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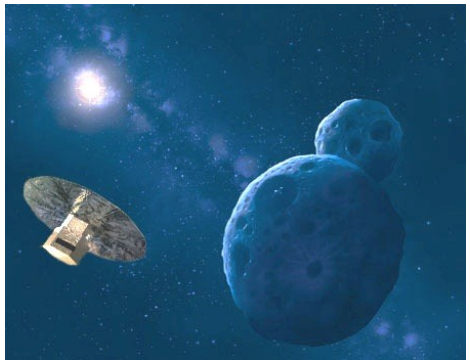

Solar System science Gaia and LSST

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Observatoire de la CÔTE d'AZUR

LAGRANGE

Big questions concerning asteroids

- Formation and evolution of Earth
  - Bringing water to Earth
  - The Earth dynamical environment (Potentially Hazardous Asteroids)

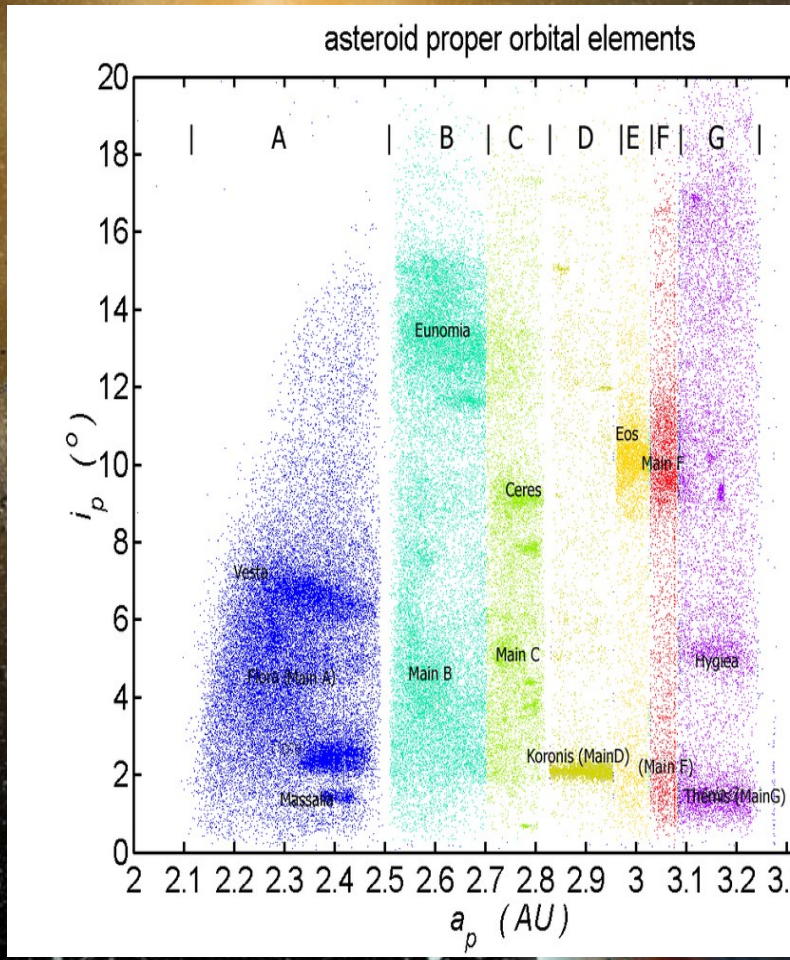
- Formation of our Solar System
  - Traces of the primordial formation
  - Dynamical evolution

- Formation and evolution of other planetary systems

→ Small bodies (asteroids, comets, TNOs…) as remnants of the planet formation processes

Motivations for Solar System / asteroid studies

- How big did the asteroids/planetesimals formed?
- Are there some primordial objects left?
- Degree of radial mixing dynamical evolution
- Were primordial objects differentiated?
- Composition and internal structure of asteroids



Past and future surveys

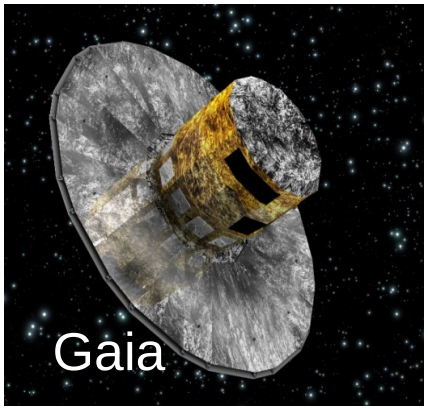
2005 2014 2020 2030

SDSS

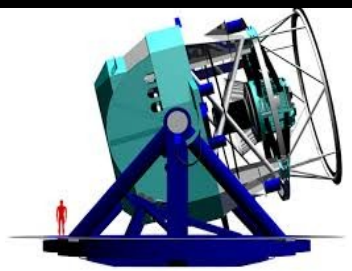
LINEAR

Catalina Sky Survey

Pan-STARRS



LSST Large Synoptic Survey Telescope



Starts when Gaia ends

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Gaia and the Solar Syster

- Gaia will NOT collect observations of « large » bodies (> 600 mas)
  - Main Planets, large satellites

- Comets
- « Small » planetary satellites
  - « regular »
  - « irregular » (retrograde orbits)

- Asteroids (~300.000)
  - Mainly Main Belt Asteroids (MBA)
  - Several Near Earth Crossers (NEO)
  - Other populations (trojans, Centaurs,..)

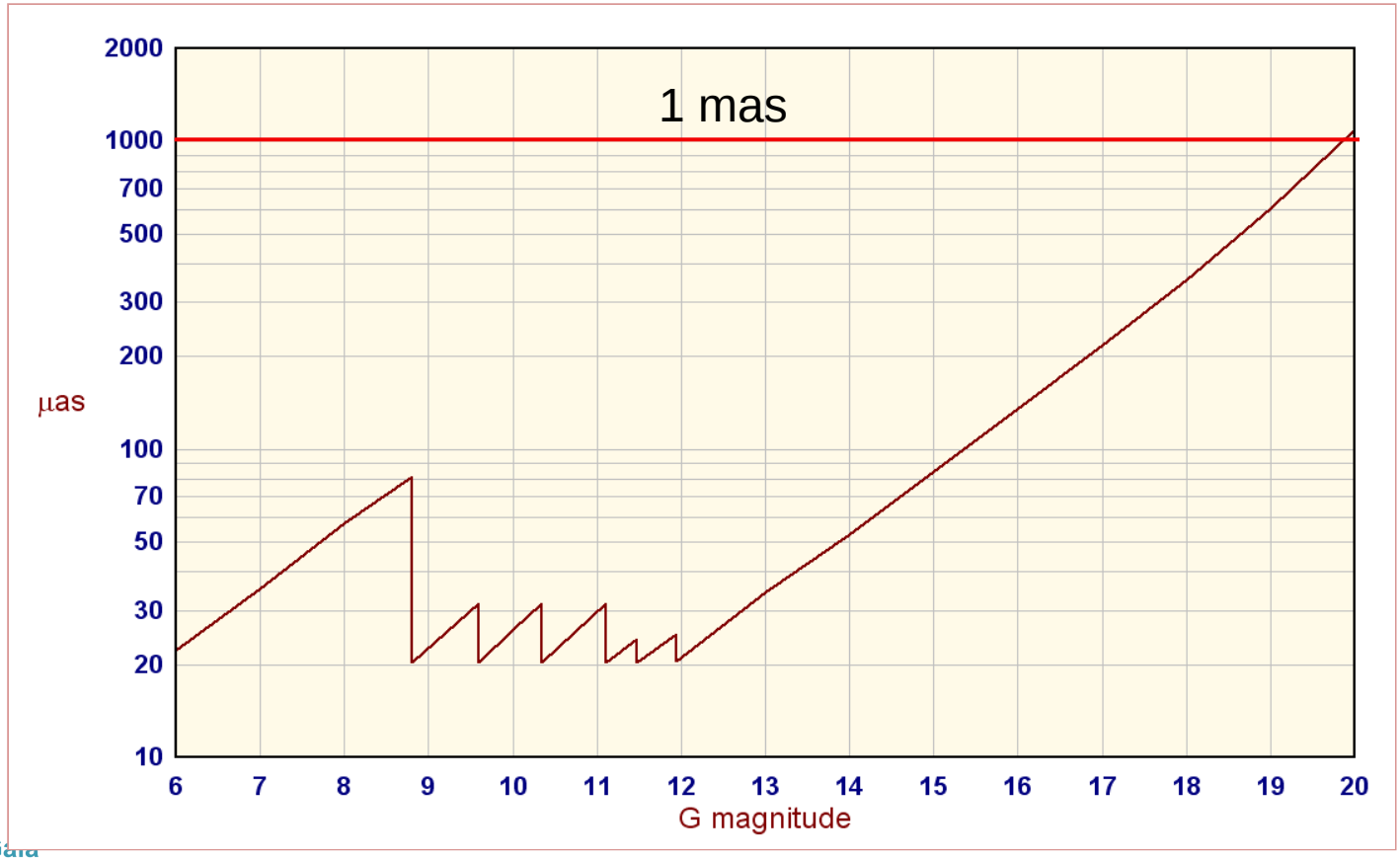
...poorly known in general:

  - >600.000 identified
  - 50% « good » orbit; <1% rotation period; <0.1% approx. shape; <0.5% spectral type; <0.01% mass.

6 < V < 20, size <600 mas ~70 observations / object

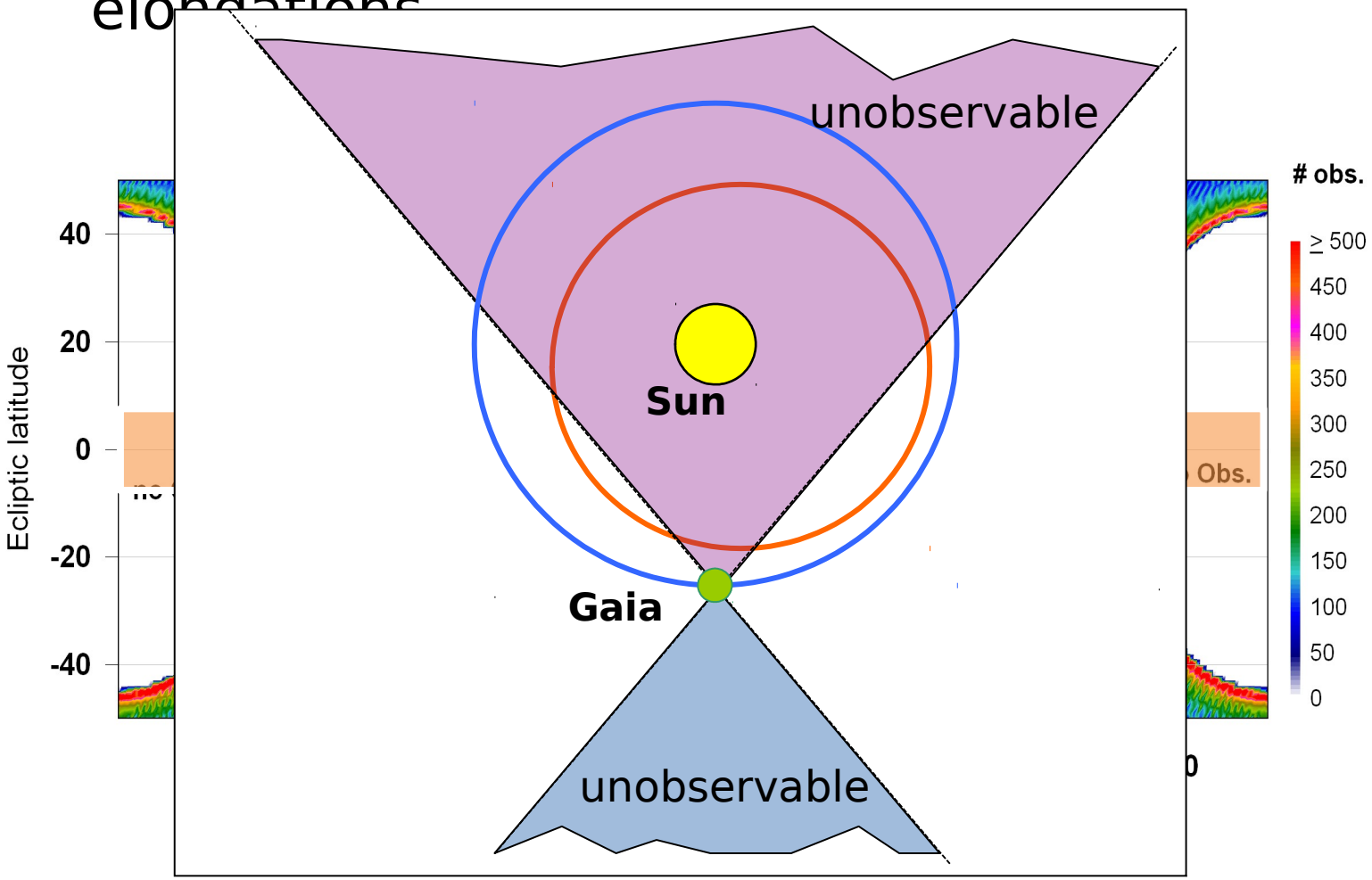
Astrometric accuracy: single observation

- Small field accuracy with final attitude
- Single observation accuracy orbit refinement (x 100)
  - one field transit, final attitude
  - point source



Gaia peculiar scanning

Solar System objects only at preferred elongations



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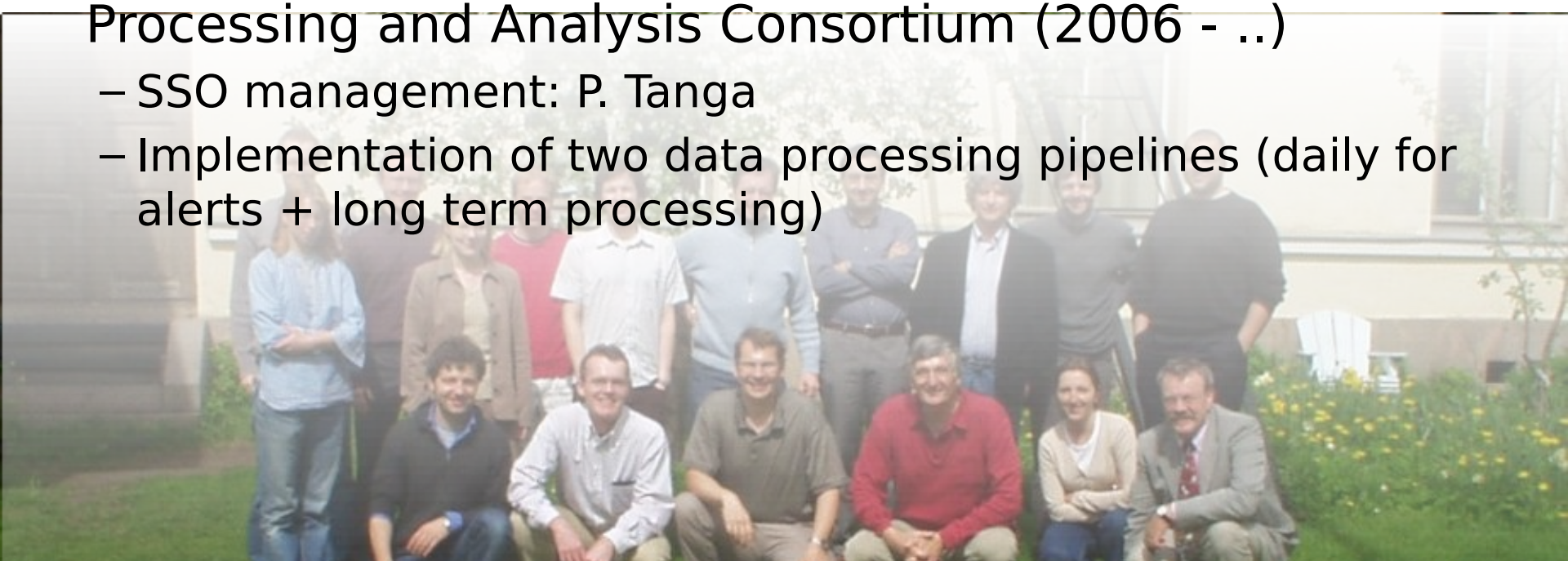
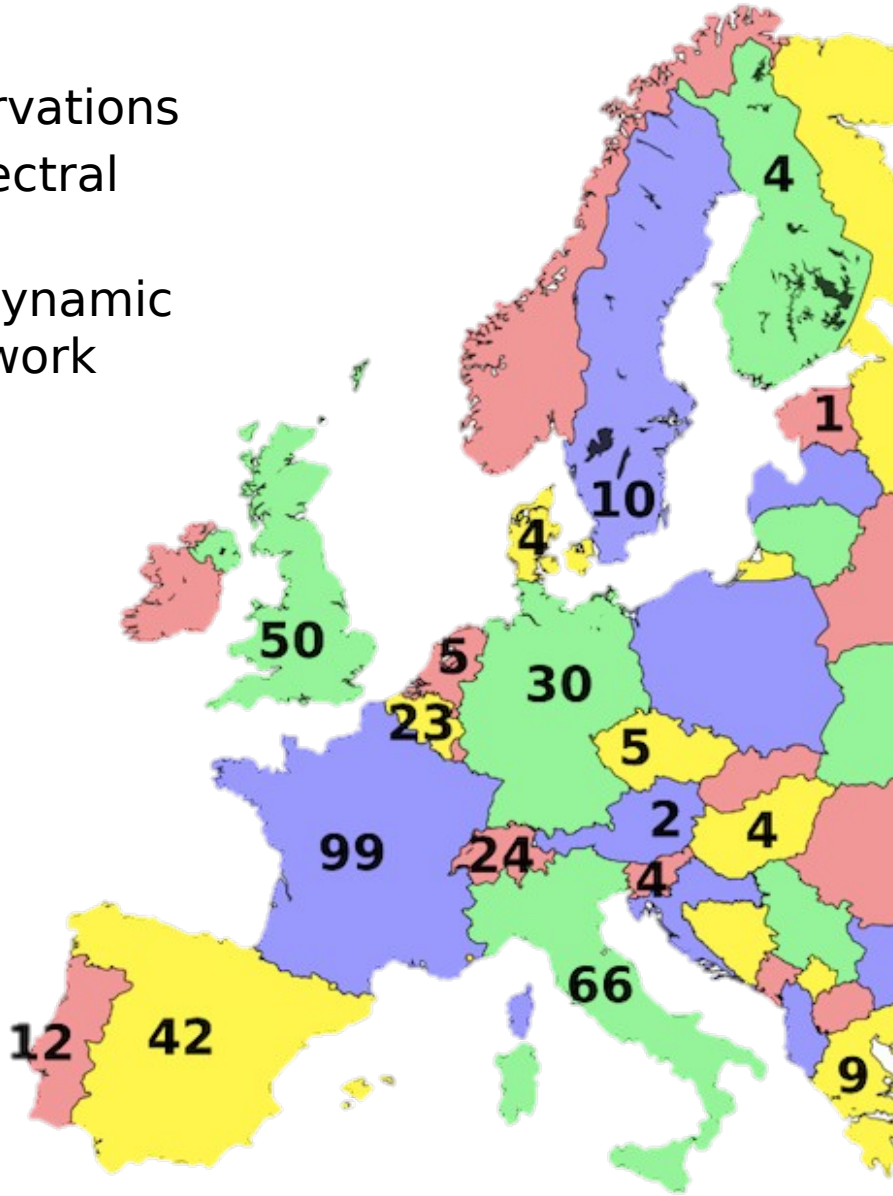
The scientific community, Solar System and Gaia

- before 2000 : preliminary studies
- 2001 – 2005 : Solar System Working Group
  - coordinator: F. Mignard
  - main achievements:
  - preliminary assessment of performance and science outcome
  - identification of problematic technical issues
- Smooth transition to Coordination Unit 4 inside the Data Processing and Analysis Consortium (2006 - ..)
  - SSO management: P. Tanga
  - Implementation of two data processing pipelines (daily for alerts + long term processing)



Strong implication of the French community

- For the Solar System:
  - Besançon “threading” of the observations
  - Nice coordination, simulations, spectral properties, photometry inversion
  - Paris object identification, global dynamic model, ground-based follow-up network
- Data Processing Center : CNES in Toulouse (specific team)
- Expertise useful for LSST ?



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Identified goals for Solar System science

Astrometry

- Systematic survey - discoveries possible (in particular at low solar elongations)
- Orbits : X 100 improvement
- Perihelion precession for 300 planets : GR tests
- Masses from close encounters ~ 100 masses expected
- Discoveries of new objects

CCD signal

- Diameter for over 100s asteroids (density)
- Binary asteroids (separate sources > 120 mas)

RP/BP spectrophot

- Spectro-photometric data: composition, taxonomic classification
- Sparse photometry over 5 years : rotation, pole, shape

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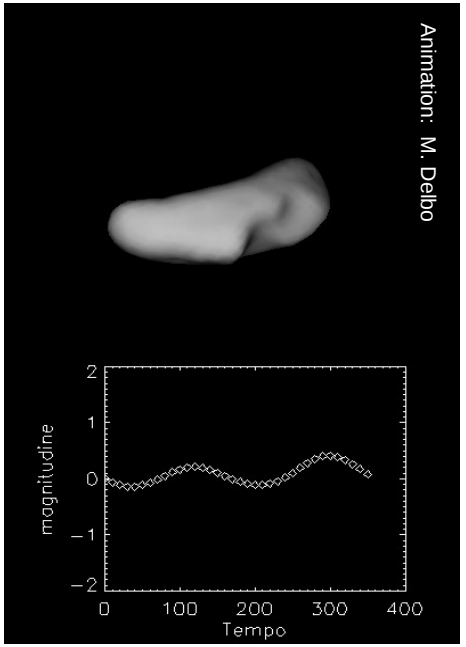
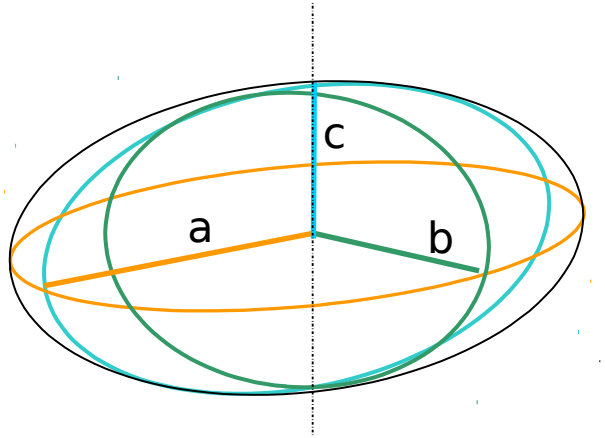
Photometry Shapes

- Inverse problem:
  - find the rotation parameters from photometric data
  - strongly non linear
  - usually solved from “dense” light curves (~100s-1000 observations)



- Choice for Gaia:
  - Three-axial ellipsoids
  - Genetic algorithm for determining 7 parameters:
  - Semi-axis (a, b, c)
  - Pole coordinates (λ, β)
  - Rotation period (T)
  - Slope magnitude vs. phase angle (scattering)



- LSST: much better time sampling

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Our knowledge – before and after Gaia

Property	today	Gaia
astrometry	~ 0"5	0"005
orbits	~ 0"1-100"	x30 times
shapes, poles	100	~100,000
rotation periods	4000	~100,000
satellites	~ 50 (MBA)	hard to pr
spectral types	~ 1000	~200,000
masses, σ < 50%	~ 50	150
size	~ 500	1000

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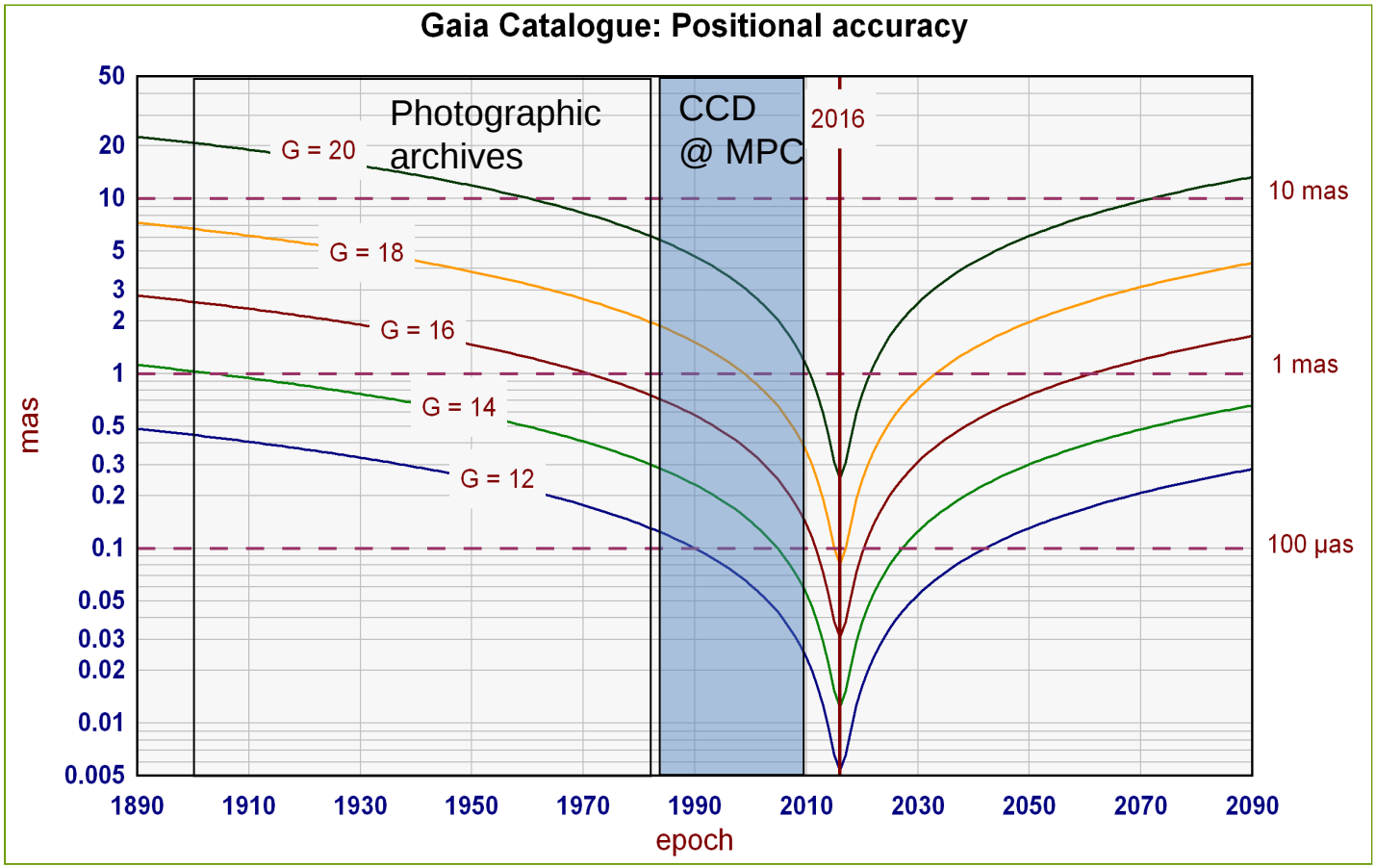
Gaia: Indirect impact for solar system science

Reprocessing “old” plates and CCD frames: very small catalogue errors



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Gaia/LSST: Similarities

- Conceptually very close projects:
  - Integrated survey systems: observatory + telescope + camera + data management
  - No PI mode, proprietary time, proposals…
  - Ultimate delivery are the fully reduced data (not the telescope/instrument, not the raw observation)

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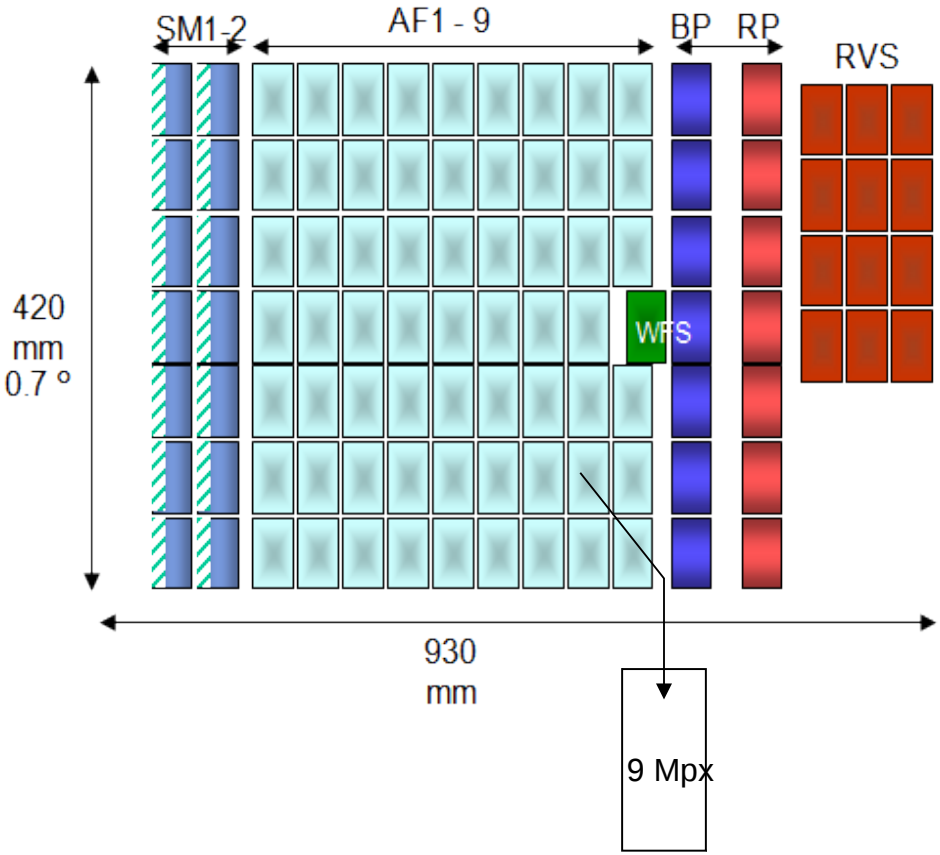
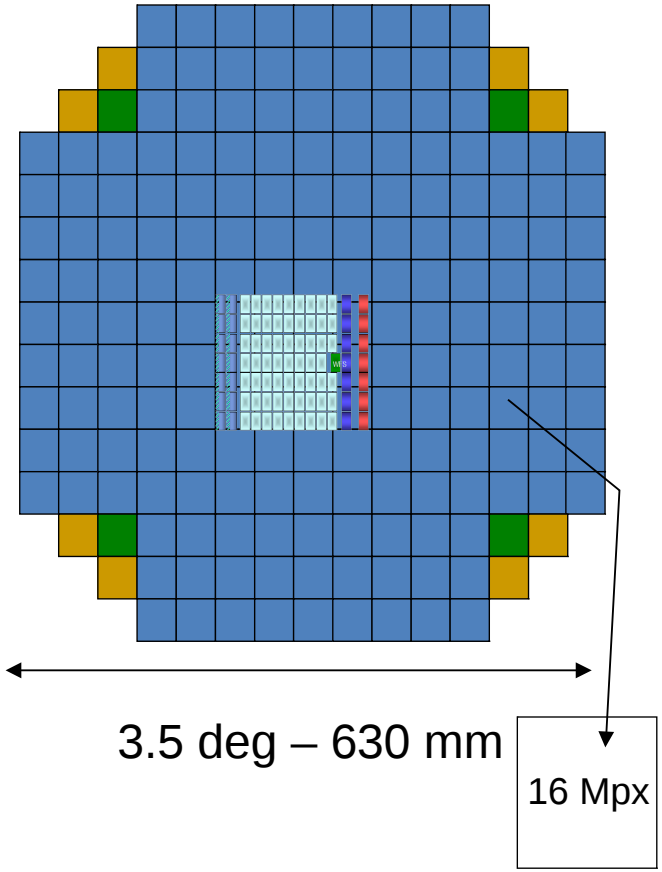
Comparison of Focal Plane

Gaia



LSST



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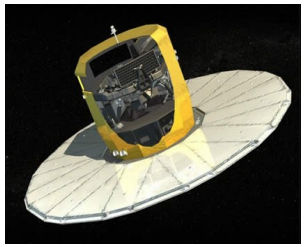
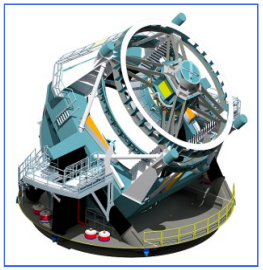
Gaia vs. LSST - Equipement





telescope (m)	1.45x0.5 m	8.4m
FOV	1 deg2	9.5 deg2
Spectro-photometry	25 bands	6 bands
operational in	2014	2020
lifetime	5 yrs	10 yrs
duty cycle	24h/day	8h/day
short term return	106 mn	30-60 mn
return period	2 months	3 days

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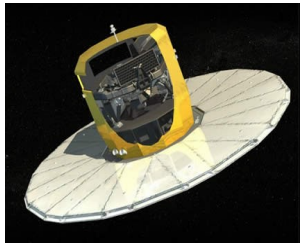
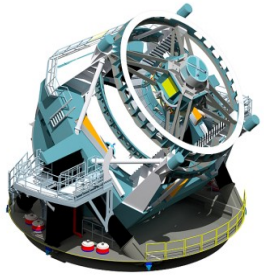
Gaia vs. LSST - Performance





(1)

sensitivity	V = 20	**V = 24.5 mag (1 visit)**
number of observations	60-70	~ 800
sky coverage	**full sky**	~ 50% (but full ecliptic)
number of SSO sources	3x105	6x106
astrometric accuracy (single obs)	**0.05 – 1 mas**	10 - 80 mas
astrometric calibration	**self calibration**	reference stars (Gaia ?)
photometric accuracy	**1-10 mmag**	10-100 mmag
Spatial resolution	**0.1" (~2 px)**	0.7" (average seeing)

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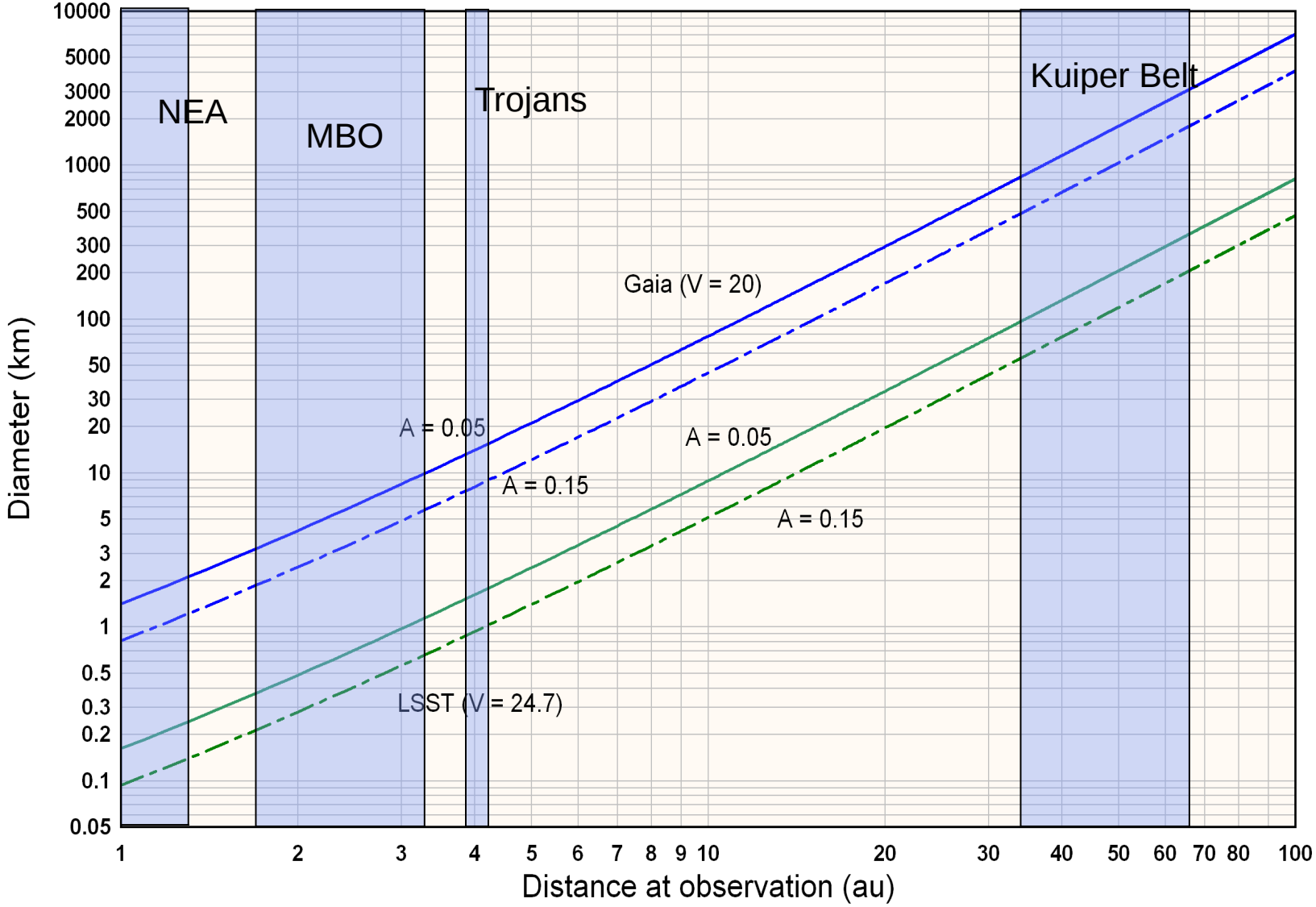
(1) : Isevic et al., 2011

Detection capabilities: diameters



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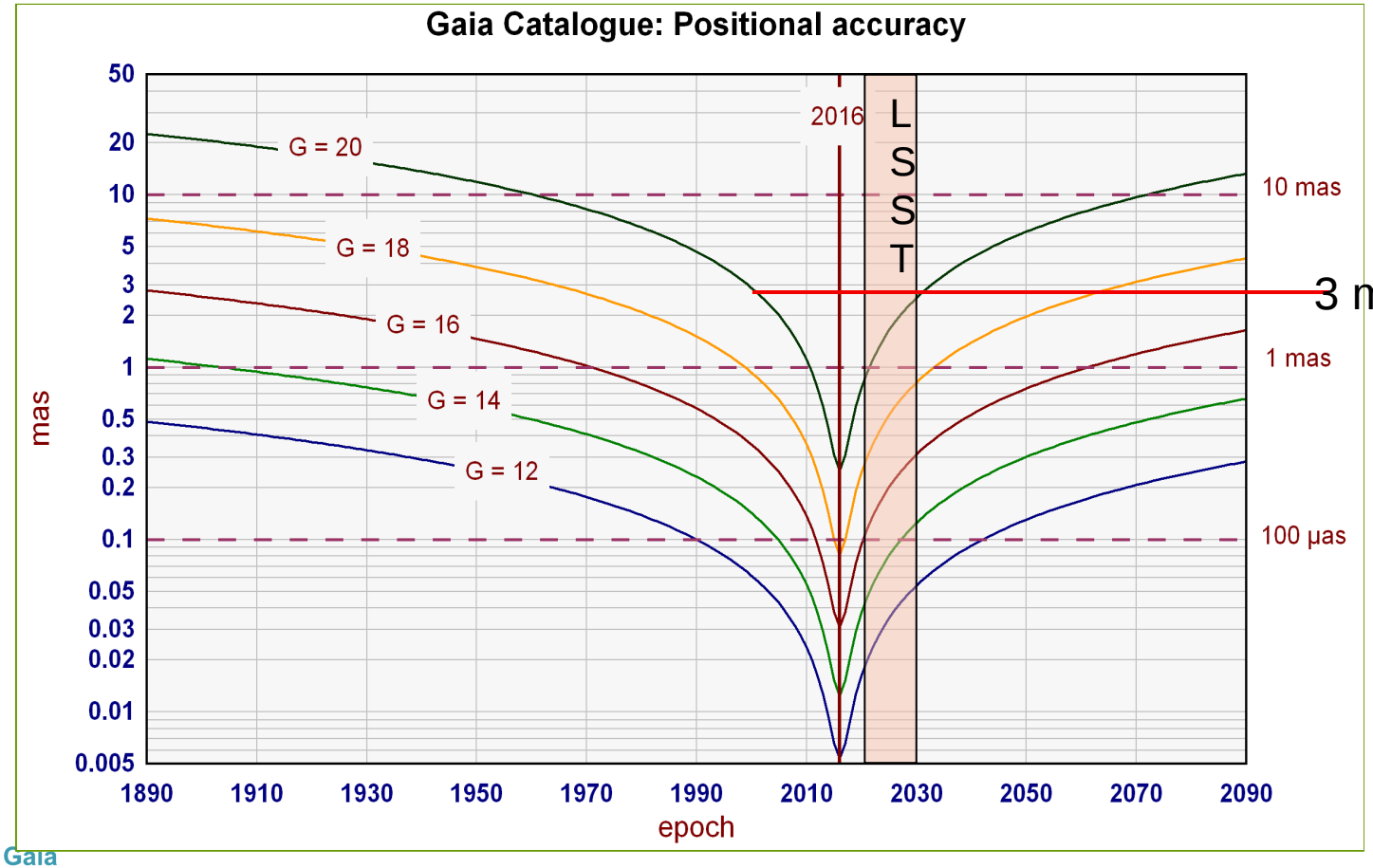
Gaia Catalogue for LLST

- Use of the Gaia catalogue for CCD processing
  - reference stars virtually error-free for LSST
  - ~ **100,000 Gaia stars in the LSST FOV !**



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Overall throughput

Population	today(*)	LSST (**)
MBA	630,000	5.5x10
NEA	10,000	100,00
PHA	1500	90% D
Trojans	2000	300,00
KBO	1000	40,000

(*) : Gaia will not change much these numbers. PanSTARR can.

(**) : LSST Science Book.

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Quantitative impact Gaia & LSST surveys

- Number of observations in MPC ~8x107 0”.4
  - best from classical astrometry (not doppler, timings..)
  - Hipparcos with post-fit residuals
    0”.08 to 0”.15

- Number of observations from Gaia ~2x107 0”.005
  - reprocessing with Gaia catalogue(50% ?) ~4x107
    0”.02 ?

- Number of observations from LSST ~2x109 0”.01-0”.07

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Challenges

- Data processing most challenging for SSO :
  - coping with the daily volume
  - matching observations of the same sources taken at different time
  - photometric inversion for millions sources does not come for free
- Difference between 'potential science' from a survey and 'actual science' with fully calibrated data
- How to maintain the resource level during 'routine operations'

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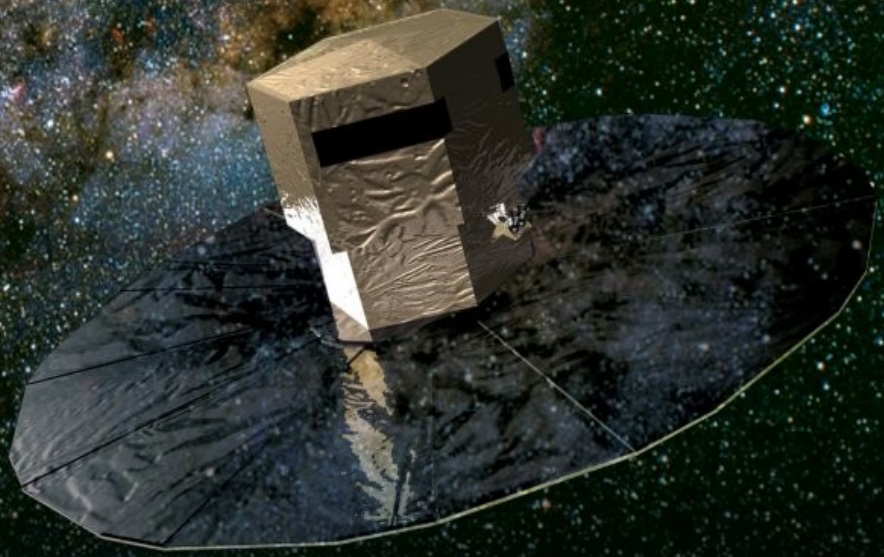
Thanks for your attention



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