The Initial Gaia Source List and the Attitude Star Catalog

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Abstract

We describe the production of the Initial Gaia Source List (IGSL) and the subset of objects that constitute the Attitude Star Catalog. The IGSL has 1.2 billion entries with positions, proper motions (if known), a red, blue, G and G_{rvs} magnitude estimate. Of these entries 8 million are indicated as entries that constitute the Attitude Star Catalog providing an average sky density of 200 per square degree. The catalog is included in the MDB and can be accessed via the MDB explorer `http://gaia.esac.esa.int/mdbexp/mdbexp/`, eventually it will also be supplied to the CDS.

Document History

Issue	Revision	Date	Author	Comment
D	0	2013-09-03	RLS	Creation
1	0	2013-09-30	RLS	Submission to livelink
2	0	2013-10-03	RLS	Added description of error for SDSS/GEPC classifications in section 11
2	1	2013-10-08	RLS	Added history and link to SVN version of this document.
2	2	2013-10-14	RLS	Added explanation of null proper motions in section 11
2	3	2013-10-17	RLS	Updated explanation of checkered pattern

Contents

1 Introduction

The Initial Gaia Source List will be the starting point for the Gaia Initial Data Treatment, to provide a source ID to the objects in the various support catalogs and to provide extra information for the science alerts program. The Attitude Star Catalog will be used by the first iteration of the on ground attitude reconstruction.

The IGSL was frozen after the September 30th 2013 delivery. Since that time some errors have been reported which will have to be adjusted in local versions of the IGSL or accounted for in down stream usage. Any know problems are reported in section 11 of this document; please make sure you consider these before using the IGSL. The SVN version of this document: `http://gaia.esac.esa.int/dpacsvn/DPAC/CU3/docs/AuxDat/IGSL/RLS004/Gaia-C3-TN-OATO-RLS-004.pdf` will always be the most recent.

1.1 Objectives

This document describes the procedures, inputs and selection criteria to produce the third and final version of the Initial Gaia Source List and the subset that constitutes the Attitude Star Catalog.

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1.3 Acronyms

The following table has been generated from the on-line Gaia acronym list:

Acronym	Description
2MASS	Two-Micron All Sky Survey
ASC	Attitude Star Catalogue
CCD	Charge-Coupled Device
CDS	Correlated Double Sampling

CTE	Charge Transfer Efficiency
DEC	Declination
EPC	Ecliptic Pole Catalogue
ESO	European Southern Observatory
ESTEC	European Space research and TEchnology Centre (ESA)
IAU	International Astronomical Union
ID	Identifier (Identification)
IDT	Initial Data Treatment
IGSL	Initial Gaia Source List
LMC	Large Magellanic Cloud (special, high-density area on the sky)
MDB	Main Database
MEGACAM	Instrument at CFHT
NOMAD	Naval Observatory Merged Astrometric Dataset
OGLE	Optical Gravitational Lensing Experiment
PM	Polarisation Maintaining
QSO	Quasi-Stellar Object
RA	Right Ascension
RVS	Radial Velocity Spectrometer
SDSS	Sloan Digital Sky Survey
SMC	Small Magellanic Cloud (special, high-density area on the sky)
TBC	To Be Confirmed
TCB	Barycentric Coordinate Time
UCAC	USNO CCD Astrograph Catalogue
USNO	United States Naval Observatory
WFI	Wide-Field Imager (ESO 2.2-m telescope)

2 Historical Context

The Initial Gaia Source List (IGSL) is envisioned to be a combination of the best optical astrometry and photometry information on celestial objects available today. A snapshot of the sky as we know it before Gaia. Nominally we have attempted to include all objects brighter than magnitude 21 in the expected Gaia G band. We have included publically available large (e.g. >10000 square degrees) catalogs, and some smaller special area catalogs.

A quick perusal of the catalogs currently available would suggest that the Naval Observatory Merged Astrometric Dataset (NOMAD, Zacharias et al. (2005)) is a perfect choice for an IGSL. The adoption of NOMAD does not however diminish the work required to produce the IGSL, we would still have to update many parameters that have been superseded and to introduce new ones starting from the original source catalogs. For this reason we decided to construct the IGSL from scratch.

3 Uses of the IGSL

The IGSL will have many functions but it's main purpose will be to simplify the interconnection of the numerous auxiliary catalogs which provide mission critical calibration and reference data with the Gaia observations. All auxiliary catalogs will be matched to the IGSL before launch thus providing each object with a name. The Gaia observations need then only be matched via position to the IGSL to allow direct access via the name to all the auxiliary data. The process of pre-matching will allow a cleaning and homogenization of the auxiliary data and the number of mismatches will be minimized as part of this process. The general software development for the Gaia reduction will be simplified by the IGSL and many potential problems will be resolved before launch.

In 2011 a decision was taken to make the IGSL the starting point for the IDT cross matching routines to simplify the operational procedures. As a result of this decision it was decided to reduce the size of the the IGSL. Originally the goal was to be complete as possible - even to R_F = 24 when possible - at a cost of having false objects or being very large. Following the new requirements, the goal is to produce a cleaner smaller catalog and not to go beyond the nominal Gaia magnitude limit. This means the IGSL cannot be used as a list of faint objects for the Charge Transfer Efficiency (CTE) evaluation and that it will be frozen before launch both of which were not in the original plan. The collection of new sky surveys for the CTE and to complete the sky in the incomplete regions will have to be carried out elsewhere if required.

4 Requirements for the IGSL

The IGSL is required to fulfill the following broad requirements: all sky positions, proper motions and magnitudes for objects to a limit of G = 21 where possible, e.g. where there are large (>10000 square degrees) object catalogs that reach that limit. In particular the galactic plane is not currently complete beyond R_F = 18 in the large Schmidt based catalogs that make the bulk of the faint IGSL input. The parameters proper motions and magnitudes, will be provided on a best effort basis, nominally with precisions of 10 mas/yr and 0.3 magnitudes respectively, but obviously limited by the currently available large catalogs. The CU3 QSO and Ecliptic Pole catalogs will be included with no selection on magnitudes to support directly the CU3 processes that require those resources.

5 Source Catalogs for IGSL Version 3

The source catalogs used to produce the IGSL are:

- GEPC: The Gaia Ecliptic Pole Catalog, version 3.0 (Altmann & Bastian, MA-002),

6.1x10^6 entries in approximately 1 square degree around the North and Southern Ecliptic Poles produced specifically for the calibration of Gaia. The observations were made with the MEGACAM on the Canadian French Hawaii Telescope for the northern ecliptic pole and with WFI on the ESO 2.2m telescope for the southern ecliptic pole. In this catalog there is a "Stellarity" that goes from 0 to 1. Since the IGSL requires a star or non-star classification all objects that have a Stellarity greater than .7 were considered star and the rest non-star. As can be seen from table 6 this only overrides the 2MASS and OGLE classifications.
In addition to the GEPC objects any bright objects (G magnitude less than 15) in the two EPC regions had the auxEPC flag set to 1. If they were not in the GEPC catalog it will be because they were either too bright and saturated on the MEGACAM/WFI frames or they were missed because of blending or other effects. The two regions were defined as 62 arcminute squares centered on 06:00:00,-66:33:41 and 18:00:00,+66:33:41. These extra objects will therefore have auxEPC=1 but idEPC = 0 in the sourceIDs catalog.

- GSC2.3: The Second Guide Star Catalog version 2.3 (Lasker et al., 2008), 9.4x10^8 objects all sky, magnitude limit R_F 21.5. This catalog forms the bulk of the photometry and defines the red and blue magnitudes as this is the sky survey with the largest number of objects on a homogenous system. All catalogs are missing some bright stars (V $<$ 8.0) and to complete GSC23 in this respect it was supplemented with the sky2000 catalog. This sometimes lead to double entries which we have attempted to clean. The IGSL should be complete in this region and most double entries have been removed except for some multiple entries of high proper motion objects that remain across the whole of the magnitude range.

- LQRF: Large Quasar Reference Frame (Andrei et al., 2009), 1.7x10^5 QSOs, magnitude limit R_F 22 and mostly fainter than R_F 18. This is a compilation of QSOs with precise positions produced as part of the Gaia auxiliary catalog development. For these objects we have included the LQRF positions and set the proper motions to zero as they are all confirmed QSOs.

- OGLE: Optical Gravitational Lensing Experiment version III (Szymański et al., 2011), 2.2x10^8 objects in the bulge, LMC, SMC and Southern-EPC. This catalog was included at the request of the Gaia science alerts team to improve the large incompleteness of the IGSL in the very crowded regions. The OGLE data is provided as catalogs of overlapping observations so many objects on the borders of chips were repeated and ended up as duplicates. To remove any duplicates if a detection was within an arcsecond of another detection we only kept the first entry.

- PPMXL: Positions and Proper Motions "Extra Large" Catalog, (Roeser et al., 2010), 9.1x10^8 entries. Produced as a combination of the USNO-B and the Two Micron Sky Survey point source catalog. The positions and proper motions should be the most precise available for the objects fainter than the UCAC4 limit.

- SDSS: Sloan Digital Sky Survey data release 9 (`http://www.sdss.org`), 4.7x10^8 entries, magnitude limit $R_F < 22$. This catalog provides precise astrometry, photometry and classification for one quarter of the sky. We have included objects to gunn $r < 22$ transforming the SDSS magnitudes to GSC2 bands when needed and including the PPMXL proper motions when available. The positions adopted are from the SDSS proper moved to J2000.

- UCAC4: USNO CCD Astrograph Catalog version 4 (Zacharias et al., 2004), 1.1x10^8 entries mostly stars, magnitude limit $R_F < 17$. This is the most precise astrometric catalog in the range V=11-16 currently available that is all sky. There are no original magnitudes in this catalog.

- Tycho-2: (Høg et al., 2000), 2.4x10^6 stars, magnitude limit $R_F < 12$. This catalog forms the backbone of all the major ground based catalogs currently available. The astrometric information is mostly superseded by UCAC4 however this catalog provides the photometric information for most objects of this brightness.

- 2MASS: Two Micron All-Sky Survey Point Source Catalog (2MASS PSC, Epchtein et al., 1999), 4.4x10^8 entries mostly stars, magnitude limit $J_s < 16$. This catalog is mainly a subset of the large Schmidt catalogs except for the red stars that were too faint. Magnitudes were calculated from a very rough extrapolation. As we only considered the PSC all objects in this catalog were considered classification star.

In addition all objects in the HIPPARCOS (Perryman et al., 1997), Sky2000 (Myers et al., 2001), and Standard Photometric Sequence Stars (SPSS, CU5) are included with not cut on magnitude.

6 Production of the IGSL

The main difference in the IGSL from previous versions that we use the PPMXL as the source of proper motion values for the majority of targets. This is the most complete catalog currently available for proper motion data at the faint end and replaces the GSC2 which is still missing these important parameters.

There is no “correct” way to match large catalogs. All procedures will in certain cases fail and the goal of any procedure adopted is to minimize the failures in the sense that is most harmful to the purpose of the match result. A very small matching radius will miss some real matches, a large one will have erroneous matches - especially when matching observations or catalogs from different epochs. In the case of the IGSL we adopt a large matching radius to minimize the number of double entries at the risk of making erroneous matches. In a compilation catalog such as the IGSL the result is also a “compilation” of the individual catalog errors. The requirement that objects have at least two magnitudes from which to calculate a G magnitude cleans the final result somewhat but while overall statistically the IGSL is reliable if you use individual objects be aware of the possible mismatches.

All the source catalogs have been included in a Mysql database and each catalog matched to a master list using a nearest-neighbor approach with a limit of $5''$. The large matching radius was adopted to minimize the number of duplicate entries and also as the original starting catalog was the GSC23 and the resolution of this catalog is around this value. If, from a new catalog two entries are matched to the same object a new entry is generated and only the closest of the two entries is listed as a match. Once the master list is generated and all the catalogs have been matched to it the production of the IGSL is just a combination of a few sql scripts.

Initially all entries are included.

Positions are assigned following the priority order UCAC4, Tycho-2, LQRF, SDSS, PPMXL, GEPC, OGLE, GSC23.

Proper motions are assigned following the priority order UCAC4, Tycho-2, PPMXL, GSC23 and the LQRF objects set to zero.

The classification is set to star for all UCAC/Tycho-2/OGLE as they have no classification indicator. The QSOs in the LQRF are also classified as stellar. The classification is then assigned in the following priority order SDSS, GSC23, GEPC (where "STELLARITY" is less than 70 constitutes a star).

The magnitudes are assigned following the equations in appendix B. The red and blue magnitudes follow this priority order Tycho, GSC23, PPMXL, SDSS, GEPC, OGLE, sky2000, 2MASS. The Gaia magnitudes follow this priority order SDSS, Tycho-2, GEPC, OGLE, red and blue as derived in the previous step.

The priorities for assignment are summerised in table 6.

Once a G magnitude has been calculated all objects with G $<$ 21 are included into the IGSL. There are many objects that do not have a G magnitude because the source catalogs do not provide a red and blue magnitude from which to calculate G. There are for example many entries with magnitudes brighter than R_F = 20 or B_J = 21 that could be reasonably assumed to have G $<$ 21. However, they may also be defects, or unmatched entries of included objects or have unreliable magnitudes, so we have not included them. The exception to this rule are the objects in the LQRF, GEPC, HIP, SKY2000 and SPSS catalogs that are included with no constraint on magnitudes.

All entries are provided with a sourceID as described in De Angeli et al. (FDA-002) and further developed in Bastian (BAS-020). We do not indicate components as we did not try to identify binary systems. The name is therefore a combination of the source healpix level 12 ID

TABLE 2: Summary of the different catalog contributions in the IGSL.

Catalog	Code	IGSL	Priorities for Assignment[1]				
		Matches	Pos	PM	Mag R_F, B_J	Mag G, G_{rvs}	Class
GEPC	67	608022	6	-	5	3	5
GSC23	1	777680797	7	5	2	5	4
LQRF	4	174715	1	1	-	-	1
OGLE	66	182451526	9	-	6	4	6
PPMXL	49	825467433	5	4	3	6	-
SDSS	2	172398260	4	-	4	1	3
2MASS	18	470005483	8	-	7	7	7
TYCHO2	5	2548506	3	3	1	2	2
UCAC	3	107701585	2	2	-	-	8

[1] The priority for assignment of a given parameter, i.e. the positions are first taken from the LQRF, if the object is not there it is taken from UCAC then TYCHO2 and so on. [2] The primary provider of the position as opposed to matches which shows how many objects are in common to the IGSL and the listed catalog.

($healpix12ID$) and the running number in the healpix level 6 ($runningnumberinhealpix6$) bit combined via the Mysql relation
SourceID $= (healpix12ID << 35) + (runningnumberinhealpix6 << 7)$.
This intrinsically assumes the Data Processing Center that enters the objects in the main data base is ESAC.

7 The Catalog

The IGSL is currently available in the Gaia MDB under CU3/Auxdata/IGSL. It is composed of 3 databases:
1) IgslSource: the main data with positional, photometric and classification information as listed in appendix A.
2) SourceCatalogReferences: a list of the source catalogs along with the code used in the sourcePosition, sourceProperMotion and sourceClassification flags, also reproduced in table 6.
3) SourceCatalogIDs: a list of the identifiers in the various input catalogs as well as the Hipparcos catalog on request from the Gaia team. Note the identifiers are sometimes reported verbatim and are sometimes simplified as shown in appendix A.

The IGSL can presently be accessed using the Data Explorer Tool `http://gaia.esac.esa.int/mdbexp/mdbexp/` under Remote Databases, MainDbAtESAC, maindb, igsllist. Simple sql queries and plots can be performed using this tool but the data is currently only indexed on the sourceid. If large subsets of the IGSL are required then using the Gaia extractor tool is the best method.

Due to differing precision and completeness in the source catalogs the distribution of the IGSL is biased. This is shown visibly by the outline of the SDSS footprint and the Schmidt plate boundaries in the distribution of object densities per region of the IGSL in Figure 1.

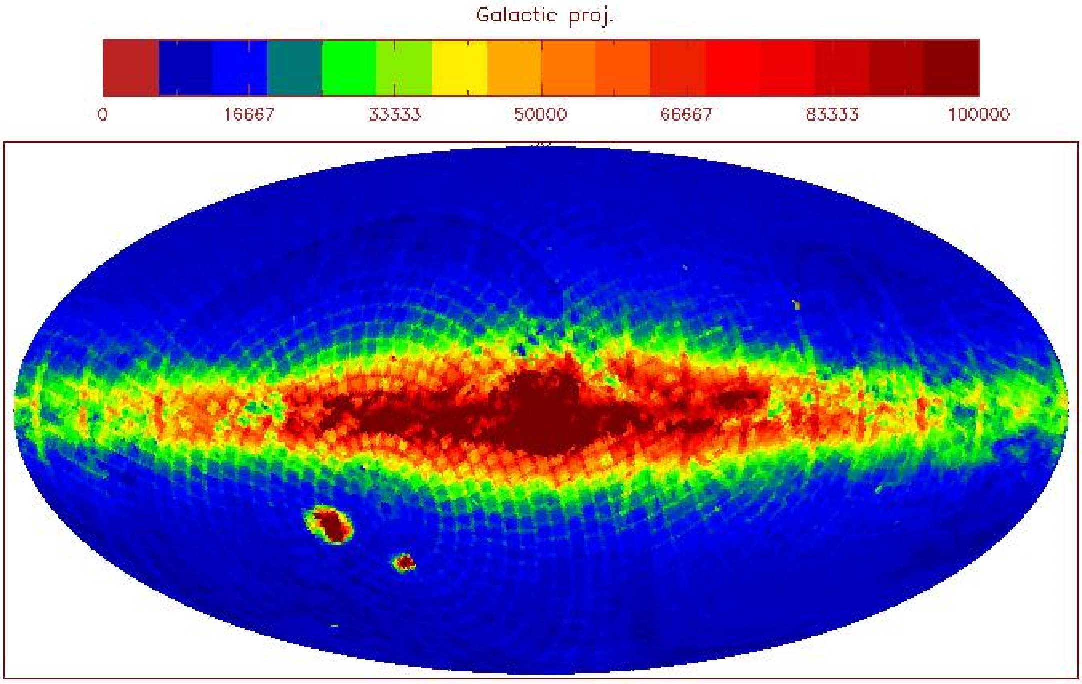

FIGURE 1: The distribution of object density per healpix 6th level region of the Initial Gaia Source List. The checkered pattern is a pattern already noted in the PPMXL (i.e. `http://alasky.u-strasbg.fr/footprints/tables/vizier/I_317_sample`) and may be worsened here by a similar pattern in the GSC23 (i.e. `http://alasky.u-strasbg.fr/footprints/tables/vizier/I_305_out`) and by extra photometric information or multiple entries of objects at the plate boundaries. The stripes across the galactic plane are due to the SDSS Segue scans that are more complete and have a higher resolution that the other large catalogs based on Schmidt photographic plates.

8 Version History

The first version of the IGSL was delivered in 2008 and is described in Smart et al. (RLS-001) which was designed only as a test case for the procedures.

The second version was delivered in 2010 and based mainly on the GSC23 catalog.

The version 3.0 was delivered in early 2013 and is the basis of the version described in this technical note. A problem was found with the Galactic and ecliptic coordinates as well as some of the magnitude transformations and it was re-issued in May 2013 and again in July. Finally it was discovered that some of the GEPC, Hipparcos and SPSS objects did not have colors so were being eliminated, the final release has corrected that problem and all of the entries in these catalogs are included regardless of their magnitude, this was delivered in September 30th 2013.

9 The Attitude Star Catalog

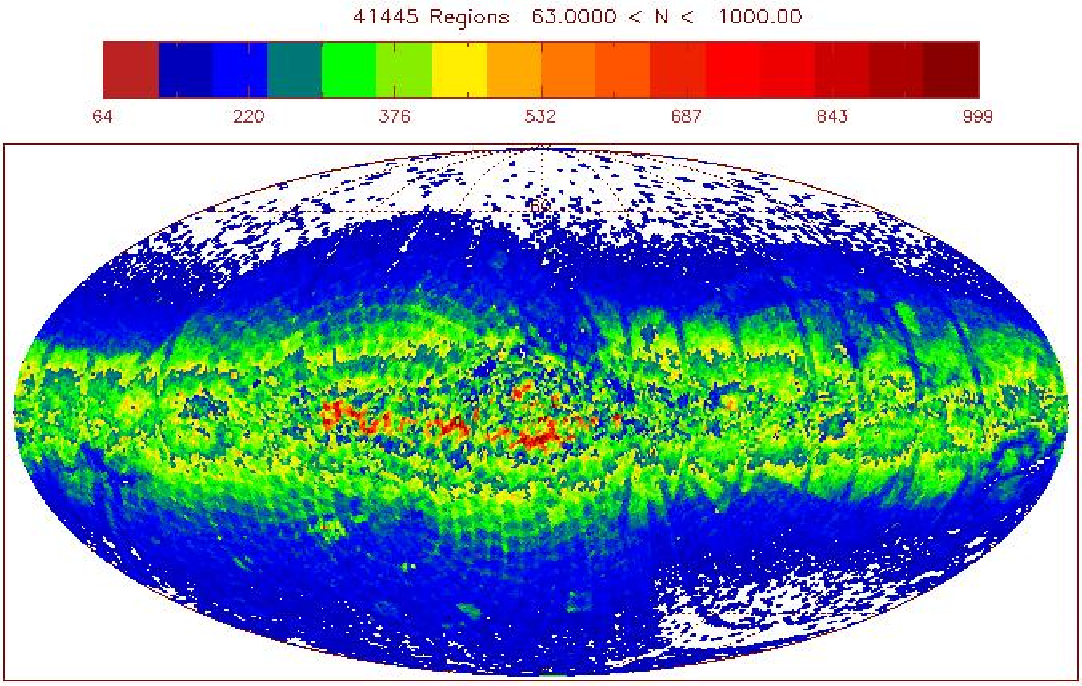

FIGURE 2: The Attitude Star Catalog. Distribution of densities in healpix6 regions after applying the basic magnitude cuts. White regions in the plane have more than 1000 stars and the white regions outside the plane have less than 63 stars.

The requirements on the Attitude Star Catalog (ASC) for on ground attitude reconstruction from Padeletti & Bastian (DMP-001) is 75 isolated bright stars per square degree. Since we have indexed in healpix6 there 41253/49152 = 0.84 degrees / pixel, so at this pixel level we have a requirement of 63 stars per pixel. A reasonable upper limit on the number of stars per pixel is 1000. The original magnitude limit for the ASC stars was G=14.2; recently a private communication from Bastian moved that up to G=13.4. There is also a requirement that the positional accuracy be better than 200 mas. Applying both these cuts: G<13.4 and $\sigma_\alpha, \sigma_\delta < 200$mas, and that the star is not in the Washington Double Star catalog Worley & Douglass (1997), we find that 41445 of the 49152 healpix6 regions have a star density between 63 and 1000. These regions are shown in figure 2, the 7879 white regions outside of the plane have too few stars.

To reduce the number of stars in the over-populated regions we simply lowered the magnitude cut off point from 13.4 to 12.4 for all regions with between 400 and 1000 objects, to 11.4 for regions with over 1000, then 10.9 for regions still over 1000 and finally 9.9 for any remaining regions with over 1000 objects. The final distribution of region densities ranges from 21 to 994 as shown in Figure 3

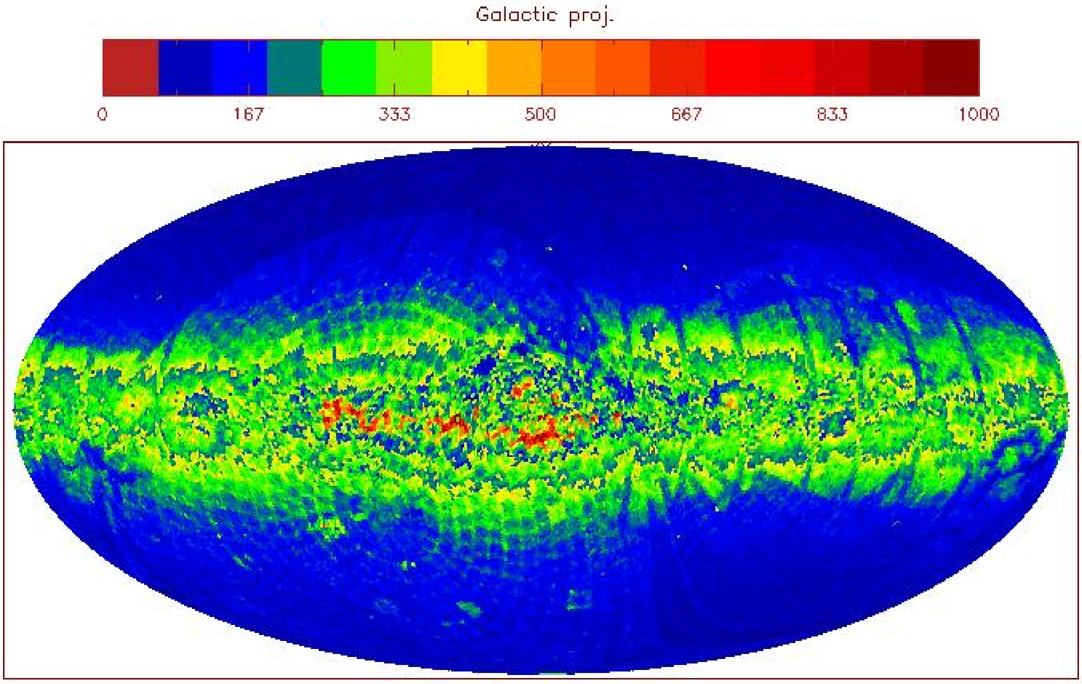

FIGURE 3: The Attitude Star Catalog. Distribution of densities in Healpix6 regions after selection procedure.

10 FAQs

10.1 Why degrade precise SDSS/OGLE/TYCHO magnitudes?

The goal of including a red and blue magnitude was to provide a all sky estimate of the color of an object usable in an easy way. This required us to value a homogenous system over precision. The GSC23 system is the most widespread so we choose that. All estimates of the Gaia magnitudes have started from the most precise magnitudes available.

10.2 Can the ASC contain binary stars?

No attempt was made to identify known binary systems from the IGSL, however matches in the Washington Double Star catalog were removed from the ASC subset.

10.3 How well does the IGSL separate binary stars?

The majority of objects come from the sky surveys based on the large Schmidt sky surveys GSC23 and the PPMXL. Any bright objects (R_F >18) within 4-5" of each other are often not resolved and included as a blended object and classified as a non-star. Outside of the galactic plane the density is such that this will usually only be a problem for true (as opposed to apparent) binary systems. In the plane the number of blends increases dramatically as shown by the dramatic increase in objects classed as non-star. In Lasker et al. (2008) they find that 90% of the GSC23 "stars" are stars, while probably only 50% of the "non-stars" are galaxies.

10.4 What are the position epochs used for

The majority of objects have been proper-motion propagated to J2000, so the equinox and epoch of the catalog is J2000. Obviously when proper motions were not available the objects are at the date of the source catalog. The errors are given at the mean epoch as this is when the position is the most precise, and correct error propagation thus requires the use of these values.

10.5 Why are there two position epochs for the two coordinates?

In some cases the mean epoch of the right ascension and declination are not the same. This is because the most precise position for the bright objects includes also meridian circle observations which sometimes only found one of the two coordinates.

10.6 Why are there some stars with primary positions from Tycho-2? Wasn't Tycho-2 incorporated into UCAC4?

The Tycho-2 catalog is made of three parts, 2,539,913 in the main catalog, 17,588 in supplement 1 fairly good bright stars, and 1146 in supplement 2 problem entries. In the UCAC4 paper they state they have 2,549,788 cross matches with Tycho-2, so we assume they have used at least both the main catalog and the first supplement. We used all three parts of Tycho-2, that is 2,558,647 objects. The stars in the IGSL with primary positions from Tycho-2 are 34,914 and are a combination of the extra objects not included in the UCAC4 and also objects where the Tycho-2 object or the UCAC4 object were mis-matched to other objects.

10.7 Why do some objects not have a complete set of magnitudes?

There are a number of reasons. All objects from the HIP, SPSS, SKY2000, LQRF and GEPC catalogs were included even if the magnitude information was not complete. In the case of OGLE/TYCHO2 objects it is because relations 10, 13, 16 and 17 are only valid to B-V or BT-VT of 2.5 so those objects we not assigned R_F, B_J magnitudes. Finally some objects just had unrealistic magnitudes probably because there was a problem with the inputed values and so we also assigned NaN to those objects.

11 Known problems and defects

11.1 02/10/2013 Errors in the Classification

The classifications have two problems. The 167055567 SDSS objects have their classification inverted, that is stars are classed as 1 and non-stars as 0 or -1. The 197921 GEPC non-stars are classified as 3 instead of 1.

In mysql these problems can be corrected with the following commands:

```
update mdbcu3auxdataigsligslsource  set classification = 2
       where(sourceClassification=2 and classification=0) ;
update mdbcu3auxdataigsligslsource set classification = 0
       where(sourceClassification=2 and classification=1) ;
update mdbcu3auxdataigsligslsource set classification = 1
       where(classification!=0) ;
```

where mdbcu3auxdataigsligslsource is the IGSL source table name.

11.2 14/10/2013 Null values in proper motions

The proper motions from the various catalogs have different ways of indicating a null value. For example the GSC23 assigns zero to both proper motion and their errors while the UCAC assigns proper motions of zero and errors of 50. Also objects taken from catalogs without proper motions have null as the error in declination proper motion. The easiest way to find those objects without proper motion is to assume that all objects with zero proper motions in both right ascension and declination are uncalculated **except** for LQRF objects, e.g. with sourceMu=4 where a value of zero is the default and a reasonable assumption.

In mysql this can be done with the command:

```
update mdbcu3auxdataigsligslsource set muAlpha = NULL,
       muDelta = NULL, muAlphaError = NULL,
       muDeltaError = NULL, sourceMu= NULL
where(muAlpha = 0 and muDelta = 0 and sourceMu != 4) ;
```

where mdbcu3auxdataigsligslsource is the IGSL source table name.

Appendix A: Overview of the tables in MDB/CU3/AuxData/IGSL/
The following table describes the parameters associated with the table IgslSource.

Name	**Description**	**Type**	**Units**
solutionId	Solution Identifier	long	
sourceId	source identifier	long	
alpha	Right Ascension at catalogue epoch	double	rad
delta	Declination at catalogue epoch	double	rad
alphaError	Error in Right Ascension	float	rad
deltaError	Error in Declination	float	rad
alphaEpoch	Mean Epoch of Right Ascension	float	GaiaTime
deltaEpoch	Mean Epoch of Declination	float	GaiaTime
sourcePosition	Source of the position estimate	byte	
muAlpha	Proper motion in RA * at catalogue epoch	float	mas/year
muDelta	Proper motion in DEC at catalogue epoch	float	mas/year
muAlphaError	Error in Proper motion in RA	float	mas/year
muDeltaError	Error in proper motion in DEC	float	mas/year
sourceMu	Source of the proper motions	byte	
galacticLon	Galactic Longditude	float	deg
galacticLat	Galactic Latitude	float	deg
eclipticLon	Ecliptic Longditude	float	deg
eclipticLat	Ecliptic Latitude	float	deg
magBJ	B mag measure, GSC23 system	float	mag
magBJError	Error in B mag measure	float	mag
sourceMagBJ	source B mag	byte	
magRF	R mag measure, GSC23 system	float	mag
magRFError	Error in R mag measure	float	mag
sourceMagRF	source of R mag	byte	
magG	G mag estimate	float	mag
magGError	Error in G mag estimate	float	mag
sourceMagG	Source G mag	byte	
magGrvs	Grvs mag estimate	float	mag
magGrvsError	Error in Grvs mag estimate	float	mag
sourceMagGrvs	Source Grvs mag	byte	

Name	Description	Type	Units
classification	Classification	boolean	
sourceClassification	source of Classification	byte	
toggleASC	Toggle for Atittude Star Catalog	boolean	
auxGSC23	Present in the GSC2.3 catalog	boolean	
auxSDSS	Present in the SDSS catalog	boolean	
auxUCAC	Present in the UCAC3 catalog	boolean	
auxLQRF	Present in the LQRF QSO aux catalog	boolean	
auxTYCHO	Present in the TYCHO2 catalog	boolean	
auxHIP	Present in the Hipparcos catalog	boolean	
auxPPMXL	Present in the PPMXL catalog	boolean	
auxOGLE	Present in the OGLE catalog	boolean	
auxTMASS	Present in the Two MASS PSC catalog	boolean	
auxEPC	Present in the Ecliptic Poles Catalog	boolean	

Parameters Detailed description

- Solution Identifier (**solutionId**): See Hernandez (JH-008).
- source identifier (**sourceId**): Source identifier as defined in GAIA-CD-TN-ARI-BAS-020-01
- Right Ascension at catalogue epoch (**alpha**): The right ascension at epoch and equinox J2000
  Range: [0, 2 * pi]
- Declination at catalogue epoch (**delta**): The declination at epoch and equinox J2000
  Range: [- pi/2, pi/2]
- Error in Right Ascension (**alphaError**): The mean error in the right ascension at mean epoch
- Error in Declination (**deltaError**): The mean error in the declination at mean epoch
- Mean Epoch of Right Ascension (**alphaEpoch**): The mean epoch of the right ascension Julian Year in TCB. Note if there are proper motions the actual position will be at J2000 to have a consistent catalog and this is provided if the user wishes to add new information or find the best position.
- Mean Epoch of Declination (**deltaEpoch**): The mean epoch of the declination Julian Year in TCB. Note if there are proper motions the actual position will be at J2000 to have a consistent catalog and this is provided if the user wishes to add new information or find the best position.

- Source of the position estimate (**sourcePosition**):

  The code that appears in the IgslReferences that describes where the positional information comes from.

- Proper motion in RA * cos(dec) at catalogue epoch (**muAlpha**): Proper motion in right ascension multiplied by cos(declination).

- Proper motion in DEC at catalogue epoch (**muDelta**): Proper motion in declination

- Error in Proper motion in RA (**muAlphaError**): Mean error of proper motion in RA * cos(declination)

- Error in proper motion in DEC (**muDeltaError**): Mean error of proper motion in declination

- Source of the proper motions (**sourceMu**):

  The code that appears in the IgslReferences that describes where this data point comes from.

- Galactic Longditude (**galacticLon**): Galactic Longditude calculated in float to use for indexing
  Range: [0, 360]

- Galactic Latitude (**galacticLat**): Galactic Latitude calculated in float to use for indexing
  Range: [- 90, 90]

- Ecliptic Longditude (**eclipticLon**): Ecliptic Longditude calculated in float to use for indexing
  Range: [0, 360]

- Ecliptic Latitude (**eclipticLat**): Ecliptic Latitude calculated in float to use for indexing
  Range: [- 90, 90]

- B mag measure, GSC23 system (**magBJ**): The B_J magnitude from the GSC23 when present or estimated from transformations when not present in the GSC23 or too bright to be reliable from GSC23. Very similar to B Johnson.

- Error in B mag measure (**magBJError**): Error in the B_J magnitude

- source B mag (**sourceMagBJ**): Code in IgslReferences that describes where this magnitude comes from.

- R mag measure, GSC23 system (**magRF**): The R_F magnitude from the GSC23 when present or estimated from transformations when not present in the GSC23 or too bright to be reliable from GSC23. Very similar to R cousins.

- Error in R mag measure (**magRFError**): Error in R_F
- source of R mag (**sourceMagRF**): Code in IgslReferences that describes where this magnitude comes from.
- G mag estimate (**magG**): Estimated G magnitude based on transformations in livelink document RLS 001
- Error in G mag estimate (**magGError**): Estimated of error on G magnitude
- Source G mag (**sourceMagG**): Code in IgslReferences that describes which transformation used.
- Grvs mag estimate (**magGrvs**): Estimated G_rvs magnitude based on transformations in livelink document RLS 004
- Error in Grvs mag estimate (**magGrvsError**): Estimated of error on G_rvs magnitude
- Source Grvs mag (**sourceMagGrvs**): Code in SourceCatalogIDs that describes where base magnitudes came from
- Classification (**classification**): Classification, simply a 0=star and 1=nonstar taken from different sources as given in the souceClass field
- source of Classification (**sourceClassification**): Code in IgslReferences that describes where this datapoint comes from.
- Toggle for Atittude Star Catalog (**toggleASC**): A boolean that indicates if the objects is to be used for the Atittude Star Catalog.
- Present in the GSC2.3 catalog (**auxGSC23**): A boolean that indicates if the objects is present in the GSC2.3 cat, 0=no, 1=yes. Version and catalog details in the SourceCatalogReferences table. If yes the GSC2.3 id is in the SourceCatalogIDs as idGSC23.
- Present in the SDSS catalog (**auxSDSS**): A boolean that indicates if the objects is present in the SDSS cat, 0=no, 1=yes. Version and catalog details in the SourceCatalogReferences table. If yes the ID is in the the SourceCatalogIDs as idSDSS
- Present in the UCAC3 catalog (**auxUCAC**): A boolean that indicates if the objects is present in the UCAC cat, 0=no, 1=yes. Version and catalog details in the SourceCatalogReferences table. If yes the ID is in the the iSourceCatalogIDs as idUCAC.
- Present in the LQRF QSO aux catalog (**auxLQRF**): A boolean that indicates if the objects is present in the CU3 QSO Aux cat GIQC, 0=no, 1=yes. Version and catalog details in the SourceCatalogReferences table. If yes the ID is in the the SourceCatalogIDs as idLQRF.

- Present in the TYCHO2 catalog (**auxTYCHO**): A boolean that indicates if the objects is present in theTYCHO2 cat, 0=no, 1=yes. Version and catalog details in the SourceCatalogReferences table. If yes the ID is in the the SourceCatalogIDs as idTYCHO
- Present in the Hipparcos catalog (**auxHIP**): A boolean that indicates if the objects is present in the Hipparcos catalog, 0=no, 1=yes=true.
- Present in the PPMXL catalog (**auxPPMXL**): A boolean that indicates if the objects is present in the PPMXL cat, 0=no, 1=yes. Version and catalog details in the SourceCatalogReferences table. If yes the ID is in the the SourceCatalogIDs as idPPMXL
- Present in the OGLE catalog (**auxOGLE**): A boolean that indicates if the objects is present in the OGLE cat, 0=no, 1=yes. Version and catalog details in the SourceCatalogReferences table. If yes the ID is in the the SourceCatalogIDs as idOGLE
- Present in the Two MASS PSC catalog (**auxTMASS**): A boolean that indicates if the objects is present in the Two-MASS cat, 0=no, 1=yes. Version and catalog details in the SourceCatalogReferences table. If yes the ID is in the the SourceCatalogIDs as idTMASS.
- Present in the Ecliptic Poles Catalog (**auxEPC**): A boolean that indicates if the objects is present in the EPC, false=no, true=yes. Version and catalog details in the SourceCatalogReference table. If yes, the number in the SourceCatalogIDs table is the number in EPC.

The following table describes the parameters associated with table SourceCatalogIDs

Name	Description	Type	Units
solutionId	Solution Identifier	long	
sourceId	Gaia source id from IGSL2	long	
idGSC23	Identifier GSC23	long	
idSDSS	Identifier SDSS DR9	long	
idUCAC	Identifier UCAC 4	int	
idLQRF	Identifier LQRF	int	
idTYCHO	Identifier Tycho - 2	long	
idHIP	Hipparcos number	int	
idPPMXL	PPMXL Identifier	long	
idOGLE	OGLE Identifier	long	
idTMASS	Identifier 2MASS	long	
idEPC	Identifier EPC	char(20)	

Parameters Detailed description

- Solution Identifier (**solutionId**): See Hernandez (JH-008).
- Identifier GSC23 (**idGSC23**): These are the IDs as published in the various input catalogs converted to a big integer. For the GSC23 we have had to alter slightly the name,specifically: GSC2.3 objects have original names that are combination of region names and running number, e.g. S00000001 is the first object in the region S0000000, we have converted the region names to the “official” numerical values in the htm level 6 structure, hence the smallest is S0000000 = 32768 and N3333333 = 65535 is the highest.
- Identifier SDSS DR9 (**idSDSS**): These are the IDs as published in the SDSS DR9 in big integer format.
- Identifier UCAC 4 (**idUCAC**): These are the IDs as published in the UCAC4 specfically a running star ID number.
- Identifier LQRF (**idLQRF**): These are the running number in the Gaia Initial Quasar Catalog - version 4 - updated September 2011 - GIQC_4.
- Identifier Tycho - 2 (**idTYCHO**): These are the IDs as published in Tycho2. In TYCHO-2 objects were identified by 3 numbers (TYC1,TYC2 and TYC3) and we have combined these into one complete number given by (TYC1*1000000.0d0)+(TYC2*10.0d0)+(TYC3*1.0d0)
- Hipparcos number (**idHIP**): If the source is a Hipparcos star this field contains the Hipparcos number.

- PPMXL Identifier (**idPPMXL**): These are the IDs as published in the PPMXL, the ipix Identifier (Q3C ipix of the USNO-B 1.0 object) converted to a big integer.
- OGLE Identifier (**idOGLE**): The OGLE ID is given by a combination of
  A region of sky identifier (RI) equal to 10, 11, 12, 13, 14 corresponding to map names blg, car, cen, lmc, mus.
  The file running number (NNN.N)
  The running number in the file (RN)
  The ID is defined as: long(string(RI)+string(NNN.N * 10000))+RN.
- Identifier 2MASS (**idTMASS**): The Two Mass provided the names in a IAU standard fashion of 2MASS JHHMMSS.S +DDMMSS.S these were codeified as +HHMMSSSDDMMSSS.
- Identifier EPC (**idEPC**): The IDs in the Gaia Ecliptic Pole Catalogue Version (GEPC 3.0) given as IAU standards: JHHMMSS.SS+DDMMSS.S.

Appendix B: Magnitude Transformations: Explanations for source codes for GSC2 blue/red magnitudes (B_J/R_f) and Gaia main / RVS magnitudes (G/G_{RVS}).

01 $R_F/B_J =$ value GSC23, $\sigma = 0.3$
02 $R_F/B_J =$ value PPMXL, $\sigma = 0.4$
10 $R_F = V - 0.0478 - 0.5739(B-V) - 0.0938(B-V)^2 - 0.4606(B-V)^3 + 0.8419(B-V)^4 - 0.3472(B-V)^5$,
$\sigma = \sigma_B$, Note valid only for $(B-V) < 2.5$.
11 $R_F = R - 0.0066 - 0.0563(V-R) - 0.2505(V-R)^2 + 0.3912(V-R)^3 - 0.0707(V-R)^4$,
$\sigma = \sigma_V$
12 $R_F = V - 0.0137 - 0.5573(V-I)$, $\sigma = (\sigma_V^2 + \sigma_I^2)^{1/2}$
13 $B_J = V + 0.0036 + 0.8768(B-V) - 0.0594(B-V)^2$, $\sigma = \sigma_B$, Note valid only for (B − V) < 2.5.
14 $B_J = R - 0.0480 + 2.4850(V-R) - 0.8760(V-r)^2 + 2.9117(V-r)^3 - 3.4144(V-r)^4 + 1.11850(V-r)^5$,
$\sigma = \sigma_V$
15 $B_J = V + 0.0442 + 0.7851(V-I)$, $\sigma = (\sigma_V^2 + \sigma_I^2)^{1/2}$
16 $R_F = V_T - 0.0478 - 0.578(B_T-V_T) - 0.0677(B_T-V_T)^2 - 0.2828(B_T-V_T)^3 + 0.4395(B_T-V_T)^4 + 0.1541(B_T-V_T)^5$,
$\sigma = \sigma_{V_T}$, Note valid only for $(B_T - V_T) < 2.5$.
17 $B_J = V_T - 0.0036 + 0.655(B_T-V_T) - 0.0429(B_T-V_T)^2$, $\sigma = \sigma_{B_T}$, Note valid only for $(B_T - V_T) < 2.5$.
18 $R_F = r + 0.1784 + 0.1187(g-r+0.259) + 0.0195(g-r+0.259)$, $\sigma = (0.04 + \sigma_r^2)^{0.5}$
19 $B_J = g + 0.0880 + 0.2434(g-r+0.259) + 0.0439(g-r+0.259)$, $\sigma = (0.04 + \sigma_g^2)^{0.5}$
20 $B_J = V_p + 0.3608 + 1.40985(V_p - R_F)$, $\sigma = 0.5$
21 $B_J = R_F + 0.3841 + 1.97440(R_F - I_N)$, $\sigma = 0.5$
28 $G = V_T - 0.0246 - 0.3354(B_T-V_T) - 0.02558(B_T-V_T)^2 - 0.05153(B_T-V_T)^3$, $\sigma = (0.2916 + \sigma_{V_T}^2 + \sigma_{B_T}^2)^{1/2}$
29 $G_{RVS} = V_T - 0.1313 - 1.3422(B_T-V_T) - 0.09316(B_T-V_T)^2 - 0.0663(B_T-V_T)^3$, $\sigma = (0.2916 + \sigma_{V_T}^2 + \sigma_{B_T}^2)^{1/2}$
30 $G = g - 0.1128 - 0.5264(g-i) - 0.0869(g-i)^2 + 0.0025(g-i)^3$, $\sigma = (0.08^2 + \sigma_g^2 + \sigma_i^2)^{1/2}$
31 $G_{RVS} = g - 0.4994 - 1.2026(g-i) - 0.0202(g-i)^2 + 0.0021(g-i)^3$, $\sigma = (0.11^2 + \sigma_g^2 + \sigma_i^2)^{1/2}$
32 $G = g - 0.089 - 0.8543(g-r) - 0.1281(g-r)^2 + 0.0471(g-r)^3$, $\sigma = (0.1681 + \sigma_g^2 + \sigma_r^2)^{1/2}$
33 $G_{RVS} = g - 0.4332 - 1.8906(g-r) - 0.0231(g-r)^2 - 0.0329(g-r)^3$, $\sigma = (0.2401 + \sigma_g^2 + \sigma_r^2)^{1/2}$
41 $B_J = J + 4.9816 - 0.38945670(J-K)$, $\sigma = 0.5$
42 $R_F = J + 2.6997 - 0.46257863(J-K)$, $\sigma = 0.5$
50 $G = R_F - 0.0158 + 0..2915(B_J-R_F) - 0.0347(B_J-R_F)^2 - 0.0301(B_J-R_F)^3$, $\sigma = 0.4$
51 $G_{RVS} = R_F - 0.0974 - 0.4830(B_J-R_F) - 0.0184(B_J-R_F)^2 - 0.0178(B_J-R_F)^3$, $\sigma = 0.5$
52 $G = V - 0.0247 - 0.2888(B-V) - 0.0353(B-V)^2 - 0.0839(B-V)^3$, $\sigma = 0.6$
54 $G = V - 0.0208 - 0.1004(V-I) - 0.1593(V-I)^2 + 0.0083(V-I)^3$, $\sigma = (\sigma_V^2 + \sigma_I^2)^{1/2}$
55 $G_{RVS} = V - 0.1333 - 1.4654(B-V) - 0.1075(B-V)^2 - 0.0768(B-V)^3$, $\sigma = 0.6$
57 $G_{RVS} = V - 0.0501 - 1.1667(V-I) - 0.0052(V-I)^2 + 0.0011(V-I)^3$, $\sigma = (\sigma_V^2 + \sigma_I^2)^{1/2}$
80 $G =$ value and sigma from GEPC
81 $G_{RVS} =$ value and sigma from GEPC

The B, V, R, I represent published Johnson-Cousins magnitudes, g, r, i SDSS magnitudes and V_T, B_T Tycho magnitudes. The σ represents the nominal error of the derived transformation, these are added in quadrature to the published errors. Equations 10-21 were determined from a combination of Johnson - GSC2 transformations derived internally and Tycho - Johnson transformations published in the “Guide to the Tycho-2 Catalog” (Hog et al., `http://www.astro.ku.dk/~erik/Tycho-2/`). Equations 41/42 were calculated internally from a GSC23 to 2MASS match. Other equations between 28-57 were taken from Jordi (CJ-041) combined with the Hog et al. and internal transformations where needed.