Simulating the Galaxy and applications to the preparation of the Gaia mission

A.C. Robin, C. Reylé
Collaborators : D. Marshall, M. Schultheis, M. Czekaj
E. Amores, et al.
and CU2, DPAC consortium

Gaia Universe Model

- Generate sources visible by Gaia or which will perturbe measurements and observable characteristics

- Provide realistic distribution on the sky of these sources in order to test detection/classification/reduction/analysis algorithms => provide fake data as realistic as possible

- "Realism" : depends on the present knowledge, and on the computation capability (Mare Nostrum, web access). Evolving.

Stellar content of the Milky Way

- Besançon Galaxy model : 4 populations
  - Disc : SFR constant, IMF 3 pentes (Haywood et al 1997)
  - Thick Disc : 700 pc, 4.6%, 10 Gyr, -0.7 dex (Reylé & Robin, 2002)
  - Spheroid : 12 Gyr, -1.5 dex (Robin et al 2000)
  - Bulge : 10 Gyr, 0 dex (Picaud & Robin 2005)
  - Simple stars.
  - Density laws => Star Generation (Mv, Tsp, Age, Masse, Teff, log g, [Fe/H], [α/H])

- Binaries (F. Arenou) : Generation of multiple components as a function of primary characteristics. Random drawing following a m2/m1 distribution and separations. Photometric, astrometric, spectroscopic corrections, eclipses, from orbites of components (up to 3)

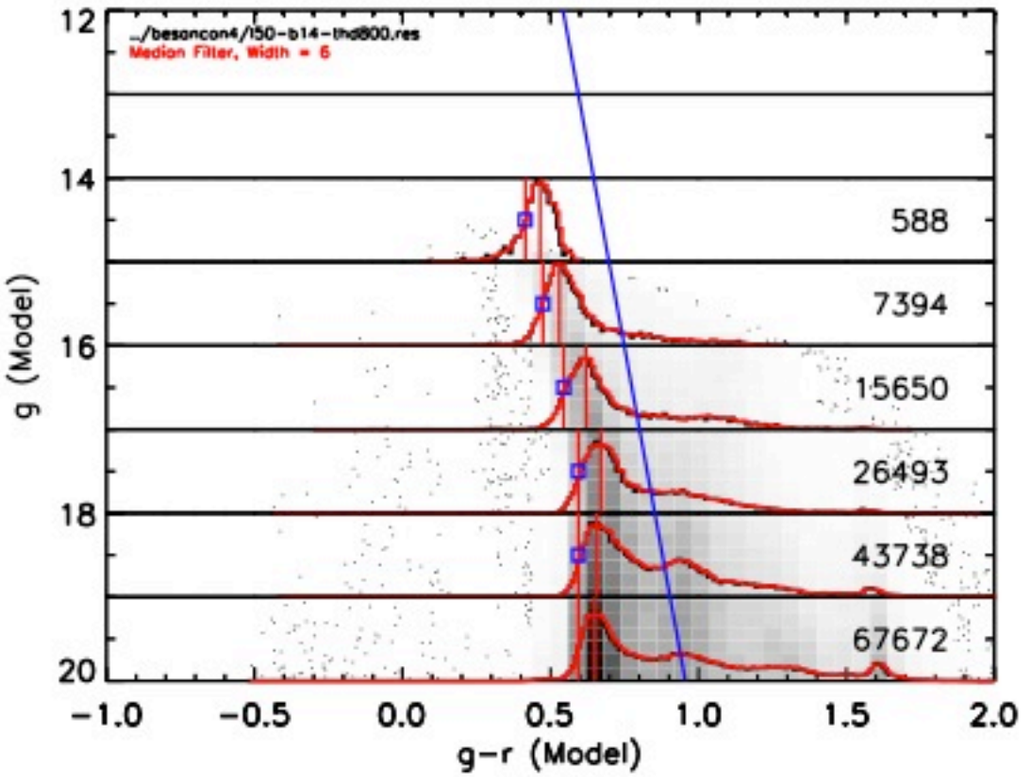
- Exoplanetes (A. Sozzetti)

- Variabilities (12 types of variables)

New improvements on BGM

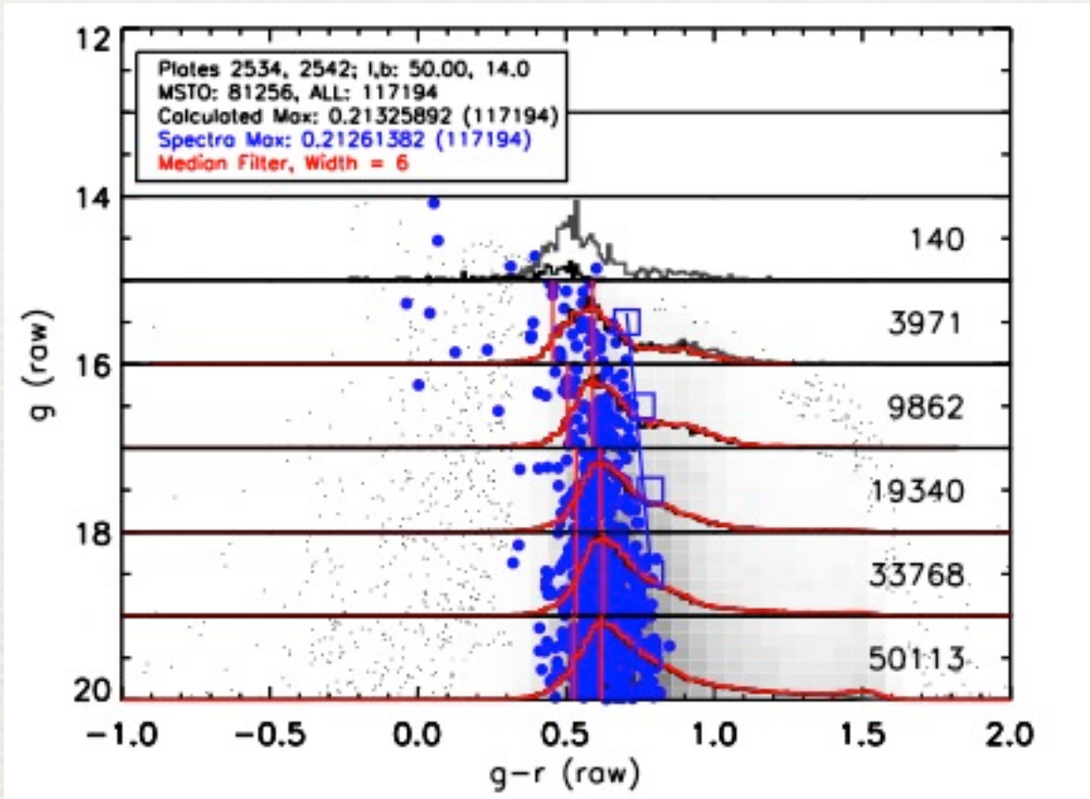
- New thick disc local density and scale height, from SEGUE data
- Warp and flare (from 2MASS)
- Bulge/bar region (from 2MASS)

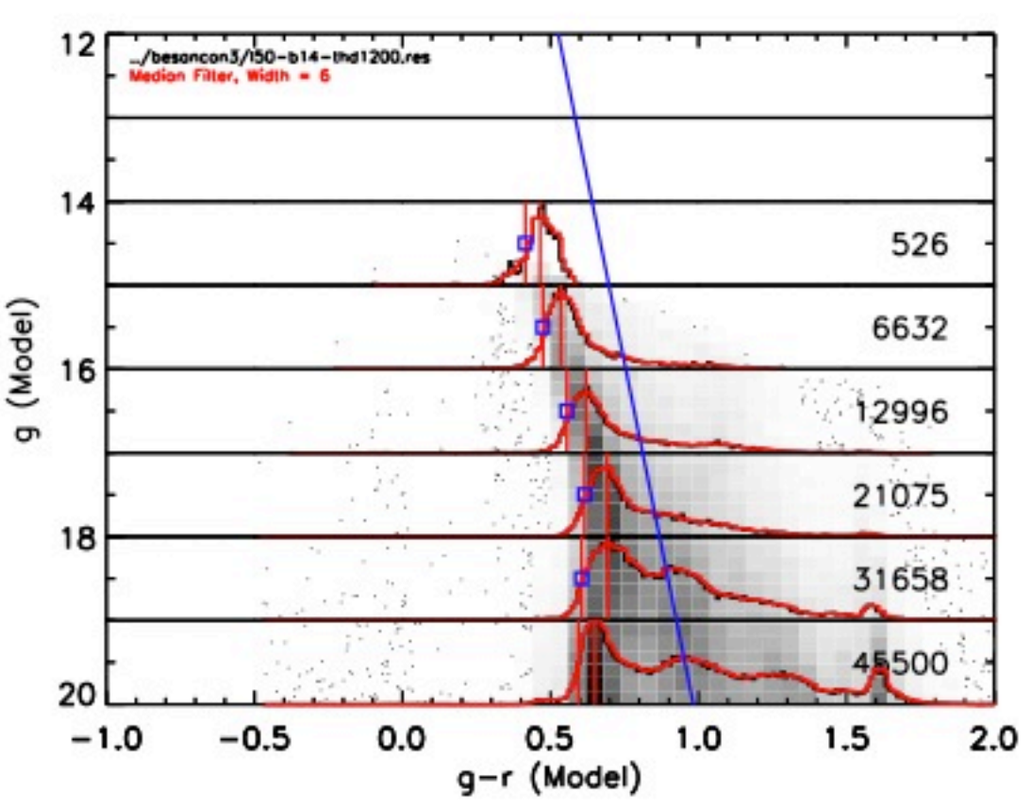
l=50° b=14°



Model thick disc hz=800 pc normalisation 4.6%

SEGUE Data





Model thick disc hz=1200 pc normalisation 2%

Bulge/bar region

New fit to 2MASS (Work in progress)

Attempt to fit the bulge region

200 fields
-20<l<20°
-10<b<10°

K/J-K star counts
K<12 (or completeness limit)

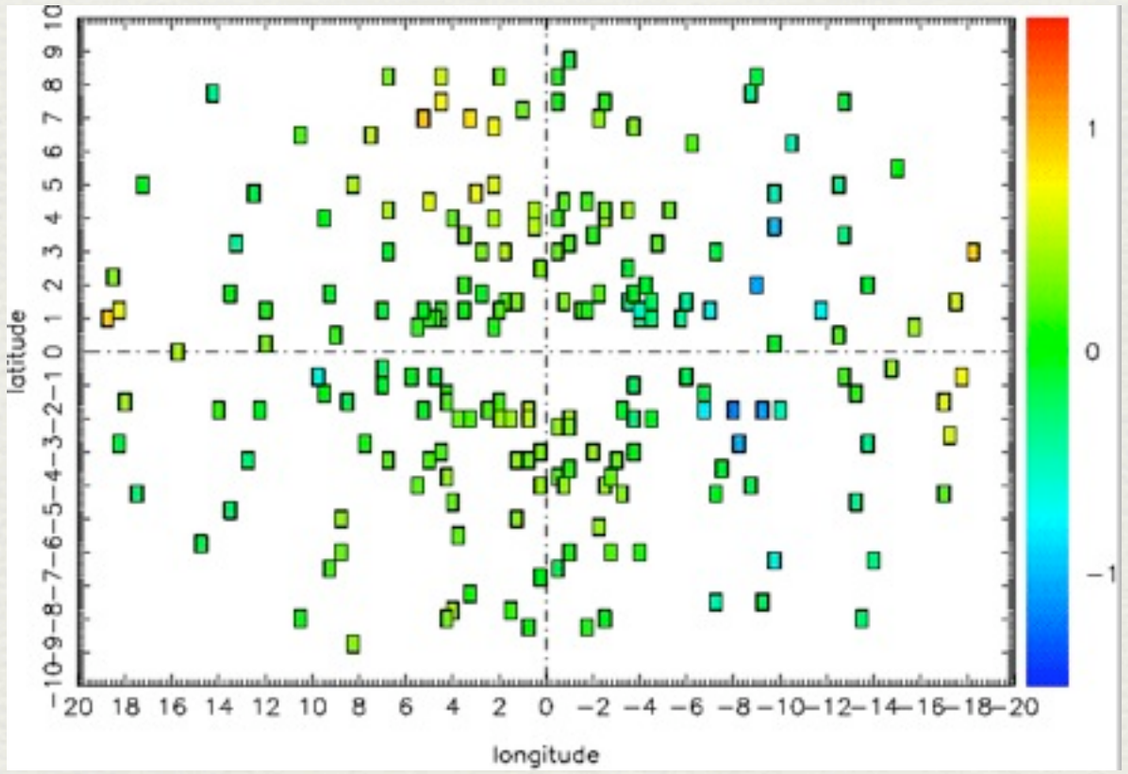
New BGM model: new bulge region fit with 2 structures (Robin et al in prep)

No good fit with 1 simple function (Freudenreich) :

$$R_{\perp}^{C_{\perp}} = \left(\frac{|X'|}{a_x}\right)^{C_{\perp}} + \left(\frac{|Y'|}{a_y}\right)^{C_{\perp}},$$

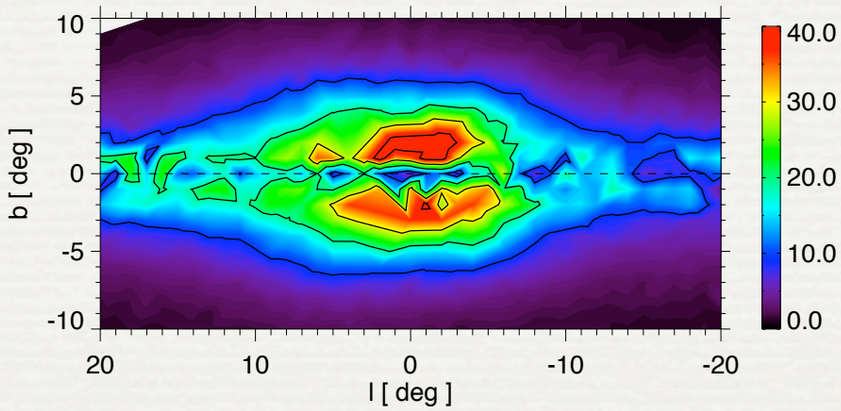
$$R_s^{C_{\parallel}} = R_{\perp}^{C_{\parallel}} + \left(\frac{|Z'|}{a_z}\right)^{C_{\parallel}}.$$

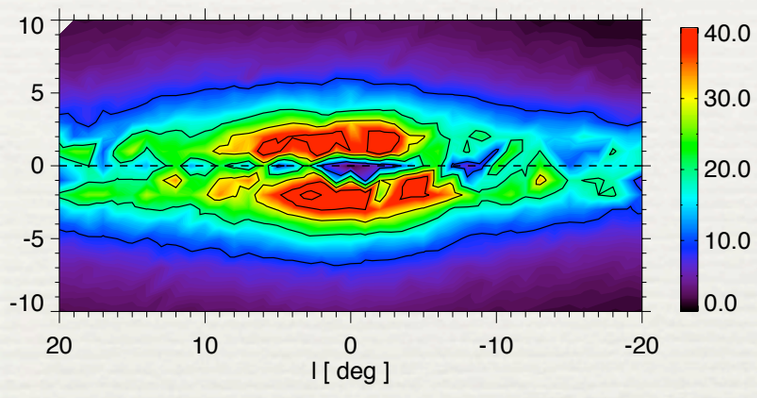
$$\rho \propto \mathrm{sech}^2\,(R_s)$$

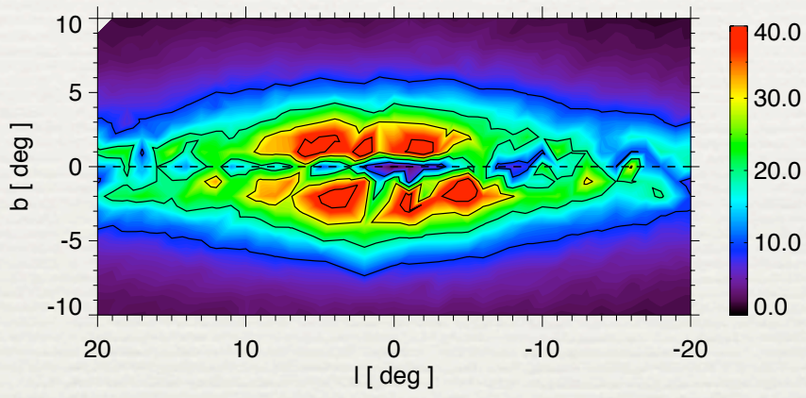


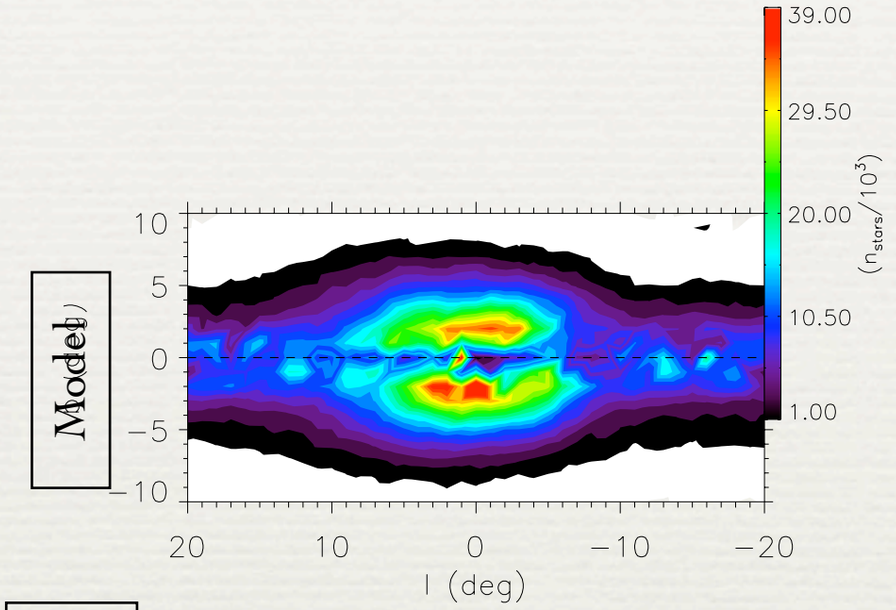
Carte des résidus

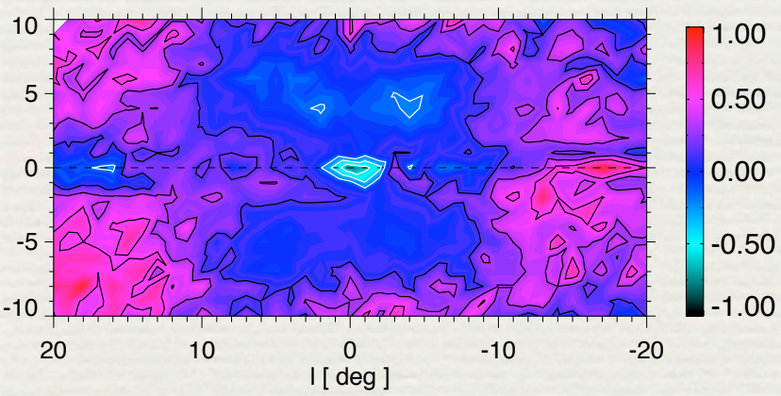
Data =>

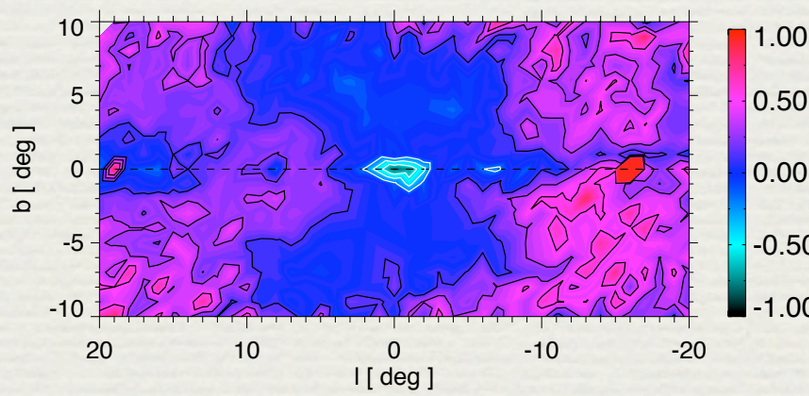


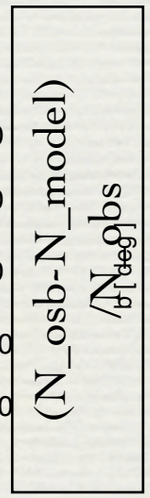


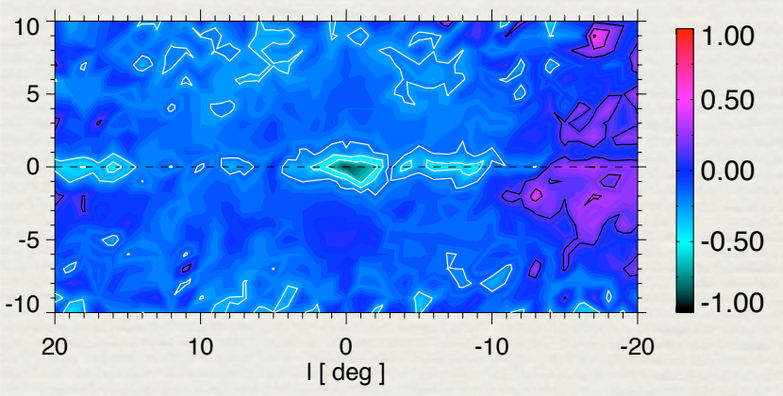












1 structure

2 structures

2 ellipsoids for
same structure, cut at 3 kpc

Φ	5.9°	18.1 / 1.8° (G + G)	12°
x0	3.17 kpc	2.9 kpc / 4.19 kpc	1.43/4.09
y0	0.62 kpc	0.87 kpc / 0.46 kpc	0.47/1.37
z0	0.38 kpc	0.42 / 0.28	0.39 / 1.41

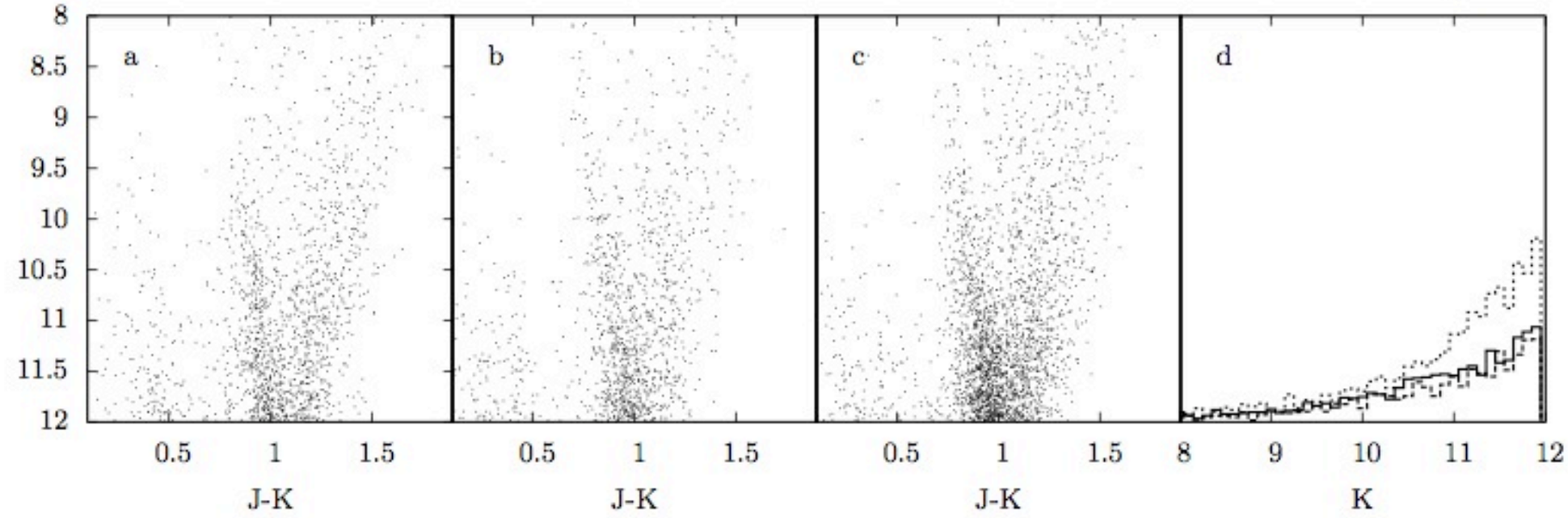
Data

New model
2 ellipsoids

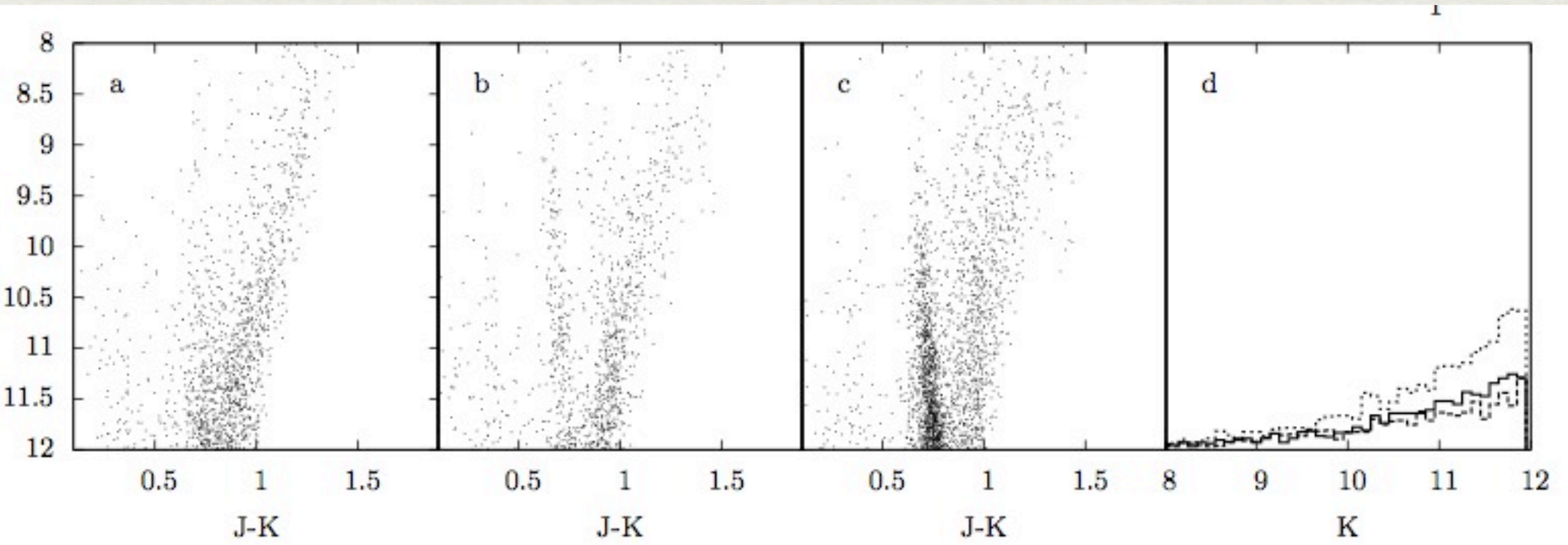
model
1 ellipsoid

__ Data
-- 2 ellipsoids
.... 1 ellipsoid

L=17
B=-4.25



L=0
B=-8



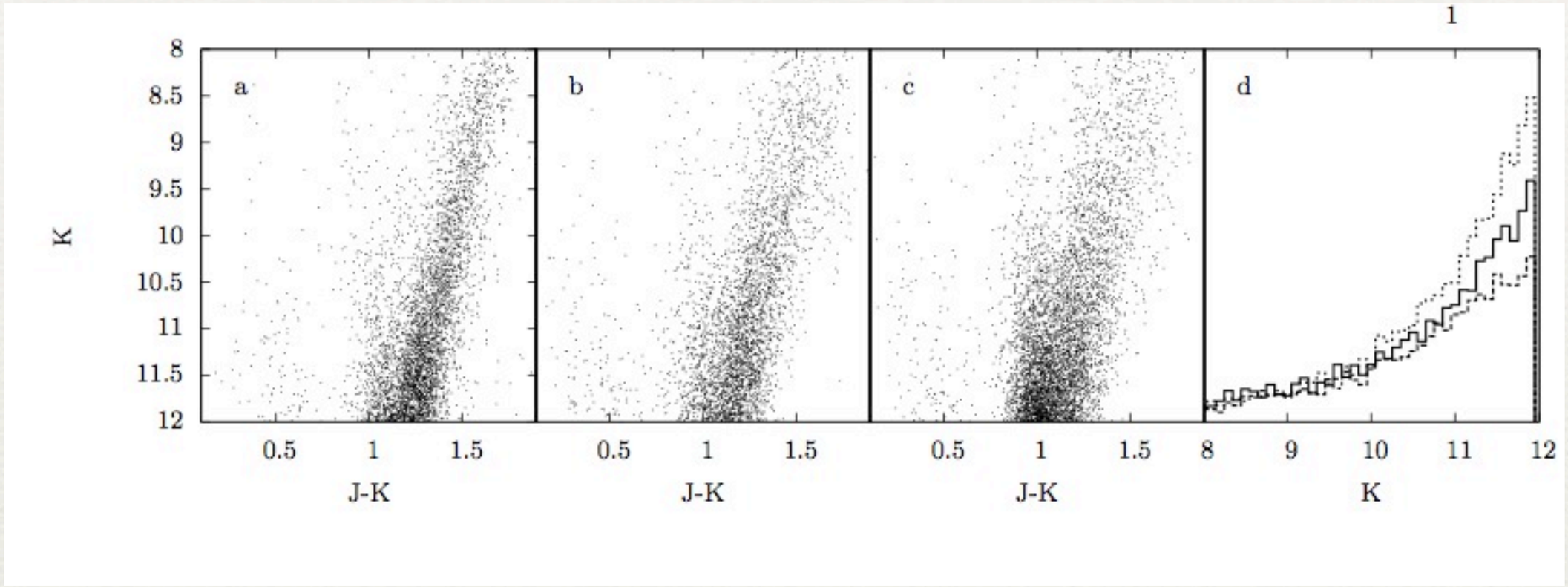
Data

New model
2 ellipsoids

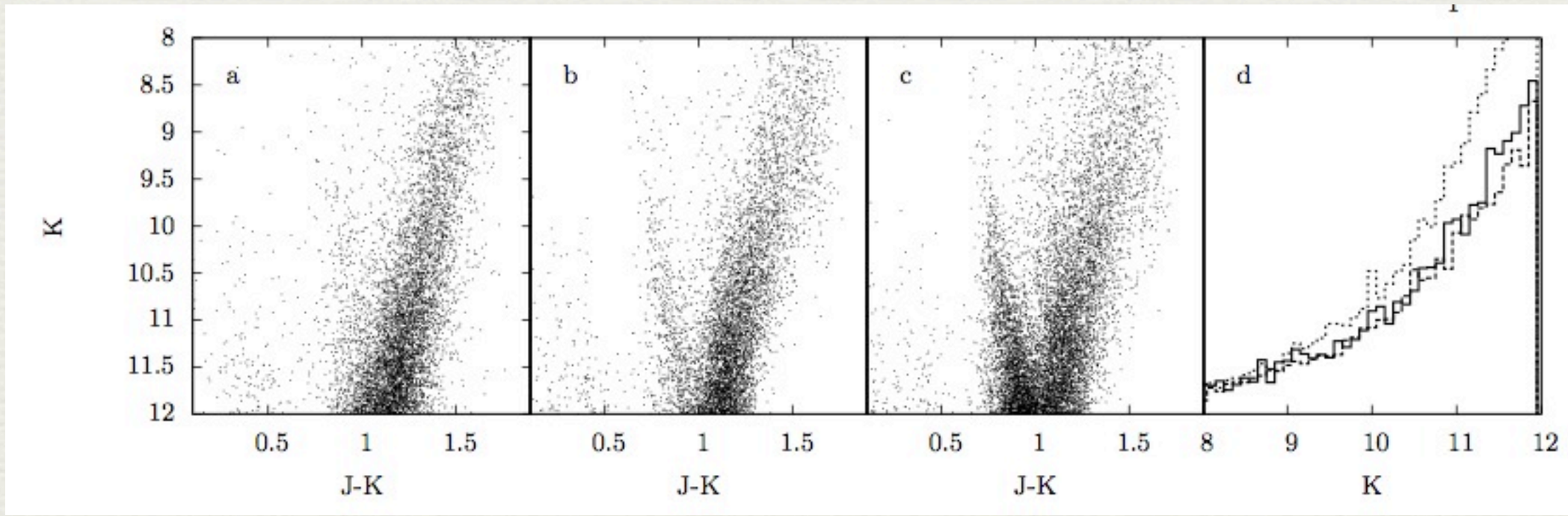
model
1 ellipsoid

— Data
-- 2 ellipsoids
.... 1 ellipsoid

L=5
B=4.5



L=0
B=-4



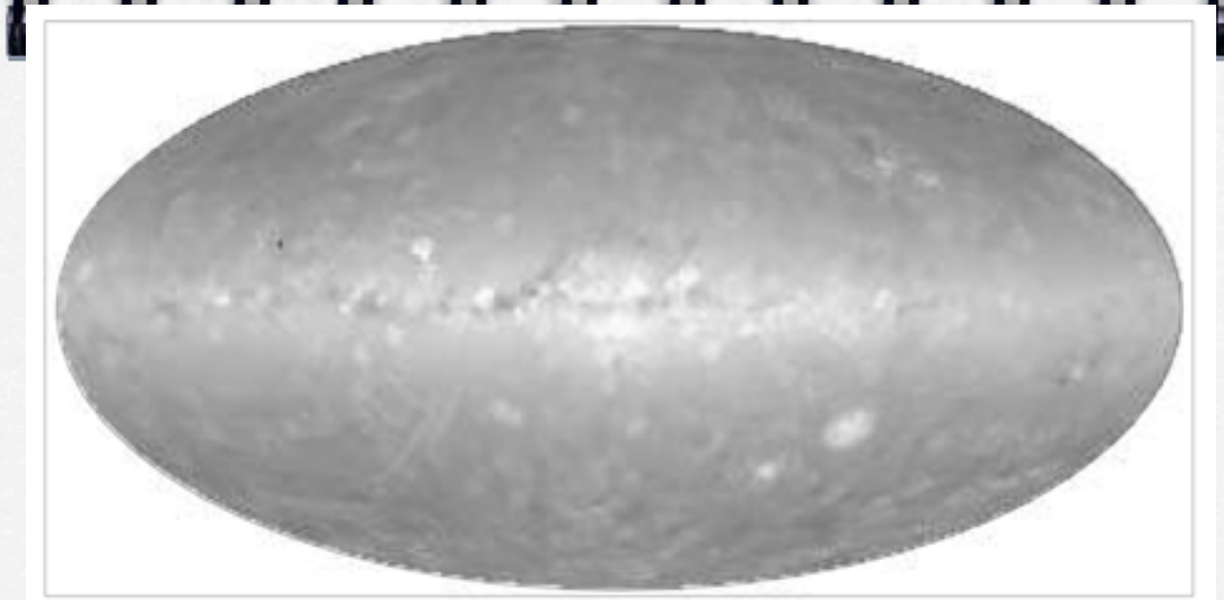
On going improvements

- Flexible evolutionary model (Czekaj et al 2011)
- Spiral structure (Amores et al 2011)
- M dwarfs and brown dwarfs (Reylé et al)

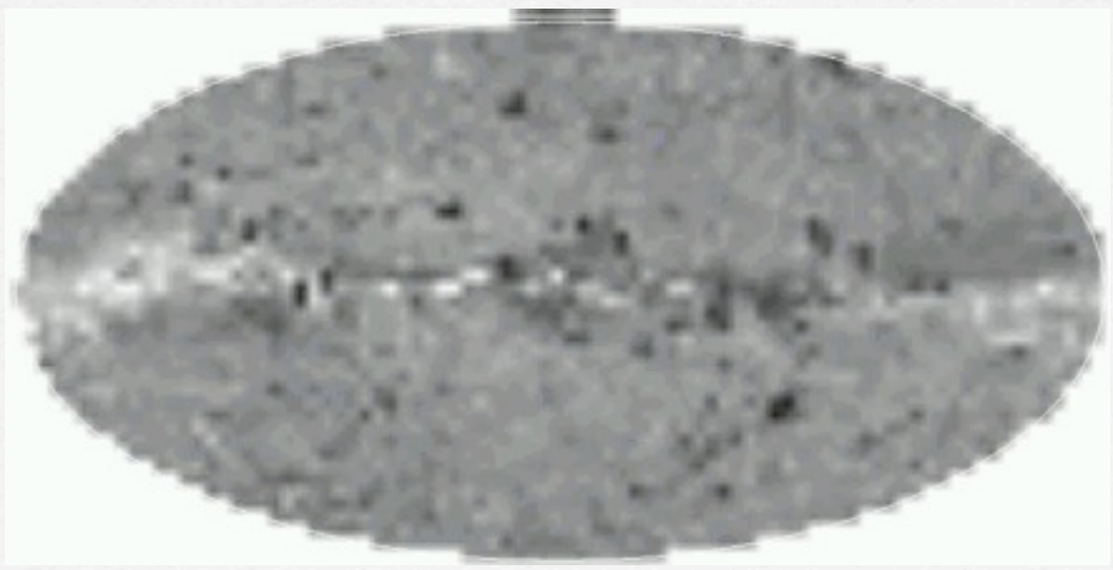
Tests

- Tests unitaires
- Tests d'intégration
- Tests de validation

G < 20

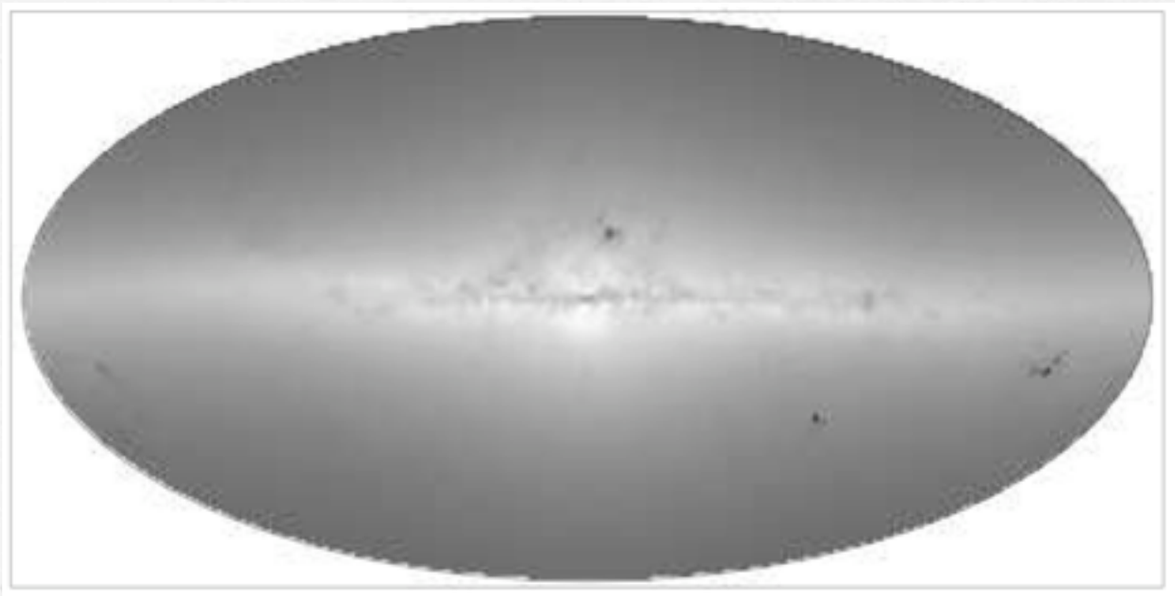


14.4< G <15



D=(Nmod -Nobs)/Nobs
log(D-min(D)+1)
D entre -2 (blanc) et 1 (noir)

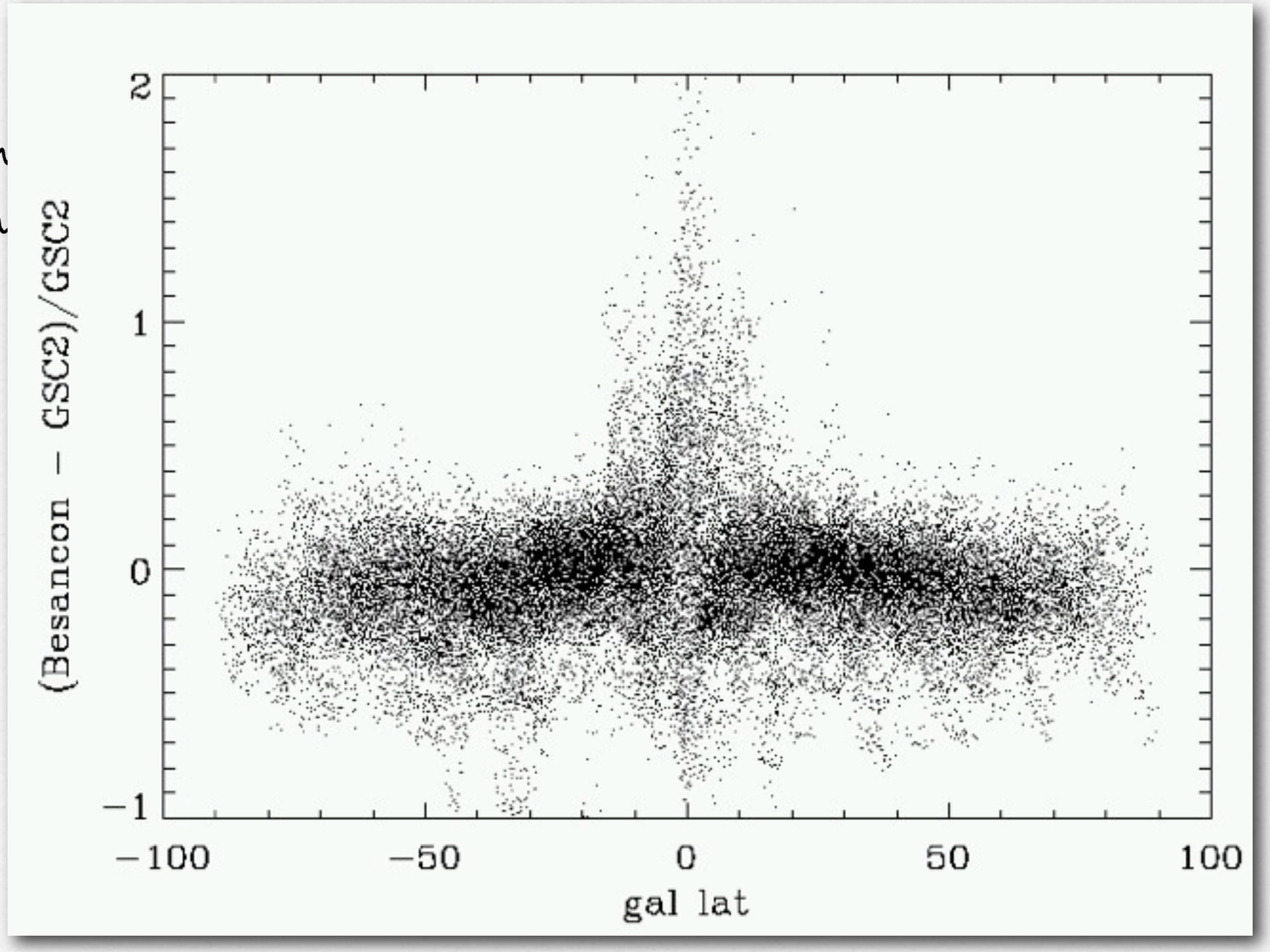
Comparaison comptages GSC2 / BGM



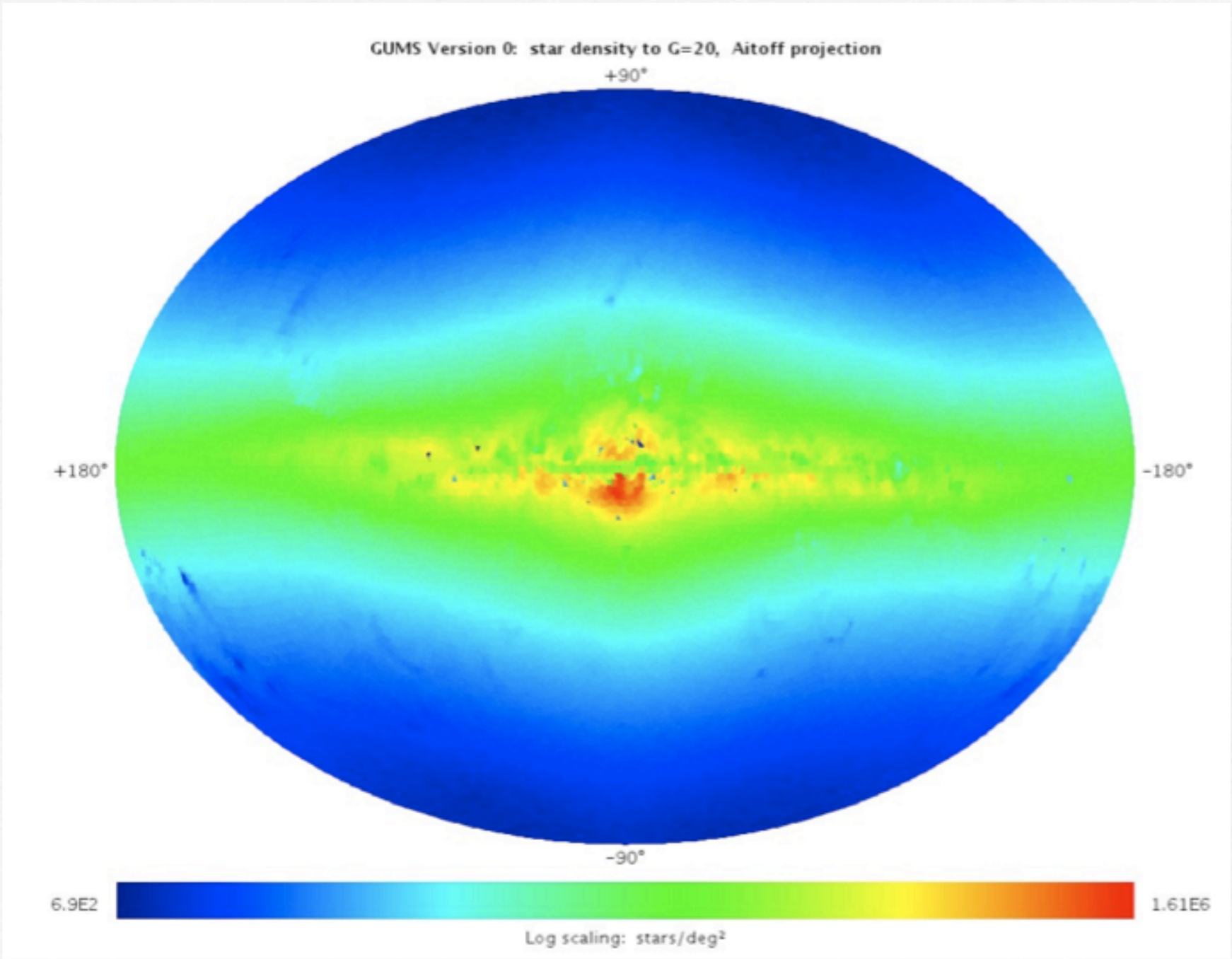
Tests

- Tests unitaires
- Tests d'intégration
- Tests de validation

At G=17. Deviation ~ 15% off the plane



GUMS : whole sky simulation



GUMS statistics summary (O. Martinez, Y. Isasi, X. Luri, et al.)

Over 1/8 sky

Statistics to validate the simulations

Distribution of source wrt observables

Update of stellar densities in Gaia

Over 1/8 of sky :

starlumclass	hierarchyLevel		
	0	1	Total
BrightGiant	15653	54492	70145
Giant	1832214	3236786	5069000
MainSequence	33223926	33752099	66976025
PreMainSequence	41616	42429	84045
SubGiant	3253211	4526679	7779890
SuperGiant	14	32	46
WhiteDwarf	29140	59881	89021
Total	38395774	41672398	80068172

Table 17: Counts by luminosity class.

starlumclass	hierarchyLevel		
	0	1	Total
BrightGiant	6595	21443	28038
Giant	220641	538672	759313
MainSequence	118576	189104	307680
PreMainSequence	3067	5619	8686
SubGiant	60142	114217	174359
SuperGiant	14	32	46
WhiteDwarf	7	3832	3839
Total	409042	872919	1281961

Table 41: Counts by luminosity class limited by Grvs minor than 12.

Spectral types

At G<20

spectralType	hierarchyLevel		
	0	1	Total
O	0	5	5
B	22957	88754	111711
A	424842	1186894	1611736
F	7490020	9580207	17070227
G	12864111	14079527	26943638
K	12086280	12183767	24270047
M	5477126	4480471	9957597
L	12	12	24
Be	0	0	0
WR	0	0	0
AGB	516	361	877
Other	29910	72400	102310
Total	38395774	41672398	80068172

Table 20: Counts by spectral type.

At Grvs limit (17)

spectralType	hierarchyLevel		
	0	1	Total
O	0	5	5
B	16358	77367	93725
A	331214	963217	1294431
F	3415861	5038394	8454255
G	5153553	6186141	11339694
K	4179879	4964899	9144778
M	1549717	1324498	2874215
L	4	7	11
Be	0	0	0
WR	0	0	0
AGB	503	346	849
Other	1682	21028	22710
Total	14648771	18575902	33224673

By populations

stellarPop	hierarchyLevel		
	0	1	Total
Disk	28639990	34061386	62701376
Spheroid	530778	385807	916585
ThickDisk	9225006	7225205	16450211
Total	38395774	41672398	80068172

Table 23: Counts by population.

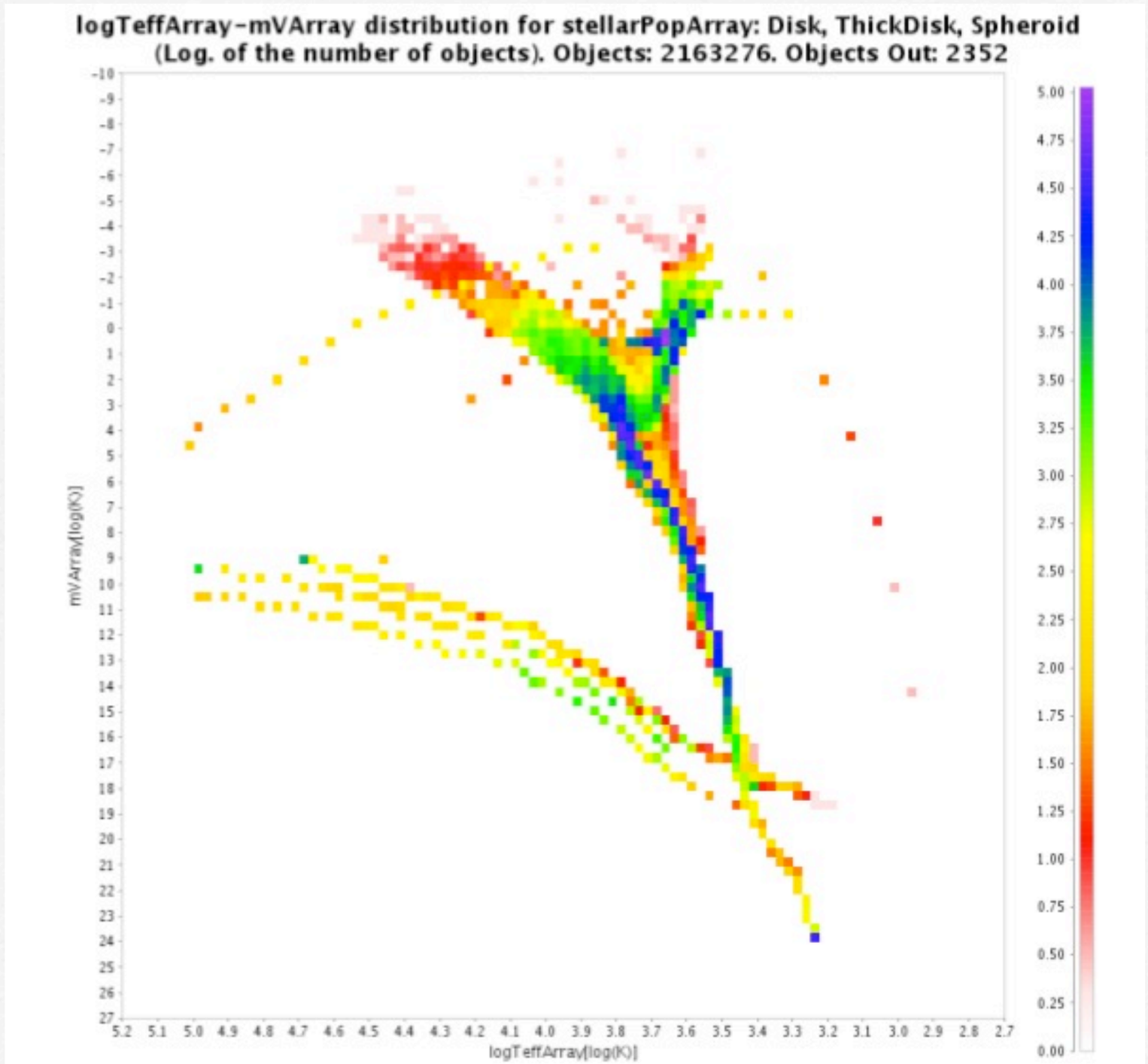
stellarPop	hierarchyLevel		
	0	1	Total
Disk	12117510	16249555	28367065
Spheroid	84201	78230	162431
ThickDisk	2447060	2248117	4695177
Total	14648771	18575902	33224673

Table 35: Counts by population limited by GrvsLimit.

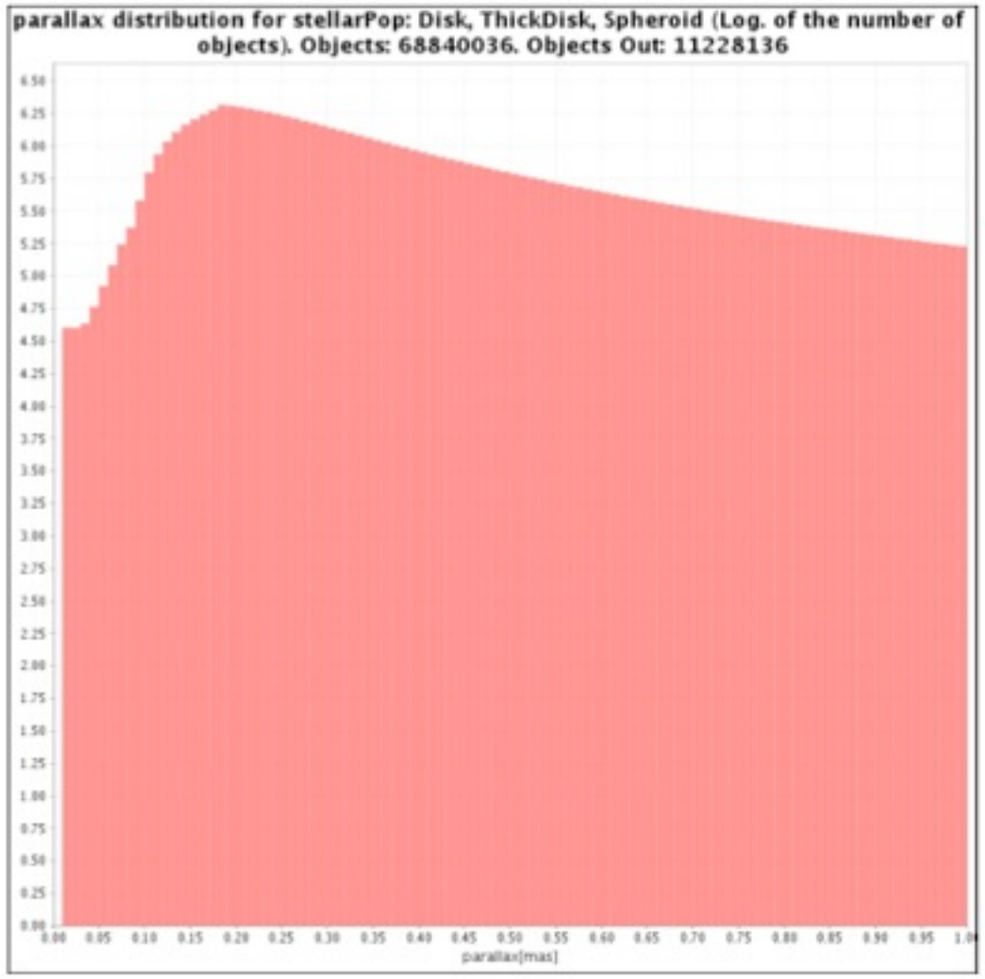
White dwarfs

stellarPop	hierarchyLevel		
	0	1	Total
Disk	28676	58850	87526
Spheroid	14	7	21
ThickDisk	450	1024	1474
Total	29140	59881	89021

Table 26: Counts by population for white dwarfs.


logTeffArray-mVArray distribution for stellarPopArray: Disk, ThickDisk, Spheroid
(Log. of the number of objects). Objects: 2163276. Objects Out: 2352
mVArray[log(K)]
logTeffArray[log(K)]


parallax distribution for stellarPop: Disk, ThickDisk, Spheroid (Log. of the number of objects). Objects: 80063478. Objects Out: 4694
parallax[mas]


parallax distribution for stellarPop: Disk, ThickDisk, Spheroid (Log. of the number of objects). Objects: 68840036. Objects Out: 11228136
parallax[mas]

Other uses of Gaia simulations

- PLATO simulations
- Cu9 : validation tests

Et après le lancement... Future uses

- Maintenance du modèle
- Utilisation pour l'analyse :
  - simuler des données et des analyses à l'avance.
- Utilisation pour une classification bayesienne
- Assimilation de données

Bayesian classification

- To classify an objects when the number of observables is limited (no RVS for example)

- In simulations : correspondance between regions in the observed parameter space and regions of intrinsec parameter space (spectral type, population/age, Teff, distance, etc…)

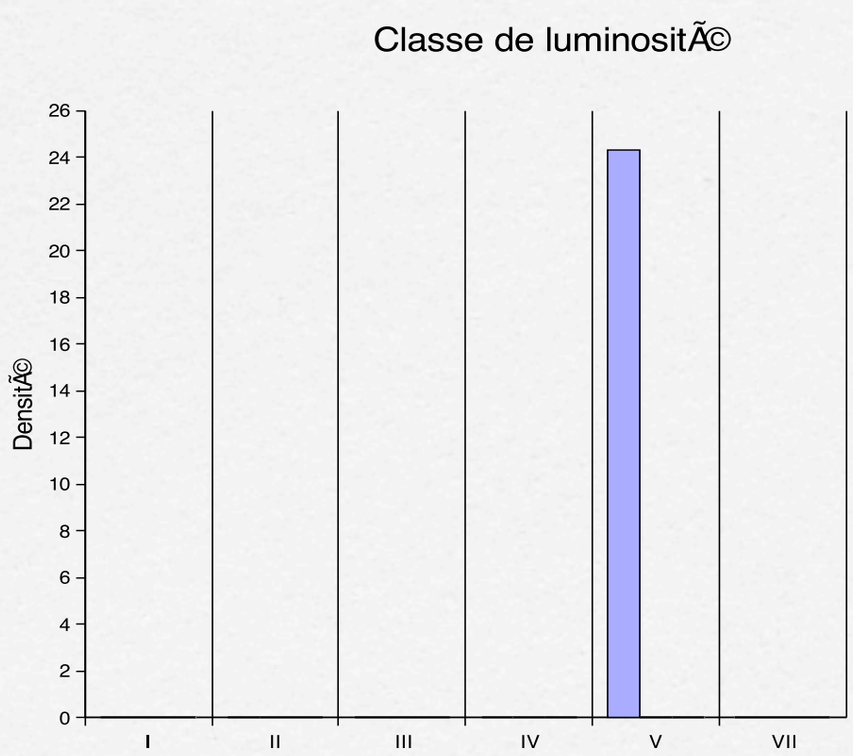
=> most probable class/type in the simulation (with confidence interval)

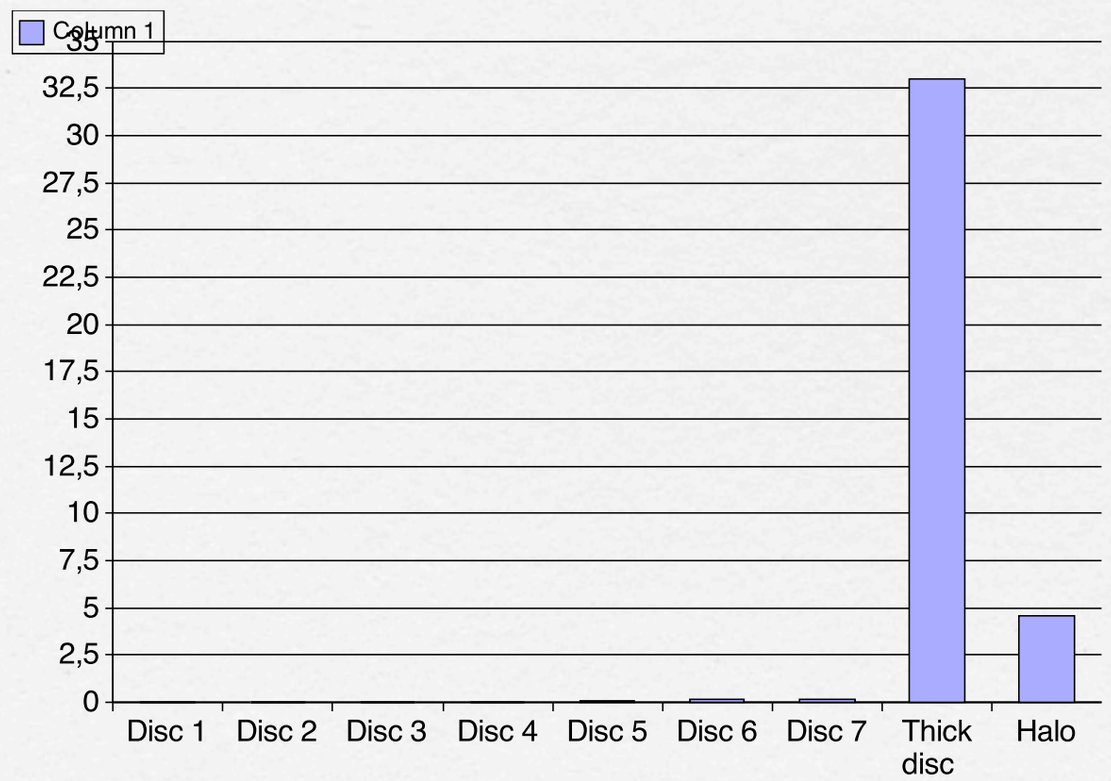
Take into account :

Systematic and random errors

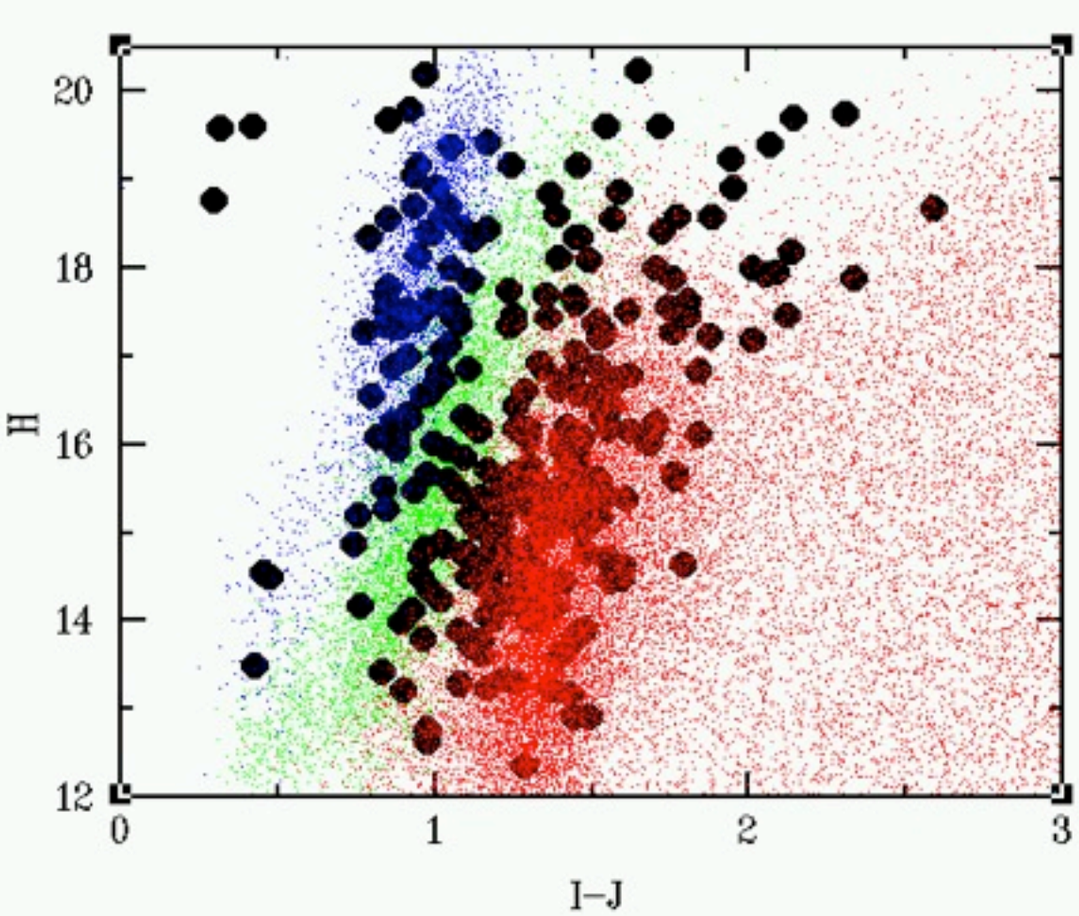
Recalibration of the model with neighbouring data (assimilation)

Example : star with magnitude V=18±1 and B-V=0.6±0.15, towards l=200° b=59°





- I-J,I,μ-> population : Determination of the photometric distancefrom theoretical relations magnitude-colour of differentes metallicities



disc
Thick disc
halo

Reylé et al., 2002

- Other application : Alerts during Gaia mission !

Conclusions

- Gaia will encompass any kind of models
- But still, modelling is useful to identify problems in our current knowledge/scenarios
- BGM needs improvements : kinematics, spiral structure,...
- Uses of existing surveys (SDSS, UCAC, ACS data,...)

Merci de votre attention

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Gracias por su atención