Gaia
Status, Astrometric Solution and Data Releases

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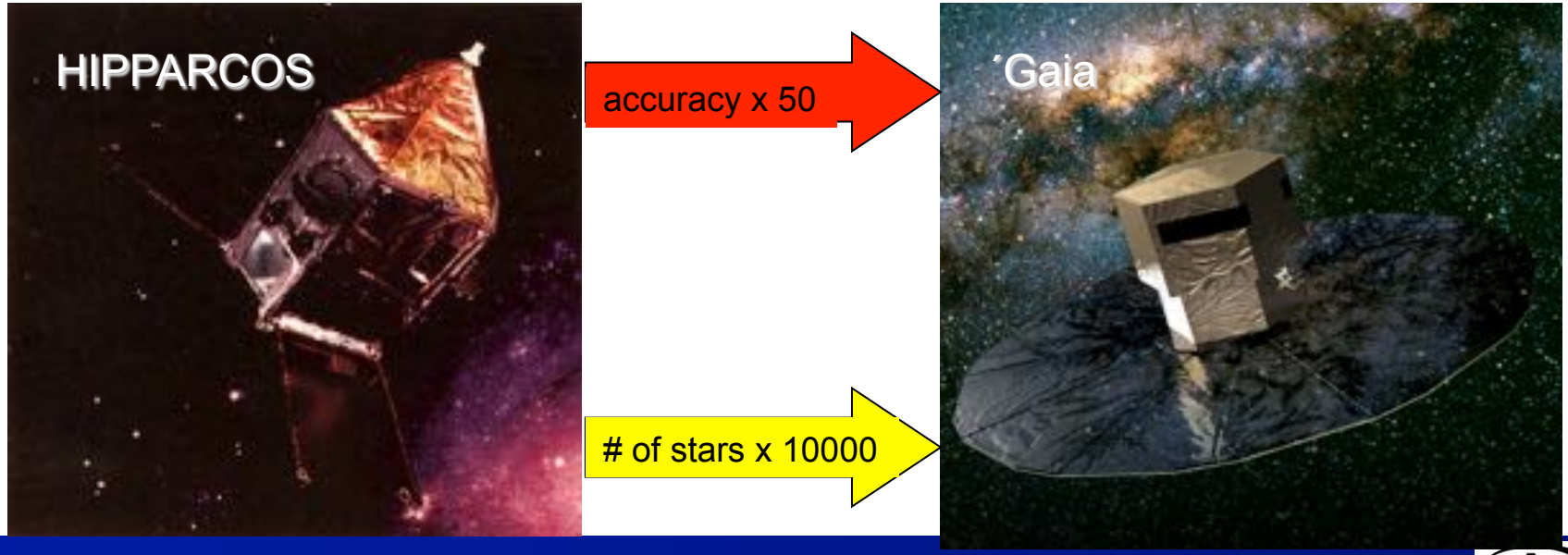
Gaia's Main Goals

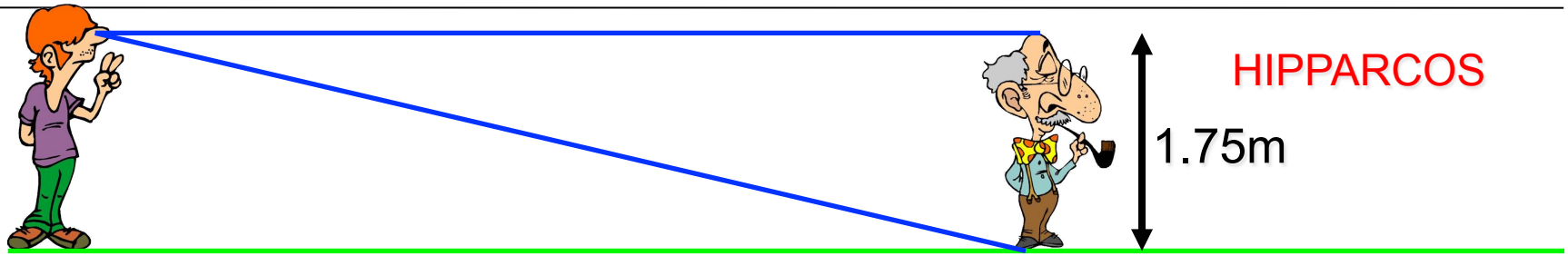
- Positions, proper motions and parallaxes for 1 billion stars
- All stars down to 20th (current limit actually 20.7) magnitude
- 20-25 microarcsecond accuracy at 15th magnitude
- Precise photometry (magnitudes and low-resolution spectra) for 1 billion stars
- High-resolution NIR IR spectra for 50-100 million stars (G<16.2)



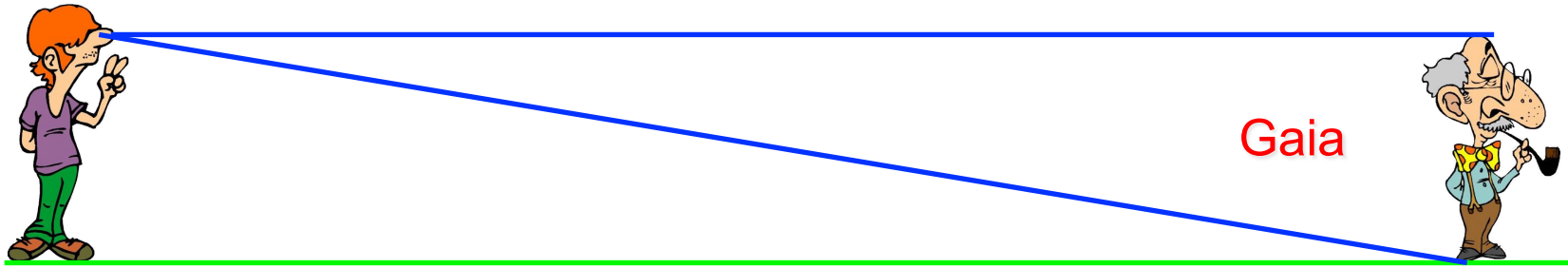
Gaia's schedule

- **1993:** First proposal to ESA
- **2000:** accepted as „Cornerstone Mission"
- **2006:** Begin of the industrial phase
- **2007:** Preliminary Design Review
- Several Reviews and hardware tests
- **Launch:** December 19, 2013
- **End of commissioning:** July 18, 2014
- **2019:** End of nominal measurements (5 years)
- **2022/23:** Publication of final catalogue?
- Intermediate catalogues will come: first one in late summer 2016

Parallaxes are small



380000 km: 1 milliarcsecond

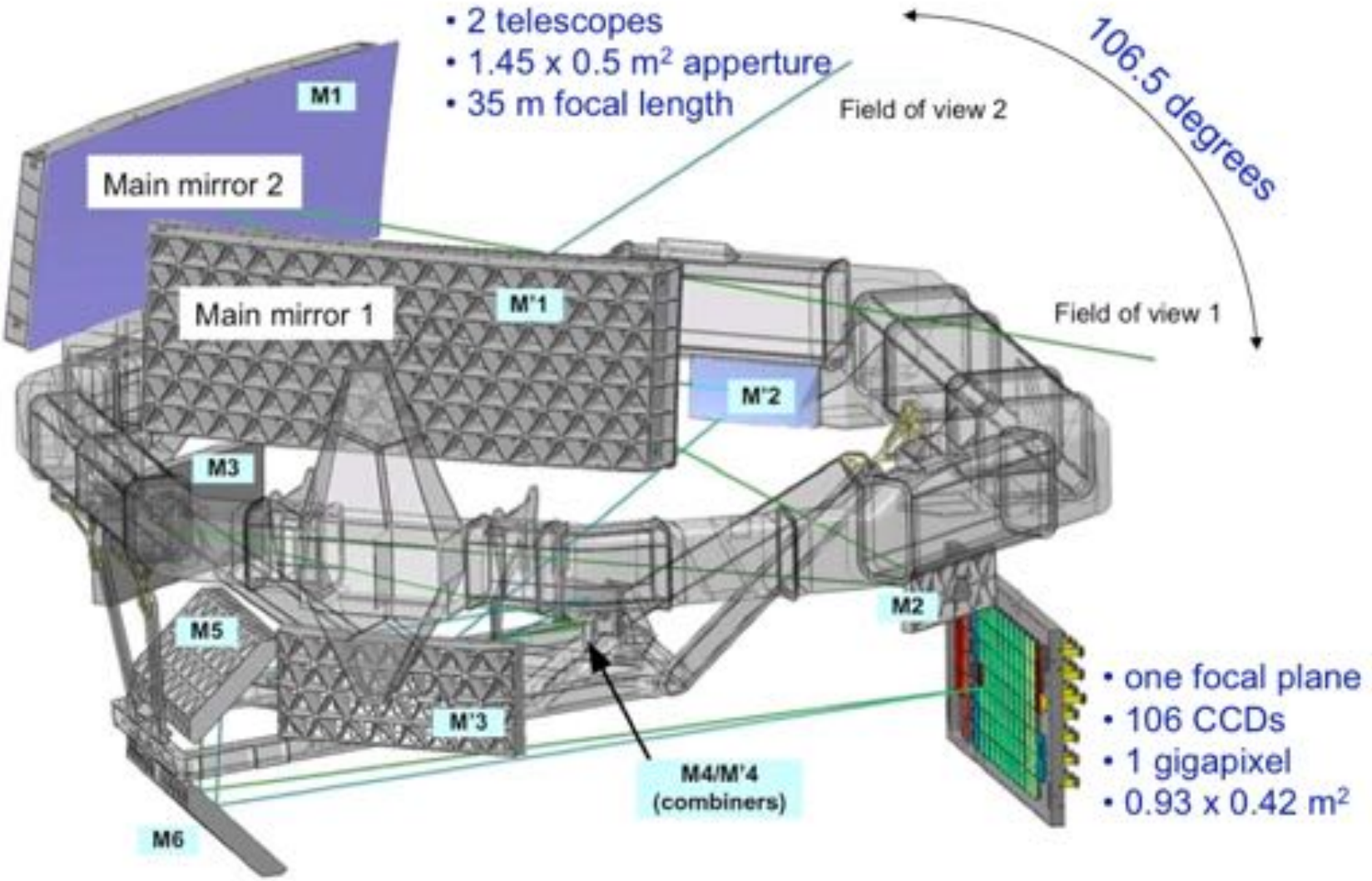


15 million km:
25 microarcsecond

$\sigma_\pi = 25\mu as$
at V = 15

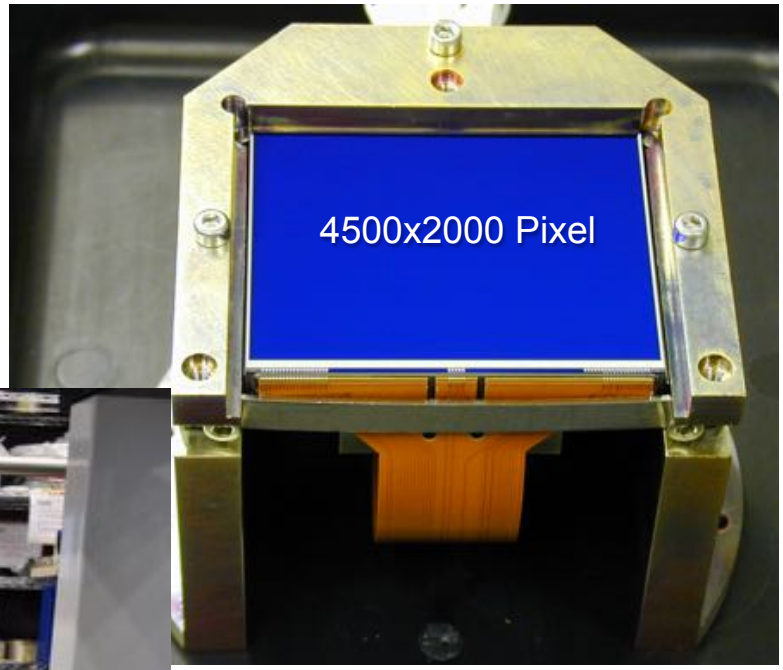
σ_π/π =	0.1%	d = 40 pc
σ_π/π =	1 %	d = 400 pc
σ_π/π =	10%	d = 4 kpc

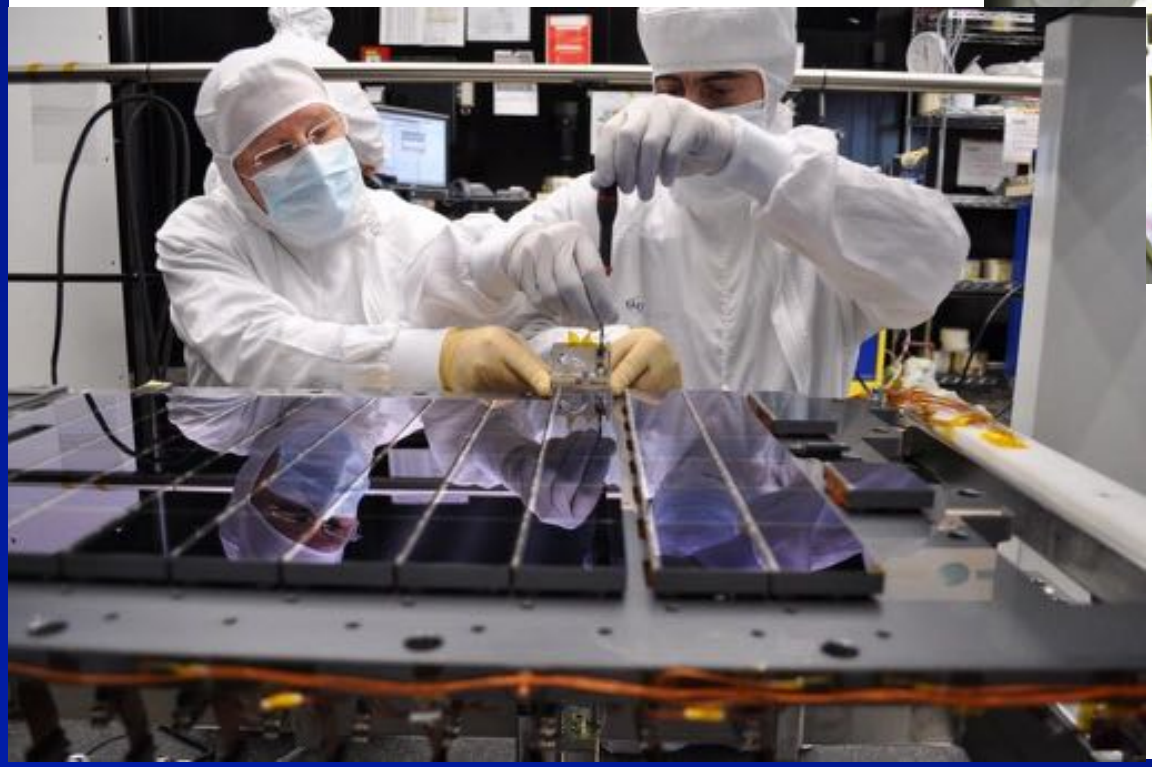
Gaia instruments



Gaia's One-giga-pixel Camera

106 CCD detektors

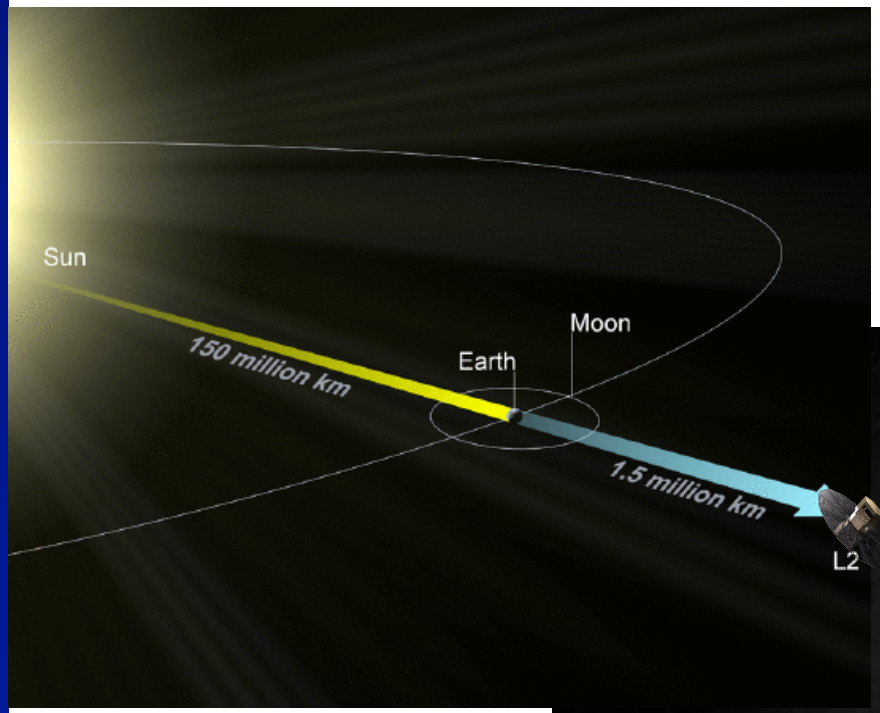




The launch

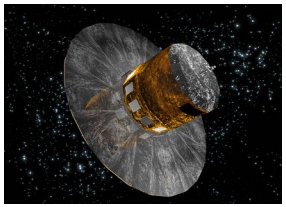
- **Soyuz-Fregat**
- 47 m high
- Sinnamary in French Guyana
- Launch date: 19. Dezember 2013

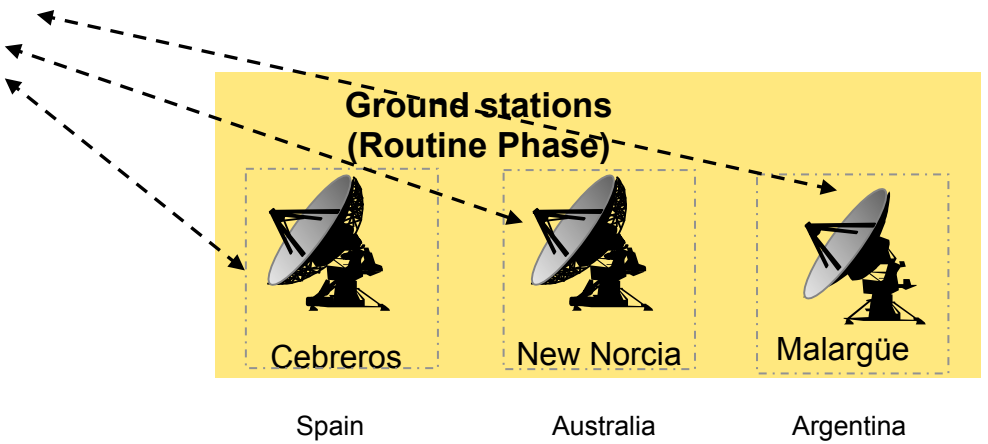
Flight to L2



Animation:
Toni Sagristà Sellés
(ARI/ZAH University
of Heidelberg)

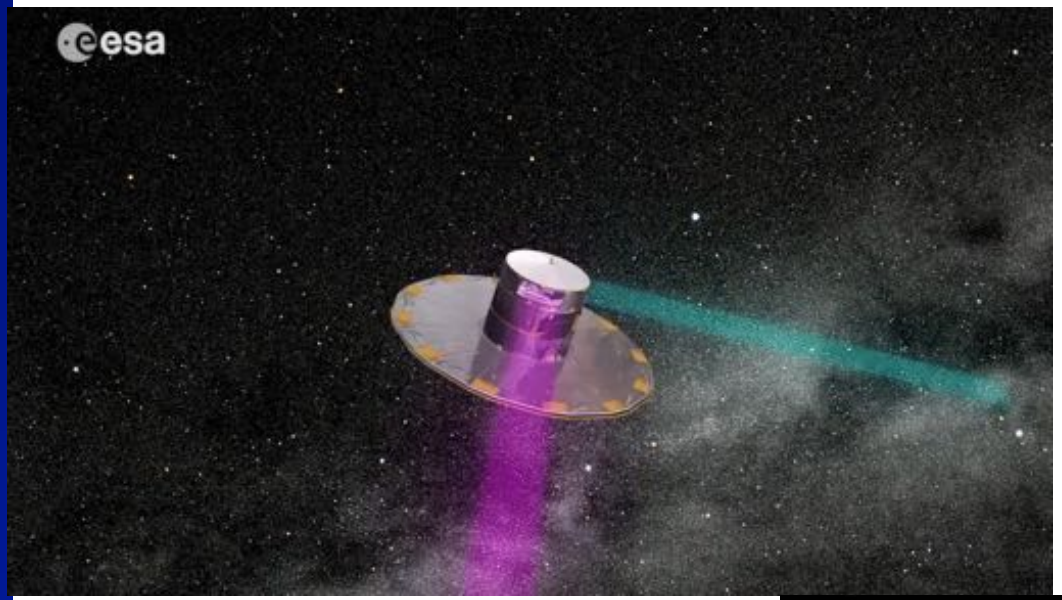
Communication to ground

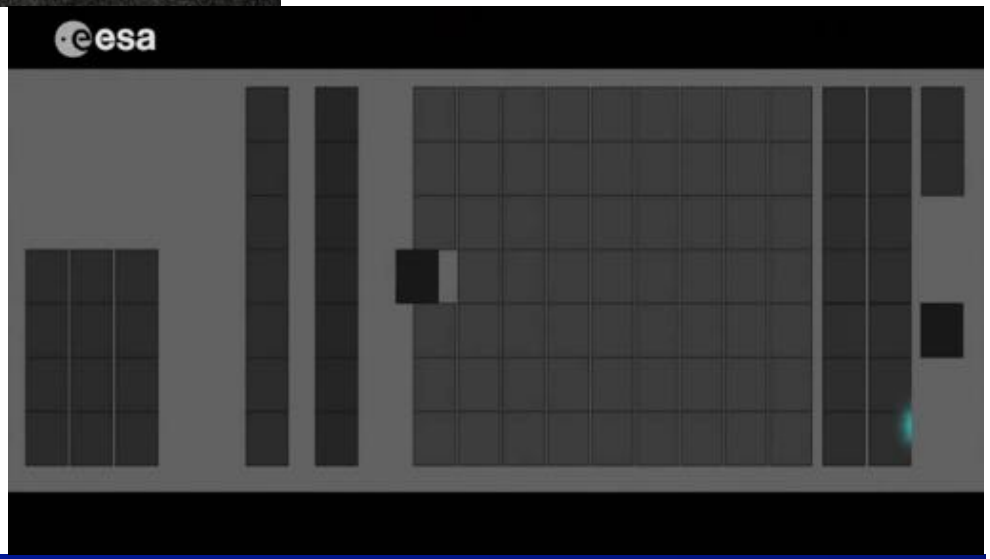




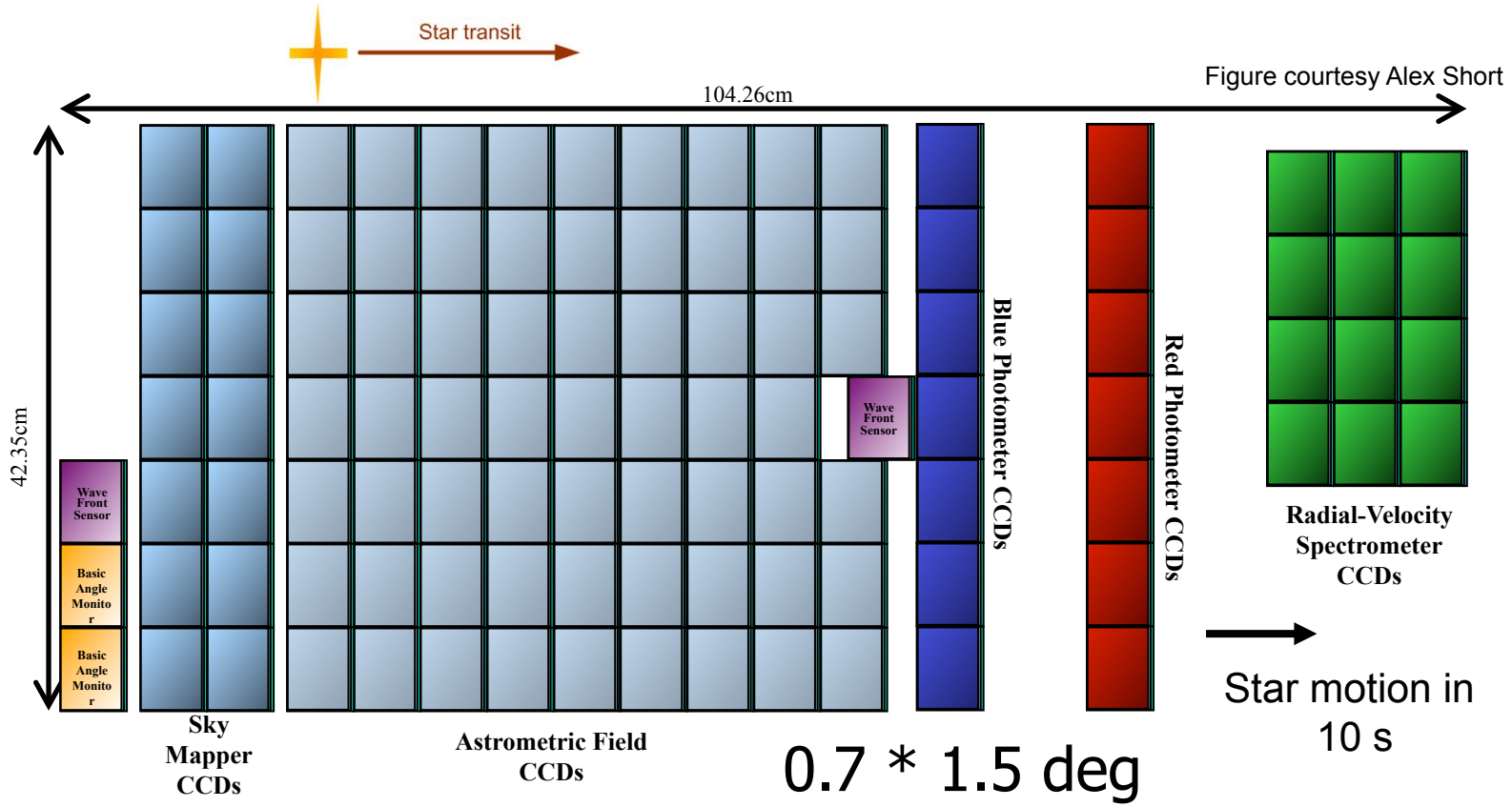
Telemetry:
3-8 Megabit per second

Scanning, Focal plane





Gaia 's focal plane



Total field:
- active area: 0.75 deg^2
- CCDs: 14 + 62 + 14 + 12
- 4500 x 1966 pixels (TDI)
- pixel size = 10 µm x 30 µm = 59 mas x 177 mas

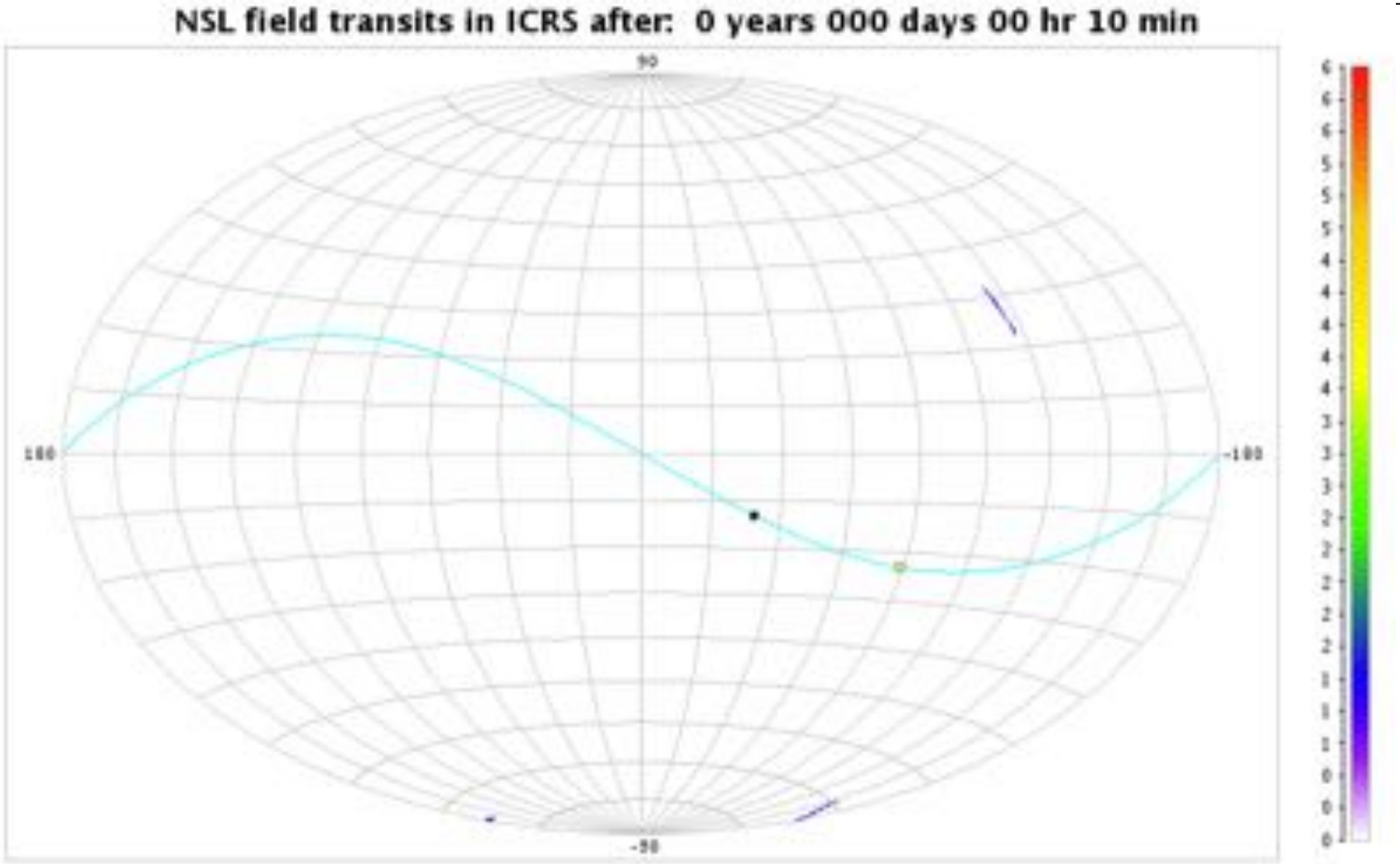
Sky mapper:
- detects all objects to 20 mag
- rejects cosmic-ray events
- FoV discrimination

Astrometry:
- total detection noise: 6 e$^-$

Photometry:
- two-channel photometer
- blue and red CCDs

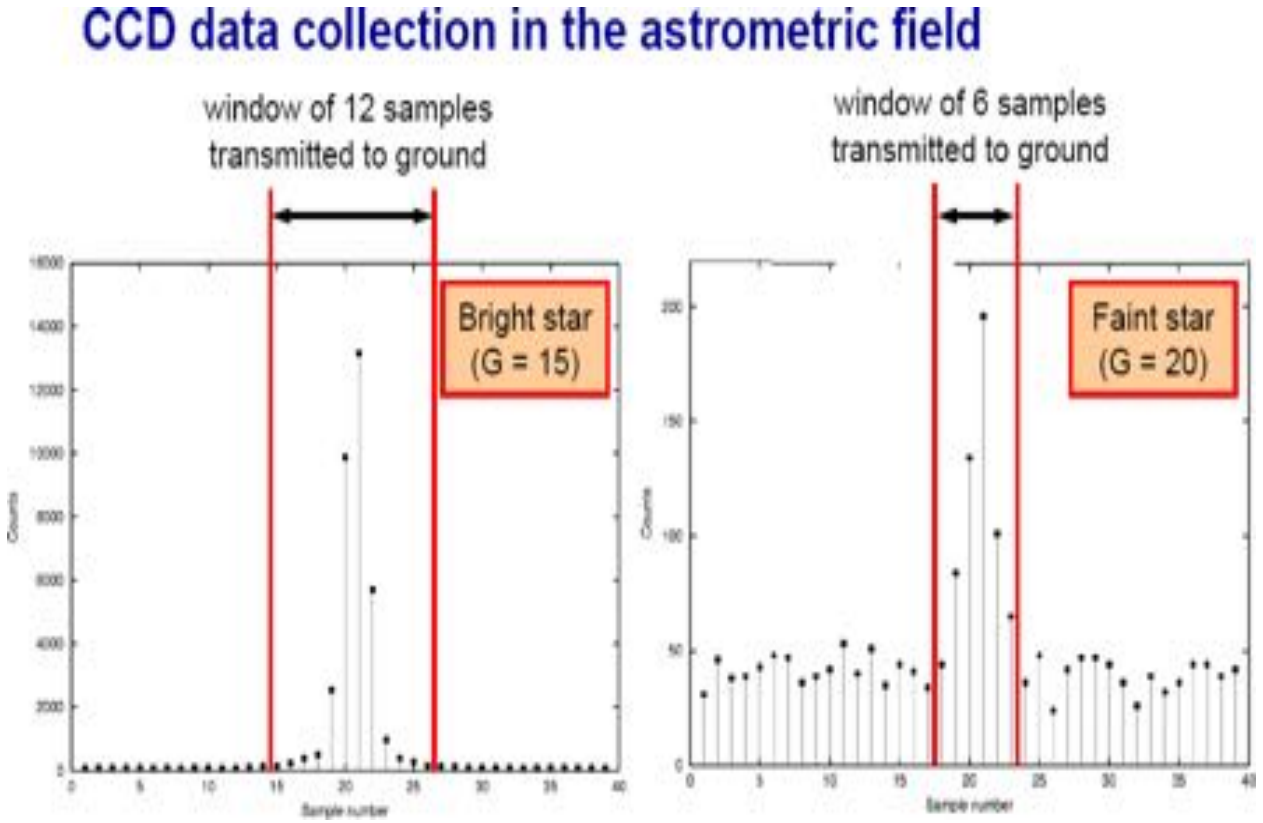
Spectroscopy:
- high-resolution spectra
- red CCDs

Scanning law



Animation: Berry Holl, Lund

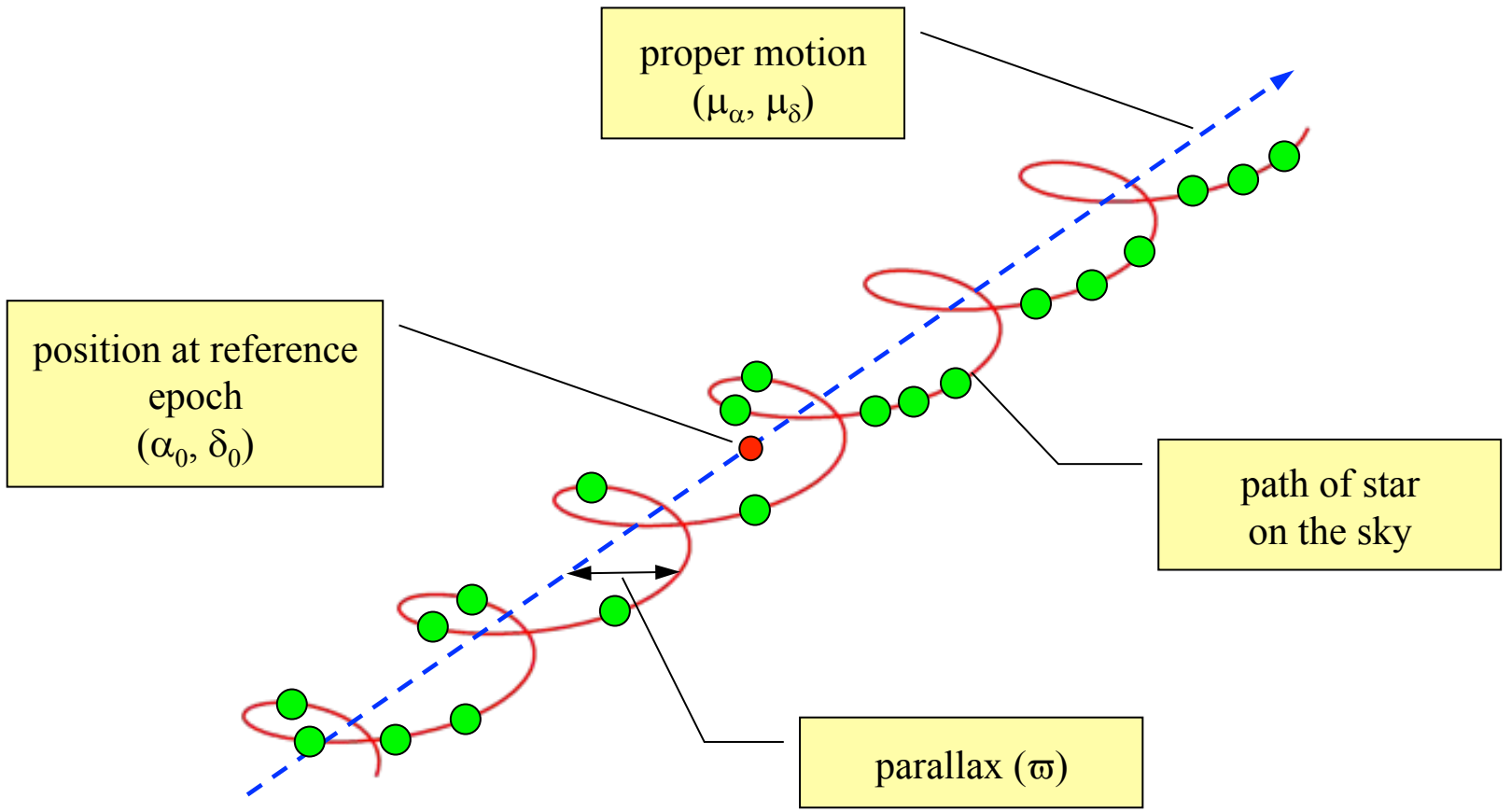
Elementary observations



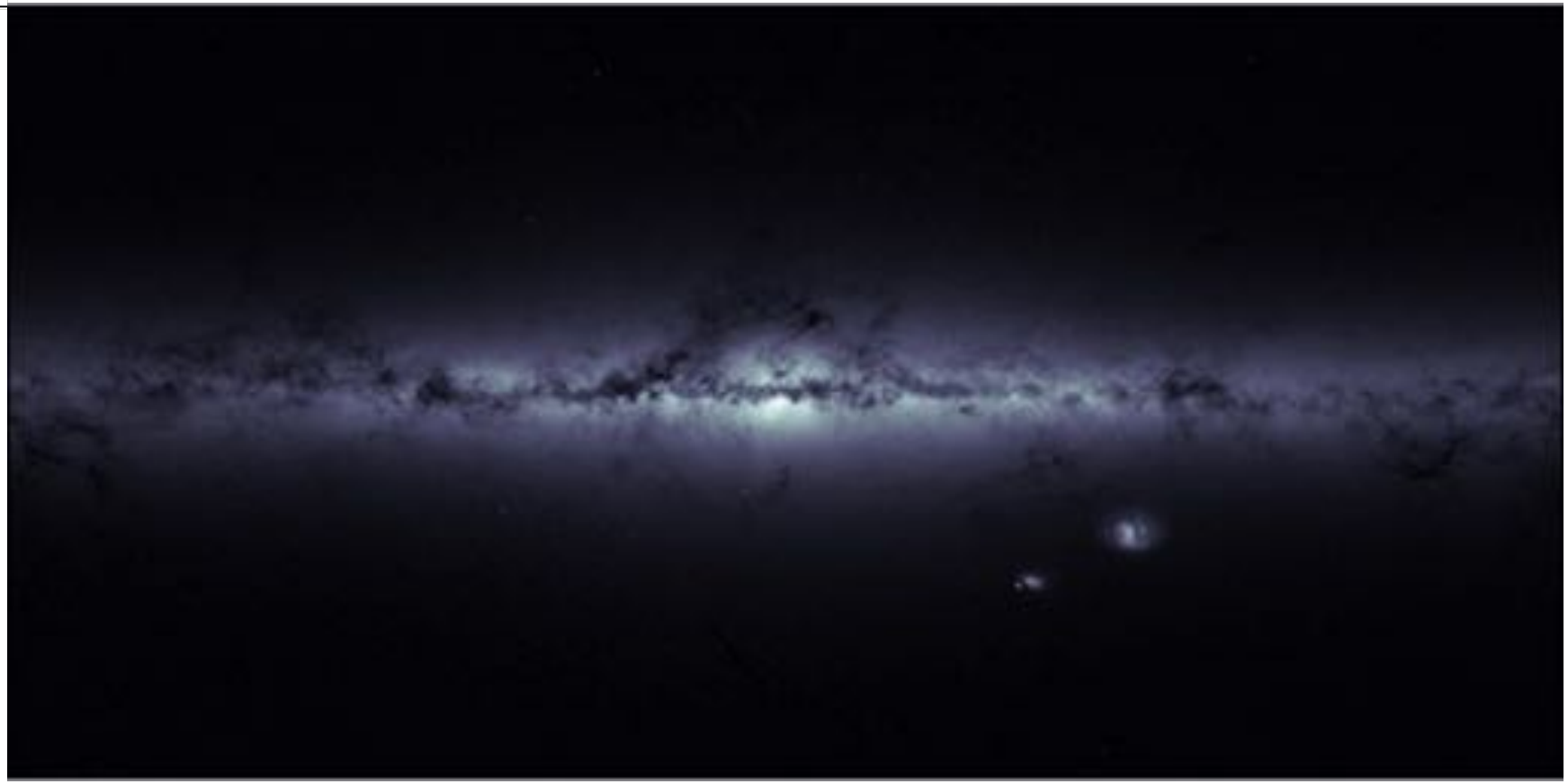
Lindegren

Over the mission, every source (star, QSO, asteroid, ...) will be observed
~ 600 times in the along-scan (AL) direction (timing data, *t*)
~ 70 times in the across-scan (AC) direction (pixel coordinate, *p*)
These are the "elementary astrometric observations" of the source

How do stars move?



Gaia in March 2016



- 378 billion positional or astrometric measurements
- 87.3 billion brightness or photometric data points
- 8 billion spectra.

Gaia 's data reduction problem

With the same accuracy with which Gaia

- measures position of stars,

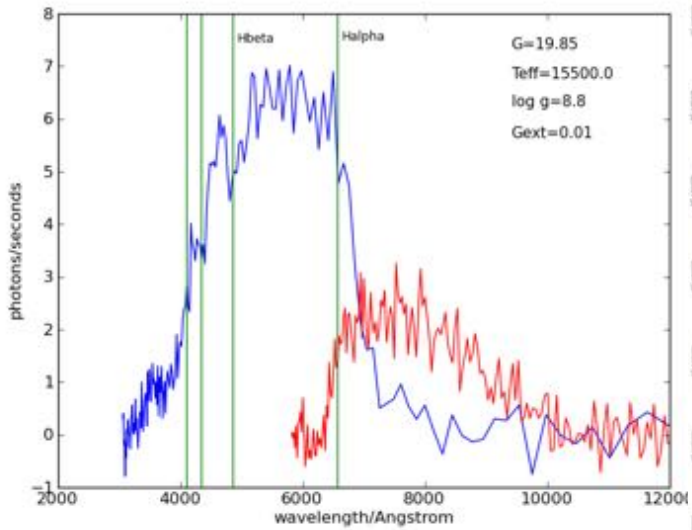
it is necessary to know

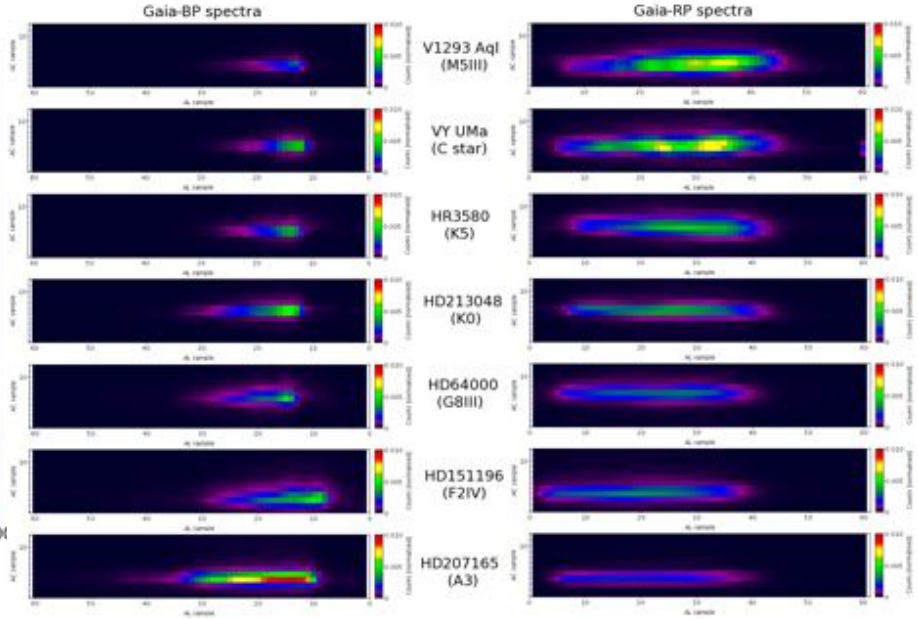
- where Gaia is pointing at (attitude), where Gaia is, how fast it is,

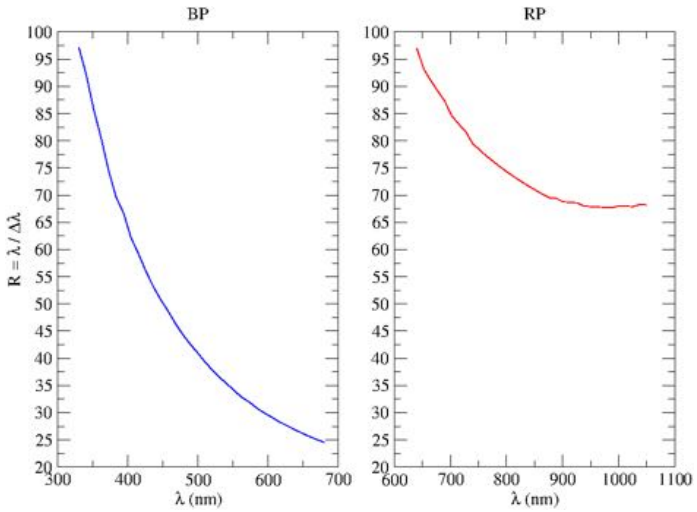
how exactly

- the optic and detectors are aligned
- and, whether Einstein was fully right!!

Blue and Red Photometer

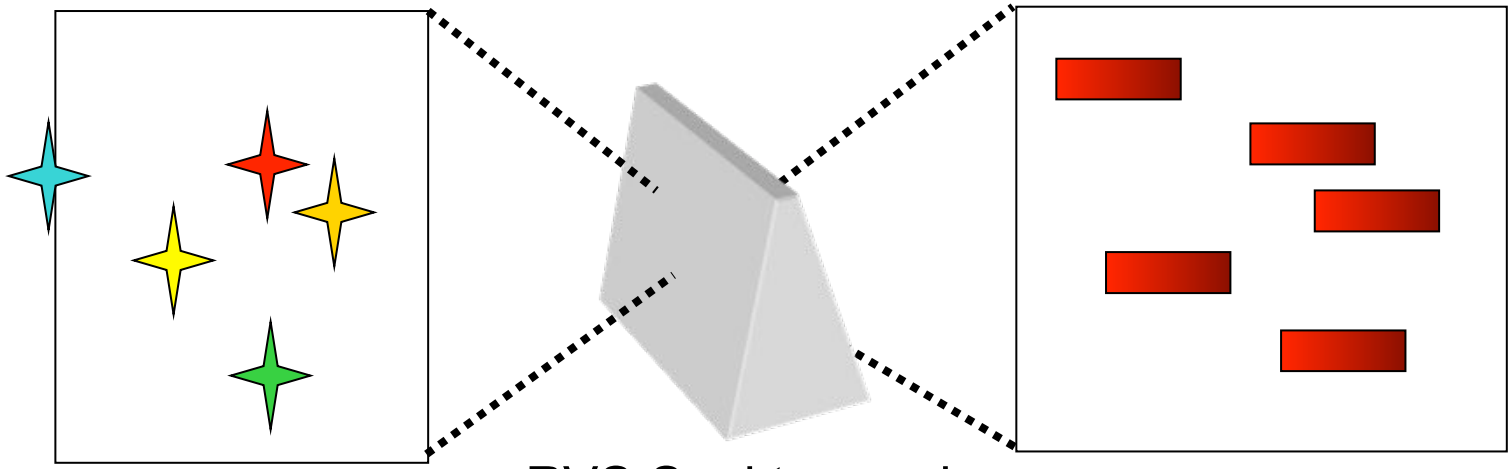


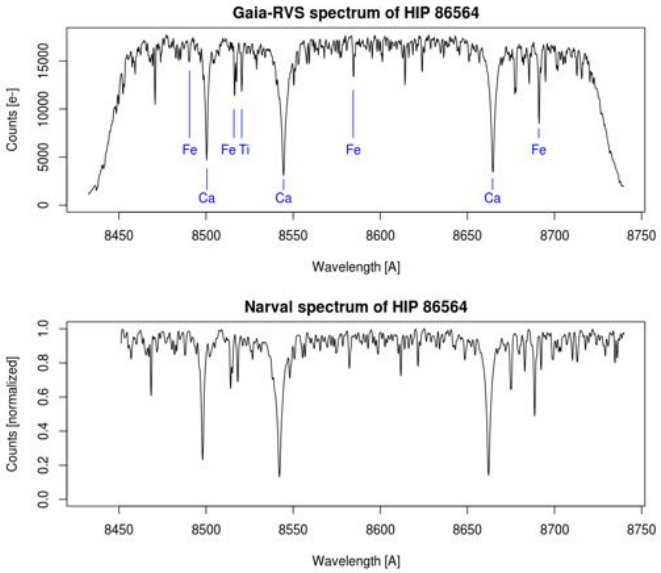




$\Delta\lambda/\lambda<100$

Radial-velocity Spectrograph





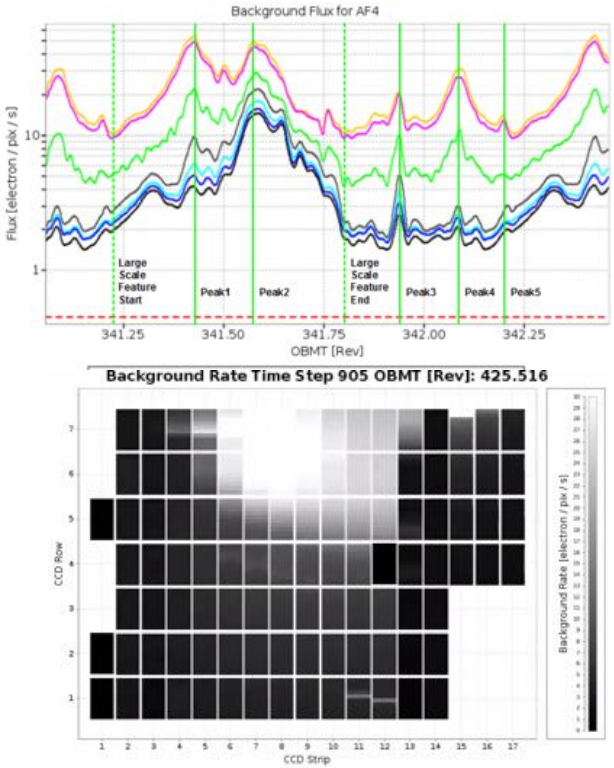
Single RVS spectrum of K5 star HIP 86563 (V=6.63) compared to a ground-based spectrum

$\Delta\lambda/\lambda=11500$

Discovery Machine

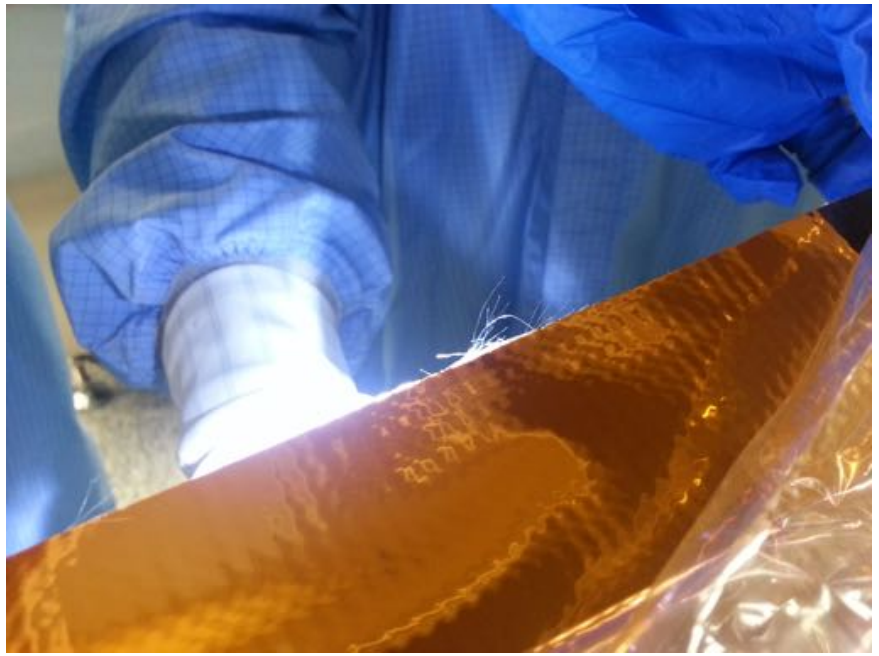
- 1-10 million new galaxies
- 5 million new quasars
- 100000 supernovae in other galaxies
- Some thousand new asteroids
- 100 million new double stars
- 400000 new white dwarfs
- A few hundred new brown dwarfs
- 21000 (±6000) new planetary systems?

Excessive Straylight



- Diffracted sunlight
- Milky Way
- Bright point objects

1. Sunshield
2. Insufficient baffling



A flight-spare blanket of the Gaia sun shield lit with a torch from the back to enhance the effect of scattered light from fibres protruding from the edge.

Contamination

After several decontamination with heaters the contamination with water ice has become very small.

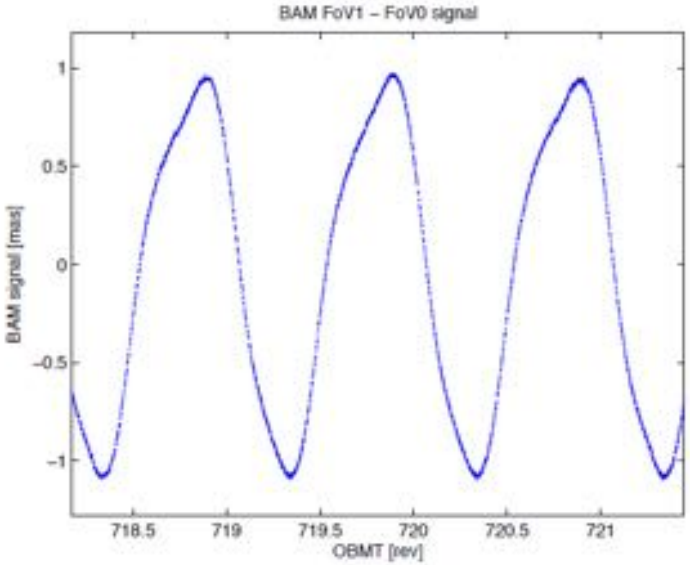
It is possible that no more decontaminations are necessary.

Cyclic Variation of the Basic Angle

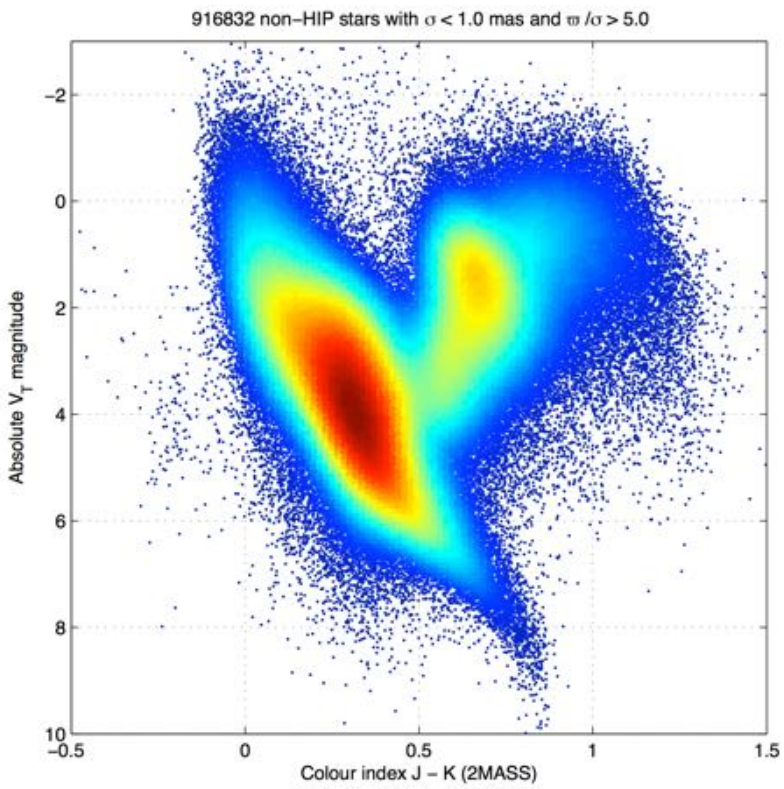
- The basic angle varies with a period of 6 hours=rotation with respect to the Sun
- Amplitude: 1.1 milliarcseconds
- Specification: 4 microarcseconds
- Corresponds to a shift of only a few nanometers

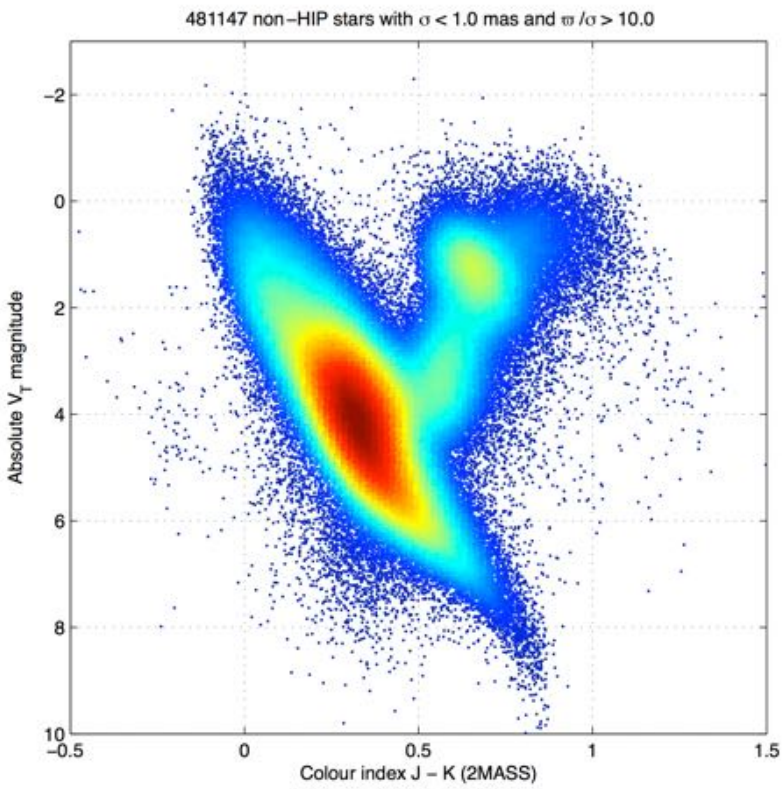
1 mas = $5 \cdot 10^{-9}$ rad < 4 nm
movement of the main-mirror edges ~ 10 Si atoms

(and even much less if it is a different mirror)
Noise: a dozen or so picometers!



HRD from TGAS





- Parallaxes from TGAS, photometry from Tycho 2 (V) and 2mass (J-K)
- Left: relative parallax errors smaller than 20%
- Right: relative parallax errors smaller than 10%

Astrometric performance

- http://www.cosmos.esa.int/web/gaia/science-performance
- The standard-error calculation includes all known instrumental effects
  - including the straylight levels
- Appropriate calibration errors are included.
- Warning: We are not yet fully calibrated!
- Every single-CCD observation is more precise than the end-of-mission precision of the Hipparcos catalogue (not in an absolute sense yet)!

	B1V	G2V	M6V
V-I_C [mag]	-0.22	0.75	3.85
Bright stars	5-14 μas (3 mag < V < 12 mag)	5-14 μas (3 mag < V < 12 mag)	5-14 μas (5 mag < V < 14 mag)
V = 15 mag	26 μas	24 μas	9 μas
V = 20 mag	600 μas	540 μas	130 μas

- Depending on how well this mode can be calibrated, end-of-mission parallax standard errors at the level of a few dozen μas could potentially be achieved for these stars.

Photometric performance

- End-of-mission photometric errors, in units of millimagnitude.
- 30 millimagnitude calibration error at CCD-level

	B1V			G2V			M6V		
G [mag]	G	BP	RP	G	BP	RP	G	BP	RP
15	1	4	4	1	4	4	1	7	4
18	2	8	19	2	13	11	2	89	6
20	6	51	110	6	80	59	6	490	24

Radial velocity performance

Spectral type	V [mag]	Radial-velocity error [km s^{-1}]
B1V	7.5	1
	11.3	15
G2V	12.3	1
	15.2	15
K1III-MP (metal-poor)	12.8	1
	15.7	15

Gaia's release schedule

- **http://www.cosmos.esa.int/web/gaia/release**
- **Late Summer 2016:** (α, δ) positions only, G magnitudes. TGAS catalogue for 2 million stars. Release of photometric Ecliptic Pole data for Cepheids and RR Lyrae stars.
- **2017:** Five parameter solution for single stars. Integrated BP/RP and AF photometry. Radial velocities for bright non-variable stars.

Gaia's schedule

- **2017/2018 (TBC):** Five parameter solution for single stars + orbital solutions for binaries with appropriate periods. Object classification, BP/RP spectra + RVS spectra for well behaving objects.
- **2018/2019 (TBC):** Additionally variable star classification, solar system objects, non-single star catalogue.
- **2022 (TBC):** "Final" catalogue.

End of talk