

Le modèle de la galaxie de Besançon

Développements et services

<http://model.obs-besancon.fr>

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Le modèle de la Galaxie

- Modèle de synthèse de populations stellaires (5 populations)
- Modèles d'extinction 3D
- Simulations de données selon des lignes de visée (catalogues, comptages)
- Paramètres pour chaque étoile simulée :
 - Intrinsèques : Magnitude absolue, température effective, gravité, métallicité, position (x,y,z) , vitesses (V_x, V_y, V_z)
 - Observables : Magnitudes apparentes, couleurs, type spectral, classe de luminosité, T_{eff} , $\log g$, métallicité, mouvements propres, vitesses radiales (rougissement interstellaire, erreurs d'observations)

- Inputs

- ✓ SFR, IMF
- ✓ Tracés évolutifs
- ✓ Lois de densité
- ✓ Cinématique
- ✓ Evolution chimique

- ✓ Extinction interstellaire

Inputs utilisateurs :

- ✓ Biais de sélection
- ✓ Modèle d'erreur

Outputs

- ✓ Catalogues d'étoiles
- ✓ Flux intégrés
- ✓ Comptages

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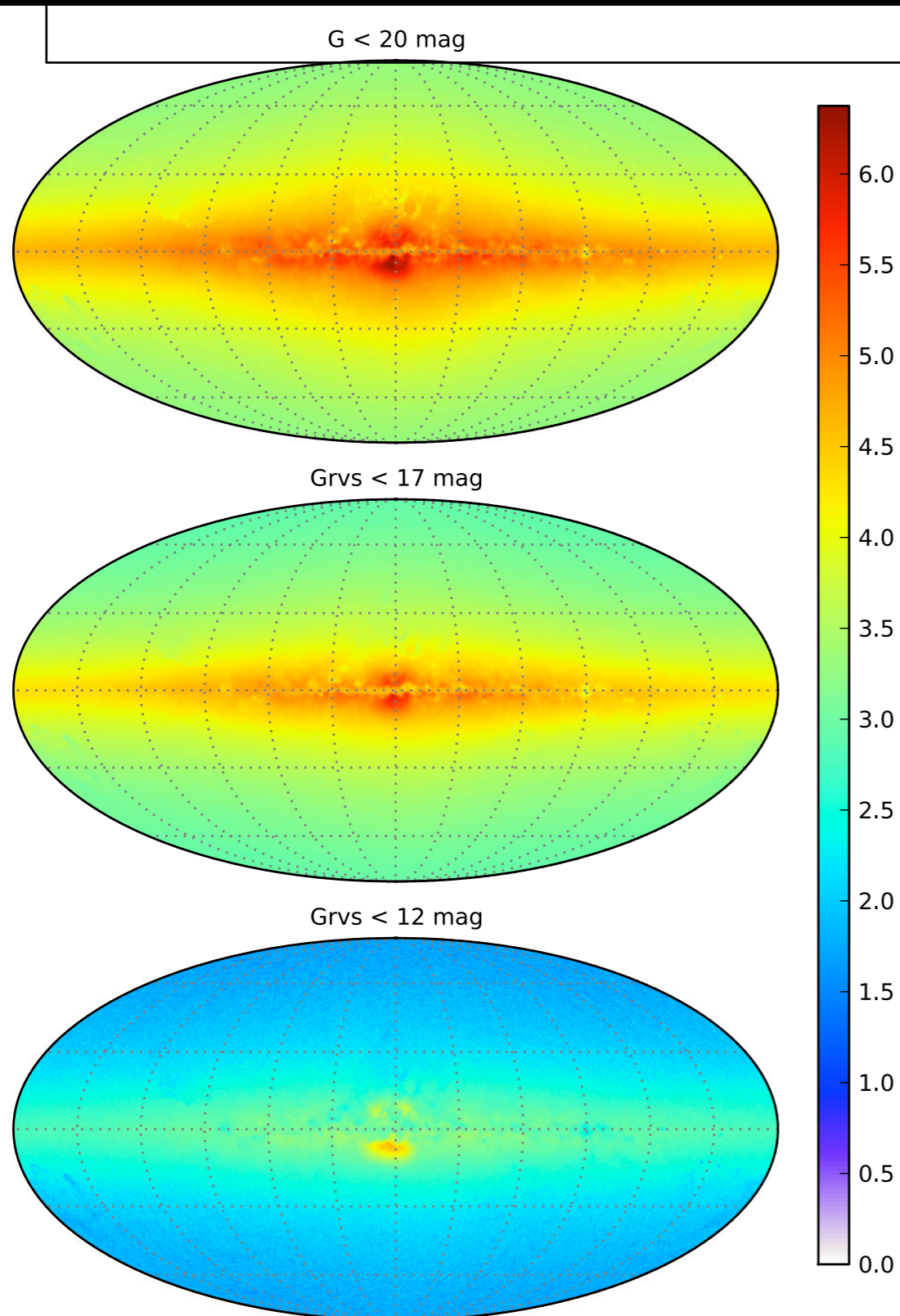
Production de comptages d'étoiles

Mag	N(m)	V	B	U	R	I	J	H	K
< 1.00		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
< 2.00		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
< 3.00		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
< 4.00		0.0	0.0	0.0	0.0	0.0	0.0	3.0	4.0
< 5.00		0.0	0.0	0.0	0.0	0.0	3.0	9.0	11.0
< 6.00		0.0	0.0	0.0	1.0	1.0	10.0	15.0	23.0
< 7.00		1.0	0.0	0.0	1.0	4.0	18.0	41.0	54.0
< 8.00		3.0	1.0	0.0	6.0	9.0	44.0	131.0	216.0
< 9.00		6.0	3.0	2.0	9.0	25.0	138.0	503.0	724.0
<10.00		18.0	8.0	7.0	36.0	96.0	549.0	1349.0	1659.0
<11.00		63.0	35.0	28.0	118.0	265.0	1576.0	2981.0	3498.0
<12.00		181.0	80.0	63.0	340.0	935.0	3642.0	6100.0	7047.0
<13.00		549.0	218.0	153.0	1077.0	2959.0	7898.0	14846.0	17862.0
<14.00		1508.0	553.0	374.0	3139.0	7208.0	20648.0	30445.0	33147.0
<15.00		3928.0	1368.0	899.0	8638.0	18292.0	38337.0	52728.0	57771.0
<16.00		11091.0	3231.0	1975.0	22963.0	38582.0	69532.0	104053.0	118432.0
<17.00		29532.0	8018.0	4587.0	46822.0	71939.0	157718.0	264078.0	306502.0
<18.00		58771.0	21085.0	10758.0	91056.0	170998.0	408941.0	649117.0	745207.0
<19.00		125292.0	50673.0	24867.0	236512.0	432563.0	875833.0	1340072.0	1518150.0
<20.00		335055.0	109585.0	61416.0	535115.0	843906.0	1605743.0	2421604.0	2755328.0
<21.00		661866.0	299934.0	173708.0	951168.0	1418278.0	2775750.0	4259123.0	4866898.0
<22.00		1069067.0	595943.0	429314.0	1492151.0	2304055.0	4783097.0	6981419.0	8016796.0
<23.00		1571997.0	933888.0	710871.0	2280459.0	3819949.0	7773131.0	11561693.0	12562879.0
<24.00		2301388.0	1315341.0	983911.0	3564490.0	6001916.0	12384556.0	13689133.0	13941767.0
<25.00		3467281.0	1810848.0	1269859.0	5436979.0	9114958.0	13929877.0	14039951.0	14047637.0

Production de catalogues d'étoiles

I	V-I	mul	mub	Vr	UU	VV	WW	Mv	CL	Typ	Teff	logg	Age	Mass	Mbol	Radius	[Fe/H]
13.674	2.141	-71.700	-49.577	-62.23	-64.04	-33.66	-17.74	10.77	5	7.00	3551.	4.87	6	0.430	9.039	0.366	0.05
15.418	2.739	-11.886	-9.173	-0.32	-0.72	-6.09	-4.63	12.92	5	7.00	3218.	5.00	2	0.220	11.212	0.164	0.12
15.957	2.797	-10.753	3.161	-7.54	-7.29	-7.47	2.87	12.80	5	7.00	3231.	5.05	1	0.230	11.144	0.168	0.18
15.224	2.383	-25.144	-18.162	28.60	27.33	-18.44	-15.97	11.57	5	7.00	3396.	4.95	3	0.330	10.007	0.256	-0.05
14.897	2.299	-71.689	30.392	10.13	12.25	-52.42	21.21	11.12	5	7.00	3471.	4.88	5	0.370	9.507	0.309	0.22
13.854	2.011	-34.838	11.673	7.75	8.53	-23.66	7.25	9.96	5	7.00	3676.	4.79	3	0.510	8.371	0.465	0.13
15.797	2.657	-19.016	-14.658	-48.31	-49.10	-14.99	-7.41	12.23	5	7.00	3298.	4.98	2	0.260	10.644	0.203	0.01
15.006	2.279	-57.817	1.571	-17.81	-17.53	-47.78	2.83	10.90	5	7.00	3471.	4.89	4	0.380	9.507	0.309	-0.07
15.013	2.205	-120.845	-66.146	-87.69	-91.83	-94.30	-43.85	11.04	5	7.00	3502.	4.90	7	0.410	9.339	0.328	-0.21
14.173	1.992	-9.872	1.487	-22.16	-21.92	-8.23	3.28	9.79	5	7.00	3676.	4.78	2	0.500	8.371	0.465	-0.04
13.310	1.809	-16.330	17.054	11.38	12.56	-12.38	12.00	8.97	5	7.00	3867.	4.75	5	0.590	7.566	0.609	0.10
13.784	1.791	-4.461	-13.809	-2.83	-3.85	-3.98	-12.03	9.05	5	7.00	3867.	4.75	2	0.590	7.566	0.609	-0.02
15.548	2.140	-44.014	2.241	-11.20	-10.74	-44.13	3.10	10.95	5	7.00	3502.	4.86	4	0.400	9.307	0.333	-0.04
14.663	1.978	-34.228	-2.487	-22.21	-22.33	-34.32	-0.59	9.87	5	7.00	3715.	4.78	3	0.520	8.203	0.492	-0.05
13.055	1.555	-35.706	-23.345	-11.53	-13.52	-34.81	-21.62	7.89	5	6.70	4166.	4.64	2	0.670	6.562	0.833	0.00
15.767	2.234	-4.710	-12.041	-8.56	-9.60	-5.45	-12.40	11.03	5	7.00	3471.	4.89	4	0.380	9.507	0.309	0.02
14.998	2.119	-45.031	4.602	-12.85	-12.27	-47.83	5.99	10.16	5	7.00	3603.	4.82	4	0.470	8.739	0.409	-0.11
14.850	2.124	-64.383	-4.920	29.34	29.01	-71.68	-7.88	9.91	5	7.00	3657.	4.81	7	0.500	8.471	0.449	-0.19
15.886	2.250	-43.442	26.387	44.55	47.12	-51.20	27.07	11.02	5	7.00	3486.	4.89	7	0.390	9.407	0.321	-0.42
14.872	2.028	-47.874	-13.318	82.68	81.29	-56.10	-22.83	9.76	5	7.00	3676.	4.79	7	0.510	8.371	0.465	0.11
14.674	1.924	-51.890	8.366	34.93	36.00	-59.82	6.37	9.45	5	7.00	3777.	4.76	3	0.550	7.934	0.539	0.24
14.532	1.840	-7.023	-2.467	-19.06	-19.22	-8.35	-1.26	9.16	5	7.00	3821.	4.74	3	0.570	7.734	0.577	-0.15
13.918	1.777	-3.775	-2.912	-14.34	-14.59	-4.21	-2.20	8.56	5	7.00	3940.	4.70	1	0.610	7.298	0.664	0.08
15.096	2.039	-25.610	-9.144	-41.25	-42.13	-33.66	-8.50	9.72	5	7.00	3696.	4.81	7	0.520	8.303	0.475	-0.06
14.452	1.792	-23.729	-2.895	-3.10	-3.36	-29.79	-3.45	8.96	5	7.00	3890.	4.72	3	0.590	7.466	0.630	0.07
13.807	1.593	-18.142	-10.311	-15.65	-16.59	-23.02	-11.50	8.05	5	6.70	4135.	4.65	1	0.660	6.662	0.808	-0.10

GUMS: Gaia Universe Model Snapshot

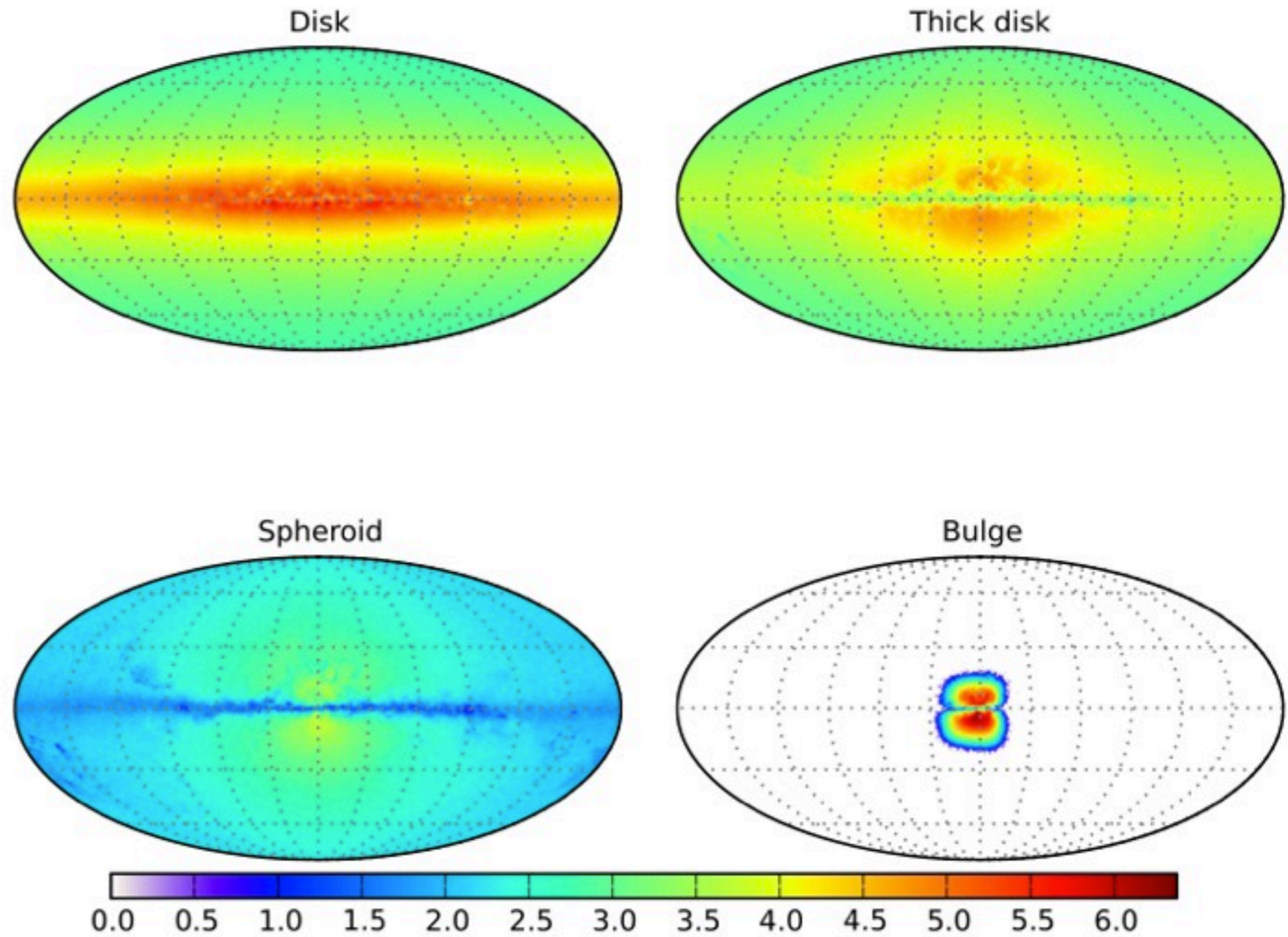


Spectral type	$G < 20 \text{ mag}$	$\text{Grvs} < 17 \text{ mag}$	$\text{Grvs} < 12 \text{ mag}$
O	<0.01%	<0.01%	<0.01%
B	0.26%	0.50%	0.88%
A	1.85%	3.30%	4.84%
F	23.13%	22.94%	13.83%
G	38.28%	31.58%	15.46%
K	27.68%	32.23%	41.75%
M	7.75%	6.78%	11.38%
L	<0.01%	<0.01%	<0.01%
WR	<0.01%	<0.01%	0.01%
AGB	0.91%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

Luminosity class	$G < 20 \text{ mag}$	$\text{Grvs} < 17 \text{ mag}$	$\text{Grvs} < 12 \text{ mag}$
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

Robin, Luri, Reylé, et al, 2012

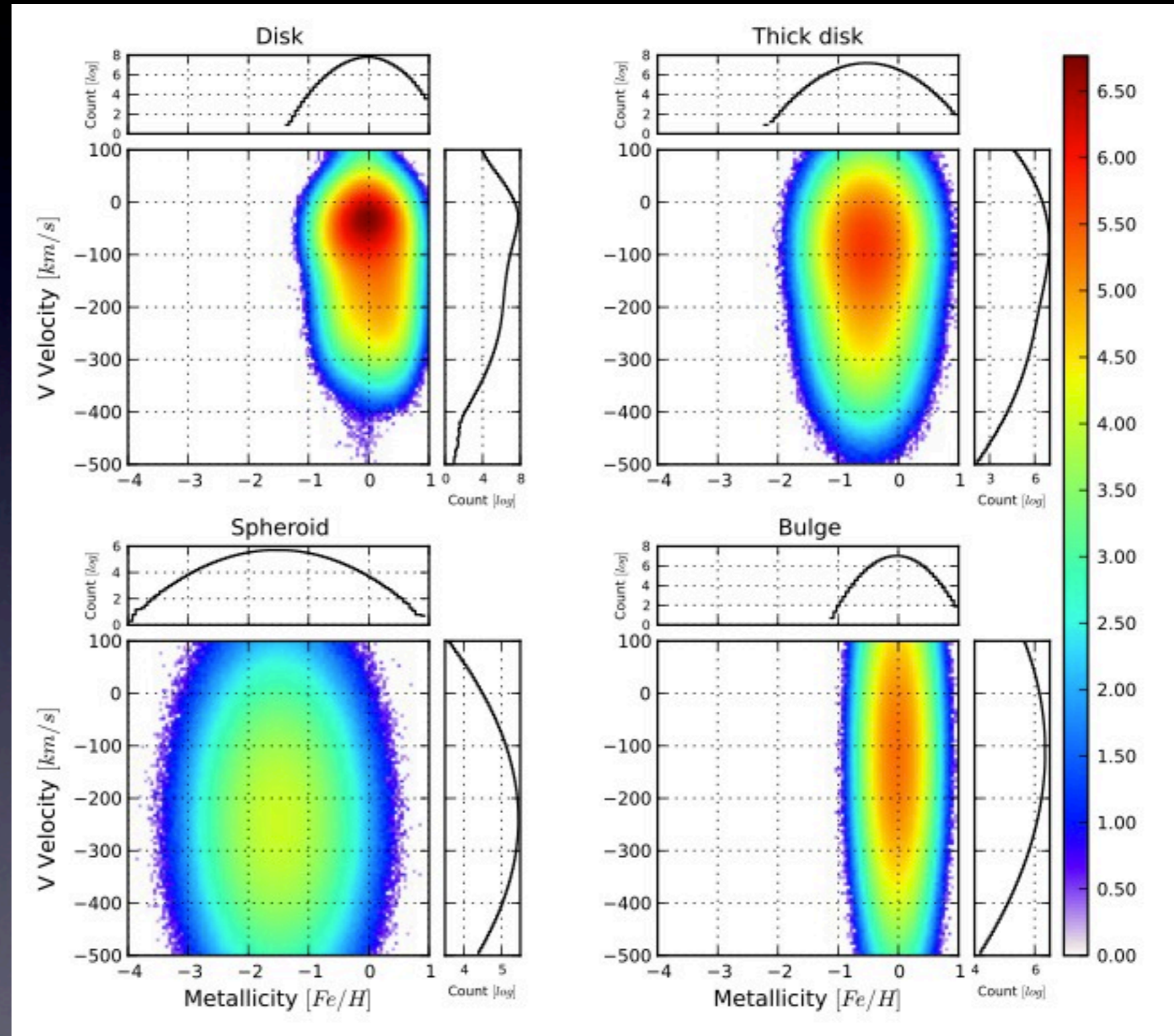
GUMS:



Population	G < 20 mag	Grvs < 17 mag	Grvs < 12 mag
disc	66.59%	76.82%	76.21%
Thick disc	21.88%	14.39%	8.75%
Spheroid	1.25%	0.58%	0.19%
Bulge	10.28%	8.22%	14.85%
Total	1,100,000,000	390,000,000	13,000,000

GUMS: Gaia Universe Model Snapshot

Kinematics and metallicity





- Autres sorties : flux intégré



Model



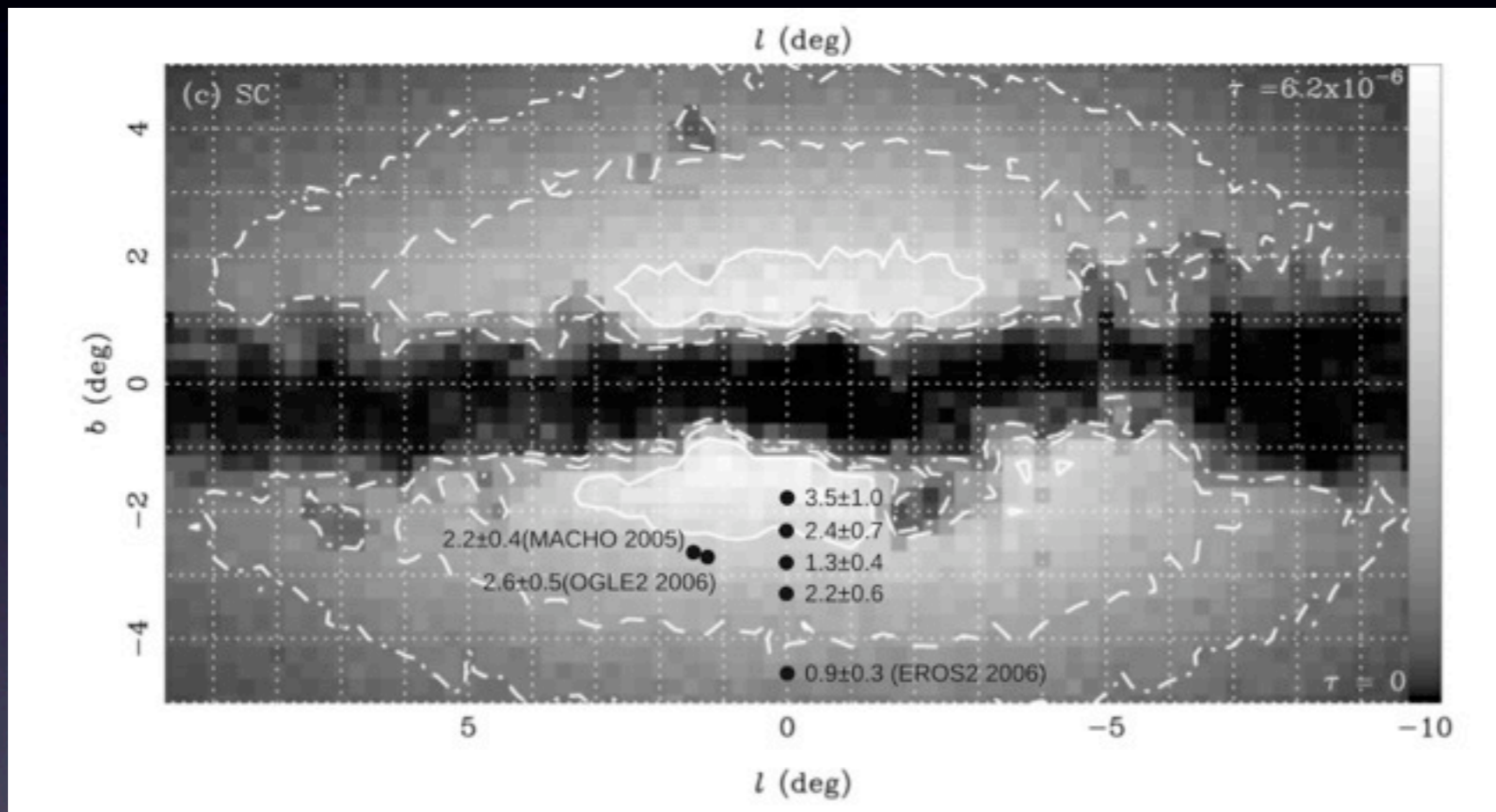
Data

Visible (from A. Mellinger)

NIR (from 2MASS)

Microlentilles

Prédictions de l'épaisseur optique dans le bulbe en V (comparaison MACHO, EROS, OGLE, MOA)



Somme toutes les paires source/lentille simulées par le modèle de la Galaxie en tenant compte de l'extinction => taux d'événements, distribution des échelles de temps

$$\Gamma(\ell, b) = \frac{\Omega_{\text{los}}}{\delta\Omega_s} \sum_{\text{Sources}} \left(\frac{1}{\delta\Omega_l} \sum_{D_l < D_s}^{\text{Lenses}} 2\theta_E \mu_{\text{rel}} \right),$$

Kerins, Robin, Marshall, 2009, MNRAS 396, 1202

Distribution de la durée moyenne des évènements

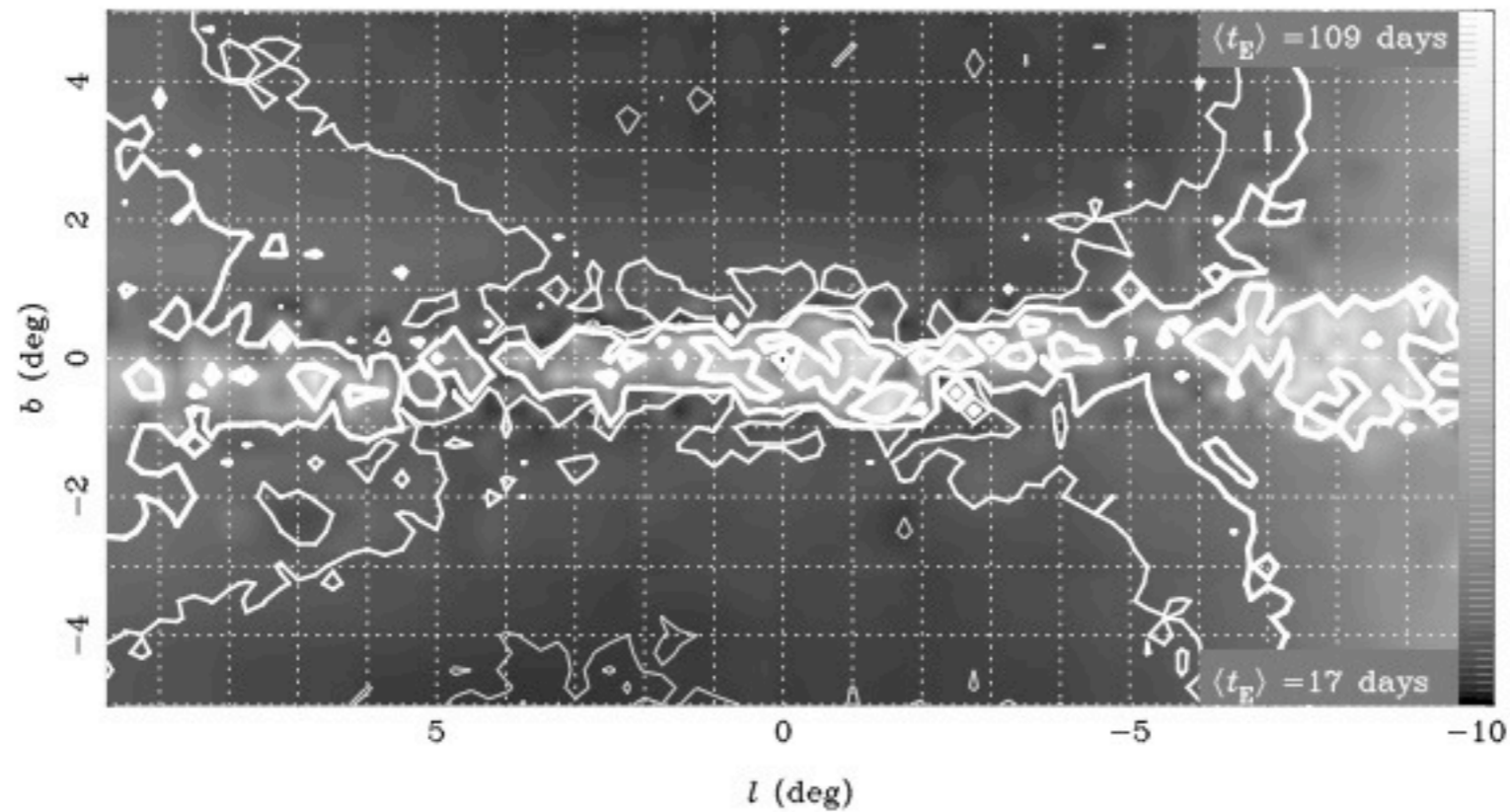
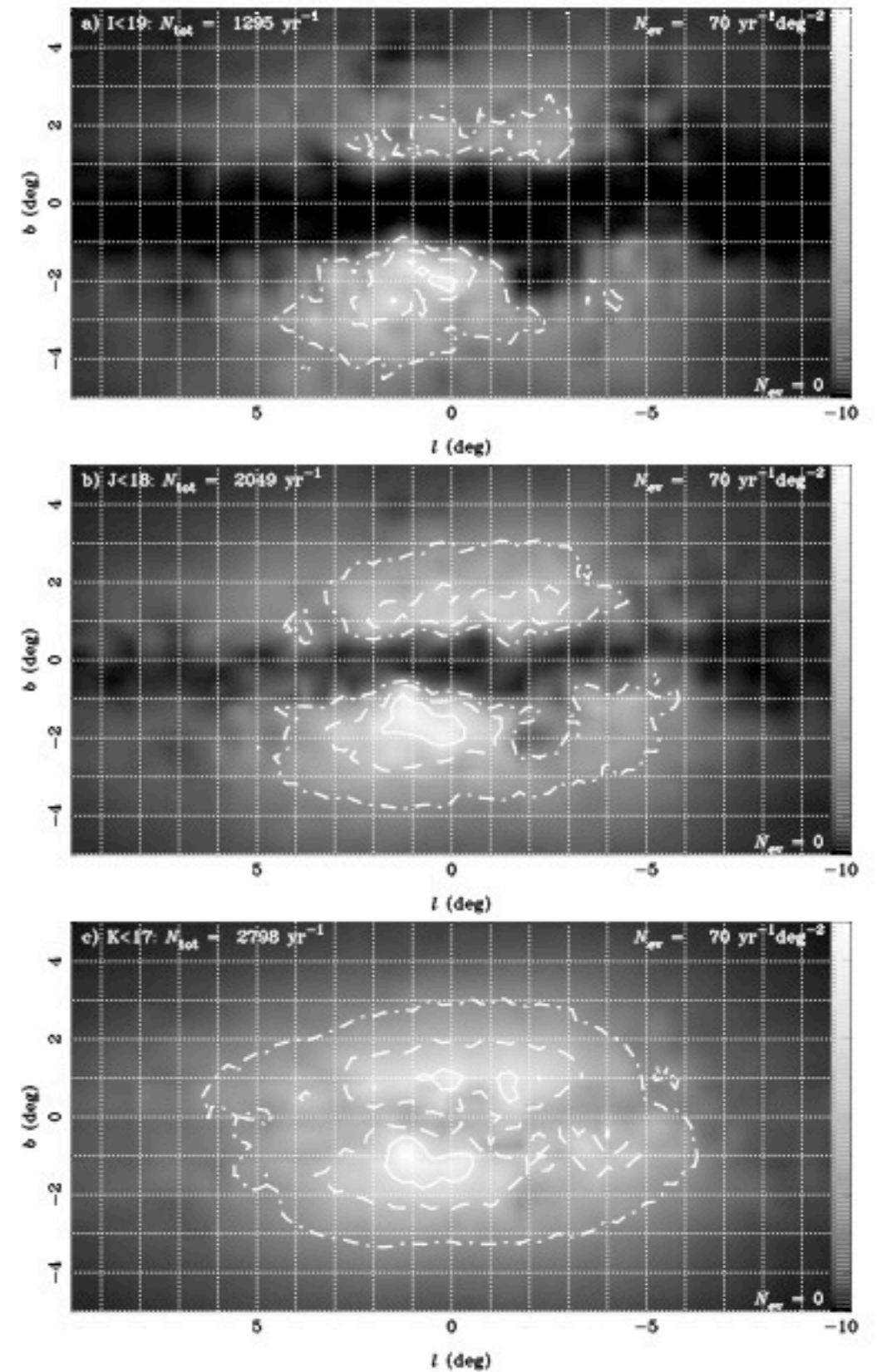


Figure 3. The distribution of average event durations $\langle t_E \rangle$ for resolved sources with baseline magnitudes $I < 19$. From the thinnest to the thickest contours the average durations are 20, 25, 30 and 60 days, respectively.

- Comparaison de l'efficacité des relevés de microlentilles dans les bandes I,J,K



Préparation proposition pour Euclide

ExELS: an exoplanet legacy science proposal for the ESA *Euclid* mission I. Cool exoplanets

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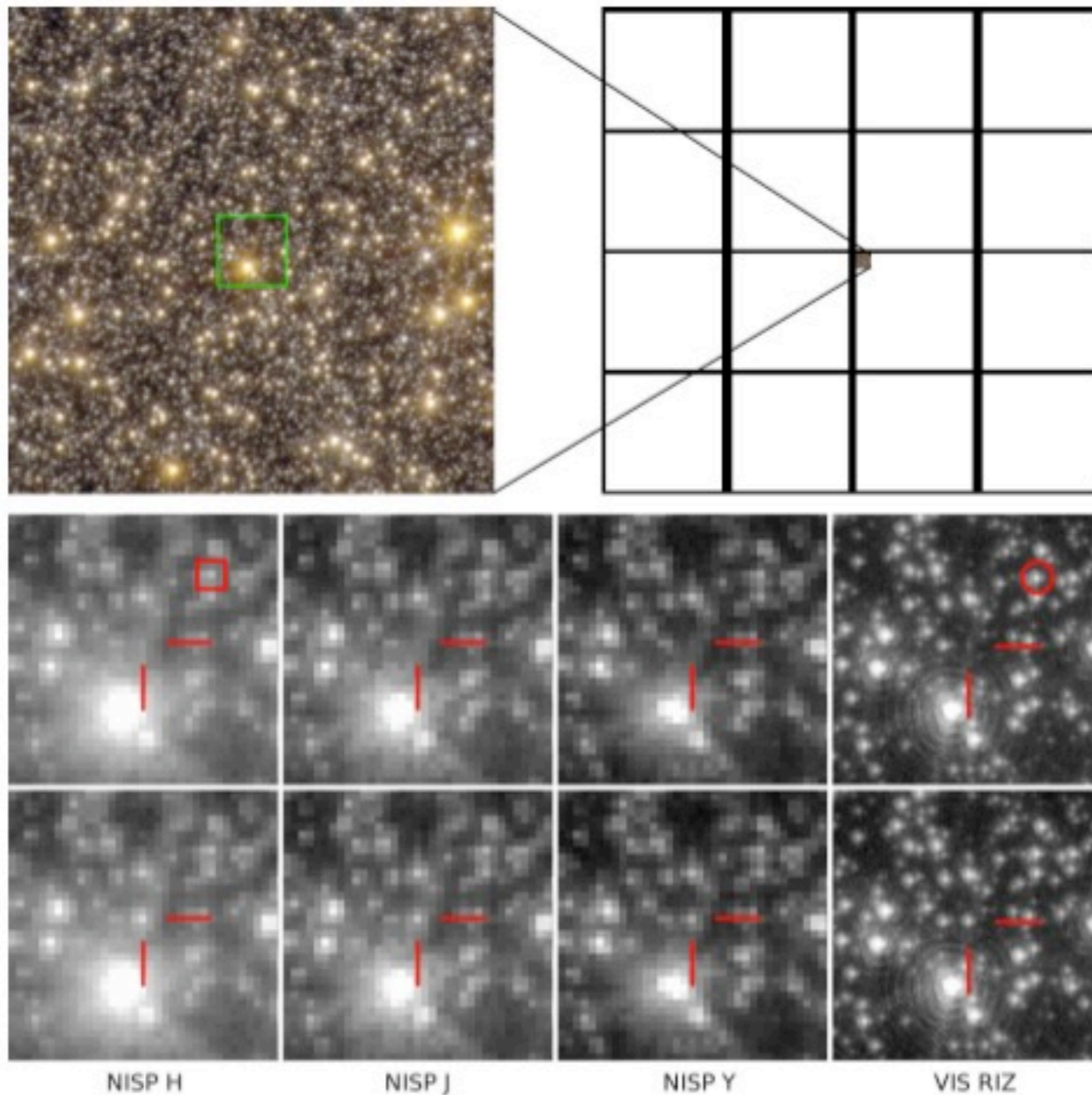


Figure 2. *Top left:* Example of a simulated false-colour composite image of a typical star-field from the ExELS simulation, with colours assigned as red-NISP *H*, green-NISP *J* and blue-VIS *RIZ*, each with a logarithmic stretch. The light green box surrounds the region that is shown zoomed-in in lower panels. The image covers 77×77 arcsec, equivalent to $1/64$ of a single NISP detector, of which there are 16. These are shown to the right. *Top right:* Approximate representation of the NISP instrument 'paw-print'. The white areas show active detector regions, while black areas show the gaps between detectors. In the corner of one of the detectors is shown the size of a simulated image relative to the detectors. *Bottom panels:* The bottom panels show a small image region surrounding a microlensing event (located at the center), the top row showing images at baseline and the bottom row showing images at peak magnification $\mu = 224$. Panels from right to left show NISP *H*, *J*, *Y*, and VIS *RIZ* images, respectively. The small red box shows the aperture that was used to compute photometry in the NISP images; the VIS aperture is a similar size but different shape. At peak, the event saturates in both NISP *H* and VIS *RIZ* images, but not in NISP *J* and *Y* images.

- Simulation des images de microlentilles (MaBuls) => efficacité de détection (Penny et al, 2012)

Développements en cours

- Nouvelles possibilités pour les systèmes photométriques :
 - Visible : couleurs SDSS
 - Ultraviolet : Galex/UVIT
 - Infrarouge : Spitzer
- Nouveau modèle d'extinction : Marshall et al (2006)
- Populations :
 - Version 2012 pour le bulbe et la barre (*Robin, A. C., Marshall, D. J., Schultheis, M., Reylé, A&A 538, A10*)
 - Disque épais et halo stellaire
 - Cinématique : modèle de Fux (1999) pour la barre, mise à jour vitesses du soleil.
 - Disque cohérence dynamique avec densité locale de van Leeuwen (Révision Hipparcos)
 - IMF aux petites masses

Besançon model :

New fit to 2MASS data

Attempt to fit the bulge region

200 fields
 $-20 < l < 20^\circ$
 $-10 < b < 10^\circ$

K/J-K star counts
 $K < 12-14$ (completeness limit)

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

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

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

Extinction: 3D model from Marshall et al (2006).

Besaçon model : New fit to 2MASS data

Attempt to fit the bulge region

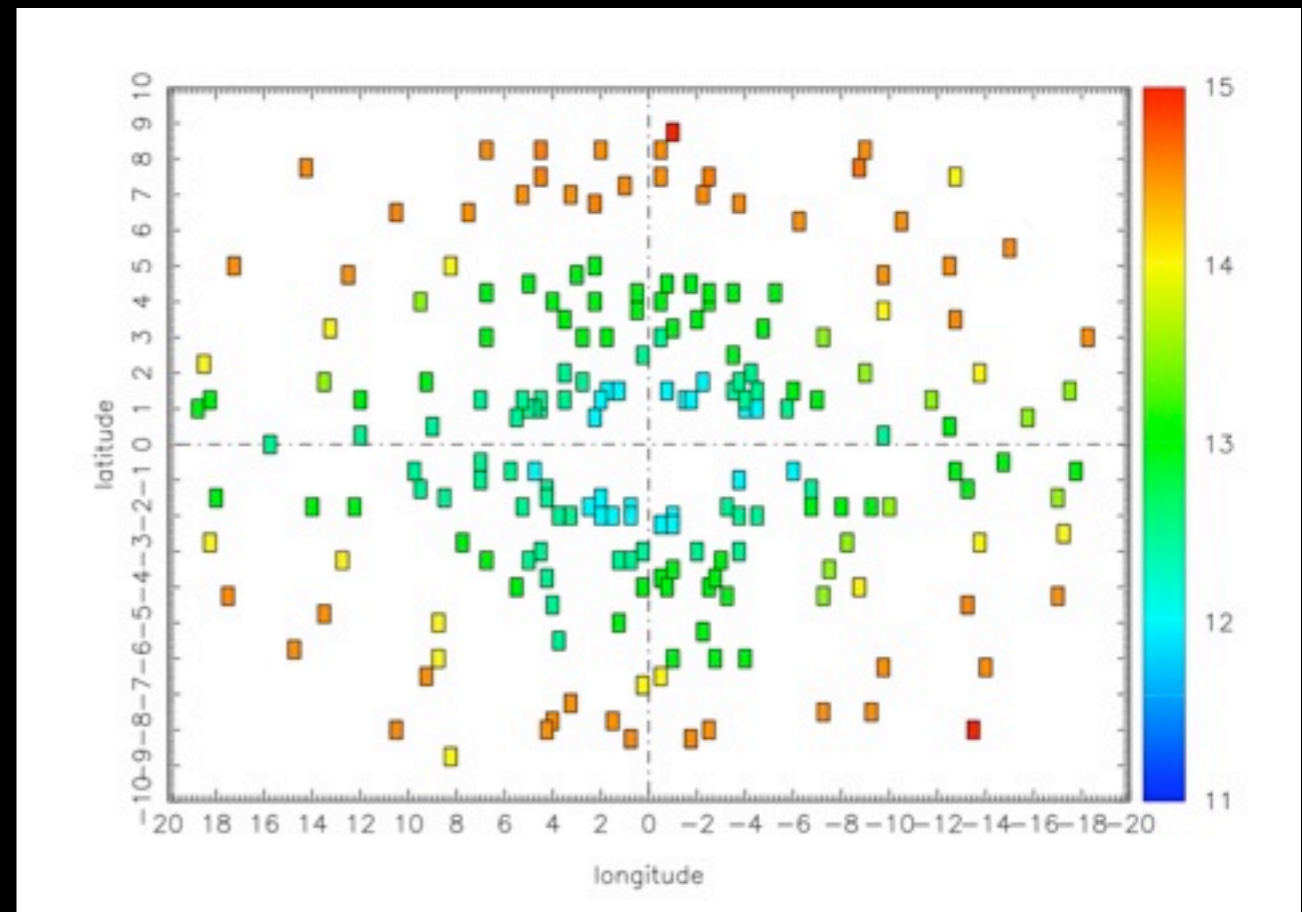
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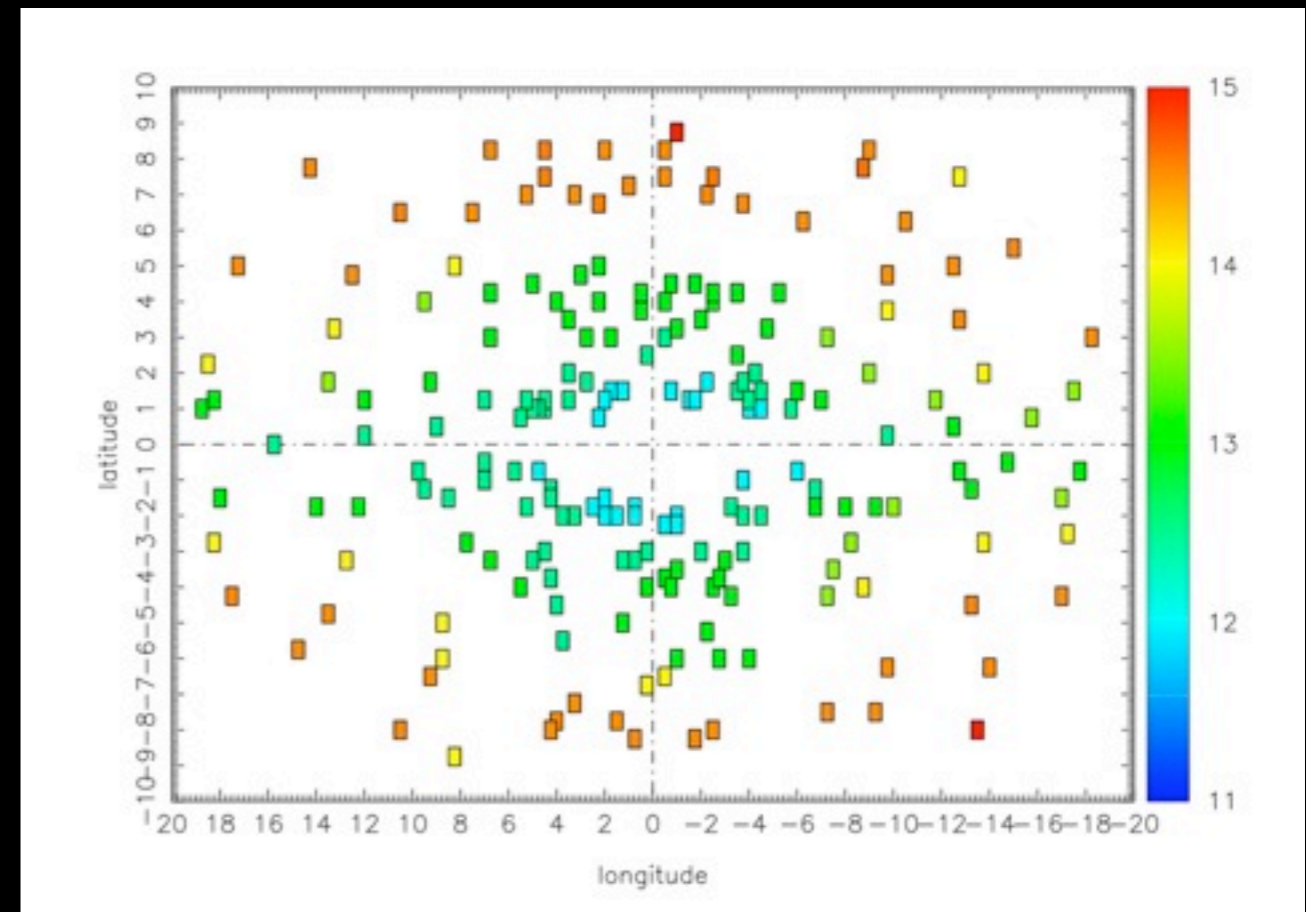
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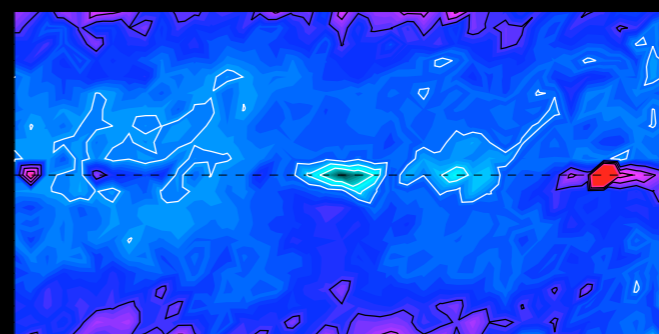
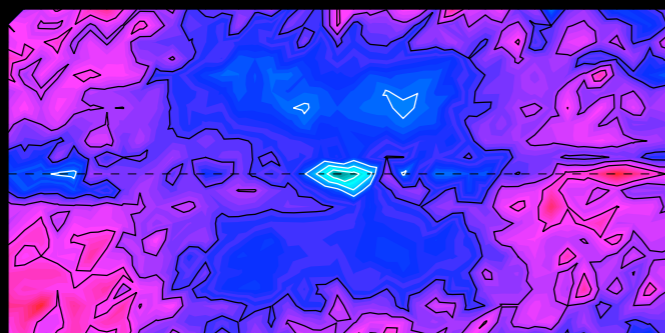
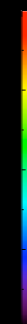
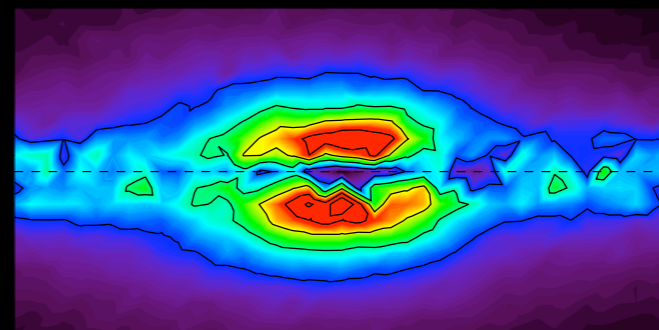
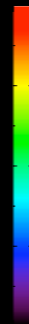
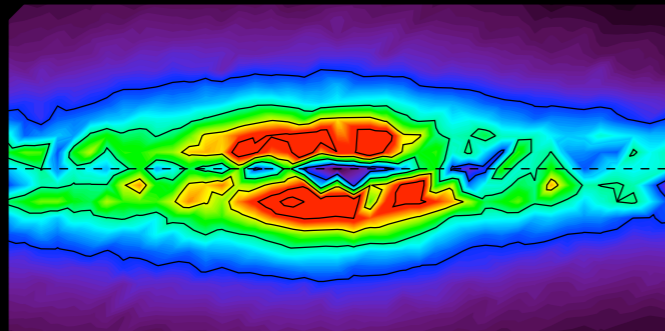
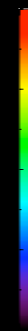
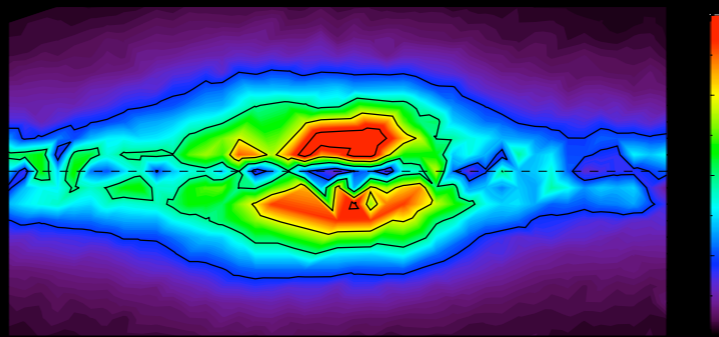


Solution : bulge region fit with 2 structures (Robin, Marshall, Schultheis, Reylé, (2012) A&A 538, A106)

Extinction: 3D model from Marshall et al (2006).

- A bar (dominating)
- A weaker «thick bulge»

Data =>



1 structure (S)

2 structures (S+E) : a bar and a bulge

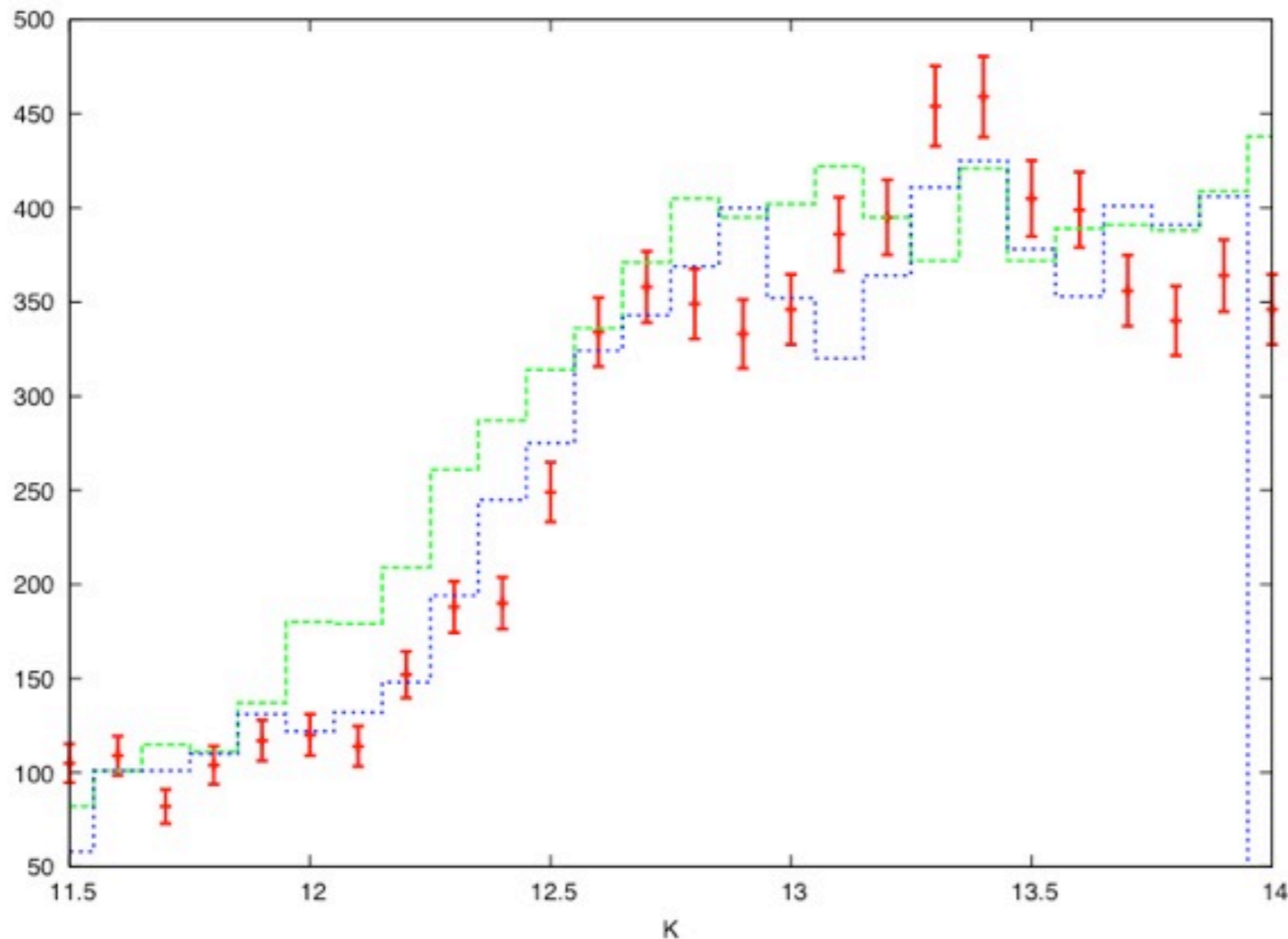
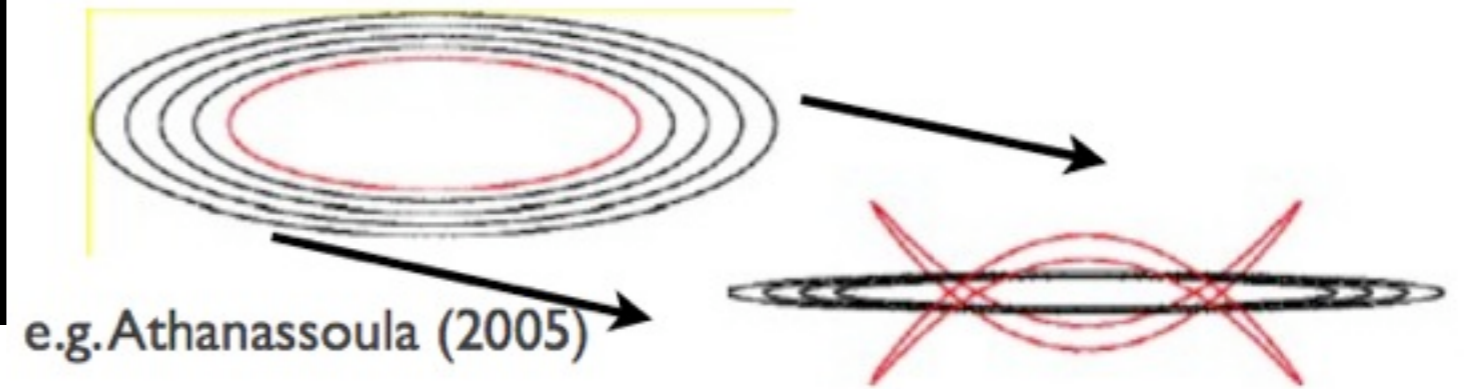
ϕ	5.9°	13°
x0	3.17 kpc	1.46 / 4.44
y0	0.62 kpc	0.49 / 1.31
z0	0.38 kpc	0.39 / 1.21
Mass	$6.1 \cdot 10^9$	$2.6 \cdot 10^8$
[Fe/H]	0.	-0.4

2 clumps can be created by a flaring bar !

$$dz = dz_0 \times (1 + 0.3 \times \sin(x/650.))$$

N-body simulations

- Bar potential
- Periodic x1 orbits buckle

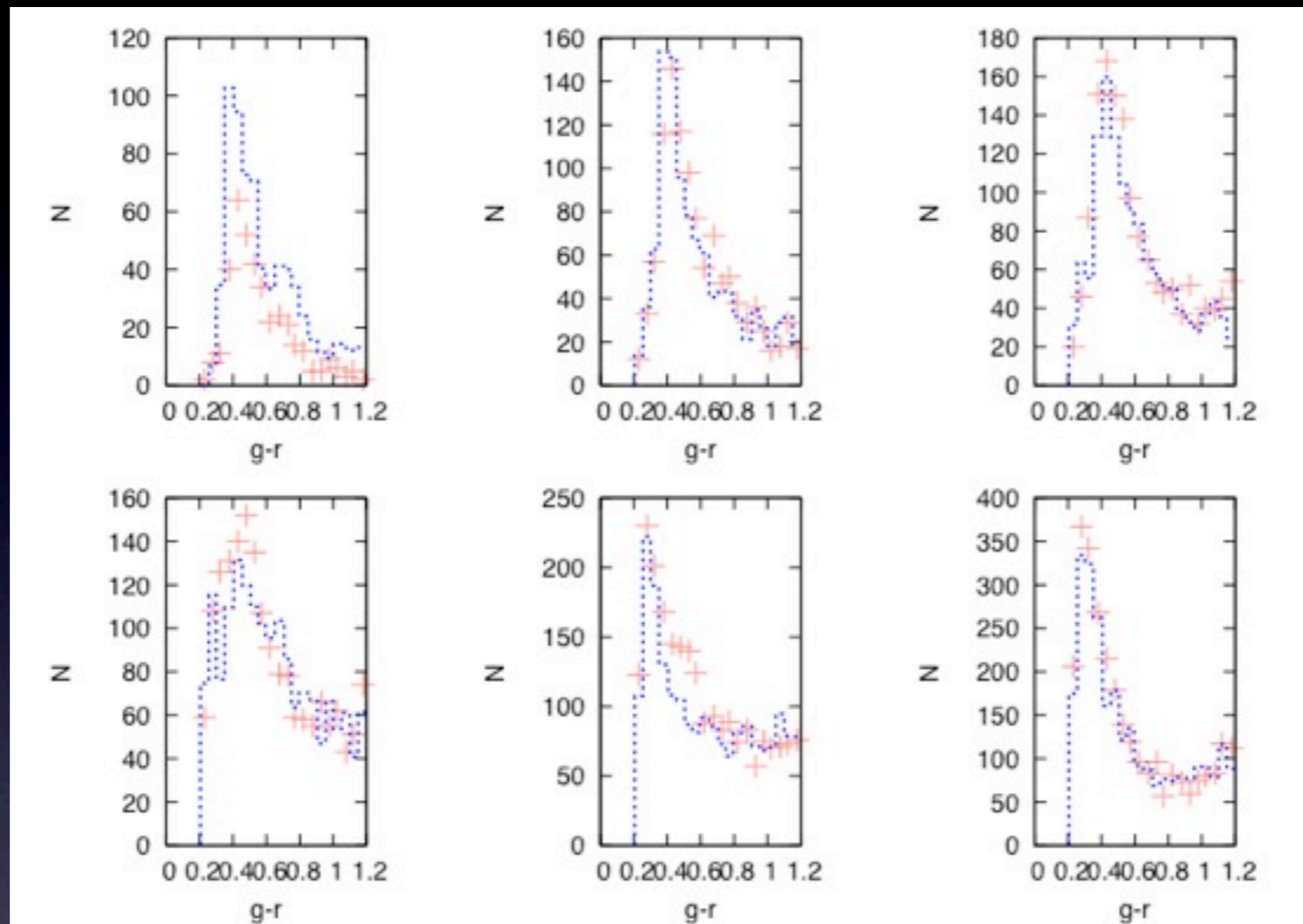


$l=0^\circ, b=-7^\circ$

- Data
- Model standard Bar
- Model with flaring bar

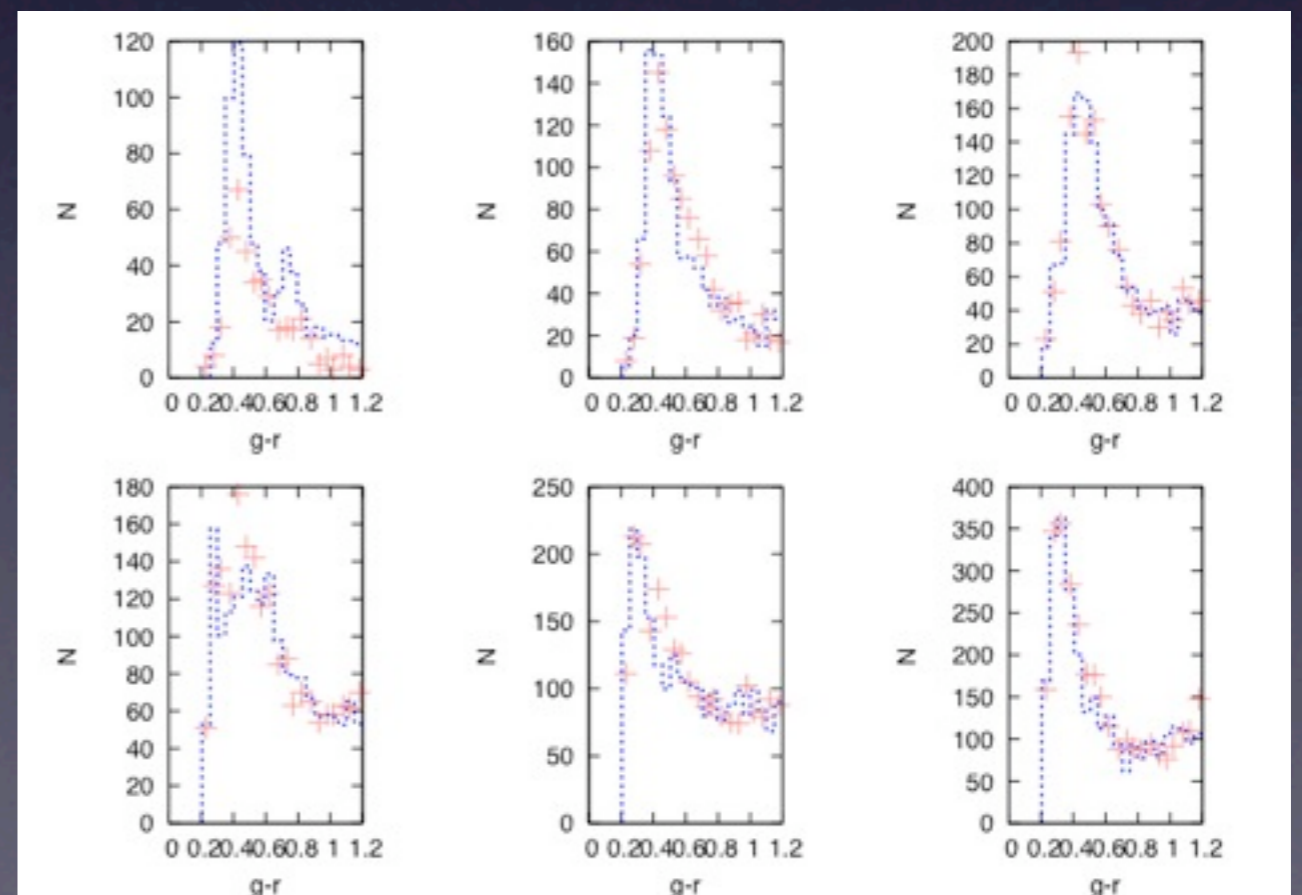
Développements en cours

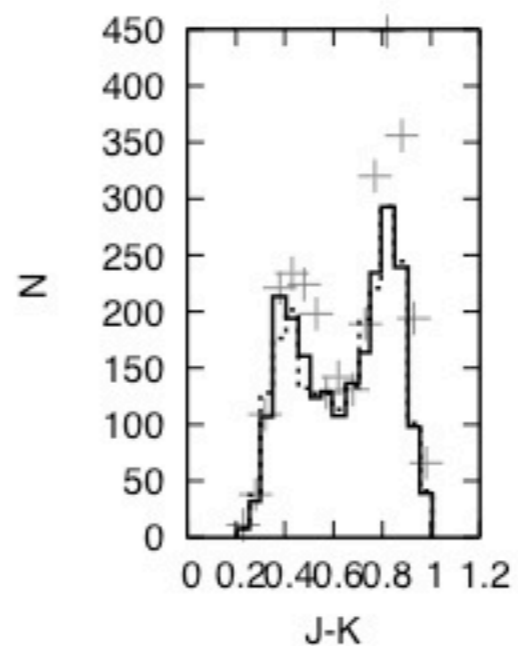
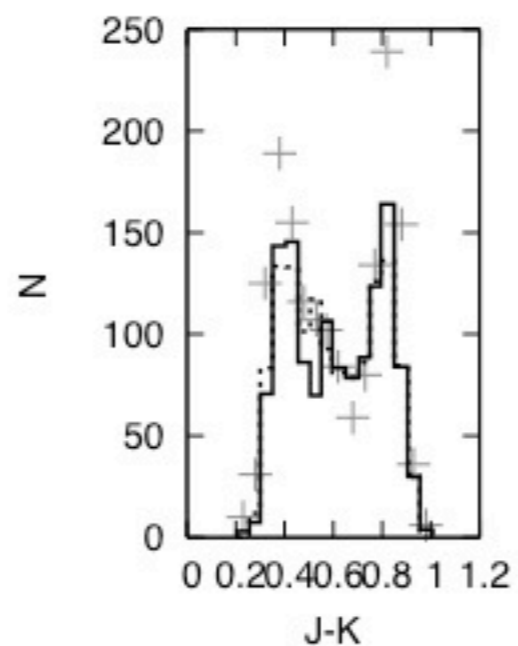
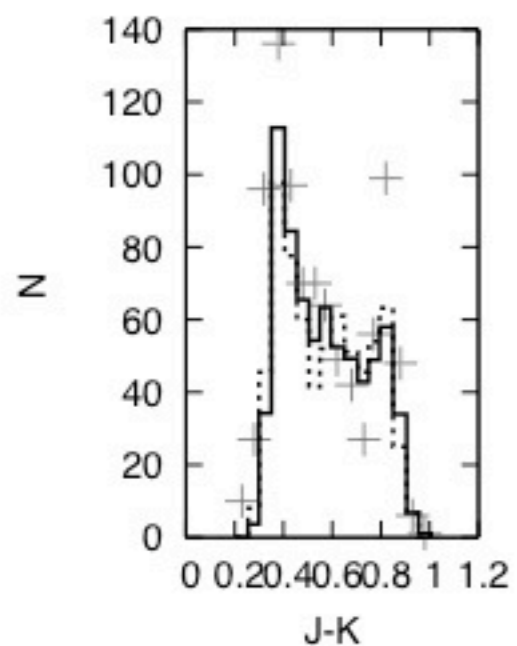
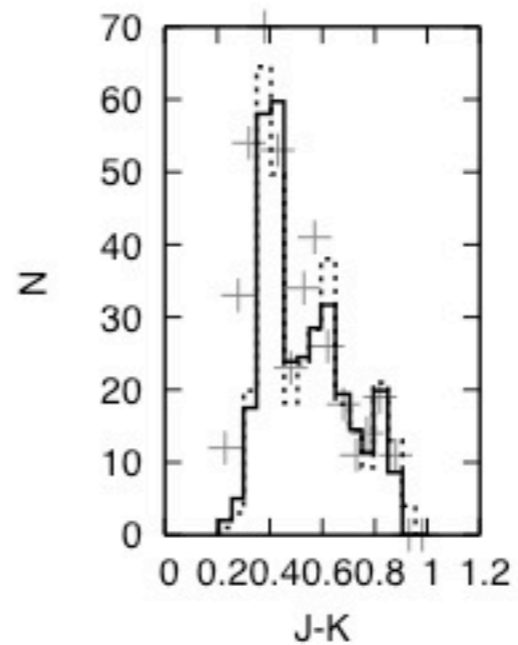
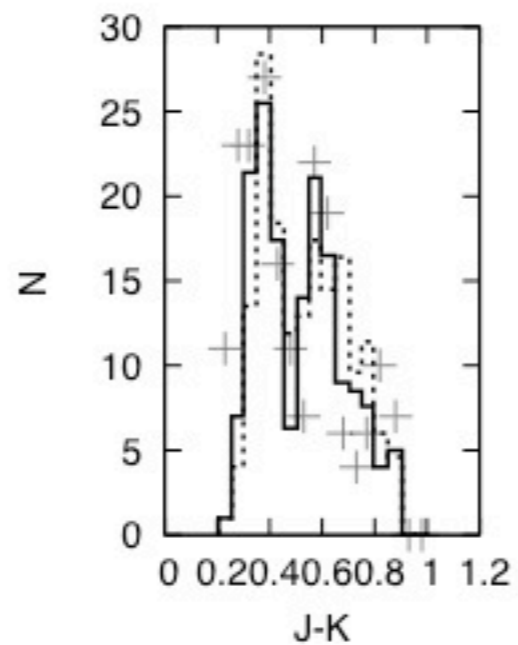
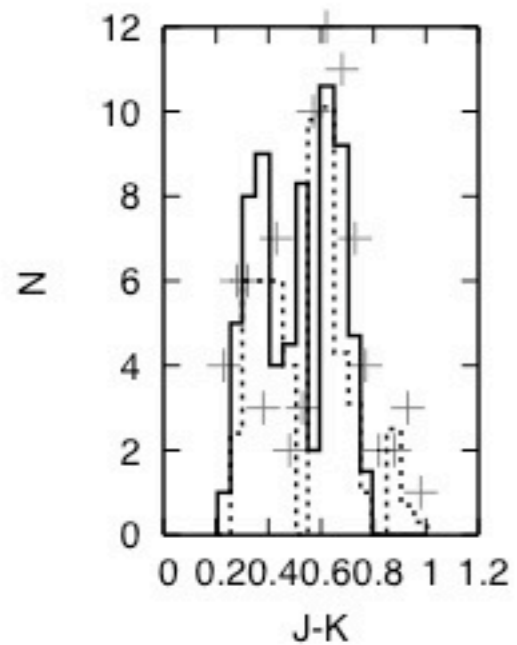
- Nouvelles possibilités pour les systèmes photométriques :
 - Visible : couleurs SDSS
 - Ultraviolet : Galex/UVIT
 - Infrarouge : Spitzer
- Nouveau modèle d'extinction : Marshall et al (2006)
- Populations :
 - Version 2012 pour le bulbe et la barre (*Robin, A. C., Marshall, D. J., Schultheis, M., Reylé, A&A 538, A10*)
 - Disque épais et halo stellaire
 - Cinématique : modèle de Fux (1999) pour la barre, mise à jour vitesses du soleil.
 - Disque cohérence dynamique avec densité locale de van Leeuwen (Révision Hipparcos)
 - IMF aux petites masses

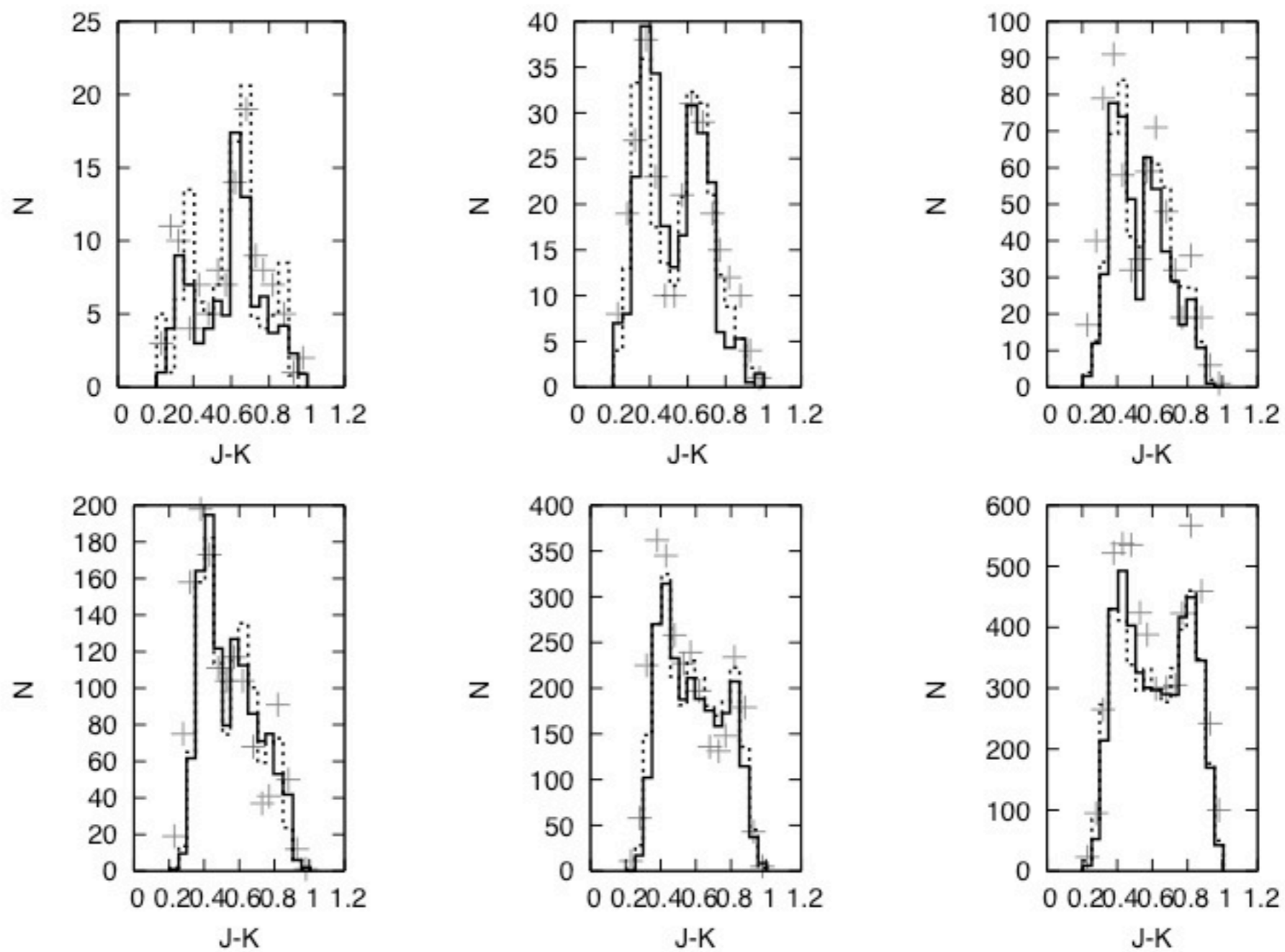


Ajustement des paramètres du disque épais et du halo (échelles de hauteur, longueur, ..., age, métallicité)
 Sur 72 champs SDSS et 60 champs 2MASS par chaînes de Markov Monte Carlo (MCMC).

Ajustement des paramètres du disque épais et du halo (échelles de hauteur, longueur, ..., age, métallicité)
Sur 72 champs SDSS et 60 champs 2MASS par chaînes de Markov Monte Carlo (MCMC).





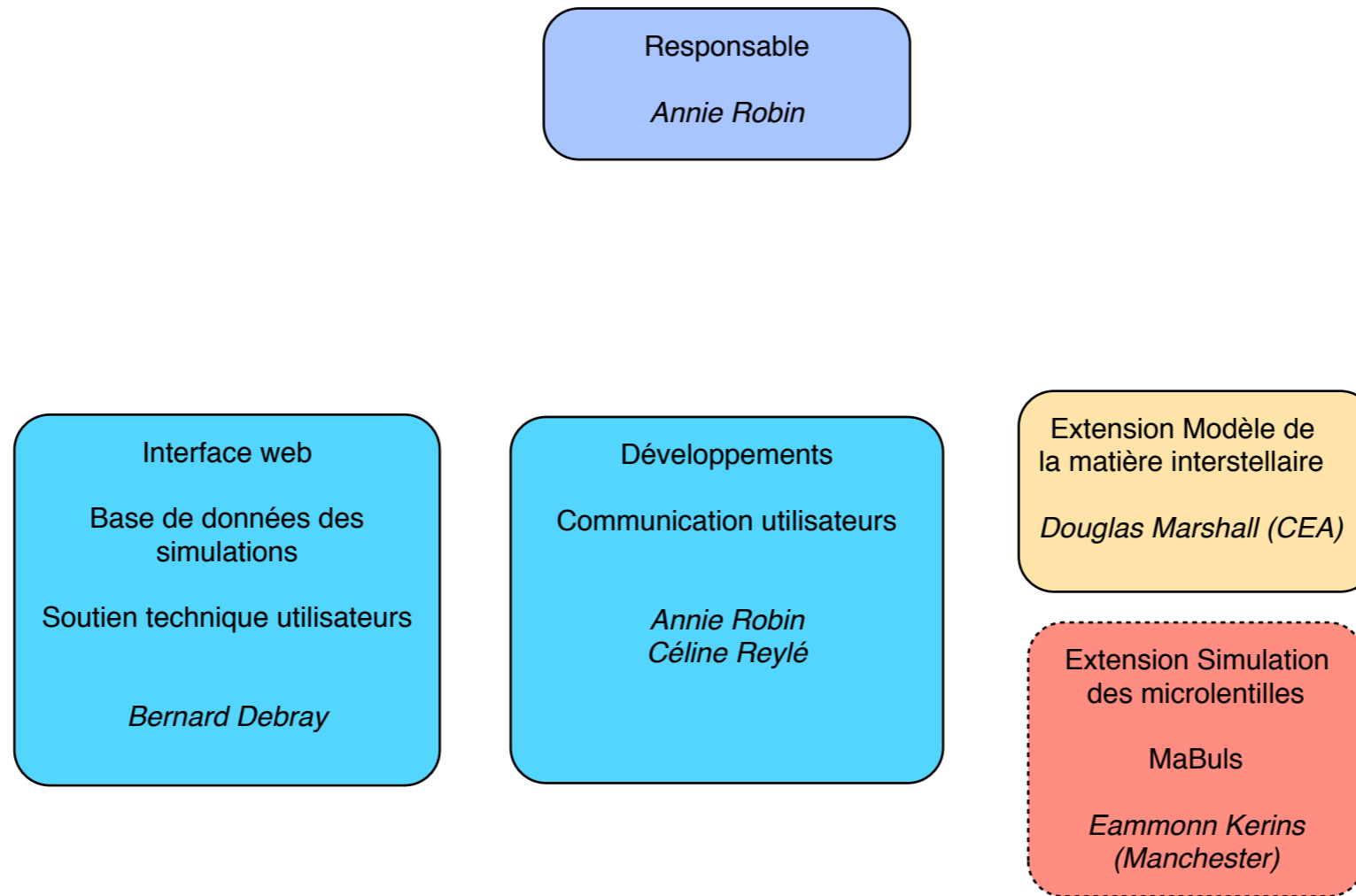


Développements en cours

- Nouvelles possibilités pour les systèmes photométriques :
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Organigramme du service

Modèle de la Galaxie de Besançon (BGM)



Labellisation du modèle comme service d'observations : mise en place
d'un comité de pilotage

Comité de «pilotage»

Hervé Wozniak
Olivier Bienaymé
Douglas Marshall
Bernard Debray
Céline Reylé
Annie Robin

Nombre de simulations :

	Nombre de connexions par mois	Nombre de visiteurs différents par mois	Volume téléchargé par mois	Nombre de pays d'origine des connexions
Pour l'année 2011 :	1523	29	25,2Go	30
Pour l'année 2012 :	1815	24	40,7Go	24

Développements techniques en cours

Interface web

- Accès par login/mot de passe : possibilité de suivi des simulations par l'utilisateur
- Sorties modèle : format VOTable 1.2
- Version bêta en ligne actuellement => publication en juin



Besançon model of stellar population synthesis of the Galaxy



Model forms

Description

References

Disclaimer

Changes log

This version of the Model of stellar population synthesis of the Galaxy was fully described in the following publication: A. C. Robin, C. Reylé, S. Derrière and S. Picaud. *A synthetic view on structure and evolution of the Milky Way*, 2003, *Astron. Astrophys.*, 409:523 (erratum: 2004, *Astron. Astrophys.*, 416:157)

Since this publication it has been affected by significant updates including:

- new photometric systems : instead of the Johnson-Cousins system, the user can have:
 - CFHT-Megacam-Wircam. See here for a complete description.
 - SDSS color can be obtained as well by simple color equations
 - Ultraviolet bands are available (Galex - UVIT)
- new extinction model; the user can apply either:
 - a simple diffuse extinction as before
 - a complexe 3D extinction map from Marshall et al (2006)
- new populations:
 - since 2012, the model includes a bar and a bulge in the central region (Robin, Marshall, Schultheis, Reylé, 2012). The kinematics of these populations will be described in Robin et al (2012) in prep.
 - the old populations (thick disc, bar, bulge, halo) now use the Padova isochrones. Their parameters (density, kinematics, metallicity) are subject to changes since new model fitting is in progress.
 - the thin disc density ellipsoid excentricities have changed to follow the new local mass density from Hipparcos re-analysis from Van Leeuwen.
 - the low mass end of the IMF fitted in Schultheis et al, *Astron. Astrophys*, 447:185 (2006) has been disregarded because of inconsistency with new deep data sets. The problem might be due to wrong model atmospheres.

Output mode:

Retrieval of result on ftp server when sim

Photometric system:

Johnson-Cousins

Form of the model simulation:

Catalogue simulation

Kinematics:

without kinematics

last modification: Fri Feb, 15 2013 10:43
CET

You are logged as user: galhis

Perspectives scientifiques

Modèle à SFR variable et simulations d'étoiles multiples (résolution variable)
Modèle d'extinction à partir des données VVV, VST, Glimpse
Amélioration de la dynamique

Perspectives du service

- Liens vers Mabuls (simulateur de microlentilles, Eamonn Kerins)
- Modèle d'extinction (régularisation par inférence bayésienne) : sous quelle forme ?
- Flux intégrés (?)
- Simulations au vol
- Publications des grands relevés (SDSS, CFHTLS, ...)
- Préparations de projets (Euclide, LSST, ...)
- Classification bayésienne