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Data mining with the multicolor GSC-II database

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Abstract. The GSC-II database - from which the GSC 2.2 catalog has been extracted - contains multi-epoch positions, classification and photographic photometry in the blue B_J, red R_F and infrared I_N passbands for about 1 billion stellar and extra-galactic objects down to $B_J \simeq 22.5$, $R_F \simeq 20.5$, and $I_N \simeq 19.0$. This archive constitutes a formidable data set for the study of the Milky Way and its stellar populations as well as for the hunt of peculiar and rare targets. Here, the content and structure of the GSC-II database is described, and some examples of its exploitation are presented.

Key words. Surveys – Galaxy: structure – Galaxy: stellar content – Stars:kinematics – white dwarfs – Methods:statistical

1. Introduction

The GSC-II is an all-sky catalog based on the photographic surveys carried out with the Schmidt telescopes at the Palomar and Anglo-Australian Observatory (AAO). All $6.4^\circ \times 6.4^\circ$ plates were digitized at STScI utilizing modified PDS-type scanning machines (15 μm/pixel, i.e. 1 arcsec/pixel). Positions, magnitudes, and classifications are produced for all objects on each plate and stored into an object-oriented federated database, COMPASS, which adopts a storage hierarchy based on 32768 sky areas defined by the Hierarchical Triangulated Mesh (HTM). Each of the triangular subdivisions corresponds to a database within the all-sky federated database (McLean et al. 2000). This strategy has also been adopted by the SDSS Science Archive and 2MASS and is an ideal example for supporting interoperations between large-scale astronomical archives.

The GSC II archive is currently a 4 TByte all-sky database with the following data accessible for about 1 billion unique entries (stars and galaxies) detected on the ~8000 survey plates processed:

- multi-epoch positions (epoch time span up to 50 years);
- multi-color photographic photometry: blue B_J, red R_F and infrared I_N passbands from POSS-II and AAO surveys, plus further photometry from the POSS-I and Quick-V surveys;
- object classification (star/non-star).

The magnitude limits are $B_J \simeq 22.5$, $R_F \simeq 20.5$, and $I_N \simeq 19.0$. Photometric errors are in the range 0.1-0.2 mag, with zero-point errors typically < 0.1 mag; absolute positional astrometry error is 0.2″-0.3″.

The primary utilization of the database is to provide rapid access to plate data for advanced astrometric and photometric calibrations as well as multi-plate operations that will yield colours and proper motions. In particular, this system is capable of exporting all-sky catalogs, like the GSC 2.2 (released in 2001) which contains 455,851,237 objects down to B_J <19.5 and R_F < 18.5, or the next version, GSC 2.3, which will include IV-N infrared photometry and proper motions for all the objects down to the plate limits.

Besides the automatic procedures optimized for the bulk of the GSC-II objects, special data processing tools have been developed to select particular classes of objects such as nearby high proper motions stars, or to attain better photometric and astrometric accuracy over specific regions needed for galactic structure studies. In the following sections, some specific studies based on the data mining of the GSC-II material are shortly illustrated.

2. Halo White Dwarfs & Baryonic dark matter

Cool white dwarf (WD) stars are the remnants of stars which were born when the Milky Way was very young. Also, Pop.II WDs are the natural candidates for the MACHOs revealed by the LMC microlensing surveys (Alcock et al. 2000) which seem to indicate that ~20% of the dark matter is tied up in objects with ~ $0.5 M_\odot$. As reviewed by Hansen & Liebert (2003), several projects have been carried out in recent years to reveal the existence of such a hidden population of dim sources. The most extensive survey to date (Oppenheimer et al. 2001) provides a controversial lower limit on the space density of ~ $10^{-4}\ M_\odot\ pc^{-3}$, that is about 1% of the expected local dark halo density.

Our survey covers an area of ~ 1100 square degrees, mostly located toward the North Galactic Pole (NGP), where faint (R_F > 16) and fast moving (μ > 0.3″/yr) stars were revealed. The RPM diagram, $H_R = R_F + 5\log\mu - 5$ vs. $(B_J - R_F)$, was adopted to identify faint objects with high proper motion and to separate disk and halo WDs from late type (sub)dwarfs (Fig. 1).

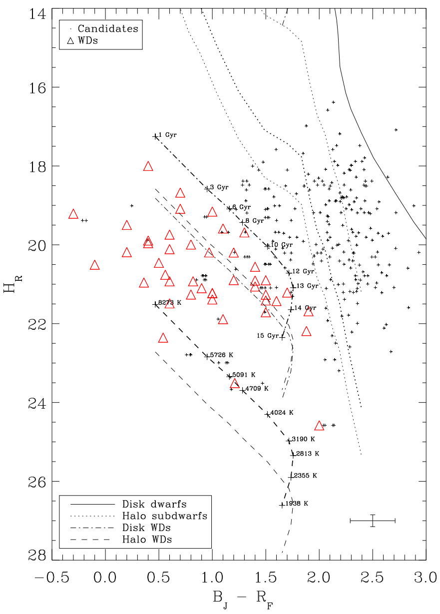

Fig. 1. Reduced proper motion (RPM) diagram of the GSC-II candidates. WDs classified by low resolution spectroscopy are shown as red triangles. The solid and dotted (thick) lines show the locus of the disk dwarfs and halo subdwarfs based on the 10 Gyr isochrones from Baraffe atmosphere models with [Fe/H]=0 and −1.5, respectively. Dashed and dot-dashed (thick) lines show the cooling tracks of 0.6 $M_\odot$ WDs with hydrogen atmosphere from Chabrier models. Thin lines indicates the 2σ kinematic thresholds of each population.

The spectroscopic follow-up (TNG, WHT, INT) provided spectra for 50 stars and confirmed 35 white dwarfs in which 14 are without Hα. These include the discovery of a few exotic objects like a carbon rich DQ WD with extremely strong C_2 molecular bands, for which Carollo et al. (2003) estimated $T_{\rm eff} \simeq 5100$ K, that corresponds by far to the coolest DQ currently known.

Finally, halo WDs have been kinematically selected with a new procedure described by Spagna et al. (2004), and the resulting preliminary local space density evaluated with the 1/Vmax Schmidt method is: $\rho_{WD} \approx 10^{-5}$ $M_{\odot}$ pc^{-3} (Carollo et al. 2004). This value is consistent with the local mass density of halo stars estimated by Gould et al. (1998), as well as by other authors who reanalyzed the Oppenheimer et al. sample and indicate that ancient cool WDs do *not* contribute significantly to the baryonic fraction of the galactic dark halo.

3. The thick disk parameters

The Thick Disk (TD) corresponds to the Intermediate Pop.II (Gilmore & Reid 1983), whose existence is now well established, although its properties and origin are not clearly defined. The currently favored model within the context of hierarchical galaxy formation theories is a bottom-up scenario that interprets the TD as the result of dynamical heating of the primordial thin disk after a merging event with a satellite galaxy mass of 5-10% that of our Galaxy (Freeman & Bland-Hawthorn 2002).

This scenario is supported by the results of Robin et al. (1996) who analyzed photometric and kinematics data from several high and intermediate galactic latitude fields (cfr. also Siegel et al. (2002)). Also, Gilmore et al (2002) measured a rotation velocity of the outer TD of about 100 km/s, instead of the more usual ~180 km/s, possibly due to stellar debris from a disrupted satellite.

A sample of about 20,000 G-K dwarfs up to 3 kpc over about 300 sq-deg towards the NGP and intermediate latitude GSC-II fields has been analysed. Photometric parallaxes (30% accuracy) have been computed taking into account the Malmquist bias, the presence of vertical metallicity gradients, extinction and the contamination of binaries. The analysis of the multi fields (Fig. 2) indicates a vertical scale-height h_z=900-1000 pc and a local relative density of 4-5% at z=0, and a radial scale-length $h_R \simeq 3$ kpc (Spagna et al., in preparation). In the future, we will extend the analysis to determine the TD kinematic parameters as well, using proper motions derived from GSC-II observations.

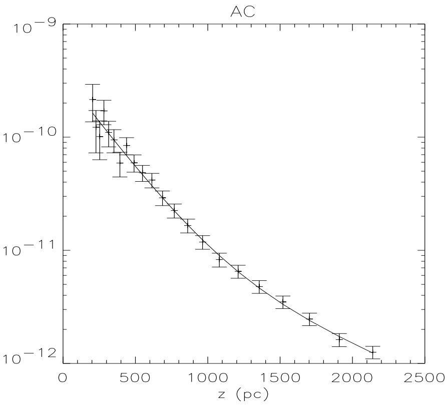

Fig. 2. Vertical space density (points with poissonian error) measured towards the anti-center field (l = 145.5°, b = +45.1°). The solid line shows a 2-component model (thin + thick disk) resulting from a multi-field best fit.

4. All sky "corrected" starcounts

The GSC-II database contains about 1 billion objects, most of them are located near the galactic plane. The issue of the unresolved objects in the crowded GSC-II regions has been modelled and the first estimate of deep source counts over the whole sky have been derived by Drimmel et al. (2004). The presence of real extra-galactic extended objects and blended stars have been disentangled, taking into account the non-linear response of the photographic emulsions, and the results have been checked against GSPC-II fields at low galactic latitudes.

Furthermore, using SDSS data, misclassification in the GSC-II has been modelled as a function of the stellar field density and magnitude, allowing a more refined estimate of source counts.

The cumulative distribution of objects down to R_F = 20 (Figs. 3-4) have been made available to support the technical-scientific studies of the GAIA mission (ESA), such as the estimation of telemetry rates and the test

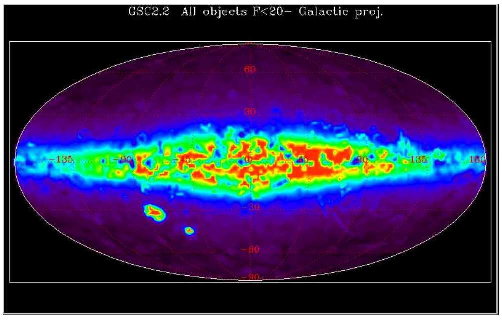

Fig. 3. Sky map showing the distribution of the GSC-II objects (stars+galaxies) brighter than $R_F = 20$. Red color corresponds to regions with a density higher than 70,000 objects per square degree.

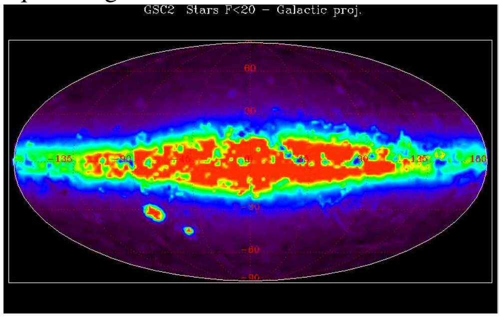

Fig. 4. Expected distribution of the stars brighter than $R_F = 20$, statistically corrected for the presence of unresolved GSC-II objects in the very crowded regions.

of the detection algorithms (Drimmel et al. 2003).

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