Gaia Mission Extension

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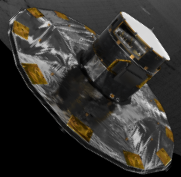
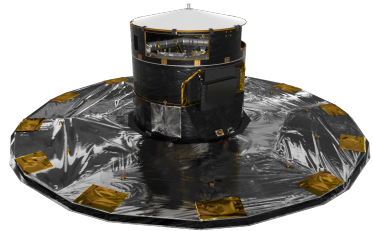


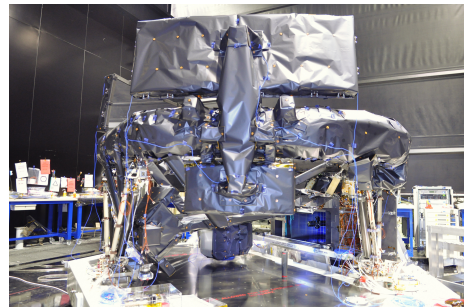
ESA/Gaia/DPAC

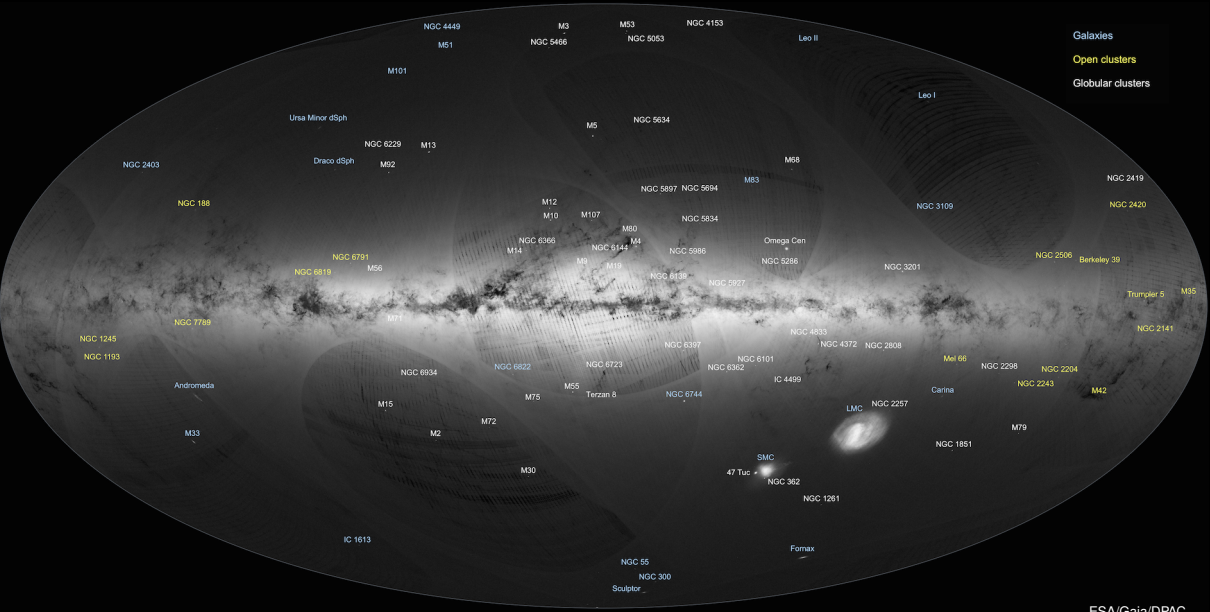
Gaia

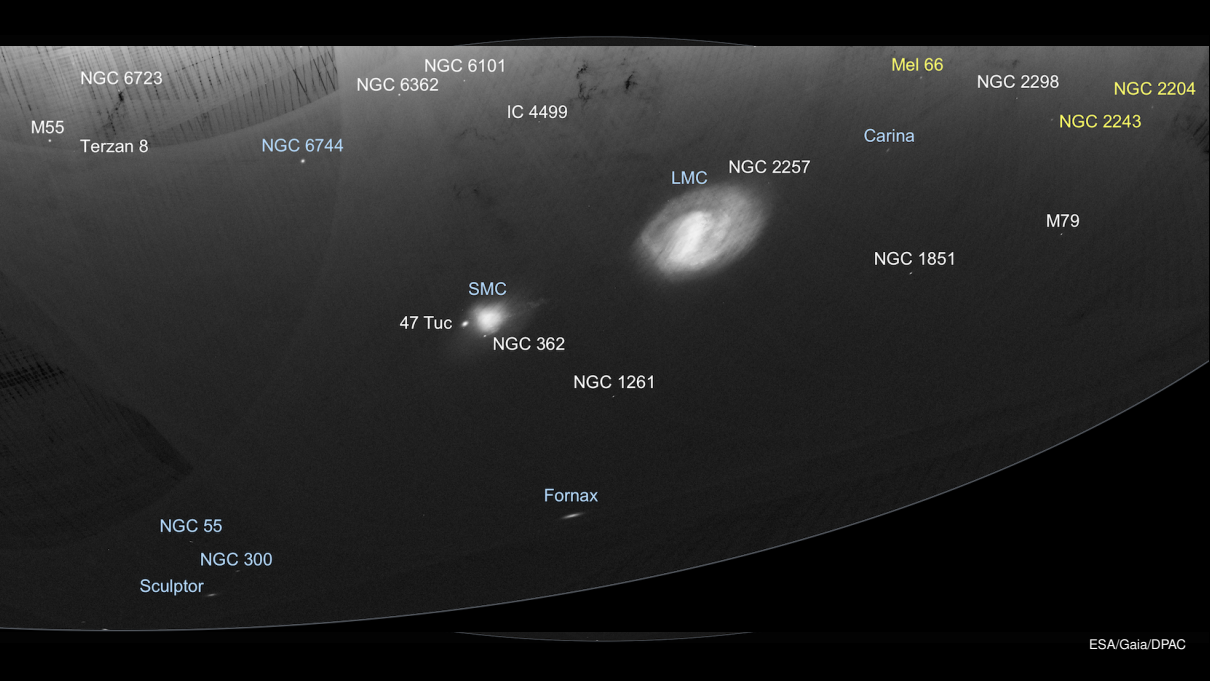
- Astrometry and spectrophotometry for >1 billion objects
- Radial velocities for >100 million objects
- Survey
  - Complete to $G = 20.7$ ($V = 20$–22)
  - Quasi-regular time-sampling over 5 years (~ 70 observations)
- Launch December 2013
- 5 years of operations at L2

- First data release Sep 2016
  - Gaia DR2 April 2018
- Photometric alerts started in 2014
- Alerts on new solar system objects started end 2016






Galaxies
Open clusters
Globular clusters
NGC 4449
M3
M53
NGC 4153
M51
NGC 5466
NGC 5053
Leo II
M101
Leo I
Ursa Minor dSph
M5
NGC 5634
NGC 6229
M13
NGC 2403
Draco dSph
M92
M68
M83
NGC 2419
NGC 5897
NGC 5694
NGC 188
M12
M10
M107
NGC 3109
NGC 2420
NGC 5834
M80
NGC 6366
M4
Omega Cen
NGC 6791
M14
NGC 6144
NGC 5986
NGC 2506
Berkeley 39
NGC 6819
M56
M9
M19
NGC 5286
NGC 3201
NGC 6138
NGC 5927
Trumpler 5
M35
M71
NGC 7789
NGC 4833
NGC 2141
NGC 1245
NGC 6397
NGC 4372
NGC 2808
NGC 1193
NGC 6822
NGC 6723
NGC 6362
NGC 6101
Mel 66
NGC 2298
NGC 2204
NGC 6934
IC 4499
Andromeda
M55
Terzan 8
NGC 6744
Carina
NGC 2243
M42
M75
LMC
NGC 2257
M15
M72
M79
M33
M2
NGC 1851
SMC
M30
47 Tuc
NGC 362
NGC 1261
IC 1613
Fornax
NGC 55
NGC 300
Sculptor
ESA/Gaia/DPAC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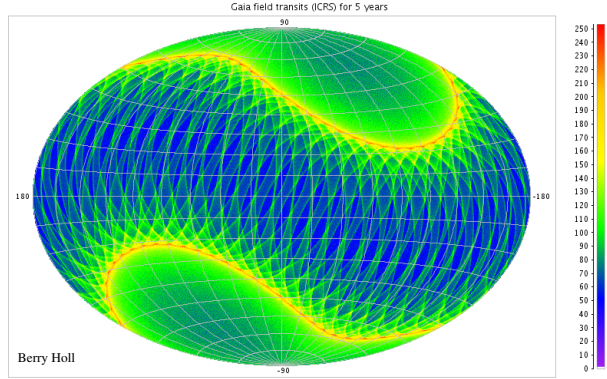
Gaia extension

- 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 mid 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 $t^{-4.5}$

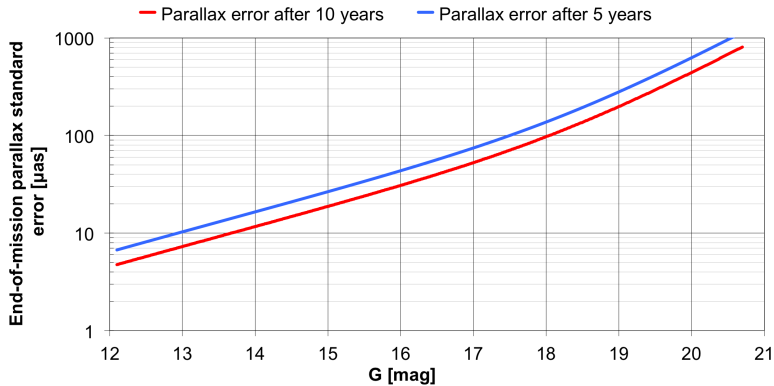
Improvement factor for mission length increase from 5 to 10 years	**Distance increase at the same accuracy**	**Volume increase at the same accuracy**
Parallax	1.4	2.8
Proper motion	2.8	23

Parallax improvement

- At a given magnitude 40% improvement is achieved

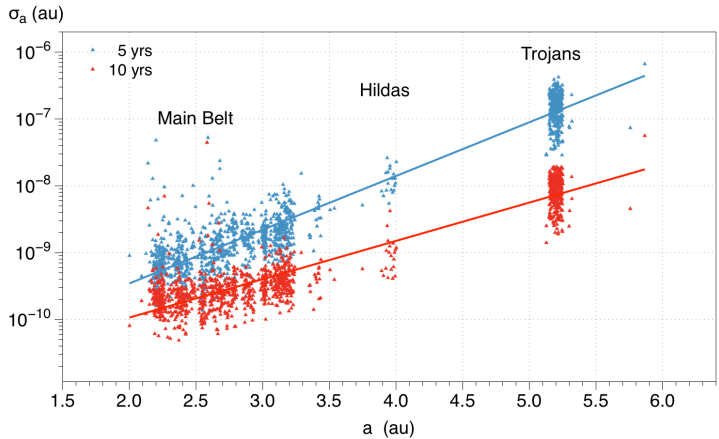
OR

- Same performance can be achieved for 0.5 mag fainter objects



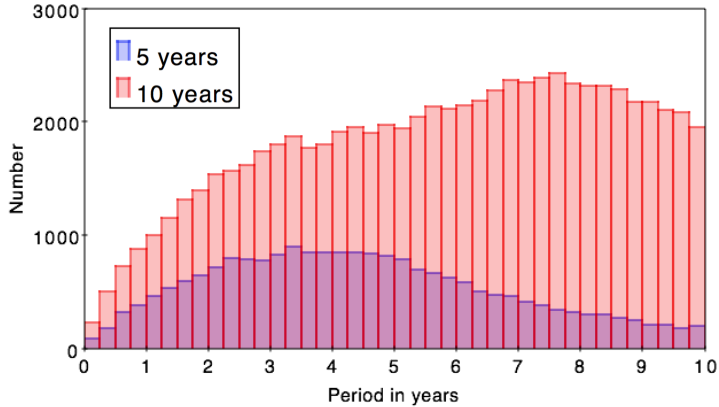
Solar system

- 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



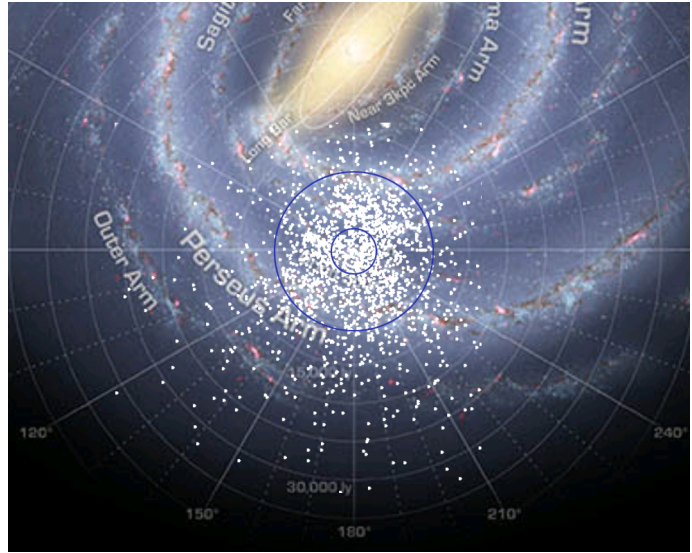
Exoplanets

- 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



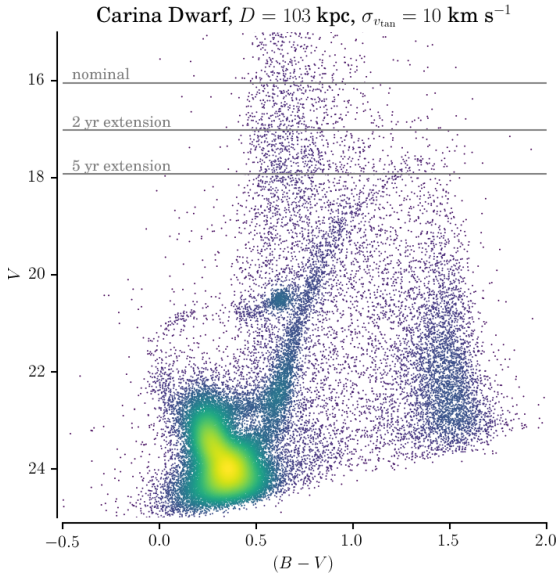
Stars and stellar clusters

- 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



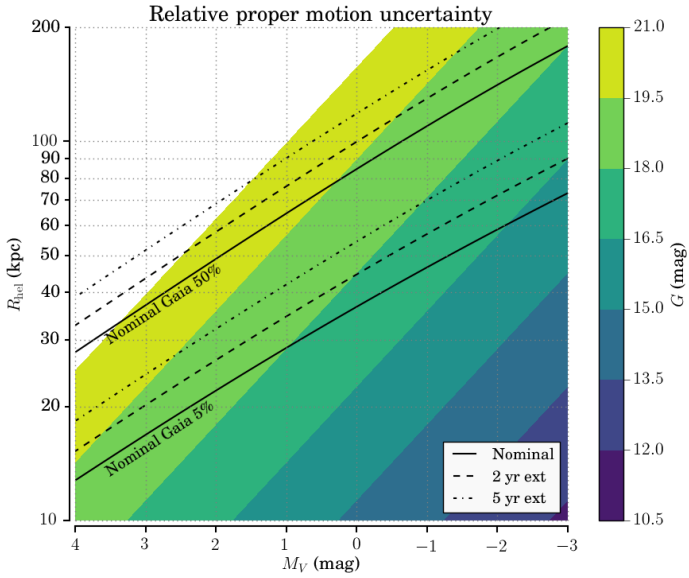
Structure and evolution of the Milky Way Galaxy

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



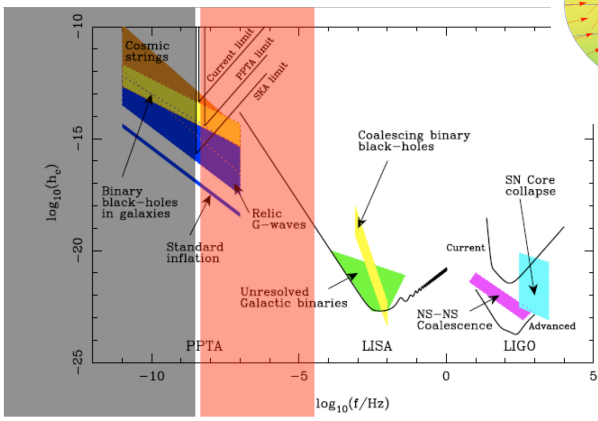
Structure and evolution of the Milky Way Galaxy

- 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

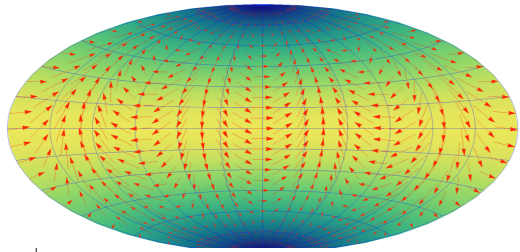


Fundamental physics

- Gravitational waves
  - Low to ultra-low frequency

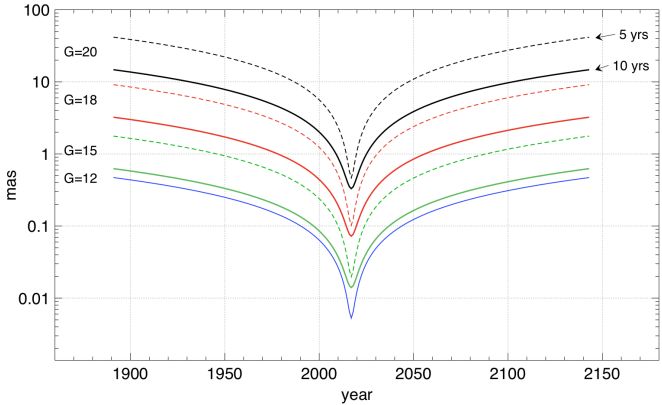


This is for a GW propagating in the direction δ=90°:



Reference frames

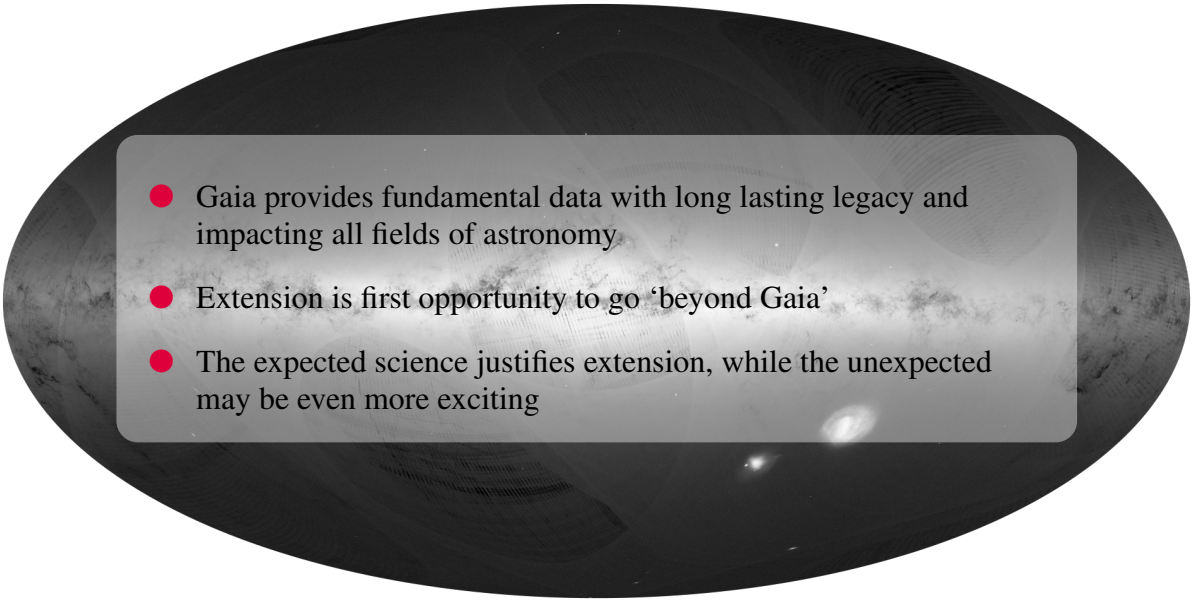
- Reference frame degradation is due to proper motion errors
- Mission extension improves proper motions quicker than parallaxes
- 30–40 m class telescopes reference frame
- Practically everything in the past limited by accuracy of reference stars will be limited by precision of the data itself



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 for exoplanet missions
- Euclid and LSST time overlap synergies



- Gaia provides fundamental data with long lasting legacy and impacting all fields of astronomy
- Extension is first opportunity to go ‘beyond Gaia’
- The expected science justifies extension, while the unexpected may be even more exciting