A galactic model as a useful tool for virtual observatories

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Abstract

Many observational data will be available through Virtual Observatories, but at some wavelengths and in some directions, no data yet exist. Concerning star counts, photometry and classifications, galactic models can be usefully included in VO for statistical inputs. The Besançon model of population synthesis [a] well calibrated at visible and near-infrared wavelengths can be useful to complement observational data :

- to extrapolate the stellar statistics to fainter magnitudes, interpolate at new wavelengths or at directions where no data are available yet.
- to classify observed stars from a computation of bayesian probabilities .

[a] http://www.obs-besancon.fr/modele/. The model will be soon available with the new version presented here. At the time being it is still the 1995 version at this site.

The Besancon model of population synthesis

The model is based on a semi-empirical approach, where physical constraints and current knowledge of the formation and evolution scenario of the Galaxy are used as a first approximation for the population synthesis. The model involves 4 populations (disc, thick disc, spheroid and bulge) each deserving a specific treatment.

Previous versions were described in Bienaymé et al. (1987ab) and Haywood et al. (1997ab). But since then many new features have been implemented and the parameters have been re-constrained with new available data. New performances include :

- A better description of the photometry with the Lejeune et al (1997) semi-empirical models, complemented by Baraffe et al (1998) at low masses. The model is well calibrated for the Johnson-Cousins system (UBVRIJHKL), for GAIA G band. The Sloan system is being studied.
- New parameters for the thin disc , due to significant improvements after Hipparcos : the potential is rebuilt to include the new constraints from Crézé et al (1998), the velocity ellipsoid is now from Gomez et al. (1997) and the local luminosity function (Jahreiss & Wielen (1997) and private communication) leads to a revision of the IMF at low masses (IMF slope of α=1.6).
- A new fit of the overall parameters of the spheroid (density law, local density and Initial Mass Function (Robin, Reylé, Crézé, 2000).
- New constraints on the thick disc population: kinematics (Ojha et al, 1996, 1999), density law, local density, metallicity

(Robin et al., 1996), and the Inital Mass Function at low masses (Reylé & Robin, 2001).

- The disc is warped and flared in the external part following new constraints from near-infrared star counts (DENIS data) (Derrière & Robin, 2001).

- A triaxial outer bulge has been included. It is based on the Dwek G2 density law, with Bruzual & Charlot isochrones. G2 parameters have been adjusted on a set of 100 low extinction windows at longitude [-8, +12] and latitudes [-4; +4] from DENIS survey data (Epchtein et al., 1997). The bulge model and the fitting process will be described in detail in Picaud et al. 2002 (in preparation).

Model predictions in various directions and wavelengths

The next figures show model predictions in the V and K bands in various directions. Observed star counts are also superimposed. The agreement between model and data is very good and gives confidence for using this model for interpolation. Extrapolations at very faint magnitudes are still risky since the predictions strongly depend on the assumed IMF at low masses which are still very uncertain.

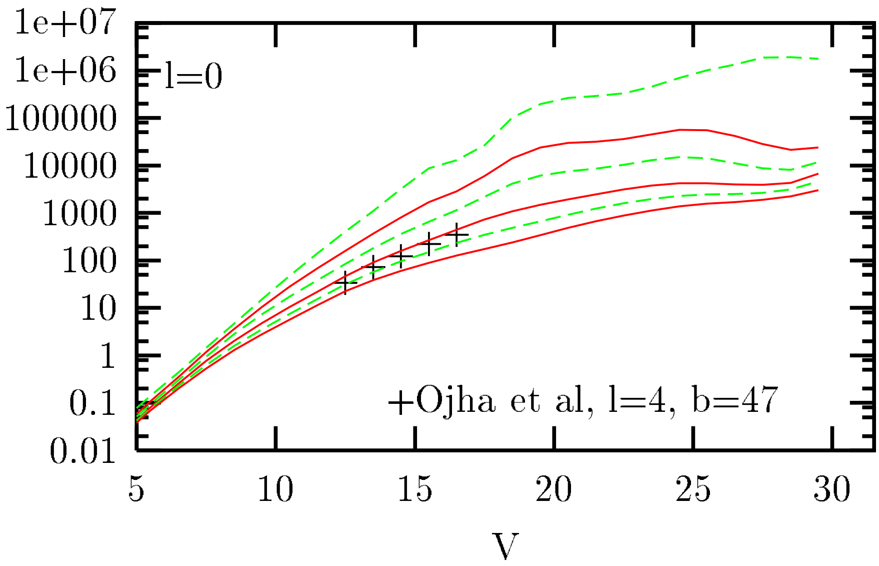

Figure 1: *Star count predictions (stars per magnitude and per square degree) in the V band at l=0, for latitudes 10 to 90 from top to bottom (10,20,45 and 90 with solid lines, 10,30,60 with dashed lines). The l=0, b=0 direction is not shown.*

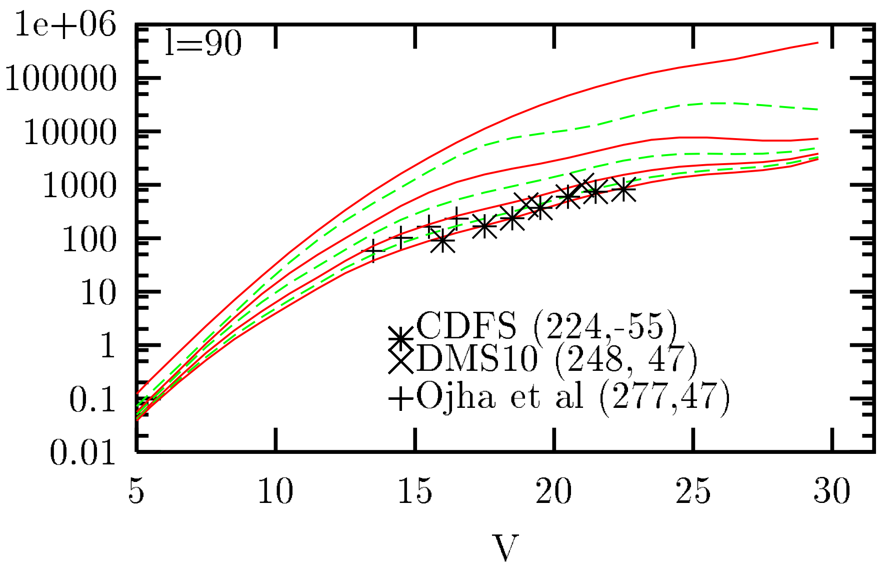

Figure 2: *Same as figure 1 but for l=90 or 270. DMS10 is a field from the DMS survey (Hall et al, 1996, Osmer et al, 1998), CDFS is the Chandra Deep Field South, observed in the EIS survey (Groenewegen et al., 2002).*

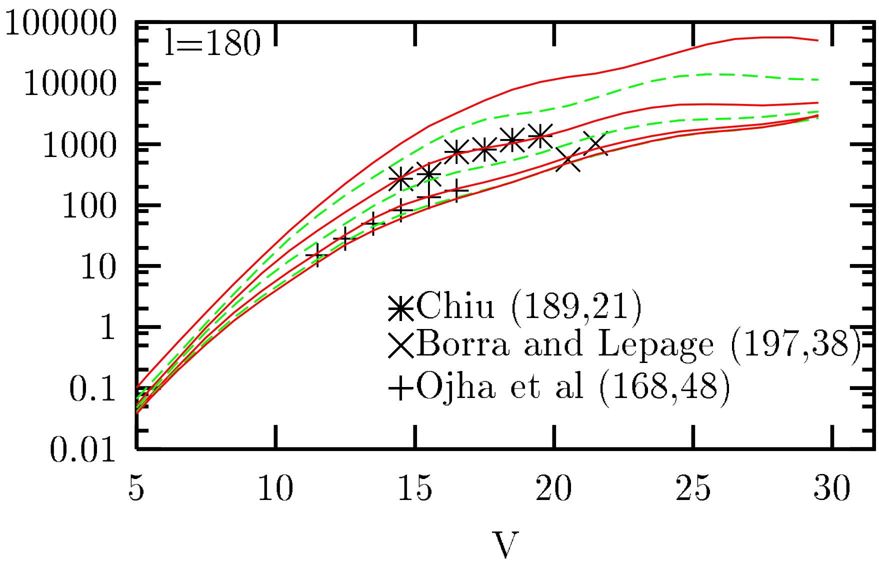

Figure 3: *Same as figure 1 but for l=180.*

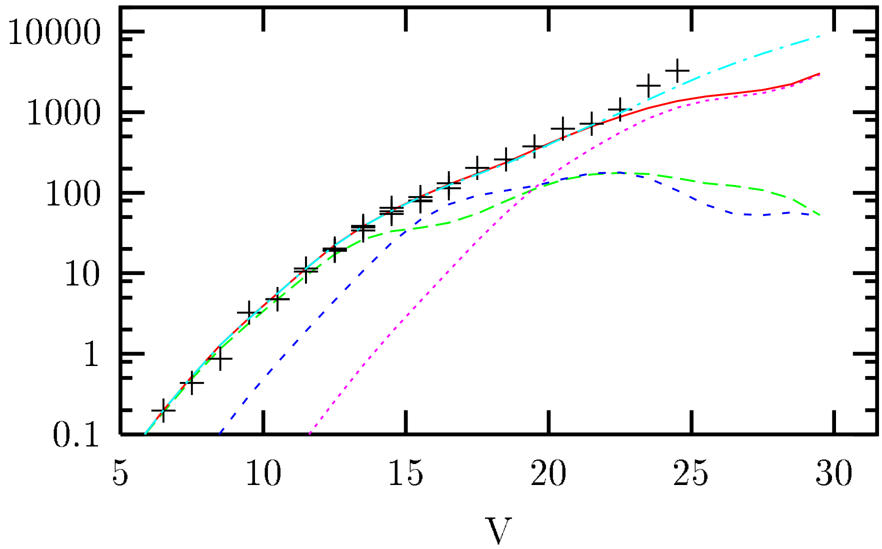

Figure 4: *Star count predictions in the V band at the galactic pole. Red solid line : total; green long dashed: disc; royal blue short dashed: thick disc; pink dotted line: spheroid. Various observed counts are indicated as crosses (error bars are smaller than symbols). The overall agreement is very good. At very low luminosity (V>23) observed star counts may be contaminated by galaxies. However a better agreement can be found by changing the IMF slope at low masses for the spheroid population (light blue dotted dashed : Simulation with a spheroid IMF slope of* $\alpha = 2$*, while the standard value is 0.5).*

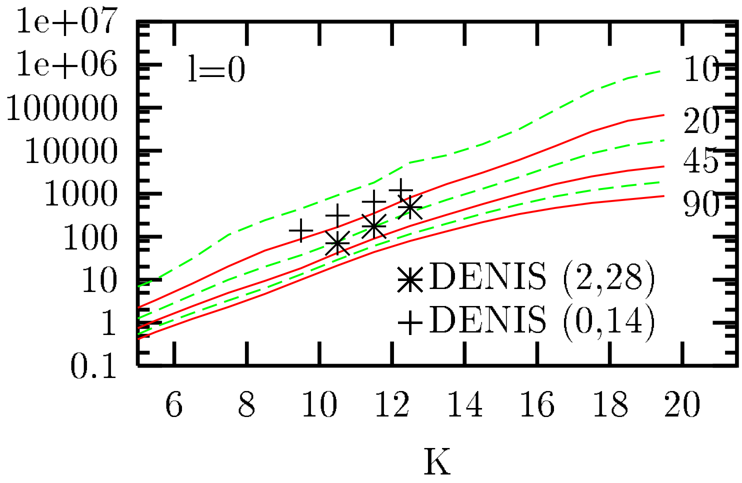

Figure 5: *Star count predictions in the K band (2.15 μ) at l=0, for latitudes 10 to 90 from top to bottom (10, 20, 45 and 90 with solid lines, 10, 30, 60 with dashed lines). The l=0, b=0 direction is omitted. Observations from the DENIS survey are superimposed in a few directions. The overall agreement is good even if the extinction has not been tuned to each field and may strongly change the predictions at* $|l| < 5$.

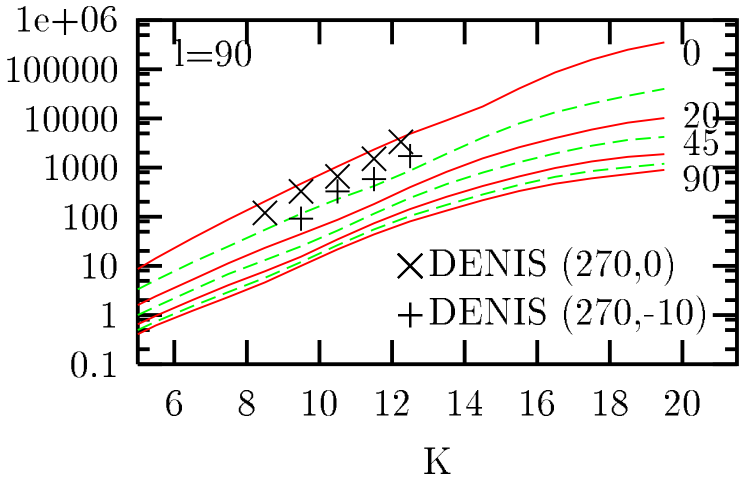

Figure 6: *Same as figure 5 at l=90 or 270*

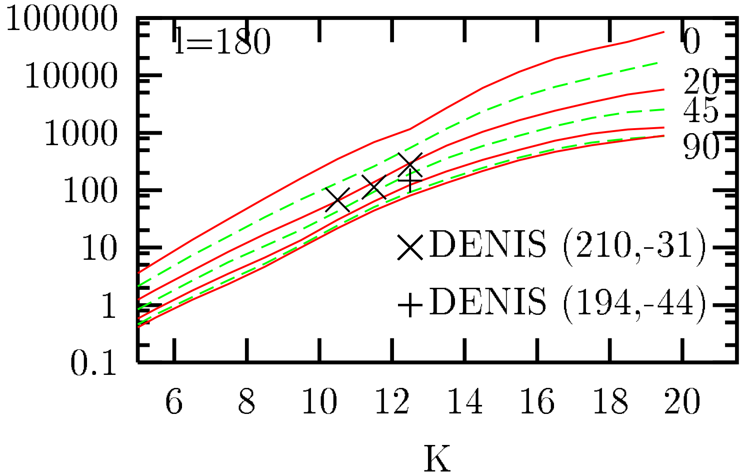

Figure 7: *Same as figure 5 at l=180*

A bayesian classification tool for a Virtual Observatory

We propose to use simulated catalogues to help classifying objects from their observed properties. Given a set of observables and observational errors, by suitable simulations of the direction of interest, the model can establish a probability classification. This classification is independent from the spectral classification: assuming that the model reproduces correctly the stellar content of the Galaxy, it allows to estimate the probable class, metallicity or population type of an observed star, using different types of observables such as direction of observation, magnitudes, colours, proper motions, radial velocities, etc...

Example: Considering a star selected in a given direction, if we know only its magnitude and colour, with a accuracy of, say, 0.10 mag., one can estimate the probability of this star to belong to a given population, or to have given intrinsic properties.

In the following tables we have computed the probabilities for a star to have its properties, assuming that we know 1) magnitude and colour; 2) magnitude, colour and radial velocity.

Table 1: *Probabilities of a star in the VIRMOS survey field (l = 171.7; b = -58.2) of magnitude I=22. ± 0.5 and V-I=1.8 ± 0.1, to have the following intrinsic properties.*

Absolute magnitude	9.75	10.25	10.75	11.25	11.75	12.25	
	0.013	0.184	0.263	0.289	0.171	0.079	
Luminosity Class	I	II	III	IV	V	VII	
	0	0	0	0	1.	0	
Spectral type	O	B	A	F	G	K	M
	0	0	0	0	0	0.105	0.895
Population	Disc	Thick disc	Spheroid				
	0	0.50	0.50				
Distance	0-2 kpc	2-5 kpc	5-8 kpc	>8 kpc			
	0	0.908	0.092	0			

Table 2: *Probabilities of the same star in the VIRMOS survey field of magnitude I=22. $\pm$ 0.5 and V-I=1.8 $\pm$ 0.1 with a radial velocity of 50 km/s, to have the following intrinsic properties.*

Absolute magnitude	9.75 0	10.25 0.167	10.75 0.167	11.25 0.667	11.75 0.	12.25 0.	
Luminosity Class	I 0	II 0	III 0	IV 0	V 1.	VII 0	
Spectral type	O 0	B 0	A 0	F 0	G 0	K 0.	M 1.
Population	Disc 0	Thick disc 0.33	Spheroid 0.67				
Distance	0-2 kpc 0.	2-5 kpc 1.	5-8 kpc 0.	>8 kpc 0.			

Adding up a new observable obviously changes the probabilities by limiting the range of possibilities. The model allows to compute easily these probabilities and also to determine which observable is more suitable for getting a better efficiency in the classification. In this example the inclusion of the radial velocity measurement allow to limit the probable interval of the absolute magnitude and distance of the star.

This tool has already been used in two occasions :

- to estimate the contamination of the Oppenheimer sample (Oppenheimer et al, 2001) of high proper motion white dwarfs by the thick disc population (Reylé, Robin, Crézé, 2001). We have then showed that the sample included a vast majority of thick disc WD while the authors thought to have observed halo WD.
- to determine the populations a sample of nearby stars belongs to, and to estimate their distance (Reylé et al 2002).

We propose to use this probability estimator in Virtual Observatories to help researchers in stellar classification and for data interpretation.

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