Treasures Hidden in High Energy Catalogues

IRAP, Toulouse France

THE SECOND RELEASE OF THE GAIA CATALOGUE (25th of April 2018)

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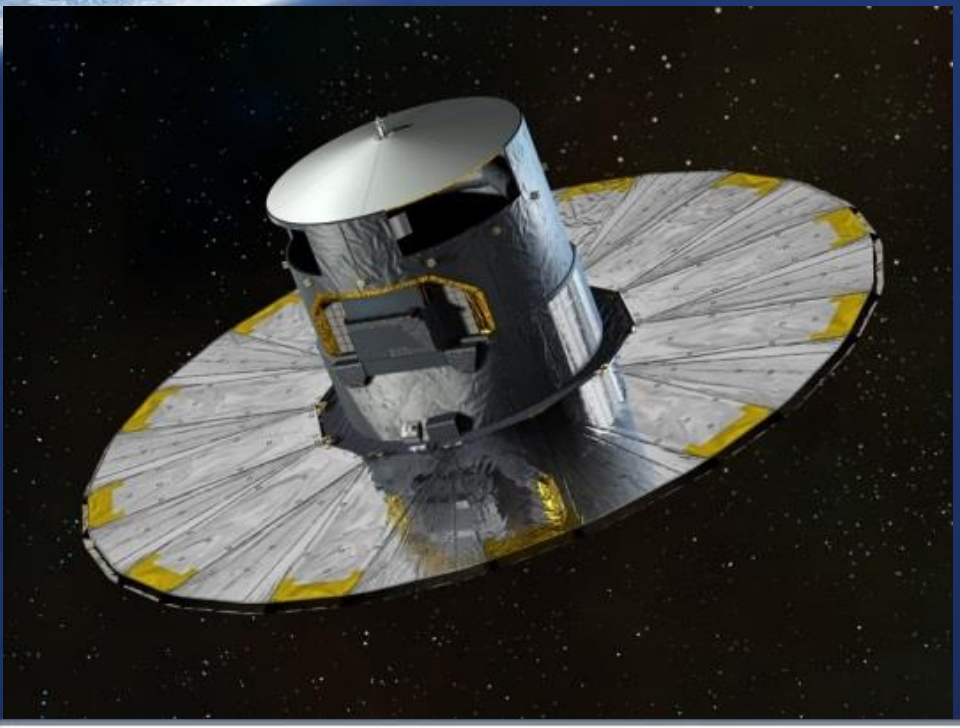
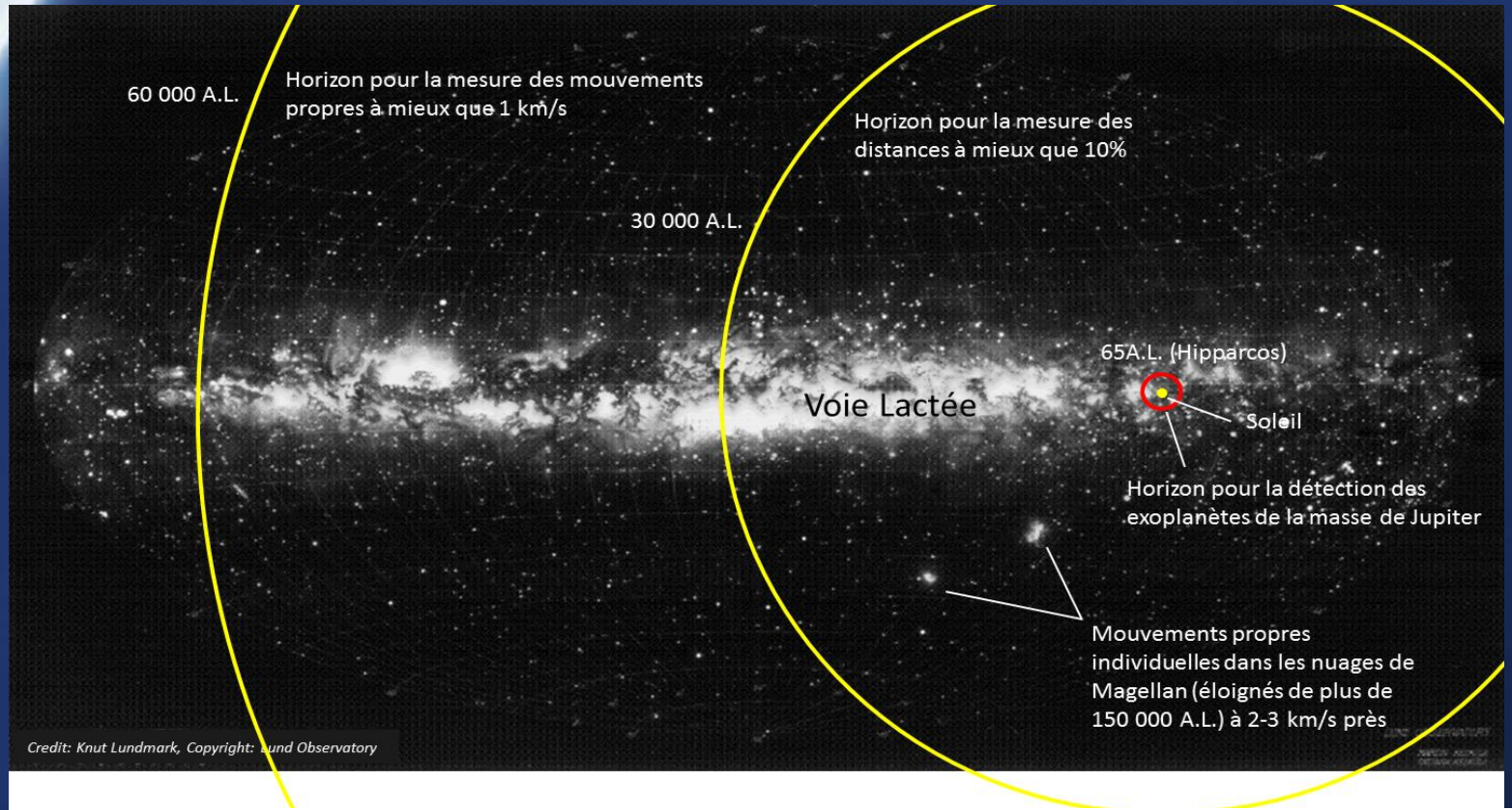


- The GAIA Mission in some words
- Role of the CNES (Space french agency) in the GAIA data processing and in the DPAC consortium
- The new release of the GAIA Catalogue on the 25th of April (see more details at https://www.cosmos.esa.int/web/gaia/data-release-2)

WHAT IS GAIA OBSERVING ?



GAIA is observing around 1% objects of our galaxy

In red, distances & proper motions measured with HIPPARCOS (65 LY), in yellow with GAIA.
Distances up to 30 000 LY and proper motions up to 60 000 LY (LY≈ 10 000 billion kms)

Image: ESA/Hipparcos/J. de Bruijne
[Published: 21/11/2013]

GAIA MISSION

Build a 3D map of more than 1 billion stars from our Galaxy and beyond

- Reveal its composition, formation & evolution
- Much more accurate than previous missions (120 000 stars /Hipparcos-1997, 2 million stars /Tycho-2 2000)

Measurements :

- Positions, parallaxes (distances), proper motions : astrometry
- Brightness (colors, fluxes, magnitudes) : photometry
- Velocities (radial & rotational velocities) : spectroscopy

Results in a catalogue :

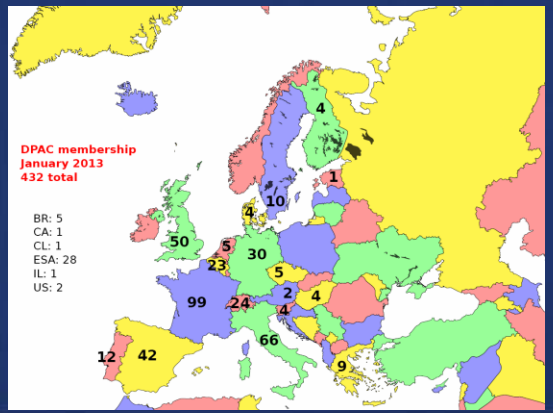
- Intermediate releases : DR1 (14 sept 2016), **DR2 (25 April 2018)**, DR3 2020, final one 2022, mission extension in discussion.

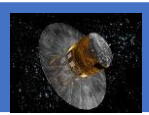
ESA GAIA Mission

- **Gaia launch : 19th December 2013 by a Soyouz-Fregat from Kourou**
- **At Lagrange L2 point (1.5 million kilometres from Earth), 5 years mission at least**
- **3 sensors : astrometric (2 telescopes), photometric (Blue Photometer / Red Photometer), spectrometric (RadialVelocitySpectrometer -** near-infrared [845; 872] nm**)**
- **Goal : map more than 1 million stars and other sky objects (SSO, quasars, galaxies, …)**
  - Scientific data processing delegated to the Data Processing and Analysis Consortium (DPAC), 20 european countries involved, around 400 people
    - Organized in 9 coordination units **(CU)**, each dealing with different aspect of data processing
    - Hosted by 6 DPC or Data Processing Center (ESAC, Barcelone, Cambridge, Turino, Geneva, **CNES Toulouse**)

Comparison with Hipparcos catalogue

GAIA is observing 10 000 times more stars & celestial objects than Hipparcos

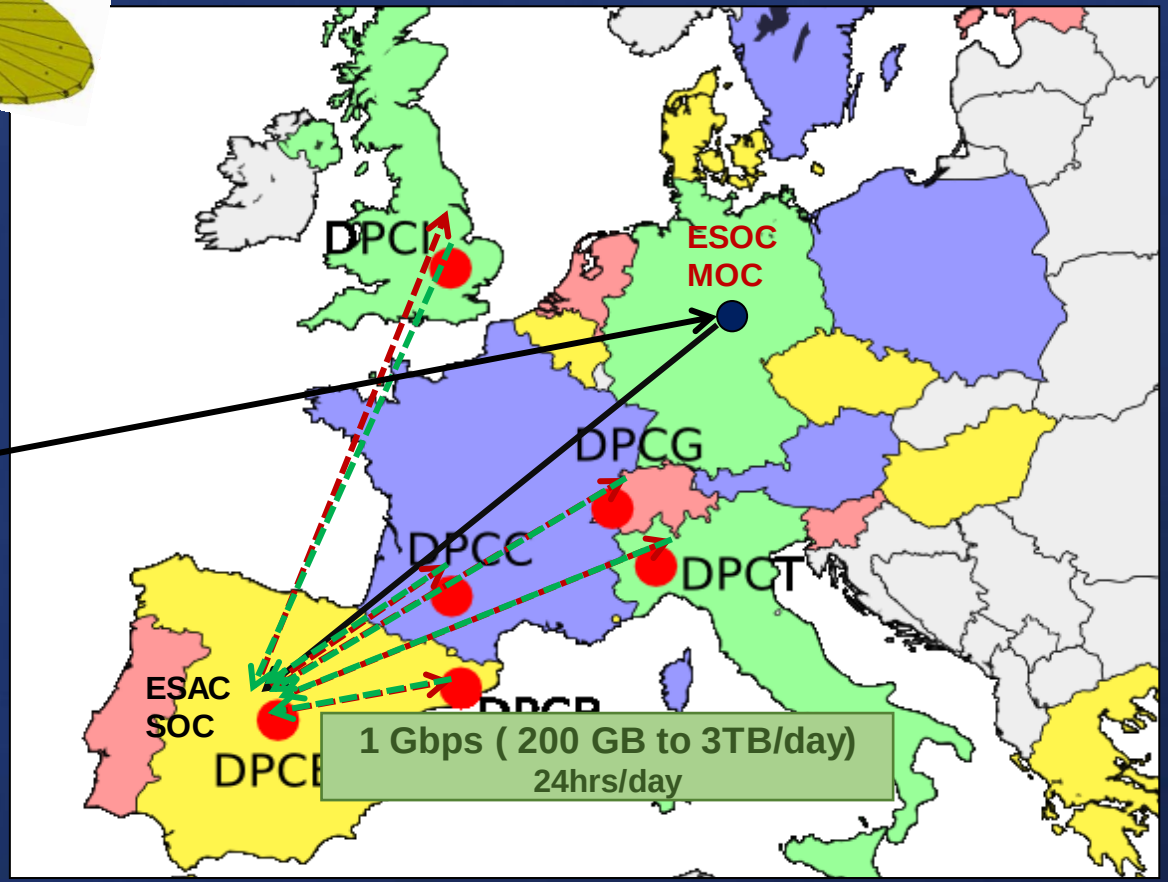


	Hipparcos (1997) 	Gaia 
Catalogue	118000 stars	> 1 billion
Magnitude limit	12	20.7
Completeness	7.3 – 9.0	20.7
Bright limit	0	6 mag
Number of objects	120 000	47 million to G=15 mag
		360 million to G= 18 mag
		1192 million to G = 20 mag
Effective distance limit	1 kpc	50 kpc
Quasars	None	500,000
Galaxies	None	1,000,000
Accuracy	1 milliarcsec	7 µarcsec at G= 10 mag
		10-25 µarcsec at G = 15 mag
		300 µarcsec at G = 20 mag
Photometry	2-colour (B and V)	Low-res. spectra to G= 20.7 mag
Radial velocity	None	15 km/s to GRVS = 16.2 mag

DATA FLOWS and DATA PROCESSING CENTRES

~100 GB/day
8-11hrs/day

Cerebros (Avila, Spain)
New Norcia (Western Australia)
Malargüe (Mendoza Argentina)



DPCE (ESAC, Spain) – for astrometric data reduction (core task)

DPCI (Cambridge, UK) – for photometric data reduction

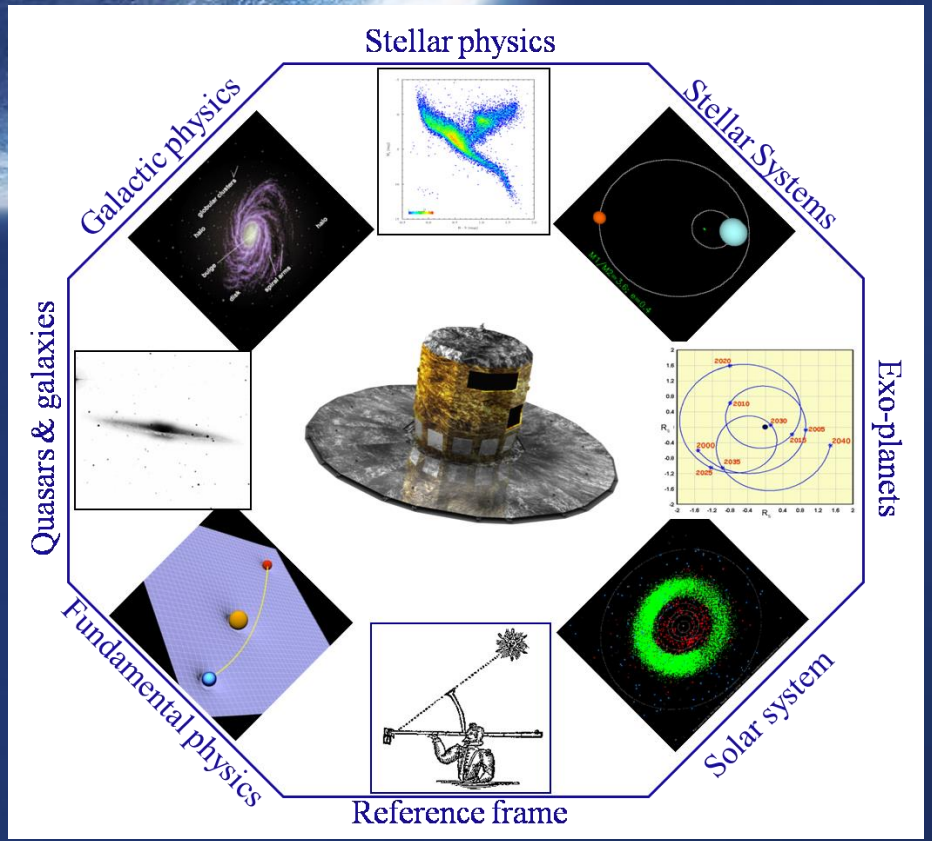
DPCC (Toulouse, France) – for spectroscopic data reduction + SSO, EO, NSS, AstroPhyParameters

DPCB (Barcelona, Spain) for Xmatch Obs and objects

DPCG (Geneva, Switzerland) for Variable Stars

DPCT (Turino, Italy) for Basic Angle

ROLE OF CNES IN GAIA

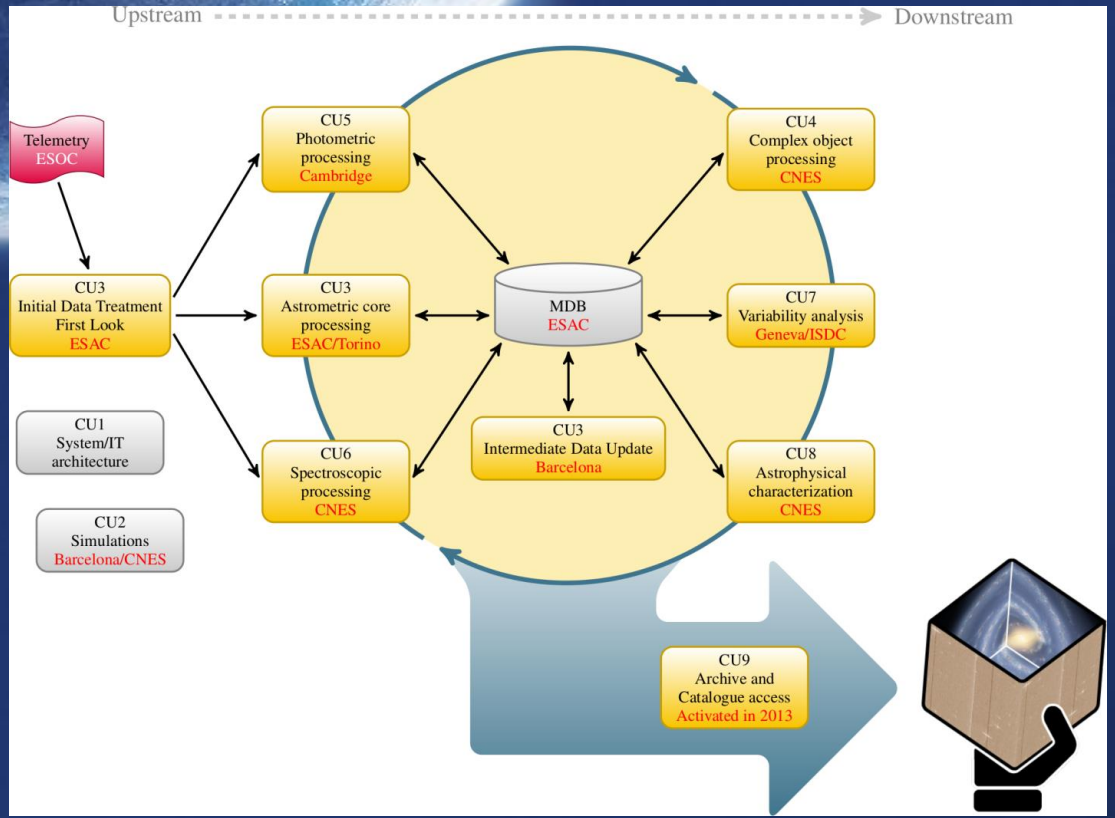


Support to French Laboratories (for technical coordination in dev. , integration of codes within pipelines and operations)

Within DPAC, DPCC (Data Processing Center CNES) hosted 7 scientific tasks (3 CUs):

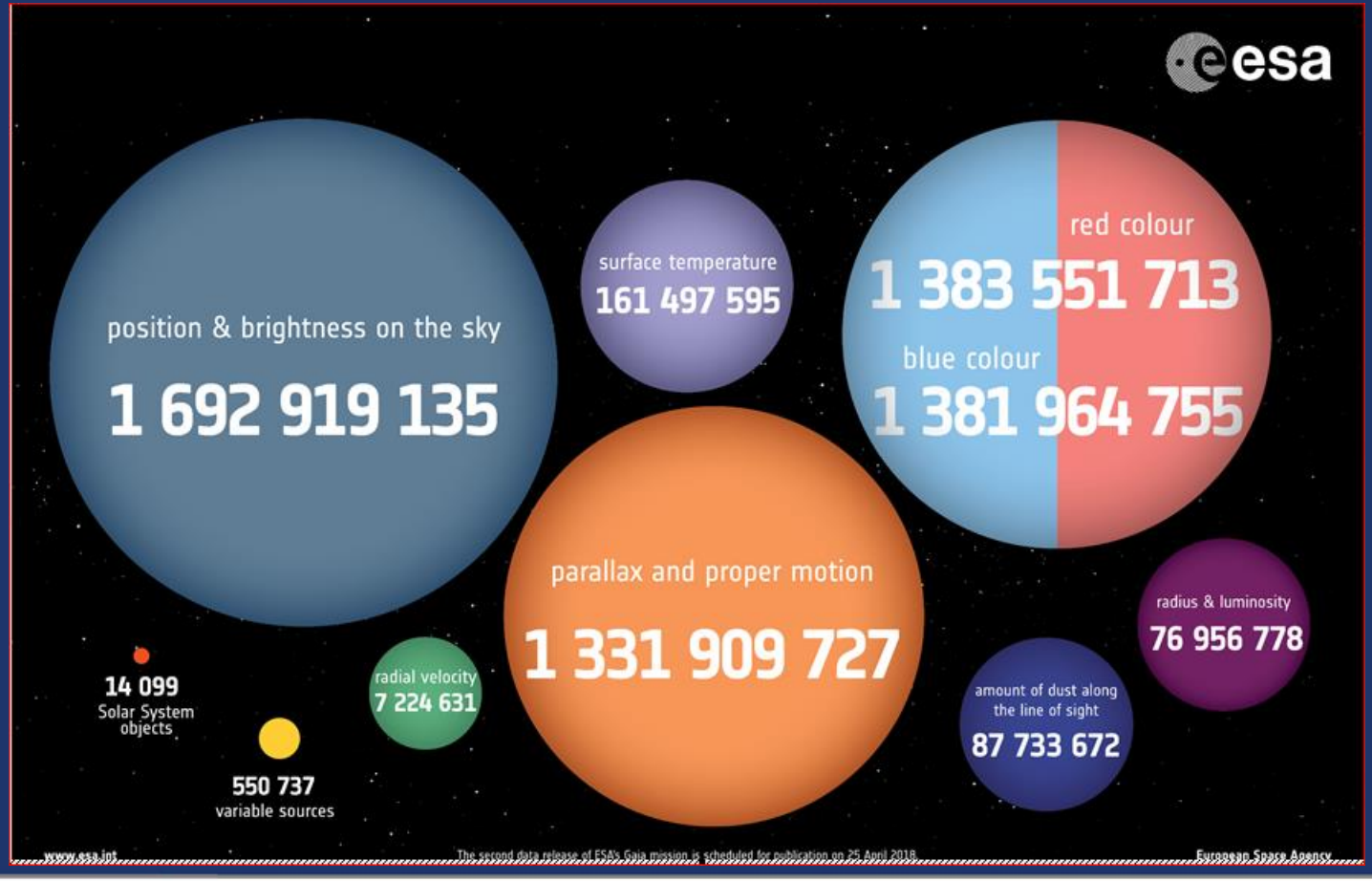
- Detection of Solar System Objects and characterization (positions, orbits, …)
- Characterisation of Non Single Stars (binaries), quasars, galaxies and gravitational lenses
- Calibration of the RVS Spectrometer and computation of radial and rotational velocities
- Classification of objects and determination of the astrophysical parameters (Teff, LogG, Fe/H, Mass, Age, …)

DATA PROCESSING CYCLES



- Daily processing on recent observations for calibration & science alerts => short delay
- Cyclic processing : massive computation on all the data since beginning of mission (1 to 5 years) , every 2 years, with updated software
- Observations & results exchanged through a Main Data Base (MDB)
- MDB used to extract the Catalog: cross validation, documentation (papers), outreach, distribution

The DR2 GAIA Catalogue : in numbers … near 1.7 billion positions & brightness but not only …



Major step in astrometry : parallaxes and proper motions : from 2 Million in DR1 to >1,3 Billion in DR2 !

Included in the DR2 for the first time:

~7 million Vr

~161 million Teff

~87 million A0 (extinction)

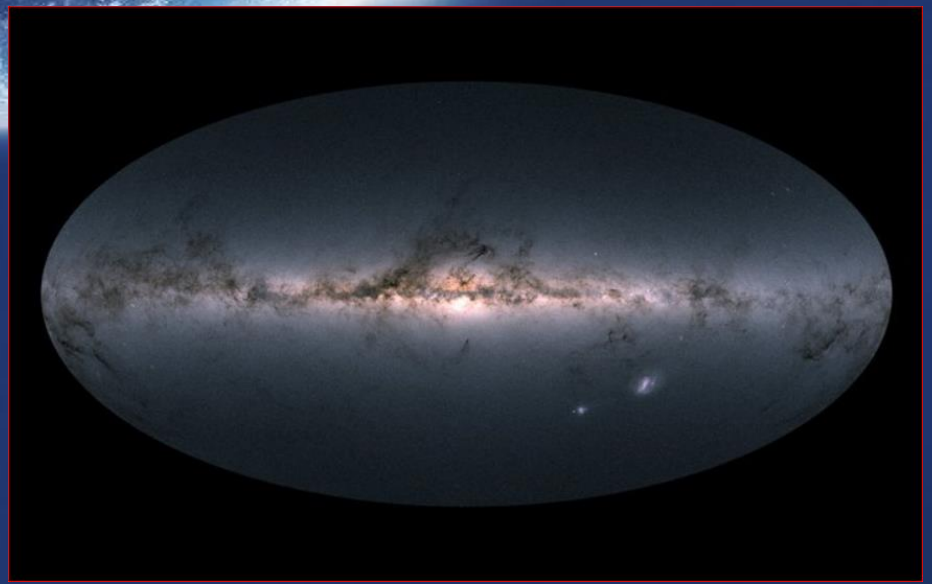
~77 million Radius & Luminosity

~14 099 asteroïds positions

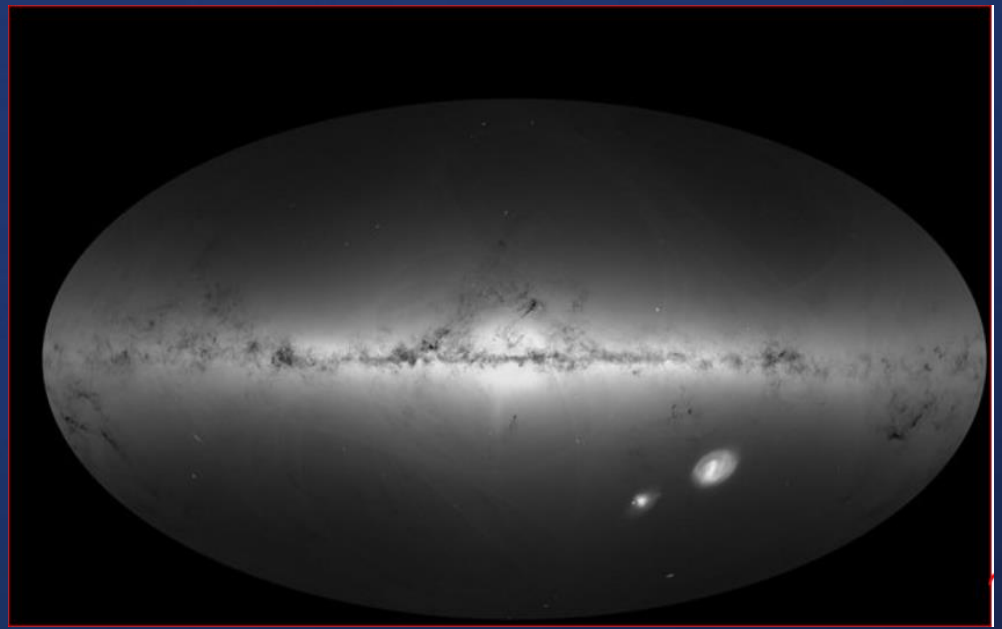
and produced by DPCC !

Gaia's new maps

Gaia's all-sky view of our Milky Way Galaxy and neighbouring galaxies, based on measurements of nearly 1.7 billion stars.



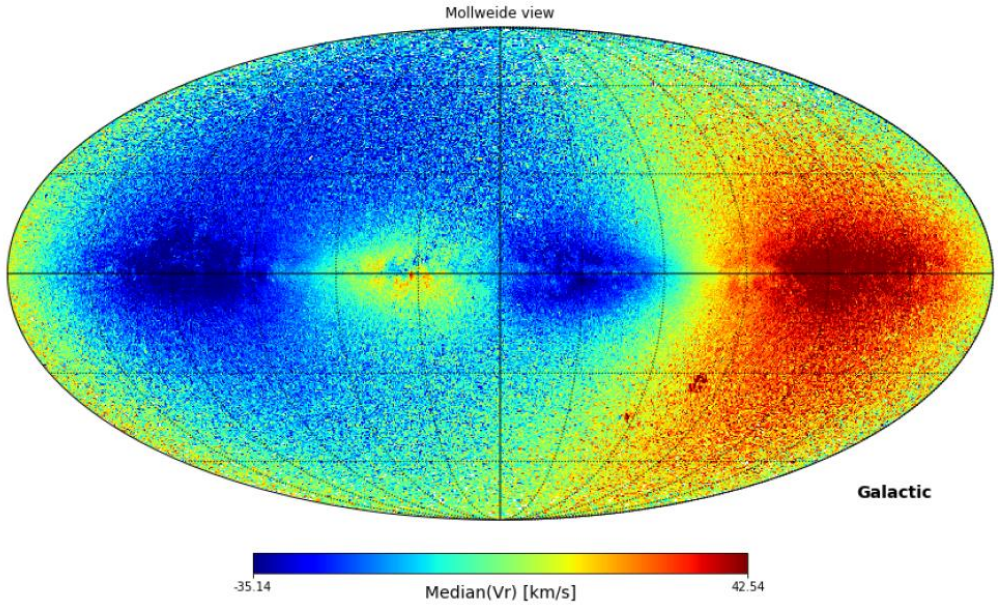
On the left, the map shows the total brightness and colour of stars observed by the Gaia satellite in each portion of the sky between **July 2014 and May 2016 (22 months).**



On the right, the map shows the density of stars observed on the same period of time

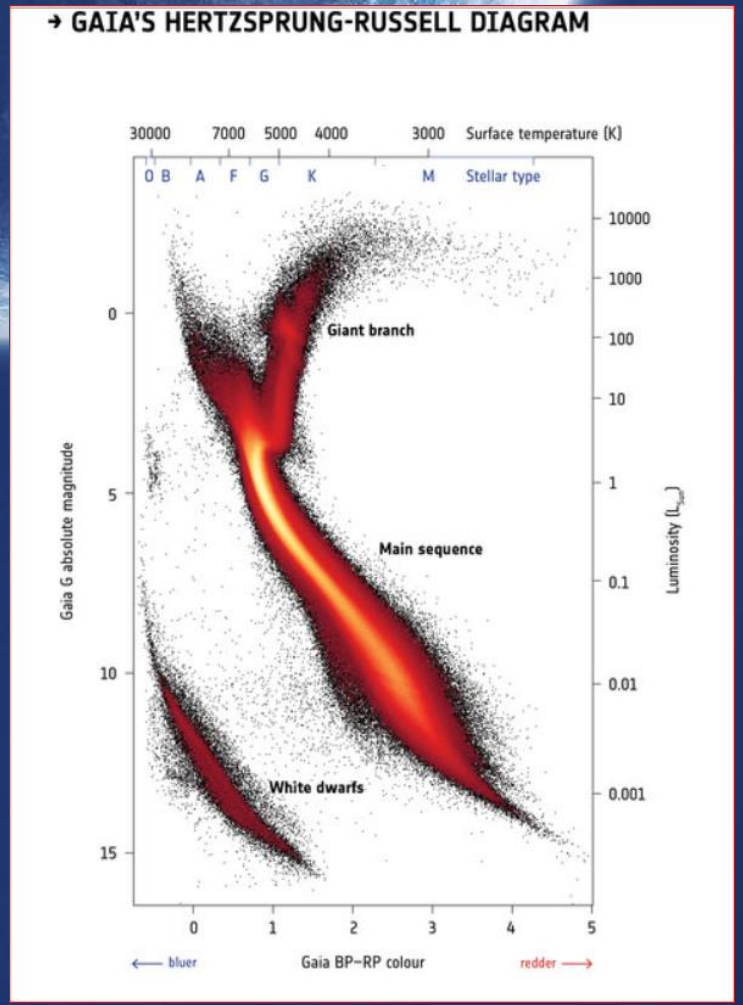
Radial Velocity's new map

- Gaia DR2 contains median radial velocities for 7 224 631 stars, with Teff in the range **[3550; 6900] °K up to Grvs=12**
- The median radial velocity residuals with respect to the ground-based surveys vary from one catalogue to another, but do not exceed a few **100 m.s^{-1}**
- Five ground-based catalogues are used : CU6GB (Soubiran et al. 2018), SIM (Makarov & Unwin 2015), RAVE (Kunder et al. 2017), APOGEE (Abolfathi et al. 2017) and Gaia-ESOSurvey (GES; Gilmore et al. 2012).



Median radial velocity map as a function of galactic coordinates. The Galactic Centre is in the middle of the figure and the galactic longitudes increase to the left. The pixel size is ~ 0.2 square degree (healpix level 7).

Image : Courtesy David Katz and Al.



Gaia's HERTZSPRUNG-RUSSELL diagram : the most detailed to date !

… a hundred times more stars than the one obtained using data from ESA's Hipparcos mission …

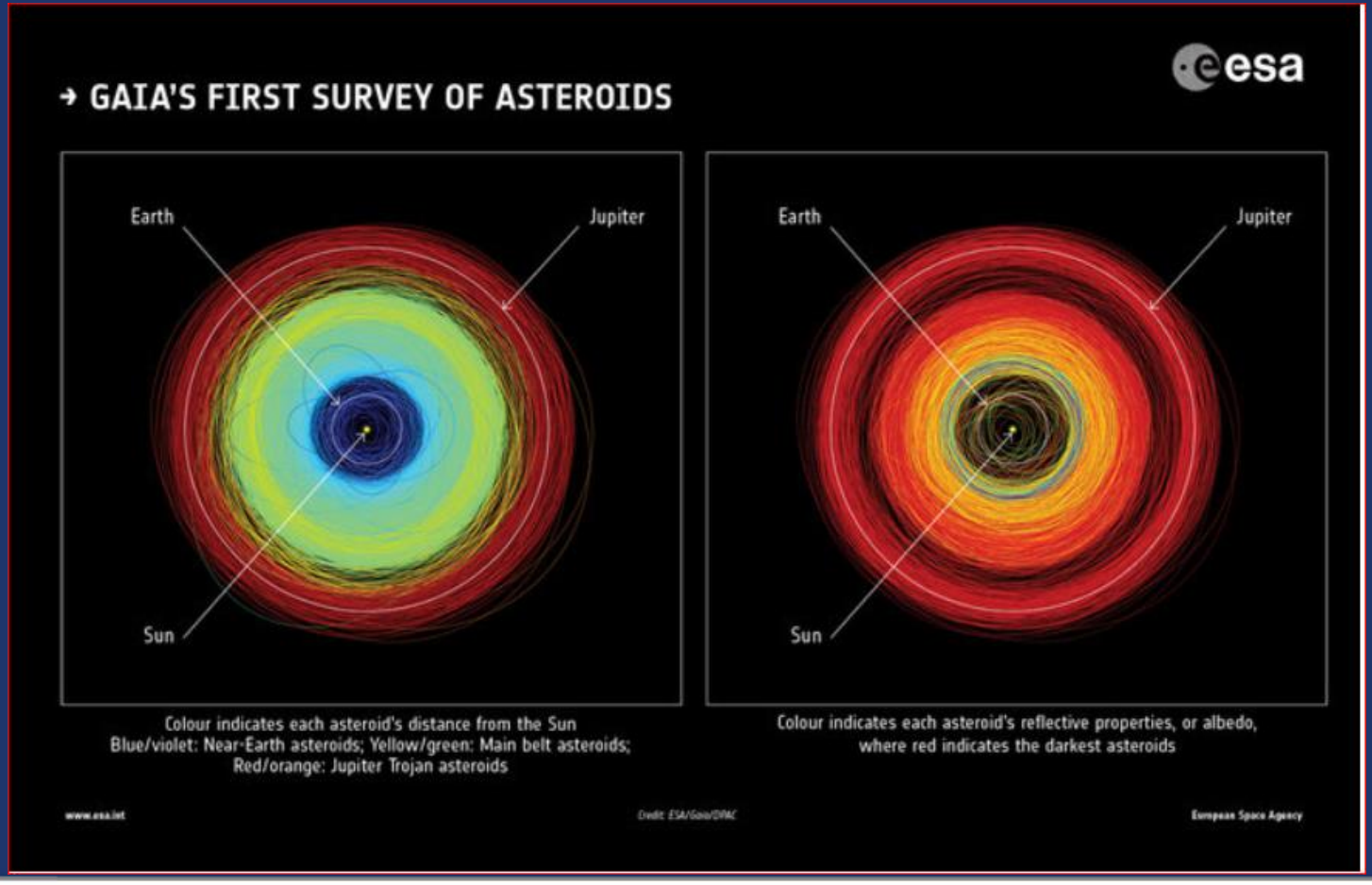
More than **4 million stars within 5 000 Light Years from the Sun** are plotted on this HR diagram using brightness (on vertical axis), colour (horizontal axis) from DR2 and they are grouped in different regions of the diagram depending mainly on their masses, chemical composition, ages, and stages in the stellar life cycle.

35 000 white dwarfs from DR2 included in this diagram => differentiation between those with hydrogen-rich cores and those dominated by helium.

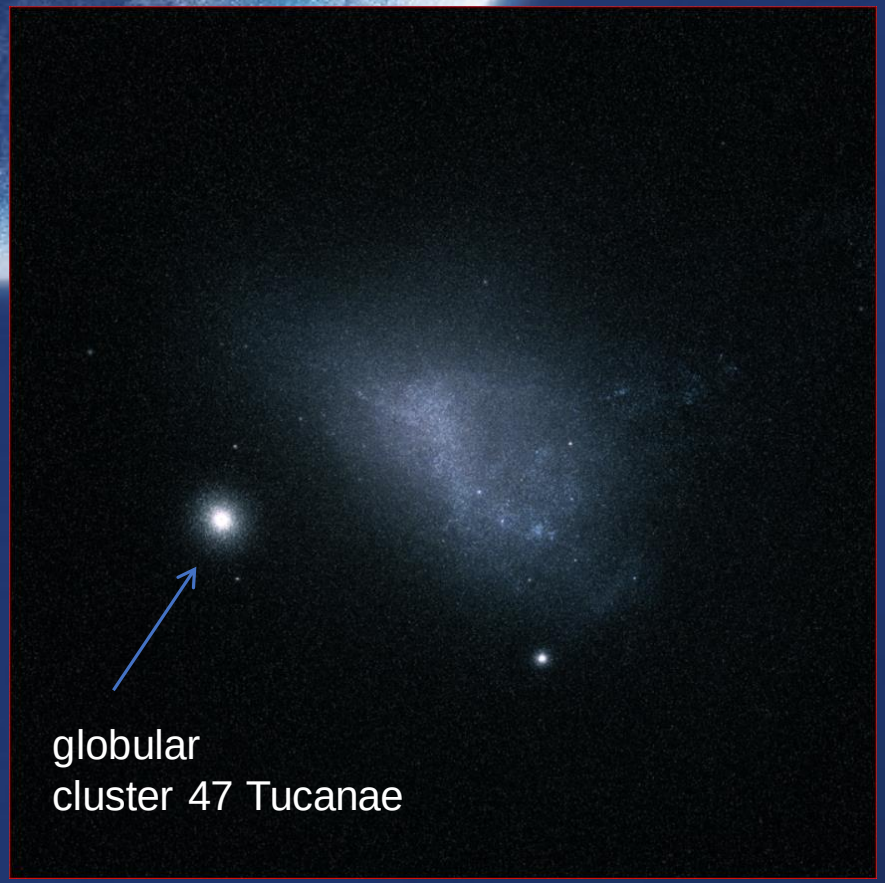
NB : The colour scale in this image does not represent the colour of stars but is a representation of how many stars are plotted in each portion of the diagram: black represents lower numbers of stars, while red, orange and yellow correspond to increasingly higher numbers of stars

Image :
http://www.esa.int/var/esa/storage/images/esa_multimedia/images/2018/04/gaia_s_hertzsprung-russell_diagram/17476330-1-eng-GB/Gaia_s_Hertzsprung-Russell_diagram.jpg

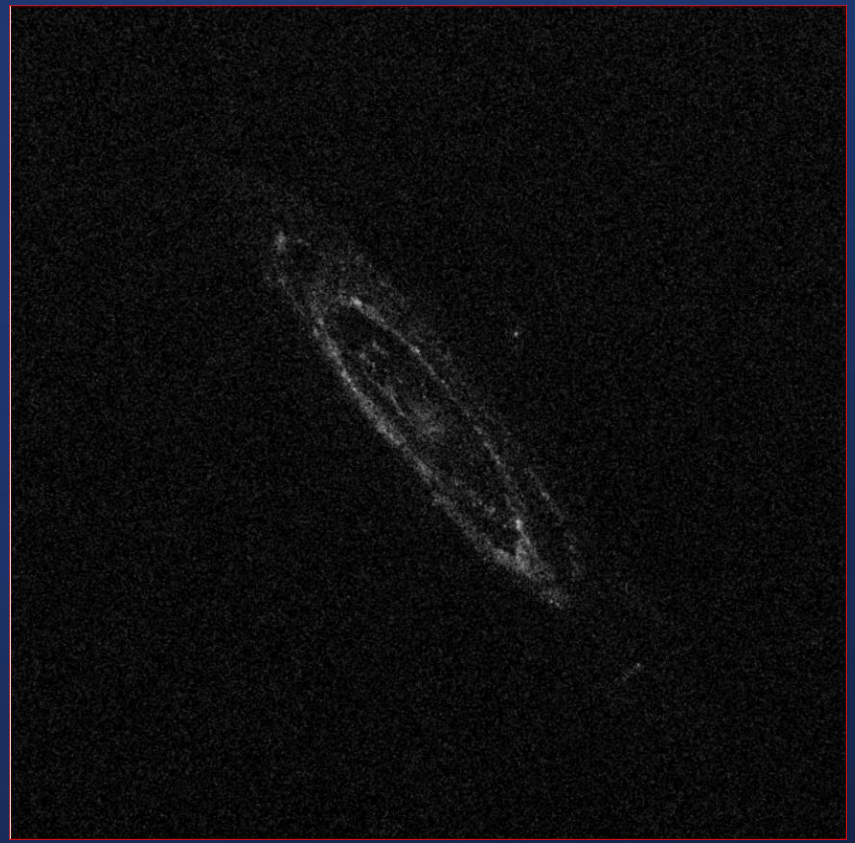
14 099 Solar System Objects (Asteroids)



Our neighbouring galaxies



Small Magellanic Cloud (SMC)



The Andromeda galaxy (M31)

What next ?

Preparing the GAIA DR3 ….

- much more complex chains still under development,
- strong inter-dependencies between chains in different data processing centers
- 2 years operations starting this autumn

French contacts in Labs

CU4 (NSS) , CU9: Frédéric Arenou (Paris-Meudon Obs)

CU4(SS0) : Paolo Tanga (OCA – Nice)

CU4(EO) : Christine Ducourant (Bordeaux Obs)

CU6GB : Caroline Soubiran (Bordeaux Obs)

CU6 : David Katz, Paola Sartoretti (Paris-Meudon Obs)

CU8 : Orlagh Creevey , Frédéric Thévenin (OCA – Nice)

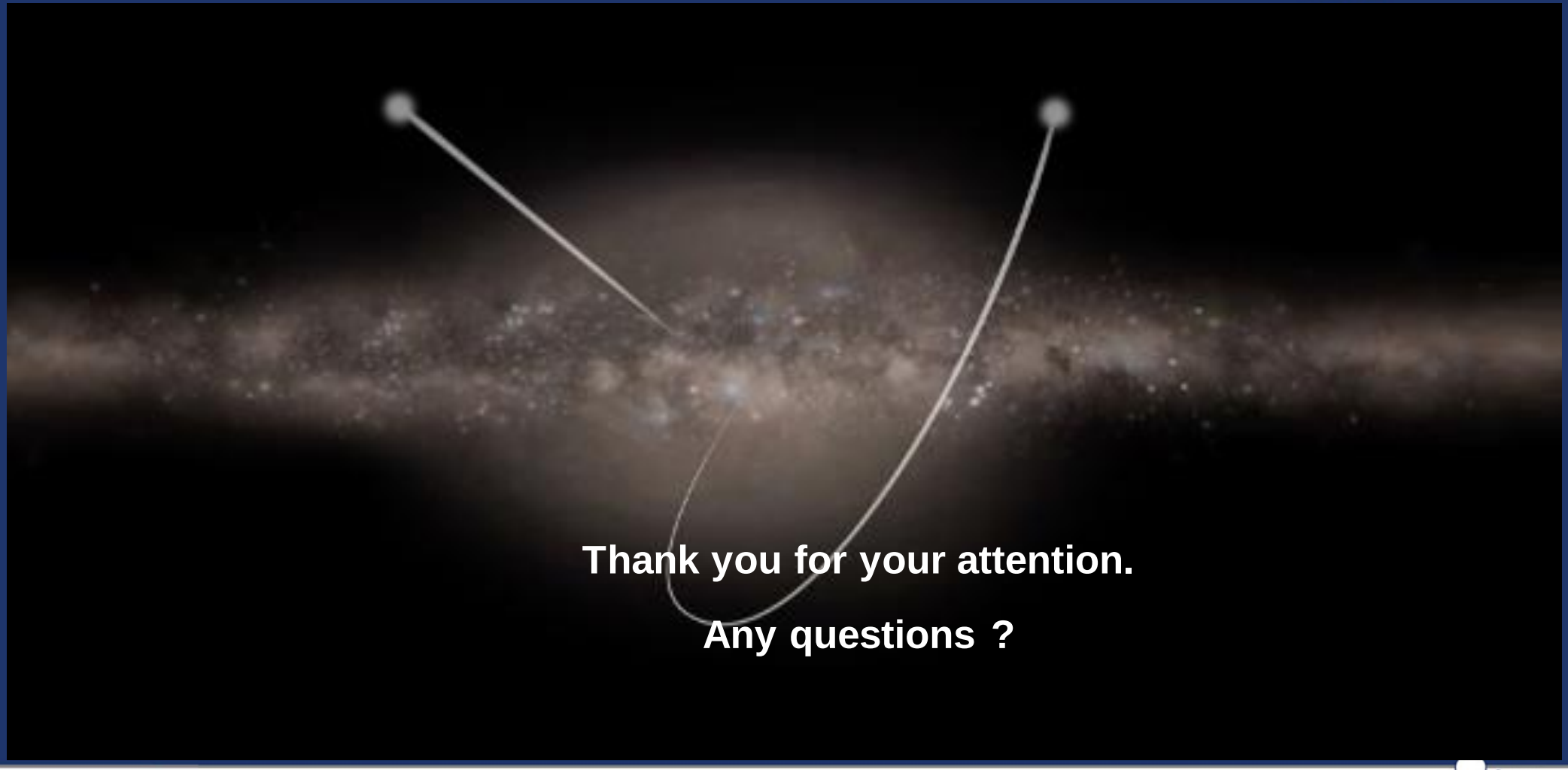
Next workshops

GAIA DR2 Exploration Labs, 25-29 June 2018, ESAC, Madrid, Spain

The objective is to stimulate state-of-the-art exploitation of the Gaia DR2 dataset in a relaxed, yet focused and productive atmosphere. The Exploration Lab aims to bring together scientists with diverse educational and cultural backgrounds, different interests, and from different locations working together for a week on exciting scientific topics in a collaborative spirit.

Alternative workshops / sprints

The Gaia New York City Sprint is given in June 2018 as well, but is at this moment fully booked. Then there will be a "Second Gaia Data Workshop" organised in Heidelberg (Germany), also in June 2018, which focuses more on providing information and tutorials, and less on science exploration. Another Gaia Sprint is planned for 2019 in Santa Barbara (USA).



Thank you for your attention.

Any questions ?