

Gaia

The Billion Star Surveyor

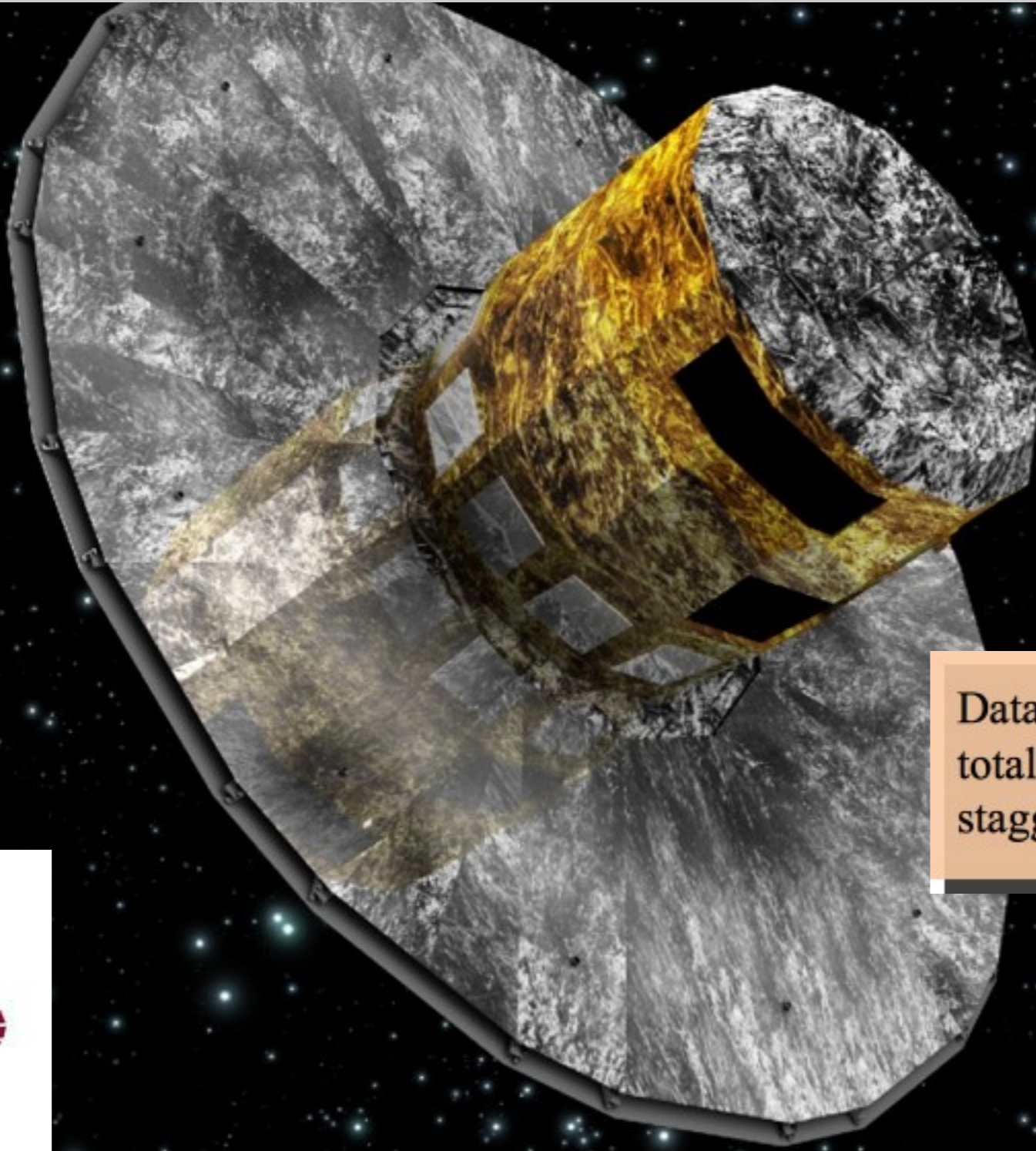
Hands on Astronomy Conference
Cardiff, 15 Apr 2015



Morgan Fraser

Institute of Astronomy, Cambridge

Gaia is transformational – the first 3-D galaxy
precision distances and motions for 1 billion stars
ESA's premier astrophysics mission of the decade



Launch:	12/2013
Work started:	1990
Project approved:	2000
Project end:	2023
Total cost:	960M€

Data flow: 50Gb/day for 5-6 years;
total processed data and archives: a
staggering 1 PetaByte



Why?

Taking the census of the Milky Way Galaxy

There is an elephant in the astrophysics room:
all distances depend on very few, inaccurate, stellar parallaxes

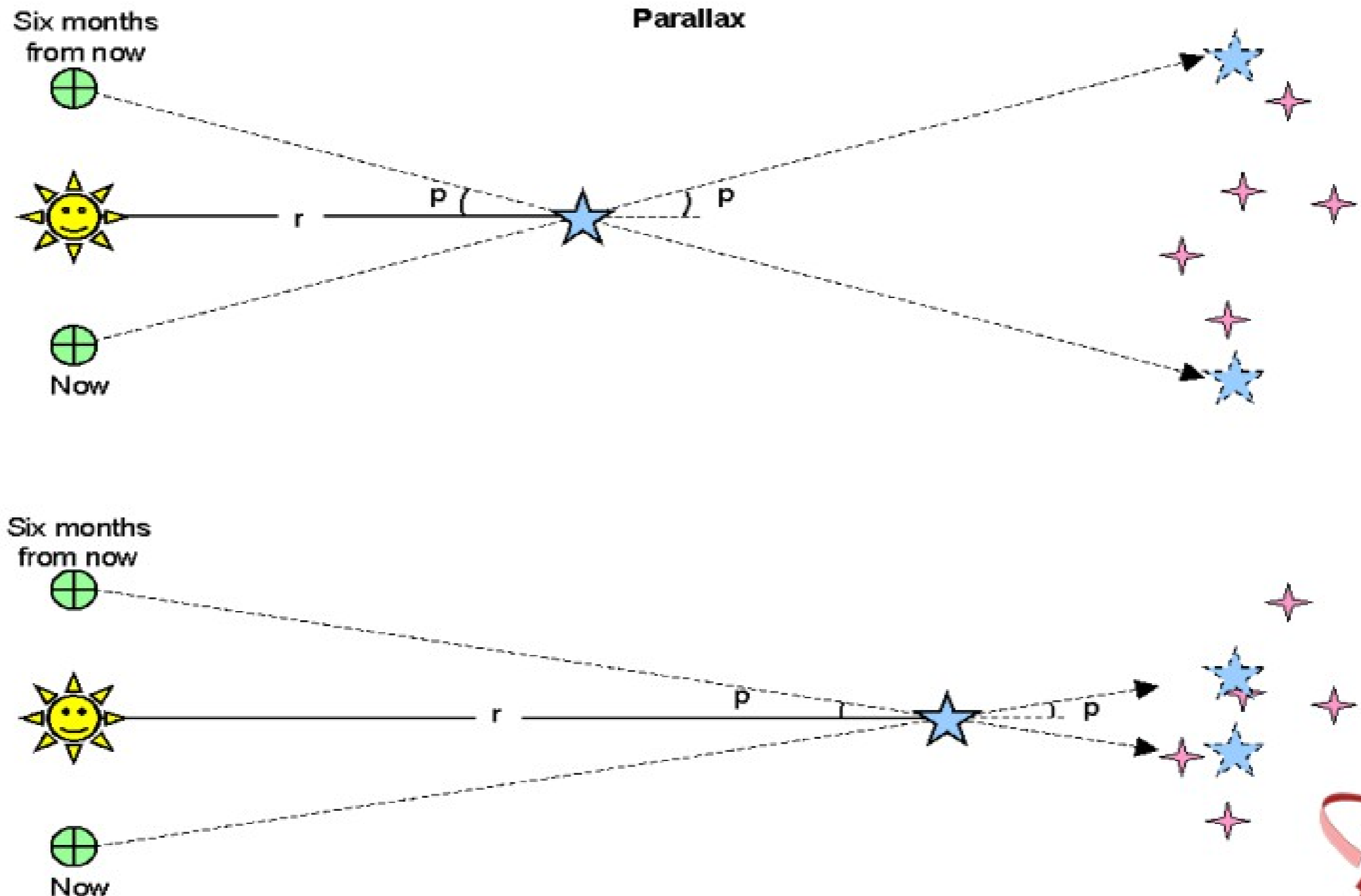
The cosmological distance scale is the weak link in modern astrophysics



Thanks to Ian for the elephant



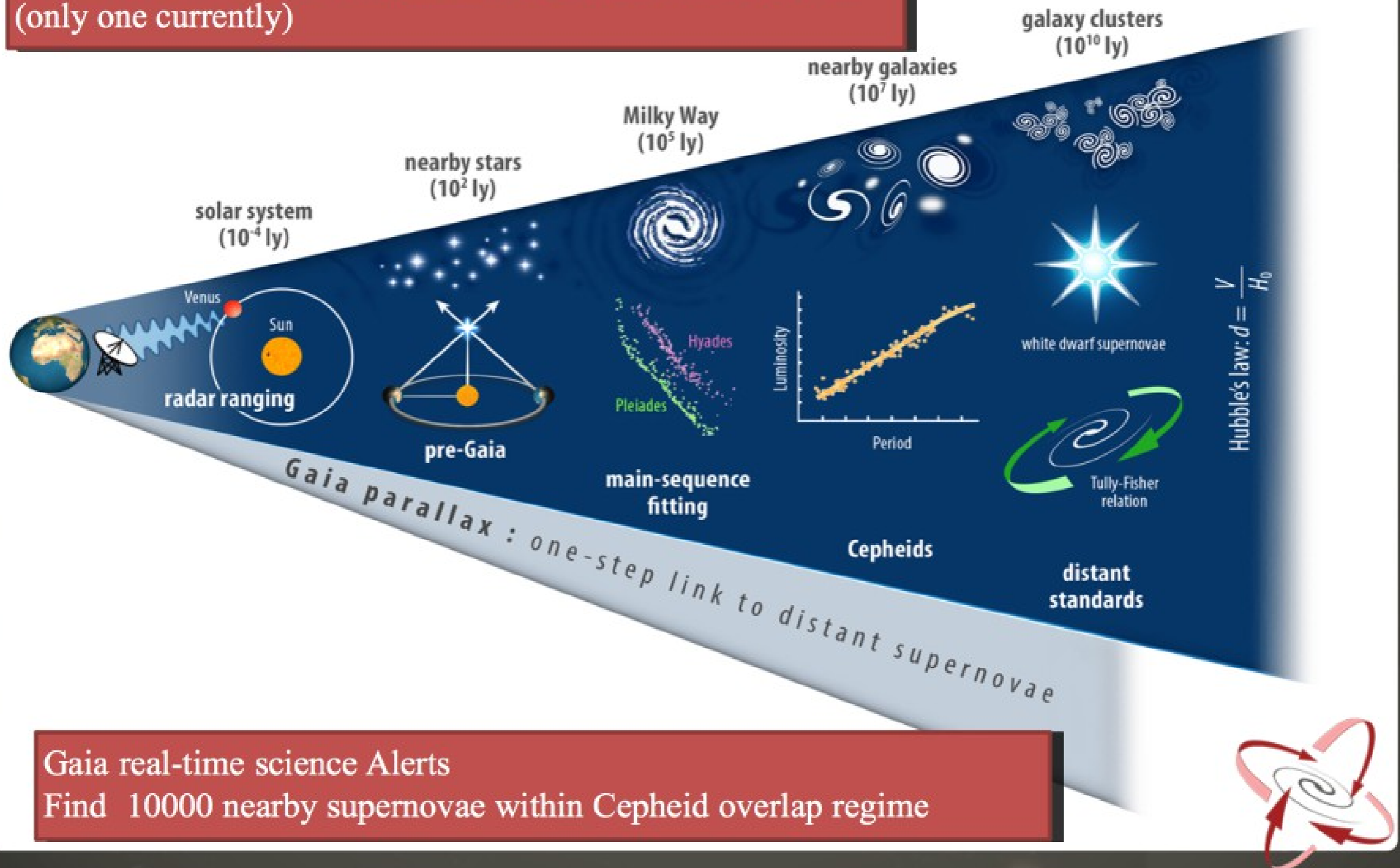
Recall that parallax provides distance



Taking the census of the Milky Way Galaxy

Precision Cosmology with Gaia

Precision calibration from parallaxes of 4400 local Cepheids
(only one currently)



Gaia real-time science Alerts

Find 10000 nearby supernovae within Cepheid overlap regime



What will Gaia see as stars move?

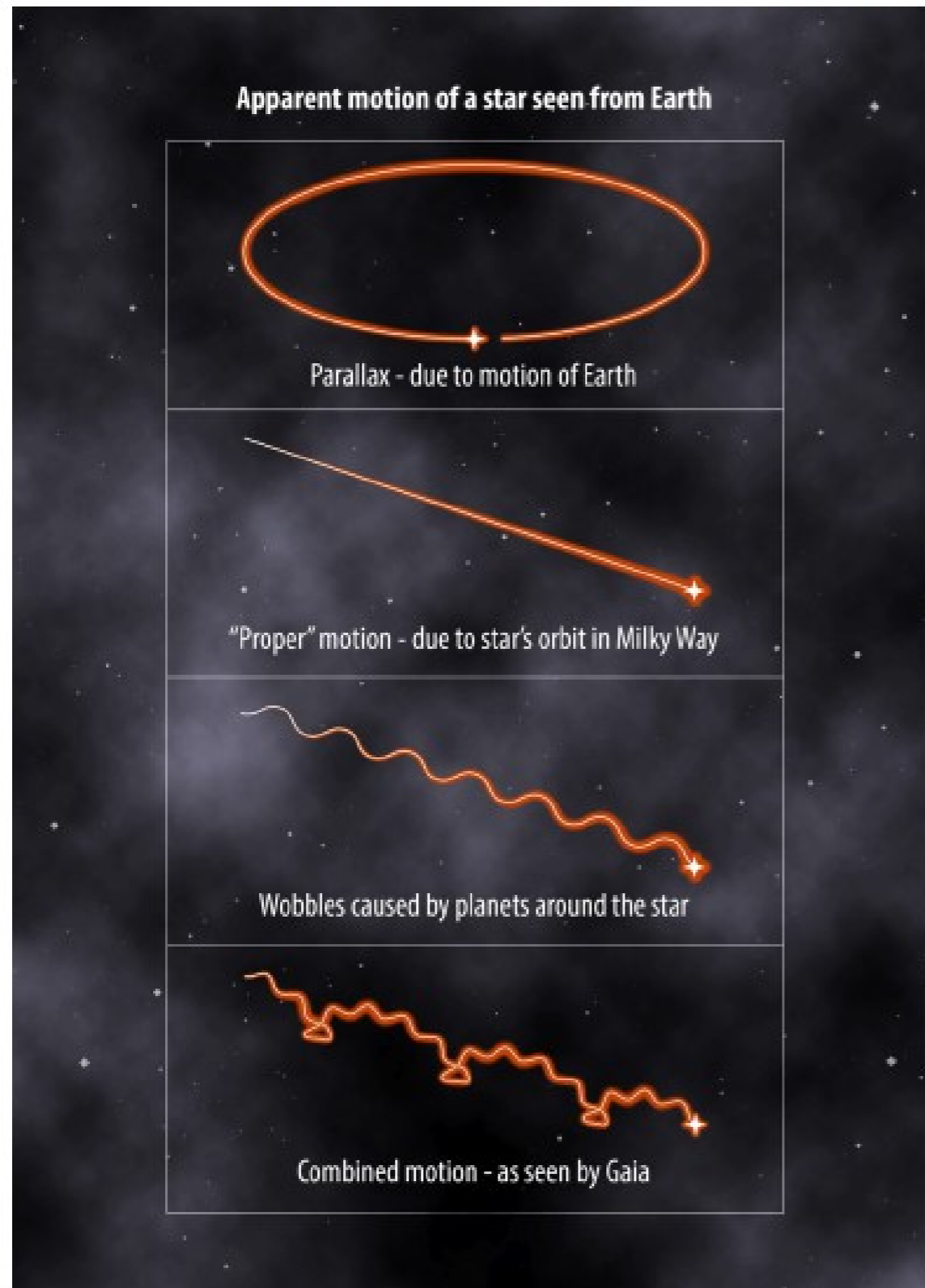
Apparent motion of a star seen from Earth



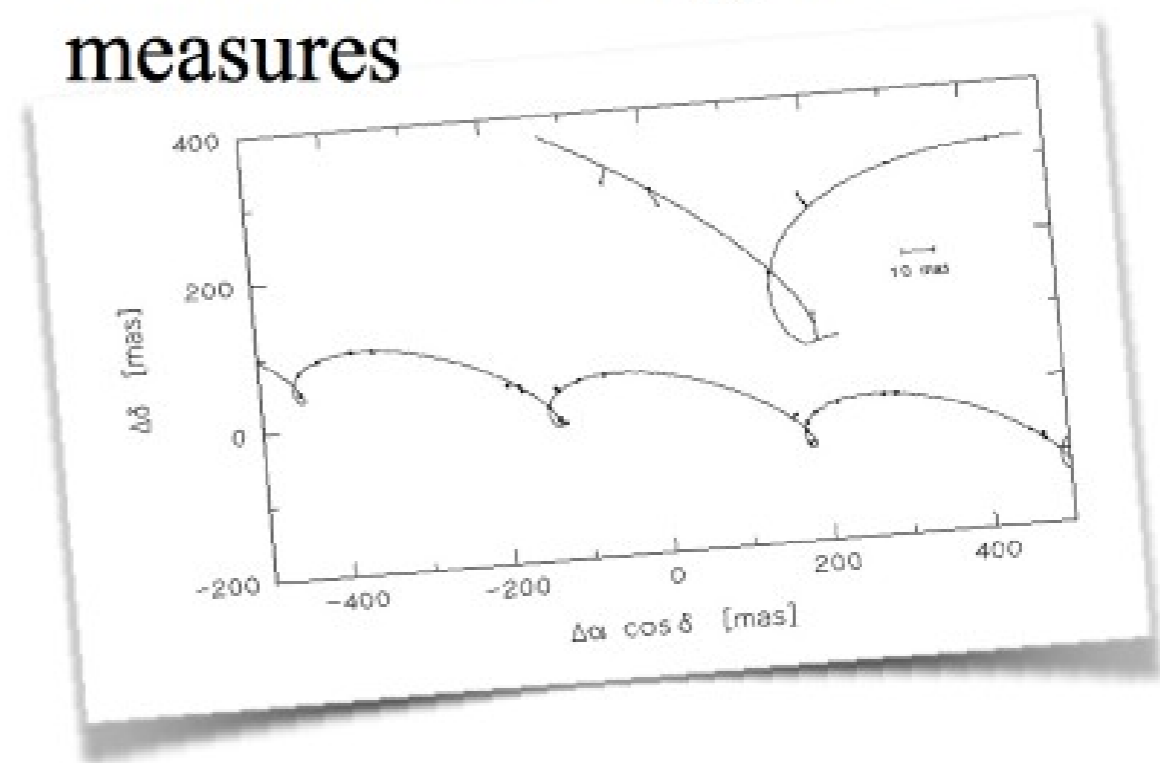
Gaia accuracy is 100 times better
Gaia precision is the same as locating
a 10p coin on the **Moon**



What will Gaia see as stars move?



These are real Hipparcos measures

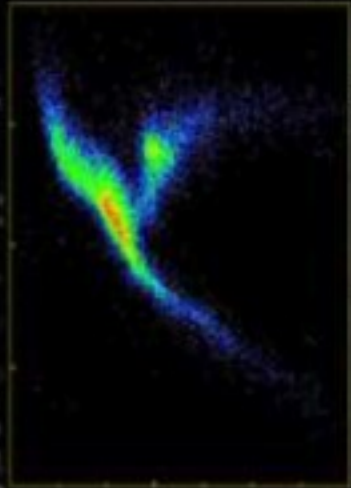


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GAIA

Stellar
Astrophysics



Star Formation
History of the
Milky Way

Galactic
Structure

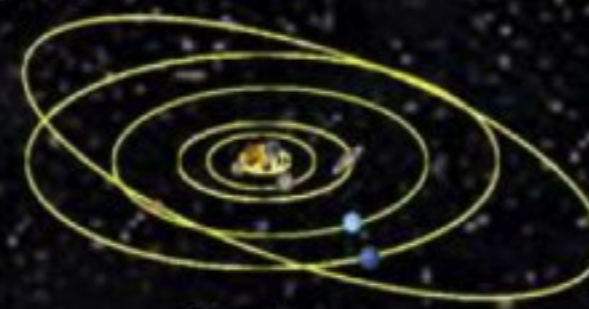


Fundamental
Physics

Binaries and
Brown Dwarfs



Extrasolar
Planets



Solar
System

Science

How

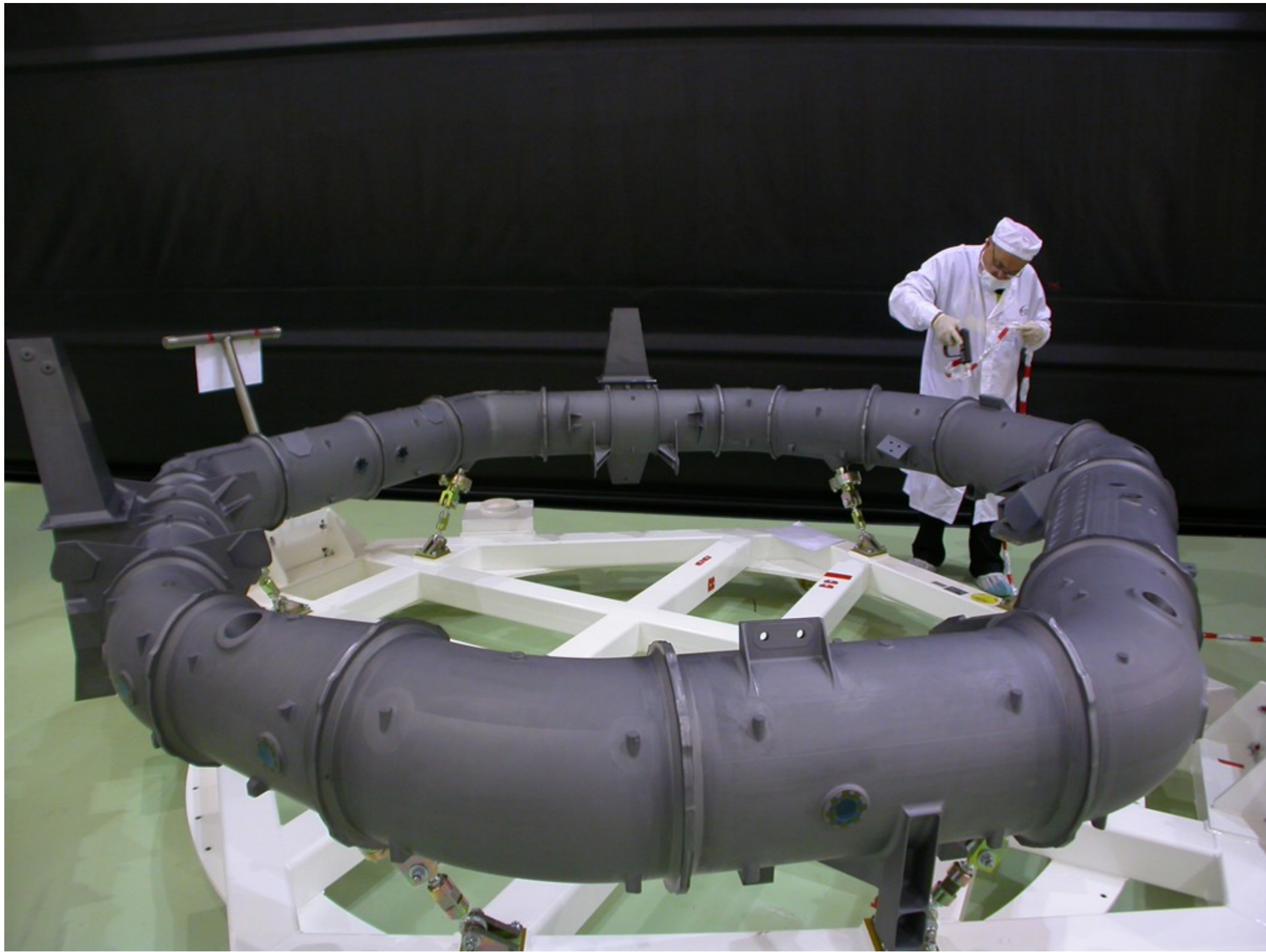


A pan-European project







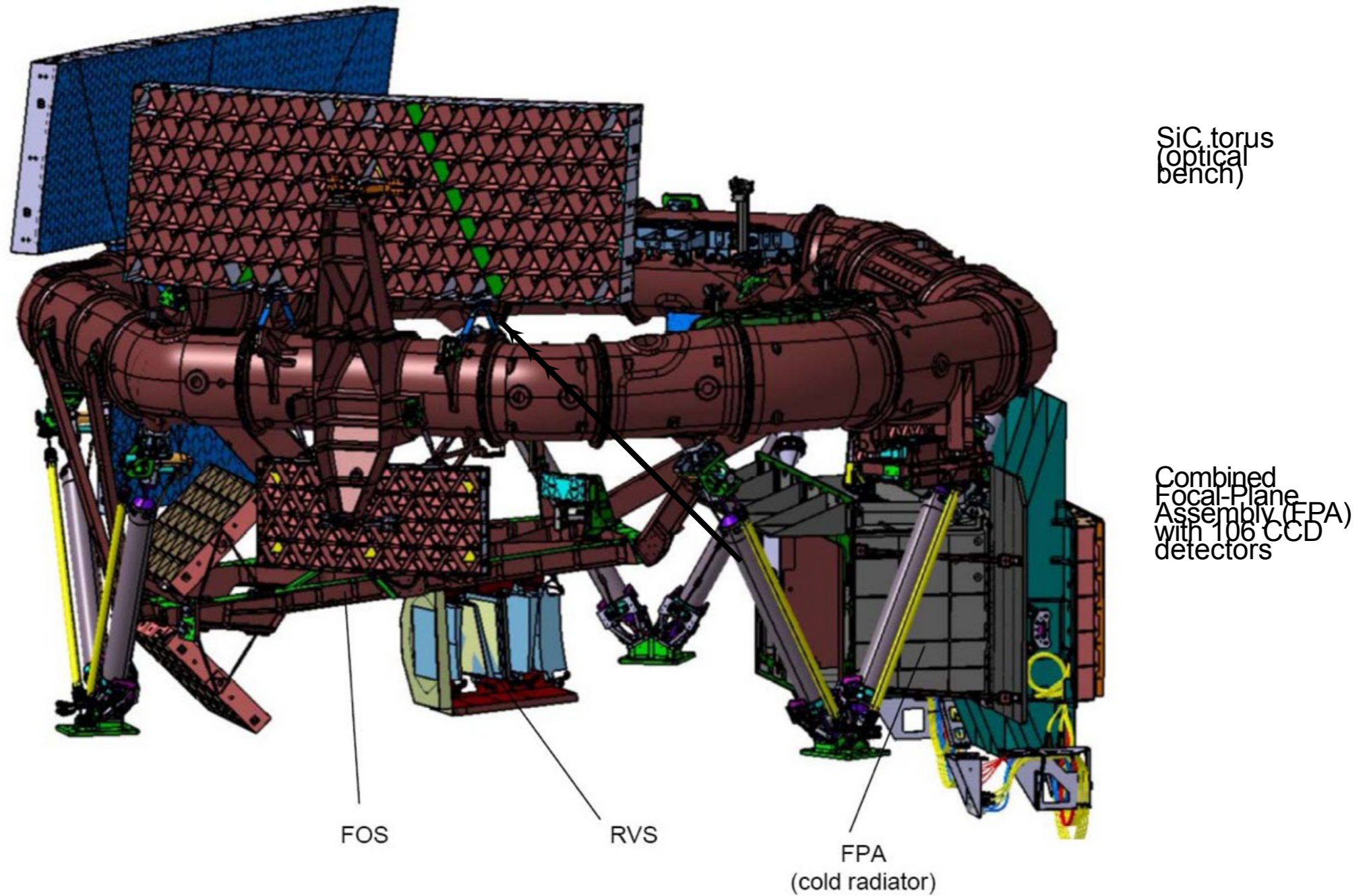


Silicon carbide - the hardest material in space

Payload and Telescope

Two primary mirrors, imaged by a common camera

Basic-Angle-Monitoring (BAM) system

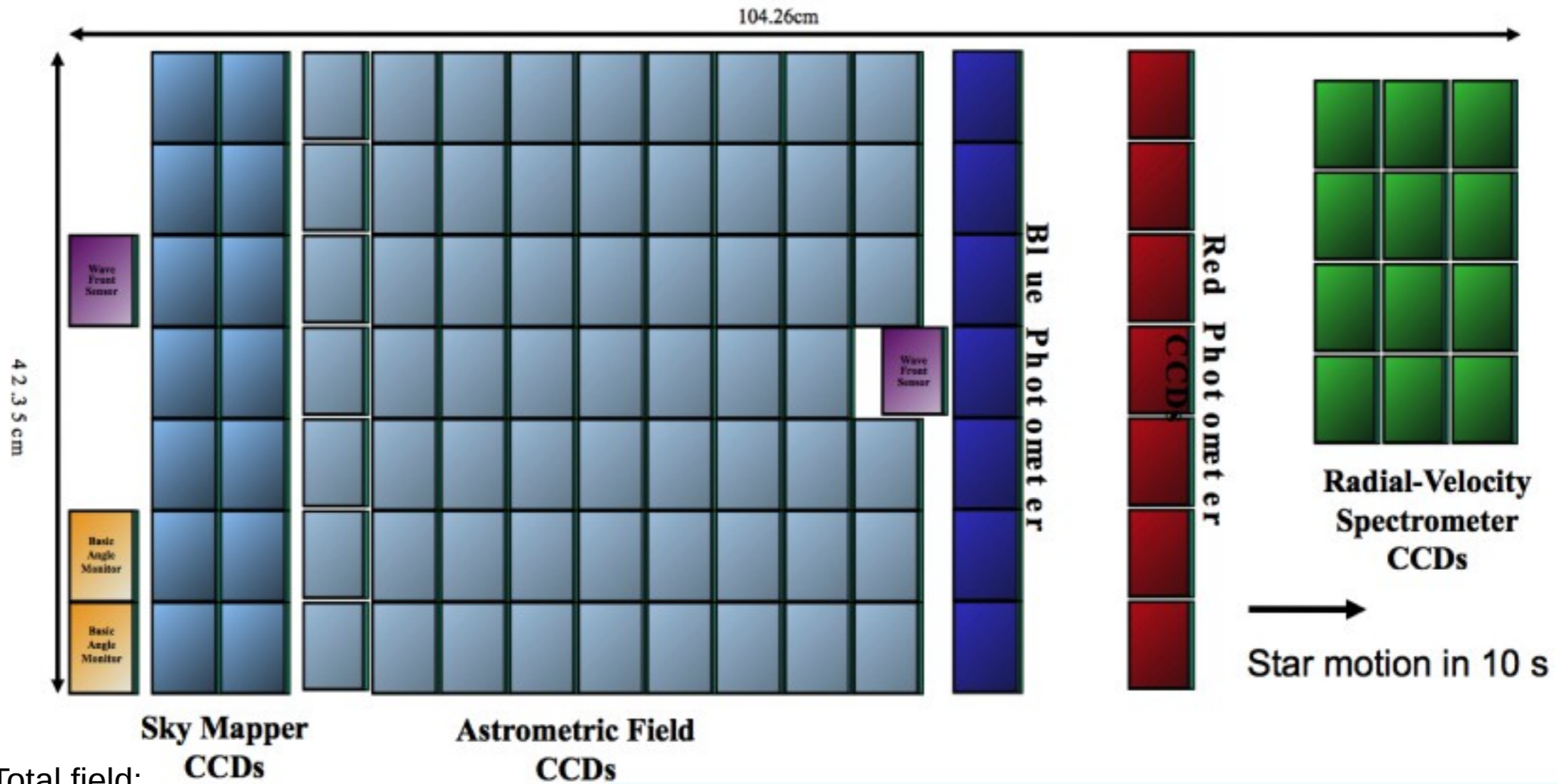


Radial-Velocity Spectrometer (RVS)

Focal Plane

The heart of **Gaia** is the largest camera array yet built, sending us a **video** of the sky for 5 years.

The imaging data will be processed in Cambridge.



Total field:

- active area: 0.75 deg²
- CCDs: 14 + 62 + 14 + 12
- (+ 4)
- 4500 x 1966 pixels (TDI)
- pixel size = 10 μm x 30 μm

= 59 mas x 177

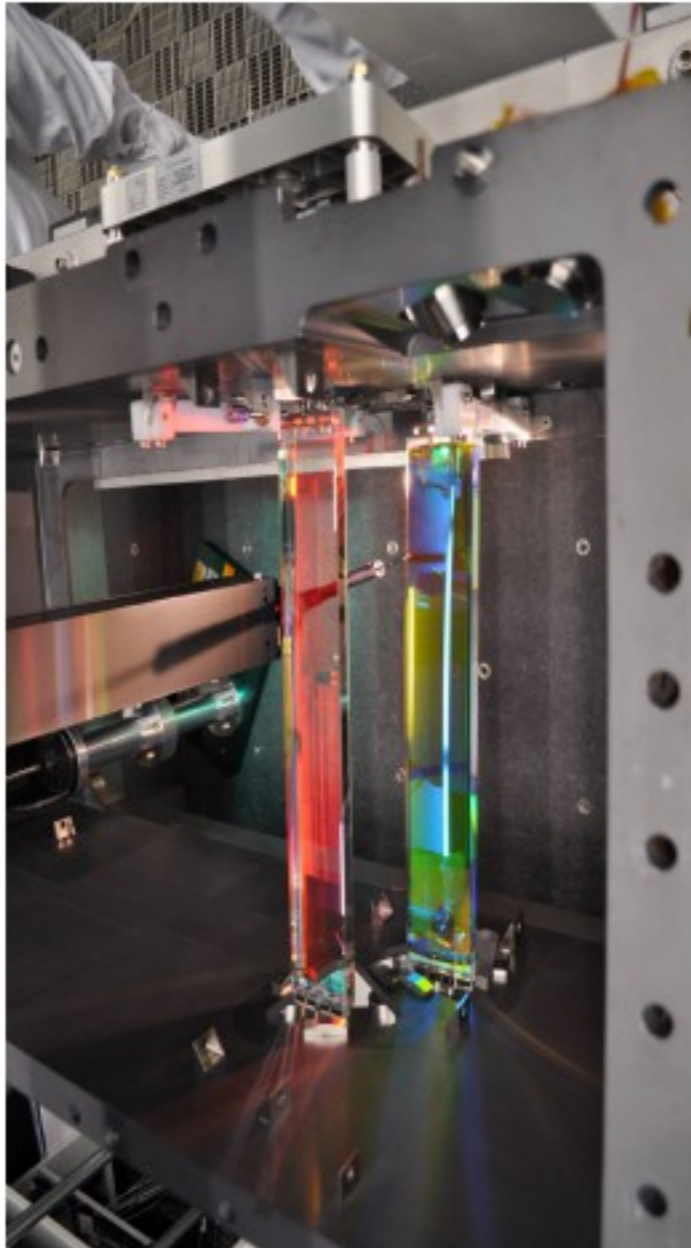
Sky mapper:

- detects all objects to G=20 mag
- rejects cosmic-ray events
- field-of-view discrimination

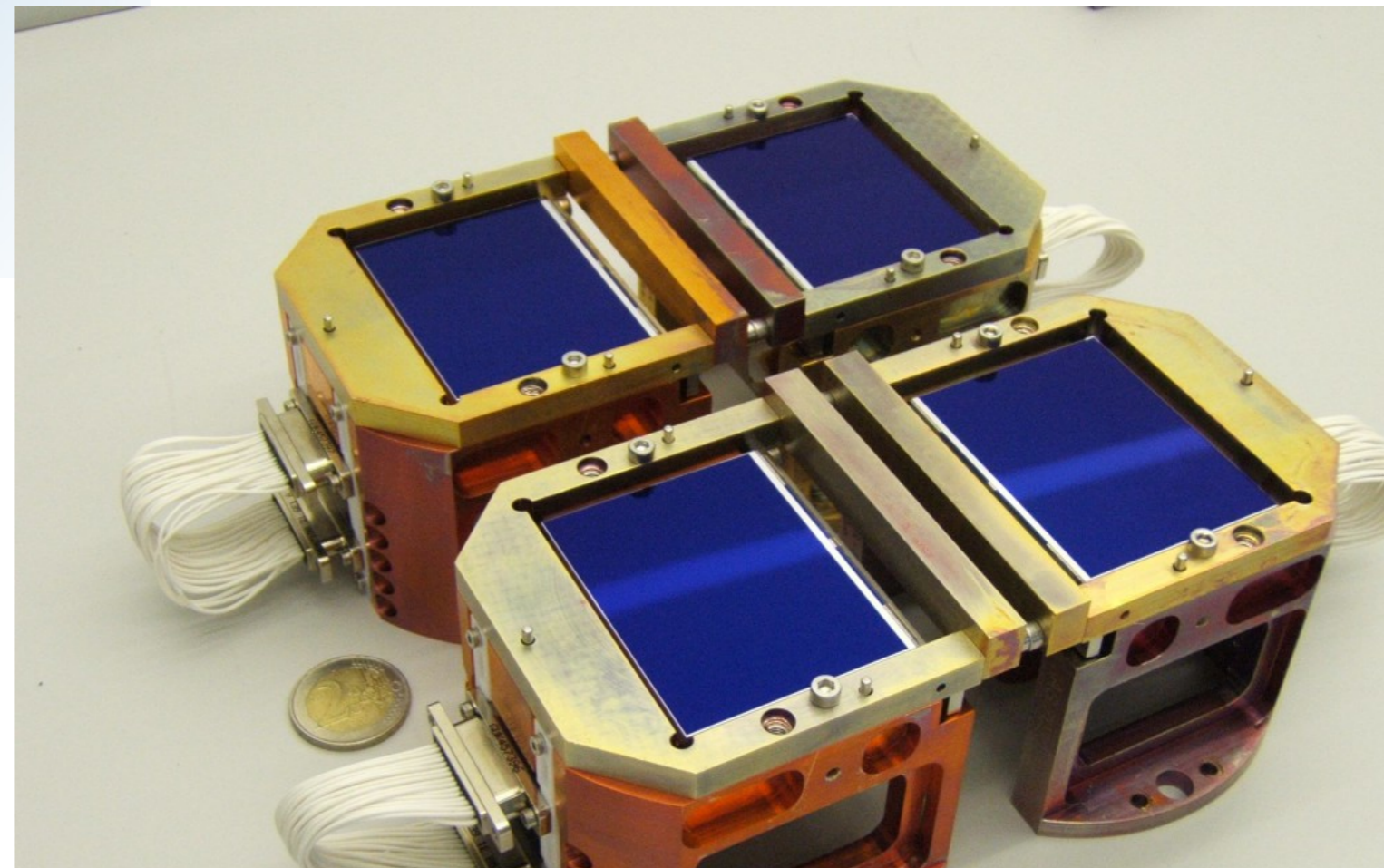
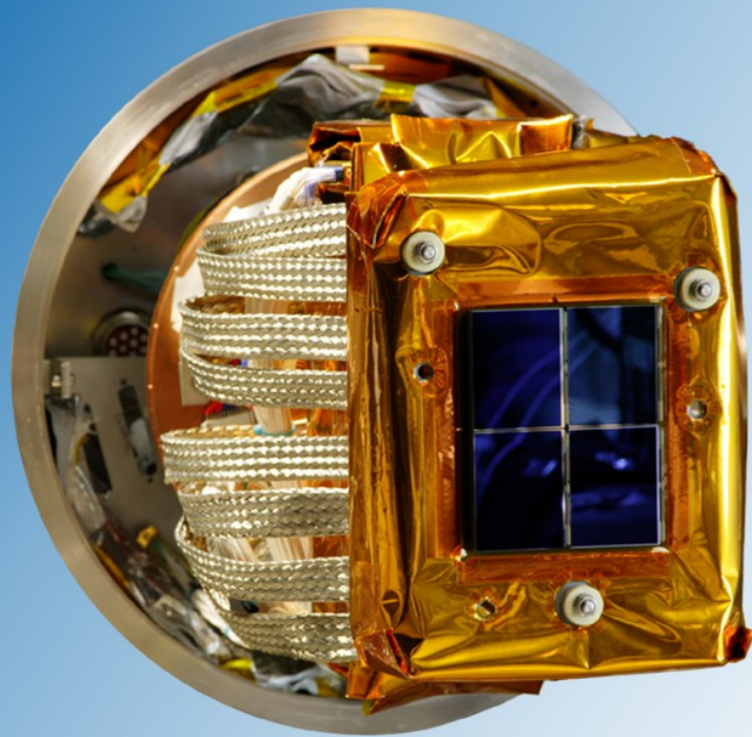
Astrometry:

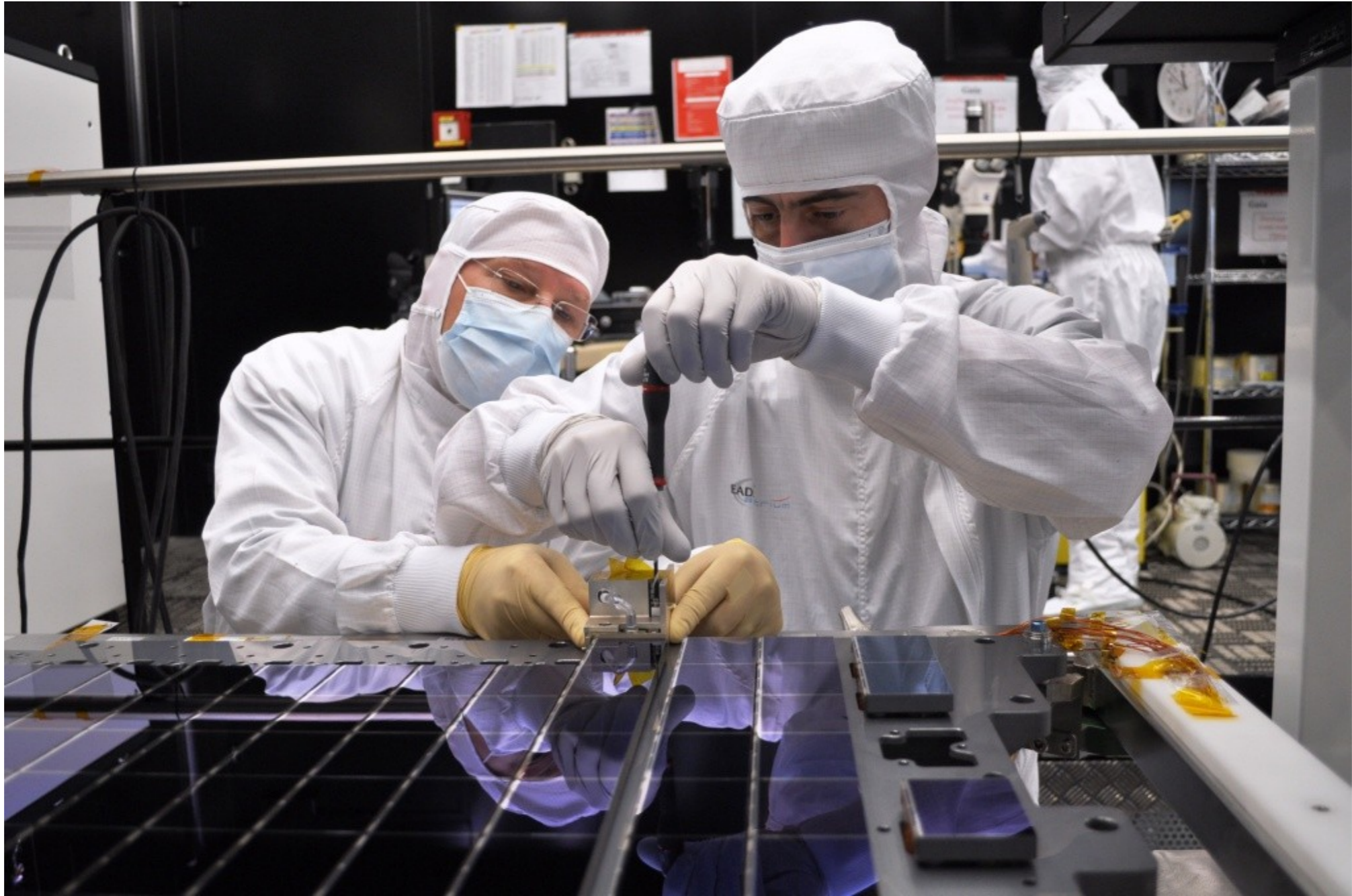
- Photometry:
 - spectro-photometer
 - blue and red CCDs
- Spectroscopy:
 - high-resolution spectra
 - red CCDs

Payload and Telescope



Gaia CCD's





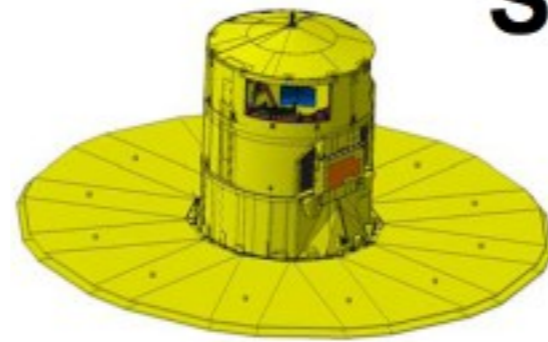
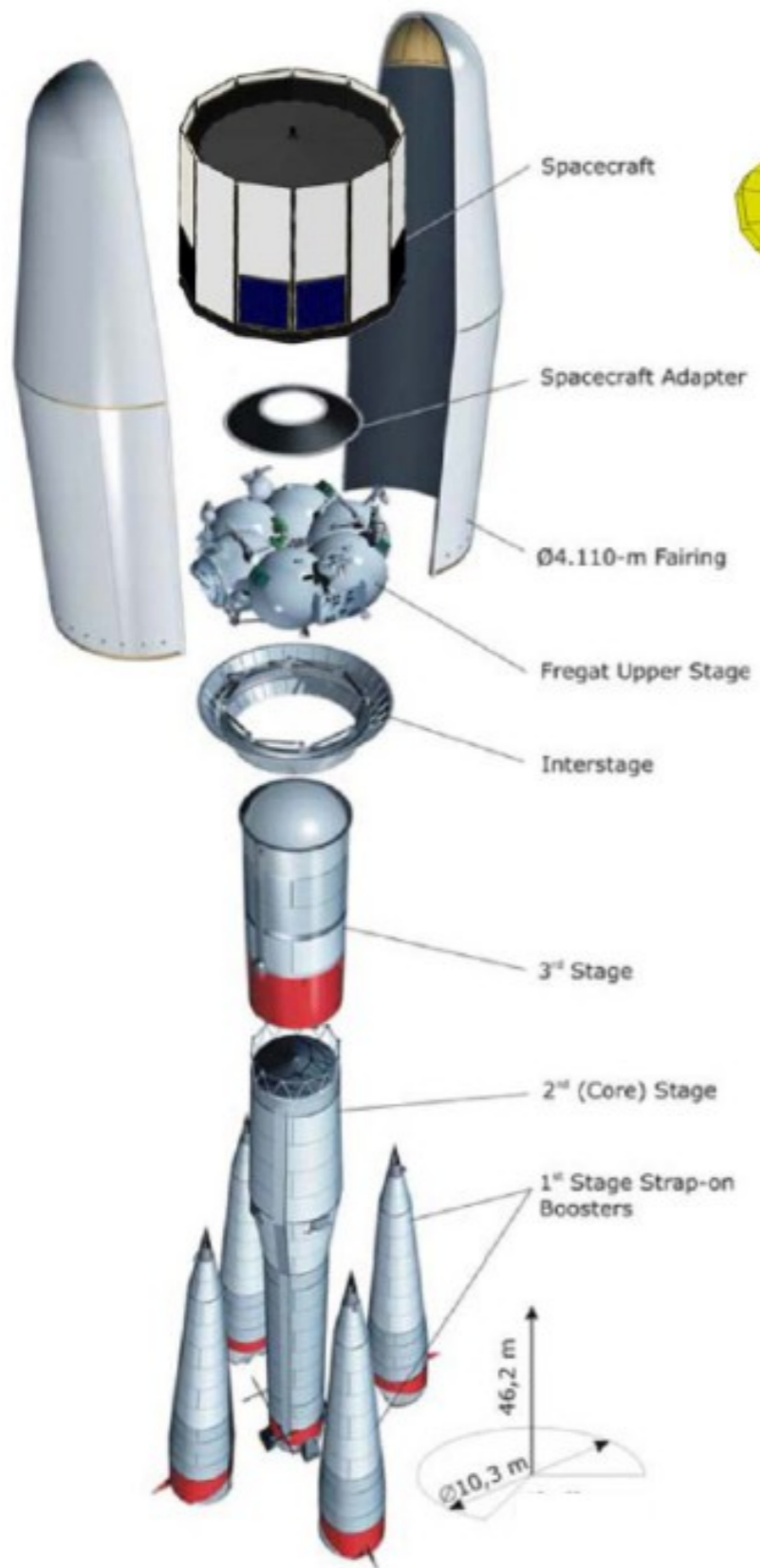
The whole focal plane is 104cm wide and 42 cm high. The production took more than a year.

Launch

Assembled at Astrium, Toulouse, France
Arrived at ESA's spaceport in Kourou, French Guiana
on 26 Aug.
See blog at <http://blogs.esa.int/gaia/>



Satellite Launch System



- Launcher: Soyuz–Fregat
- Orbit: L2

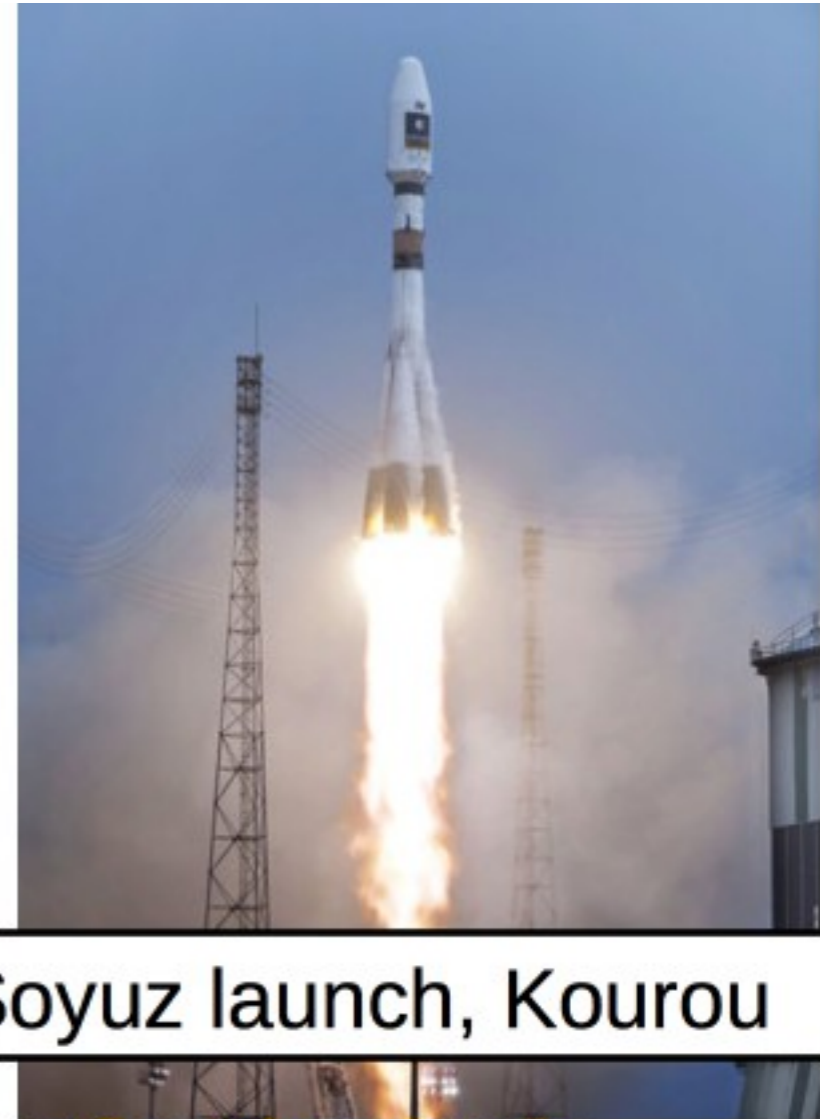




Gaia's arrival at Kourou



Testing *Gaia's* camera



Soyuz launch, Kourou



Orbit

- large Lissajous orbit around L2
- duration of transfer to L2 one month
- 1.5 million km from Earth
- eclipse free

Satellite attitude

- three axis stabilized
- 6 hour spin period
- 63 day spin axis precession
- 45 degree solar aspect angle

Ground stations

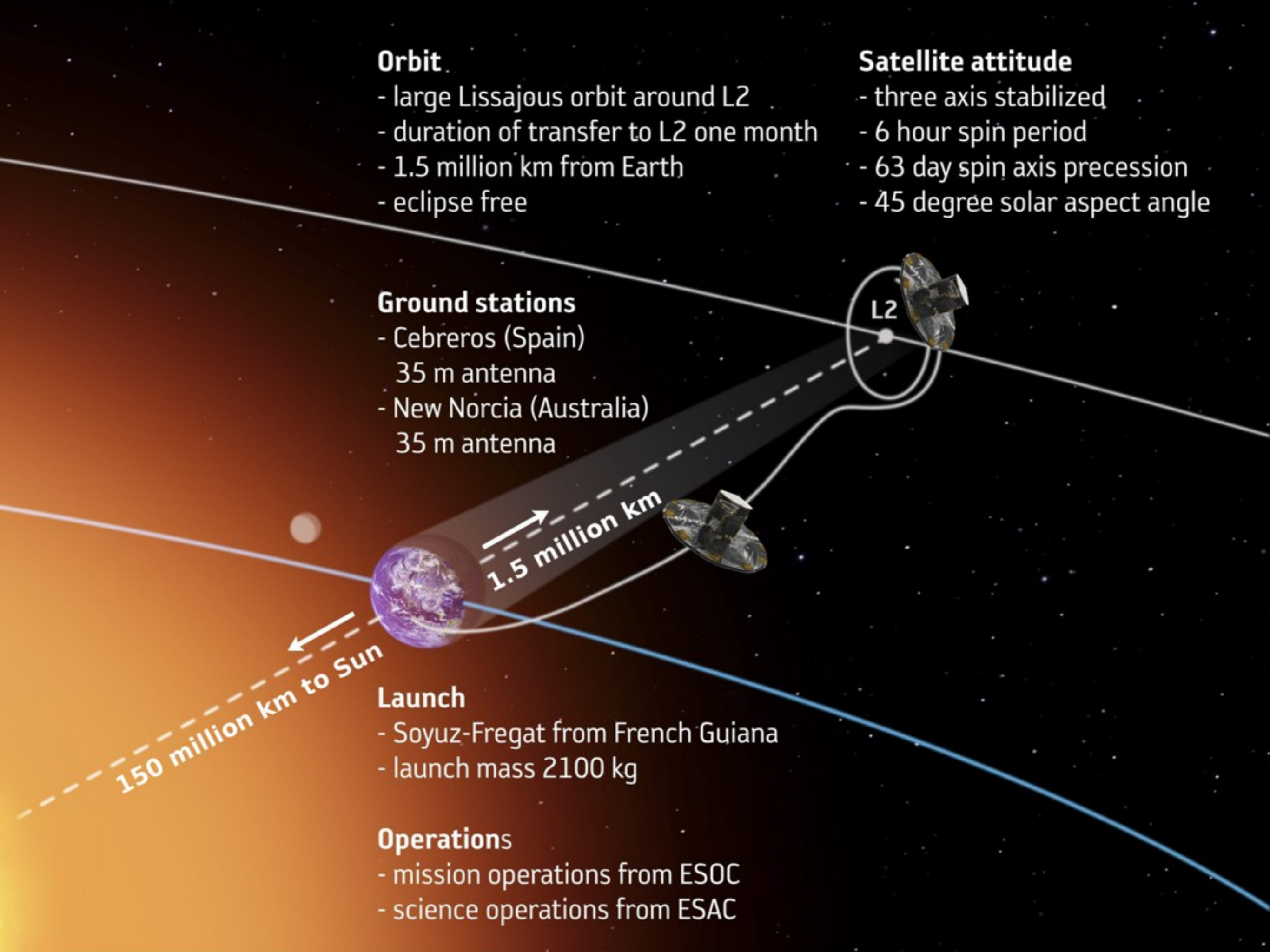
- Cebreros (Spain)
35 m antenna
- New Norcia (Australia)
35 m antenna

Launch

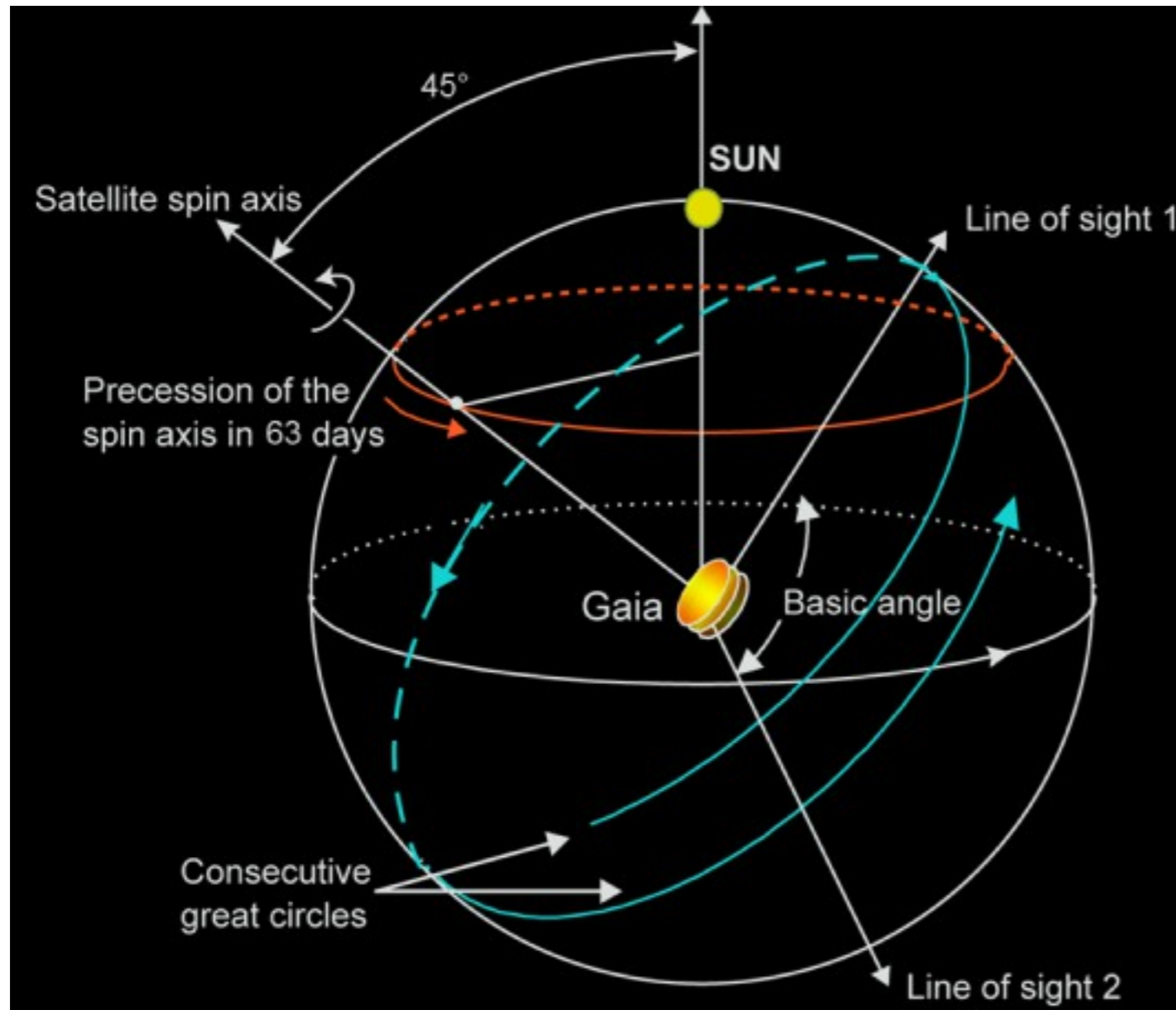
- Soyuz-Fregat from French Guiana
- launch mass 2100 kg

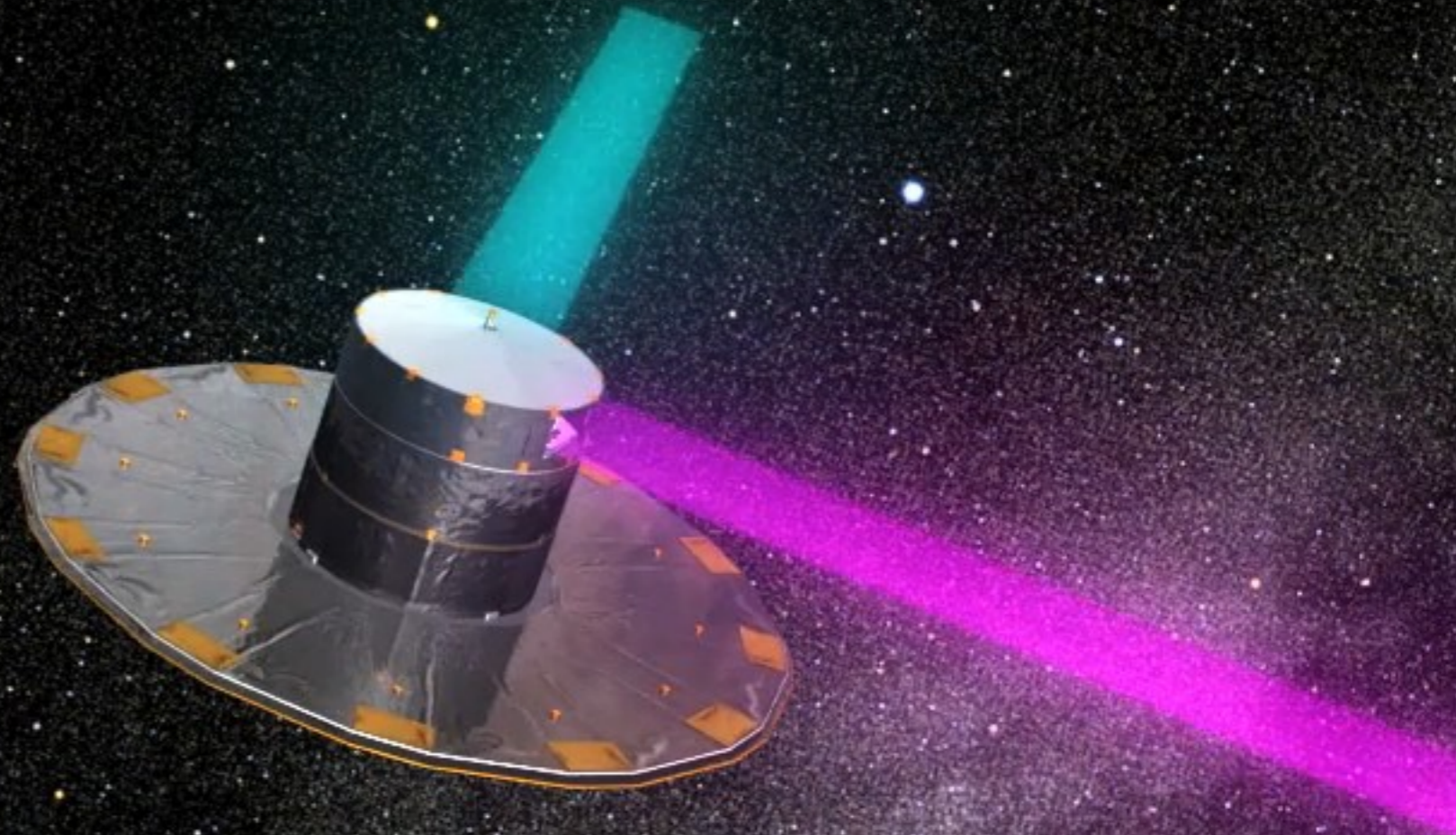
Operations

- mission operations from ESOC
- science operations from ESAC

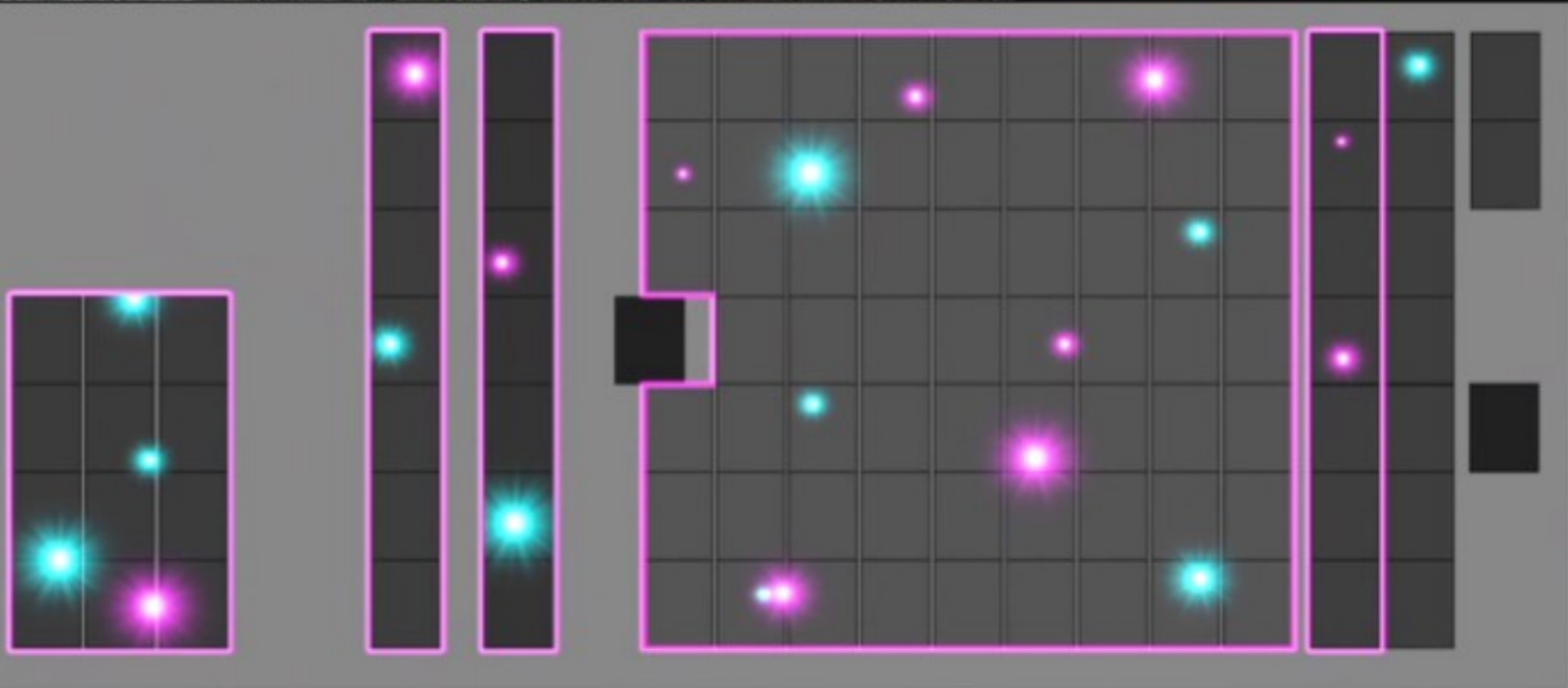
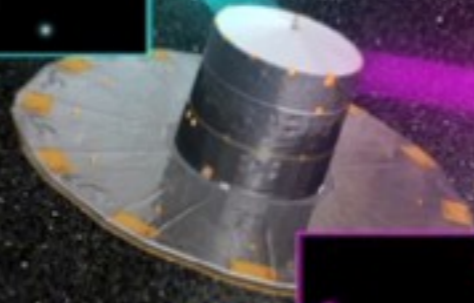


Operations



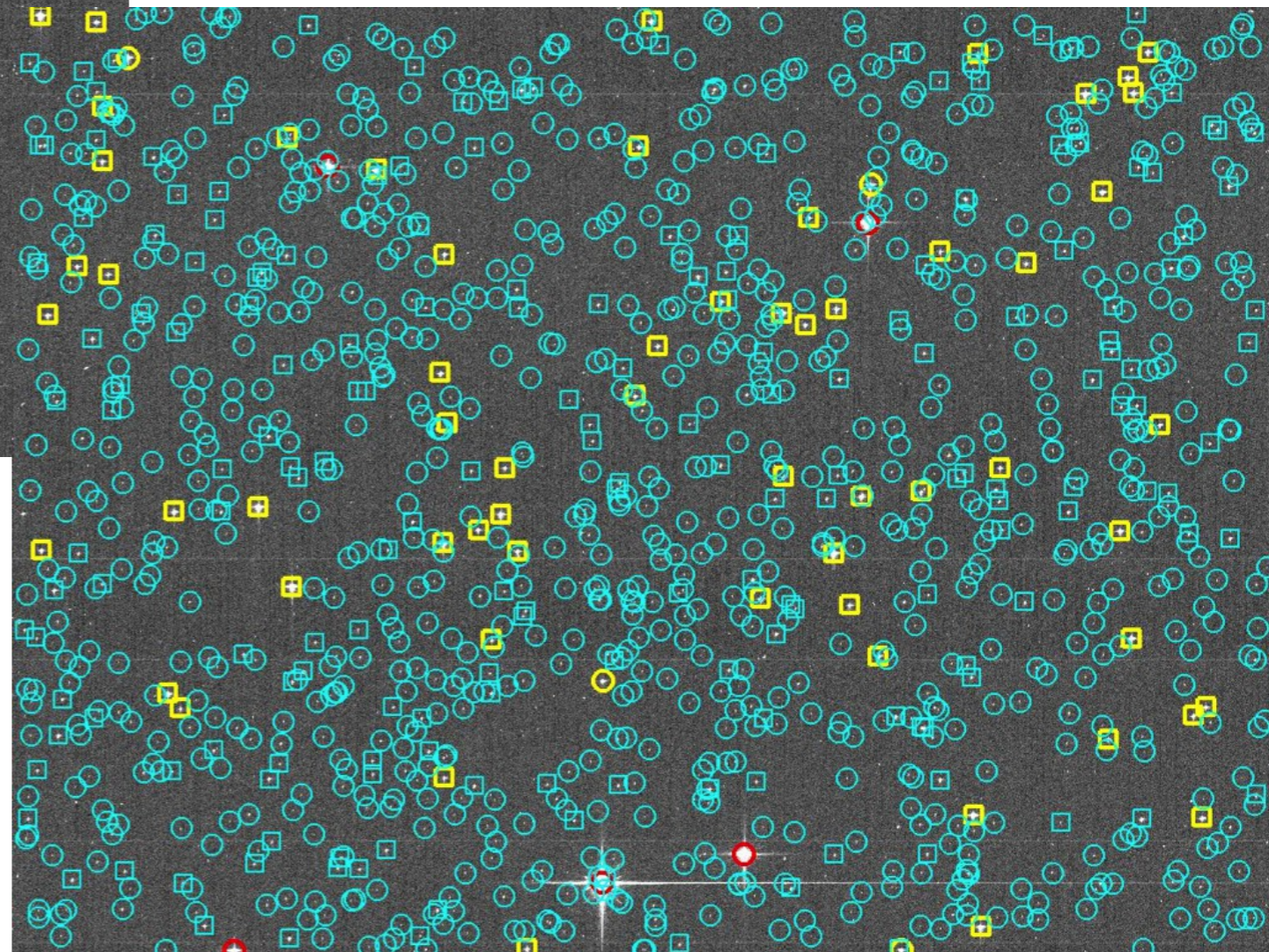
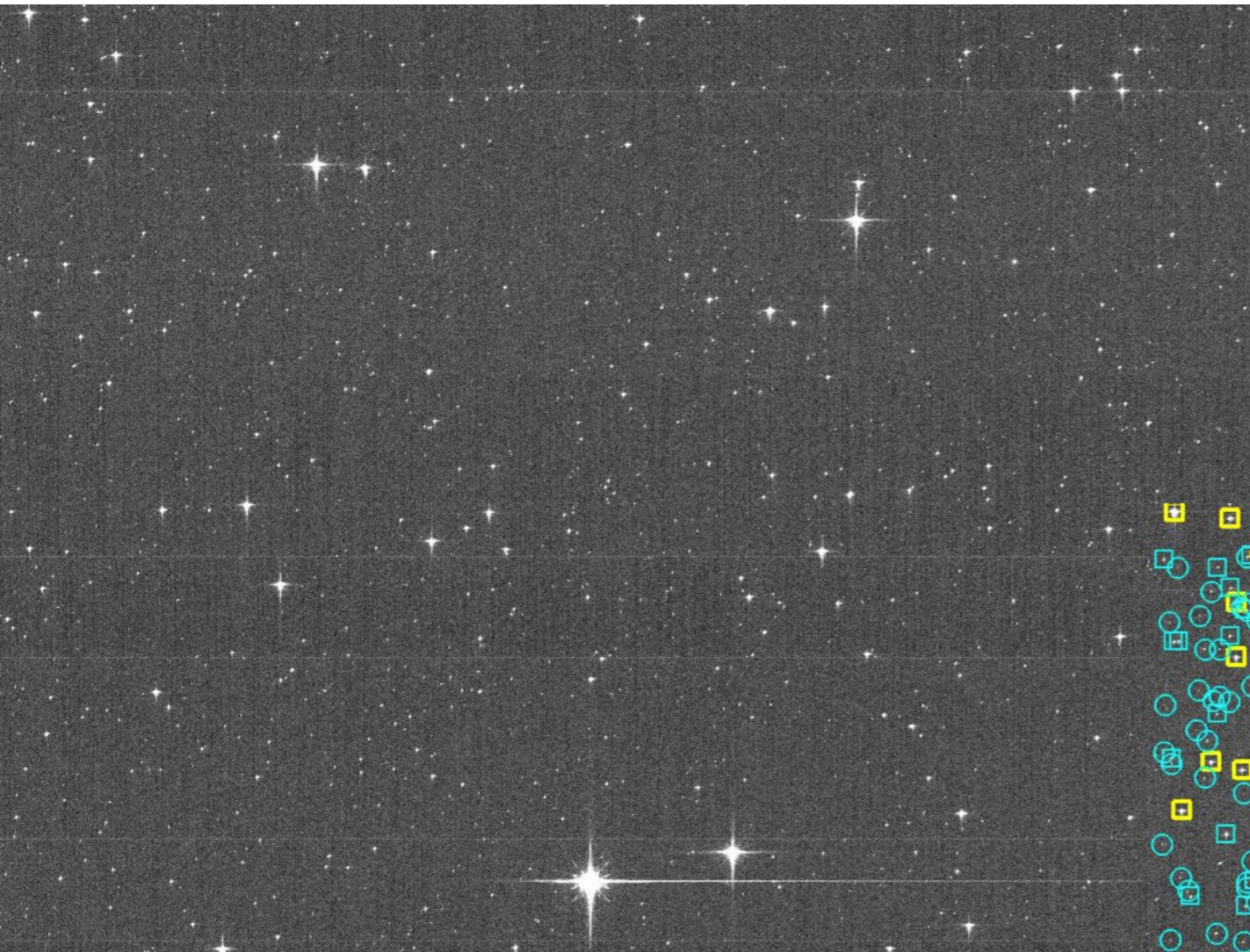


Gaia's Eyes



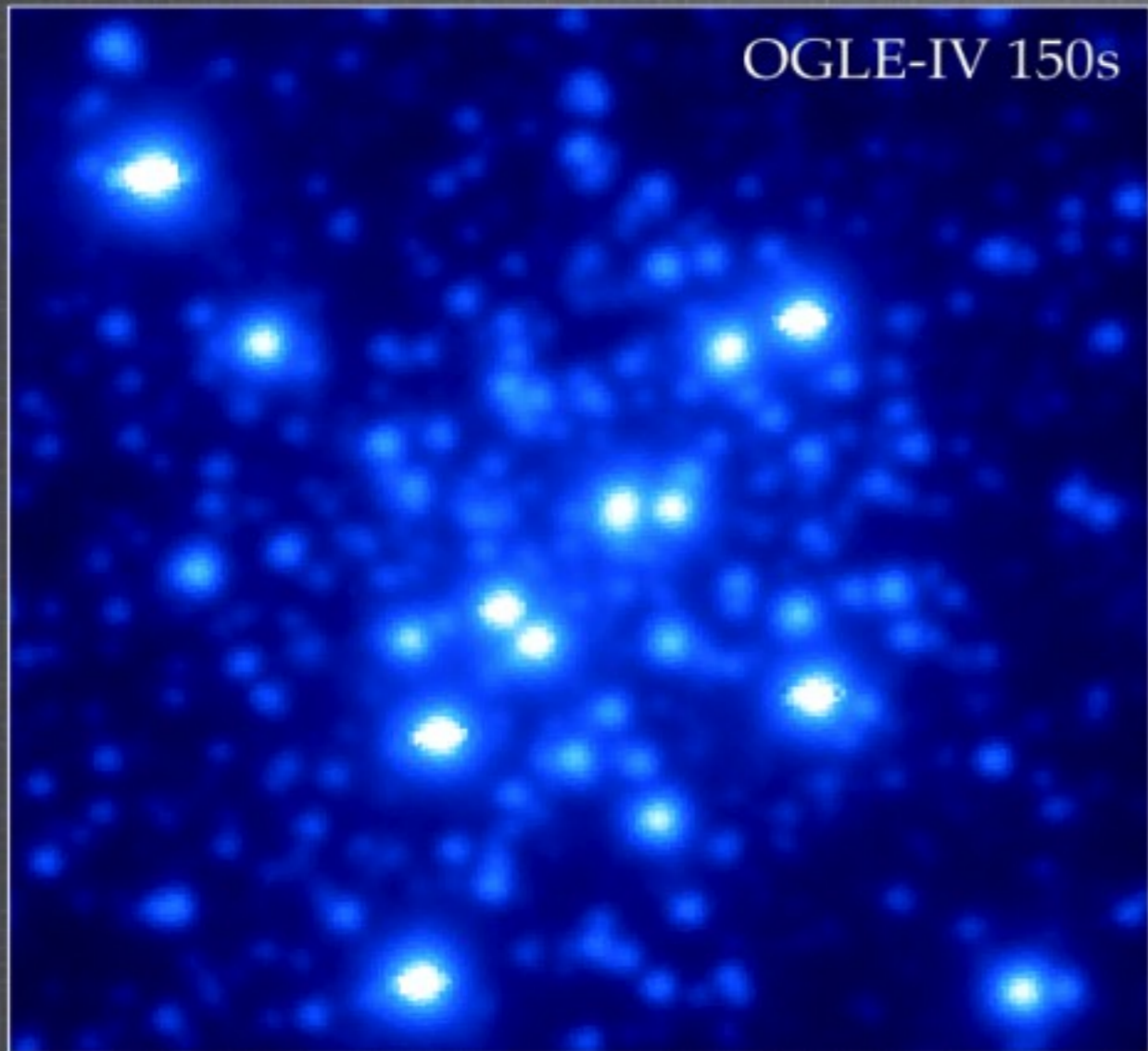
What Gaia is seeing?

Image from Gaia showing sources detected
Each source is given a window, which follows it across the
CCD

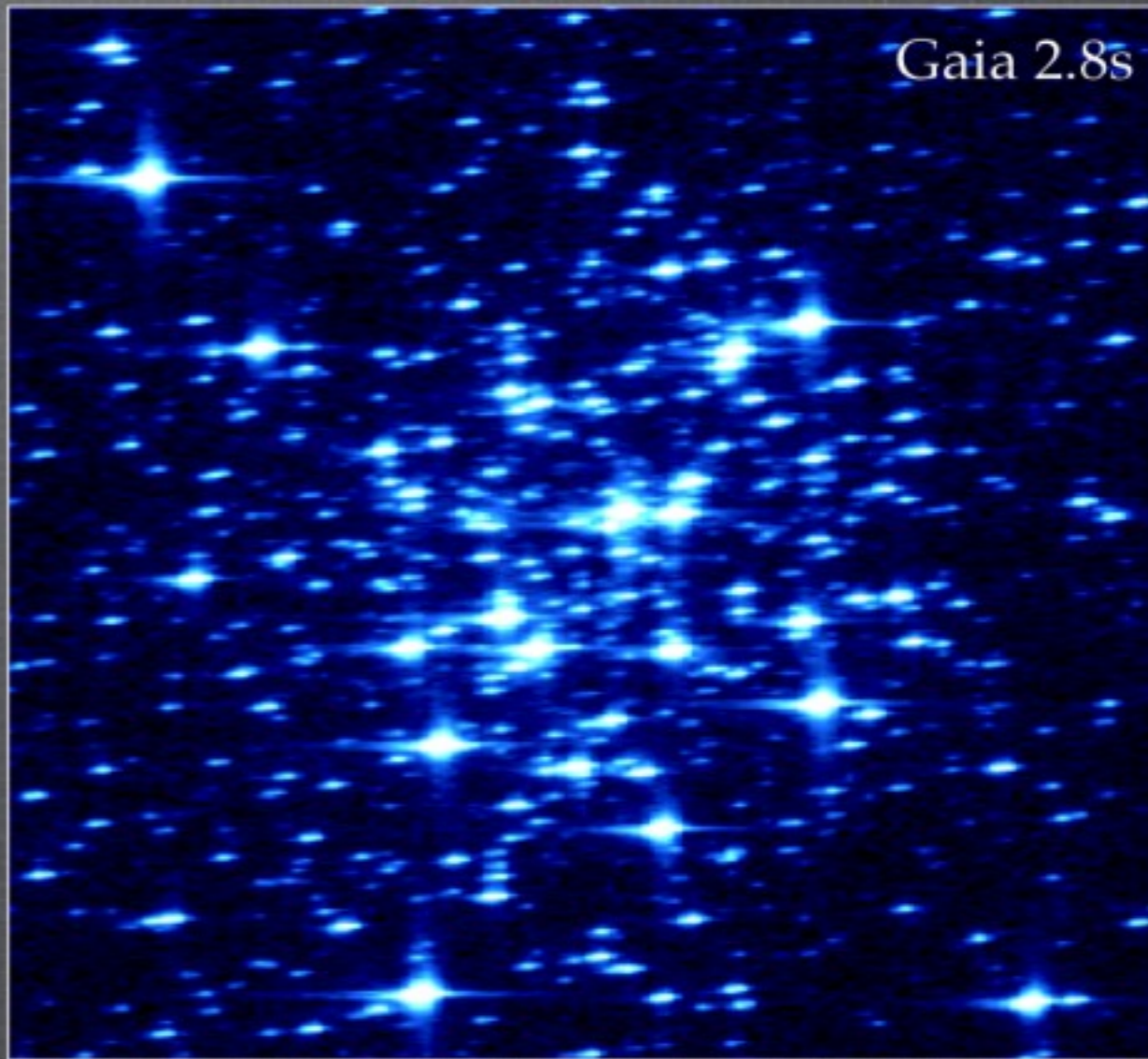


NGC 1818

OGLE-IV 150s

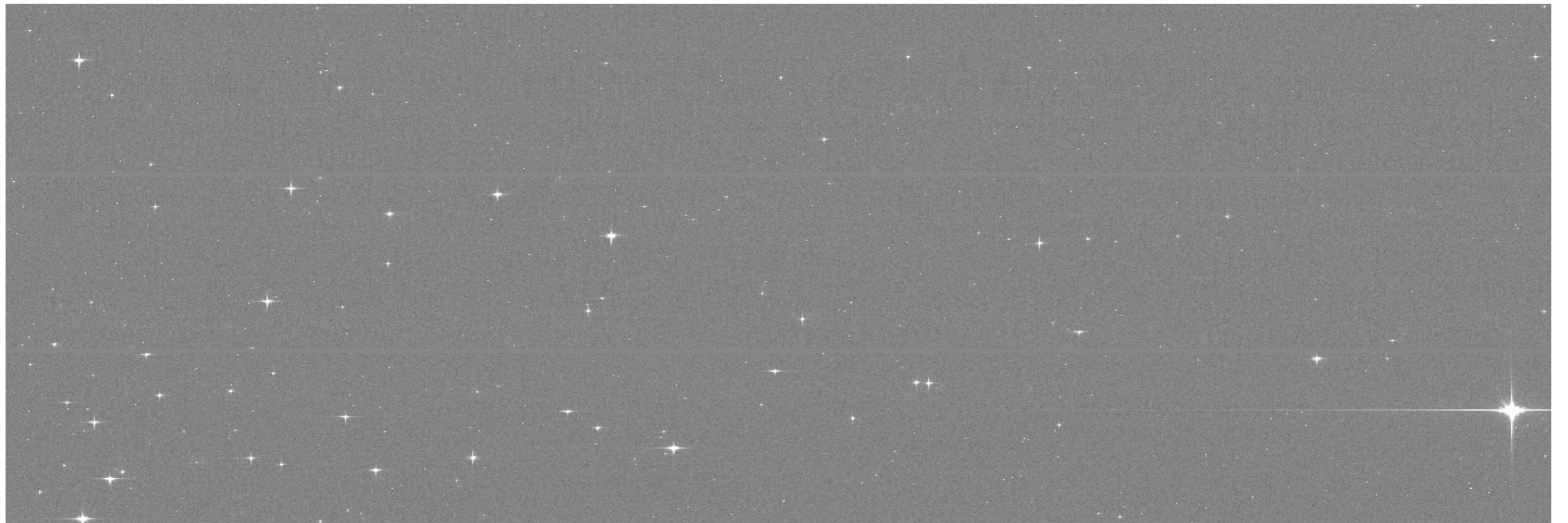
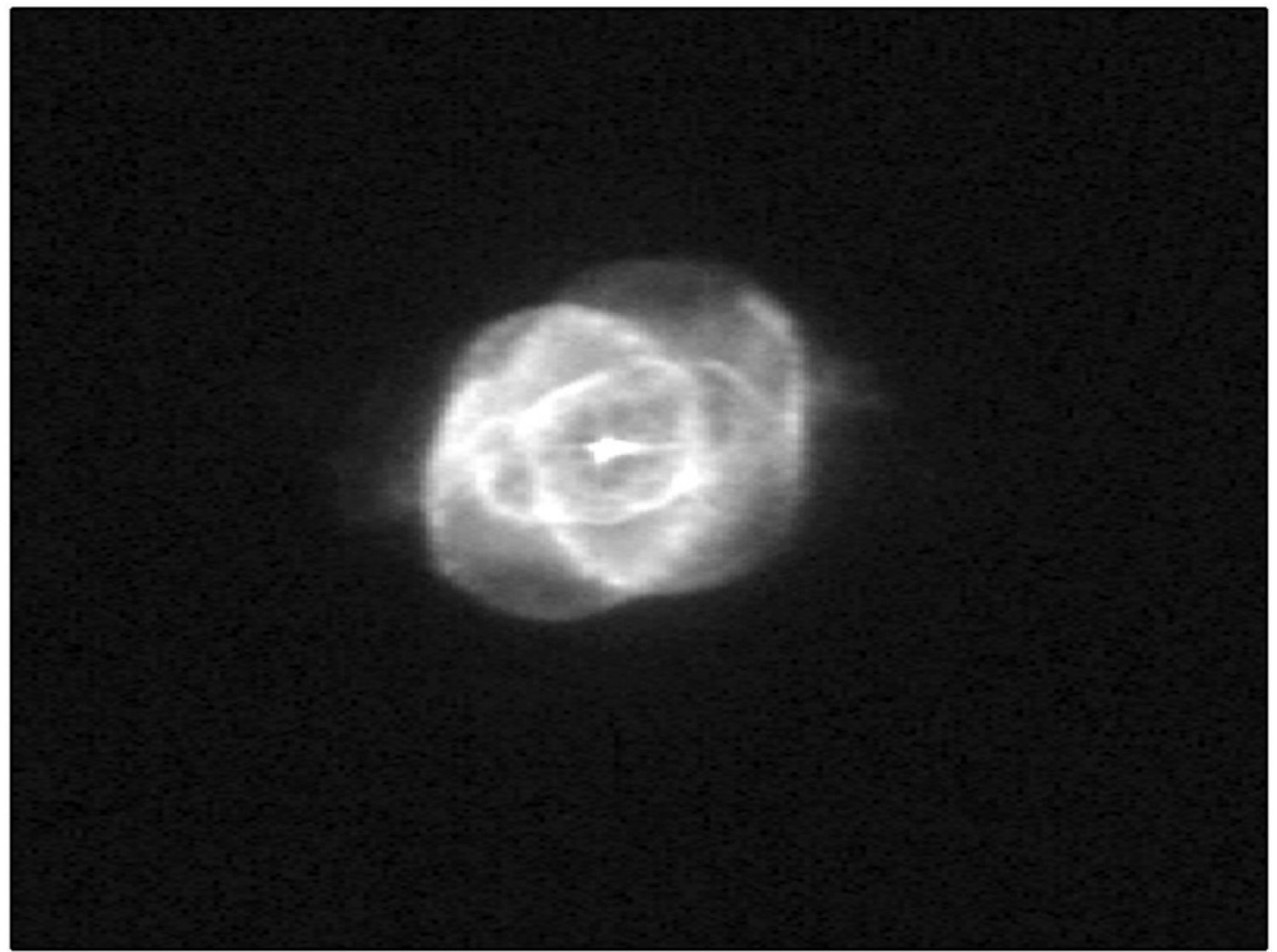


Gaia 2.8s

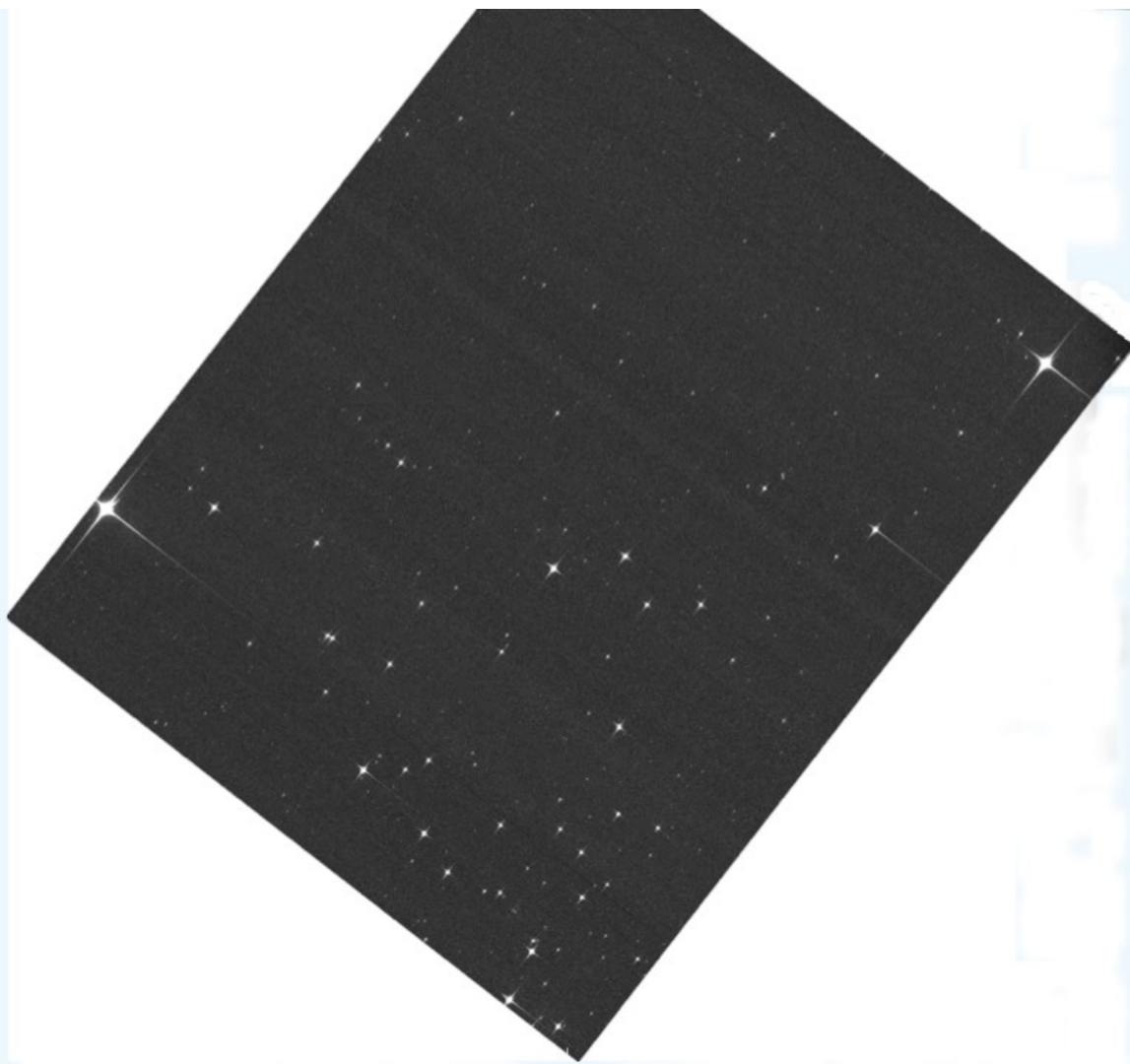


Cateye

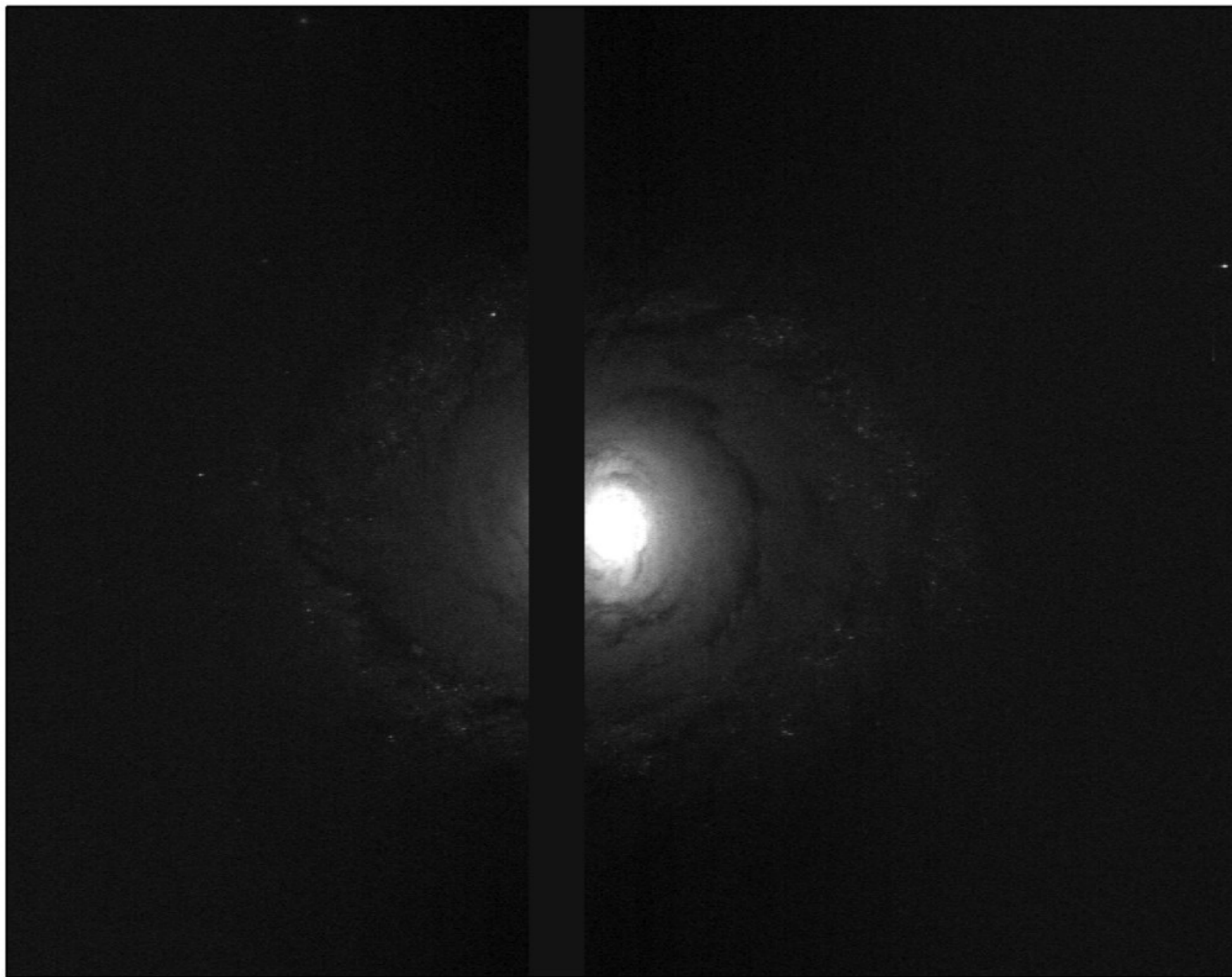
Cluster



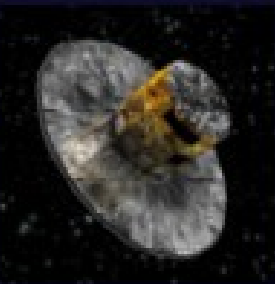
Gaia vs Digital Sky



M94

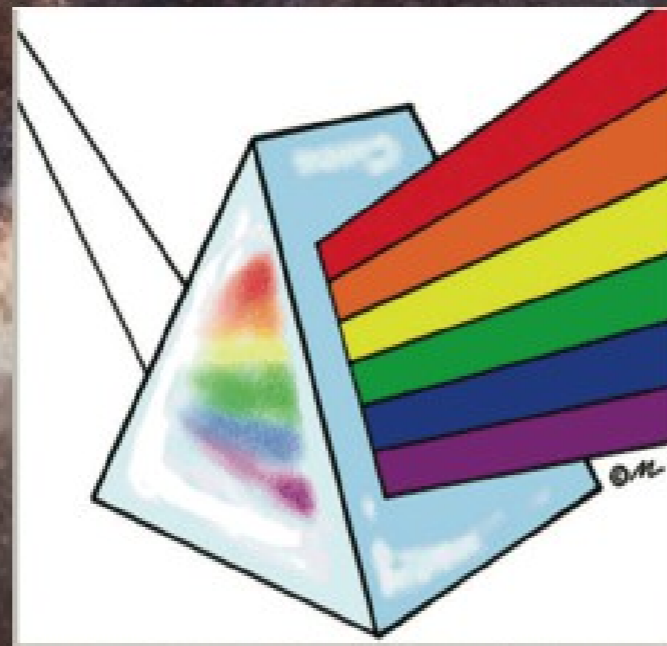
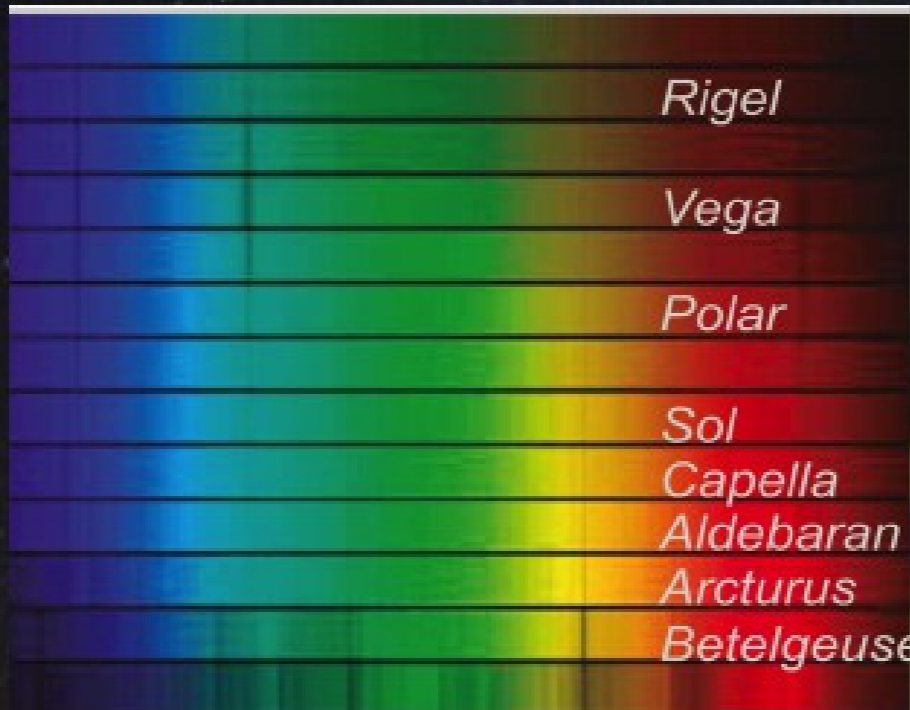


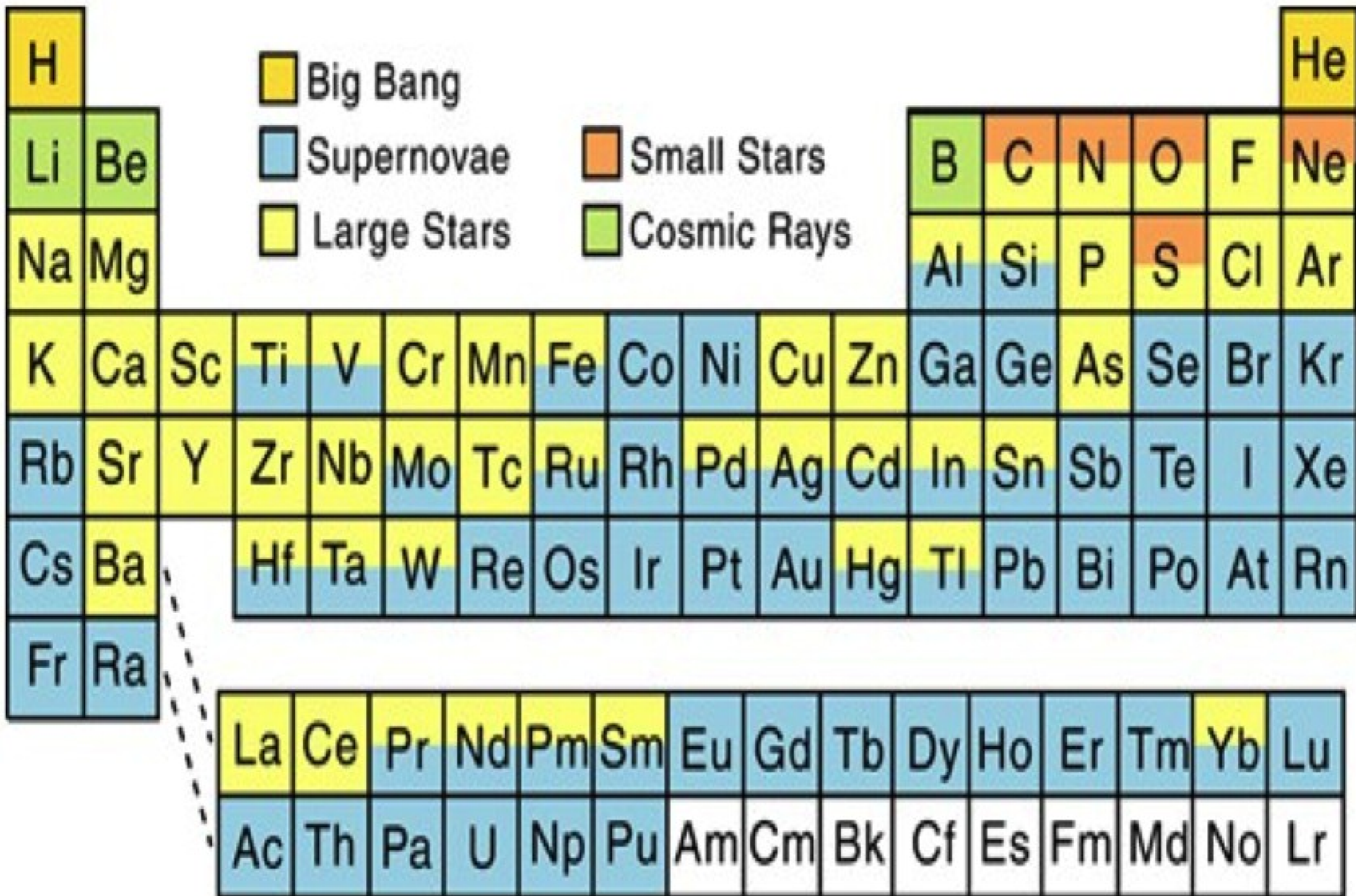
data every day



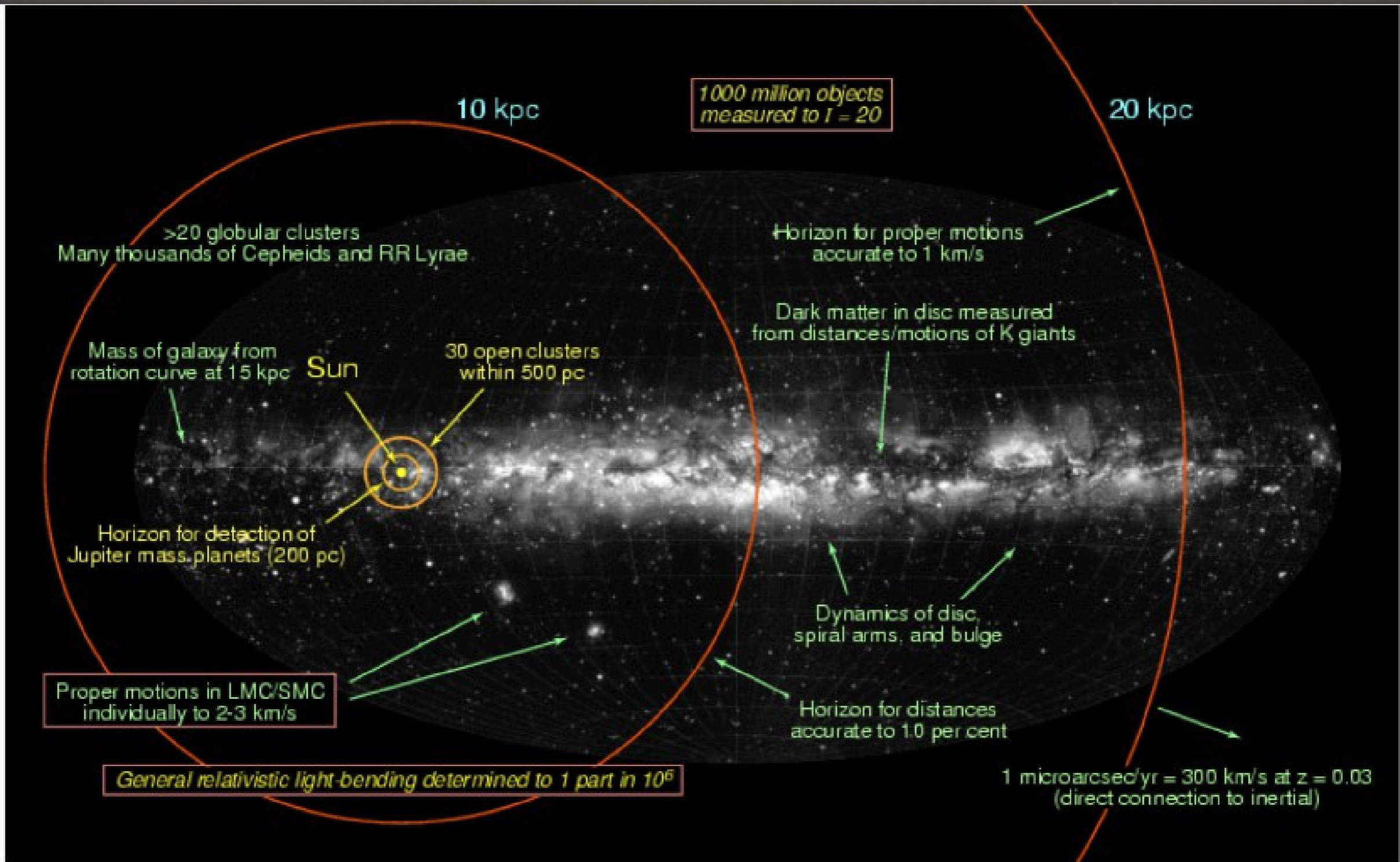
Science

Use spectra to measure the elemental composition of the stars





Taking the census of the Milky Way Galaxy

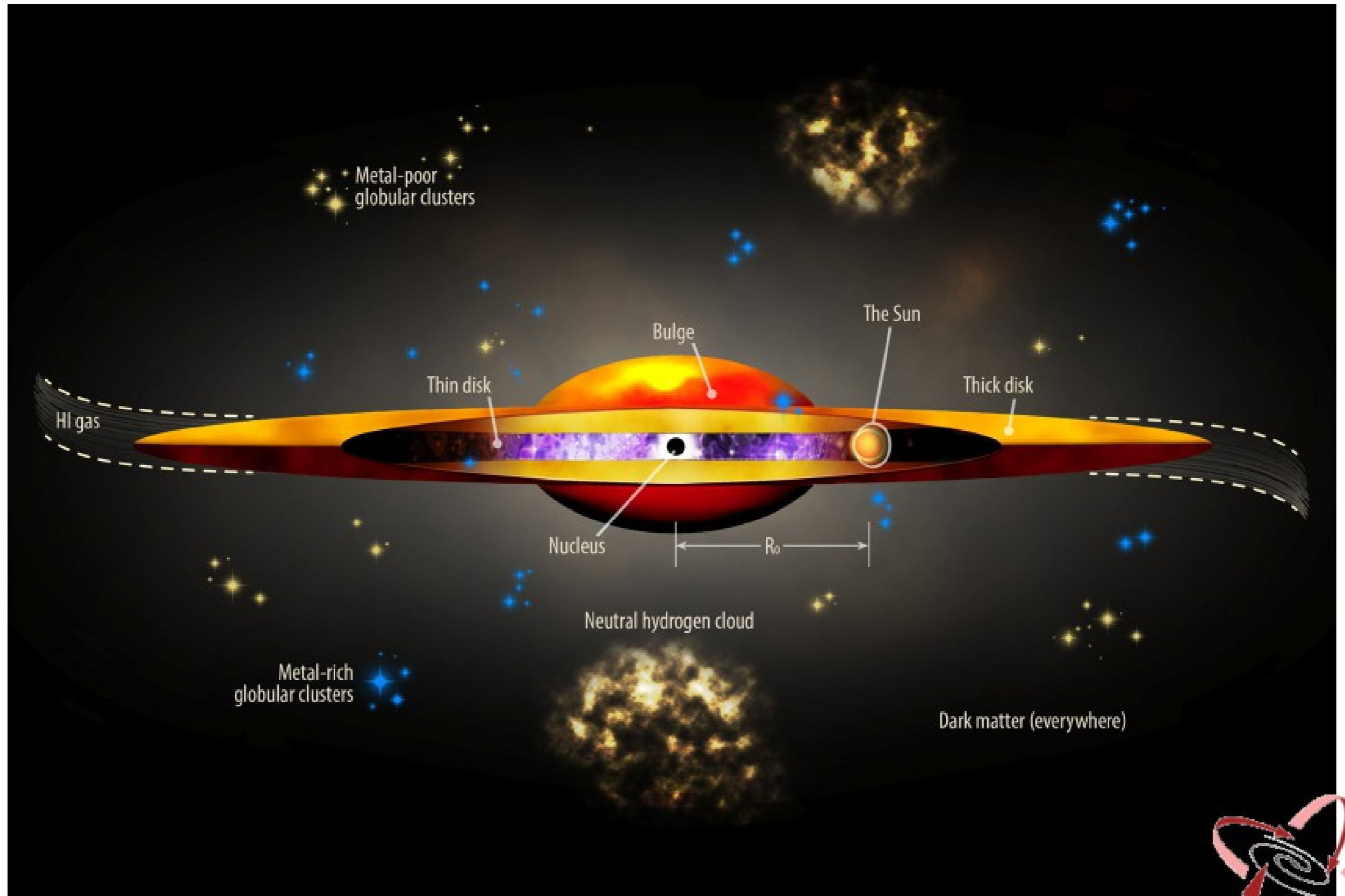


$10 \mu\text{as} = 10\%$ distances at 10 kpc

$10 \mu\text{as/yr} = 1 \text{ km/sec}$ at 20 kpc

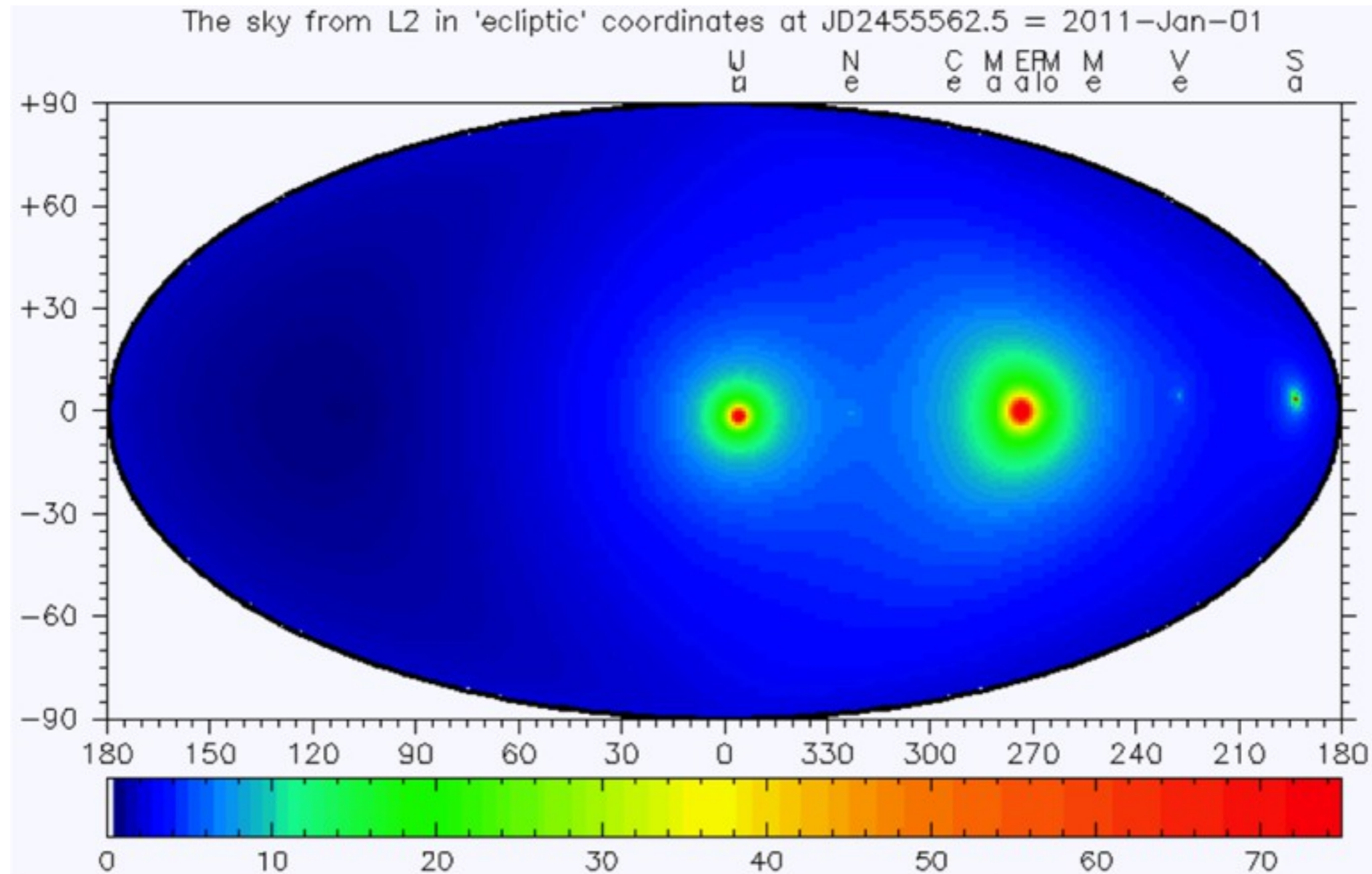


Taking the census of the Milky Way Galaxy



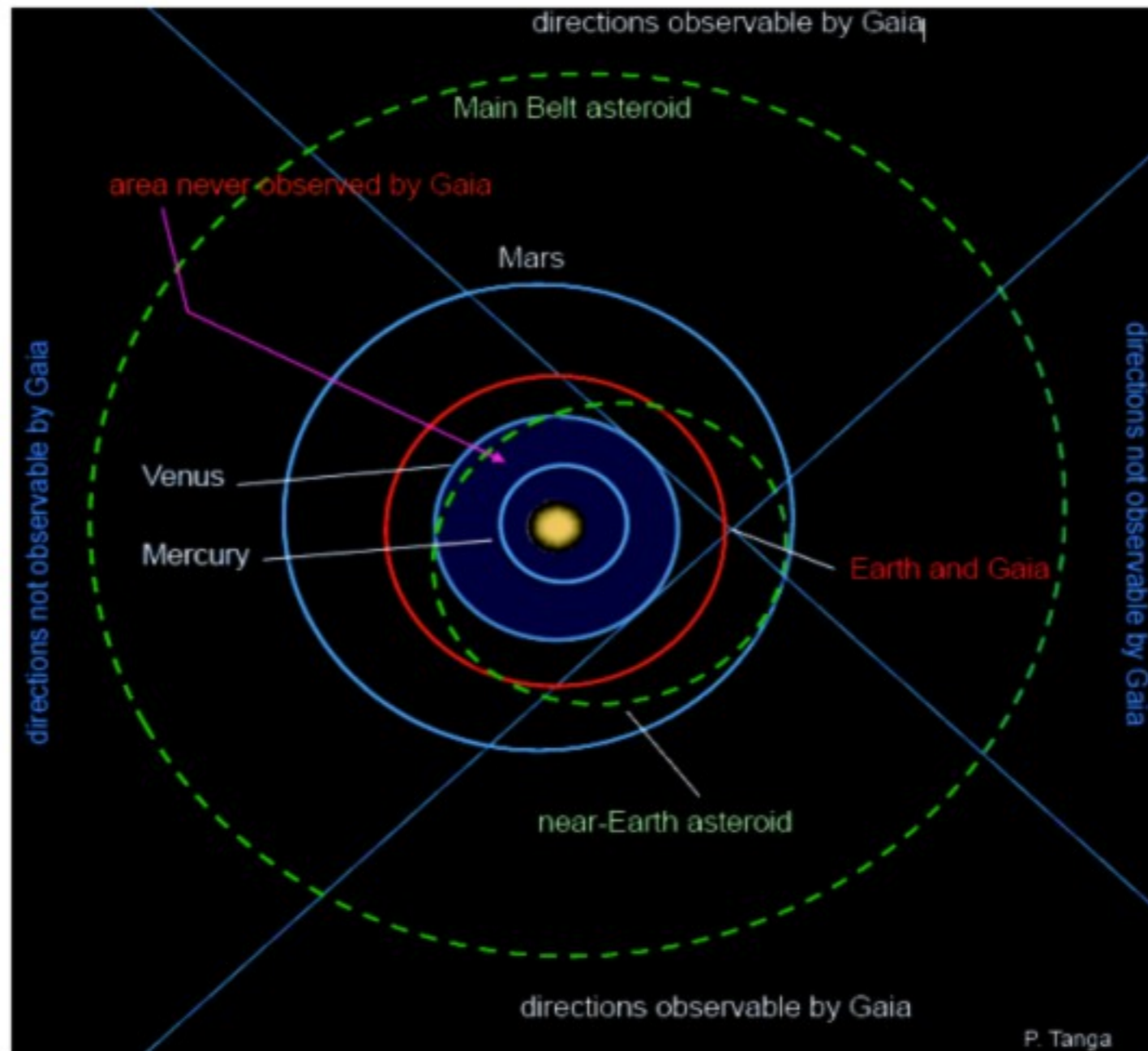


Light Bending in Solar System



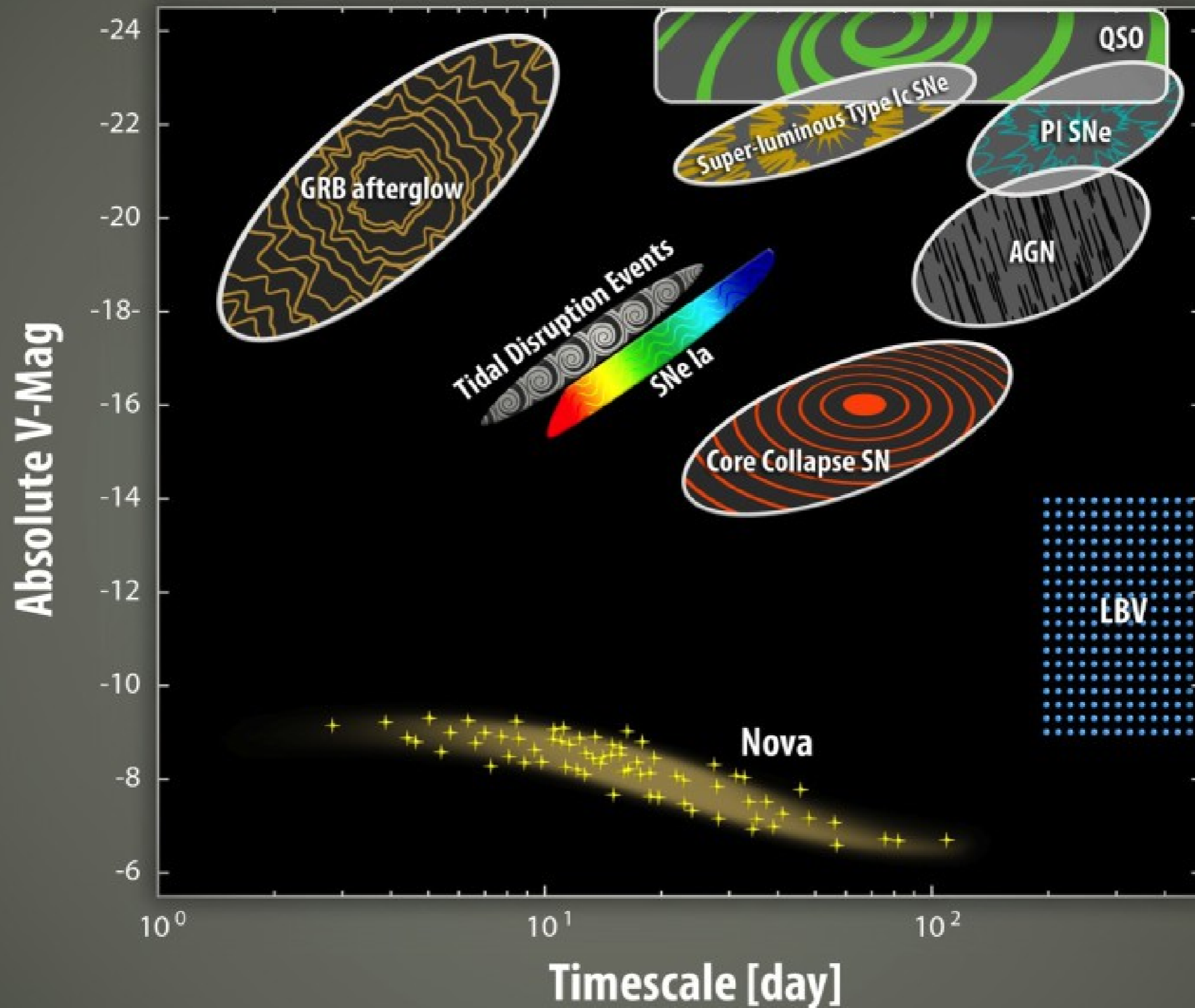
Light bending in microarcsec, after subtraction of the much larger effect by the Sun

Killer Asteroids



PLUS: 1 million galaxies; 500,000 quasars; 250,000 asteroids; 15,000 extra-solar planets; 200,000 white dwarfs and more....

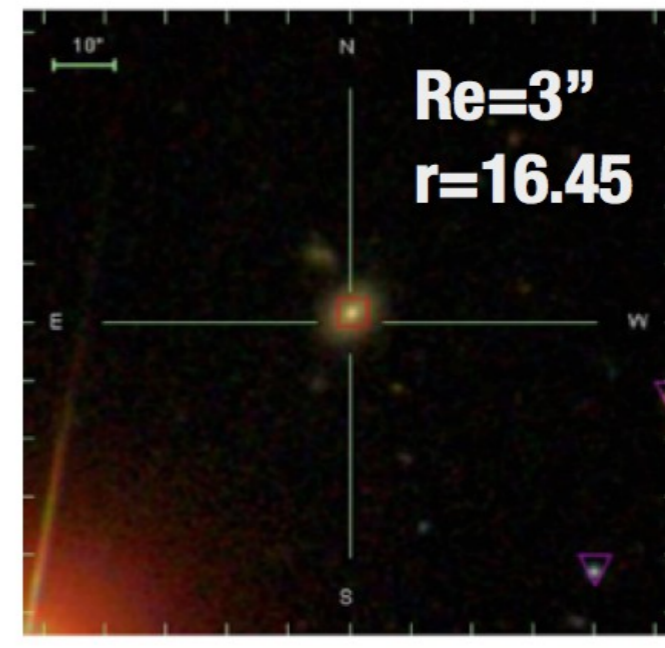
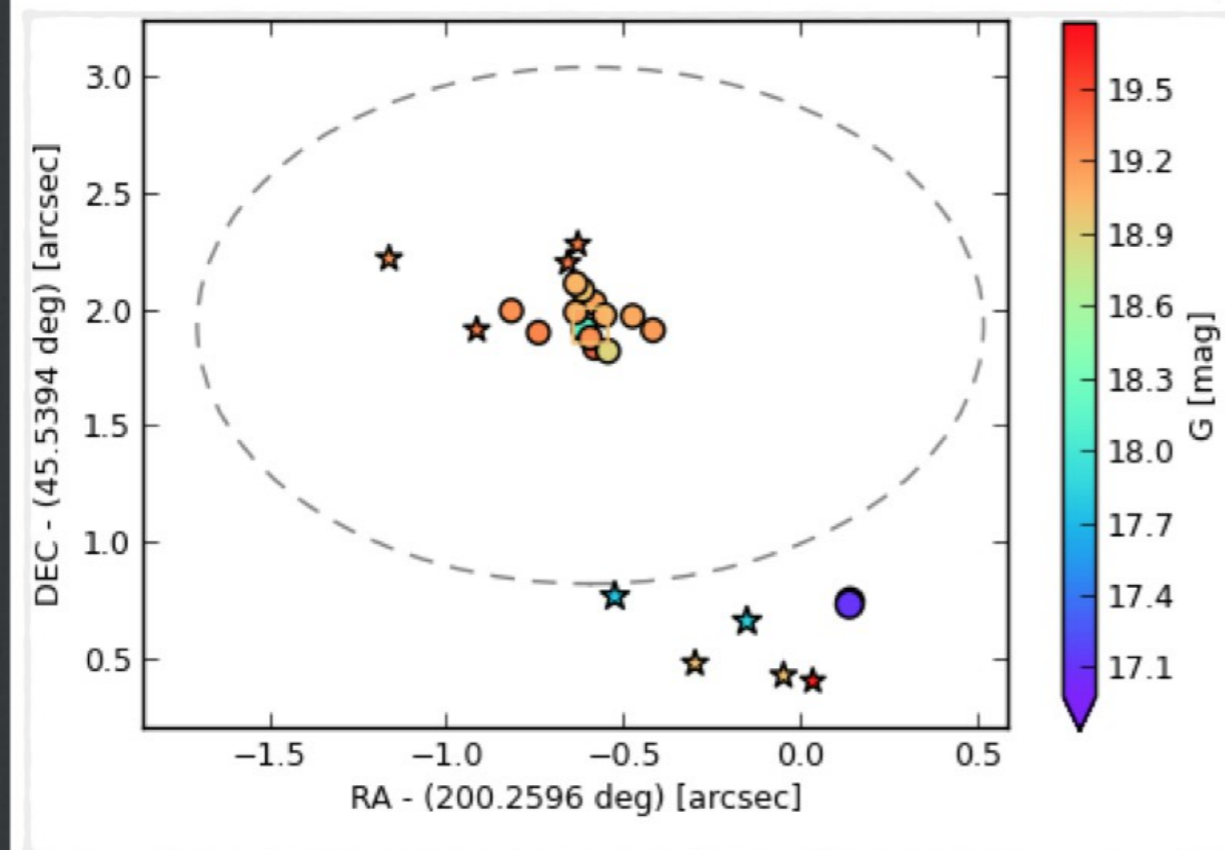
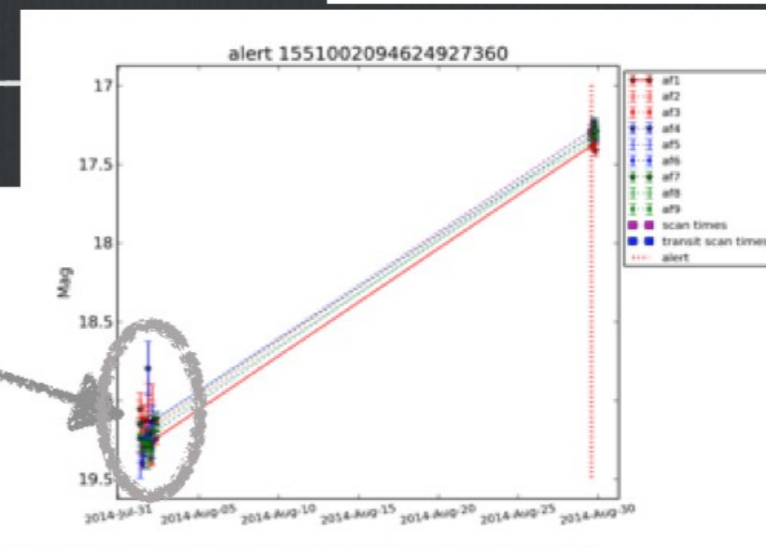
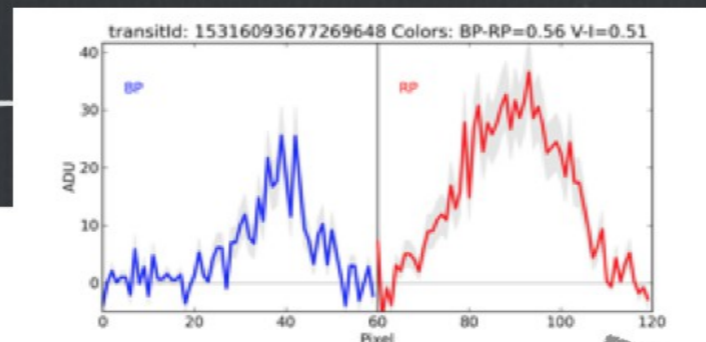
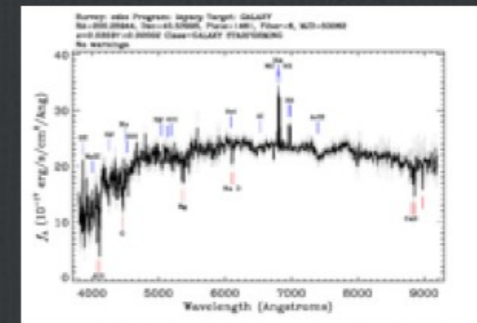
There are many kinds of transients in the Universe that we are only just beginning to discover.



alerts 1-2 days later

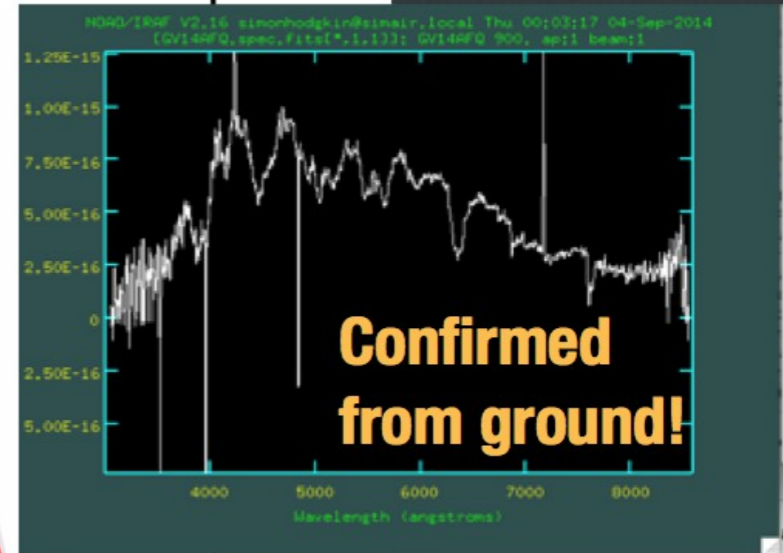
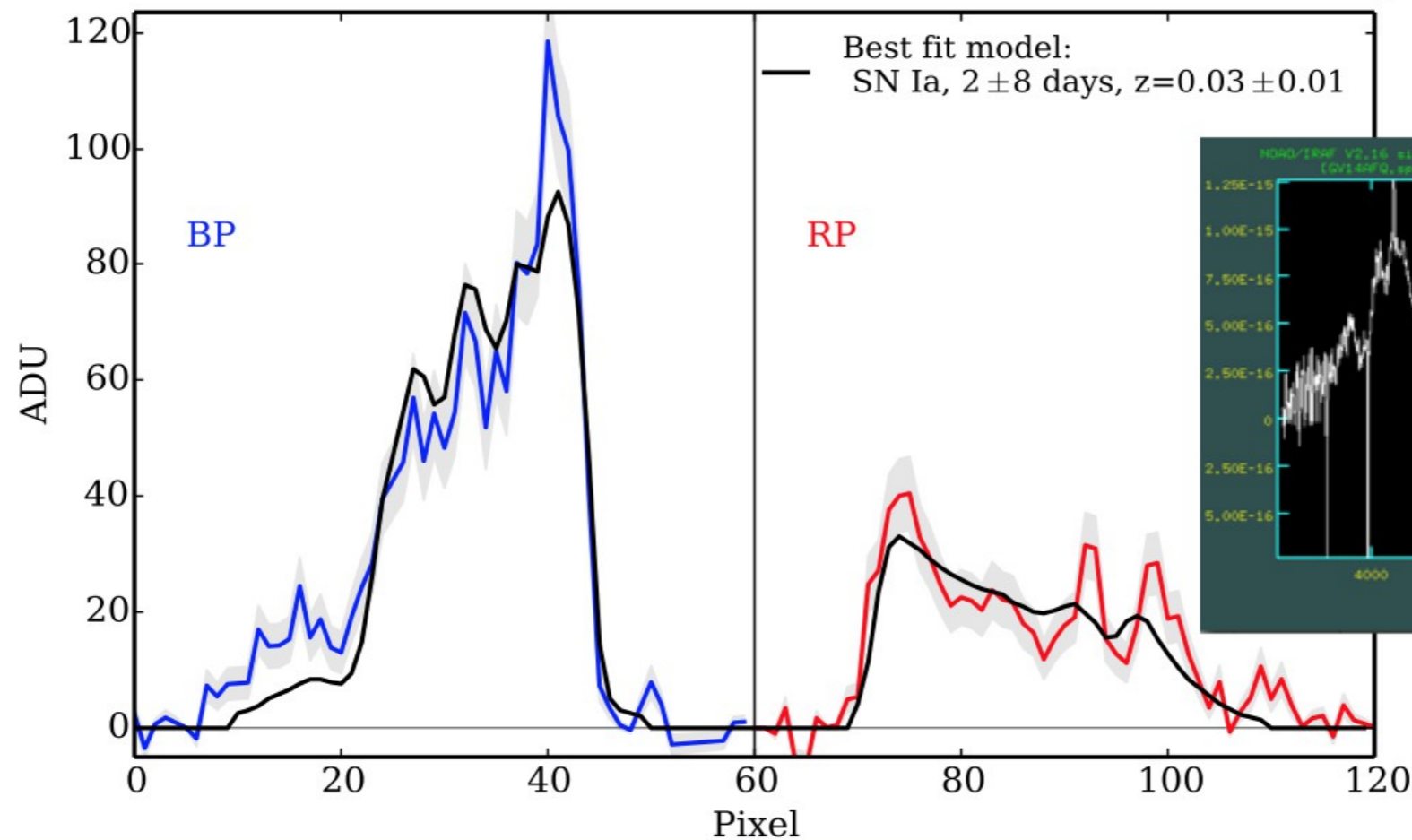
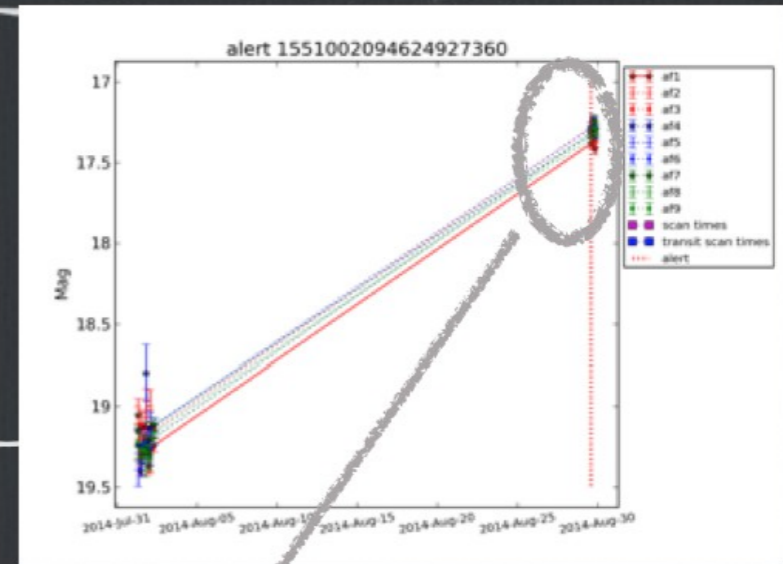


First Gaia SN candidate



First Gaia SN!

Identification of the first Gaia SN as SN Ia at $z=0.03$!



gaia.ac.uk



Gaia has exciting potential
for you to take part!

Contributing to real science

We expect to find **3 new supernovae every day**, novae and other kinds of cataclysmic variables at a rate of **4 per week**.

Gaia will see them all. But we will need lots of help to follow them up and classify them.

We might find **new kinds of objects and new physics**.

gaia.ac.uk

Morgan Fraser
Sergey Koposov
Nadia Blagorodnova
Nic Walton
Anna Hourihane
Floor Van Leeuwen

Heather Campbell
Gerry Gilmore
Simon Hodgkin
Lukasz Wyrzykowski
...many more



Plus many colleagues world-wide
(e.g Las Cumbres Observatory Global Telescope
/ Faulkes Telescope Project)