Gaia: Mission and Status

Nicholas Walton
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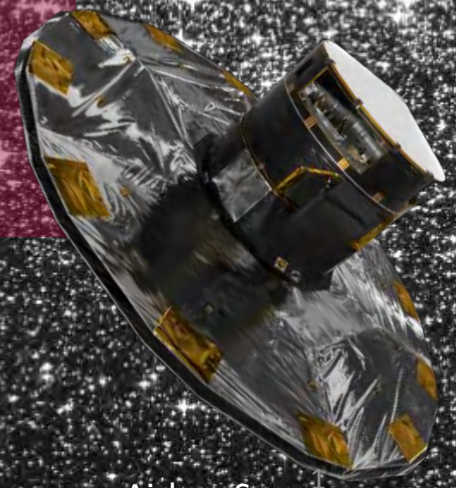
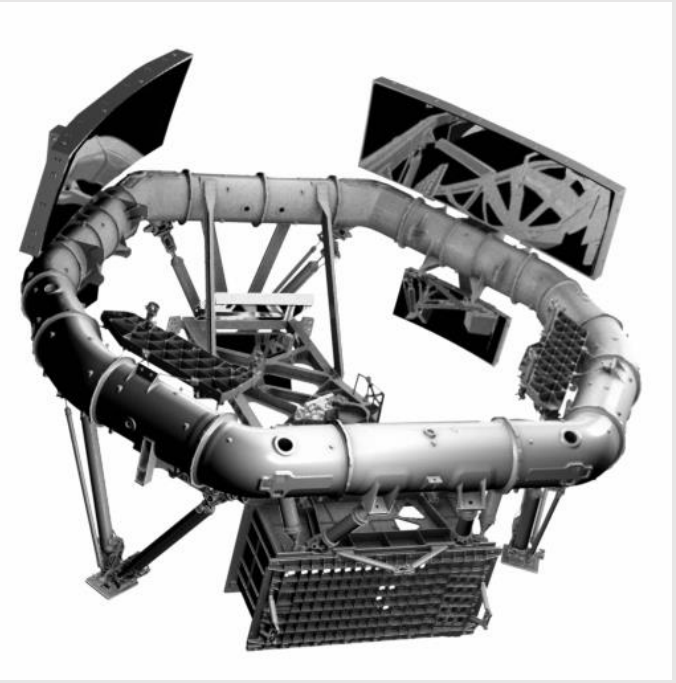
University of Cambridge

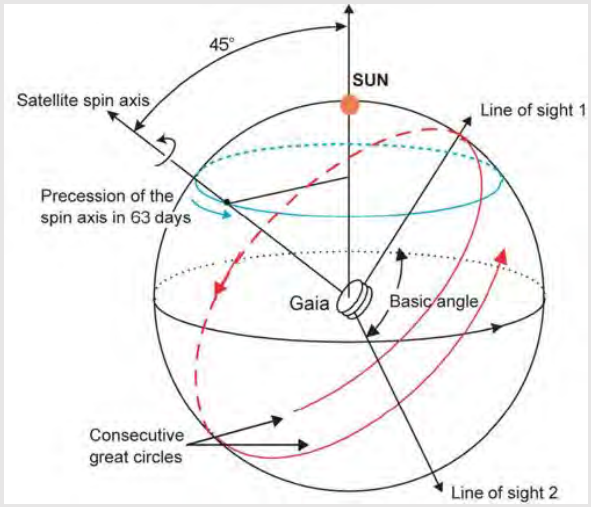
ESA/Gaia/DPAC

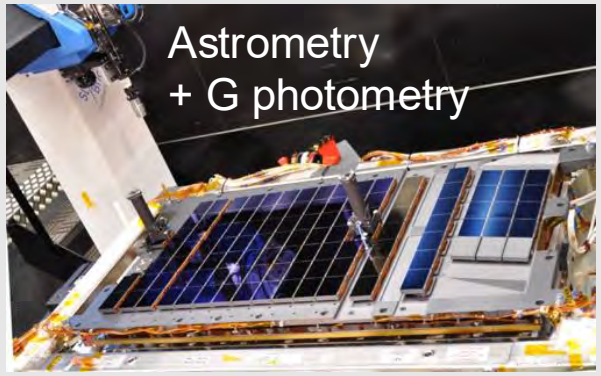


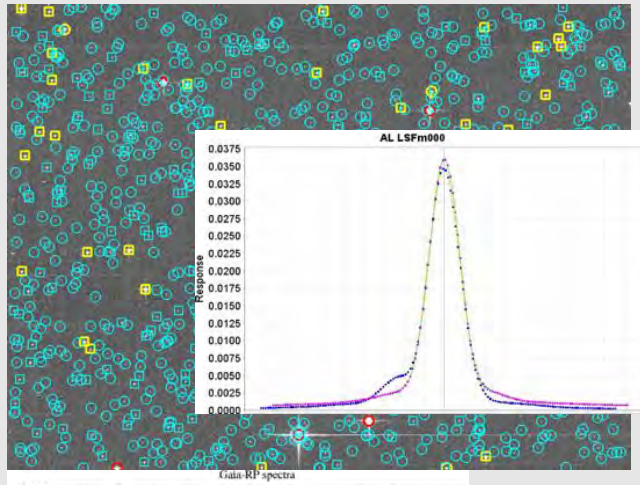
Airbus Space

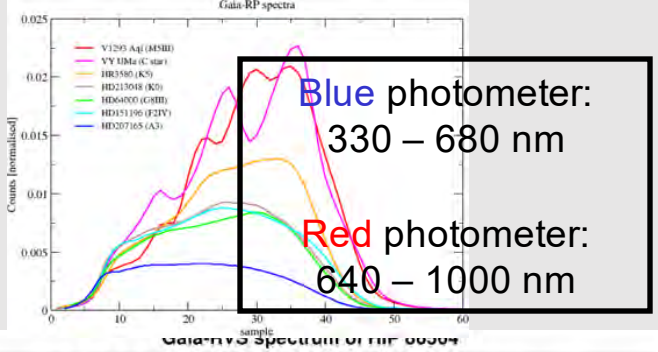
The Gaia Payload Instruments

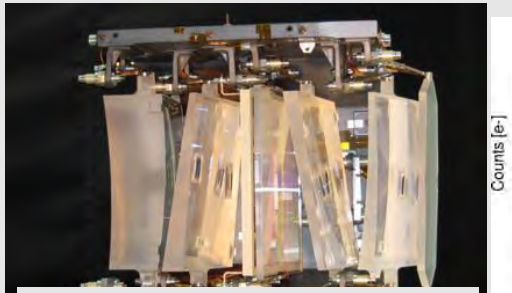


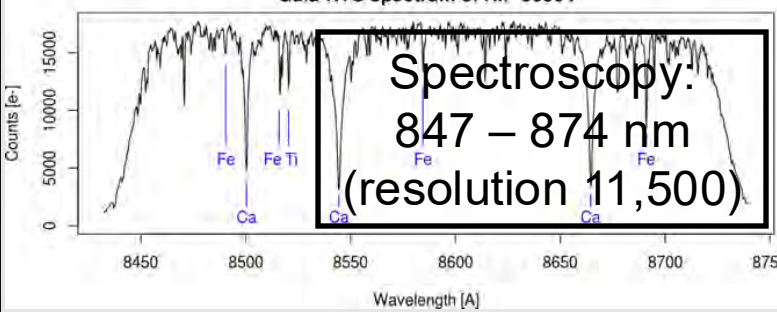












- Astrometry and spectrophotometry for > 2 billion objects (~1.8 billion in Data Release 3)
- Radial velocities for > 100 million objects
- Survey complete to G=20.7 (V=20-22)
- Observing programme autonomous with onboard detection and unbiased
- Quasi regular time sampling (~ 70 obs in 5 yrs)
- Launched Dec 2013
- 10+ years of operation at L2: final data release ~2030

Image credits EADS-Astrium/ ESA/ DPAC

In flight operations ended 15 Jan 2025

SKY-SCANNING COMPLETE FOR ESA'S MILKY WAY MAPPER GAIA

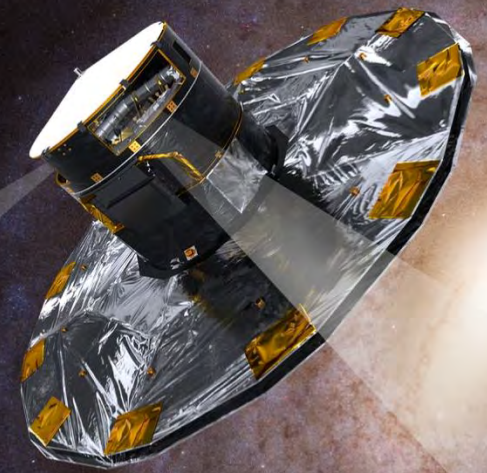
From 24 July 2014 to 15 January 2025, Gaia made more than three trillion observations of two billion stars and other objects, which revolutionised the view of our home galaxy and cosmic neighbourhood.

3 TRILLION
Observations

2 BILLION
Stars & other objects observed

938 MILLION
Camera pixels on board

15 300
Spacecraft 'pirouettes'



580 MILLION
Accesses of Gaia catalogue so far

13 000
Refereed scientific publications so far

2.8 MILLION
Commands sent to spacecraft

142 TB
Downlinked data (compressed)

500 TB
Volume of data release 4
(5.5 years of observations)

55 KG
Cold nitrogen gas consumed

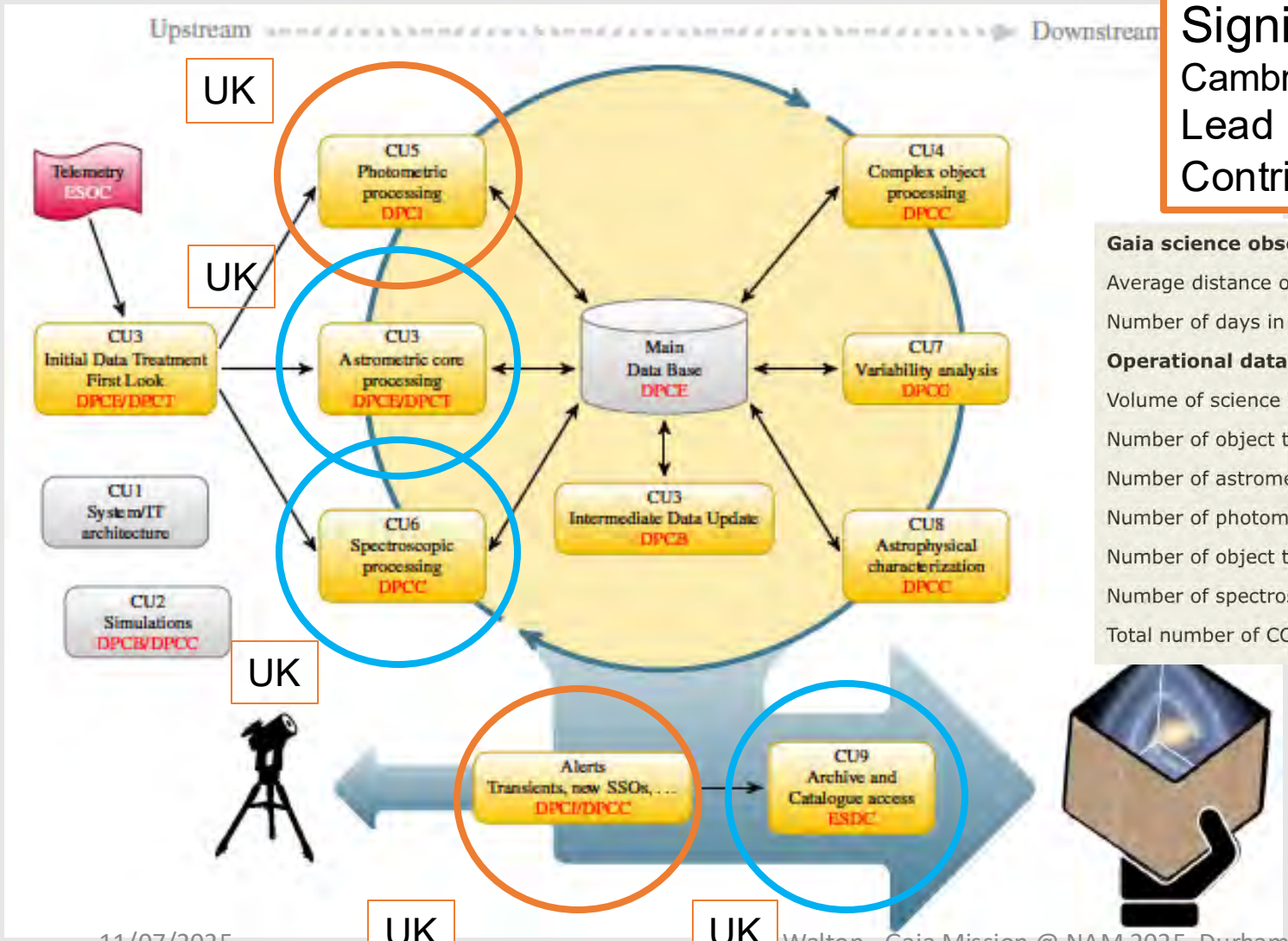
3827
Days in science operations

50 000 HOURS
Ground station time used

Gaia: Processing is complex

a pan European effort

Gaia:UK at www.gaia.ac.uk



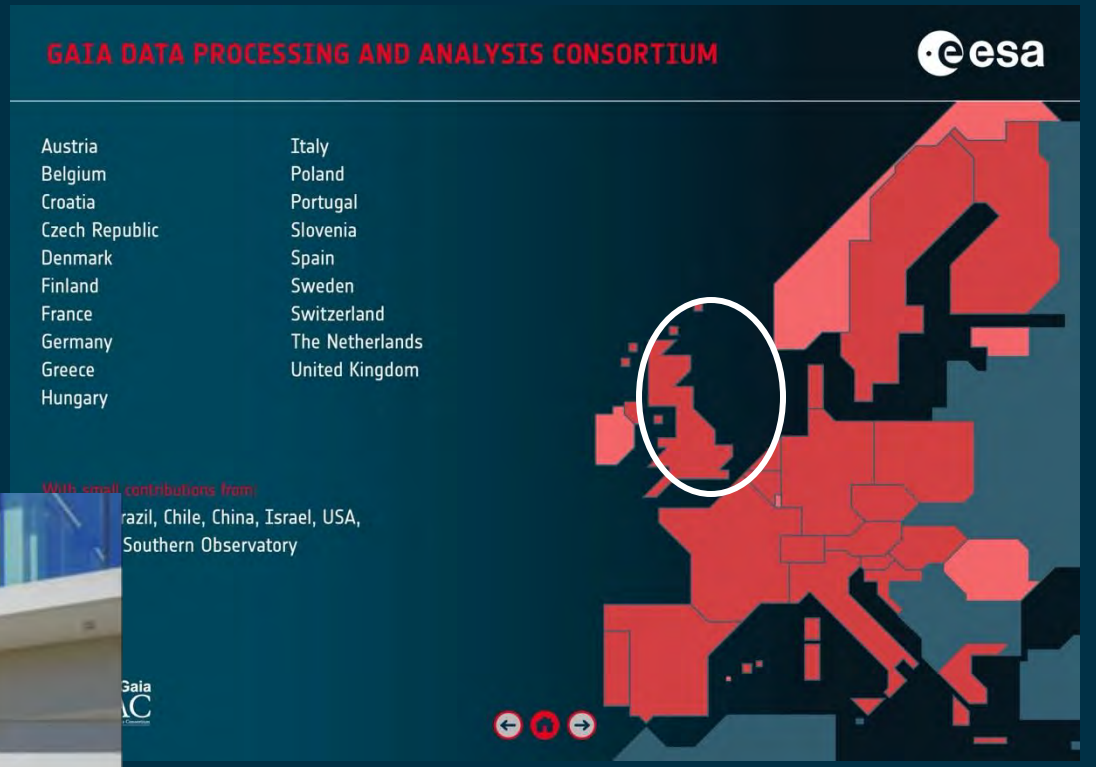
Significant UK involvement:
Cambridge Gaia Data Processing Centre
Lead Photometric processing and Flux alerts
Contribute to pre-processing, RVS, archive

Gaia science observation phase	
Average distance of Gaia space telescope from Earth (in km)	1,510,000
Number of days in science operations (25 July 2014 - 15 January 2025)	3827
Operational data collected	
Volume of science data collected (in GB)	141,064
Number of object transits through the focal plane	267,356,167,925
Number of astrometric CCD measurements	2,635,367,940,969
Number of photometric CCD measurements	530,852,459,518
Number of object transits through the RVS instrument	17,476,697,079
Number of spectroscopic CCD measurements	52,066,956,051
Total number of CCD measurements (astrometric + photometric + spectroscopic)	3,218,287,356,538

3.2 Trillion observations made during the 3827 days of inflight operations!

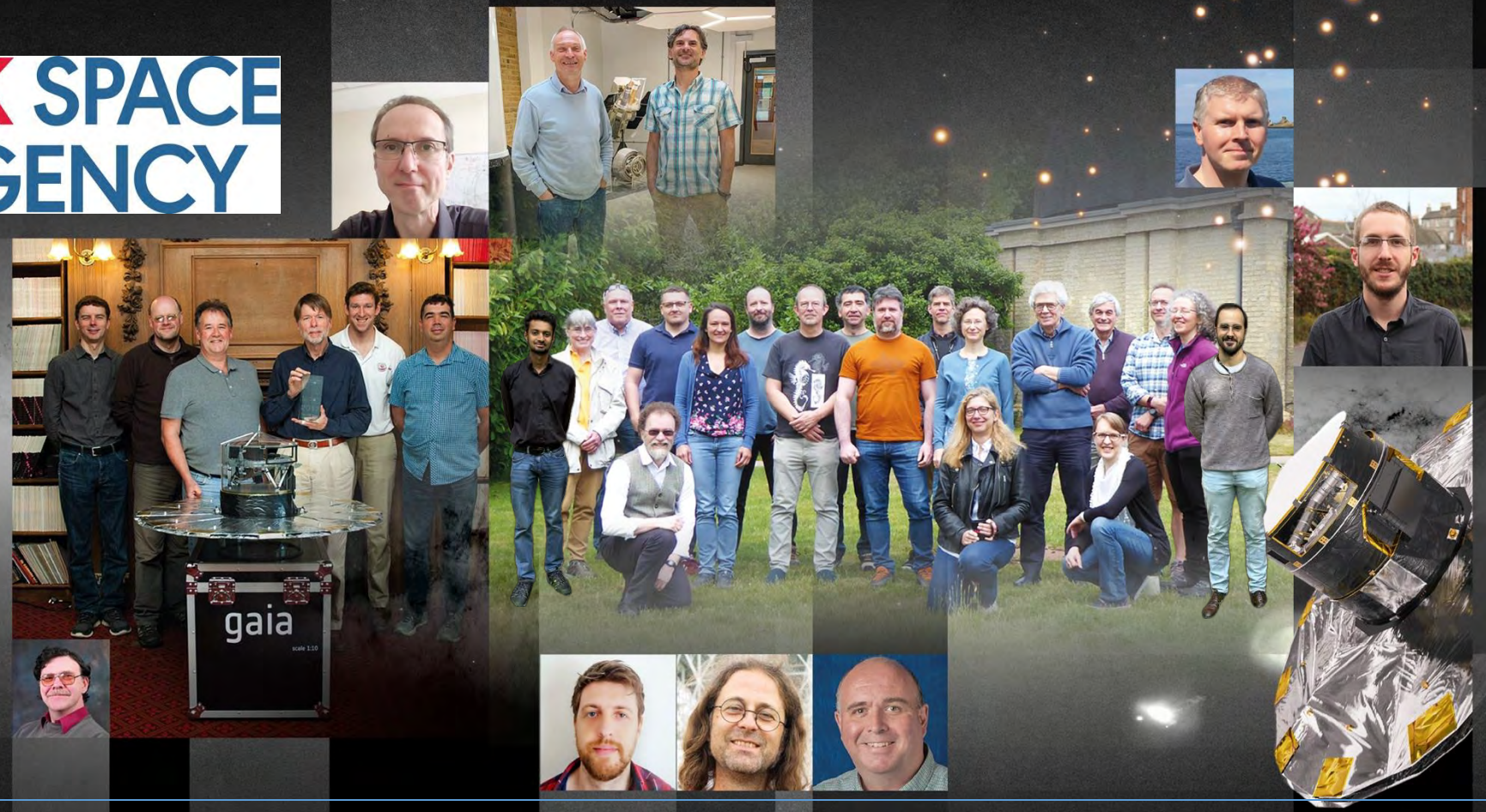
The People Behind Gaia Data Releases

Gaia UK responsible for the processing and analysis of the photometric data, the spectrophotometric data, photometric science alerts and with essential contributions to the spectroscopic data



DPAC8 @ Cambridge
Excited to bring Gaia DR4/5 to the World

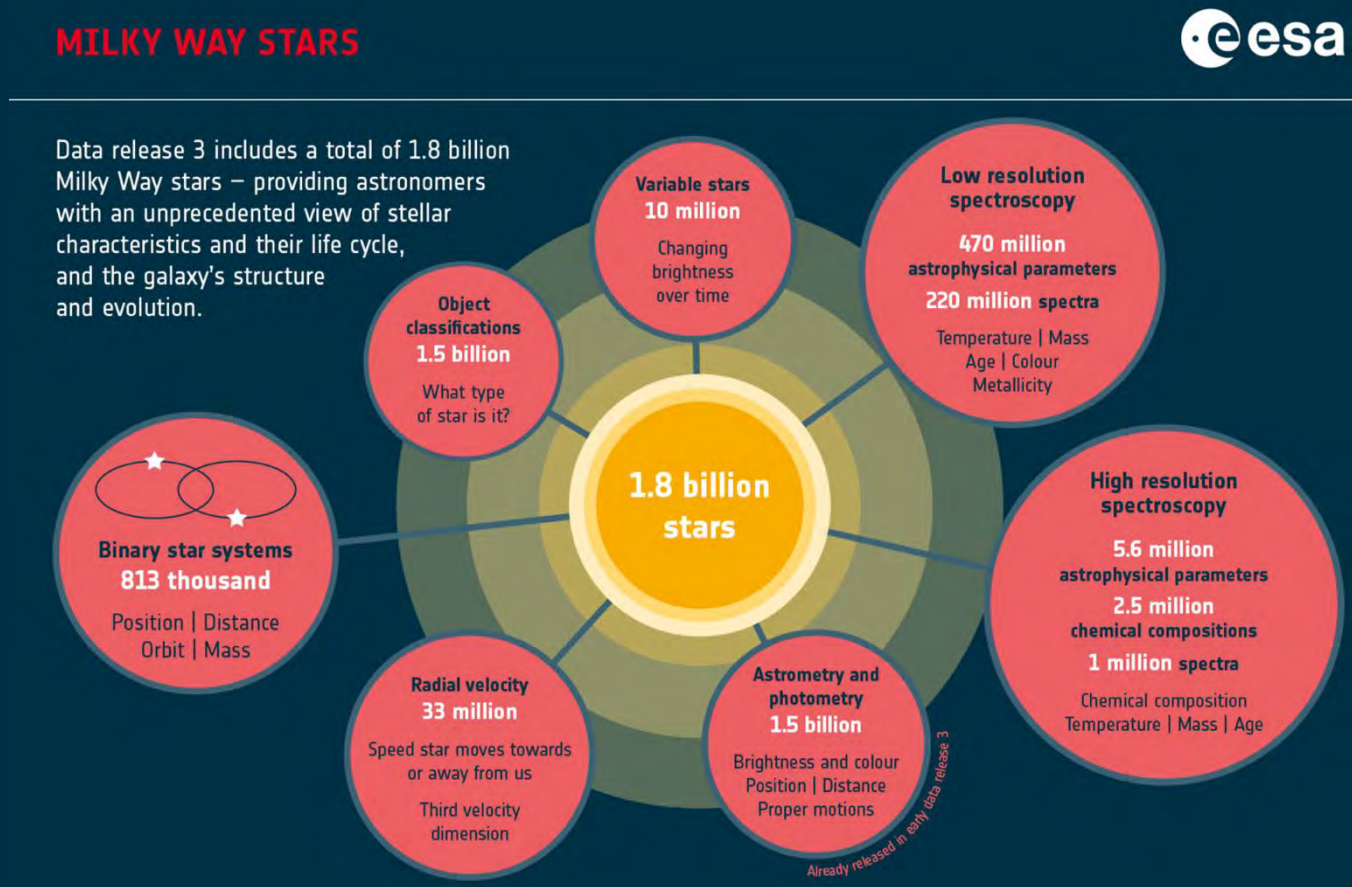
The Gaia Team in the UK: Bringing Gaia data to the community



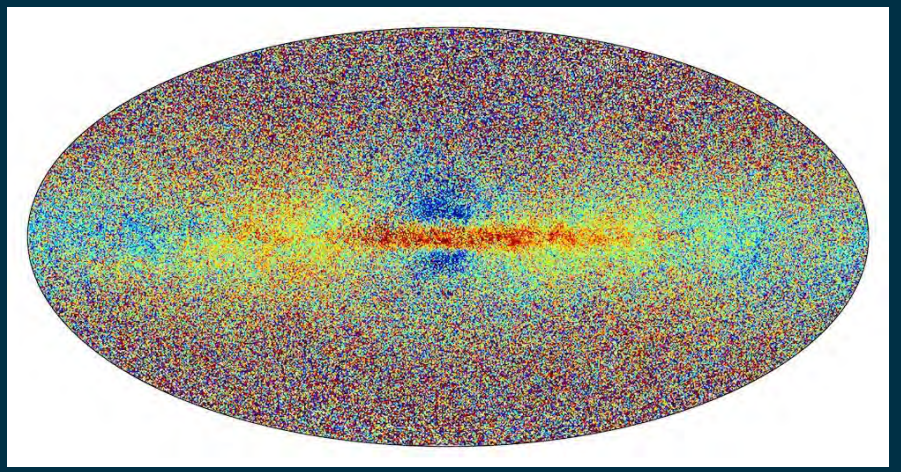
Cambridge, Edinburgh, University College London, Leicester, Bristol

Gaia: Currently at Release Gaia DR3

Gaia data leads to insight across astrophysics

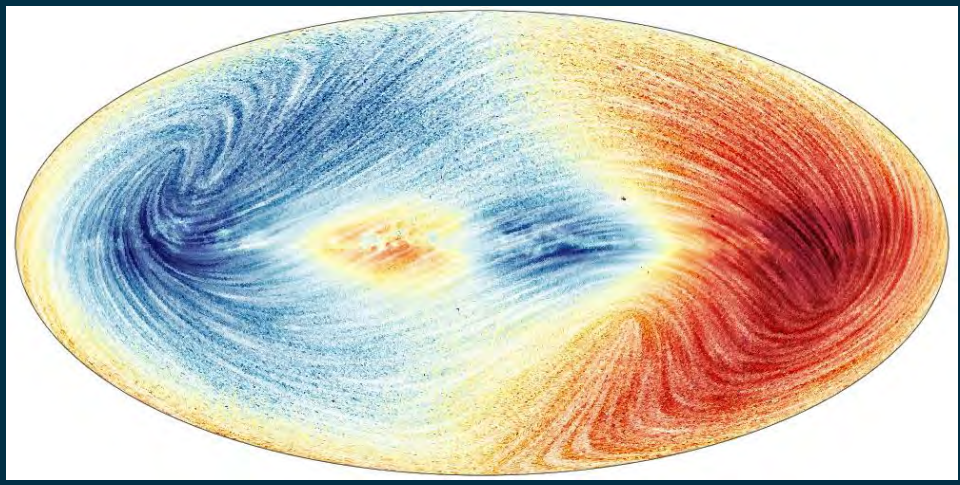


Gaia EDR3/ DR3: with larger to come



Credit: ESA/ Gaia/ DPAC

Stellar abundances



Stellar velocities

Credit: ESA/ Gaia/ DPAC

Over 3.2 Trillion observations

Gaia Focused Product Release: 10 Oct 2023

gaia

esa

Home | Data | Mission | People & Institutes | News & stories | Science Results | Resources | Questions

GAIA FPR CONTENTS

Information on the contents of Gaia's Focused Product Release.

GAIA FPR PAPERS

The papers describing the data processing and verifying the science performance of Gaia's Focused Product Release.

GAIA FPR DOCUMENTATION

Data release documentation for Gaia FPR. The Gaia FPR data model is contained inside. Also published as PDF.

GAIA FPR DATA RELEASE EVENTS

Overview of the Gaia events for the Focused Product Release.

PYTHON ACCESS

Gaia data can be accessed using Python

TUTORIALS AND HELP

Help is available to guide you through the

GAIA DATA CREDITS

When using Gaia FPR data, please

GAIA FPR KNOWN ISSUES

The known issues for Gaia FPR. If you find an

Sampling Gaia's Science

14,000 peer reviewed papers to date: Gaia is ESA's most productive space science mission

Hubble investigates a magnetar's birthplace

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Farewell, Gaia! Spacecraft operations come to an end

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Wobbling stars reveal hidden companions in Gaia data

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Last starlight for ground-breaking Gaia

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Gaia spots possible moons around hundreds of asteroids

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Gaia discovers a new family of black holes

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Gaia reveals the past and future of the Sun

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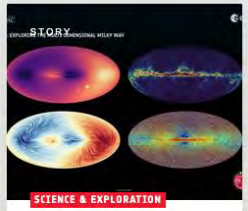

Gaia sees strange stars in most detailed Milky Way survey t...

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Jupiter's moon Europa to obscure distant star

Media invitation: new details about our Milky Way in the th...

Gaia finds parts of the Milky Way much older than expected

Gaia snaps photo of Webb at L2

Gaia reveals that most Milky Way companion galaxies are new...

Is the nearest star cluster to the Sun being destroyed?

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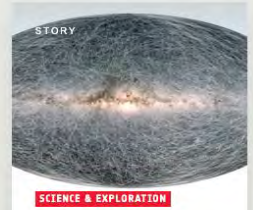

Gaia's new data takes us to the Milky Way's anticentre and ...

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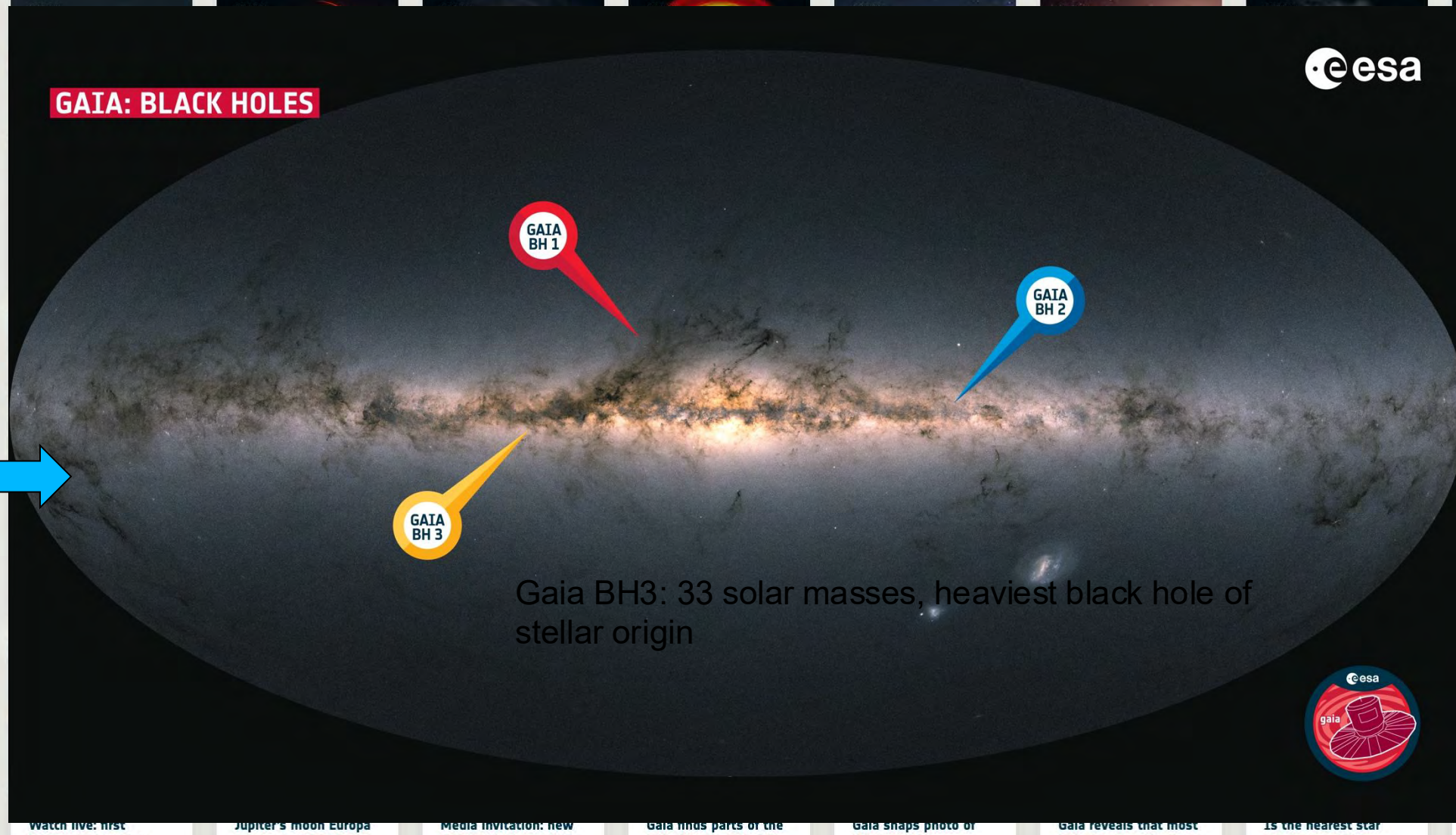
READ →

See https://www.esa.int/Science_Exploration/Space_Science/Gaia/(archive)/0

Sampling Gaia's Science



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Hubble investigates a magnetar's birthplace

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Sailing among the stars – Gaia's role in discovering distan...

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4.70 billion years old

SCIENCE & EXPLORATION

Gaia reveals the past and future of the Sun

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Gaia's new data takes us to the Milky Way's anticentre and ...

03/12/2020 122215 VIEWS 400 LIKES

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See https://www.esa.int/Science_Exploration/Space_Science/Gaia/(archive)/0

The morphology of the Milky Way: We now see that it's more complex than we thought!

Before Gaia

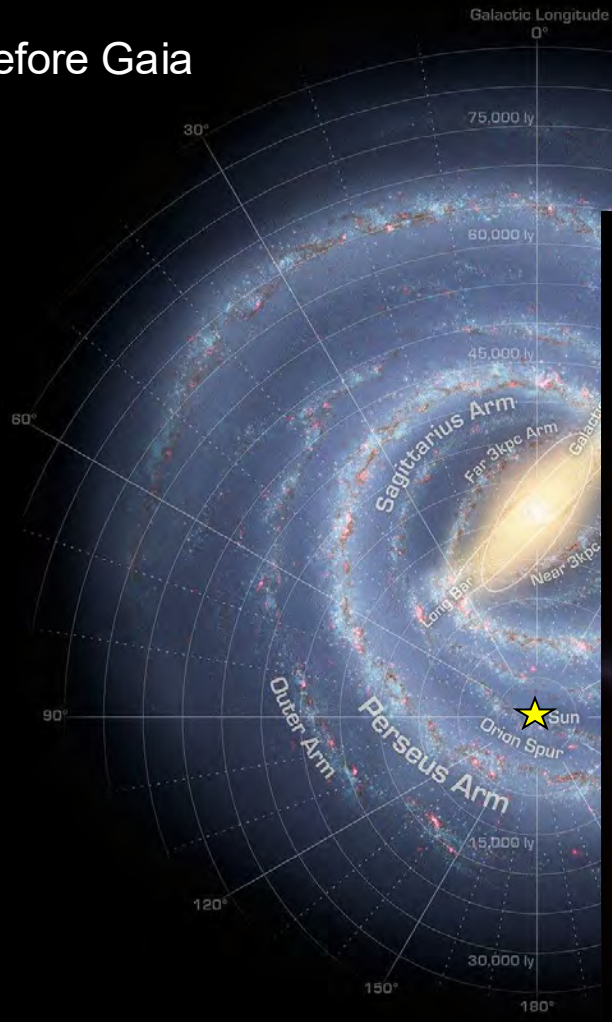
NASA/JPL-Caltech/R. Hurt (SSC/Caltech)

With Gaia

Artistic impression of the Milky Way - face-on, based on the latest Gaia data.
Credits: ESA/Gaia/DPAC, Stefan Payne-Wardenaar - CC BY-SA 3.0 IGO

The morphology of the Milky Way: it's way more complex!

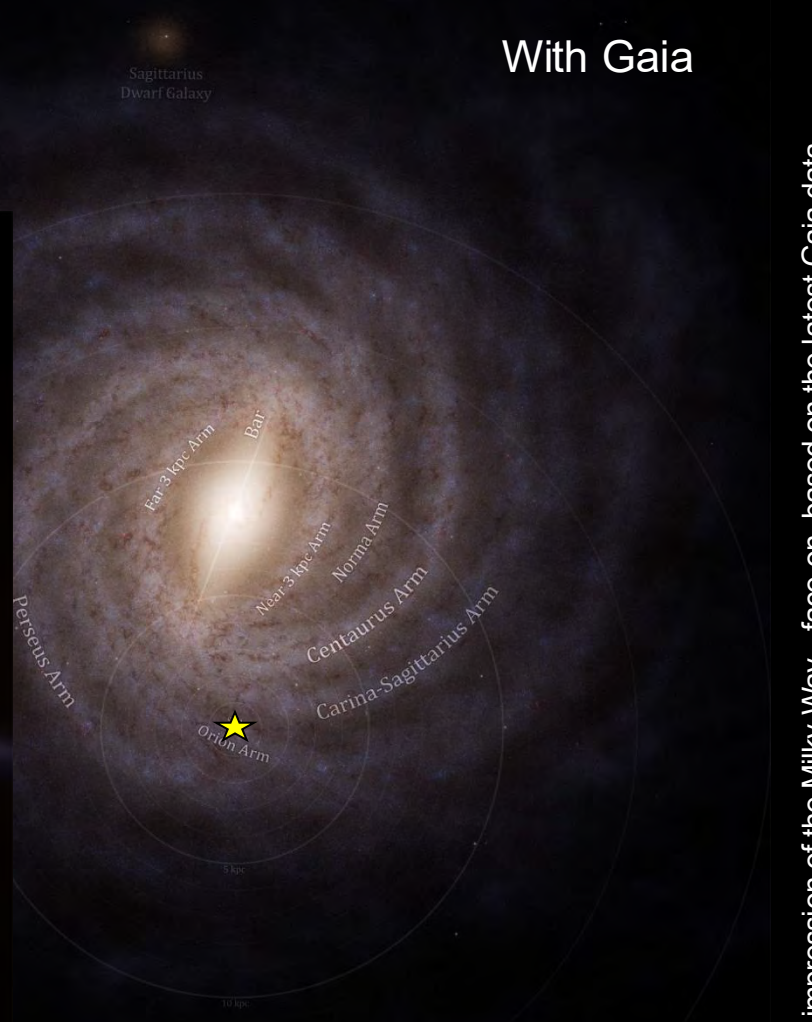
Before Gaia



NASA/JPL-Caltech/R. Hurt (SSC/Caltech)

Artistic impression of the Milky Way - edge-on
Credits: ESA/Gaia/DPAC, Stefan Payne-Wardenaar - CC BY-SA 3.0 IGO

With Gaia



Artistic impression of the Milky Way - face-on, based on the latest Gaia data.
Credits: ESA/Gaia/DPAC, Stefan Payne-Wardenaar - CC BY-SA 3.0 IGO

https://www.esa.int/Science_Exploration/Space_Science/Gaia/Gaia_s_decade_of_discoveries_unravelling_the_intricacies_of_our_galaxy

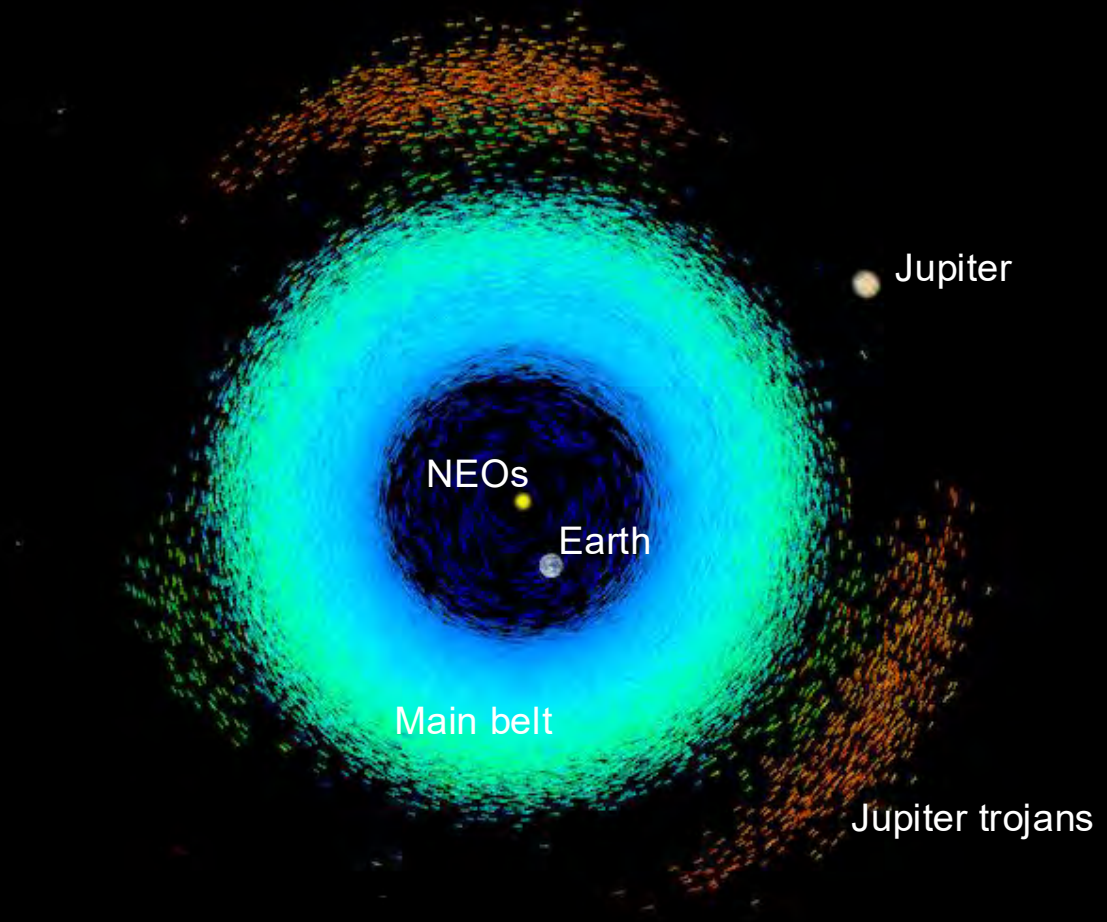
Revealing our Milky Way's Mergers

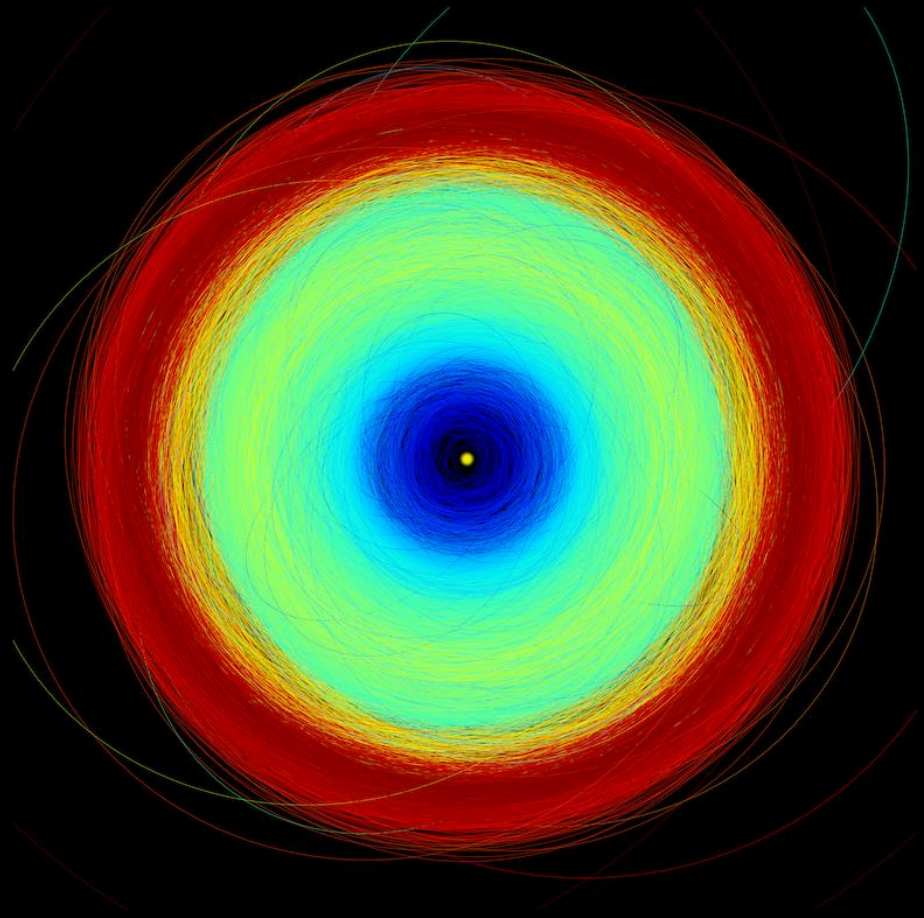
Credit: V. Belokurov (Cambridge, UK and CCA, New York, US) based on the image by ESO/Juan Carlos Muñoz

Credit: ESA (artist's impression and composition); Koppelman, Villalobos and Helmi (simulation); NASA/ESA/Hubble (galaxy image)

Gaia and the Solar System

ESA/Gaia/DPAC/P. Tanga

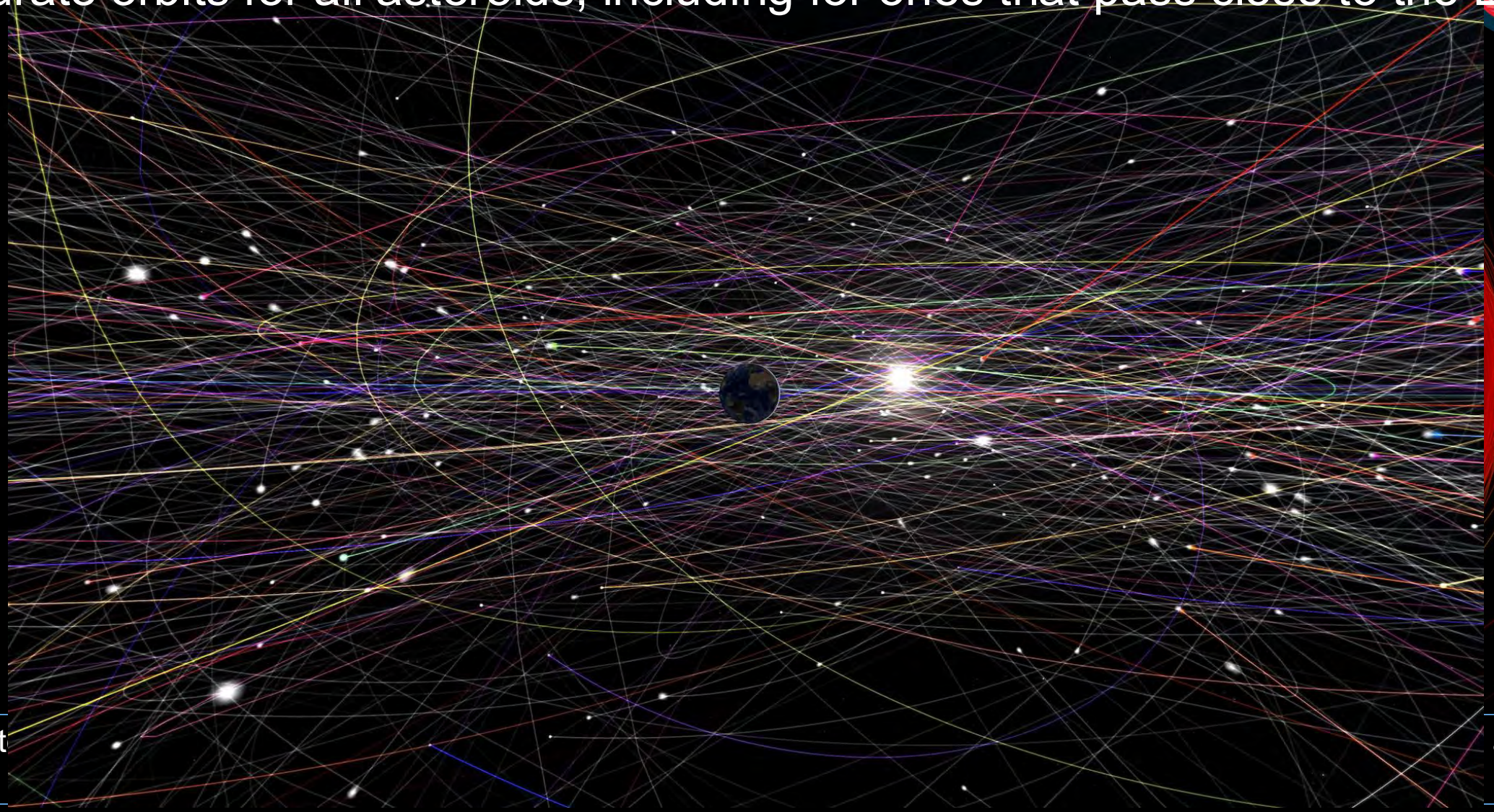




Each asteroid observed by Gaia on 13 June 2022 (DR3 day) and 10 days of motion	All asteroid orbits in Gaia DR3 out to the Trojans at the distance of Jupiter

Gaia and the Solar System

Accurate orbits for all asteroids, including for ones that pass close to the Earth



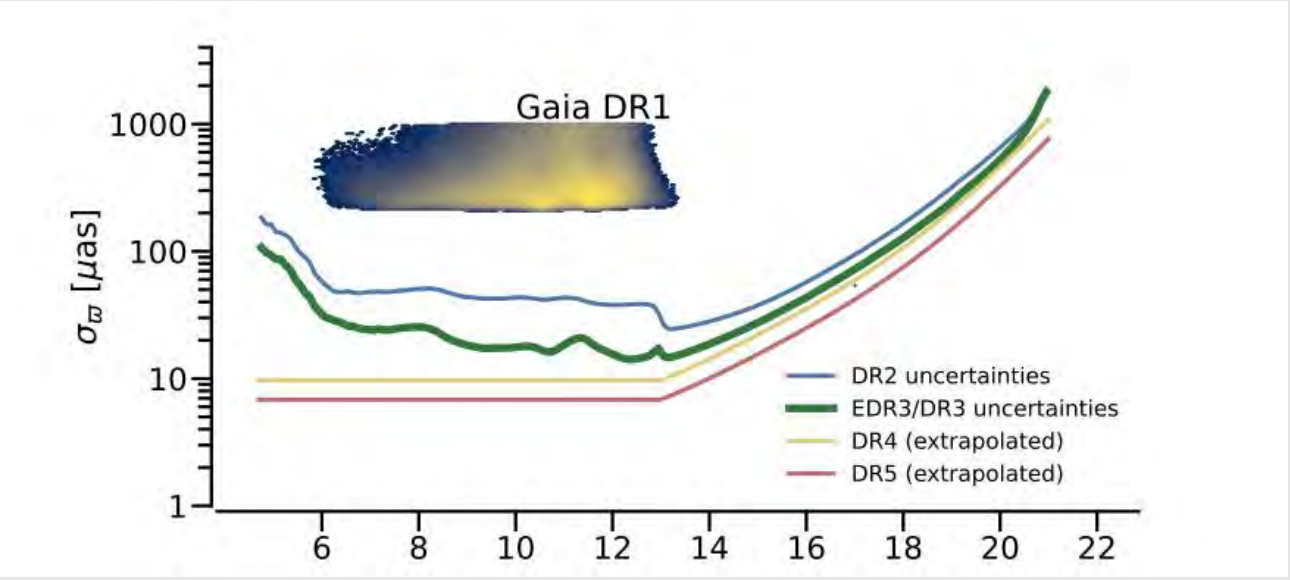
ESA/Gaia/DPAC/P. Tanga

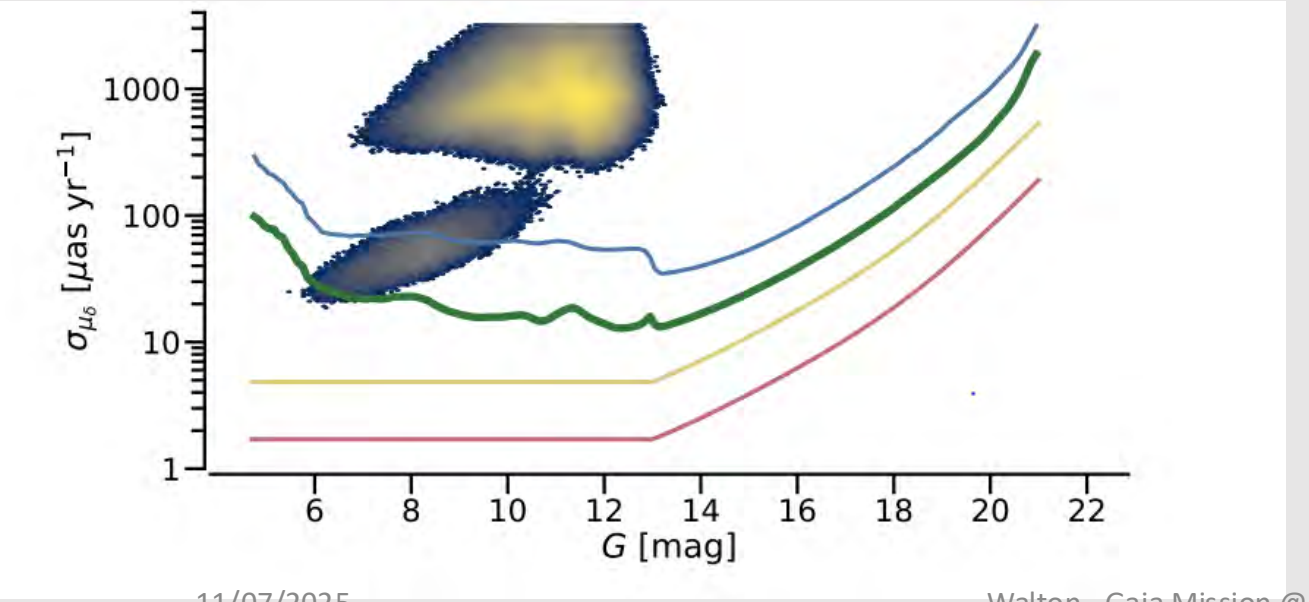
Each ast at the

Towards Gaia DR4:

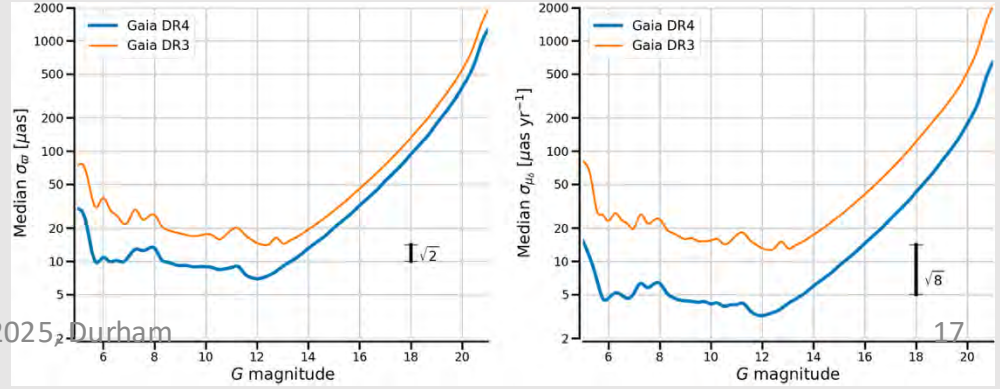
- Gaia in-flight operations completed Jan 2025 (no more cold gas propellant)
  - Nominal mission ended in 2019
  - Post operations phase until the release of Gaia DR5.
- **Gaia DR4 : December 2026**
- Gaia DR4 is the final release for the nominal mission, 66 months of data
  - Including a 6 months period of reverse direction of the satellite precession (mitigates degeneracy between AC stellar motion and parallax
  - Full Epoch data: astrometry, broad band photometry, radial velocity, BP/RP, RVS
  - Full astrometric, photometric, and radial-velocity catalogues, variable-stars and non-single-star solutions, classification, exoplanet list, RB/RP and RVS spectra
- Gaia DR5 : will include the extended mission data.

Gaia Performance from DR1 to DR5



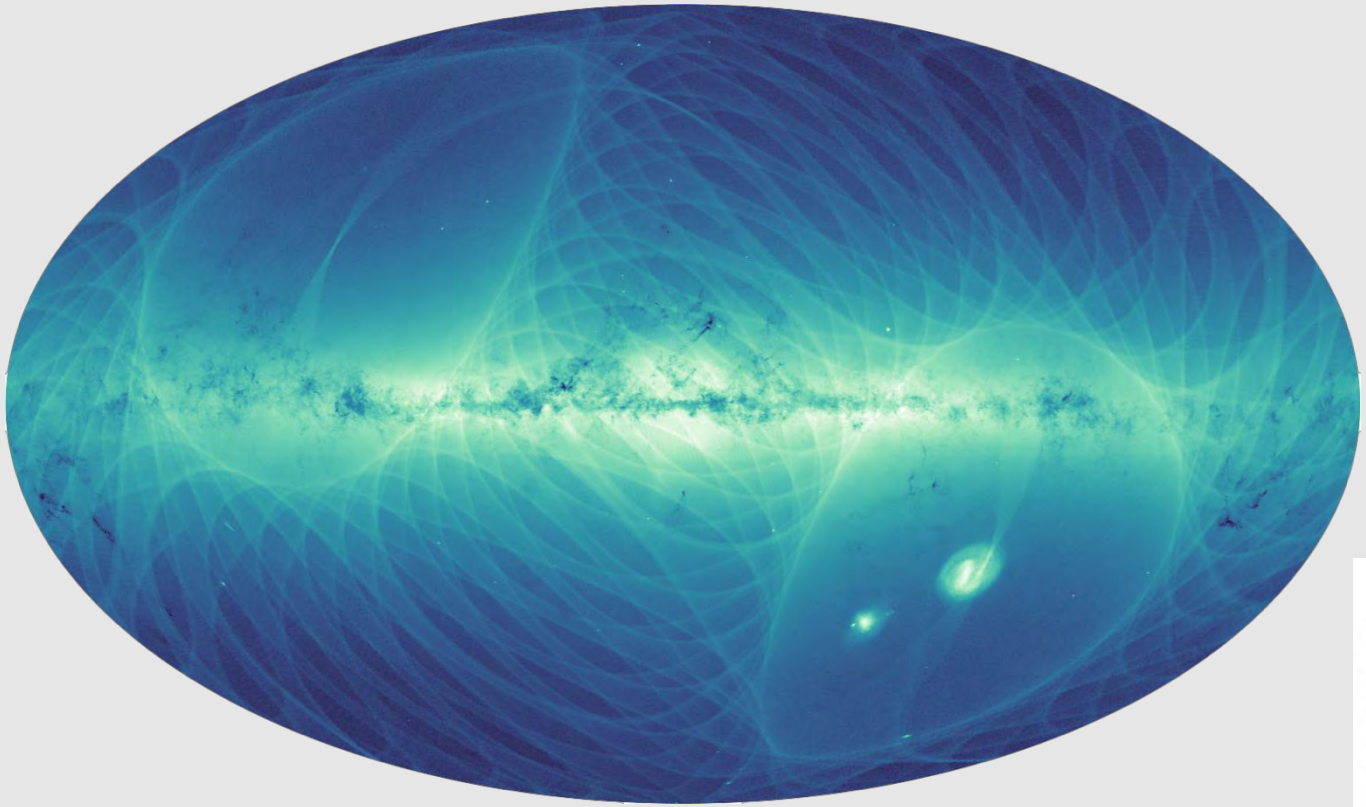


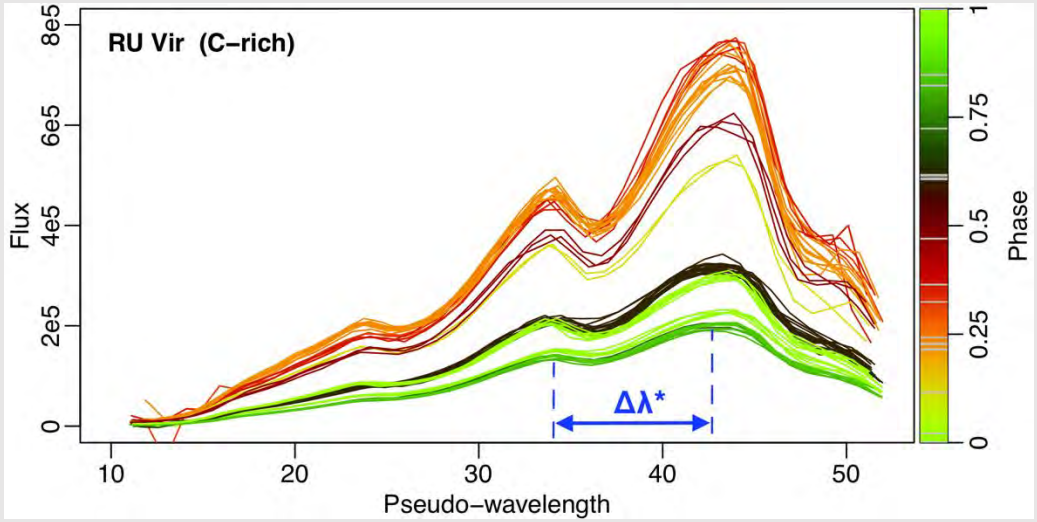
- Basic mission results improve as $t^{-0.5}$
  - Positions, parallaxes, photometry and radial velocities → factor 1.4 (DR4), 1.9(DR5)
- Proper motion improves as $t^{-1.5}$
  - Rapidly increasing gain in kinematics and dynamics → factor 2.7 (DR4), 6.6 (DR5)
- Higher order terms scale more! e.g. improvement in unambiguous determination of orbital period, mass and distance of a perturbing body scales as $t^{-4.5}$

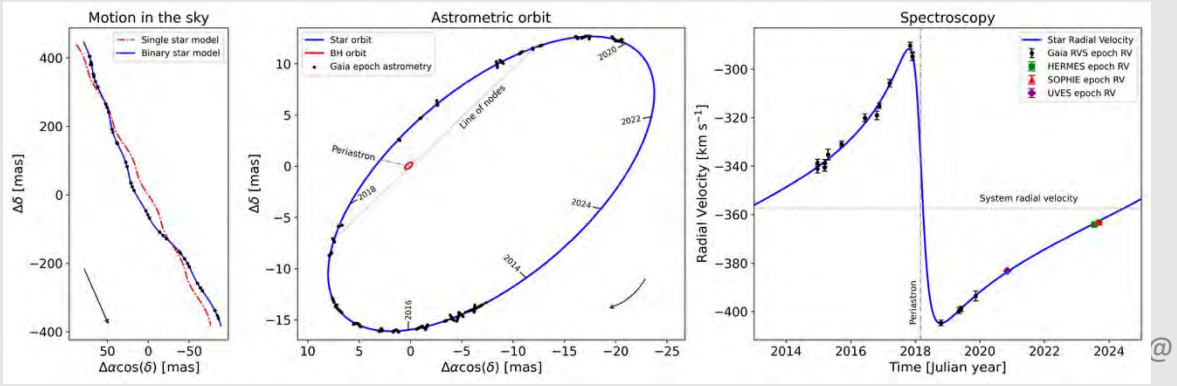


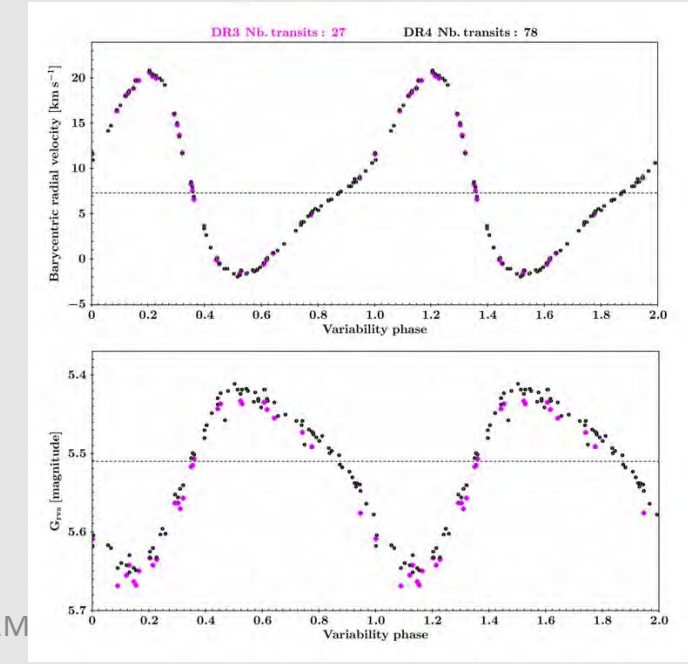
Gaia Collab, Vallenari et al (2022)

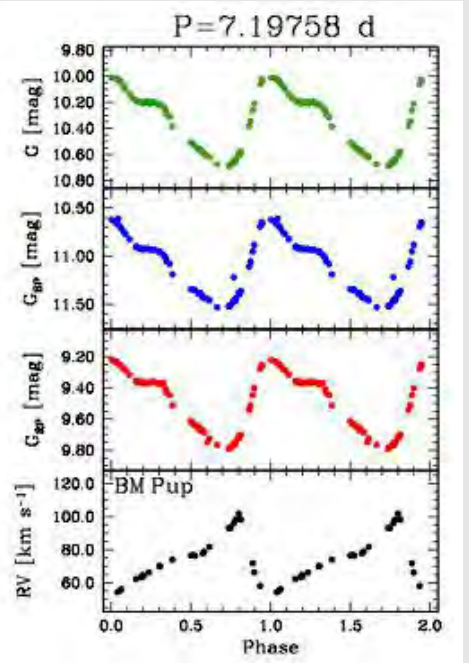
Gaia DR4: Epoch data for 2.5 Billion Sources



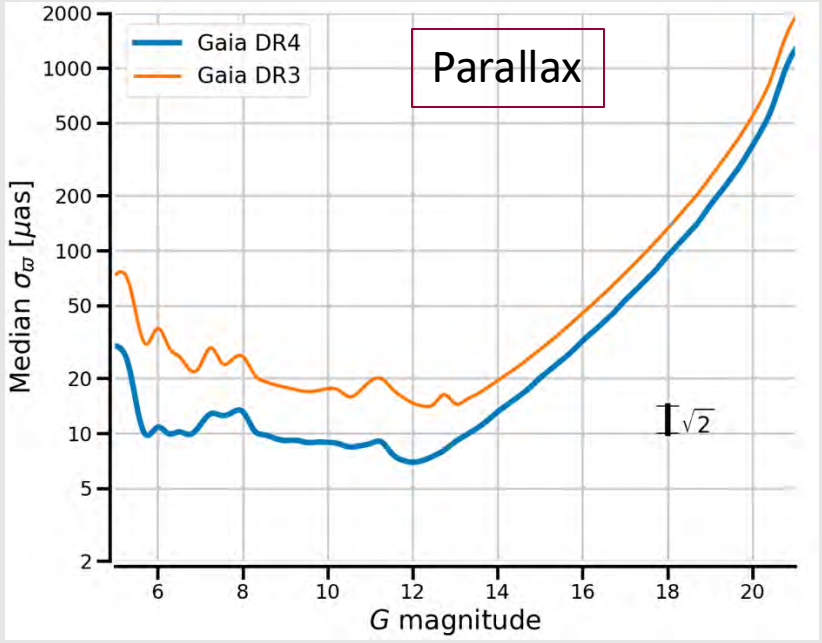




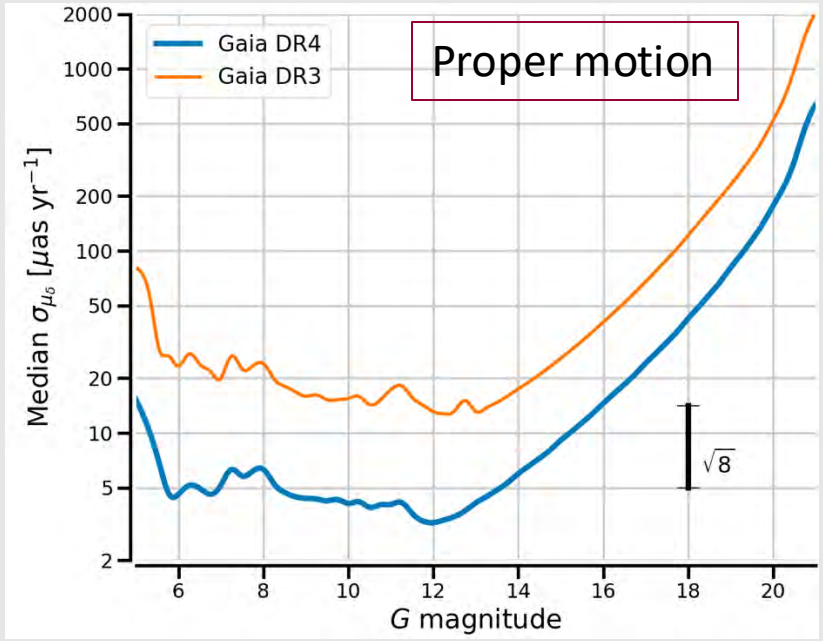




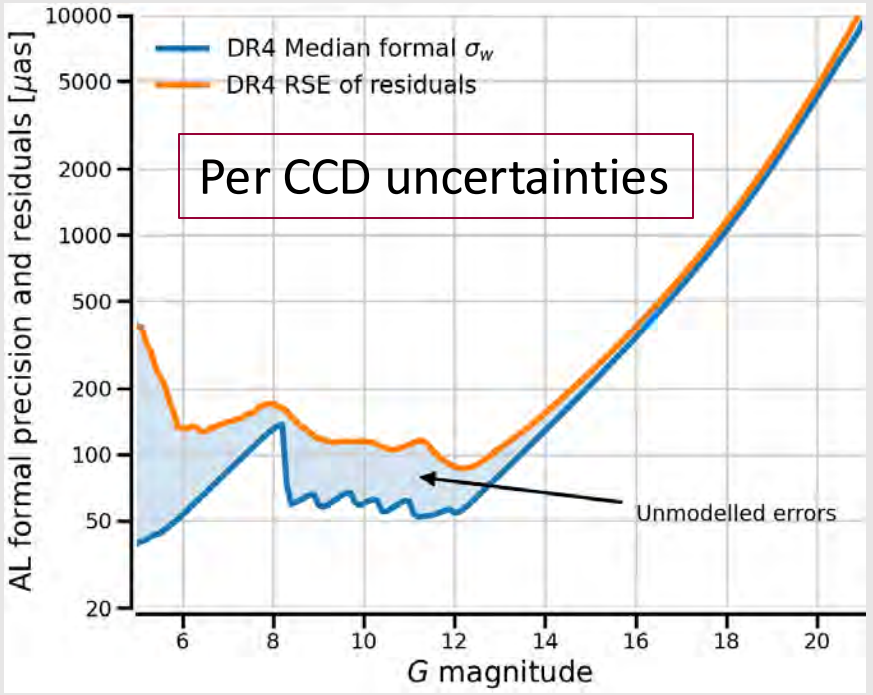
Gaia DR4 Astrometric Uncertainties



For G<13 the improvement is better than the √2 expected



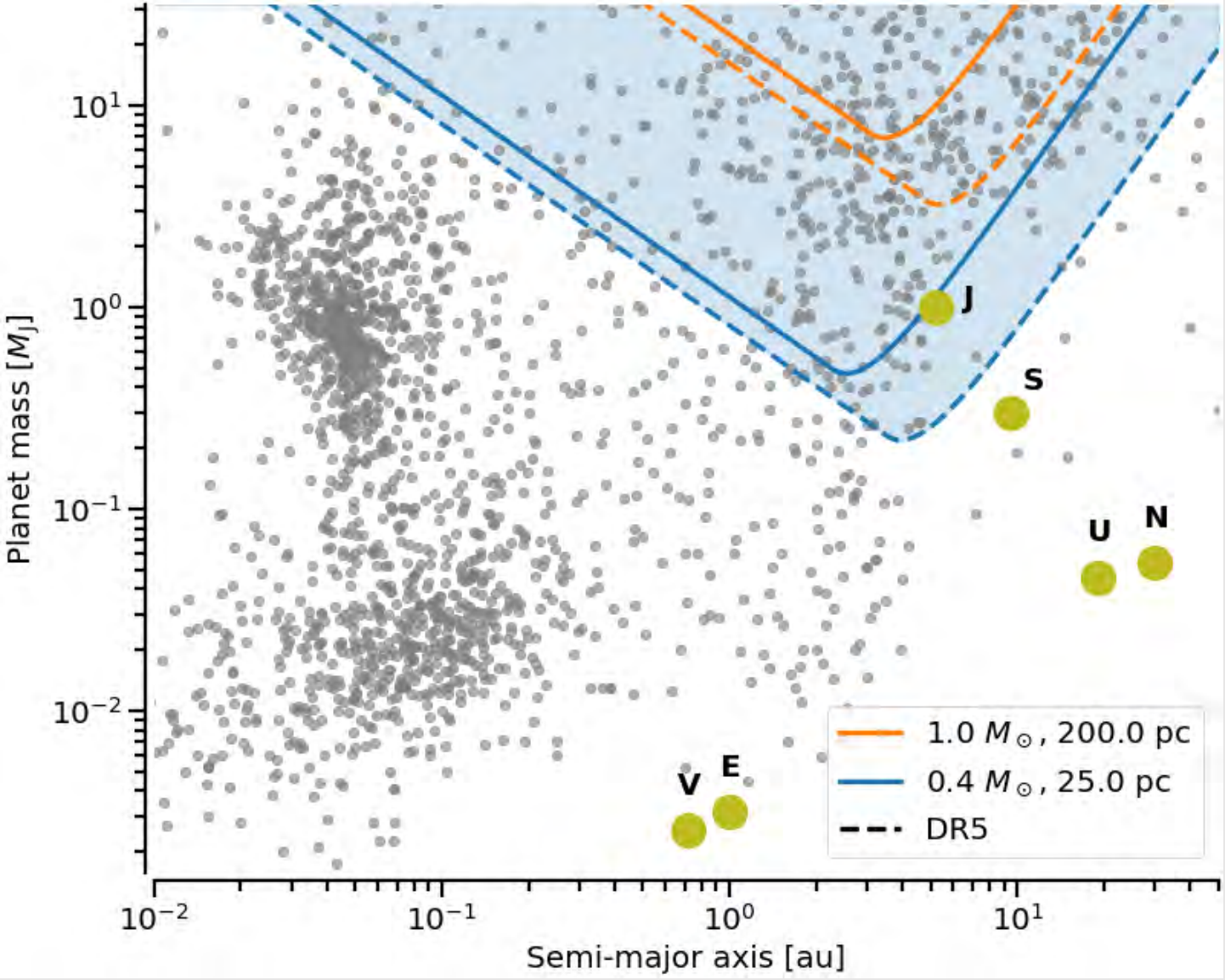
Expected √8 improvement for all magnitudes



- Gaia DR4 formal per CCD astrometric uncertainties ~ 50 μas at G ≲ 13
(~ 15 μas averaged over 9 CCDs)
- But: total uncertainties limited by calibration errors to ~ 80–150 μas (30–50 μas averaged over 9 CCDs)

Figure credits: DPAC/ CU3/ AGIS/ DPCE teams

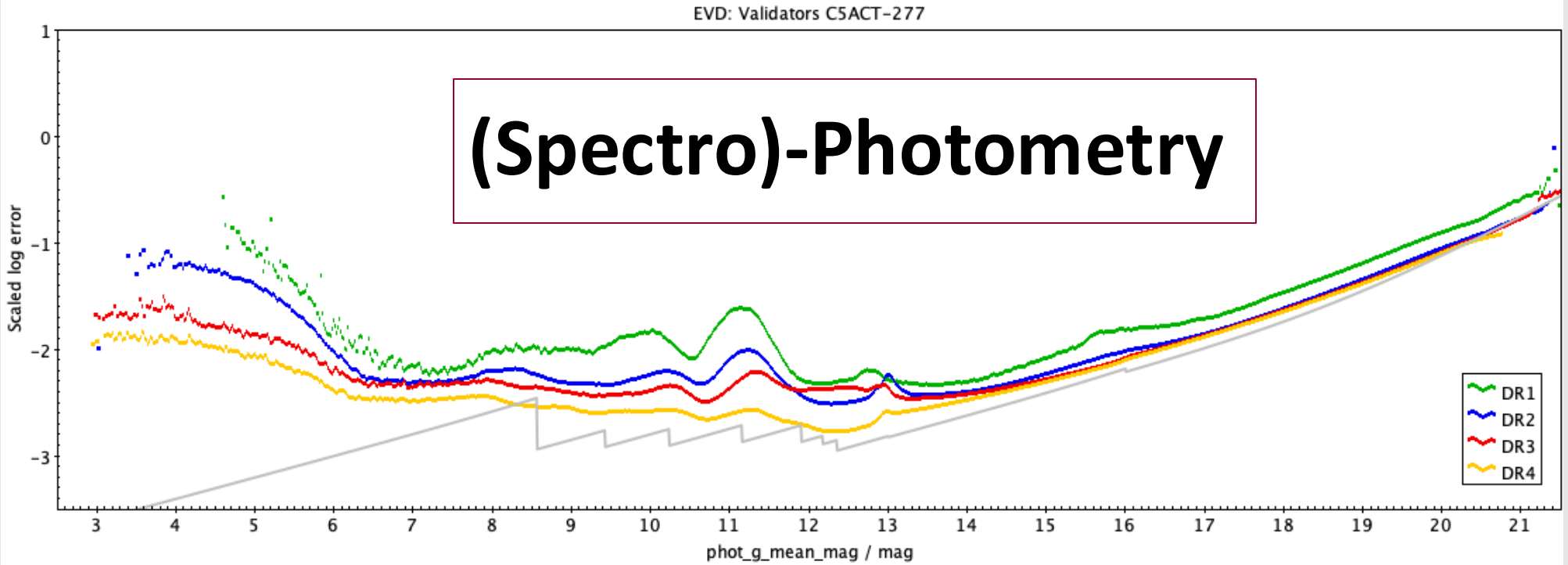
Gaia DR and the Exoplanet Discovery Space



- 10^6–10^7 stars, unbiased across spectral type, age, chemical composition of the primary
- Thousands of giant planet (< 15 M_{Jup}) discoveries predicted around A to M type stars
- Number could triple for the 10 year observation time span of Gaia DR5
- Possibly ~ 10^3 transiting hot Jupiters (see Gaia-1b and Gaia-2b)
- Gaia DR3 exoplanet contents: see Holl et al (2023), Gaia Collaboration, Arenou et al (2023) and the Gaia exoplanet candidate list

Assuming estimated 50 μas per epoch uncertainty

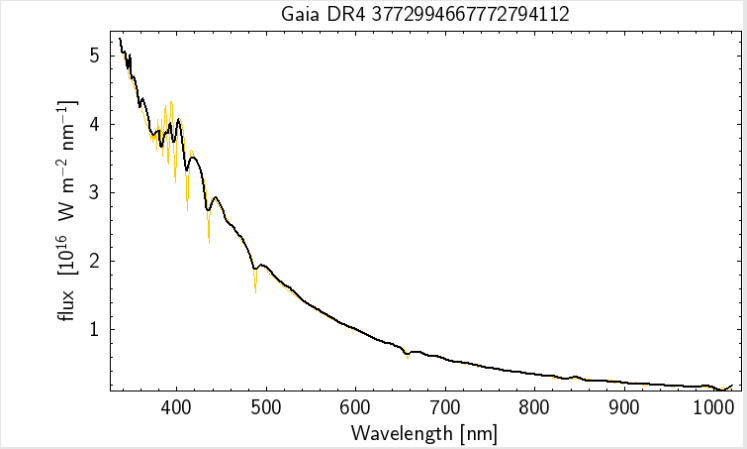
(Spectro)-Photometry

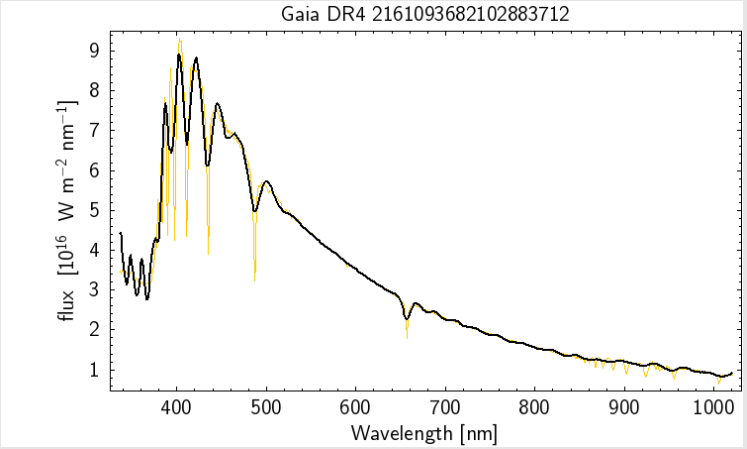


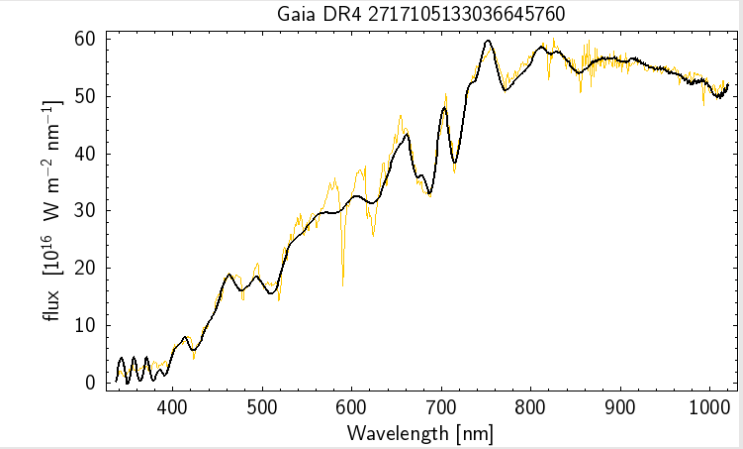
Credit: DPAC/ CU5/ DPCI team

Improvements with each release.
DR4 bright G<13 calibration significantly improved.

Example XP spectra, fit to spectrophotometric standard stars (yellow ground spectra, black Gaia XP)

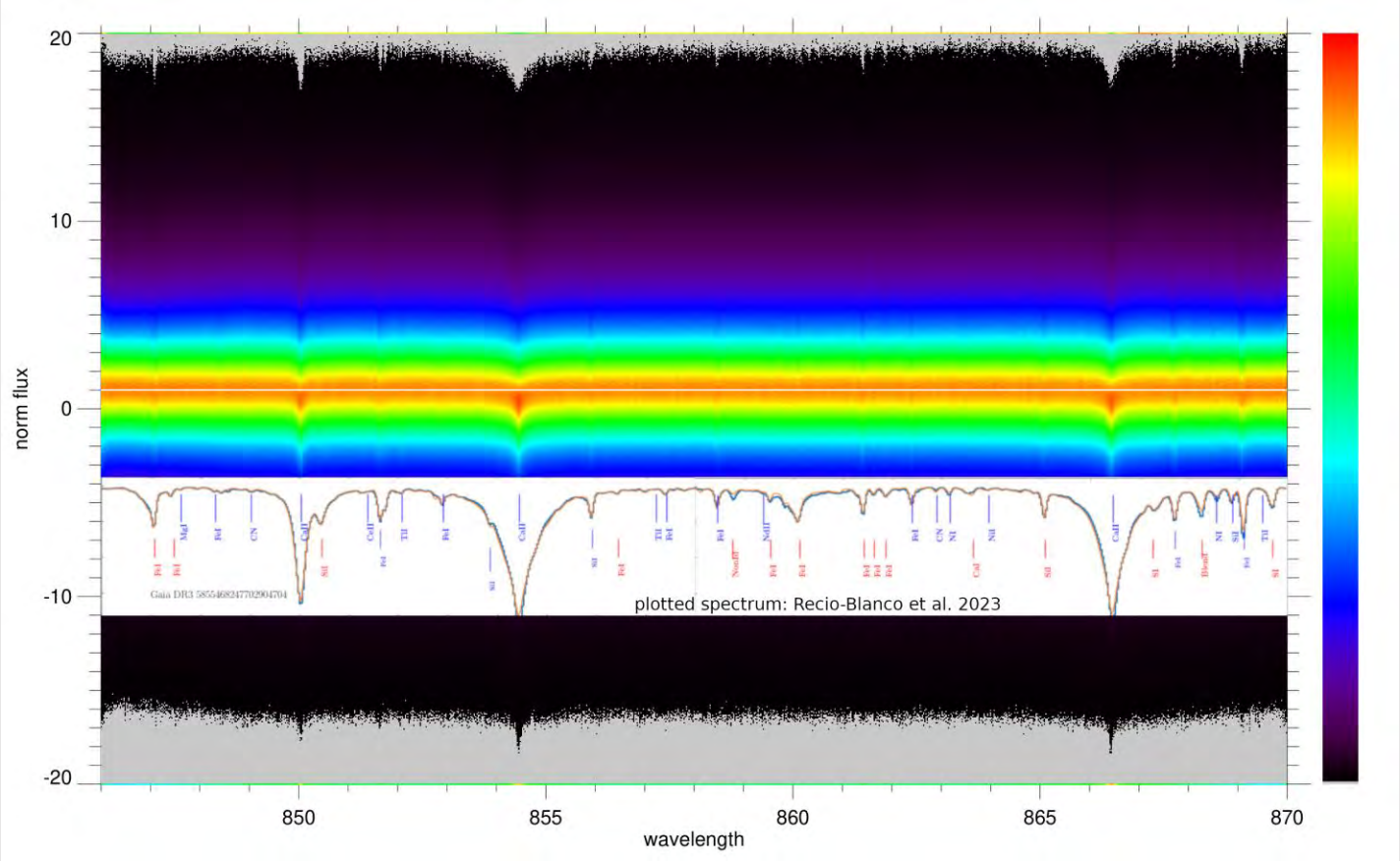


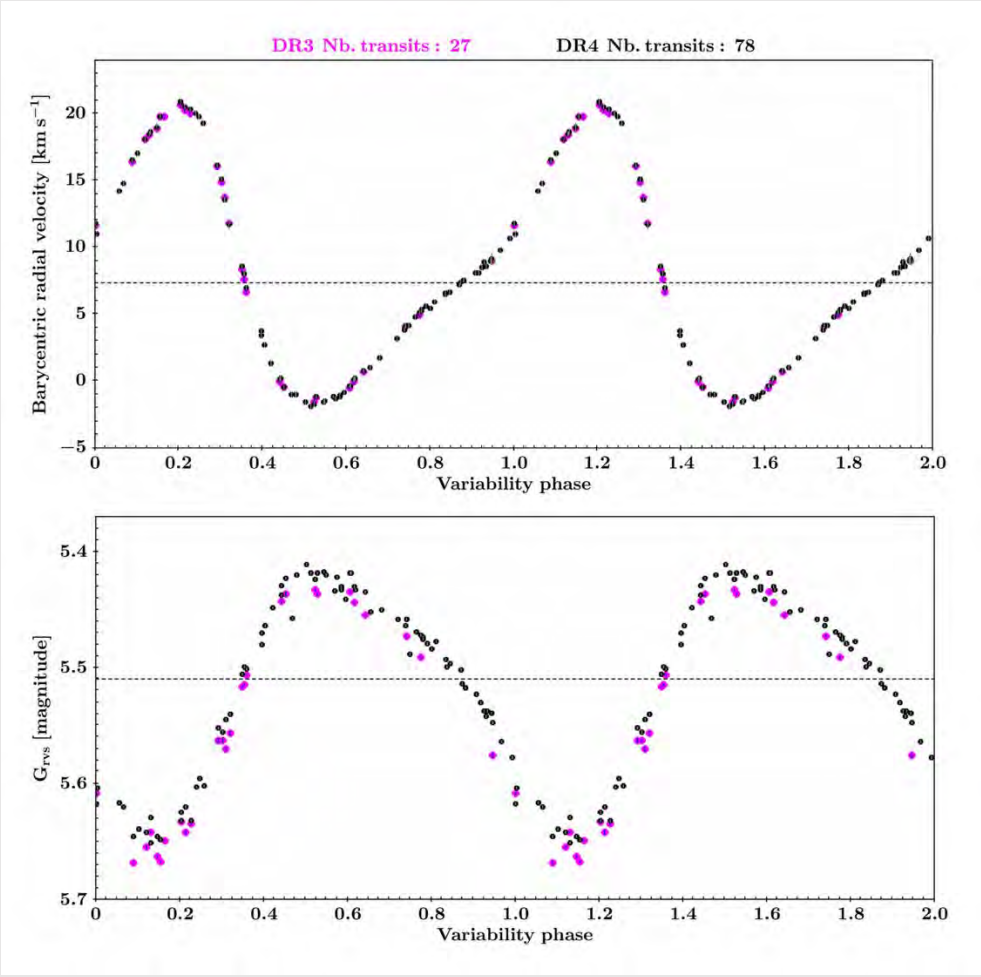




Approximately 6 million faint (GRVS > 14) combined spectra. The colour scale shows the number density of the fluxes at each wavelength bin. Credit: DPAC/ CU6/ DPCC team

Spectroscopy



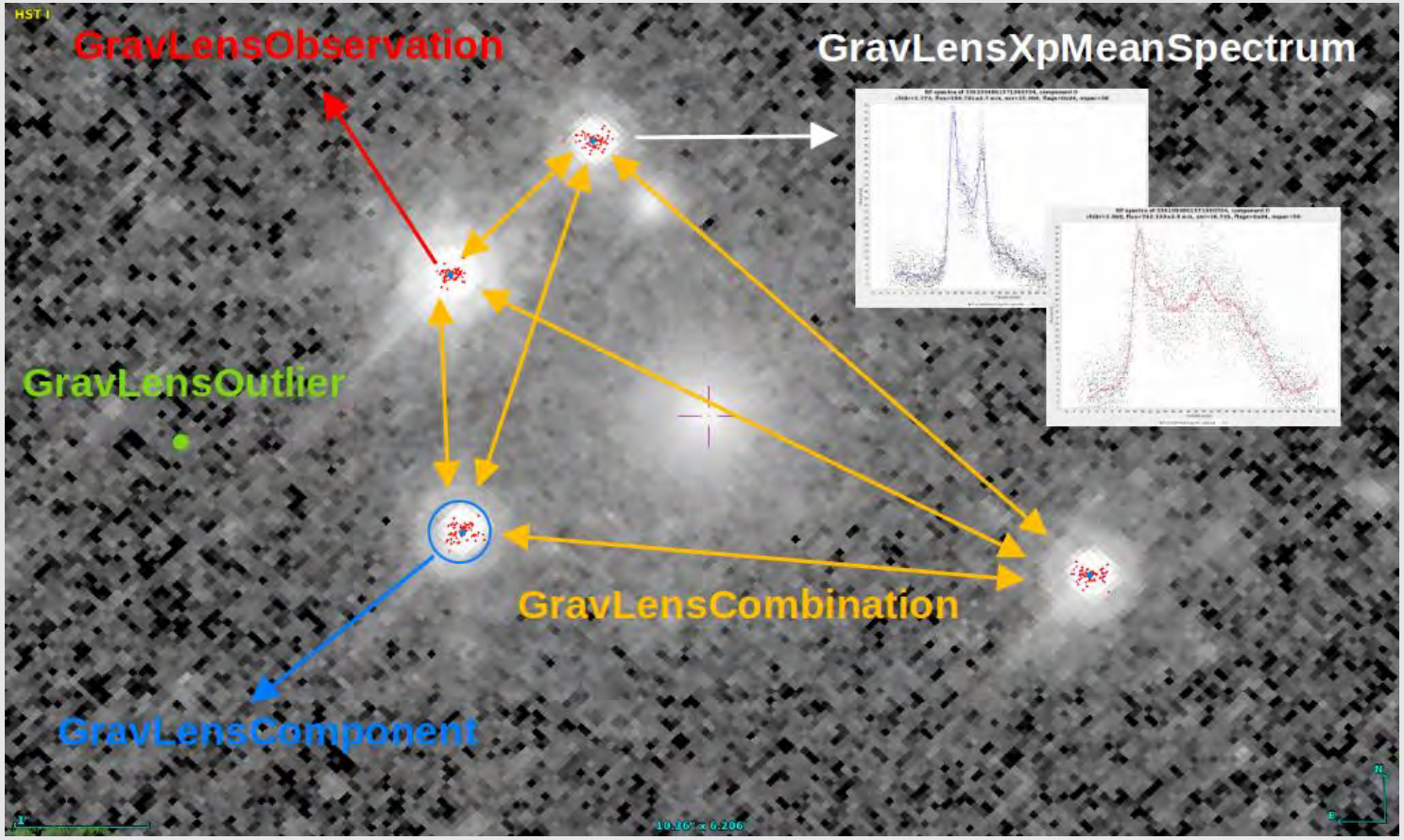


Pulsational RV variations for a Cepheid variab
Credit: DPAC/ CU6/ DPCC team

Gaia DR4 includes time series for all bright sources (GRVS < 14) → 650 million reliable epoch RVs (1.3 billion total)

Many lines in addition to Ca seen, high S/N spectrum shown for comparison

Extended Objects



Credit: DPAC/ CU8/ DPCC team

- QSOs: 4.5 million candidates, 163 000 surface brightness profiles for host galaxies (z < 0.4, 10x Gaia DR3)
- Galaxies: 6.6 million candidates, 3.9 million surface brightness profiles (3x Gaia DR3)
- Gravitational lenses: more robust lens identification, including spectral similarity; time delay measurements as a new data product

GREAT Plenaries

slides on-line at: http://great.ast.cam.ac.uk/Greatwiki/GreatMeet-PM18

Last GREAT plenary was held at the EAS Annual Meeting 2025 in Cork as Symp S1 (26-27 Jun 2025)

https://eas.unige.ch/EAS2025/session.jsp?id=S1

Programme

- Gaia DR3: Highlight Science including a review of recent major science highlights from Gaia DR3, Gaia FPR and science discovery enabled by Gaia, with attention to the potential of Gaia DR4.
- Gaia / GREAT/MW-Gaia / Gaia Unlimited Status
- Gaia EDR3/DR3/FPR: Highlight Science (The Milky Way as a Galaxy)
- Gaia EDR3/DR3/FPR: Highlight Science (The Birth, Life and Death of Stars)
- Gaia EDR3/DR3/FPR: Highlight Science (from Solar system to reference frames)
- Gaia networking and ground based synergies with Gaia
- Lunch session with an update on the Gaia Archive, and update on the ESA Voyage 2050 L mission concept (GaiaNIR), and also an opportunity for poster presenters to deliver a 'lightening' talk of their (e-)poster.

Gaia: A remarkable mission revolutionising our understanding of the Milky Way, its constituent components and the Universe more widely. Much discovery to come with the future data releases!

https://www.cosmos.esa.int/web/gaia/data-release-3

Get the data:https://gea.esac.esa.int/archive/

https://www.cosmos.esa.int/web/gaia/data-release-4