The Gaia Universe Model



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CU2, DPAC consortium

SIMULATORS FOR GAIA

- **GIBIS** (C. Babusiaux) : Image simulator : pixels. Important to optimize detection algorithms, estimations of CTI effects...

- **GASS** (E. Masana): Telemetry simulator

- **GOG** (X. Luri) : Simulate intermediate and final data : test reduction algorithm, classification, production of final data, final database...

GAIASIMU : DATA USED BY SIMULATORS

- **Universe model :** Astro-sources and their characteristics (astrometry, photometry, spectra), variations with time, and their distribution on the sky

- **Instrument model** (D. Guardiol): Characteristics of all the Gaia instruments, optics, CCDs, scanning law...

UNIVERSE MODEL : OBJECTIVES

Generate astro-sources which Gaia will see (or which can perturb measurements) with all the observable characteristics

Degree of realism : depend on our knowledge, on the simulator needs, on computer capacity. Evolve at each cycle.

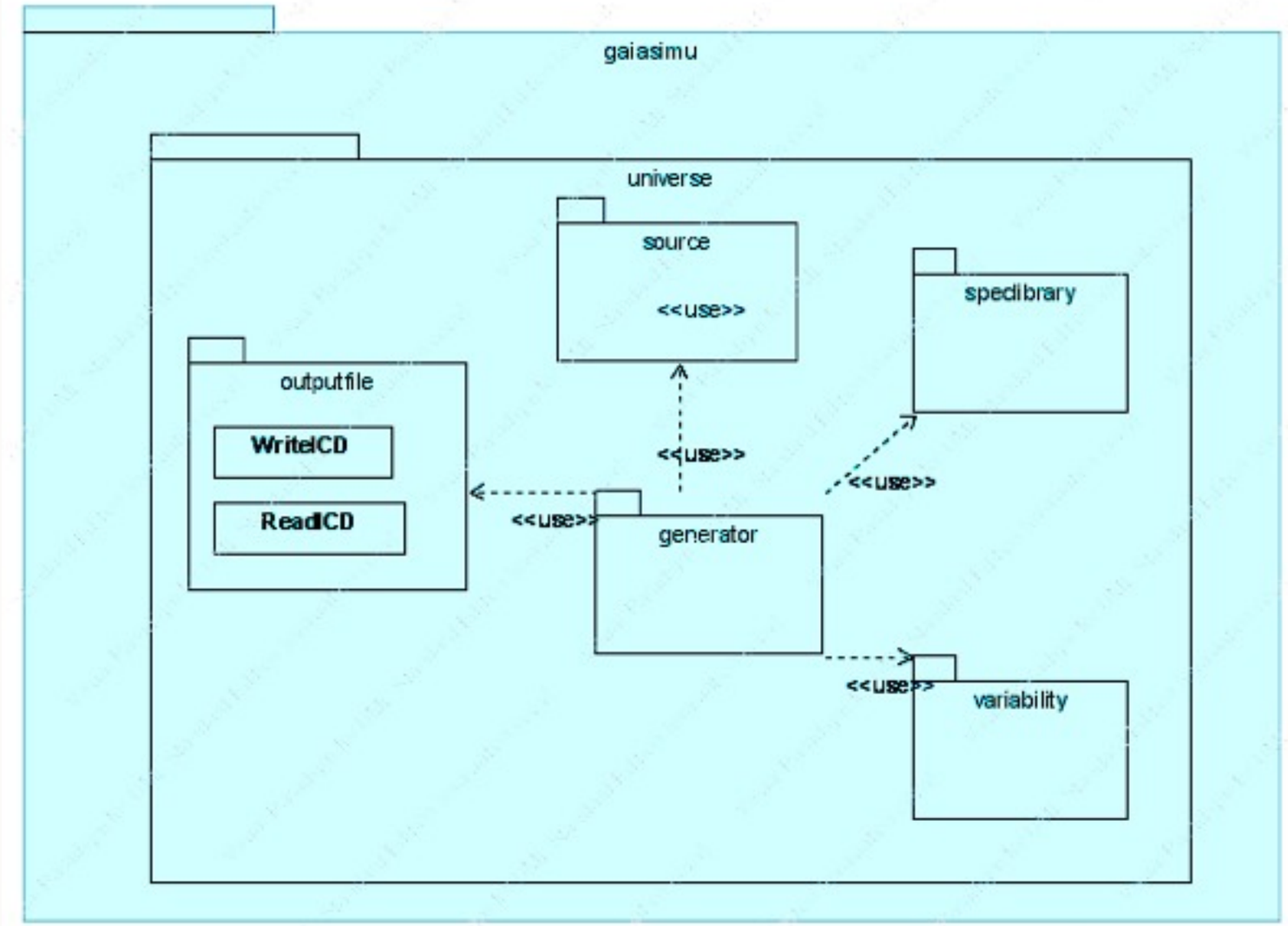
UNIVERSE MODEL INGREDIENTS

- Planets, asteroids, comets
- Exoplanets
- Stars, multiple stars, variables
- Star clusters
- Nebulae, HII regions
- Galaxies
- QSOs
- Supernovae
- Gamma Ray Bursts

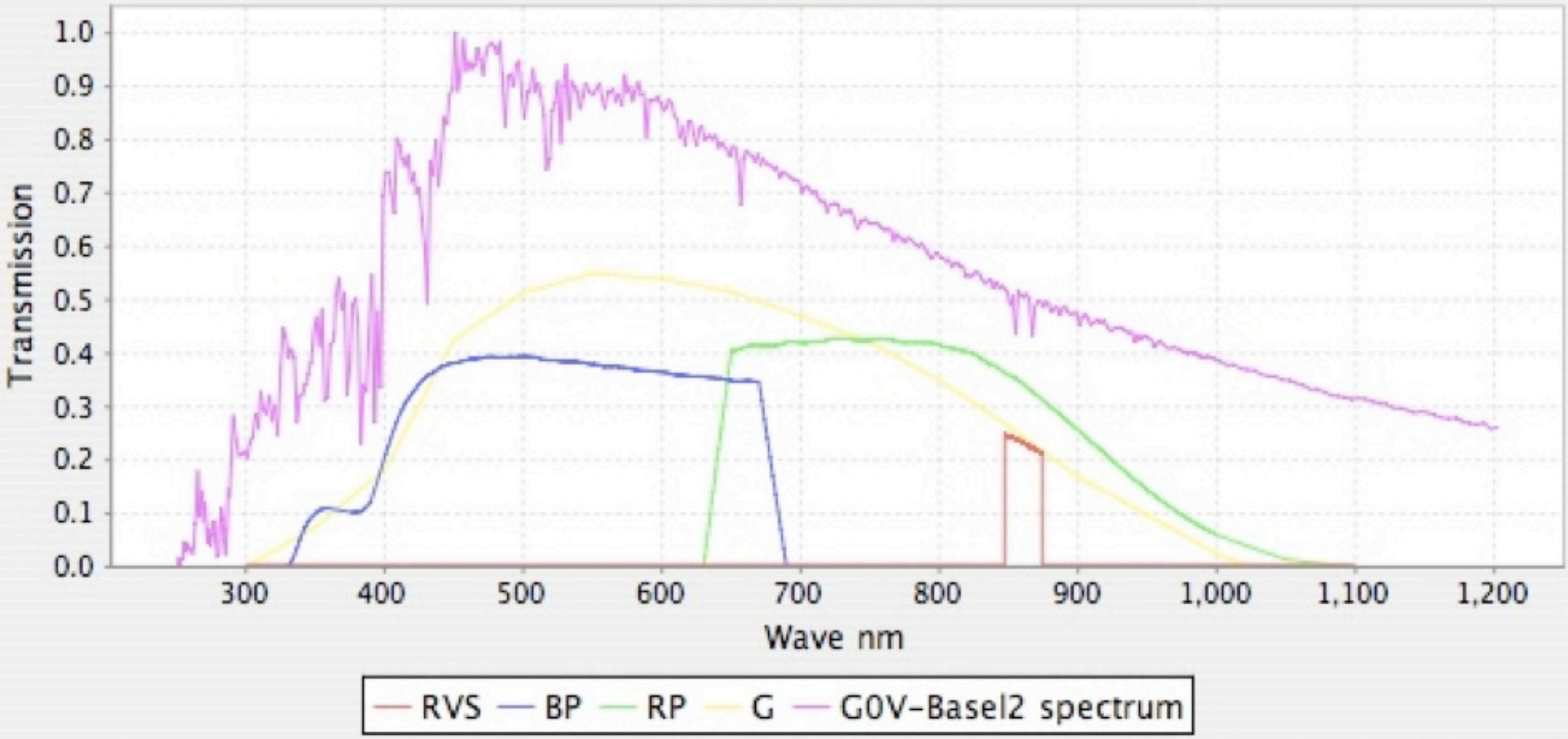
- Relativity Model
- Interstellar extinction
- Backgrounds
- Radiation environnement

SOURCE CHARACTERISTICS

- Photometry (G, millimag)
- Astrometry (10 μas)
- Spectra (BP/RP, RVS)
- Images (for extended objects)
- Time dependency : Displacements and variability



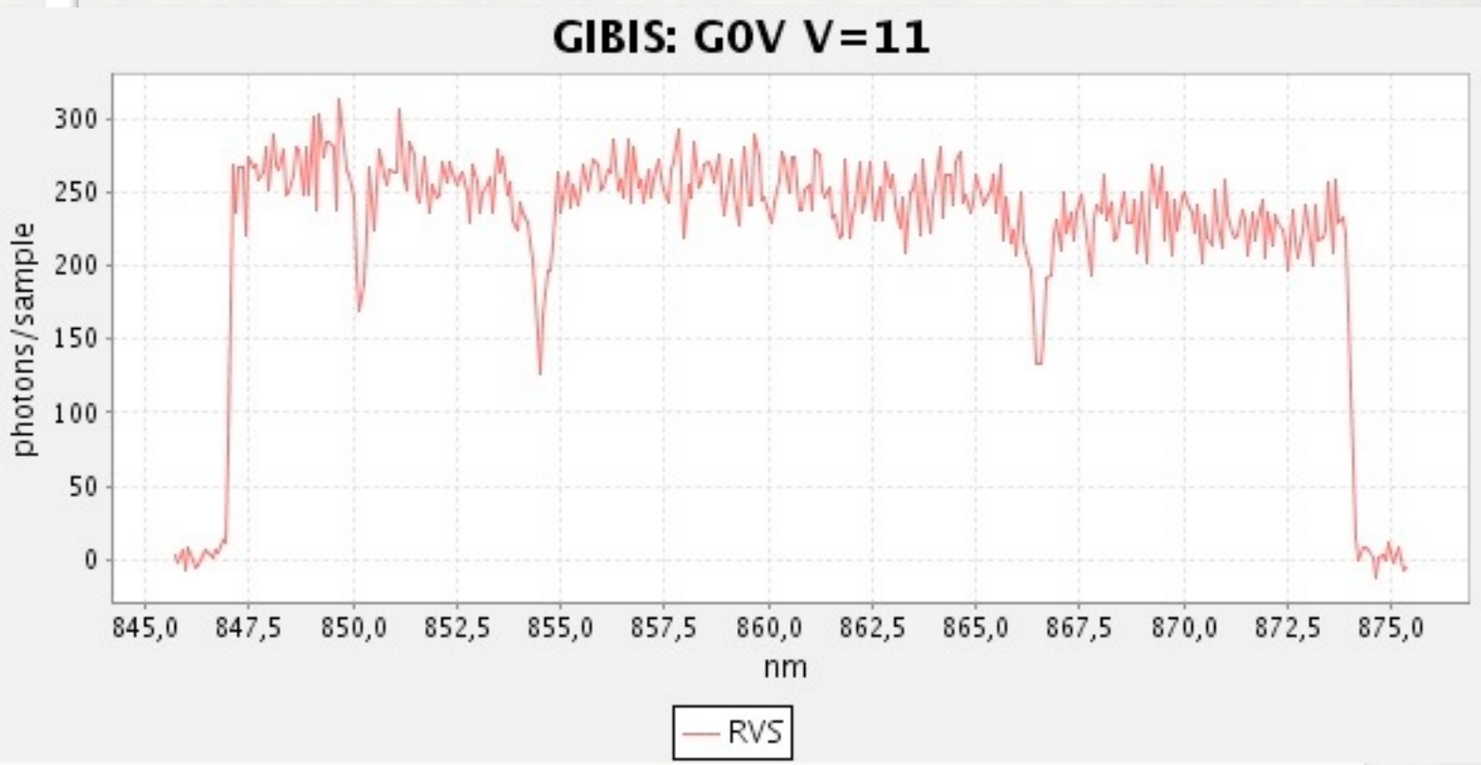
Gaia bands


Transmission
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
300
400
500
600
700
800
900
1,000
1,100
1,200
Wave nm
RVS
BP
RP
G
G0V-Basel2 spectrum

SPECTRAL LIBRARY

- Stars : Basel, Kuruz, Marcs (CU8)
- Galaxies : Stuff, PEGASE
- QSOs : Claeskens, Slezak & Mauduit
- Asteroids : M. Delbo (en cours)

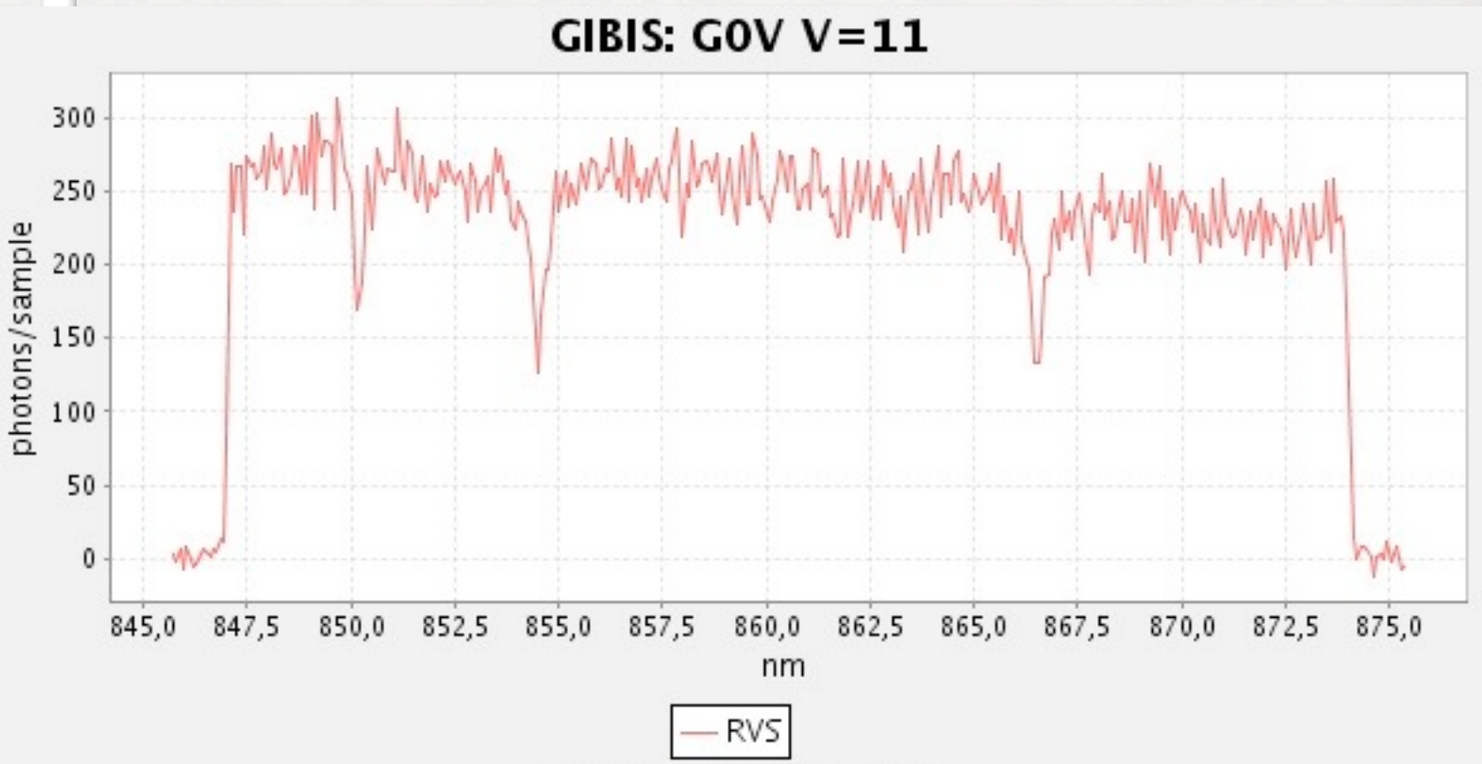
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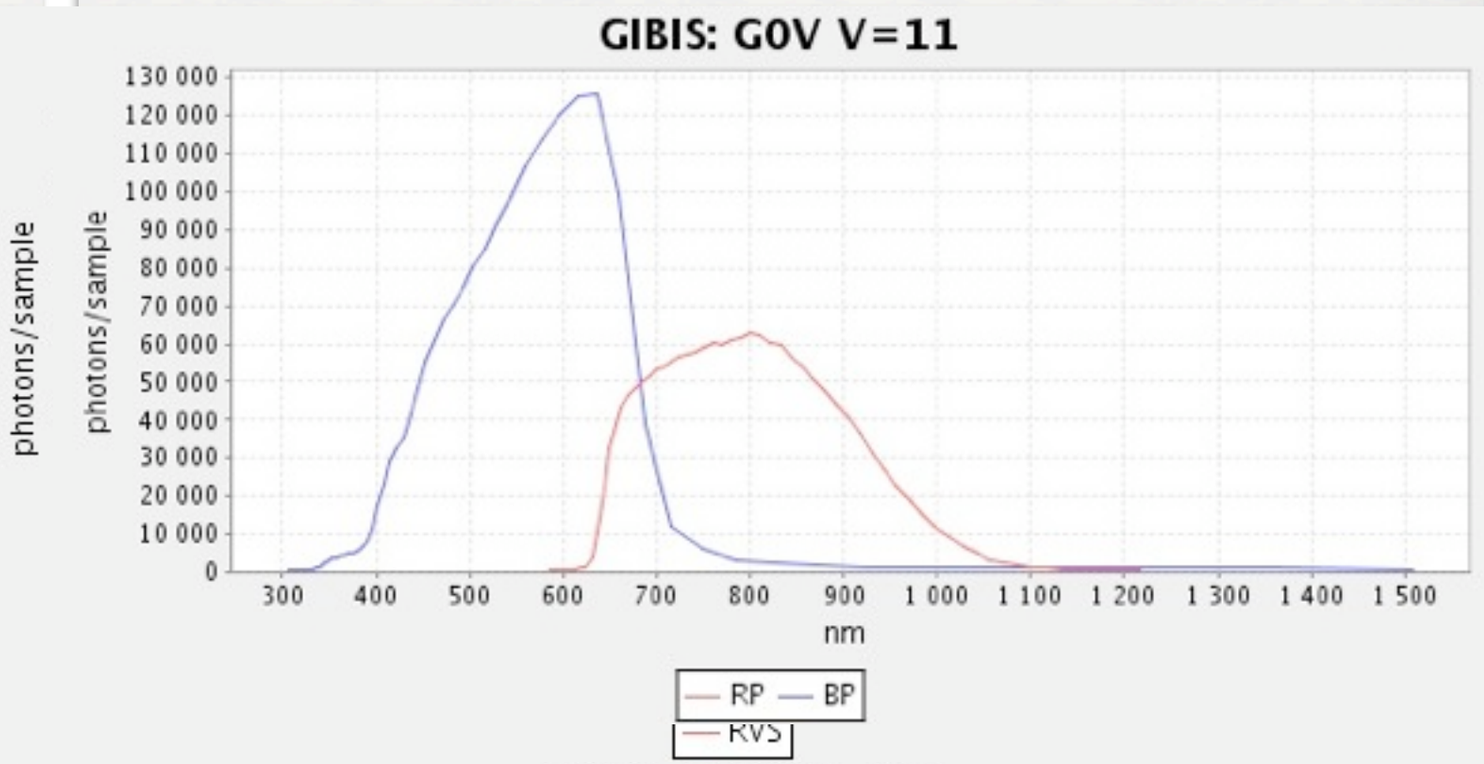
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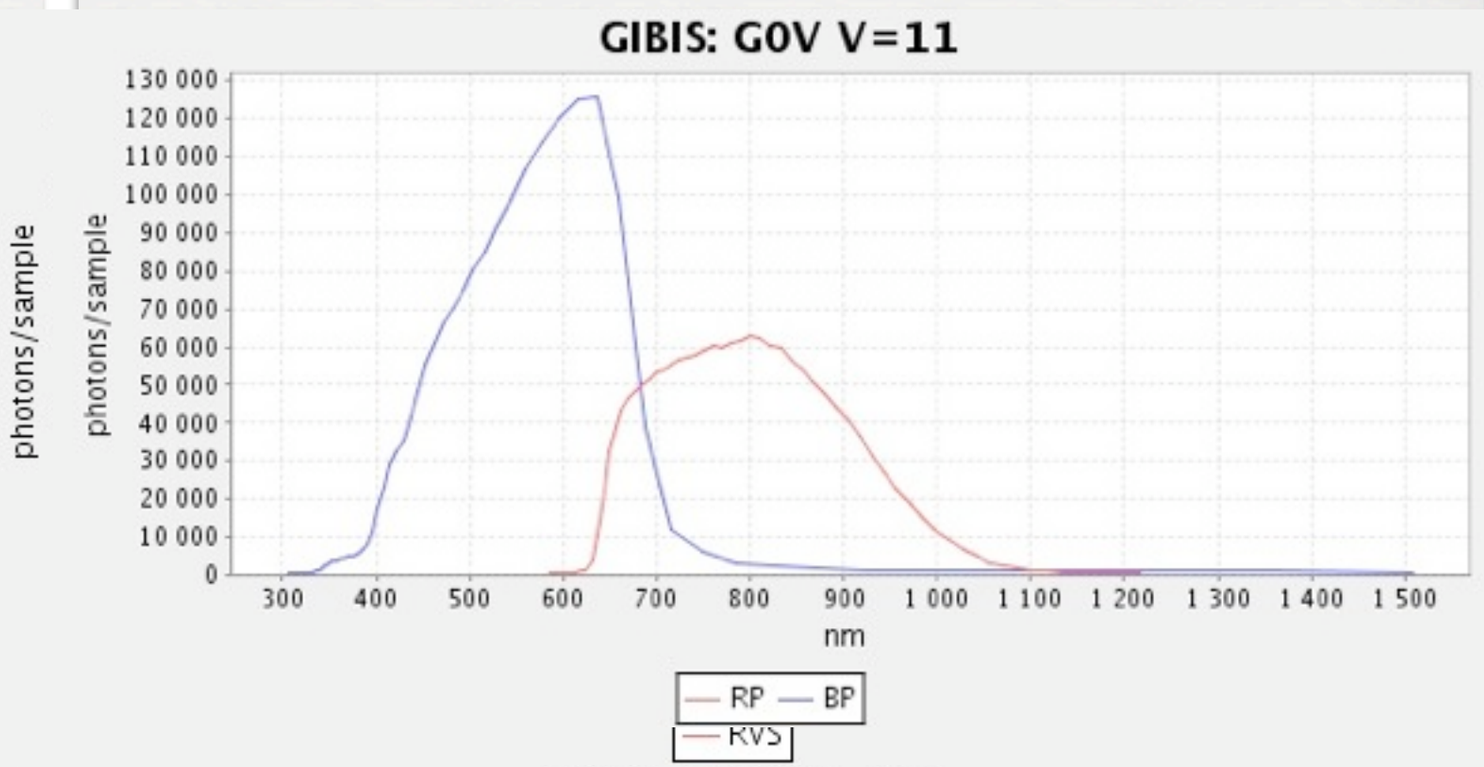
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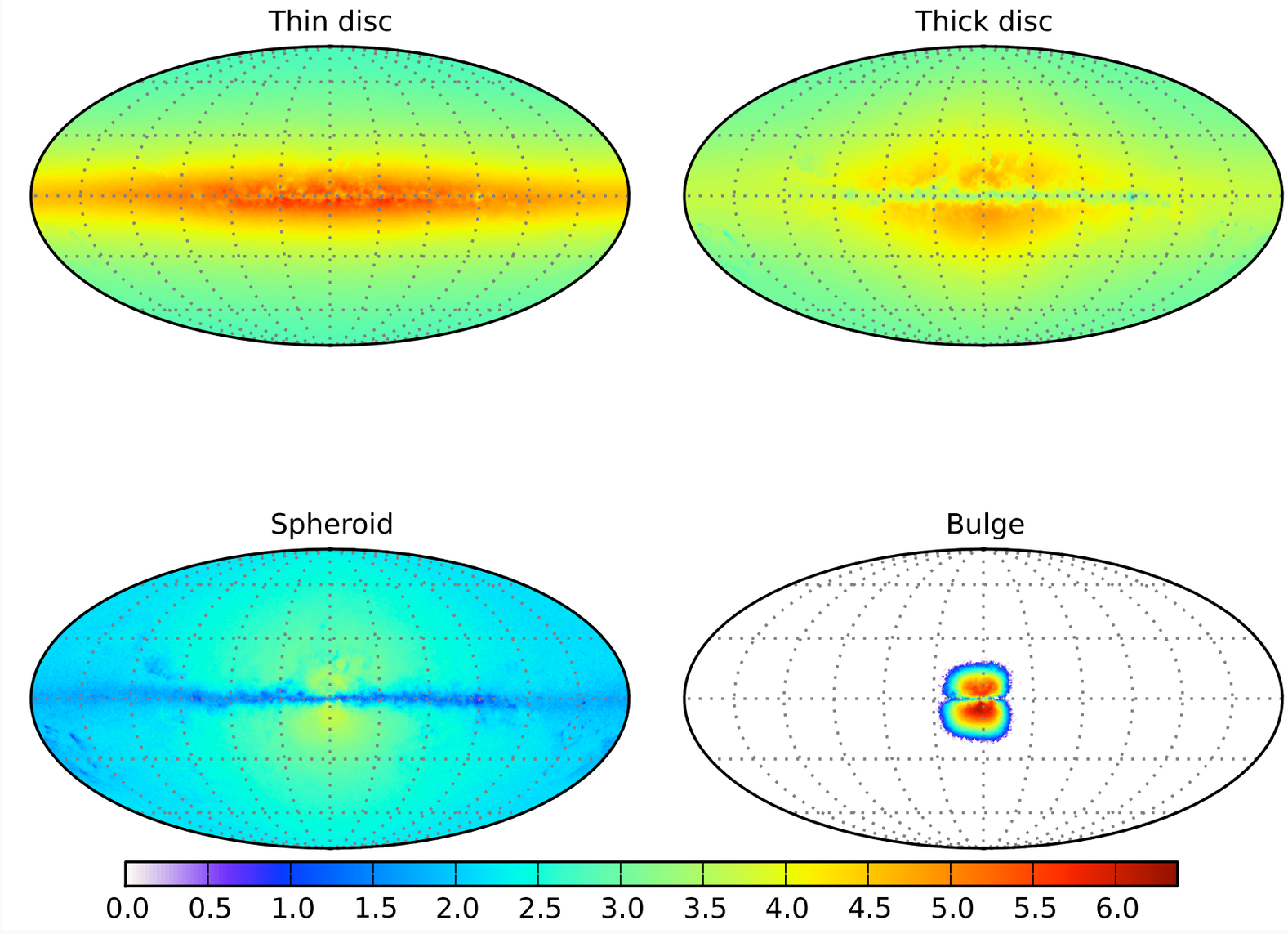


SPECTRAL LIBRARY

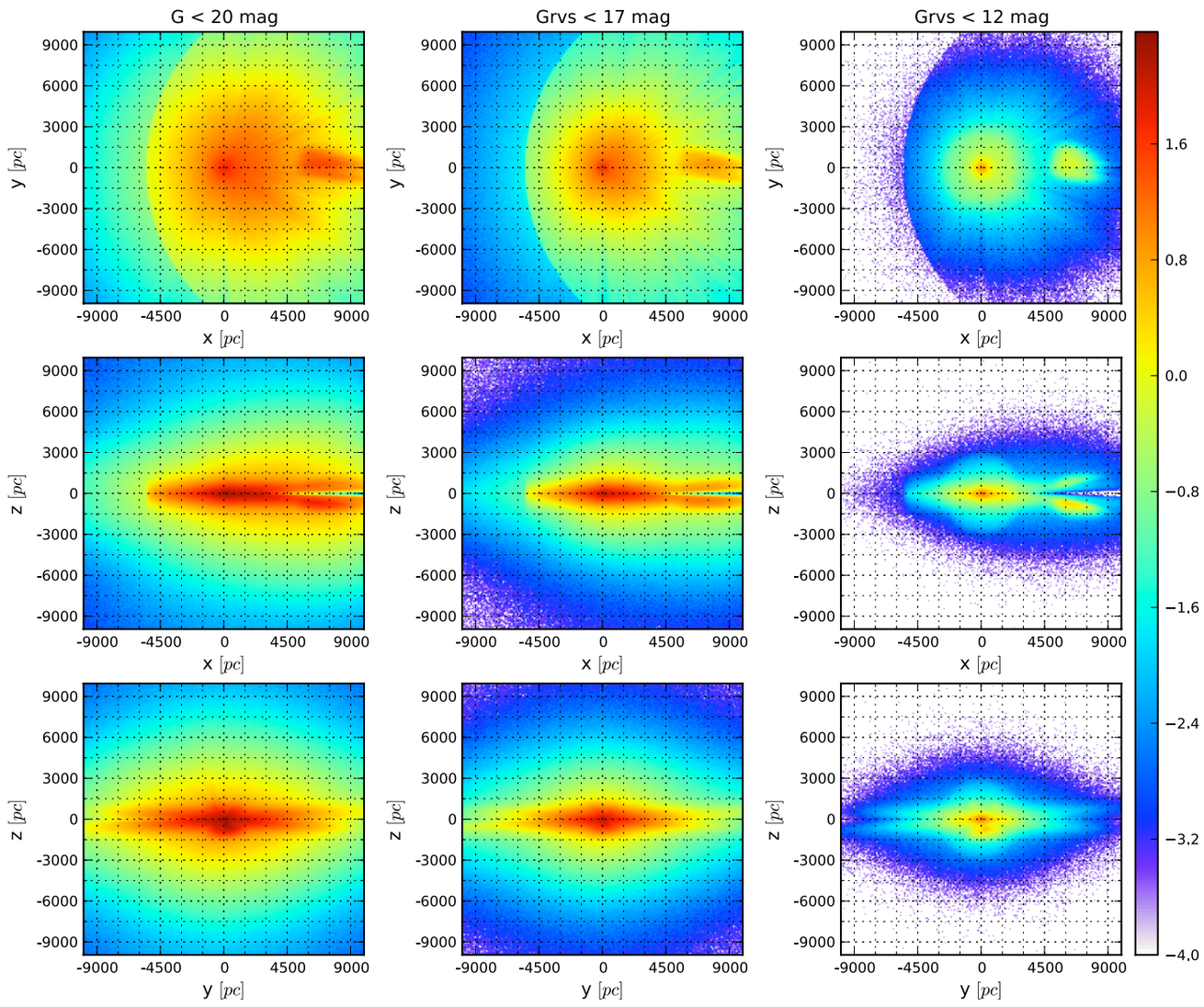
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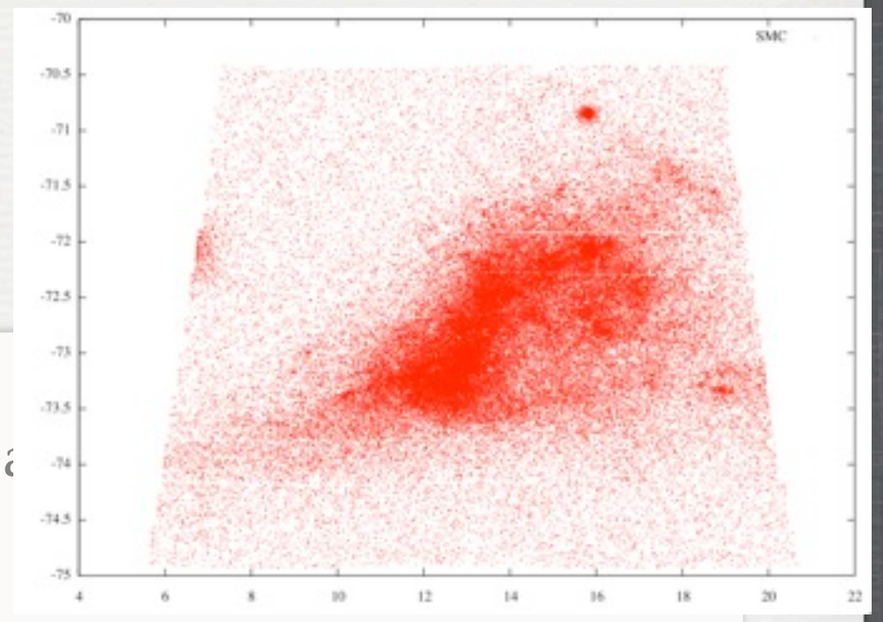
STELLAR POPULATIONS



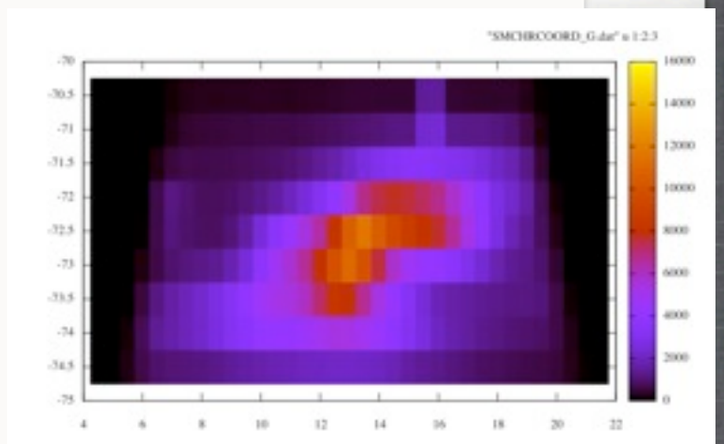
THE GALAXY (X,Y,Z)

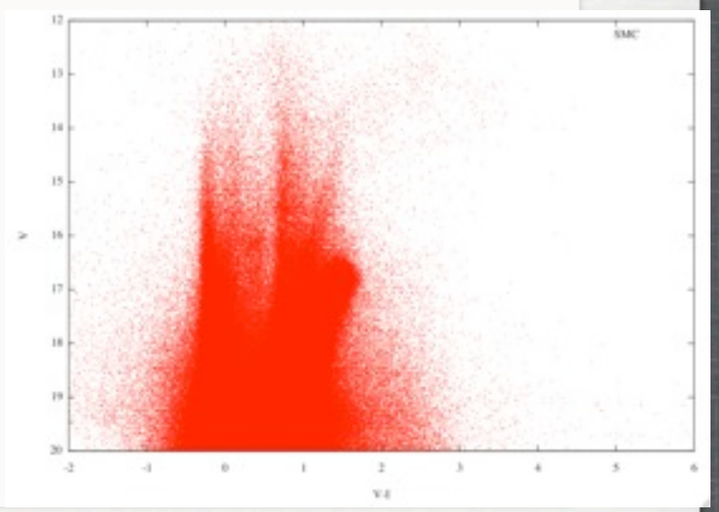


RESOLVED GALAXIES

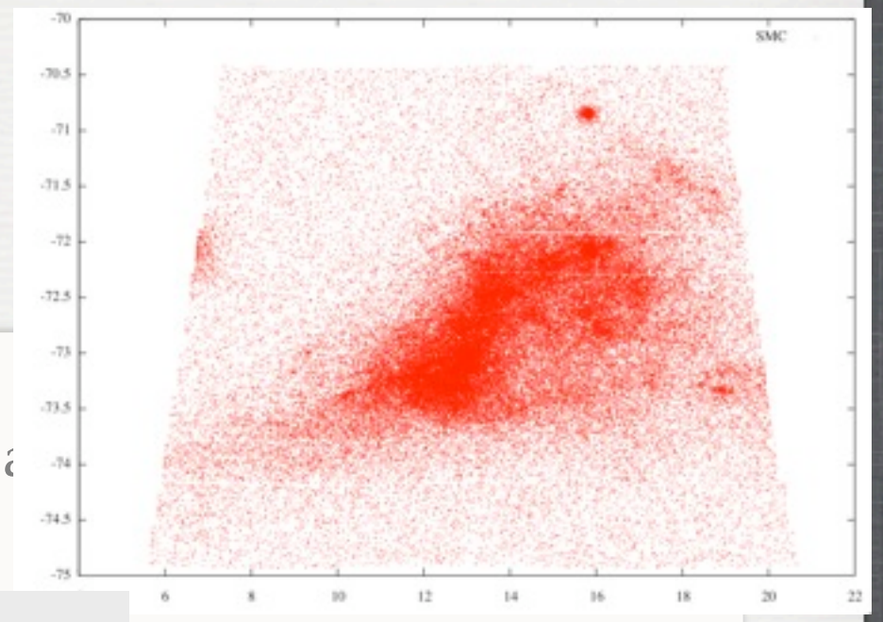


- LMC and SMC implemented (Belcheva, Kontizas, et a
- LMC: 6,762,648 stars
- SMC: 1,501,056 stars
- Catalogues: position, B,V,I, Sp. Type, Teff, logg
- Binaries added
- No variables, fixed distance, p.m., Vrad.
- No plan for extended objects in LMC/SMC

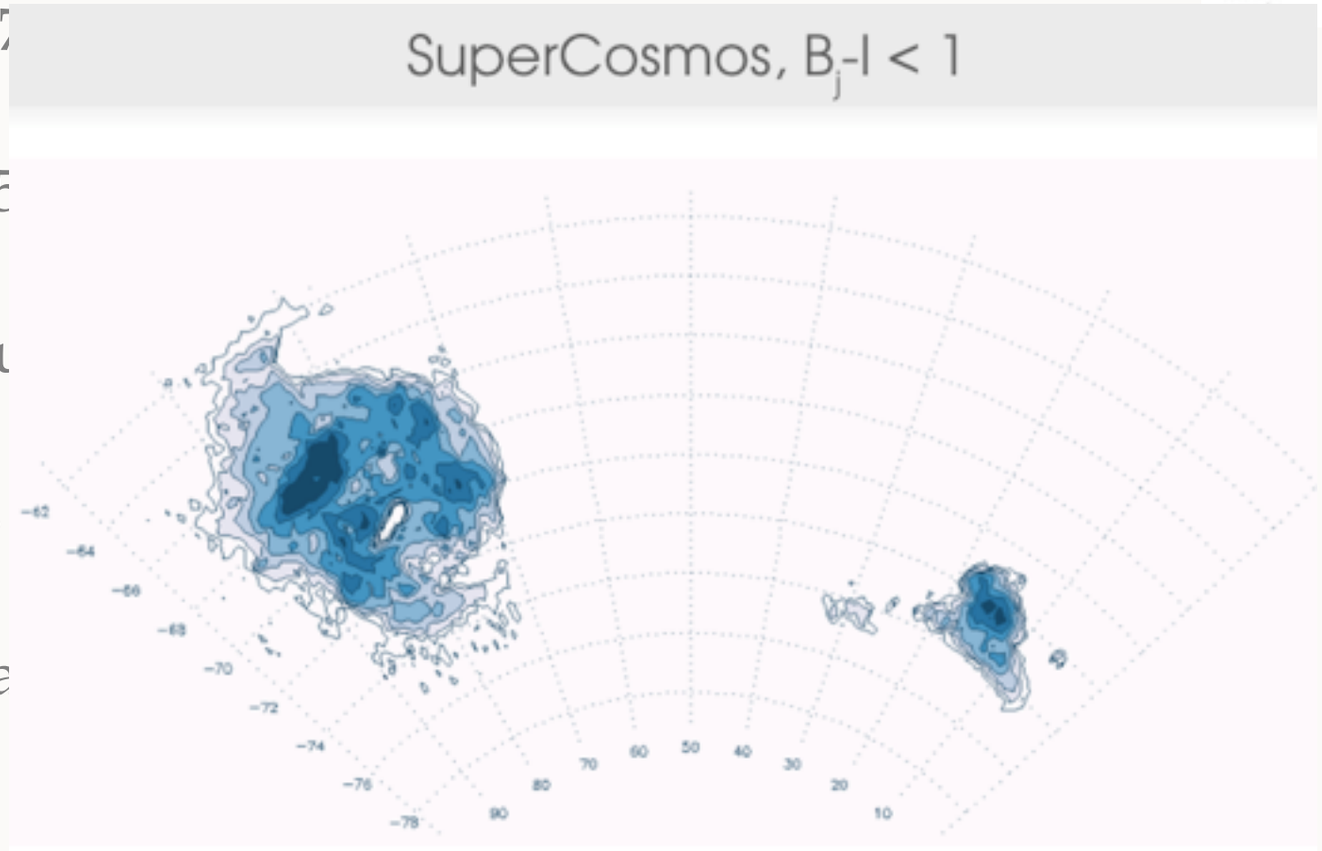


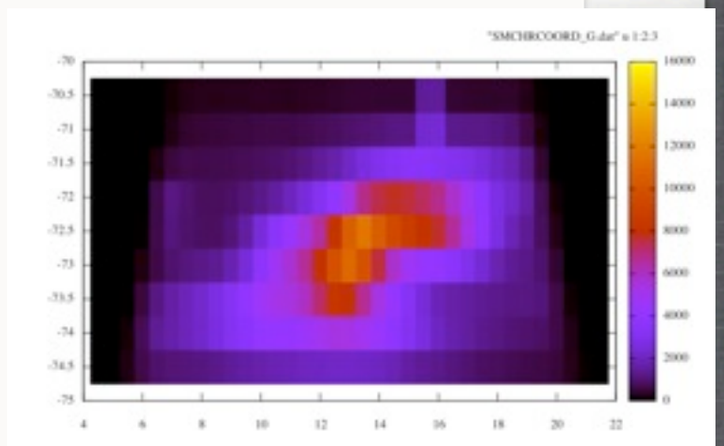


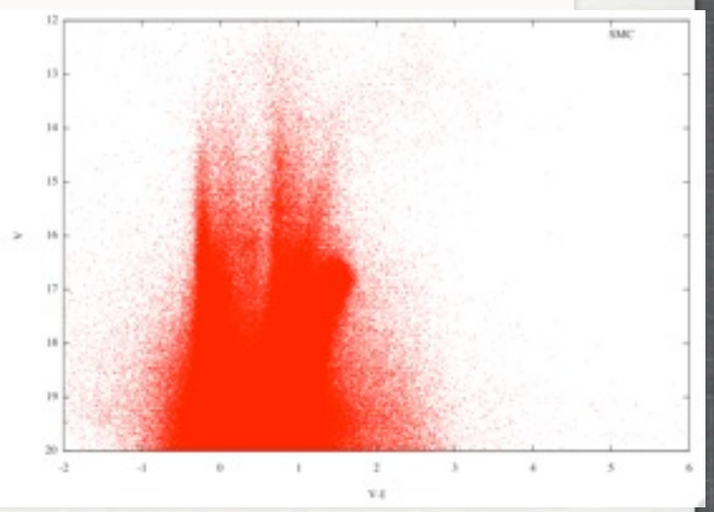
RESOLVED GALAXIES



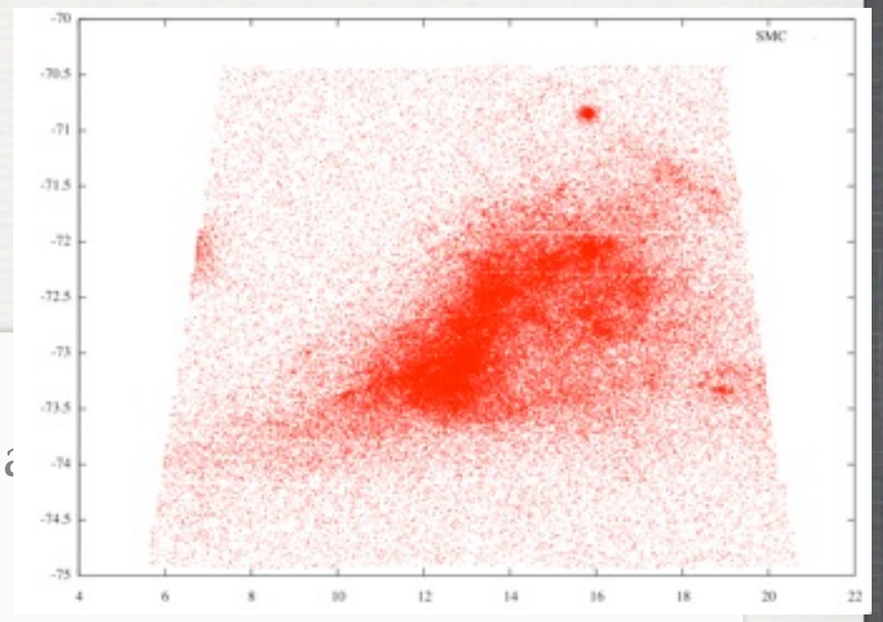
- LMC and SMC implemented (Belcheva, Kontizas, et a
- LMC: 6,7
- SMC: 1,5
- Catalogu
- Binaries
- No varia
- No plan



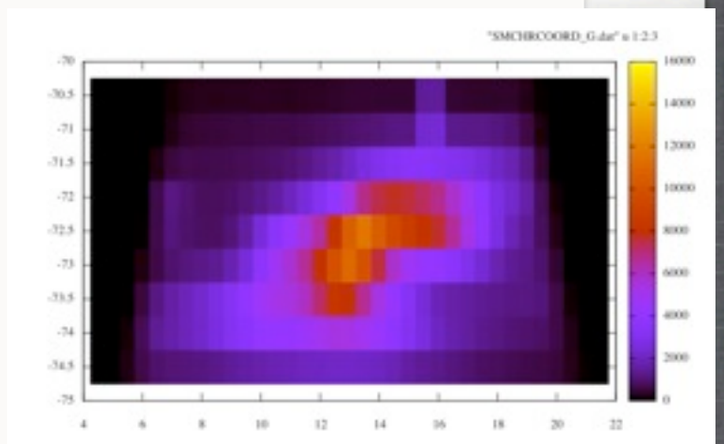


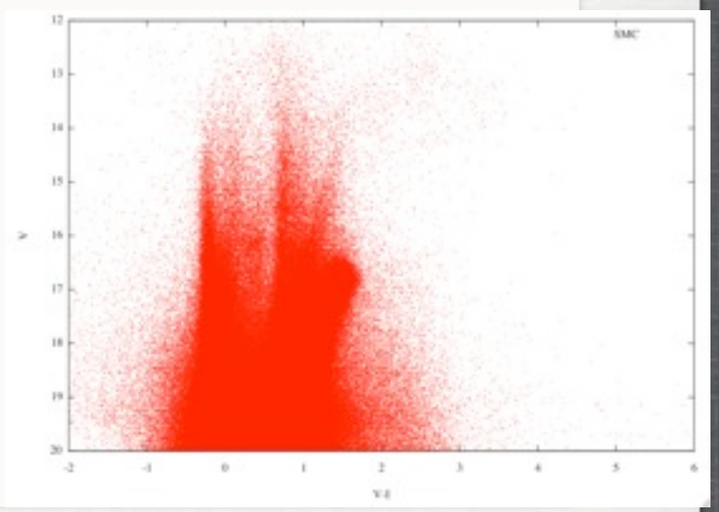


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Parameter	Units	LMC	SMC	Reference
Distance	kpc	48.1	60.6	LMC: 1; SMC: 2
Depth	kpc	0.75	1.48	LMC: 3; SMC: 4
$\mu_\alpha \cos(\delta)$	mas/yr	1.95	0.95	5
μ_δ	mas/yr	0.43	−1.14	5
V_{los}	$km\,s^{-1}$	283	158	6
[Fe/H]	dex	−0.75 ± 0.5	−1.2 ± 0.2	7
[α/Fe]	dex	0.00 ± 0.2	0.00 ± 0.5	7

ferences. (1) Macri et al. (2006); (2) Hilditch et al. (2005); (3) Sakai et al. (2000); (4) Subramanian & Subramaniam (2009); (5) Costa et al. (2009); (6) SIMBAD
S); (7) Kontizas et al. (2011).

UNRESOLVED GALAXIES

(A. KRONE-MARTINS, C. DELLELUCHE, P. GAVRAS, M. KONTIZAS, B. ROCCA-VOLMERANGE, E. LIVANOU, A. KARAMPELAS, V. TSALMANZAS,I. BELLAS-VELIDIS, A. DAPERGOLAS)

- Galaxies: sky distribution following Skymaker and Stuff (Bertin et al.)
- Generation of images of galaxies : 2 options
  - Image library from HST rescaled to Gaia (MAGIL)
  - SkyMaker shapes (bulge+disc) : default option
- Spectra from Pegase.2 library

Random apparent bulge flattening as a function of cos(inclination) (Sandage et al. 1970)

(random) disk scale-size (in m) as a function of the absolute magnitude (de Jong & Lacey 1998)

include: internal and external extinction

Apparent B/T from approximate SEDs

Luminosity	Schecter function	parameters	Fioc & Rocca-Volmerange,	
			1999, AA, 344,393	
Galaxy types	Φ*	M* absolute	alpha	bt (bulge/total)**
	Mpc-3	magnitude (bj)		
E2	1.91e-3	-20.02	-1.	1.0
E-SO	1.91e-3	-20.02	-1.	0.9
Sa	2.18e-3	-19.62	-1.	0.57
Sb	2.18e-3	-19.62	-1.	0.32
Sbc	2.18e-3	-19.62	-1.	0.32
Sc	4.82e-3	-18.86	-1.	0.16
Sd	9.65e-3	-18.86	-1.	0.049
Im	9.65e-3	-18.86	-1.	0.
QSFG	1.03e-2	-16.99	-1.73	0.

LF from Schechter:

$$\phi(M)dM = \phi^* exp(0.92(\alpha+1)(M^*-M) - exp(0.92(M^*-M)))dM$$

GALAXY SPECTRAL LIBRARY

Created from PEGASE.2
(www.iap.fr/pegase)

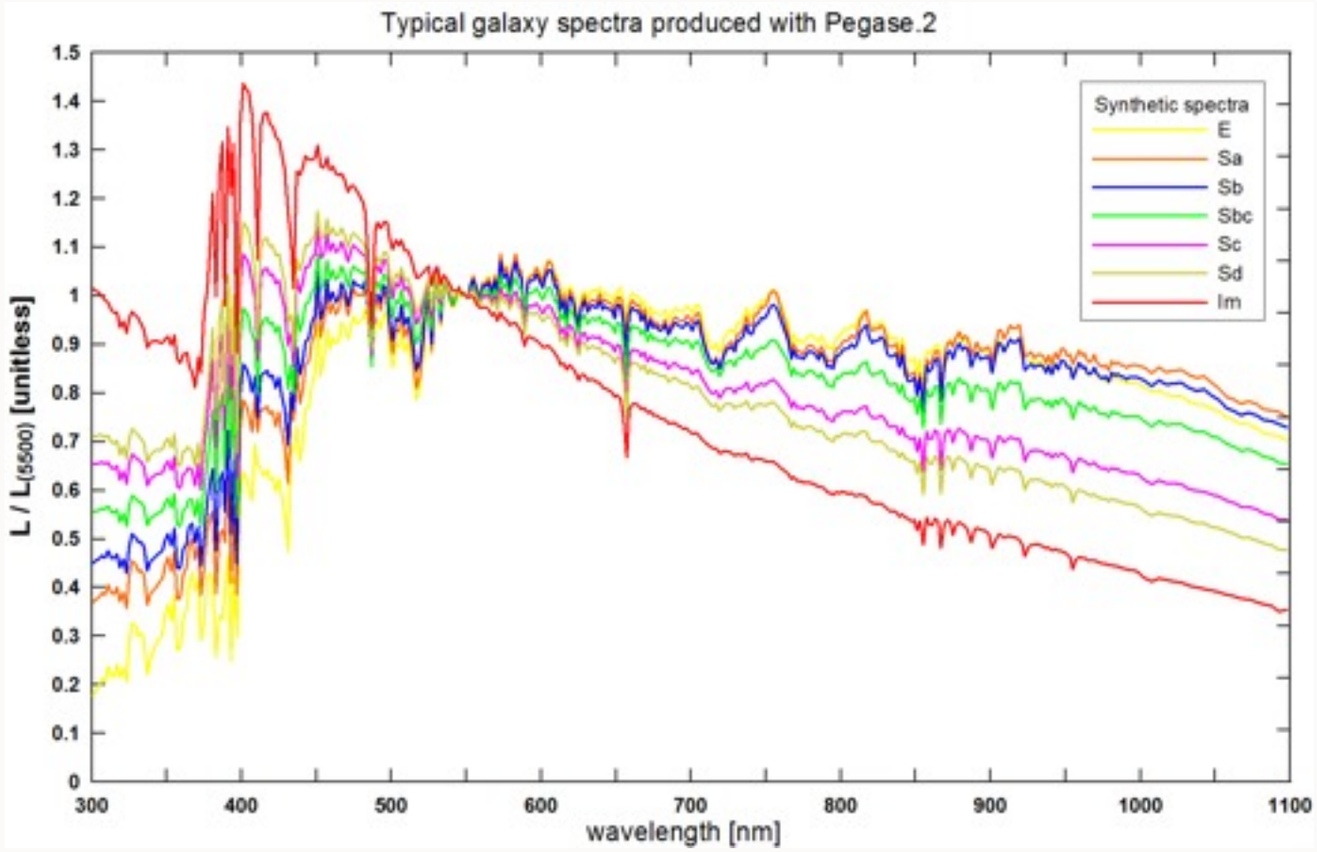
1 E2 red Elliptical
2 E_SO normal Elliptical or S0
3 Sa
4 Sb
5 Sbc
6 Sc
7 Sd
8 Im Irregular magellanic
9 QSFG Quenched star forming galaxy

Values of inclination (degrees): 0.00, 22.5, 45.0, 67.5, 90.0
Values of redshifts : 0.00, 0.02, 0.04, 0.06, 0.08, 0.10, 0.12, 0.14, 0.16, 0.18, 0.20

GALAXY SPECTRAL LIBRARY

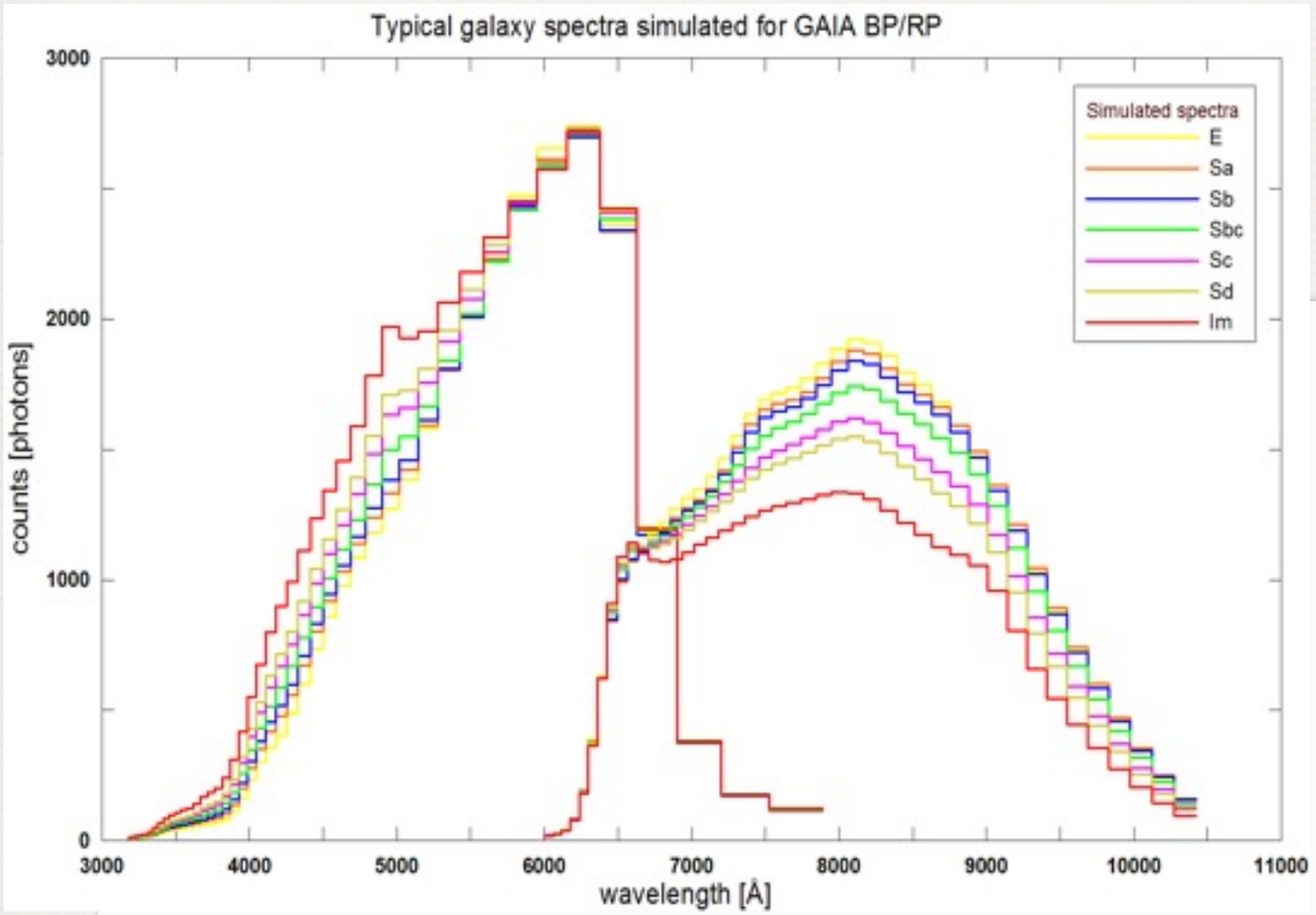
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1 E2 red Elliptical
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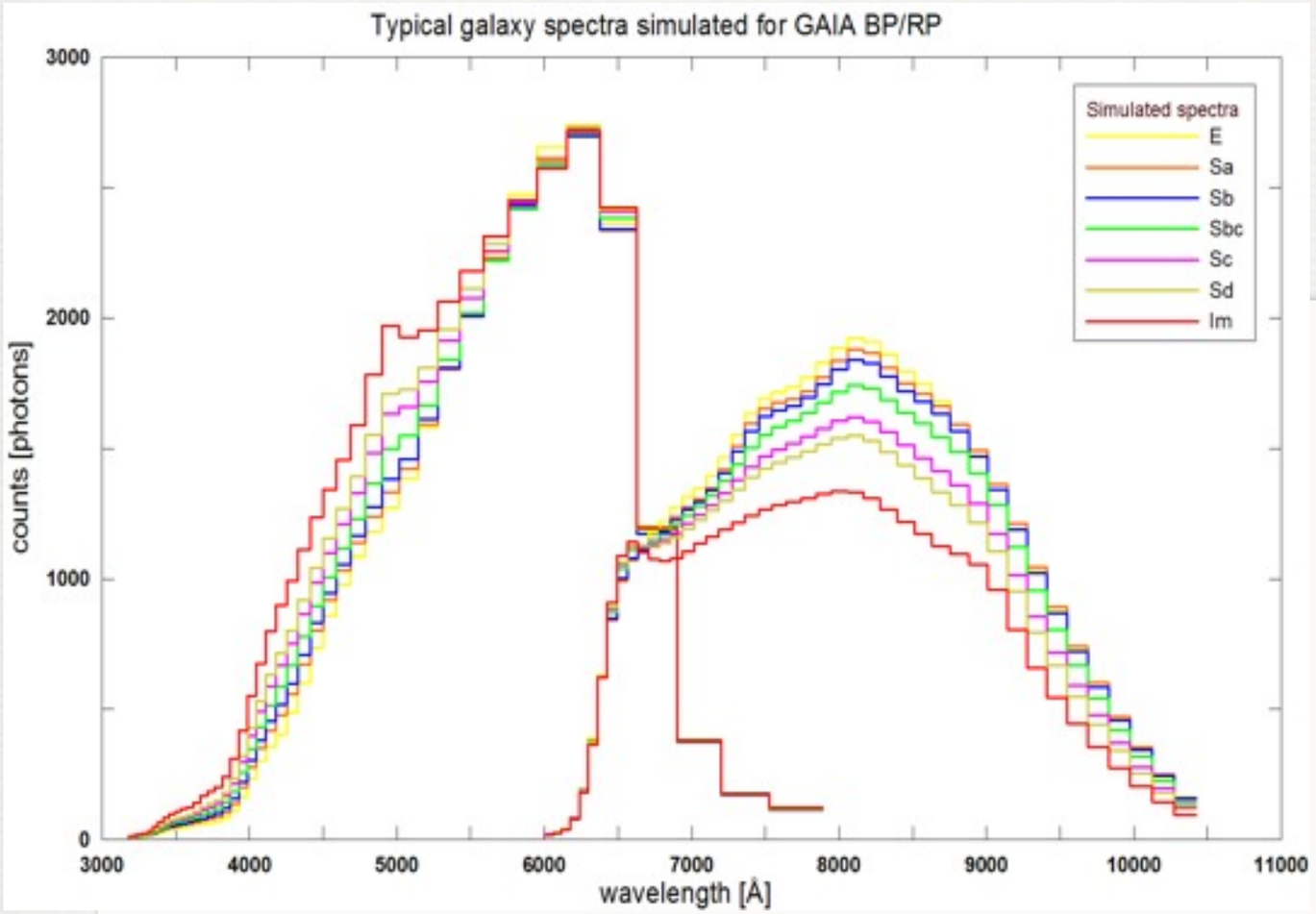
Courtesy M. Kontizas

Values of inclination (degrees): 0.00, 22.5, 45.0, 67.5, 90.0
Values of redshifts : 0.00, 0.02, 0.04, 0.06, 0.08, 0.10, 0.12, 0.14, 0.16, 0.18, 0.20

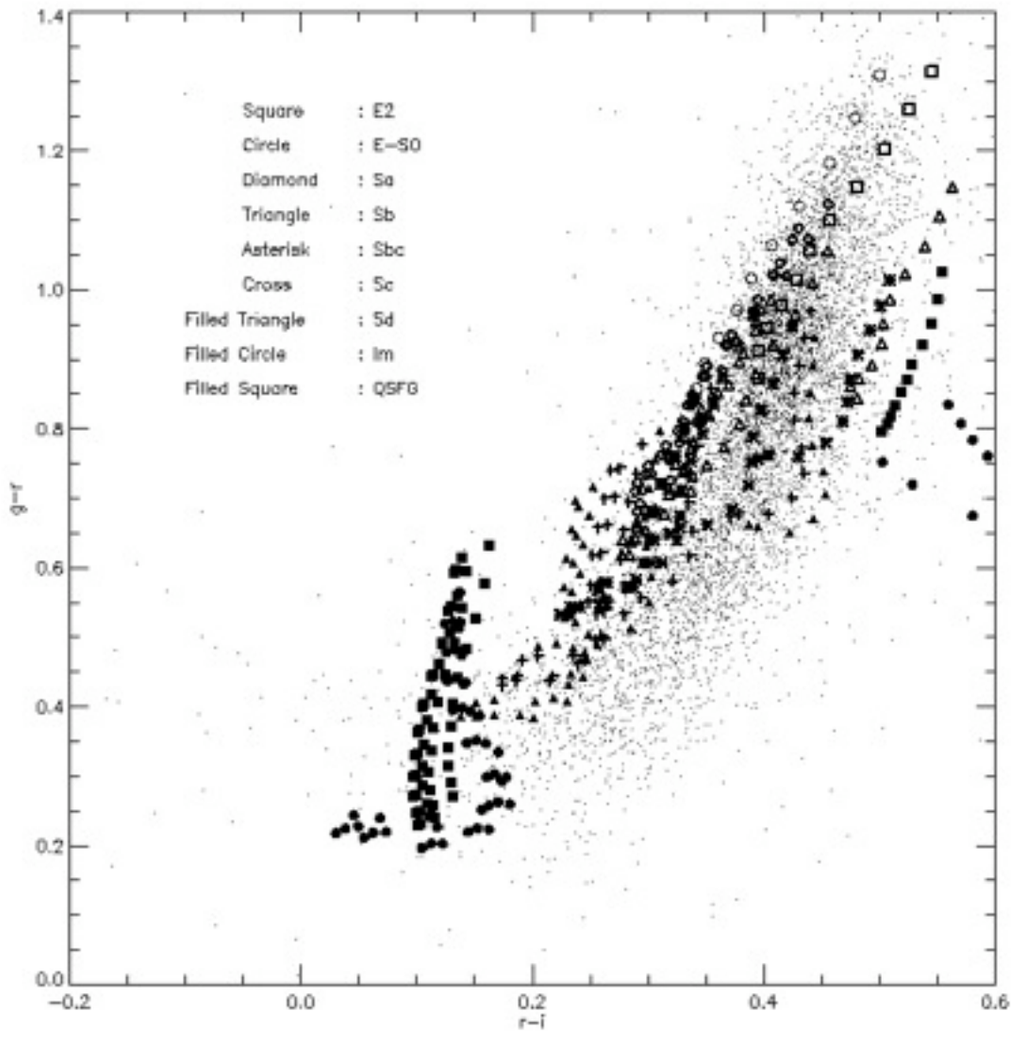


Courtesy M. Kontizas

Simulated galaxies / SDSS



Courtesy M. Kontizas

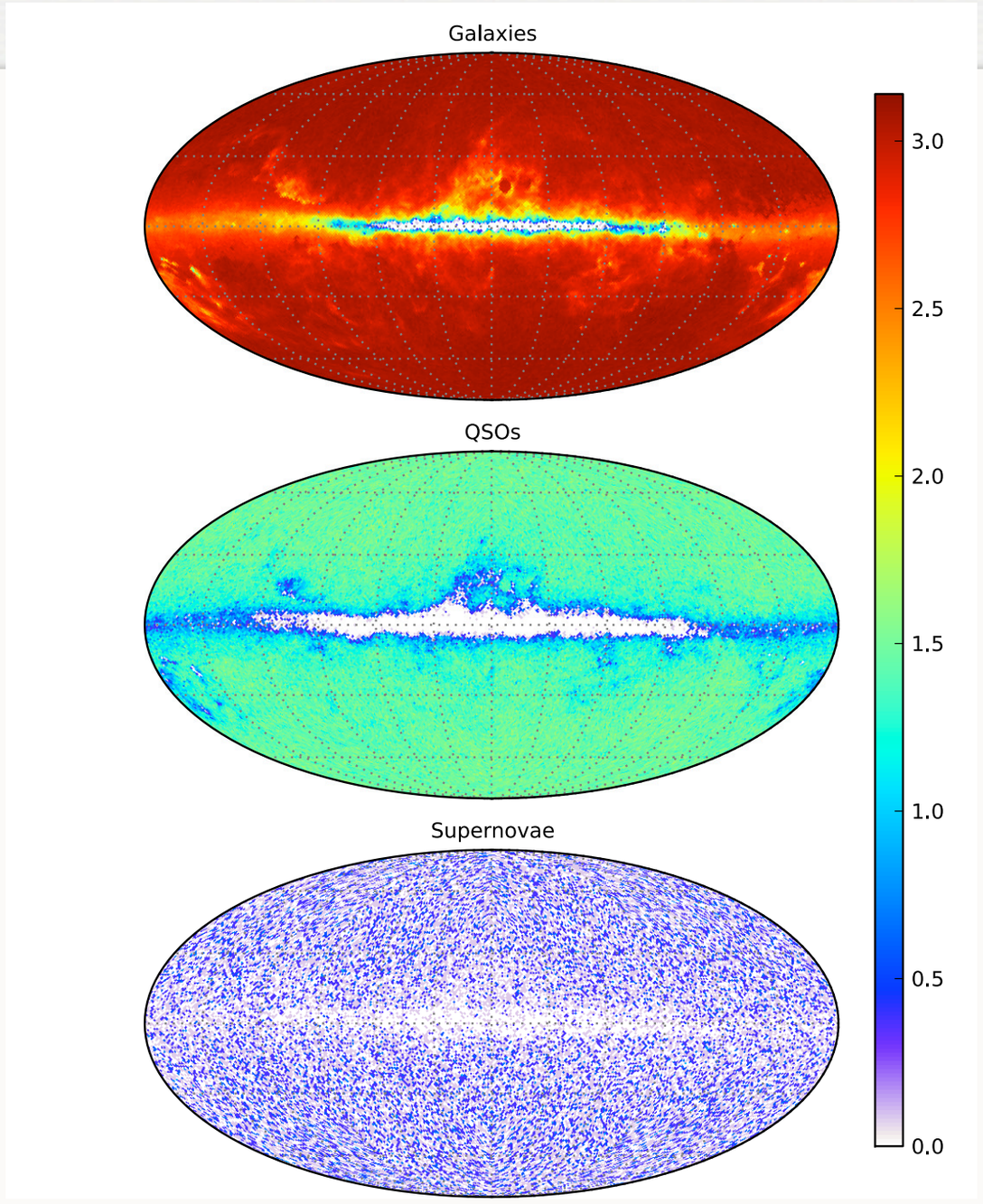


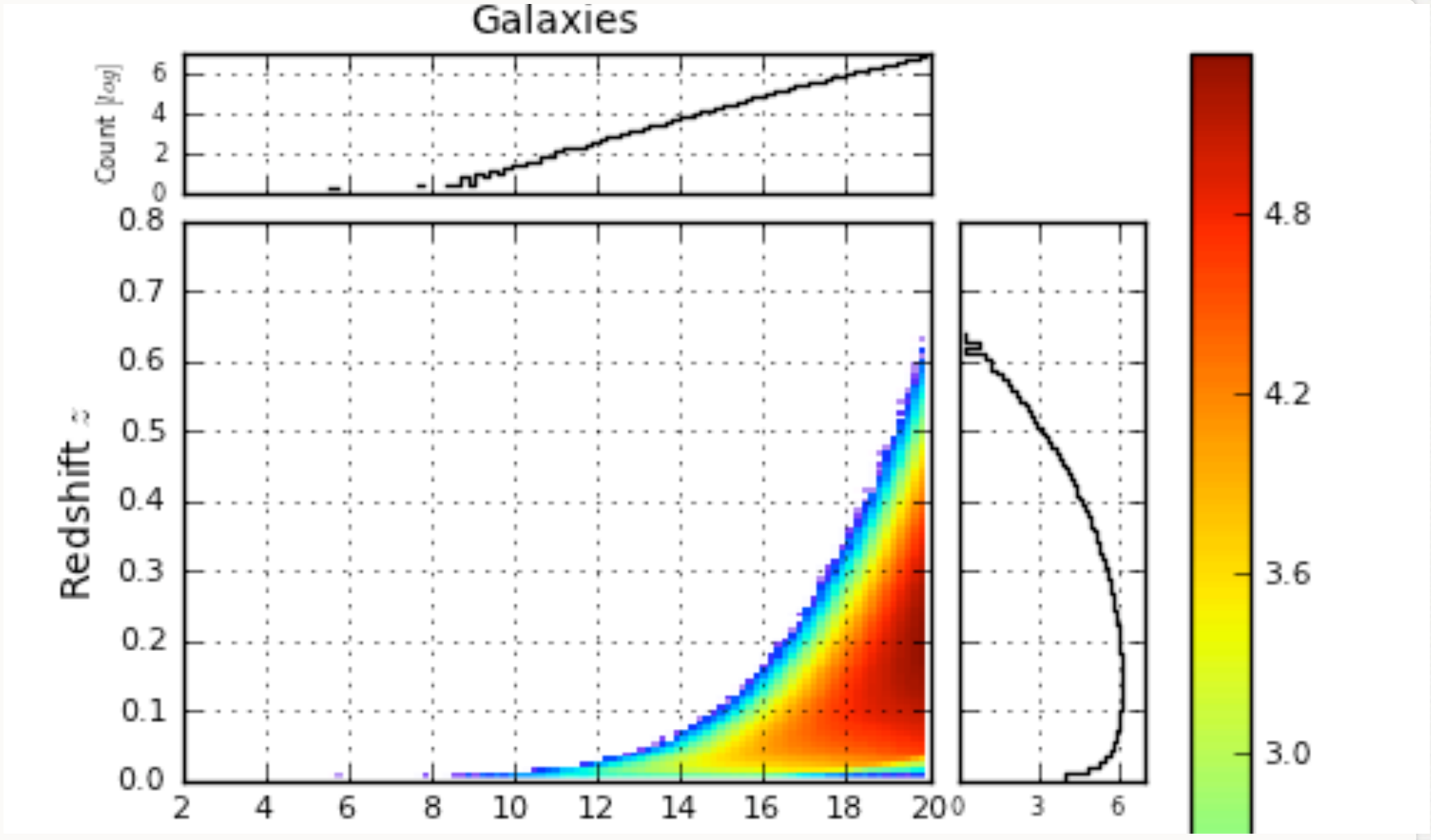
NUMBERS OF GALAXIES IN GAIA

Galaxies	G < 20 mag	G_{rvs} < 17 mag	G_{rvs} < 12 mag
E2	6.36%	10.24%	10.51%
E-S0	7.03%	11.67%	12.85%
Sa	7.51%	10.55%	10.05%
Sb	9.21%	12.39%	13.70%
Sc	10.21%	8.50%	8.08%
Sd	22.08%	17.08%	15.00%
Sbc	9.21%	12.35%	13.73%
Im	24.77%	15.46%	14.44%
QSFG	3.61%	1.76%	1.64%

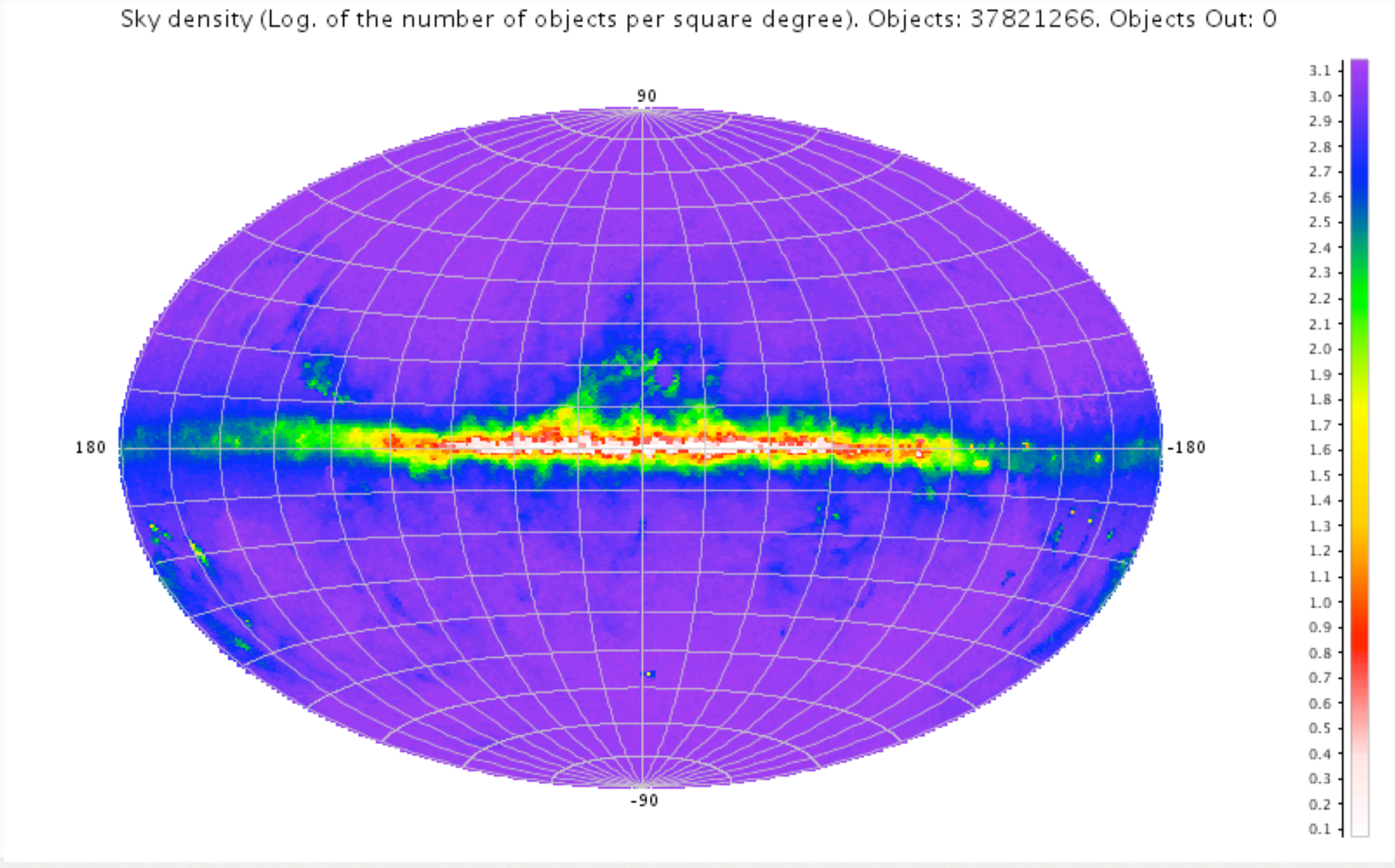
Nota : not all detectable/observables !

DISTRIBUTION ON SKY

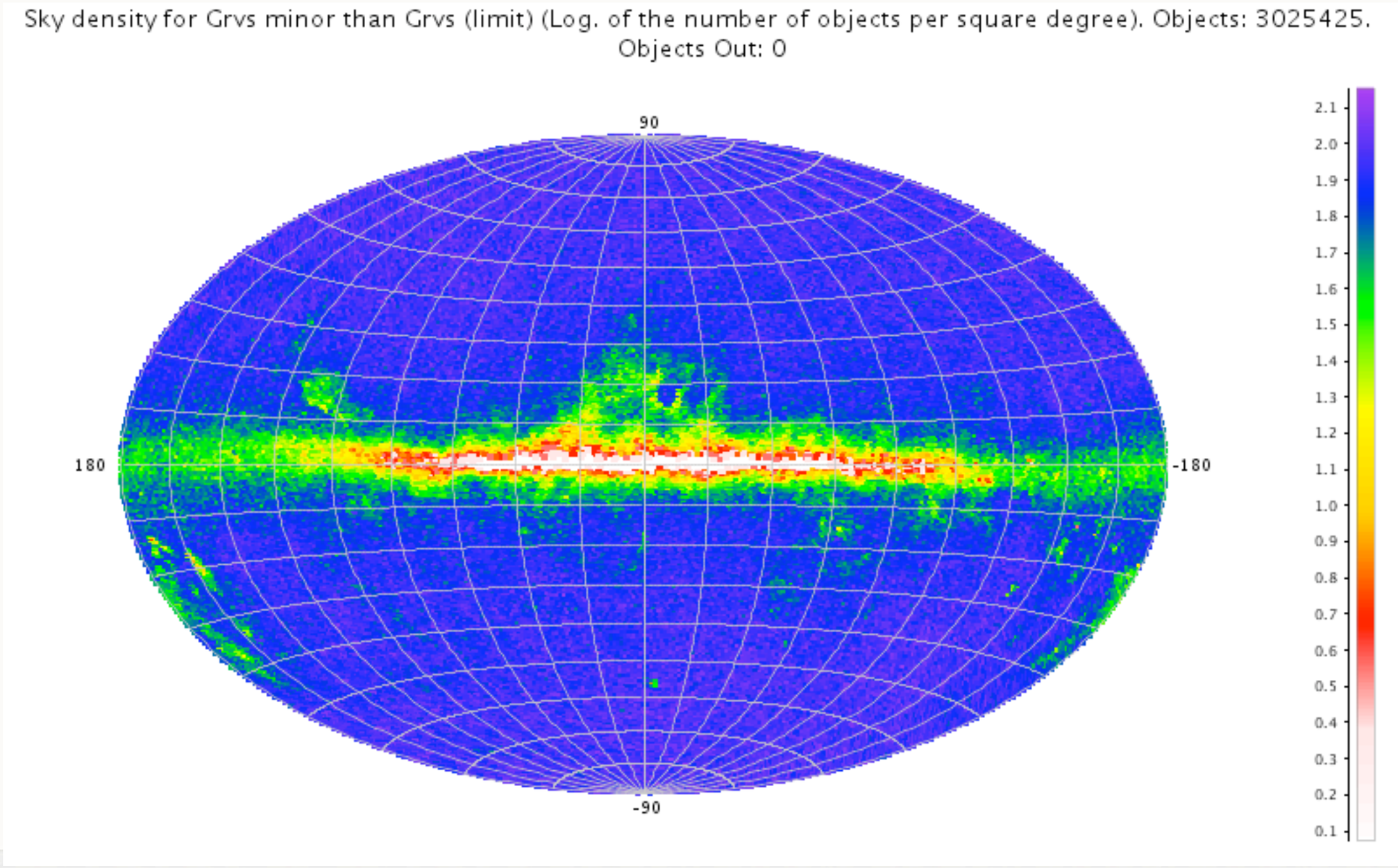



Galaxies
Count [log]
6
4
2
0
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Redshift z
2
4
6
8
10
12
14
16
18
20
0
3
6
4.8
4.2
3.6
3.0

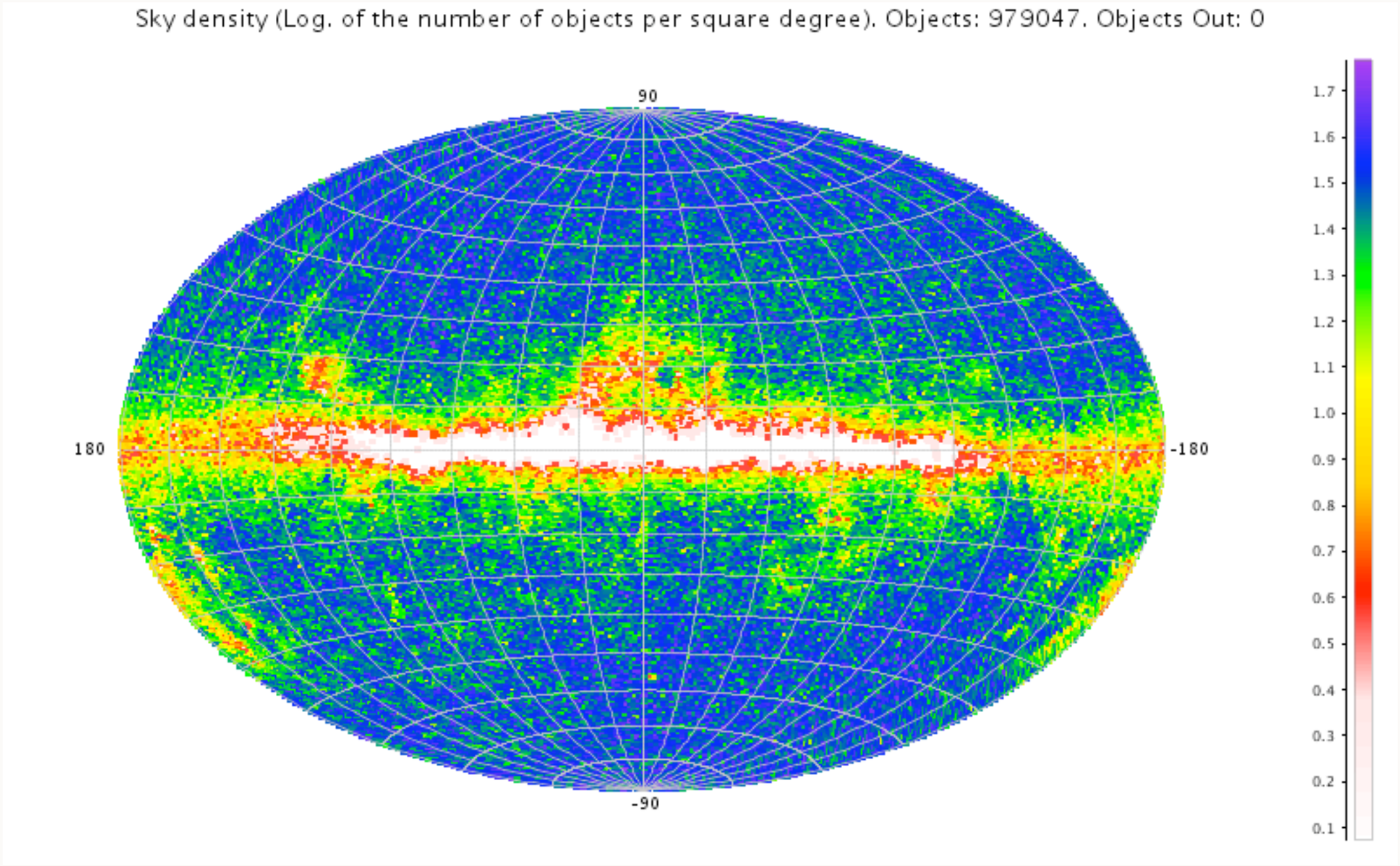
GALAXIES AT G<20



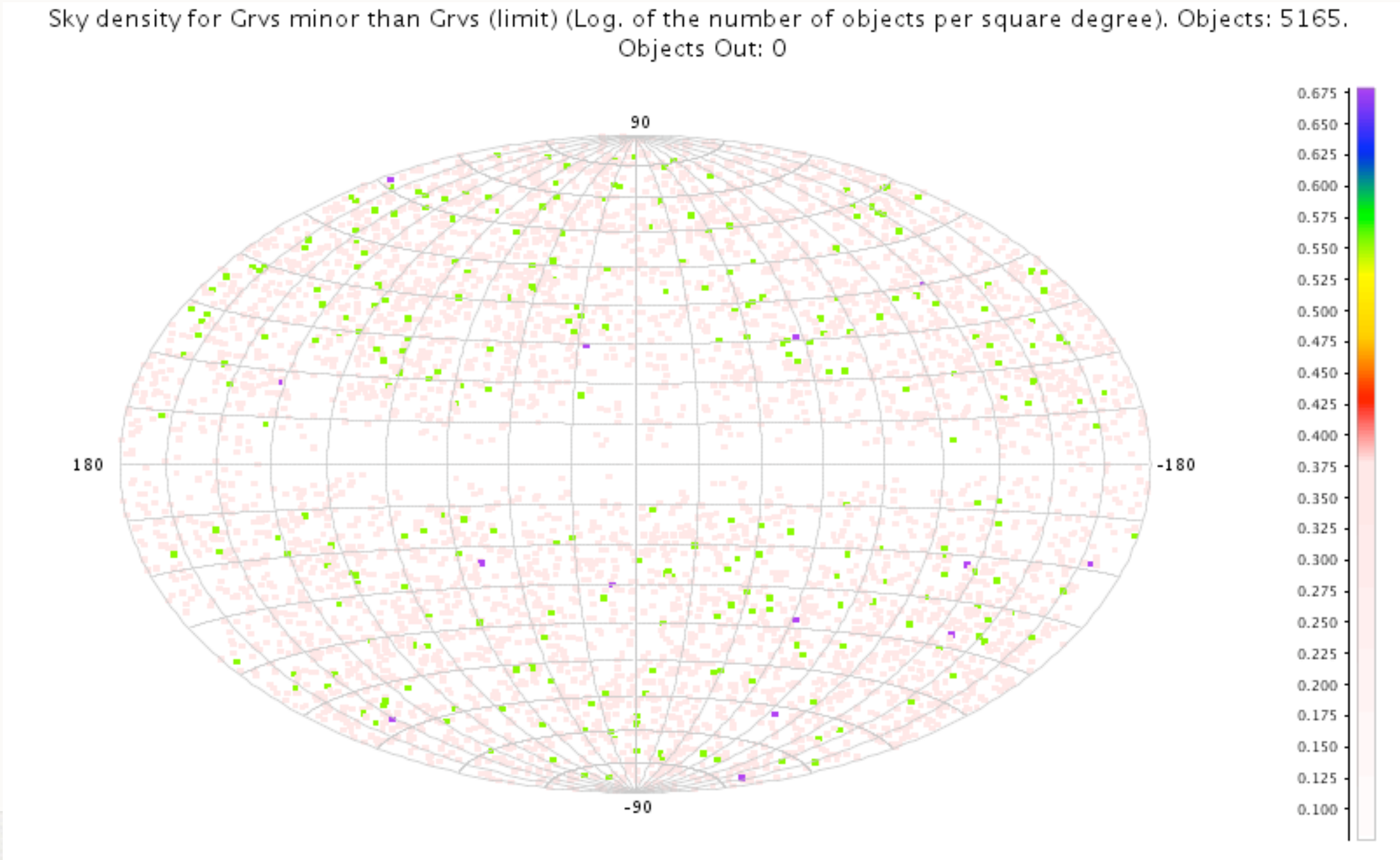
GALAXIES AT G<17.

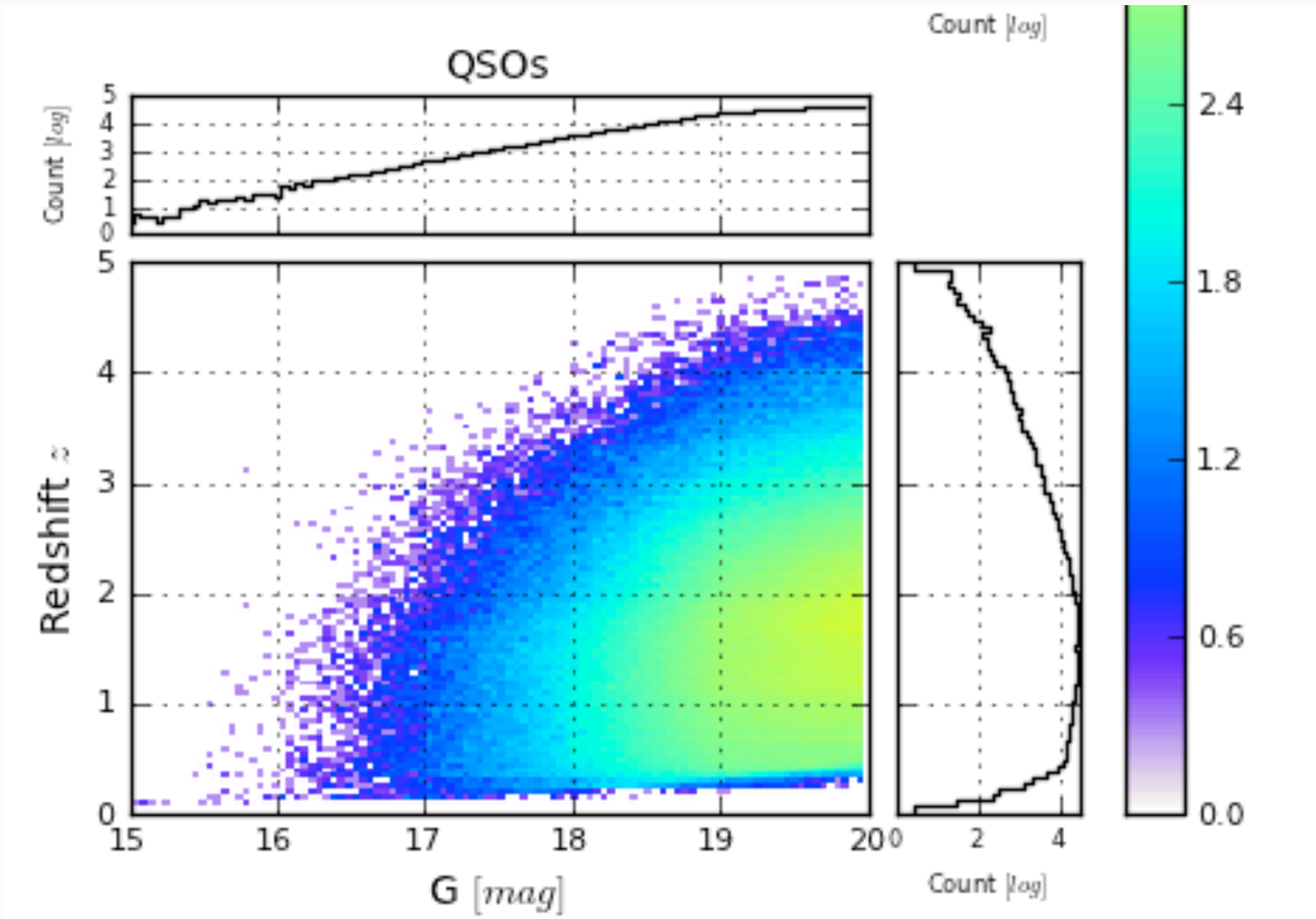


QSOS G<20


Sky density (Log. of the number of objects per square degree). Objects: 979047. Objects Out: 0
90
180
-180
-90
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1

QSO G<17 (RVS LIMIT)




QSOs
Count [log]
Redshift z
G [mag]
Count [log]
Count [log]
2.4
1.8
1.2
0.6
0.0

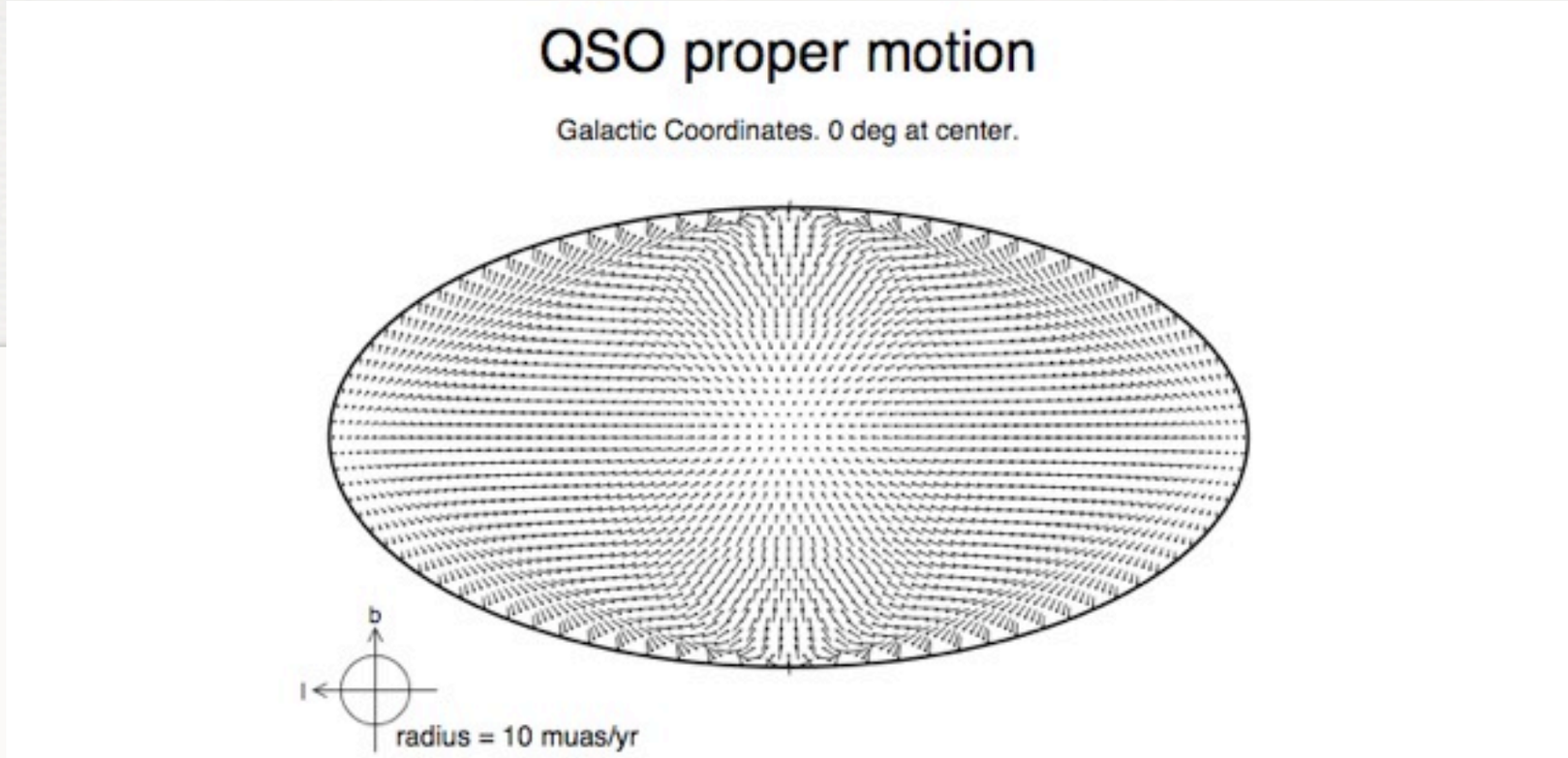


Figure 22: The regular QSO proper motion field resulting from the accelerated motion of the solar system around the galactic center. The diagram in galactic coordinates shows the systematic stream along the direction of the galactic center.

$$\mu_\alpha \cos\delta = -\frac{\Gamma_x}{c}\sin\alpha + \frac{\Gamma_y}{c}\cos\alpha$$

$$\mu_\delta = -\frac{\Gamma_x}{c}\sin\delta\cos\alpha - \frac{\Gamma_y}{c}\sin\delta\sin\alpha + \frac{\Gamma_z}{c}\cos\delta$$

Centripetal acceleration of the motion of the solar system around the galactic center (*Mignard*)

$\Gamma \simeq v_G{}^2/R$, $\Gamma/c \sim 4$ microarcsec/yr

Catalogue : Positions, Gmag, redshift, p.m., spectrum slope, lines EW

SUPERNOVAE

- 4 SN types: Ia, Ib/c, II-L, II-P

II-L	102
II-P	18
Ia	547
Ib/c	59

- Light curves from Peter Nugen

Galaxy types	SN2 /cen	SN1a/cen
E2	0.	0.05
E-SO	0.	0.05
Sa	0.4	0.11
Sb	0.62	0.13
Sbc	1.07	0.16
Sc	0.62	0.07
Sd	0.65	0.07
Im	0.60	0.05
QSFG	0.	0.05

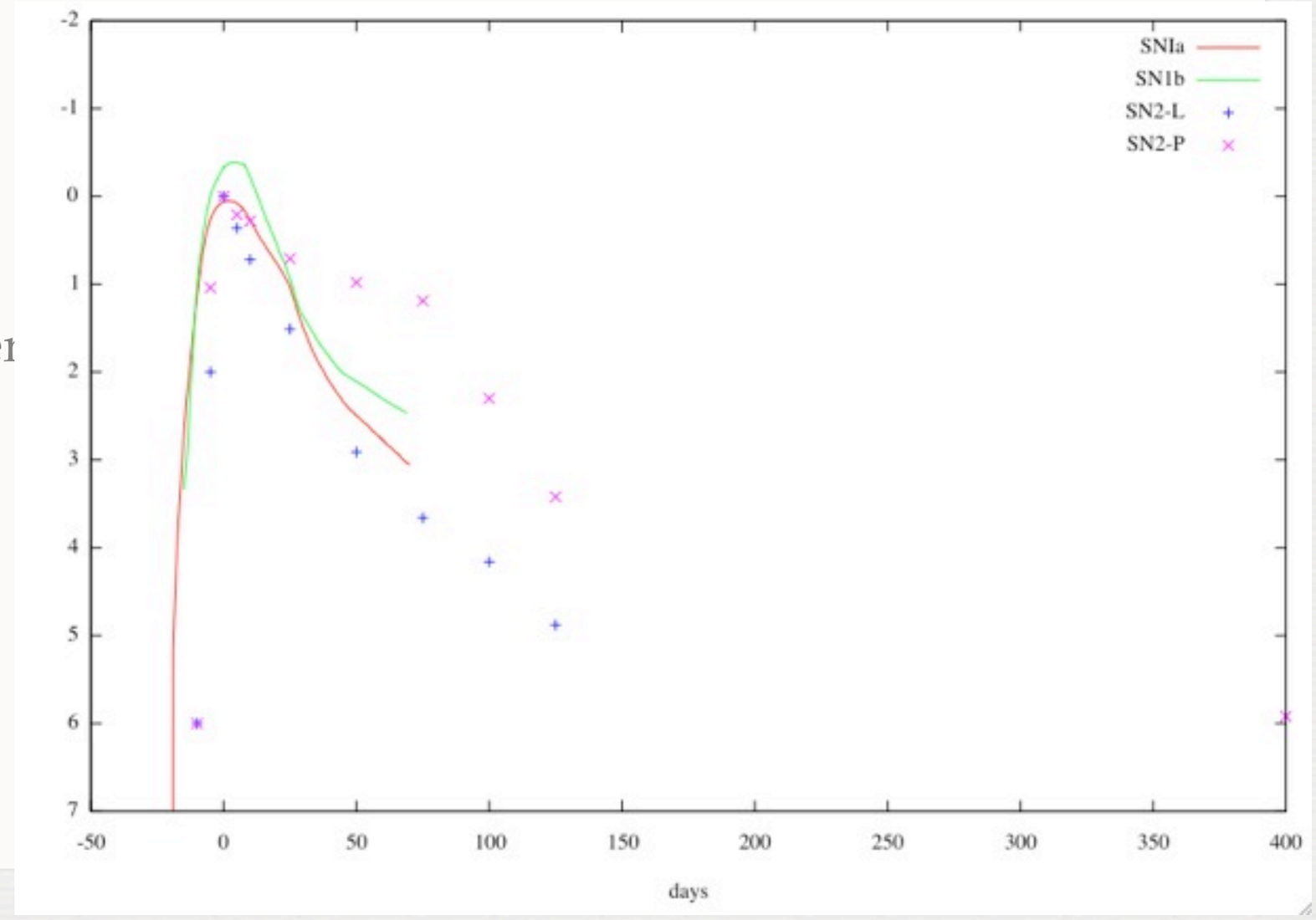
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QSFG	0.	0.05

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Sc	0.62	0.07
Sd	0.65	0.07
Im	0.60	0.05
QSFG	0.	0.05

- Partly generated randomly on the sky
- Partly linked with galaxies

Supernovae characteristics (Belokurov & Evans, 2003)

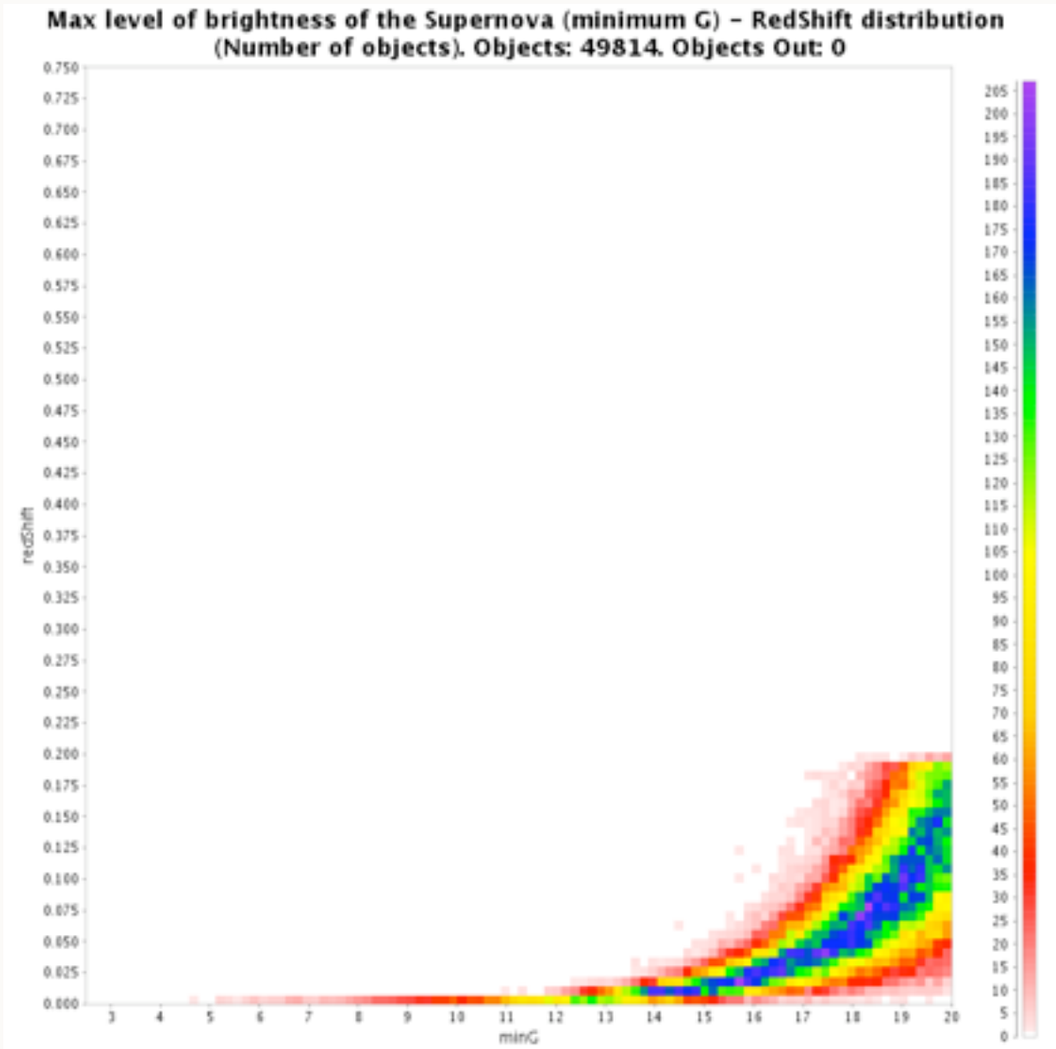
Type	Probability	M_G	Sigma
Ia	0.6663	−18.99	0.76
Ib/Ic	0.0999	−17.75	1.29
II-L	0.1978	−17.63	0.88
II-P	0.0387	−16.44	1.23

Supernovae rate for each Hubble type

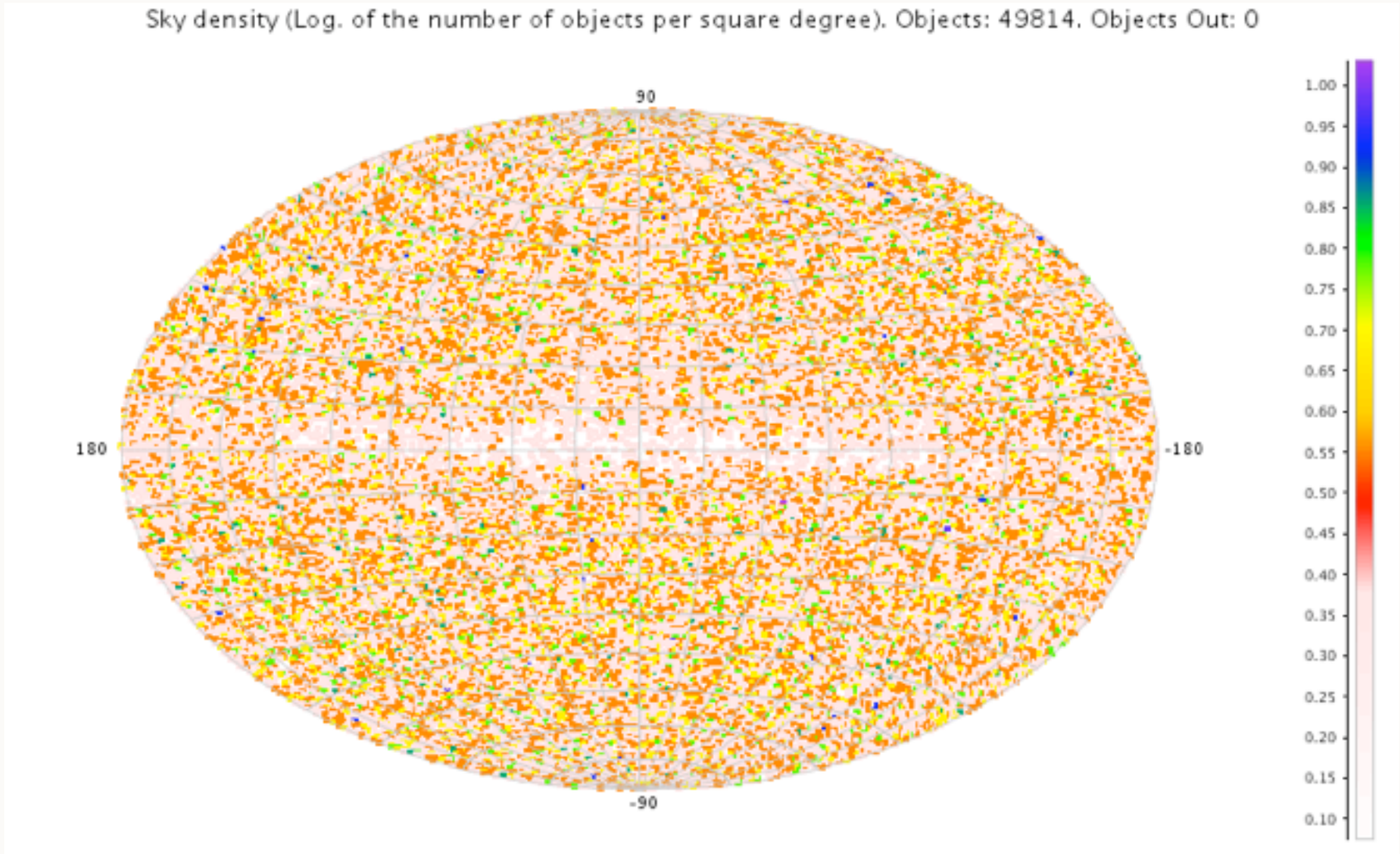
Hubble type	SNII /century	SNI /century
E2	0.0	0.05
E-S0	0.0	0.05
Sa	0.4	0.11
Sb	0.62	0.13
Sbc	1.07	0.16
Sc	0.16	0.07
Sd	0.049	0.07
Im	0.60	0.05
QSFG	0.0	0.05

- Supernovae in Gaia : ~50,000
- SNIa : 77%
- Ib/c : 7%
- II-L : 14%
- II-P : 2%

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SUPERNOVAE SKY DISTRIBUTION



CONCLUSIONS

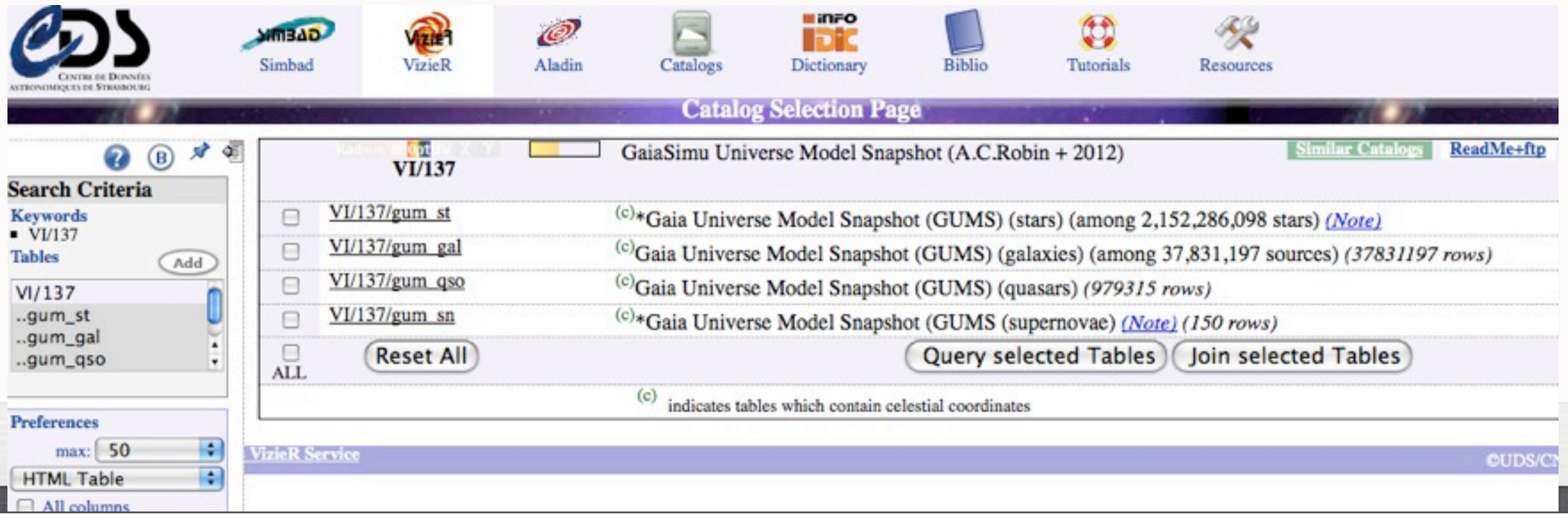
No improvements planned
GUMS available on-line at CDS

A&A 543, A100 (2012)

Gaia Universe model snapshot

A statistical analysis of the expected contents of the *Gaia* catalogue

A. C. Robin[1], X. Luri[2], C. Reylé[1], Y. Isasi[2], E. Grux[1], S. Blanco-Cuaresma[2], F. Arenou[3], C. Babusiaux[3], M. Belcheva[4], R. Drimmel[5], C. Jordi[2], A. Krone-Martins[7], E. Masana[2], J. C. Mauduit[8], F. Mignard[8], N. Mowlavi[6], B. Rocca-Volmerange[9], P. Sartoretti[3], E. Slezak[8] and A. Sozzetti[5]



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	-	-