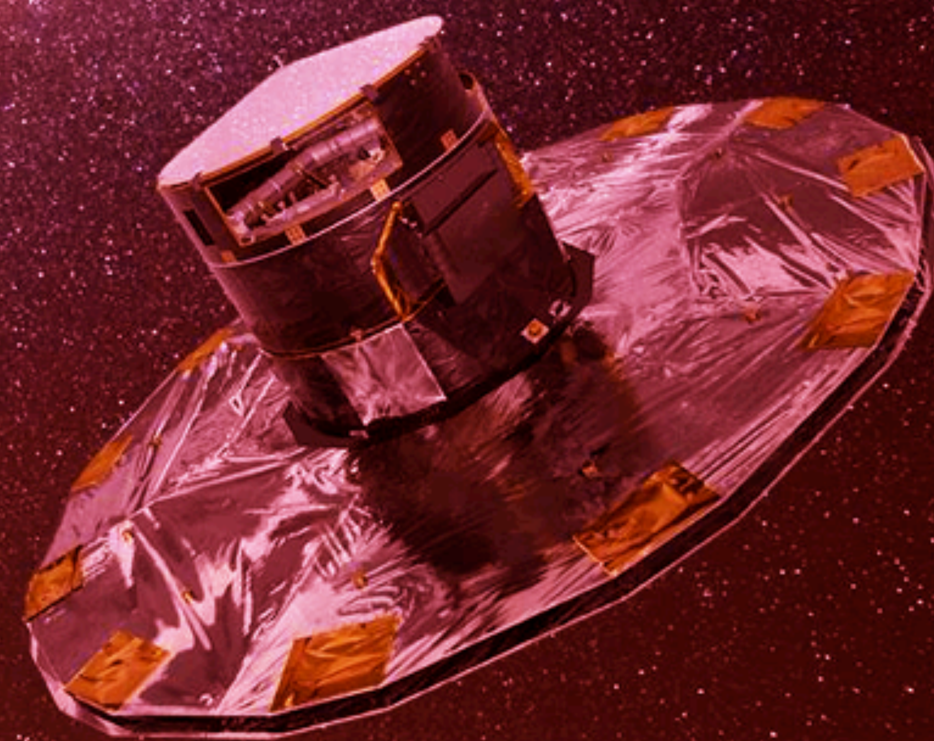
GaiaNIR

Future Space Astrometry



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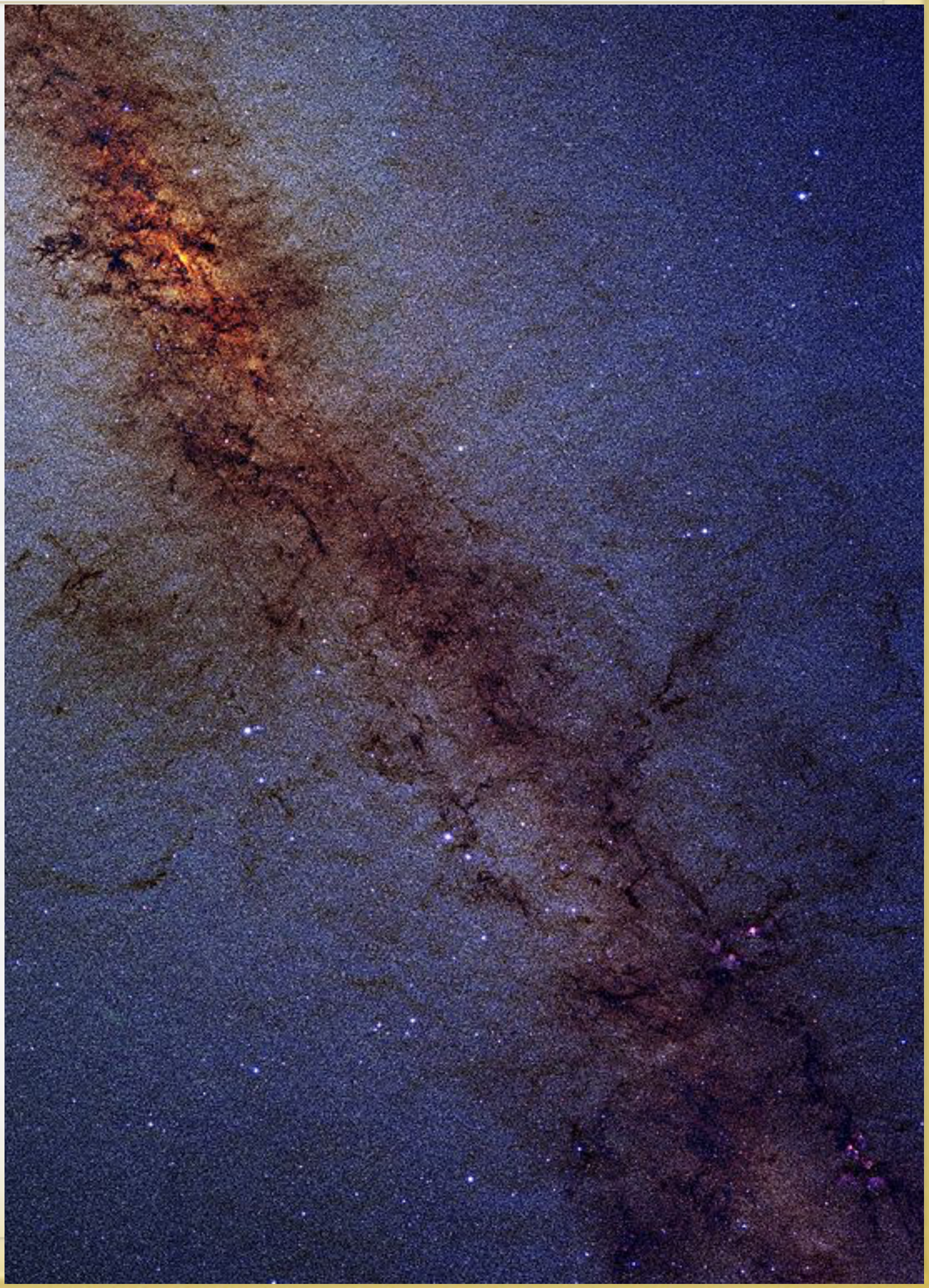
Which direction?

IR image from the Two Micron All-Sky Survey (image G. Kopan, R. Hurt)



Future space astrometry can move in several directions:

- All-sky (Gaia-like μas) but expand into NIR to study Galactic centre and spiral arms. Go deeper - LSST! Improved PMs of common stars from the long time baseline and expand RF to NIR.
- Pointed relative astrometry in NIR (e.g. small JASMINE) to add important regions to the Gaia catalogue such as the Galactic centre and spiral arms which are obscured by interstellar extinction.
- Pointed relative astrometry missions (SIM, NEAT, Theia, …), targeted ultra accurate (nas), aimed at answering specific questions on dark matter, exoplanets (e.g. exo-earths), etc.

Clearly there is overlap between science cases!

Global Gaia-like astrometry in the NIR can do more!

What will GaiaNIR observe?

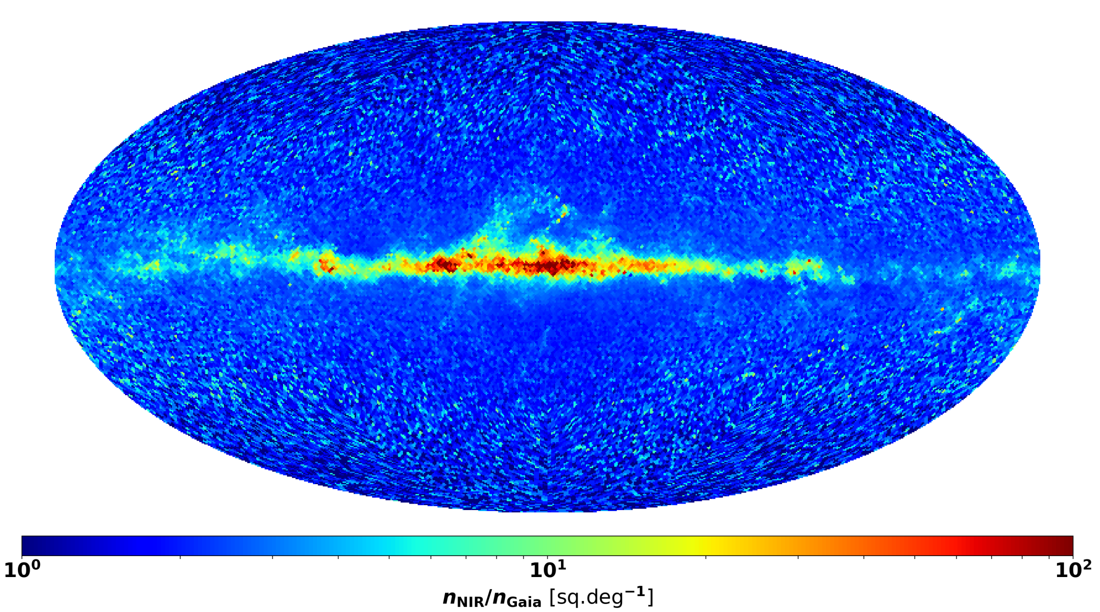
Left: Star count ratio between GaiaNIR and Gaia (G-band limit of 20.7th mag) gives 5 times more stars, especially in the disk for a H-band limit of 20th mag and 6 times more stars for a K-band limit of 20th mag. This implies about 10 or 12 billion sources for H or K-band cutoffs.

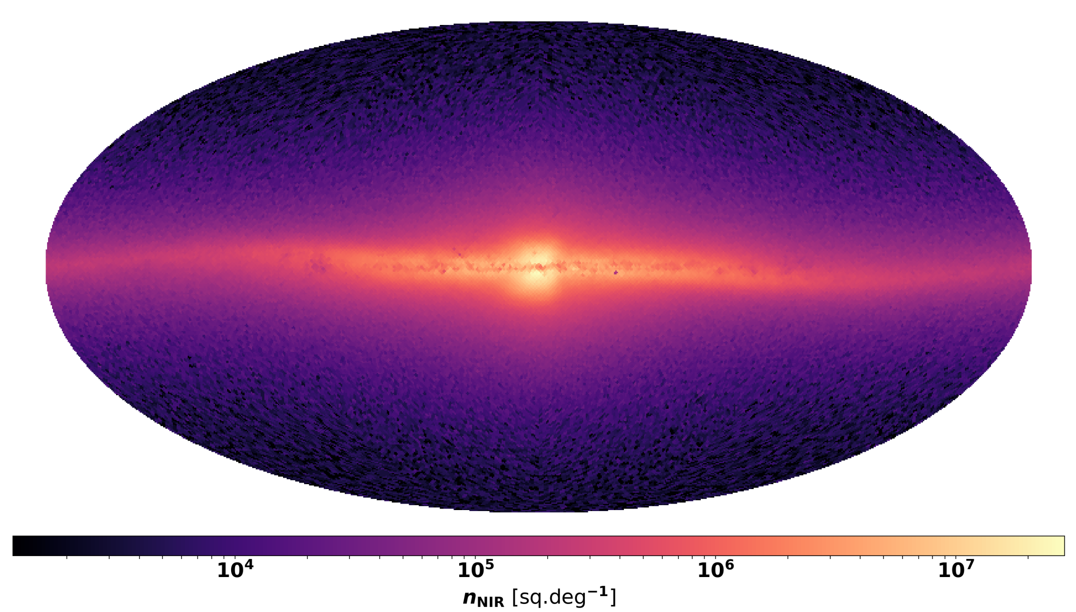
Right: Corresponding H-band number densities.

The star count ratio is uncertain due the extinction model used (older models a ratio of 3).

This uncertainty is a key science case in itself that cannot be resolved by Gaia alone.

GaiaNIR is not simply an increment on Gaia but will create an astrometric revolution in itself through 3 main science cases!

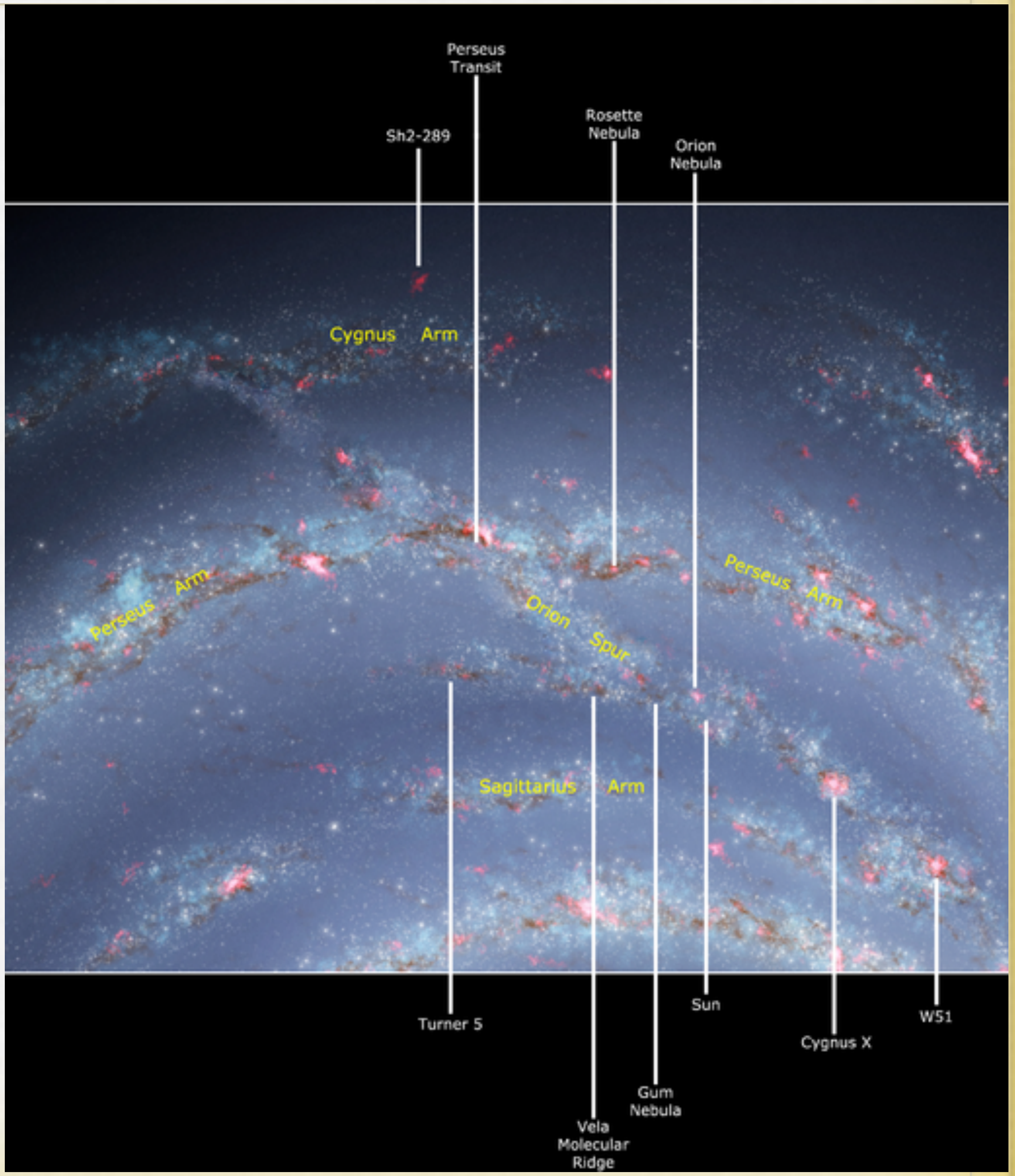




1. NIR Astrometry

- Dusty Bulge/bar region is dynamically important:
  - E.g. radial migration, bar perturbations of the bulge affecting DM density profile, etc.
- Unveil the inner disk which is not well known.
- Probe DM in the thin disc and spiral arms?
- Vastly improve measurements of rotation curve.
- Map in detail the dusty spiral arms for 1st time - astrometry for 100's of millions of objects.
- Study internal & bulk dynamics of young clusters.
- Many other science cases: brown dwarfs, M-dwarfs, cool white dwarfs, free floating planets, PL relations of red Mira's, etc.

All of this for up to ~8 billion stars!



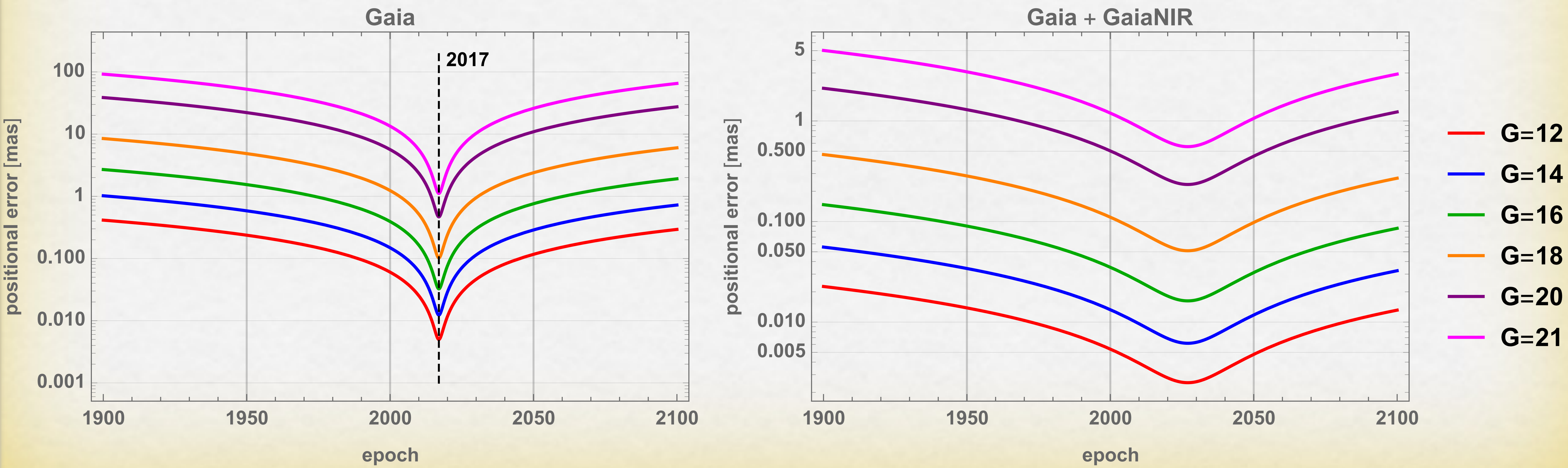
2. Improved Accuracy

- Improved PMs allow sub-structure in streams, dwarf galaxies and the Halo to be resolved.
- Better estimates of Galaxy mass and help resolve the cusped/flat dark matter Halo problem?
- Internal dynamics of local group galaxies, dwarf spheroids, globular clusters, LMC & SMC.
- Map the DM sub-structure in the local group.
- PMs of hyper-velocity stars to trace their origin and constrain triaxial models.
- Exoplanet & binary detectable period is 30 - 40 yr with Gaia + GaiaNIR (Saturn P=29 yr).
- Solar System orbits for >100,000 objects - greatly improved if based on 2 missions.

All of this for up to ~2 billion stars!

3. RF & Catalogue Ageing

- The RF degrades slowly (RF spin accurate to < 0.5 μas yr^{-1}) but other systematic PMs patterns will show up, e.g. Galactic-centric acceleration of ~4.3 μas yr^{-1}.
- The positional accuracy of the catalogue will degrade due to PM errors - requiring a new mission to update the catalogue.
- A strong science case is to expand the Gaia RF to the NIR increasing its density in obscured regions for use in future observational astronomy.
- Spin offs such as PM patterns and GW constraints are improved due to to better PMs



Degradation of the astrometric accuracy of the individual sources in the Gaia catalogue (left pane) and of the common solution using 10 years of Gaia and 10 years of GaiaNIR data (right pane), Image S. Klioner.

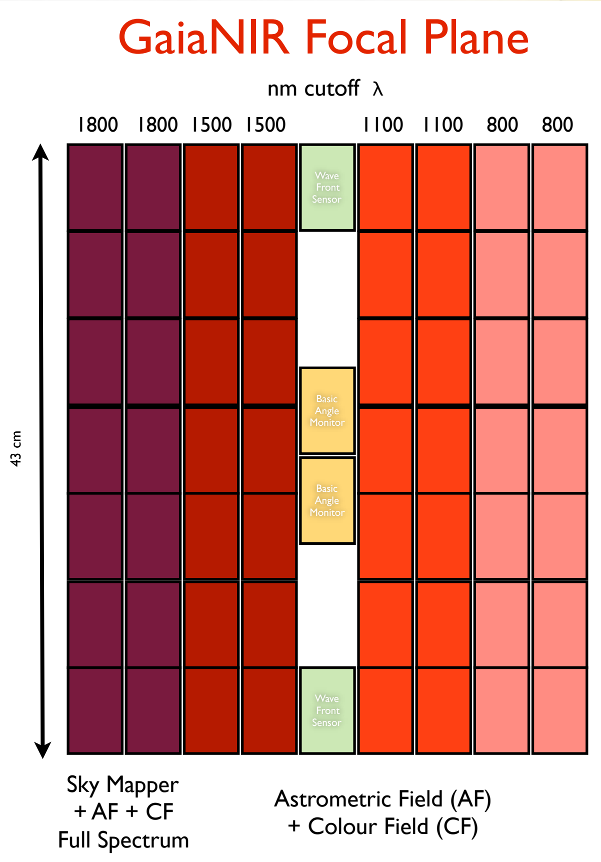
New Detectors

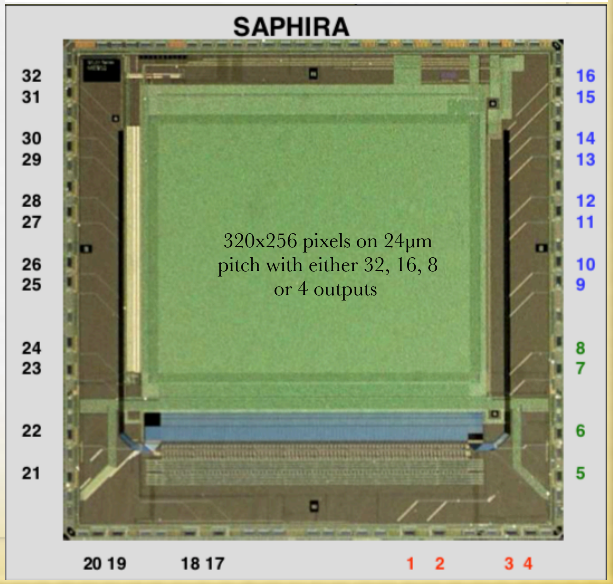
All-sky NIR astrometry needs new types of detectors:

- Both visible & NIR needed.
- GaiaNIR needs Time Delayed Integration (TDI) mode or similar to compensate for rotation.
- The challenge is how to scaled to them large format arrays at affordable prices?

For ASTRO-2020 four types of new technology have been identified:

- A hybrid solution with HgCdTe bump bonded to Si CCD - can electrons transfer without noise?
- HgCdTe e-APDs with TDI signal processing technology - scaled to large format arrays?
- Ge detectors sensitive to 1600 nm - very new and must scale further to large format detectors?
- MKID with high time resolution and TDI signal processing technology - require active cooling?





White Papers

- In 2016 ESA announced a call for new and innovative science ideas for future space missions.
- 26 proposals were received and 3 were selected for further study - including NIR global astrometry.
- In late 2017 ESA conducted a Concurrent Design Facility (CDF) study of our proposal and the results were published in early 2018.
- In 2019 a science and a technical white paper submitted to ASTRO-2020 for a US-EU collaboration on all-sky NIR astrometry.
- A Voyage 2050 science case white paper was submitted in August.
- ESA are currently inviting tenders for large format NIR detector technology development.

esa

CDF Study Report

GaiaNIR

Study to Enlarge the Achievements of Gaia with NIR Survey

gaia nir

GaiaNIR is an off-axis f=35m Korsch silliar to Gaia, but differs in:
Mirror surfaces are simple conics to simplify manufacturing.
Entrance pupil is at a flat folding mirror in front of the primary instead of on the primary mirror itself.

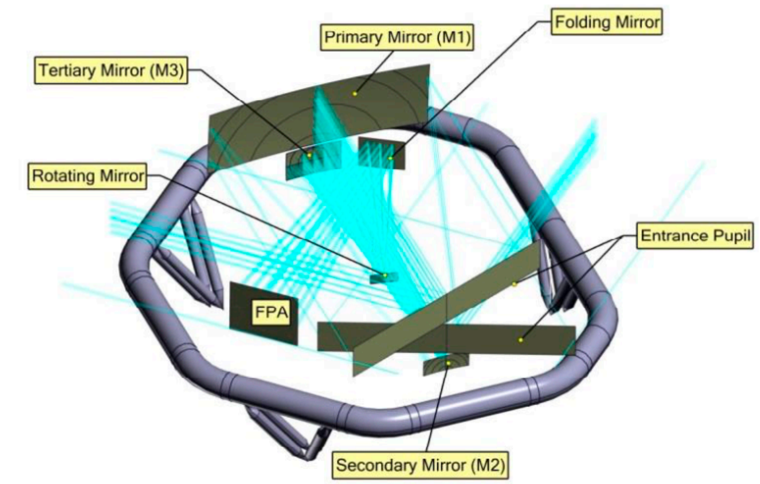


Figure 5-34: GaiaNIR optical surfaces and the light path