# The Guide Star Catalog II: Properties of the GSC 2.3 Release

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## ABSTRACT

The Guide Star Catalog II (GSC-II) is a joint project of the STScI (Baltimore) and INAF-OATo (Italy) for the construction of an all-sky astronomical catalogue containing position, multicolour photometry, classification and proper motions for 1 billion of stars and galaxies down to R~20 mag. Astrometric and photometric data have been derived from the analysis and calibrations of about 8000 digitized Schmidt plates of the Palomar and AAO surveys.

This material makes up a formidable data set for the hunt of rare targets as late type stars, white dwarfs, etc., as well as for the study of the main galactic stellar populations (thin/thick disk and halo).

The last public release, GSC 2.3, contains positions, photographic photometry $B_J$,$R_F$,$I_N$, and classification for approximately 997,028,547 entries extracted from the complete GSC-II database. GSC 2.3 is currently used for HST Bright Object Protection and it replaces GSC-I for HST pointing since cycle 15.

Here we describe the properties of GSC 2.3 and discuss its astrometric and photometric accuracy with respect the other large surveys.

## Plate material and image processing

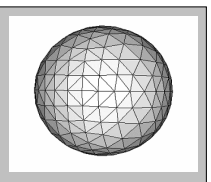
The GSC-II is based on the photographic surveys carried out with the Schmidt telescopes at the Palomar and Anglo-Australian Observatory (AAO).

| Source | Survey | Epoch | Band | Filter | Mag. Limit | plates | sky coverage |
|---|---|---|---|---|---|---|---|
| N | Pal-QV | 1983-85 | IIaD+W12 | $V_{12}$ | 19.5 | 616 | $\delta \geq 0°$ |
| S | SERC-J | 1975-87 | IIIaJ+GG395 | $B_J$ | 23.0 | 606 | $\delta \leq 0°$ |
| S | SERC-EJ | 1979-88 | IIIaJ+GG395 | $B_J$ | 23.0 | 288 | $\delta \leq 0°$ |
| XE | POSS-I E | 1950-58 | 103aE+red | E | 20.0 | 935 | $\delta \geq -30°$ |
| XO | POSS-I O | 1950-58 | 103aO | O | 21.0 | 935 | $\delta \geq -30°$ |
| XJ | POSS-II J | 1987-00 | IIIaJ+GG385 | $B_J$ | 22.5 | 897 | $\delta \geq 0°$ |
| XP | POSS-II F | 1987-99 | IIIaF+RG610 | $R_F$ | 20.8 | 897 | $\delta \geq 0°$ |
| XI | POSS-II N | 1989-02 | IV-N +RG9 | $I_N$ | 19.5 | 897 | $\delta \geq 0°$ |
| XS | AAO-SES | 1990-00 | IIIaF+OG590 | $R_F$ | 22.0 | 606 | $\delta \leq 0°$ |
| ER | SERC-ER | 1990-98 | IIIaF+OG590 | $R_F$ | 22.0 | 288 | $\delta \leq 0°$ |
| IS | SERC-I | 1990-02 | IV-N +RG715 | $I_N$ | 19.5 | 731 | $\delta \leq 0°$ |
| IS | M W Atlas | 1978-85 | IV-N +RG715 | $I_N$ | 19 | 173 | $\delta \leq 0°$ |
| XV | SERC QV | 1987-88 | IIaD +GG495 | $V_{495}$ | 14 | 94 | $\delta \leq 0°$ |
| GR | AAO SR | 1996-99 | IIIaF+OG590 | $R_F$ | 20 | 118 | $\delta \leq 0°$ |

All these plates were digitized at STScI utilizing modified PDS-type scanning machines with 15 µm/pixel (1") and 25 µm/pixel (1.7"). Then, images were processed and calibrated by means of a software pipeline which computed positions, magnitudes, and object classification.

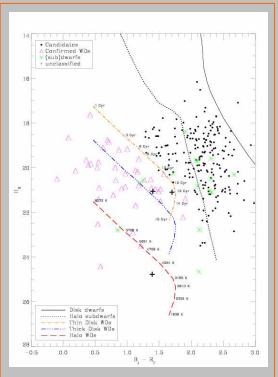
These data are stored into an object-oriented federated **database**, COMPASS, which adopts a storage hierarchy based on 32768 sky areas defined by the Hierarchical Triangulated Mesh (HTM) level 6 (McLean et al. 2000).

## GSC-II database (COMPASS)



- Astronomical data
  - ALL-SKY Archive
  - image analysis and calibration of **~8000** digitized Schmidt plates from POSS and AAO surveys
  - ~ 1 billion stars, galaxies, and other objects down to $B_J$<22.5, $R_F$<20.5 and $I_N$<19.5
  - Multi-epoch **positions** (0.2-0.3" accuracy)
  - multicolor photographic **photometry** (0.1-0.15 mag accuracy)
  - Object **Classification** (stellar/extended object)
- Archives
  - No. 2 mirror copies at STScI and OATo
  - Windows 2003 server+EIDE RAID Array (4TB)

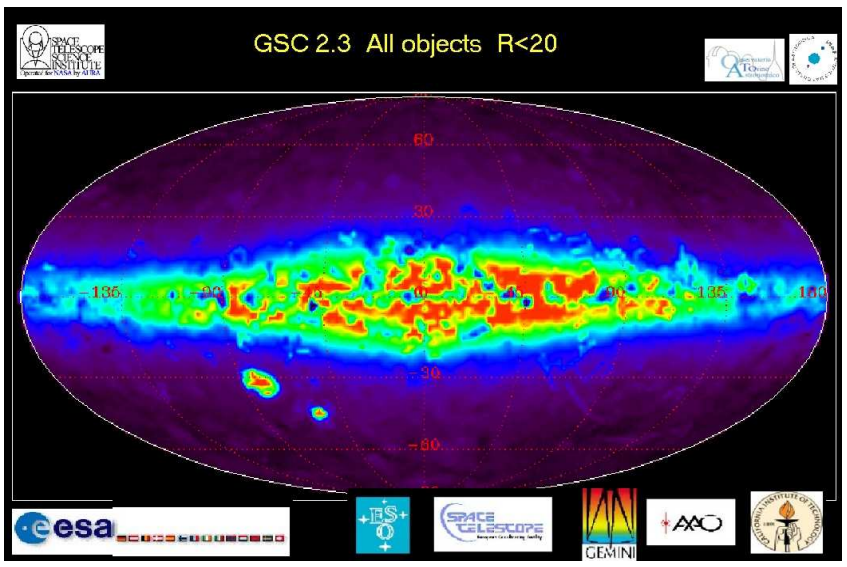
## GSC-II data mining for Galactic Astronomy



*RPM diagram showing selected high proper motion targets and identified WDs.*

We briefly mention:

- The WD high proper motion surveys (1150 deg$^2$) to search for ancient halo WDs and measure the baryonic fraction of local dark matter. We found 41 WDs, including 24 new discoveries (*Carollo et al. 2006, A&A, 448, 579*), whose analysis is in preparation.
- Kinematic study towards the NGP to measure the velocity ellipsoid rotation velocity gradients of the thick disk and halo and constrain its IMF (*Vallenari et al. 2006 A&A 451,125*)




**GSC 2.3** As of October 2006, the version 2.3.02 contains **positions**, **classifications**, and photographic **magnitudes $B_J$ $R_F$ $I_N$** for **approximately 997,028,547** objects down to the plate limits, $B_J$ ≈22 $R_F$ ≈20.5.
Public releases of GSC 2.3 are currently available to the community via the Web services:

- http:// galex.stsci.edu/GSC2/GSC2WebForm.aspx (STScI)
- http:// vo.oato.inaf.it/gsc2sql/sql.aspx (INAF-OATo)

and via the Open Sky Query of the National Virtual Observatory (NVO):
http:// openskyquery.net/

## Photometry

GSC-II magnitudes were derived via modeling of the non-linear density-to-intensity response of plate-based photometric calibrators, in the natural system defined by each individual plate. The calibrators are based on Johnson-Cousins B,V,R standards from the Guide Star Photometric Catalog I (Lasker, Sturch et al. ApJS 1988, 68, 1) and II (Bucciarelli et al. 2001, A&A 368, 335) down to V≈19; additionally, B,V photometry of TYCHO stars was included in the calibration to constrain the bright range of the response.

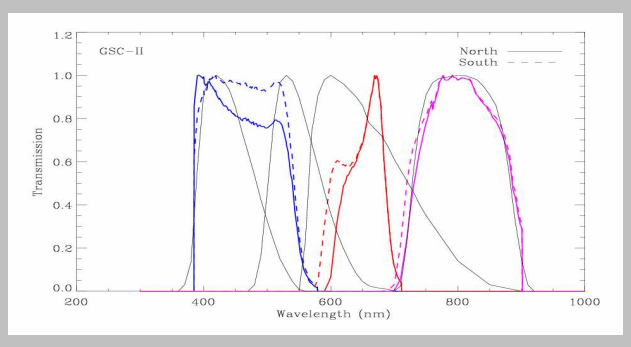



*Figure: $B_J$, $R_F$, $I_N$ passbands compared with Johnson-Cousins BV(RI)c filters*

For *stellar objects*, photometric precision attains **magnitude errors of 0.1 mag**, with comparable systematic errors of 0.1, mag due to zero point variation as a function of position. *Extended objects,* which include galaxies and (un)resolved blends, show larger random and systematic errors up to about 0.5 mag.

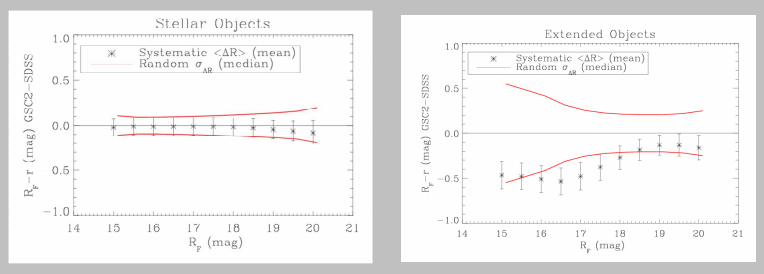



*Figure: GSC2 $R_F$ vs. SDSS **r** - Red solid lines show ± RMS of the magnitude residuals averaged on all the HTM regions in common between the two catalogues (⇒ random error) . Asterisks indicate the mean magnitude residuals (⇒ global systematic error) with error bars showing the RMS of the mean (⇒ position systematic error). Statistics have been derived after applying a color transformation as a function of the mean color.*

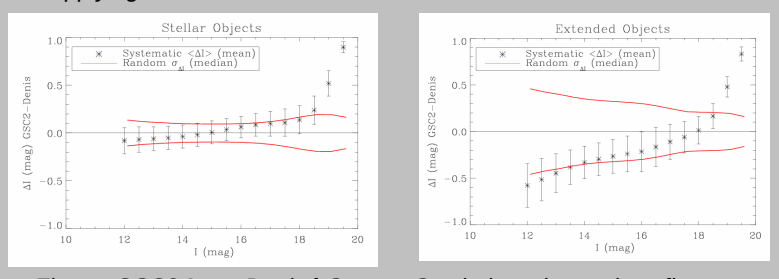



*Figure: GSC2 $I_N$ vs. Denis **i-Gunn** – Symbols as in previous figure.*

## Object classification

*Star/nonstar* classifications were assigned by voting all available classifications from 15 µm scans. Classifications from 25 µm scans were used only if no 15 µm data were available for the object. Ties were broken in favour of nonstar, and defect classifications were considered to be nonstellar for matched objects. Unmatched plate defects were excluded from the catalog. The incompletess due to misclassification and image-blending is discussed in more details by Drimmel et al. ("What Gaia will see", poster JD13-40).

## Astrometry

GSC-II positions were computed by means of astrometric calibrations based on reference stars extracted from the **Tycho-2** catalogue (Hog et al 2000). A *quadratic polynomial* was adopted to model the transformation from the plate coordinates X,Y, previously corrected for refraction, to the standard coordinates from which celestial $(\alpha,\delta)_{J2000}$ were derived. Finally, **astrometric masks** were applied to remove the typical 2D pattern of the position residuals which affect Schmidt plates.
Finally, GSC 2.3 positions have been selected from the second epoch surveys, preferably from the objects closest to the center of the IIIaF plates.

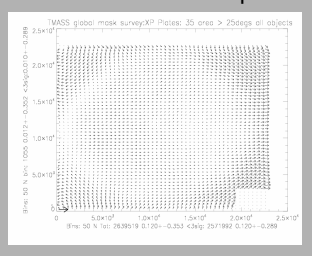


*Figure. Left panel: 2D mask showing the astrometric esiduals vs. 2MASS for POSS-II XP (IIIaF) plates. The size of the arrow in the bottom left corner is1 arcsec. Right panel: stellar PSF's of two bright stars.*

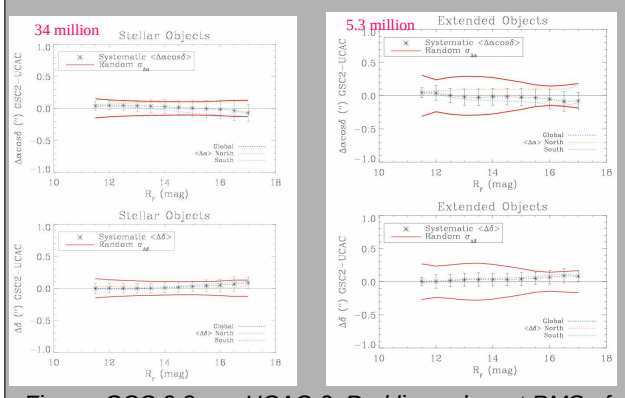



*Figure: GSC 2.3 vs. UCAC-2. Red lines show ± RMS of position residuals between the catalogs, while asterisks (with error bars) represent the mean (and its error) of the position residuals, averaged on all the HTM regions. Orange and blue dotted lines indicate the mean residuals for the Northern and Southern regions respectively.*

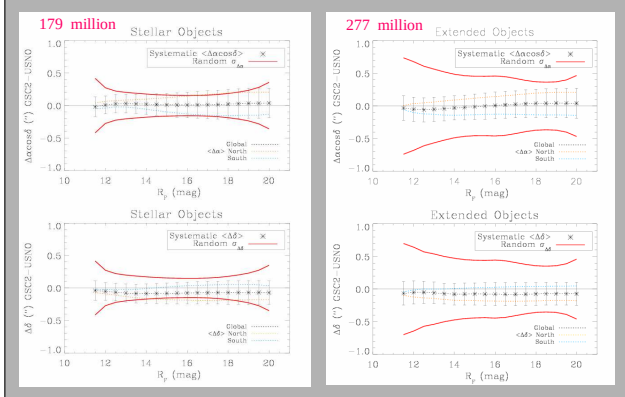



*Figure: position diffence between GSC 2.3 and USNO-B Same symbols as in previous figure.*

Comparisons with external catalogues (see figures) are consistent with an astrometric precision having a *random error* of **0.1-0.2 arcsec** for *stellar* objects respectively brighter than $R_F$<17 and 19.5. The position error of *extended objects* (including both galaxies and blends) is about twice these values.
In addition, local *systematic errors* at the HTM region level (1 deg$^2$) with RMS of about **0.1-0.15 arcsec** are present. Globally, the GSC 2.3 reference frame is consistent with that of other all-sky catalogs (USNO, 2MASS, UCAC) at level better than 0.1 arcsec. Finally, a systematic difference of about 0.1 arcsec is found between the North and South hemisphere possibly due to the presence of an uncorrected *magnitude term* which is currently under investigation and that will be removed in the next GSC release.

**GSC 2.3 vs UCAC2**

| $R_F$ (mag) | Object type | RMS ⟨Δα⟩ | RMS ⟨Δδ⟩ | RMS Δα | RMS Δδ |
|---|---|---|---|---|---|
| 11.5 | stellar | 0.07 | 0.08 | 0.15 | 0.15 |
| | extend | 0.07 | 0.06 | 0.30 | 0.27 |
| 13.0 | stellar | 0.09 | 0.07 | 0.11 | 0.11 |
| | extend | 0.12 | 0.10 | 0.29 | 0.27 |
| 15.0 | stellar | 0.12 | 0.08 | 0.10 | 0.10 |
| | extend | 0.13 | 0.09 | 0.20 | 0.20 |
| 16.5 | stellar | 0.16 | 0.11 | 0.13 | 0.13 |
| | extend | 0.15 | 0.11 | 0.16 | 0.16 |

**GSC 2.3 vs USNO-B**

| $R_F$ (mag) | Object type | RMS ⟨Δα⟩ | RMS ⟨Δδ⟩ | RMS Δα | RMS Δδ |
|---|---|---|---|---|---|
| 12.5 | stellar | 0.14 | 0.14 | 0.22 | 0.22 |
| | extend | 0.18 | 0.18 | 0.61 | 0.57 |
| 15.0 | stellar | 0.18 | 0.16 | 0.16 | 0.15 |
| | extend | 0.20 | 0.17 | 0.46 | 0.44 |
| 17.5 | stellar | 0.22 | 0.18 | 0.17 | 0.16 |
| | extend | 0.21 | 0.17 | 0.39 | 0.38 |
| 20.0 | stellar | 0.22 | 0.18 | 0.36 | 0.35 |
| | extend | 0.23 | 0.18 | 0.47 | 0.46 |

*Tables: position differences (arcsec) GSC2.3 vs. UCAC2 and USNO-B. RMS of Δα, Δδ and mean ⟨Δα⟩, ⟨Δδ⟩, averaged on the HTM regions in common between the catalogs (cfr. figures above).*

## Acknowledgements

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