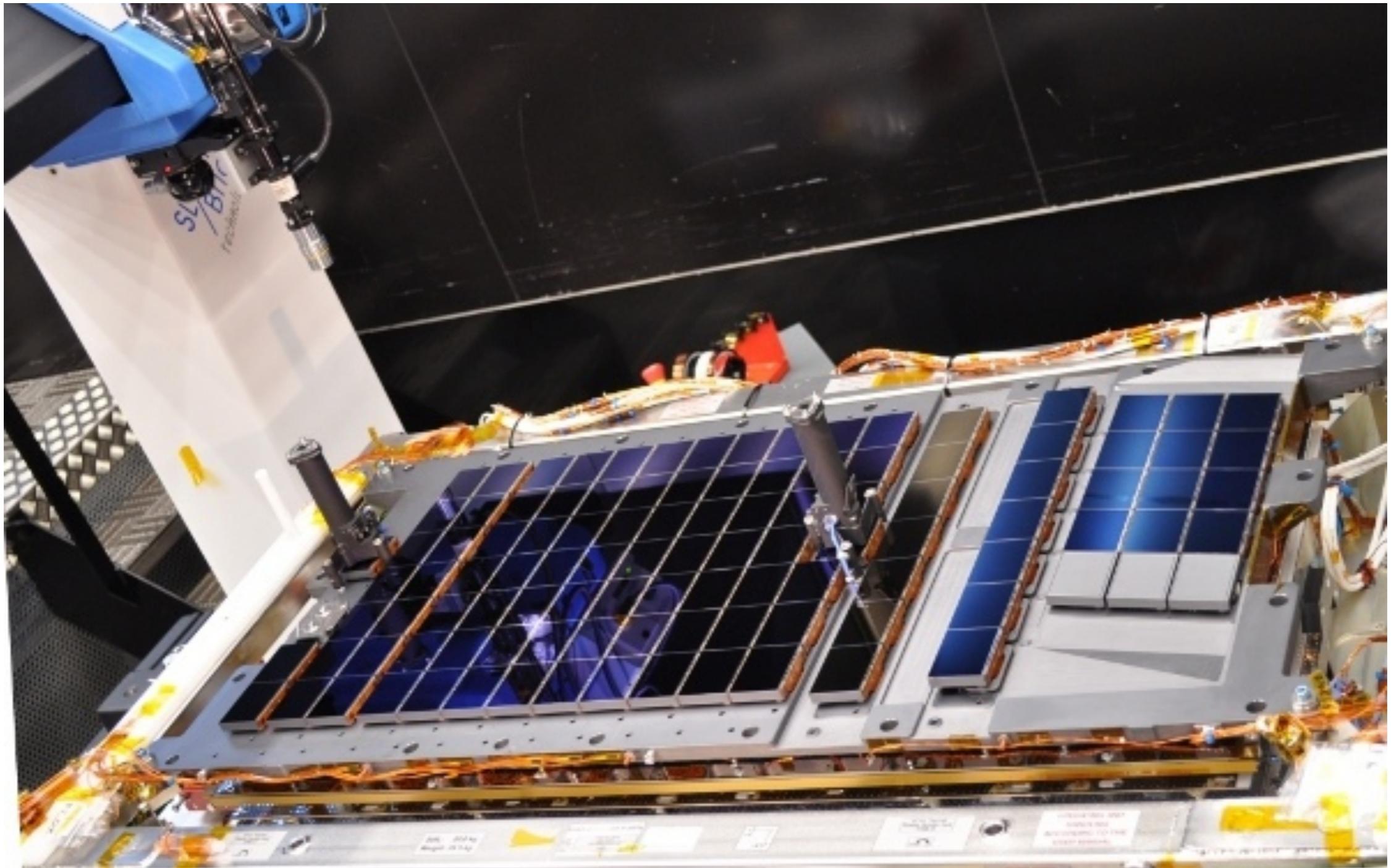


# Gaia: Science and Data Products

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# Gaia focal plane: astrometric, photometric and radial velocity CCDs



Astrium, January 2012

# Gaia: sunshield and solar array deployed



# Gaia: mission products

- astrometry:
  - $10^9$  stars to 20 mag
  - complete: on-board detection
  - represents  $\sim 1\%$  of the Galaxy stellar population
  - accuracy at 15 mag: 25 microarcsec
  - accuracy at 20 mag: 300 microarcsec
  - applies to positions, parallaxes, annual proper motions
- photometry (from low-res spectroscopy):
  - multi-colour, in about 10 bands (cf 2 for Tycho)
  - optimised for  $T_{\text{eff}}$ , metallicity, reddening
- radial velocities (from 860nm CaII triplet):
  - $V < 17$ : radial velocities, 1-10 km/s ( $\sim 150$  million objects)
  - $V < 13$ : multi-epoch (5 million objects)
  - $V < 13$ : rotational velocities, atmospheric parameters, reddening
  - $V < 12$ : abundances (2 million objects)

# Gaia compared with Hipparcos

	Hipparcos	Gaia
Magnitude limit	12	20 mag
Completeness	7.3 – 9.0	~20 mag
Bright limit	~0	~3-7 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	$\sim 5 \times 10^5$
Galaxies	None	$10^6 - 10^7$
Accuracy	~1 milliarcsec	7 $\mu$ arcsec at V = 10 25 $\mu$ arcsec at V = 15 300 $\mu$ arcsec at V = 20
Photometry	2-colour (B and V)	Spectrum to V = 20
Radial velocity	None	1-10 km/s to V = 16 -17
Observing programme	Pre-selected	Complete and unbiased

# Stellar astrophysics

- Comprehensive luminosity calibration, for example:
  - distances to 1% for  $\sim$ 10 million stars to 2.5 kpc
  - distances to 10% for  $\sim$ 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 and luminosity function
    - e.g., white dwarfs ( $\sim$ 400,000) and brown dwarfs ( $\sim$ 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 ...

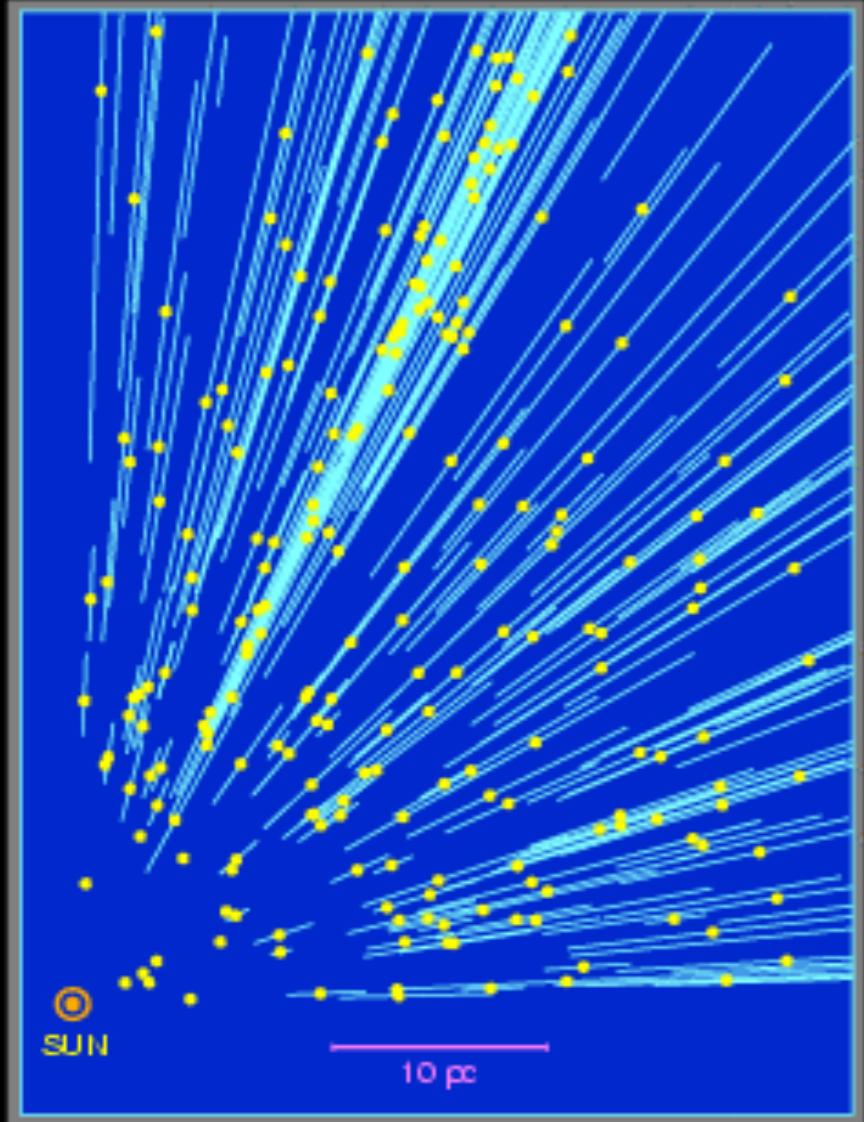
- in our Galaxy ...
  - the distance and velocity distributions of all stellar populations
  - the spatial and dynamic structure of the disk and halo
  - its formation history
  - a detailed mapping of the Galactic dark-matter distribution
  - a rigorous framework for stellar-structure and evolution theories
  - a large-scale survey of extra-solar planets ( $\sim 10,000$ )
  - a large-scale survey of Solar-system bodies ( $\sim 250,000$ )
- ... and beyond
  - definitive distance standards out to the LMC/SMC
  - rapid reaction alerts for supernovae and burst sources ( $\sim 20,000$ )
  - quasar detection, redshifts, microlensing structure ( $\sim 500,000$ )
  - fundamental quantities:  $\gamma$  to  $2 \times 10^{-6}$  ( $2 \times 10^{-5}$  present)

# Why a Survey to 20 mag?

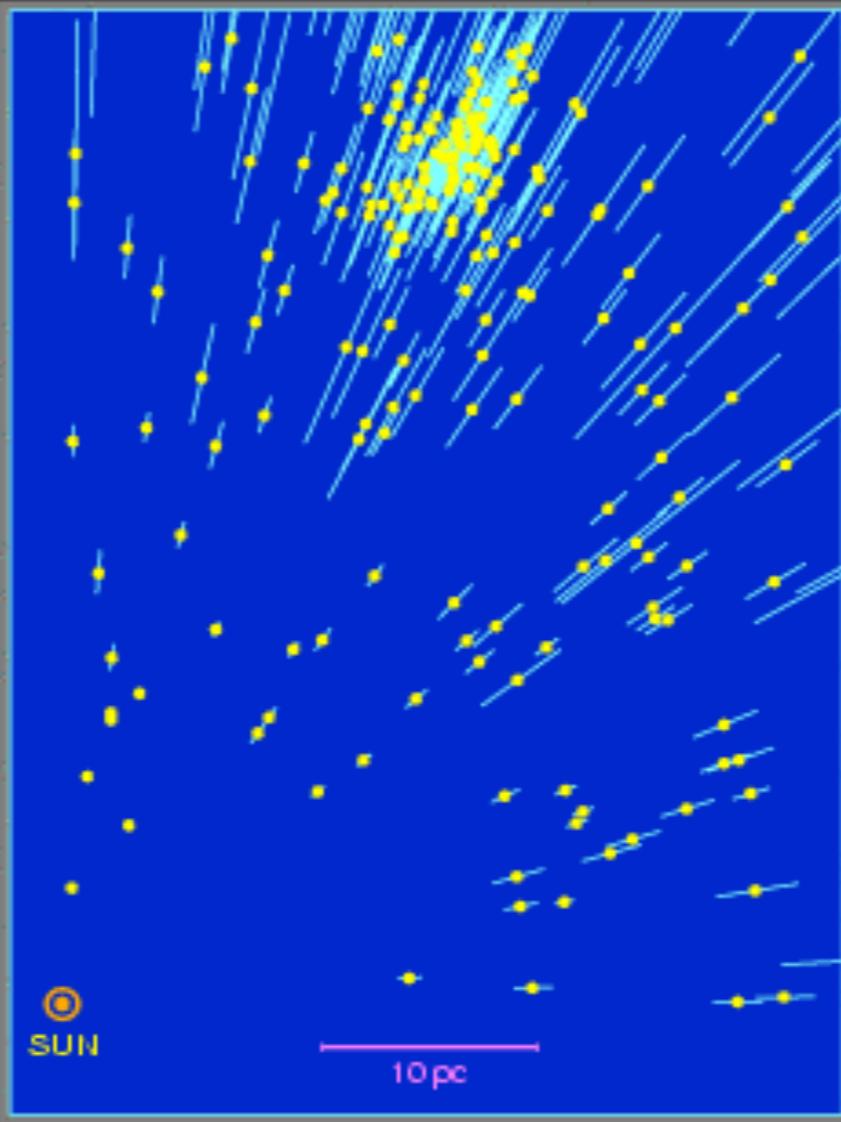
Population	Tracer	M <sub>v</sub>	l	b	d	A <sub>v</sub>	V <sub>1</sub>	V <sub>2</sub>	ε <sub>T</sub>	σ <sub>μ<sub>1</sub></sub>	σ <sub>μ<sub>1</sub></sub>	σ <sub>π<sub>1</sub></sub>
		mag	deg	deg	kpc	mag	mag	mag	km/s	μas/yr	-	-
Bulge	<b>gM</b>	-1	0	<20	8	2-10	15	20	100	10	0.01	0.10
	<b>HB</b>	+0.5	0	<20	8	2-10	17	20	100	20	0.01	0.20
	<b>MS</b>	+4.5	1	-4	8	0-2	19	21	100	60	0.02	0.60
Spiral arms	<b>Cepheids</b>	-4	All	<10	10	3-7	14	18	7	5	0.03	0.06
	<b>B-M supergiants</b>	-5	All	<10	10	3-7	13	17	7	4	0.03	0.05
	<b>Perseus Arm (B)</b>	-2	140	<10	2	2-6	12	16	10	3	0.01	0.01
Thin disk	<b>gK</b>	-1	0	<15	8	1-5	14	18	40	6	0.01	0.06
	<b>GK</b>	-1	180	<15	10	1-5	15	19	10	8	0.04	0.10
Disk warp	<b>gM</b>	-1	All	<20	10	1-5	15	19	10	8	0.04	0.10
Thick disk	<b>Miras, gK</b>	-1	0	<30	8	2	15	19	50	10	0.01	0.10
	<b>HB</b>	+0.5	0	<30	8	2	15	19	50	20	0.02	0.20
	<b>Miras, gK</b>	-1	180	<30	20	2	15	21	30	25	0.08	0.65
	<b>HB</b>	+0.5	180	<30	20	2	15	19	30	60	0.20	1.50
Halo	<b>gG</b>	-1	All	<20	8	2-3	13	21	100	10	0.01	0.10
	<b>HB</b>	+0.5	All	>20	30	0	13	21	100	35	0.05	1.40
Gravity, K-z	<b>dK</b>	+7-8	All	All	2	0	12	20	20	60	0.01	0.16
	<b>dF8-dG2</b>	+5-6	All	All	2	0	12	20	20	20	0.01	0.05
Globular clusters	<b>gK</b>	+1	All	All	50	0	12	21	100	10	0.01	0.10
Satellite orbits	<b>gM</b>	-1	All	All	100	0	13	20	100	60	0.30	8.00

Example:  
distances from ground, Hipparcos, and Gaia  
in the region of the Hyades open cluster

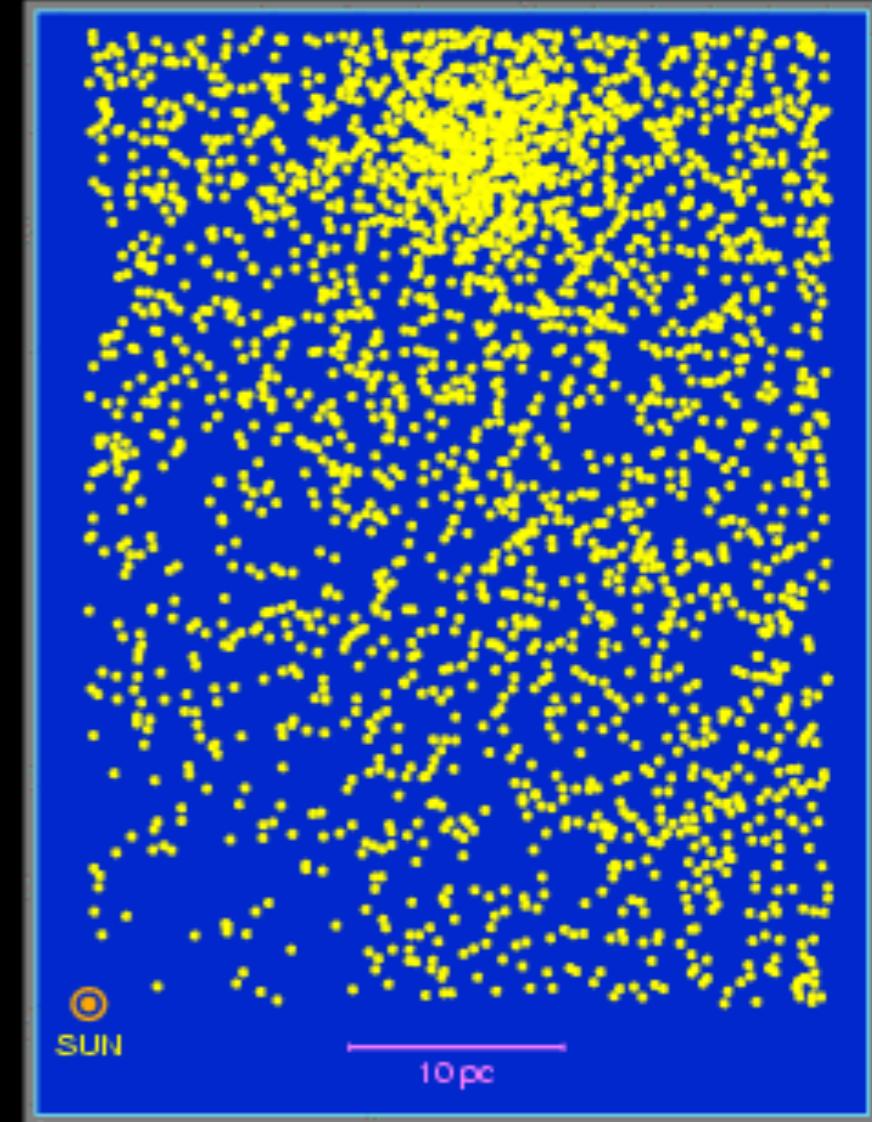
Ground



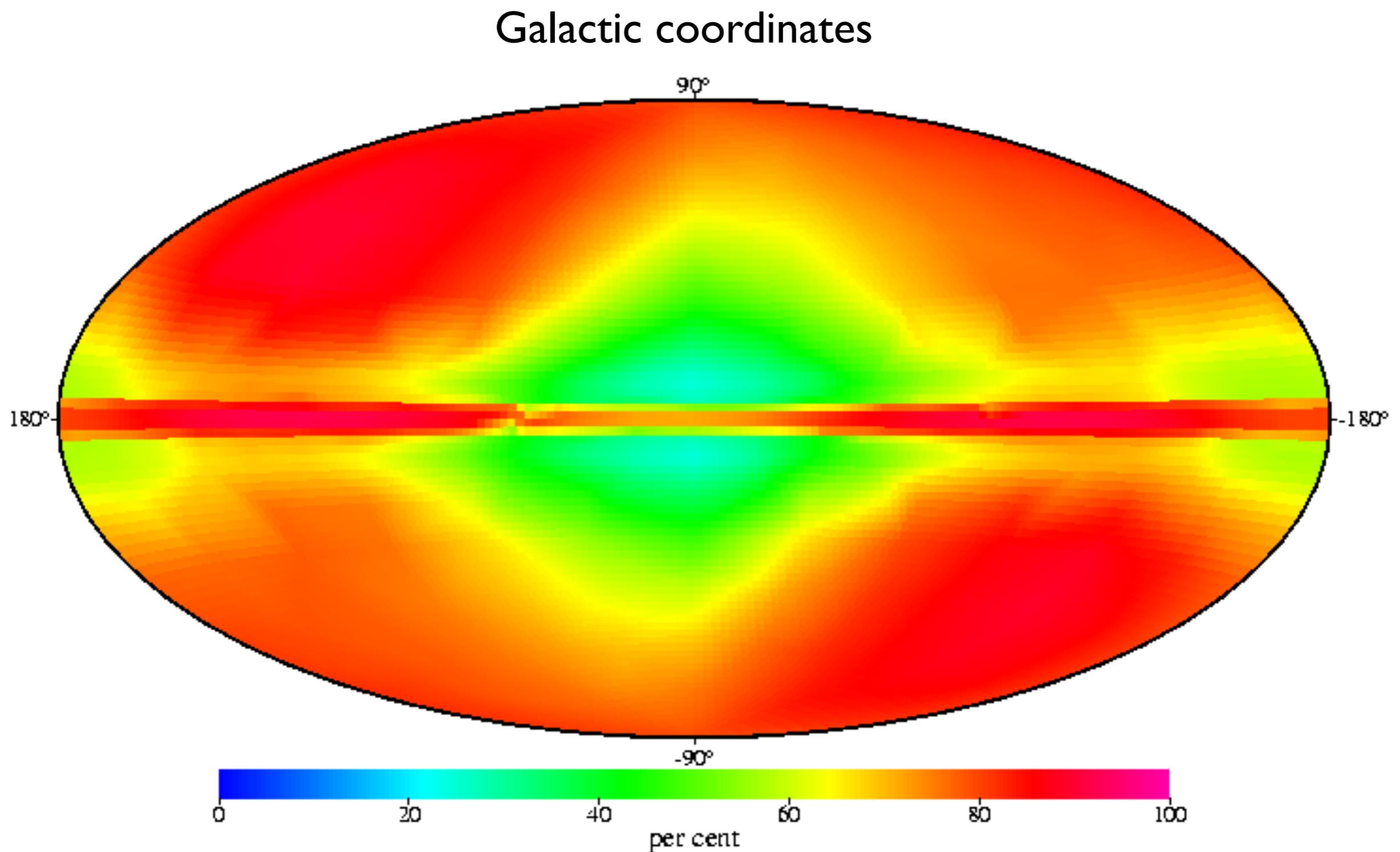
Hipparcos



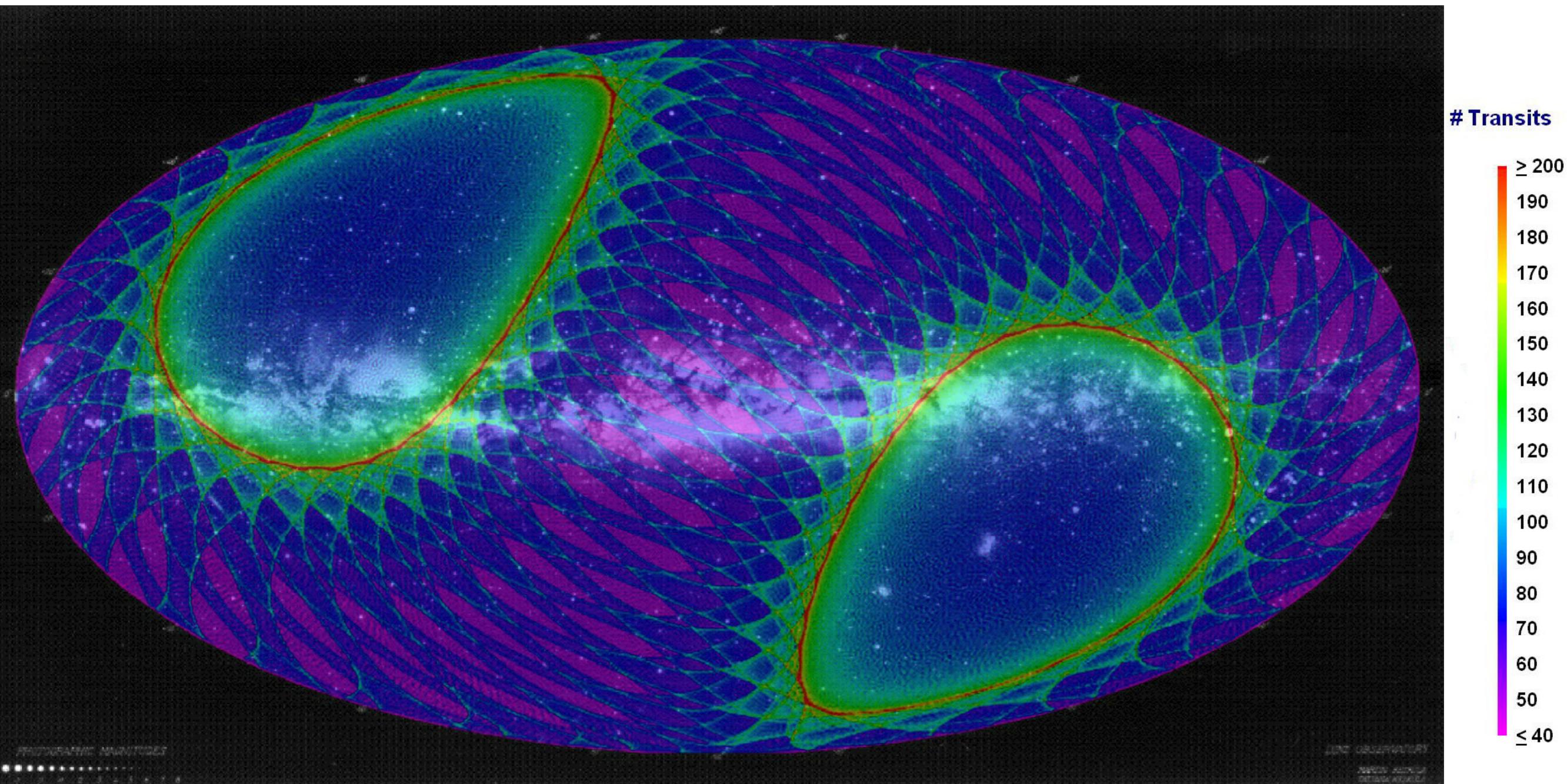
GAIA



Accuracy example: stars at 15 mag with  $\sigma_{\pi}/\pi \leq 0.02$



## Number of field of view transits



# Gaia data release: open to all

## Logistics:

- L+6 months: positioning at L2, commissioning
- L+12m: first full sky scan completed
- L+24m (18 months data): parallaxes and proper motions separable
- internal database to public archive (validation): ~3 months

## Products:

- L+22m: positions + G mag (all sky, single stars, alerts, NEOs)  
+  $10^5$  proper motions (Hipparcos + Gaia) at 50 micro-arcsec/yr
- L+28m: full astrometry, radial velocities for brighter stars
- L+40m: orbital solutions, some red/blue photometry, radial velocities, RVS spectra, some astrophysical parameters
- L+65m: updates on previous, more sources, classification, variable star solutions, epoch photometry
- end(5yr)+36m (~2021): everything

End