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The Construction of a Reference Star Catalog for the Euclid Mission

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Abstract Optimization of scientific throughput from the ESA Euclid mission imposes stringent requirements on the performance of satellite absolute pointing. This will be achieved by the on-board Fine Guidance Sensor (FGS) with the aid of a specific stellar catalog, which must comply with well-defined, FGS-driven astrometric and photometric properties. By means of the OATo Star Catalog Database, used for the production of the Initial Gaia Source List, we present a preliminary assessment of the methods of construction of such a reference catalog.

1 Satellite Attitude Requirements and the FGS Reference Star Catalog

The ESA Euclid mission will investigate the nature of dark energy, dark matter and gravity by detecting weak gravitational lensing and barionic acoustic oscillations. Euclid will cover the extragalactic sky at $|b| > 30^\circ$ (with foreseen extension to the entire sky) by observing strips of adjacent fields along great circles of roughly constant ecliptic longitude. To meet the demanding pointing performance, the satellite Attitude and Orbital Control System will be endowed with a Fine Guidance Sensor instrument (FGS). The FGS must achieve an Absolute Pointing Error of $< 2.5''$ (1 σ), and a Relative Pointing Error over 700 sec of $< 0.025''$ (1 σ) in the X and Y telescope axes. In Absolute Tracking Mode, targets will be selected using an input star catalog, which will be derived from the FGS *Reference Star Catalog*, complying with 3 main requirements: *a)* 5 (with a minimum of 3) or more stars brighter than $R_{FGS} = 19$ mag per Field-of-View (FGS)[1] , the limit operating magnitude; *b)*

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[1] the FGS photometric bandpass can be assimilated to the photographic magnitude R_F, with variations below 0.1 mag, for all spectral types with the exclusion of very low-mass stars, for which R_{FGS} can be sensibly brighter (¿ 0.5 mag) than R_F

astrometric accuracy of 0.4″ absolute position (per coordinate) at epoch 2025; and *c)* more than 2″ distance from nearest neighbor, or with a difference in brightness of more than 2 magnitudes.

2 Selection and Analysis of Test Fields from the OATo Database

The catalog database hosted at OATo, a compilation of the major astronomical catalogs presently available, represents a resource for various scientific and technical activities. The cross-matched object list is mapped onto the celestial sphere using a level-6 HEALPIX[2] scheme; in practice, the sphere is pixelized in 49152 equal areas of 0.84 square degrees each. This database provided the basis for the production of the Initial Gaia Source List [3] (IGSL) that is being used as starting point for the Initial Data Treatment of Gaia's observations, and includes the following parameters, when available: positions, object classification, proper motions, magnitude and color information of all objects brighter than Gaia magnitude 21 over the entire sky.

SEP $\alpha = 90°$, $\delta = -67°$ (b=-30°)	$10 < R_F < 19$ stars	$10 < R_F < 19$ "single stars" $\sigma_{POS} < 0.4$"
Total number of stars (Ns)	4.25e+006	677393
Mean density per square degree	35131	5598
FOV mean density (Ns / FOV)	425	68
FOV density dispersion (Ns/FOV)	946	59
Min / Max counts per FOV	11 / 9176	9 / 387
Probability Ns / FOV ≥ 3	1.0	1.0

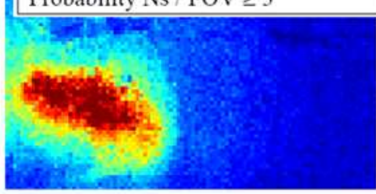

Fig. 1 Analysis of 100x100 FOVs in the SEP region. The color-coded map show the density of a sub-sample of "single" stars with astrometric accuracy better than 0.4″ (the red, i.e., denser area is in the direction of the Large Magellanic Cloud). The table reports the complete objects statistics before and after FGS selection criteria are applied

We have extracted from the IGSL basic data some representative sky regions 11x11 square degrees in size, each sampling 10,000 independent FGS FOV areas

[2] http://healpix.jpl.nasa.gov/

[3] http://www.rssd.esa.int/SYS/docs/ll_transfers/project=PUBDB&id=3223578.pdf

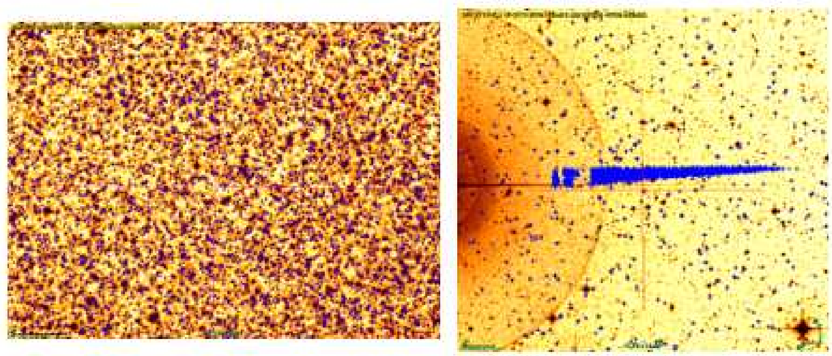

Fig. 2 $\approx$ 14x10 arcmin fields from the SEP region; catalog objects (blue crosses) are overplotted to the Anglo-Australian Schmidt Survey plate image. *Left Panel:* In spite of the high crowding, some candidate reference stars are available but we must consider the limited reliability of the sources provided by the current astronomical catalogues *Right Panel:* Typical example of false object detection caused by the diffraction spike of a very bright star from a Schmidt image

of $7' \times 7'$. Then, we have selected all the potential FGS reference stars complying with the requirements specified above. A color-coded stellar density map of each 100x100 FOV areas is a useful tool for identifying lack of stars, anomalous gradients, or peculiar features not obviously attributable to the real sky (see figures). We analyzed a few of these cases by overlaying the catalog objects onto the digitized astronomical images available from the ALADIN Sky Atlas (aladin.u-strasb.fr). The figures show some results of the analysis of the Southern Ecliptic Pole (SEP) region centered at $\alpha = 90°$, $\delta = -67°$, and galactic latitude $b = -30°$

3 Conclusions and Future Work

This preliminary assessment of the catalogue extracted from the OATo Database has highlighted some deficiencies, which must be cured in order to build an *operational Reference Star Catalog* for the Euclid FGS. We foresee better performances by including the new proper motions from GSC2.3 material (Qi Z. et al. 2015,*"Absolute Proper Motions outside the Plane (APOP), A step towards GSC2.4"*, submitted to AJ) and, also, by paying special attention to critical sky areas. Moreover, the integration of novel data coming from ongoing ground-based CCD surveys such as PAN STARSS, Sky Mapper, VST, and ultimately Gaia, will help improve count completeness as well as astrometric and photometric accuracy.

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