

# GUMS & GOG: simulating the universe for Gaia

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**Abstract** A key component of the Gaia mission development is its simulator. This system can generate a realistic simulation of the data stream that will be produced by Gaia, a critical milestone to verify the data reduction programs. A core piece of the simulator is its universe model, a module that can generate synthetic catalogues of objects to obtain simulated observations. GUMS is the application that can generate the object catalogue up to a particular magnitude limit. As an example of application that uses the model, we describe GOG, a simulator of Gaia catalogue intermediate and final data. It combines the source observation of the universe model with the satellite instrumental specifications and the available error models.

## 1 GUMS: Gaia Universe Model Simulator

The basic component of the universe model is the Besançon Galaxy Model (BGM) that includes modules for quasar, asteroid and galaxies. In particular, Gaia will detect and measure up to  $10^9$  objects that are part of our Galaxy, being this the main contribution to the final mission catalogue. For this reason, it is necessary a realistic model of the star distribution in the sky, with a realistic spectral distribution and kinematics for these objects. The Besançon galaxy model synthesises the stellar map using four different stellar populations: thin disk, thick bulge, external bulge and the spheroid. GUMS uses the synthesis of stellar population given by the BGM [7] to produce object catalogues using a parametrized configuration. Moreover, it assigns

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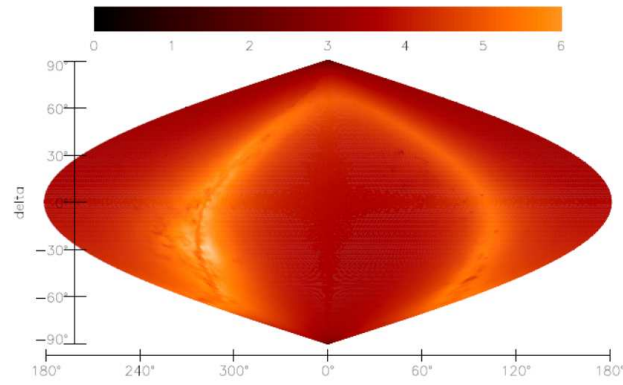
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to each star information such as its magnitude, color, distance, kinematics and physical parameters. The Gaia consortium aims to include continuous improvements of its ingredients (local luminosity function, age-velocity-metallicity relation, among others) using observational data. The current version generates six different types of stellar variability : cepheids, RRab, scuti, roAp, ACV being the variability probabilities assigned as a function of the position on the HR diagram. The light curves have been modelled for each type of variability [6]. To generate multiple systems for each simple star (generated by BGM) a companion may (or may not) be generated according a probability function that depends on the primary spectral type. The separation function distribution and the primary/secondary mass ratio are imposed by [1]. At the current stage, the simulator is able to generate major solar system bodies with their real ephemerids (the sun, the moon, planets and their satellites). Minor objects are generated using observational catalogues: little asteroids, new comets, Kuiper belt objects and centaurs. The probability of assigning exoplanets to FGK dwarf stars as function of the metallicity is assigned following [8]. To produce extragalactic objects the universe model uses Stuff as object generator and Skymaker for modelling its shape/image. Resolved near galaxies are not yet implemented. In addition, the simulator has an embedded, large-scale, interstellar tridimensional extinction model as proposed by [4] . (This module has been designed as a plug and play component in java). Also the background will play a critical role on the object detection , and reduction process. GUMS considers a uniform background with respect the solar spectra. Only GIBIS [2] can generate a variable background for specific directions.

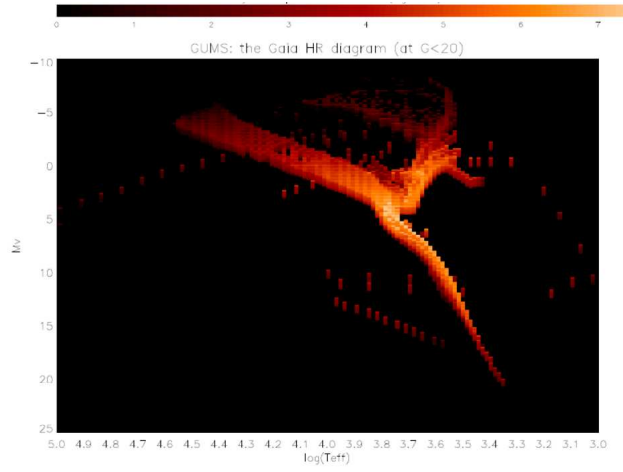
Figures 1, 2 depict a first approximation of the sky as it will be seen by Gaia and the stellar content. The picture shows the star densities in each direction. The only observational limitation is the one forced by the apparent magnitude ( $G=20$ ). Usages of this data are: telemetry compression studies, data processing strategy algorithms to deal with highly populated regions (different spatial resolution in astrometry and spectroscopy), reduction model tests of the astrometric data used by AGIS (Astrometric Global Iterative Solution), or test of the proposed calibration models (depending on the number of objects, colour, aparent magnitude,...) among others.

## 2 GOG: The Gaia Object Generator

GOG is a tool designed to directly obtain intermediate and final catalogue data for Gaia. Current specifications of GOG include analitical and numerical error models for astrometry (centroid error determination), spectrophotometry and radial velocity data including the calibration errors. The models are partially given by EADS-Astrium (satellite manufacturer) and experts within the Gaia consortium. Future versions will include estochastic errors coming from the data reduction processes. Errors are applied per source transit (epoch data) and for several transits (mean/combined data). GOG error models are continously refined and in the future



**Fig. 1** Sky map generated using GUMS as seen by Gaia for all stars up to  $G=20$

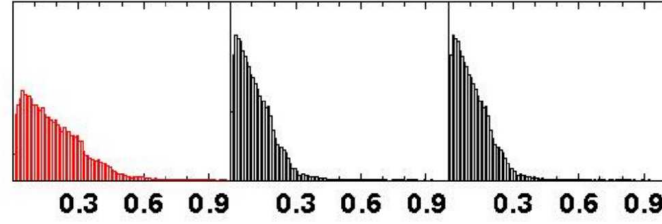


**Fig. 2** HR diagram generated using GUMS for an apparent limit magnitude  $G=20$

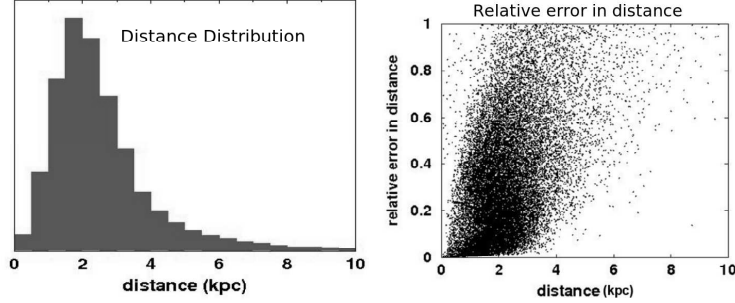
will include effects such as the radiation damage(charge losses) or smearing that will impact on the final catalogue data results. A few examples of Gog uses are:

- Trigonometric parallax accuracy studies for different values of colour and magnitude.
- Astrometric binaries : Orbit parameter recovery algorithms can be fed using Gog outputs. To do so, single transit observations (including their errors) are used.
- BP/RP Spectra processing: GOG provides low resolution spectra (BP/RP) for normal and peculiar stars, galaxies and QSO, generating their spectra and associated errors for epoch and combined observations. [5, 3].

As an example of results, figure 3 shows the astrometric error distribution on some astrometric parameters for stars pointing to the galactic center. Figure 4 illus-



**Fig. 3** Expected accuracy on astrometric data for stars at the galactic center direction  $(l,b) = (0,0)$ . Left: parallax; center:  $\mu\alpha\cos\delta$ ; right:  $\mu\delta$ . Units: mas and mas/yr



**Fig. 4** Stars in the galactic center direction  $(l,b) = (0,0)$  as seen by Gaia. (**left**: distance distribution **right**: distance accuracy)

trates the heliocentric distance and error distribution for the stars to be observed in the galactic center direction.

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