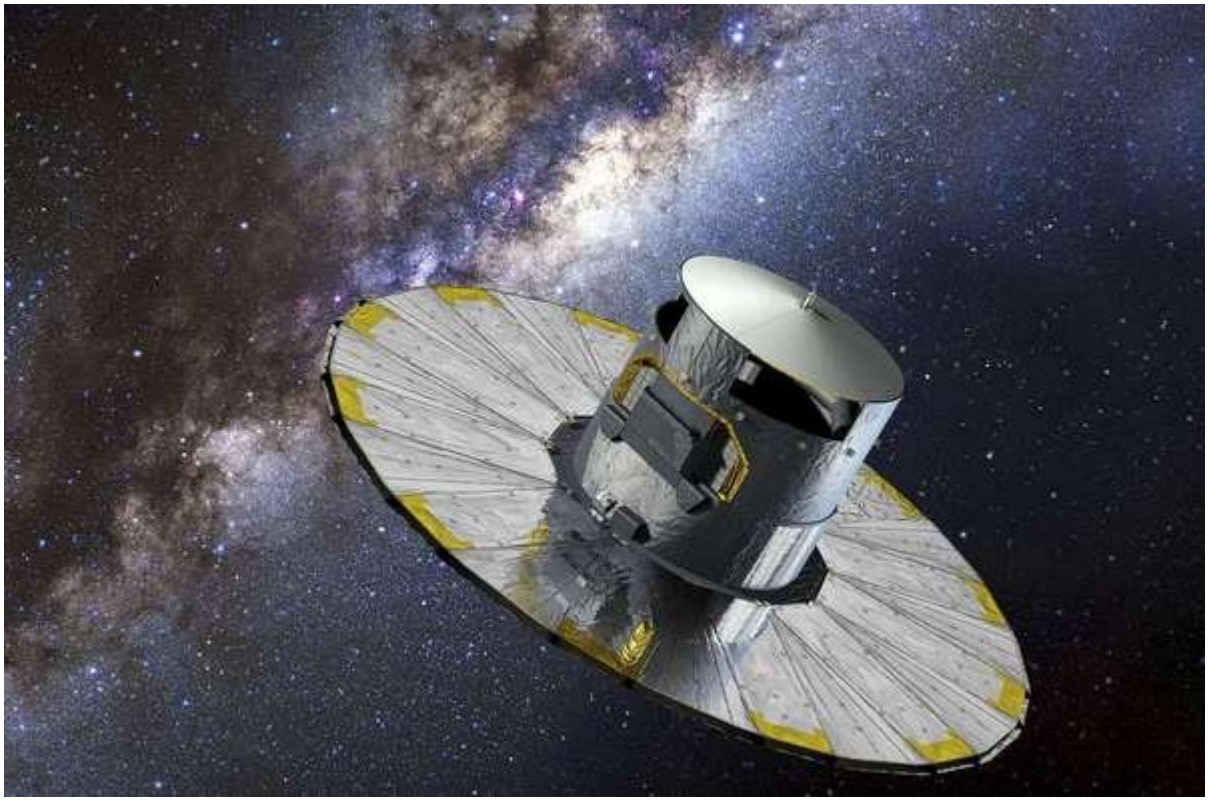
GENIUS Mid Term review

Context:
the Gaia mission and the DPAC

gaia

Gaia
DPAC
Data Processing & Analysis Consortium

X. Luri
Universitat de Barcelona



Gaia: an ESA's cornerstone mission

- Selected in 2001
- Launched in Dec. 2013
- Now on operations

Gaia: a (mainly) astrometric mission

- >10^9 objects (~1% Milky Way)
- Complete up to 20th magnitude
- Positions, velocities and parallaxes
  - Nominal precision (15^{th} mag): ~25μas
- Spectrophotometry
- Spectroscopy and radial velocities (G<16)
- No input catalogue → unbiased survey

A data processing challenge

Astrometry

- Astrometric centroid of the CCD image to be determined to an accuracy of 1% of the pixel size!
  - 150TB downlinked, need to handle ~1PB
  - 10^{12} individual images to process
    - At 1 millisecond each that is 30years
  - Processing estimate remains 10^{20} FLOP
- Gaia attitude is required to the order of ~20 μarcsec
  - Path of light through instrument needed to nanometre level
  - System must be extremely stable
  - Must consider (among other things) relativistic light bending from solar system objects with great detail (unprecedented)
- Attitude and Geometric calibration can only be done using Gaia's own observational data (self-calibration)

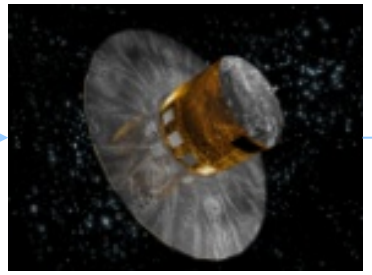
BP/RP & RVS

- G magnitudes for all stars to few millimag
- BP/RP spectra are collected using red and blue enhanced CCDs (low resolution)
  - Extracting the signal will be hard
  - Calibration will be difficult: flux scale (all types of objects) from data, using different gates
  - Some ground based observations needed

- RVS spectra for 150 million stars (x40 times)
  - All light in FOV dispersed on RVS - disentangling spectra will be difficult
  - Calibration again tricky

Organizing it: the DPAC

Industry/ESA CSG/ESOC

(2013)

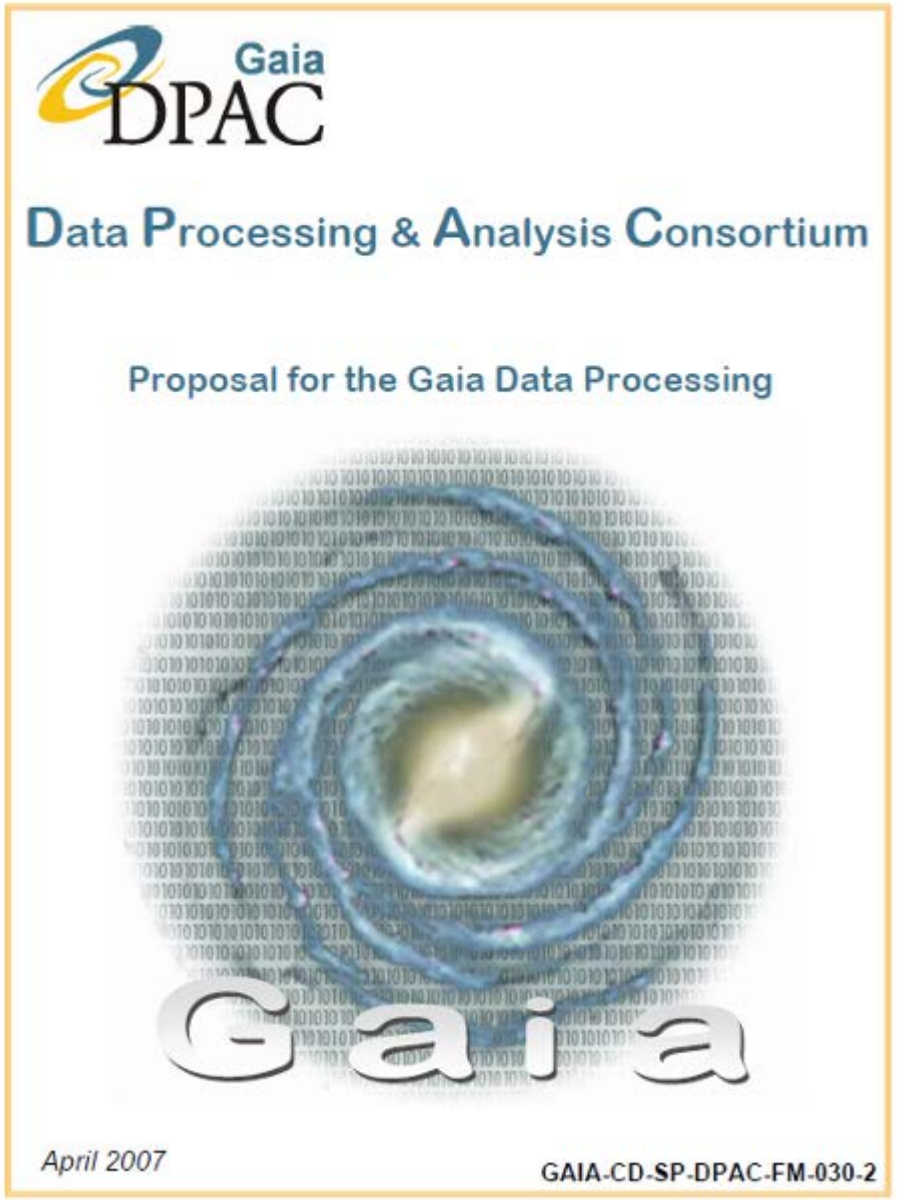
One consortium: the DPAC

The final responsibility of the Mission is in the hands of ESA


Data reduction is a responsibility of the scientific community, funded by the member states

Data Processing and Analysis Consortium

- **Formed to answer the Announcement of Opportunity (AO) for Gaia data processing**
- **Involves large number of European institutes and observatories (>400 people, >20 institutes)**
- **The science community must fund the majority of the Gaia processing (not ESA)**

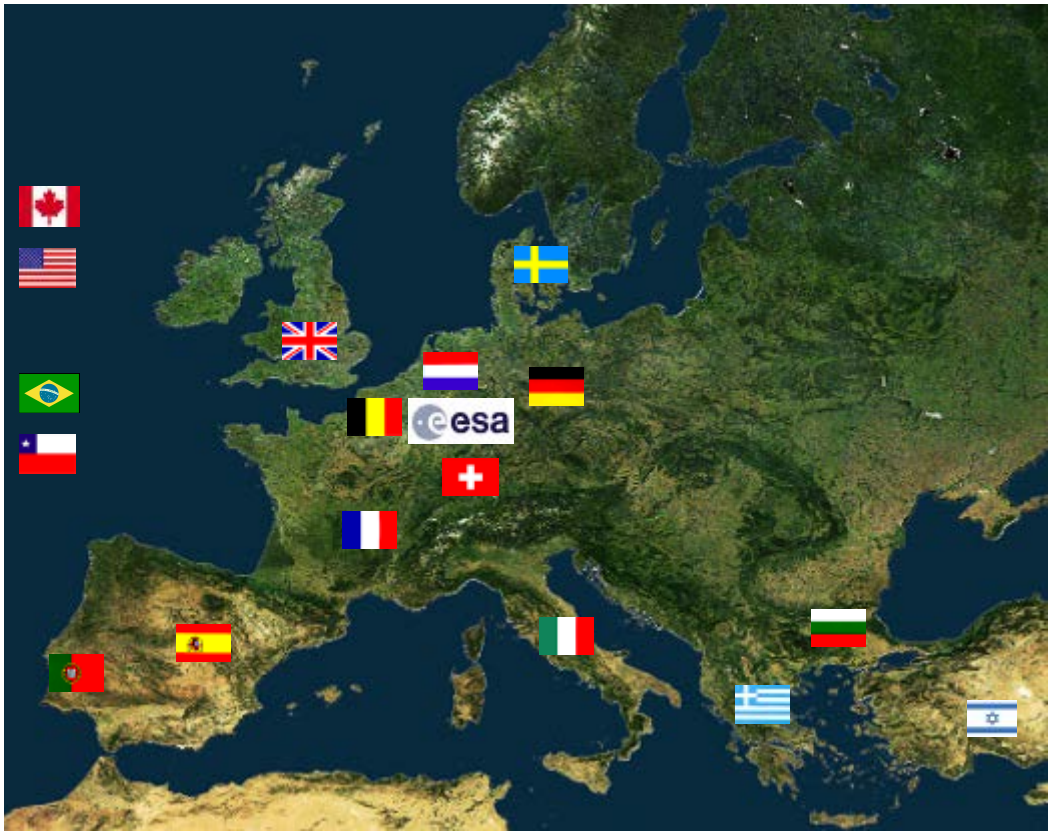


AO response (2006)

- Presents the initial design for the processing of the Gaia data
- Also defines the structure of DPAC
- Concepts have evolved since then

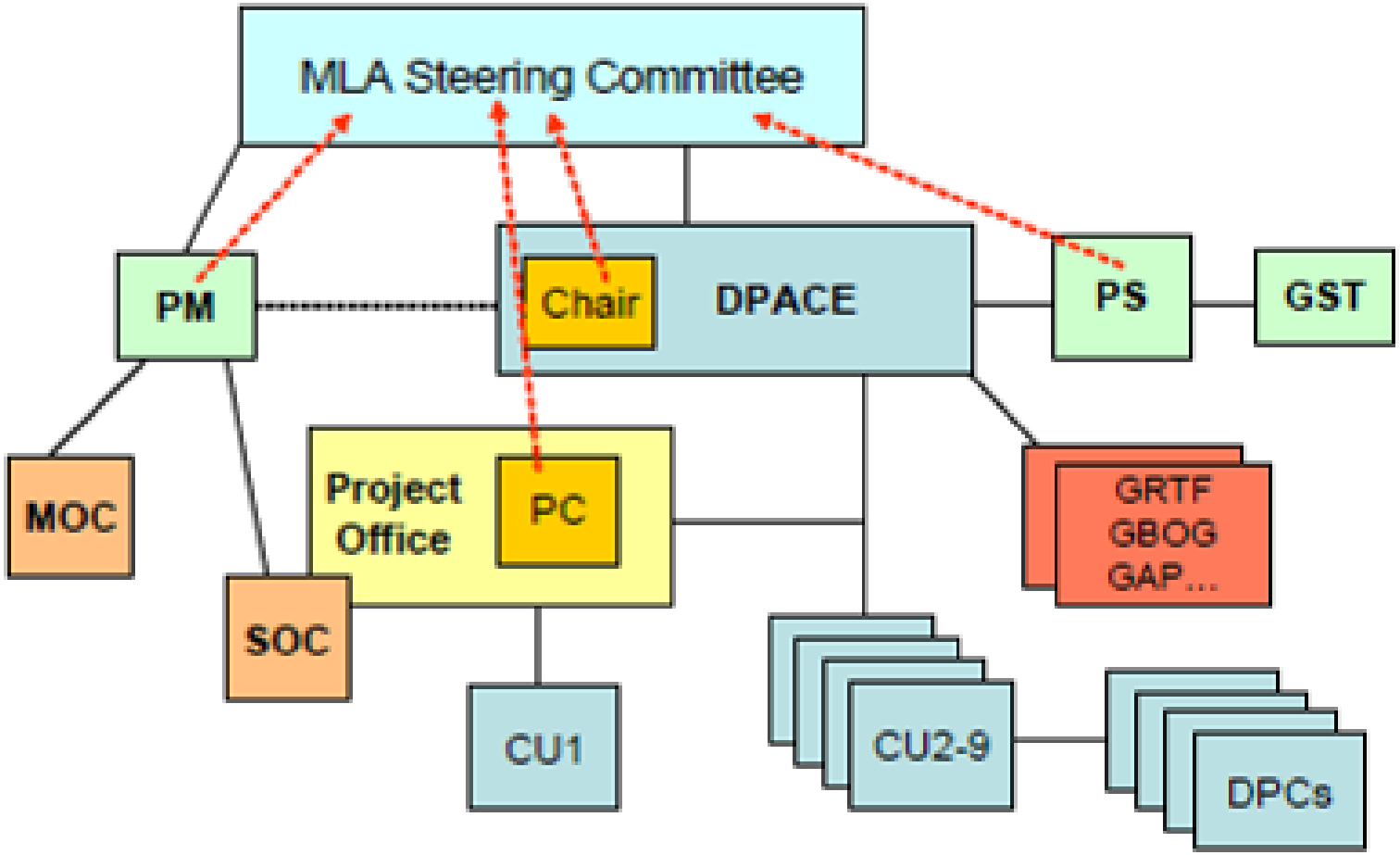
GENIUS (EC)

- 459 members
- 25 Funding Agencies
- 93% in the 10 largest



- With a 5 years mission, ~33% of DPAC cost will be dedicated to Operations

MLA duration: 2007-2022
FTEs/year up to 2011: 270
Average yearly cost: ~30Meuros
Global cost: ~500M€



Coordination units

Data processing centers

- **The leaders of CUs and the PO + very few others**
  - **organize the work**
  - **see it is carried out**
  - **resolve schedule conflicts/dependencies**

- **The Gaia Science Team (GST)**
  - **looks after the science**
  - **ensures DPAC is on track**
  - **DPAC chair sits in GST**

DPAC coordination units

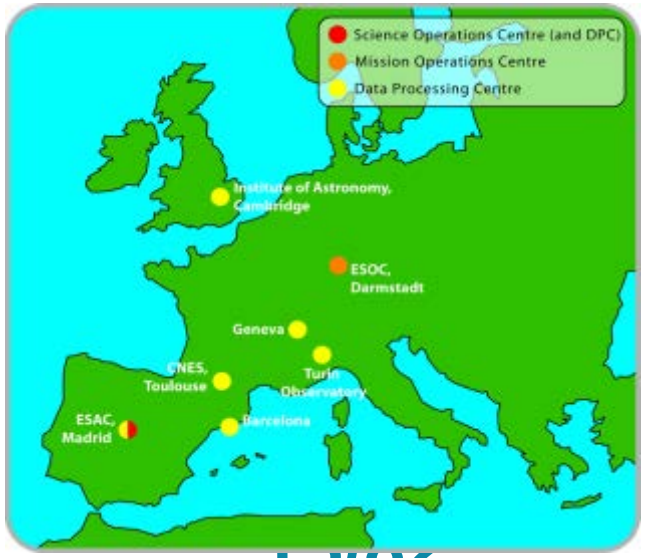
- **CU1: System Architecture**
- **CU2: Data Simulations**
- **CU3: Core Processing**
- **CU4: Object Processing (multiple objects)**
- **CU5: Photometric Processing**
- **CU6: Spectroscopic Processing**
- **CU7: Variability Processing**
- **CU8: Astrophysical Parameters**
- **CU9: Catalogue Access**

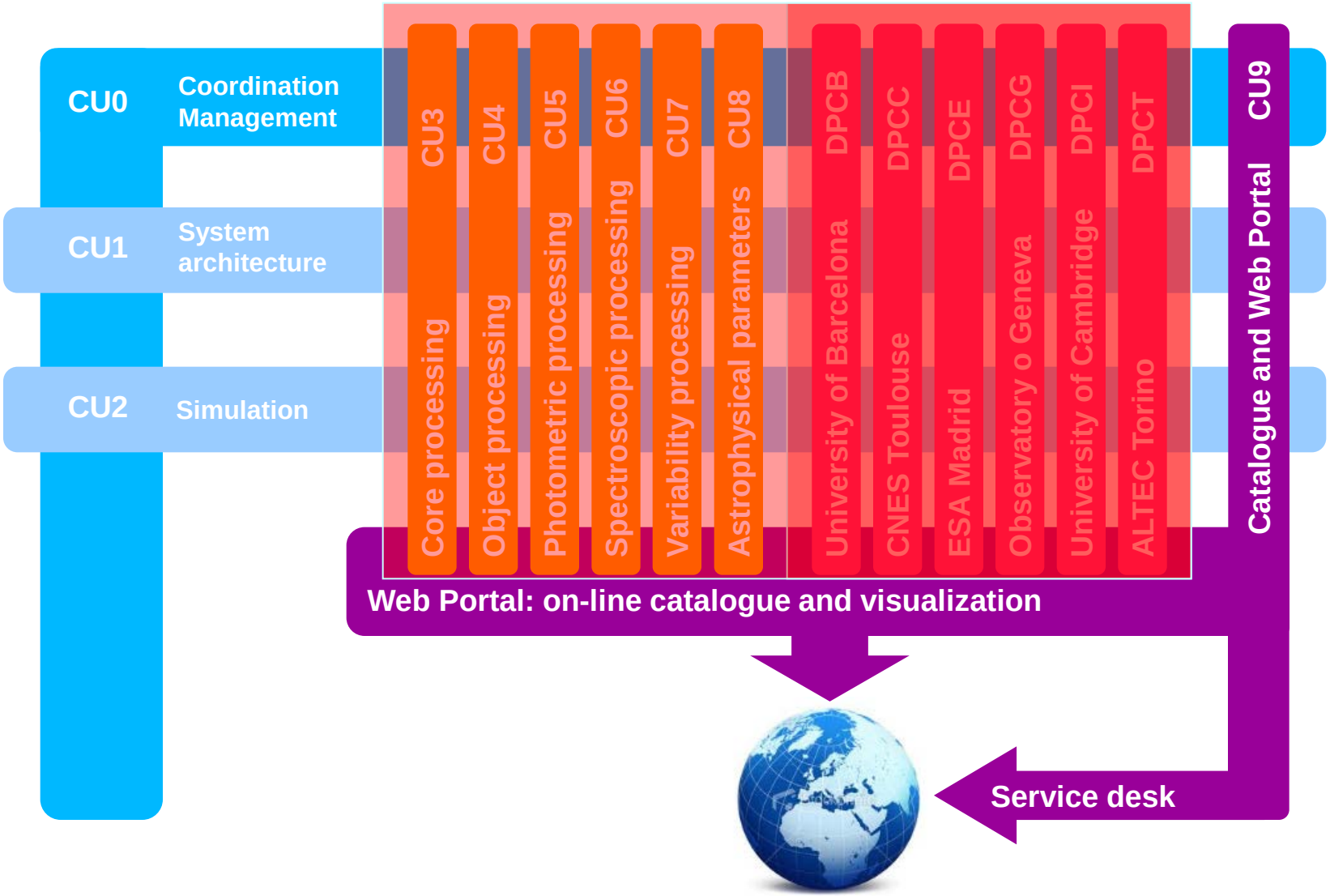
GENIUS

DPCs underpin and support CUs

- Software support and production
- Operation of processing system(s)

- ESAC (CU1,3) Madrid
- BPC (CU2,3) Barcelona
- CNES (CU4,6,8) Toulouse
- ISDC (CU7) Geneva
- IoA (CU5) Cambridge
- OATO (CU3) Torino



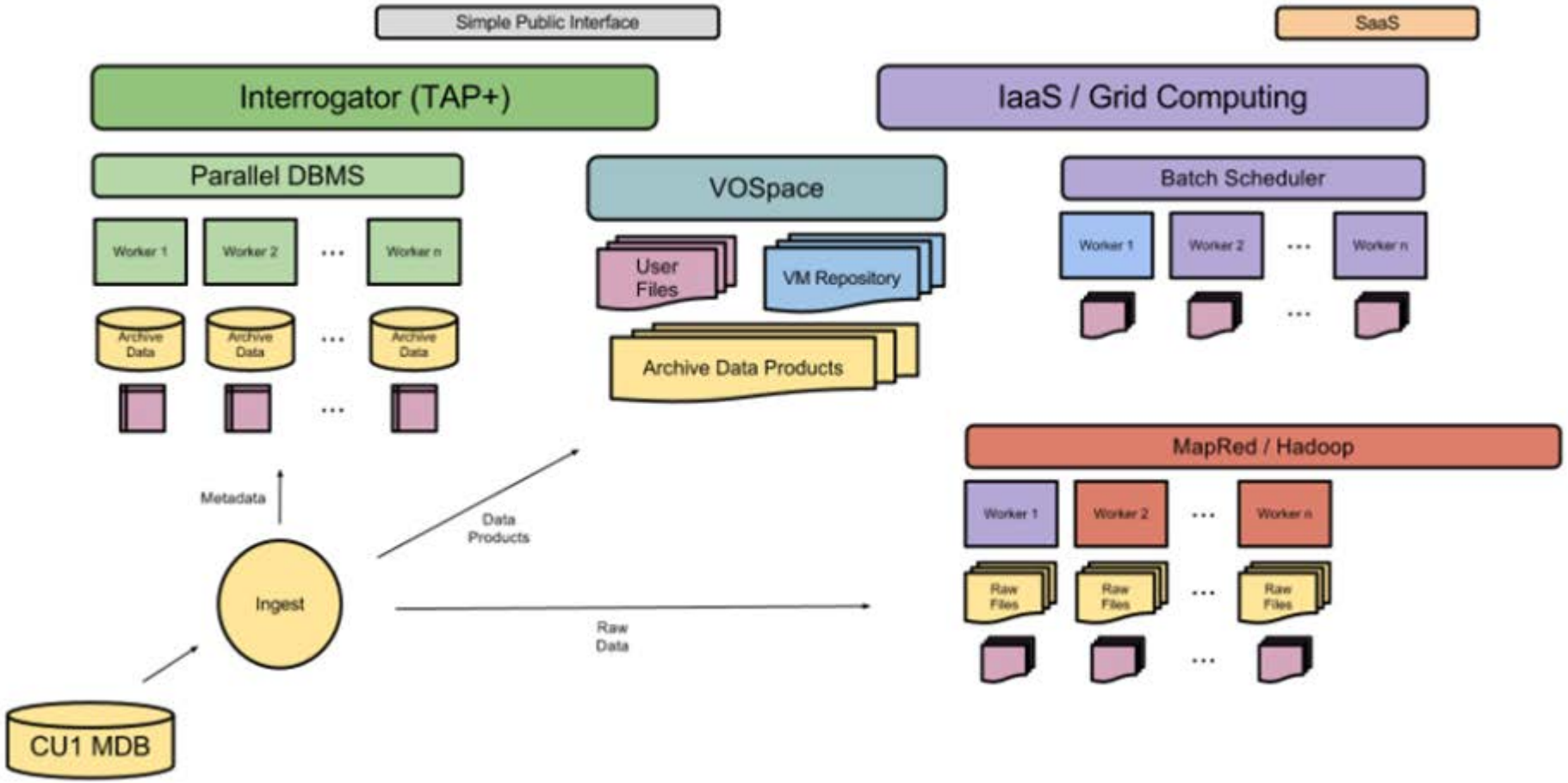

CU0
Coordination Management
CU1
System architecture
CU2
Simulation
CU3
Core processing
CU4
Object processing
CU5
Photometric processing
CU6
Spectroscopic processing
CU7
Variability processing
CU8
Astrophysical parameters
DPCB
University of Barcelona
DPCC
CNES Toulouse
DPCE
ESA Madrid
DPCG
Observatory o Geneva
DPCI
University of Cambridge
DPCT
ALTEC Torino
CU9
Catalogue and Web Portal
Web Portal: on-line catalogue and visualization
Service desk

The final archive: CU9

CU9 role

The CU9 is in charge of designing, implementing and operating the Gaia archive. It will be responsible of actually making the Gaia data available to the scientific community.

Archive architecture at SOC



Gaia status

Launch December 19 2013 09:12:19 UTC

1. First 1h43m: First signal acquisition and automatic start-up sequence monitoring
   - ✓ transmitter, gyroscopes, PLM bipod release, CPS priming, thermal control configuration
2. Acquisition of sun pointing attitude
3. Sunshield deployment completed at 10:38 UTC
4. Payload decontamination started
5. Star tracker switch-on and preparation for trajectory correction

Insertion into orbit around L2

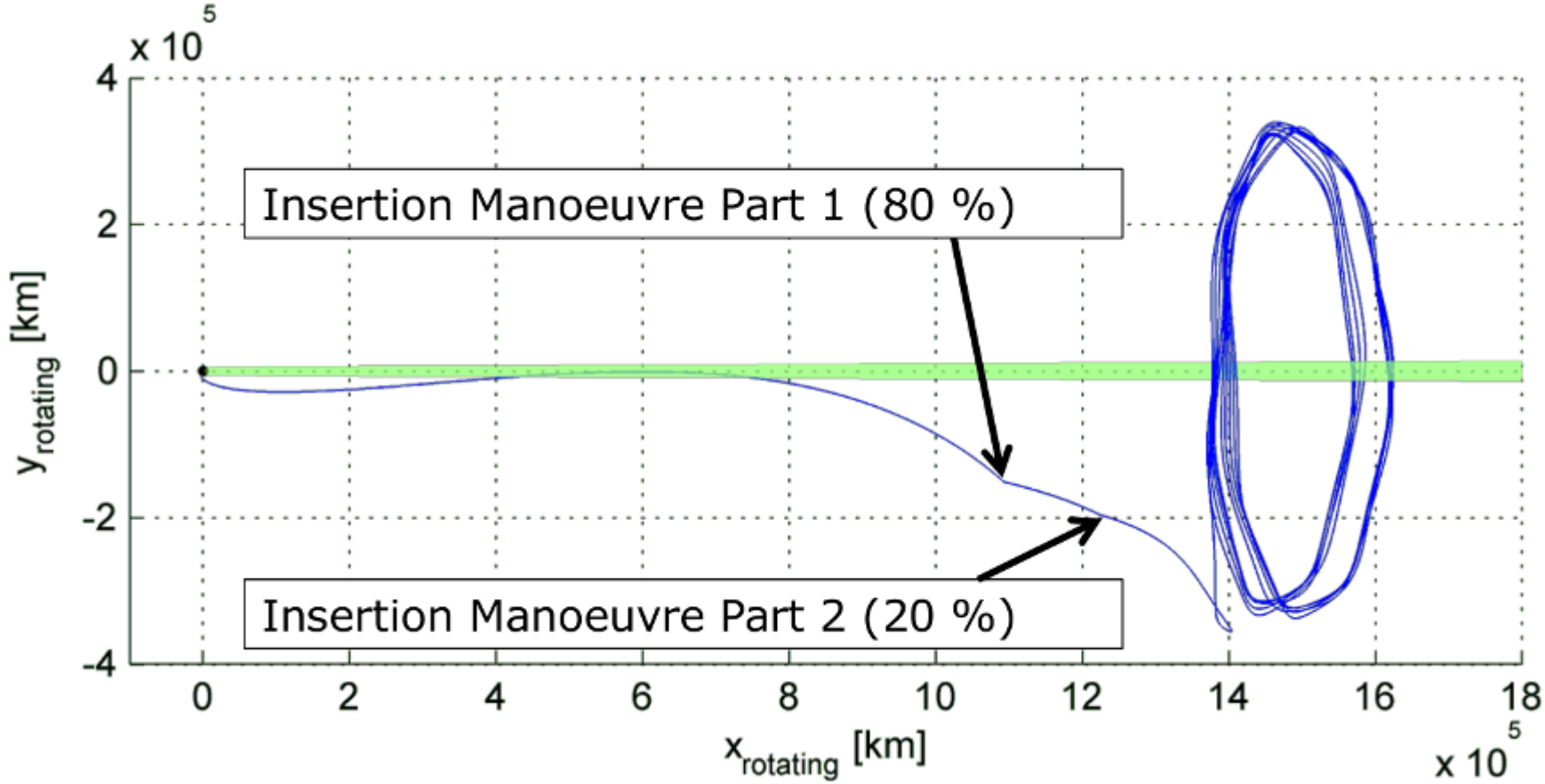
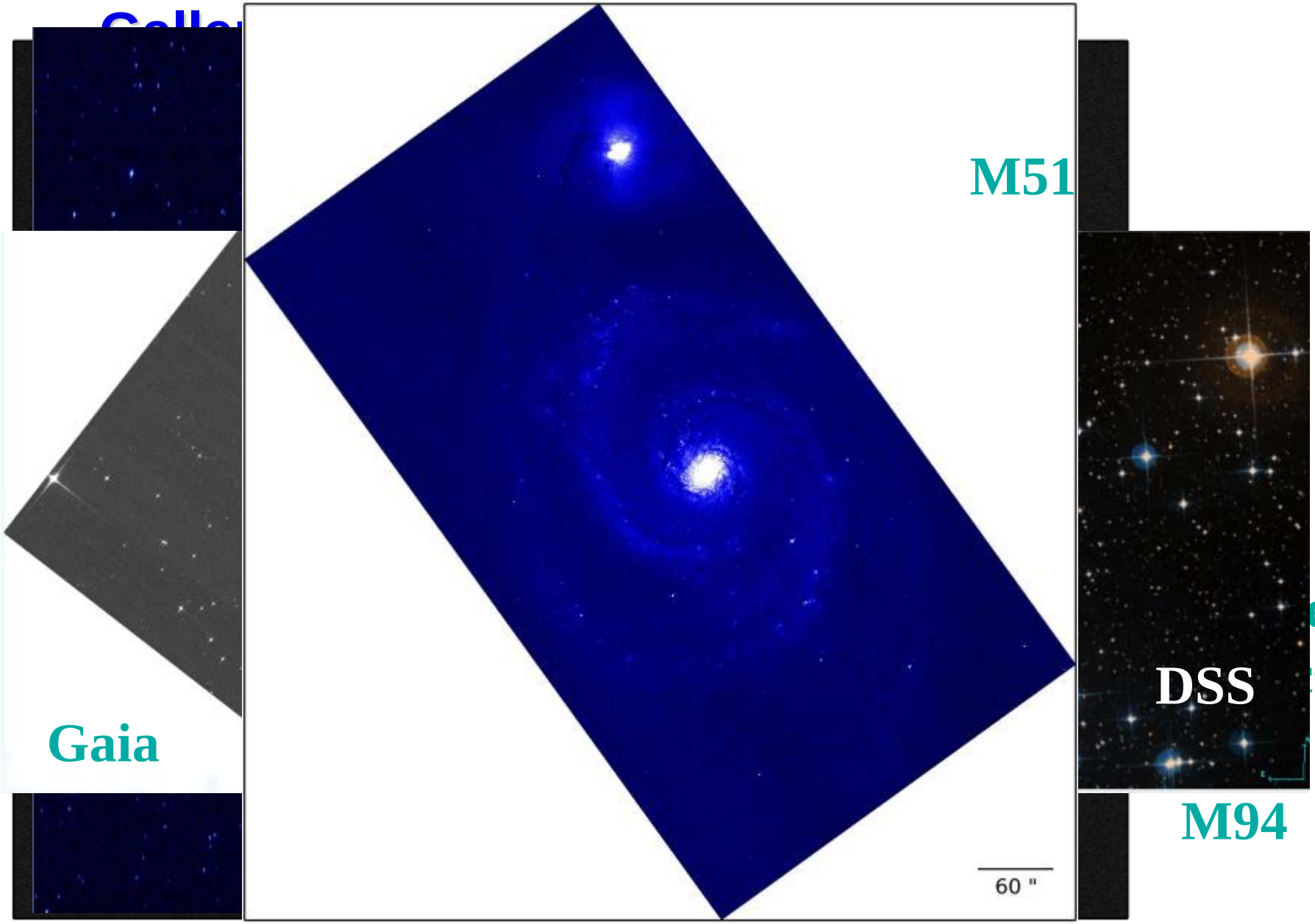


Image courtesy A. Rudolph and D. Milligan (ESOC)


M51
Gaia
DSS
M94
60 "

Updated science performances (G2V star)

V-magnitude	Astrometry (parallax)	Photometry (BP/RP integrated)	Spectroscopy (radial velocity)
Pre-launch predictions			
6 to 12	5-14 μas	4 mmag	1 km/s
15	24 μas	4 mmag	3 km/s
16.5			13 km/s
20	290 μas	40 mmag	
Revised estimation			
3 to 12	5-16 μas	4 mmag	1 km/s
15	24 μas	4 mmag	15 km/s
16.5			
20	540 μas	60 (RP) – 80 (BP) mmag	

http://www.cosmos.esa.int/web/gaia/science-performance

One year into science observations

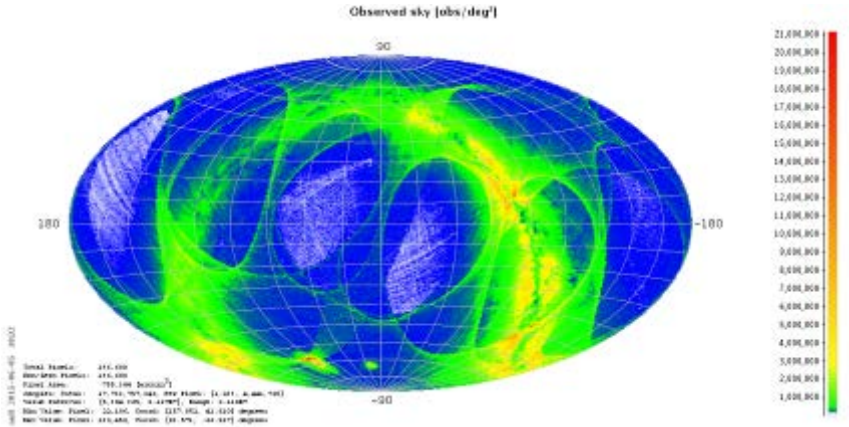
In 5-year nominal science operations phase since July 18 2014

Data collection stats:

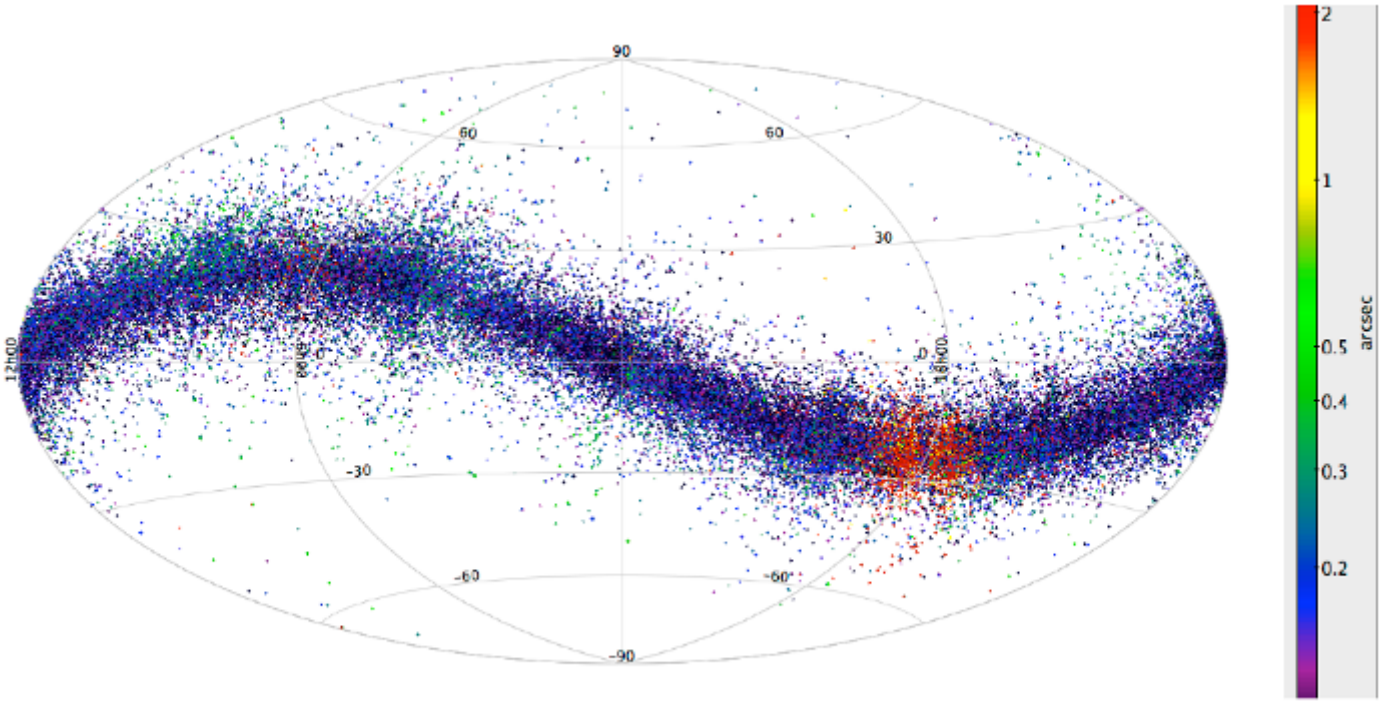
- 272 billion astrometric measurements
- 54:4 billion photometric (BP/RP) measurements
- 5:4 billion RVS spectra

Survey limits

- Astrometry and photometry for 2 < G < 20:7 mag
- Stars brighter than G = 3 captured with Sky Mapper imaging
- Spectra up to GRVS = 16:2 (and G > 2 mag)



Solar System Objects

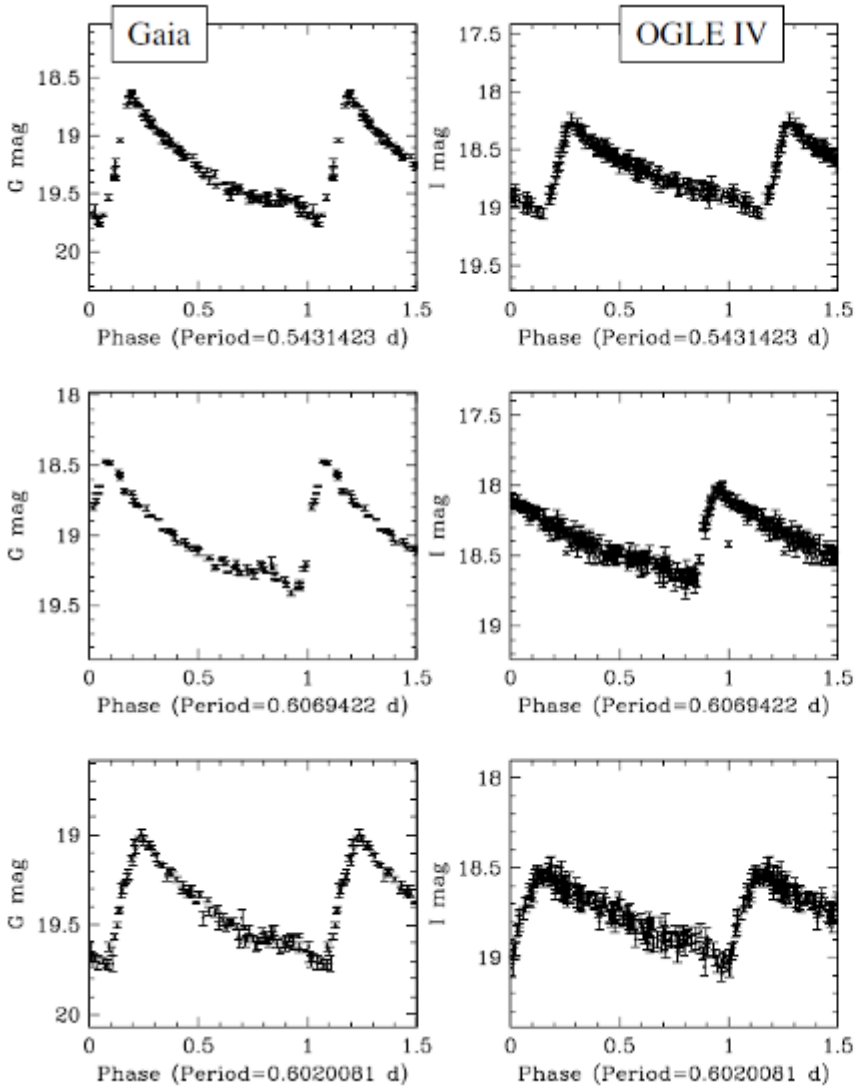


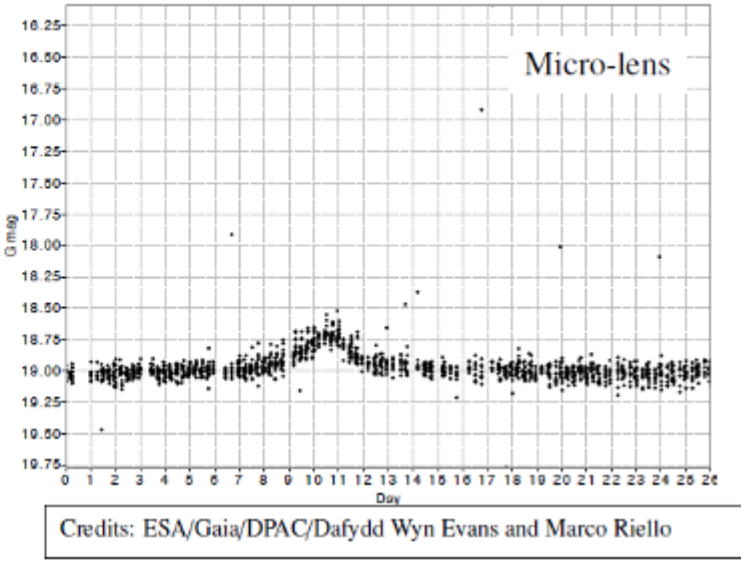
Credits: ESA/Gaia/DPAC/CU4, L. Galluccio, F. Mignard, P. Tanga (Observatoire de la Côte d'Azur)

Test of asteroid detection chain on 50 000 known asteroids

- 90% completeness
- colour coding shows error relative to predicted position (with larger errors towards Galactic centre region)

Variable stars



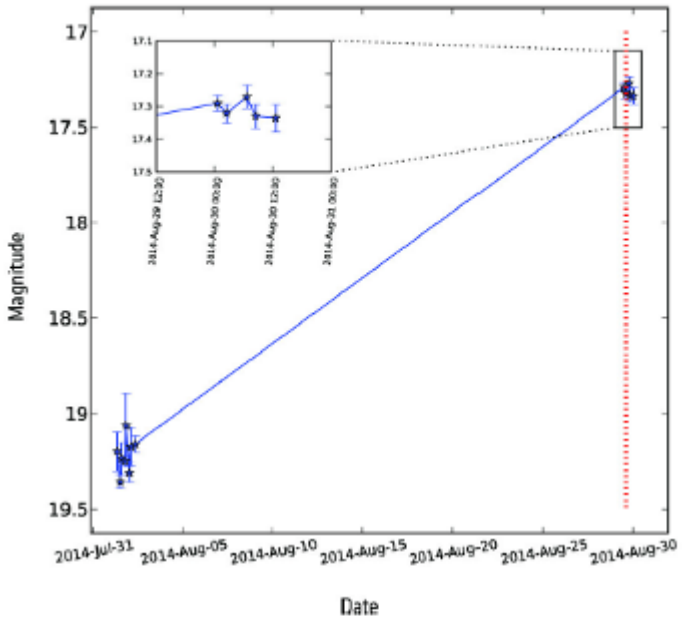


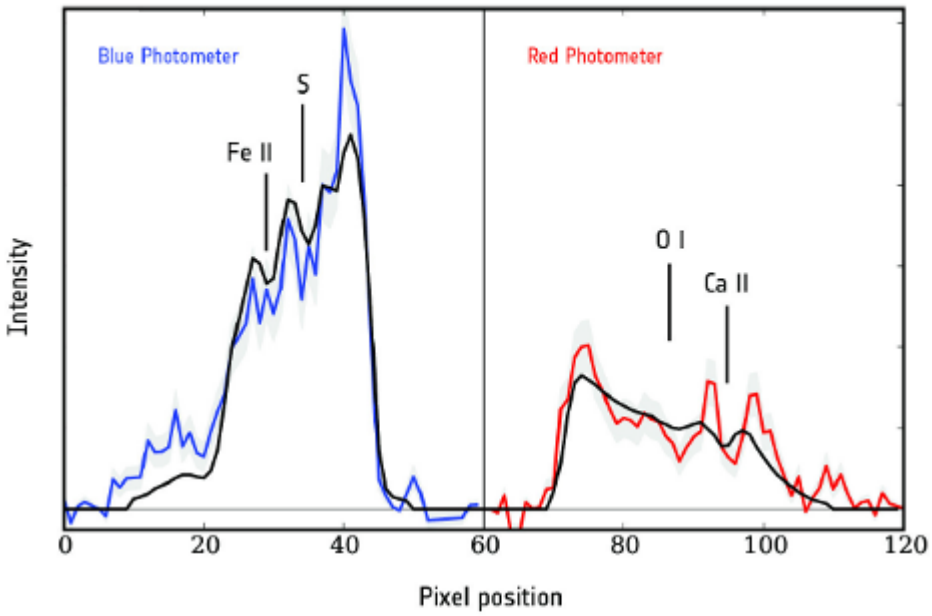
Credits: ESA/Gaia/DPAC/Dafydd Wyn Evans and Marco Riello

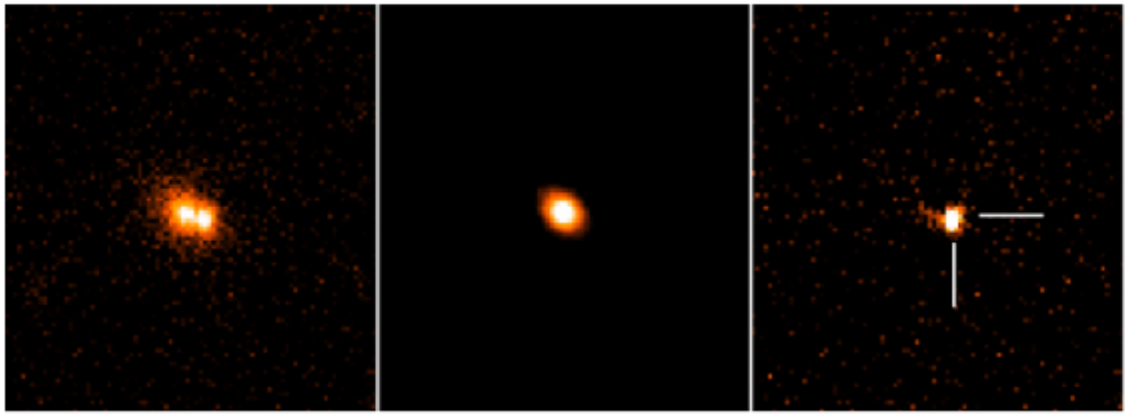
Illustration of photometric data quality: 4 weeks of Gaia data with preliminary calibrations compared to OGLE IV

Credits: ESA/Gaia/DPAC/CU5/CU7/INAF-OABo, Gisella Clementini, Dafydd Evans, Laurent Eyer, Krzysztof Nienartowicz, Lorenzo Rimoldini and the Geneva CU7/DPCG and CU7/INAF-OACN teams

Science Alerts: first supernova discovery

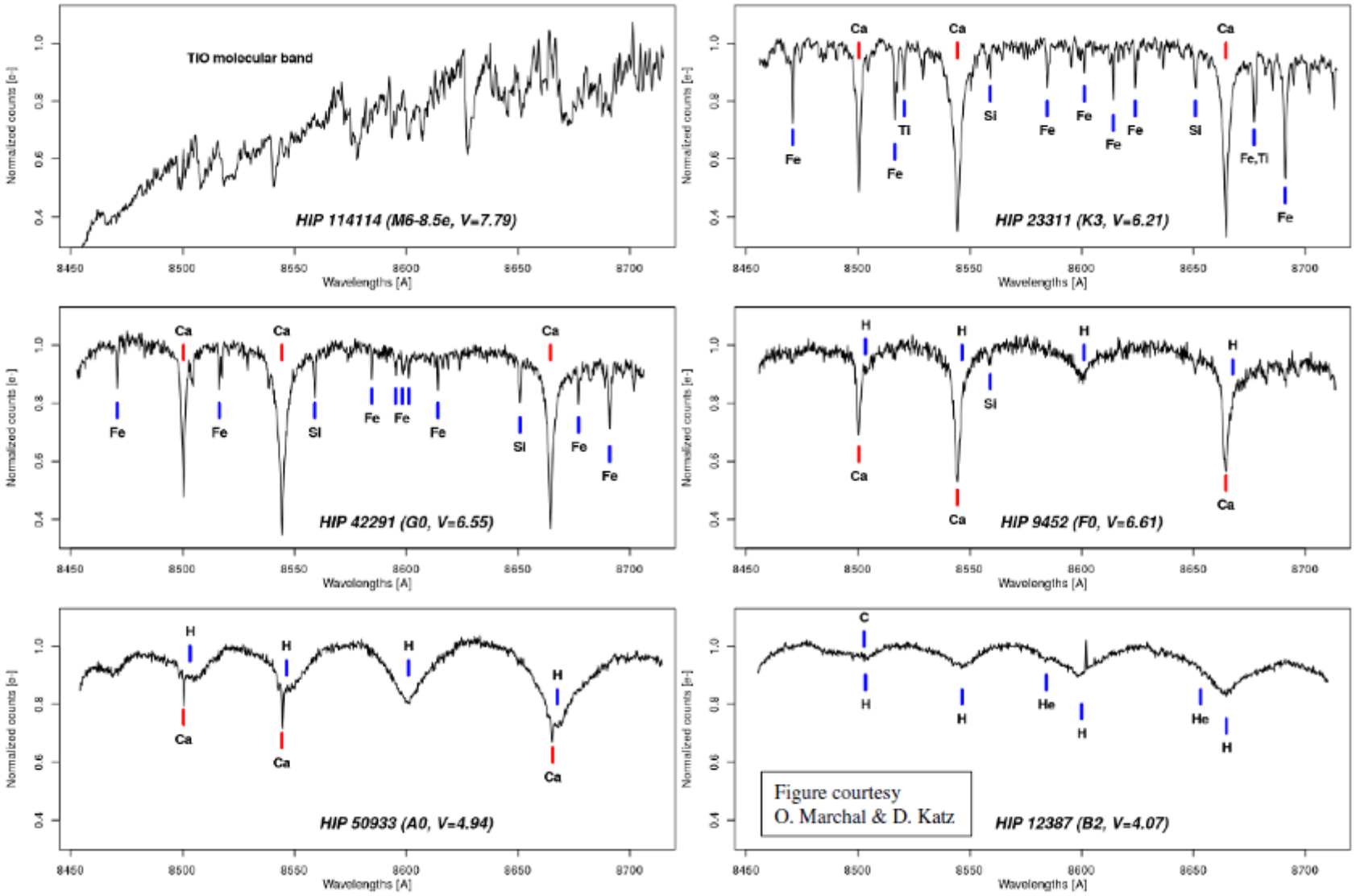


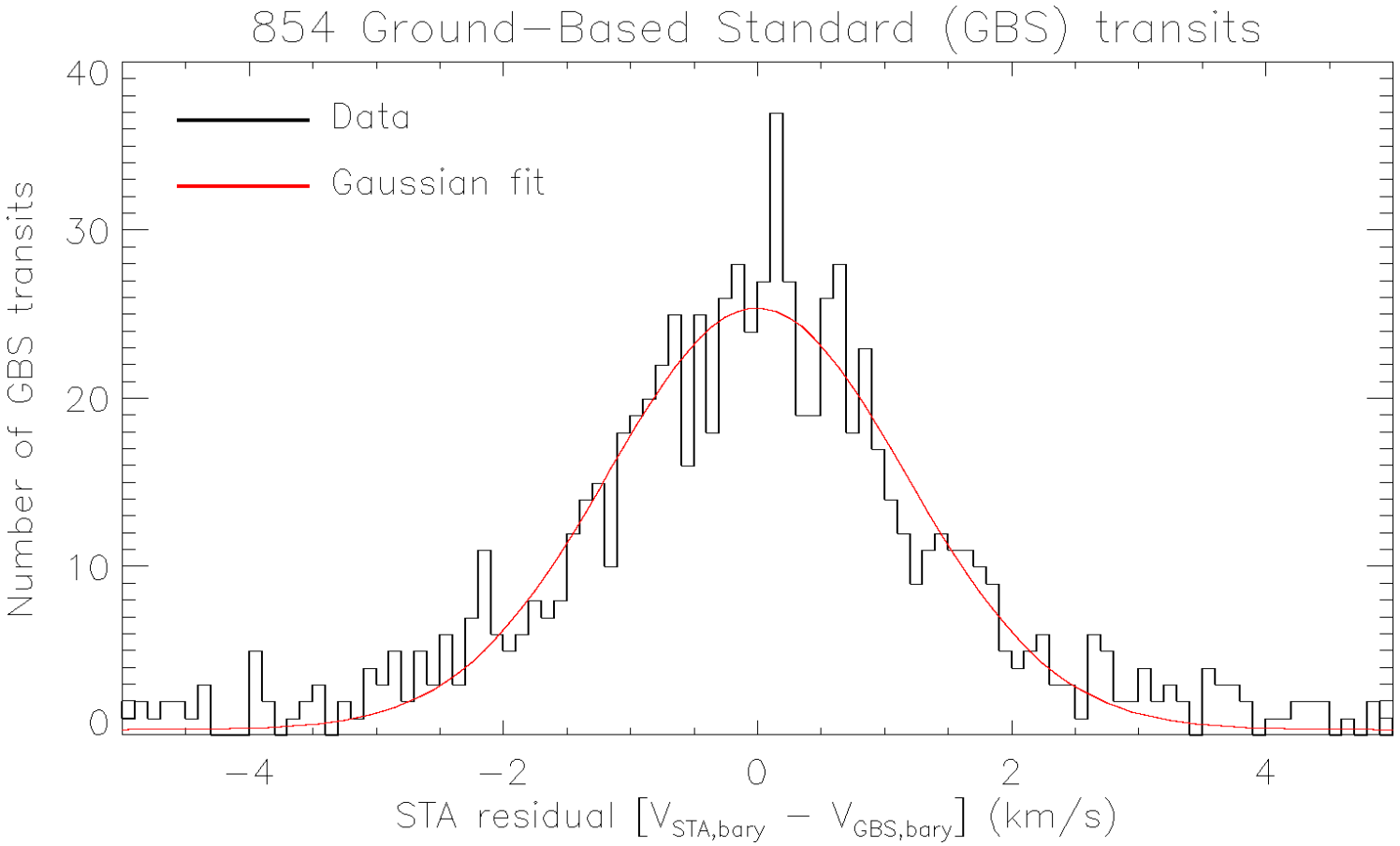




Credits: M. Fraser/ S. Hodgkin/
Ł. Wyrzykowski/ H. Campbell/
N. Blagorodnova/ Z. Kostrzewa-Rutkowska/
Liverpool Telescope/ SDSS/ ESA/ Gaia/ DPAC

Preliminary RVS performance assessment





Bright end performance assessed by comparing RVS velocities to the known values for ground based standards

RVS values refer to single transits

Preliminary photometric performance assessment

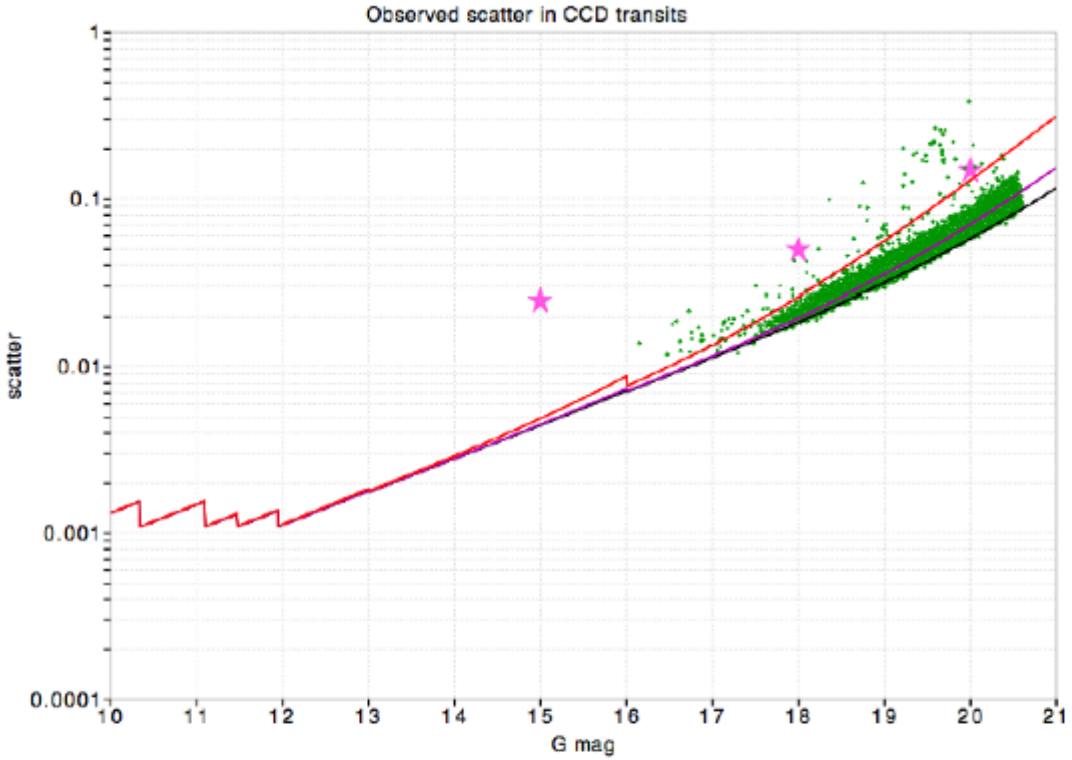
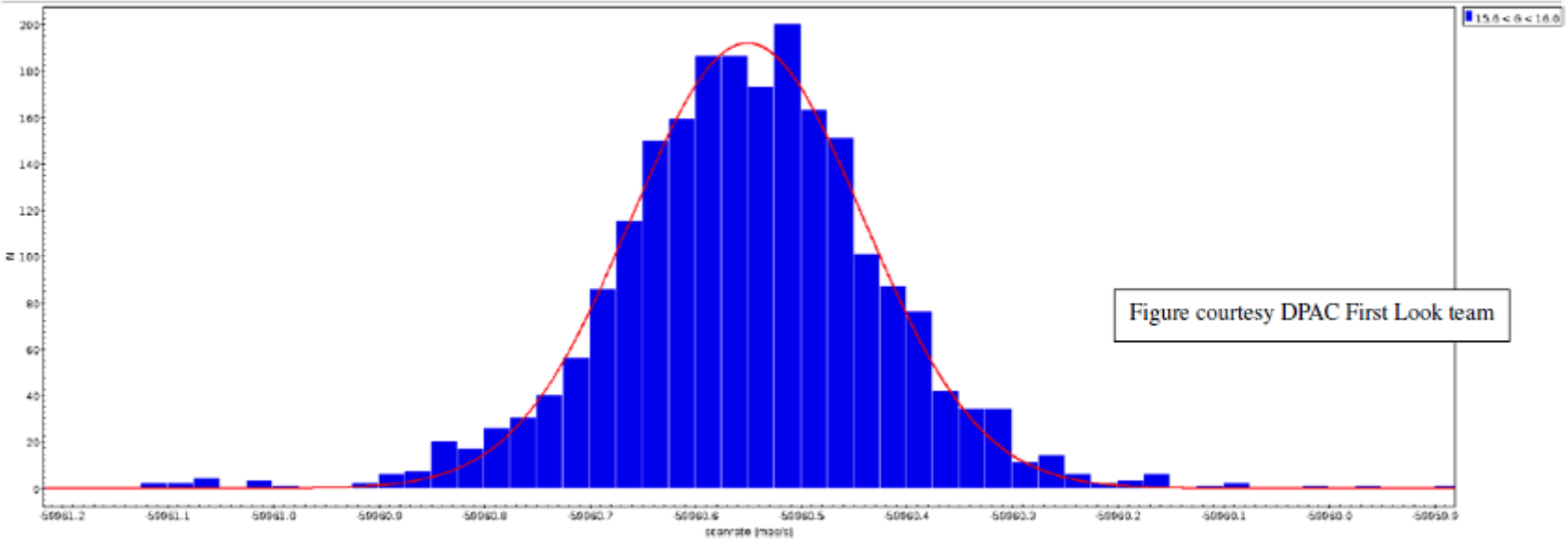


Figure courtesy D. Evans, DPAC/CU5

- Precision estimated from scatter of CCD transits of constant sources
- Lines: predictions from Jordi et al. 2010 methodology
  - Different stray light levels accounted for
- Quoted performances (magenta stars) from Gaia webpage are high
- End of mission equivalent for the mean photometry will be 25× smaller than CCD transit level accuracies
  - Limited by a calibration floor
- Early results — not all calibrations applied yet

Astrometry one year into the mission



- First runs of core astrometric solution (AGIS) completed
- Early indication of performance; analysis of CCD-to-CCD transit time differences (figure above) point to single CCD measurement precision of 0.38 mas at $G = 15.8$
  - 17 per cent above target
- Caveats at this stage
  - poor PSF calibrations, no source colours
  - imperfect stray light corrections

TGAS

TGAS (Tycho-Gaia Astrometric Solution): lifting the degeneracy

- Data used: ~ 275 days over 10 months
- 2 201 246 sources
  - Hipparcos: 99 070
  - Tycho-2 only: 2 102 176
- No. of CCD observations: 227 219 102 (most both AL and AC)
- Hipparcos proper motions and positions and Tycho-2 positions as priors
- *No Hipparcos parallaxes used*
- Empirical corrections for basic angle variations

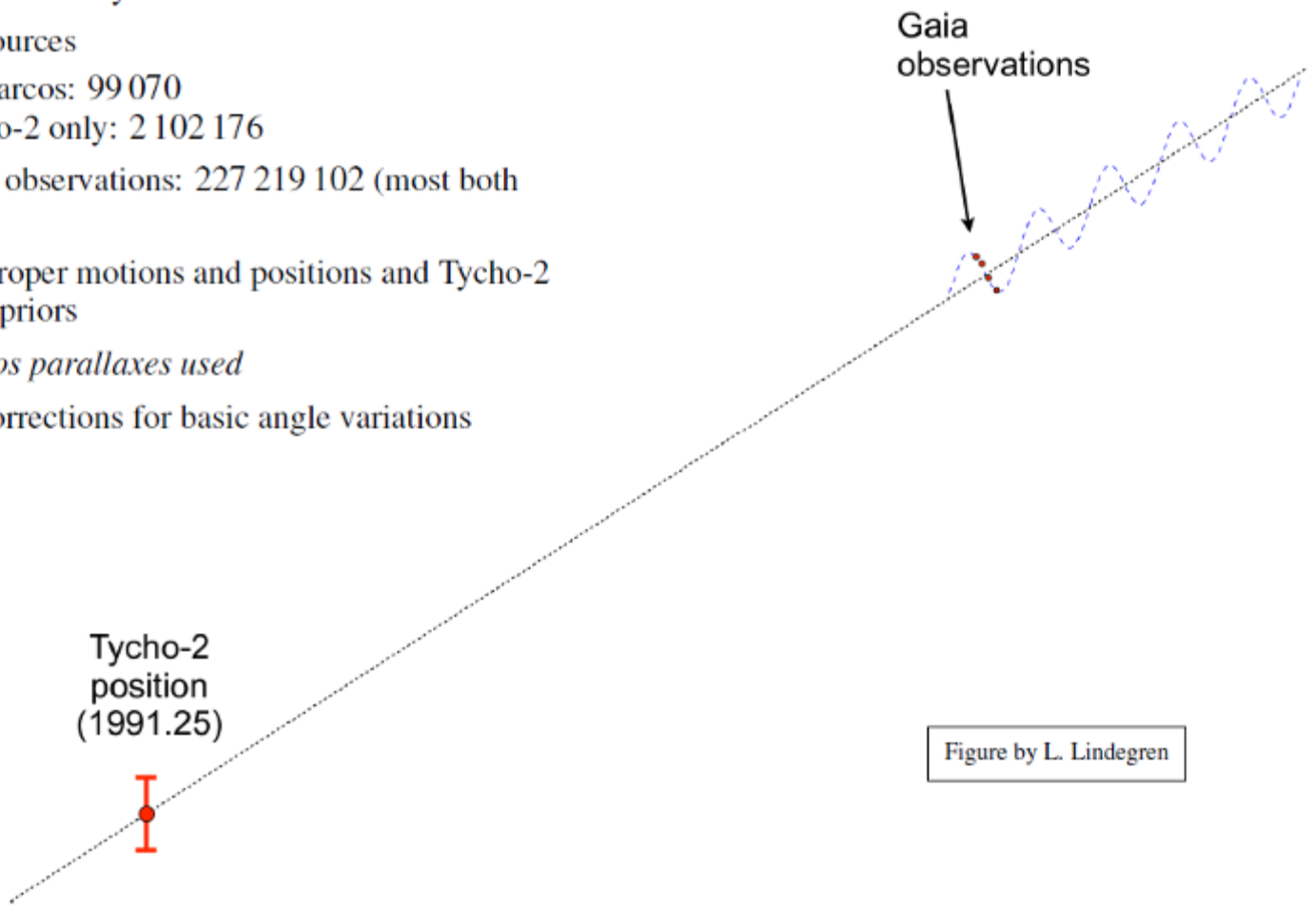
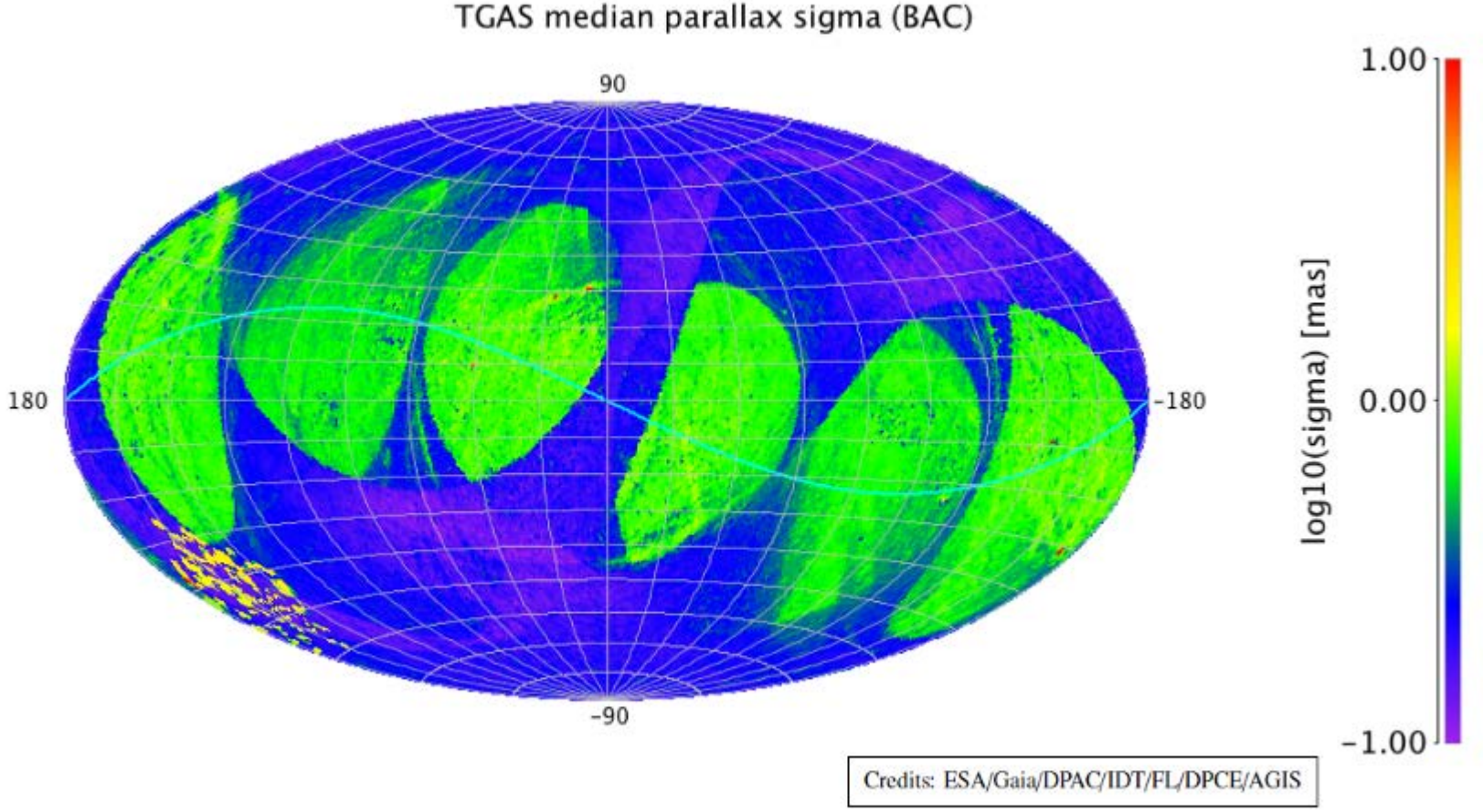


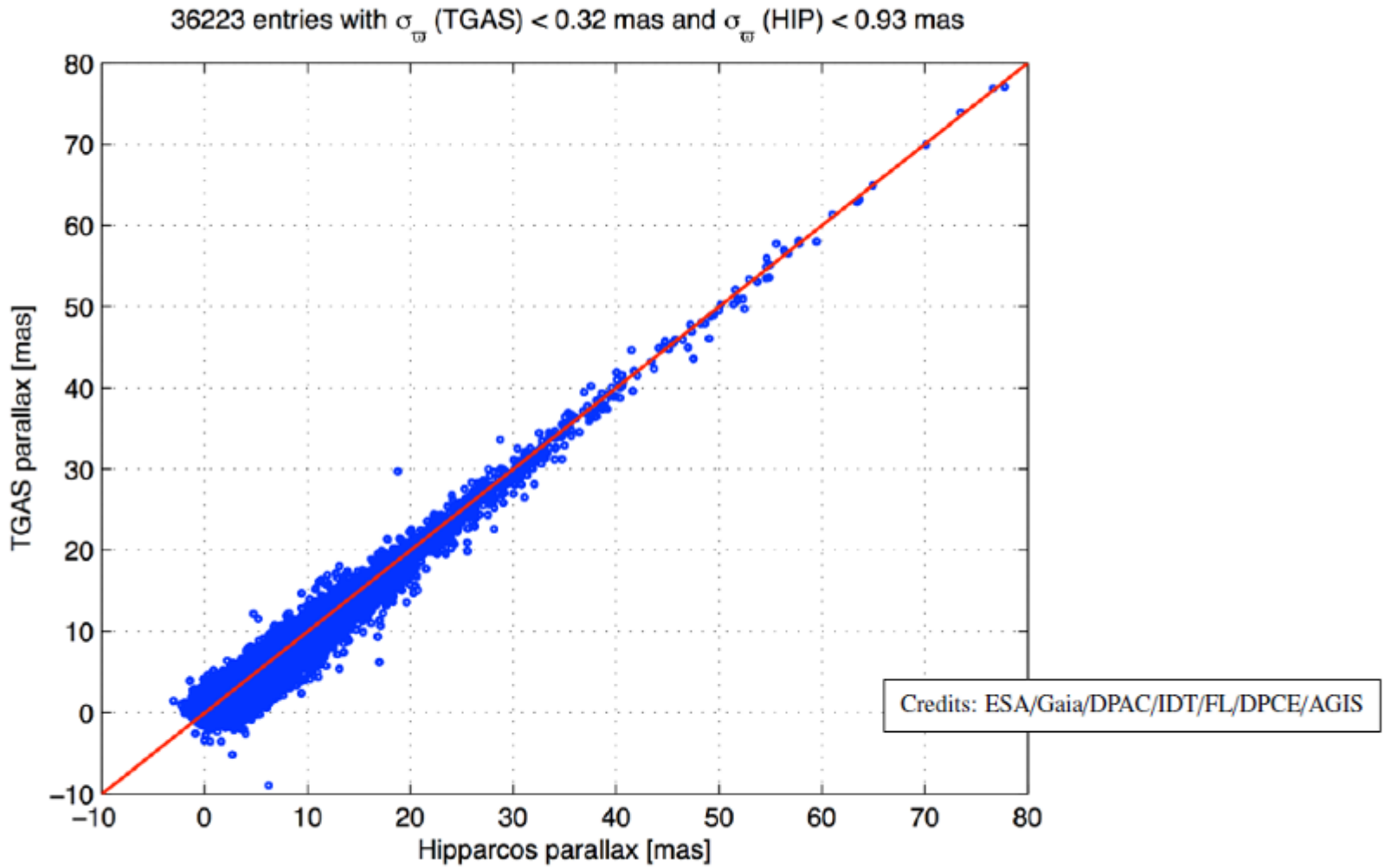
Figure by L. Lindegren

Parallax formal standard uncertainties



Parallax distributions (negative tails) shows that σ_{ϖ} values are meaningful but require empirical adjustment.

ϖ_{TGAS} VS. ϖ_{HIP}



NOTE: TGAS parallaxes are independent of HIP parallaxes!

Initial data release schedule

- **First release:** launch + 22 months (~90% of the sky)
- **Second release:** launch + 28 months (~90% of the sky)
- **Third release:** launch + 40 months
- **Fourth lease:** launch + 65 months
- **Final release:** end of mission + 3 years (2022-2023)

Updated data release scenario

- **Based on assumption of smooth development and operations!**
- **Each release updates the previous and contains significant new additions**
- **Science alerts started already**

Mid-2016 Positions + G magnitude (all sky, single stars)
- Includes more often scanned Ecliptic pole regions
- Hundred Thousand Proper Motions (Hipparcos-Gaia, 50 as/yr)

Early 2017 radial velocities for bright stars, two-band photometry, and full astrometry ($\alpha\delta\pi\mu_\alpha\mu_\delta$) where available.

2017/2018 (TBC) full astrometry, orbital solutions for short period binaries, (GBP - GRP), BP/RP Spectrophotometry and astrophysical parameters , radial velocities, RVS spectra

2018/2019 (TBC) Updates on previous release— including more sources, source classifications, multiple astrophysical parameters, variable star solutions and epoch photometry for them, solar system results

2022 (TBC) Everything