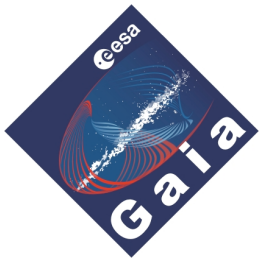


Gaia

A Stereoscopic Census of our Galaxy

http://www.rssd.esa.int/Gaia

March 2009

Timo Prusti

ESA

Gaia: Design Considerations

- Astrometry (V < 20):
  - completeness to 20 mag (on-board detection) ⇒ 10^9 stars
  - accuracy: 10–25 μarcsec at 15 mag (Hipparcos: 1 milliarcsec at 9 mag)
  - scanning satellite, two viewing directions
    ⇒ global accuracy, with optimal use of observing time
  - principles: global astrometric reduction (as for Hipparcos)

- Photometry (V < 20):
  - astrophysical diagnostics (low-dispersion photometry) + chromaticity
    ⇒ΔT_{eff} ~ 200 K, log g, [Fe/H] to 0.2 dex, extinction

- Radial velocity (V < 16–17):
  - application:
    - third component of space motion, perspective acceleration
    - dynamics, population studies, binaries
    - spectra: chemistry, rotation
  - principles: slitless spectroscopy using Ca triplet (847–874 nm)

Gaia: Complete, Faint, Accurate

	Hipparcos	**Gaia**
Magnitude limit	12	20 mag
Completeness	7.3 – 9.0	20 mag
Bright limit	0	6 mag
Number of objects	120 000	26 million to V = 15 250 million to V = 18 1000 million to V = 20
Effective distance limit	1 kpc	1 Mpc
Quasars	None	5×10^5
Galaxies	None	$10^6 – 10^7$
Accuracy	1 milliarcsec	7 μarcsec at V = 10 10-25 μarcsec at V = 15 300 μarcsec at V = 20
Photometry	2-colour (B and V)	Low-res. spectra to V = 20
Radial velocity	None	15 km/s to V = 16-17
Observing programme	Pre-selected	Complete and unbiased

Stellar Astrophysics

- Comprehensive luminosity calibration, for example:
  - distances to 1% for ~10 million stars to 2.5 kpc
  - distances to 10% for ~100 million stars to 25 kpc
  - rare stellar types and rapid evolutionary phases in large numbers
  - parallax calibration of all distance indicators

    e.g. Cepheids and RR Lyrae to LMC/SMC
- Physical properties, for example:
  - clean Hertzsprung–Russell diagrams throughout the Galaxy
  - solar neighbourhood mass function and luminosity function

    e.g. white dwarfs (~200,000) and brown dwarfs (~50,000)
  - initial mass and luminosity functions in star forming regions
  - luminosity function for pre main-sequence stars
  - detection and dating of all spectral types and Galactic populations
  - detection and characterisation of variability for all spectral types

One Billion Stars in 3-d will Provide …

- in our Galaxy …
  - the distance and velocity distributions of all stellar populations
  - the spatial and dynamic structure of the disk and halo
  - its formation history
  - a rigorous framework for stellar structure and evolution theories
  - a large-scale survey of extra-solar planets (~10–20,000)
  - a large-scale survey of Solar System bodies (~100,000)

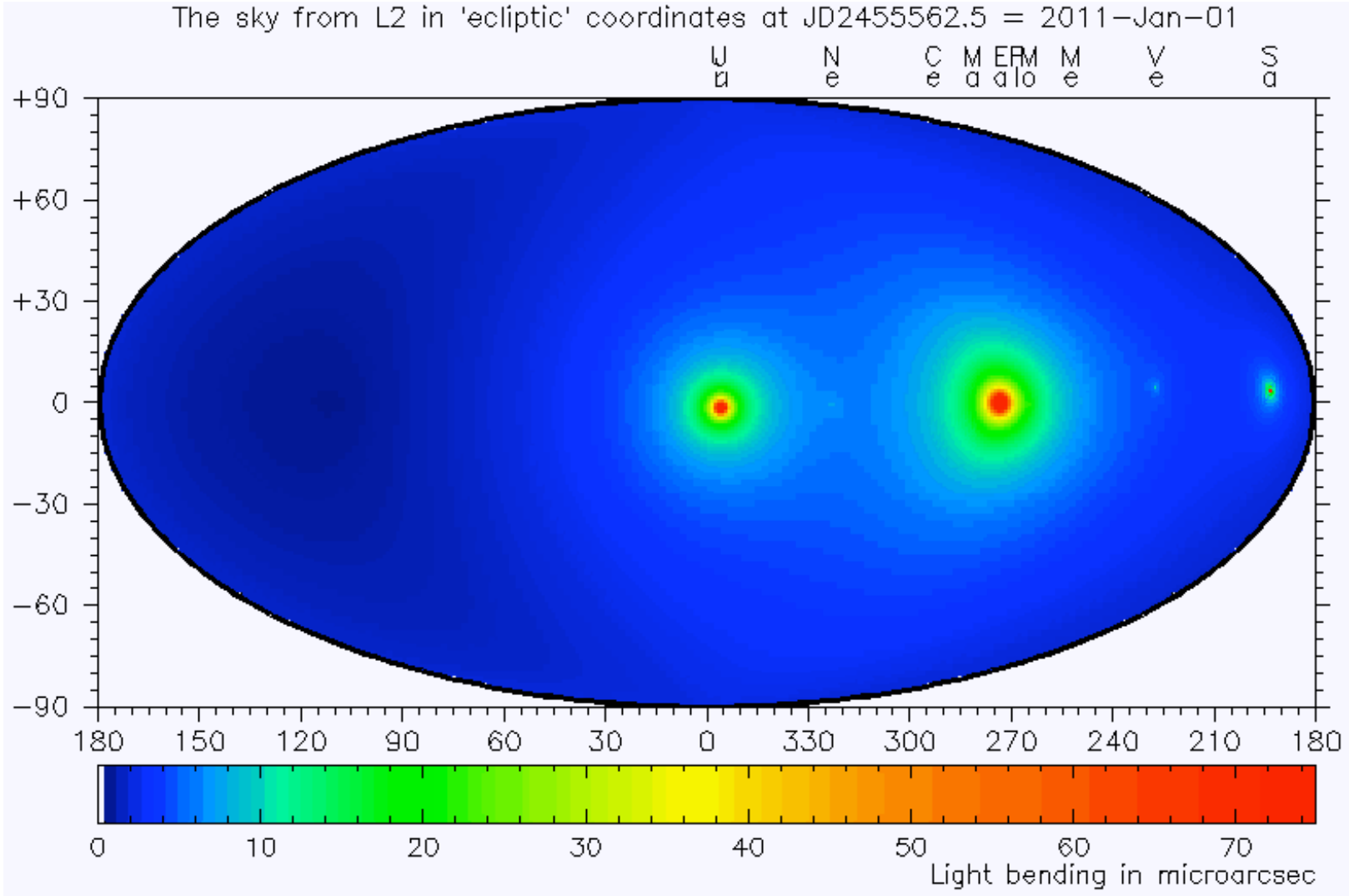
- … and beyond
  - distance standards out to the LMC/SMC
  - rapid reaction alerts for supernovae and burst sources (~20,000)
  - QSO detection, redshifts, microlensing structure (~500,000)
  - fundamental quantities to unprecedented accuracy: γ to 10^{-7} (10^{-5} present)

Gaia: Studies of the Solar System

- Asteroids etc.:
  - deep and uniform (20 mag) detection of all moving objects
  - 10^5–10^6 new objects expected (340,000 presently)
  - taxonomy/mineralogical composition versus heliocentric distance
  - diameters for ~1000, masses for ~100
  - orbits: 30 times better than present, even after 100 years
  - Trojan companions of Mars, Earth and Venus
  - Kuiper Belt objects: ~300 to 20 mag (binarity, Plutinos)

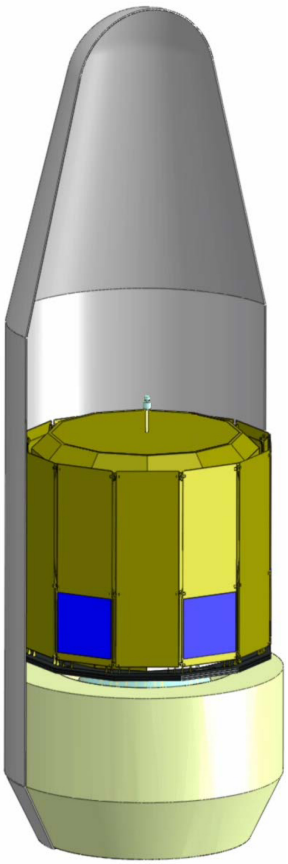
- Near-Earth Objects:
  - Amors, Apollos and Atens (1775, 2020, 336 known today)
  - ~1600 Earth-crossers >1 km predicted (100 currently known)
  - detection limit: 260–590 m at 1 AU, depending on albedo

Light Bending in Solar System

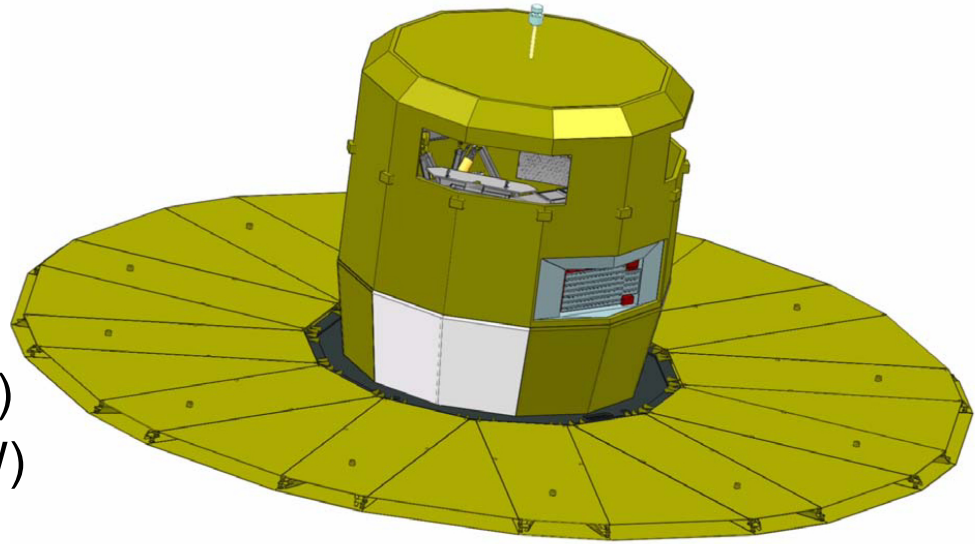


Movie courtesy Jos de Bruijne

Satellite and System



- ESA-only mission
- Launch date: 2011
- Lifetime: 5 years
- Launcher: Soyuz–Fregat from CSG
- Orbit: L2
- Ground station: New Norcia and/or Cebreros
- Downlink rate: 4–8 Mbps



- Mass: 2030 kg (payload 690 kg)
- Power: 1720 W (payload 830 W)

Figures courtesy EADS-Astrium

Payload and Telescope

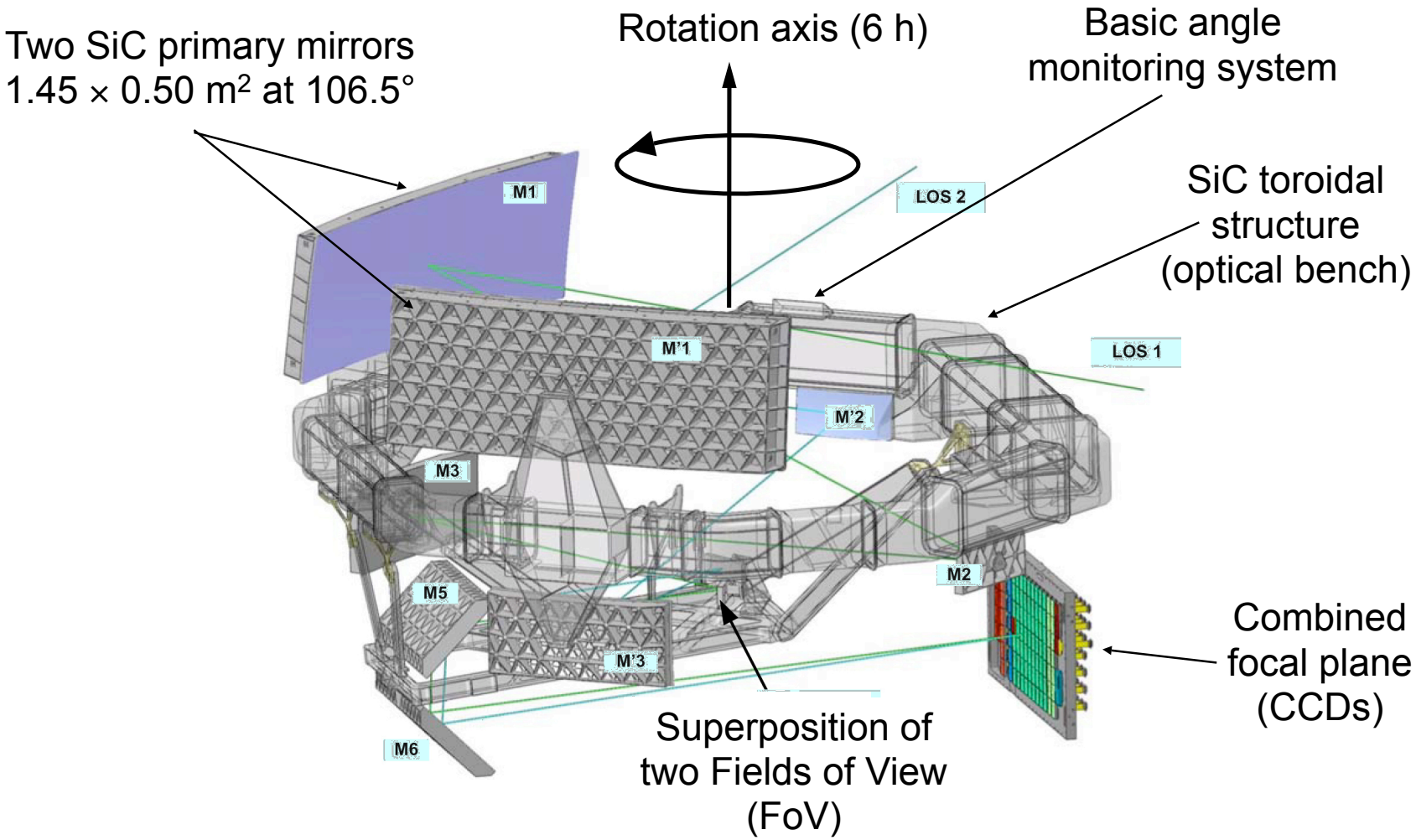
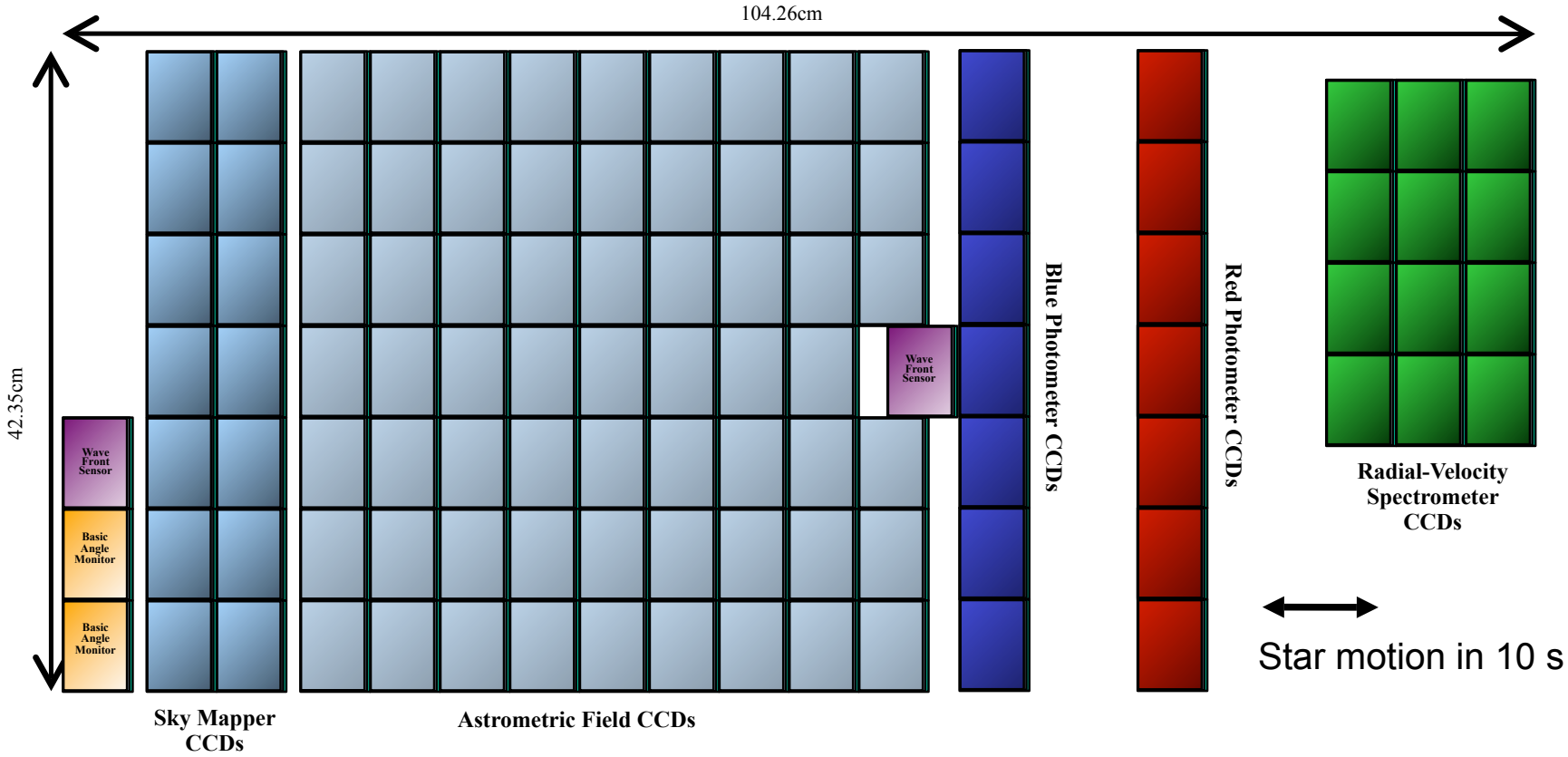


Figure courtesy EADS-Astrium

Figure courtesy Alex Short

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$^-$

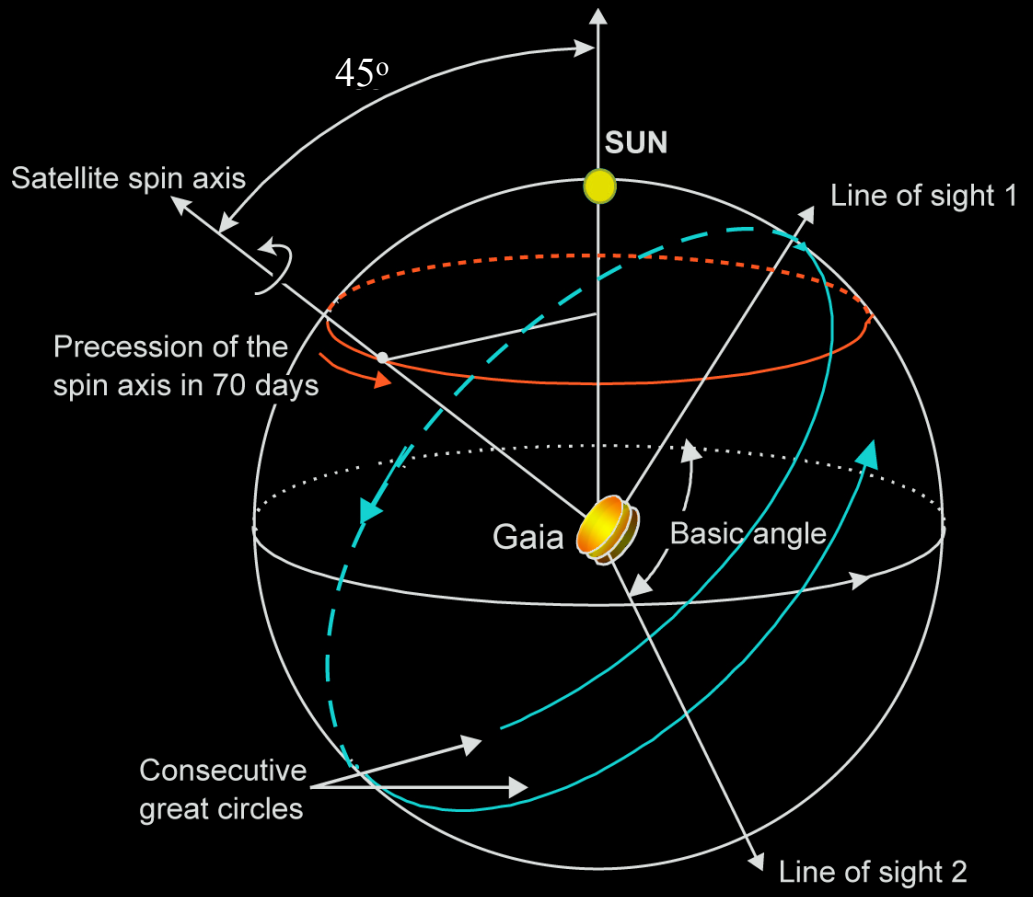
Photometry:

- two-channel photometer
- blue and red CCDs

Spectroscopy:

- high-resolution spectra
- red CCDs

Sky Scanning Principle



Spin axis	45º to Sun
Scan rate:	60 arcsec/s
Spin period:	6 hours

Figure courtesy Karen O'Flaherty

Comments on Astrometric Accuracy

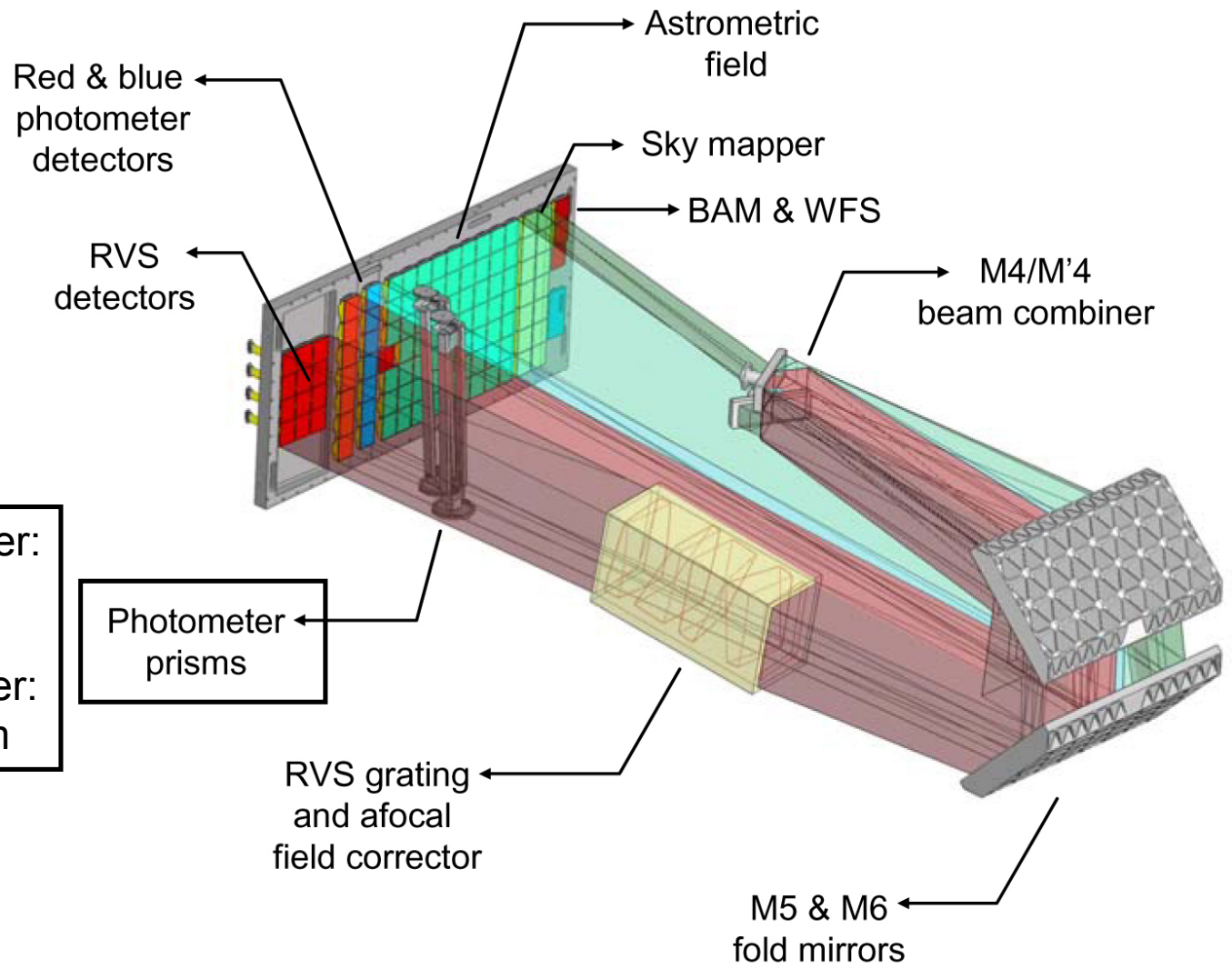
- Massive leap from Hipparcos to Gaia:
  - accuracy: 2 orders of magnitude (1 milliarcsec to 7 microarcsec)
  - limiting sensitivity: 4 orders of magnitude (~10 mag to 20 mag)
  - number of stars: 4 orders of magnitude (10^5 to 10^9)

- Measurement principles identical:
  - two viewing directions (absolute parallaxes)
  - sky scanning over 5 years $\Rightarrow$ parallaxes and proper motions

- Instrument improvement:
  - larger primary mirror: 0.3×0.3 m^2 $\rightarrow$ 1.45×0.50 m^2, $\sigma \propto D^{-(3/2)}$
  - improved detector (IDT $\rightarrow$ CCD): QE, bandpass, multiplexing

- Control of all associated error sources:
  - aberrations, chromaticity, solar system ephemerides, attitude control …

Photometry Measurement Concept

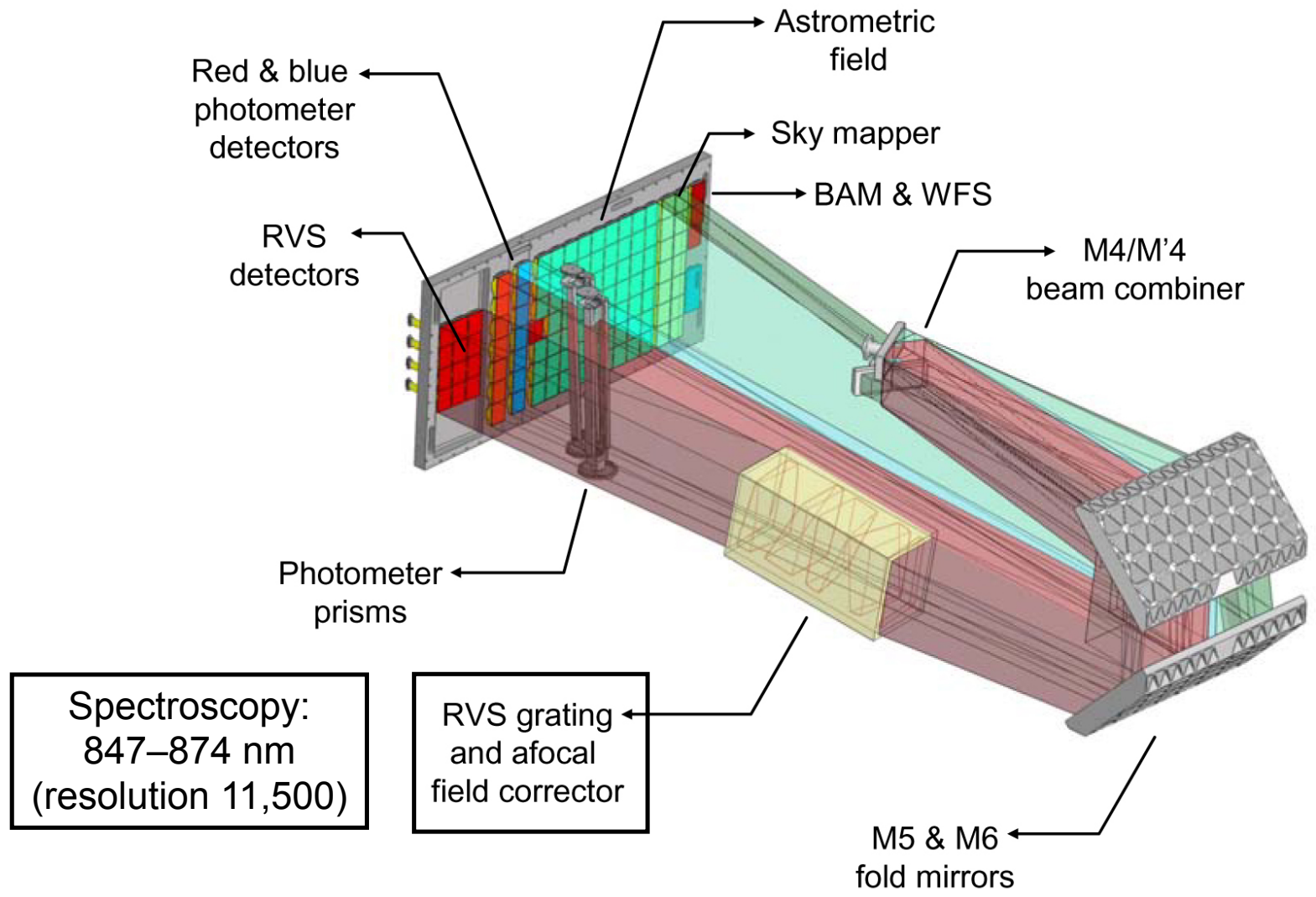


Blue photometer: 330–680 nm

Red photometer: 640–1000 nm

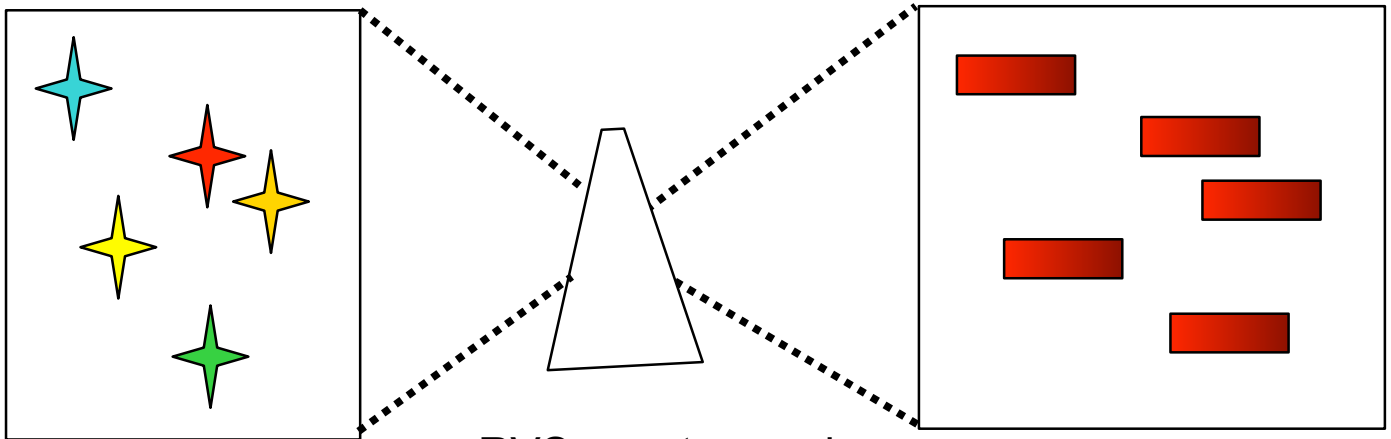
Figures courtesy EADS-Astrium

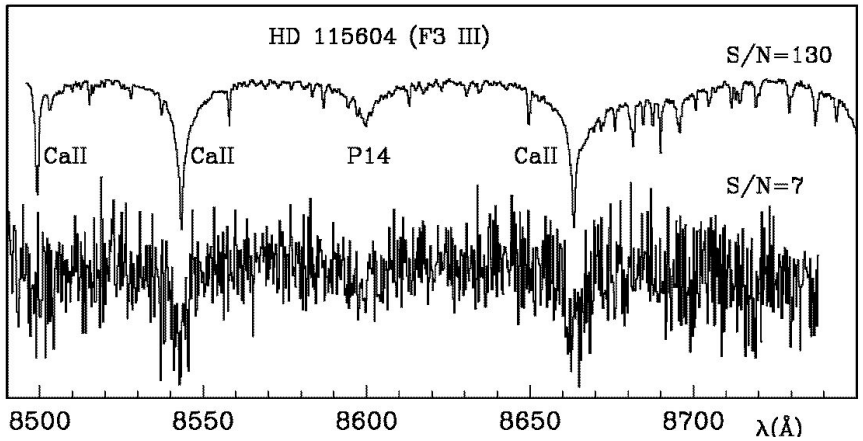
Radial Velocity Measurement Concept (1/2)



Figures courtesy EADS-Astrium

Radial Velocity Measurement Concept (2/2)





RVS spectra of F3 giant (V=16)
S/N = 7 (single measurement)
S/N = 130 (summed over mission)

Figures courtesy David Katz

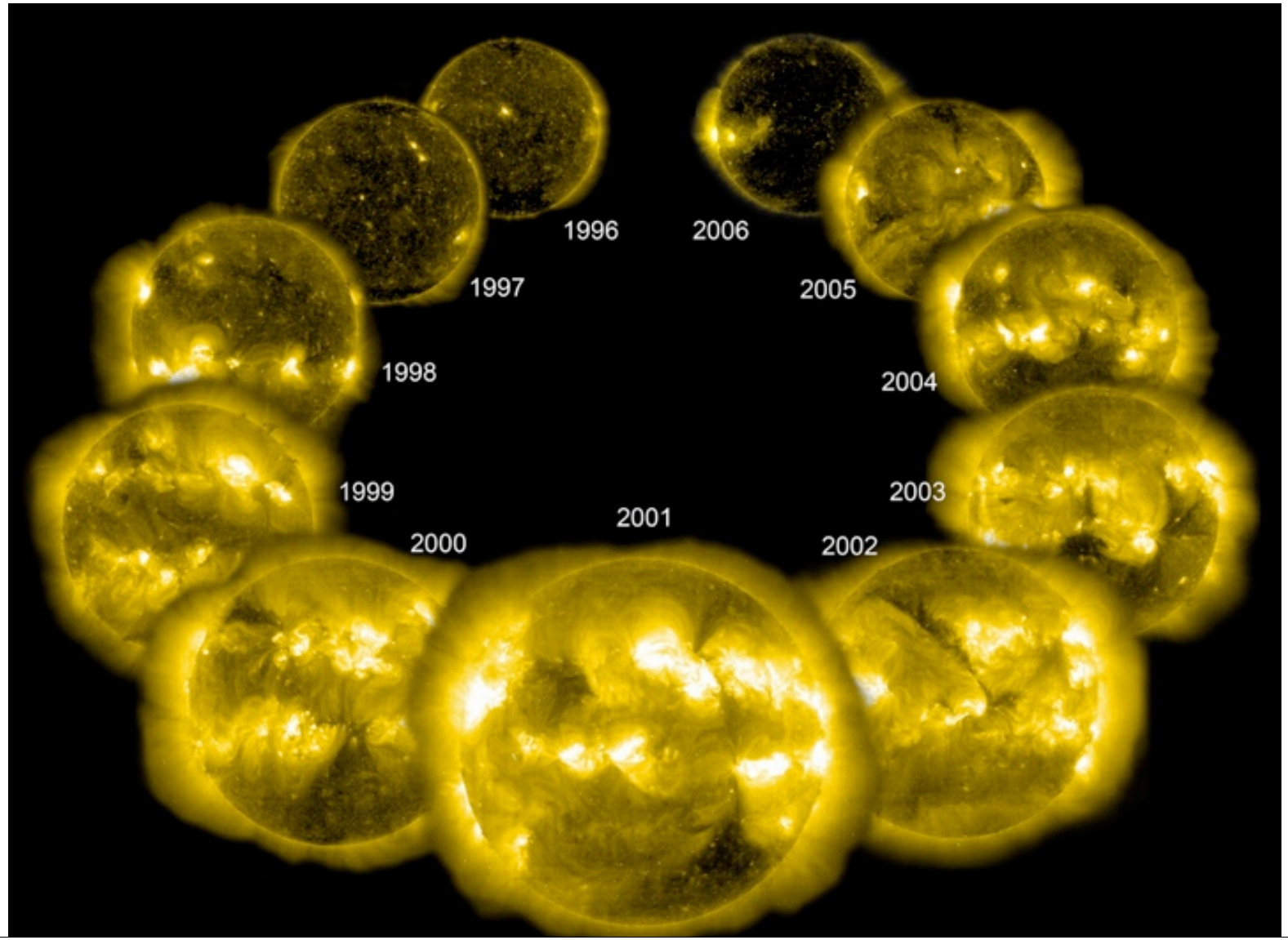
Scientific Organisation

- Scientific community:
  - organised in Data Processing and Analysis Consortium (DPAC)
  - ~350 scientists active at some level
- Gaia Science Team (GST):
  - 7 members + DPAC Executive Chair + ESA Project Scientist
- Community is active and productive:
  - regular science team/DPAC meetings
  - growing archive of scientific reports
  - advance of simulations, algorithms, accuracy models, etc.
  - visibility in scientific meetings
- Data distribution policy:
  - final catalogue ~2019–20
  - intermediate catalogues as appropriate
  - science alerts data released immediately
  - no proprietary data rights

Status and Schedule

- Prime contractor: EADS-Astrium
  - implementation phase started early 2006
- Main activities and challenges:
  - CCDs and FPA (including PEM electronics)
  - SiC primary mirror
  - high-stability optical bench
  - payload data handling electronics
  - phased-array antenna
  - micro-propulsion
  - scientific calibration of CCD radiation-damage effects
- Schedule:
  - currently in Phase C/D
  - launch in 2011

The Radiation Effect on CCD

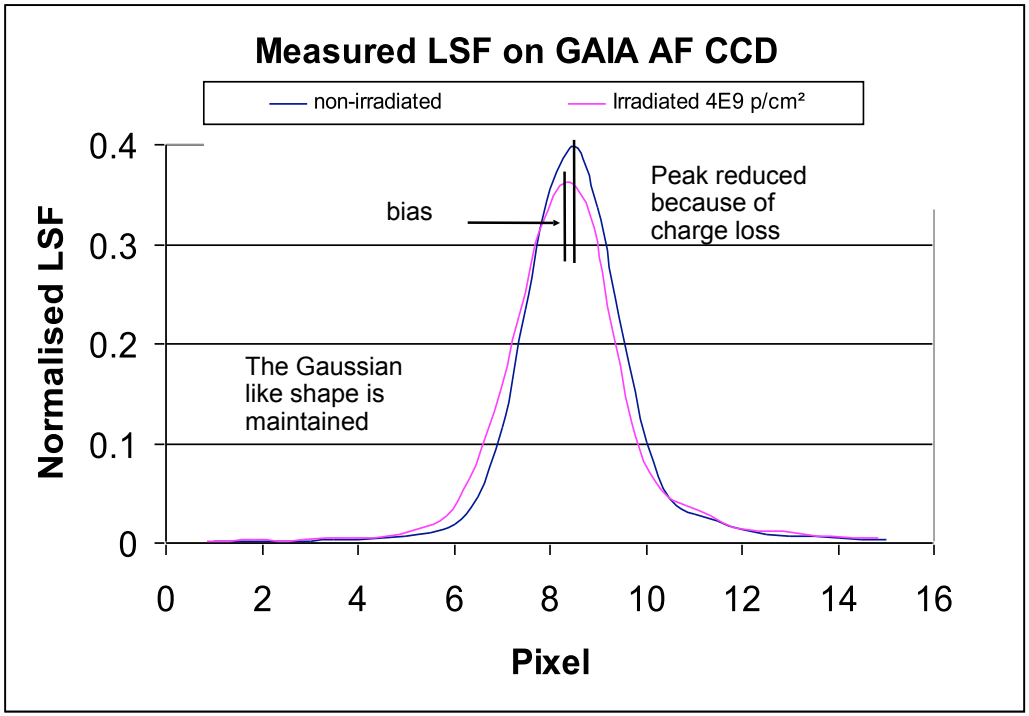


The Radiation Effect on CCD

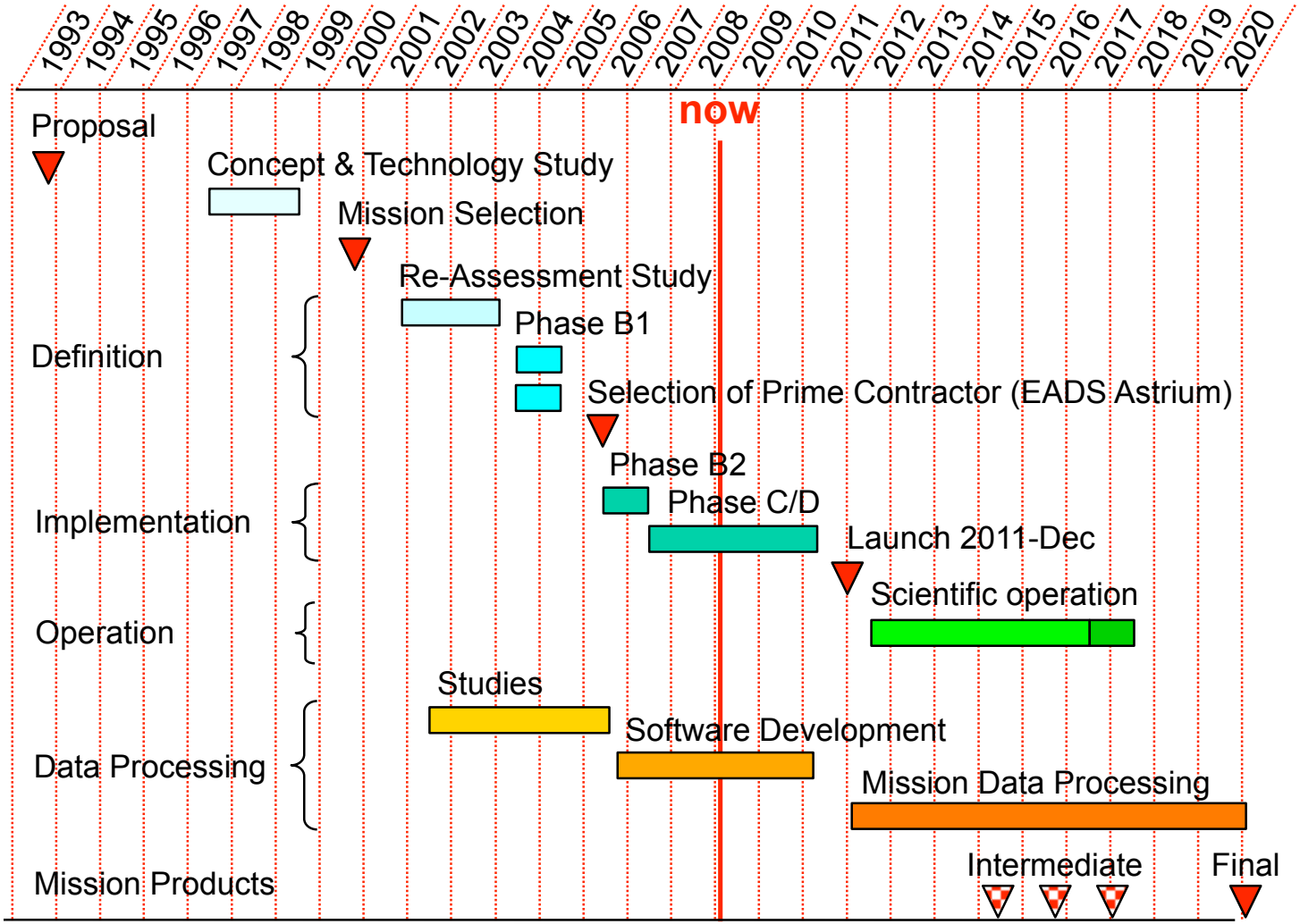
❑ CCD performance is progressively degraded due to the radiation accumulated in space, two effects are important:

Charge loss: total S/N is reduced due to electrons being trapped.

Star position bias: trapping and re-emission of electrons bias the star localization measurement.. Position bias is ~10 mas at EOL (0.16 pixel) for magnitude 15 and 410^9 p/cm² irradiation level.



Schedule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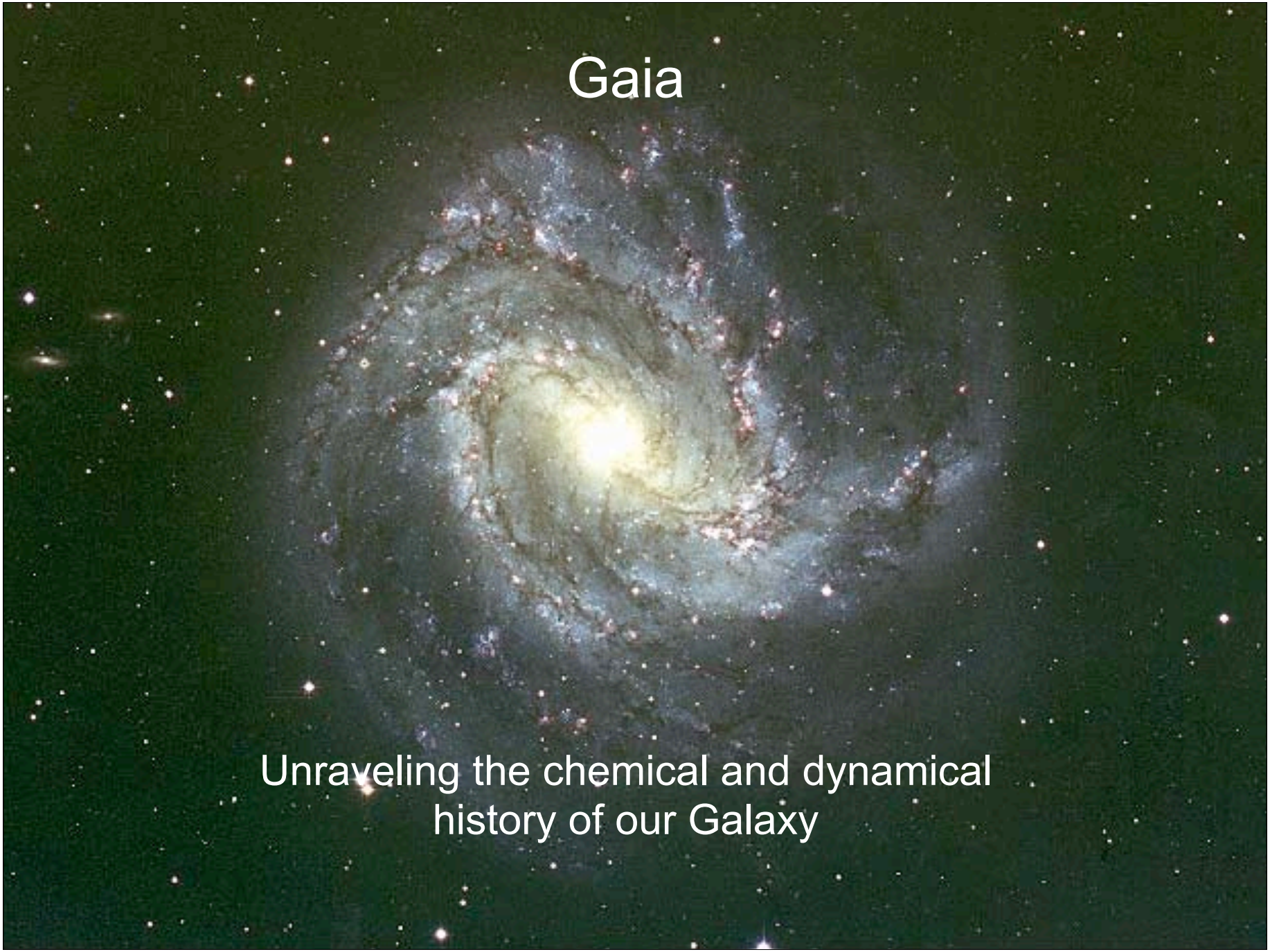
Concept & Technology Study
Mission Selection
Re-Assessment Study
Phase B1
Definition
Selection of Prime Contractor (EADS Astrium)
Phase B2
Phase C/D
Implementation
Launch 2011-Dec
Scientific operation
Operation
Studies
Software Development
Data Processing
Mission Data Processing
Intermediate
Final
Mission Products


Gaia
Unraveling the chemical and dynamical
history of our Galaxy