La misión Gaia: estado actual de desarrollo

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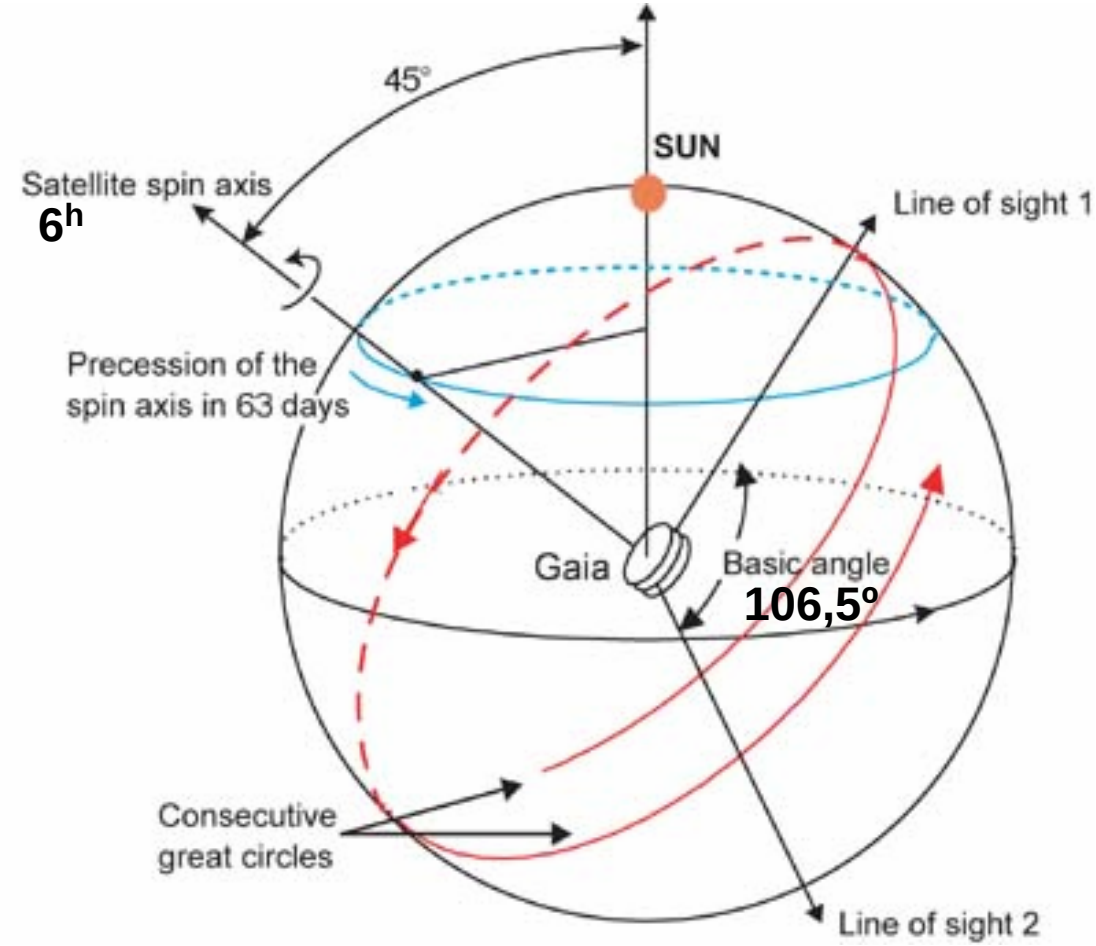
Mission goals/requirements

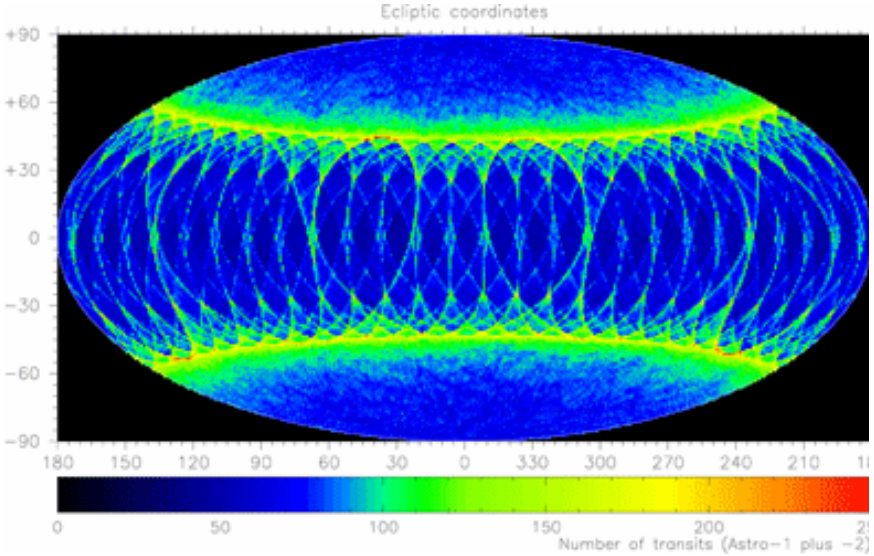
- A Stereoscopic Census of Our Galaxy
- Astrometry:
  - completeness to 20 mag (on-board detection) 10^9 stars
  - parallax accuracy: 7 μas at <10 mag; 12–25 μas at 15 mag; and 100–300 μas at 20 mag
- Photometry (V < 20):
  - astrophysical diagnostics (low-dispersion photometry) + chromaticity
  - 8–20 mmag at 15 mag: T_{eff} ~ 200 K, log g, [Fe/H] to 0.2 dex, extinction
- Radial velocity (V < 16.5–17):
  - third component of space motion, perspective acceleration
  - <1 km/s at 13-13.5 mag and <15 km/s at 16.5-17 mag

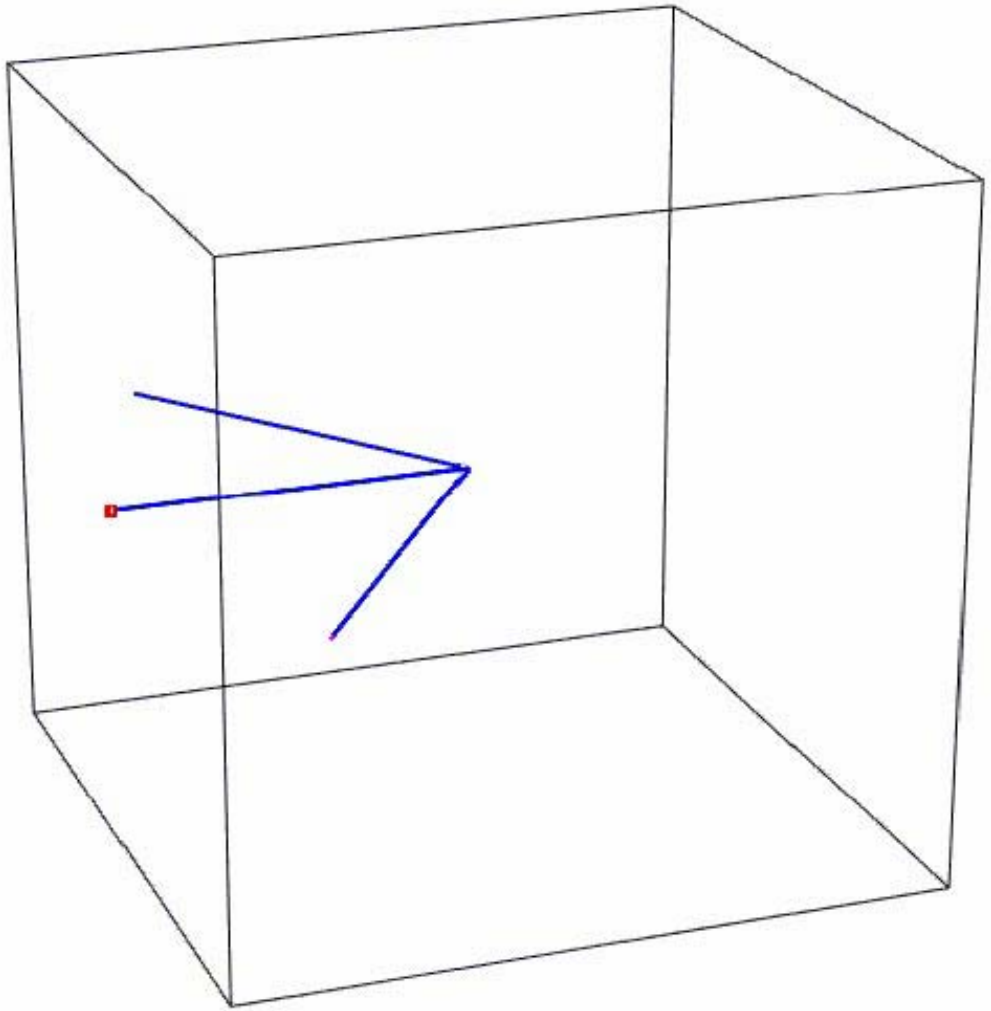
Gaia principle

Two telescopes continuously scanning the sky
Lissajous orbit, Lagrangian point L2 Sun-Earth



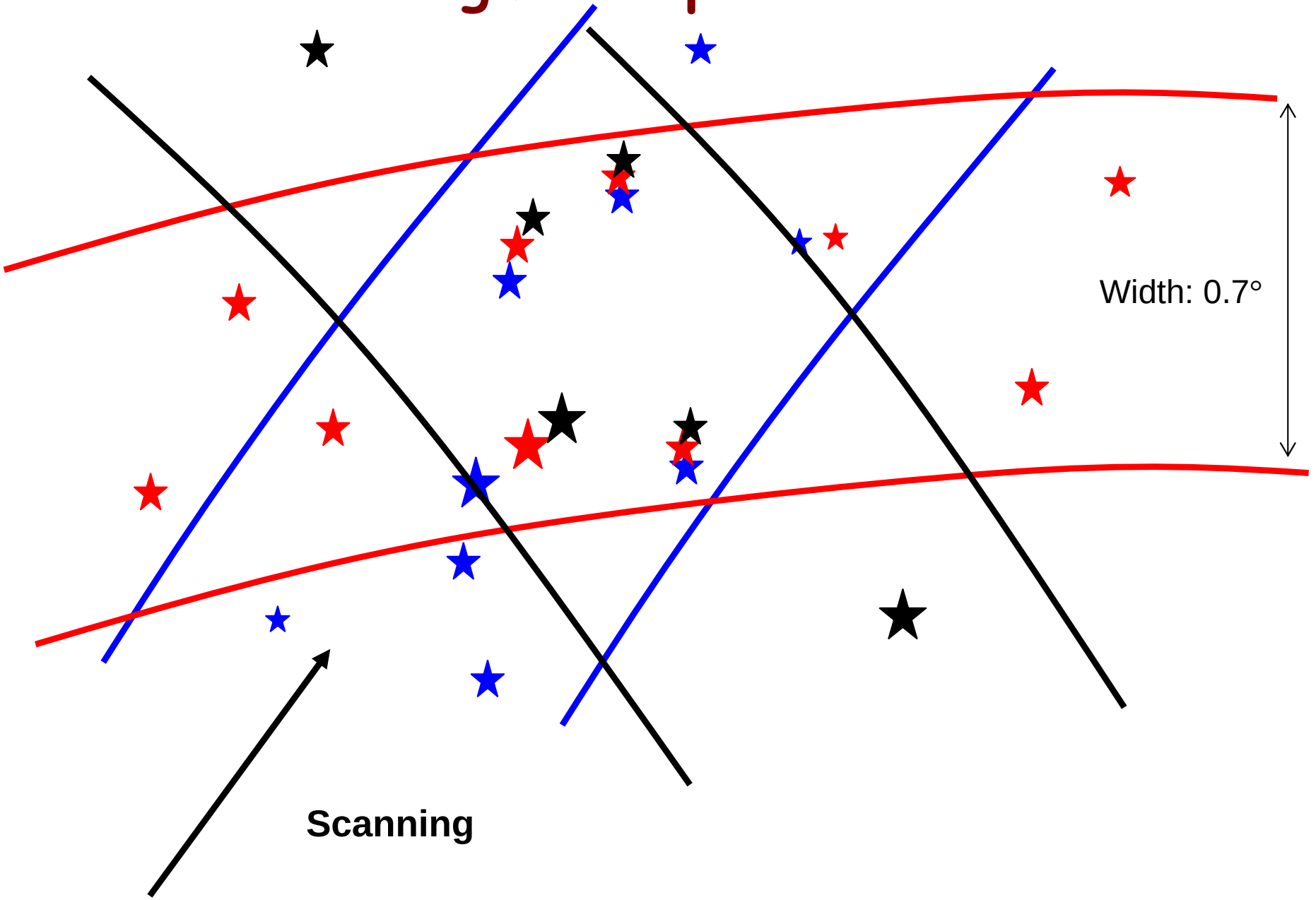
The scanning law provides full sky coverage



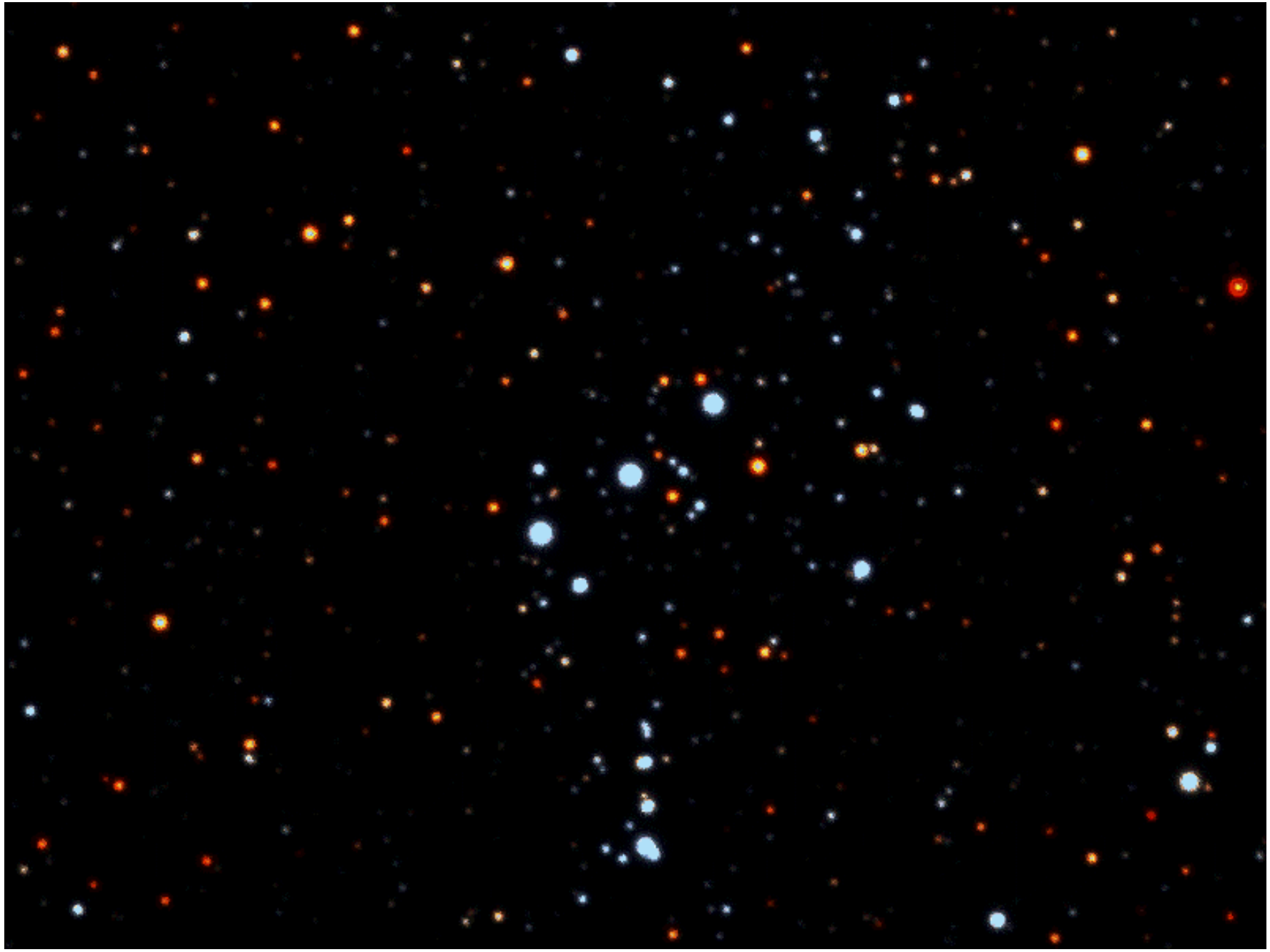


5 years: average of 80 observations

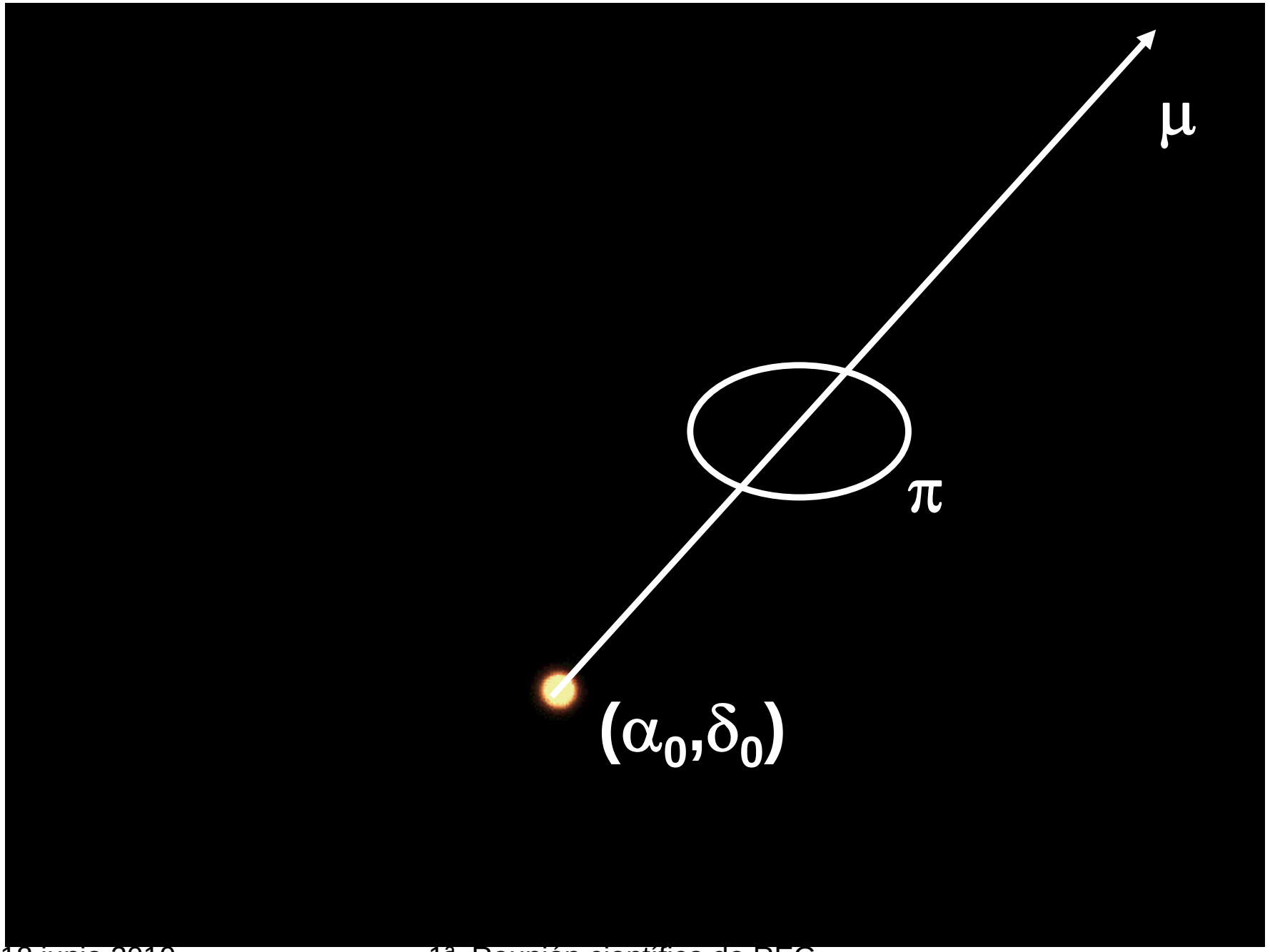
Global Astrometry: all-sky grid of large angular separations



Parallax and proper motion



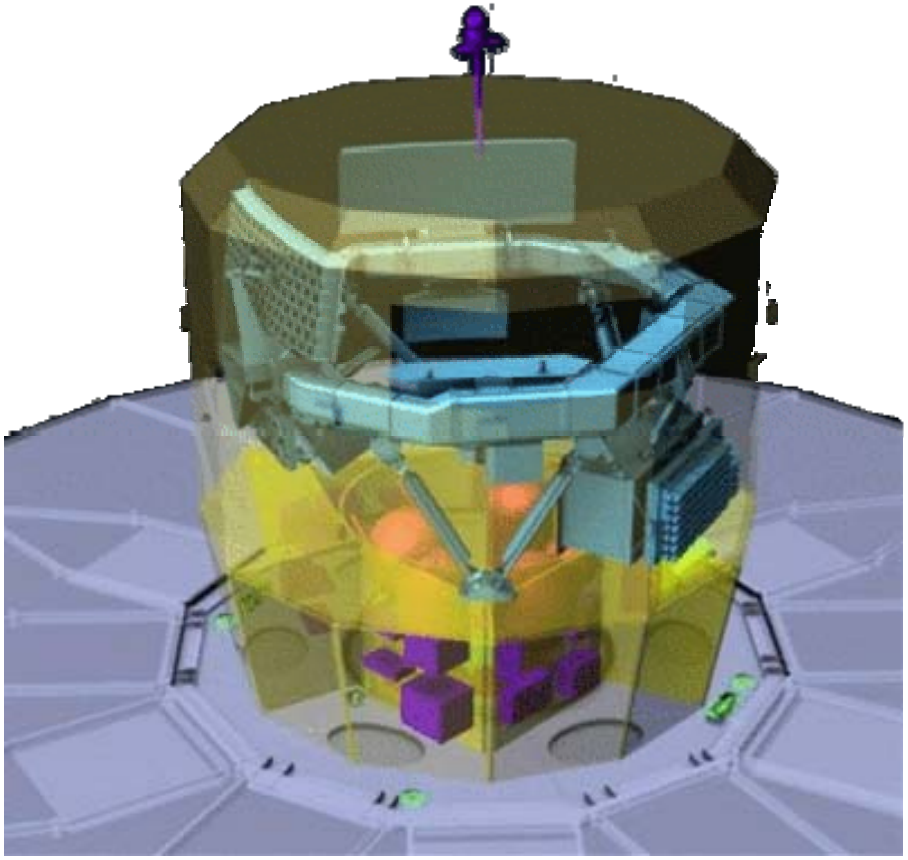
Parallax and proper motion



Mission elements

- Satellite and Payload: EADS Astrium
- Launch: Soyuz-Fregat from Kourou
- Mission Operations Centre: ESA-ESOC and ground stations Cebreros and New Norcia
- Science Operations Centre: ESA-ESAC
- Gaia Data Processing and Analysis Consortium (DPAC)

The Satellite



- Mass: 2120 kg (instruments 743 kg)
- Power: 1631 W (solar panels)
- Cost: 560 M€
- Launcher: Soyuz–Fregat from Kourou

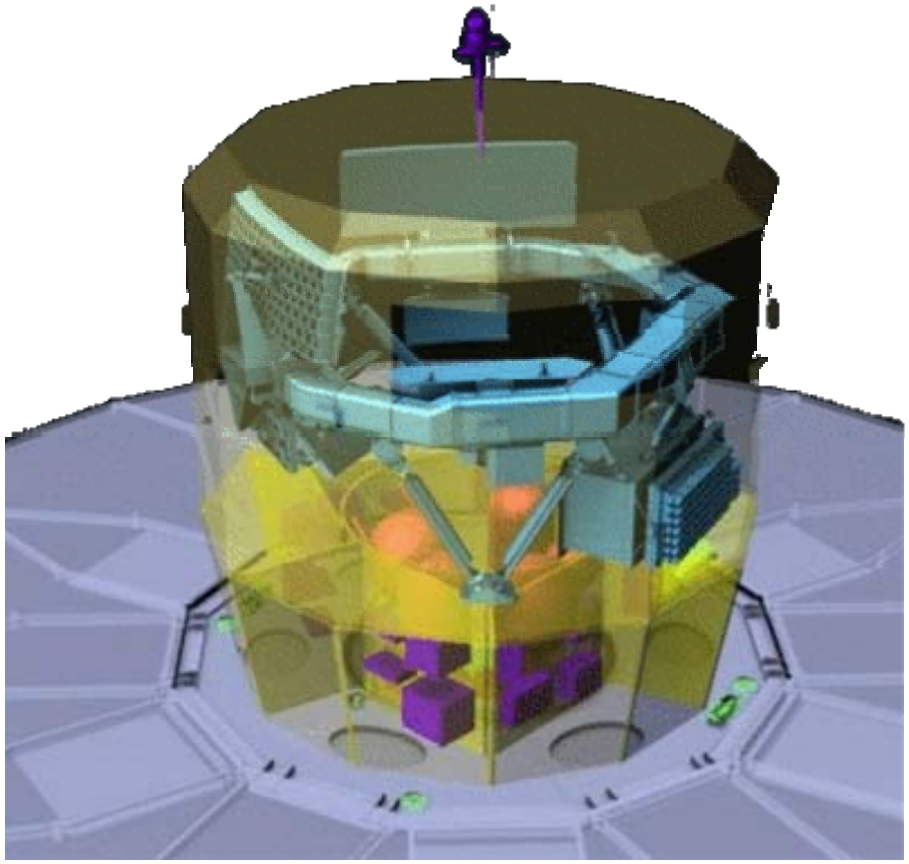
Thermal tend

Thermic stability:

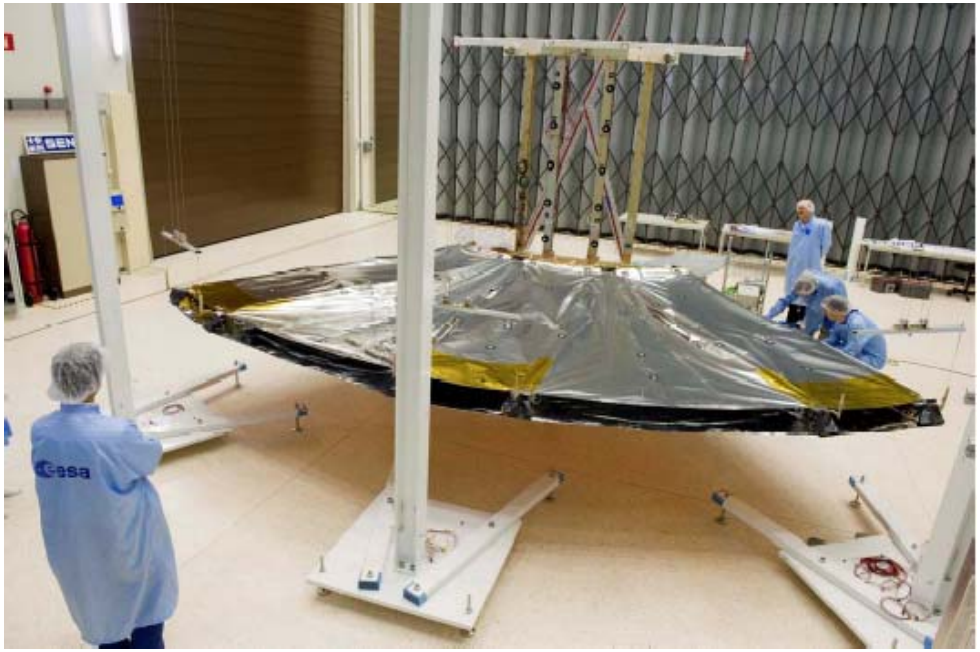
CCDs operate at
~ -110ºC

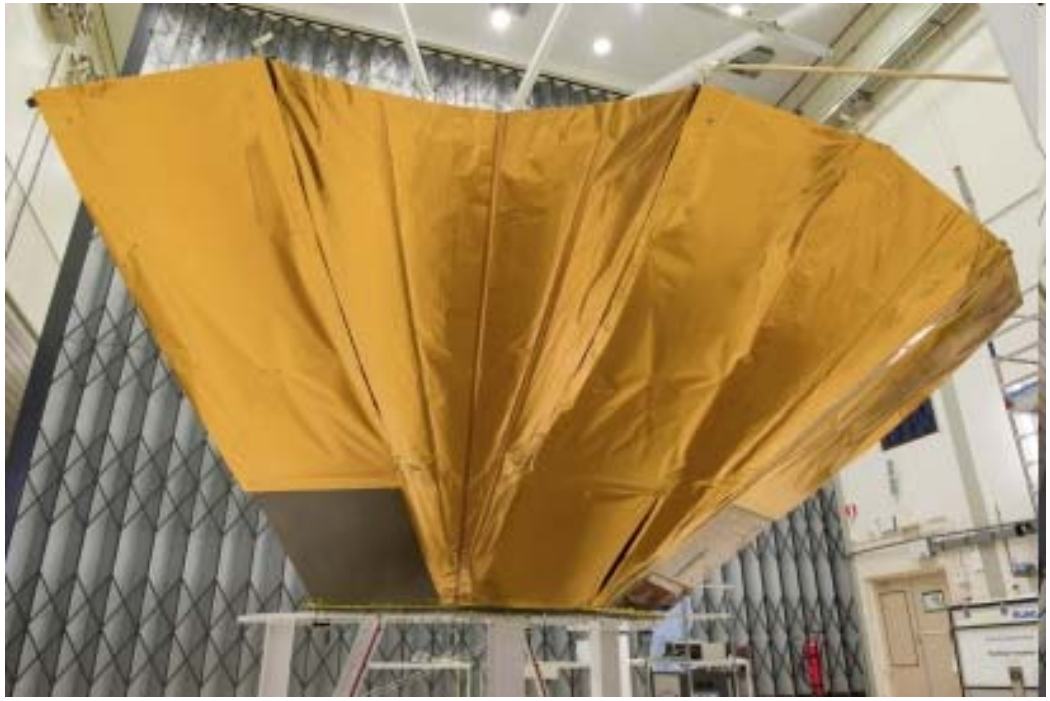
<1mK at focal plane

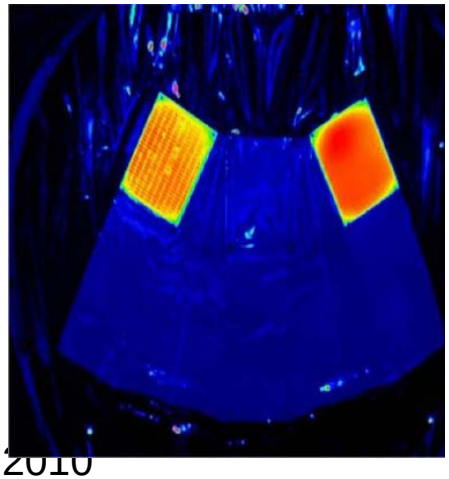
~μK in the torus



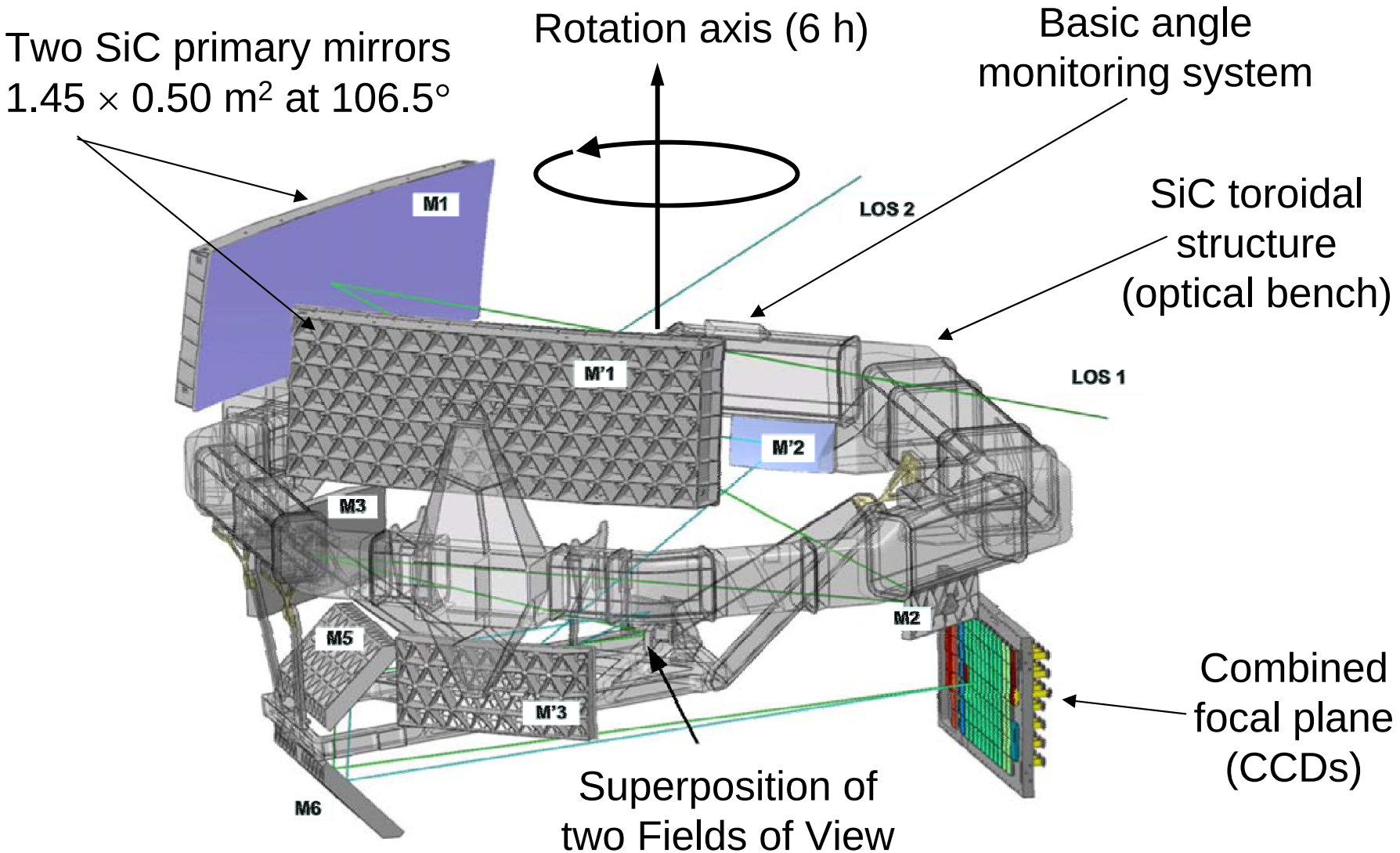
Deployable solar planels







The scientific instrument



light-weight, robust and ultra stable

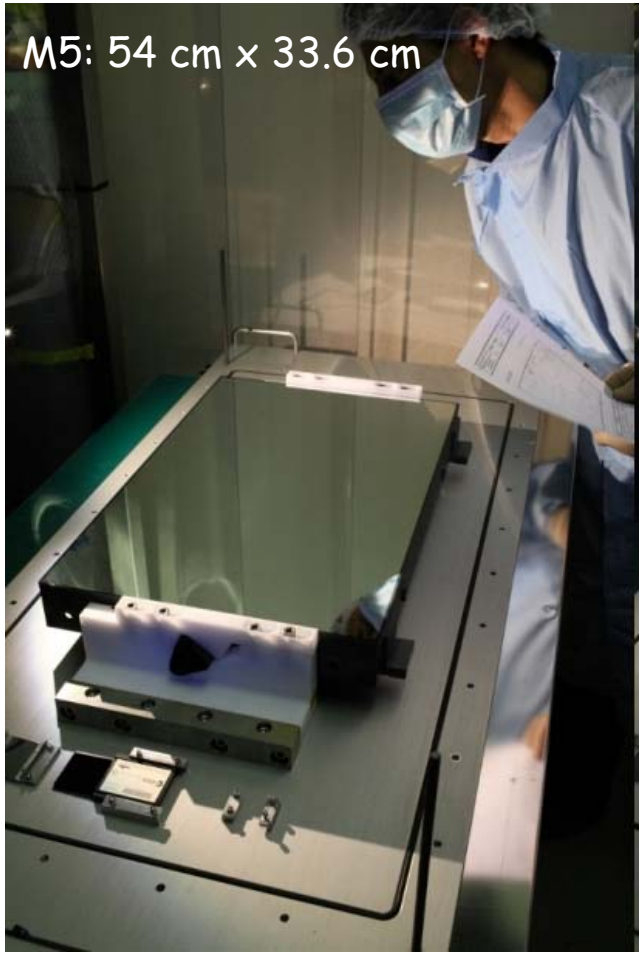
Boostec, 2010
17 pieces, 3m

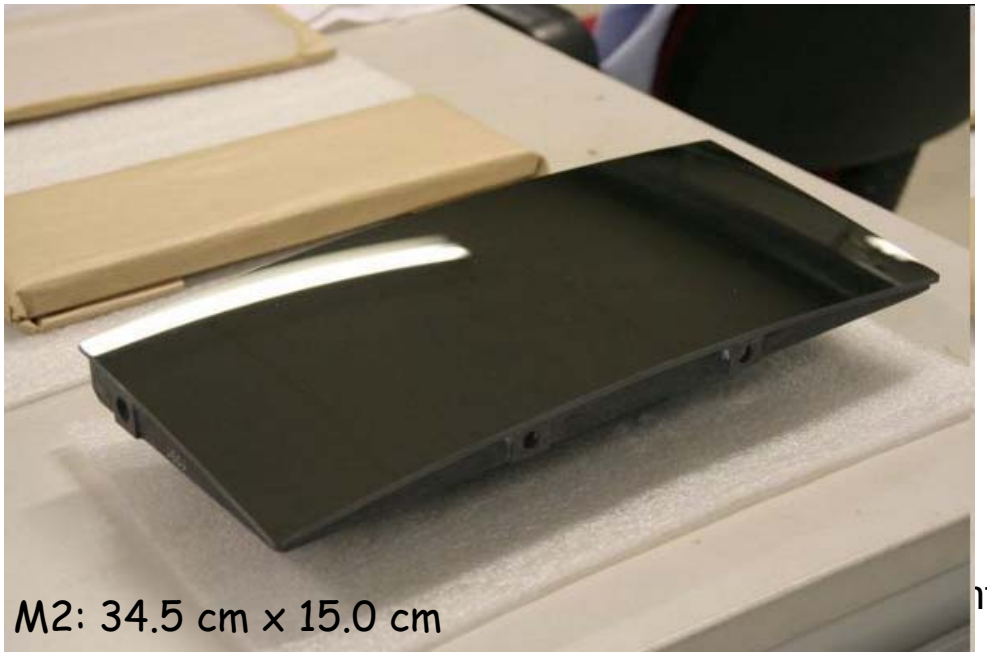
M2, M4 and M5 mirrors

Fabricated from SiC by Boostec Tarbes, France

Chemical vapour deposition of a SiC layer of is applied by Schunk Kohlenstofftechnik in Heuchelheim, Germany.

Inspection and tests at Advanced Mechanical and Optical Systems (AMOS) at Liège, Belgium





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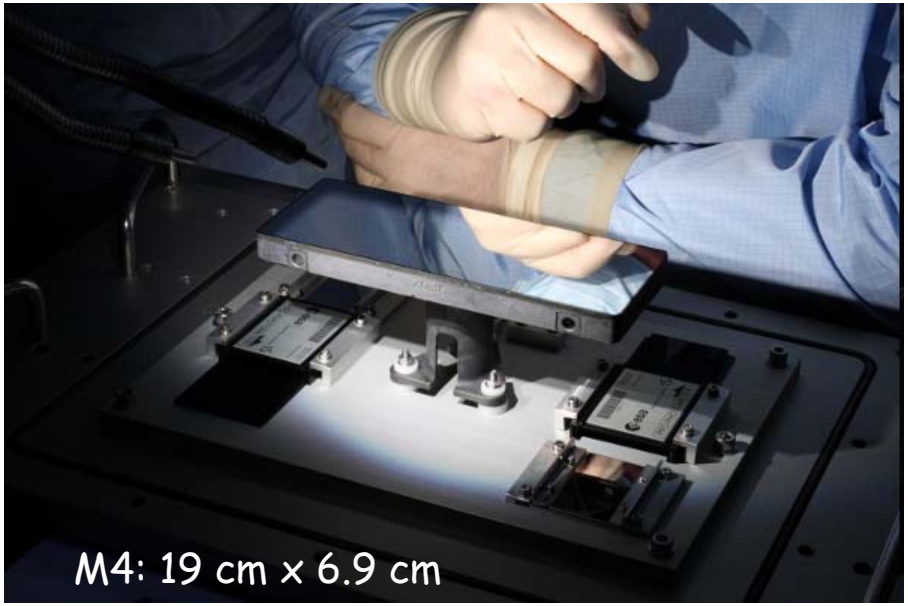
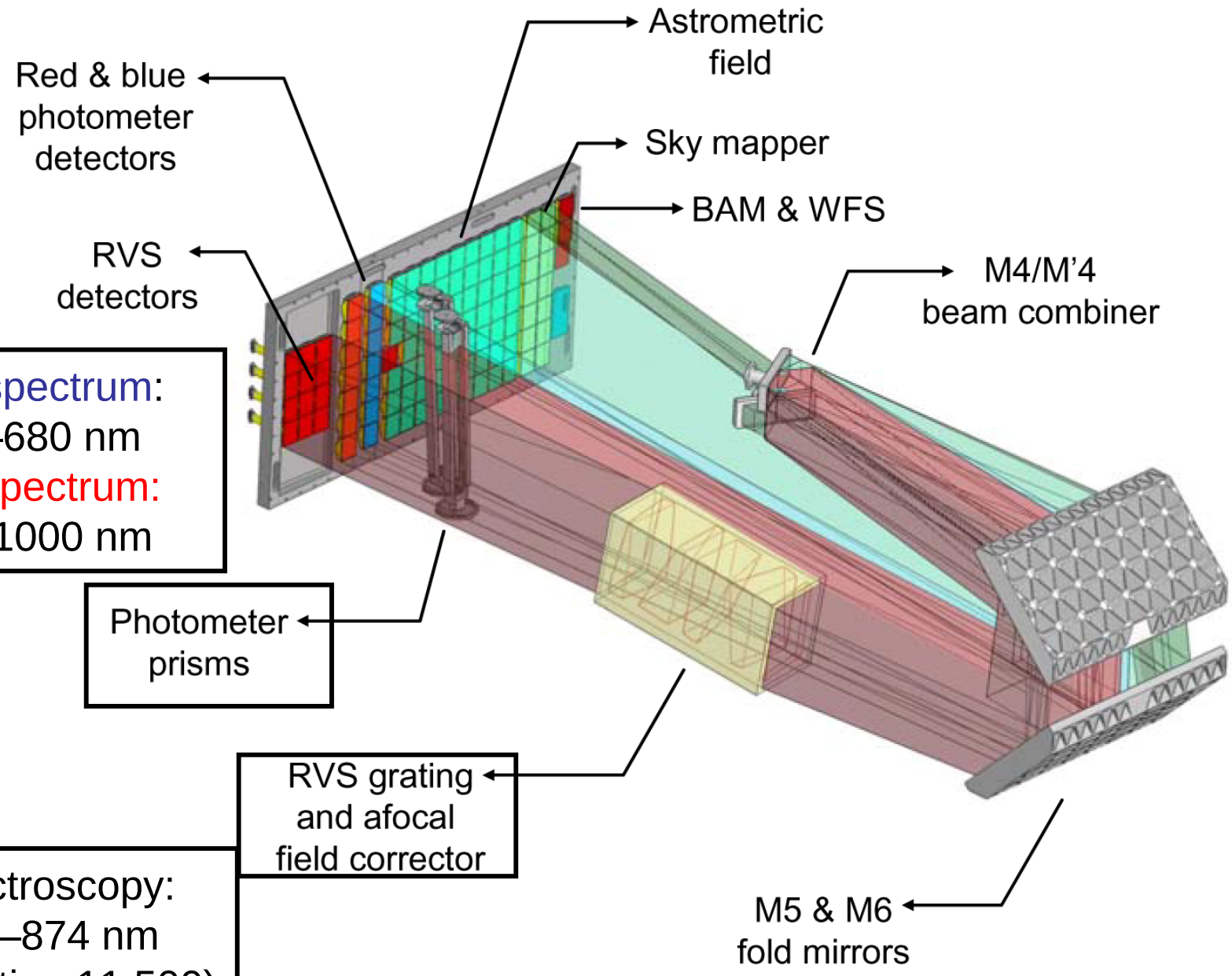
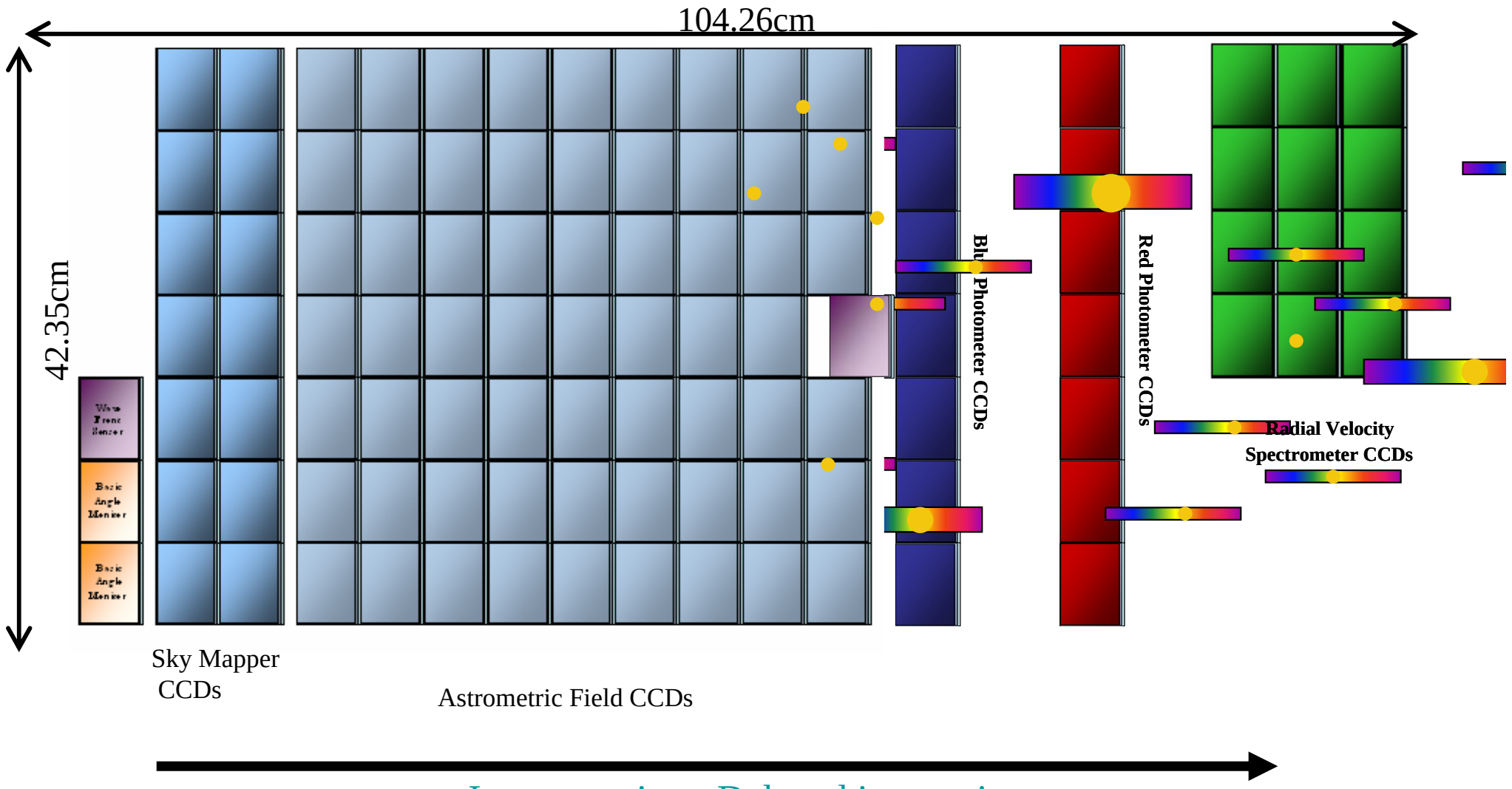


Focal plane assembly



Focal plane

106 CCDs , 938 million pixels, 2800 cm^2
pixel size= 60 mas, angular resolution=0.12”



Structure of CCD support

90% of CCDs are ready

Science performances

http://www.rssd.esa.int/index.php?project=Gaia

Science performances

- astrometry
- photometry
- spectroscopy

For sky-averaged position and proper-motion errors, σ_0 and σ_μ, the following relations can be used, based on scanning-law simulations:

$$\sigma_0 = 0.743 \cdot \sigma_\varpi$$
$$\sigma_{\alpha^*} = 0.787 \cdot \sigma_\varpi$$
$$\sigma_\delta = 0.699 \cdot \sigma_\varpi$$
$$\sigma_\mu = 0.526 \cdot \sigma\varpi$$
$$\sigma_{\mu\alpha^*} = 0.556 \cdot \sigma\varpi$$
$$\sigma_{\mu\delta} = 0.496 \cdot \sigma\varpi$$

where the asterisk denotes true arcs on the sky ($\sigma_{\alpha^*} = \sigma_\alpha \cdot \cos\delta$, etc.)

The following table summarises Gaia's performance as function of G:

	G<13	G=13	G=14	G=15	G=16	G=17	G=18	G=19	G=20	G=21
σ_0 [μas]	5.22	6.54	10.17	16.04	25.56	41.35	68.56	117.92	214.20	413.28
σ_ϖ [μas]	7.02	8.81	13.68	21.58	34.41	55.65	92.28	158.70	288.28	556.24
σ_μ [μas yr^{-1}]	3.69	4.63	7.20	11.35	18.10	29.27	48.54	83.48	151.64	292.58

Gaia Astrometric Accuracy Tool (courtesy J. de Bruijne, ESA)

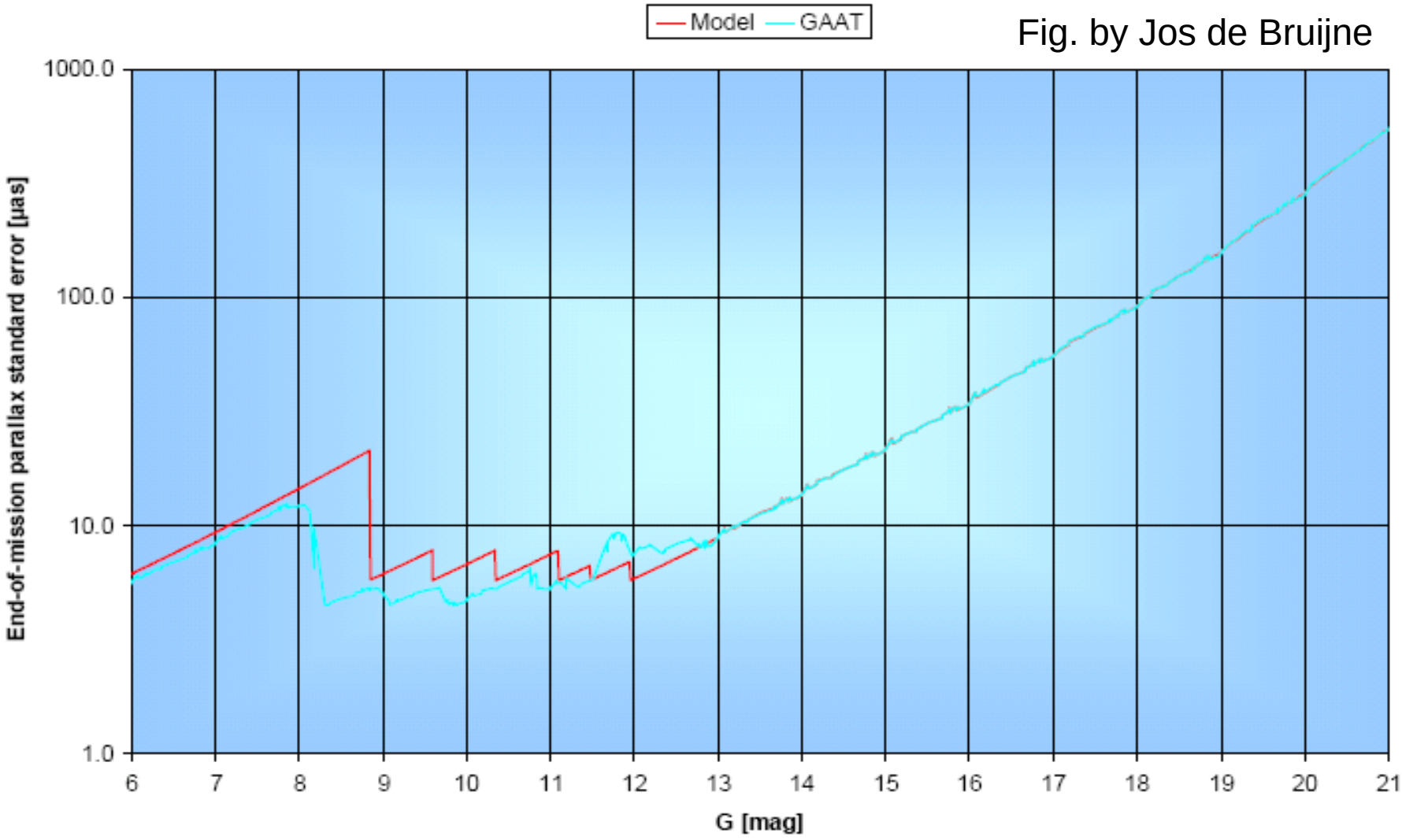


Fig. by Jos de Bruijne

Number of transits

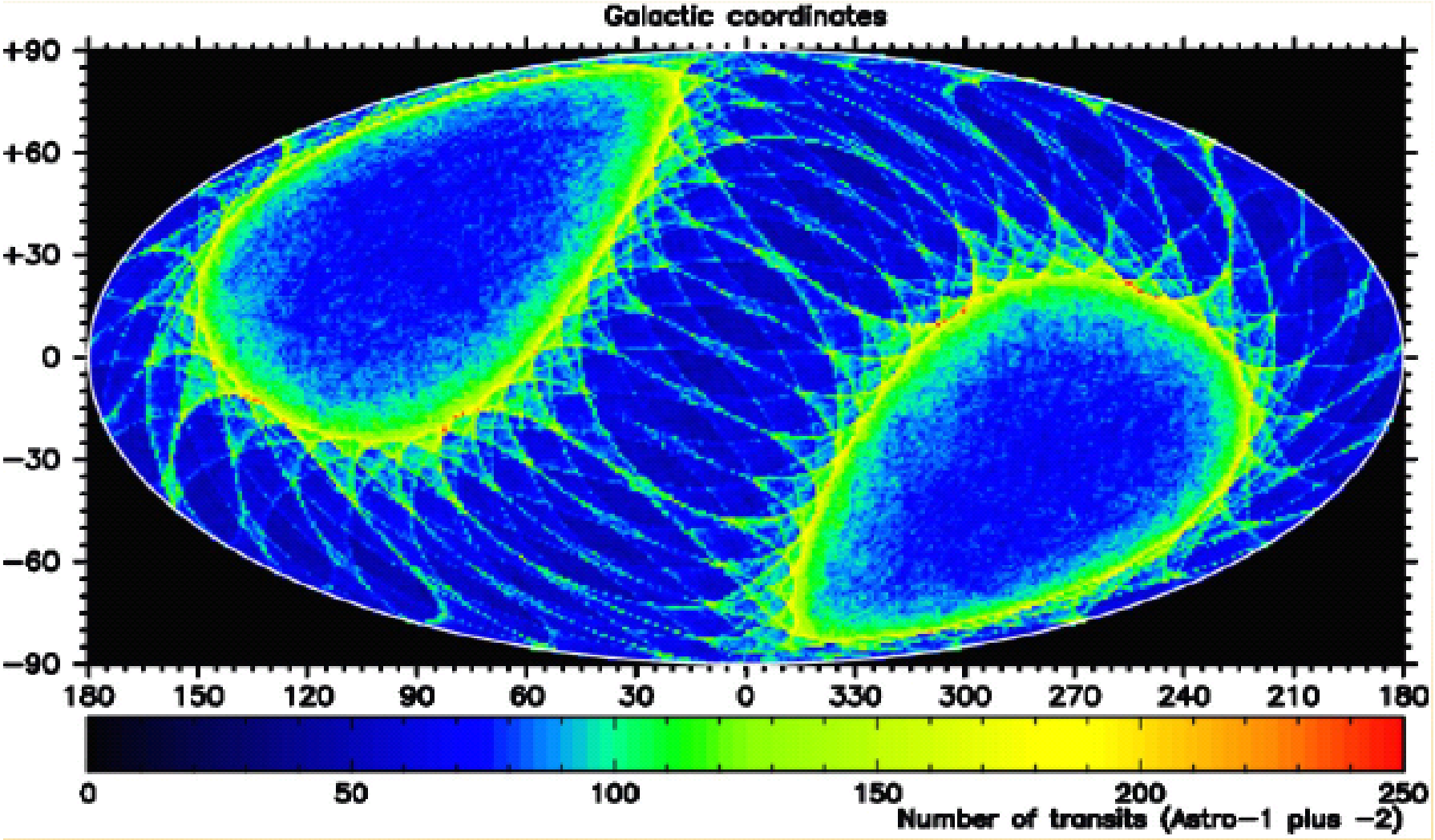


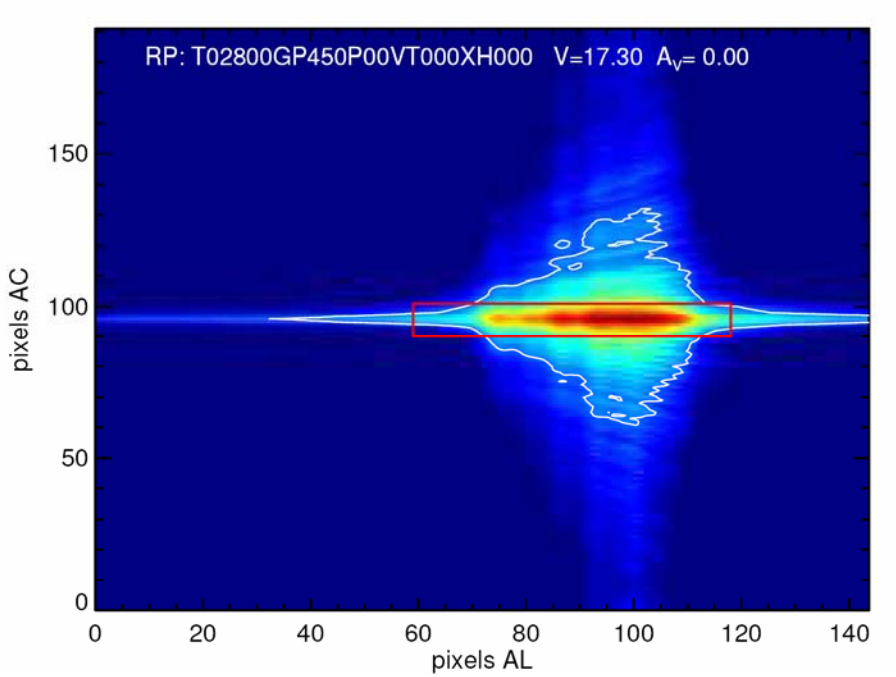
Table 5. Distances for which the relative parallax error is ∼10%: d_o is the value of this distance for zero interstellar extinction and d_{abs} is the value for an average Galactic plane interstellar extinction of 0.7 mag kpc^{-1}. $V(d_o)$ and $V(d_{abs})$ are the corresponding apparent V magnitudes. Parallax accuracies are from Table 8.4 in ESA (2000)

SP	M_V	d_o(pc)	$V(d_o)$	d_{abs}(pc)	$V(d_{abs})$	SP	M_V	d_o(pc)	$V(d_o)$	d_{abs}(pc)	$V(d_{abs})$
B1 V	−3.2	20 000	13.2	7000	15.7	G8 III	0.8	9000	15.6	4400	17.1
A0 V	0.65	8500	15.2	4500	16.8	K3 III	0.3	10 000	15.3	4800	17.1
A3 V	1.5	7000	15.7	3800	17.1	M0 III	−0.4	13 000	15.2	5500	17.2
A5 V	1.95	6500	16.0	3500	17.3	M7 III	−0.3	17 000	15.9	6300	18.1
F2 V	3.6	4500	16.7	2700	17.8						
F8 V	4.0	4000	17.0	2500	18.1	B0 Ib	−6.1	33 000	11.5	9500	15.4
G2 V	4.7	3500	17.2	2200	18.2						
K3 V	6.65	2400	18.4	1700	19.1	WD	8.0	1500	18.9	1200	19.2
M0 V	8.8	1500	19.7	1200	20.0						
M8 V	13.5	500	21.8	450	22.1						

Photometry & Spectrophotometry

Blue and red spectrophotometers

Resolution ~100

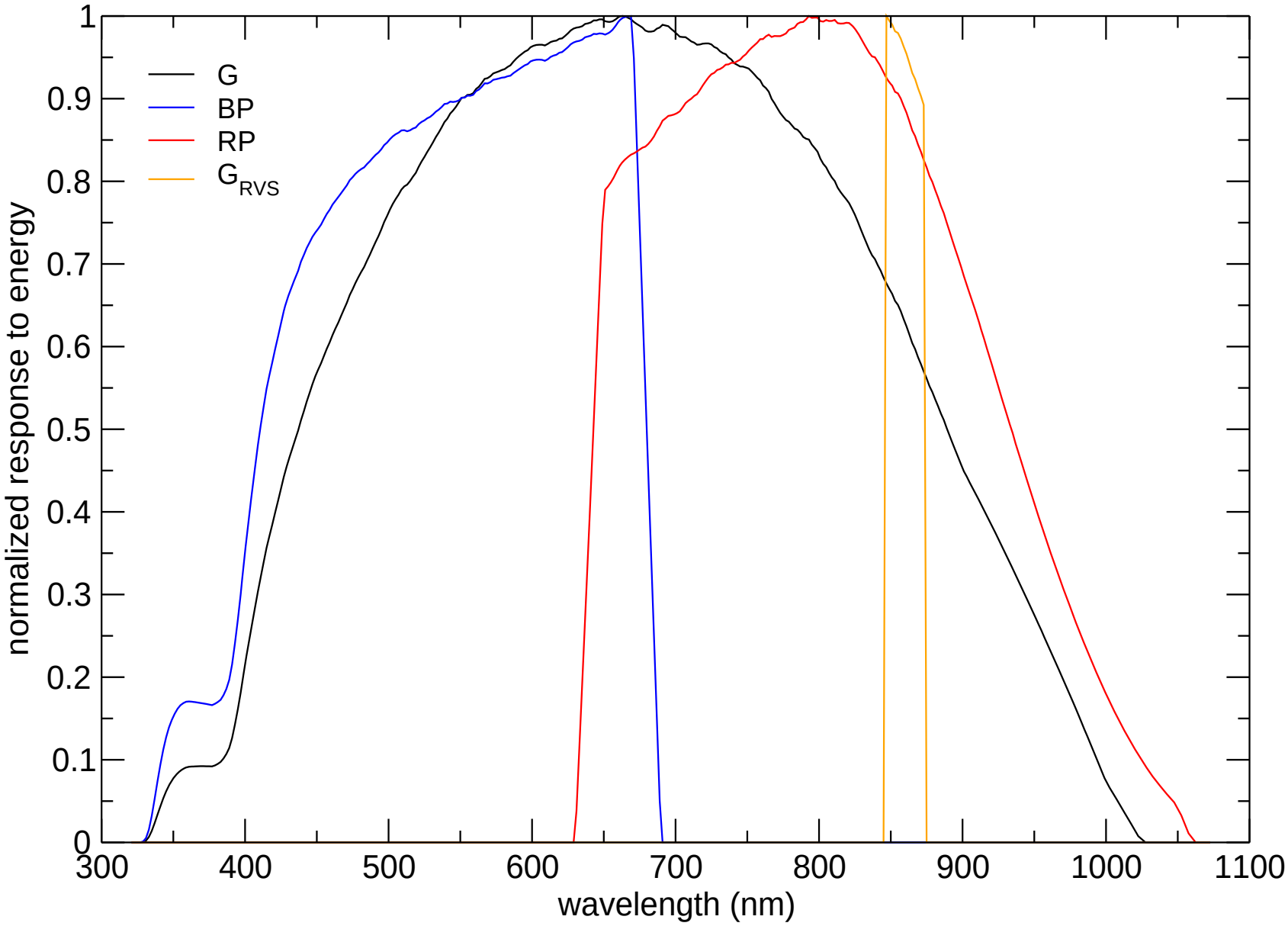


Red spectra of a M-dwarf (V=17.3)

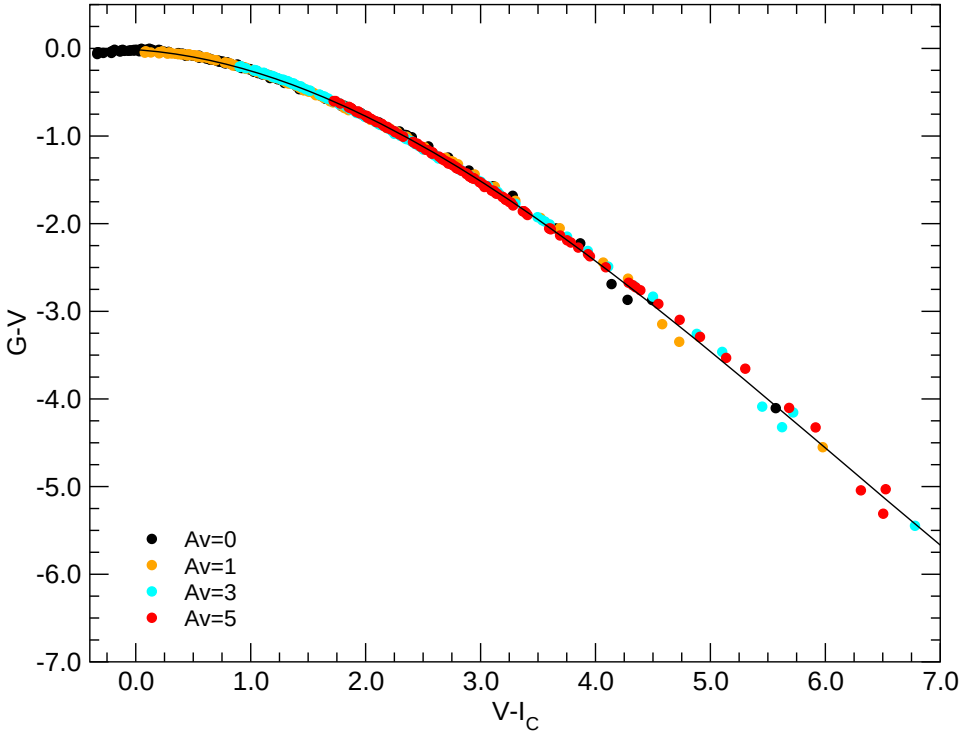
Red box: extracted window sent to the Earth

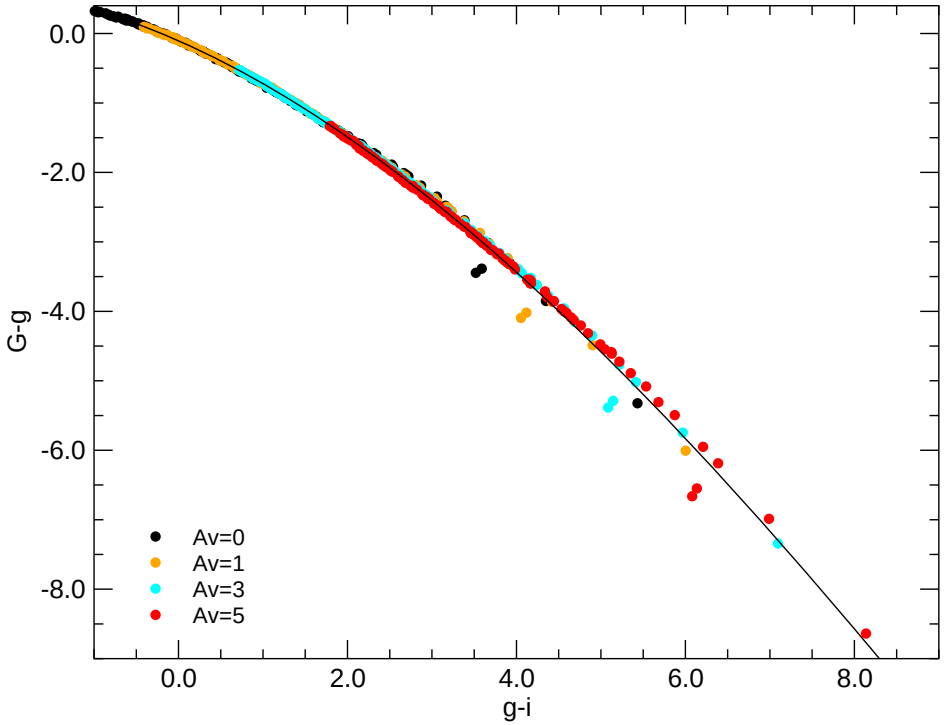
Figures courtesy Anthony Brown

Gaia passbands

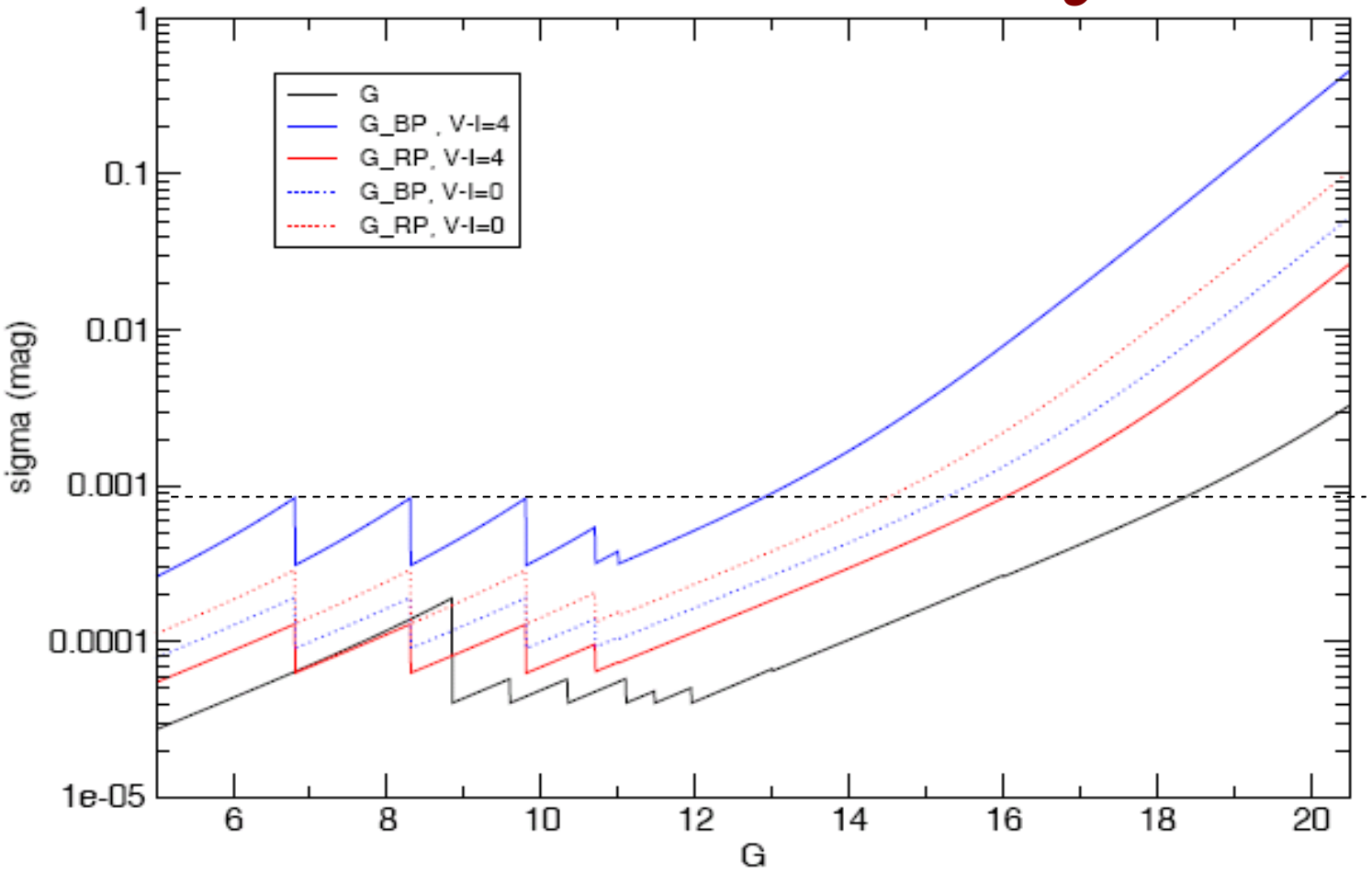


Relationships among Gaia and other phot systems
G_{BP}-G_{RP} vs T_{eff}
Absorption, BC, isochrones



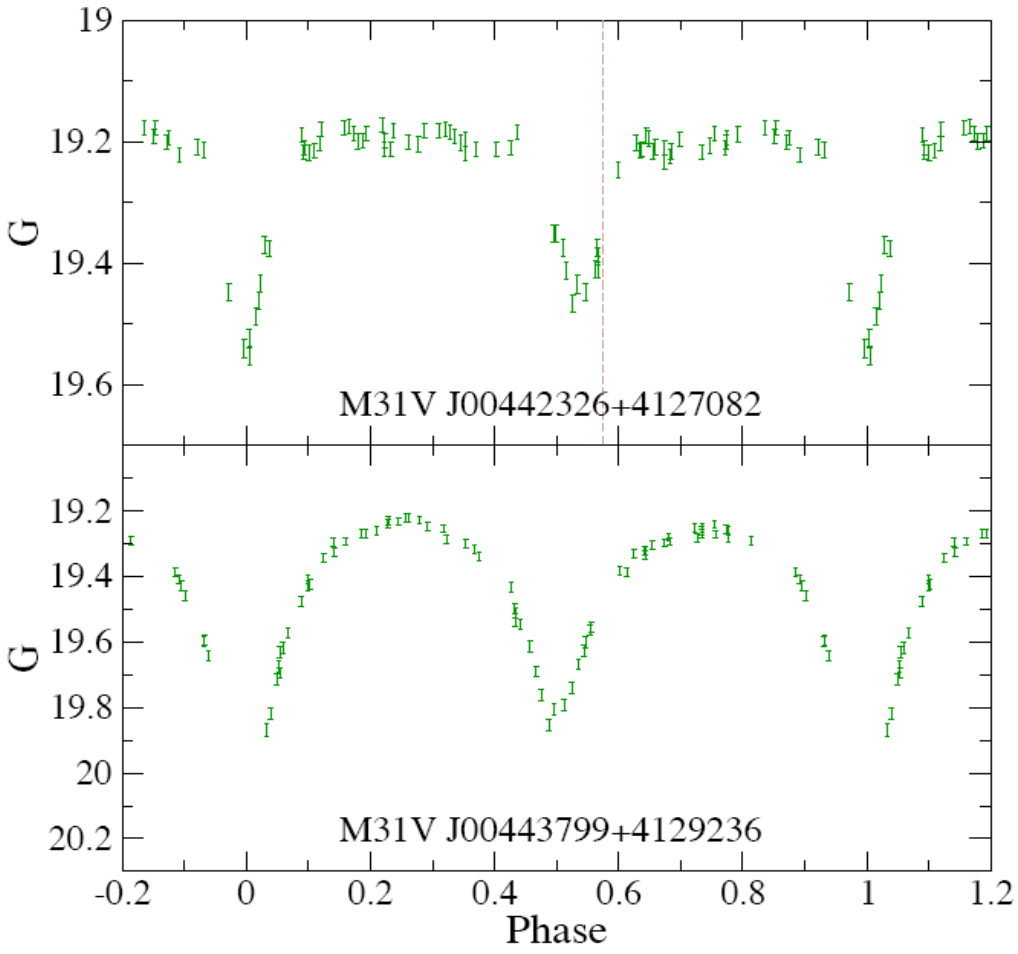


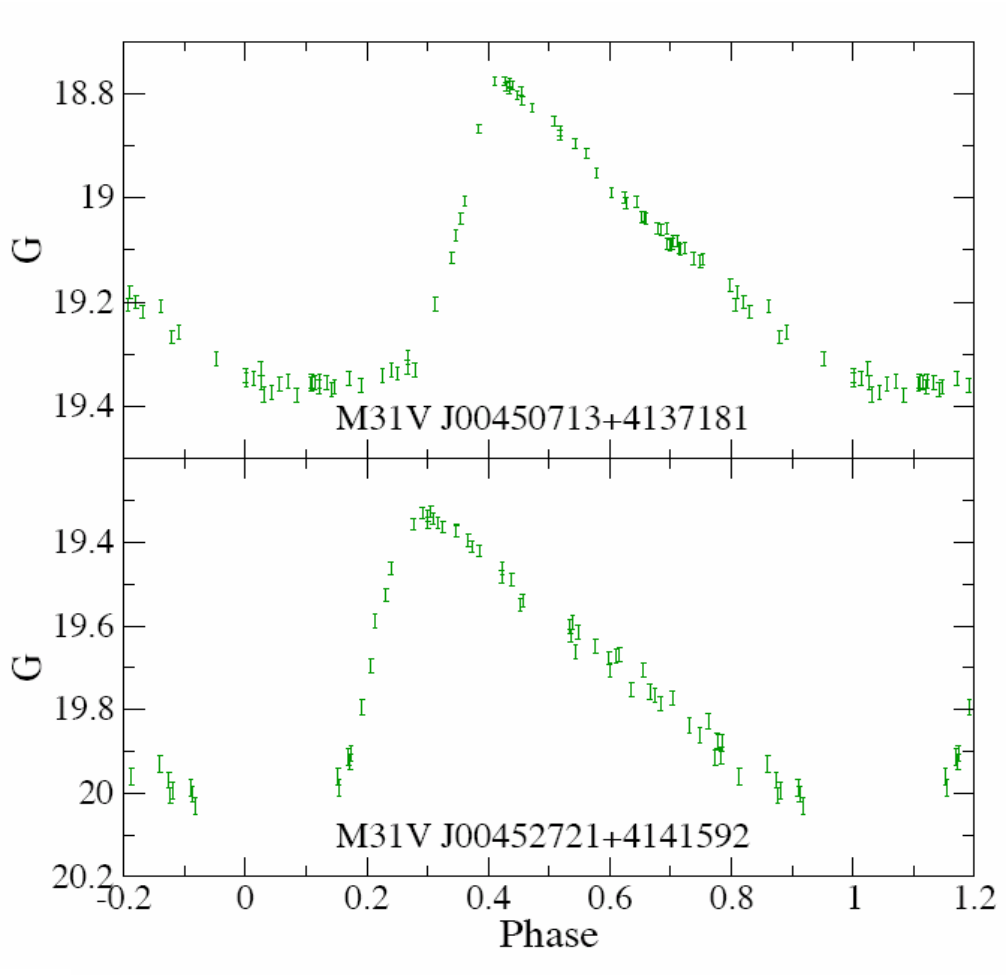
end-of-mission σ_G



Aperture photometry

Variability





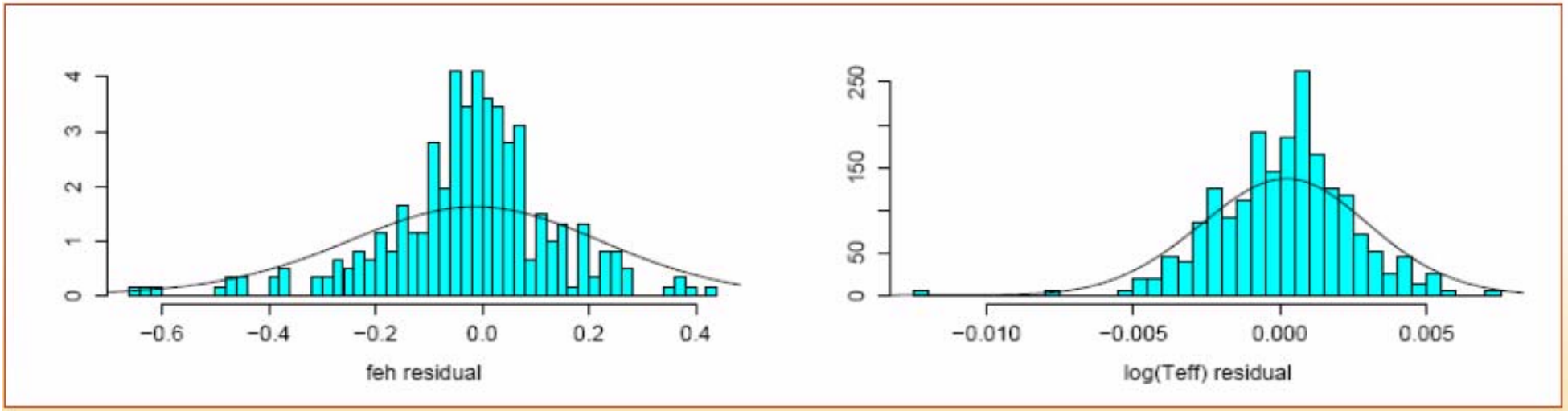
Light curves of stars in M31

Vilardell et al (2007)

Stellar parameters

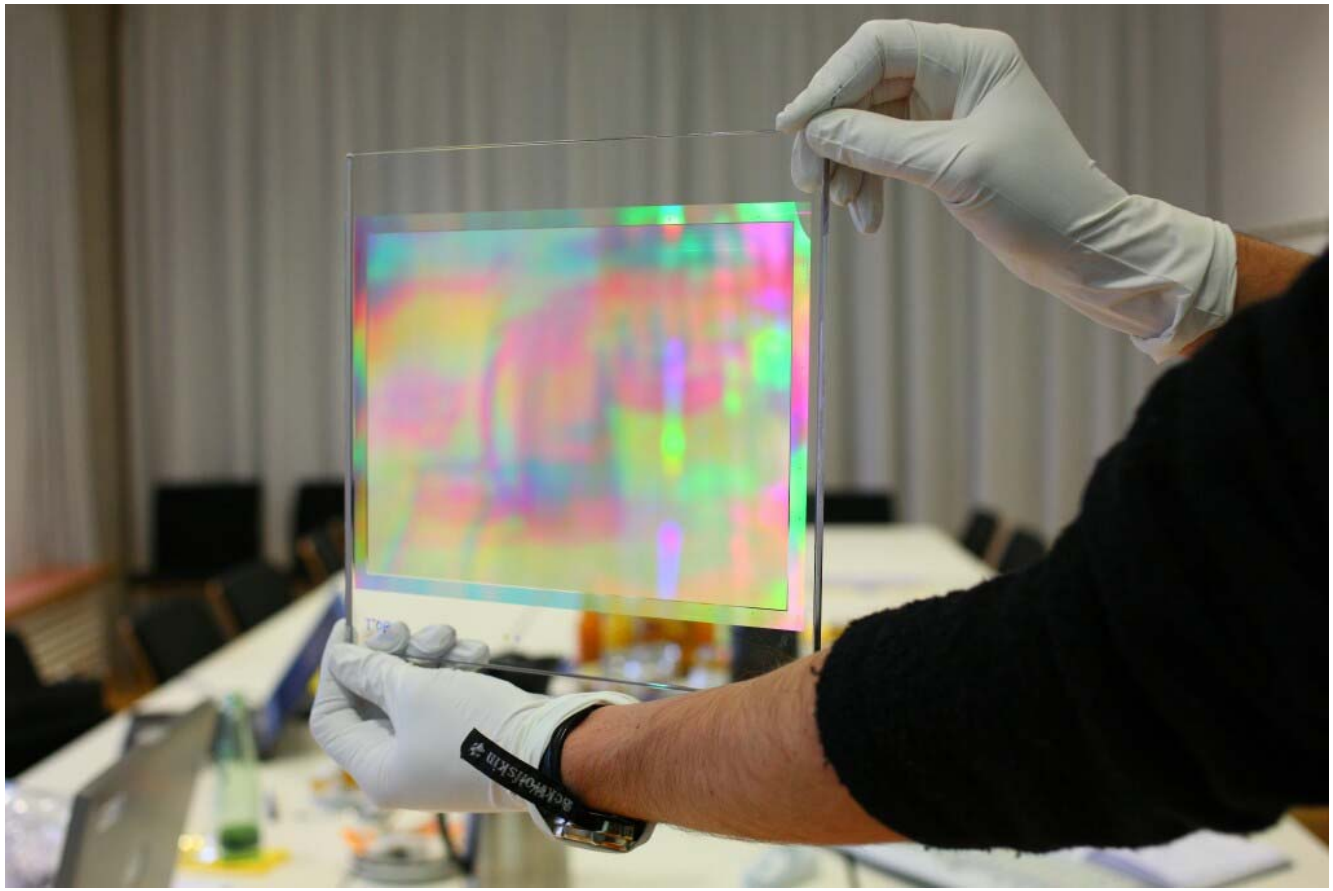
	T_{eff}	Av	log g	[M/H]	[α/Fe]
G<16	<5%	0.05-0.2	0.2-0.3	0.2-0.4	0.2
G=18	5-15%	0.05-0.3	0.2-0.5	0.5-0.7	?

- Ranges in errors reflect the influence of the spectral type, metallicity



dwarfs, G = 15, T < 7000 K, [Fe/H] > -2 C. Bailer-Jones, GAIA-C8-TN-MPIA-CBJ-043

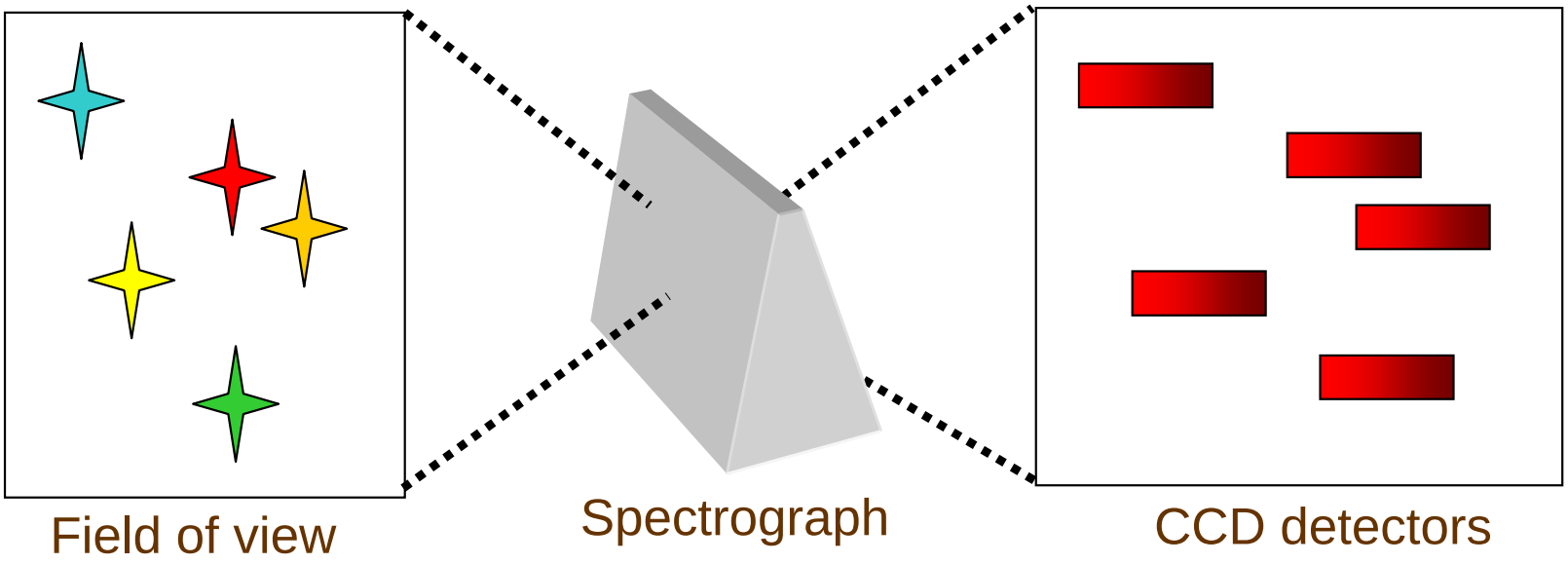
Spectroscopy

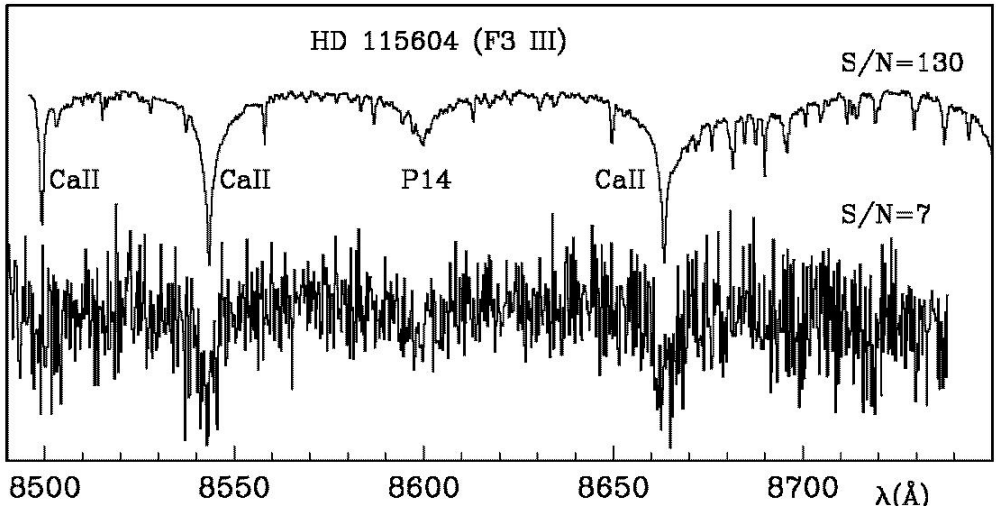


Full size demonstrator of RVS grating

302.11 grooves per mm

Spectroscopy





Spectrum of a F3 giant (V=16 mag)

S/N = 7 (one transit)
S/N = 130 (end of mission)

Figures courtesy David Katz

Radial velocity

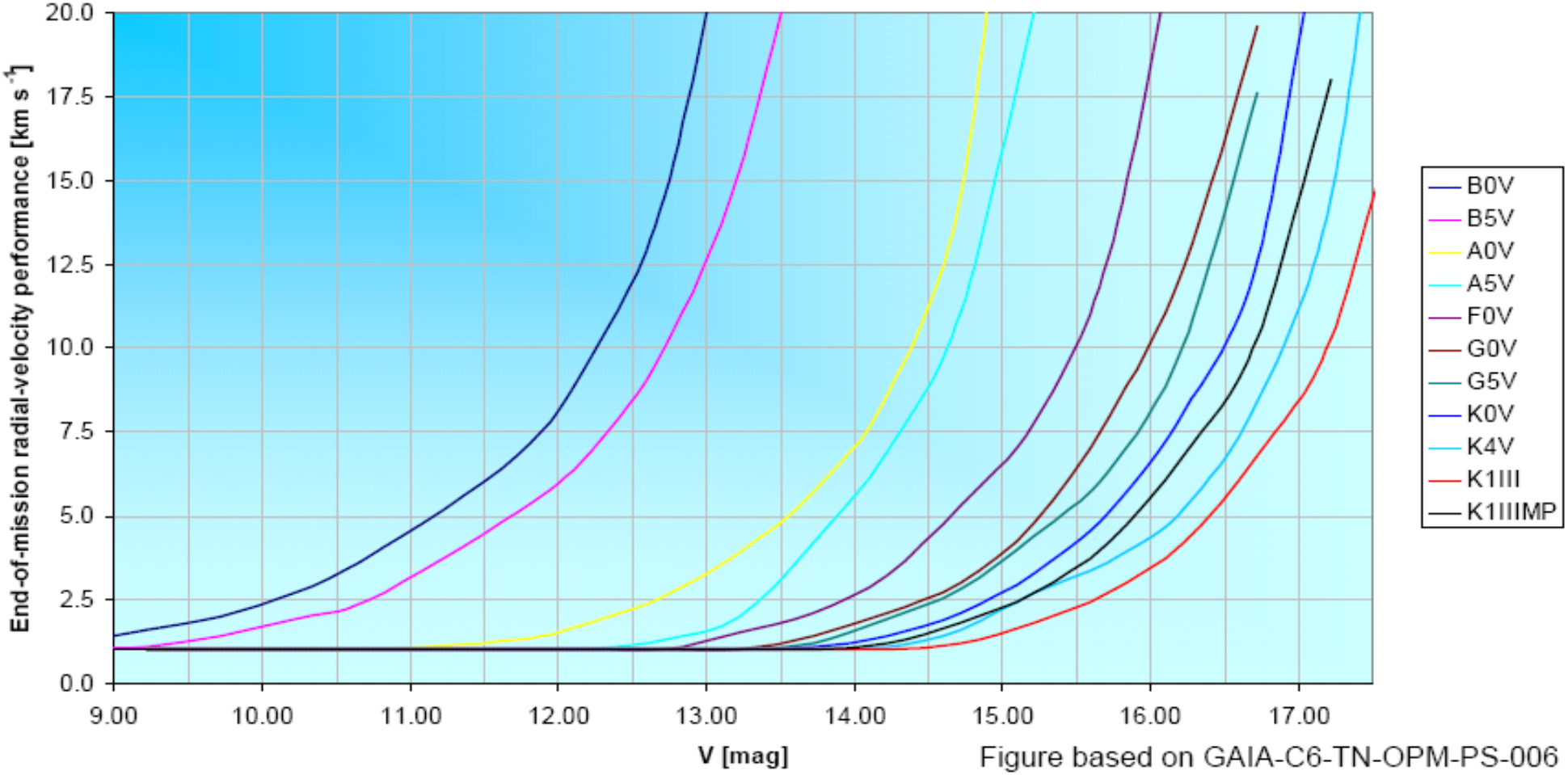


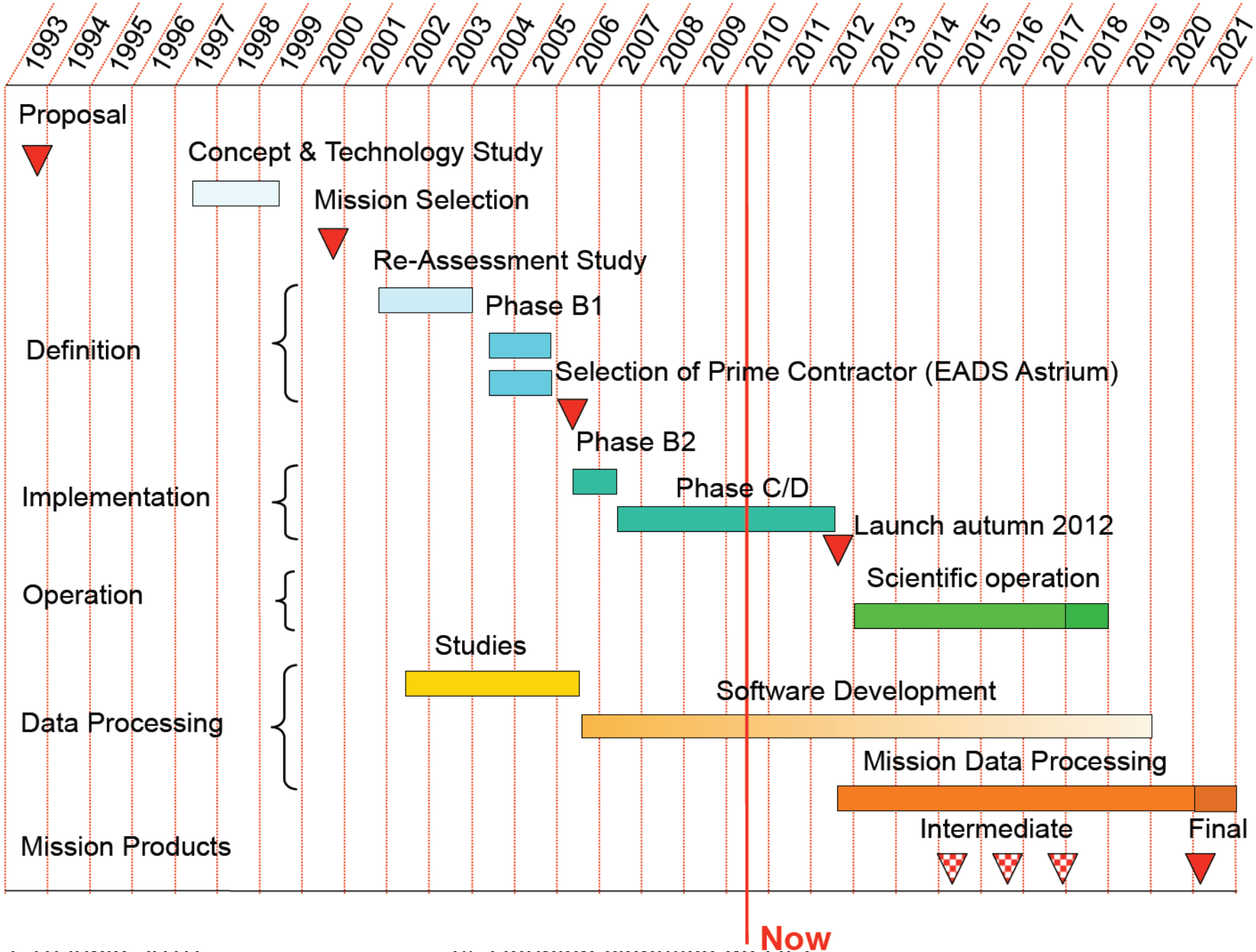
Figure based on GAIA-C6-TN-OPM-PS-006

Main caveats

1. **Radiation damage (shape deformation AL)**
   astrometry: flux loss included
   residual bias-calibration errors not included
   photometry & RVS: not included
2. **Serial register charge loss (shape deformation AC)**
   consolidated information is lacking
3. **Offset non-uniformity**
   residual errors or calibration errors not included
   (preliminary indications yield errors < 3 e-
   astrometric degradations < 1%)
4. **Laser frequency variation**
   Monitoring of basic angle more complex

PLM CDR (March 2010) and s/c CDR (Summer 2010)

Schedule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2021
Proposal
Concept & Technology Study
Mission Selection
Re-Assessment Study
Definition
Phase B1
Selection of Prime Contractor (EADS Astrium)
Phase B2
Implementation
Phase C/D
Launch autumn 2012
Operation
Scientific operation
Studies
Data Processing
Software Development
Mission Data Processing
Mission Products
Intermediate
Final
Now

Conclusions

- Design ready: EADS Astrium focusing on assembly, integration and testing
  - some problems (under control or being studied)
- DPAC focusing on calibrating Gaia
  - new instrumental effects require more complex processing
- Scientific Community getting ready and GREAT is there to help
  - for instance, this meeting