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GAIA AND THE EXTRAGALACTIC

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Abstract. Gaia's main goal is to study the Milky Way and its stellar content and to provide us with their highly accurate astrometric and photometric parameters. However the satellite will also survey many other objects. Gaia will especially observe a few millions of tiny galaxies of the local Universe and will give us a unique chance to access to a whole sky survey of these objects that no ground-based survey such as Sloan Digital Sky Survey has ever recorded, thanks to its high resolution. We present here the "Extended Object" DPAC DU470 work to retrieve the morphology of such objects and a theoretical study concerning the expected detections by Gaia. We show that most of the detected galaxies by Gaia will be bulge-type and elliptical.

Keywords: Gaia, quasars, galaxies, gravitational lens

1 Introduction

In the Gaia Data Processing and Analysis Consortium (DPAC), the division unit Extended Objects (DU470) is a group which has dedicated its efforts to retrieve from Gaia observations the objects presenting a spatial extension (essentially galaxies) (Krone-Martins et al. 2013). Its aim is to extract the morphology of a category of tiny galaxies, very rarely observed from the ground, and to characterize their morphology by measuring their bulges and disks characteristics. The DU470 group is also interested in the QSOs which are the objects that will allow Gaia to perform its global solution and from which a sub sample will allow the link between the Gaia sphere (defined in optical) and the ICRF sphere (defined in radio).

2 The detection of galaxies

Gaia observes in Time Delay Integration mode which is to say that it is going to measure any object brighter than magnitude G=20. The stars from the Milky Way will therefore be observed together with a large sample of galaxies. For the detection, the Video Processing Unit (VPU) analyses the light profile of the candidate and if it is sufficiently similar to a star profile, the object will be detected. After the detection process by the VPU, a window is centered onto the detected object and the data from this window is transmitted to earth. So a galaxy with a flat profile (such as a disk galaxy) will probably not pass the VPU test and so will not be detected while a galaxy with a bright bulge will probably be detected. Moreover the size of the windows transmitted to earth will never exceed $4.72''$ which is another constraint on the detection of extragalactic objects.

A recent theoretical study developed within DU470 (de Souza et al. 2014) has shown that the satellite will rarely succeed in observing the pure disk galaxies. On the contrary the spheroidal component of elliptical galaxies and bulges having higher central surface brightness and steeper brightness profile should be more easily detected.

To validate this theoretical estimation of the detectability of the extragalactic objects we have performed numerical simulations of 10 000 galaxies (De Bruijne et al. 2014) with disks half intensity radius ranging from 0.2 to $2''$ by $0.1''$ steps and integrated magnitudes from G=14 to 20 by 0.2 mag steps. We used the *skymaker*

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and the GIBIS Gaia simulators for the simulation and the detection of objects in the conditions of the mission. In Fig. 1 we present the detection rate of these galaxies as function of their morphologic and photometric characteristics. It is obvious from this figure that most of spiral galaxies (pure disks situation) will not be detected by the satellite and therefore that the data corresponding to them will not be transferred to earth. On the contrary the pure bulges galaxies appear well detected by the satellite. The faintest of these will be detected only if their half light radius is small enough.

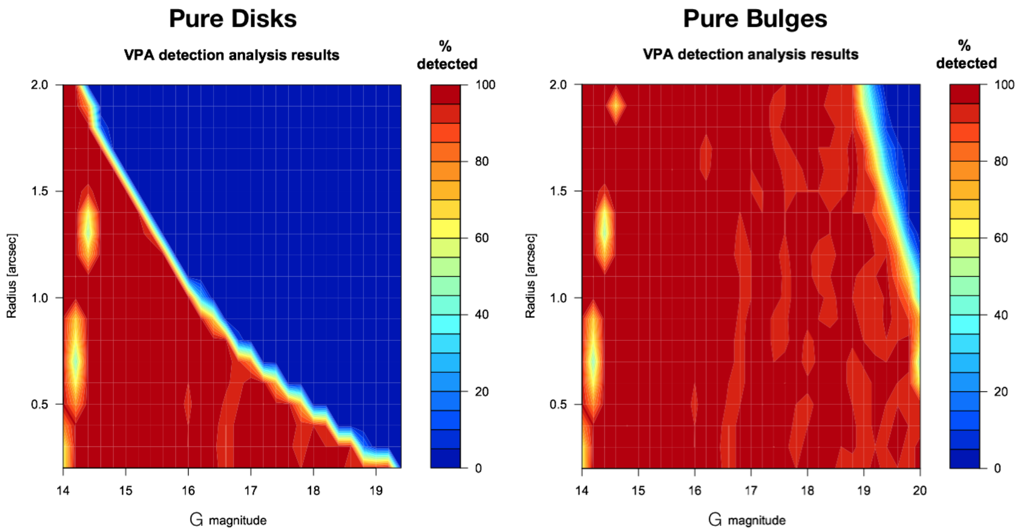

Fig. 1. Detection efficiency functions of pure disks and pure bulges galaxies.

3 The coverage fraction at the end of the mission

Once the observations (i.e. the pixels values) of a galaxy are sent to ground base segment, is it possible to retrieve its morphology? The Gaia observations are very specific; windows of variable sizes (depending on the magnitude of the object) are extracted onboard around the detections. Most extragalactic objects will fall in the magnitude range G=18-20. For these objects the Sky Mapper data will be two dimensional (SM window size = $4.72''$x$2.12''$) and the Astro Field Data will mostly be one dimensional (AF window size = $0.71''$x $2.12''$). These observational windows are formed by samples (binned pixels) of rectangular shape ($0.236''$x $0.79''$) for SM and ($0.059''$x $2.12''$) for AF. Various attempts of two dimensional image reconstruction have been performed (Dollet et al. 2004). The quality of the morphology that one will be able to recover for extended objects with Gaia will obviously strongly rely on the variety of transit angles under which the satellite will observe the object as illustrated in Fig. 2.

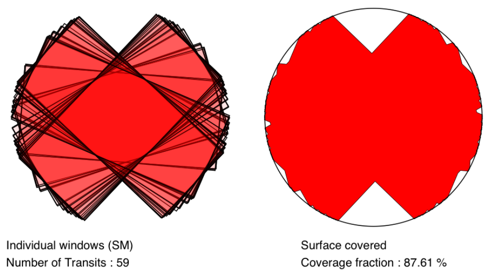

Fig. 2. Surface covered by various observations of a single extended objects.

We present the coverage fraction at the end of the mission as function of the galactic latitude in Fig. 3.

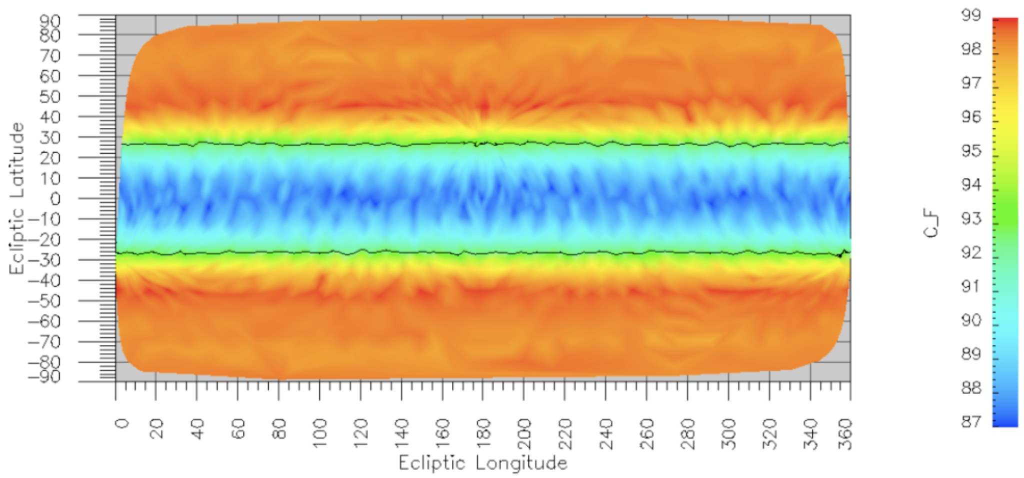

Fig. 3. Dependence of coverage fraction (CF) as function of ecliptic position at the end of the mission.

4 The recovery of the morphological parameters of the galaxies

To recover the morphological information of the extended objects we perform a global analysis (based on Genetic Algorithms and Radon transforms) of the individual Astro Field and Sky Mapper observations to fit the appropriate bulb and disk profiles. Our forward model aims at measuring the characteristic parameters such as size and boxyness of bulb and disk, axis ratio, position angle and relative surface brightness of each component by fitting simultaneously an exponential disk and a Sersic bulge. A total of 11 parameters are searched for. Using the nominal scanning law of Gaia, AF and SM synthetic observations of the objects are produced for the entire time of the mission. The signal of these images are then combined into the Radon space to produce the synthetic Radon image of the object. This image is then compared to the observed Radon image of the object, the L^2 norm is minimized and the process is iterated until convergence. To test the efficiency of our model, we have performed simulations of 10 000 galaxies with radius at half intensity variying from 0 to 4″. We present in Fig. 4 the efficiency of the recovery of the bulge and disk radius.

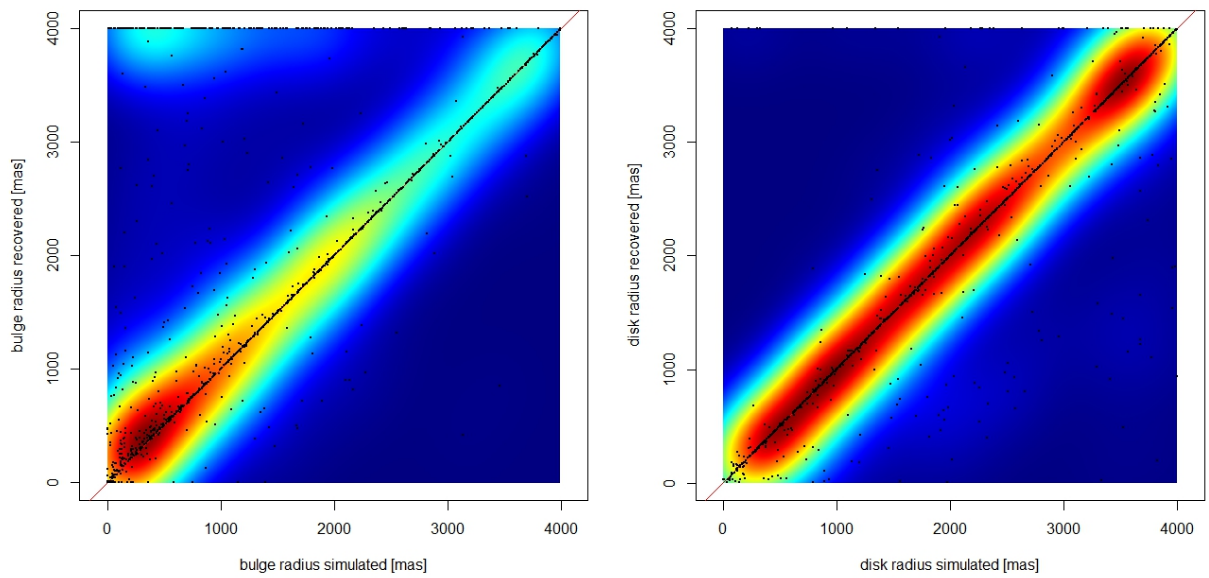

Fig. 4. Left: Recovery of Bulge radius (red=100%). **Right:** Recovery of Disk radius.

In this last figure one can observe an excellent recovery of the simulated Disk radius while the large simulated bulges are poorly recovered. This is easily explained by the fact that the high resolution information of Gaia is provided by the AF observations along scan (AL) in very small windows (0.71″x 2.12″).

5 The QSOs of Gaia

The QSOs are a special type of objects which have a great importance for the Gaia mission. Indeed, the global astrometry of Gaia will be based on a subsample of the 500 000 QSOs that Gaia should detect. Popović et al. (2012) has showed that a perturbation in the disk of the host galaxy can cause a significant offset to the photo-center in the Gaia observations. It is therefore important to be able to diagnose an eventual perturbation of the quasar astrometry due to his host galaxy (originated for example by a star burst in the disk). That is why we have adapted our forward model to this specific case in order to measure the offset between the disk center and the QSO center together with the morphologic parameters of the host galaxy. We show in Fig. 6 the recovery of this offset by our adapted model in 10 000 simulations (the offset varies from 0 to $\pm 1''$).

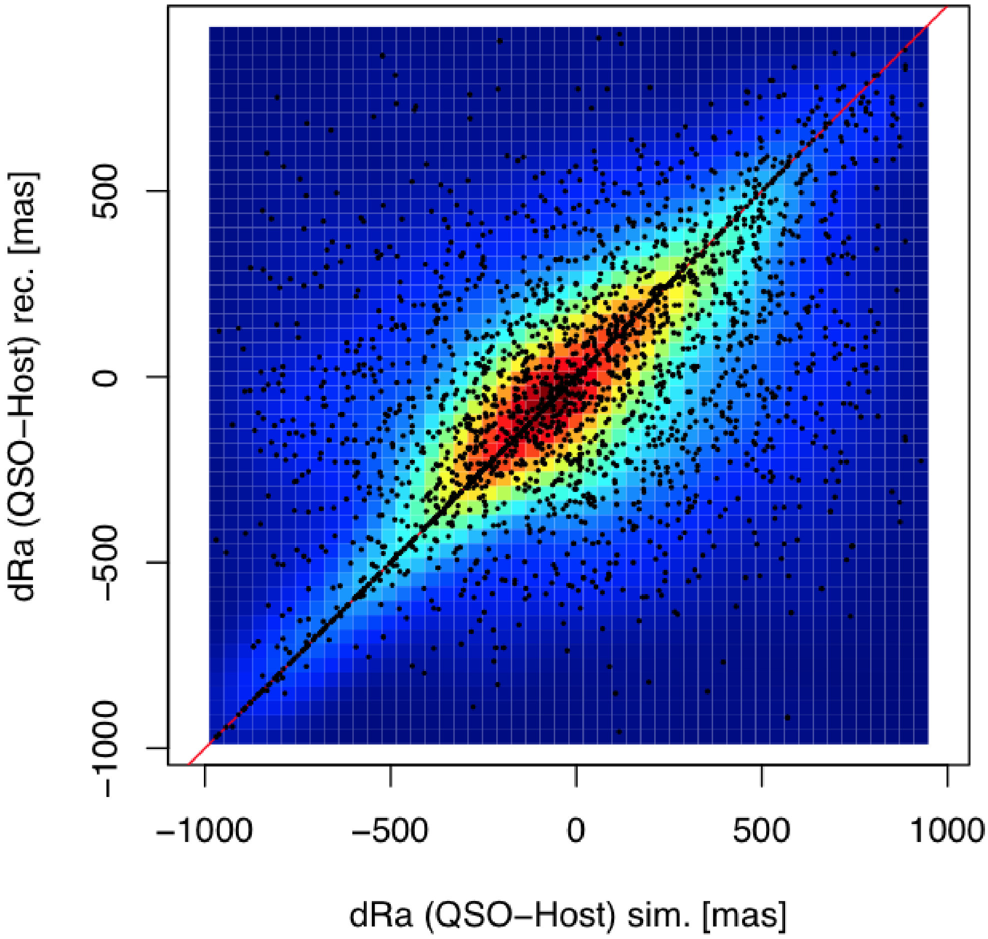

Fig. 5. Recovered offset in right ascension between QSO and host galaxy.

In this last figure we see that it is possible to diagnose problematic QSOs and even to measure the amplitude of the astrometric perturbation. When all classified QSOs will have been so analyzed, it will be possible to select a clean sample of QSOs without structure in optics to perform the global solution of Gaia. Then from these objects, we will select the QSOs called Defining source in the ICRF that will be used to perform the link between the radio and the Gaia system.

6 Conclusion

In this work we have shown that it is possible to enlarge the Gaia horizons by recovering the morphology of the extragalactic objects that the satellite is observing and so, provide important information about the local Universe. The systematic analysis of the QSOs host galaxies will allow a selection of a pure sample of point-like QSOs that could safely be used to perform the most accurate global solution and also to perform the link of the Gaia sphere with the ICRF reference system.

References

De Bruijne, J., Allen, M., Prodhomme, T., Krone-Martins, A., & Azaz., S. 2014, A&Asubmitted

de Souza, R. E., Krone-Martins, A., dos Anjos, S., Ducourant, C., & Teixeira, R. 2014, A&A, 568, A124

Dollet, C., Bijaoui, A., & Mignard, F. 2004, A&A, 426, 729

Krone-Martins, A., Ducourant, C., Teixeira, R., et al. 2013, A&A, 556, A102

Popović, L. Č., Jovanović, P., Stalevski, M., et al. 2012, A&A, 538, A107