Gaia: data processing for Solar System alerts

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Gaia DPAC
Data Processing & Analysis Consortium

Gaia and the Solar System

- Minor Planets (~350.000)
  - Most of them already known
- Comets
- « Small » planetary satellites
- Gaia will NOT collect observations of « large » bodies (> 600 mas)
- Expected data: astrometry, low-resolution spectroscopy (~25 bands) and photometry

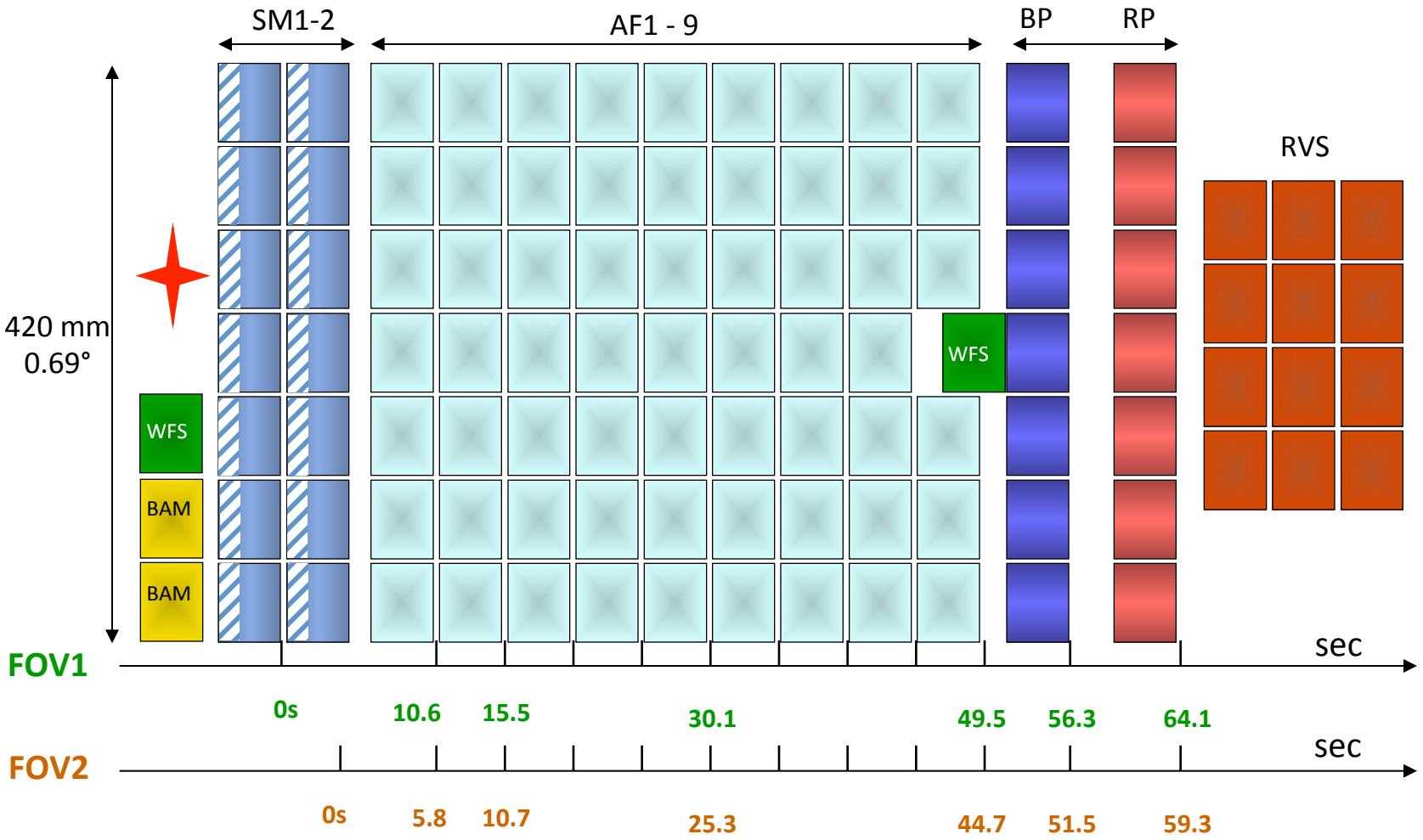
6(?) < V < 20, size <600 mas

~70 observations / object (up to ~200)

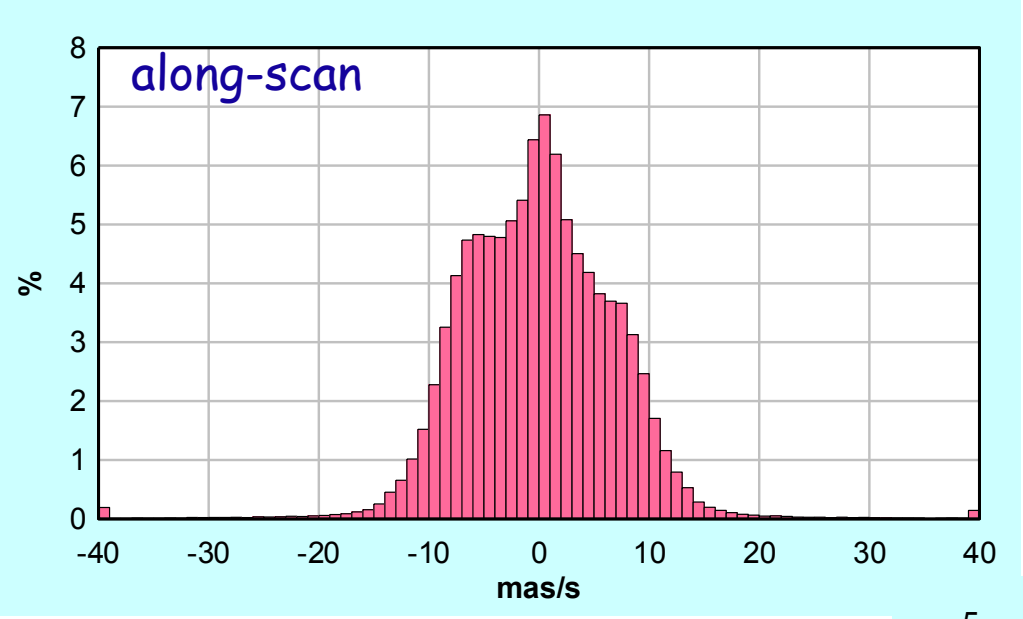
Focal plane

1 pixel 60 x 180 mas

106 CCDs (4.5 x 2 kpix) = 1 Gpixel

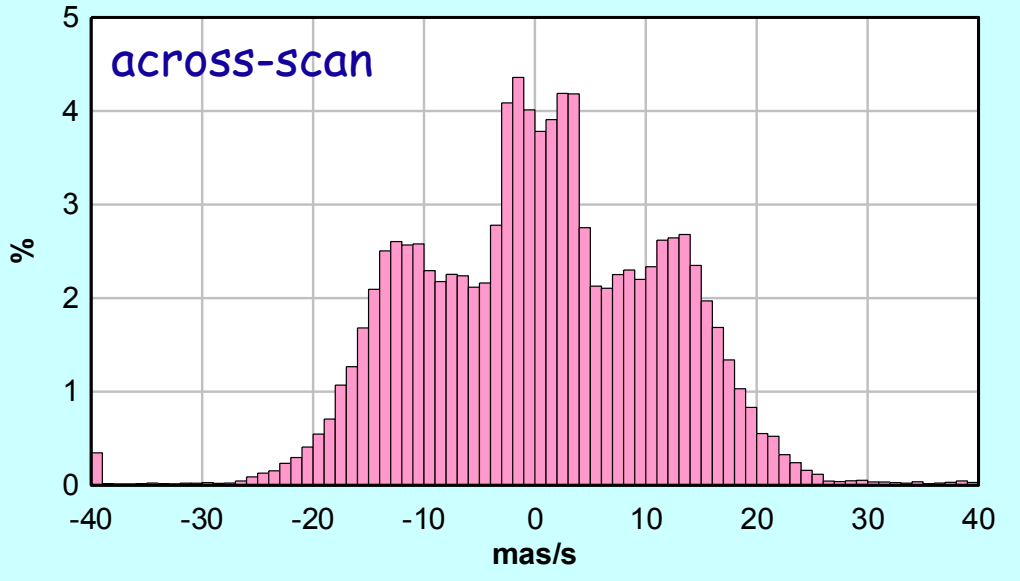


Velocity distribution



motion detectable during a single observation (= transit on the focal plane)

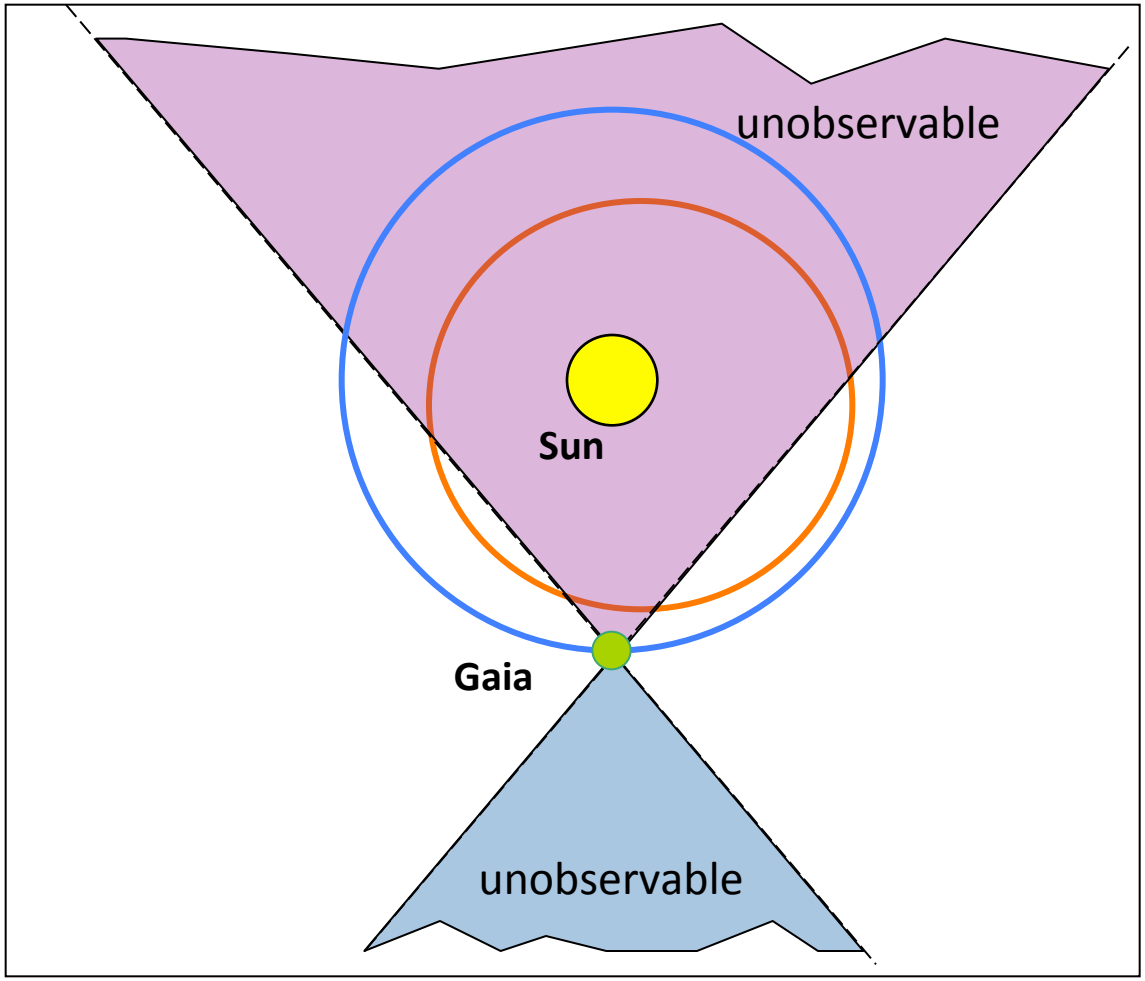
$\sigma \sim 7$ mas/s



$\sigma \sim 12$ mas/s

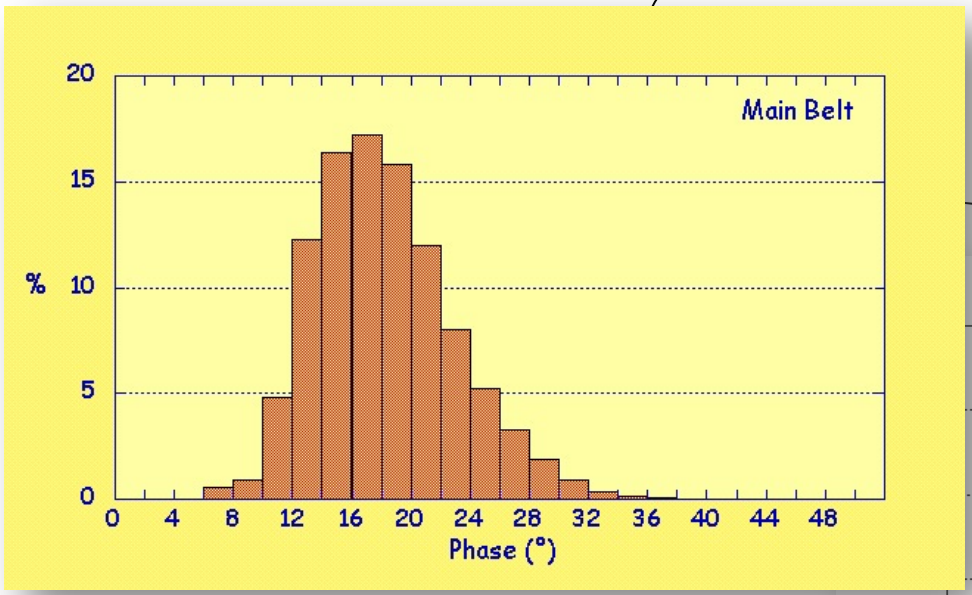
Gaia scanning the ecliptic

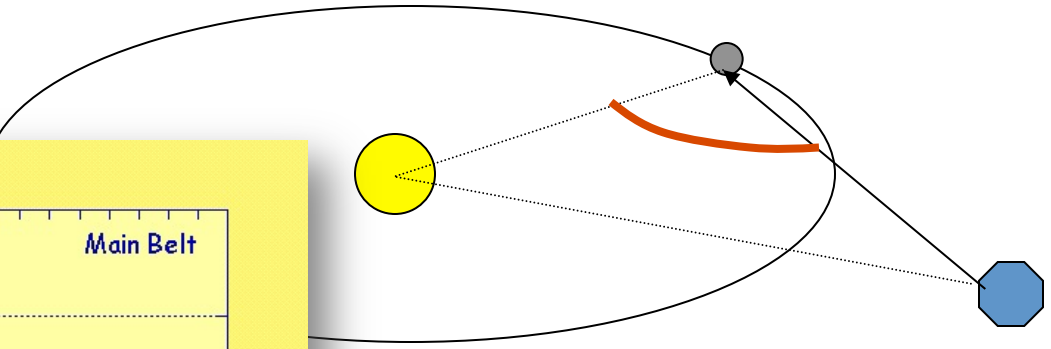
Solar System objects, only at preferred elongations

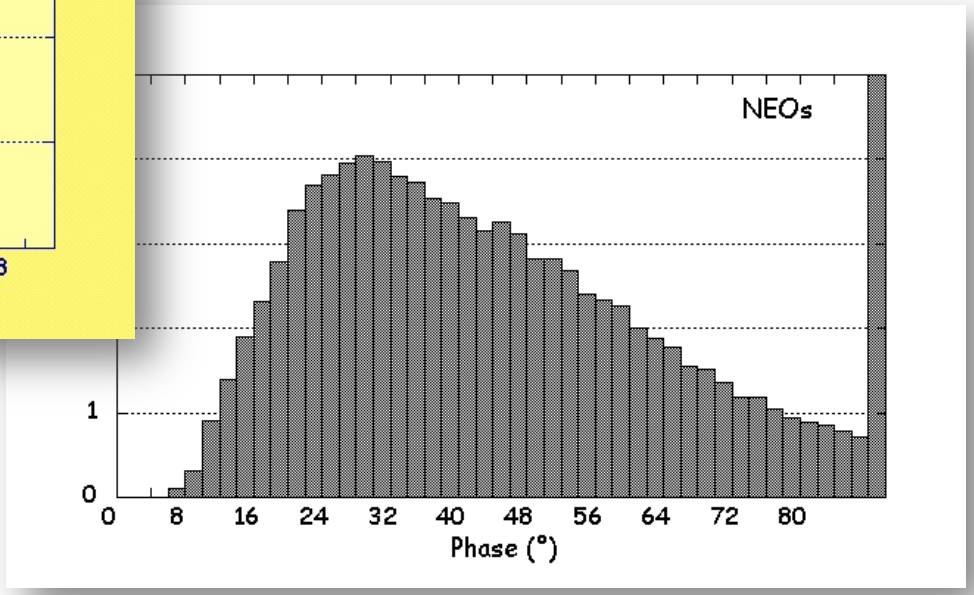


F. Mignard

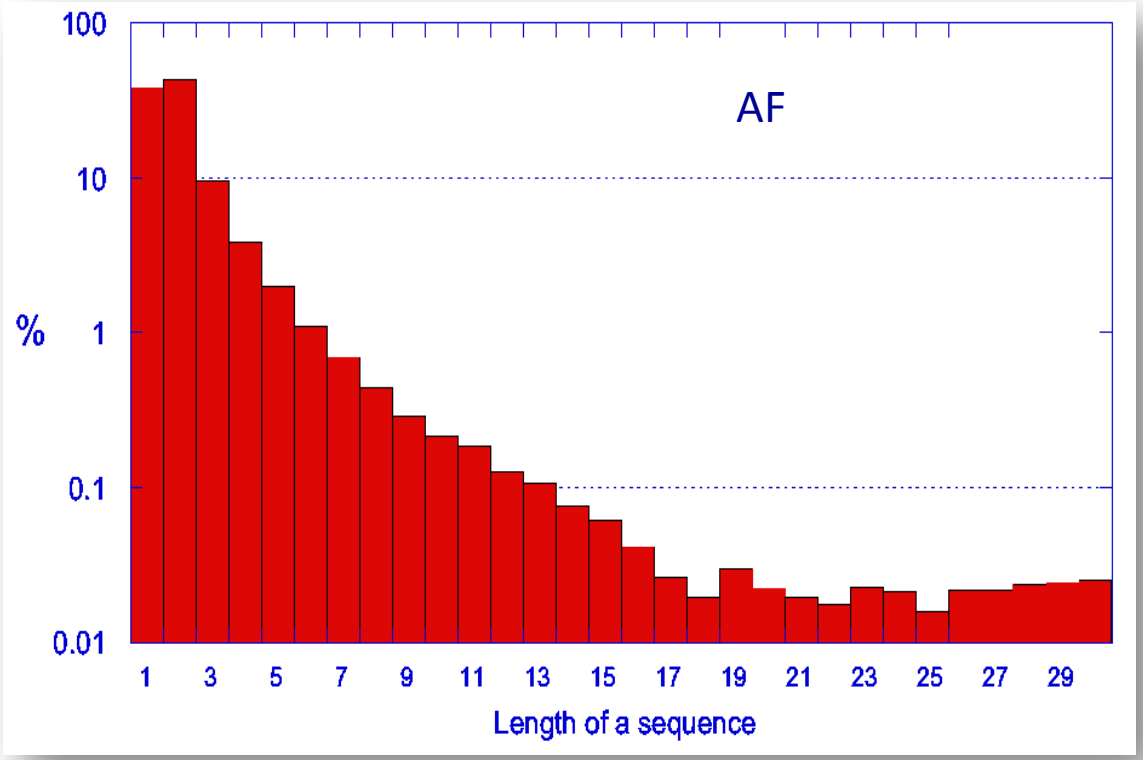
Phase angles

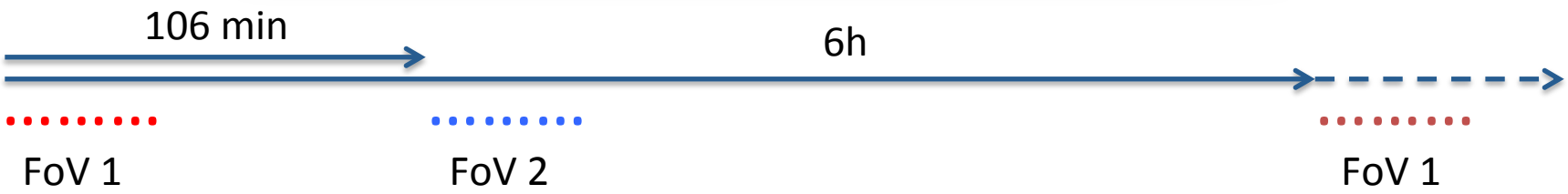






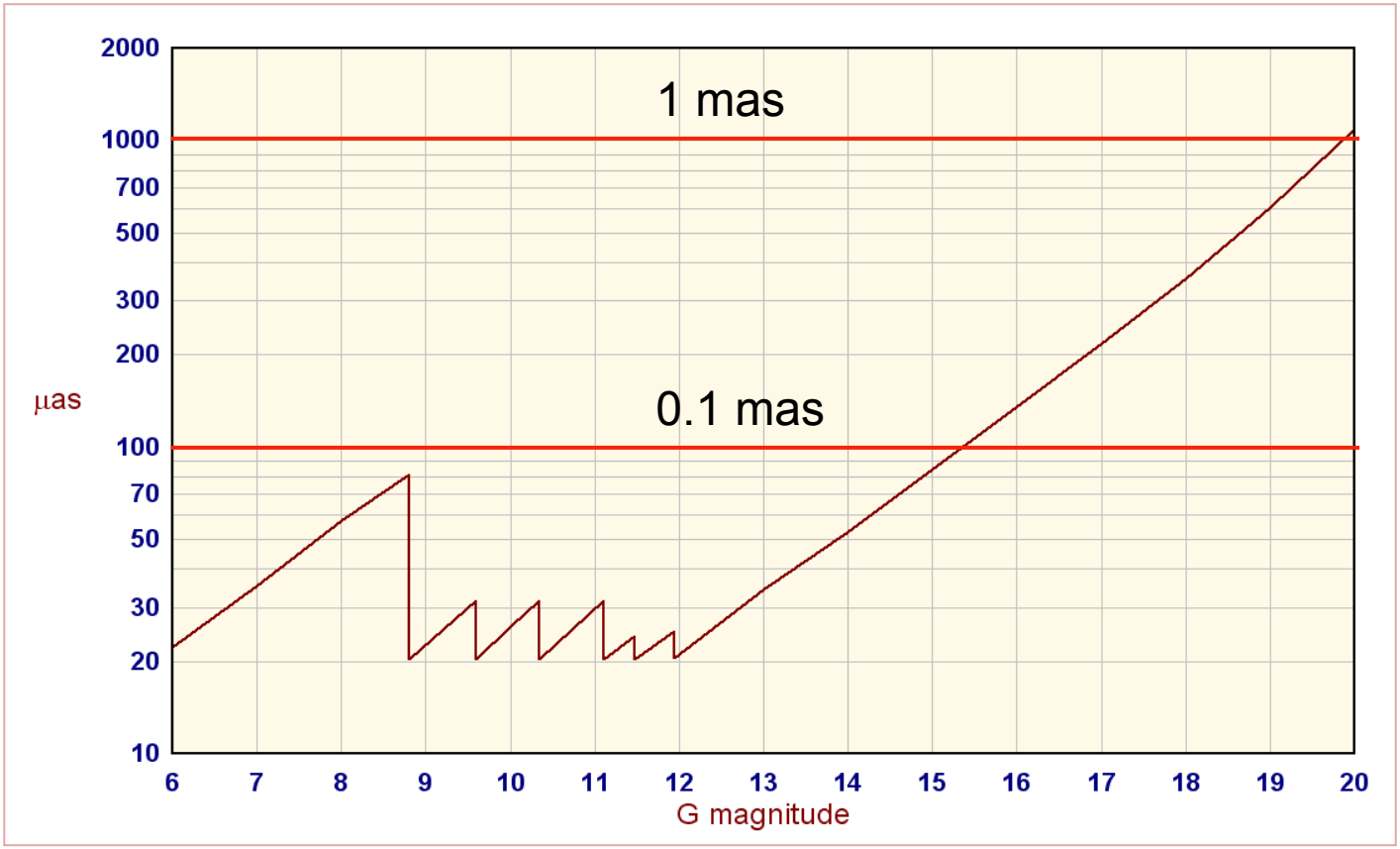
Length of detection sequences



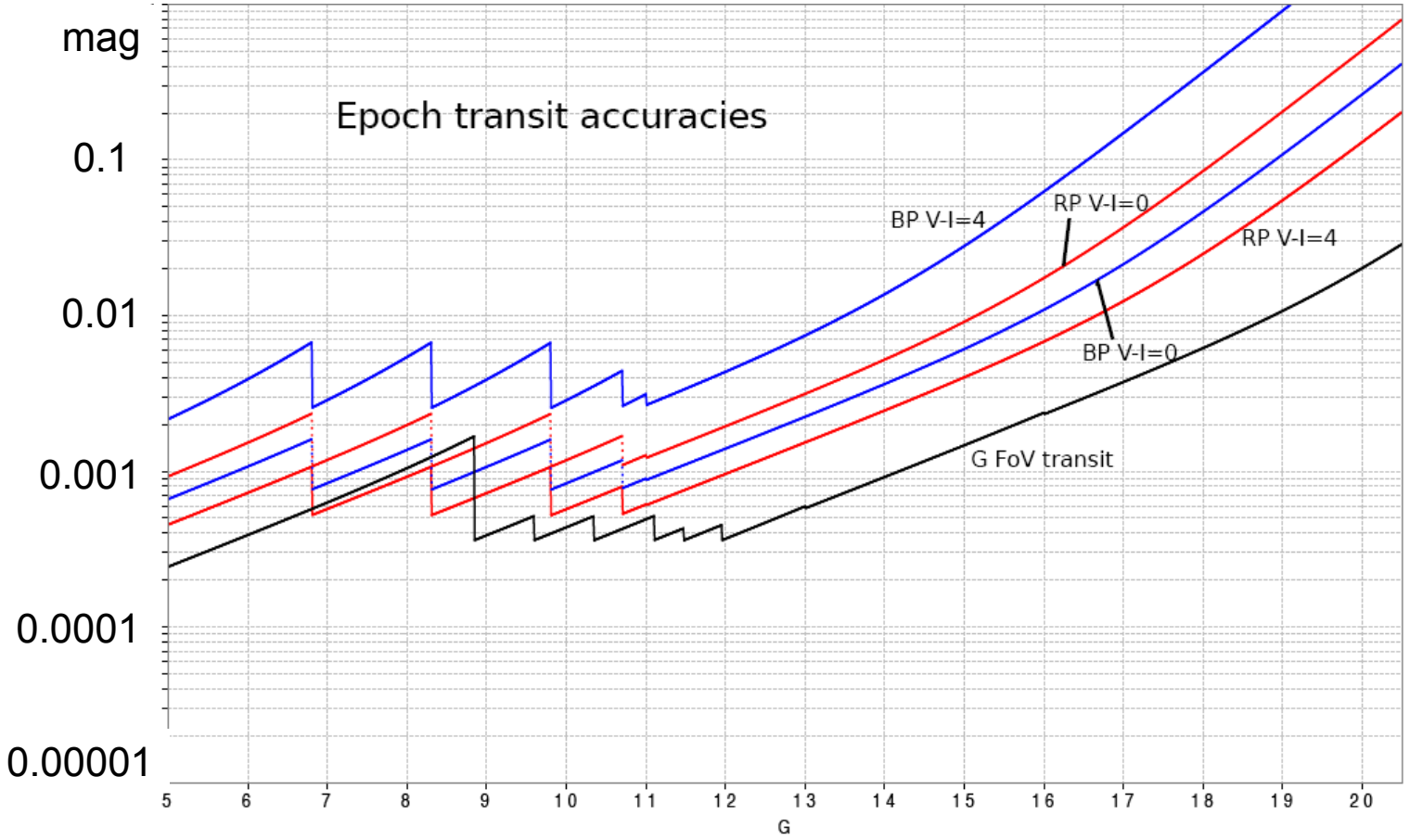


Gaia single-epoch astrometric accuracy

Final attitude, single FoV transit, point-like



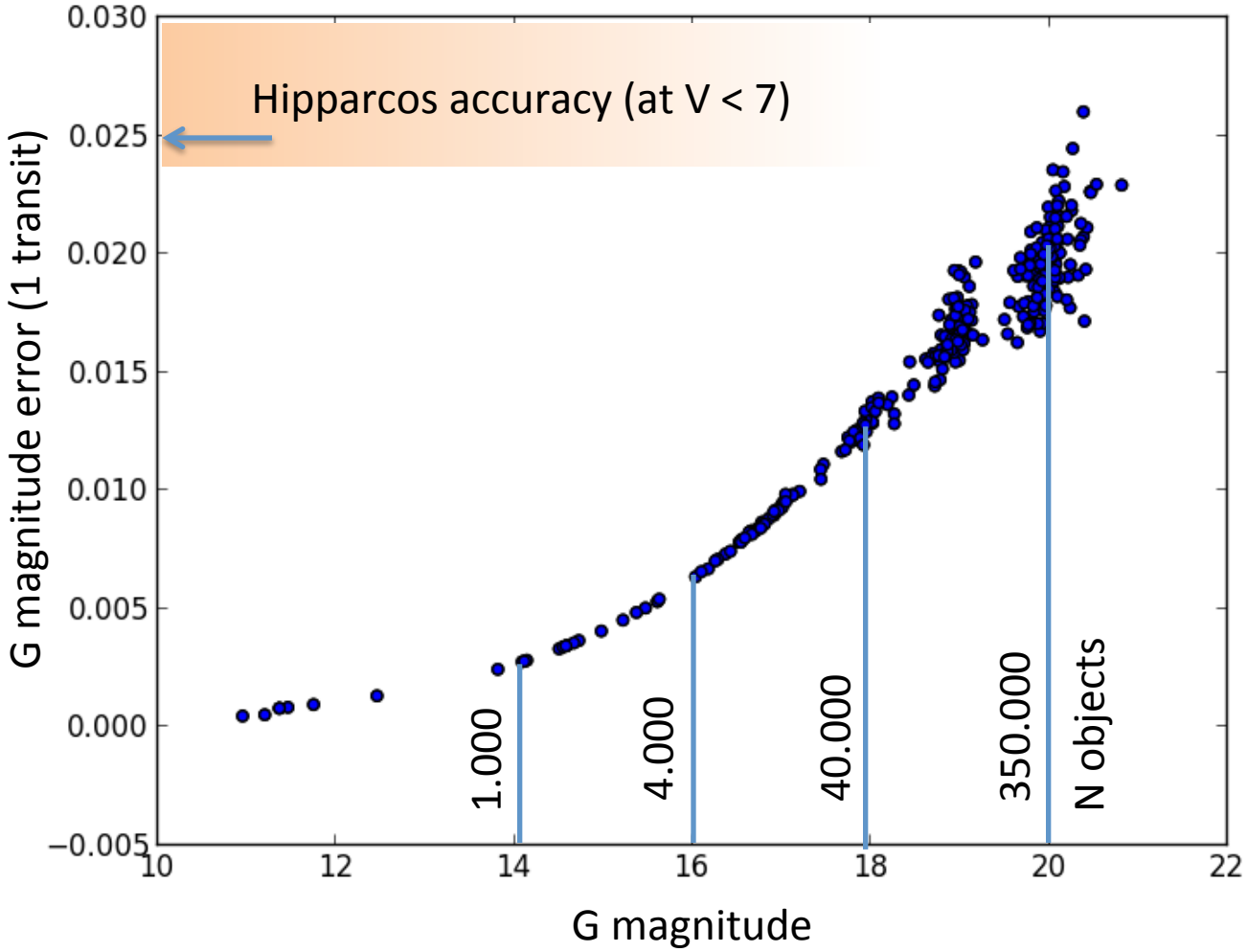
Photometric accuracy



D. Evans

Measured photometric accuracy

300 observed asteroid transits in the FoV



ESA/Gaia/DPAC/Airbus DS

Identified data processing goals

Astrometry

- Systematic survey - discoveries possible
- 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
- Light curves over 5 years : rotation, pole, shape.

DPAC: two pipelines for the science goals

- Daily processing
  - Processing of « new » asteroids or ambiguous identifications
  - Per-object, on 48h time frames
  - Preliminary astrometric solution
  - Preliminary calibration

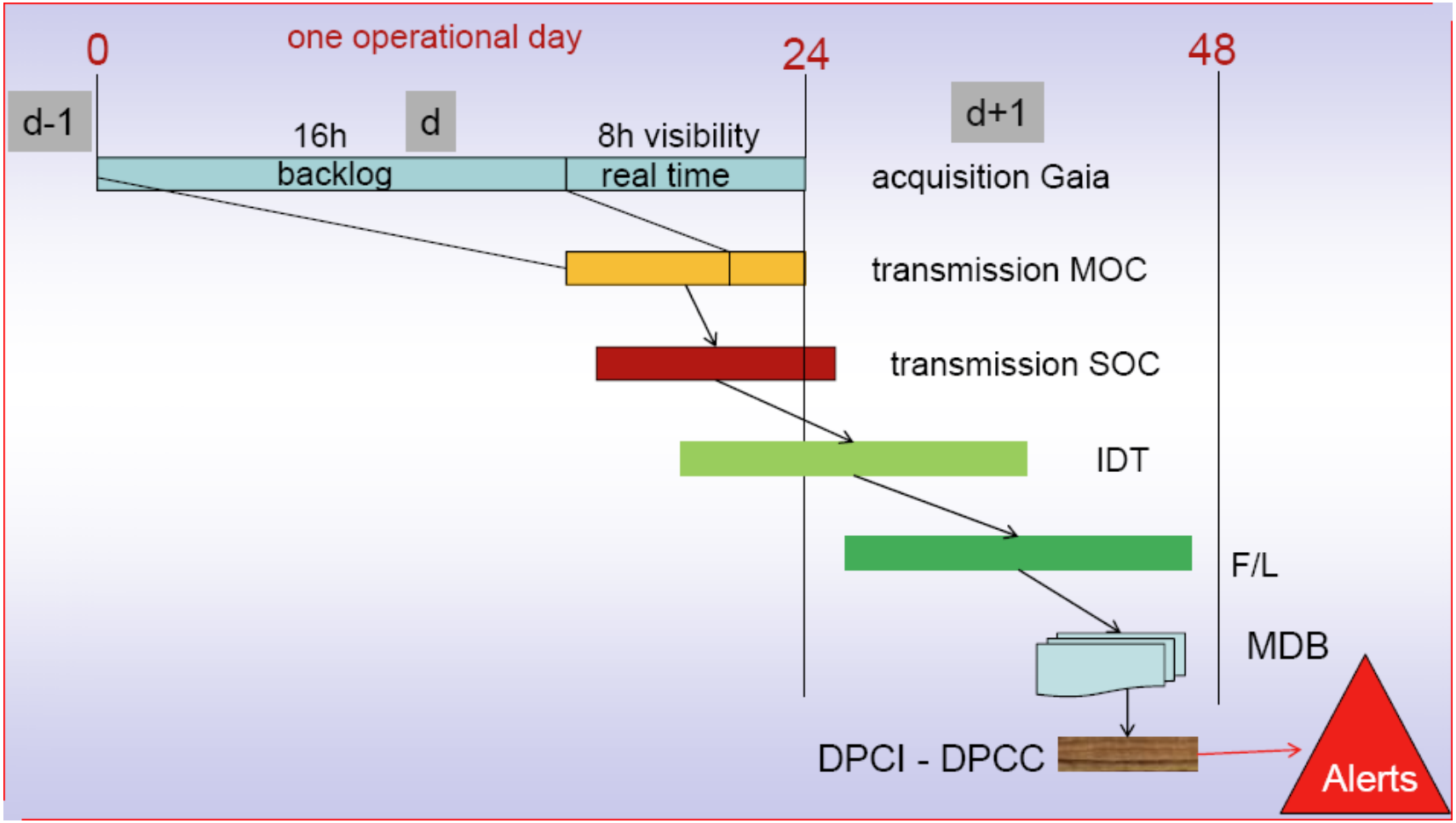
Rapid delivery of astrometry to MPC and ground-based alert network

- Long –term processing
  - All sources
  - Best calibrations, best astrometric model
  - Devoted to obtain the best possible final output of the mission

The challenges of data reduction

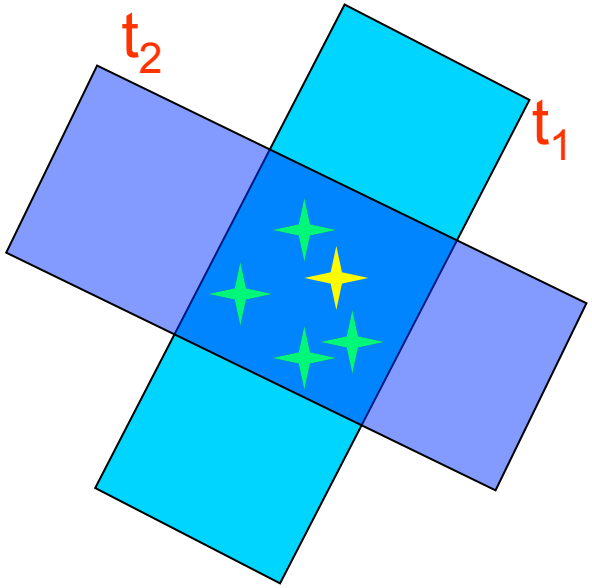
- 1 source out of 2500 is a SSO
- SSO rate in the Gaia FOVs: ~ 1 SSO / 6 s (= 12.000 /day)
- Moving objects identification:
  - cannot proceed as for the stars (cross - matching)
  - Motion detection: poor accuracy during a single transit (~40 seconds)
  - needs an orbit catalogue (not all orbits are « good»)
- Problems
  - Potentially « new » asteroids: relies upon cross-matching efficiency (by the Intermediate Data Processing)
  - Short-arc orbit determination (2-3 transits) for ground-based follow-up

The whole data pipeline



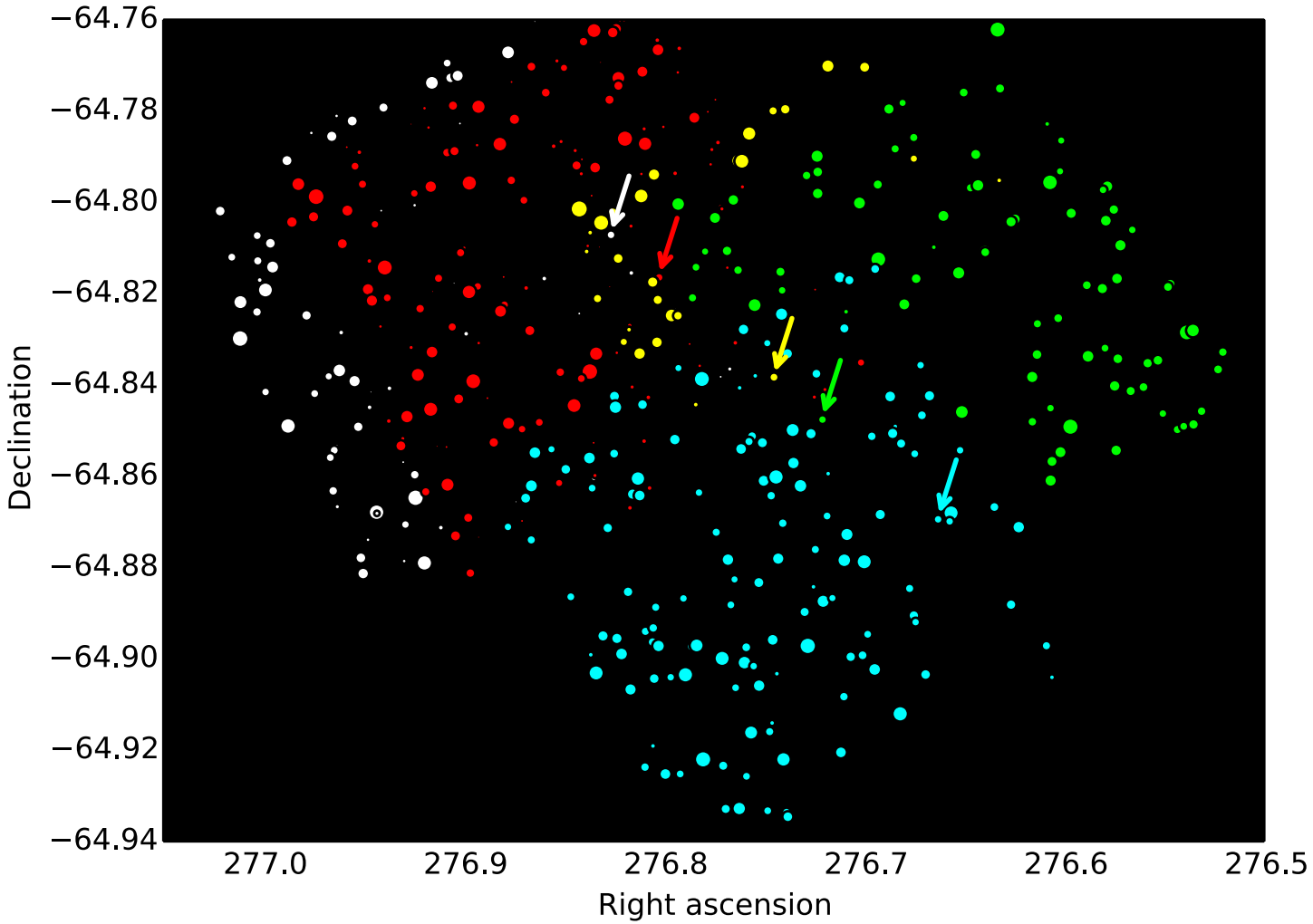
How SSO are selected for CU4?

- A result of the ***Initial Data Treatment***
  - Cross – matching of sources
    with previous observations
    …or with a catalogue
    at the beginning of the mission
  - Negative cross match:
    Potentially moving/variable sources



- Unmatched sources are sent to CU4 as potential SSOs
- Key issue: efficiency of IDT cross-matching
  - In OR#3: ~8% unmatched sources (!)

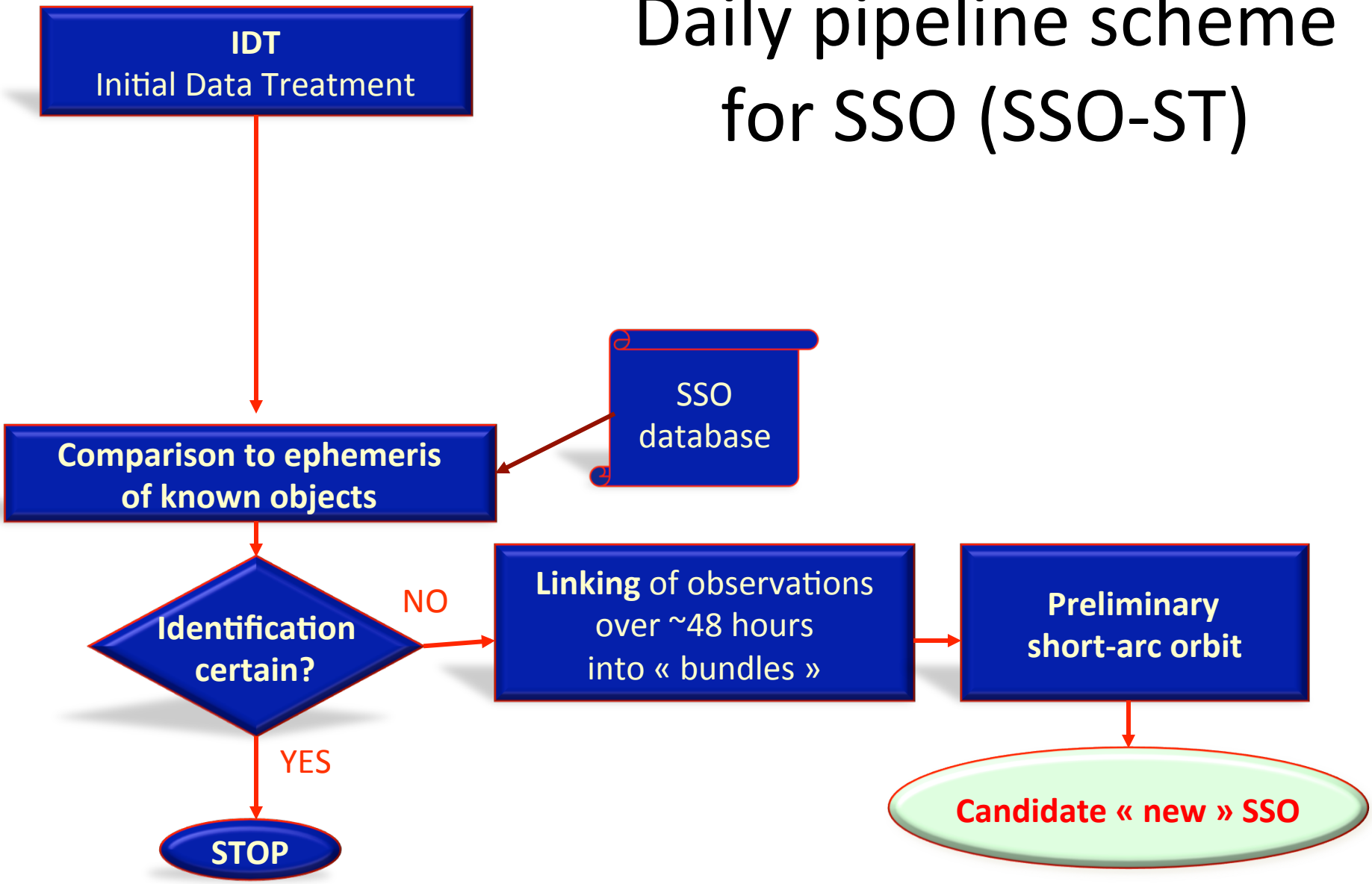
Detection of asteroid 4997 Ksana



ESA/Gaia/DPAC/Airbus DS

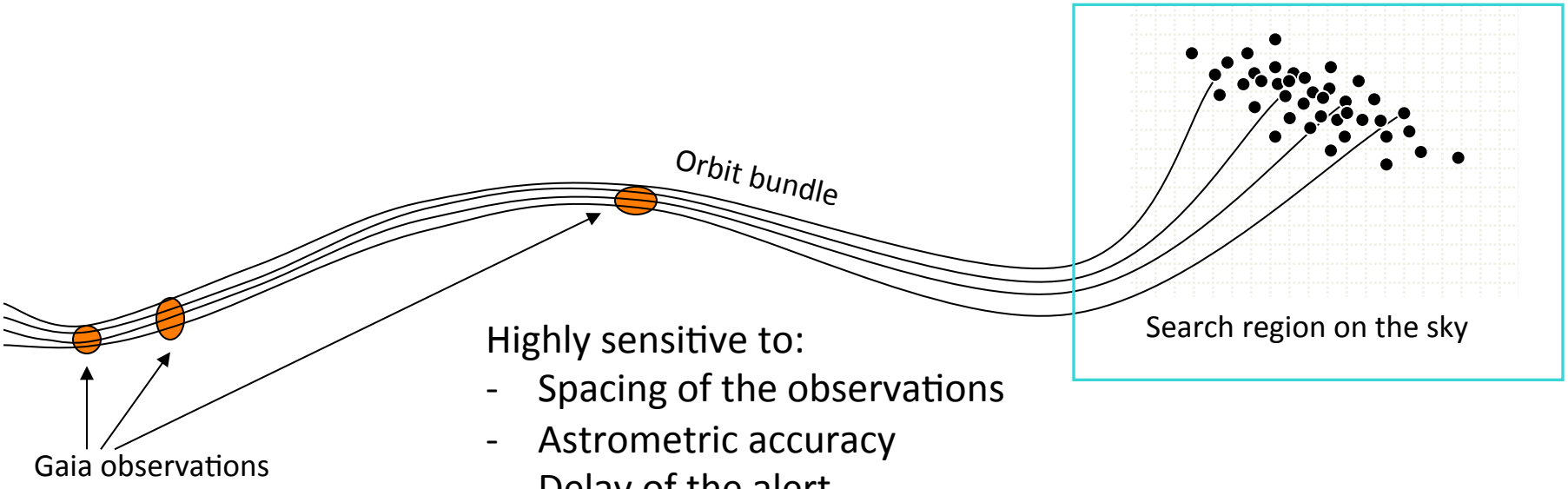
(54) Alexandra

Daily pipeline scheme for SSO (SSO-ST)



Core of the daily chain

- Short arc threading (bundling)
  - 2-3 consecutive transits are frequent
  - Algorithm based on velocity extrapolation
- Short arc orbit determination
  - It exploits single CCD observations
  - Statistical method : Markov-Chain Monte-Carlo, MCMC → bundle of orbits



Highly sensitive to:
- Spacing of the observations
- Astrometric accuracy
- Delay of the alert

3 issues for the SSO-ST chain

- Completeness of the data
  - 48h data segments needed for the processing (8 satellite rotations) / each day
- Alert mode: it requires a rather “clean” input
  - A large amount of “contaminants” can prevent to pick up the few unknown asteroids
- Astrometric accuracy
  - Only a “daily” astrometric solution available
  - …improvement expected over time

Recent steps

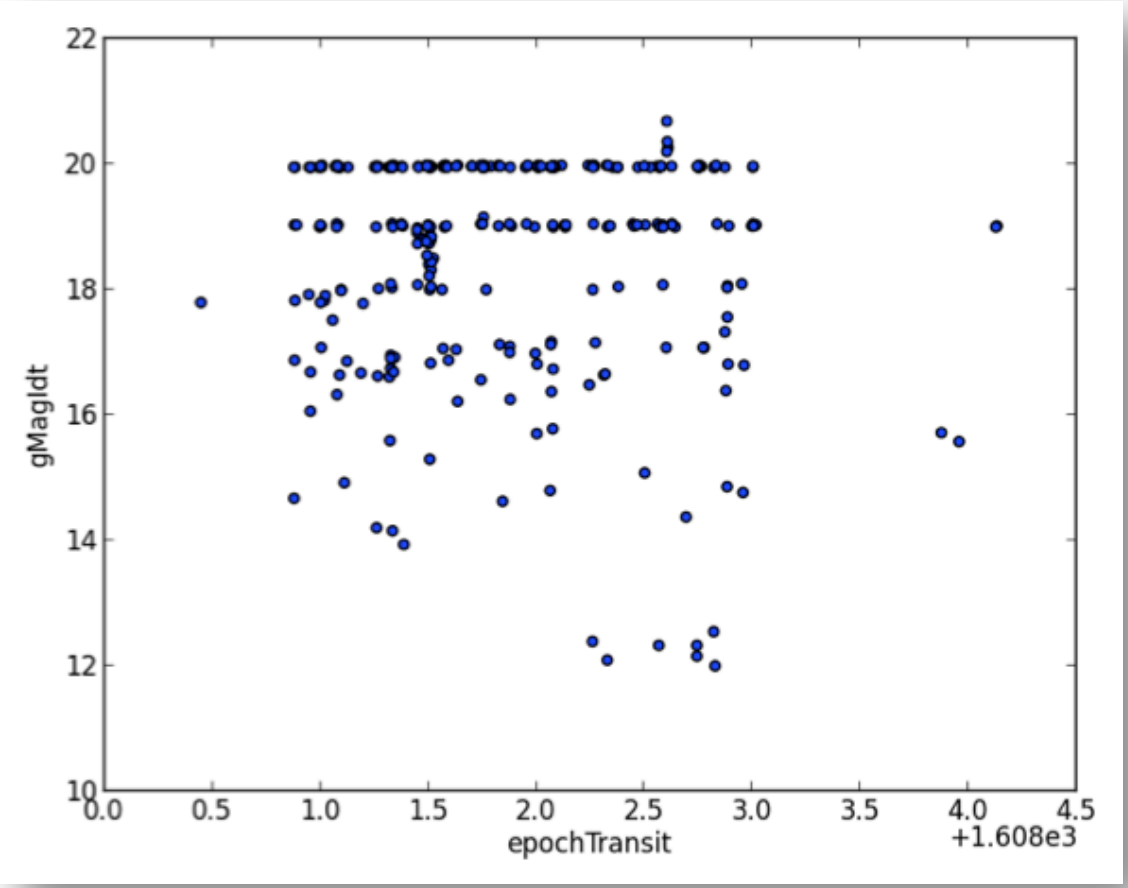
- Tests on *known objects*

- June 19, 2014: chain running, end-to-end
  - Data in NSL phase, end of May
  - Problem: completeness
  - Large astrometric uncertainty (→ calibration problem)

- November 3 – new test results (September data)
  - Dramatic improvement in the astrometry
  - Puzzling strings of transits…

- New test on more recent data
  - To be analyzed

Completeness problem (now mitigated)



Typical statistics (recent test)

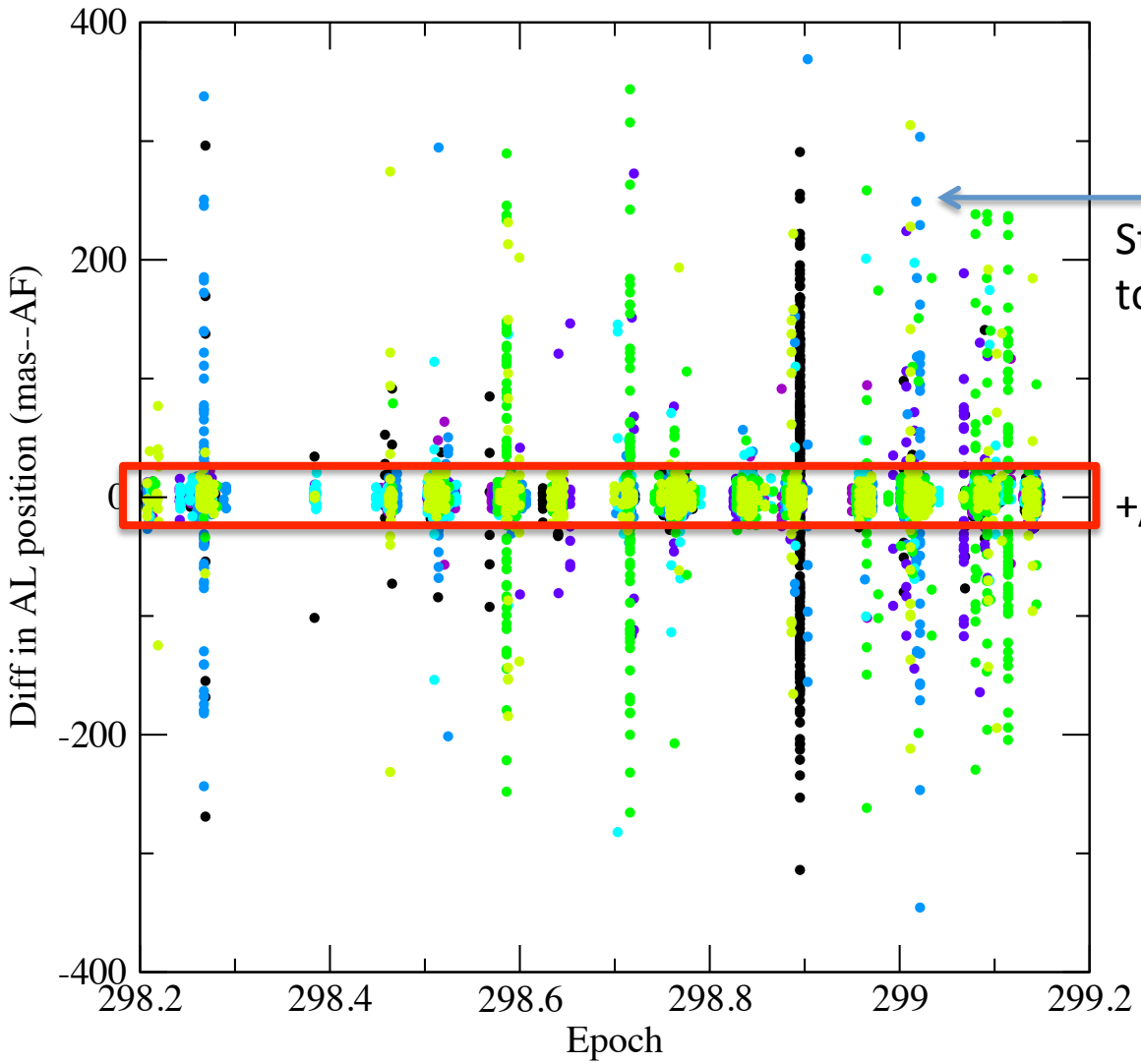
- Total transits in input 6.152.794
- Filtering:
  - multiple detections -2.935.362
  - bad signal (truncated etc.) -1.196.632

= 2.020.800

Among them:…. only 1244 SSO !

…but the performance of IDT cross-matching is improving

Dispersion of the astrometry



Stellar spikes close to a SSO!

+/- 20 mas

New proposed framework for SSO-ST

- Motivations
  - IDT is improving but performance is unpredictable (we could still have too many contaminants in > 6 months…..)
  - Filtering the input appears very difficult (under investigation)
- Proposed solution
  - start running the SSO-ST chain routinely (every day)
  - ...in the mode used for the recent tests: i.e. on known objects only.
- Advantages
  - flexibility for testing
  - Large sample statistics for checking detection/identification efficiency, exceptions, etc.
  - Possibility to activate the SSO alerts → Gaia-FUN-SSO

“Transitory” alert mode

- Launch the SSO-ST on a daily basis
- Identify interesting alert targets among the “known” asteroids:
  - NEOs
  - Poorly known orbits
  - Missing detections…
- Activate alerts with validation by the Gaia-FUN-SSO network

Thank you!