Gaia status

Anthony Brown

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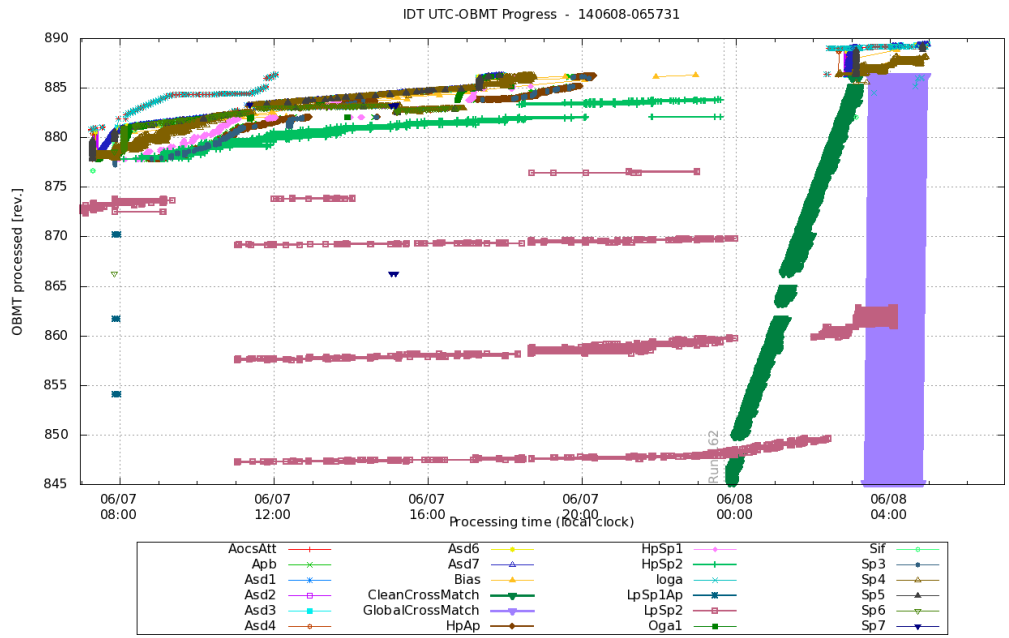
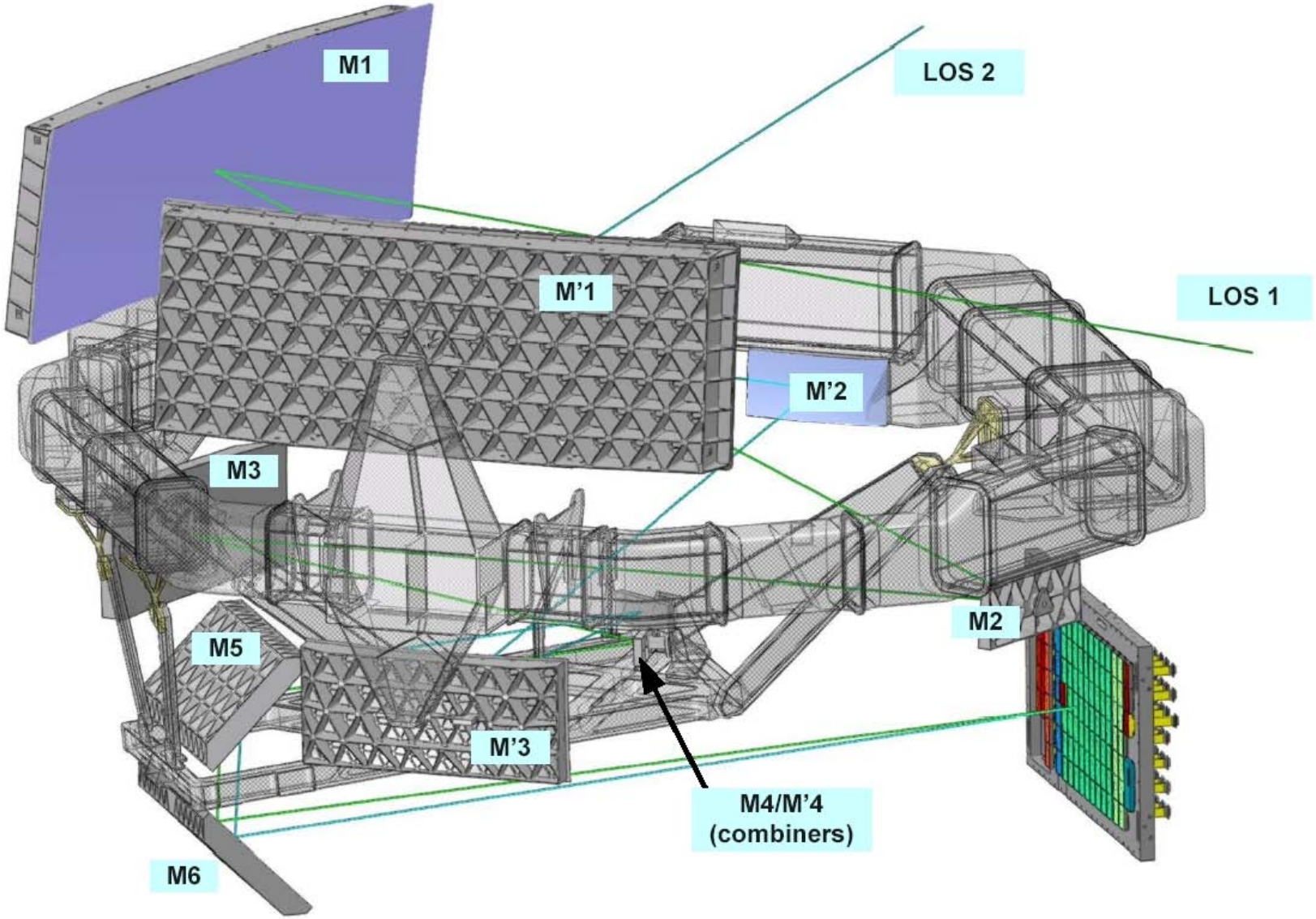


Gaia summary

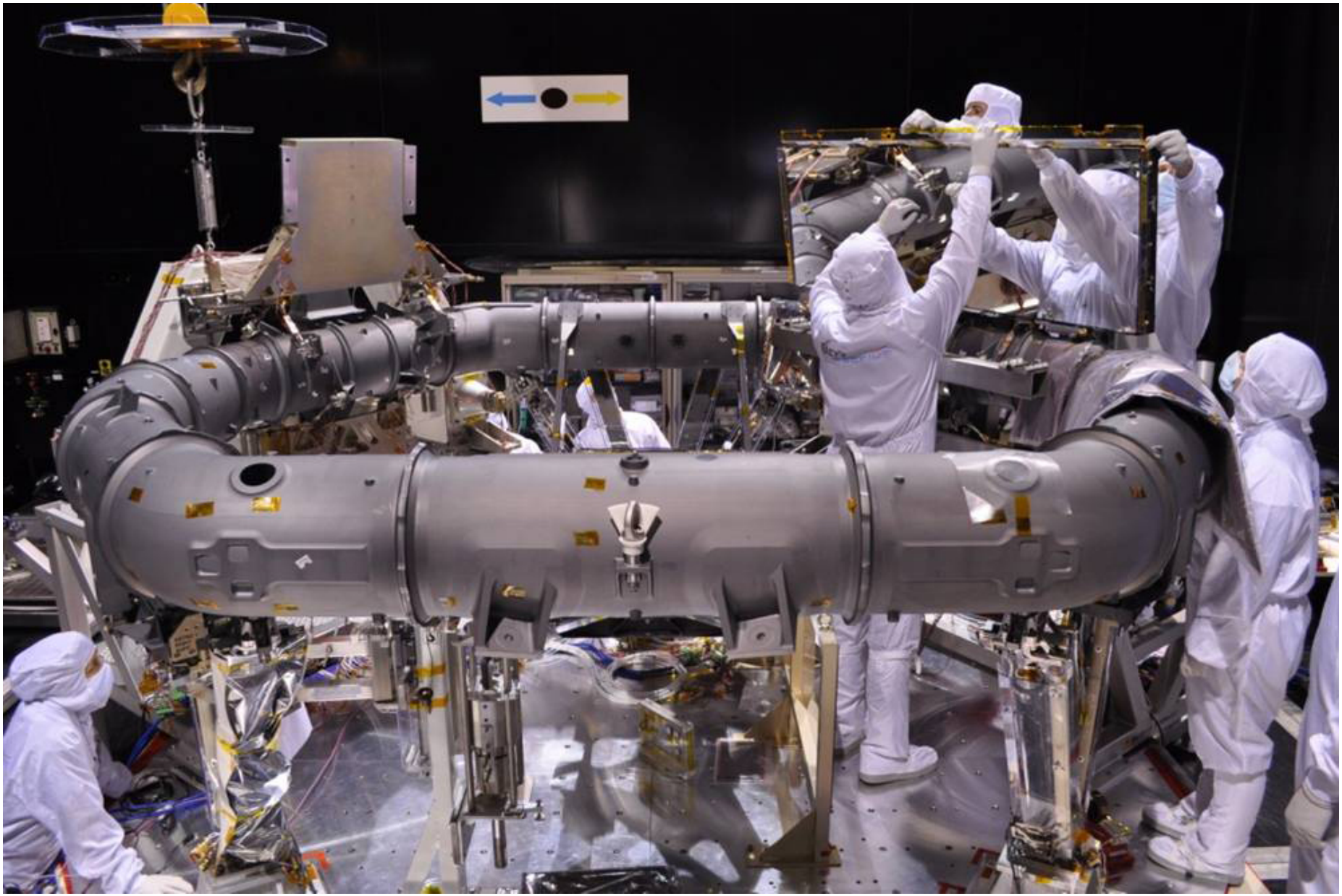
- Gaia: science with 1 billion objects in three dimensions
- ESA corner stone mission building on the Hipparcos heritage
- Astrometry, Photometry and Spectroscopy
- Satellite and payload, by industry, management and operations by ESA, and data processing by scientists (DPAC)
- Launch 19 December 2013 with Soyuz from Kourou
- Commissioning formally completed 18 July 2014
- 5 years of operations at L2
- First intermediate data release summer 2016, but Science Alerts start earlier

www.cosmos.esa.int/gaia

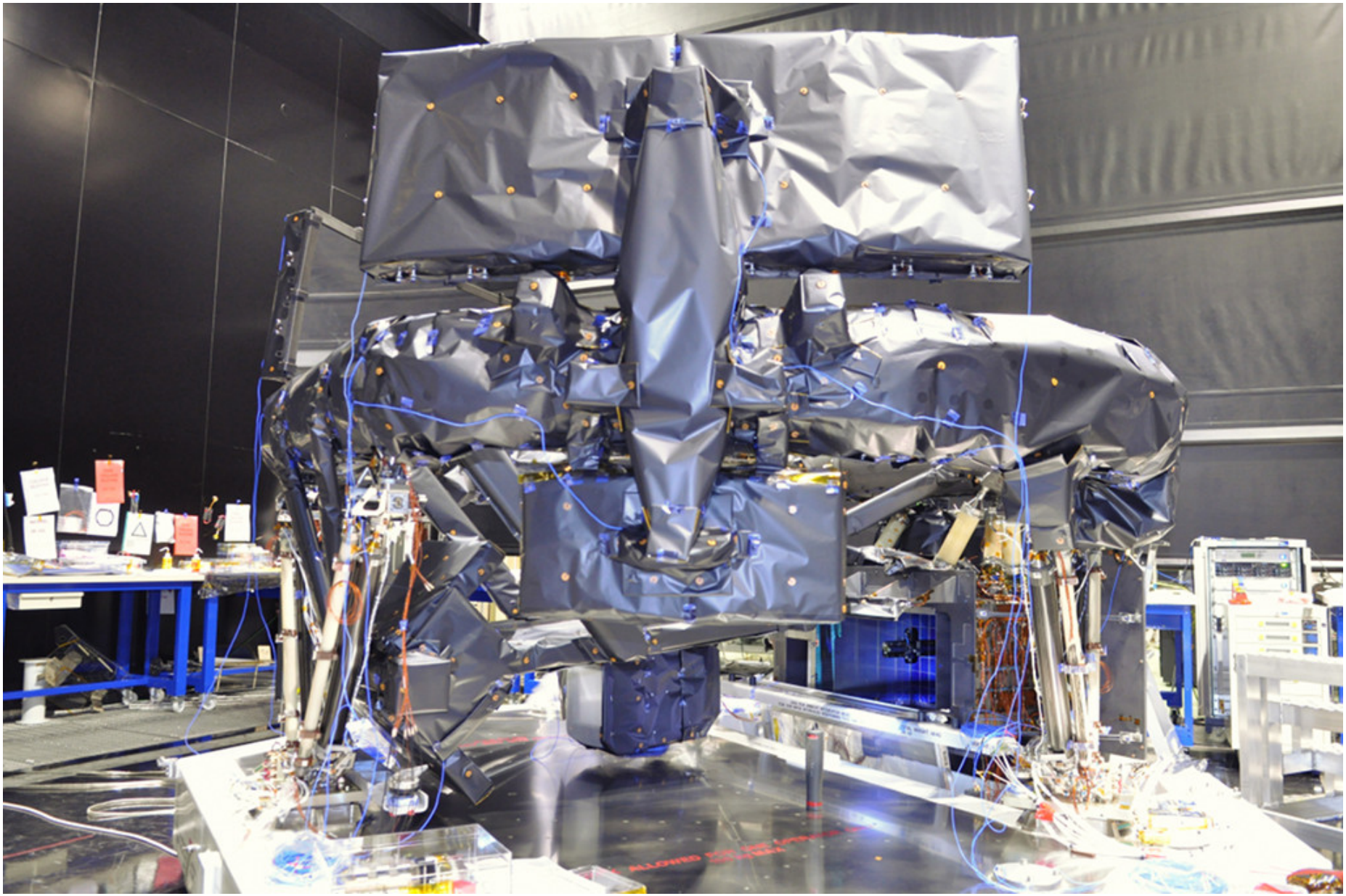
Telescope and payload



Telescope and payload

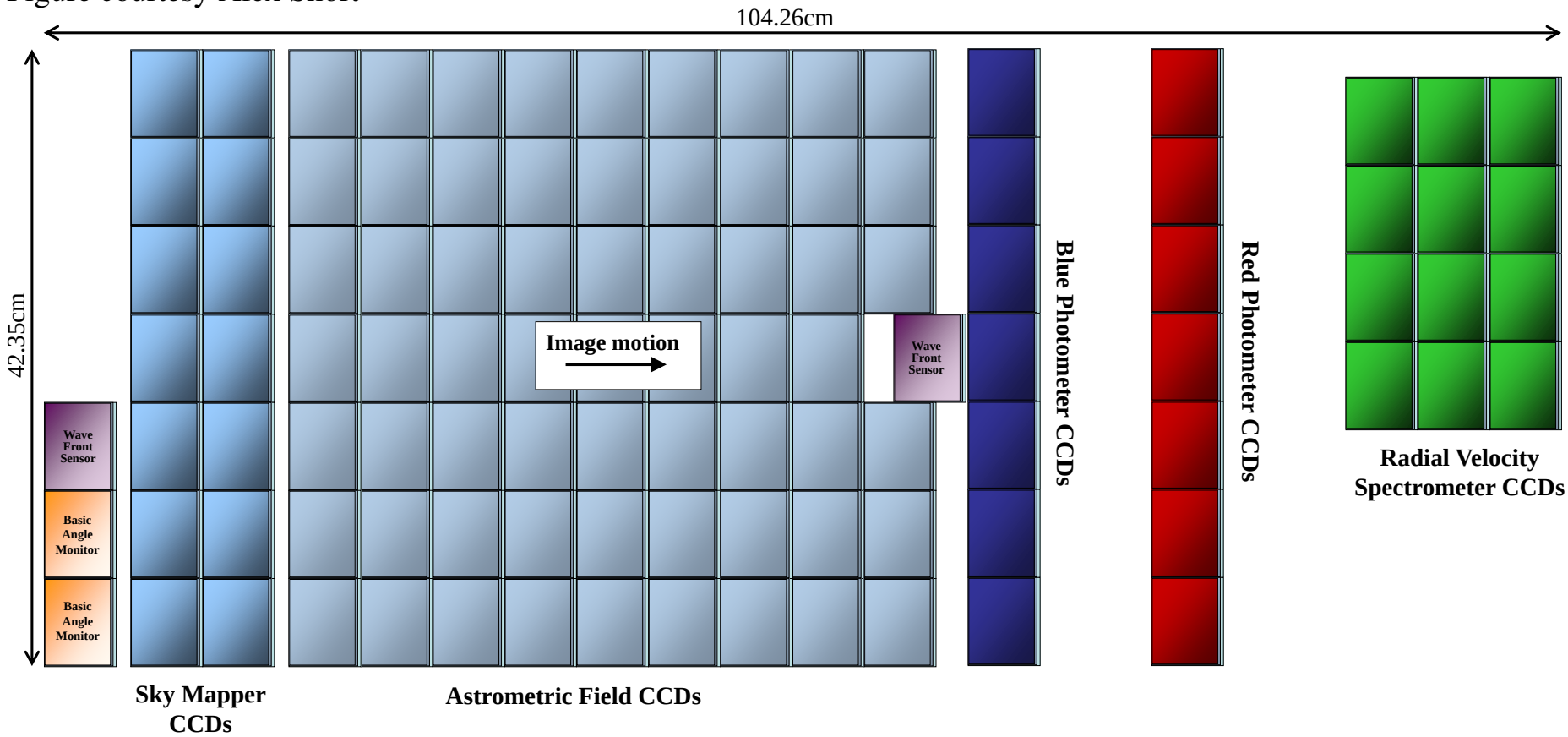


Telescope and payload



Focal plane

Figure courtesy Alex Short



Total field:

- active area 0.75 deg^2
- CCDs 106 = 14 + 62 + 14 + 12(+4)
- 4500 × 1966 pixels (TDI)
- pixel size = 10 × 30 μm^2 = 59 × 177 mas^2

Sky mappers

- detect all objects to $G = 20$
- rejection cosmic rays
- field-of-view discrimination

Astrometry

- total detection noise $\sim 6e^-$

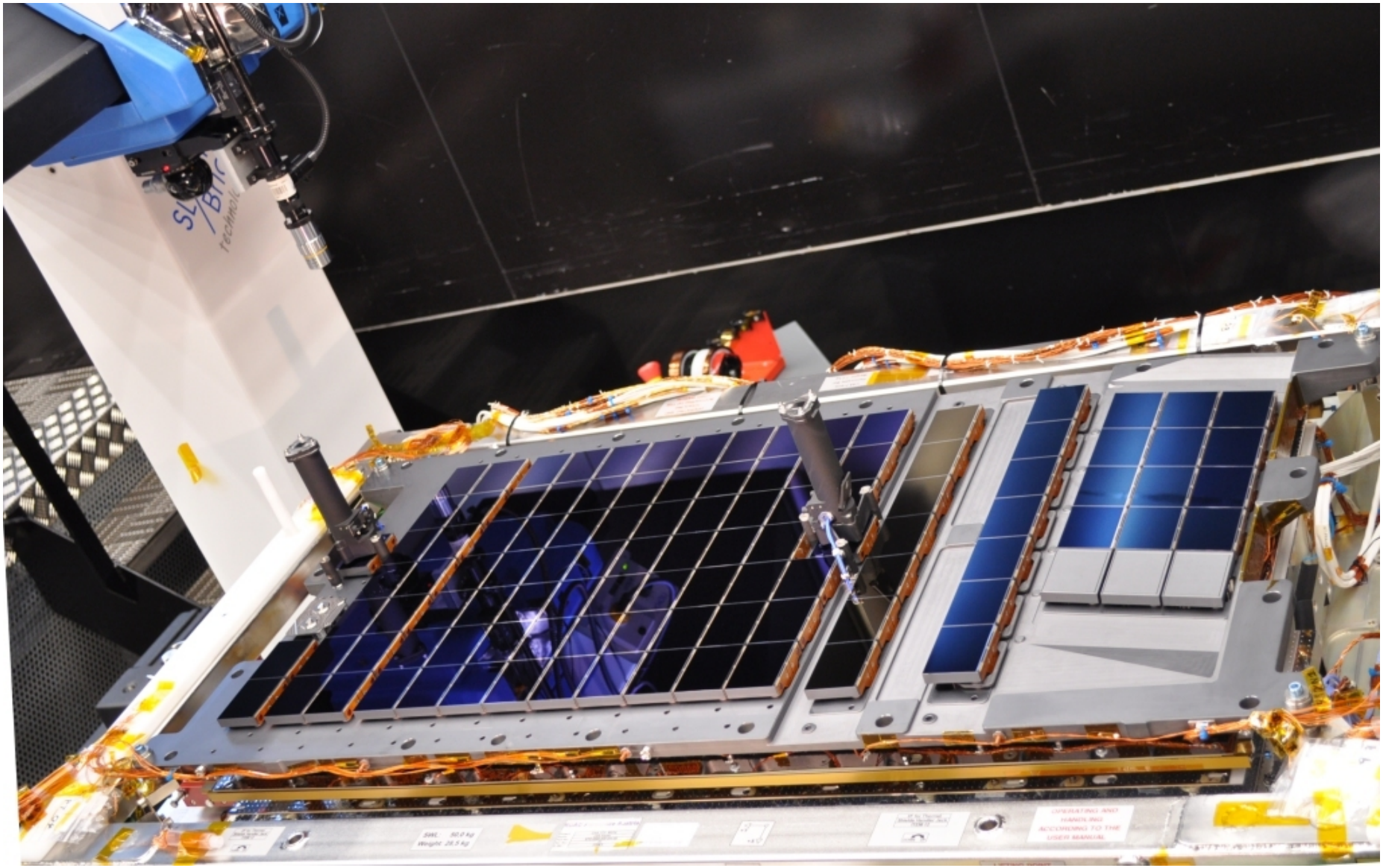
Photometry

- prism spectra
- blue and red CCDs

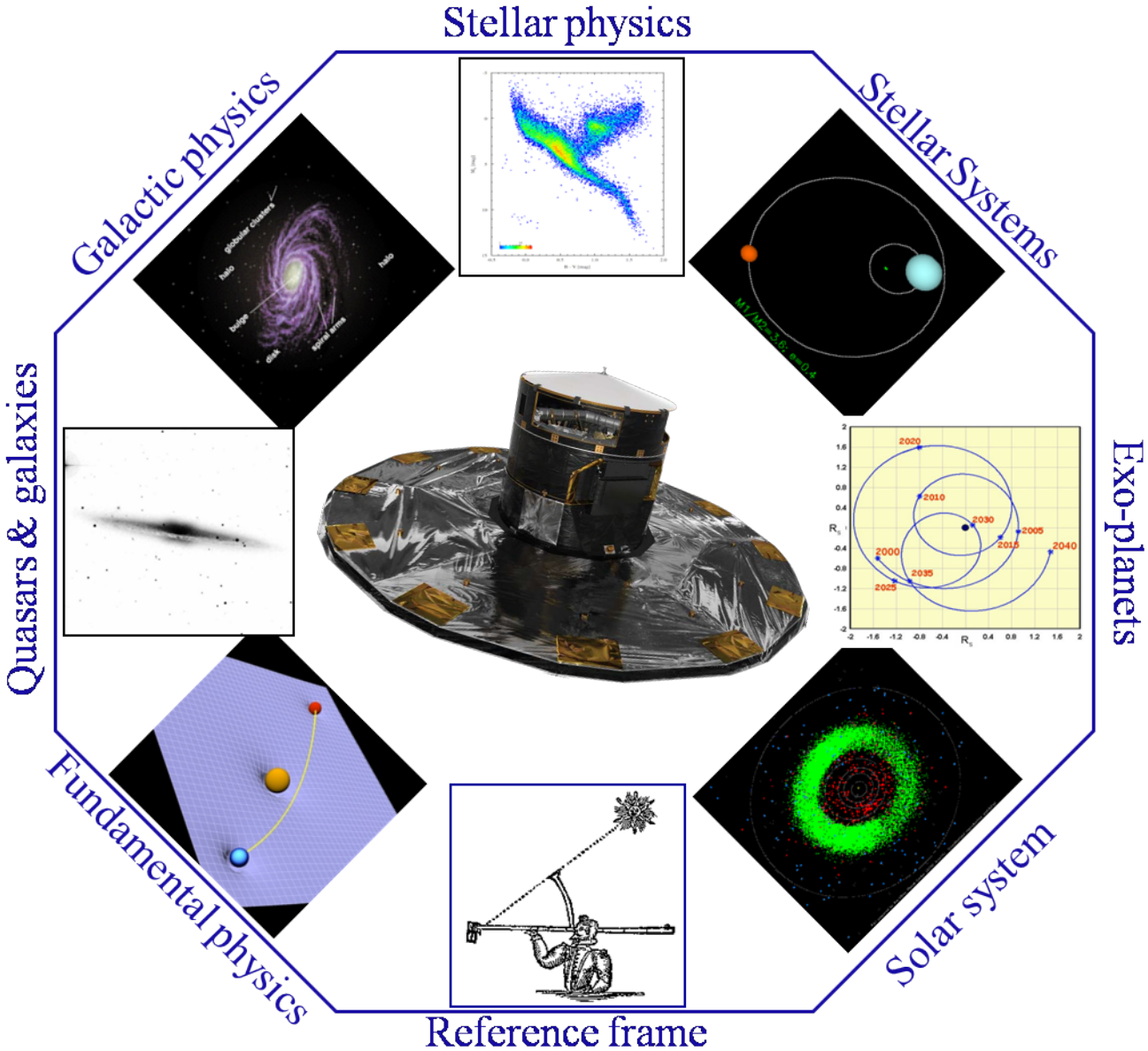
Spectroscopy

- high-resolution spectra
- red CCDs

Focal plane



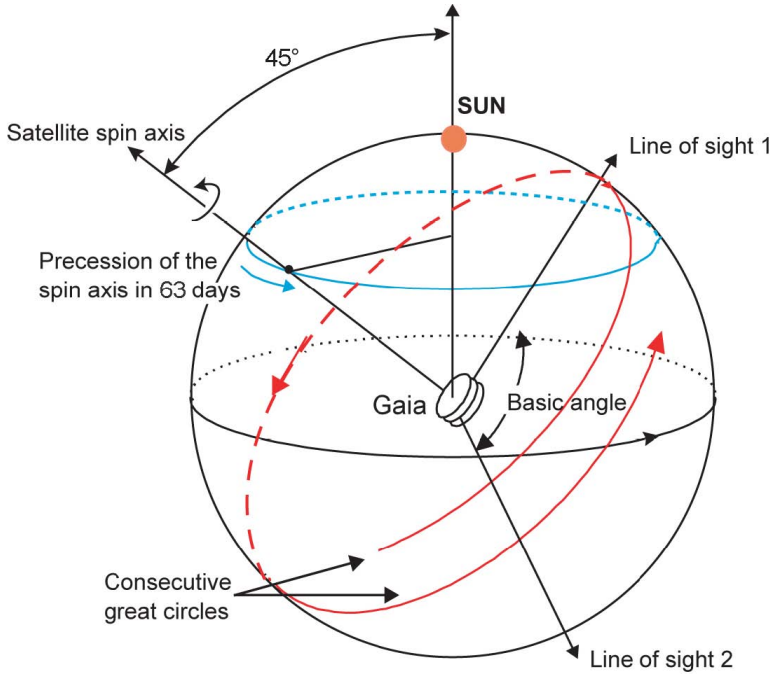
Science topics

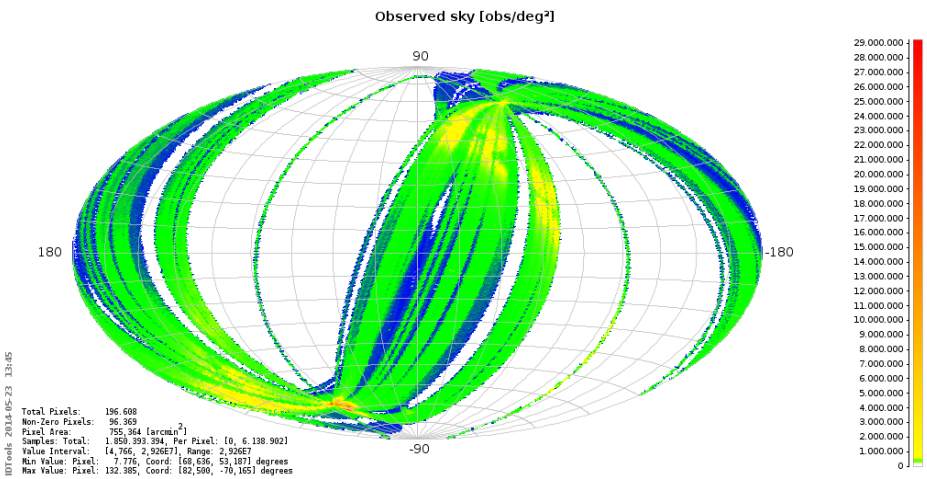


arianespace
service & solutions

VS06 • gaia - December, 19th 2013

- Focal-plane switch-on on 3 January 2014
- L2-orbit-insertion burns on 7 + 14 January
- Ecliptic-pole scanning + 6-h spin started on 8 January
- Commissioning concluded on July 18 2014



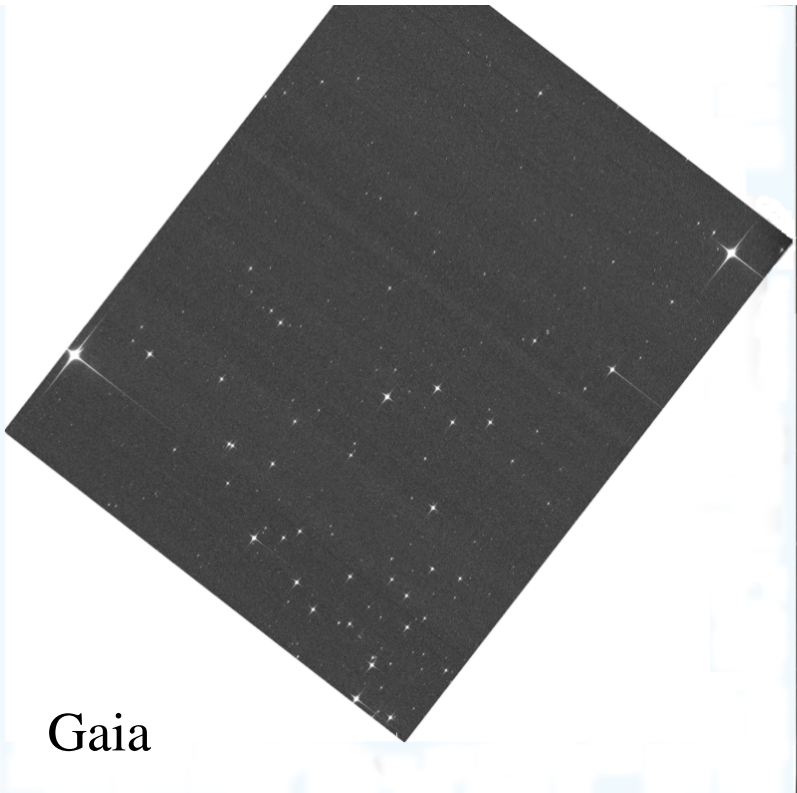


Detailed report:
GAIA-CO-TN-LEI-AB-052

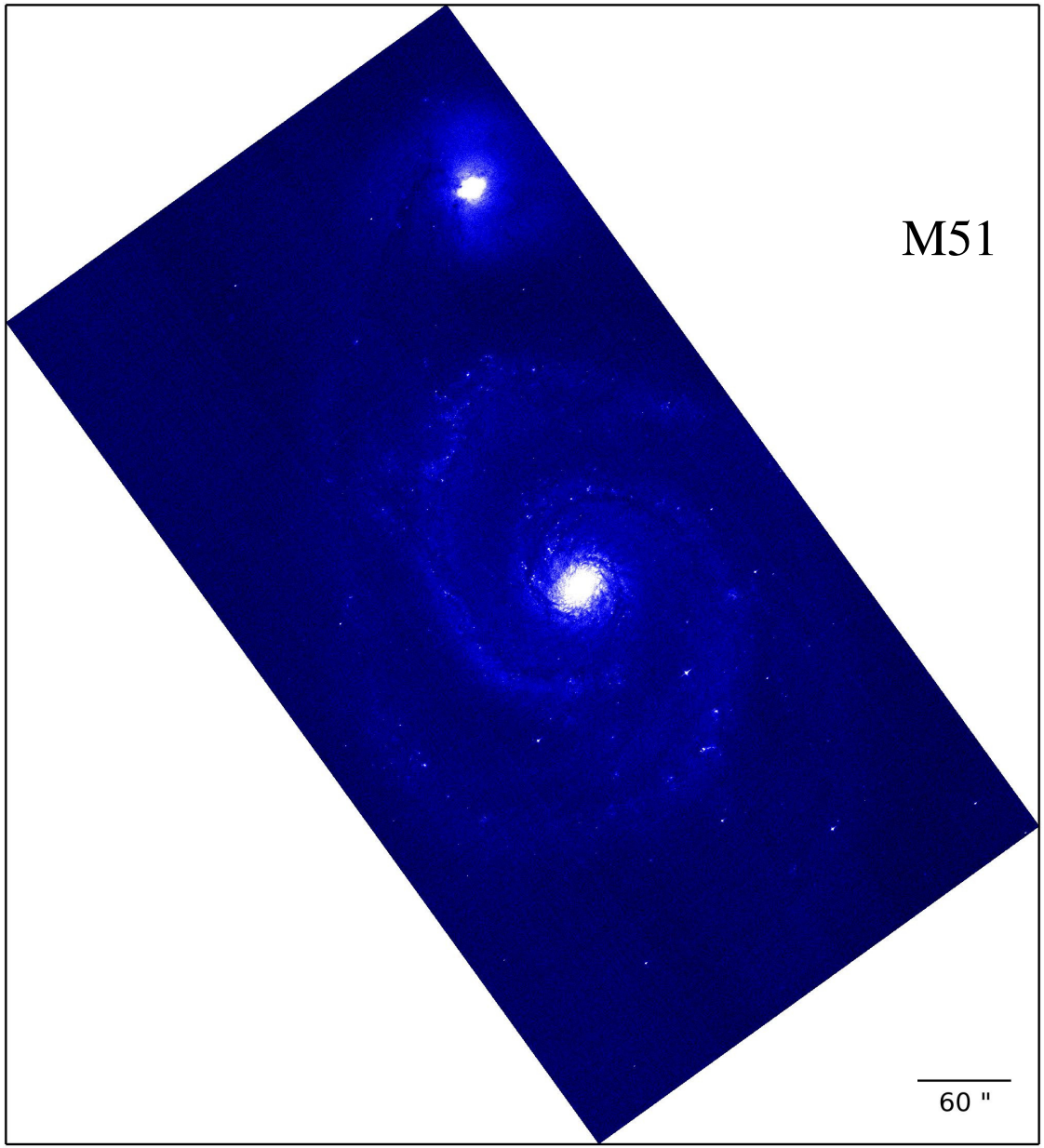
Sky coverage Feb 7 to May 24
IDT team @ University of Barcelona

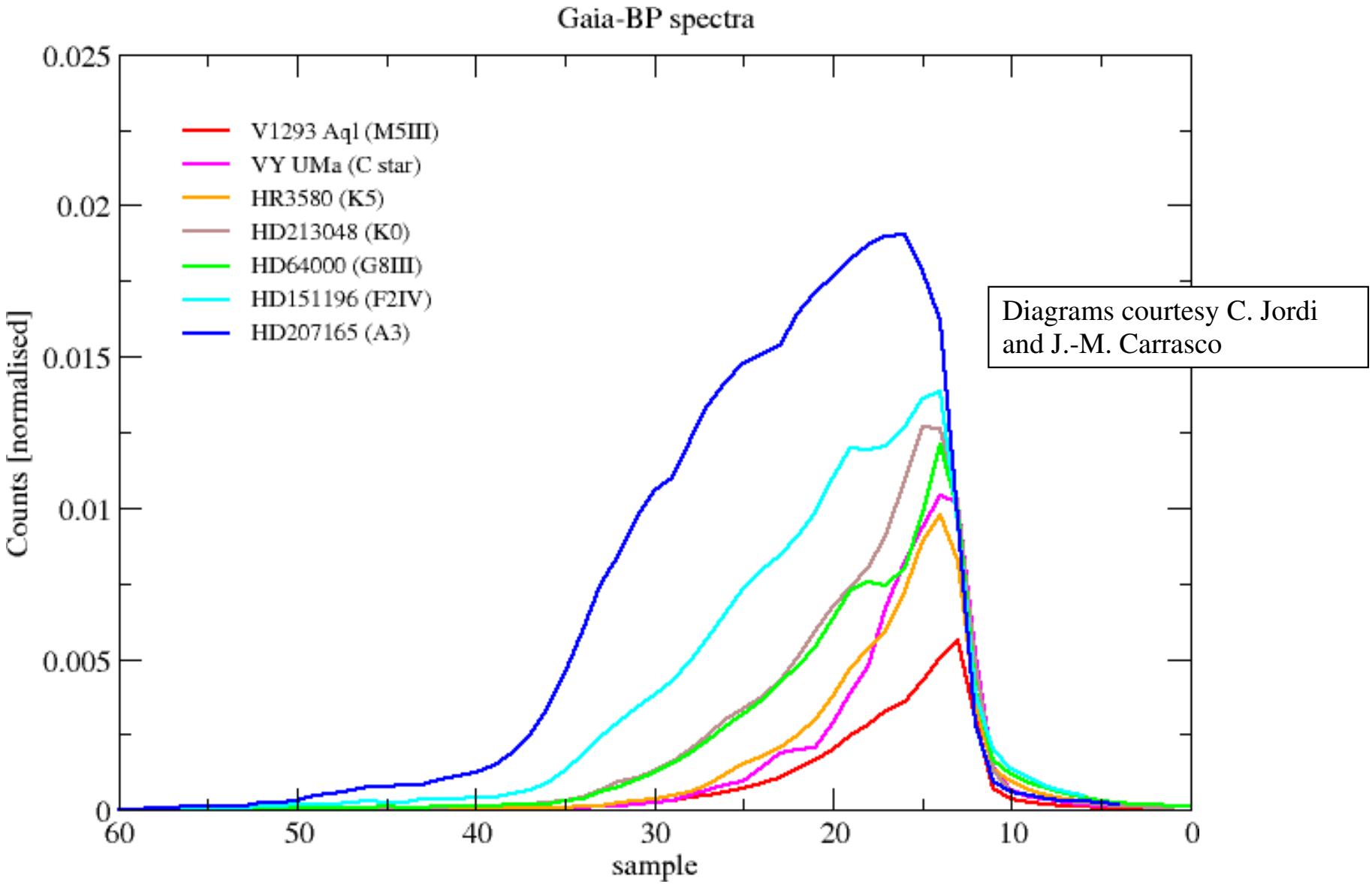
Examples of Gaia imaging capabilities

NGC 2516

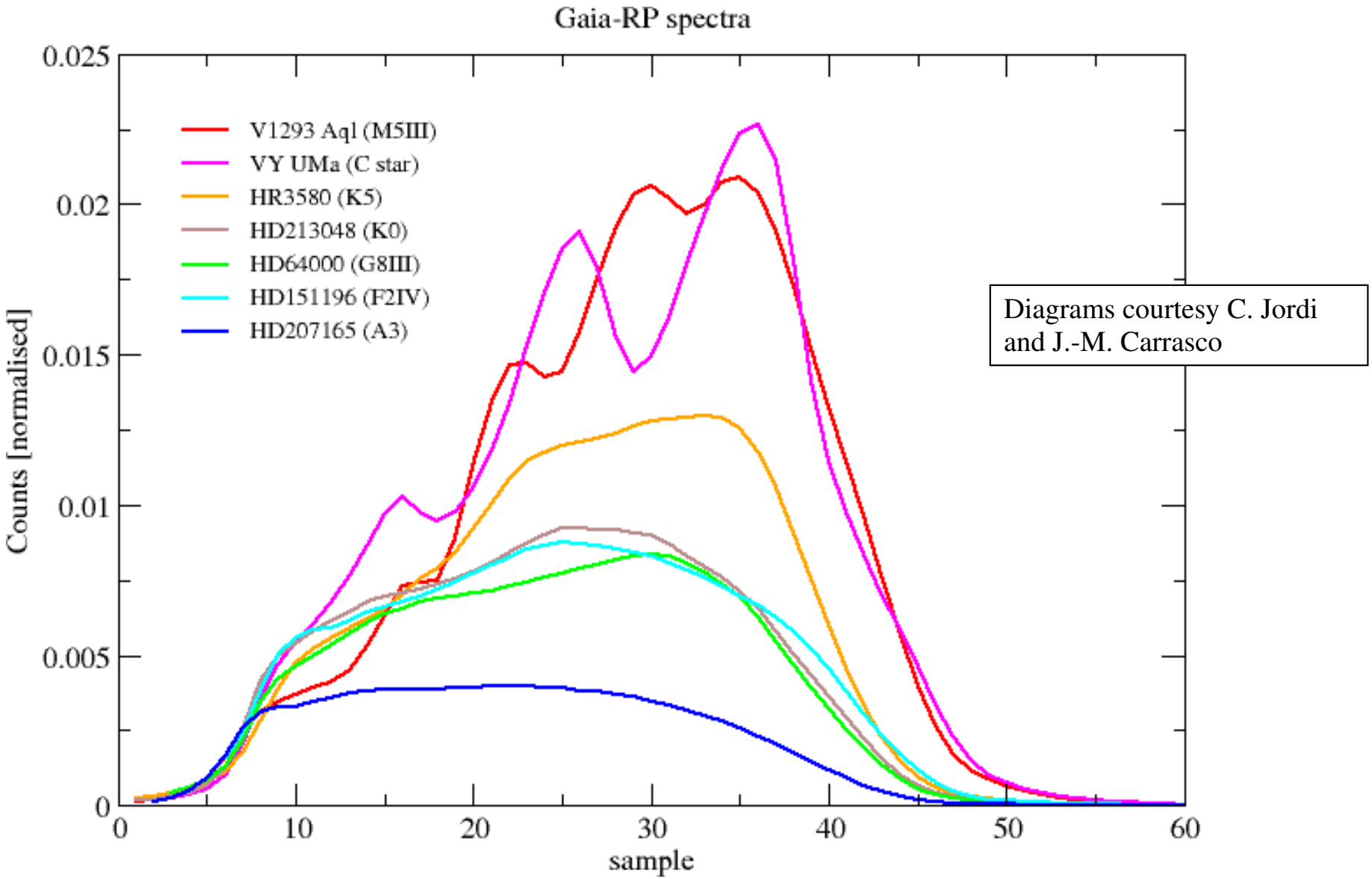


Examples of Gaia imaging capabilities

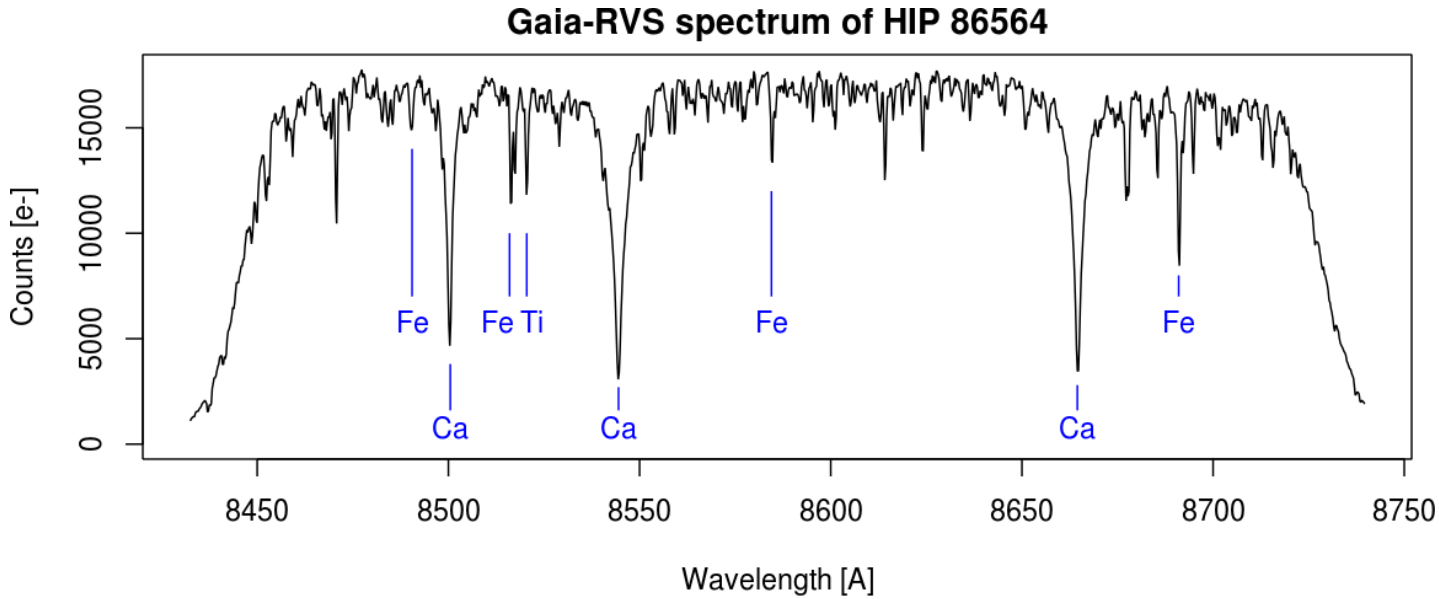




Diagrams courtesy C. Jordi and J.-M. Carrasco



Diagrams courtesy C. Jordi and J.-M. Carrasco



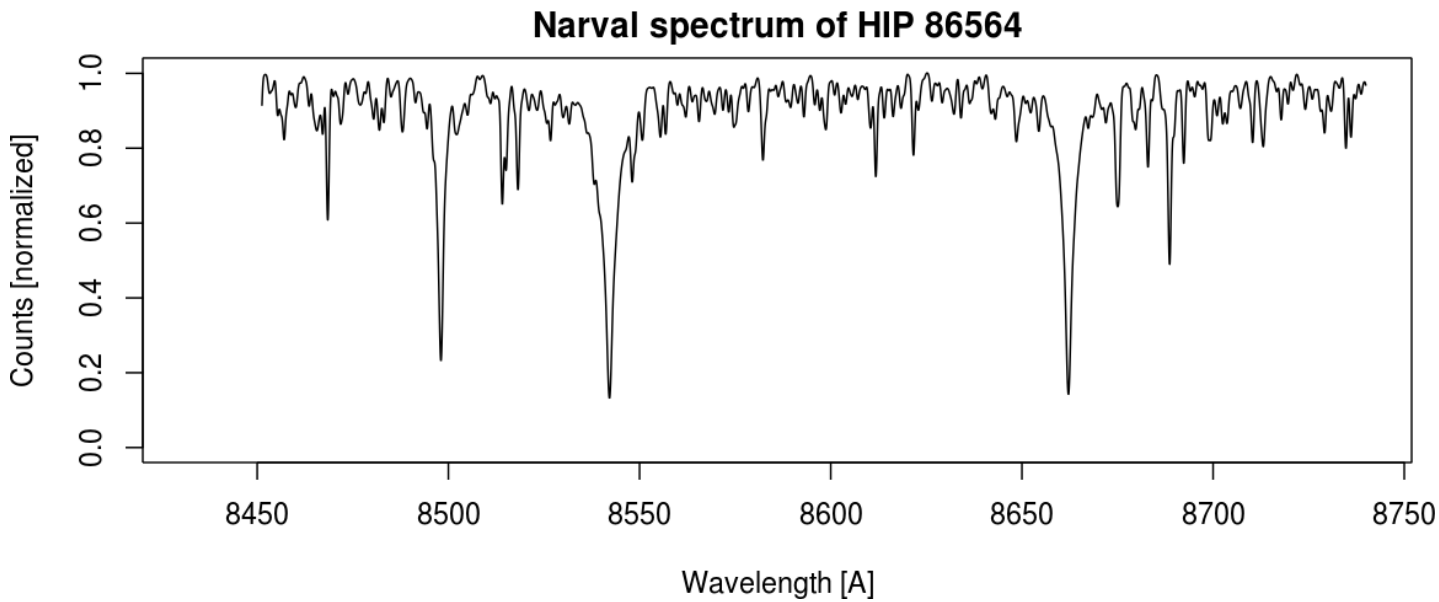
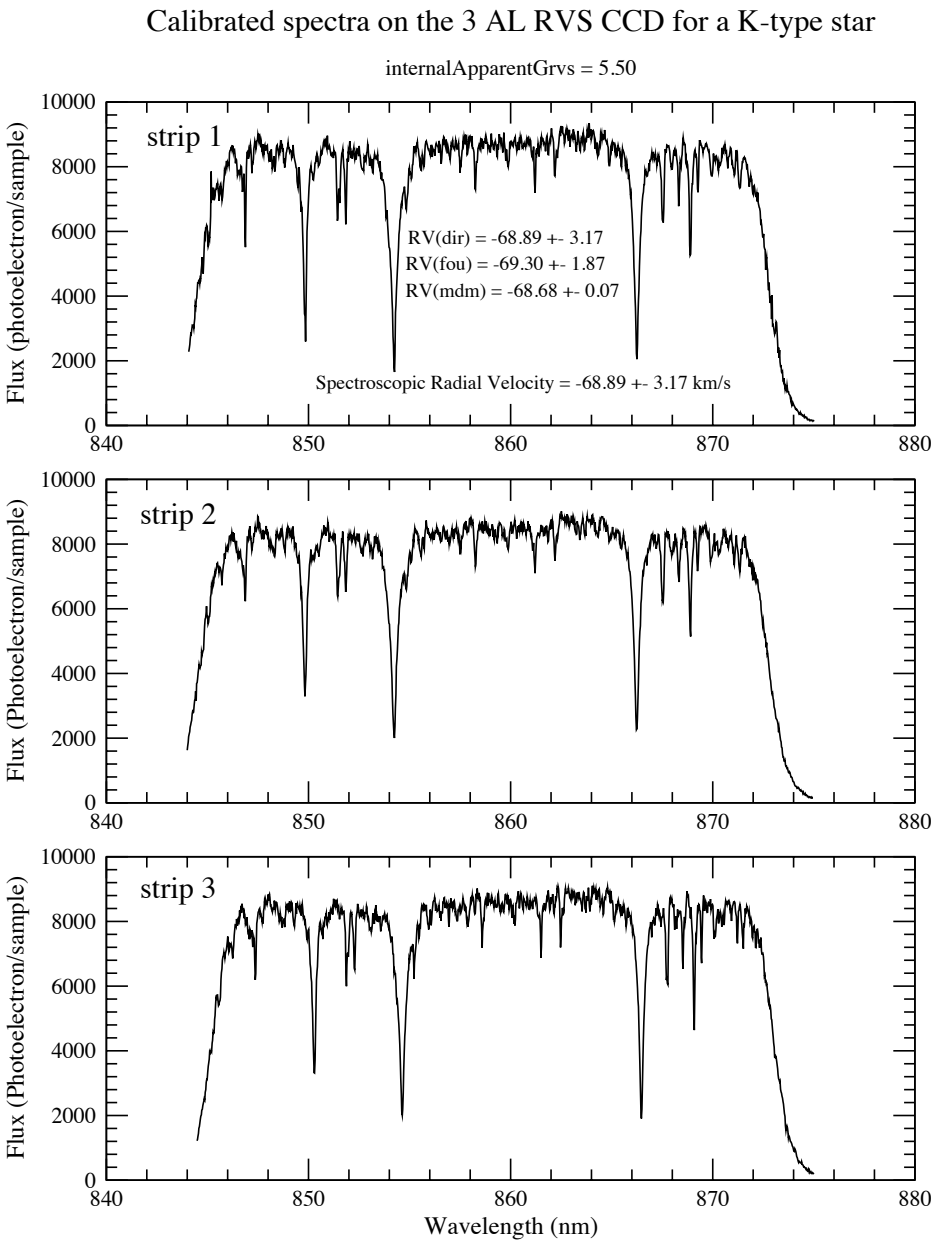


Figure courtesy D. Katz, O. Marchal, C. Soubiran



Early result from automated RVS processing

Credits: ESA/Gaia/DPAC/CNES/Yves Viala and Francoise Crifo

Overall status after commissioning

- Good launcher and orbit insertion performance
  - plenty of propellant left for future manoeuvres
- Service module commissioning went smoothly
  - Chemical propulsion system for large manoeuvres
  - Micro propulsion system to maintain Gaia's spin rate and compensate solar radiation pressure torque
  - Attitude and Orbit Control System works will within specs; thermal control fine
  - Good link budget for phased array antenna $\rightarrow$ high data rates possible
- Rubidium atomic clock working to required accuracy at this stage
  - Validation of high accuracy time correlation pending
- Payload module
  - 106 CCDs and 106 back-end electronics units all working fine
  - 7 on board computers managing the CCDs and electronics
  - Payload and data handling unit for storing and down-linking data
  - Telescopes aligned and focused; good image quality over full FPA
- Gaia $\rightarrow$ ESOC $\rightarrow$ DPAC/SOC $\rightarrow$ AirbusDS chain working smoothly
  - Excellent flight control team at ESOC
  - DPAC operations teams calm and competent
  - About 40 DPAC Payload Experts analyzed the data; supported commissioning
  - Many S/W patches and fixes but all in controlled manner

Optical tracking of Gaia

Gaia seen by ESO-VST: image courtesy ESO

Optical tracking of Gaia

Background

- Orbit should be known to 150 m in position (solar system object parallaxes) and 2.5 mm/s in each velocity axis (aberration correction bright stars)
  - 1 mm/sec upper limit on systematic error!
- 20 mas accurate position of Gaia on the sky needed, every day
  - Can only be achieved after first AGIS solution

Status

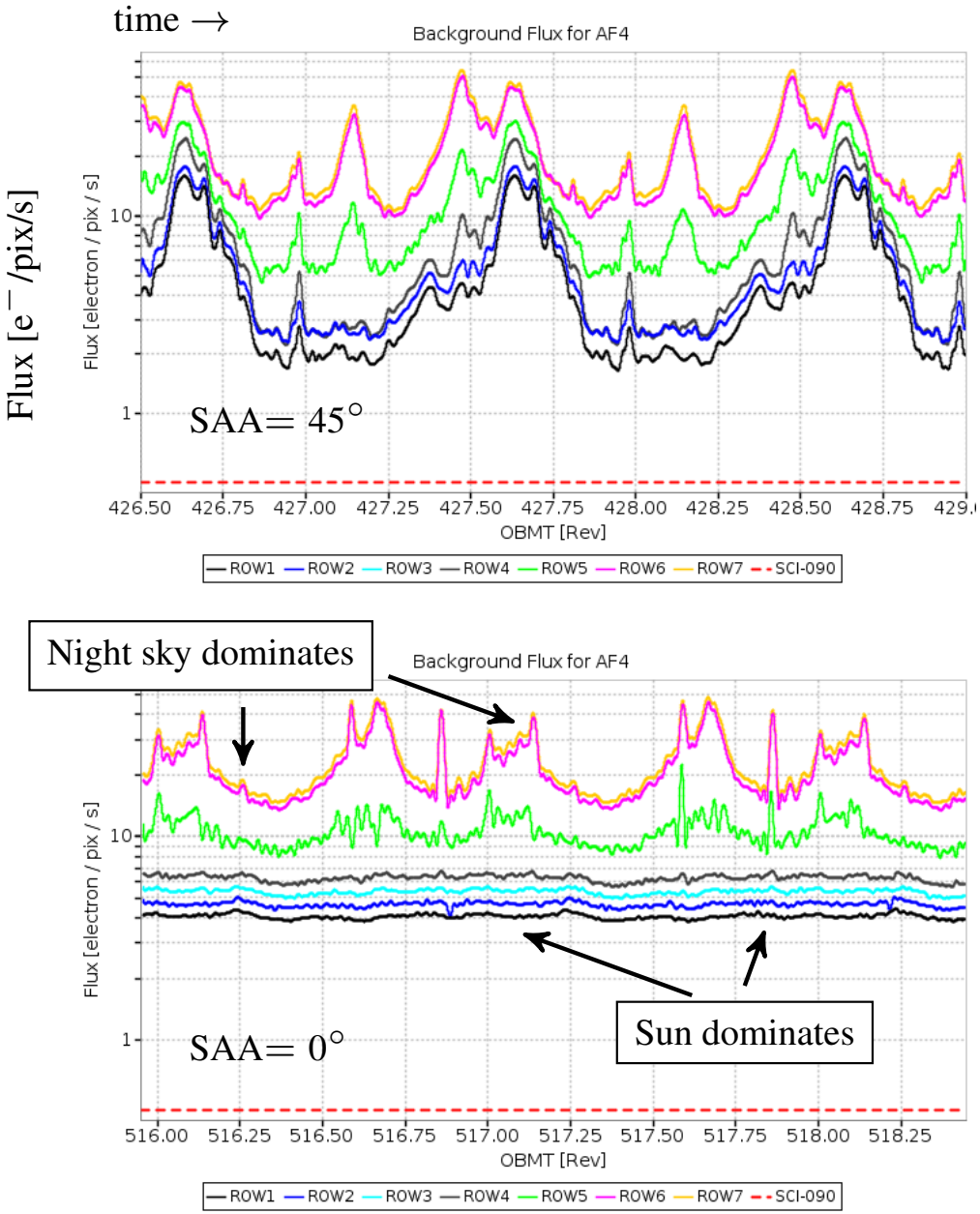
- Gaia fainter than hoped for at $r \sim 20.5$
- GBOT team worked hard to revise observing and data processing strategies
  - VST@ESO can deliver the required astrometric precision most of the time and is now the backbone of GBOT
  - Observing/processing strategy being adapted at Liverpool Telescope, which should deliver the required astrometric precision
  - Test observations underway with Las Cumbres 2m telescopes
- ESOC can complement with VLBI-type observations (few mas accuracy)
- GBOT issue is under control

Micro and Chemical Propulsion System anomalies

- Malfunctioning mass-flow sensor in one of the thrusters (#3A) of the micro propulsion system
  - Erroneous feedback from this thruster to the Attitude and Orbit Control System, leading to increased gas consumption, and possibly degraded attitude control
- MPS anomaly root cause still under investigation
- AOCS now working on B-branch
  - AOCS works very well
  - Slight cold gas over-consumption due to thruster bias drifts
  - Bias being monitored and calibrated
  - Studies ongoing to optimize MPS usage

- Chemical thruster #3B is electrically dead
- Using the redundant unit now
  - lost redundancy for this CPS thruster
  - New CPS mode implemented which makes Gaia robust against thruster 3A failure

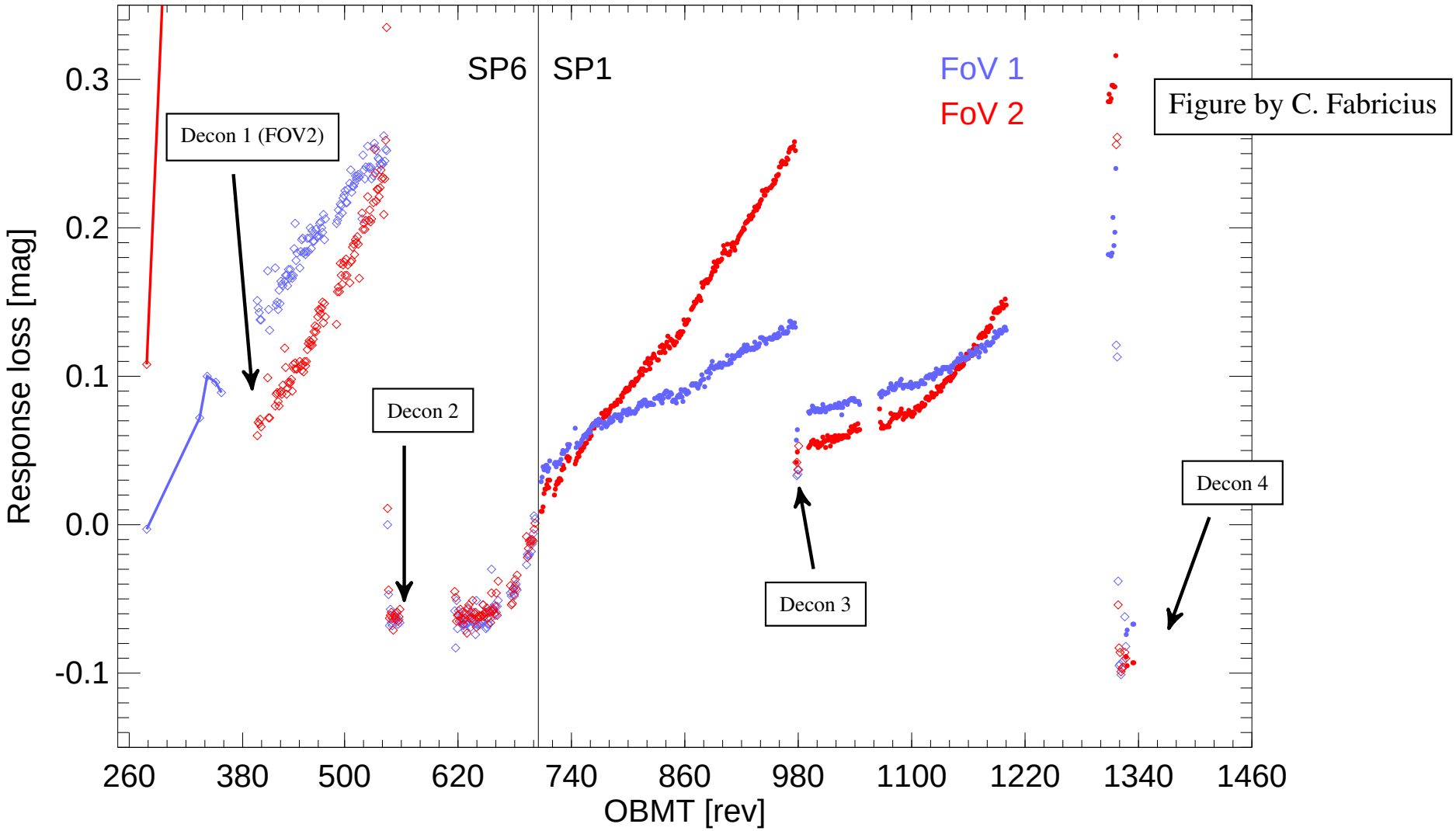
Stray light



- Strong stray light levels all over focal plane
- In the peaks orders of magnitude above requirements
- Sun light diffracted and/or scattered at sun-shield edges
  - Varies over 6 hour spin period
- Light from night sky sources along unforeseen paths
  - Varies according to sky scanned

Figures by M. Davidson

Throughput loss



Monitoring of response by comparison to Tycho-2 photometry

Throughput loss

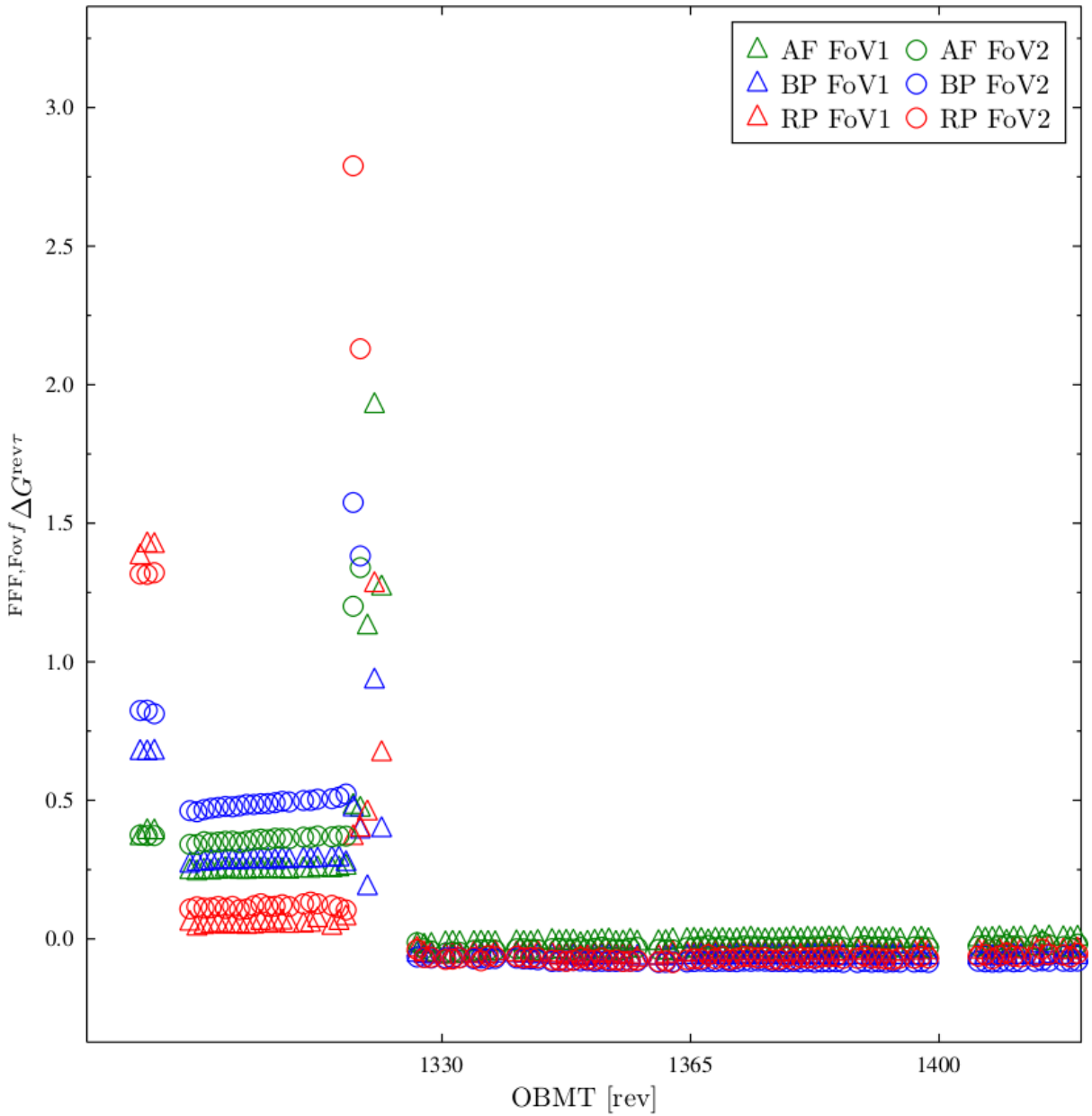
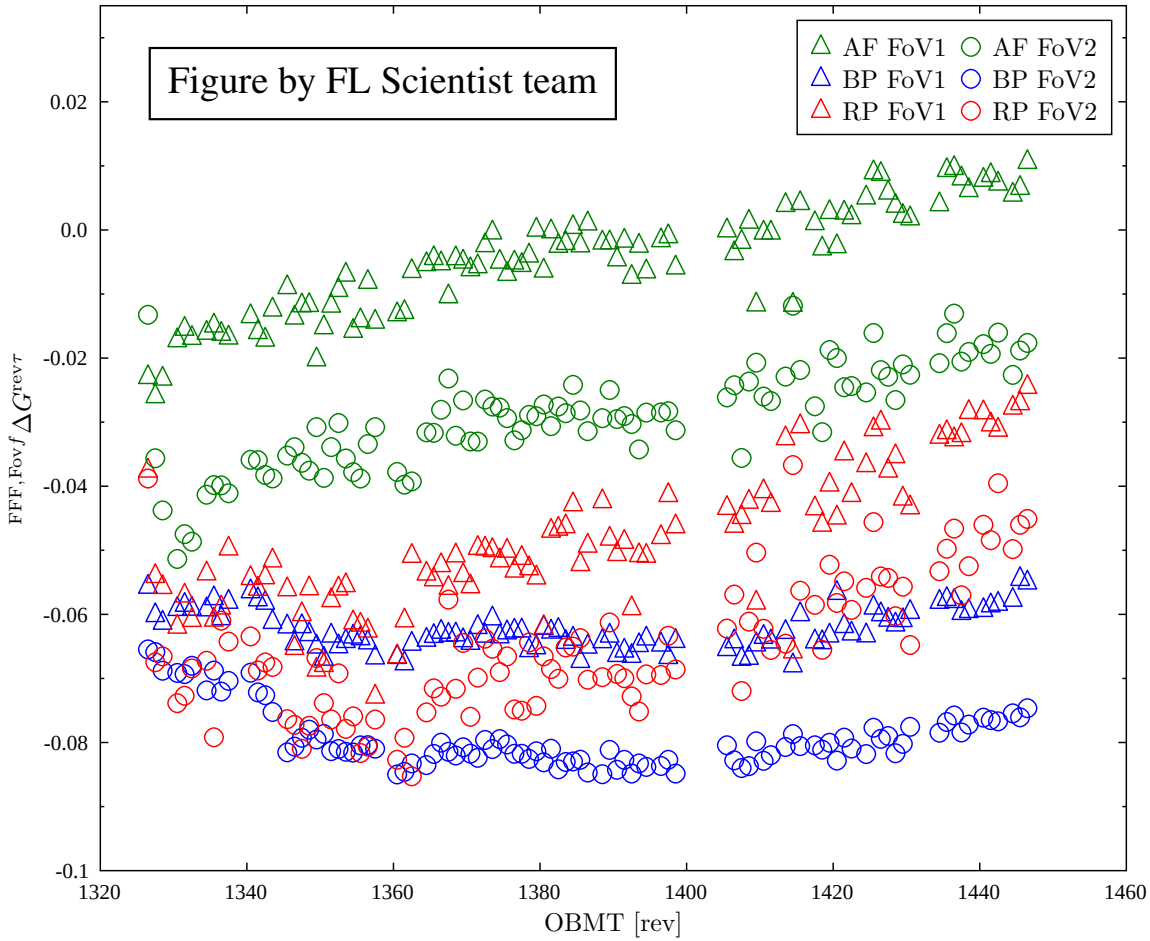


Figure by FL Scientist team

Throughput loss

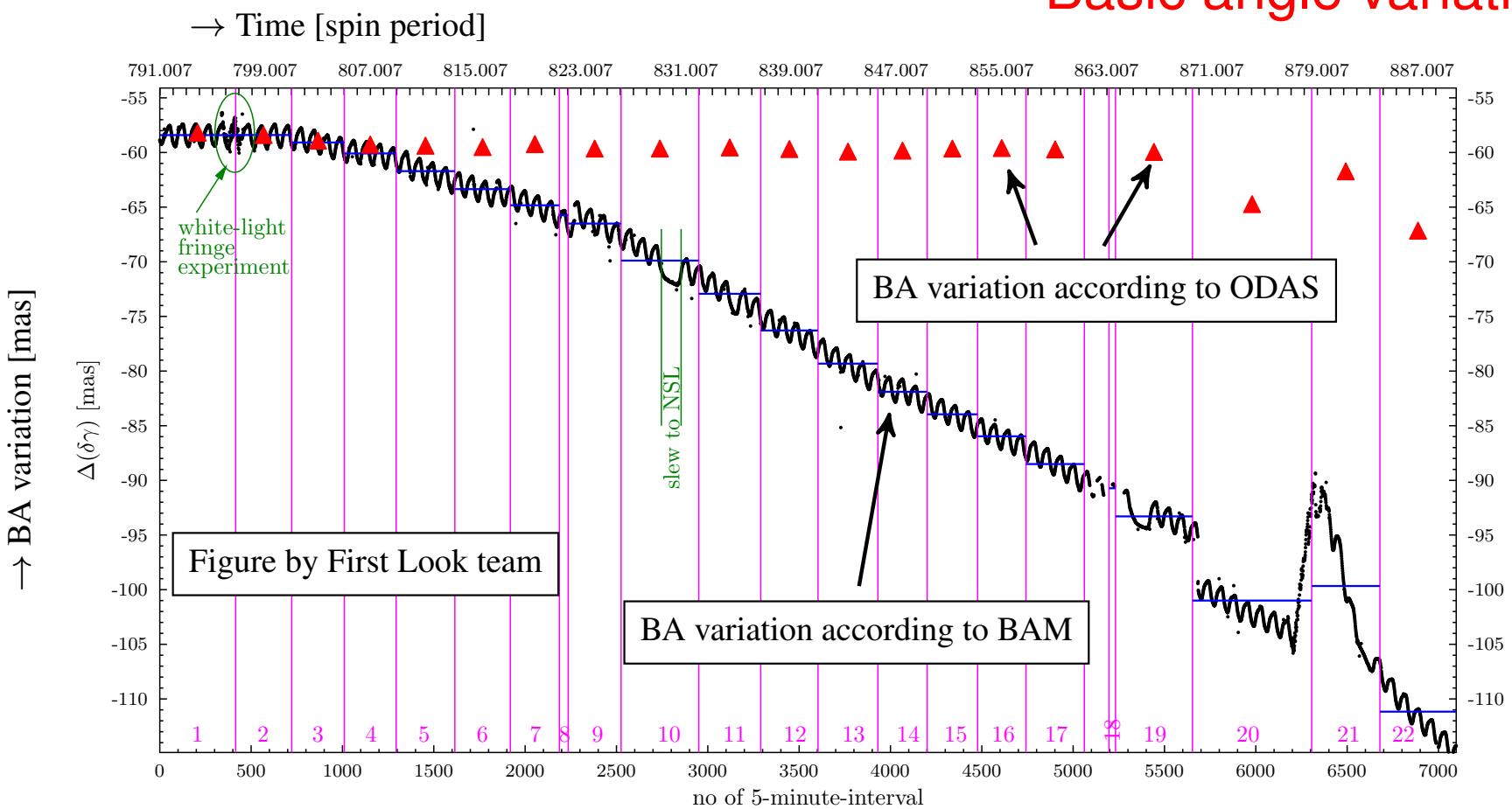


PE analyses

- Modelling effects of ice on mirrors
  - XP spectral signatures
  - image quality
- Optimization of the decontamination procedure
  - heating all mirrors seems necessary

- Throughput loss in AF, BP, and RP (FLS report 2014-10-28)
- Future decontamination campaigns unavoidable
  - Not clear at the moment how many more

Basic angle variations



- Trends and jumps with 6 hour period variation superposed
  - 6 hour variations can cause systematic errors in astrometry
  - Basic Angle Monitor (BAM) in place to measure the variations so they can be accounted for in processing
- Astrometric solutions indicate that BAM measures real variations
- Analysis shows BAM measurements precise to $\sim$ 10 μas level or better

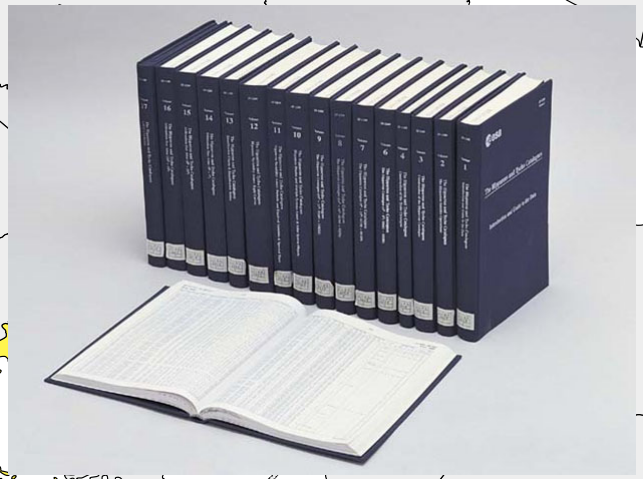
Gaia DPAC
Data Processing & Analysis Consortium

- Gaia data processing is a Pan-European cooperation
  - Academic institutions and national space agencies
  - Supported through national funding
  - Processing power spread over 6 centres
  - SOC/DPCE integral part of DPAC

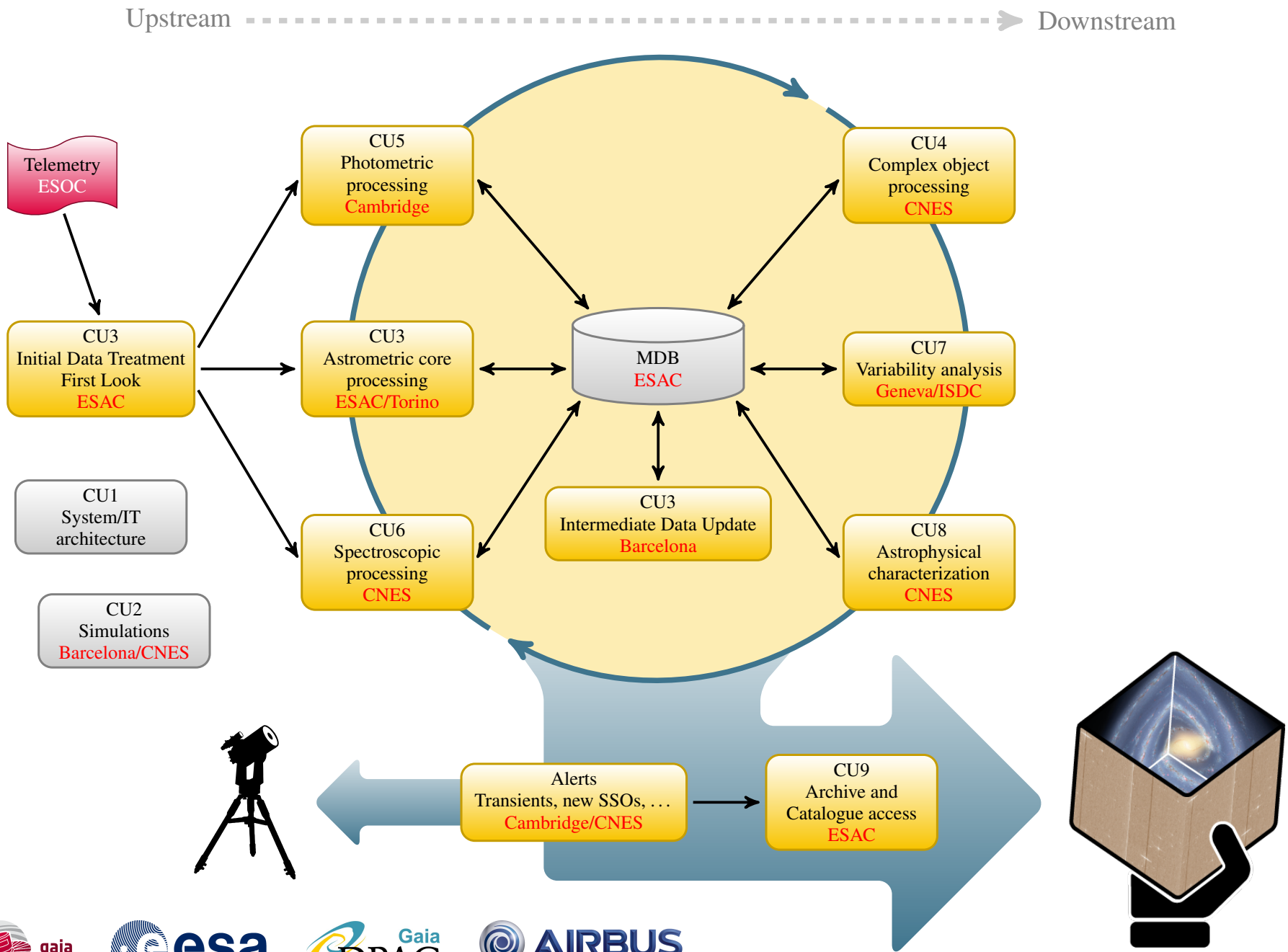
DPAC participating countries October 2013 450 members

Including:
BR
CA
DZ
ESA
IL
US

DPCI
DPCG
DPCC
DPCT
DPCB
DPCE



DPAC overview



Data collection stats

Example TM time line with Galactic plane crossings (OBMT rev 516–517, courtesy J. Hernández)

Data collection stats

Statistics up to October 10

Data collected or processed

Type of Data	Amount	
Science telemetry	7.6 TB	
Astrometry transits	9.0×10^9	90×10^9 images
Photometry transits	8.8×10^9	17.6×10^9 images
Spectroscopy transits	1×10^9	3×10^9 spectra

Early astrometric performance assessment

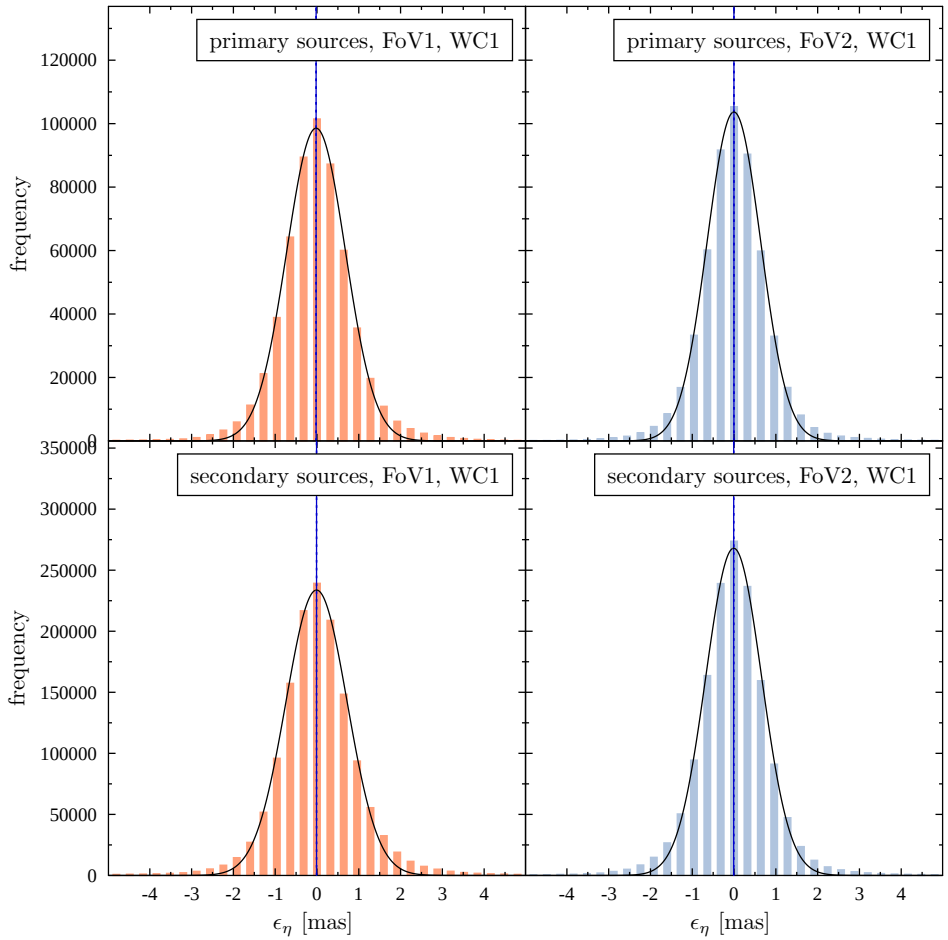
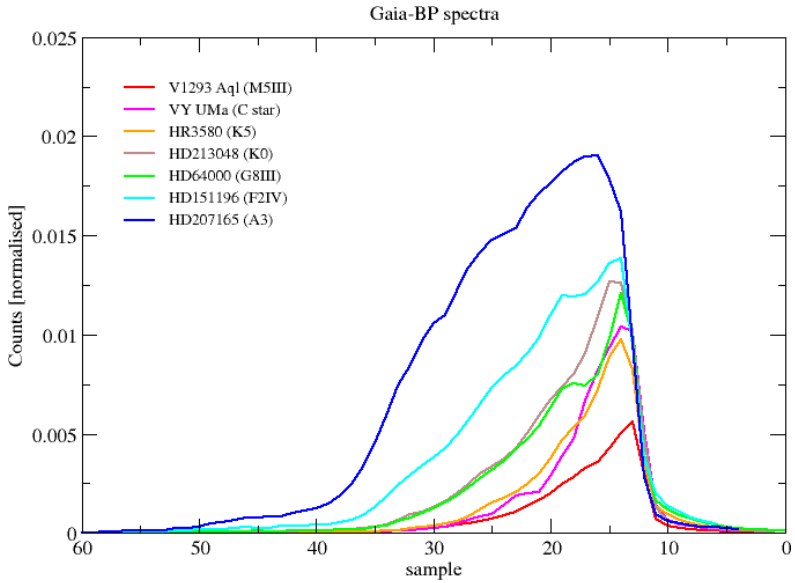
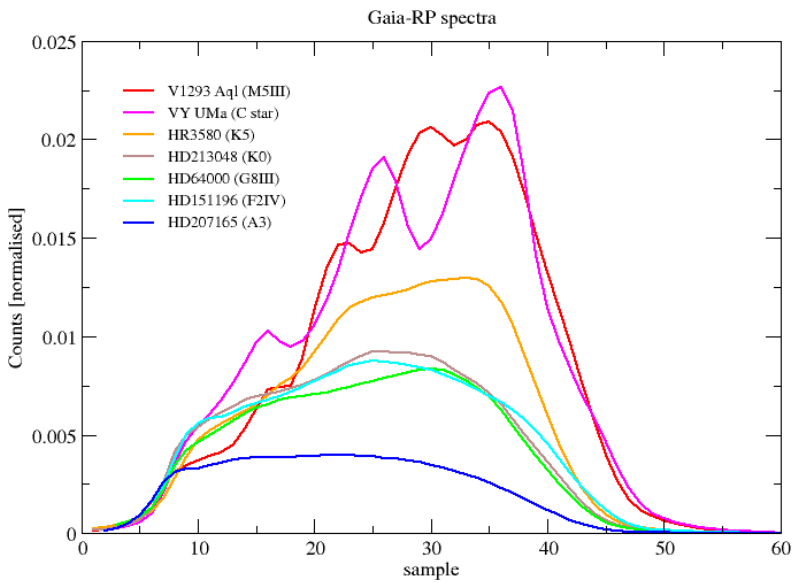


Figure courtesy First Look team

- Residuals from one-day astrometric solution at $G = 15$ already better than 1 mas
- Caveats at this stage
  - unstable instrument
  - poor PSF calibrations
  - imperfect stray light corrections
  - throughput loss
- For clean telescopes throughput is as expected
- Read noise within requirements
- Corrections for bias non-uniformity under control
- High accuracy timing works nominally (detailed verification pending)

Early photometric performance assessment





- Spectra appear as expected: classification and parametrization possible
- For clean telescopes throughput is as expected
- Read noise within requirements
- Corrections for bias non-uniformity under control

Figure courtesy C. Jordi & J.-M. Carrasco

Early spectroscopic performance assessment

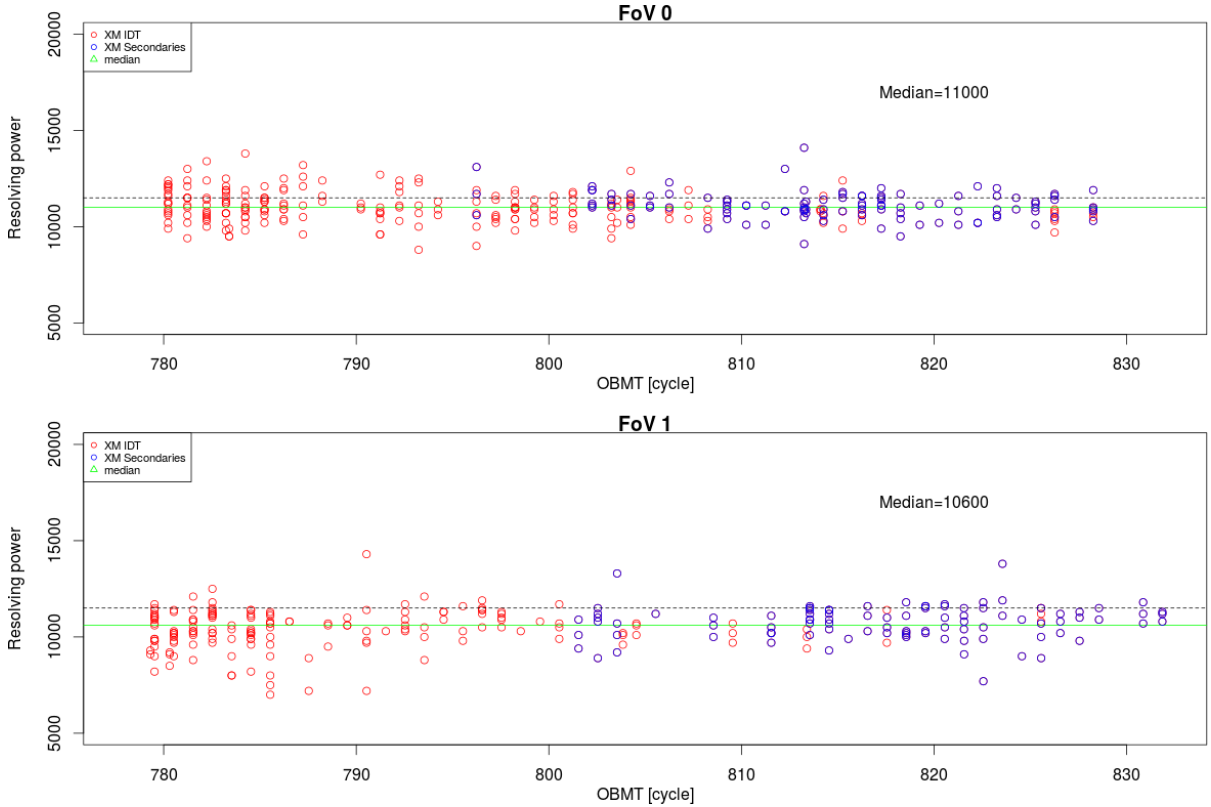


Figure courtesy D. Katz & O. Marchal

- Resolving power nominal
- Read noise within requirements
- Corrections for bias non-uniformity under control
- Wavelength zero point stability pending

Preliminary RVS performance at bright end

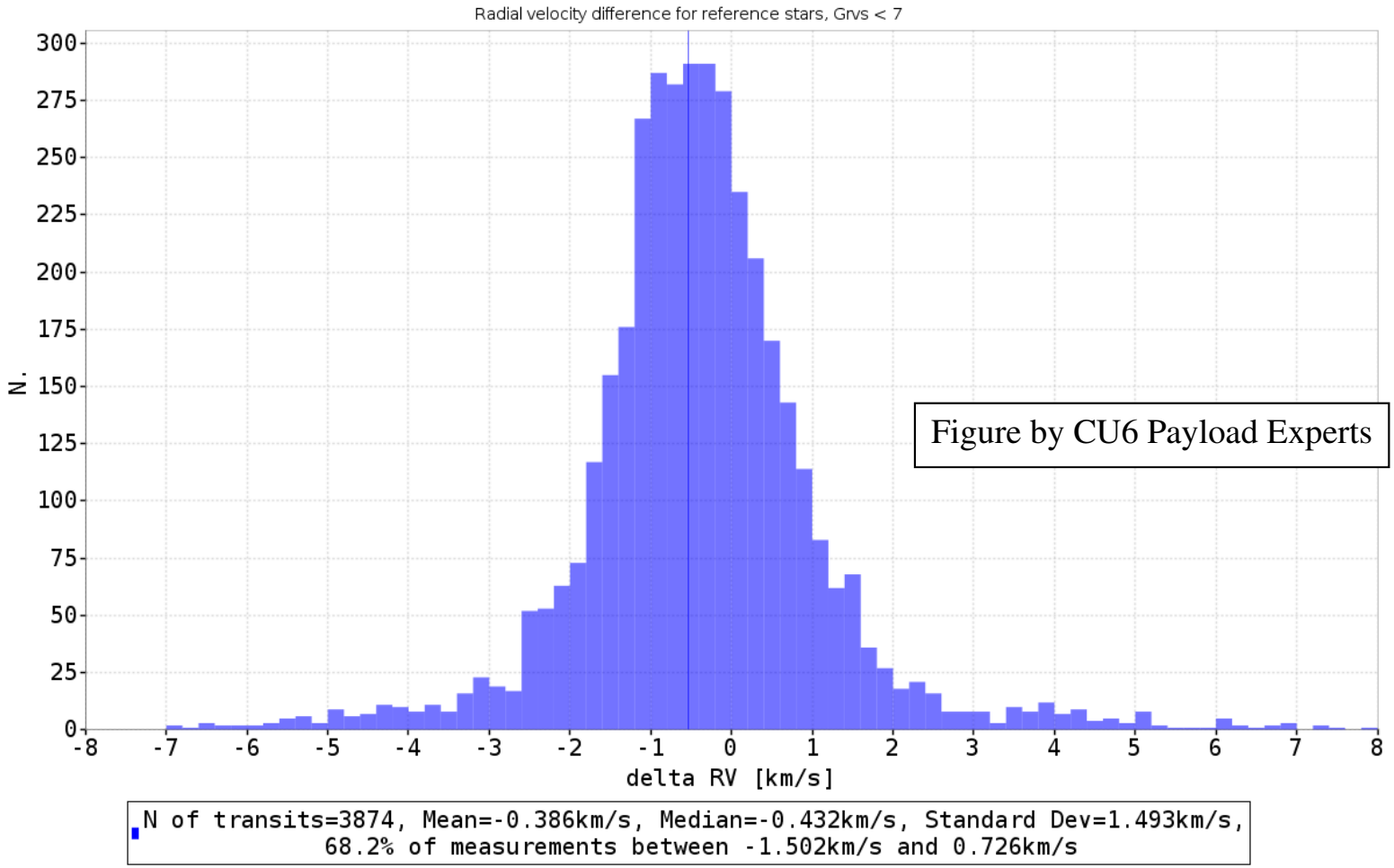
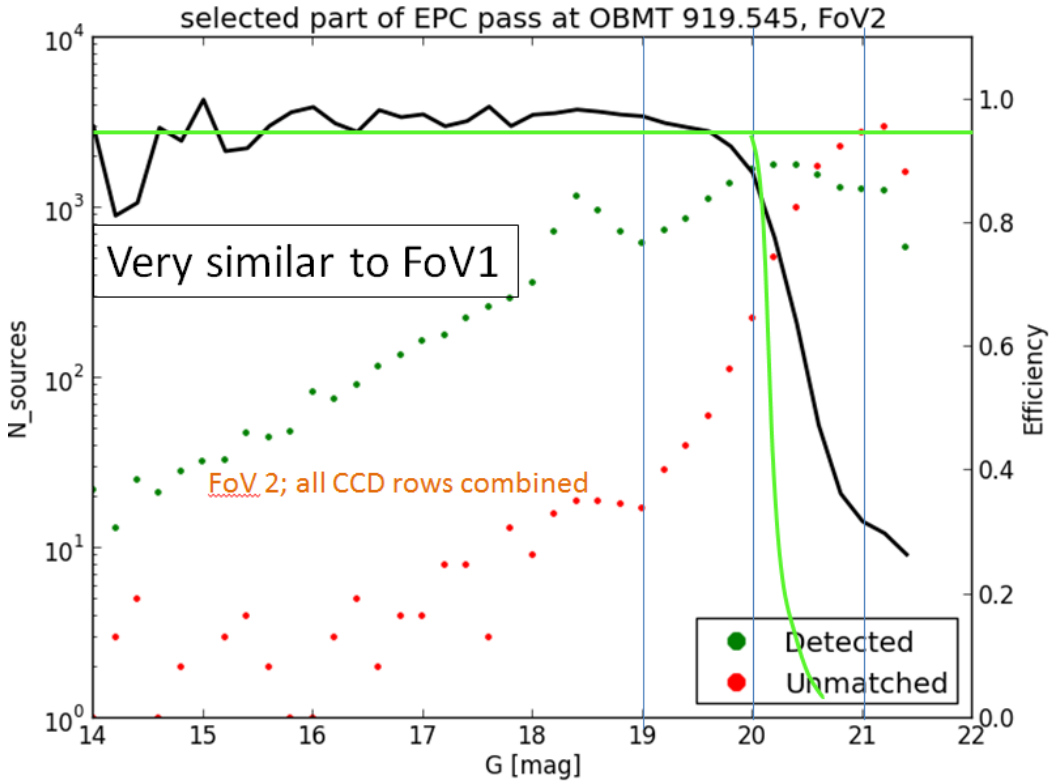


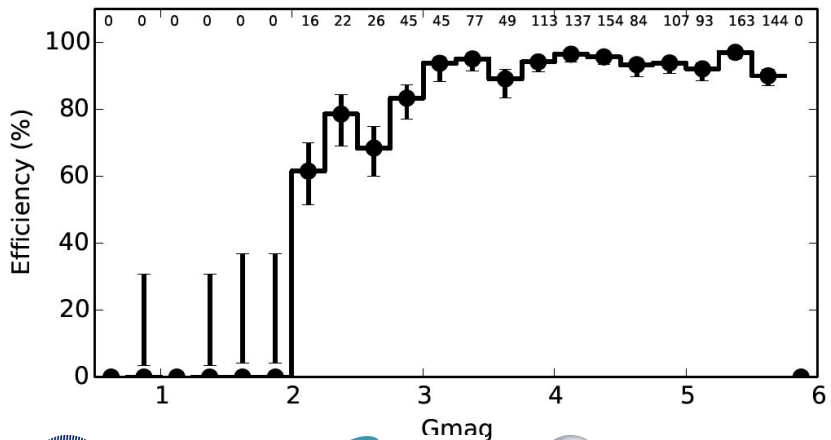
Figure by CU6 Payload Experts

- Differences between measured and expected $v_{\rm rad}$ for bright ($G_{\rm RVS} < 7$) ground based radial velocity standards
- 68% of measurements are within 1.1 km s^{-1} from the median!

Detection efficiencies

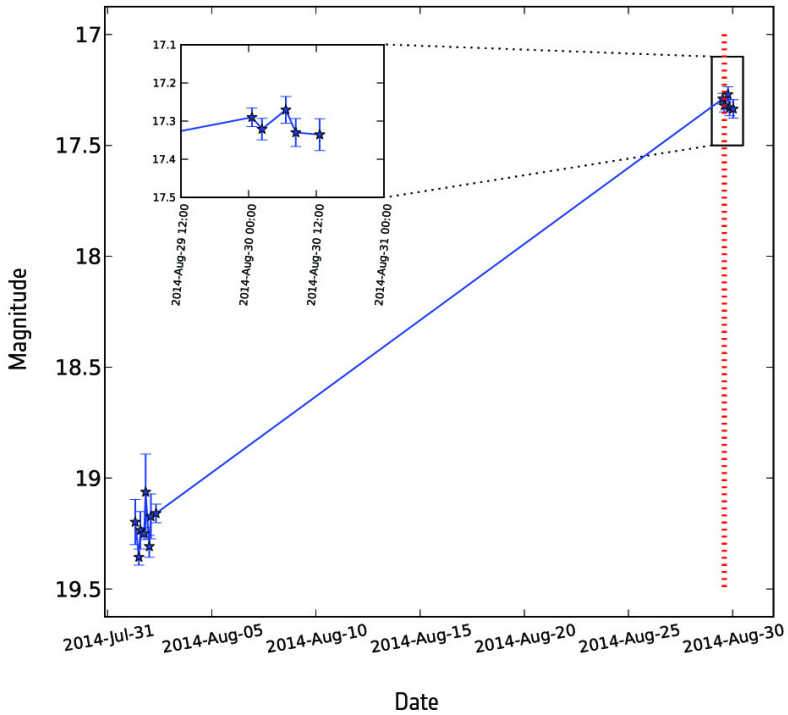


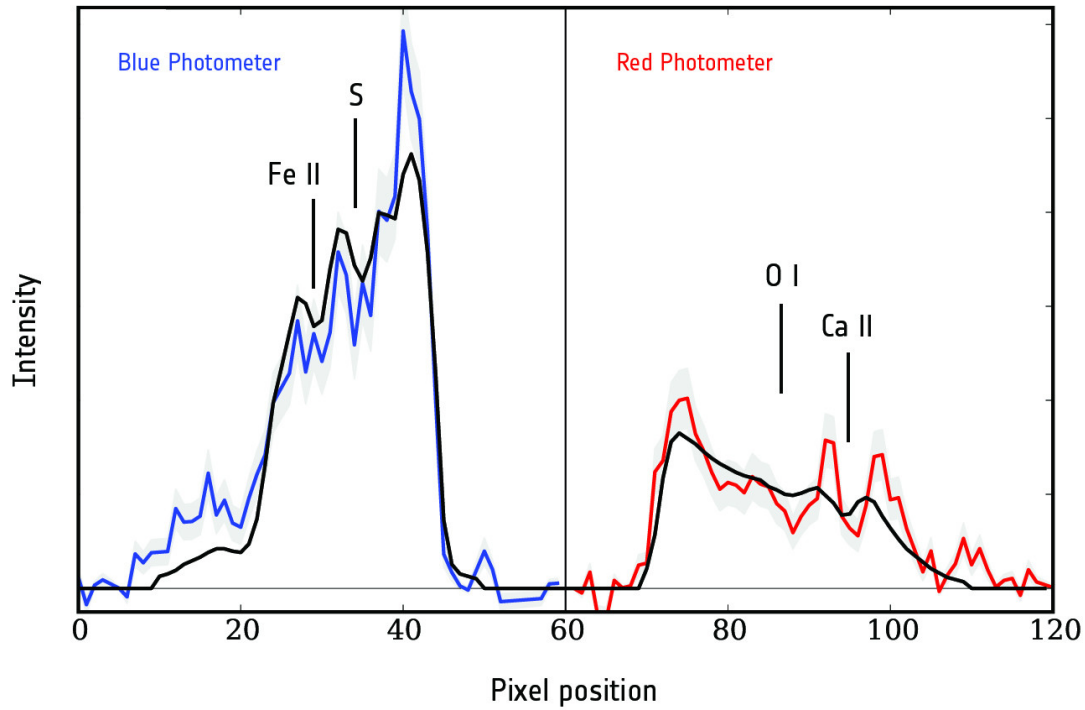
- Faint end efficiencies measured against dedicated Ecliptic Pole survey
- Bright end extended to $G < 6$ through detection algorithm improvements and employment of special observing mode

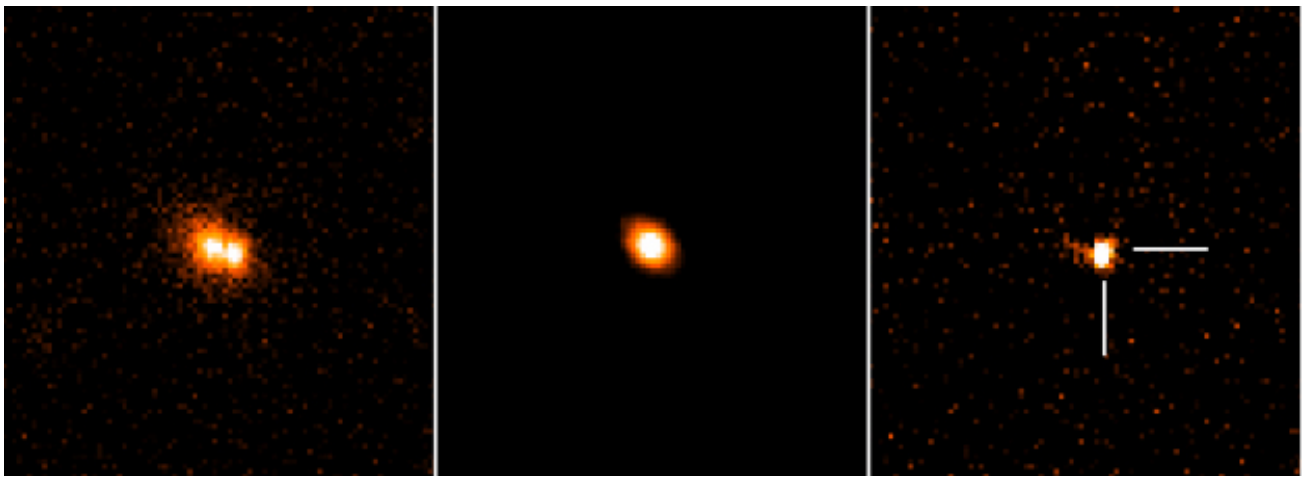


Figures courtesy U. Bastian and SOC Calibration Team

First supernova discovery







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

Gaia performance predictions at IOCR (July 2014)

Performance predictions for G2V star			
V magnitude	Astrometry (parallax)	Photometry (BP/RP integrated)	Spectroscopy (radial velocity)
3 to 12	5–14 μas	4 mmag	
3 to 12.3			1 km s^{-1}
15	24 μas	4 mmag	
15.2			15 km s^{-1}
20	540 μas	60 (RP) – 80 (BP) mmag	

Up-to-date information always at:
`http://www.cosmos.esa.int/web/gaia/science-performance`

Gaia performance predictions at IOCR (July 2014)

- Stray light impact assessed with respect to extra noise
  - Systematics not accounted for
- On the assumption that BA variations and micro-meteoroid hits can be accounted for perfectly, the current numbers provide an optimistic performance estimate
- Too early to provide quantitative estimates of the effects of:
  - Basic Angle variations
  - Throughput loss (with corresponding optical quality degradation)
  - Micro-meteoroid hits
  - Radiation damage

Gaia will still deliver a fantastic survey of our Galaxy and the Solar system

Impacts on data processing

- 3 months longer commissioning period
  - Later start of nominal operations and processing
- Extra development and processing effort needed to deal with:
  - Effect of future decontamination campaigns
  - Stray light effects
  - Change in RVS observing strategy
  - Account for basic angle variations through BAM measurements
  - Deal with high rate of micro-meteoroid hits
  - More complex data validation

First data release expected by mid-2016

Operations since IOCR

- Start of nominal operations on July 25
- 28 days of undisturbed EPSL data collection July 25 – August 21
- Orbit maintenance manoeuvres 25/7, 21/8, 9/9, 9/10
- Transition to NSL on August 22
- PDHU configured to deal with G=21 survey
- Latest decontamination on September 23
- Switch to GAREQ optimized NSL on September 25
- One occurrence of 10 minutes data loss due to rain at Cebreros
  - only data loss so far

- Gaia now routinely observes all sources $3 \leq G \leq 21$
  - objects at $G < 3$ via special mode (SIF)
- Data collected: 150 GB HKTM, $>$ 6.5 TB science data
  - Operational data base 62 TB

Basic angle related Working group will look into root cause of BA variations (Airbus DS, ESA, DPAC). Research and development on calibrating the BA variations using a combination of AGIS adaptations and BAM measurements $\longrightarrow$ will take time!

Contamination Optimize strategy to deal with future decontamination campaigns (with Airbus DS support): procedure when to do decontamination, thermal conditions, recovery time

Stray light related Support from Airbus DS to develop and implement an optimized observing strategy for RVS and AF (i.e. VPU S/W changes to be managed by Airbus).

Credits

DPAC Payload Experts at institutes throughout Europe

Initial Data Treatment, First Look, and AVU/BAM+AIM teams

Operations teams at ESAC, Torino, CNES-Toulouse, Cambridge, Barcelona, Geneva

ESA Gaia-SOC calibration team

DPAC Project Office

ESA Gaia Project Scientist team

ESOC flight control team

ESA Gaia project team

Airbus Defence & Space

Arianespace, Soyuz, CNES-Kourou launch teams

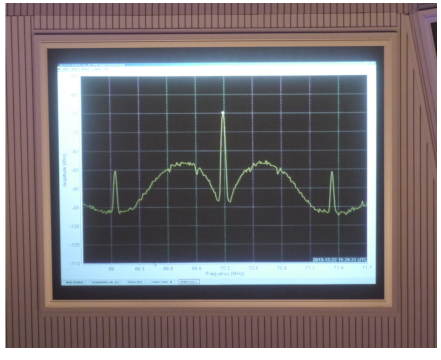

arianespace
service & solutions
VS06 • gaia • December, 19th 2013

esa

gaia


Satelliet Gaia 19-12-2013 van 19h08m-19h12m U.T.
H.M.


FPA

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