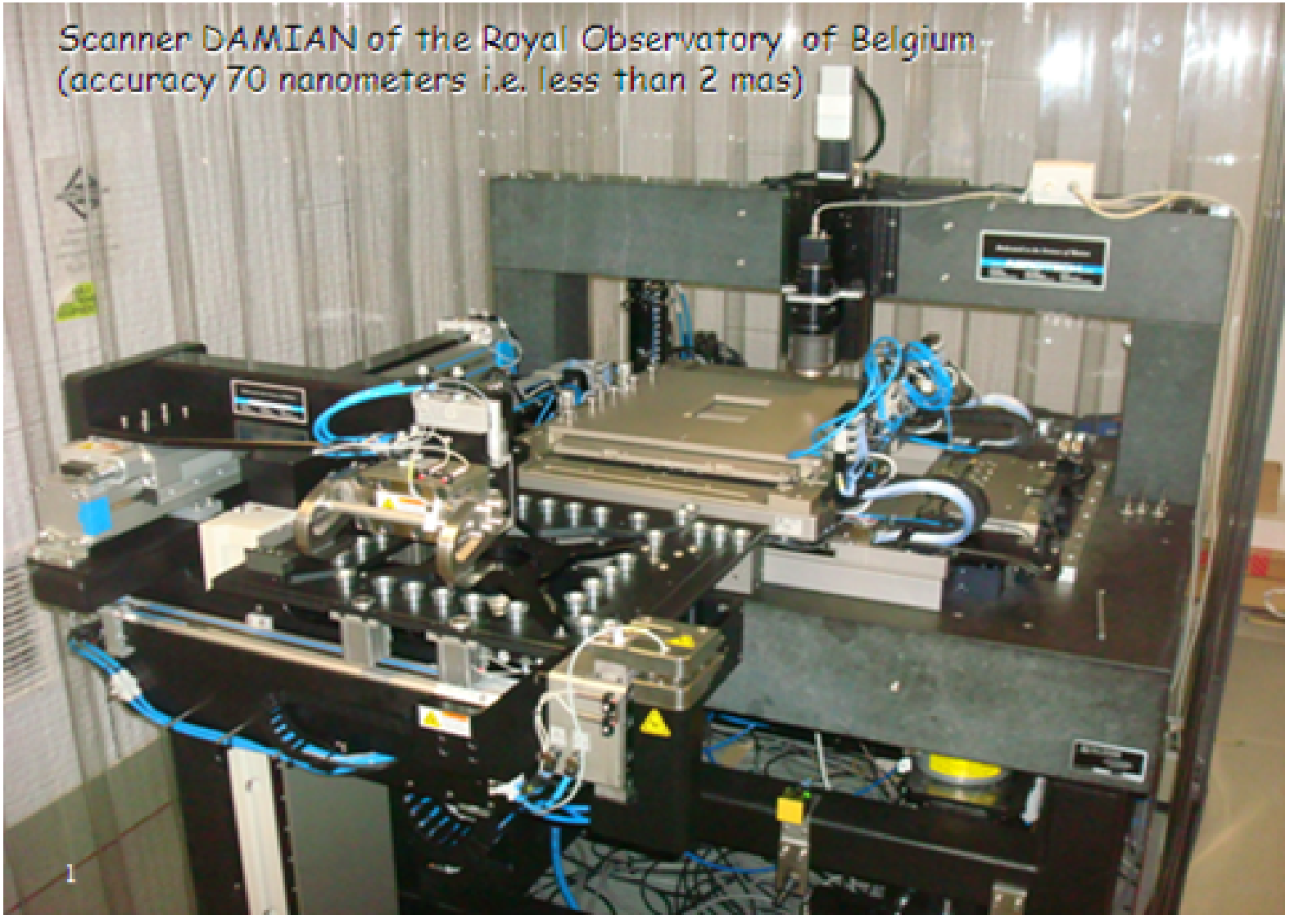
Previous projects

- MAMA - Paris Observatory (1000 nm)
- StarScan - U.S. Naval Observatory (500 nm)

- Harvard University scanning "historic sky project" (1000 nm)
- Pulkovo Fantasy digitizer (1000 nm)
- DAMIAN - Royal Observatory of Belgium (70 nm)

	MAMA	StarScan	DAMIAN
Scan speed	1 h	20 min	8 min
XY positioning	1 μm	0.1 μm	0.001 μm
XY positioning repeatability	1.17 μm	0.50 μm	0.07 μm

The example of the DAMIAN machine for the first tests



Preliminary works

- Selecting the observed objects :
  - Icy moons
  - Irregular satellites
  - Planets from satellites
  - Pre-discoveries of asteroids, TNO's, comets and NEO's
  - Be stars
- Selecting the photographic plates :
  - Huge number of available photographic plates (200.000)
  - Plates taken with long focus refractors (3-20 m)
  - Plates taken with mean and long focus reflectors (Schmidt plates eventually)
  - Plates since 1890 with corresponding metadata
  - Plates in good condition

Preliminary results

- Tests with the DAMIAN machine :
  - 500 photographic plates of the Galilean satellites from 1967 to 1998
  - Use of the UCAC2 catalog
  - Comparison with previous reductions

(X, Y) positions

Accuracy of 30 mas (90 km) instead of 100 mas (300 km) !

(α, δ) psitions

Accuracy of 60 mas (180 km) with spherical positions for the first time !

Galilean residuals

	$\overline{(O-C)}_{\alpha \cos \delta}$	$\sigma_{\alpha \cos \delta}$	$\overline{(O-C)}_{\delta}$	σ_{δ}
DE421	-1.7	63.0	40.0	73.1
DE423	-1.8	62.8	38.1	71.5
INPOP06	-6.1	63.0	37.4	71.6
INPOP08	44.1	69.3	47.8	91.6
INPOP10	3.0	62.8	37.4	71.1
EPM08	-2.3	63.1	37.6	71.3

Residuals observation/ephemerides for the planet Jupiter.
Validation of the dynamical models.

Testing the planetary ephemerides (for Jupiter)

	DE200	DE405	DE421	INPOP06	INPOP08	INPOP10
1967-1979	-36	20	-4	-7	75	0
1980-1989	-88	12	-2	-8	42	3
1990-1998	-119	-8	-6	-12	12	-2

α residuals in mas.

	DE200	DE405	DE421	INPOP06	INPOP08	INPOP10
1967-1979	4	30	35	29	59	22
1980-1989	6	32	30	25	41	27
1990-1998	46	19	14	17	-5	22

δ residuals in mas.

Colloquium communications and papers

- ADASS : De Cuyper J.P., Winter L., De Decker G., Zacharias N., Pascu D., Arlot J.E., Robert V., Lainey V., 2009, ADASS XVIII, New astrometric reduction of the USNO photographic plates of planetary satellites, 411, 275
- EPSC : Thuillot, W. ; Lainey, V. ; Dehant, V. ; Arlot, J. E. ; de Cuyper, J. P. ; Gurvits, L. I. ; Hussmann, H. ; Oberst, J. ; Rosenblatt, P. ; Marty, J. C. ; Vermeersen, B. : 2011, ESPACE, European Satellite PArtnership for Computing Ephemerides
- DPS : Robert, Vincent, J. ; Arlot, J. ; Lainey, V. ; Pascu, D. : 2012, A new reduction of USNO Photographic Plates of the Martian satellites
- GREAT SSO : J.E. Arlot, J. Desmars, V. Lainey, V. Robert, The astrometry of the natural planetary satellites applied to their dynamics before and after Gaia, workshop in Pisa, Italia, 2011 may
- USNO seminar : Arlot J.E., Robert V. : Latest results on astrometric observations of natural satellites and giant planets, 2013 may

Publications

- Robert et al. : 2011, A new astrometric reduction of photographic plates using the DAMIAN digitizer : improving the dynamics of the Jovian system, MNRAS 415, 701
- J.-E. Arlot, J. Desmars, V. Lainey, V. Robert : 2012, The astrometry of the natural planetary satellites applied to their dynamics before and after Gaia, PSS 73, 66
- Robert et al. : 2014, Results from the analysis of Galilean satellite plates 1967-1998, A&A in review
- Robert et al. : 2014, Results from the analysis of Martian satellite plates 1967-1998, A&A in review
- Robert et al. : 2014, Results from the analysis of Saturnian satellite plates 1967-1998, A&A in review

Questions