Simulations of perspective acceleration for GAIA

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Expressed in mas/yr^2, the perspective acceleration is

$$g_p = -2.046\,10^{-9} \mu \pi V_R$$

where μ is the proper motion in mas/yr, π is the parallax in mas and V_R in km/s. At the half of the mission, the corresponding effect on position is

$$\epsilon_p = \frac{1}{2} g_p (\frac{t}{2})^2$$

where we assume a 5-year mission.

Using a Galaxy model, the number of stars concerned by this effect is computed below. The parameters of the model are described in next section. We keep all stars with $I \leq 20$ mag and $R \leq 300$ pc. The simulation has not been done with a larger limit distance, because of CPU time and disk place.

About 1 600 stars with $\epsilon_p \geq 10\,\mu$as were found, and about 56 500 stars with $\epsilon_p \geq 1\,\mu$as. The distribution of the sample in I magnitude, $R = \frac{1}{\pi}$, V_R and μ is shown figure 1, for all stars with $\epsilon_p \geq 0.1\,\mu$as. It represents 7% of all stars within 300 pc.

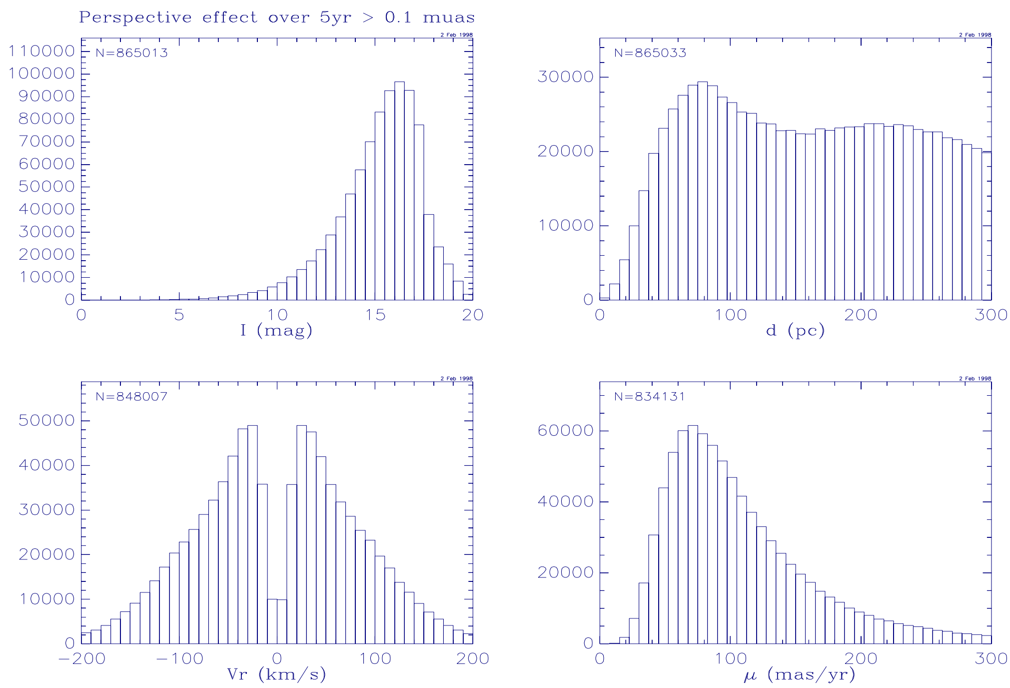

Figure 1: Distribution of stars with $\epsilon_p \geq 0.1\,\mu$as.

The bimodal distribution in distance is due to stars of different ages from population I in the solar neighbourhood, and to population II stars at larger distance. The simulation was done up to 300 pc, but simulations on small sky zones show that the number of stars is negligible at 500 pc. An extrapolation of the simulation to the whole sky thus indicates that about one million stars would then be concerned.

This systematic effect would then concern the solar neighbourhood (65% of stars closer than 50 pc have $\epsilon_p \geq 0.1\,\mu$as), and this is a problem e-g for planet search. The effect will also concern the thick disk and halo stars.

It is not that obvious to verify the figures given by the simulations. One test has been done, using stars from Hipparcos Catalogue up to $V = 7.3$ and $R = 18$ pc. The galaxy model gives 233 stars whereas 232 are estimated from the observations for this sample which is nearly complete (up to $M_V = 6$). Using the criteria applied for the Hipparcos stars (perspective effect on position greater than 0.1 mas over 2 years), 16 stars are found on the average with these simulations, not far from the 21 stars which were really concerned.

Alternatively, what would be acceptable as systematic effect may also be seen as a fraction of the astrometric error, which depends mainly on magnitude. Using as a rough approximation

$$\sigma_p = \max(1, e^{0.5m_I - 5})\ \mu\text{as}$$

other simulations have been done, concerning stars with $\epsilon_p \geq 0.1\sigma_p$ μas. It is shown on figure 2. In this case, radial velocities would be necessary up to $I = 15$ only.

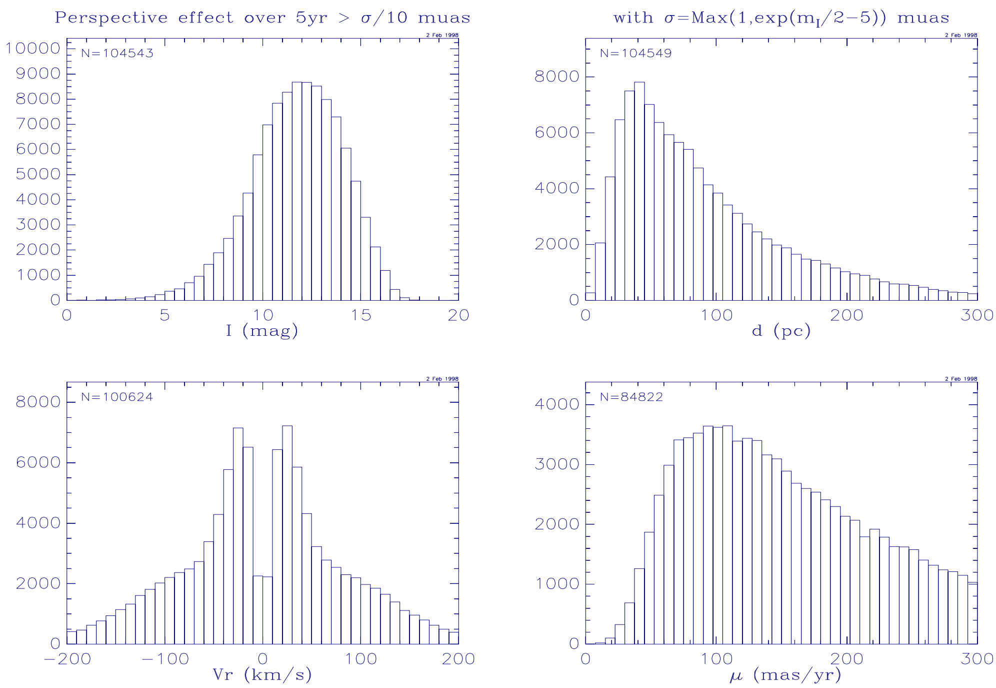

Figure 2: Distribution of stars with $\epsilon_p \geq 0.1\sigma_p$ μas.

Given that proper motion and parallax would be known accurately, the relative error on the perspective effect is

$$\frac{\sigma_{\epsilon_p}}{\epsilon_p} \approx \frac{\sigma_{V_R}}{V_R}$$

In our case $\sigma_{V_R} \approx 1$, and $V_R \gg 1$, then the relative error on ϵ_p would be better than 1.

1 Parameters of the model

These results depend of course on the following model parameters:

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See Bienayme et al. for details of Galaxy model
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                                SELECTION CRITERIA

Position        l: [  0 , 360] deg
                b: [-90 , +90] deg
Distance        r: [0 , 300] pc
Photometry      m_I [ , 20] mag (I cousins)

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                                HR DIAGRAM

Evolutionnary tracks:   Padova +
                        Chabrier et al. for <0.8 MSun +
                        Schaller et al. for horizontal branch 1-1.7 MSun

Thin disk       age: 10 Gyr
                percentage of binaries: 50%

IMF for primaries
        mass interval  [  0.0900,  1.0000]    [  1.0000,  2.0000]    [  2.00
slope of IMF (M^(-1+x))        0.7                    1.7              1.7
same IMF for secondaries (with mass constraint given by the primary)

Metallicity distribution
        thin disk: [Fe/H]=      N(0,0.15) dex   (gaussian mean=0, sigma=0.15)
        thick disk:             N(-0.8,0.2) dex
        halo:                   N(-1.5,0.3) dex

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                                DENSITY LAWS

Density law = Einasto
Distance sun-galactic centre:            8500 pc
Disk radius:                            14000 pc
Sun height above galactic plane:            7 pc

Population I:
age  interval (Gyr)      0-.15  0.15-1  1-2     2-3     3-5     5-7     7-
Excentricities          0.014   0.0253  0.0303  0.0497  0.0594  0.0632  0.0632
Local mass (Msun/pc3)   .002781 .005308 .005743 .003436 .005728 .005346 .716627
Scale length    K+      5000.0  2500.0  2500.0  2500.0  2500.0  2500.0  2500.0
Scale length    K-      3000.0  500.0   500.0   500.0   500.0   500.0   500.0

Population II:
Scale height h:         800 pc  with cut at hc=400 pc
Scale length:           2500 pc
Halo excentricity:      0.8     exponent: -3.1
Thick disk local mass   0.002652 Msun/pc3
Halo local mass density 0.0000528 Msun/pc3

Extinction: nothing
Missing mass: nothing

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                                KINEMATICS

                      Disk velocity dispersions (km/s)
        U :             11.5    18.5    21.0    23.5    25.2    26.0    26.0
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V :	10.5	11.5	13.1	14.8	16.5	16.5	16.5
W :	6.0	8.0	9.0	12.7	14.5	15.2	15.2

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Sun velocity ( U, V, W )    11.0     5.3     7.0 km/s

Rotational velocity
thin disk:      (220 km/s) from rotation curve
thick disk:     180 km/s
halo:           0
bulge:          150
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velocity dispersions

	thick disk	Halo	Bulge
U :	80.0	131.0	113.0
V :	60.0	106.0	115.0
W :	55.0	85.0	100.0

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halo ellipsoid with
Z cylindric symetry

Radial gradient: U disk: -0.20E-03 km/s/pc

Kent bulge      (hl, c/a, exponent, density)    2500   0.60  3.60   5.0
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2 References

Bienayme, Robin, Creze, 1987, *Astron. Astrophys* **180**, 94

Van de Kamp, 1967, *Principles of Astrometry*