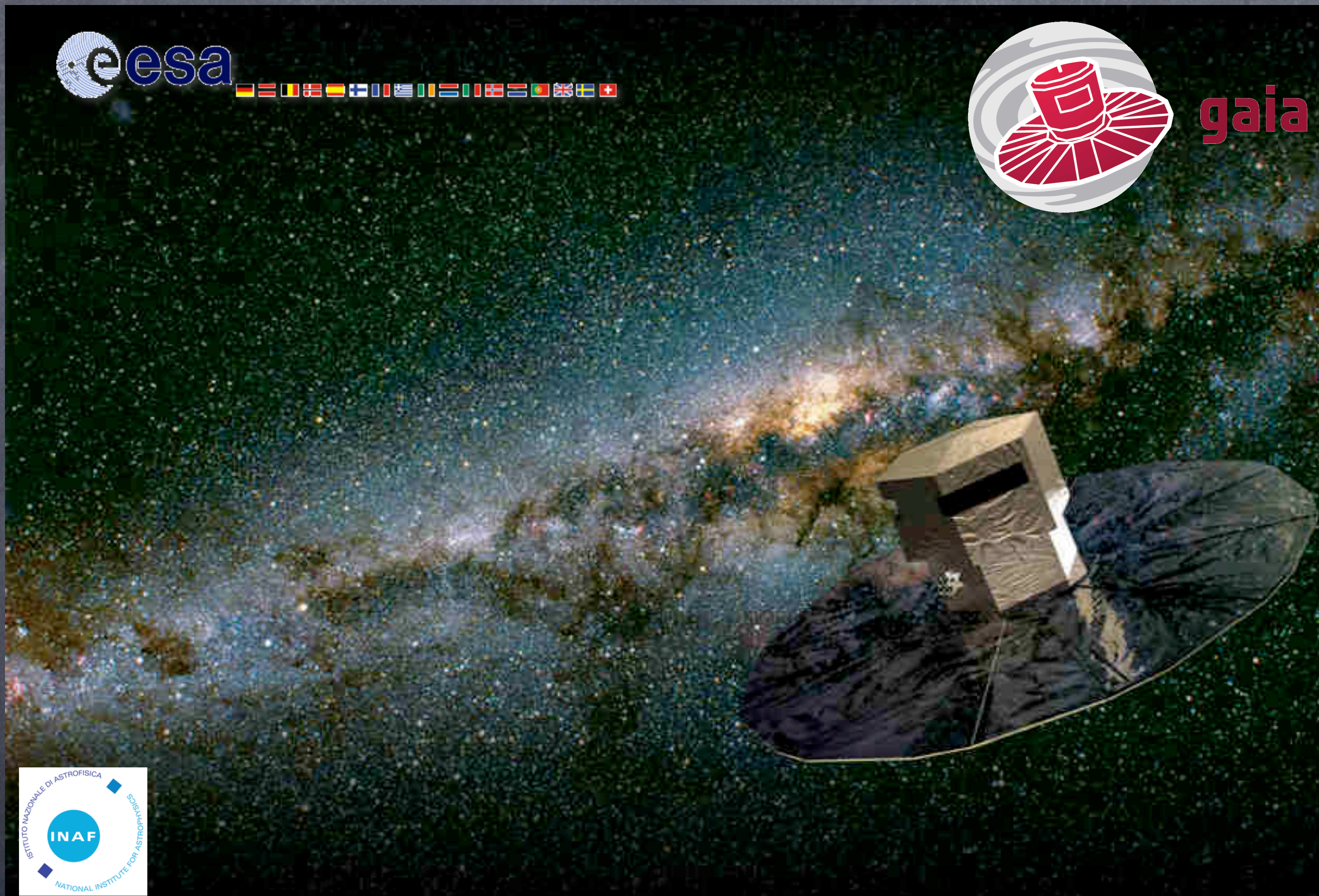
QSO & Gaia : There and Back Again



G. Giuffrida

GAIA@ASDC team
P.M. Marrese - G. Giuffrida - S. Marinoni

- ESA Cornerstone mission within Horizon 2000+
- 3 goals = 1 goal

- ESA Cornerstone mission within Horizon 2000+
- 3 goals = 1 goal

3 goals

- µas Astrometry
- Spectrophotometry
- Spectroscopy

- ESA Cornerstone mission within Horizon 2000+
- 3 goals = 1 goal

3 goals

- µas Astrometry
- Spectrophotometry
- Spectroscopy

→

1 goal

Milky Way
6D map

- ESA Cornerstone mission within Horizon 2000+
- 3 goals = 1 goal

3 goals

- µas Astrometry
- Spectrophotometry
- Spectroscopy

→

1 goal

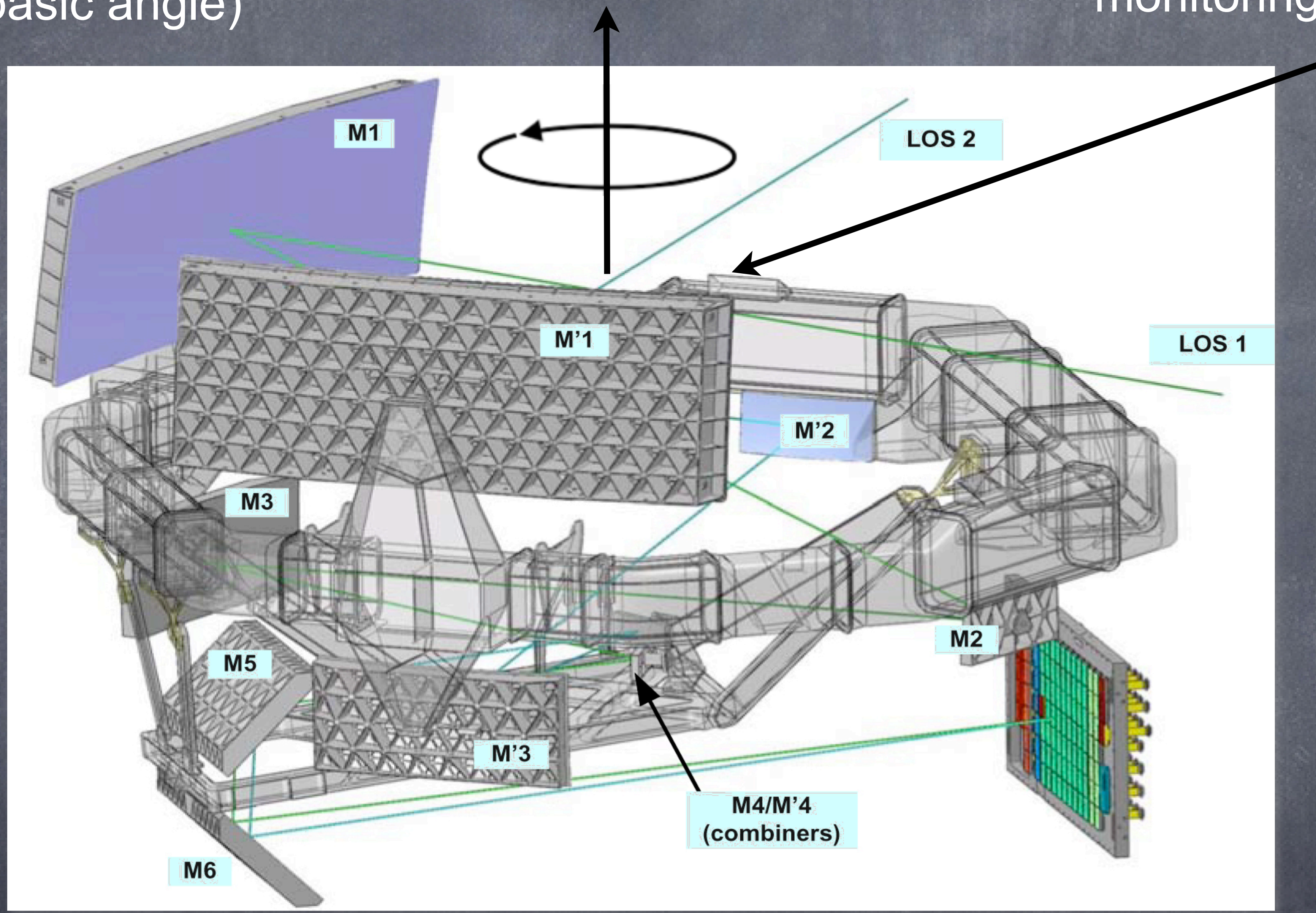
Milky Way 6D map

1,000,000,000 Objects

2 primary mirrors
1.45x0.50 m^2
at 106.5° (basic angle)

rotation axis (6h)

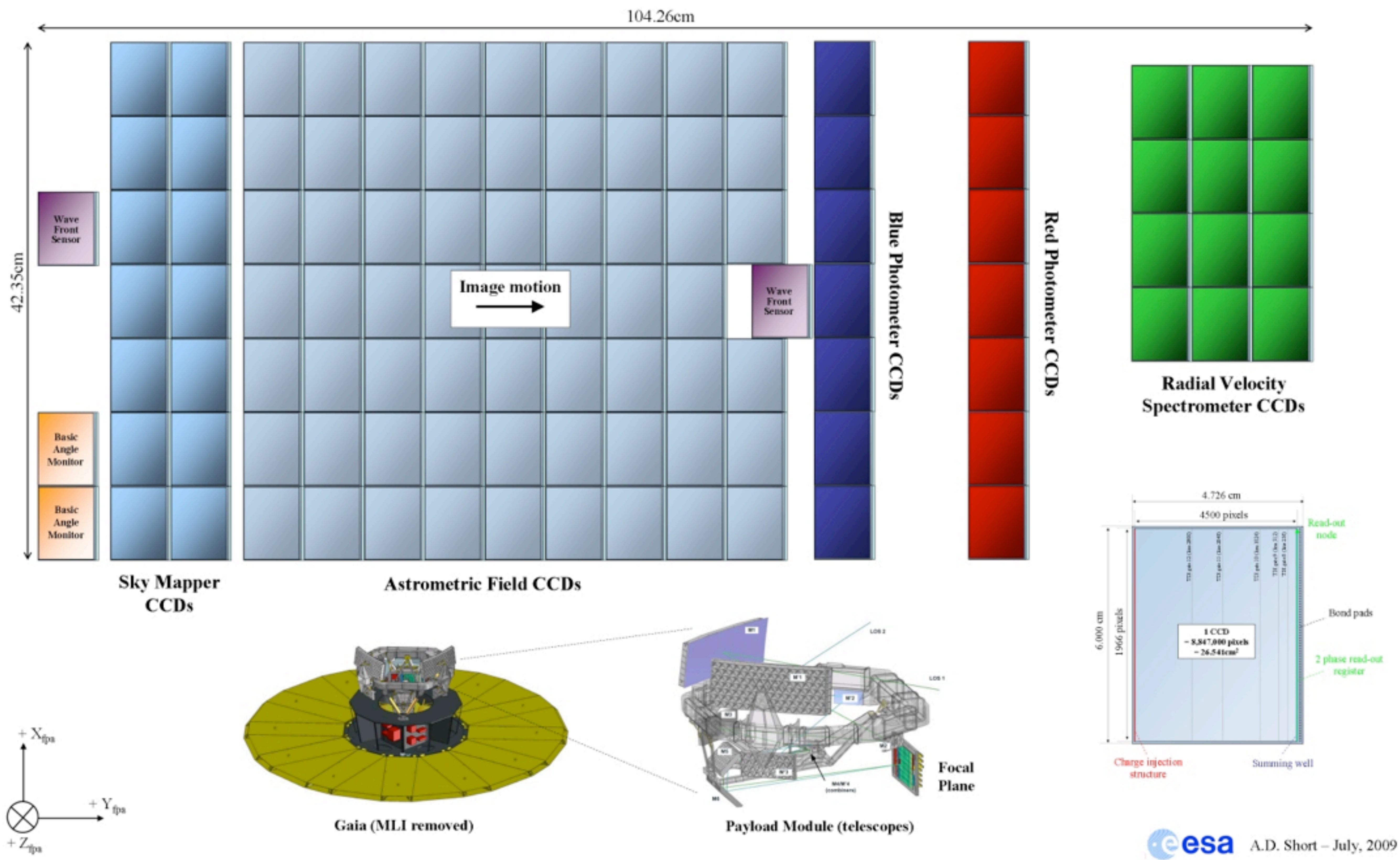
basic angle
monitoring system



superposition of
two Fields of
View (FoV)
common focal
plane
106 CCDs

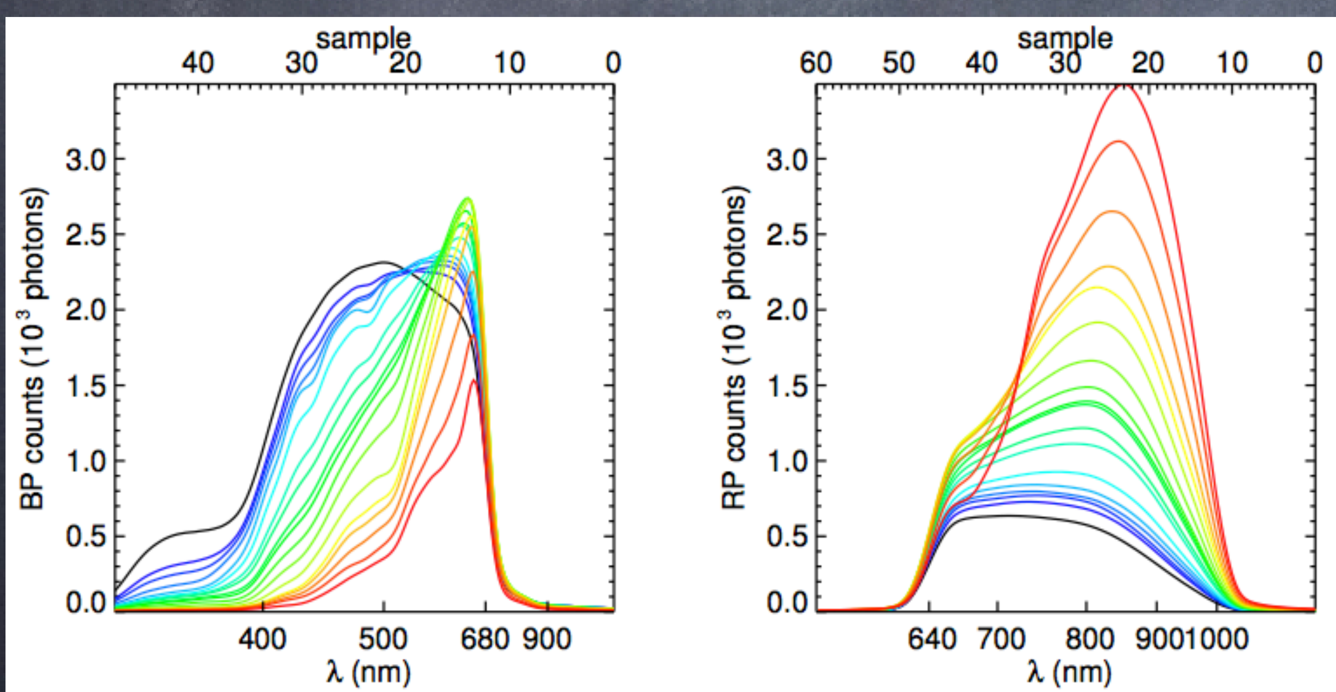
Gaia Focal Plane

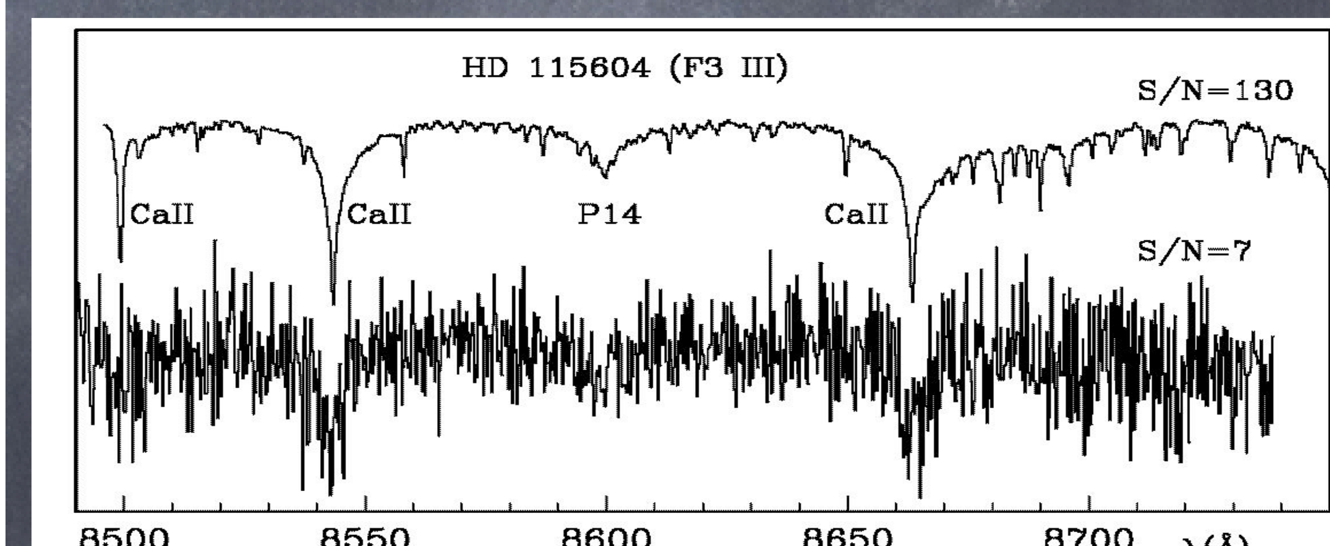
106 CCDs ≈ 938 million pixels ≈ 2800 cm^2



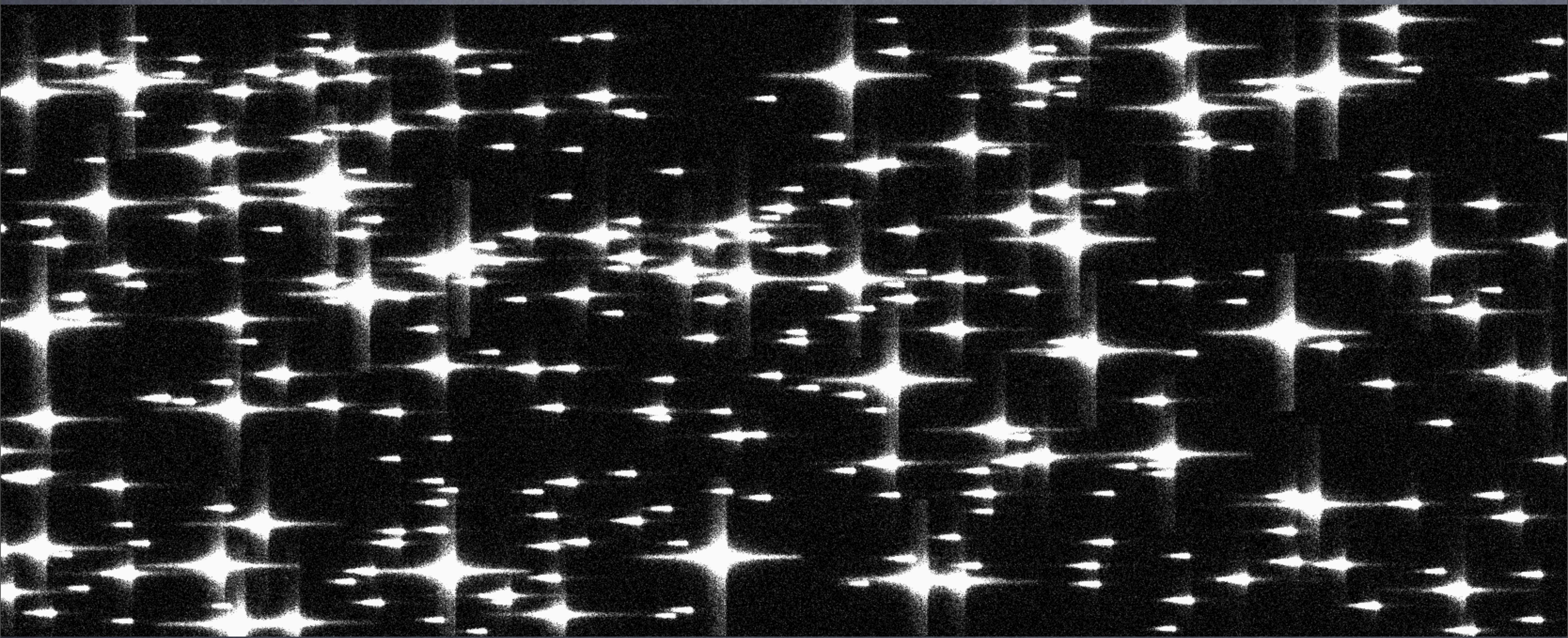
Gaia will provide:

- Astrometry – Proper motions – Parallaxes - G<20 (V=20-22) 10^9 objects (px for 10^8)
- Radial Velocities – Spectra (R=10000, CaT) – V<17 (~ 150 million stars)
- Spectrophotometry (R=100, 330-1050nm) – Colors and Astrophysical Parameters 10^9 objects

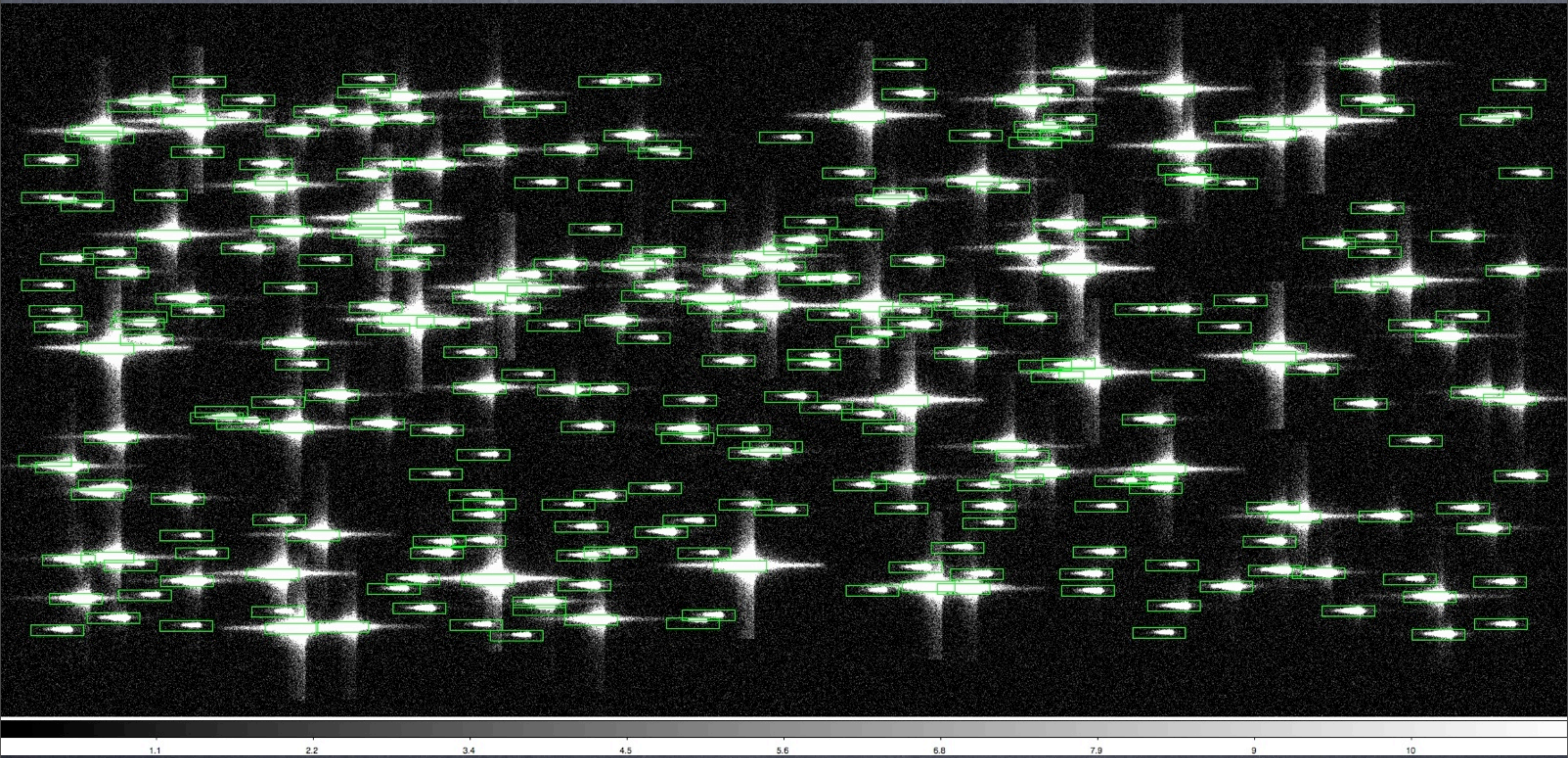


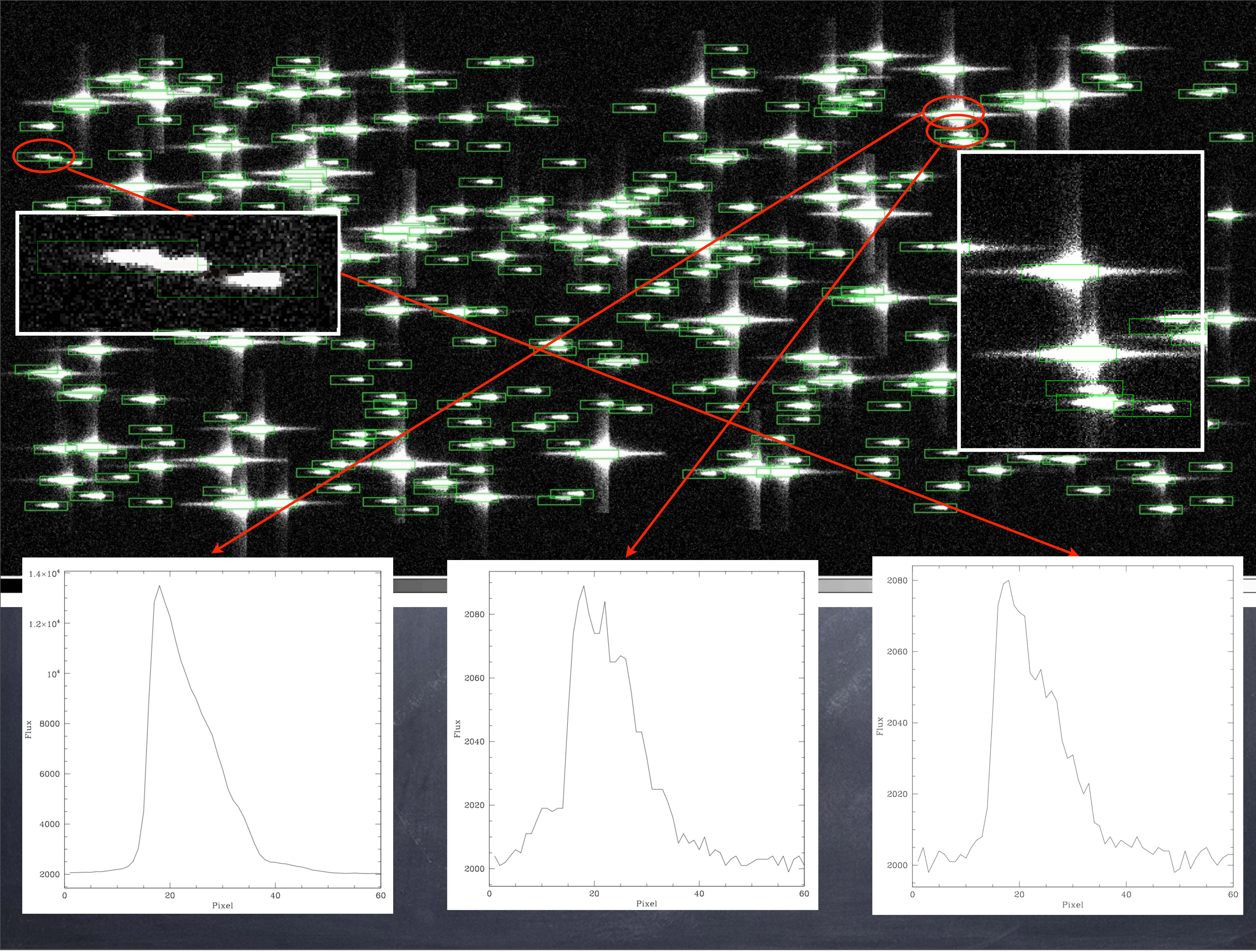


BP (300-660 nm) ~ 3–30 nm/pixel



BP (300-660 nm) ~ 3–30 nm/pixel




1.4×10^4
1.2×10^4
10^4
8000
6000
4000
2000
Flux
0
20
40
60
Pixel
2080
2060
2040
2020
2000
Flux
0
20
40
60
Pixel
2080
2060
2040
2020
2000
Flux
0
20
40
60
Pixel

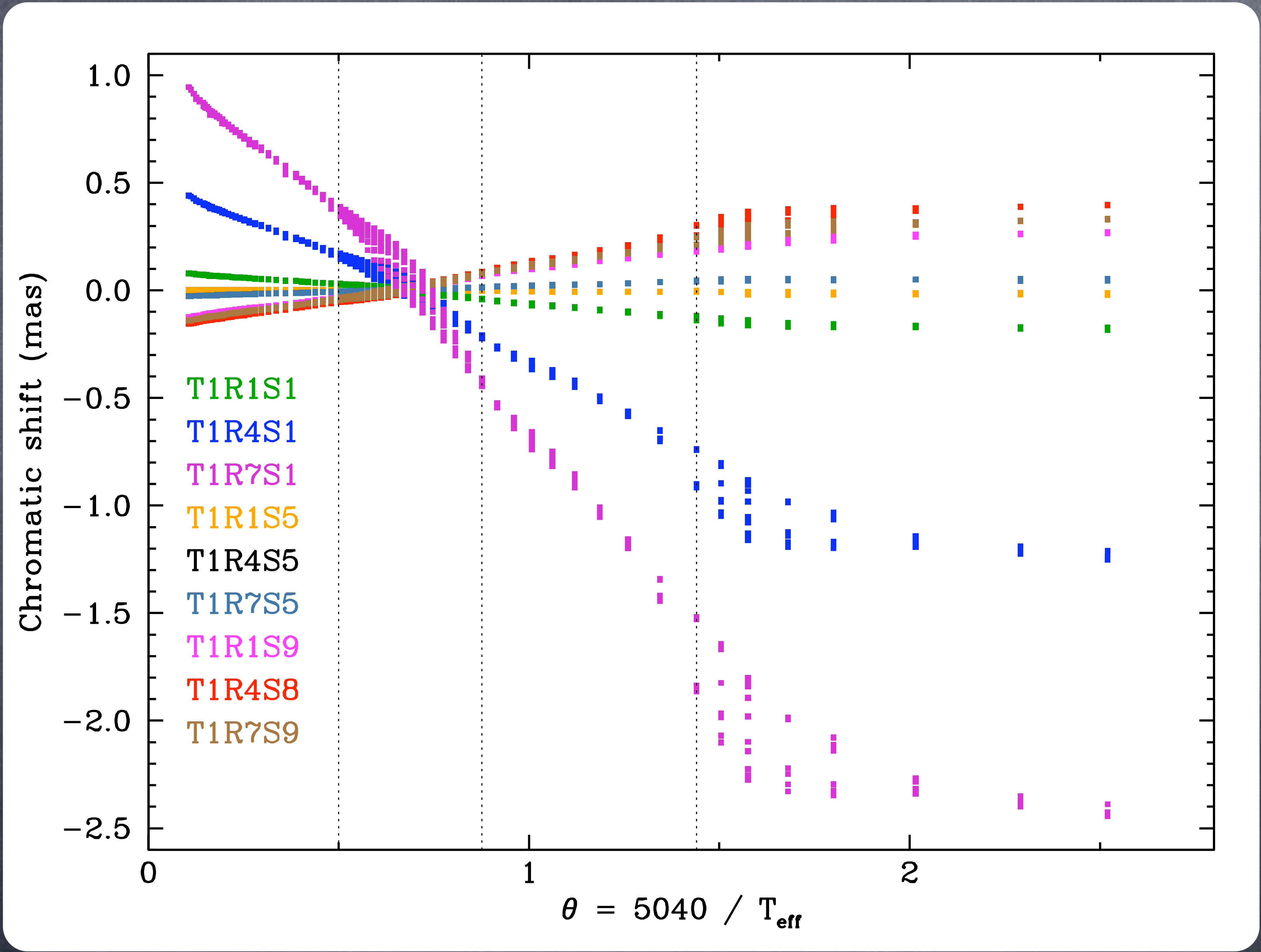
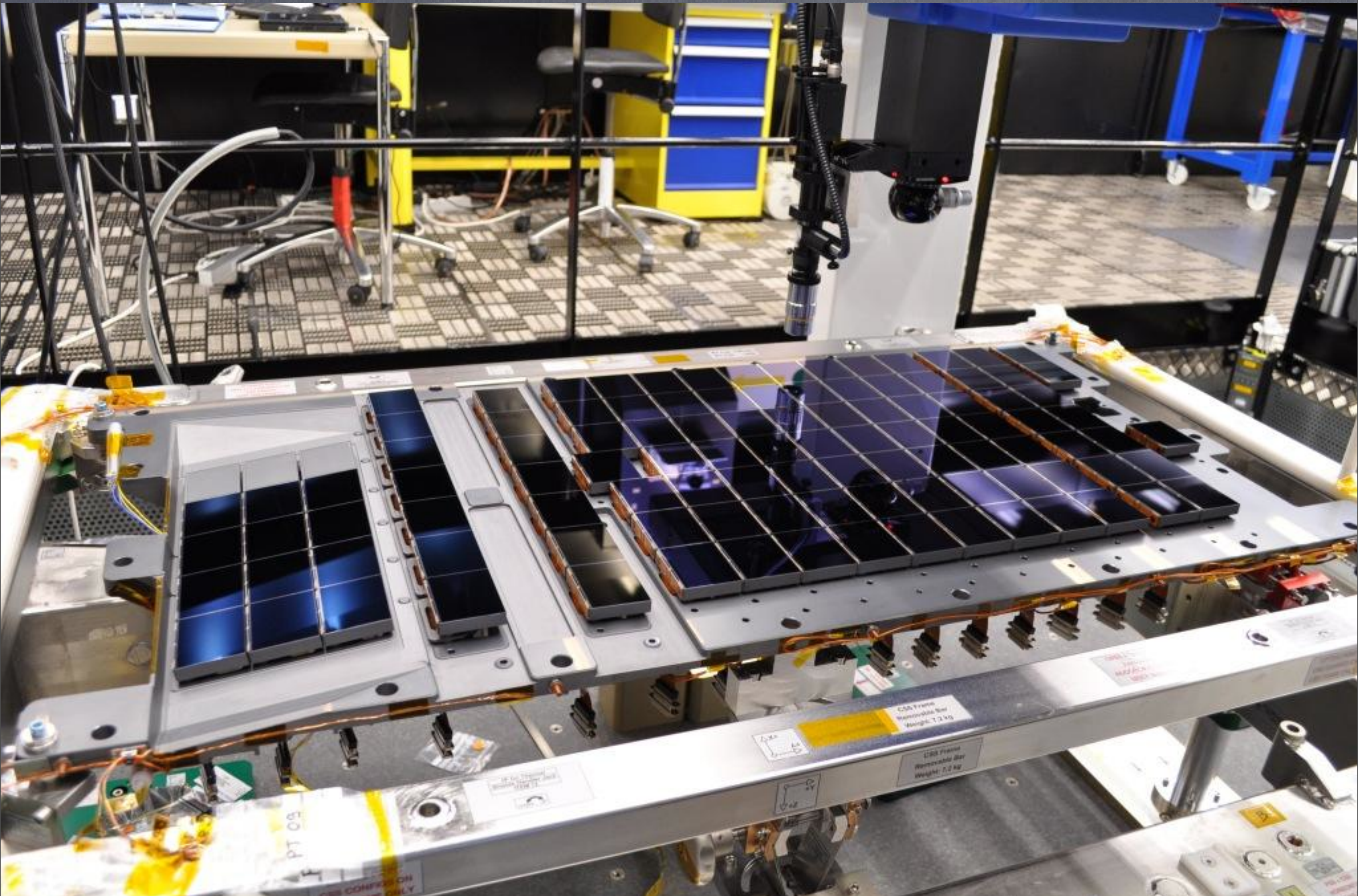
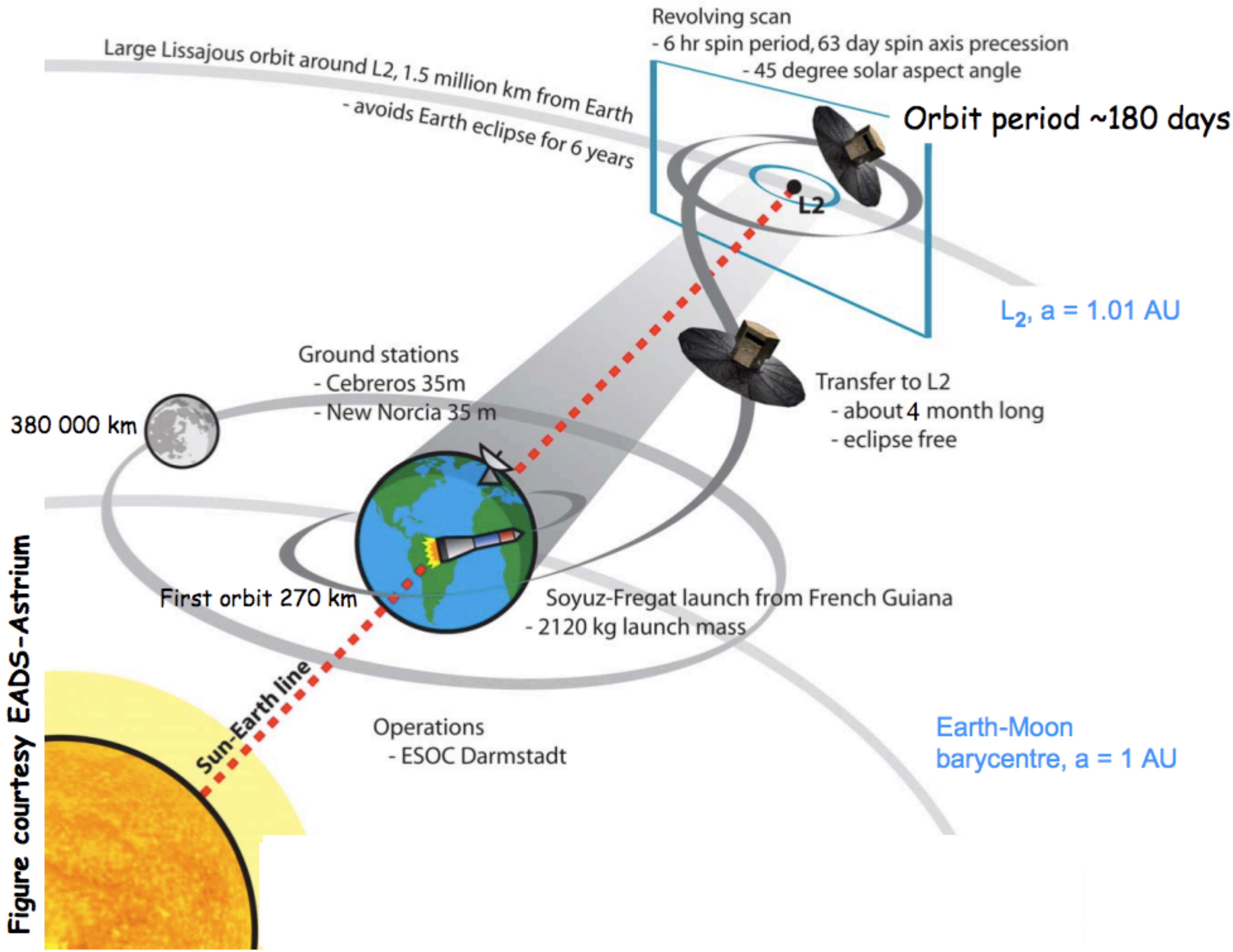


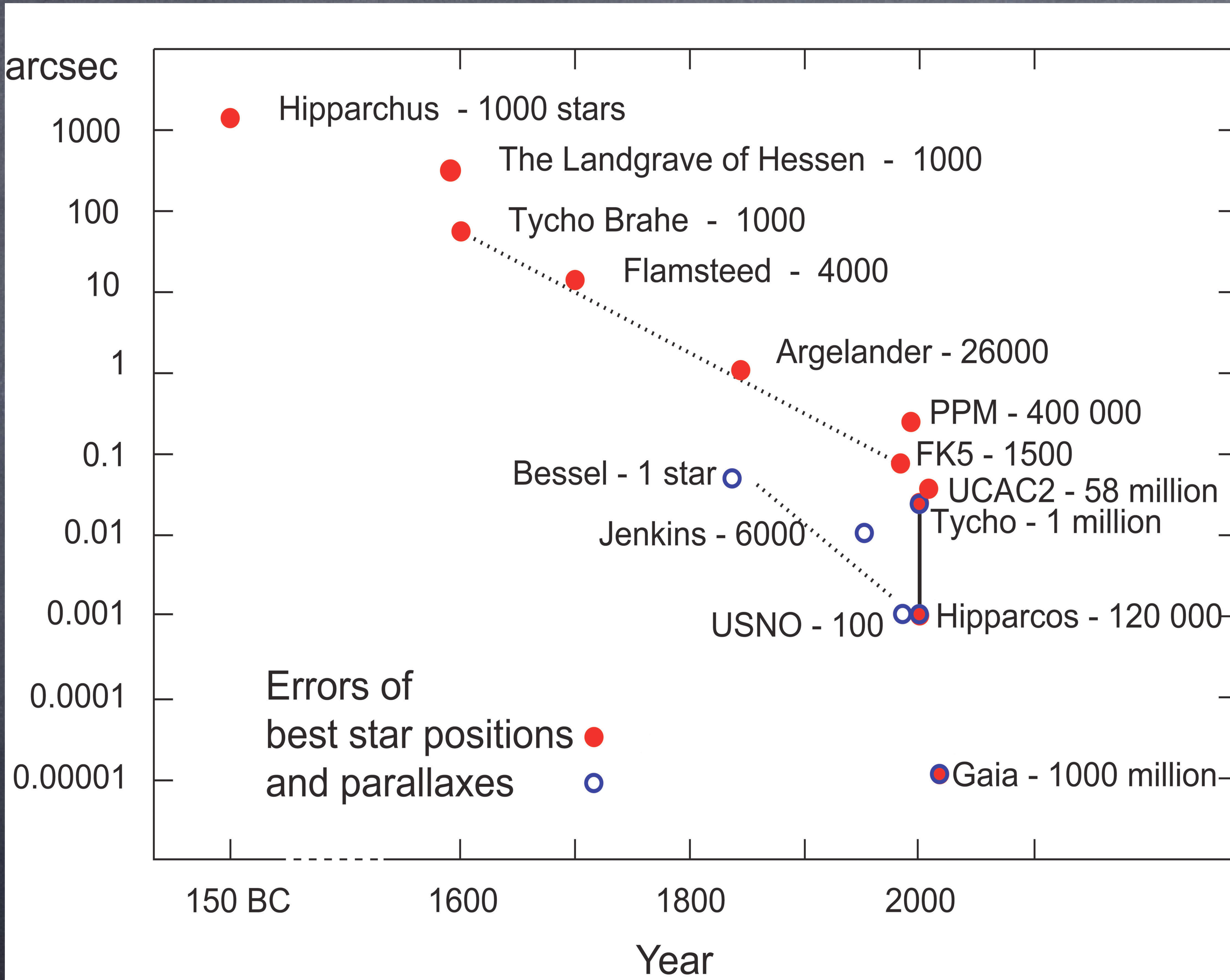
Figure courtesy GAIA-C5-TN-LEI-PM-004




ASTRIUM
ASTRIUM
TEST ADAPTER
ASTRIUM


Revolving scan
- 6 hr spin period, 63 day spin axis precession
- 45 degree solar aspect angle
Large Lissajous orbit around L2, 1.5 million km from Earth
- avoids Earth eclipse for 6 years
Orbit period ~180 days
L2
L_2, a = 1.01 AU
Ground stations
- Cebreros 35m
- New Norcia 35 m
Transfer to L2
- about 4 month long
- eclipse free
380 000 km
First orbit 270 km
Soyuz-Fregat launch from French Guiana
- 2120 kg launch mass
Sun-Earth line
Operations
- ESOC Darmstadt
Earth-Moon
barycentre, a = 1 AU
Figure courtesy EADS-Astrium

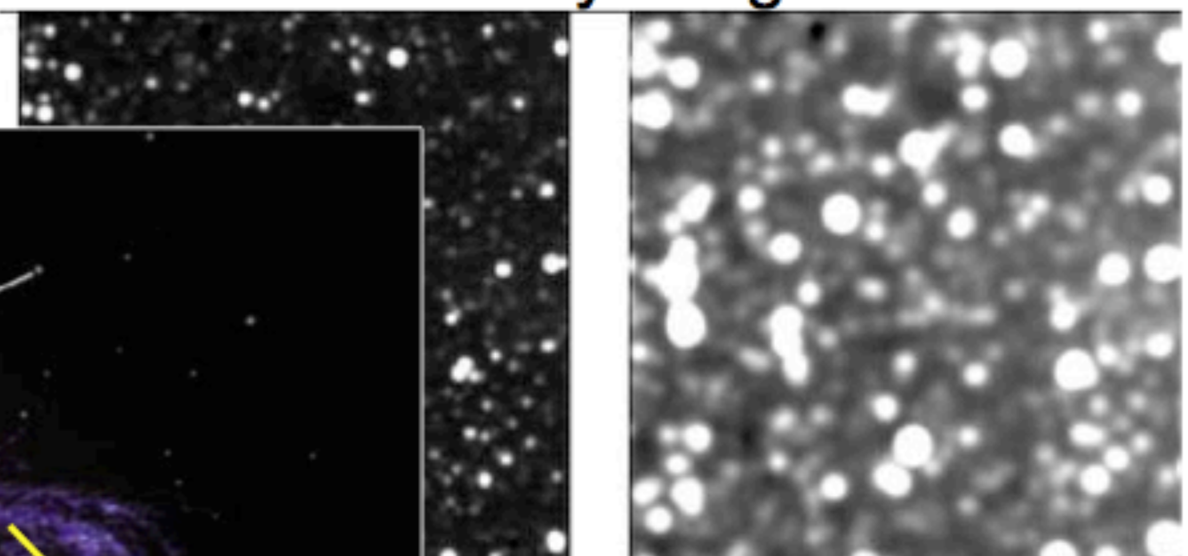
µas !!!!



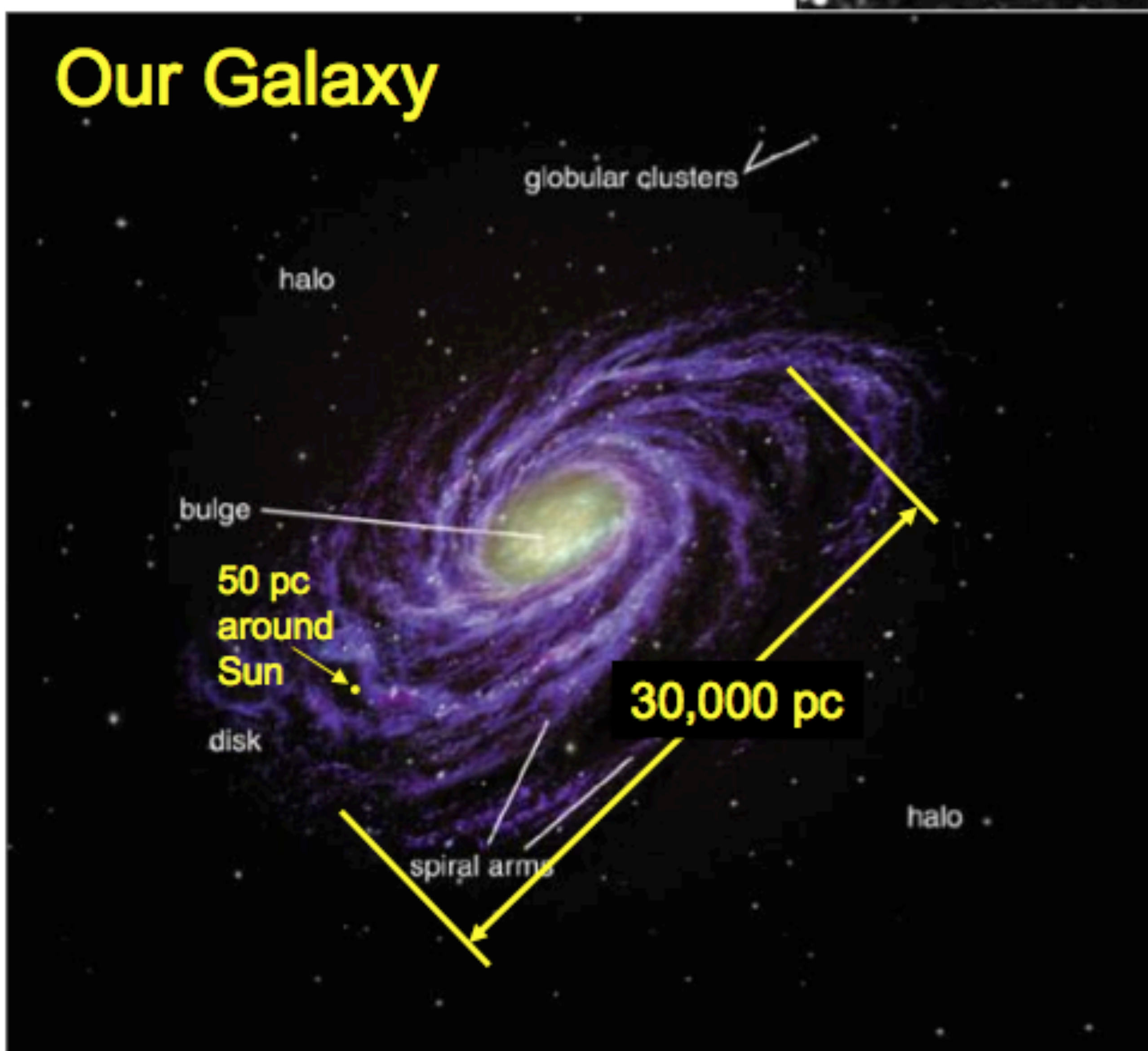
arcsec
1000
100
10
1
0.1
0.01
0.001
0.0001
0.00001
Hipparchus - 1000 stars
The Landgrave of Hessen - 1000
Tycho Brahe - 1000
Flamsteed - 4000
Argelander - 26000
PPM - 400 000
FK5 - 1500
UCAC2 - 58 million
Bessel - 1 star
Tycho - 1 million
Jenkins - 6000
USNO - 100
Hipparcos - 120 000
Errors of
best star positions
and parallaxes
Gaia - 1000 million
150 BC
1600
1800
2000
Year

What sets the parallax limit?

Fuzzy images



...blurred by Earth's atmosphere.

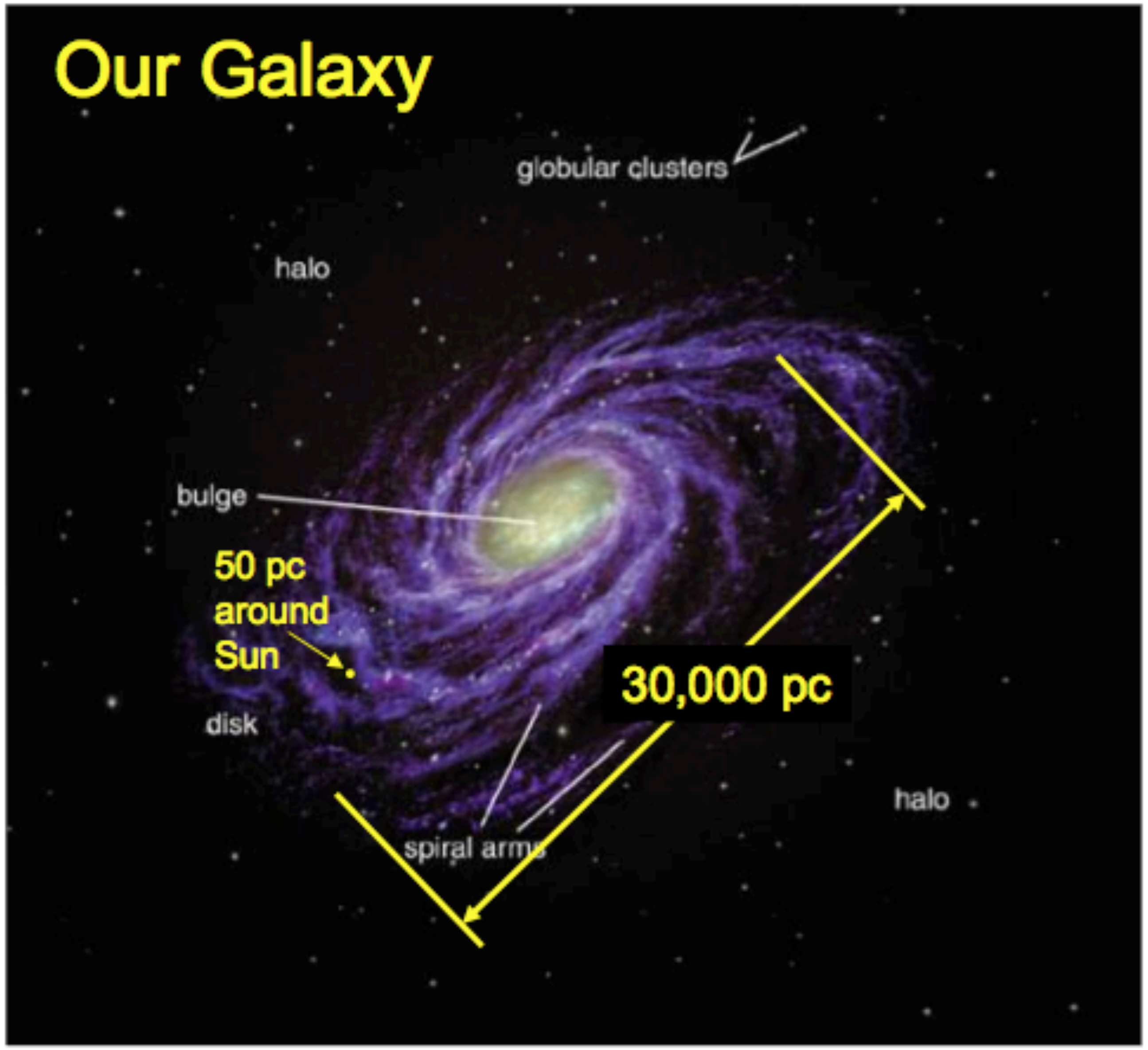


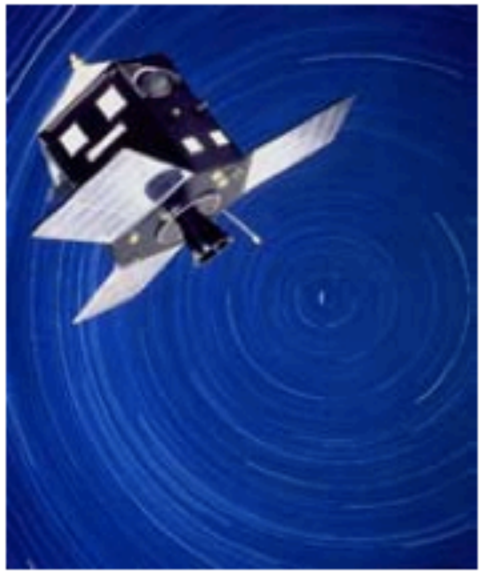
Old limit for parallax distances:
20-50 parsecs

Astrometry

Hipparcos

Sharp Images from Space





Hipparcos

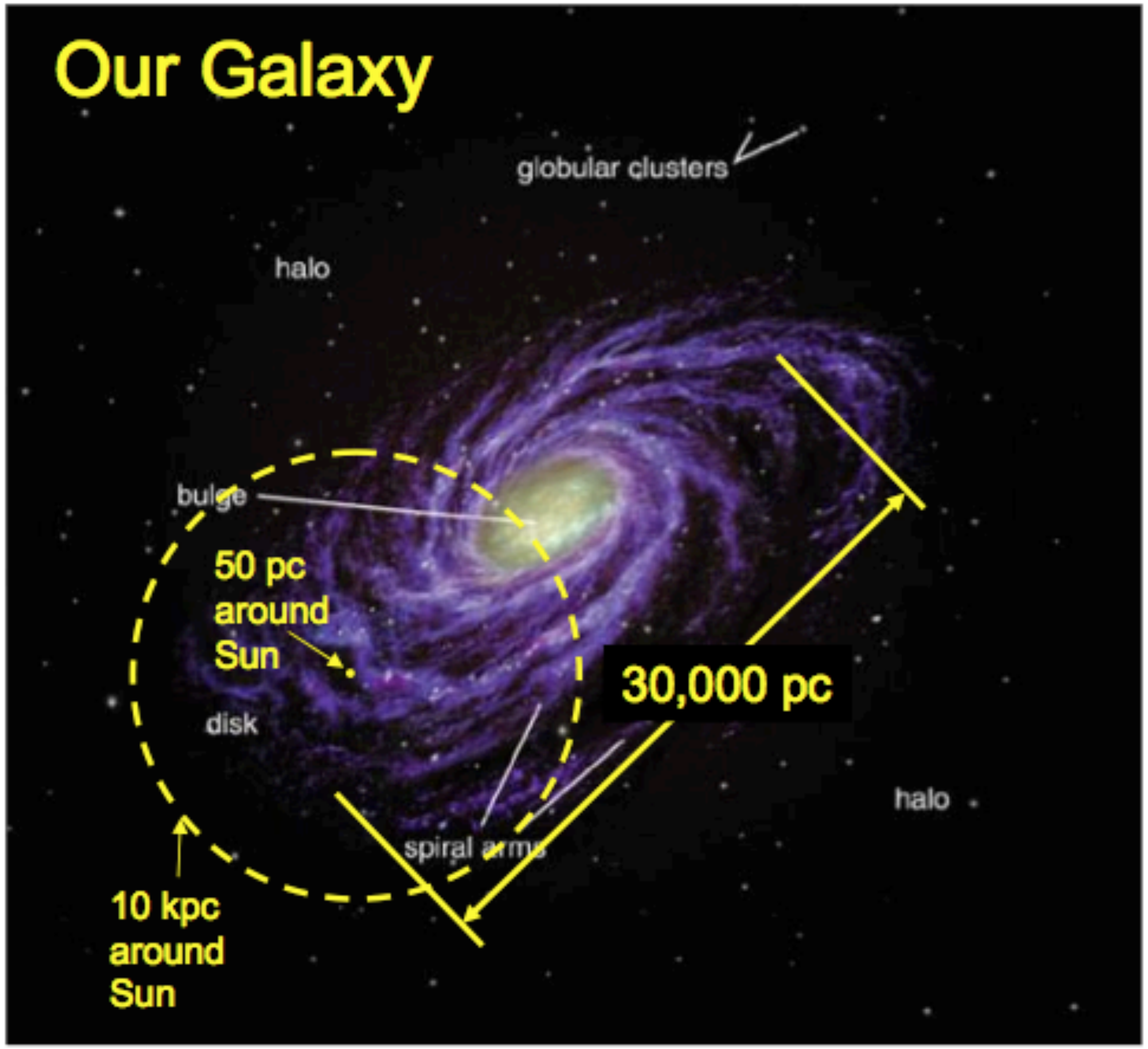
Old limit for parallax distances:
20-50 parsecs

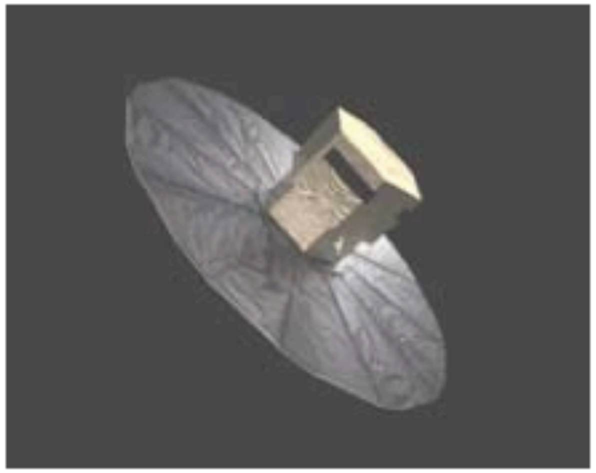
Hipparcos (1989-1993):
100-200 parsecs
(1σ =1 milliarcsec = 1kpc)

Astrometry

Gaia

Coming Attraction





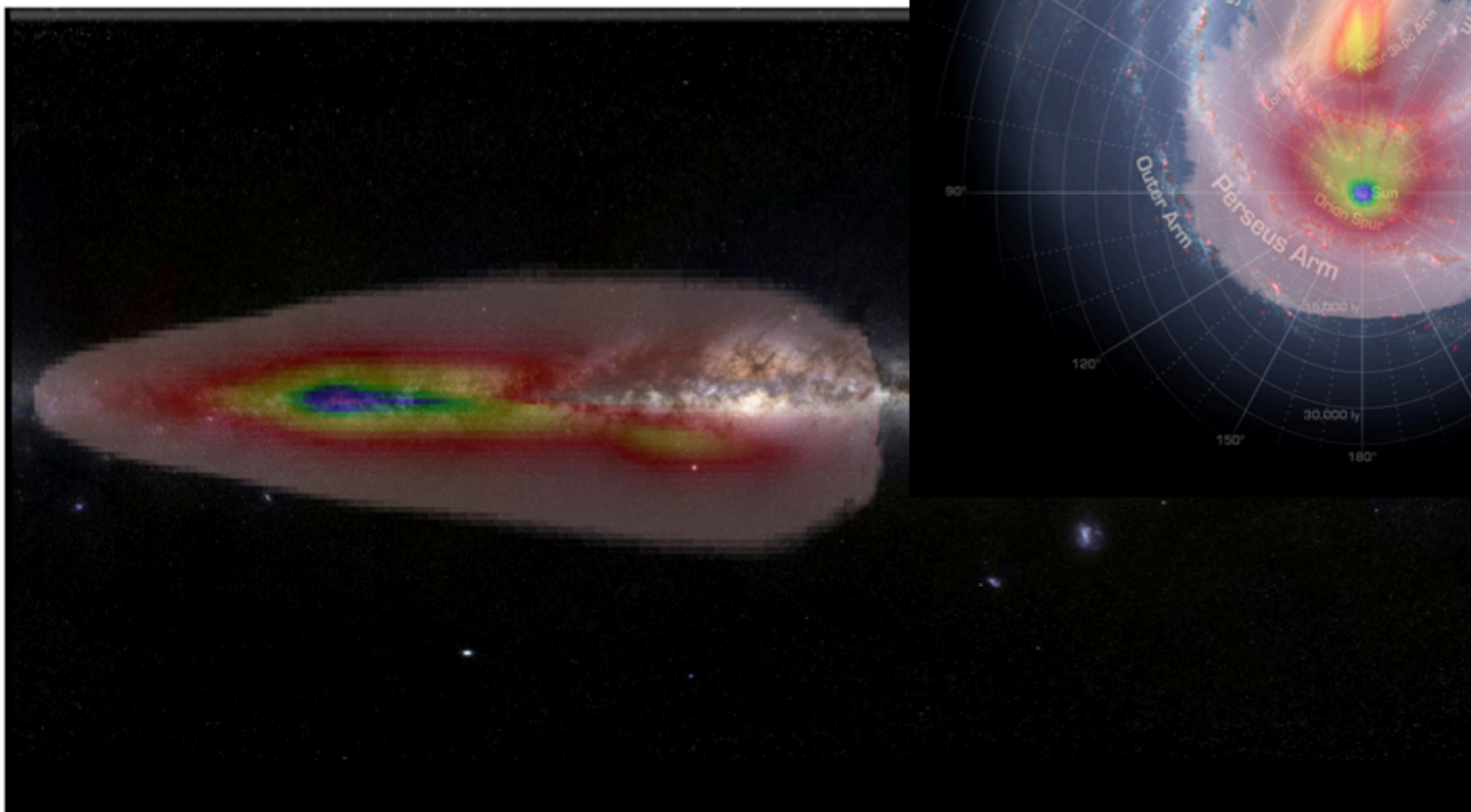
GAIA spacecraft: Dec 2011 launch

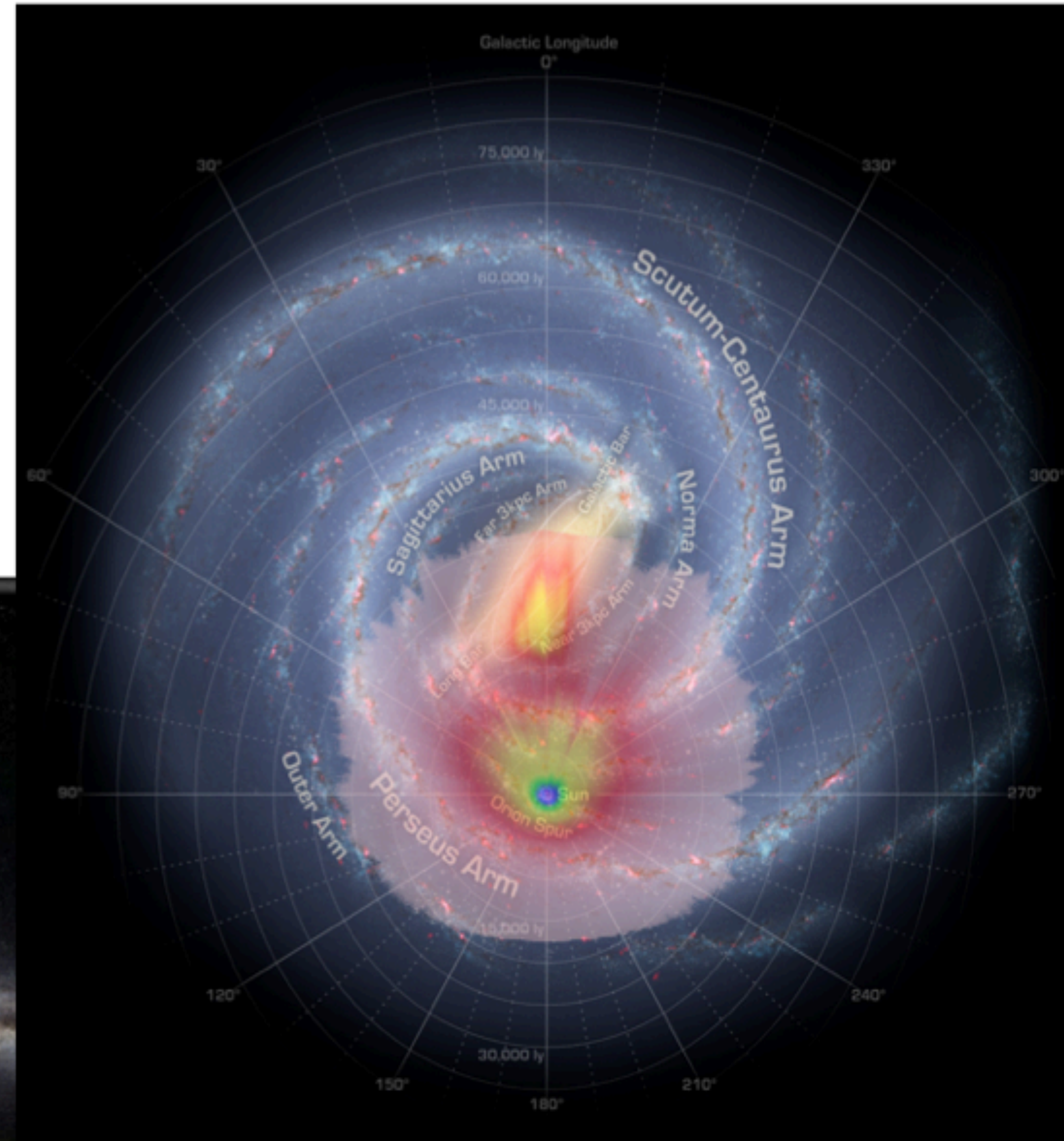
Old limit for parallax distances:
20-50 parsecs

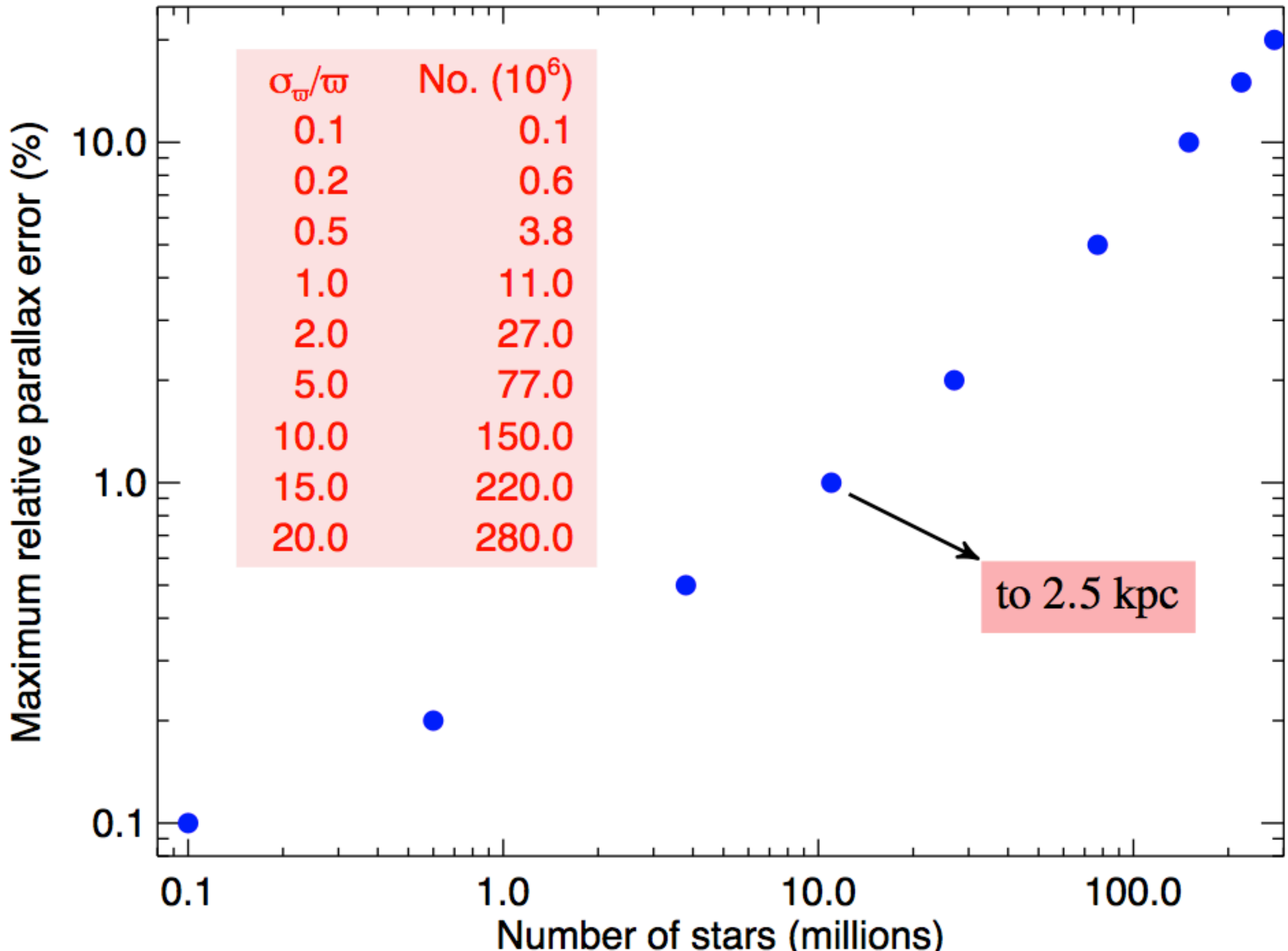
Hipparcos (1989-1993):
100-200 parsecs
(1σ =1 milliarcsec = 1kpc)

GAIA: 10 kpc

Figures courtesy Xavier Luri, DPAC-CU2 and NASA/JPL-Caltech/R. Hurt



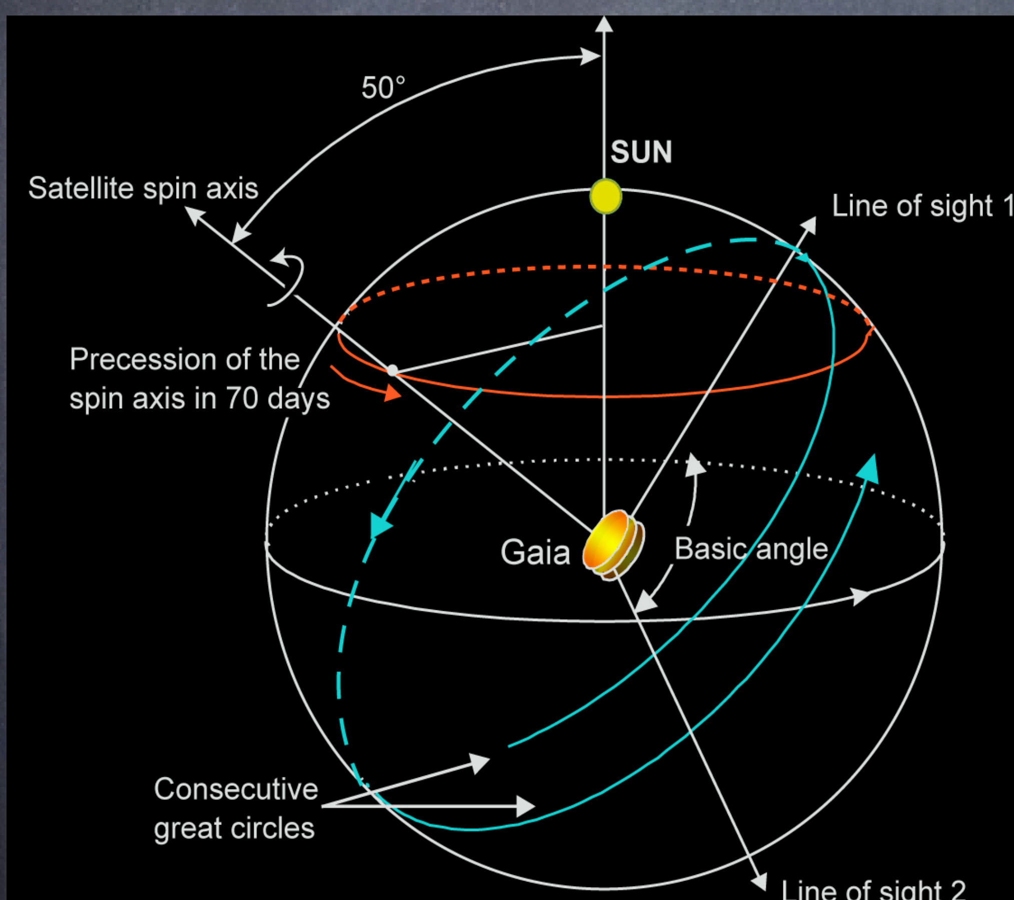



σ_ϖ/ϖ
No. (10^6)
0.1 0.1
0.2 0.6
0.5 3.8
1.0 11.0
2.0 27.0
5.0 77.0
10.0 150.0
15.0 220.0
20.0 280.0
to 2.5 kpc
Maximum relative parallax error (%)
Number of stars (millions)
0.1
1.0
10.0
100.0

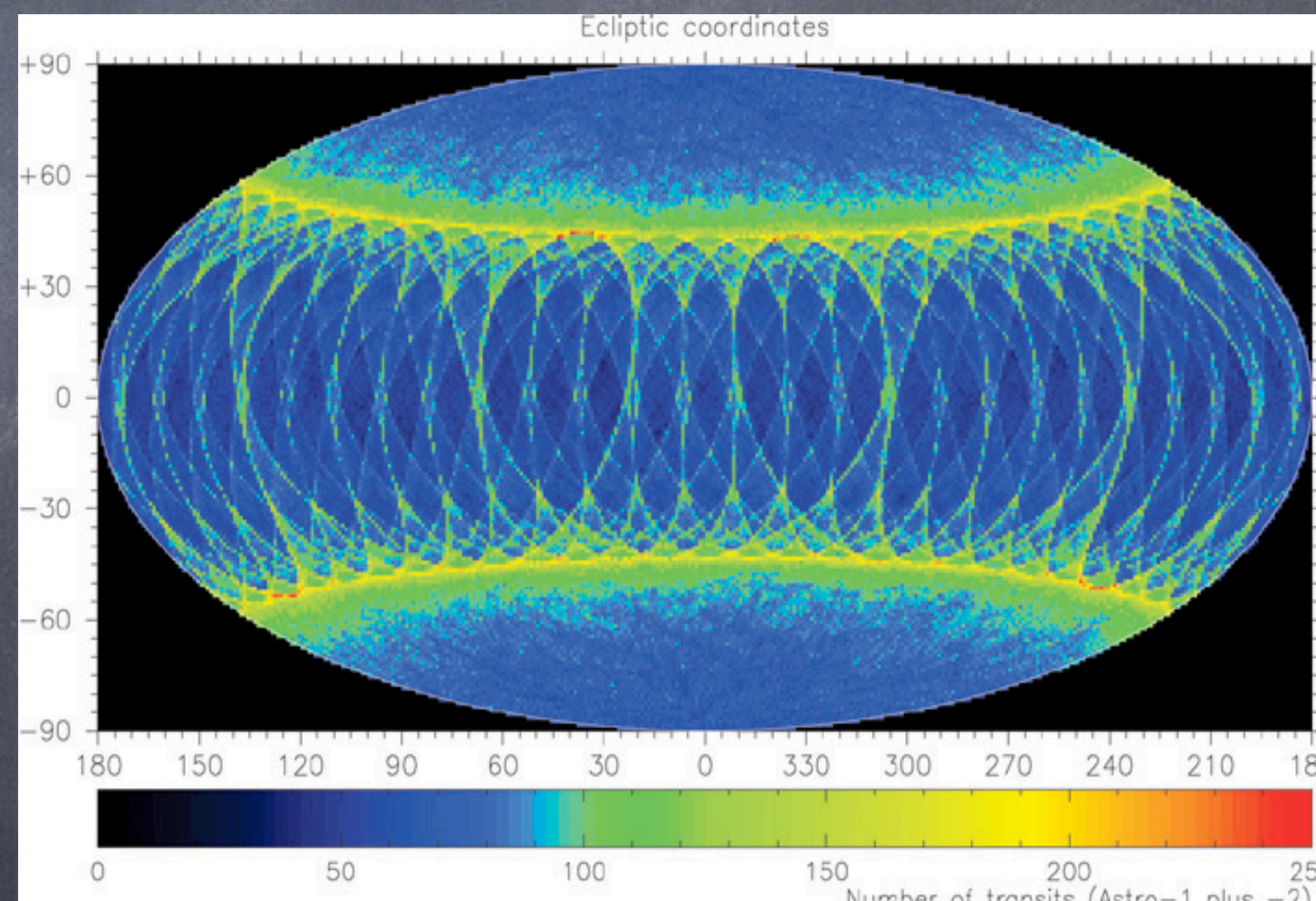
All-Sky Scanning

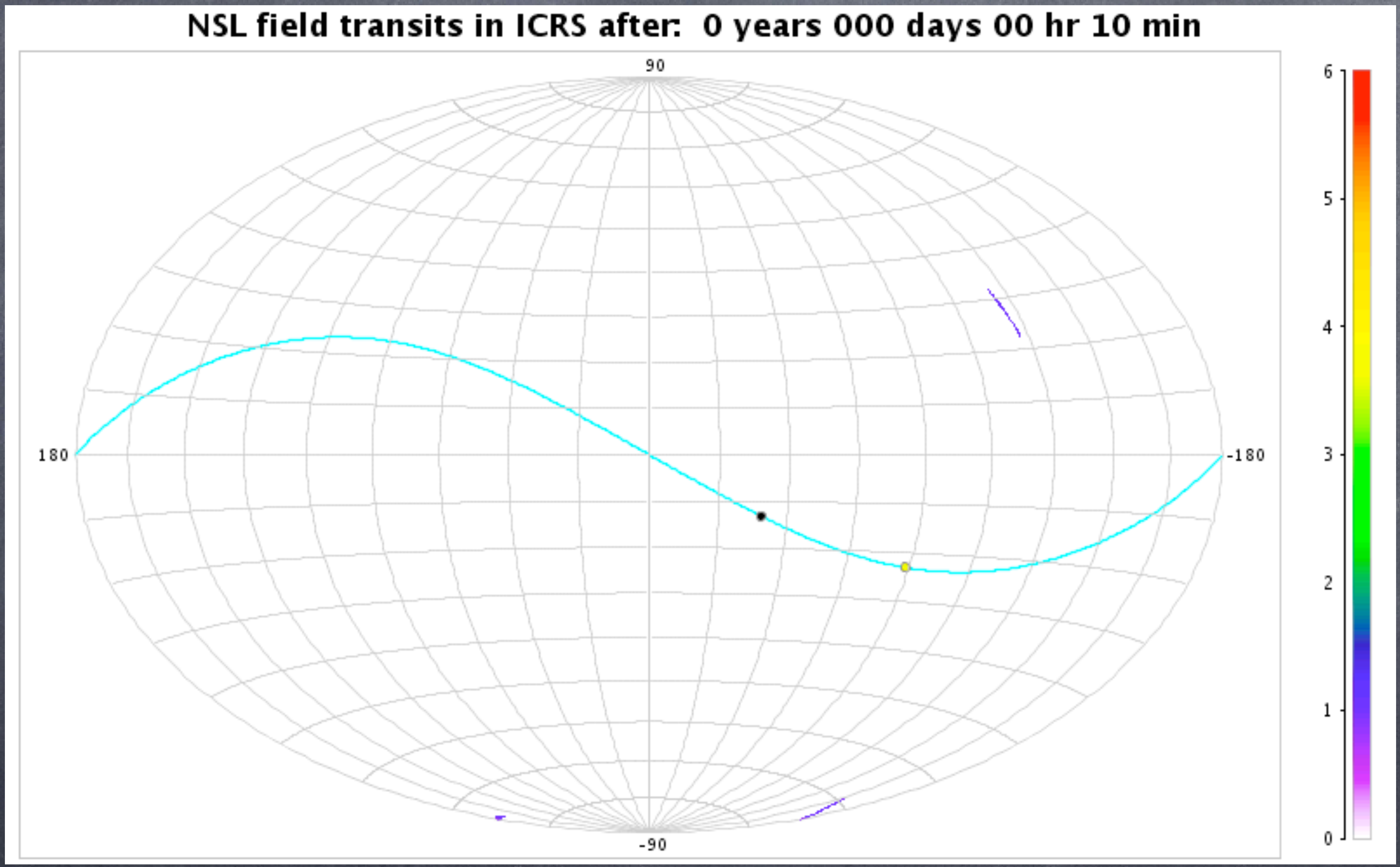
- Initial calibration phase on **Ecliptic Poles** (2 weeks)
- Maximum number of passages around ±45° from EP
- Each object observed 10-250 times (avg = 70-80)

Scanning Law

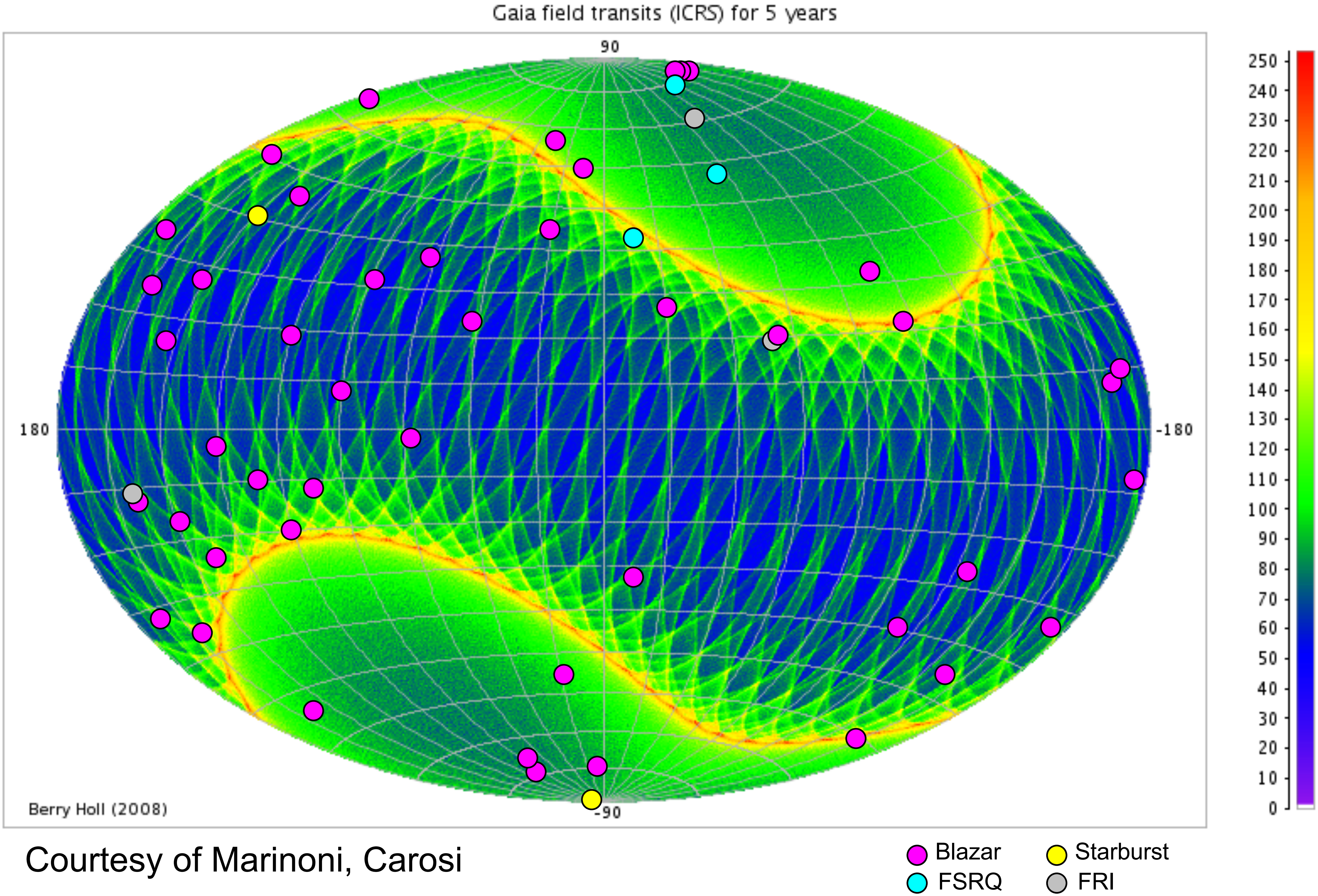


Sky Coverage

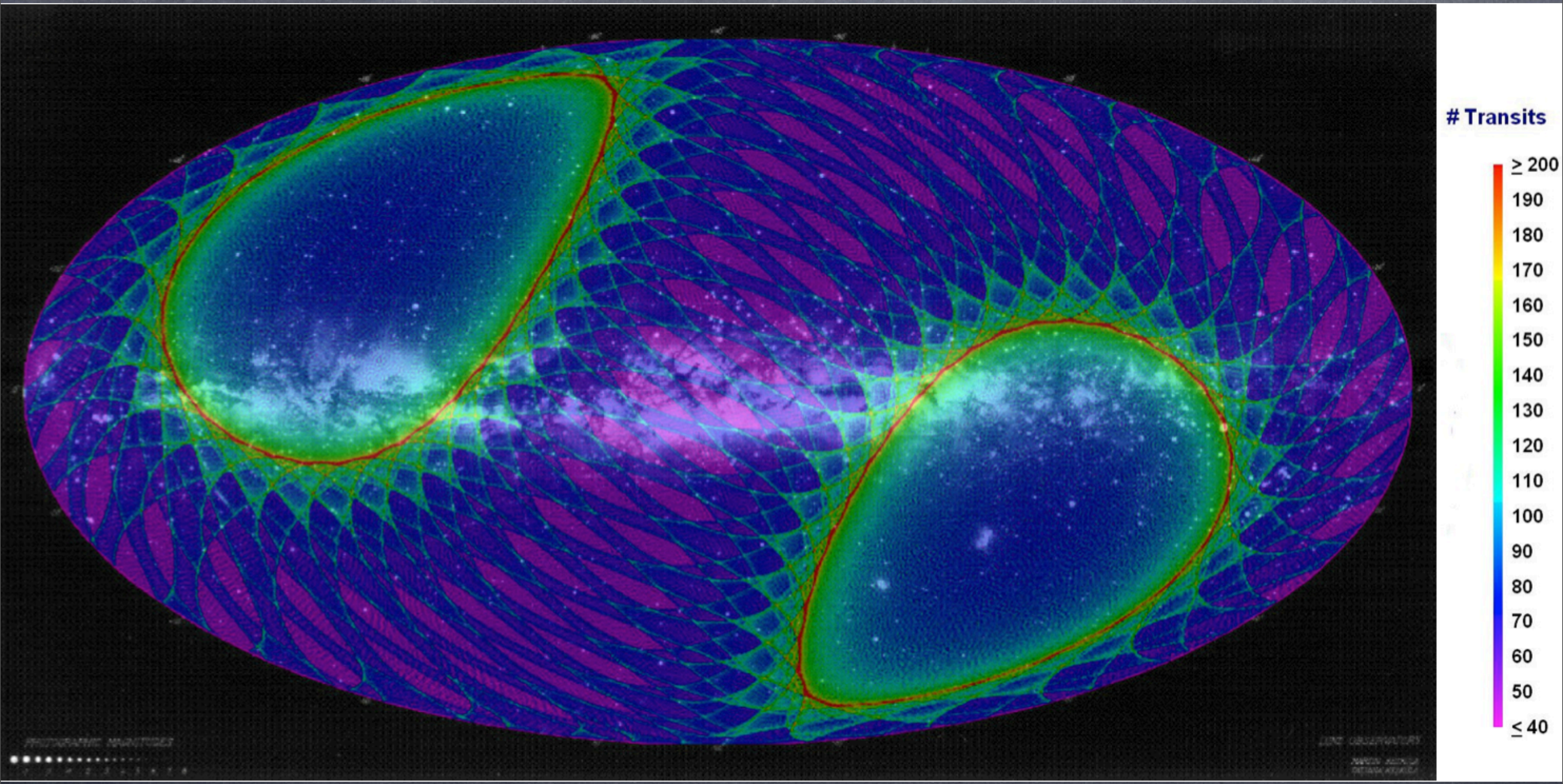



NSL field transits in ICRS after: 0 years 000 days 00 hr 10 min
90
180
-180
-90
6
5
4
3
2
1
0

The TeGeV Catalogue @ ASDC (v1)
(Extragalactic sources)



Courtesy of Marinoni, Carosi



Transits
≥ 200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
≤ 40

Gaia & QSO

“Stellar” mission but....

Gaia & QSO
“Stellar” mission but....

GCRF

Gaia Celestial Reference Frame

(at least 10000 astrometrically stable (μas) QSO)

Gaia & QSO
"Stellar" mission but....

GCRF

Gaia Celestial Reference Frame

(at least 10000 astrometrically stable (μas) QSO)

GIQC (Gaia Initial QSO Catalogue)
187505 objects (from LQAC-2
Souchay et al 2011)

Gaia & QSO

“Stellar” mission but....

GCRF

Gaia Celestial Reference Frame

(at least 10000 astrometrically stable (μas) QSO)

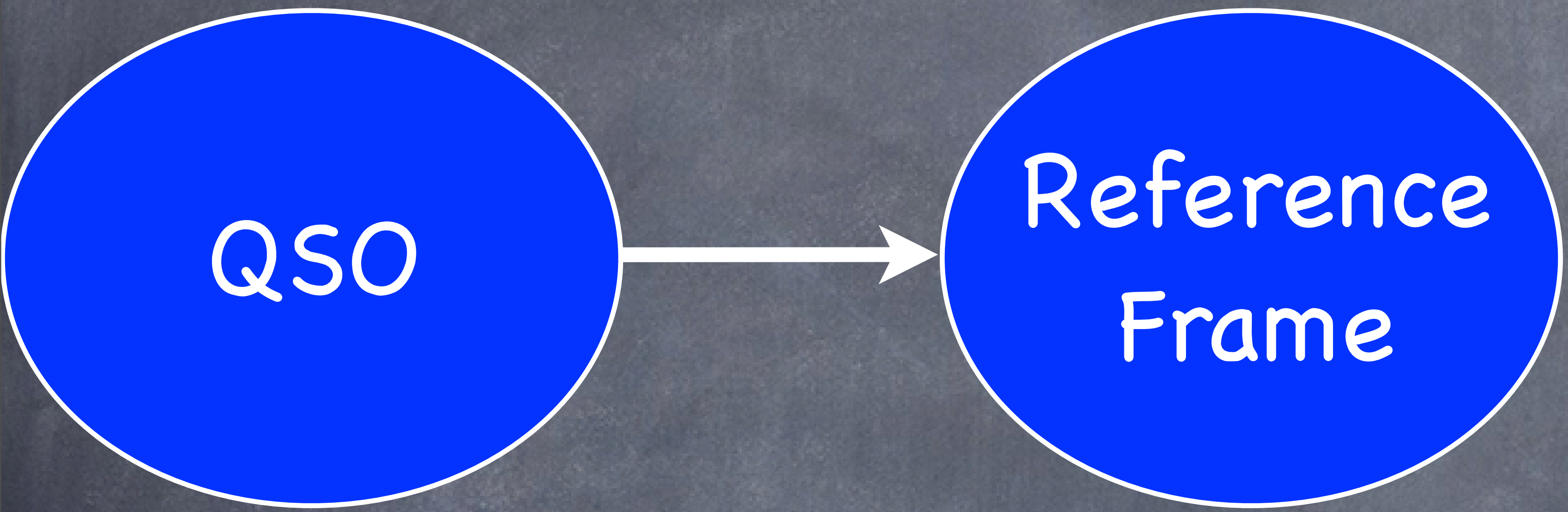
GIQC (Gaia Initial QSO Catalogue)
187505 objects (from LQAC-2
Souchay et al 2011)

↓

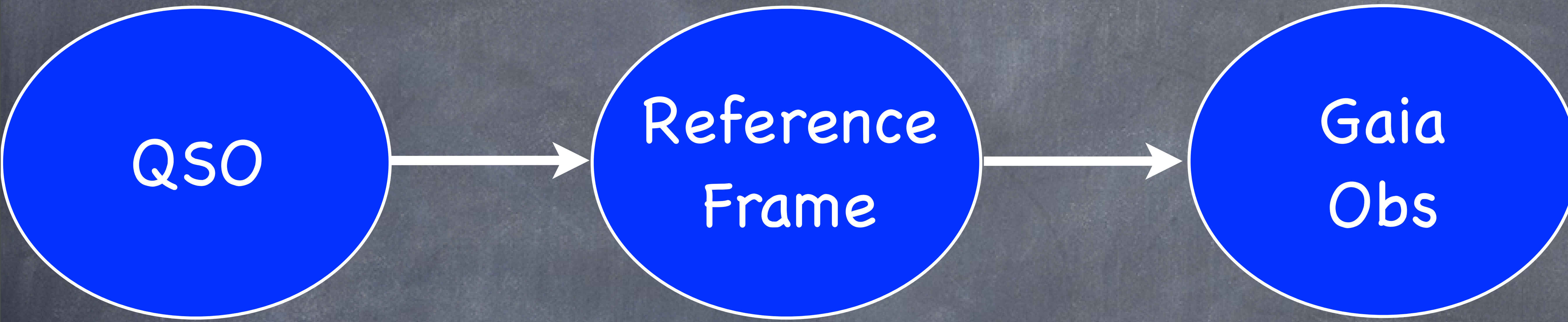
Observation - Cleaning (remove unstable QSO) - Confirmation and Integration (new QSO)

Gaia - QSO CONNECTION

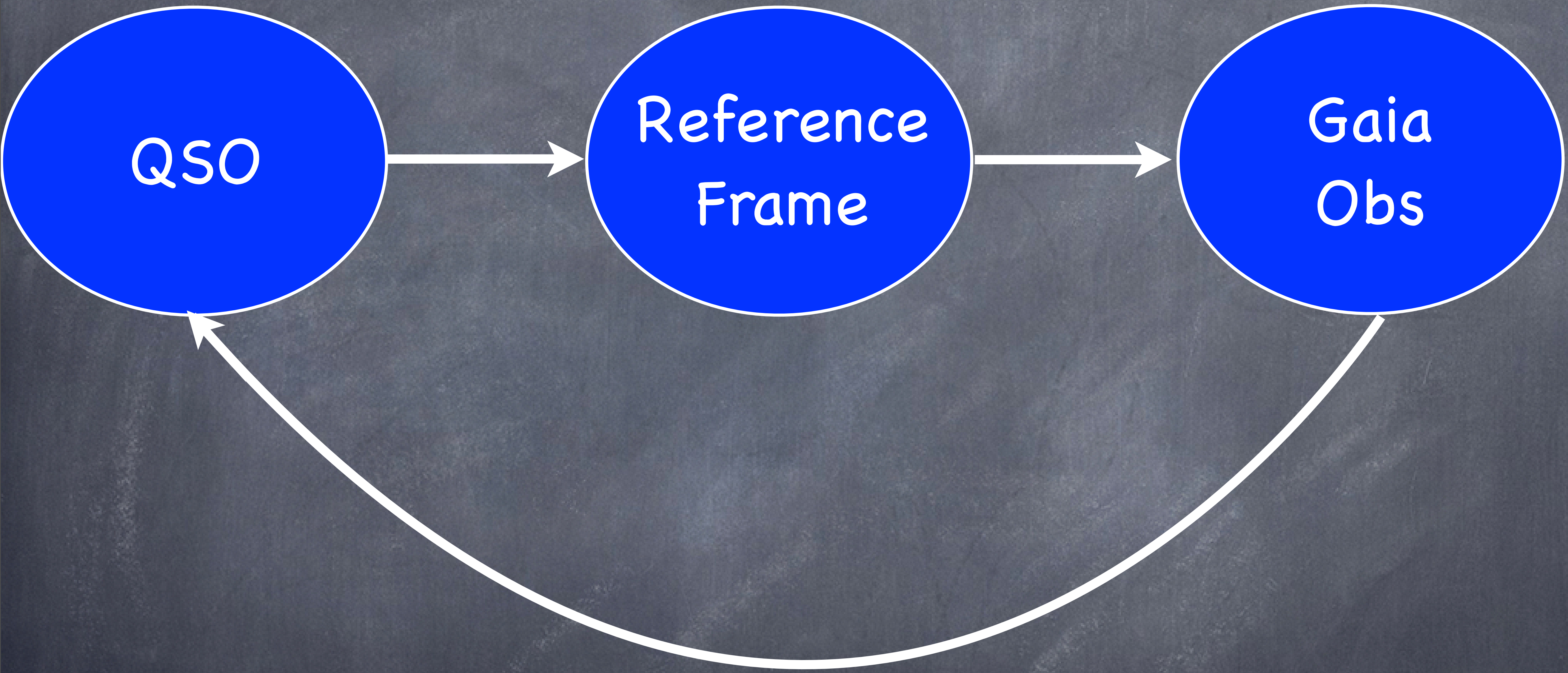
Gaia - QSO CONNECTION



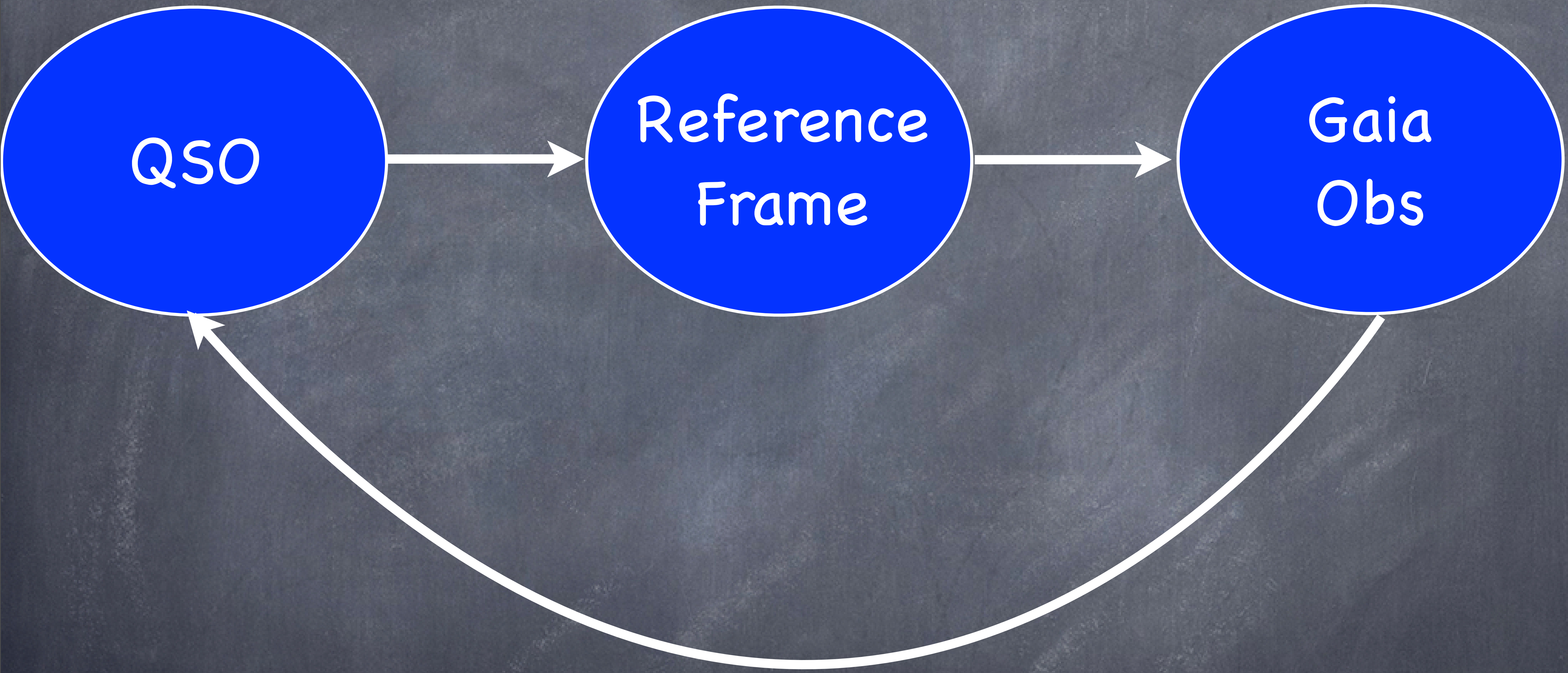
Gaia - QSO CONNECTION



Gaia - QSO CONNECTION



Gaia - QSO CONNECTION



QSO & Gaia : There and Back Again

QSO in Gaia

Mignard 2012

- 30.000-40.000 QSO up to V=18
- 5-7 x 10^5 QSO up to V=20
- 80% will be NEW detected sources

QSO in Gaia
Confirmation and Integration

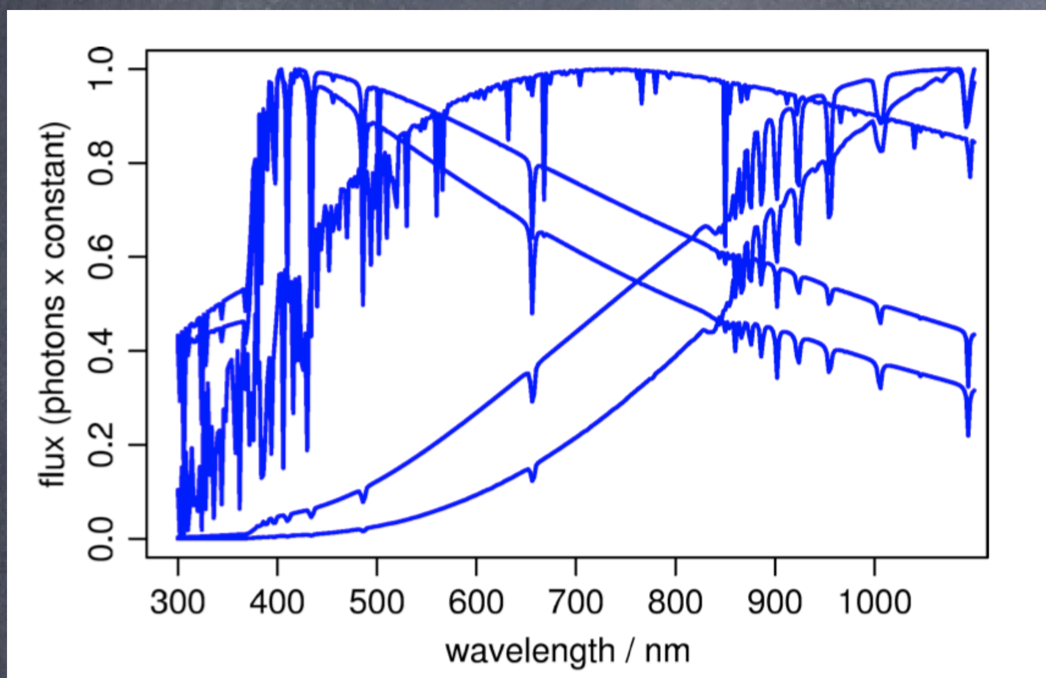
HOW ?

3 criteria:

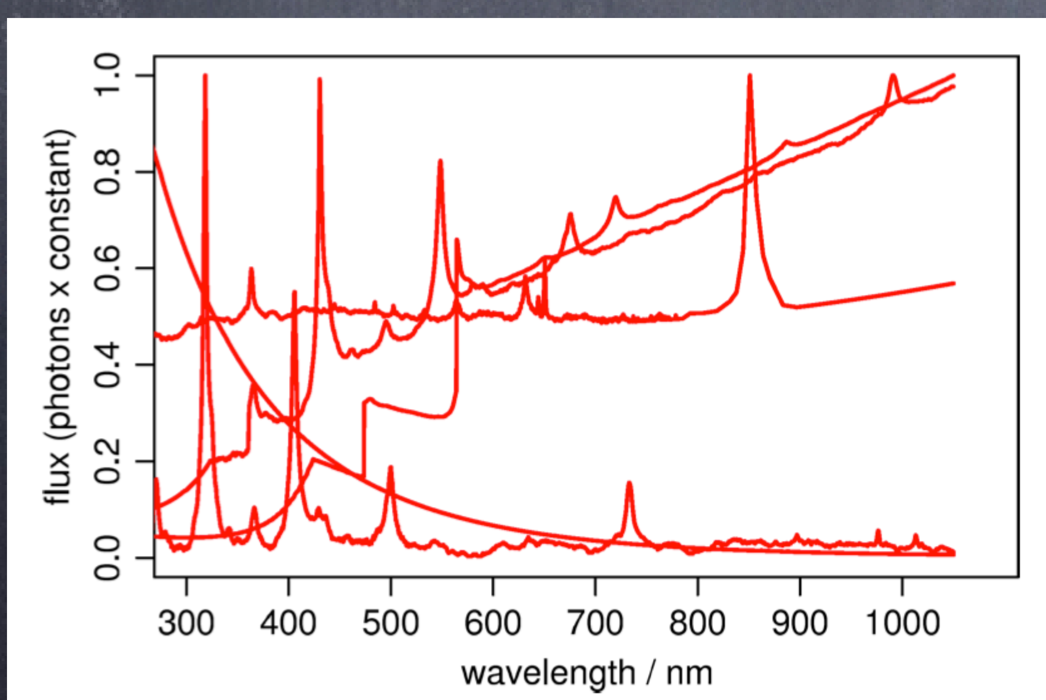
- Parallax
- Proper Motions
- BP/RP low resolution spectral shape

QSO in Gaia

Bailer-Jones et al 2008



Stars



QSO

BP

RP

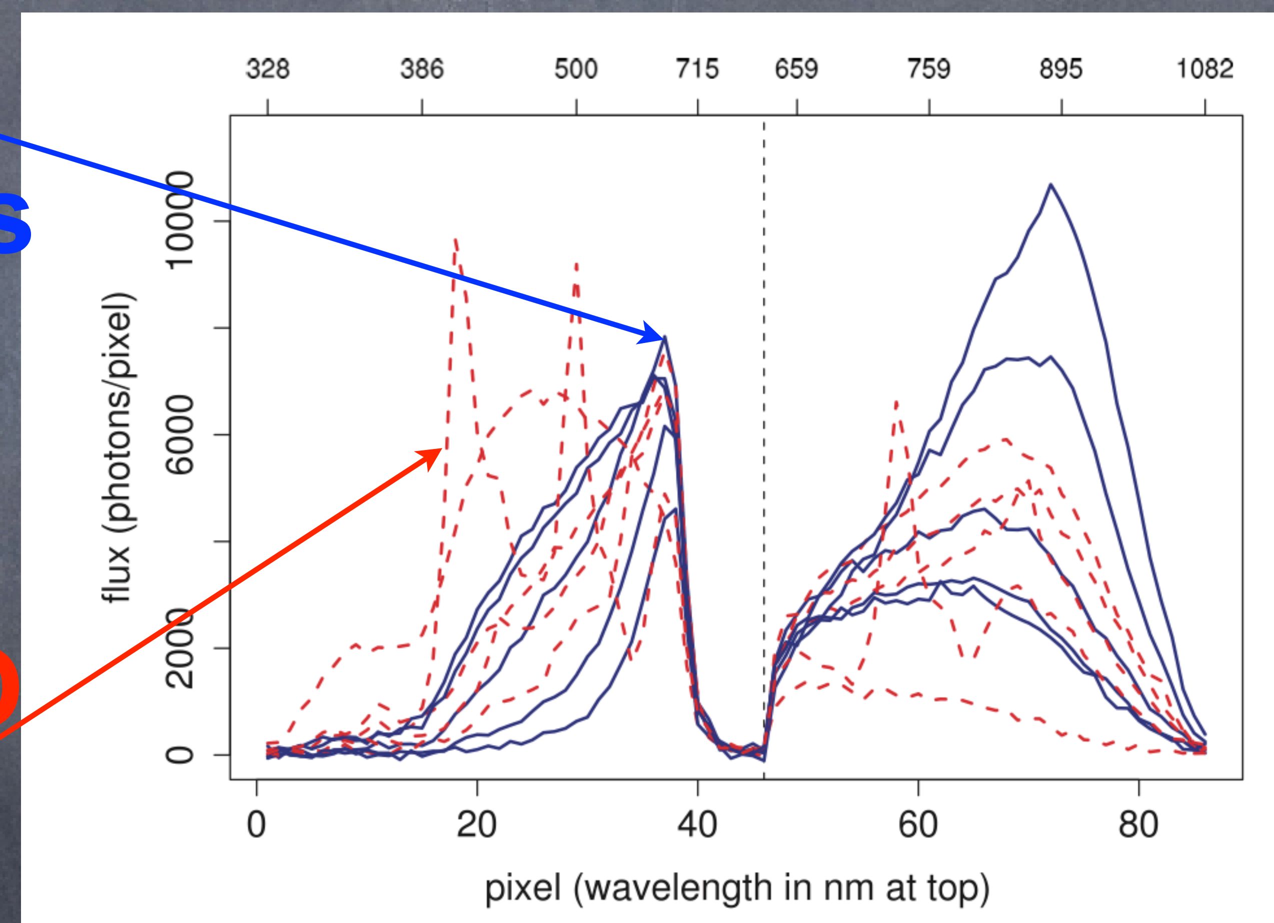


Figure 2. Random selection of five stars (blue solid lines) and five quasars (red dashed lines) ($G = 18.5$, noise included). The first 46 pixels are the blue channel (Blue Prism, BP), the remaining 40 the red channel (Red Prism, RP), separated by a dashed line.

QSO in Gaia
Confirmation and Integration

3 criteria:

- Parallax
- Proper Motions
- BP/RP low resolution spectral shape

= new QSO detection

Astrophotometric variability of CFHT-LS Deep 2 QSOs⋆,⋆⋆

F. Taris[1], J. Souchay[1], A. H. Andrei[2,3,4,1], M. Bernard[1], M. Salabert[1], S. Bouquillon[1], S. Anton[5], S. B. Lambert[1], A.-M. Gontier[1], and C. Barache[1]

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e-mail: Francois.Taris@obspm.fr
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[3] Observatório do Valongo/UFRJ, Rio de Janeiro, Brasil
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[5] CICGE-Fac. Sciences Univ. Porto, Porto, Portugal

Filtering

Received 29 July 2010 / Accepted 12 October 2010

ABSTRACT

Context. The current conventional realization of the ICRS (International Celestial Reference System) is, in the radio wavelength, the International Celestial Reference Frame 2 (ICRF2). The individual positions of the defining sources have been found to have accuracies better than 1 milliarcsecond (mas). In 2012, the European astrometric satellite Gaia will be launched. This mission will provide an astrometric catalog of an estimated number of 500 000 QSOs. The uncertainty in the coordinates is anticipated to be 200 microarcsecond (μas) for the magnitude = 20. If this were achieved, the ICRF and the Gaia related reference frame could be related with a μas accuracy.
Aims. The goal of this work is both to measure the photometric variability of a set of quasars in a given field, and search wether this variability can be related to an astrometric instability characterized by a motion of the quasar photocenter. If this correlation existed for some given QSO, then it would be inadequate to materialize the Gaia extragalactic reference frame at the level of confidence required, i.e. the sub-milliarcsecond one. This should be an important result in the scope of the Gaia mission.
Methods. We use QSO CCD images obtained over 4.5 years with the Canada France Hawaï Telescope (CFHT) in the framework of the CFHT-Legacy Survey (CFHT-LS). The pictures were analysed with both the SExtractor software and customised codes to perform a photometric calibration together with an astrometric one. A total of 41 QSOs in the Deep 2 field were analysed. Magnitude variations during more than 50 months are given at three different bandwiths G, R, and I. Among the set above, 5 quasars were chosen to test the ties between the postion of their centroid and their magnitude variations. For one of these 5 QSOs, the proximity of a neighbouring star allows the comparison between the PSFs.
Results. We clearly show significant photometric variations reaching sometimes more than one magnitude, for a good proportion of the 41 quasars in our sample. We show that these variations often occur within a few months, and that the correlation between the photometric curves in the three bands, G, R and I is obvious. As a second important result, we show that with a reasonably high probability, photometric variations for one quasar in our sample are accompagnied by substantial modification of its PSF.

Key words. reference systems – astrometry – quasars: general

Photocentric variability of quasars caused by variations in their inner structure: Consequences for Gaia measurements

L.Č. Popović[1,2], P. Jovanović[1,2], M. Stalevski[1,2,8], S. Anton[3,4], A. H. Andrei[5,6,7], J. Kovačević[1,2], and M. Baes[8]

[1] Group for Astrophysical Spectroscopy, Astronomical Observatory, Volgina 7, 11060 Belgrade 74, Serbia
[2] Isaac Newton Institute of Chile, Yugoslavia Branch, Serbia
[3] CICGE, Faculdade de Ciências da Universidade do Porto, Portugal
[4] SIM, Faculdade de Ciências da Universidade de Lisboa, Portugal
[5] Observatório Nacional/MCT, R. Gal. José Cristino 77, CEP 20921-400 Rio de Janeiro, Brazil
[6] Osservatório Astronomico di Torino/INAF, Strada Osservatório 20, 10025 Pino Torinese, Italy
[7] SYRTE/Observatoire de Paris, 61 Avenue de lObservatoire, 75014 Paris, France Obswervatrio do Valongo/UFRJ, Ladeira Pedro António 43, CEP 20080-090 Rio de Janeiro, Brazil
[8] Sterrenkundig Observatorium, Universiteit Gent, Krijgslaan 281-S9, Gent, 9000, Belgium

Received May 12, 2011; accepted — —, 2011

ABSTRACT

Context. We study the photocenter position variability caused by variations in the quasar inner structure. We consider the variability in the accretion disk emissivity and torus structure variability caused by the different illumination by the central source. We discuss the possible detection of these effects by Gaia. Observations of the photocenter variability in two AGNs, SDSS J121855+020002 and SDSS J162011+1724327 have been reported and discussed.
Aims. For variations in the quasar inner structure, we explore how much this effect can affect the position determination and whether it can (or not) be detected with the Gaia mission.
Methods. We use models of (a) a relativistic disk, including the perturbation that can increase the brightness of part of the disk, and consequently offset the photocenter position, and (b) a dusty torus that absorbs and re-emits the incoming radiation from the accretion disk (central continuum source). We estimate the value of the photocenter offset caused by these two effects.
Results. We found that perturbations in the inner structure can cause a significant offset to the photocenter. This offset depends on the characteristics of both the perturbation and accretion disk and on the structure of the torus. In the case of the two considered QSOs, the observed photocenter offsets cannot be explained by variations in the accretion disk and other effects should be considered. We discuss the possibility of exploding stars very close to the AGN source, and also that there are two variable sources at the center of these two AGNs that may indicate a binary supermassive black hole system on a kpc (pc) scale.
Conclusions. The Gaia mission seems to be very promising, not only for astrometry, but also for exploring the inner structure of AGNs. We conclude that variations in the quasar inner structure can affect the observed photocenter (by up to several mas). There is a chance to observe such an effect in the case of bright and low-redshift QSOs.

Key words. galaxies: active – galaxies: quasar – astrometry: reference systems

QSO & Gaia

- Several 10^5 new qso detected + classification with BP/RP

- Variability analysis

- Photocentric variability

- MWL approach mandatory!

(astrometric+photometric variability + X, γ, .. , variability)

DATA RELEASES

NO proprietary time

- Launch date - September - October 2013
- Anticipate ~ 6 Months for cruise to L2, commissioning, DPAC systems initialization
- First full sky coverage after 6 months of nominal scanning
- Disentangling parallaxes and proper motions requires at least 18 Months of data collection
- Processing, calibration, validation take time
- Each data release requires time to go from DPAC internal database to public archive (3 Months)

DATA RELEASES

To be confirmed data releases — highly summarized:

- Assumes smooth operations!
- All values prior to final release may be truncated at some confidence level
- Each release updates the previous and contains significant new additions

L=Launch (9-10/2013)

L+22M Positions + G magnitude (~ all sky, single source)

- Includes more often scanned Ecliptic pole regions
- Hundred Thousand Proper Motions (Hipparcos-Gaia, ~ 50 μas/yr)

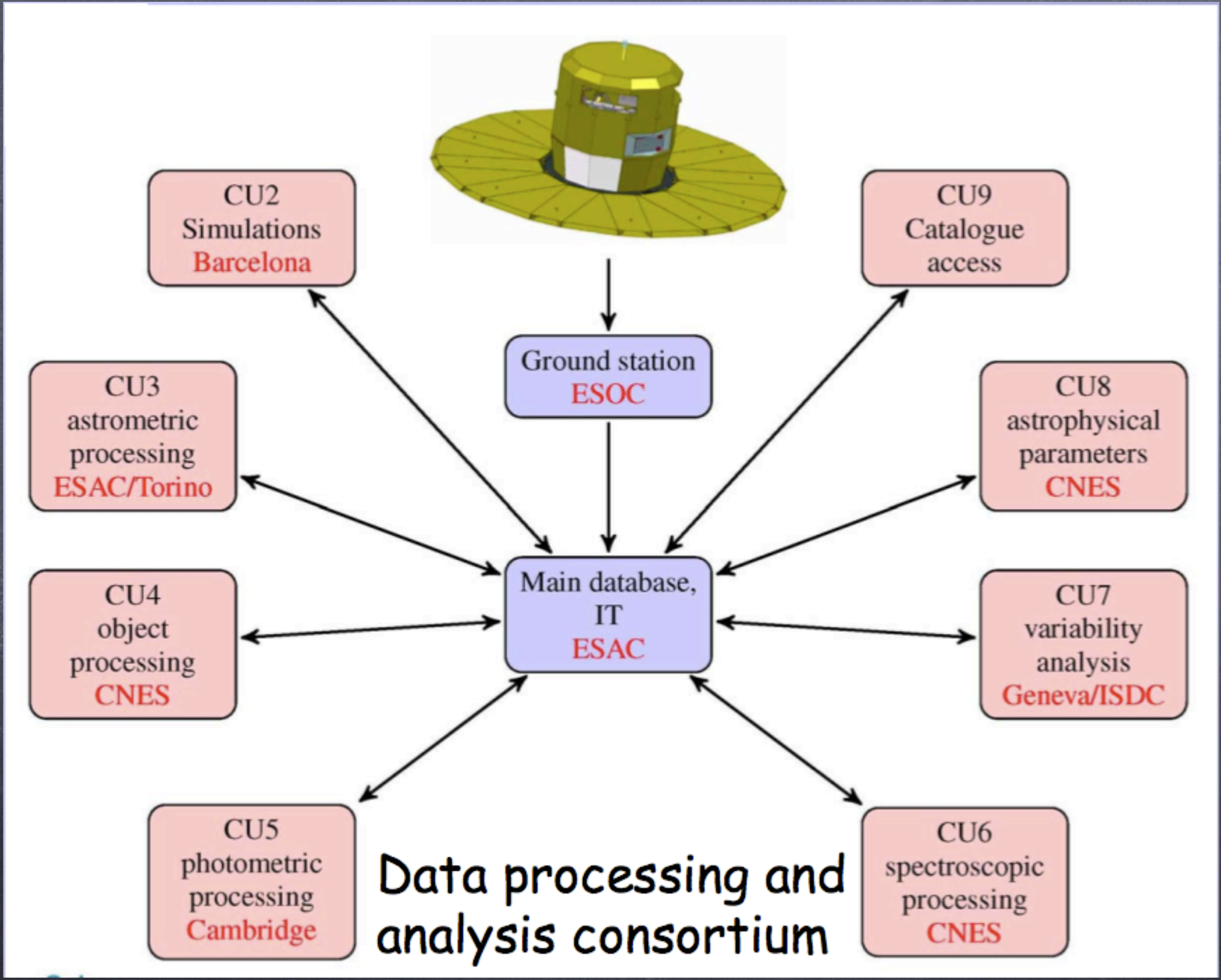
L+28M more tentative some radial velocities for bright stars + BP/RP integrated

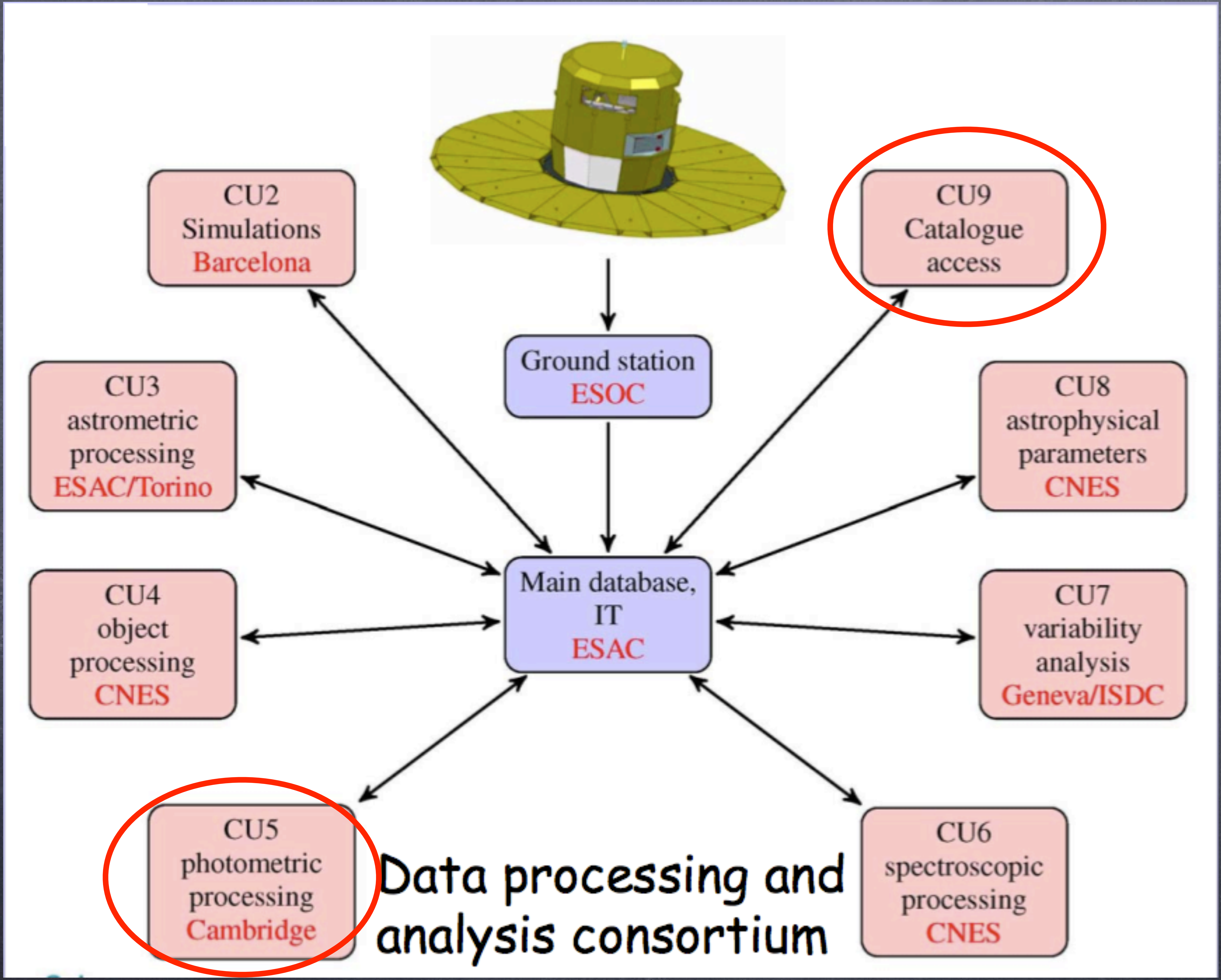
L+40M full astrometry (α, δ, π, $\mu\alpha$, $\mu\delta$), orbital solutions, ($G_{BP} - G_{RP}$), some

BP/RP Spectrophotometry and astrophysical parameters , RVS spectra

L+65M Updates on previous release — including more sources, source classifications, multiple astrophysical parameters, variable star solutions and epoch photometry for them, solar system results

End+3yr Everything


CU2
Simulations
Barcelona
CU9
Catalogue
access
Ground station
ESOC
CU3
astrometric
processing
ESAC/Torino
CU8
astrophysical
parameters
CNES
Main database,
IT
ESAC
CU4
object
processing
CNES
CU7
variability
analysis
Geneva/ISDC
CU5
photometric
processing
Cambridge
CU6
spectroscopic
processing
CNES
Data processing and
analysis consortium


CU2
Simulations
Barcelona
CU9
Catalogue
access
Ground station
ESOC
CU3
astrometric
processing
ESAC/Torino
CU8
astrophysical
parameters
CNES
Main database,
IT
ESAC
CU4
object
processing
CNES
CU7
variability
analysis
Geneva/ISDC
CU5
photometric
processing
Cambridge
Data processing and
analysis consortium
CU6
spectroscopic
processing
CNES

CU5

- Pipeline development for photometric processing
- SPSS grid for absolute calibration (BP/RP/G)

CU9

- Archive mirror
- Multiwavelength cross match
- Ancillary (IT) Database