The Gaia Mission and its Extension

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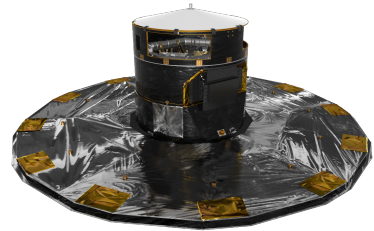
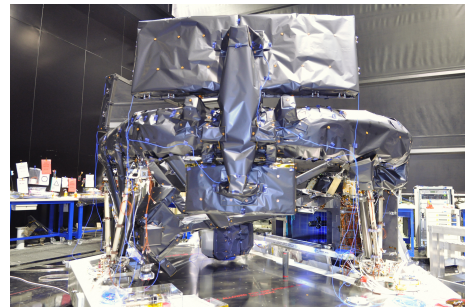
ESA/Gaia/DPAC

Gaia

- Astrometry and spectrophotometry for $>$ 1 billion objects
- Radial velocities for $>$ 100 million objects
- Survey
  - Complete to $G = 20.7$ ($V = 20$–22)
  - Quasi-regular time-sampling over 5 years ($\sim$ 70 observations)
- Launch December 2013
- 5 years of operations at L2

- Second data release April 25 2018
- Photometric alerts started in 2014
- Alerts on new solar system objects started end 2016

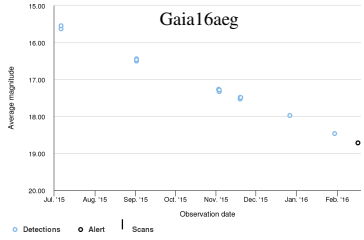


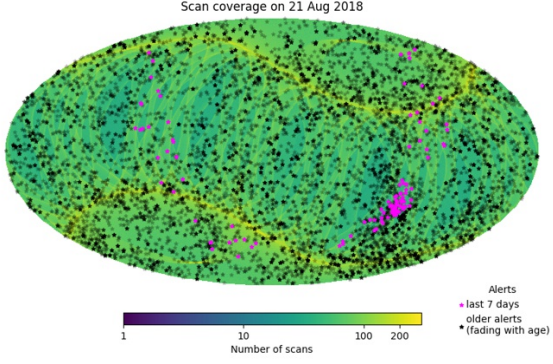


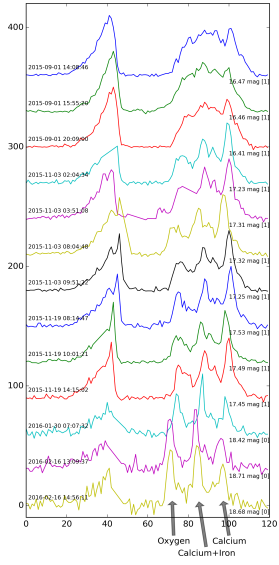
Photometric alerts

ESA/Gaia/DPAC/Gaia Science Alerts
Team/Morgan Fraser/Simon
Hodgkin/Lukasz Wyrzykowski

http://gsaweb.ast.cam.ac.uk/alerts/home







Solar system alerts

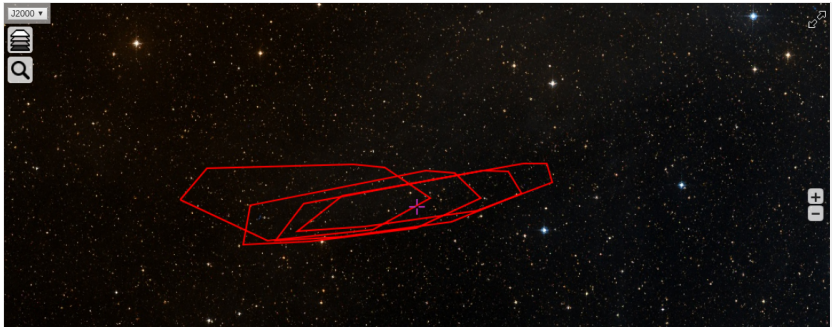
- **Gaia ID:** -4194951672
- **Database ID:** 51453
- **Name:** g2h09E
- **Magnitude (V):** $19.4^{+0.1}_{-0.1}$
- **Date of observation:** 8/21/2018

Back to Gaia alerts

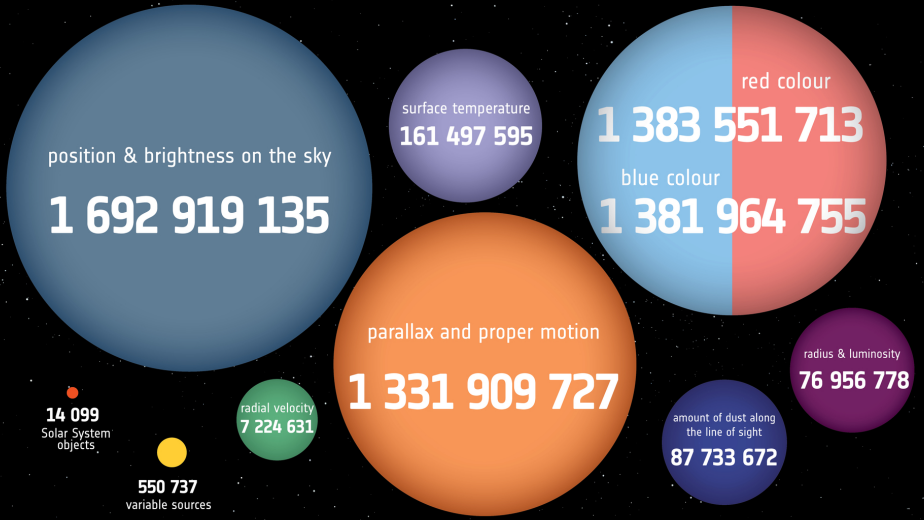
https://gaiafunsso.imcce.fr/index.php

B. Carry (OCA), W. Thuillot (IMCCE)

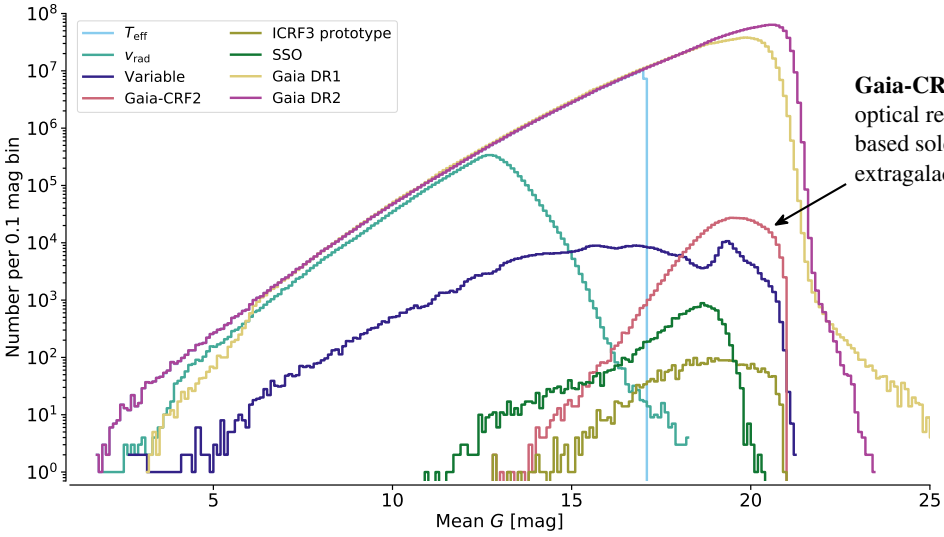
Sky view with Aladin -- Object expected magnitude V= $19.4^{+0.1}_{-0.1}$



Gaia DR2 in numbers



Source counts



Gaia-CRF2: First optical reference frame based solely on extragalactic sources

WAITING FOR GAIA...

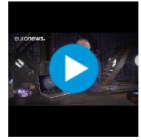
GAIA DATA RELEASE 2 PRESS CONFERENCE

THE HYADES CLUSTER

360 DEGREE VIEW OF GAIA'S SKY

INTERVIEW WITH ANTHONY BROWN

EURONEWS: GAIA'S REVOLUTION IN ASTRONOMY



GAIA DR2 INFO

Information on Gaia Data Release 2 contents, completeness and limitations.

GAIA DR2 PAPERS

Titles and links to papers describing the data processing and demonstrating the science potential of Gaia Data Release 2.

GAIA DR2 DOCUMENTATION

The full documentation for the second data release, both on webpages and with a downloadable PDF-file

GAIA DR2 DATA

Gaia Data Release 2 data is now available.

GAIA DATA CREDITS

When using Gaia data, please acknowledge the work of the people involved and provide credits and necessary citations.

GAIA DR2 KNOWN ISSUES

Issues with the Gaia DR2 data important for the users to know that were discovered after the release of data and documentation

TUTORIALS AND HELP

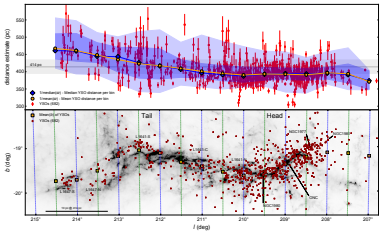
Help is available to guide you through the process of getting the data you need. Check out the tutorials as they are very instructive!

LEARN ADQL

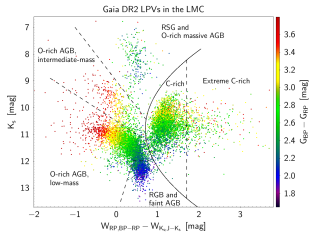
Gaia Data Release 2 contains a lot of data. While downloading the data will be possible, you can also bring your code to the data and access the data in a smart way. You can use ADQL queries to extract the data and then download the resulting

Some 240 papers on arXiv.org since April 25

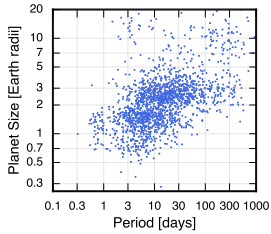
Großschedl et al.



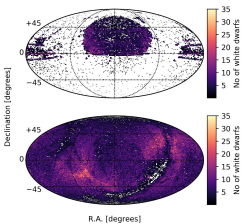
Lebzelter et al.



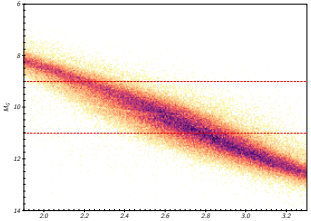
Fulton & Petigura



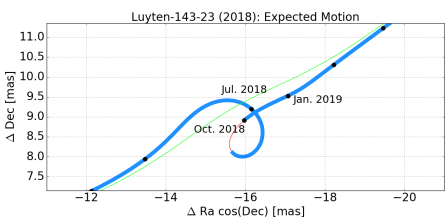
Gentile-Fusillo et al.



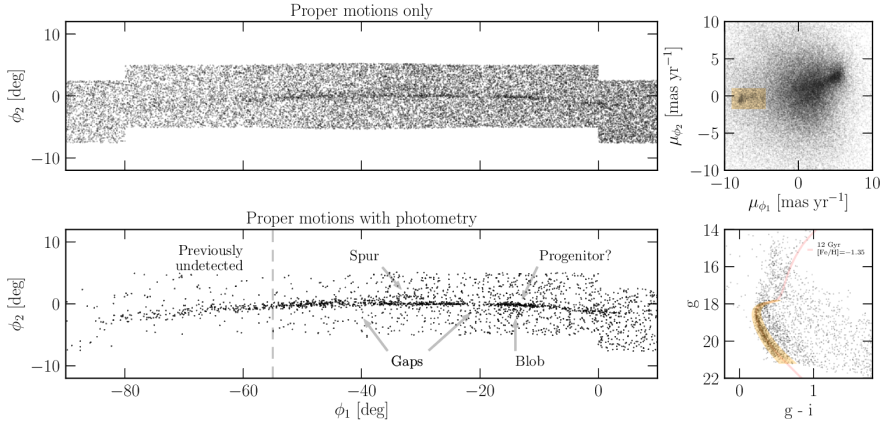
Jao et al.



Klüter et al.



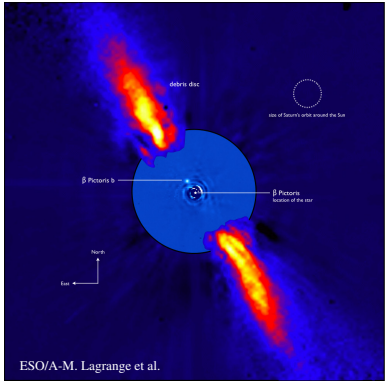
Mapping the GD1 stream

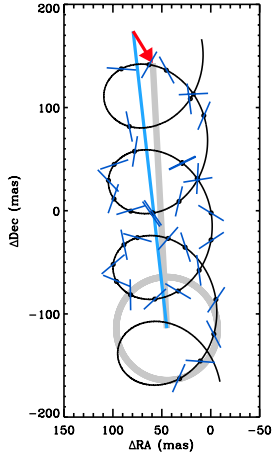


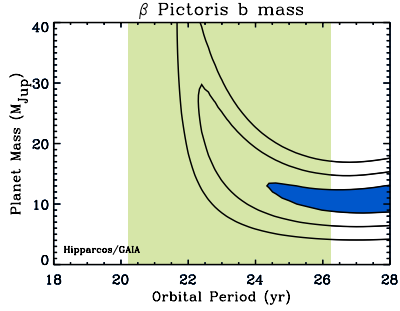
Price-Whelan & Bonaca, arXiv:1805.00425

- Gaia DR2 + Pan-STARRS; length of stream extended by 20 degrees
- High contrast gaps, possible progenitor location, off-stream stars
- Probe of large scale dark matter structure and of dark matter substructure

Beta Pictoris b



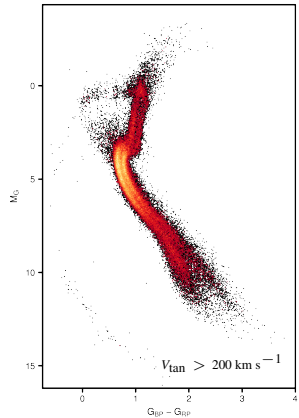


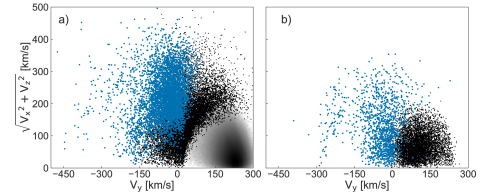


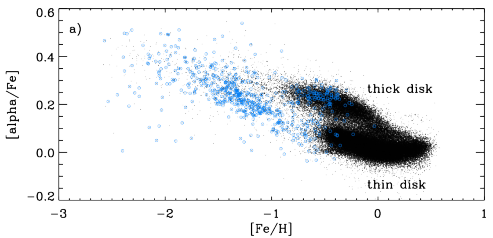
Snellen & Brown, Nature Astronomy, arXiv:1808.06257

- Difference Hipparcos and Hipparcos-Gaia proper motions reveals mass of planet ($11 \pm 2\ M_{\rm Jup}$)
- Residuals of Hipparcos observations with respect to long term proper motion constrain orbital period

Gaia-Enceladus: a major event in the Milky Way's history







Gaia Collaboration, Babusiaux et al., A&A, arXiv:1804.09378

Helmi et al., arXiv:1806.06038

Belokurov et al., MNRAS, arXiv:1802.03414

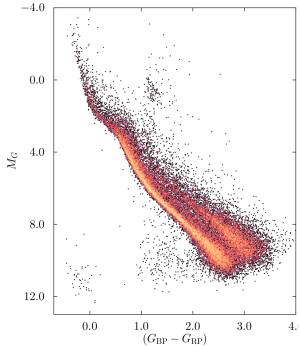
Haywood et al., ApJ, arXiv:1805.02617

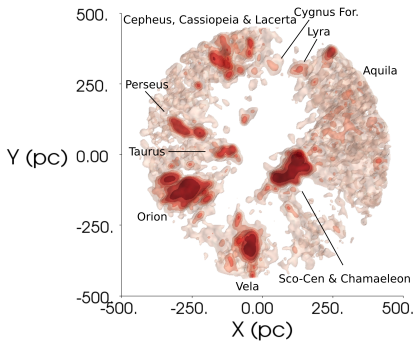
- Halo near sun dominated by slightly retrograde population
- Abundance analysis and HRD point to this being remnant of last major merger (4:1) experienced some 10 Gyr ago
- Contributed to formation of thick disc through heating of precursor

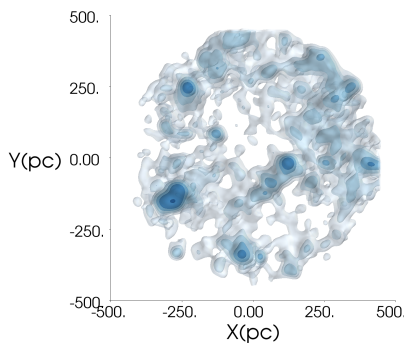
Mapping the young stellar population near the Sun

Pre-main sequence, $\lesssim 20$ Myr

Upper main sequence



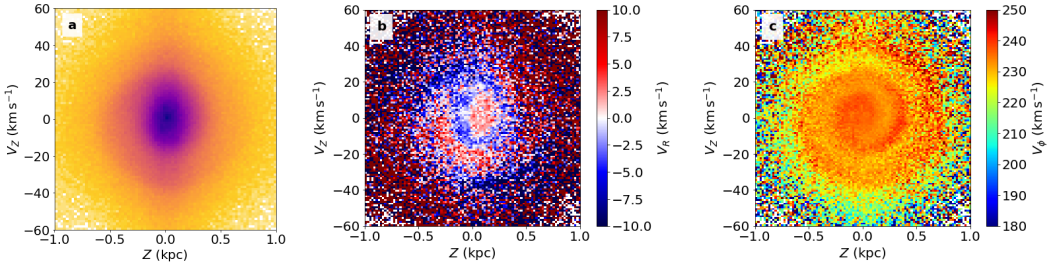




Zari et al., in prep.

- Selection of young stars in HRD after correctioning for extinction using Gaia DR2 A_G, $E(\mathrm{BP}-\mathrm{RP})$
- Further selection on tangential motions
- Global mapping of space, age distribution and kinematics of young stars near sun

Wrinkles in the Milky Way disk kinematics



Antoja et al., arXiv:1804.10196

- Never before seen spiral pattern and ridges in position-velocity space
- Points to Milky Way disk in the process of phase mixing from an out of equilibrium state as well strong influence of bar/spiral arms
- Milky Way gravitational potential, its time evolution, and effects of perturbers to follow from modelling of the rich phase space structure unveiled by Gaia DR2

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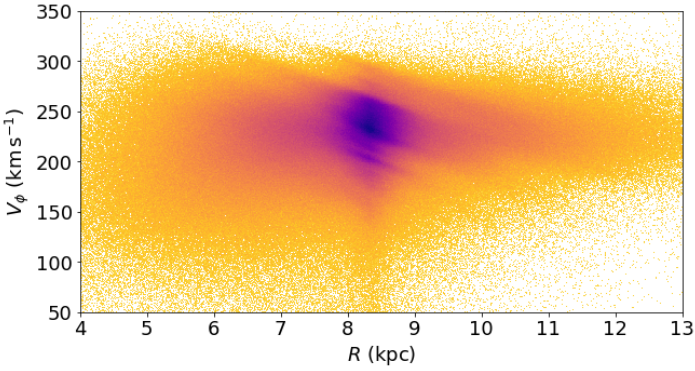

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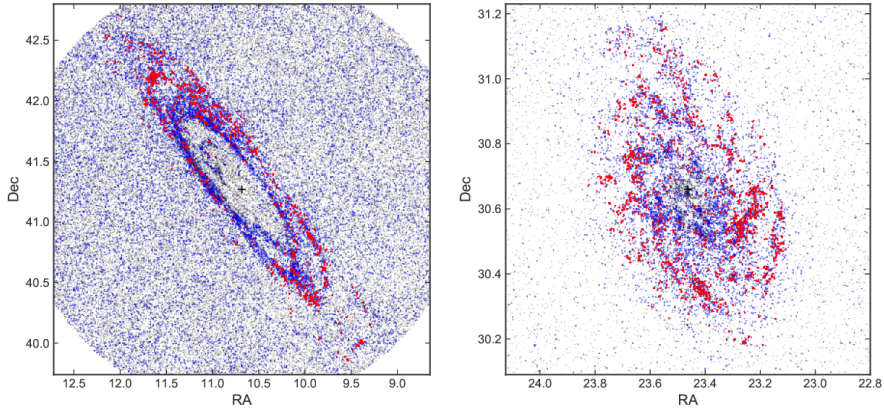
Rotation of Andromeda and Triangulum galaxies



van der Marel et al., arXiv:1805.04079

- Averaging over carefully selected sample of stars allows measurement of rotation of M31 and M33
  - More precise measurement possible after nominal mission
  - Extension to 10 year Gaia mission would result in factor 12 gain in precision
- New insights into past and future of Milky Way - Andromeda system

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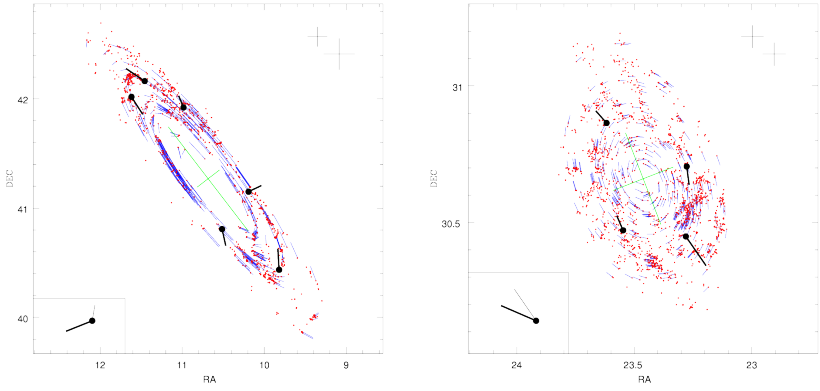

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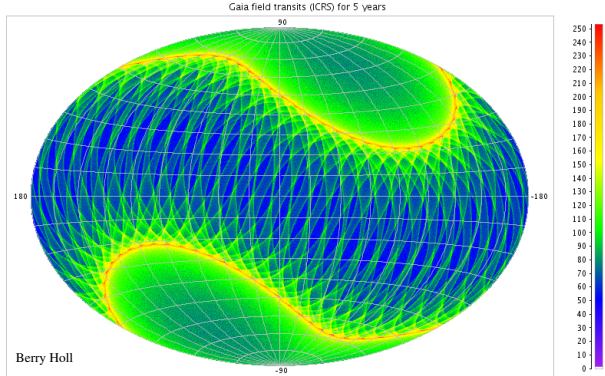
Gaia extension

- Nominal Gaia mission ends mid-2019 after 5 years of measurements
- Hardware and operations designed for a 5-year survey for sky homogeneity
- Scientifically the best option is to start a new 5-year survey on top of the nominal 5-year survey

Notes on continued S/C operations

- All hardware in good shape
- Only limiting factor is micro-propulsion system fuel
- Estimated to run out by Nov 2024



Improvement of scientific performance

- Basic mission results improve with $T^{-0.5}$
  - Positions, parallaxes, photometry and radial velocities
- Rapidly increasing gain in kinematics and dynamics
  - Proper motion improvement scales as $T^{-1.5}$
  - More complex systems scale faster, e.g. improvement in unambiguous determination of orbital period, mass and distance of a perturbing body scales as $T^{-4.5}$

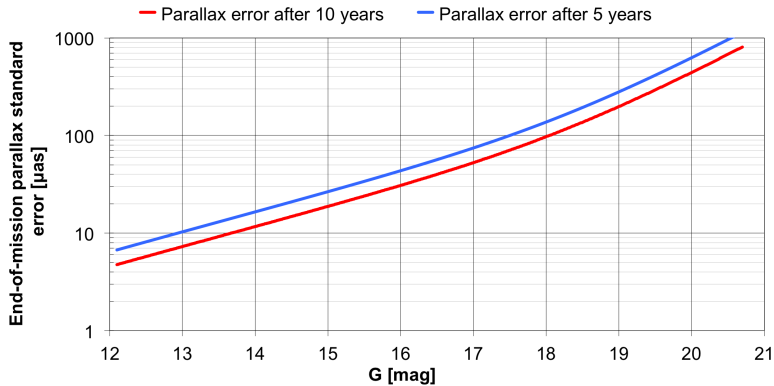
Improvement factor for mission length increase from 5 to 10 years	**Distance increase at the same accuracy**	**Volume increase at the same accuracy**
Parallax	1.4	2.8
Proper motion	2.8	23

Parallax improvement

- At a given magnitude 40% improvement is achieved

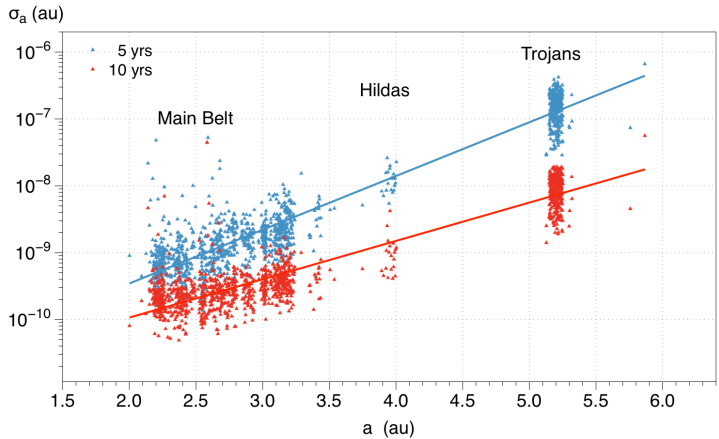
OR

- Same performance can be achieved for 0.5 mag fainter objects



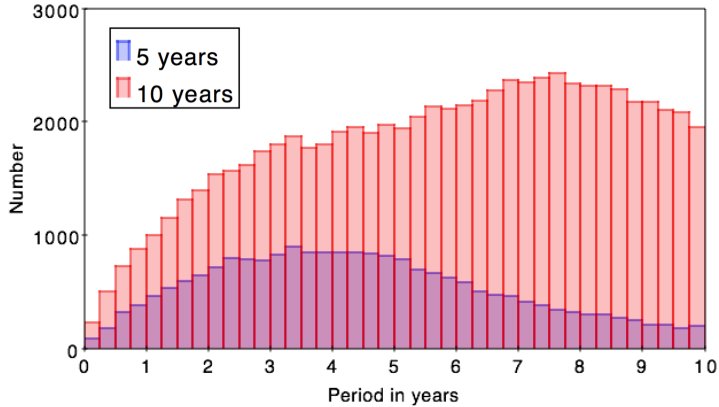
Solar system

- For the main belt asteroids, Hildas and Trojans the huge improvement is related to covering a larger fraction of the orbit
- Masses from close encounters
- Improvement of stellar catalogues allow re-calibration of old images and plates



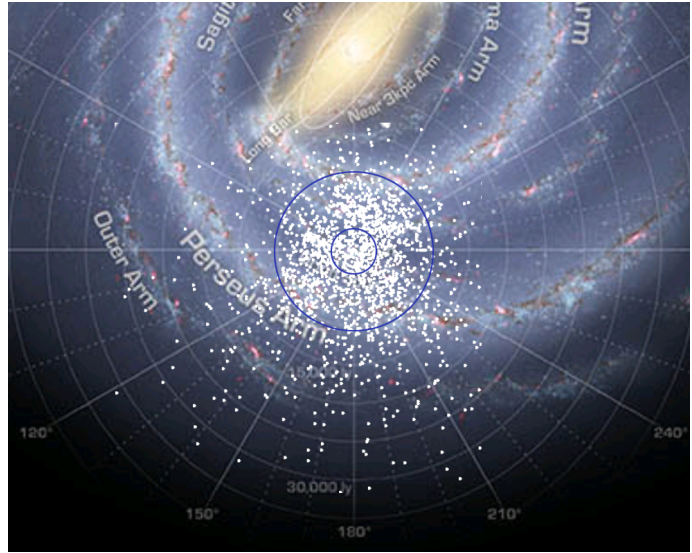
Exoplanets

- Gaia's strength is Neptune-Jupiter mass planets around stars
- Mission extension reveals population of giant planets above several AU distances from the parent star
  - giant planets before migration, systems with giant 'guarding' habitable zone
- Exoplanets research gains enormously from the improved parallaxes helping to describe the host star



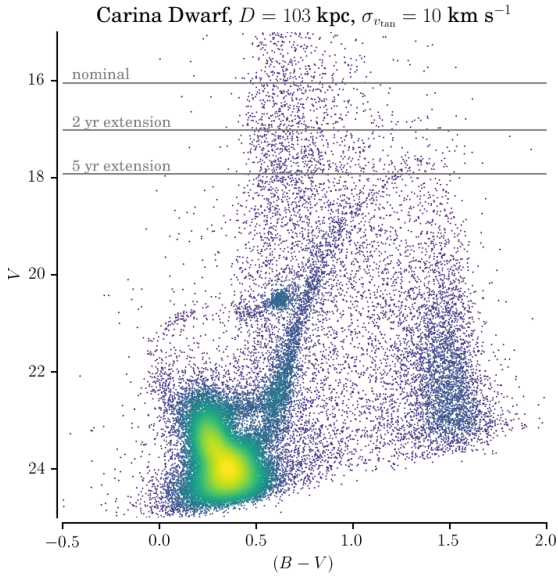
Stars and stellar clusters

- Factor $\sim$ 8 more clusters
- Reach inner and Perseus spiral arms
- Reach larger diversity of environments and cluster types
- Probe low stellar masses at larger distances



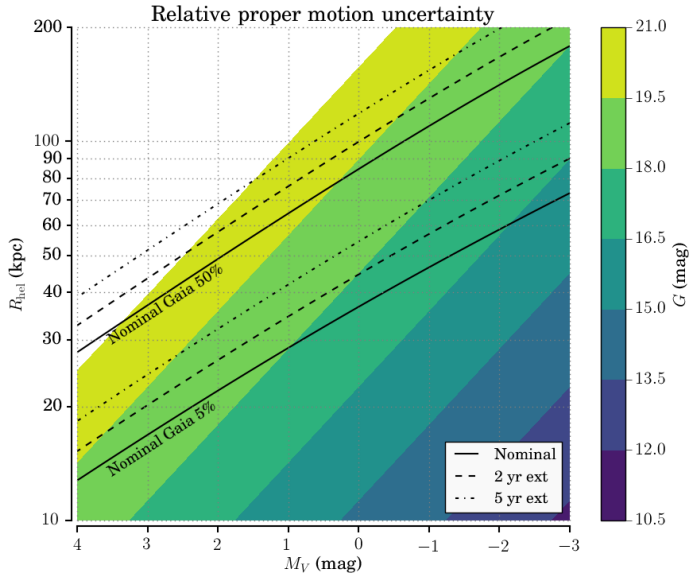
Structure and evolution of the Milky Way Galaxy

- Internal kinematics of local group galaxies
- Brightest populations in classical dwarf galaxies at $\sim$ 100 kpc only reachable with 5 yr extension



Structure and evolution of the Milky Way Galaxy

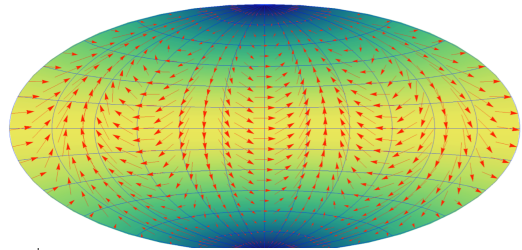
- Larger volume reached throughout the halo at given proper motion accuracy
- Tidal streams detection improvement
- Probe young and unmixed debris located beyond 20–30 kpc
- Calibration of photometric distance indicators on nearby samples ⇒ full gain in tangential motion performance

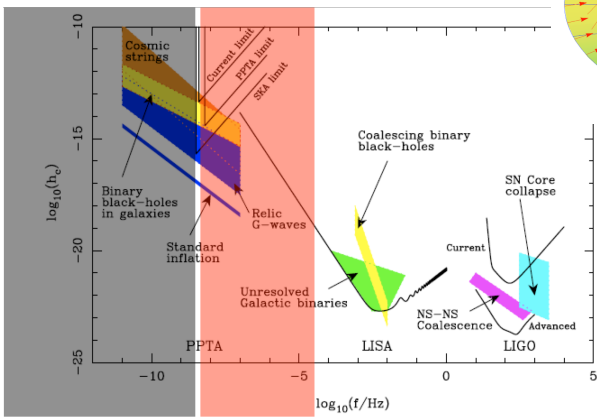


Fundamental physics

- Gravitational waves
  - Low to ultra-low frequency

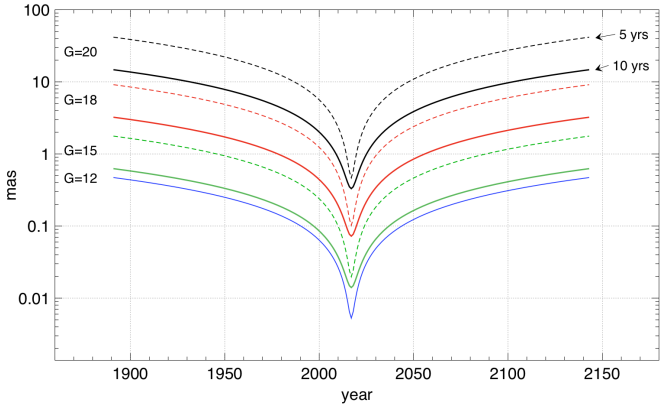
This is for a GW propagating in the direction δ=90°:





Reference frames

- Reference frame degradation is due to proper motion errors
- Mission extension improves proper motions quicker than parallaxes
- 30–40 m class telescopes reference frame
- Practically everything in the past limited by accuracy of reference stars will be limited by precision of the data itself



Other example science cases

- Near Earth Objects
- Variability of sources over decade time scale
- Double stars with 5–10 year orbits
- Distance ladder improvements with Cepheids and RR Lyrae
- Solar system (barycentre) motion around the Galactic centre
- Jupiter quadrupole moment

- Target selection and sample cleaning for exoplanet missions
- Euclid and LSST time overlap synergies

Your papers are the best argument for an extended mission

Gaia

- Please acknowledge the work by DPAC and ESA in your papers!
  - helps us argue the case for continued funding of the data processing
  - strengthens the mission extension case
  - `https://gea.esac.esa.int/archive/documentation/credits.html`


ESLAB #53
The Gaia Universe
8–12 April 2019
ESTEC, The Netherlands