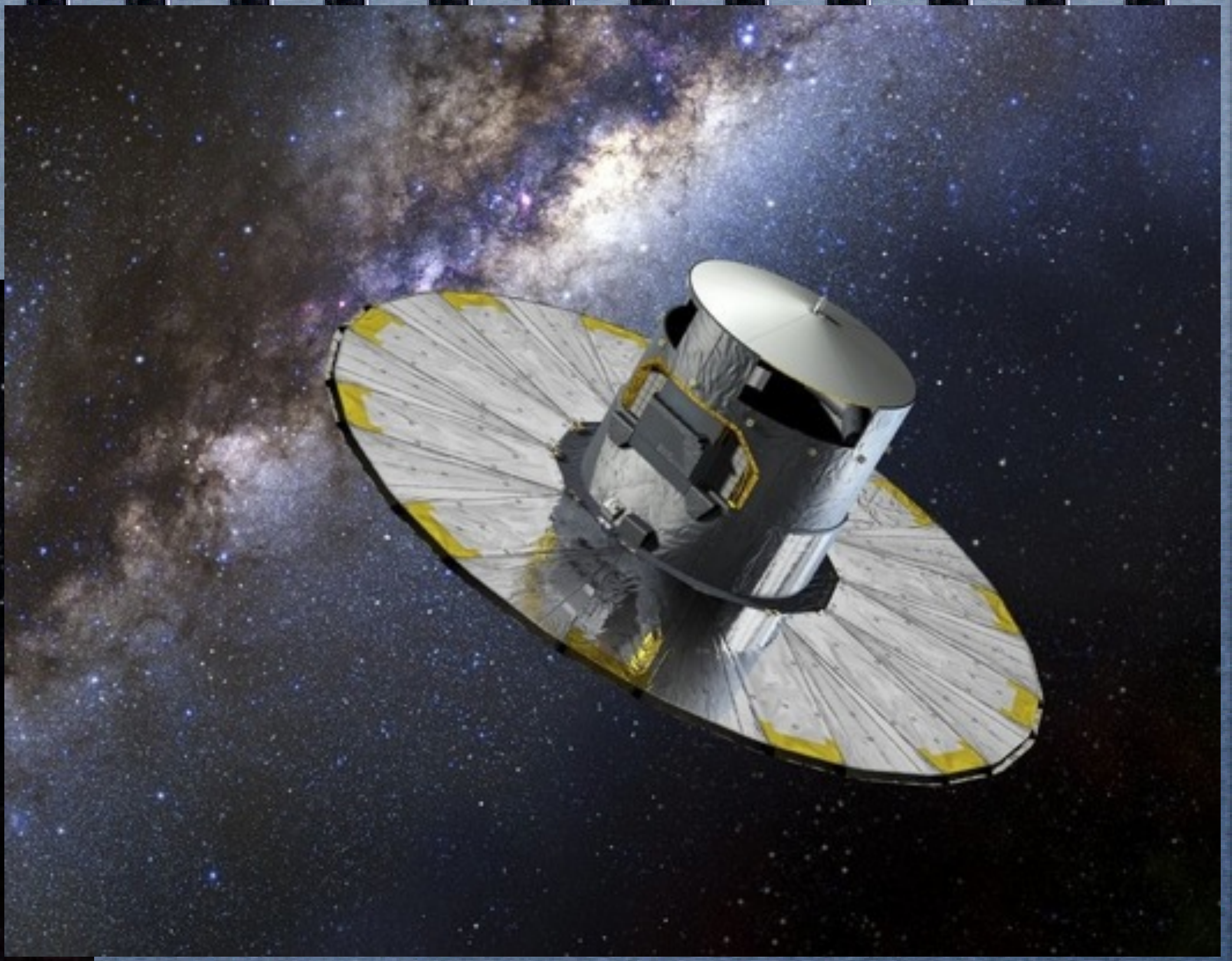
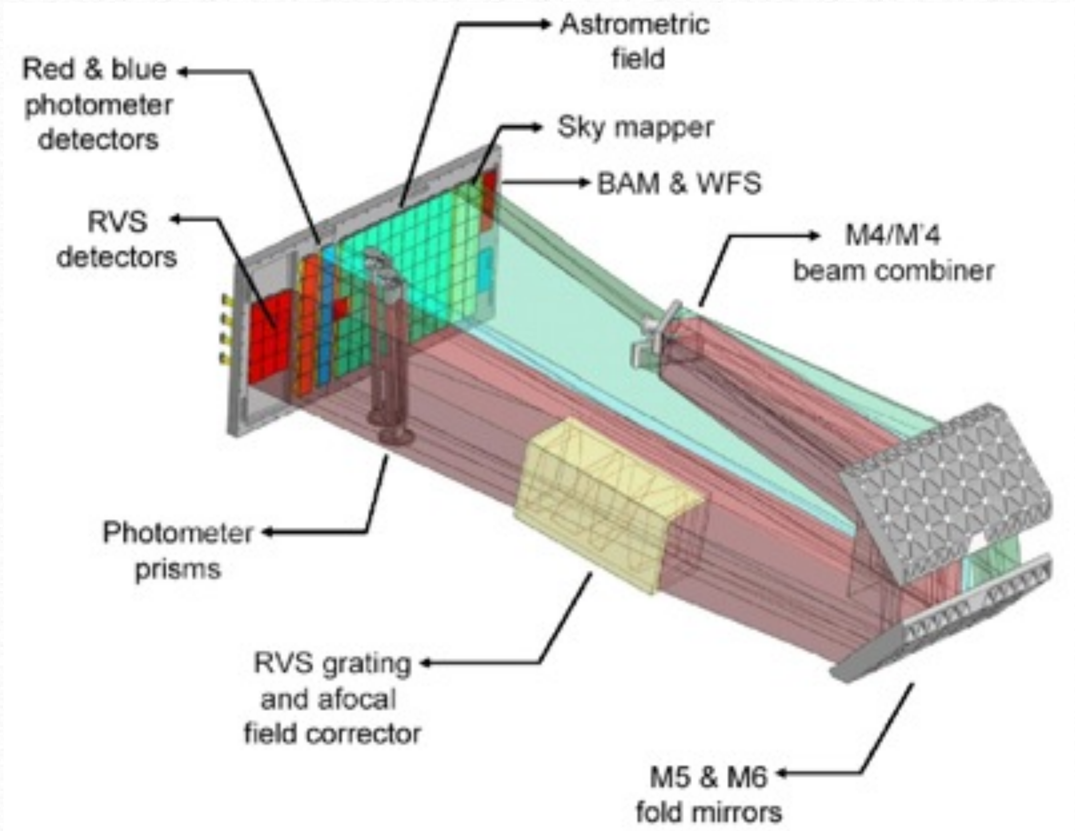


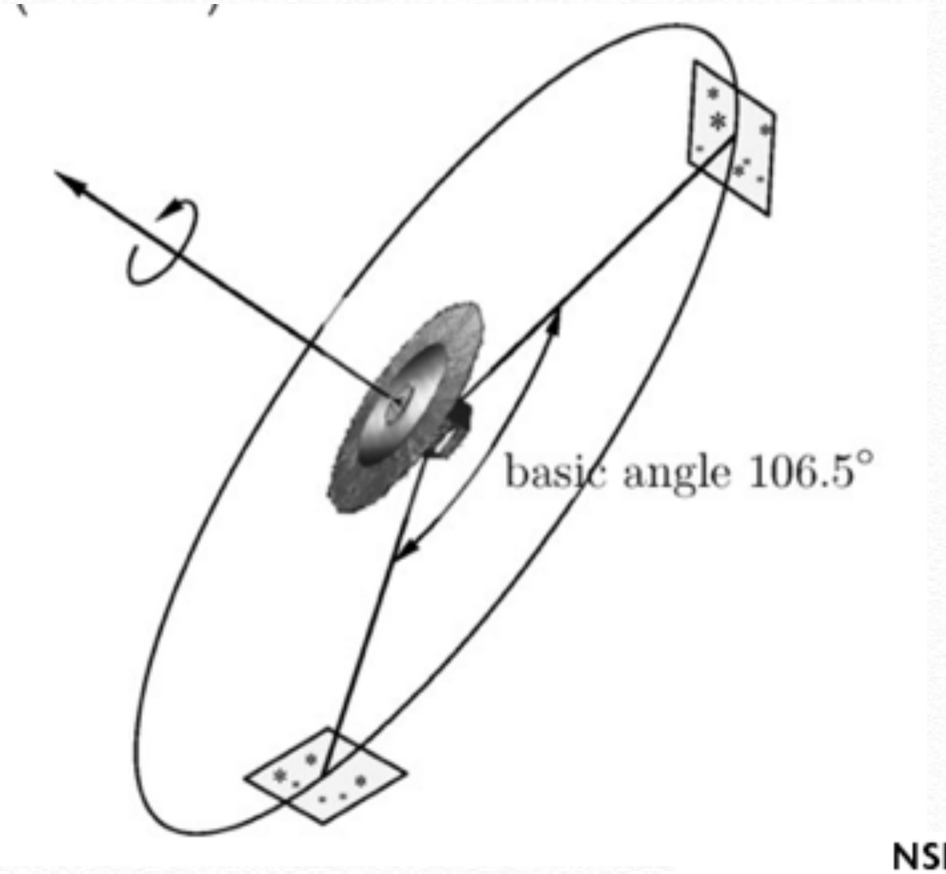
Synergie LSST-GAIA for galactic science

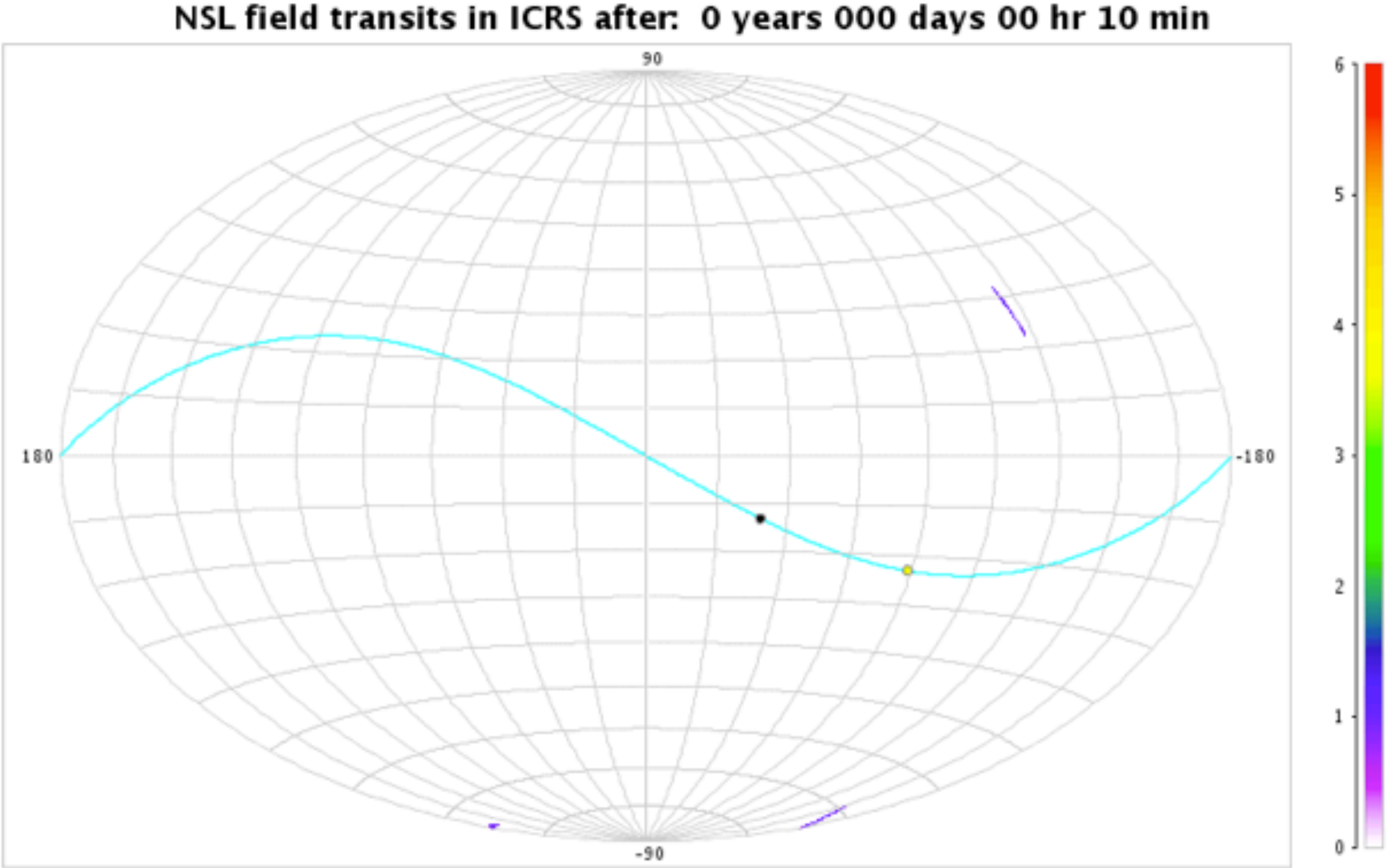
A. Robin, Institut UTINAM, OSU THETA Franche-Comté-Bourgogne

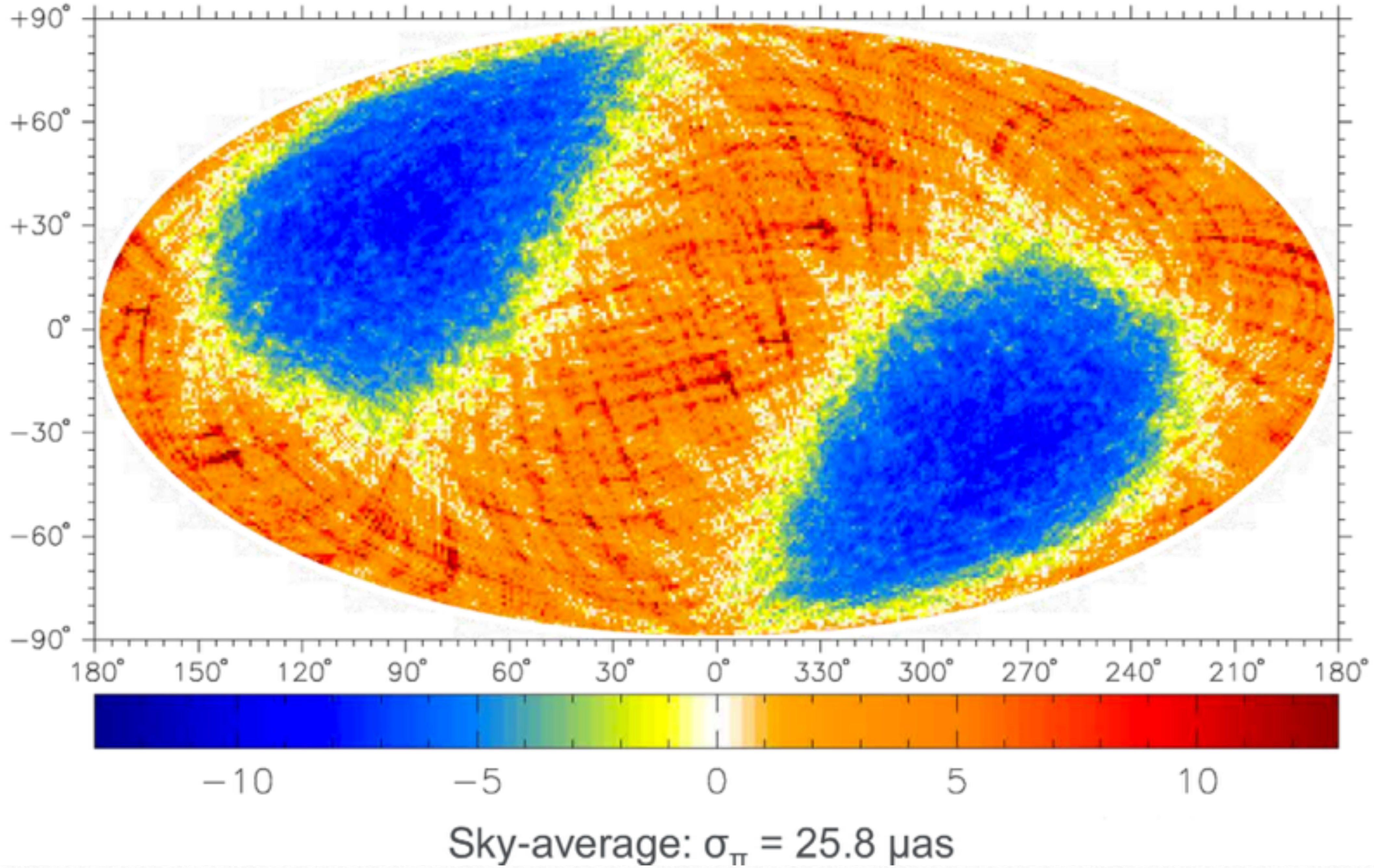
Gaia

- Astrometry (G<20): parallaxes, Proper motions
- Photometry (BP/RP) (G<20)
- Spectroscopy (G<16-17) (Teff, logg, Av, Vlos, [Fe/H] ([a/Fe] G<12)

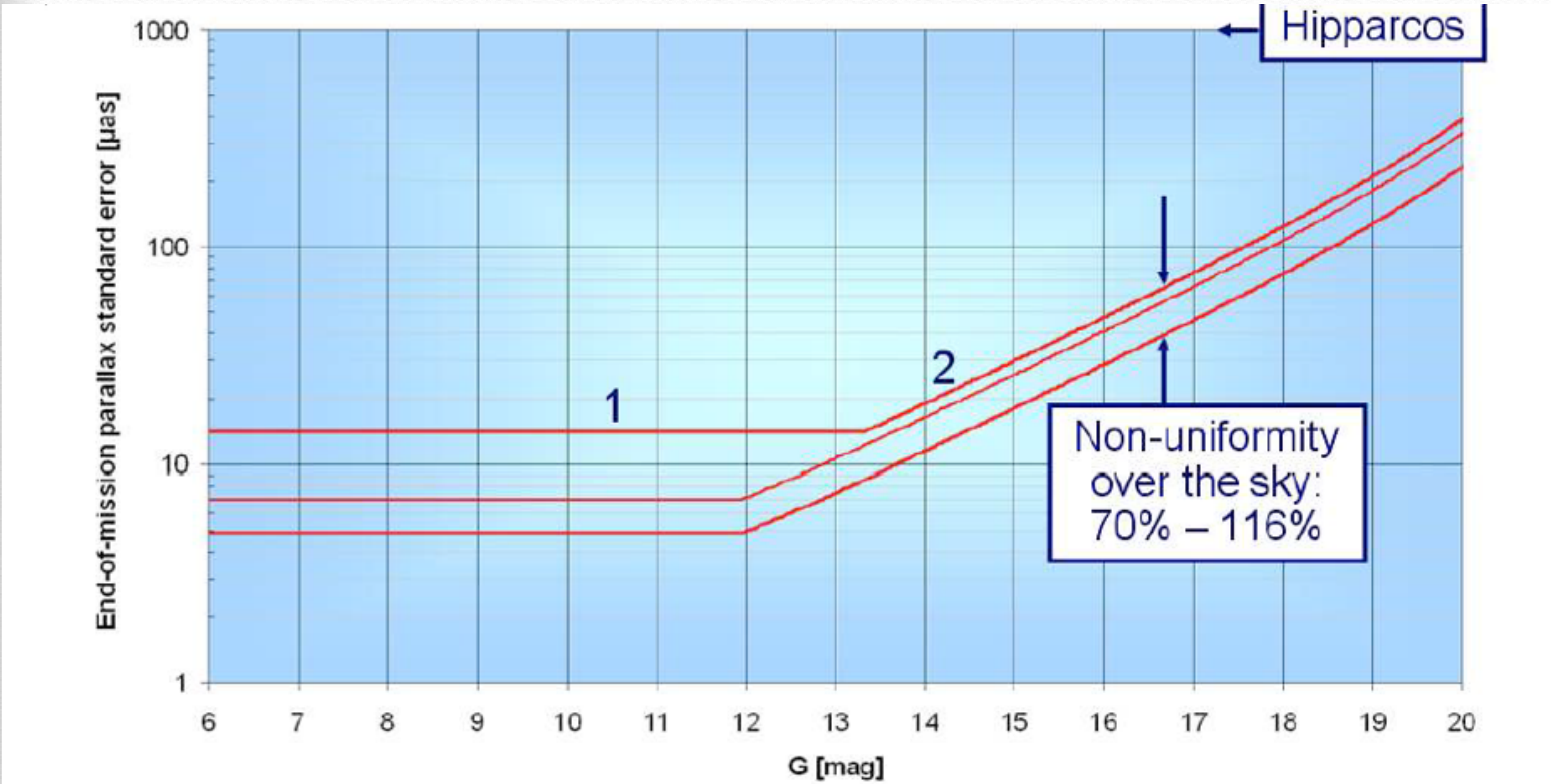



basic angle 106.5°


NSL field transits in ICRS after: 0 years 000 days 00 hr 10 min
90
180
-180
-90
6
5
4
3
2
1
0



Parallaxe error over sky (galactic coordinates)



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

Luri & Turon, 2011

Expected errors on Vlos

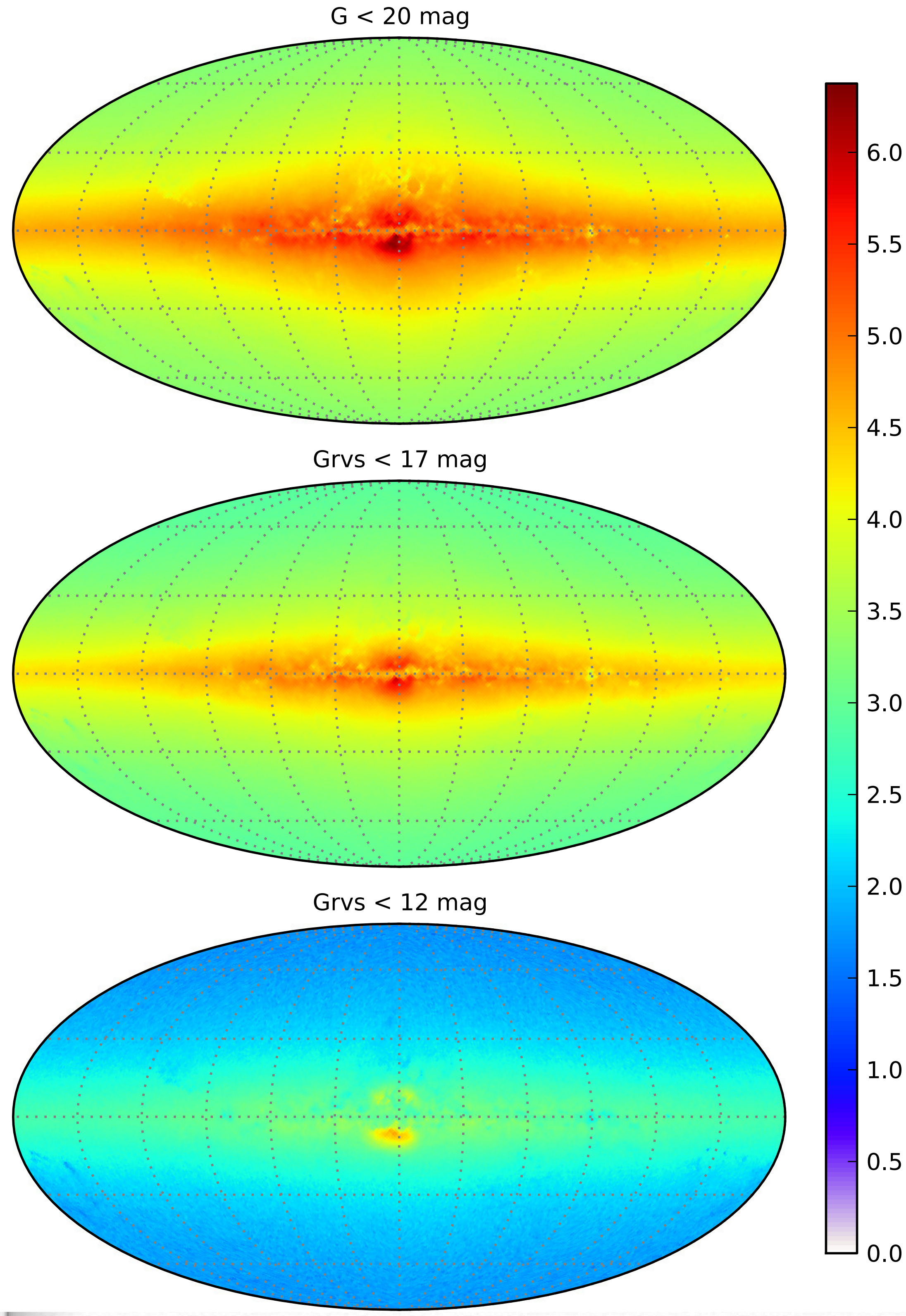
Type \ V	8.5	9.0	9.5	10	10.5	11.5	12	12.5	13	13.5	14	14.5	15	15.5	16	16.5	17	17.5
B0V	1.2	1.6	2	2.7	3.8	6.8	9.7	14.5	24.8	n	n	n	n	n	n	n	n	n
B5V	1	1.1	1.4	1.9	2.5	5.1	6.9	10	15.3	24.1	n	n	n	n	n	n	n	n
A0V	1	1	1	1	1	1.3	1.8	2.6	3.9	5.7	8.6	14.6	32.5	n	n	n	n	n
A5V	1	1	1	1	1	1	1	1.3	2	4.2	6.9	11.1	20.1	n	n	n	n	n
F0V	1	1	1	1	1	1	1	1	1.5	2.1	3.2	5.3	7.8	12.7	23.4	n	n	n
G0V	1	1	1	1	1	1	1	1	1	1.4	2.1	3	4.8	7.9	12.4	19.6	n	n
G5V	1	1	1	1	1	1	1	1	1	1.2	1.9	2.8	4.4	6.3	10.1	17.6	n	n
K0V	1	1	1	1	1	1	1	1	1	1.1	1.4	2.1	3.3	5.1	8.1	12.6	24.9	n
K4V	1	1	1	1	1	1	1	1	1	1	1.1	1.6	2.7	3.6	5.2	8.4	14.5	30
K1III	1	1	1	1	1	1	1	1	1	1	1	1.2	1.8	2.7	4.2	6.8	10.3	18

Table 1. The average end of mission formal error in radial velocity with an assumed average of 40 field of view transits, in km·s^{-1}, for each spectral type. The numbers in the top row are Johnson apparent V magnitudes. Fields marked by "n" are assumed to be too faint to produce spectra with sufficient quality for radial velocity determination. Stars with these magnitudes will have no radial velocity information.

To be revised with real data

GUMS: Gaia Universe Model Snapshot

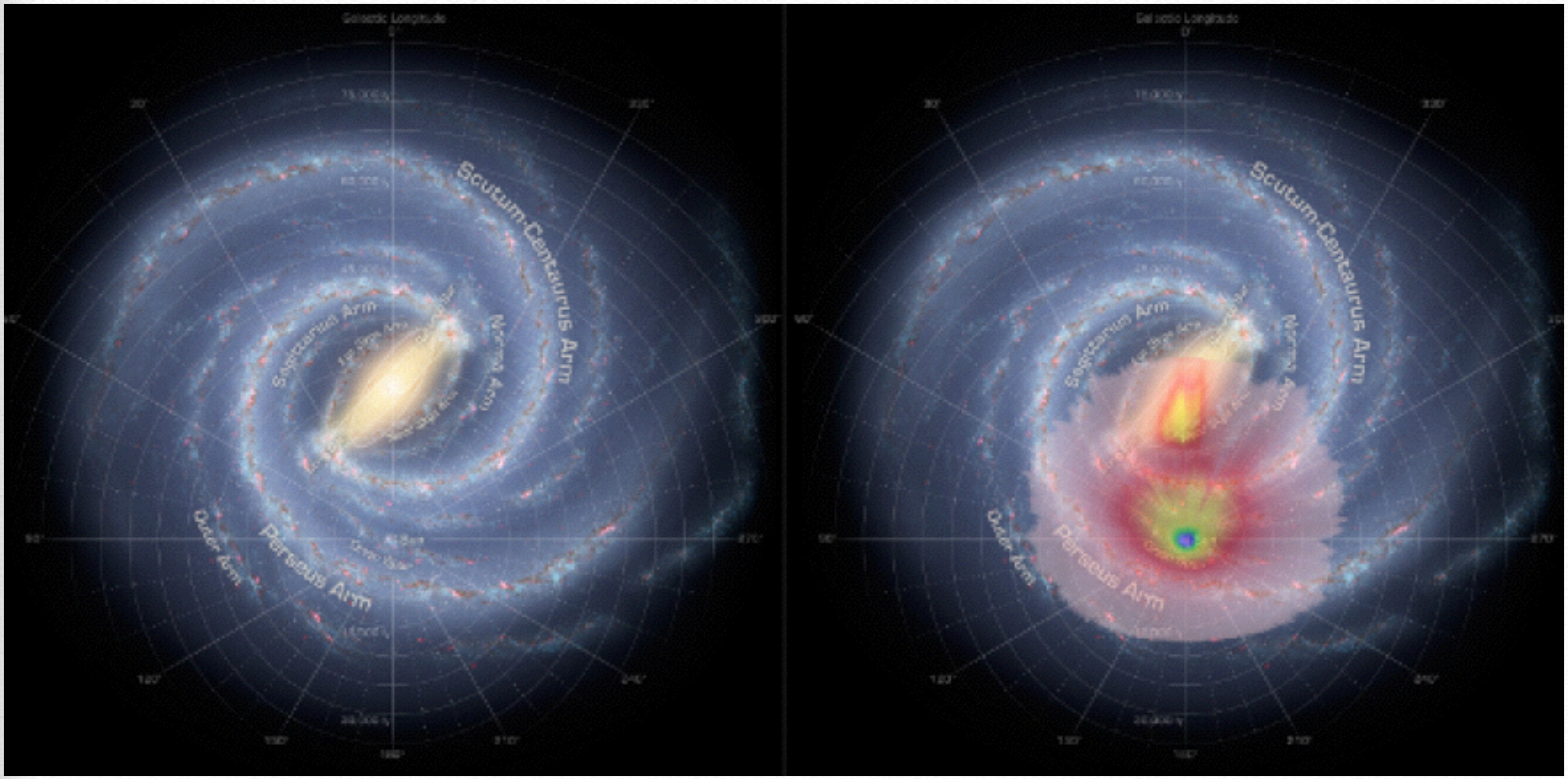
AR, X. Luri, C. Reylé et al, A&A 2012 (CDS)



Spectral type	G < 20 mag	Grvs < 17 mag	Grvs < 12 mag
O	<0.01%	<0.01%	<0.01%
B	0.26%	0.50%	0.88%
A	1.85%	3.30%	4.84%
F	23.13%	22.94%	13.83%
G	38.28%	31.58%	15.46%
K	27.68%	32.23%	41.75%
M	7.75%	6.78%	11.38%
L	<0.01%	<0.01%	<0.01%
WR	<0.01%	<0.01%	0.01%
AGB	0.91%	2.50%	11.37%
Other	0.09%	0.07%	0.33%
Total	1,100,000,000	390,000,000	13,000,000

Luminosity class	G < 20 mag	Grvs < 17 mag	Grvs < 12 mag
supergiant	0.00%	0.01%	0.07%
Bright giant	0.81%	2.18%	11.01%
Giant	14.47%	28.38%	62.71%
Sub-giant	15.08%	14.38%	10.32%
Main sequence	69.40%	54.82%	15.76%
Pre-main sequence	0.18%	0.20%	0.08%
White dwarf	0.05%	0.01%	0.03%
Others	0.01%	0.02%	0.02%
Total	1,100,000,000	390,000,000	13,000,000

Density of stars in the final Gaia catalogue

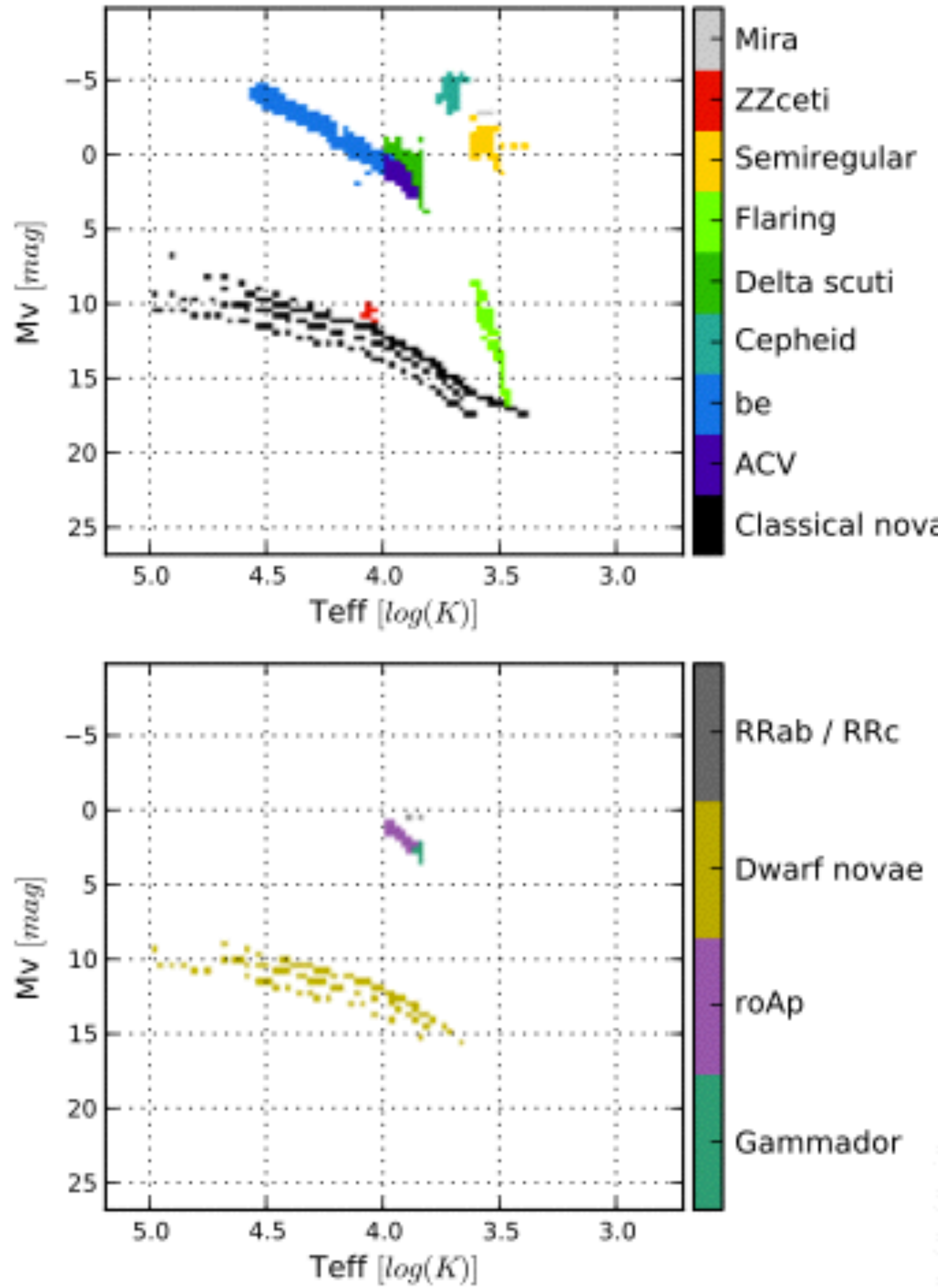


Stars in the MW

- Variability:
  (L. Eyer, CU7)

21 x 10^6 variable stars

Variability type	G < 20 mag	Grvs < 17 mag	Grvs < 12 mag
ACV	0.61%	0.52%	0.18%
Flaring	1.46%	0.49%	0.01%
RRab	0.37%	0.34%	0.02%
RRc	0.09%	0.09%	0.01%
ZZceti	0.12%	<0.01%	<0.01%
Be	2.15%	2.02%	0.87%
Cepheids	0.03%	0.04%	0.11%
Classical novae	0.05%	0.06%	0.19%
δ scuti	48.57%	41.01%	14.11%
Dwarf novae	<0.01%	<0.01%	0.00%
Gammador	0.09%	0.01%	<0.01%
Microlens	4.27%	1.87%	0.91%
Mira	0.19%	0.24%	0.91%
ρ Ap	0.05%	0.04%	0.01%
Semiregular	41.94%	53.27%	82.6%
Total	21,500,000	16,000,000	2,000,000



Stars in the Milky Way

- Multiplicity and exoplanets: (F. Arenou)

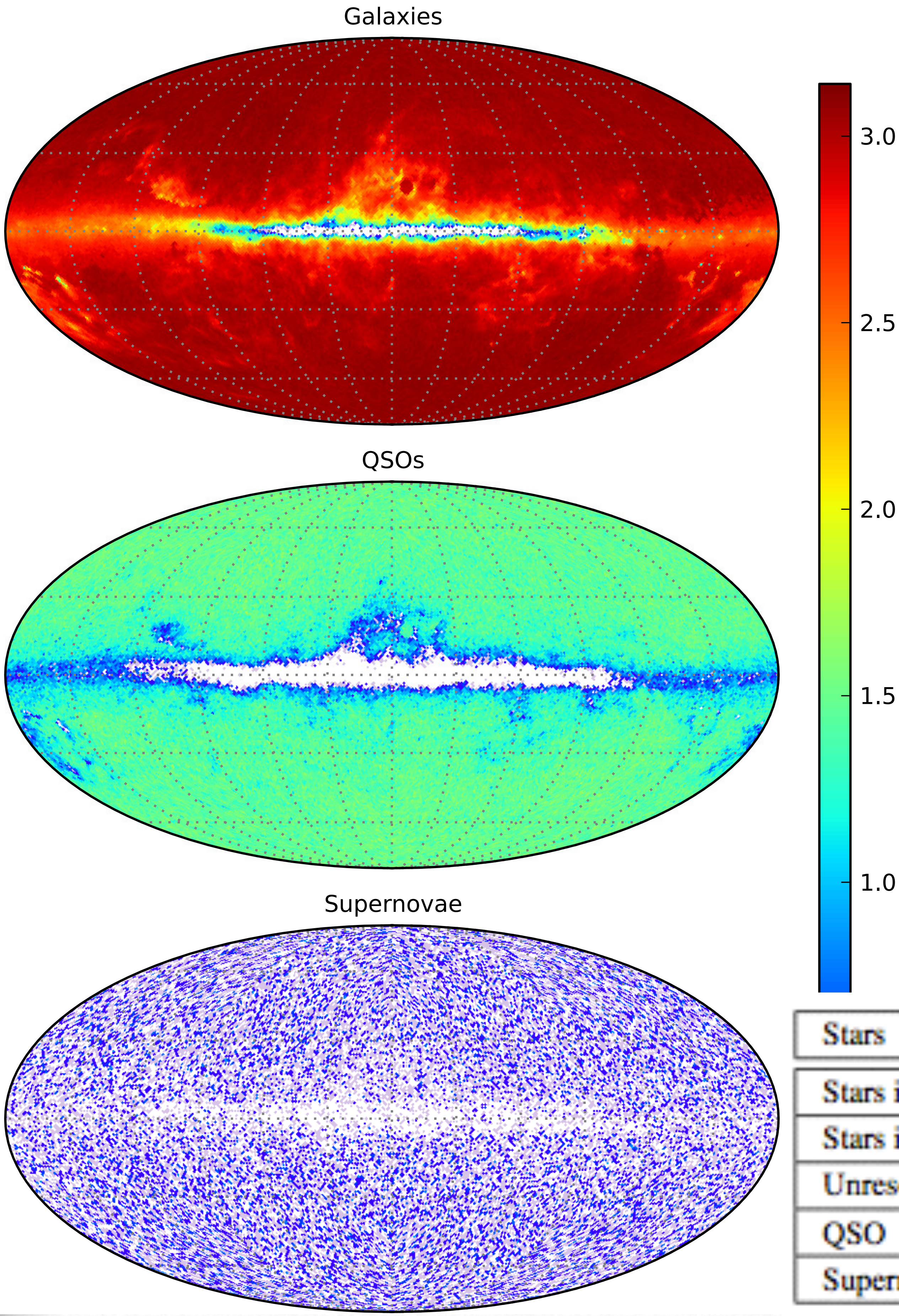
  410×10^6 binary systems

  - 67% of primary stars are main sequence
  - 62% of systems are a double main sequence system
  - 30 % of systems are subgiants and giants as primary with a main sequence star

- Exoplanets: (A. Sozetti)

  34×10^6 exoplanets

Stars	G < 20 mag	Grvs < 17 mag	Grvs < 12 mag
Total stars with planets	27,500,000	9,000,000	182,000
⇒ *Stars with one planet*	*75.00%*	*74.99%*	*74.93%*
⇒ *Stars with two planets*	*25.00%*	*25.01%*	*25.07%*
Total number of planets	34,000,000	11,000,000	228,000



Color scale: $\log_{10}$ of number of objects per sq. deg.

Stars	G < 20 mag	Grvs < 17 mag	Grvs < 12 mag
Stars in LMC	7,550,000	1,039,000	5,600
Stars in SMC	1,250,000	161,000	950
Unresolved galaxies	38,000,000	3,000,000	4,320
QSO	1,000,000	5,200	11
Supernovae	50,000	-	-

References

Gaia Universe Model Snapshot : **A statistical analysis of the expected contents of the Gaia catalogue.** Robin et al, 2012, A&A 543, A100.

Find it at CDS: Separated catalogues for stars, LMC/SMC, galaxies, QSOs.

With errors : Luri et al, 2014, Overview and stellar statistics of the expected Gaia Catalogue using the Gaia Object Generator

=> Catalogue with simulated errors (as expected before launch)

Gaia / LSST

- Gaia irregular time, Variables : redefinition of standard candles, not all variables (~21 millions)

- paral. err. 0.02-0.3 mas
- Photometer (~25 bands)+ spectro (G<16)
- 40 to 100 epochs

- 1 billion stars

- Whole sky

- Follow-up spectra : 4m/8m

- LSST periodic observations.
- More variables (short periods) ~50 millions

- paral. err. 0.2-1 mas
- 5 mag fainter
- 6 bands
- 800 epochs

- ~ a few100 million stars

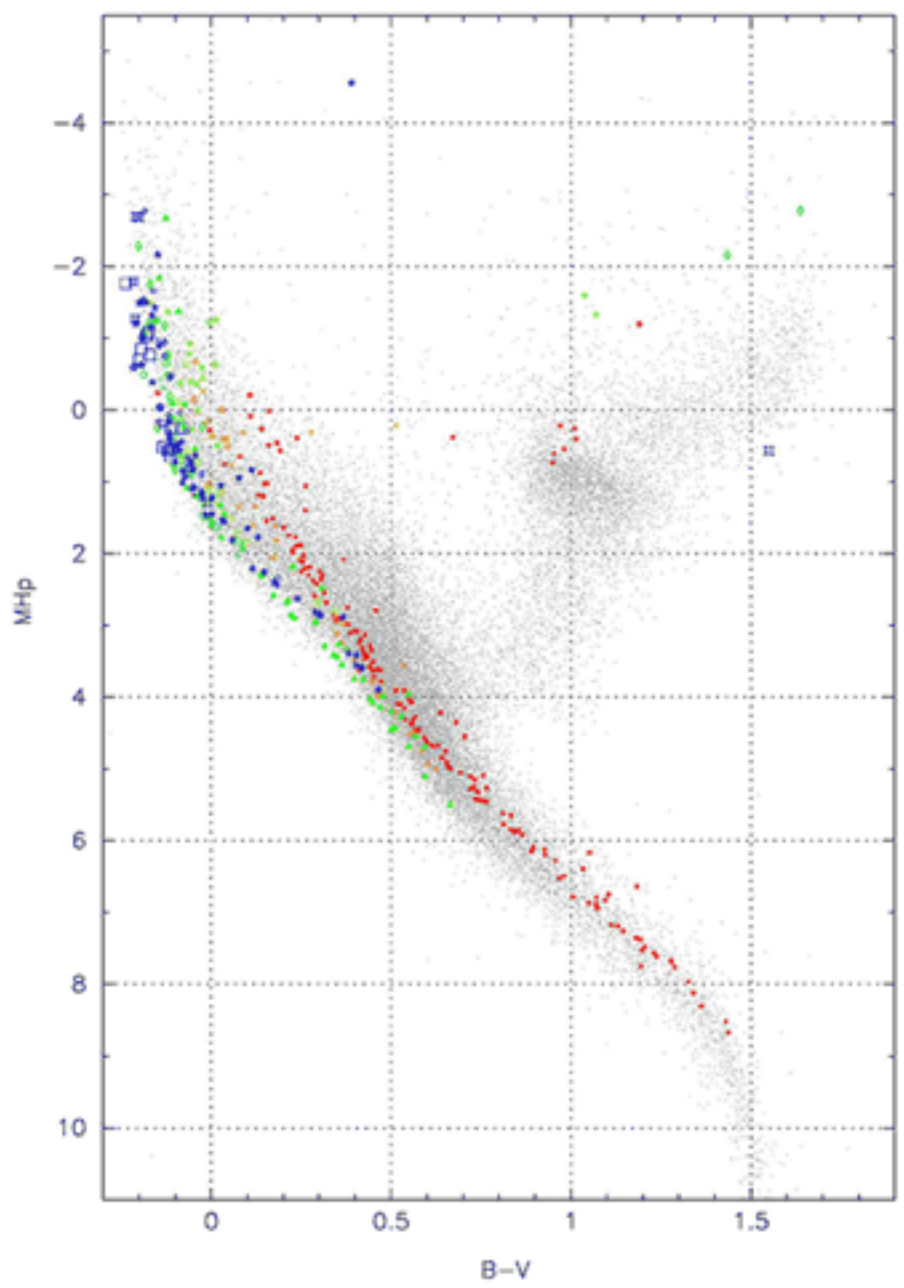
- Half sky (not 1st and 4th quadrants of the galactic plane)

- Follow-up ?

Gaia-LSST synergie

- Magnitude range : LSST, intrinsically fainter, further away than Gaia
- LSST will provide complementary constraints, specially on remote populations (**halo** substructures), and on very faint stars (brown dwarfs)
- LSST will provide proper motions (calibrated by Gaia) for very faint objects. Tool for kinematics and dynamics of the thick disc, outer galaxy (warp) and halo substructures
- LSST misses spectroscopy

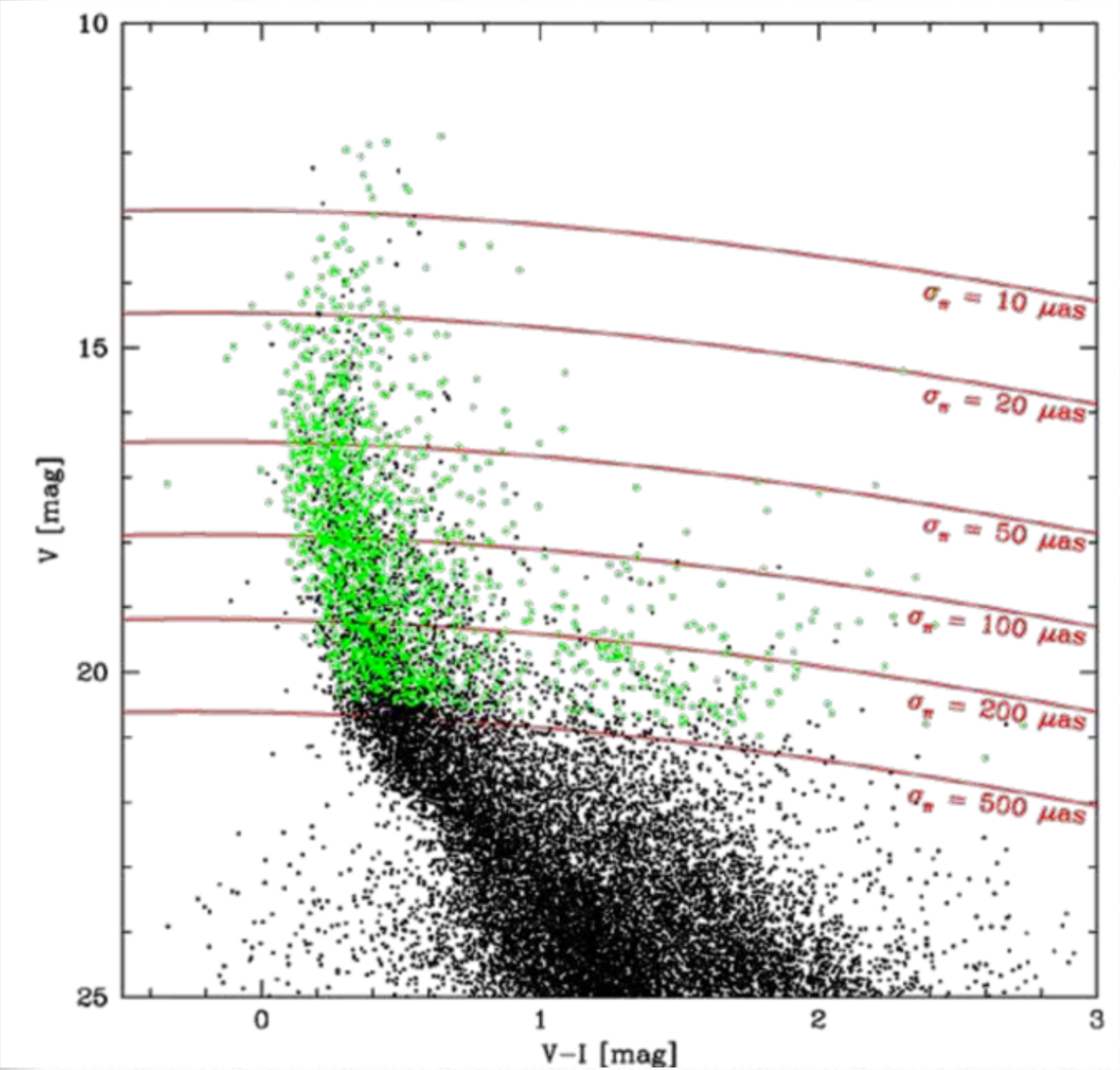
Stellar physics



Hipparcos=> Gaia
120 000 => 1 milliards
precision x 5 à 50

- Distances => absolute luminosity
- Masses in binaries
- Rare objects
- Variables
- => Constraints on stellar interiors/ atmospheres

Région dense R136



Green: Gaia detection
Black: HST

De Bruijne & De Marchi (2011)

Gaia late type dwarfs / brown dwarfs

Parallaxes, kinematics => stellar physics, constraints on stellar interiors, masses, ages (binaries)

- 50 000 brown dwarfs but in a restricted solar neighborhood

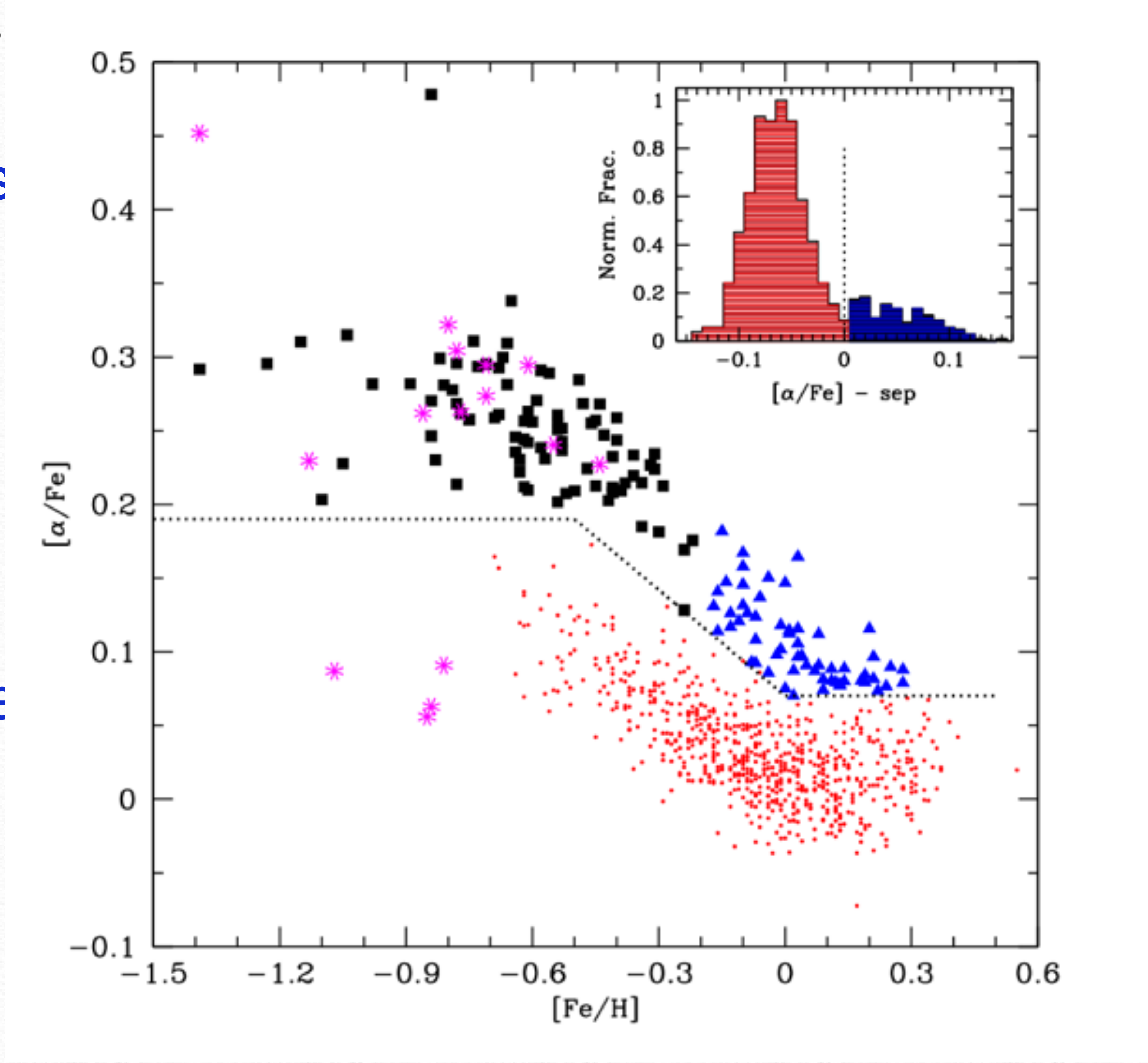
LSST late type dwarfs / brown dwarfs

« Complete census of all stars above the hydrogen-burning limit that are closer than 500 pc, including thousands of L and T dwarfs ». Will improve the detection of very faint brown dwarfs

Mapping the structure and stellar metallicity content of the Milky Way's dis

Gaia abundances

LSST abundance



rs

s

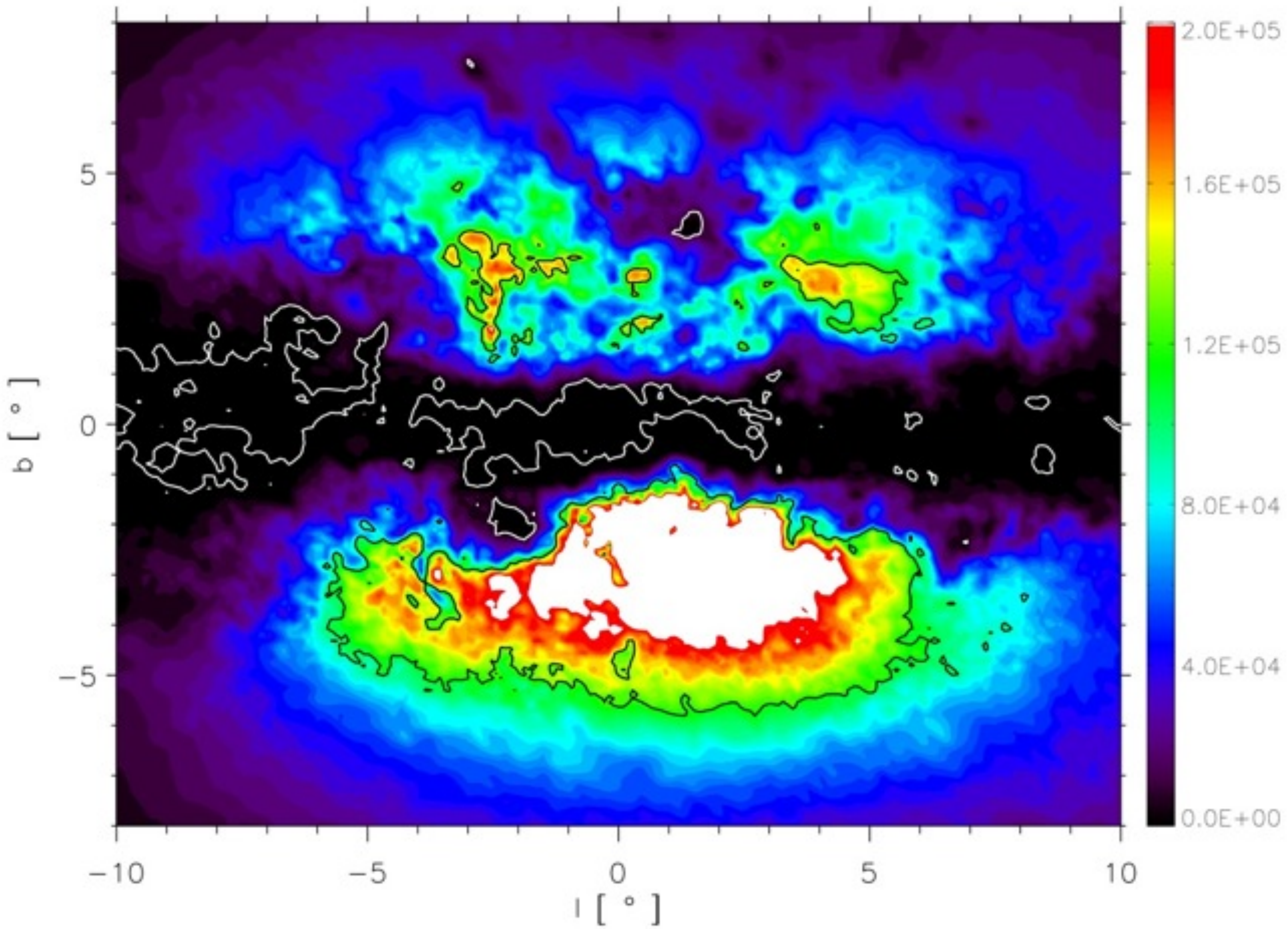
- No elemental abundances

- Mapping the 3D distribution of dust throughout the MW's disc
    - Gaia : whole sky, including the plane, limited in high extinction regions (hardly reaches the bulge), Teff
    - LSST : part sky, parallaxes, 6 bands, bulge

- Understanding the smooth distribution of stars in the MW and other nearby galaxies
    - Gaia : Milky Way; LSST : nearby galaxies

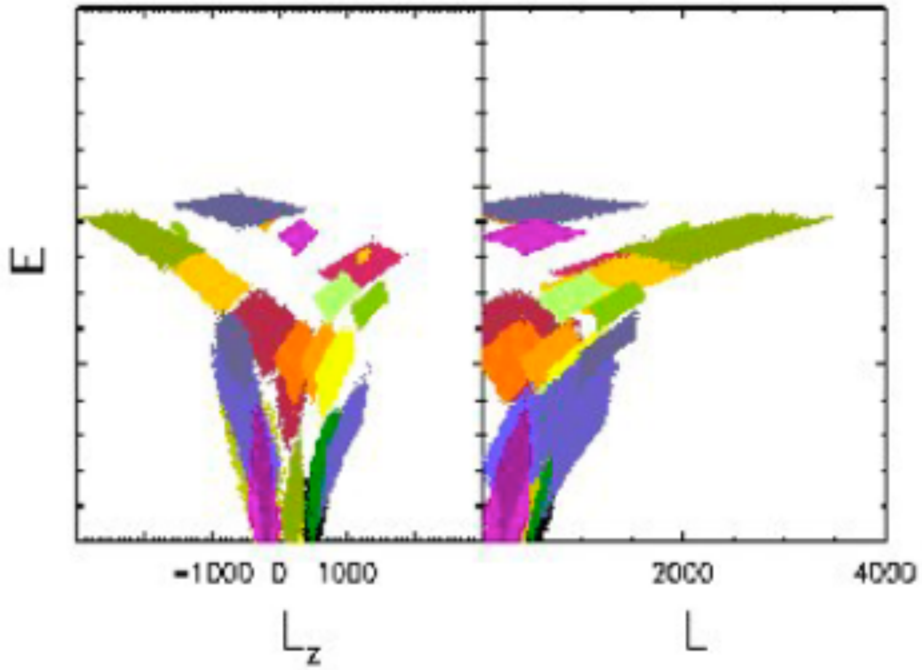
- Discovering lumps and streams in metallicity and phase-space
    - Gaia : for bright streams (whole sky), LSST : for faint streams (part sky)

- Inferring the mass distribution in the MW
    - Gaia (bright tracers and radial velocities => 6D space) and LSST (to complement with more tracers => more tests on homogeneity, no spectra)

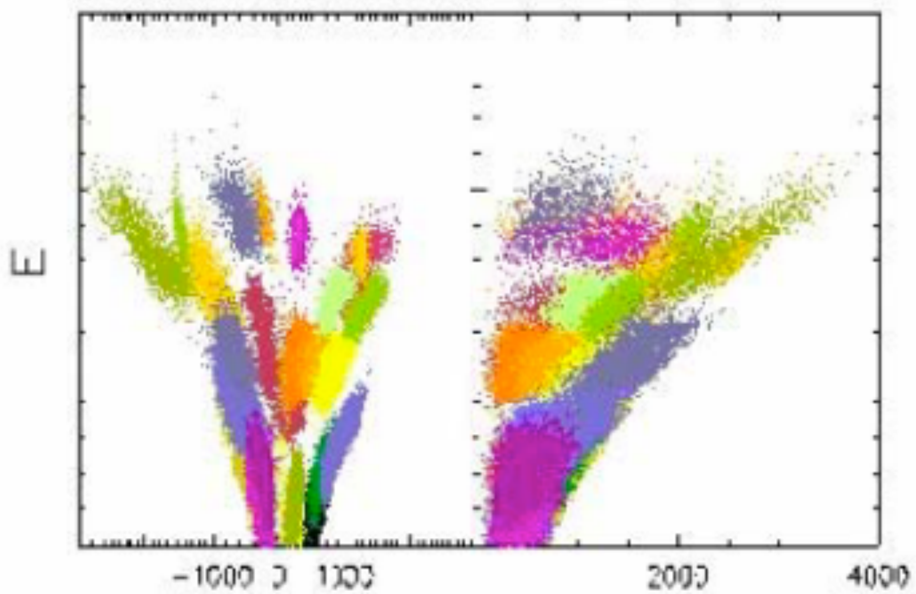


Bulge star density in Gaia G<17

Accretion in integral space (E,L_z)



Input - different colors represent different satellites



Output after 12 Gyr
-stars within 6 kpc of
-the sun - convolved with
GAIA errors

Helmi & de Zeeuw

Measuring the mass of the Galaxy with Gaia

– distances to 1% for ~10 million stars to 2.5 kpc

– distances to 10% for ~100 million stars to 25 kpc

- Velocities of globular clusters and dwarf galaxies

- Radial velocities in the halo : 10000 BHB d<15 kpc

  A few 100 TRGB d<50 kpc

  AGB d<60 kpc

  1000 carbon stars d< 60 kpc

=> Gaia: galaxy mass at 10% *(Wilkinson, 2007)* thanks to spectroscopy

Conclusions

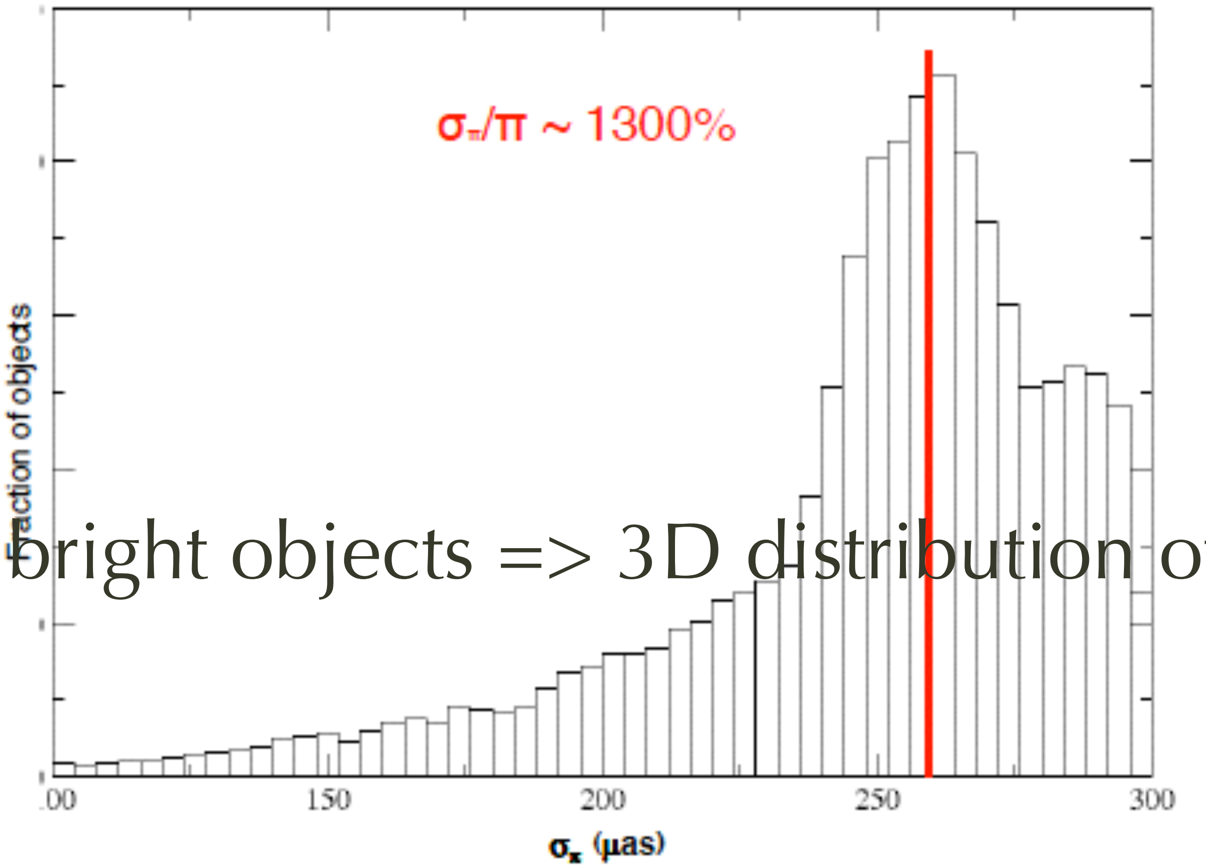
- Gaia 1st catalogue : end 2015
- Gaia final catalogue : 2020

- LSST commissioning : 2020, will benefit from Gaia calibrations
- LSST will extend to fainter objects, to larger distances
- LSST will extend Milky Way studies to the local group

Thanks for your attention

Gaia and the Local Group

- LMC-SMC : 7.5 millions and 1.5 millions of stars observable by Gaia
- Mean parallaxe error : 0.5% - 1.5% (from the mean of all observable stars)



Cepheids and bright objects => 3D distribution of the MC

Fig. 4. Distribution of the errors in parallax for the simulated LMC objects. Notice that the maximum is at a relative error of 1300%, but that there is a significant tail of objects reaching low relative errors.