Gaia Mission Extension

Anthony Brown & Timo Prusti
Leiden Observatory & ESA
brown@strw.leidenuniv.nl
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
First data release Sep 2016
  - Gaia DR2 April 2018
Photometric alerts started in 2014
Alerts on new solar system objects started end 2016
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 $t^{-4.5}$

<table>
<thead>
<tr>
<th>Improvement factor for mission length increase from 5 to 10 years</th>
<th>Distance increase at the same accuracy</th>
<th>Volume increase at the same accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parallax</td>
<td>1.4</td>
<td>2.8</td>
</tr>
<tr>
<td>Proper motion</td>
<td>2.8</td>
<td>23</td>
</tr>
</tbody>
</table>
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 ~ 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 $\delta=90^\circ$: [Diagram of gravitational waves]
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.