The 3D structure of the Galactic Spheroid

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Abstract

The scientific activity of our quintuplet was focused on the identification of variable stars in crowded stellar fields. To accomplish this goal, we proposed and organized an LSST Task Force (chair: M. Dall'Ora). We performed accurate and deep photometry on time series multiband images collected with DECam at the Blanco 4m telescope of the Bulge (Baade Window). We found that PSF photometry is mandatory to reach the required photometric accuracy for investigating radial variables in crowded and reddened regions of the Galactic Spheroid.

We also submitted a white paper including more than 50 co-Is interested in a double LSST survey of the innermost Galactic regions. The "Shallow Survey" relies on multiband (*ugrizy*) photometry of bright variables (RR Lyrae, Type II Cepheids, Classical Cepheids, Miras) across the entire Bulge. The use of a novel algorithm will allow us to estimate the individual distance, reddening and metal content. The "Deep Survey" is aimed at tracing old (t > 10 Gyr) stellar populations (RR Lyrae, Type II Cepheids) in the innermost Galactic regions in the reddest LSST bands (*izy*). This suvey is aimed at constraining the density profile of old stellar population from the outer bulge to the Galactic center in order to constrain the pristine Milky Way (MW) dark matter profile.

1 Quintuplet Information 2018

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2 Quintuplet Information 2019

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1. **Scientific Collaborations:** Transient and Variable stars (TVS) — Stars, Milky Way, and Local Volume (SMWLV)

3 Scientific Activity

The main aim of this experiment is to take advantage of the deep and accurate multiband optical photometry that is going to be collected by LSST to constrain the 3D shape of the Galactic Spheroid. To fully exploit the capabilities of LSST we plan to use radial variables as stellar tracers of the old (RR Lyrae, Type II Cepheids), intermediate-age (Miras) and young (classical Cepheids) stellar populations. These objects will be used as beacons to drill the Galactic structure and, in particular, to investigate the early formation (Halo, Bulge, globular clusters, dwarf galaxies) and evolution (thin/thick disk) of the Milky Way.

We are also interested in using primary distance indicators (low- and intermediate-mass stars) in the Gaia era to constrain systematic errors in the calibration of secondary distance indicators (Faber-Jackson, Tully-Fisher, SN Type Ia, SN II Plateau) in early/late type galaxies. This means the opportunity to constrain the present day Hubble constant with an accuracy better than 2%. Moreover, we plan to use radial variables to estimate the chemical enrichment history of old, intermediate and young stellar populations using photometric indices and to compare them with chemical evolution models.

During the last year the scientific activity of our group was focussed on stellar populations of the Galactic Bulge. The reasons are manifold. i) Multiband (*ugriz*) time series data collected with DECam at the 4m Blanco telescope of several low-reddening Bulge regions became publically available. This means the unique opportunity to test the impact photometric accuracy is going to have on the identifications and the caracterization of radial variables (Vivas et al. 2017; Saha & Vivas 2017). ii) The long term photometric survey OGLE released a new catalog of 39043 RR Lyrae in the Galactic Bulge (Soszyński et al. 2014). This means an almost complete census of Bulge evolved variables. iii) New integral field spectrographs (MUSE at VLT) and multi-object fiber spectrographs (GIRAFFE/FLAMES at VLT) are providing a wealth of radial velocity and abundance measurements (Valenti et al. 2018; Zoccali et al. 2018).

These are the reasons why we are running a specific Task Force focussed on variability in crowded stellar Fields. The main aim of the Crowded Field Task Force (CFTF) is to develop and test the most popular automatic photometric pipelines to perform accurate and deep photometry in crowded stellar fields. Accurate and precise photometry over a broad time interval is mandatory to identify and characterize (period, pulsation mode, luminosity amplitudes, mean magnitudes) variables. To accomplish this goal we selected a photometric data set available in the NOAO science archive (PI: A. Saha, Prod.ID:2013A-0719). This data set includes roughly 50 images in five SDSS bands (*ugriz*) covering 6 square degrees of the Baade Window (five pointings, see orange circles in the left panel of Fig. 1).

The CFTF started his activity at the beginning of the year and the project is still running. The photometric analysis was performed on a single CCD, since the main aim of this experiment was to test the algorithms adopted for PSF photometry and for the characterization of the varibles. The key advantage of the selected data set is that the variables in this area are already well known (OGLE IV). The outcome of our project are very promising. **i)** PSF photometry (DAOPHOT/ALLSTAR/ALLFRAME) based on 50 g

and r band images allowsed us to reach a completeness of the order 50% down to r ∼22 mag. The right panel of Fig. 1 shows the $r, g-r$ CMD based on our photometry and the completeness is color-coded on the right axis. **ii)** We performed tests to investigate the robustness of the algorithms currently adopted in the literature to determine the pulsation period and the pulsation parameters. Data plotted in the left panel of Fig. 2 show the light curve of a fundamental variables phased by using the period estimated by using the FFT (top, Ransom et al. 2002, and references therein) and the PDM (bottom, Stellingwerf et al. 2011). The middle panel shows the light curve of the same varibles phased using the period estimated by using the Lomb & Scargle method (Braga et al. 2016) while the right panel the light curve phased with a period estimated using a new algorithm we are developing. Our approach seems to significantly more accurate than those available in the literature, since it works very well with sawtooth light curves.

In the near future we plan to extend the same analysis to fainter variables, for which the OGLE-IV catalog is far from being complete.

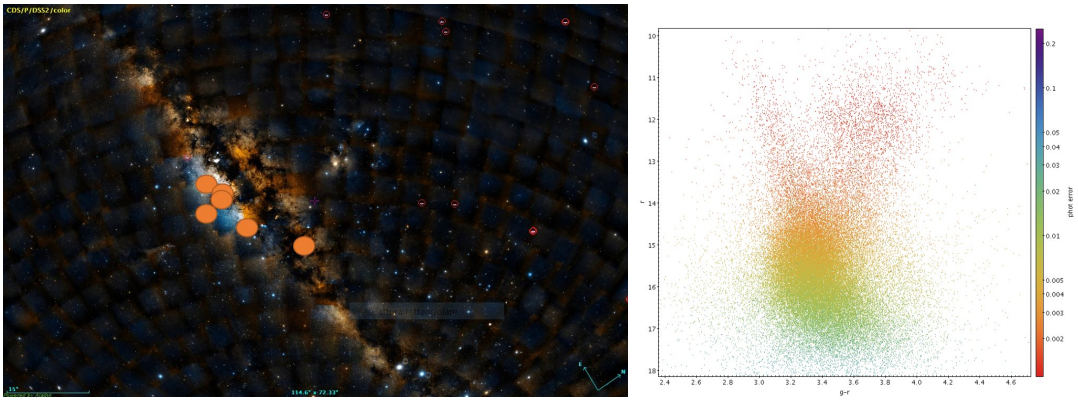

Figure 1: *Left:* Distribution of the DECam pointings used by the Crowded Field Task Force. *Right:* instrumental r-$g-r$ color magnitude diagram for one CCD, with the instrumental error color coded. The CMD is based on a DAOPHOT/ALLFRAME PSF reduction.

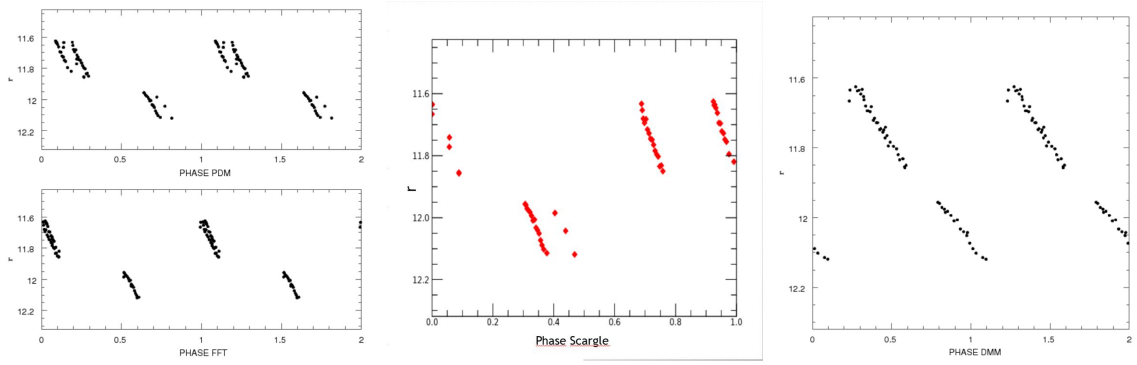

Figure 2: *Left:* light curve of the OGLE-BLG-15327 RR Lyrae, phased automatically with the FFT and the PDM algorithms. *Center:* same object, but automatically phased with the Scargle algorithm. *Right:* Same as the other panels, but automatically phased with our custom algorithm.

4 Scientific and technical deliverables

please list the papers/proposals/documents and/or the technical deliverables in which you have been involved during the last year, if any.

The TVS analyzed one CCD of the DECam dataset in the g, r bands, in order to test the efficiency of a fully automated PSF reduction in a crowded field. A deep (211K sources) photometric catalogue was produced, and automatic search of the periods of the candidate variable stars (on the basis of the Stetson's index) was carried out with four different algorithms, of which one was new and designed for the experiment. The catalogs have been shared and discussed during the CFTF telecons, and are available to the entire LSST community.

1. **List of attached documents:** White paper (Vestale)

5 Other information

The members of the quintuplet participated in several Skype sessions for both the TVS and SMWLV Science collaboration. Moreover and even more importantly, they also created and managed an LSST Task Force focused on the detection and characterization of variable stars in crowded stellar fields. Finally, let us mention that G. Bono participated in the face-to-face meeting of the LSST board organized in Tucson last October and remotely in the LSST board meeting held in December. M. Dall'Ora participated in the LSST Europe meeting organized in Lyon in June focused on science with LSST and, in October, once again in Lyon concerning the possible participation to an H2020 project. G. Bono, M. Dall'Ora and G. Fiorentino participated in the LSST Italia meeting organized in Naples on April focused on the science collaborations for the Italian communities. G. Bono and M. Dall'Ora also participated in LSST Italia meeting organized in Palermo in October focused on the Italian plans for the LSST white papers.

6 References

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