Gaia simulations of dense fields

SAG_SWG_001 Rev: 1.5

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1 Work in Meudon

Using the informations given by Fabio Favata, about the use of IRAF package `artdata` for the simulation of GAIA images, several simulations have been done in some dense areas, using his procedure:

- a list of objects is first simulated in a $9 \times 9\mu$ pixel space
- an image is generated, using the scaled psf, the 0.86 s exposure time, and the zero-point magnitude parameters. The psf comes from François Mignard, with smearing added by Fabio ("average" across-scan smear of 140 mas)
- the image is rebinned by a factor of 3 in the vertical direction, simulating a $9 \times 27\mu$ pixel size.
- RON, poisson noise and background are finally added

Although the used parameters are described below, the FITS header of each file should in any case provide the necessary informations.

The size of each image is 19.5×19.5 arcsec^2 ($512 \times 512/3$ pixels).

- simulations of globular clusters M92, M55, Omega Centauri

  The projected density for each cluster is based on the empirical law from King (1962), using the core radius / tidal radius from Harris (1996) and number of stars. The latter has been approximately estimated using the total mass from Prior et al. (1993) and the luminosity cutoff. The density function and the I luminosity function are finally combined to produce each simulation. The mass segregation has not (yet) been taken into account. All simulations have been done in the core of the clusters. An approximate position is given in the FITS header.

  empirical profile fit: King I., 1962, AJ 67, 471

$r_t, r_c, m - M$ parameters : Harris W.E., 1996, AJ 112, 4

cluster masses : Pryor C., Meylan G., 1993, in Dynamics of Globular clusters, ASP conf. series, vol. 50, Djorgovski & Meylan Eds.

The respective luminosity functions come from :

M55 Zaggia S.R., Piotto G., Capaccioli M., 1997, A&A 327 1004.
Mandushev G.I., Fahlman G.G., Richer H.B., 1996, AJ 112, 1536

M92 : Piotto G., Cool A.M., King I., 1997, AJ 113, 1345
Hartwick F.D.A., 1970, ApJ 161, 845

ω Cen : Elson R.A.W., Gilmore G.F., Santiago B.X., Casertano S., AJ 110, 682 Lynga G., 1996, A&Asup 115, 297
Richer H.B., Fahlman G.G., Buonanno R., Fusi Pecci F., Searle L., Thompson I.B., 1991, ApJ 381, 147.

- Baade window

  The Besançon Galaxy model (Robin et al.) has been used to generate stars up to $I = 25$ in the Baade window.

The first simulations have been done using:

- I magnitude
- mag zero point: 25.6
- background = 0
- RON=9.5

The files are:

- `M55I.fits`: 299 stars from I=15.57 to 21.75
- `M92I.fits`: 26165 stars from I=11.8 to 25
- `omcenI.fits`: 7560 stars from I=13.93 to 23.25
- `baadeI.fits`: 6744 stars from I=16.72 to 25

with `-nonoise` added for the file names for simulations with no RON, poisson nor background added.

The images have also been generated with Ga magnitudes, using the following parameters:

- $Ga = f(I, V - I)$ magnitude from François Mignard (SAG_FM_002.ps)
- mag zero point= 26.5 (as pointed out by the Barcelona team, see below)
- background = 0.28 (see below)
- RON=9.5

The corresponding filenames are `M55Ga.fits, M92Ga.fits, omcenGa.fits`

2 Work in Barcelona

Simulations for 47 Tuc and NGC 288 halo globular clusters using `artdata` IRAF packages have been done. For each globular cluster two simulated images have been constructed, one following the read-out-noise of the PSM chip and the other the read-out-noise of the faint stars astrometric chip (FSAF1).

- Simulation for 47 Tuc Globular cluster using IRAF package `starlist`:

  The halo globular cluster 47 Tuc is placed at $(l, b) = (304, -44)$. From Barcelona Galaxy model we checked that the contribution of field stars in a GAIA PSM chip in this region is negligible (only 18 field stars with $Ga < 25$), so they have not been considered.

  The simulation is done at 4.6 arcmin E of the center of the cluster. The spatial density function follows a King's 1962 model (AJ 67, 471) with a core radius of 0'.37 (598 pixels) extracted from Harris (1996)

  We simulate in absolute magnitudes (M_V) using the globular cluster luminosity fuction given by Pioto et al., 1997 (A.J. 113, 1345)

  10000 stars have been simulated in the PSM chip. This number is obtained by fitting the number of simulated stars in the V magnitude range $18 < V < 21$ to the real stars observed with the HST (De Marchi et al. (1995) A&A 304, 211).

- Simulation for NGC 288 Globular cluster using "starlist":

  This cluster is placed in the south galactic pole $(l, b) = (152, -89)$, the contribution of field stars to the GAIA PSM chip being also negligible.

  The simulation is done at center of the cluster. The spatial density function follows a King's 1962 model (AJ 67, 471) with a core radius of 1'.66 (2684 pixels) extracted from Harris (1996)

  We simulate in absolute magnitudes (M_V) using the globular cluster luminosity fuction given by Pioto et al., 1997 (A.J. 113, 1345)

  We simulated 6000 stars in the PSM chip. This number is obtained by fitting the number of simulated stars in the V magnitude range $V < 19.5$ to the real stars observed by Bergbusch (1993) A.J. 106, 1024.

- Computation of the Ga apparent magnitude:

  Real distance modulus (14.06 for 47 Tuc and 15.30 for NGC 288) and $E(B-V)$ (Harris, 1996) have been used to compute V apparent magnitudes.

  $(M_V, B-V)$ relation of 47 Tuc and the $((B-V), (V-I))$ relation of Grenon (SP-1200) are used to obtain colour indices for each star in the two simulated clusters.

  The GAIA magnitude (Ga) comes from Mignard (SAG_FM_002) equations $(Ga-V) = f(V-I)$.

  The data for the two globular clusters (x, y positions in the chip and Ga mag.) are stored in the files `gc47tuc.g` and `gcNGC288.g` (can be obtained from the WEB).

- From this point on, the Fabio's chain is followed with modifications described below. The background is added only in `mknoise`.

  `rfits psfs` (to convert `psfs.fits` from Fabio to `psfs.imh`)

  - To construct a PSM images, the adopted `artdata` parameters are:

    ```
    mkobjects gcNGC288GaPSM background=0 ncols=2780 nlines=3225
    objects=gcNGC288.g star=psfs radius=28.44 distance=1.
    exptime=0.8618 magzero=26.5 gain=1.0 rdnoise=0.
    ```

Rebinning:

```
blkavg gcNGC288GaPSM gcNGC288GaPSM-R 1 3 op=sum
```

Read-out-Noise and background:

```
mknoise gcNGC288GaPSM-R output=gcNGC288GaPSM-F background=0.28
gain=1 rdnoise=16.  poisson=yes seed=1234
```

Final images on fits format:

`gcNGC288GaPSM.fits`
`gcNGC288GaPSM-F.fits` (including binning, noise and background)

`gc47tucGaPSM.fits`
`gc47tucGaPSM-F.fits` (including binning, noise and background)

– To construct FSAF1 images:

In order to avoid a very large image we have only simulated a chip of 2780×1075 although, according to MMS, this chip is double 2780×2150

```
mkobjects gc47tucGaFSAF1 background=0 ncols=2780 nlines=3225
objects=gc47tuc.g star=psfs radius=28.44 distance=1.
exptime=0.8618 magzero=26.5 gain=1.0 rdnoise=0.
```

Rebinning:

```
blkavg gc47tucGaFSAF1 gc47tucGaFSAF1-R 1 3 op=sum
```

Noise and background:

```
mknoise gc47tucGaFSAF1-R output=gc47tucGaFSAF1-F background=0.28
gain=1 rdnoise=9.5 poisson=yes seed=1234
```

Final images in FITS format:

`gc47tucGaFSAF1.fits`
`gc47tucGaFSAF1-F.fits` (including binning, noise and background)

`gcNGC288GaFSAF1.fits`
`gcNGC288GaFSAF1-F.fits` (including binning, noise and background)

- A field of galaxies has also been generated for PSM-CCDs using the IRAF `gallist` package: 100 galaxies simulated with integrated *Ga* magnitudes 15 and 21. The other `gallist` defaults have been kept (e.g galaxy luminosity profiles using a Schecter law – see FITS headers). Thus the simulations are not completely realistic. No field stars have been added.

3 Comments on the image simulations chain

3.1 Zero magnitude

According to magnitude-flux transformation within mkobject, a star with magnitude=magzero gives 1 electron/s.

Using Kurucz's stellar atmosphere models, we calculated the amount of photons/s collected of several stars (different spectral types). Our figures were compared with independent calculations by L. Lindegren using empirical stellar fluxes by Gunn & Stryke. As indicated in SAG_LL_017 both computations agree within 4%, except for very cool stars, for which Kurucz's models may be unreliable.

In our simulations, however, we use Ga magnitude derived from V and $V - I$. So, for a K4V star with $Ga = 20$ we would collect about 400 photons/s yielding 1 electron/s for $Ga = 26.5$ mag. This is the magzero value that we use.

3.2 Background

According to SAG_LL_015, the background was adopted as $V = 21$ mag/arcsec^2 with $V - I = 0.7$, i.e. a G2 V spectral type (solar). According to the Kurucz's stellar fluxes, this corresponds to 171 photons/s/arcsec^2. Taking into account an exposure time of 0.86 seconds and a pixel size of 37.1 mas $\times 3 \times 37.1$ mas, the background contribution was computed to be of 0.6072 electrons/pixel.

However, according to SAG_GG_005, the background is possibly smaller in all ecliptic latitudes of GAIA observations. Taking an average value of $V = 22.0$ as possibly more realistic, the background contribution should be around 0.28 electrons/pixel.

4 Files

These images may be accessed via http or ftp at the following address:
`wwwhip.obspm.fr/gaia/restricted/images/`
`username: xxxx`
`password: xxxxxxxxx`

All contributions or modifications may be done using telnet, ftp,... at `wwwhip.obspm.fr` into the directory `restricted/images`. The URL `http://wwwhip.obspm.fr/gaia/restricted` contains all documents concerning simulations which have been made available to us.

5 Future work

The next simulation step will be to use real images. Various HST images and DENIS images have been obtained from respective projects, in particular in the Baade window. Concerning DENIS images in this area, sources have been extracted but they are far from being complete up to $I = 18$ as thought before, because of the density in this area.

Then we will try to obtain images more realistic, with a mixing of stars, (including binaries of various periods) and extended sources. The fields will be simulated at different epochs, following an assumed scanning law, in order to assess the astrometric precision.