The SDSS quasars as a testbench for the Gaia fundamental reference frame grid-points

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THE BEGINNING

Gaia is an ESA mission, planed to be launched in November 2013, it will perform astrometric measurements with an accuracy down to 20 µas, that require a well defined grid of points which constitute the fundamental Gaia reference frame. Due to their point-like appearance and cosmological distance QSOs are the best objects to define such reference frame. Along the five years – the predicted duration of the mission – Gaia will detect ~500000 QSOs, and the extreme accuracy in their positions will produce a reference frame that will change the future paradigm of the International Celestial Reference Frame–ICRF [1].

QSOs are active galactic nuclei so powerful that their luminosity may surpass that of the entire host galaxy by 2 or 3 magnitudes. So QSOs are not real point-like sources they just appear to be.

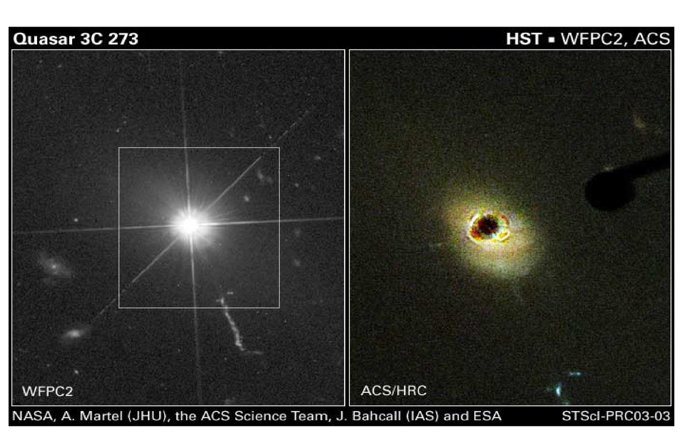

Figure 1. Example of a QSO where the host galaxy is just revealed when the light from the central part is blocked.

The presence of the host galaxy could be an issue in a mission of high astrometric precision as Gaia. Models revealed that the error in the determination of centroid position increased considerably, in the Gaia pixel scale this simulation would correspond to a 60 µas increment of the error.

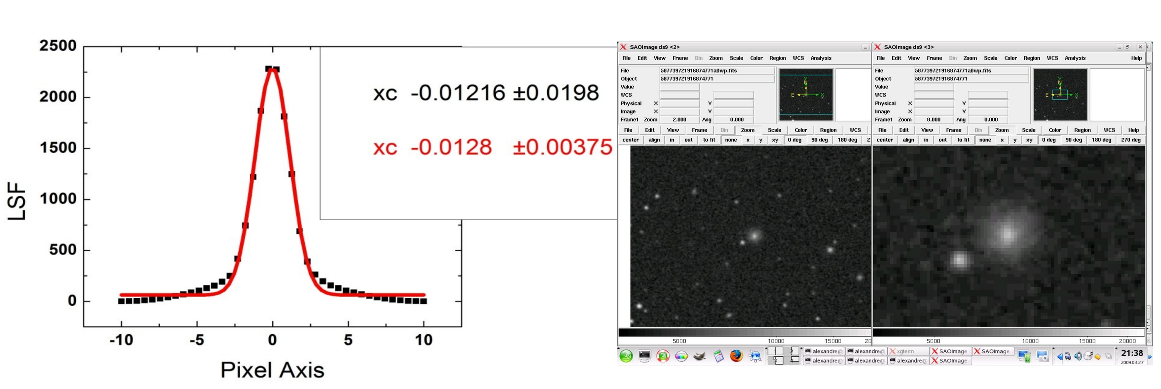

Figure 2. Simulation of the effect of a host galaxy component in the determination of the centroid position. One can see a variation in the measured position and an increment of the error.

To minimize this problem we developed a method to detect the QSOs that reveal the presence of their host galaxy [2], [3]. We make use of 3 morphological parameters which measure the skewness (SHARP), the circularity (SROUND) and normalness (GROUND) of the PSF. Comparing the QSO profile with the average PSF of nearby stars might reveal differences in the 3 PSF parameters. Those differences are interpreted as host galaxy tracers. We are testing this method using the 105783 QSOs sample of the SDSS DR7 [4]. All of them are spectroscopically confirmed, covering a sky area of ~9380 deg^2 and having redshift (z) between 0.065 to 5.46, with a median value of 1.49.

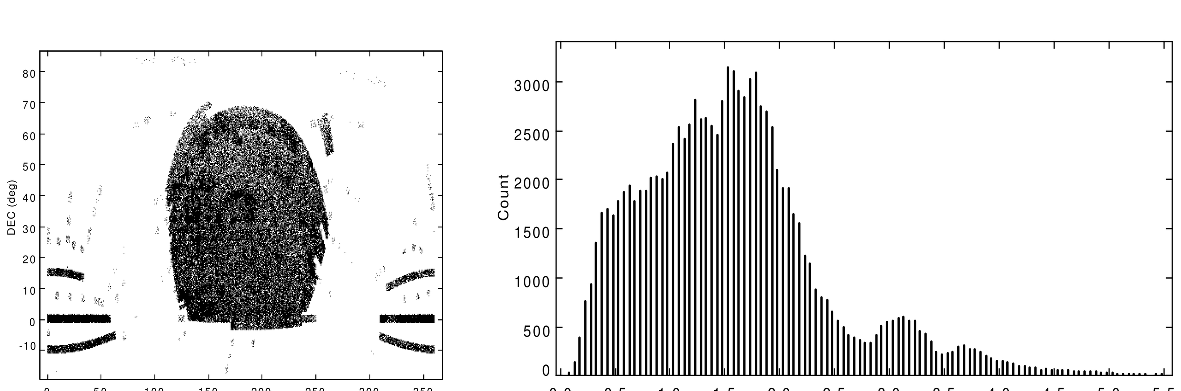

Figure 3. QSOs sample of the SDSS DR7. Left – Sky distribution. Right – Distribution with redshift.

We obtained frames in u, g, r, i and z bands for all SDSS DR7 QSOs, this means: 528 915 frames with 2048x1489 pixels (0.39 arcsec/pix) and ~4 MB per frame totaling 1.5-2TB of data. We run an IRAF pipeline on all frames to issue the 3 PSF parameters. When a given parameter is >2σ of the mean PSF, the QSO is considered extended.

FIRST RESULTS

PSF parameters were obtained for: 79.85%(u), 86.5%(g), 82%(r), 74.5%(i) and 59.3%(z) of the 105783 QSOs. Of the 105783 QSOs were classified as extended: 15.3% in the u band, 11% in the g, 13.3% in the r, 14.9% in the i and 18% in the z. The PSF parameters were obtained in all 5 bands for 54858 out of the 105783 (~51.9%).

For the 54858 QSOs

band	u	g	r	i	z
N extende QSOs	7272	4056	6312	8920	16570
%	13.2	7.4	11.51	16.26	30.20

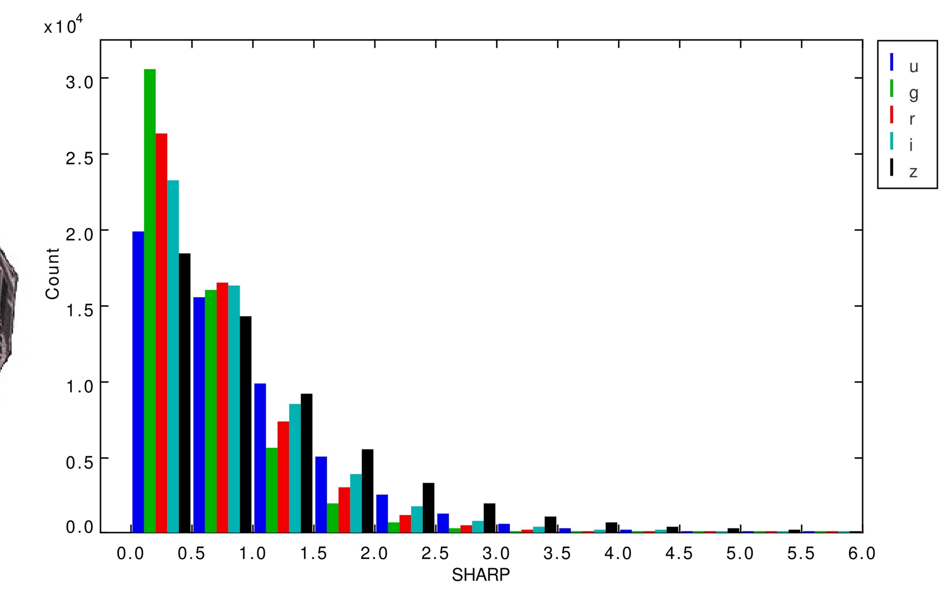

Figure 4. Distribution of the SHARP parameter for the 54858 QSOs sub-sample. The different colors represent the 5 SDSS bands. SHARP>2 is interpreted as QSO host galaxy signature.

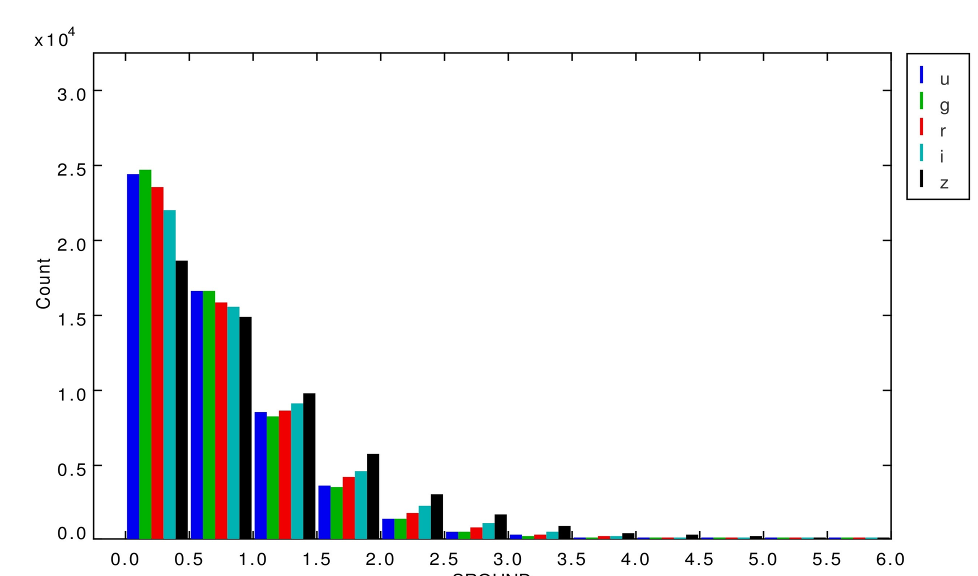

Figure 5. Distribution of the SROUND parameter for the 54858 QSOs sub-sample. The different colors represent the 5 SDSS bands. SROUND>2 is interpreted as QSO host galaxy signature.

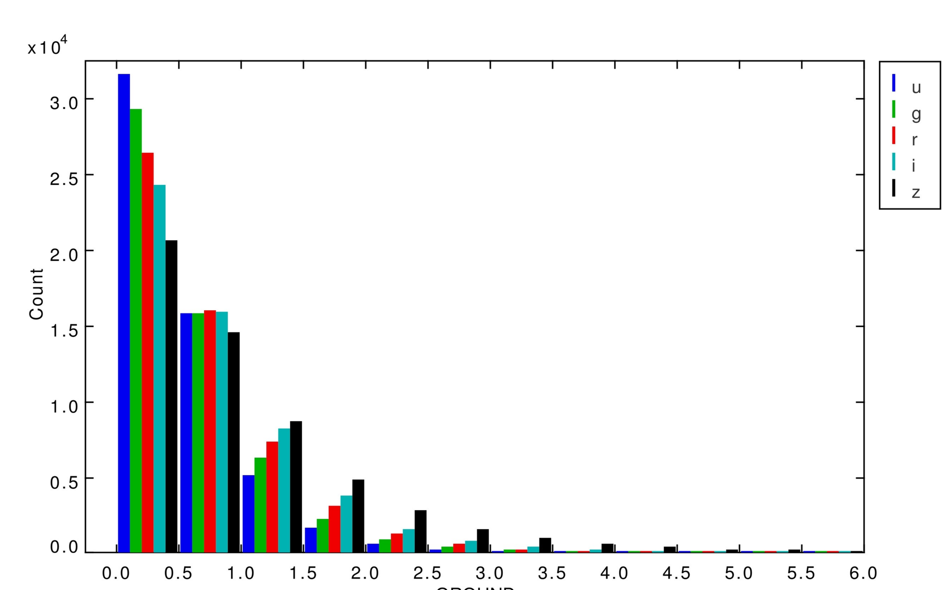

Figure 6. Distribution of the GROUND parameter for the 54858 QSOs sub-sample. The different colors represent the 5 SDSS bands GROUND>2 is interpreted as QSO host galaxy signature.

Figures 4, 5 and 6 show the distributions of the 3 PSF morphological parameters. The results reveal consistence because in all of them the majority of QSOs present point-like appearance, but a non negligible fraction are classified as extended sources. It is also noticed that the redder bands tend to be more sensitive to the presence of the host galaxy.

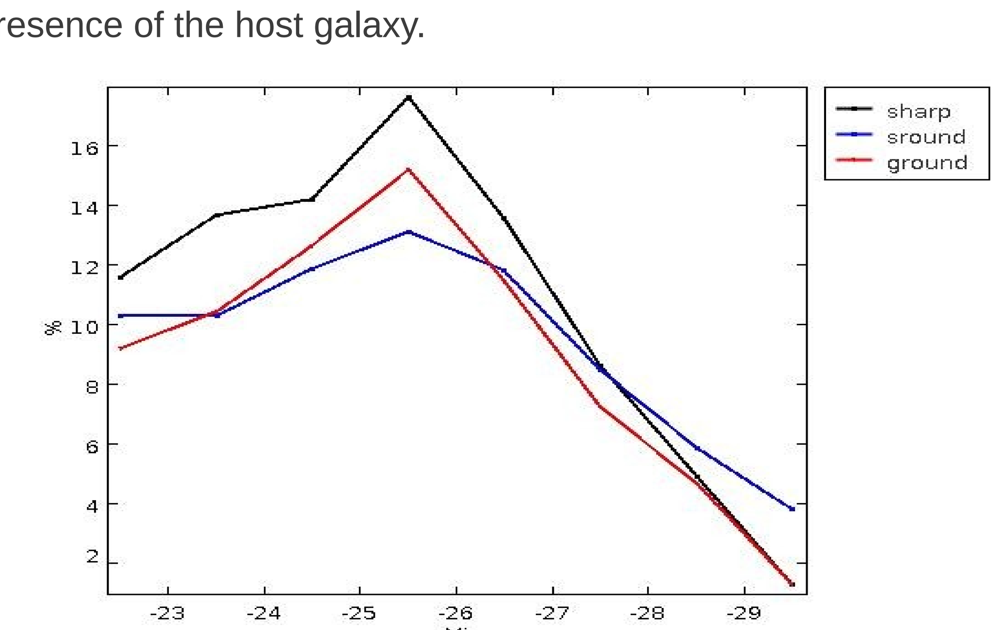

Figure 7. Fraction of extended objects per bin of absolute magnitude(i band) classified according to the 3 PSF morphological parameters.

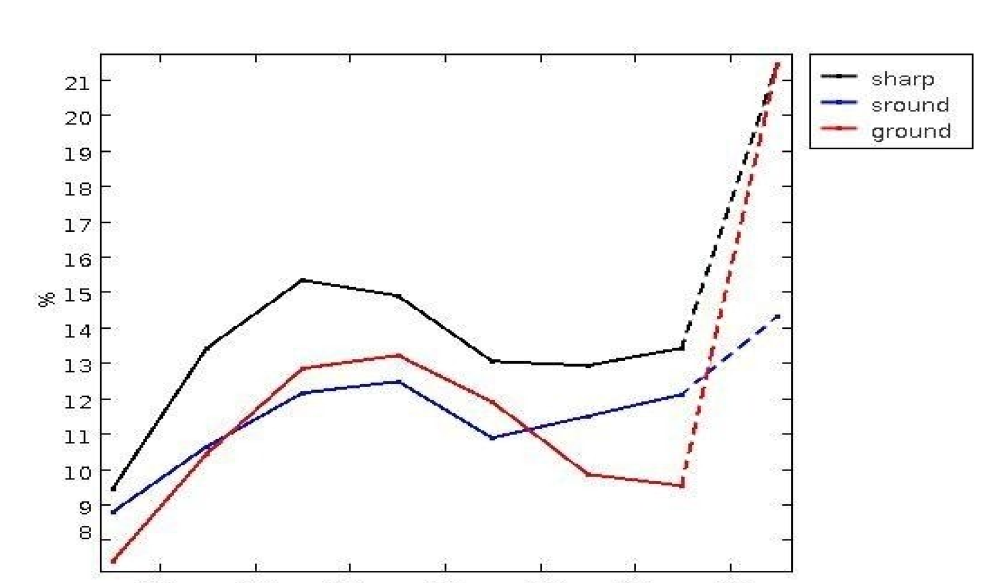

Figure 8. Fraction of extended objects per bin of redshift classified according to the 3 PSF parameters (using i band). The last bin (dashed line) must be ignored because it has no statistical meaning due to the low number of QSOs with z>3.5.

In figure 7 one can see that the larger fraction of extended sources appears for absolute i magnitudes Mi~-25 to Mi~-26. All parameters revealing similar behavior. In figure 8 is noticed that the largest fraction of extended sources are detected for redshift z~1 to z~2. Is interesting to see that the SHARP and SROUND parameters reveal an increase in the fraction of extended objects for redshifts of z>2.5, though the last bin has no statistical meaning and for that is not considered in the analysis.

COMPARISONS WITH OTHER CLASSIFICATION METHODS

We already started some comparisons with the classification available in SDSS DR7 QSOs catalog [4], which is based in the difference between the PSF magnitude (more suited to point-like sources) and the model magnitude (more suited to extended sources because makes use of light profiles typical of galaxies). Our first test revealed that our method fails the classification in the extreme extended and bright sources, but on the other hand appears to be more sensitive to the presence of the host galaxy in higher redshift rage.

OBTAINING ABSOLUTE MAGNITUDES

Due to the redshift effects is not trivial obtain absolute magnitudes. Is then necessary to apply k-corrections which depend on the redshift, on filter used to preform the observations, and on SED of the source.

The SED continuum of QSOs is usually approached by a power law were the flux is proportional to υ^(-α), being α the spectral index. It is common to use for QSOs α=0.5. But like Richards et al. [5] described, an important fraction of QSOs emission arrives us as emission lines, so an additional correction for that is necessary to compute absolute magnitudes. Usually QSOs catalogs give the Mi absolute magnitude because is expected minor contribution of emission lines in this waveband and so minor corrections.

In the present we are developing an algorithm to calculate absolute magnitudes in the 5 SDSS (u, g, r, i and z). We are going to use the Gaia spectral library [6], which contains synthetic spectra built with the modified template technique [6]. The absolute magnitudes will be obtained for α=0.5, and the calibration will be made using the Mi available in Schneider et al. [4].

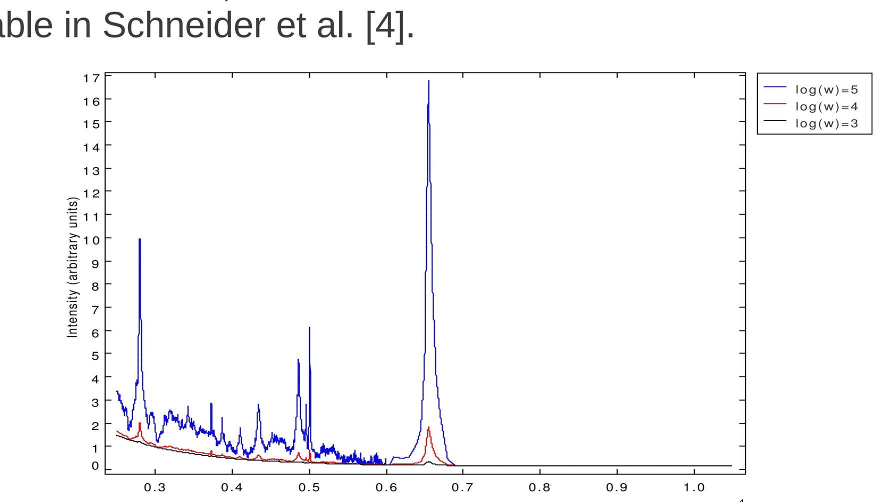

Figure 9. Example of synthetic spectra from the Gaia library [3]. Here 3 spectra for z=0, α=-0.5 and different w values are shown. One can see the variation of synthetic spectra for the different values of w.

STUDYING THE HOST GALAXY POPULATION

In general it is poorly known the relationships between the AGN and the host galaxy properties. From the observational point of view such relationships must be worked out because, due to the size of the spectrometers fibers and the smallness of the QSO emitting regions, there is always a large fraction of light from the host when the core is studied.

The QSO age and ageing are fundamental questions for the interpretation of cosmological chronology and the formation and evolution of galaxies. Their timeline can be traced by emission lines of heavy elements such as FeII that is mainly produced in Type Ia supernovae, which requires long-lived progenitors. Thus, FeII emission can be used to constrain the epoch of the first star formation in QSOs host galaxies [7]. That evolution can be disclosed also from the host galaxy stellar population, brightness and colors. On the other hand the study of nearby sources revealed relationships between host galaxies morphology and fundamental properties of the AGNs [8], such as luminosity and perhaps black hole mass and/or accretion rates. By consequence those relationships permit to use the hosts morphology to obtain some insights of the evolutionary state of the AGN and the galaxy itself.

In our investigation we seek how u, g, r, i, z magnitudes and morphological indexes differences can inform about those characteristics that may reveal the story of host/AGN co-evolution.

FINAL COMMENTS

The presence of a host galaxy component in the QSO light interfere with the determination of PSF centroid, and this is an issue that affects astrometric missions like Gaia. Here we revealed that the study of the PSF morphology allows to trace the presence of the host galaxy, which can be used to minimize the precision issue in the Gaia context.

The study of these parameters will be explored by us in more detail, in order to seek some QSOs hosts properties. In the process we are developing new methods to determine absolute magnitudes, and we want also to compare different morphological classification methods.

References

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[7] Dong et al., 2011, ApJ, 736, 86
[8] Cales et al., 2013, ApJ, 726, 20

Acknowledgment:
CAPES
MARIE CURIE ACTIONS