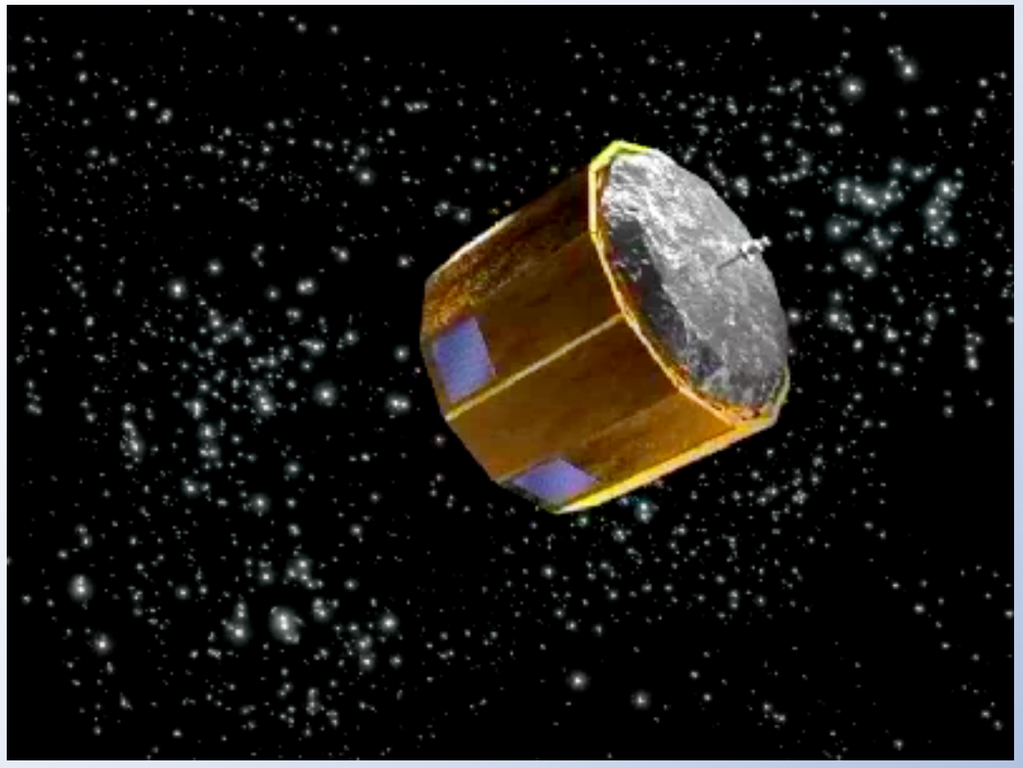
Gaia

Timo Prusti

Gaia Summary

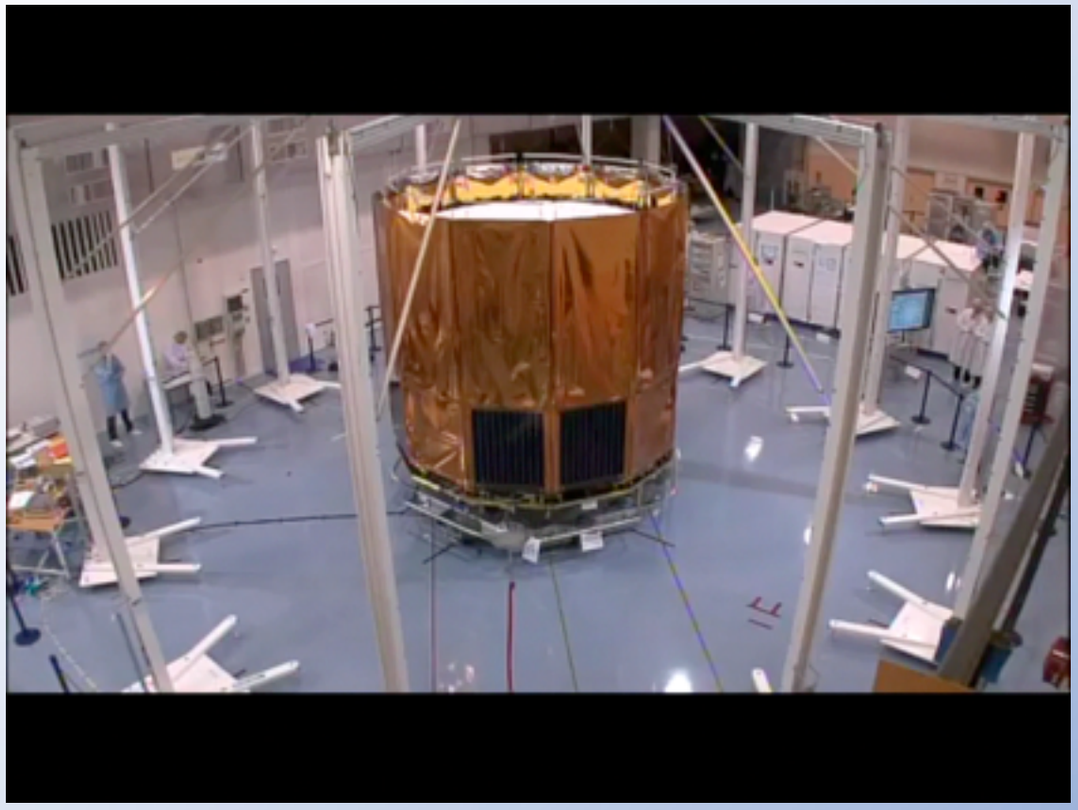
- ESA mission building on the Hipparcos heritage
- Astrometry, Photometry and Spectroscopy
- Launch September 2013
- Satellite, including the payload, by industry (Astrium, Toulouse), operations by ESA and data processing by scientists (DPAC)
- Science Alerts early on
- First intermediate data release 22 months after launch



www.rssd.esa.int/Gaia

Science Topics

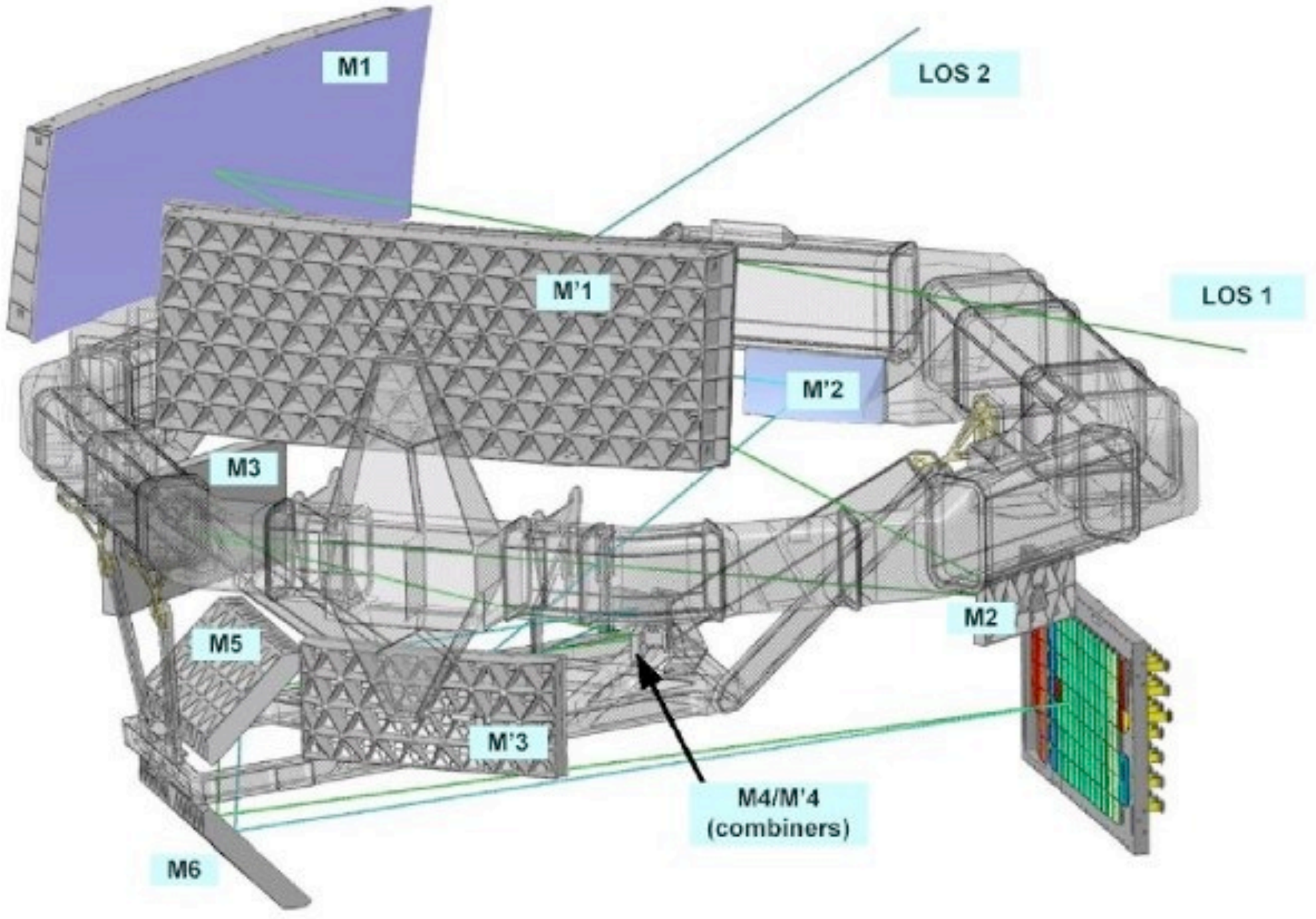
- Structure and dynamics of the Galaxy
- The star formation history of the Galaxy
- Stellar astrophysics
- Binaries and multiple stars
- Brown dwarfs and planetary systems
- Solar system
- Galaxies, Quasars and the Reference Frame
- Fundamental physics: General relativity

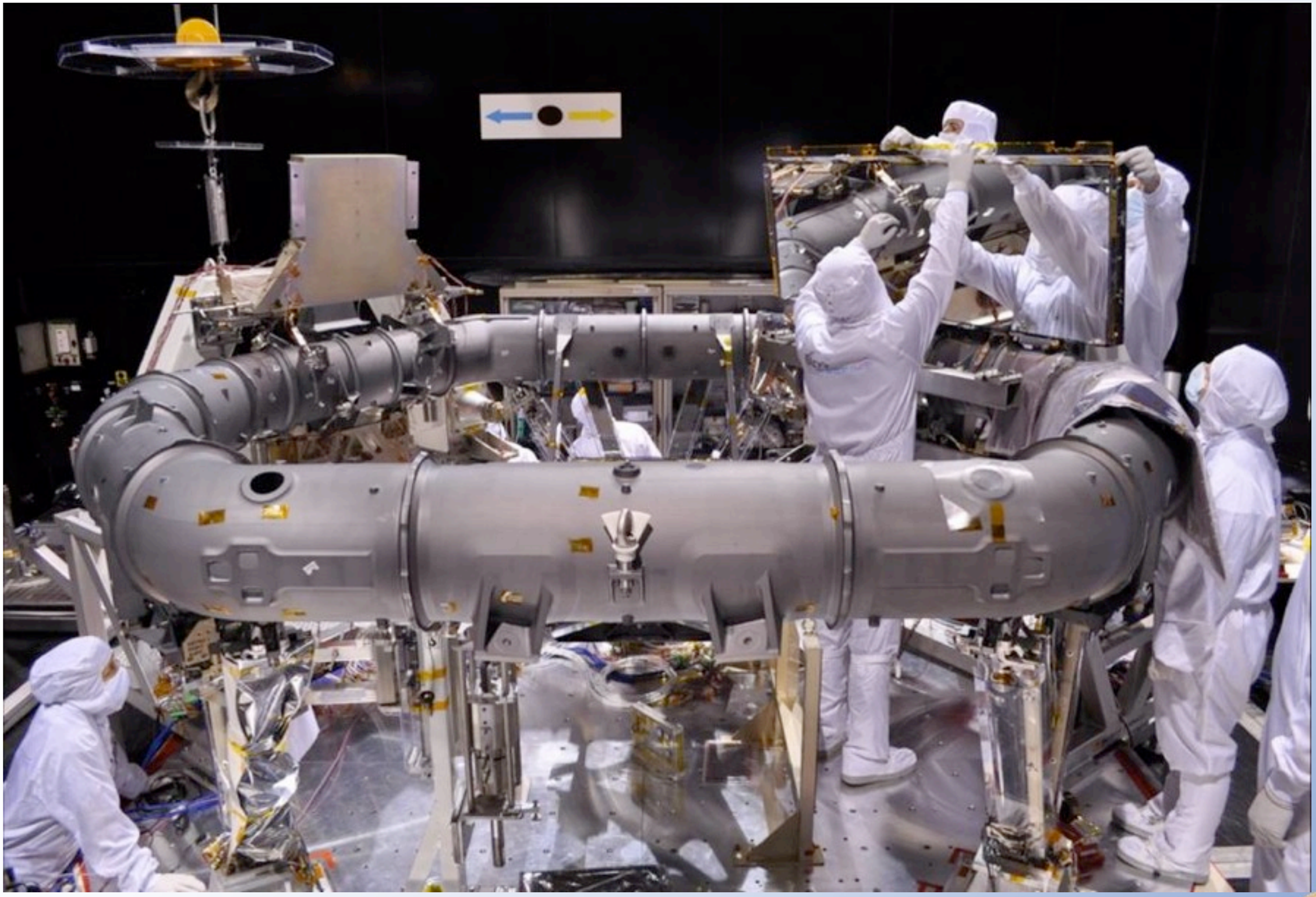


Gaia vs. Hipparcos

- Magnitude limits:
  - Hipparcos <12 mag
  - Gaia 6 - 20 mag
- Number of objects: 120,000 => 10^9
- Accuracy: milliarcsec => μarcsec
- Radial velocity: none => 150 million objects
- Pre-selected => Unbiased survey

Payload and Telescope





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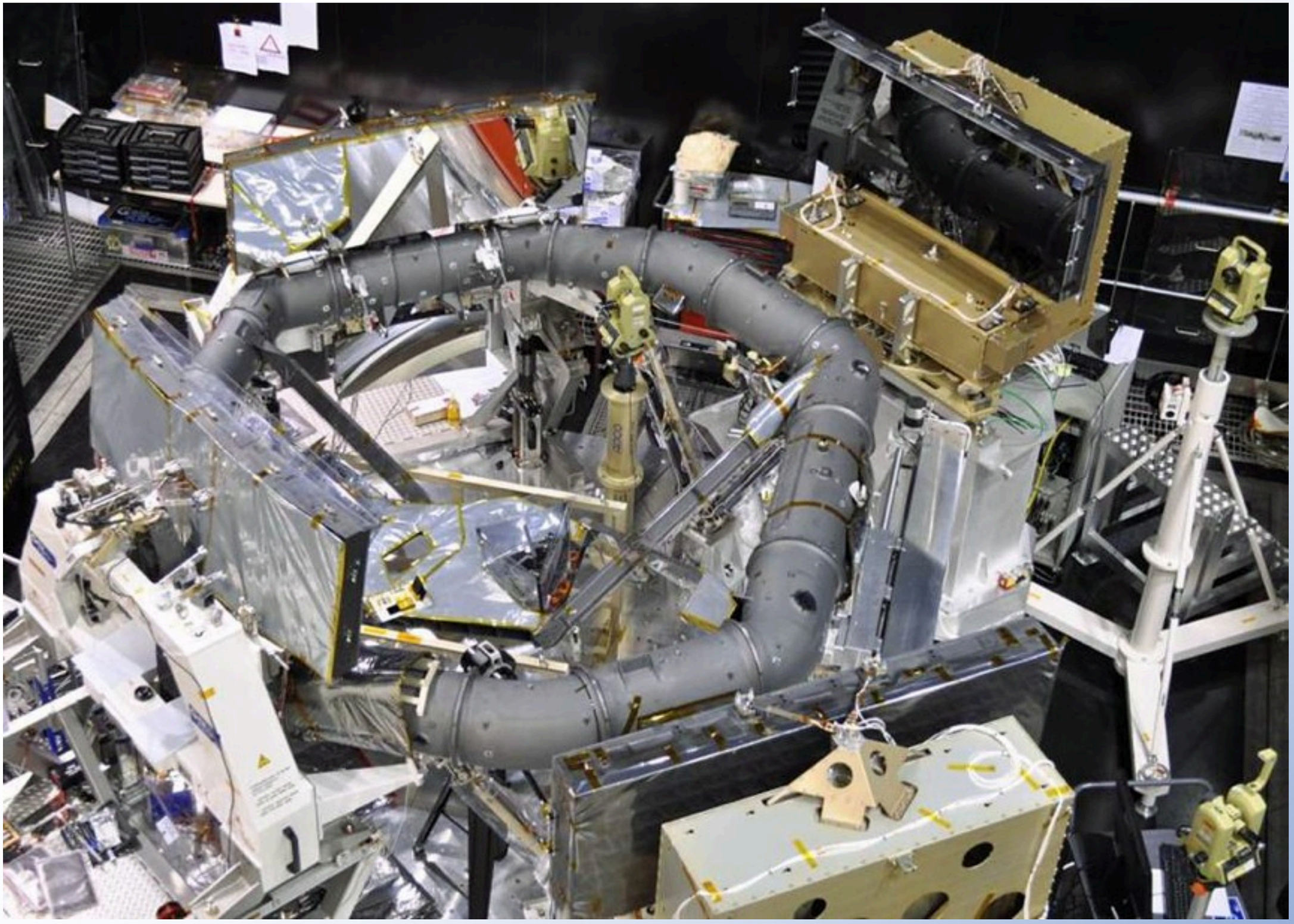

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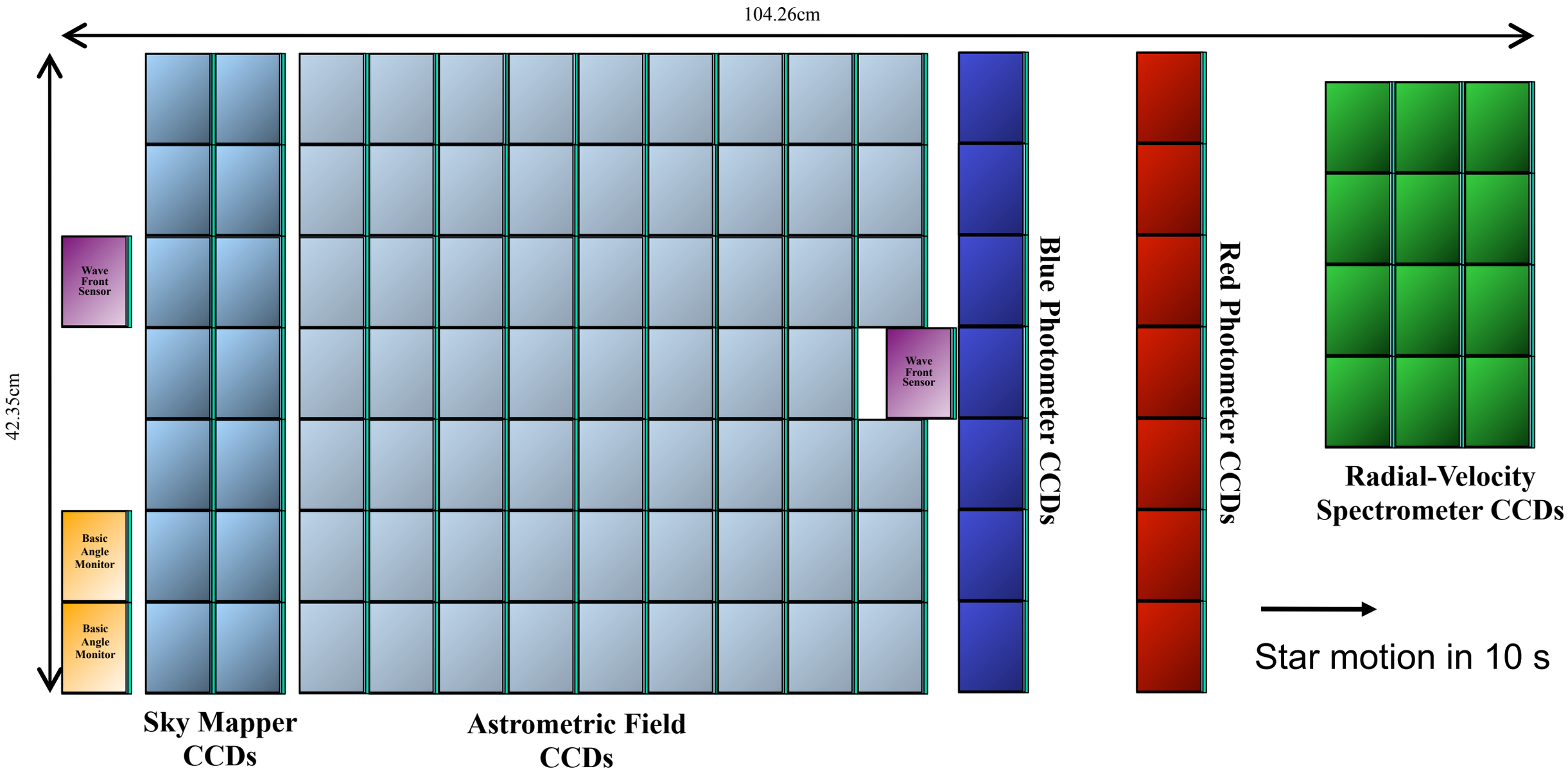
Figure courtesy Alex Short

Focal Plane



Total field:

- active area: 0.75 deg^2
- CCDs: 14 + 62 + 14 + 12 (+ 4)
- 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
- field-of-view discrimination

Astrometry:

- total detection noise ~ 6 e$^-$

Photometry:

- spectro-photometer
- blue and red CCDs

Spectroscopy:

- high-resolution spectra
- red CCDs

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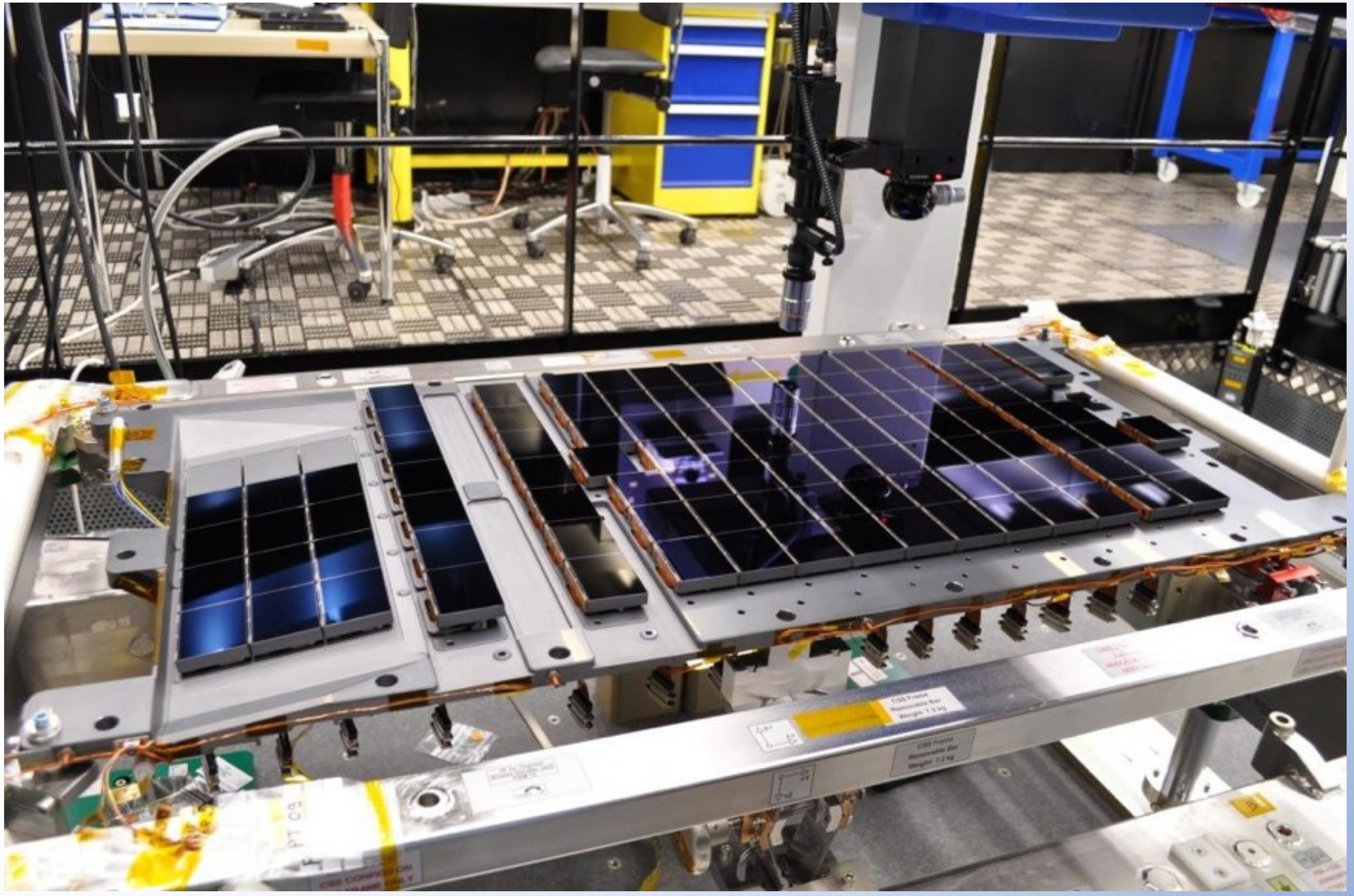
Gaia

- Basic Angle Monitor (BAM)



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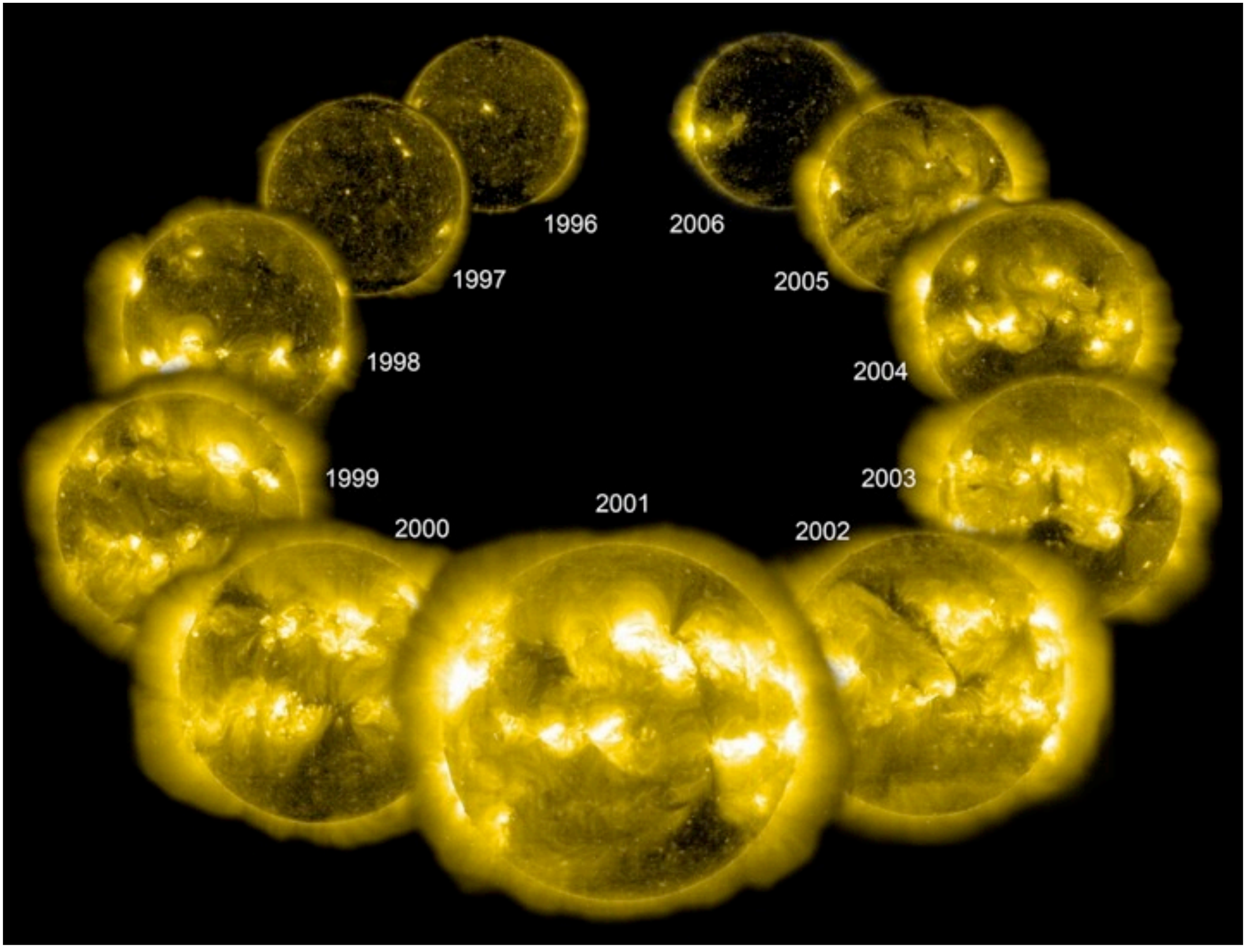
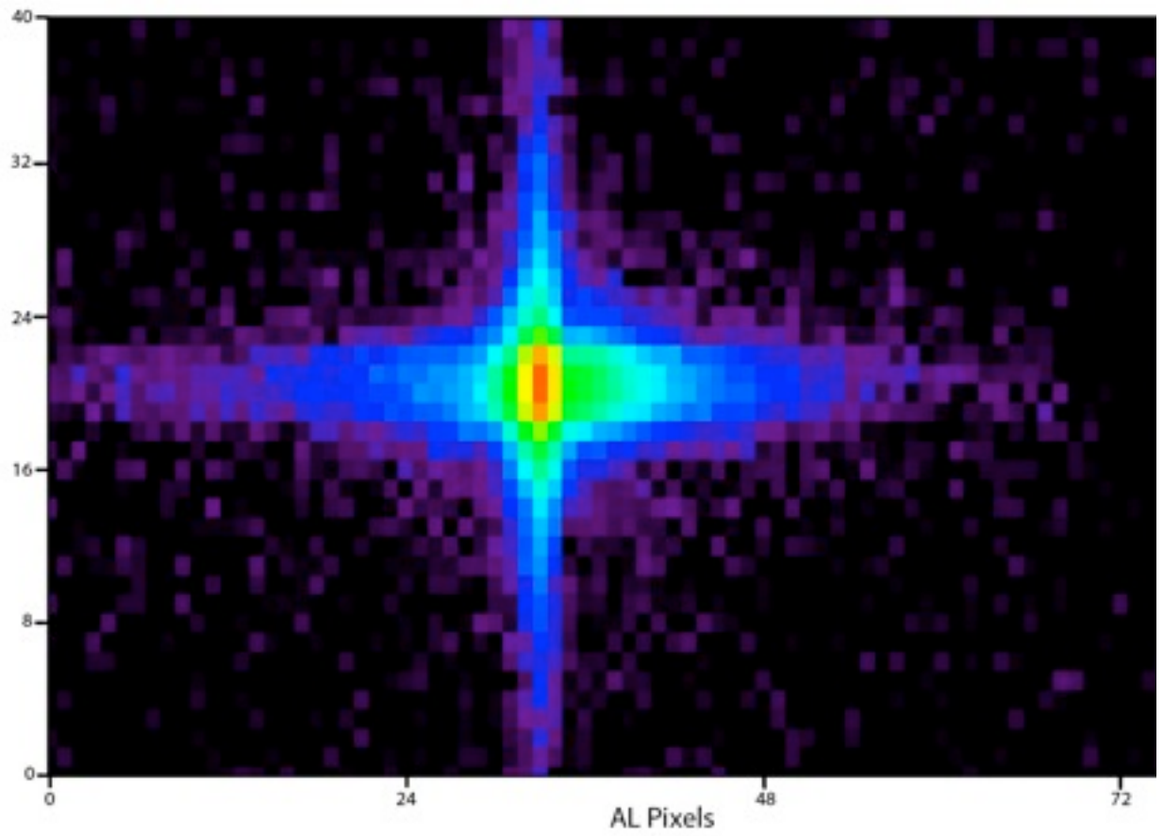
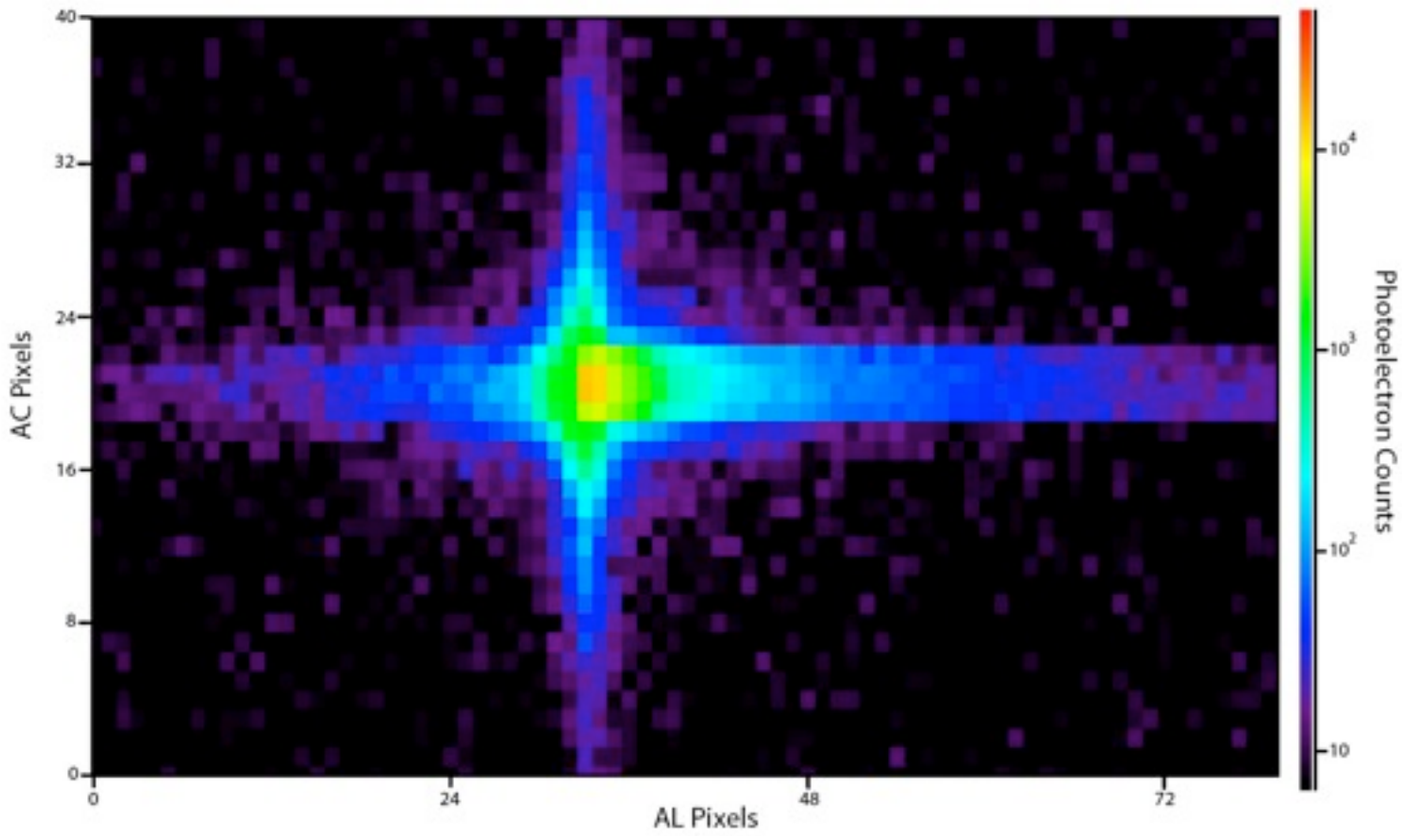
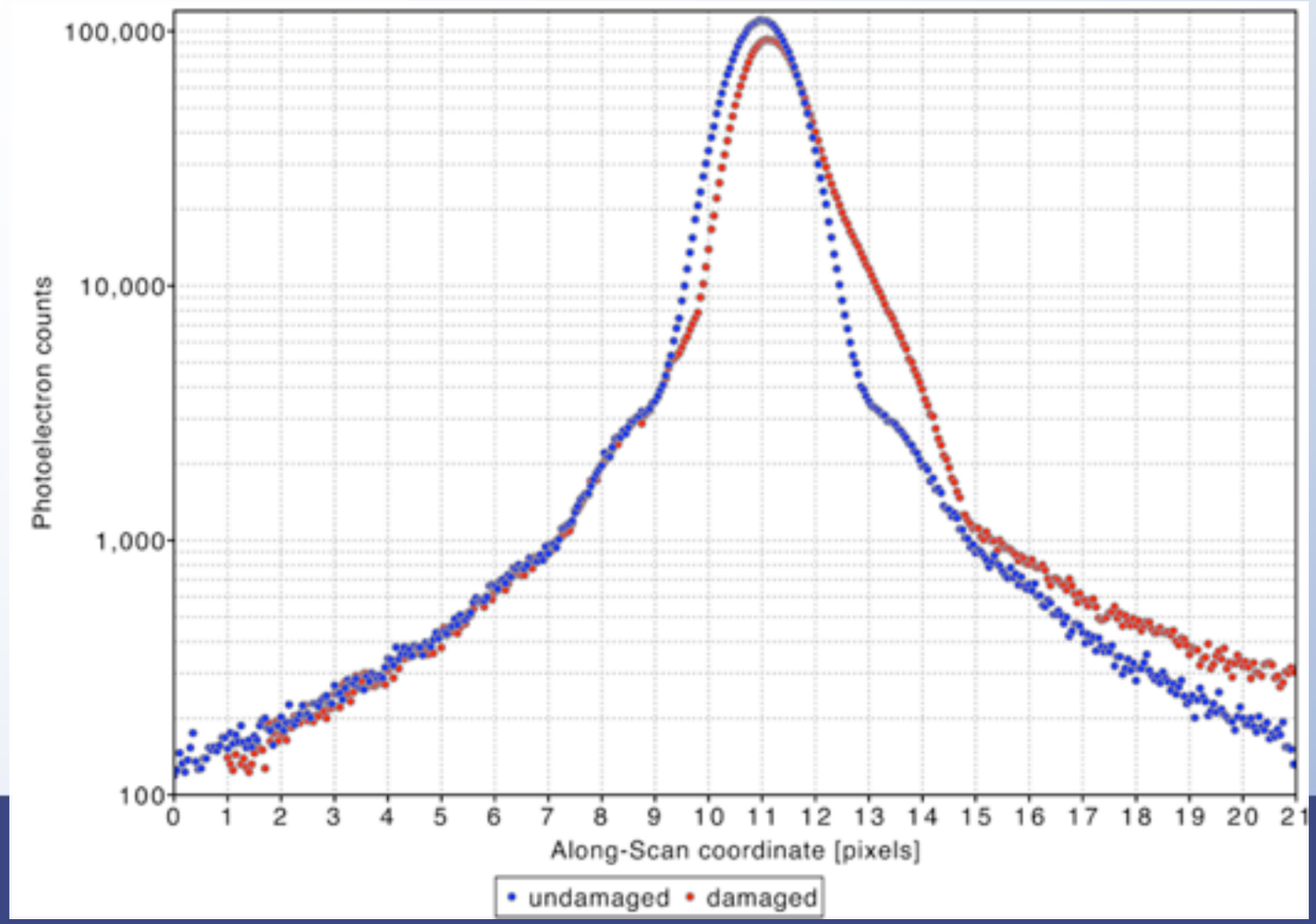
The Radiation Effect on CCDs

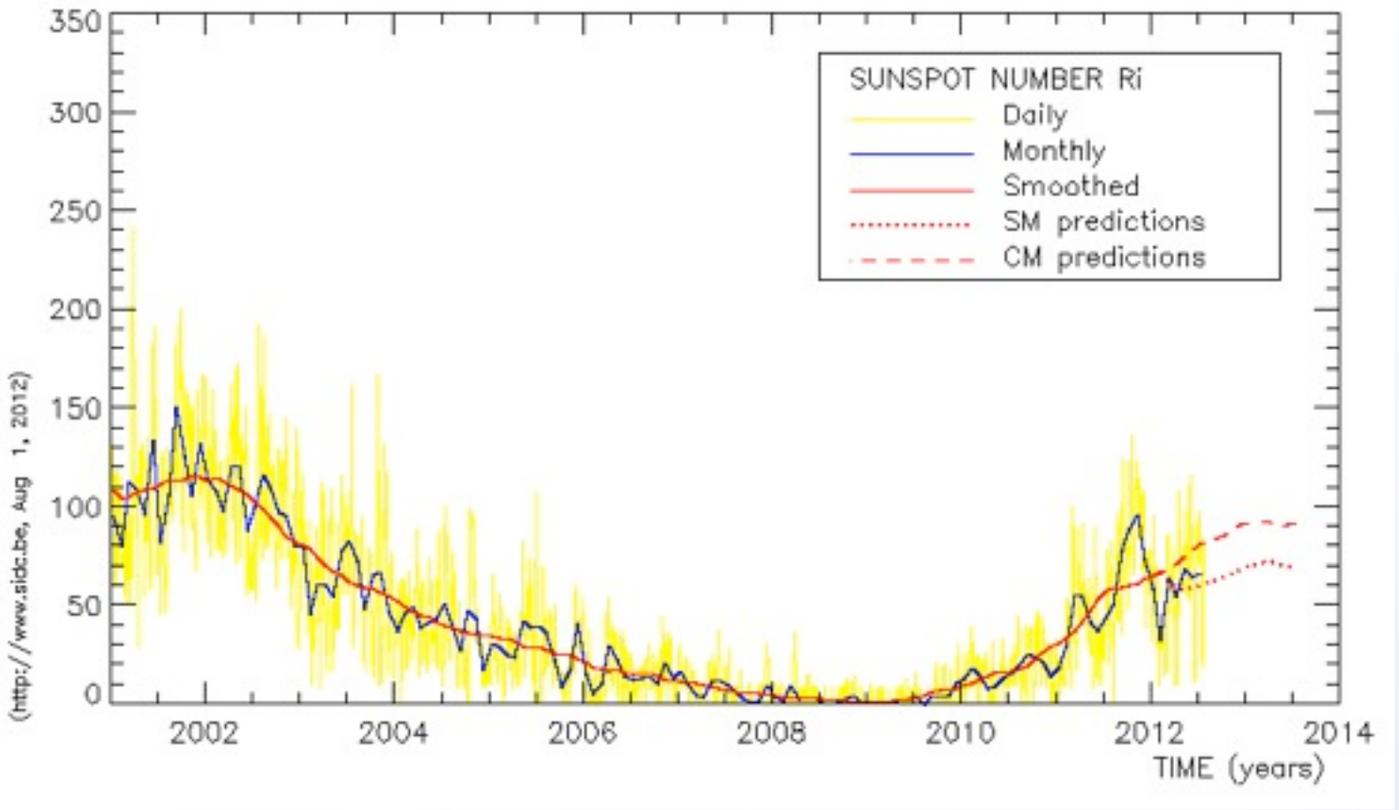


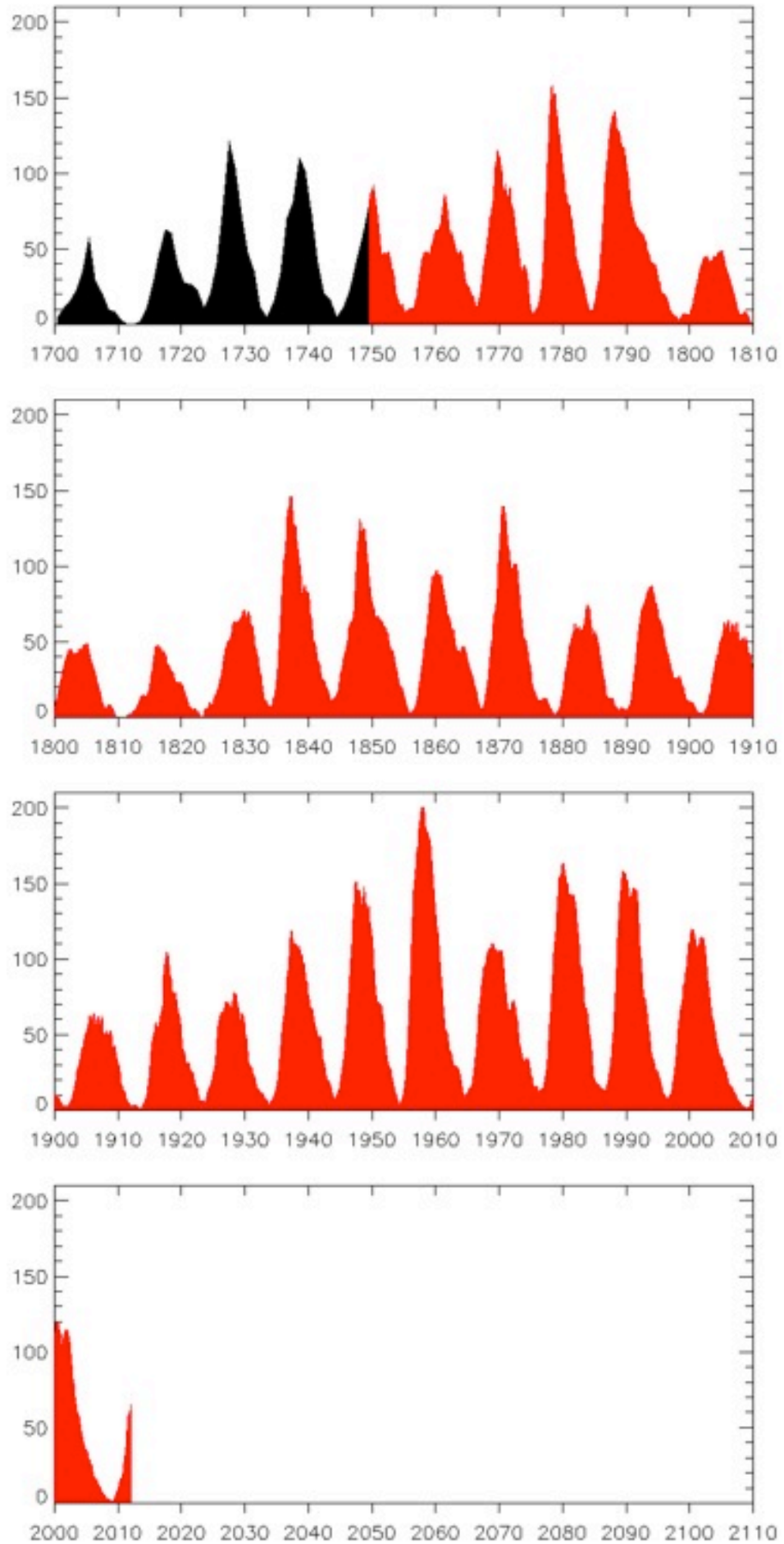

AL Pixels
0
24
48
72
0
8
16
24
32
40

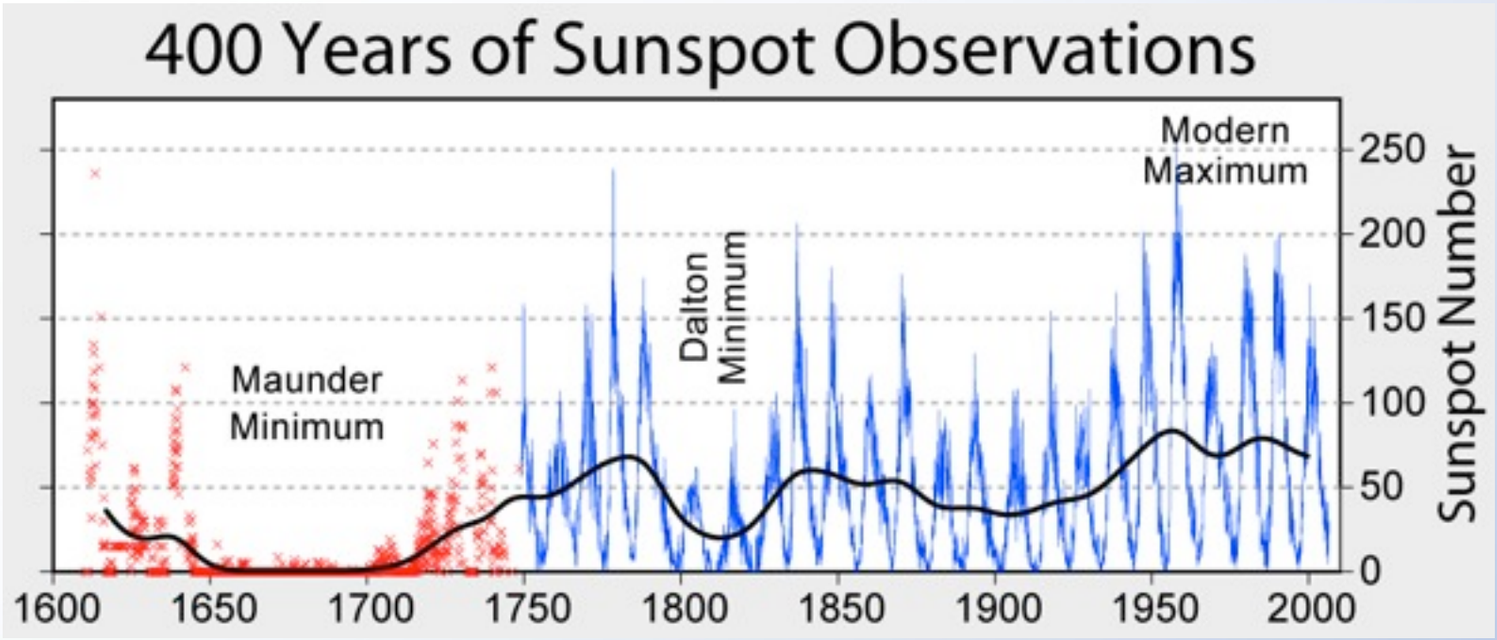

AC Pixels
AL Pixels
Photoelectron Counts
10
10^2
10^3
10^4

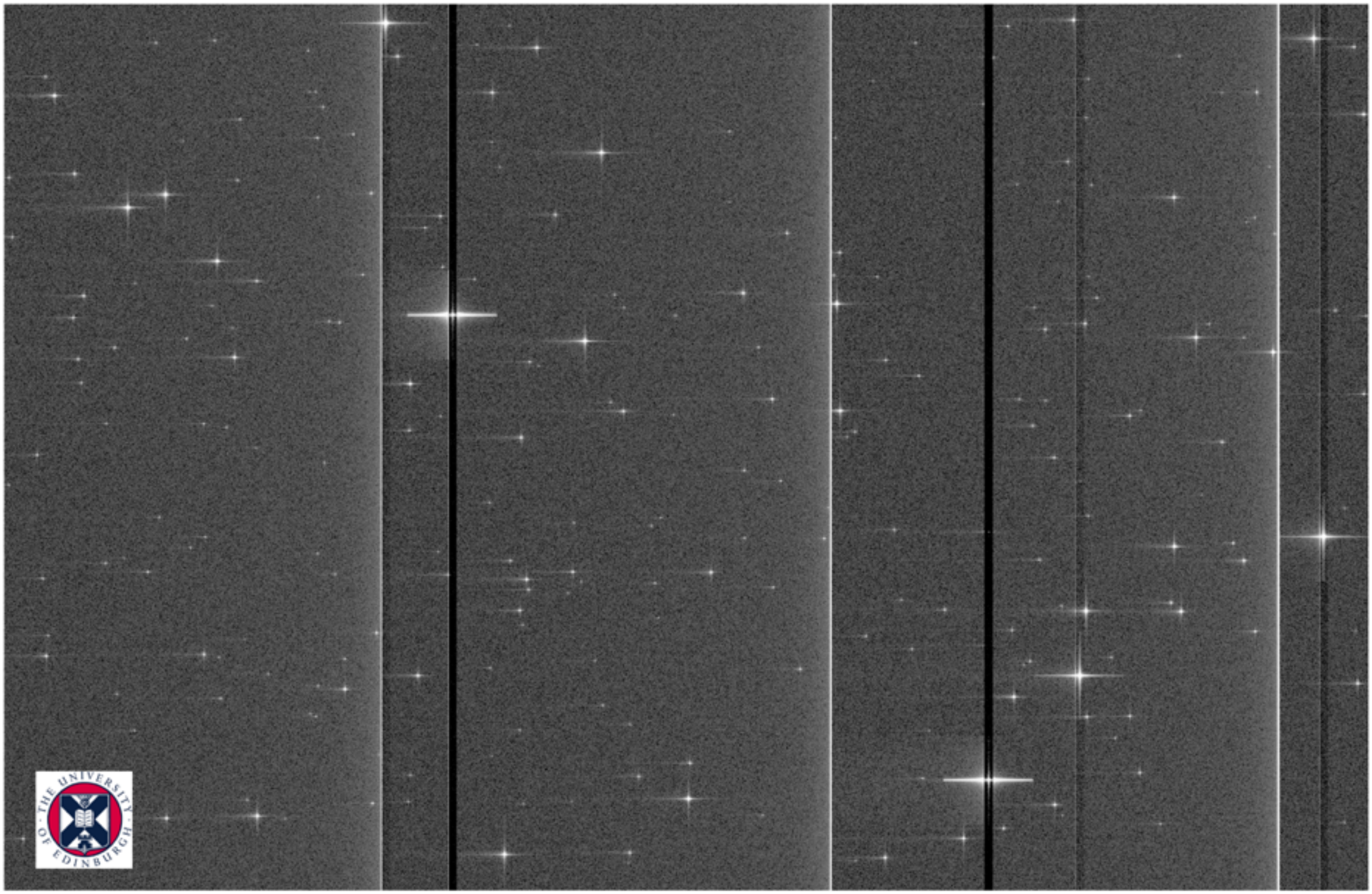

Photoelectron counts
100,000
10,000
1,000
100
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21
Along-Scan coordinate [pixels]
undamaged
damaged


Gaia


SUNSPOT NUMBER Ri
Daily
Monthly
Smoothed
SM predictions
CM predictions
(http://www.sidc.be, Aug 1, 2012)
TIME (years)

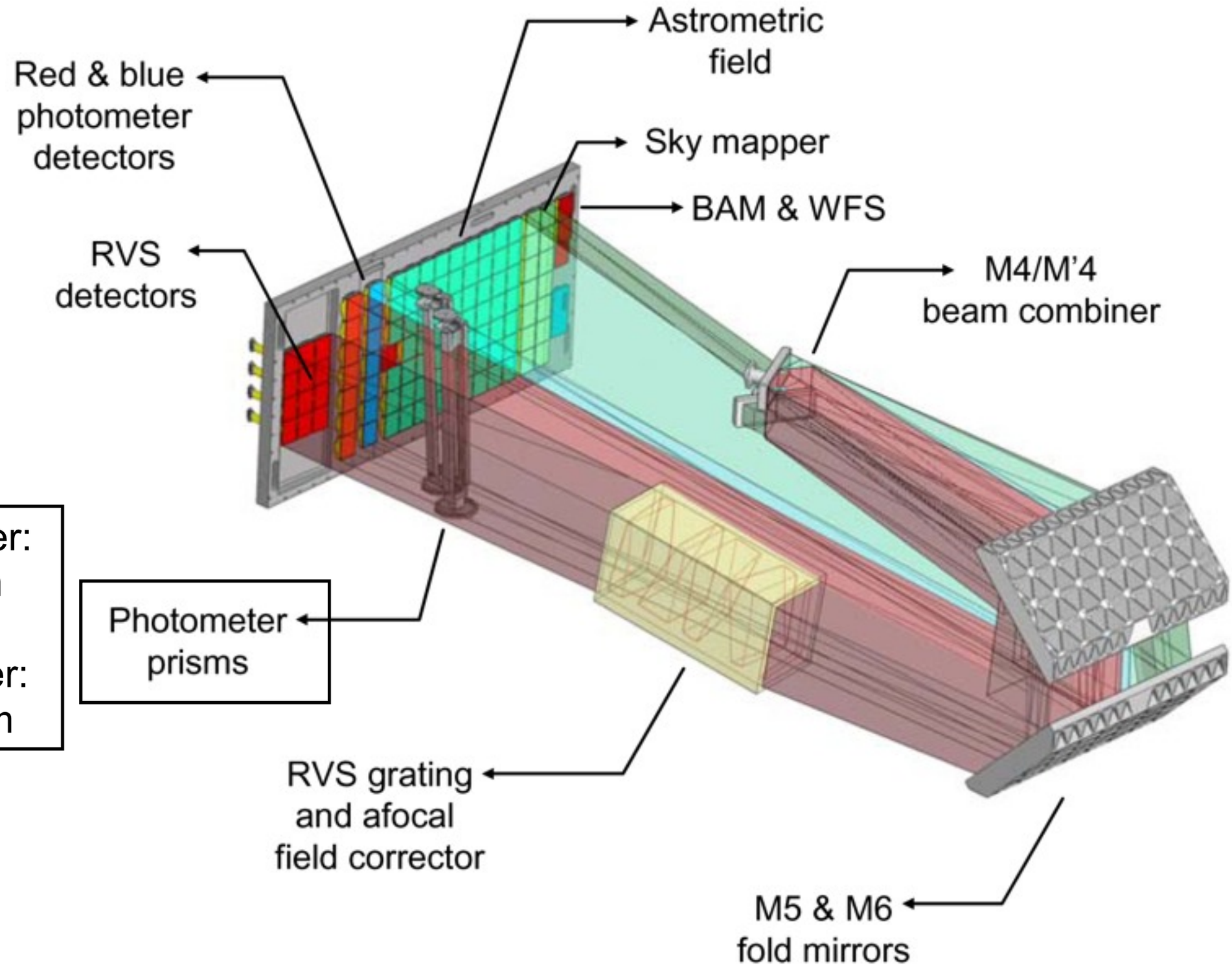

(http://www.sidc.be, Aug 1, 2012)


400 Years of Sunspot Observations
Modern Maximum
Dalton Minimum
Maunder Minimum
Sunspot Number



Credit Michael Davidson

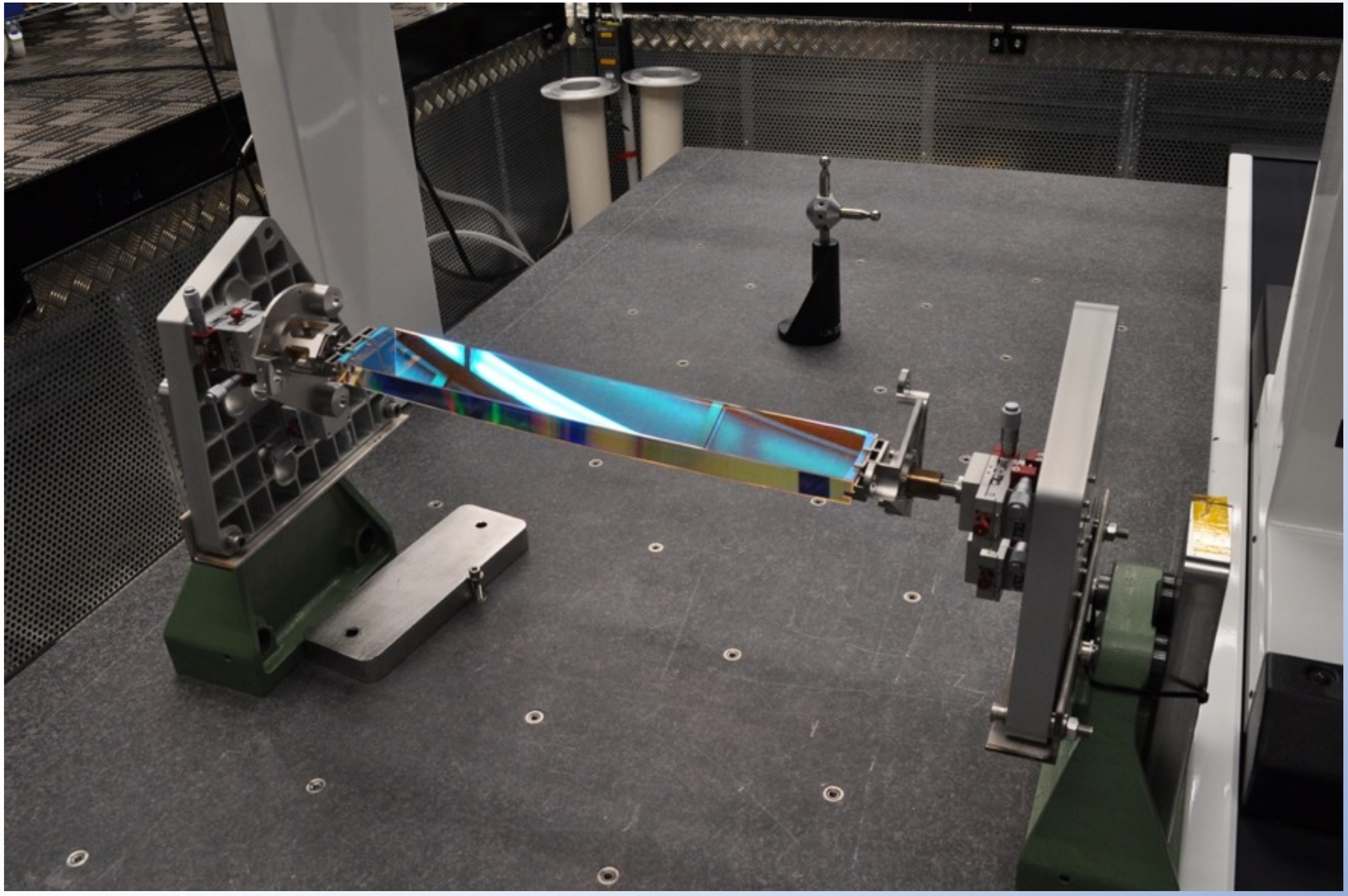
Photometry Measurement Concept

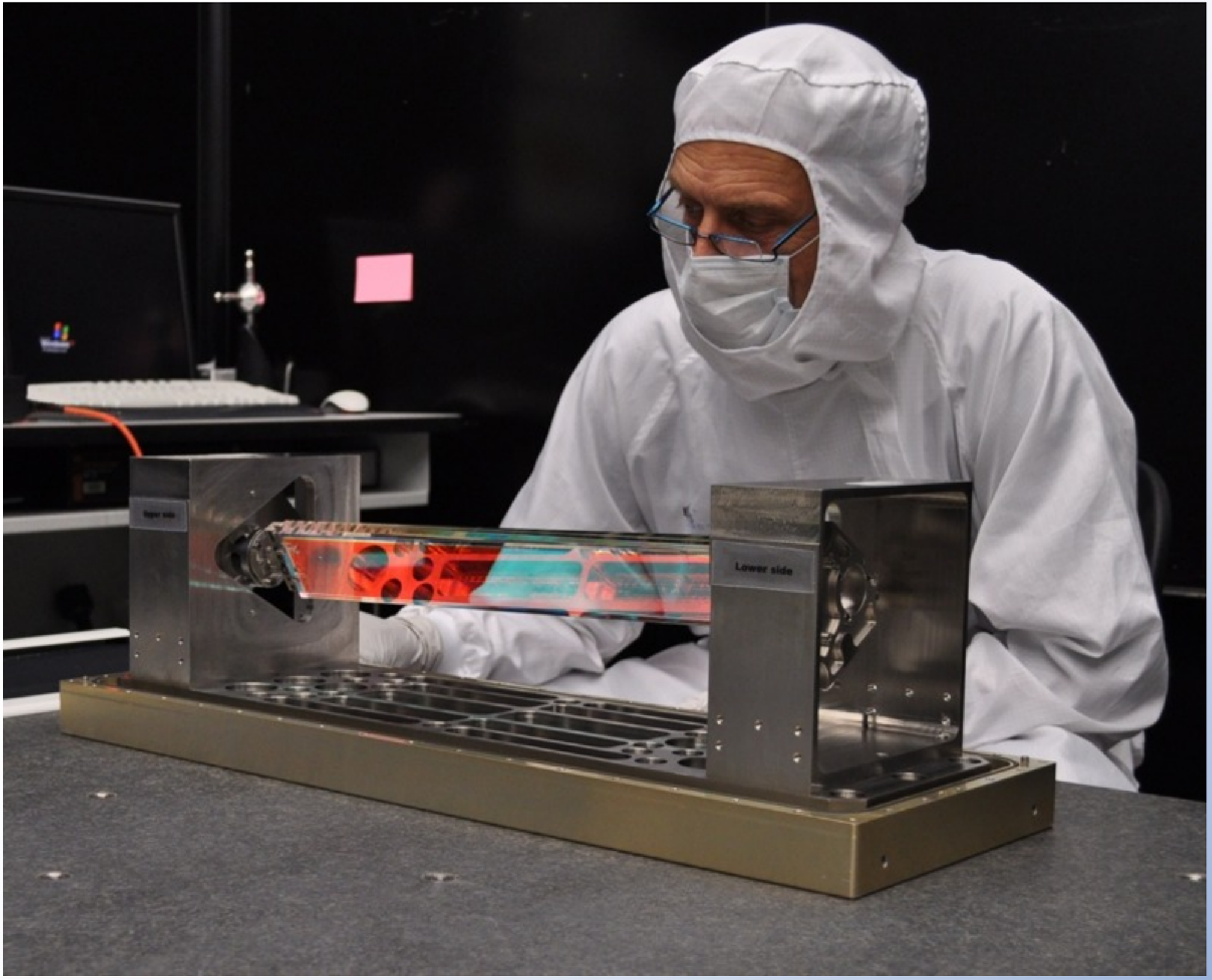


Blue photometer:
330 – 680 nm

Red photometer:
640 – 1000 nm

Figure courtesy EADS-Astrium





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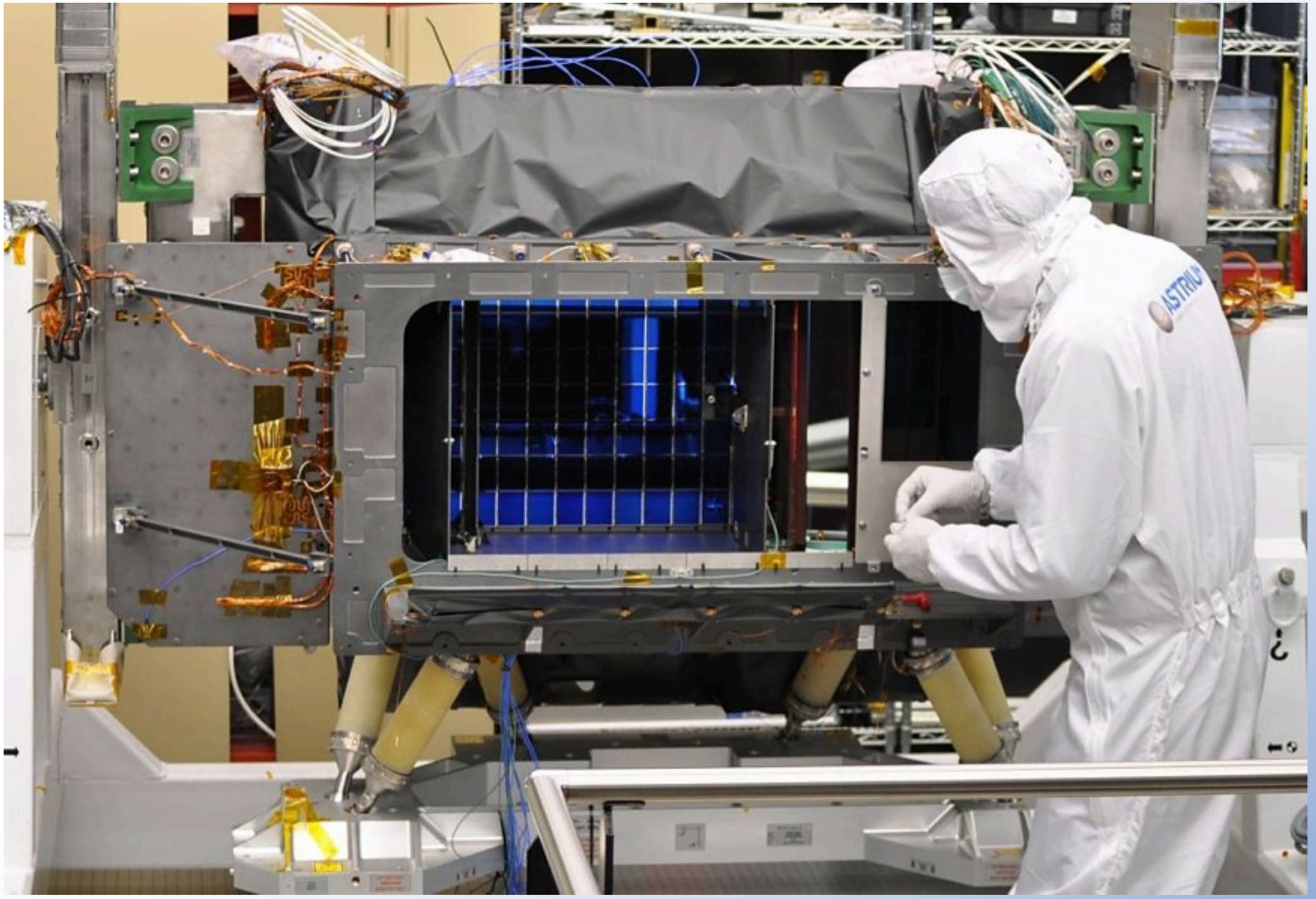


Radial-Velocity Measurement Concept

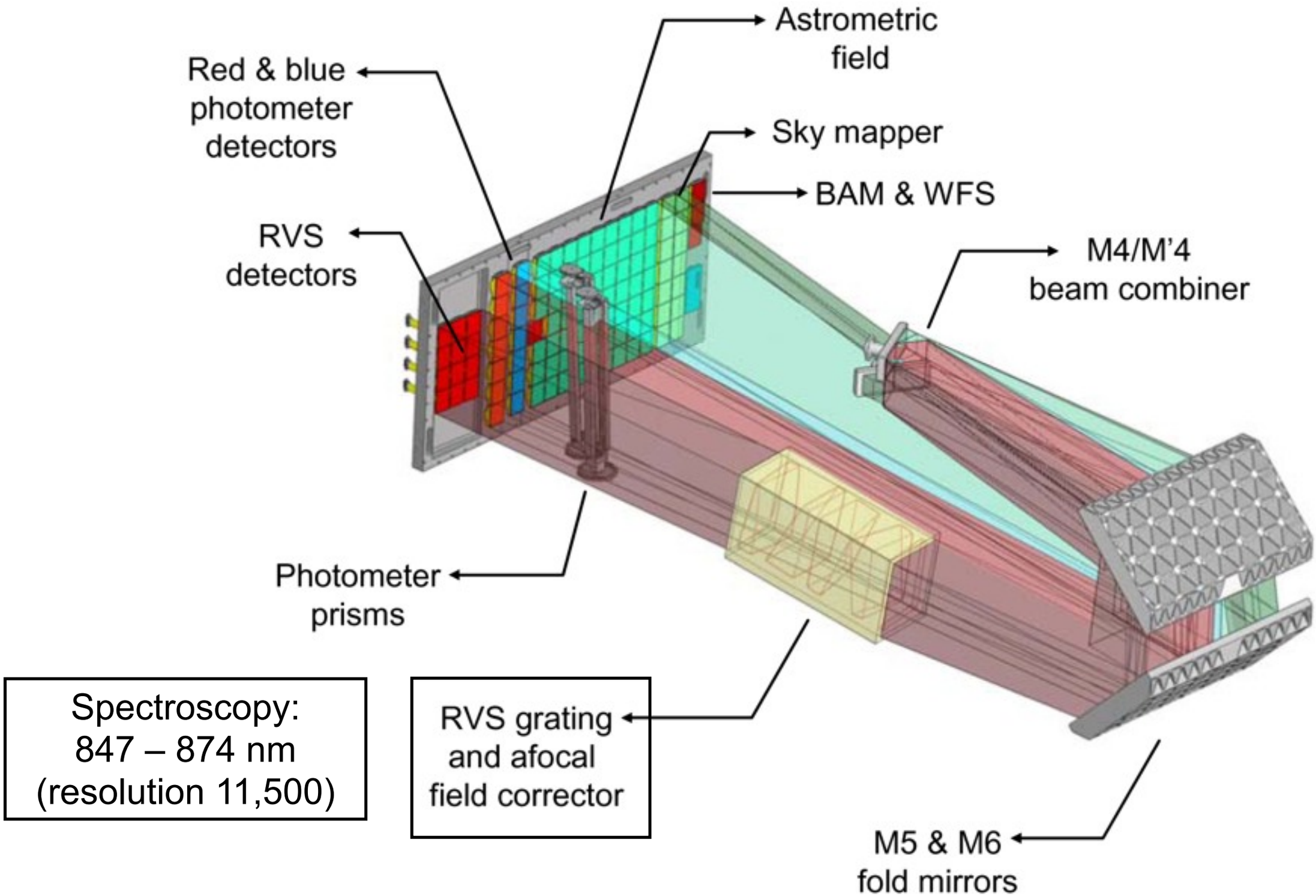
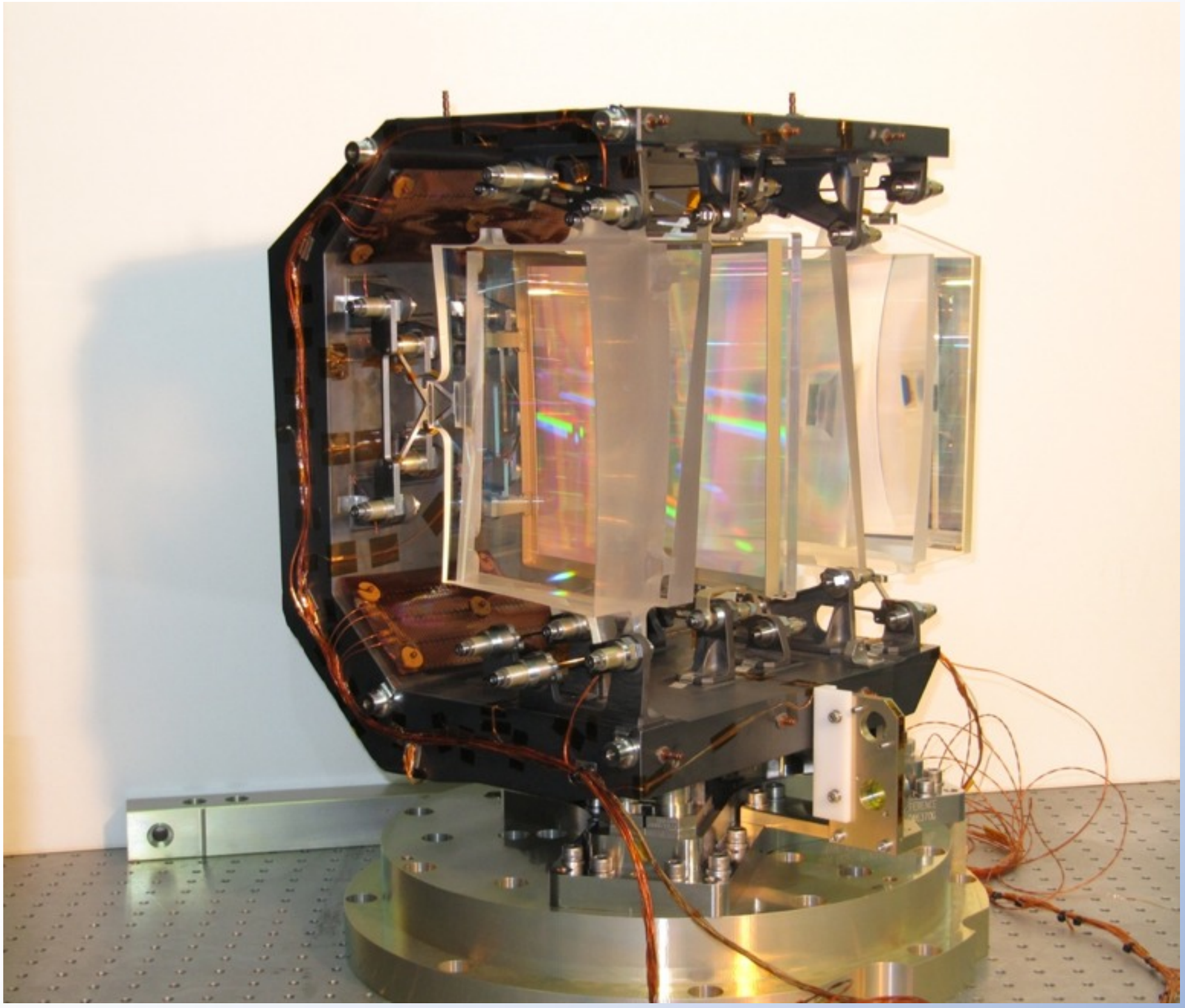
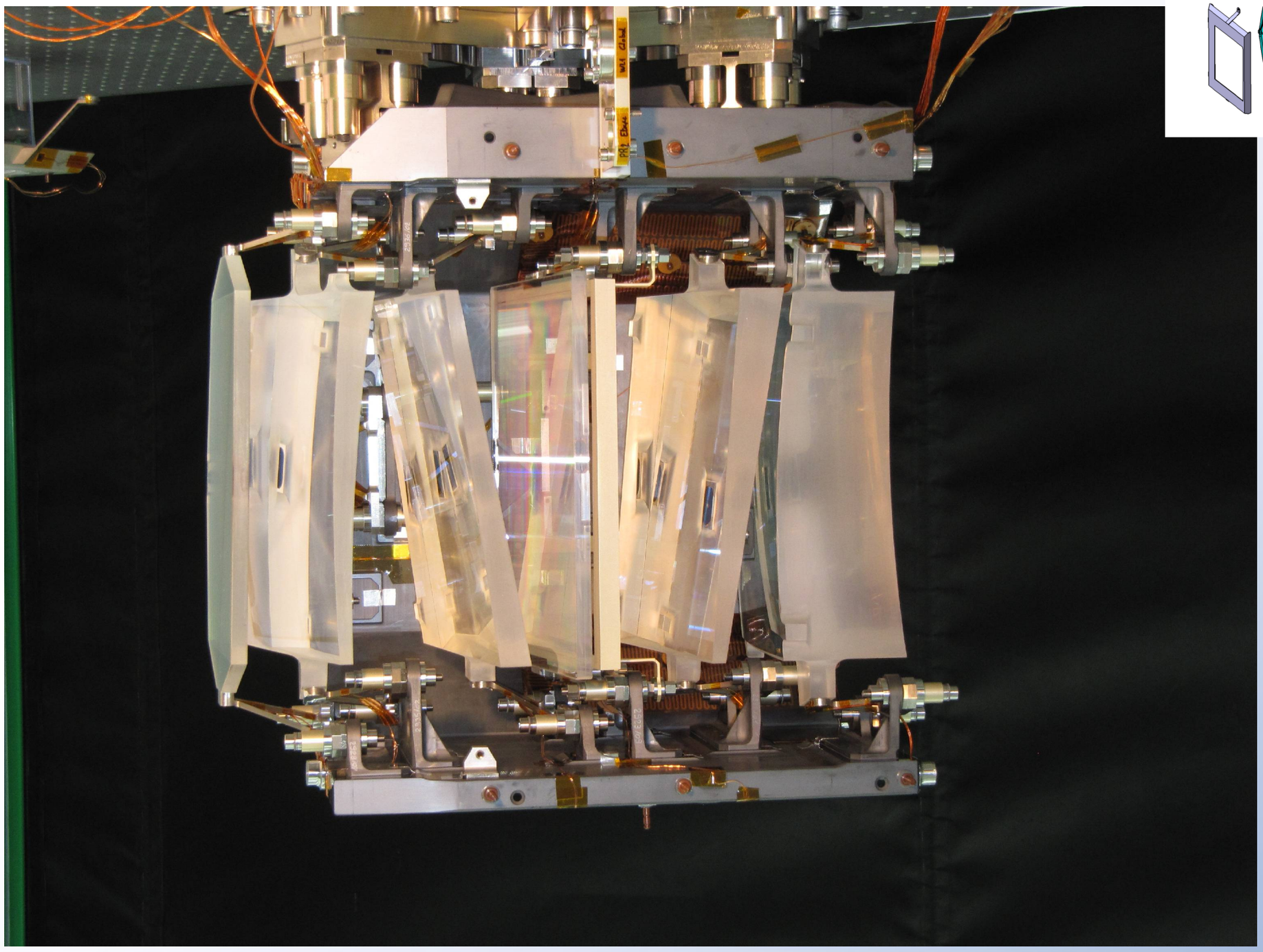
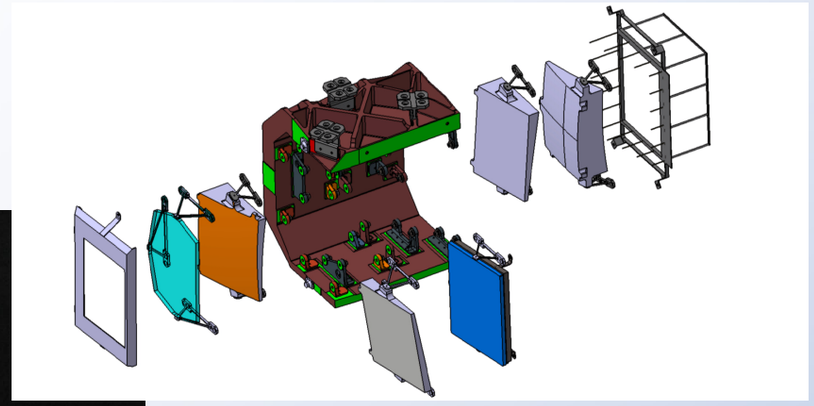
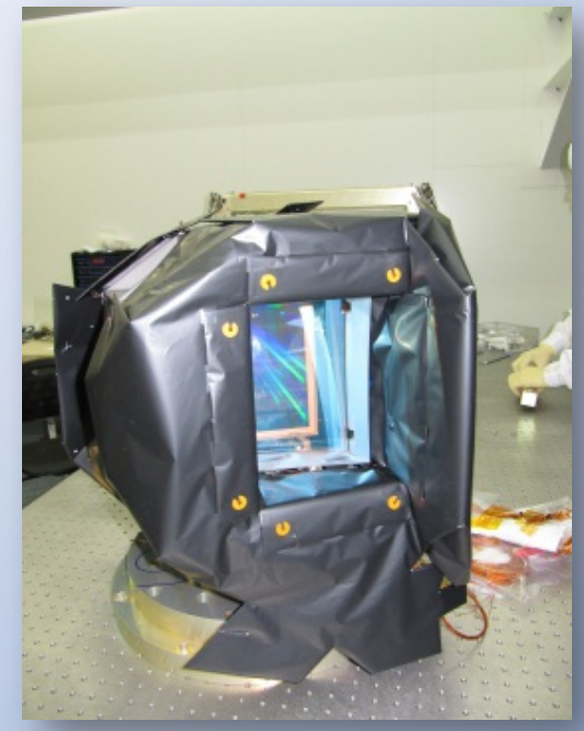


Figure courtesy EADS-Astrium



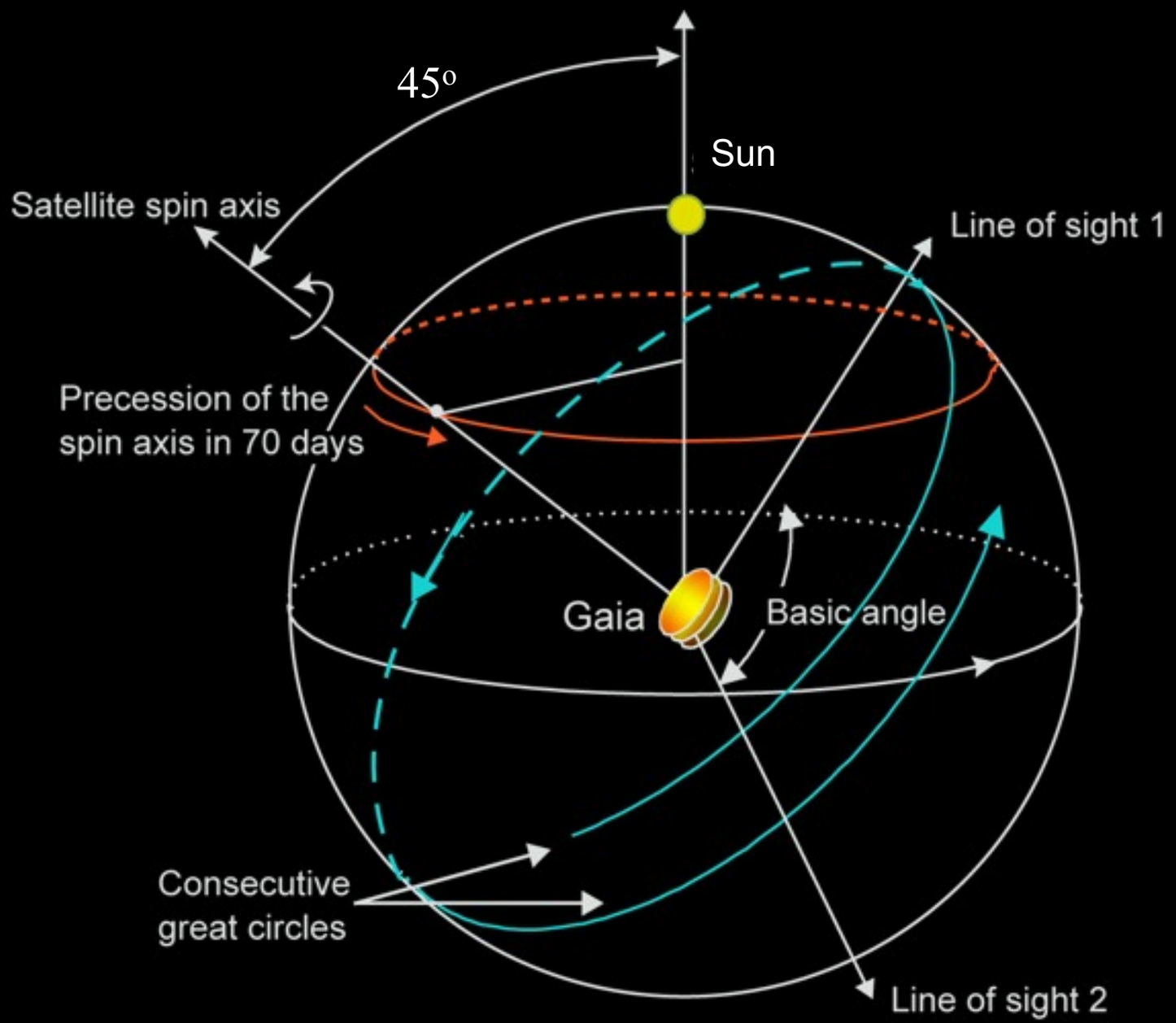







Gaia

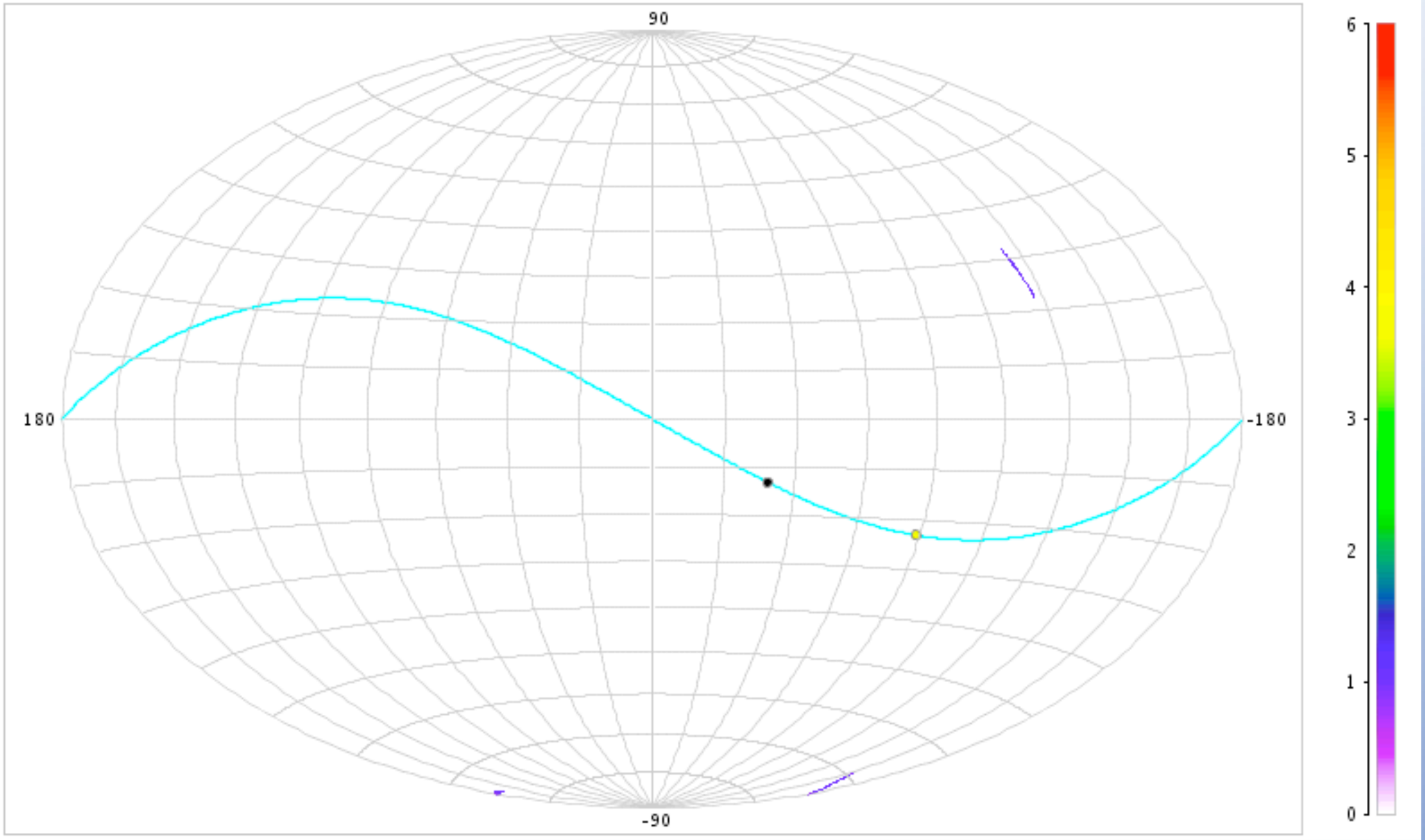
Sky-Scanning Principle



Spin axis	45^{o} to Sun
Scan rate:	60 arcsec s^{-1}
Spin period:	6 hours

Figure courtesy Karen O'Flaherty

NSL field transits in ICRS after: 0 years 000 days 00 hr 10 min



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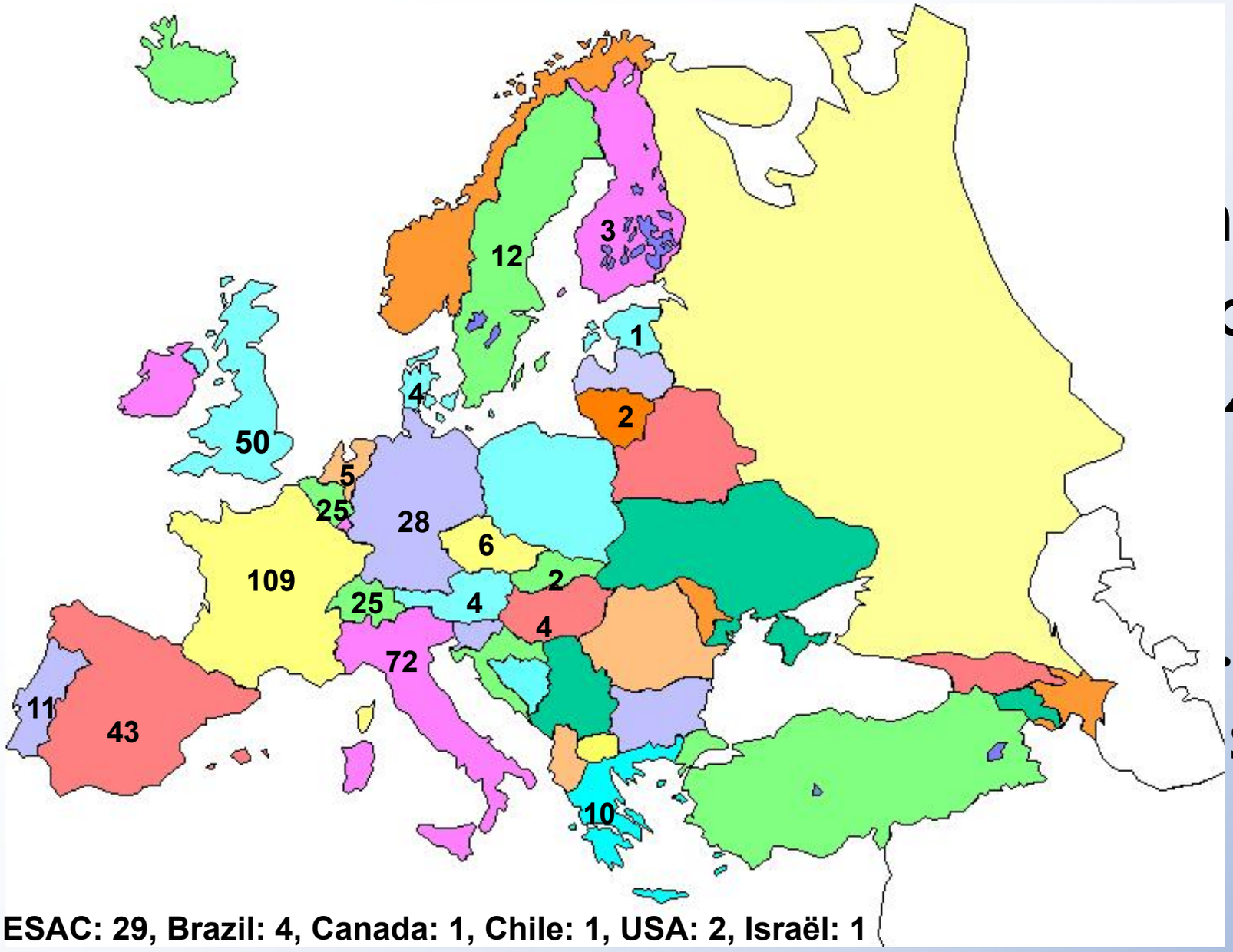
Data Processing

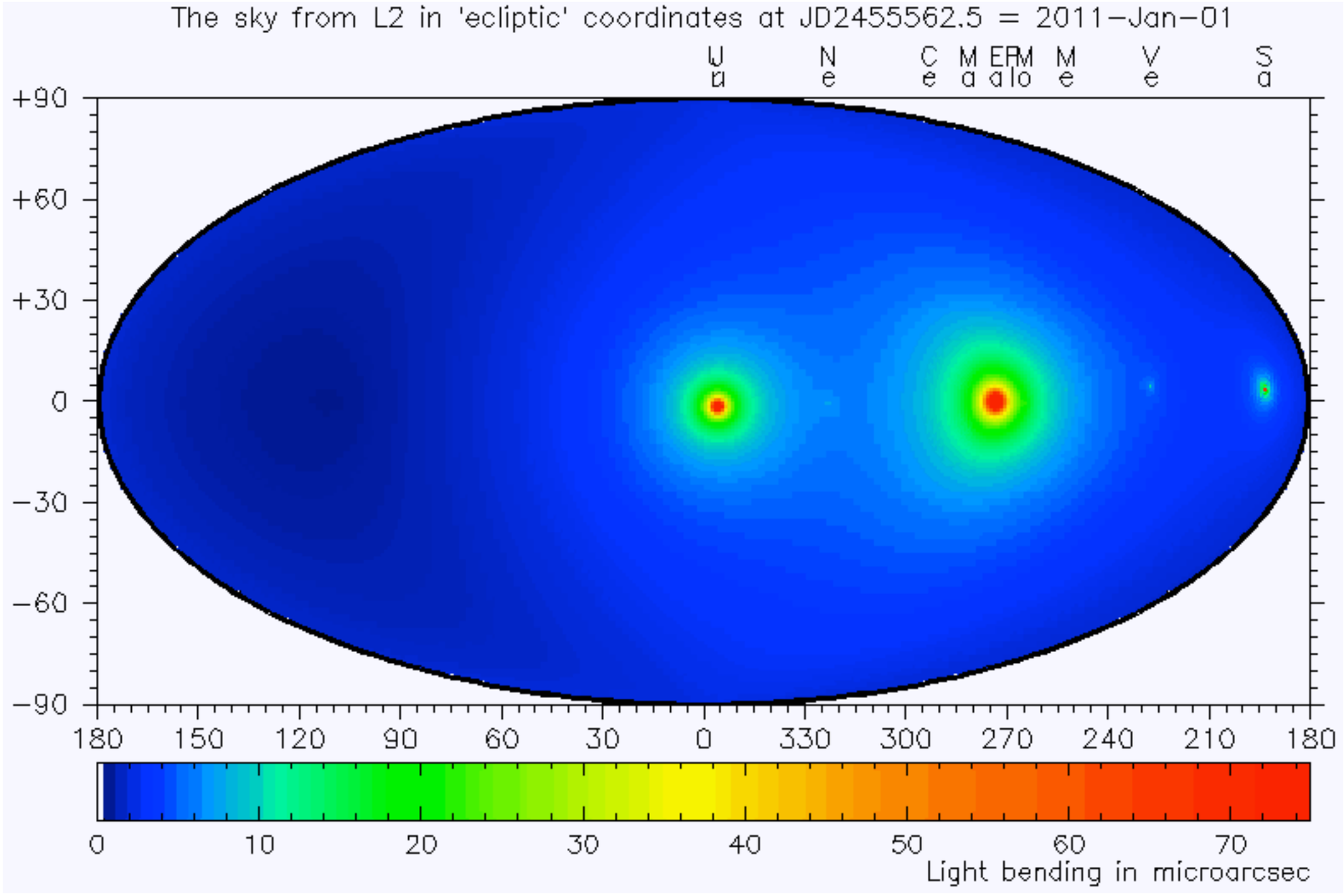


ESAC: 29, Brazil: 4, Canada: 1, Chile: 1, USA: 2, Israël: 1

…e
…on is 40
…400

…e. 10
…stars

Light Bending in Solar System



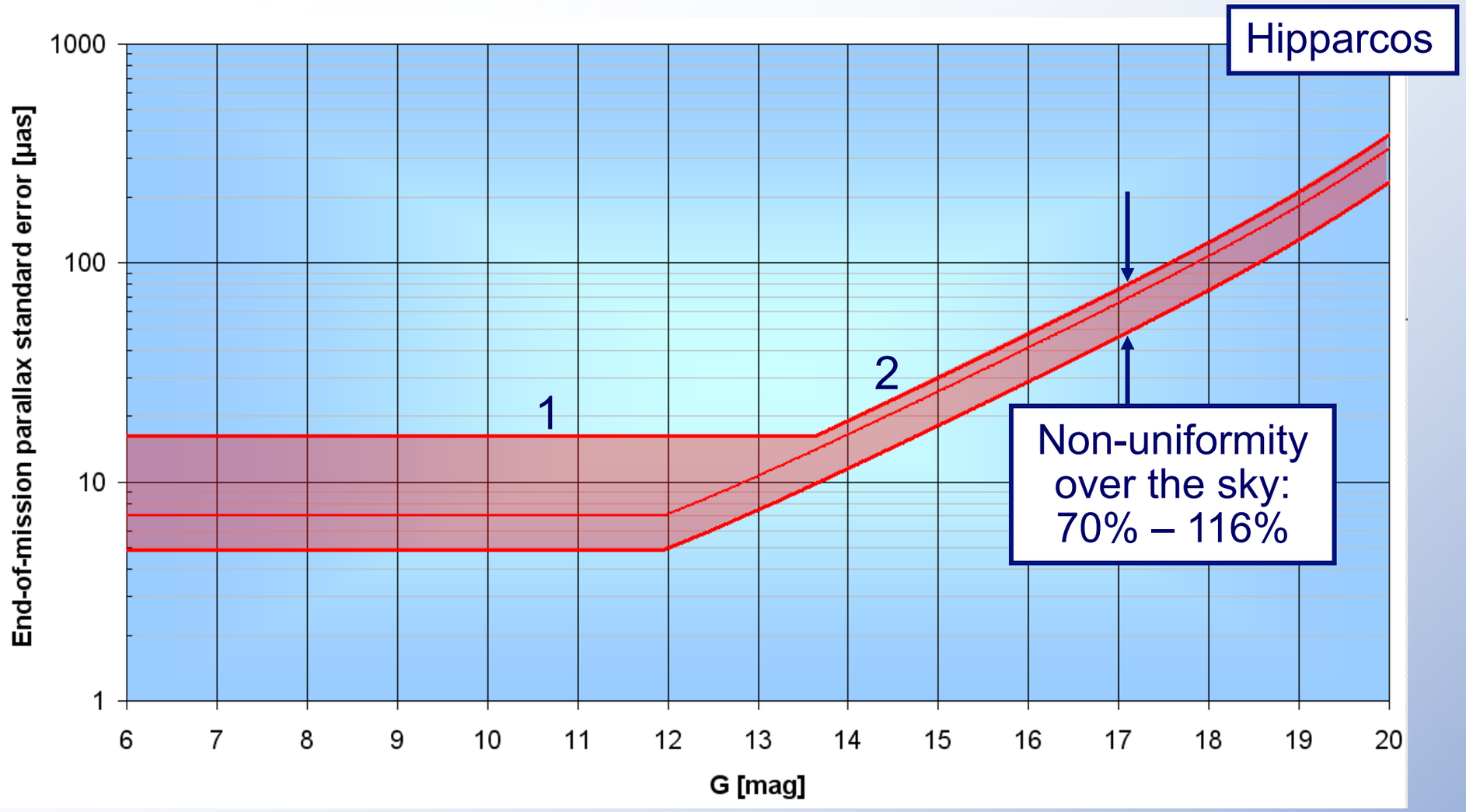
Light bending in microarcsec, after subtraction of the much larger effect by the Sun

Movie courtesy Jos de Bruijne

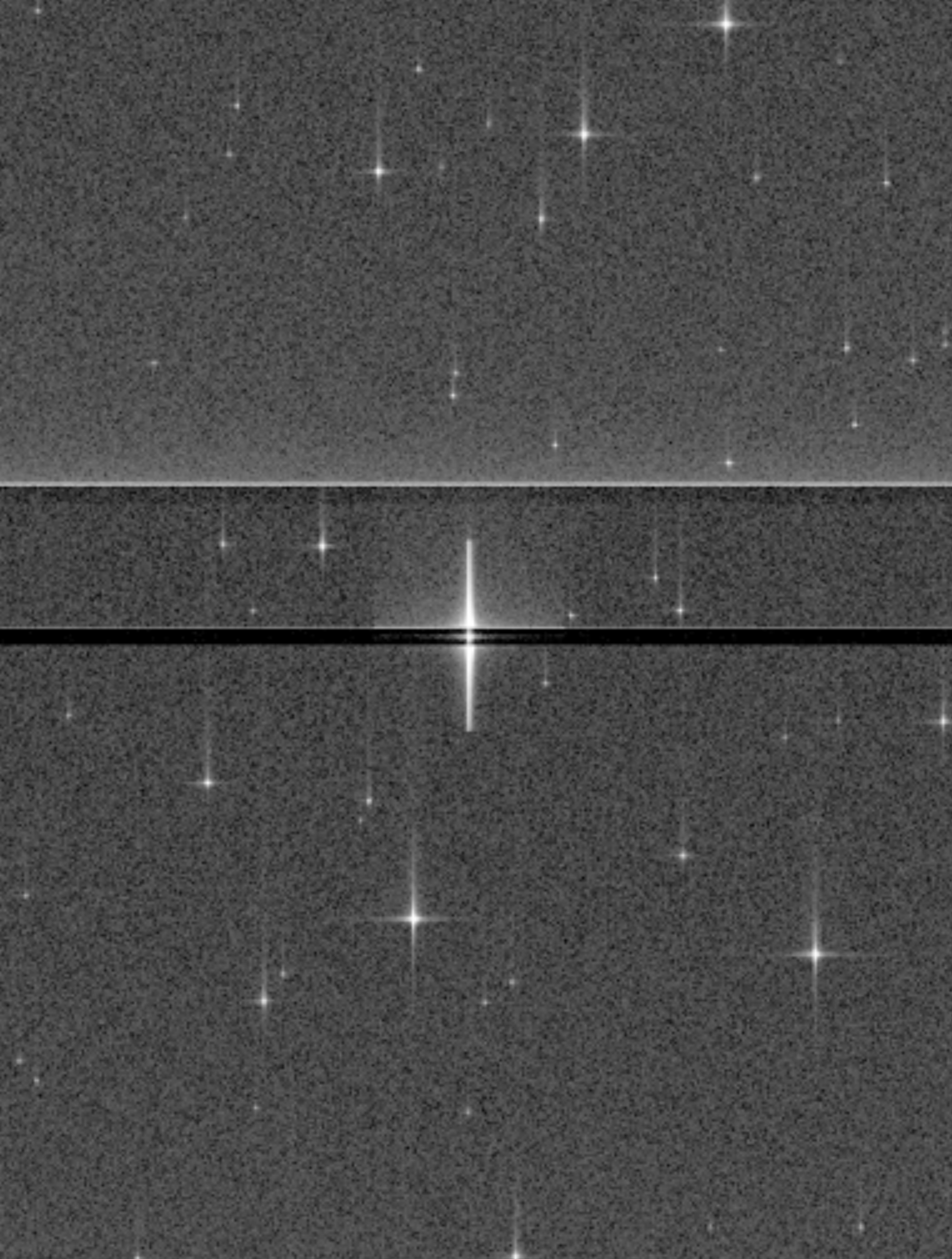
Gaia

Scientific Performance

Astrometry



1. 6 < G < 12: bright-star regime (calibration errors, CCD saturation)
2. 12 < G < 20: photon-noise regime, with sky-background noise and electronic noise setting in around G ~ 20 mag



Parallax horizon for G0V stars (no extinction)

Figure courtesy Lennart Lindegren

Parallax horizon for G0V stars

10 kpc

$A_V = 0$

$A_V = 5$ mag

20%

1

2

5

10

20%

Figure courtesy Lennart Lindegren

Parallax horizon for K5III stars

20%

10

A_V = 0

A_V = 5 mag

10 kpc

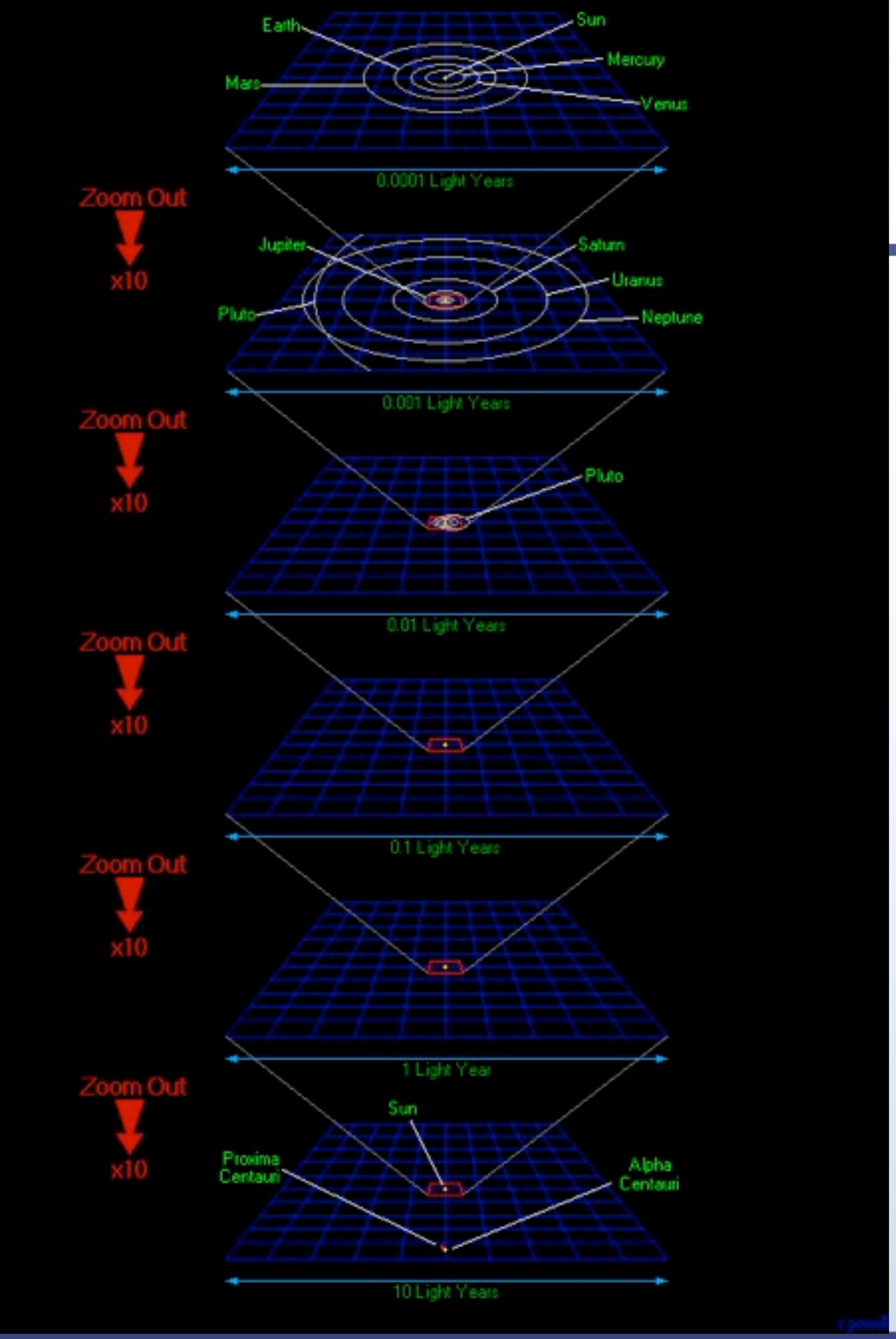
1 2 5 10 20%

1

2

5

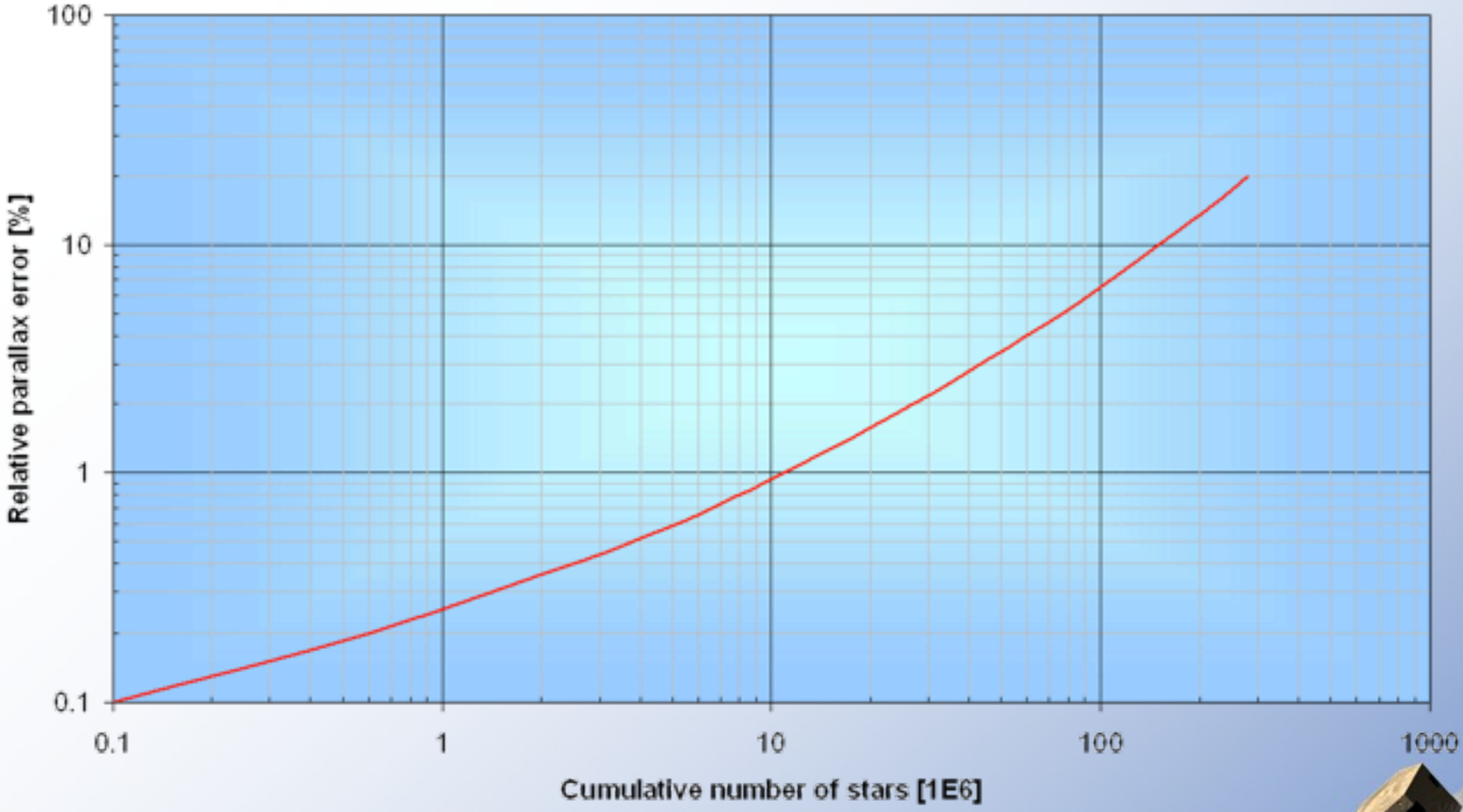
Figure courtesy Lennart Lindegren



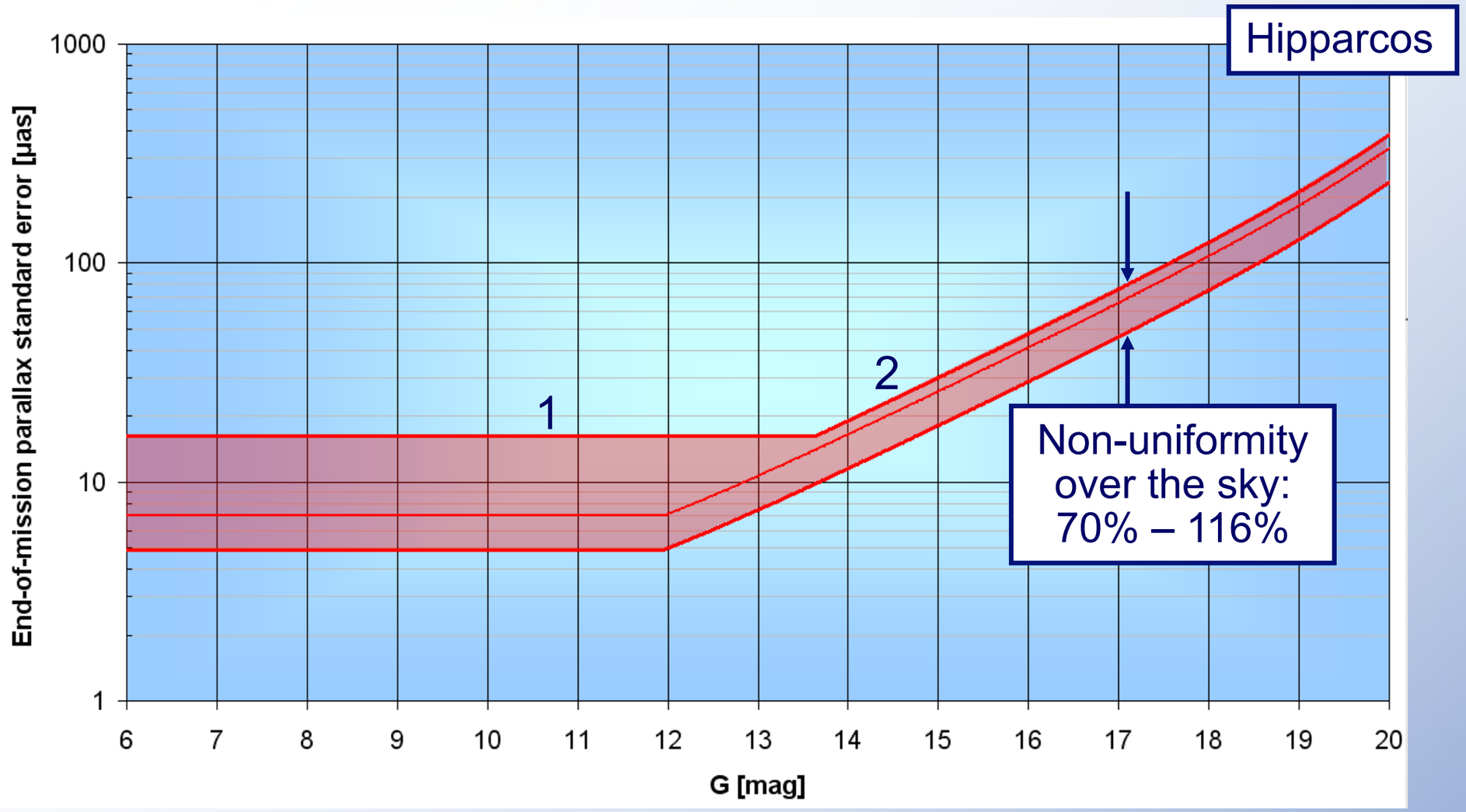
Parallax

- Closest star 1.30 pc (4.24 light years) parallax 769 mas
- Gaia: 1.30xxx ±0.00001pc
- Parallax known to 1% for 719 stars
- Gaia > 10^7

Parallax statistics



Astrometry



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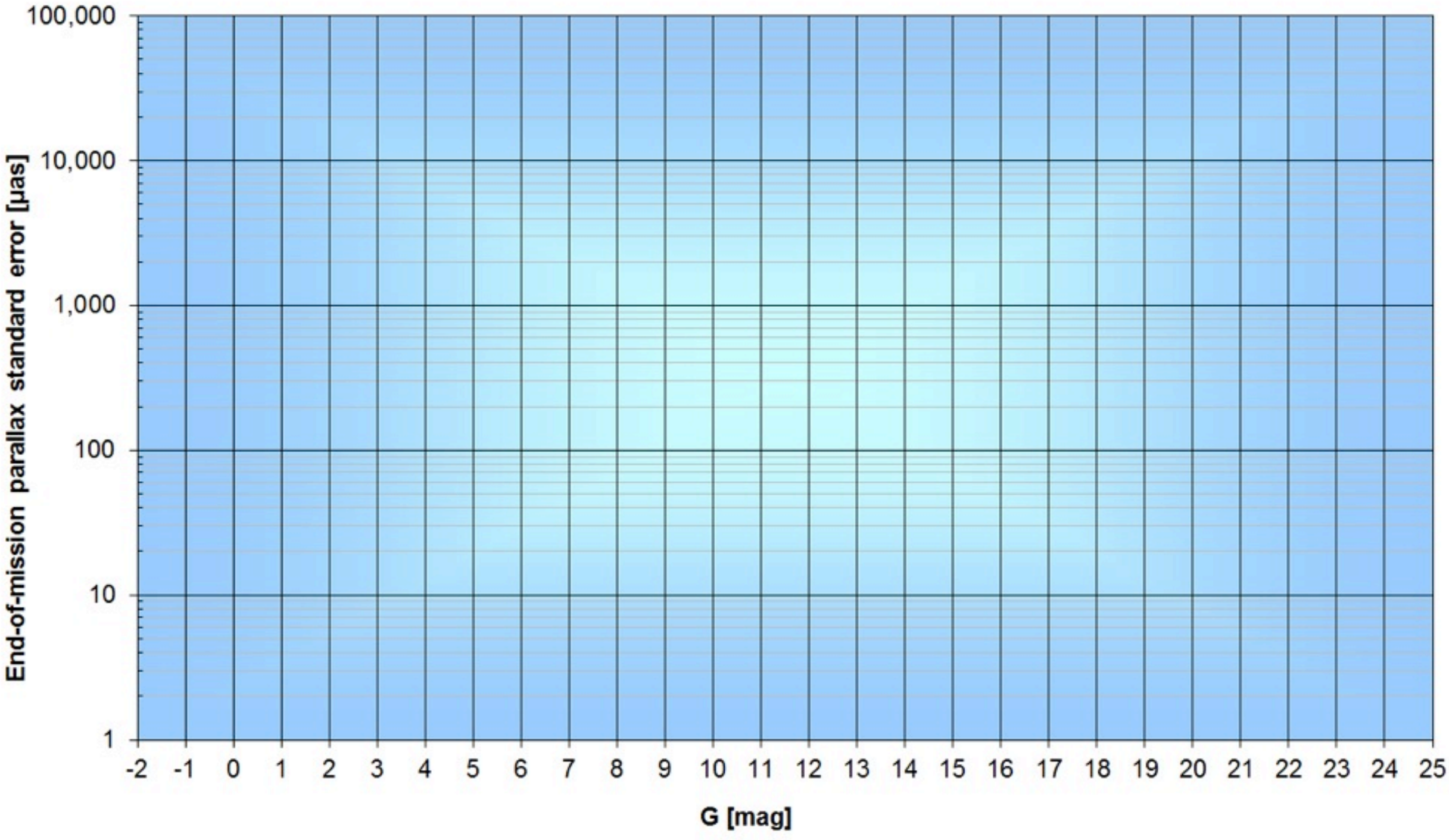
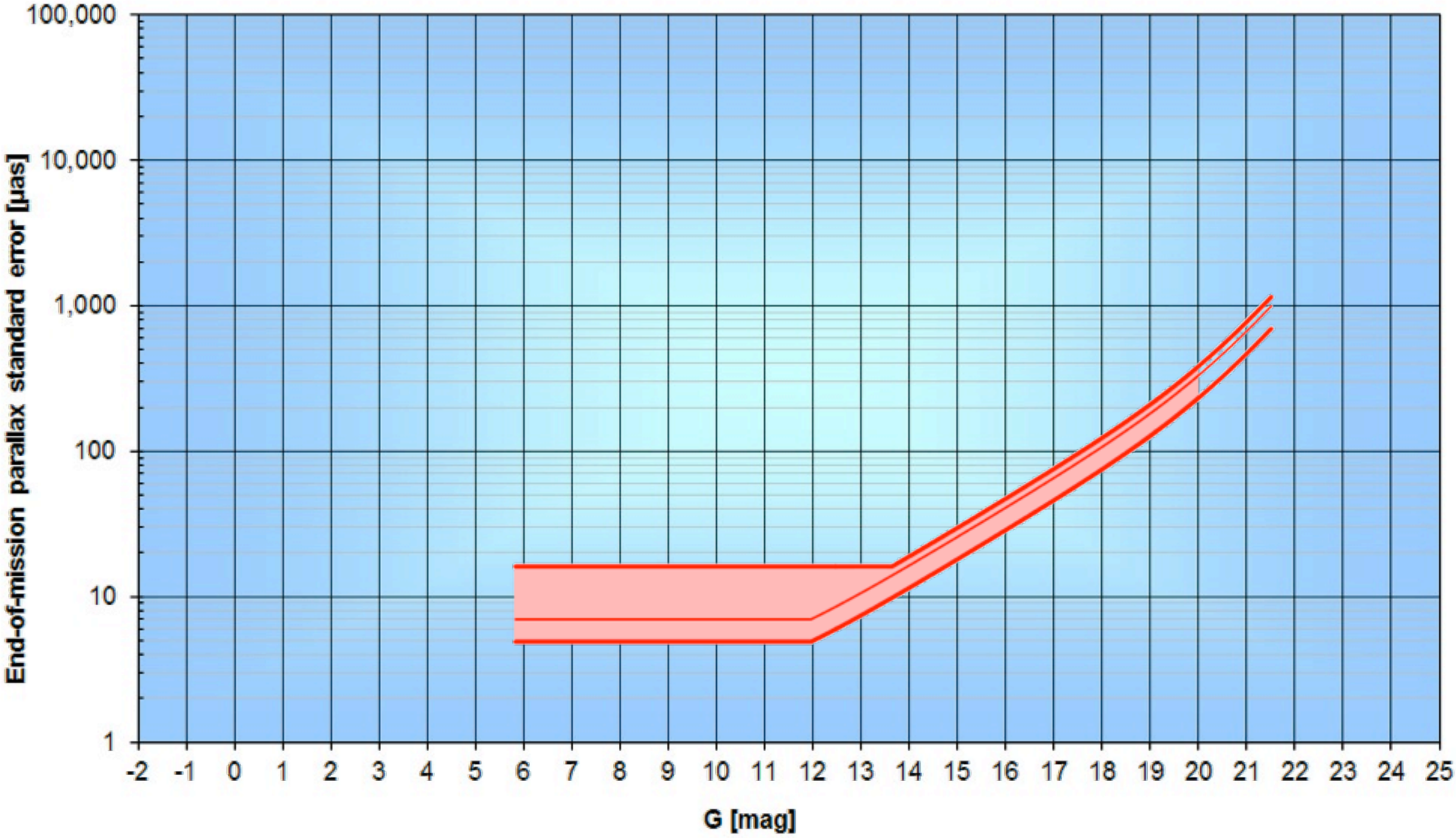

End-of-mission parallax standard error [μas]
100,000
10,000
1,000
100
10
1
-2
-1
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
G [mag]


100,000
10,000
1,000
100
10
1
End-of-mission parallax standard error [µas]
-2
-1
0
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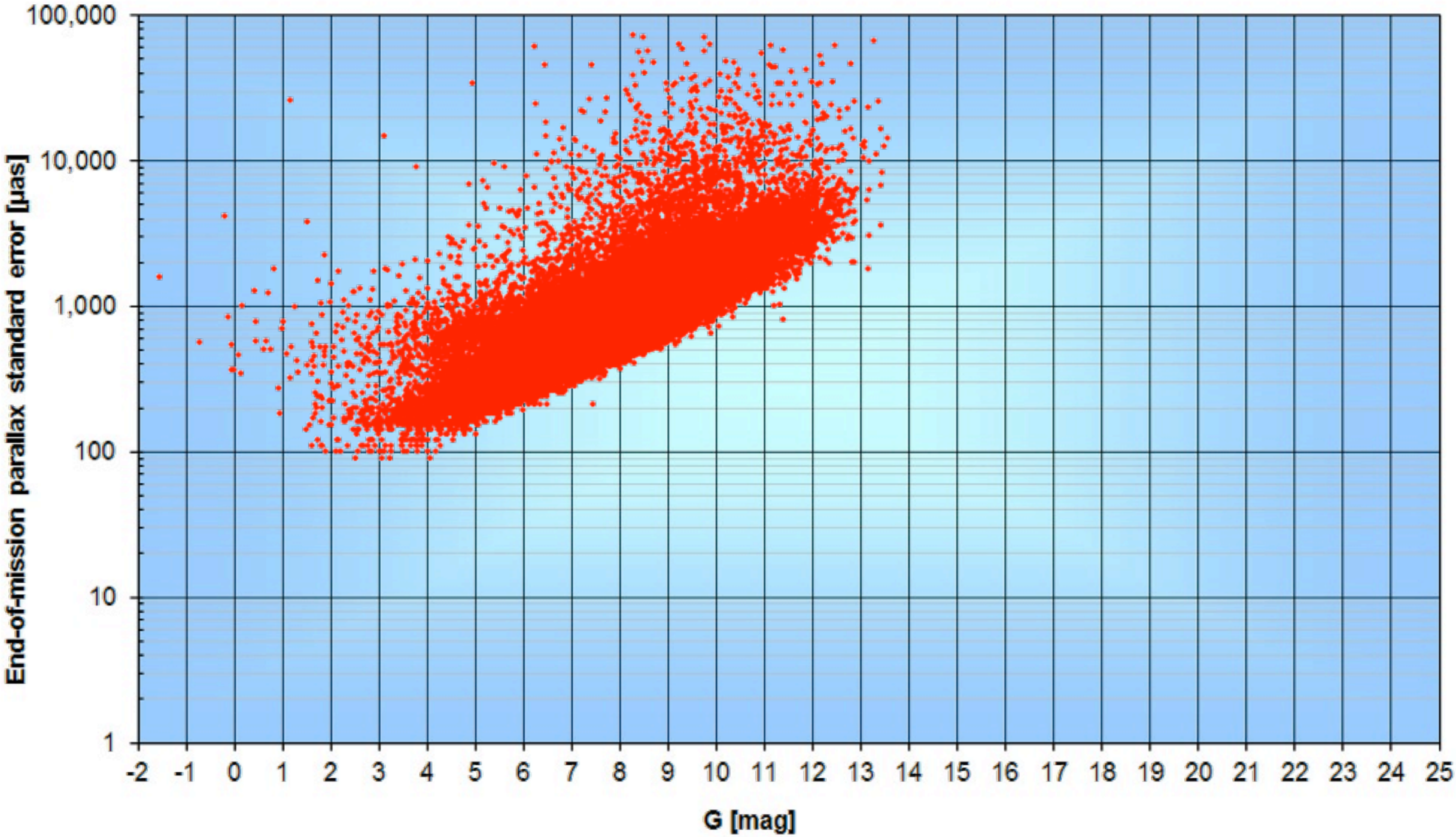
21
22
23
24
25
G [mag]


End-of-mission parallax standard error [µas]
100,000
10,000
1,000
100
10
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-2
-1
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20
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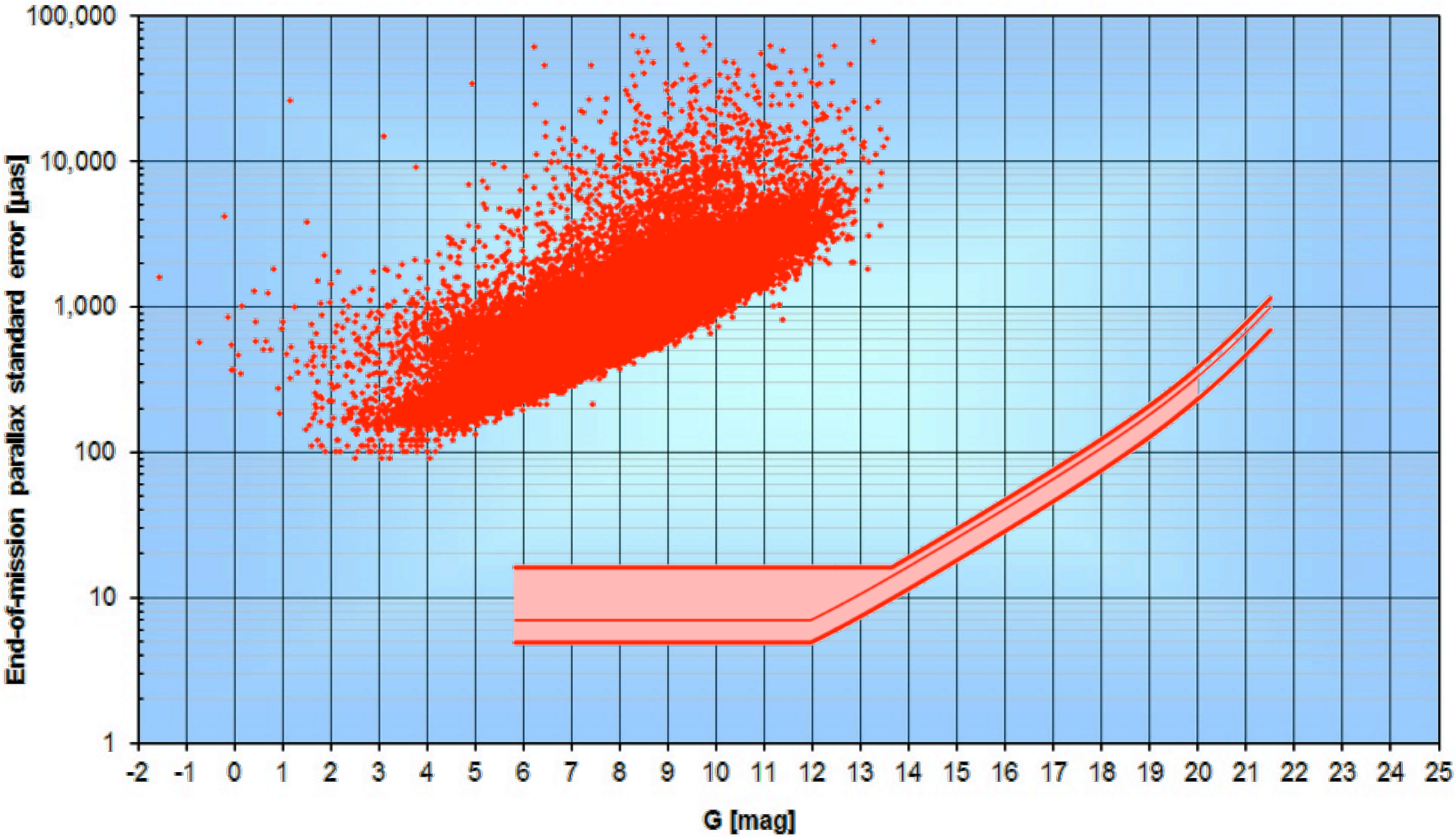
22
23
24
25
G [mag]


100,000
10,000
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100
10
1
End-of-mission parallax standard error [μas]
-2
-1
0
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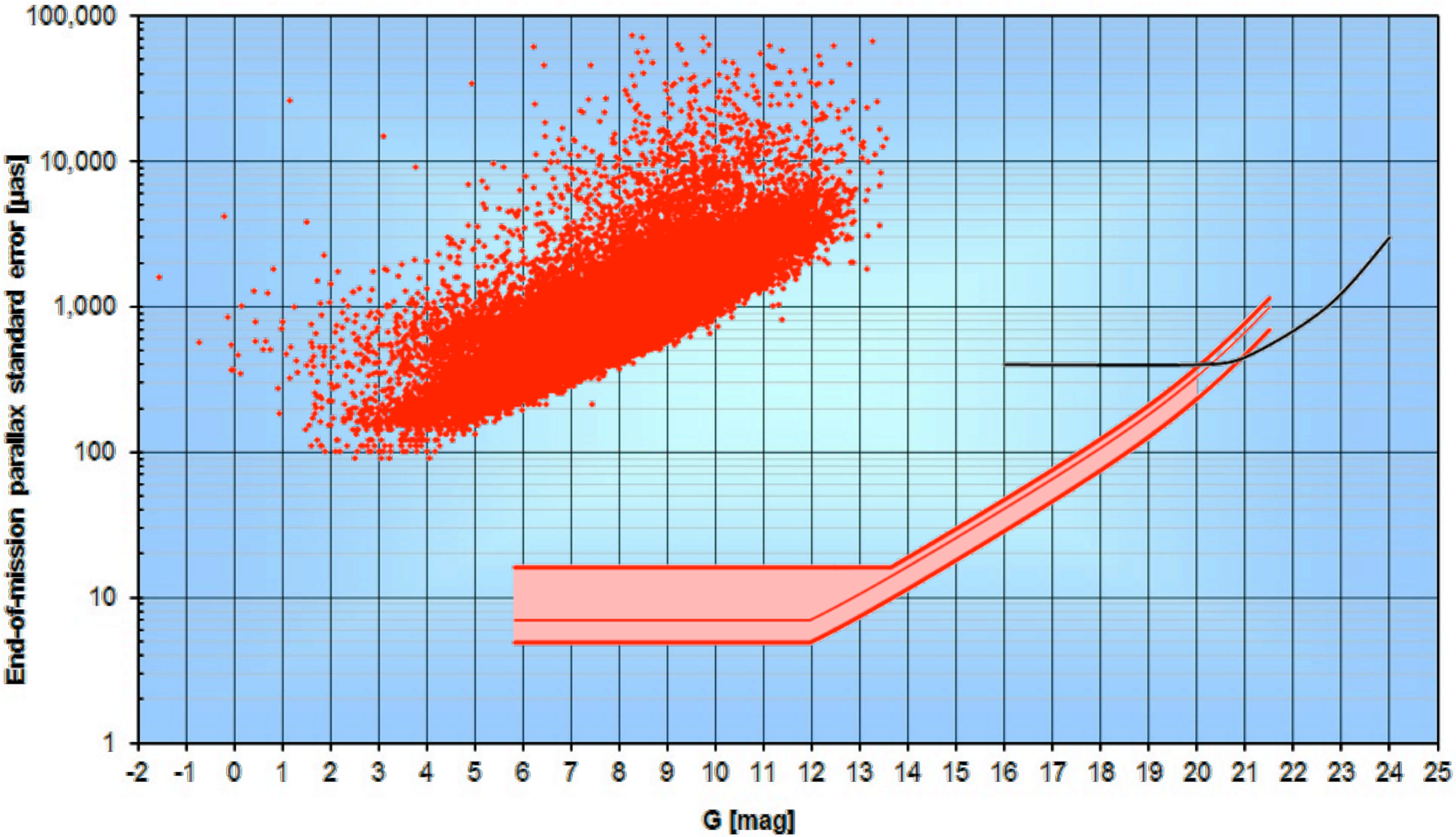
24
25
G [mag]


End-of-mission parallax standard error [μas]
100,000
10,000
1,000
100
10
1
-2
-1
0
1
2
3
4
5
6
7
8
9
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11
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15
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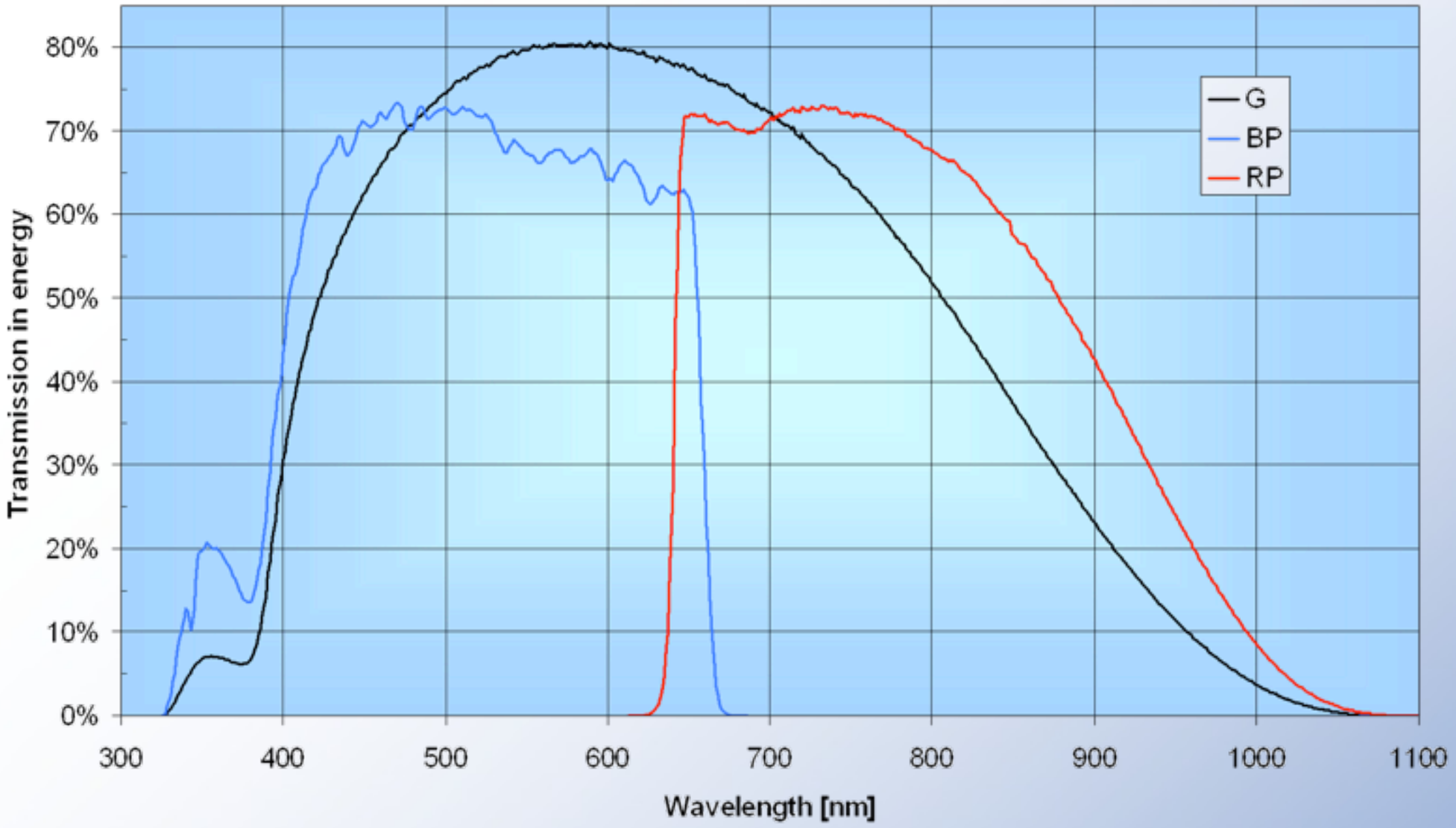
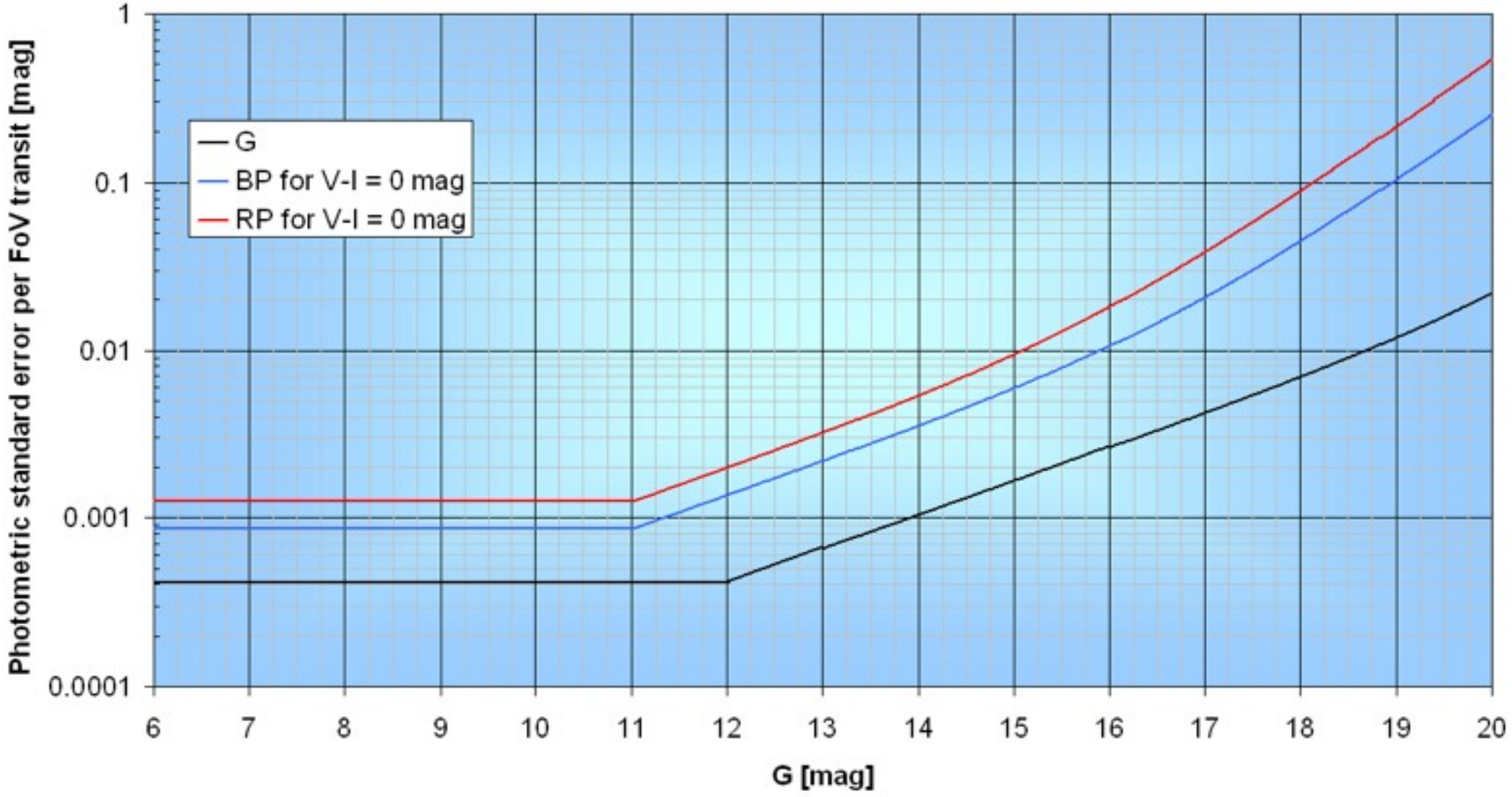
23
24
25
G [mag]

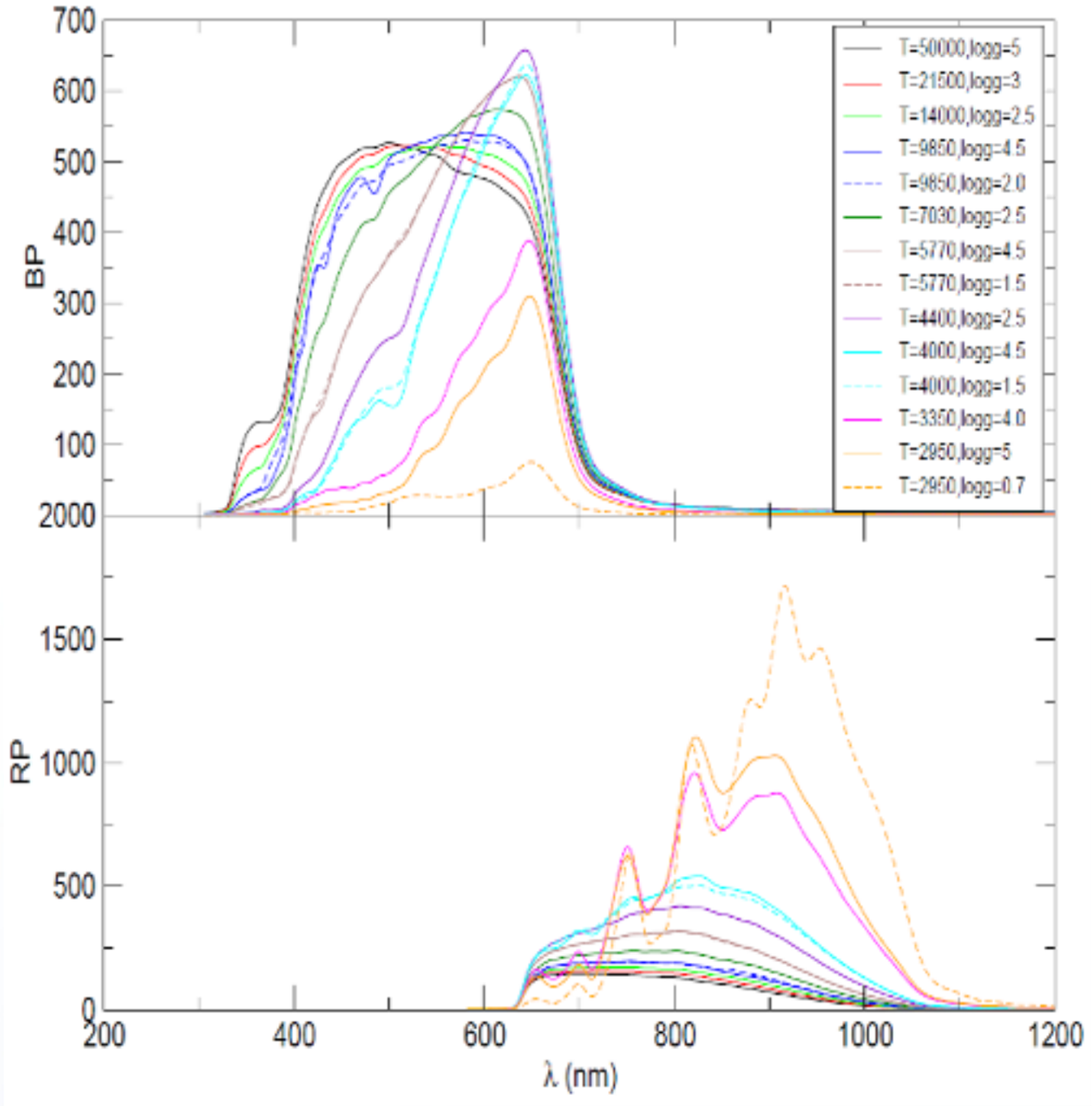
Photometry


80%
70%
60%
50%
40%
30%
20%
10%
0%
Transmission in energy
300
400
500
600
700
800
900
1000
1100
Wavelength [nm]
G
BP
RP

Transit level integrated photometry

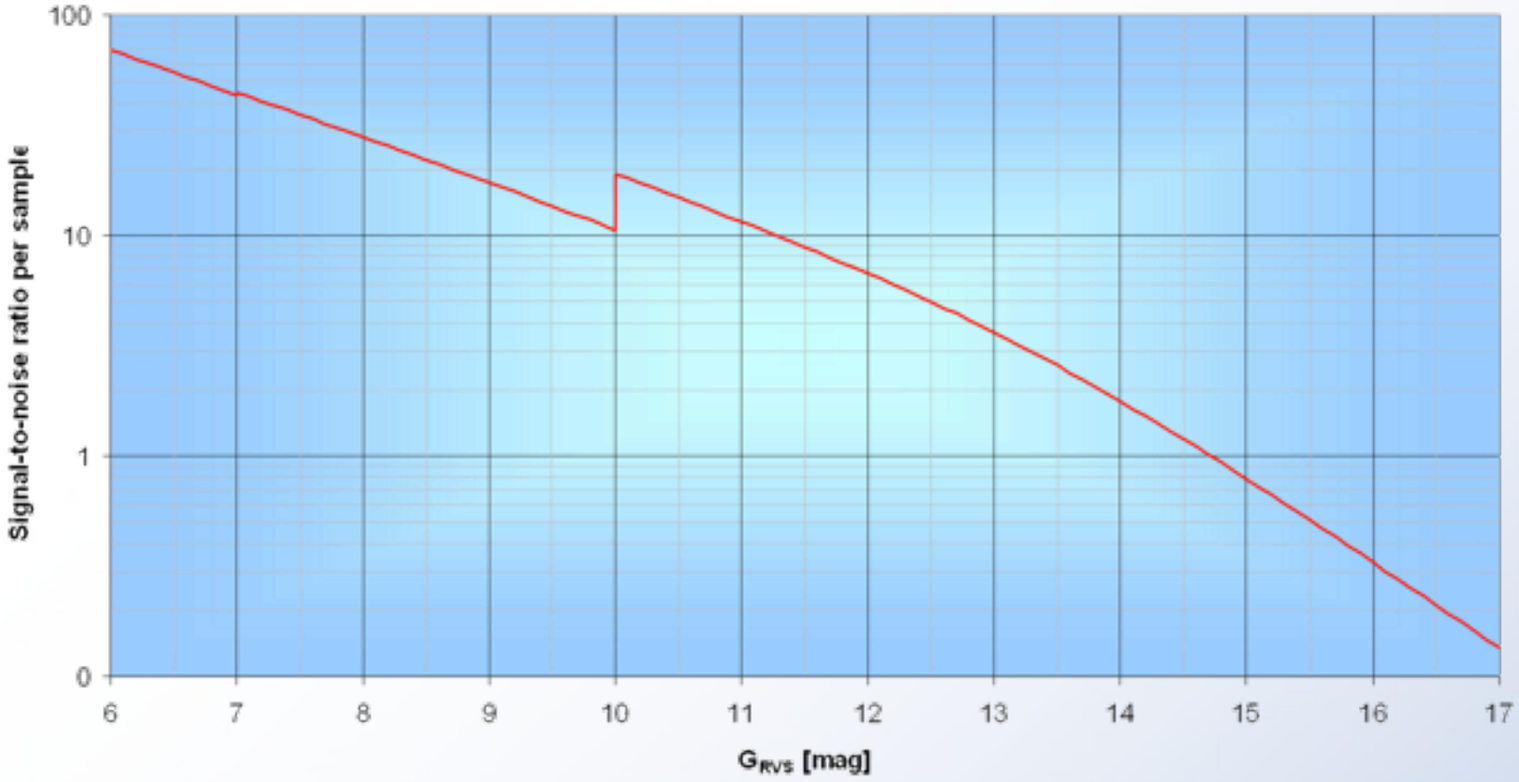


Spectro-photometry



- Illustrative spectra for G=15 mag stars (Jordi et al. 2010)
- Goals at G=15 mag e.g. extinction within 0.1mag, surface gravity 0.2dex, metallicity 0.2dex and effective temperature within 200K (Bailer-Jones 2010)

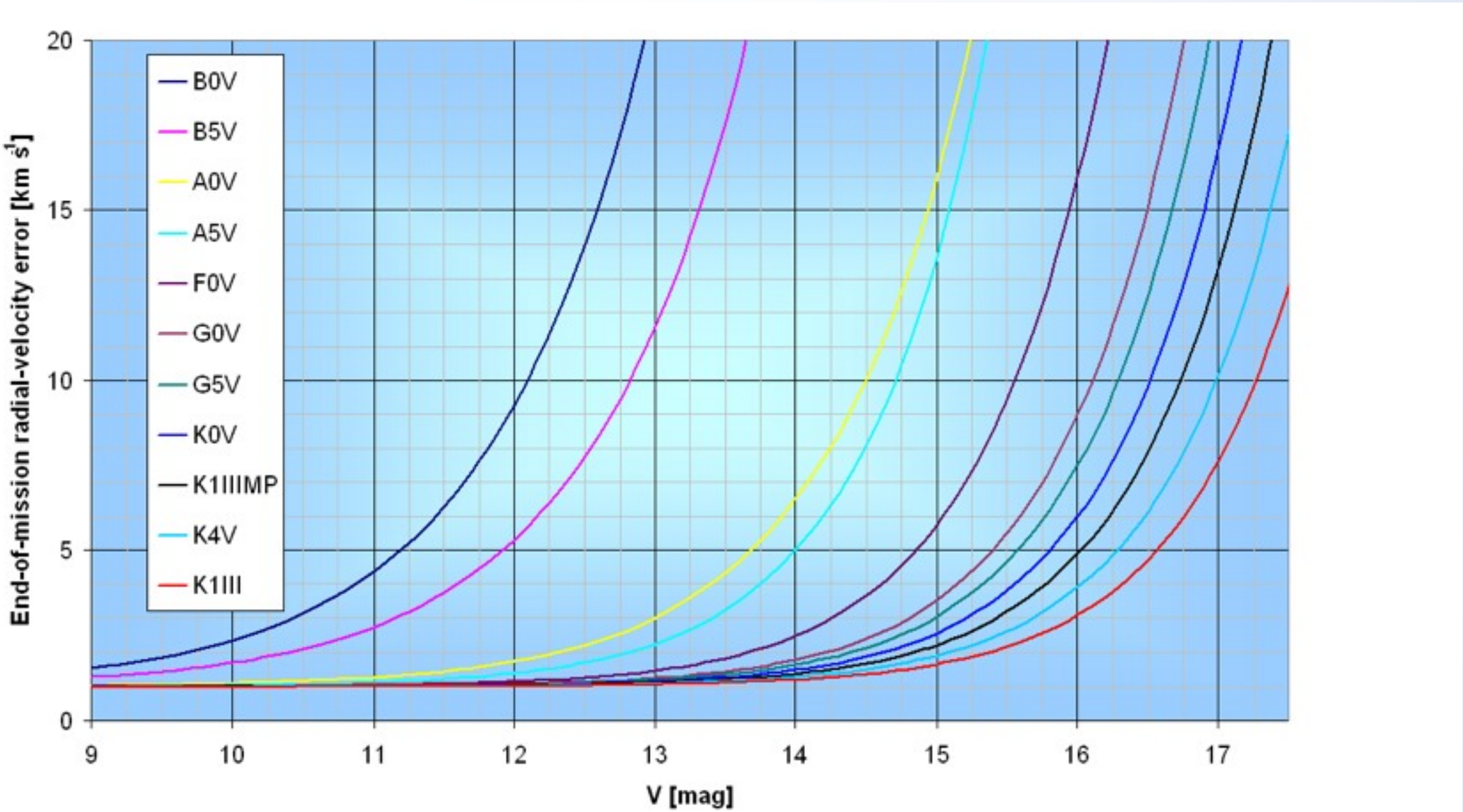
Spectroscopy



Single CCD S/N estimate

- Interstellar reddening, atmospheric parameters, and rotational velocities, for stars brighter than $G_{RVS} \approx 12$ mag (~5 million stars)
- provide element abundances for stars brighter than $G_{RVS} \approx 11$ mag (~2 million stars)

End-of-life Radial Velocity Errors



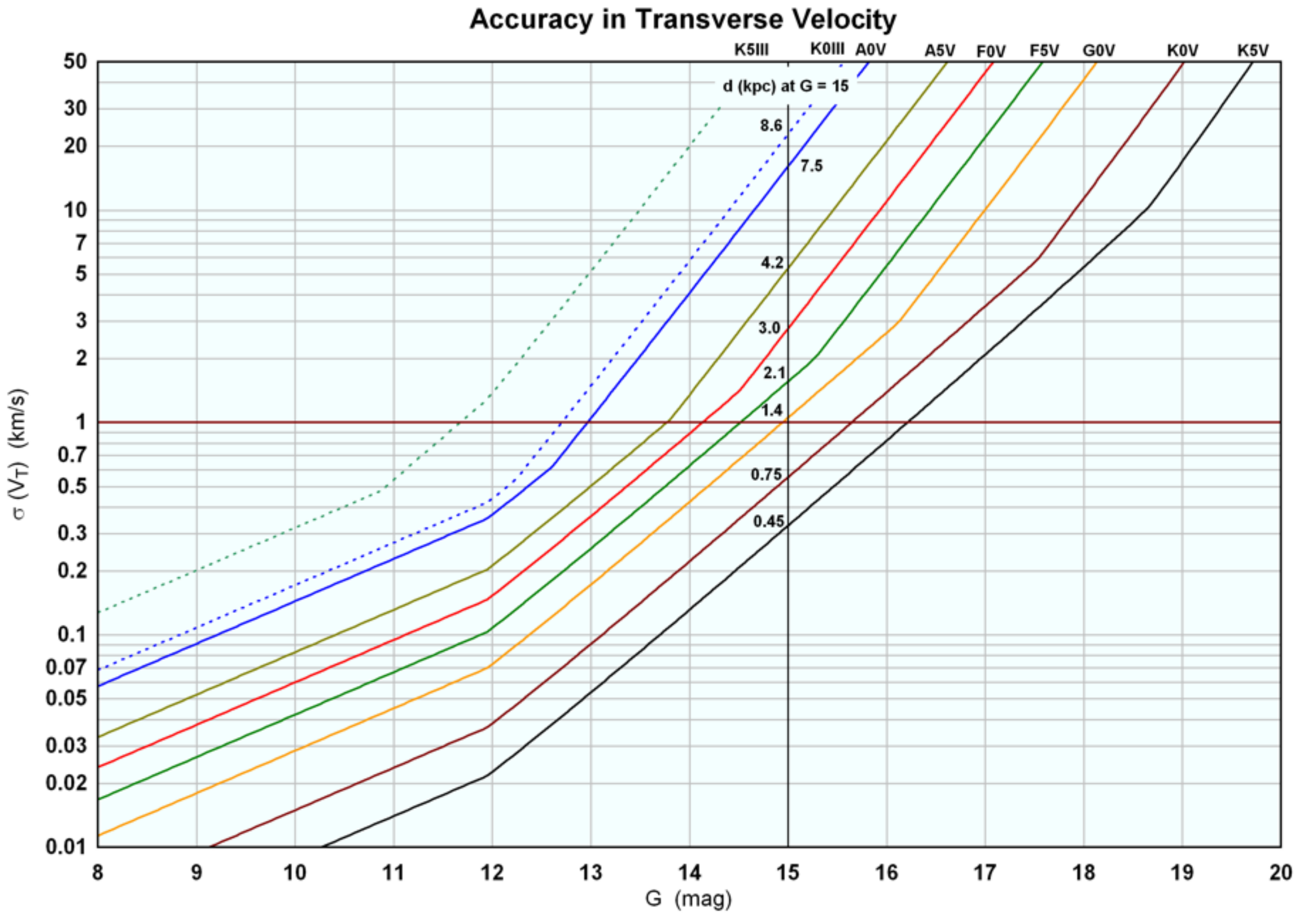


Figure courtesy of Francois Mignard

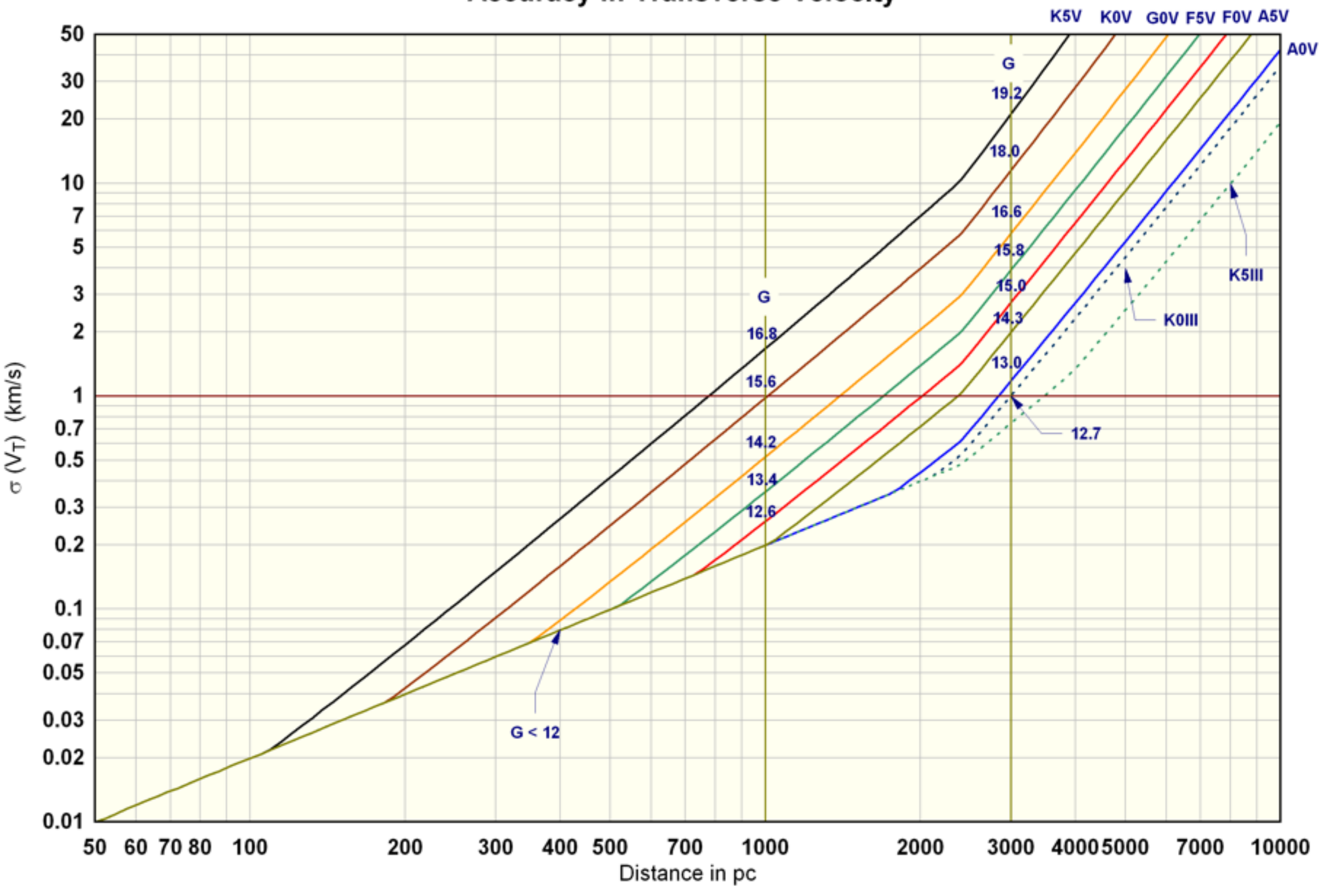


Figure courtesy of Francois Mignard

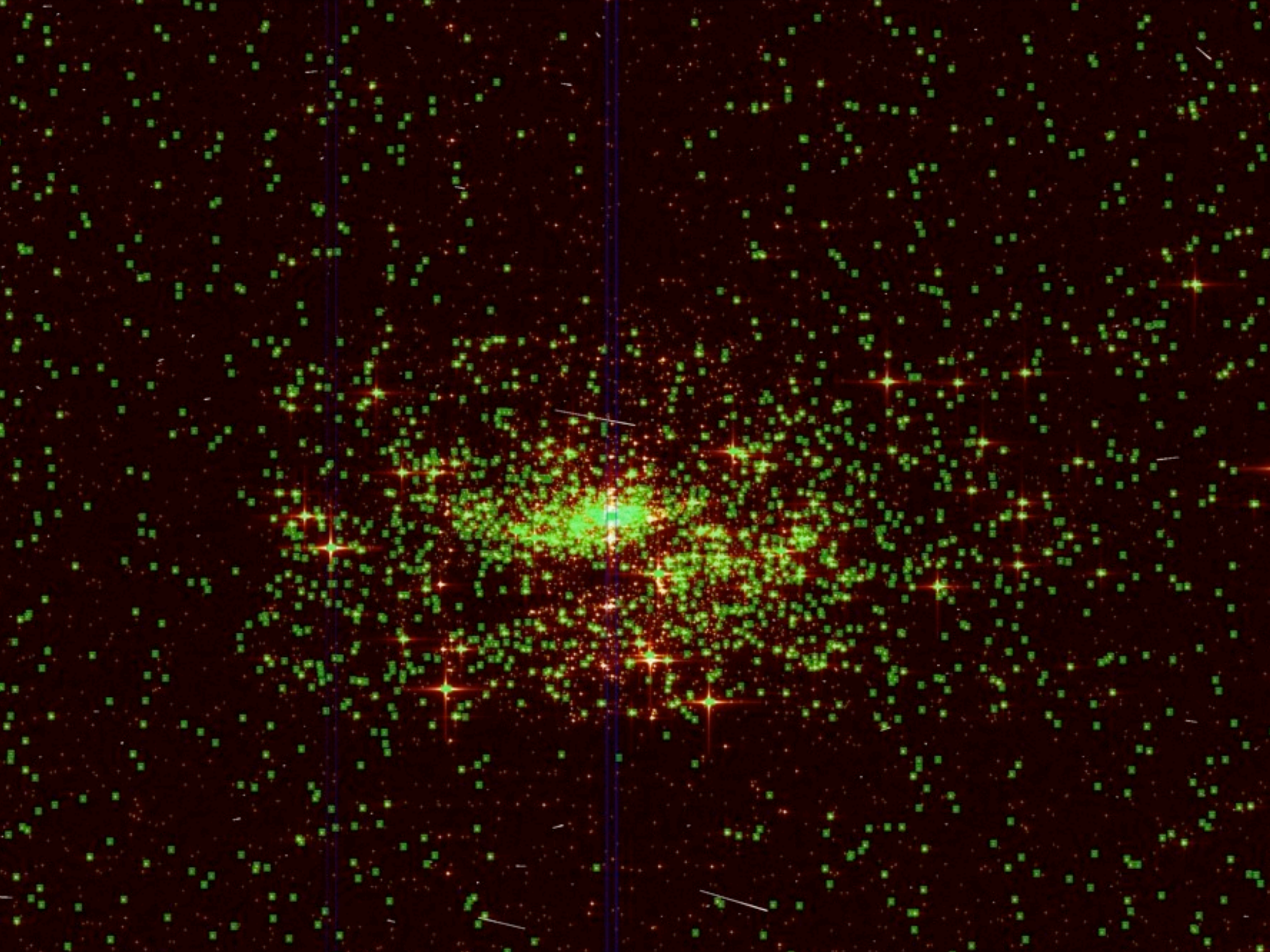
Star-Forming Region 30 Doradus

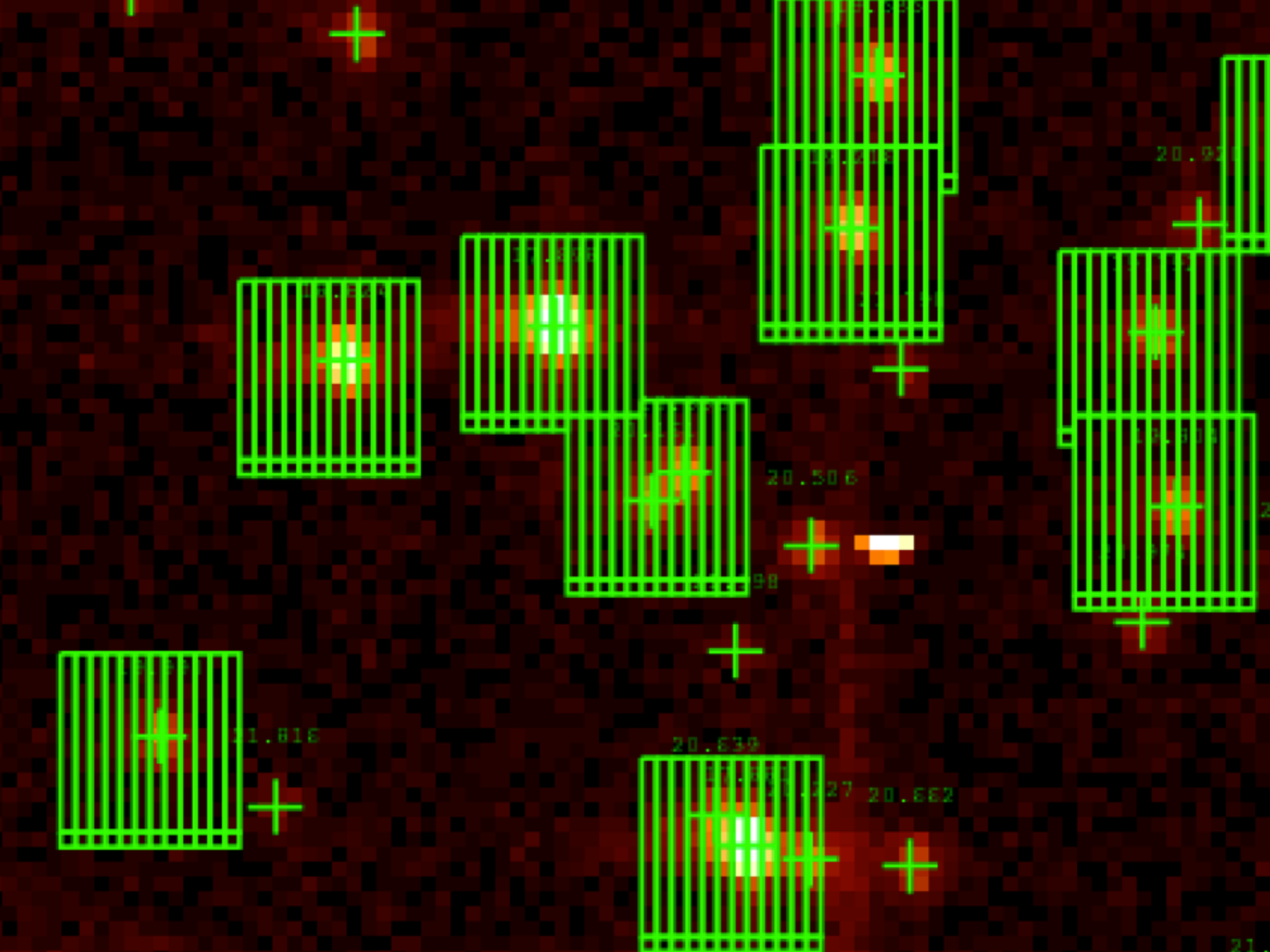
Hubble Space Telescope • WFC3/UVIS

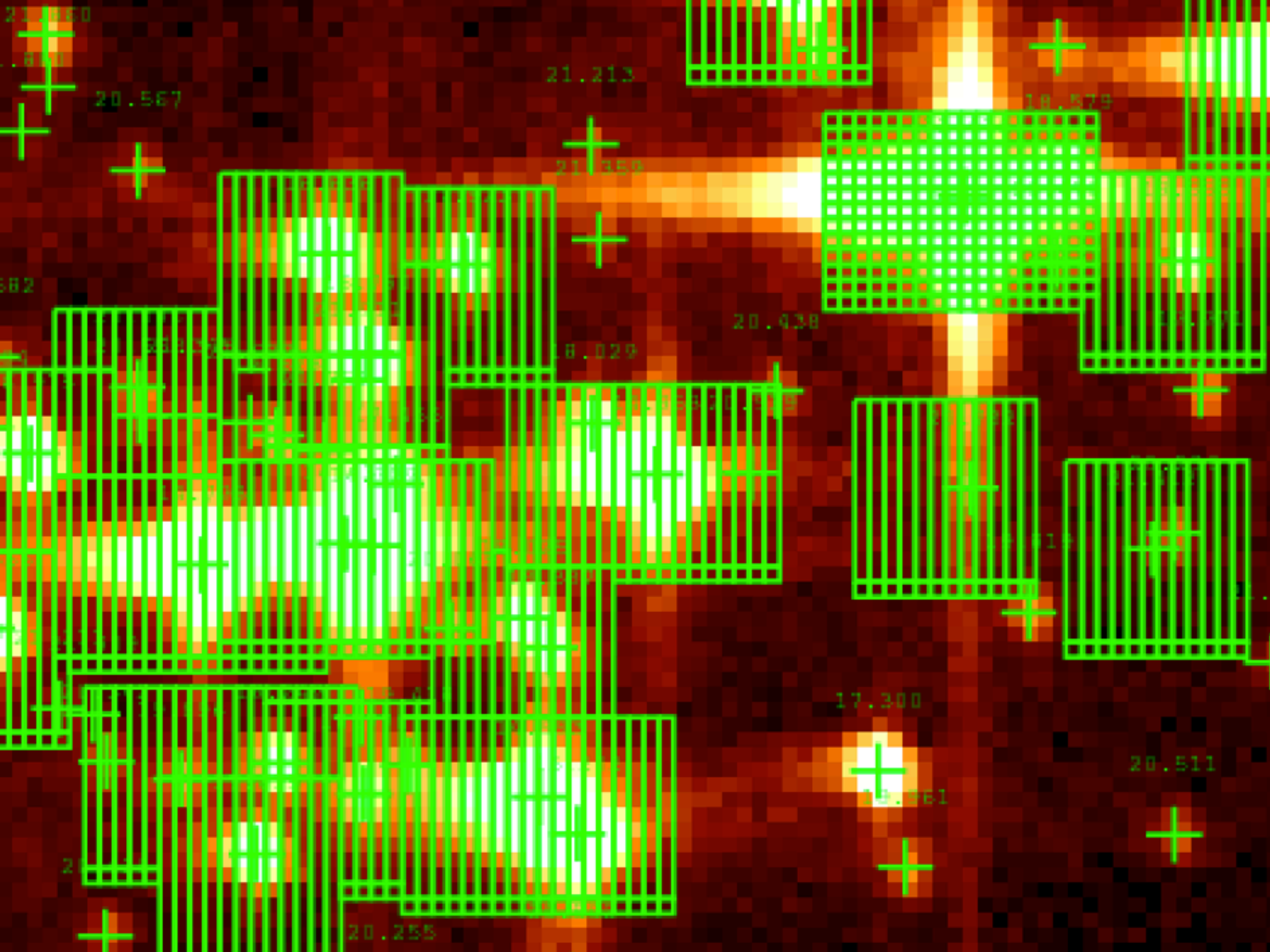
NASA, ESA, F. Paresce (INAF–IASF, Italy), and the WFC3 Science Oversight Committee STScI-PRC09-32a

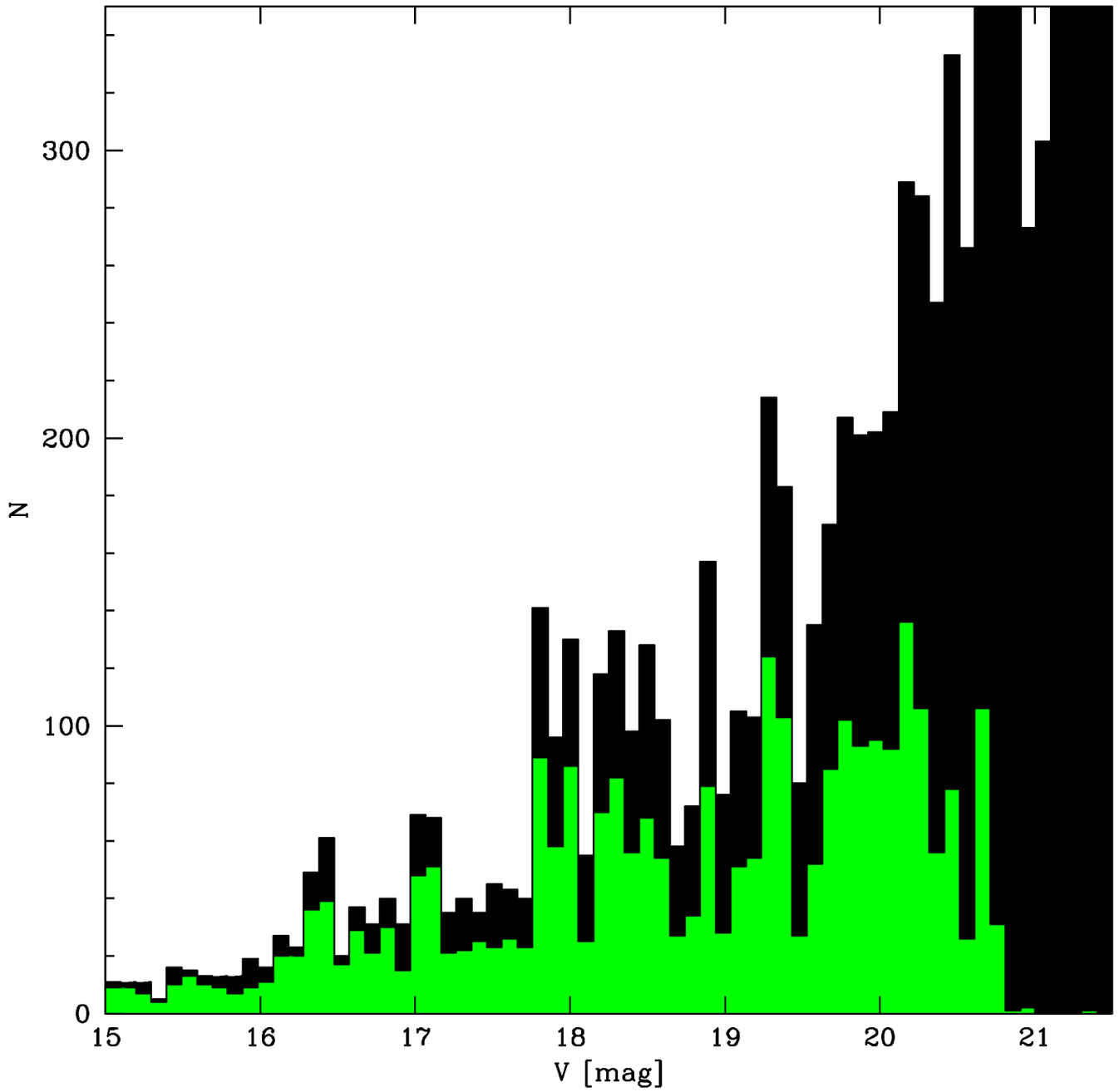
esa

Gaia




20.506
20.630
20.662

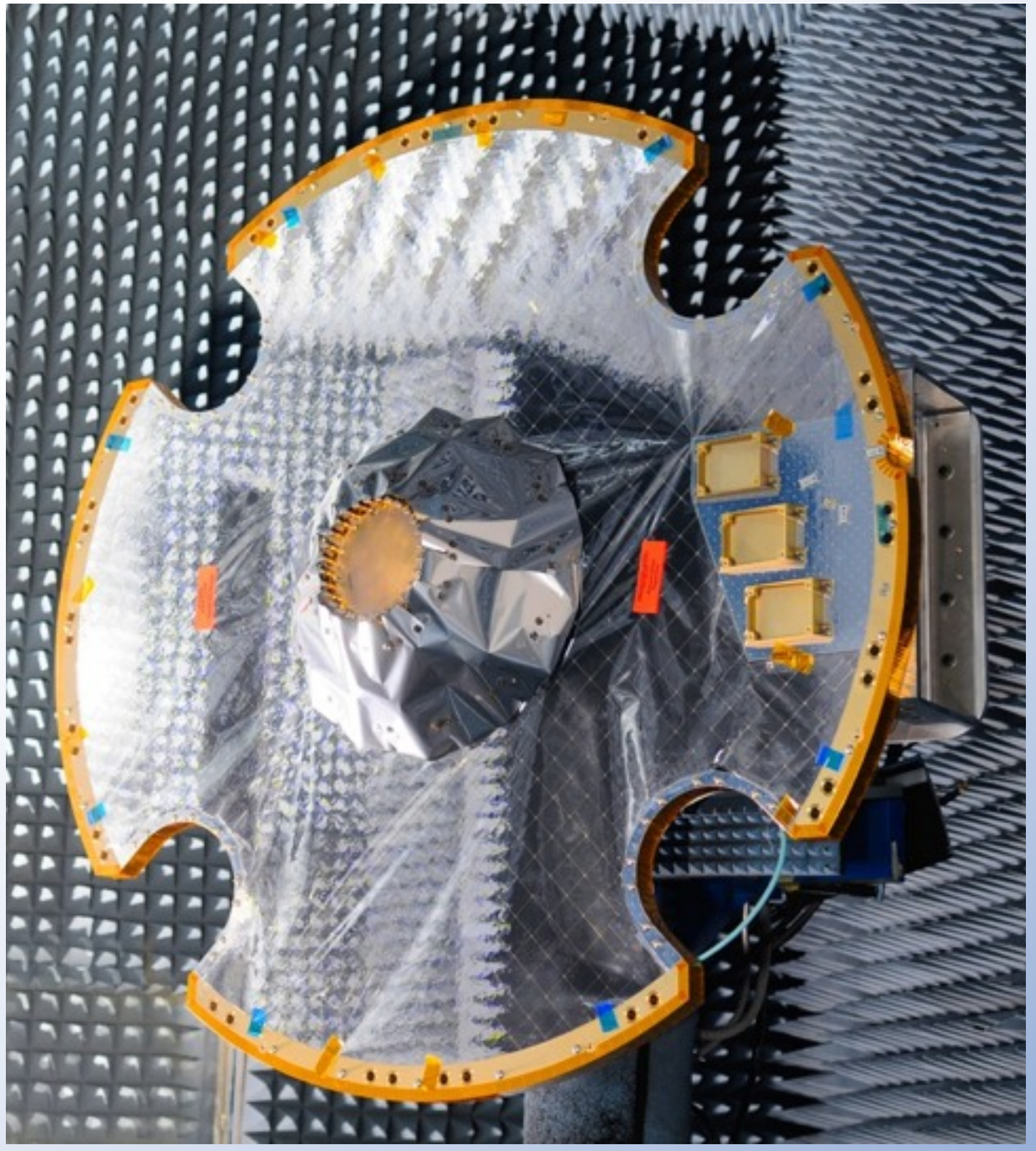

21.213
20.567
20.438
17.300
20.511
20.255



- HST (black) vs. one epoch of 4.4s of Gaia (green) observations on one CCD in R136

Figures courtesy of de Bruijne & de Marchi

- Phased Array Antenna (PAA)

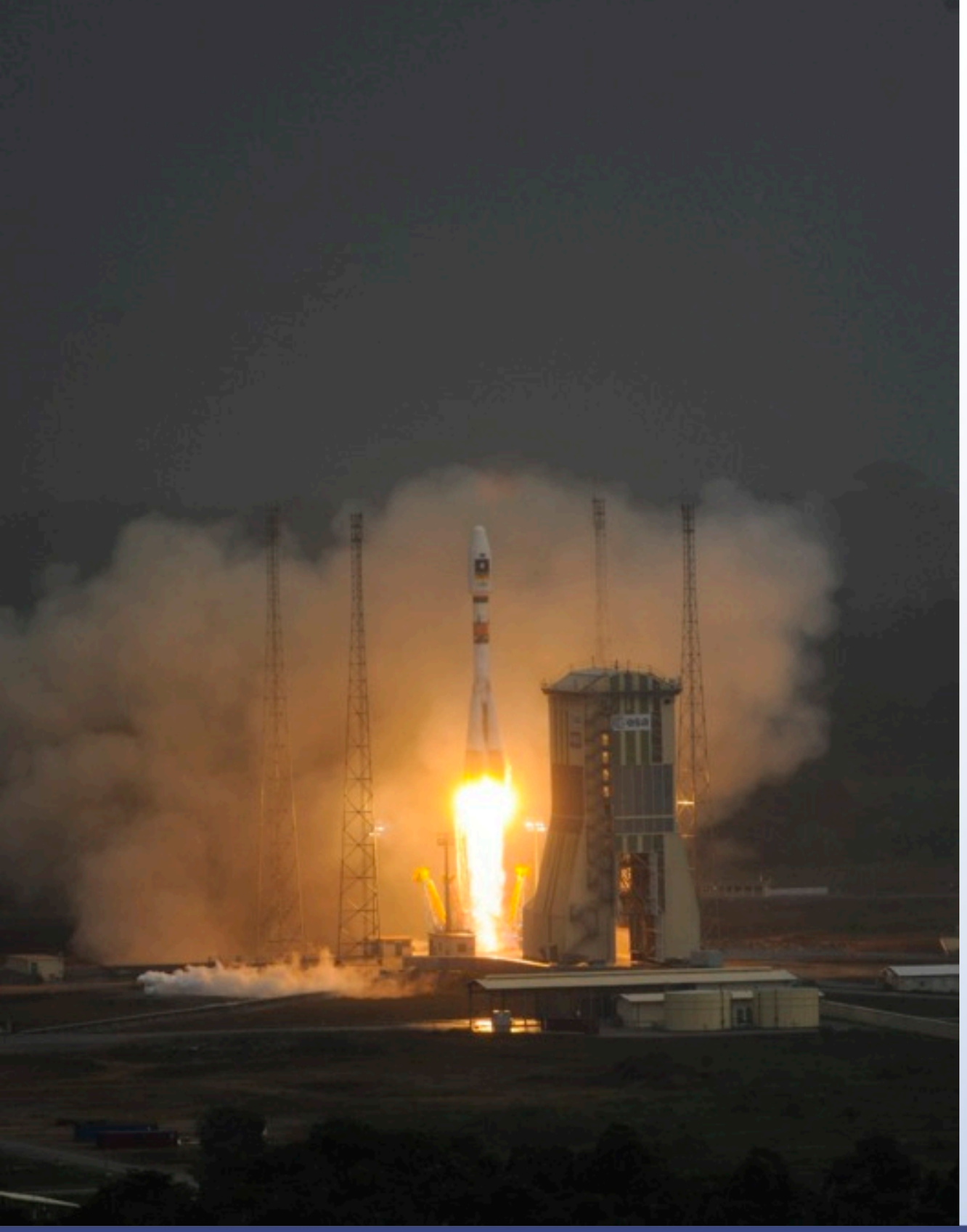


- Micro-thruster Assembly (MTA)

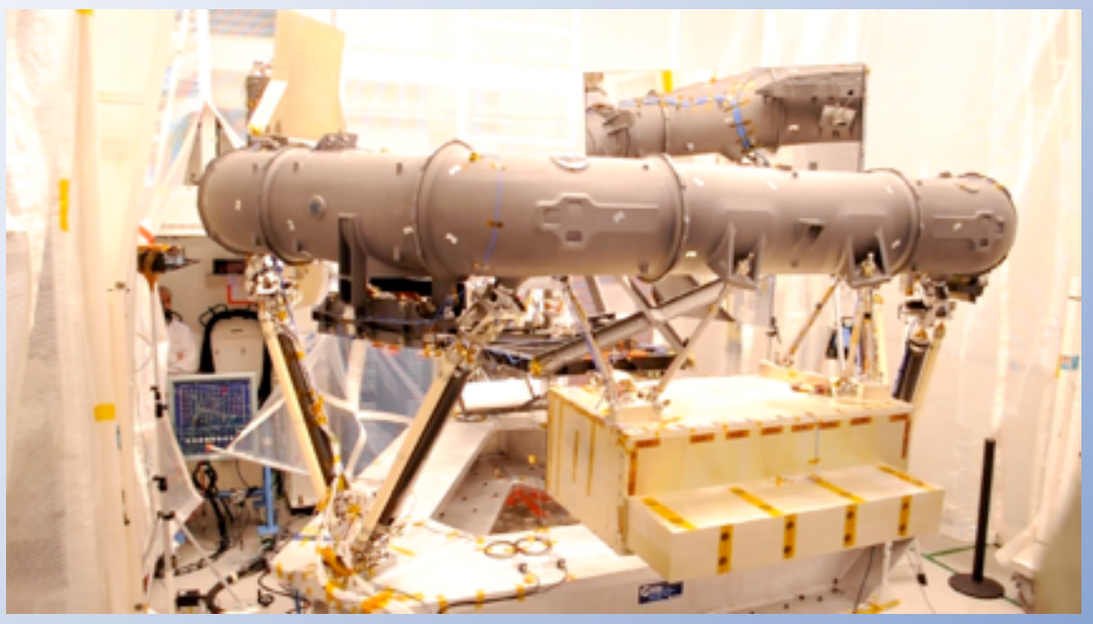
- Deployable Sunshield Assembly checked after testing, dismounted from the Service Module (SVM) and put into storage

Intermediate Data Releases

- Intermediate Data Release Scenario agreed with inputs from Data Release Policy and DPAC Operations Plan
  - Science Alerts as soon as possible
  - L+22m positions, G-magnitudes, proper motions to Hipparcos stars, ecliptic pole data
  - L+28m + first 5 parameter astrometric results, bright star radial velocities, integrated BP/RP photometry
  - L+40m + BP/RP data, some RVS spectra, astrophysical parameters, orbital solutions for short period binaries
  - L+65m + variability, solar system objects
- Scenario needed, in addition to technical planning, for establishing Archive Access coordination unit



- Galileo launch in October 2011 successful and with mechanical loads as anticipated
- Gaia launcher manufacturing started
- Soyuz rocket Sz-013



Schedule

- Service Module in Thermal Balance/Thermal Vacuum (TB/TV) at this moment
- Payload Module TB/TV starting October
- Spacecraft level assembly starting January 2013 leading to launch in September
- Commissioning phase 4 months and data processing initialization during the following 2 months of ecliptic pole scanning
- Start of Science Alerts 2014
- First intermediate data release summer 2015
- First data release with five parameter astrometry late 2015/early 2016
- End of nominal operations and start of operations extension 2019
- "Final release" 2021

Promises of Gaia

- Orders of magnitude improvements
- Schedule stabilising: launch September 2013
- Science alerts early on and intermediate releases starting two years after launch
- Get ready for **the** promise of Gaia

...astronomy will change

Gaia

Unraveling the chemical and dynamical history of our Galaxy