GWP-947 Cluster selection requirements for the first Gaia data release

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Abstract

The intention of this document is to define the requirements for the cluster selection to be used for to validate the first data release in the GWP-947. The cluster target list is provided

Document History

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Contents

1 Introduction

1.1 Scope and Objectives

Our objective is to use clusters to validate the first data releases of the Gaia Catalog. For that several tests were proposed on the Arenou (FA-061). Here, for each of the proposed tests, we define the requirements to be fulfilled by the selected clusters and we provide the list of candidates together with the reference for the auxiliary data. A detailed description of the Auxiliary data Catalogs is provided by **?**

2 Test description

2.1 Test WP947-VAL-10-10

The test intends to check the proper motion systematic errors as function of the magnitude. We will test the spatial and magnitude properties of relative proper motions rather than absolute values.

This is tested using distant clusters of Hundred Thousand Proper motion catalog based on Hipparcos Catalog. The HTPMC is described in Mignard (FM-040). Even if the nominal performances described there will be degraded because of the problems found during the commissioning, let us assume the nominal values of the uncertainties for the time being. For the purpose of this document this precision can be considered sufficient. If necessary the discussion will be revised as soon as the expected Gaia performances are defined.

In the HTPMC, the expected accuracy on the proper motions will be 30 to 250 μas/yr, with an average of 50 μas/yr (20 times better than the average 1000 μas/yr of the Hipparcos values). Since stars are very bright, the stray light found during commissiong should have little effect on the performances. Furthermore, for stars having radial velocities known to within 1 to 2 km/s, the modeling error can be reduced to below 10 μas/yr. The accuracy will depend on the coordinates, and will be lower around the ecliptic as a result of the lower accuracy in the Hipparcos right ascension. The effect of the scanning law from Hipparcos and Gaia are expected to be visible in right ascension and almost not relevant in declination. The limited coverage in time of Gaia will produce a secondary dependence on the ecliptic longitude as a result of the lack of uniformity of the number of observations.

Requirements

1. Object type. The suitability of OB associations should be studied: the associations may have subgroups with distinct proper motions and this would add further com-

plication to the tests. For the first data release we will restrict the tests to open clusters.

2. coordinates. If possible clusters in different location should be choosen. This requirements will hardly be fulfilled in the first data release, due to the limitation of the available data in the HTPMC, but might be considered in the data releases second+.

3. magnitude/color coverage. The HTMPC will be limited in magnitude to Hip$<$12, or G$<$**. The stars brighter than the Gaia saturation limit of G=5.4(to be revised after commissioning) will not be observed by Gaia, but will be anyhow included in the final HTPMC. These stars will have PM as given by Hipparcos and should not be considered in the test. The selected clusters should cover the whole Hipparcos magnitude range as much as possible, and a large range in colours (this will discard very distant clusters)

4. statistics. The number of stars should be sufficient to obtain a reliable determination of the uncertainties as a function of the magnitude. Ideally all the Gaia gates covered by the Hipparcos magnitude interval should have sufficient statistics. This will not be possible, due to the Hipparcos statistics limitations.

5. the selected cluster must be at a sufficient distance from us that the formal errors on the proper motions $\delta_{\mu G}$ are larger than the intrinsic dispersion of the proper motions expected in an open cluster (about 1-2 km/s) δ_v. This requitement should be strictly true if the goal is to derive random uncertainties. However, having being close to this limit, will improve the results.

6. the proper motions may contain the orbital motion when stars are multiples. Consequently, we will need to handle long period astrometric binaries which may at best pop up with clearly outlying values, but will more generally add an extra ”noise” due to the large fraction of those which will go undetected, (and perhaps not far from half of objects may have an orbital motion larger than 50 muas/yr at 390pc). So, even if this will not be enough, this means that in the requirements one more req./catalogue may be added for a strong selection of putative non-multiple members (using classical DMS catalogs, but also e.g. suspected trends in RV, etc.). The test is vs magnitude, but since the expected binary fraction decreases towards fainter absolute (and thus apparent) magnitude, the noise will decrease and an (this time, expected) effect related to magnitude may already be present without being due to Gaia problems. This extra noise complicates the data analysis (with no noise, correlations which may be anticipated between members would be seen by comparison to the formal errors). So, this noise should be modeled.

A good candidate in the Hipparcos Catalog, is Collinder 70.

Data from Kharchenko+2012 Catalog:
Collinder 70
Right Ascension (2000) 05 35 31
Declination (2000) -01 06 00
Galactic longitude 205.03
Galactic latitude -17.35
Distance [pc] 391
Reddening [mag] 0.04
Distance modulus [mag] 8.08
Log Age 6.71

About 500 stars are found in the Hipparcos Catalog over a radius of 3.7 deg, covering a magnitude range from 4.70 to 11.6 about. Of those Francis & Anderson (2012) quotes 179 members and gives a distance of 368±10 pc based on Hipparcos stars (see Fig.1). At this distance the internal velocity dispersion will be of the order of 380 $\mu-$arcsec/y, comparable as order of magnitude to the expected Gaia uncertainties. At about 500 pc, the internal velocity dispersion will result in a vt of the order of 280 $\mu-$arcsec/y. At about this distance there are 2 associations LacOB1 ($\alpha(J2000), \delta(J2000) = +340.25, +38.50$) and VelOB2 ($\alpha(J2000), \delta(J2000) = +122.37, -47.90$) having 67 and 73 members respectively, and a radius of 4.2 deg and 2.9 deg respectively, mag range between $\sim 5 - 10.5$. However associations might not be suitable for this test, since they might have different kinematic subgroups.

2.2 Test WP947-VAL-10-20

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The test intends to study small angular scale of astrometric correlations. This can be done deriving the separation among stars in the cluster from Gaia data and from external data. The test will be done for faint Gaia stars using high precision HST relative positions in external regions of globular clusters. For the stars in the cluster,the mean separation should be the same. Random errors on the positions should not significantly affect the structure. This tests can make use of stars whose membership is known from literature studies. An MST algorithm can be used to quantify the cluster structure.

Requirements

1. In the first data release, the limited coverage in time of Gaia will produce a dependence on the positions as a result of the lack of uniformity of the number of observations.
2. clusters having statistically significant number of members (larger than a few hun-

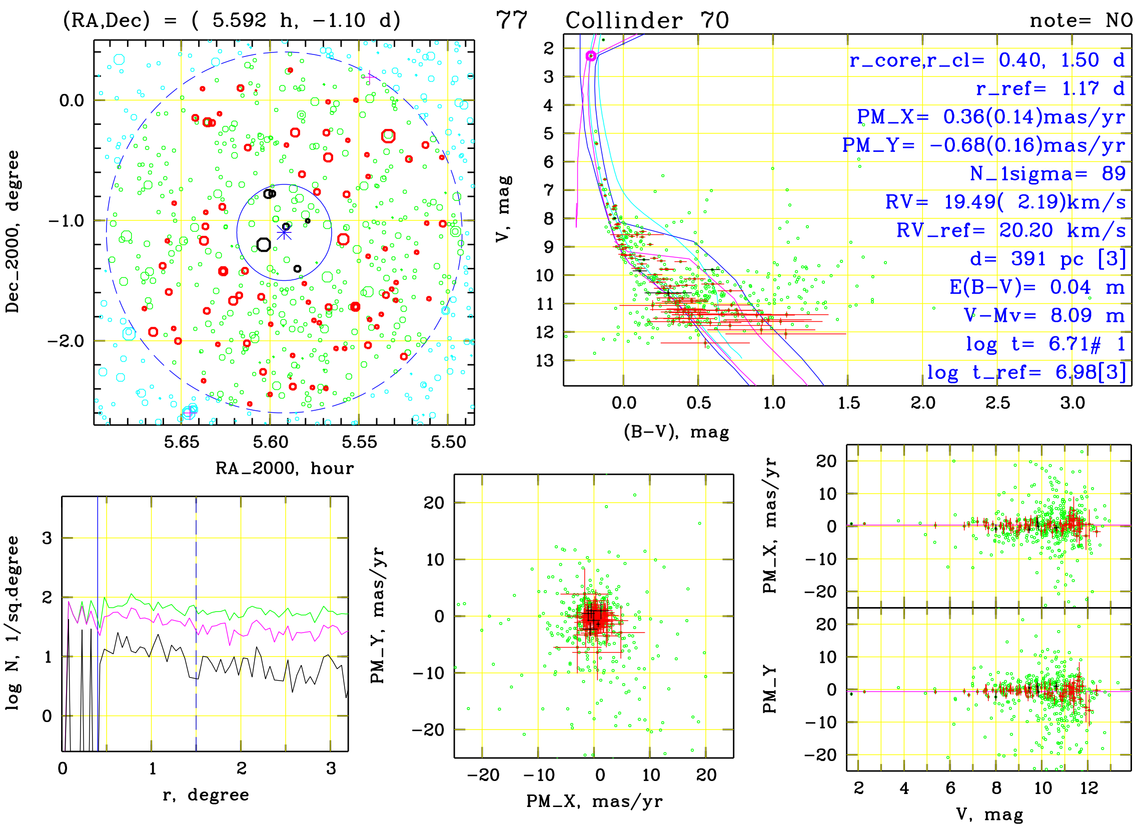

FIGURE 1: Data on Collinder 70

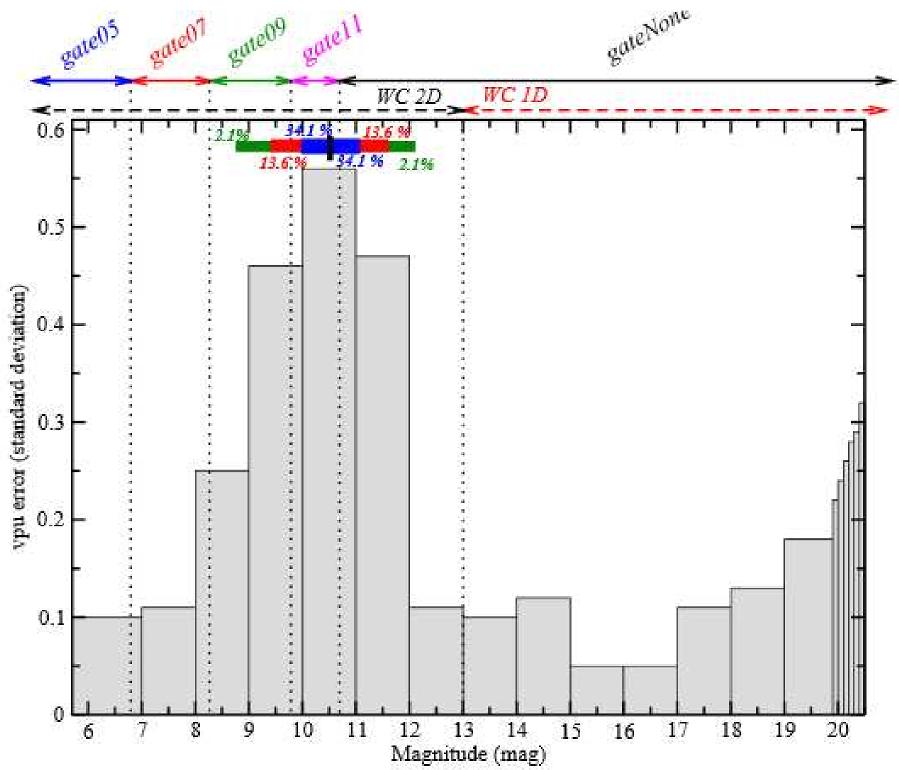

FIGURE 2: VPU uncertainty on magnitude measurements. Data taken from the GPDB. Gating system on the top (lines)

dreds, if we use MST, a few thousands would be more reliable)

3. precise external relative positions. One could check several deep catalogues, cross-match them and check if there are systematics among catalogues and if this procedure can be of application to Gaia positions. In principle we can apply this test also to HTPMC, if external data of sufficient quality are found

4. clusters having large apparent diameters in the sky to check for systematics depending on the coordinates This would possibly be affected by external Catalog biases. Small fields with internal accurate relative astrometry in different regions of the sky can be a good alternative. Tests about that will be conducted using real data

5. crowding in the cluster should be relatively small (i.e. the numer of star per sq deg $<$ 750,000 stars for the BP/RP to apply chromaticity correction)

A good candidate can be M4. Data from Bedin et al. (2013) taken in the HST project GO-12911 are available. 120 orbits have been allocated during HSTs Cycle2 with WFC3/UVIS having small pixel size (0.039775 arcsec). The filters F467M is used, since archival images showed that it saturated at the same level as F390W, but the PSF is 10% sharper. In addition images taken with WFC3/UVIS F775W and ACS/WFC F606W and F814 will be taken. details on teh data can be found in the quoted paper. Data are now under reduction and analysis and they will be available mid 2015. These authors have recently published a distortion solution for the ten most commonly used filters that is accurate to better than 0.01 pixel (Bellini, Anderson & Bedin 2011). The solution accounts for the camera optics, filter-specific perturbations, and a ± 0.03 pixel manufacturing defect. Once the distortion has been removed, they are able to recover the full astrometric capabilities of UVIS. With a single measurement they can reach a precision of the order of 0.35 mas. This can be improved by taking many independent exposures at a variety of dithered positions within each epoch, and by adopting a local-transformation approach. They expect to reach a precision of about 50-100 μ arcsec in about 50 observations, in a field of view of about $4x4$ armin for star in the magnitude range 15-21 (About 10,000 stars will be measured, and about 2000 stars are expected to be in the central region where the precision is higher. The goal of their work is to detect and study binaries. So information about binarities can be taken into account in the test.

M4 Basic information, data from Simbad
Right Ascension (J2000) 16 23 35.22
Declination (J2000) -26 31 32.7
Galactic longitude 350.9729
Galactic latitude +15.9722
Distance [pc] 1700
Since the cluster is nearby, the crowding whould not be an issue (TBD). Figures 3 and 4 present the observed field and the CMD.

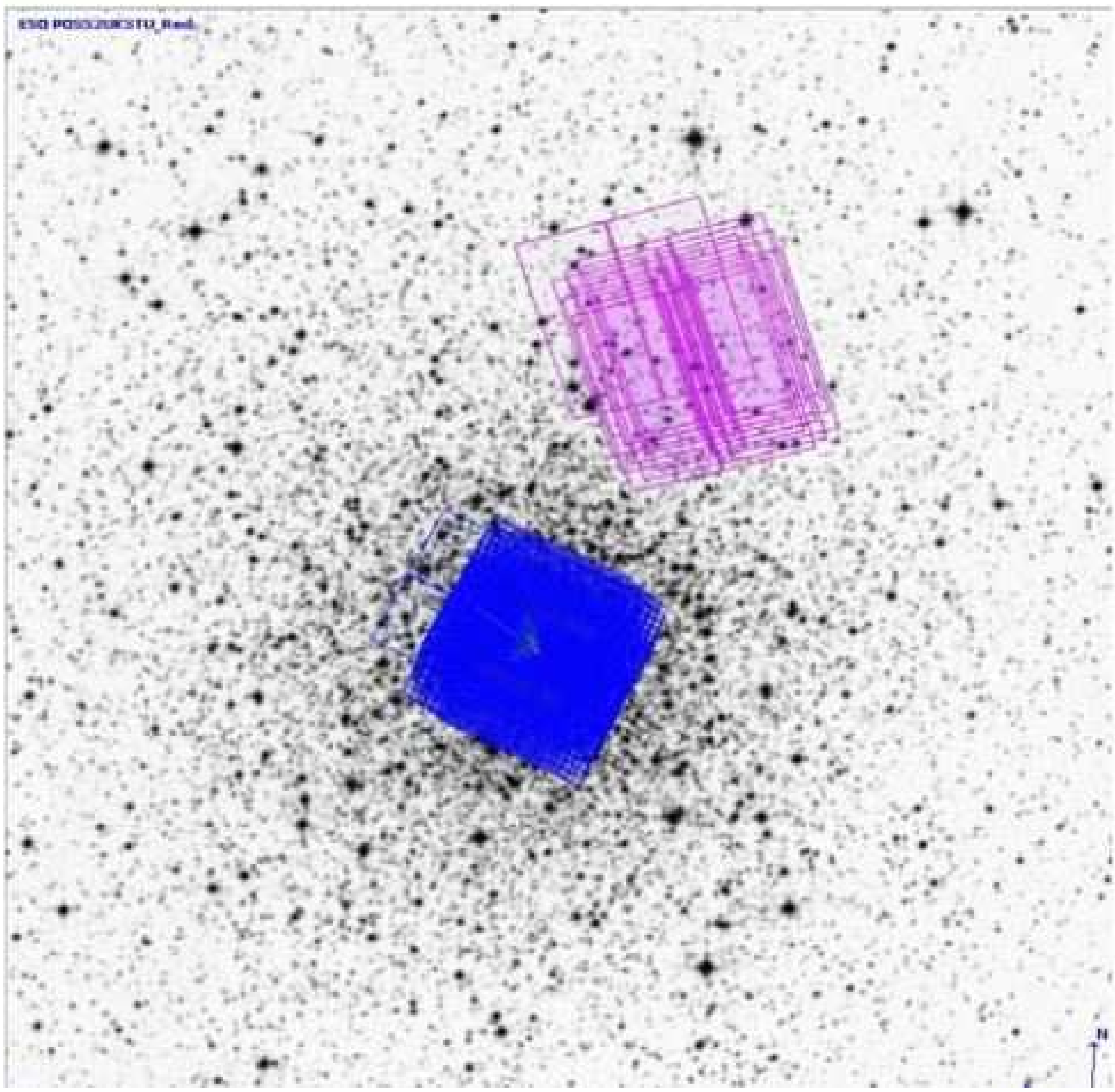

FIGURE 3: Indicative position of the observed fields. ACS/WFC in magenta, WFC3/UVIs in blue. In the image, Nord is up; East left. The figure is taken from Bedin et al 2013- their fig4

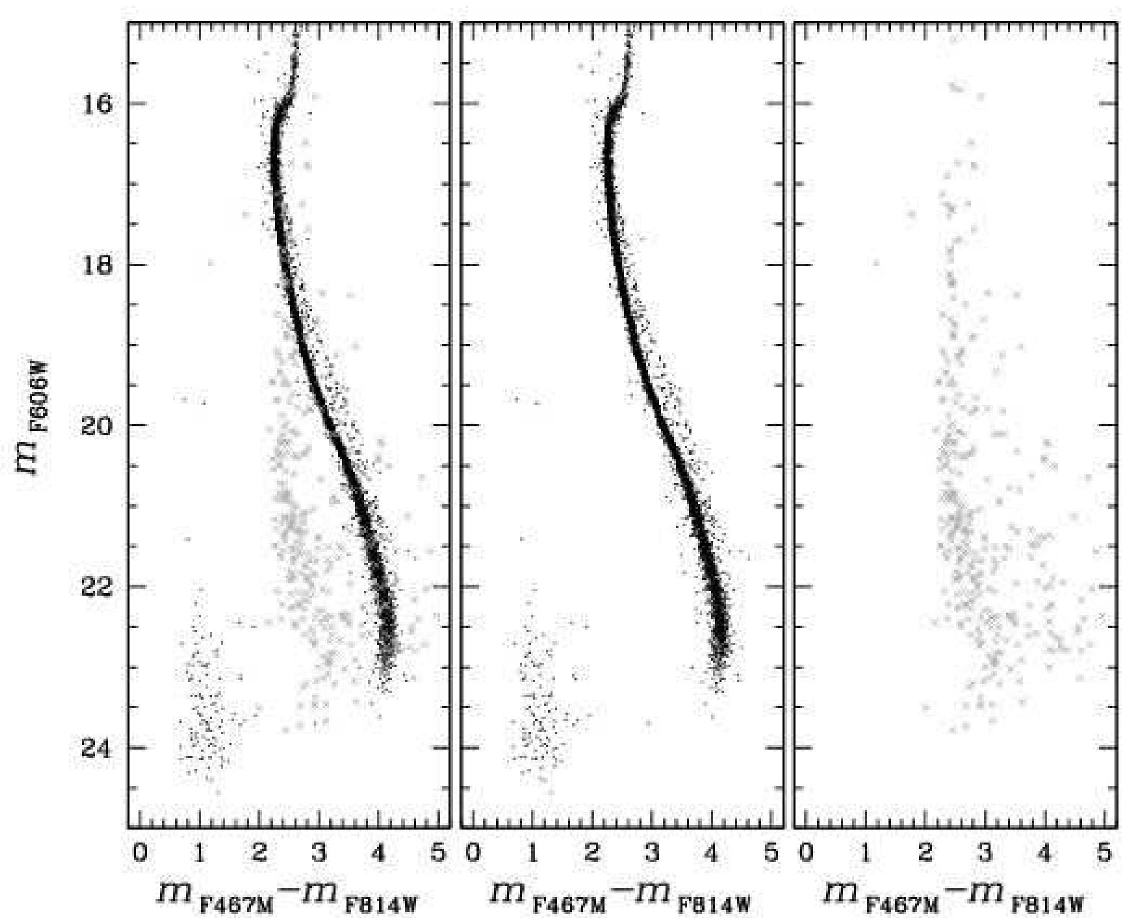

FIGURE 4: Color magnitude diagram of the observed stars in the core of M4; left panel full data in common between ACS and WPC3 observations; mid panel: only cluster members selected using proper motions; right panel only field stars. The figure is taken from Bedin et al 2013- their fig.10

2.3 Test WP947-VAL-10-51

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The goal is to test the photometric consistency. External photometry will be converted in Gaia Magnitudes to detect systematics. The photometric calibrations carried out by CU5 are split by FoV, row, strip, gate/window class configuration. If there is a systematic difference in the photometric response between observations of different photometric configurations, and if there are sources that are preferentially observed in one or other of these, the formation of multiple photometric systems is possible. In particular:

1. Test05-01 Verification of systematic magnitude terms for bright stars. The external photometry can be used to predict G magnitude and compare with the same quantities in Gaia catalog to detect systematics
2. consistency between faint and bright star properties. This test should not be restricted to clusters, but use the whole catalog; the only point of including it here is because it is perhaps easier for clusters regions to find deep studies in the literature

These tests can be done in the first release using stars whose membership is known from other studies.

Requirements:

1. coordinates coverage. Clusters in different regions of the sky are needed.
2. magnitude coverage. Ideally all the Gaia gates should be covered and have sufficient statistics. Clusters at different ages and distances should be selected to cover Gaia gates/windows. The gating system is given in the GaiaParameterDataBase. Fig2 show the gating system taken from Fernandez-Hernandez et al. (JFH-001). Stars brighter than about G=13 are observed through gates. Since the VPU uncertainty on the mag determination can range from 0.1 at G=6 and G=12-13 to about 0.55 at G=10-11, care should be paid to have stars in these magnitude ranges.
3. statistics. The number of stars should be sufficient to obtain a reliable determination of the systematics as a function of the magnitude.
4. External magnitude accuracy. The photometry of different authors should be compared to avoid systematic differences
5. precision of the transformation external-Gaia magnitudes. Transformations for any passbands can be computed. As shown in Jordi (CJ-041), the $V - I_C$ provides

a transformation with lower residuals (~ 0.03), while (B-V) have large scatter with a stronger dependence from the extinction and the stellar temperature (cool stars). The transformations involving Sloan passbands yield residuals larger than with Johnson passbands. Other passbands (GSCII) should be avoided. HST transformations could be easily derived and used after testing.

2.4 Test WP947-VAL-10-52

. External photometry will be converted in Gaia G magnitude. The completeness of Gaia data as a function of the magnitude will be tested by comparison with HST photometry at the faint end. Here the HST photometry is requested to derive a more reliable cross-match in possibly crowded areas of the sky still accessible to Gaia such as external regions of globular clusters. The limiting separation to resolve close binaries in clusters should be taken into account (see Spagna (ASP-006)).

Requirements:

1. coordinates coverage. The Gaia completeness can be different depending on the number of passages and density in the sky
2. magnitude coverage. Ideally all the Gaia gates should be covered and have sufficient statistics. Clusters at different ages and distances should be selected to cover Gaia gates/windows.
3. External magnitude accuracy. The requirements on accuracy and precision of the photometry might be partially released, since no direct comparison among the photometries is expected.
4. precision of the transformation external-Gaia magnitudes. Transformations from HST magnitudes to Gaia magnitudes are needed to properly select themost suitable passbands
5. high completeness of the external data down to G=21. HST data on open or globular clusters, having comparable resolution to Gaia data must be used. However, only a small number of open clusters having compatible range of magnitudes are found in HST archive. The test must make use of globular clusters

Possible candidates for test 10-51 and 10-52 are clusters locatyed at a distance modulus of (m-M)$\sim$13-14 can be sampled 2-3 mag below the turnoff. These clusters are: 47Tuc, Omega-Cen, NGC6656 (M22), NGC6752, NGC6397, NGC6121, NGC6809 (M55), NGC6838 (M71).

NGC6121 and NGC6752 and NGC 6397 are the closest objects (according to the Harris catalogue (1996, AJ, 112, 1487, and subsequent revisions) (`http://physwww.physics.mcmaster.ca/~harris/mwgc.dat`).

These clusters are well studied and their photometry can be found in Stetson Database of globular clusters including data from several archives, from HST to ground based observations (ESO telescopes for instance). In the case of OmegaCen, 47Tuc and M22 several thousands of images are analysed. Monelli et al. (2013) is the first paper of a series where these data will be published. HST data can be used and selected to test completeness and photometry, provided that the transformations from HST magnitudes to G mag are calculated.

3 Applicable Documents

Arenou (FA-061)	CU9 Validation Test Specification
O'Mullane et al. (WOM-086)	CU9 Software Development Plan

4 Reference Documents

[AV-013], A-Vallenari, 2014, *GWP-947 Auxiliary data*,
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URL `http://gaia.esac.esa.int/dpacsvn/DPAC/CU9/docs/WP940_Validation/GWP-947`

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`GAIA-C9-SP-OPM-FA-061-D`,
URL `http://gaia.esac.esa.int/dpacsvn/DPAC/CU9/docs/WP940_Validation/ECSS/VTS/GAIA-C9-SP-OPM-FA-061.pdf`

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5 Acronyms, and abbreviations

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

Acronym	**Description**
AV	Astrometric Verification
CU	Coordination Unit (in DPAC)
DB	DataBase
DPC	Data Processing Centre
DPCE	Data Processing Centre ESAC
OS	Observatoire de Strasbourg (France)
PDP	Project Development Plan
PE	Payload Expert
POR	Payload Operations Request
SE	Standard Edition
SGS	Science Ground Segment
SOC	System On a Chip
UL	Ultimate Load
XM	Cross-Matching