LSST-Italy report 2018

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December 2018

Abstract

We produced the first version of a huge simulation of the stellar content in LSST, using NCSA computers. They were summarized, transferred to both University of Washington and NOAO, and partially implemented as a database in a NOAO Data Lab. They also produced material useful for two LSST Cadence Optimization white papers, especially regarding estimates of star counts, crowding limits, and expected variables in The Galactic Plane, Bulge, and central areas of the Magellanic Clouds. In parallel, we have improved the underlying TRILEGAL software (with better geometry, variable resolution, expanded libraries of tracks, inclusion of interacting binaries, eclipsing light curves, periods and amplitudes of long period variables, etc.) in preparation for a second version of the simulation.

1 Quintuplet Information 2018

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Junior member 1: Yang Chen, postdoc at UNIPD, INAF associate
Junior member 2: Piero Dal Tio, PhD student at OAPD+UNIPD, INAF associate
Junior member 3: Giada Pastorelli, postdoc at UNIPD, INAF associate
Junior member 4: Michele Trabucchi, postdoc at UNIPD, INAF associate

2 Quintuplet Information 2019

The same as in 2018.

3 Scientific Collaborations and Task Forces

1. the LSST Stars, Milky Way & Local Volume Science Collaboration

2. our "LSST stellar simulation" task force, comprising our team + Zeljko Ivezic and Mario Juric (UW), Knot Olsen (NOAO), with collaborators in LSST-Chile (Dante Minniti, Mauro Barbieri), LSST-Brazil (Adriano Pieres, Basilio Santiago), LSST-Hungary (Robert Szabo), LSST-Germany (Maria-Rosa Cioni), LSST-Italy (Gisella Clementini, Marcella Marconi, Ilaria Musella). Other key collaborators in Italy: Paola Marigo, Alessandro Bressan, Simone Zaggia, Yazan Momany, Alessandro Mazzi.

4 Scientific Activity

Simulations of the LSST stellar content The long-term goal of our project is to develop the stellar populations synthesis tools needed for the interpretation of LSST data. The initial goal is to provide improved simulations of the LSST stellar content, which would replace those previously computed with the GALFAST code by Mario Juric (see the LSST Science Book). The general content and format of the new simulations were discussed in a meeting at University of Washington (UW) in 2017, and then refined in a series of email exchanges and skype calls (mainly with Zeljko Ivezic and Mario Juric in Seattle, and Knut Olsen's team at NOAO in Tucson) in the following year. A dedicated account for the simulations was set at the NCSA, in a virtual machine set by Mario Juric.

The first full simulations were run for a healpix resolution of $nside = 128$. They took about 3 weeks using 12 CPUs, plus twice as many weeks for checking and fixing all files. Figure 4 gives an overview of the covered sky area, in a stellar density plot. The complete MW simulation down to $r < 27.5$ mag, contains over 19 Gstars and take up 3.7 Tby of disk space. The latter refers to FITS files containing all quantities of interest: sky coordinates, stellar parameters (mass, luminosity, effective temperature, surface abundances), population parameters (initial metallicity and mass, age, distance, extinction, kinematics), and the LSST+Gaia photometry. With these information, it is also possible to derive the expected photometry in any other photometric system (e.g. for 2MASS, VISTA, WISE, etc.).

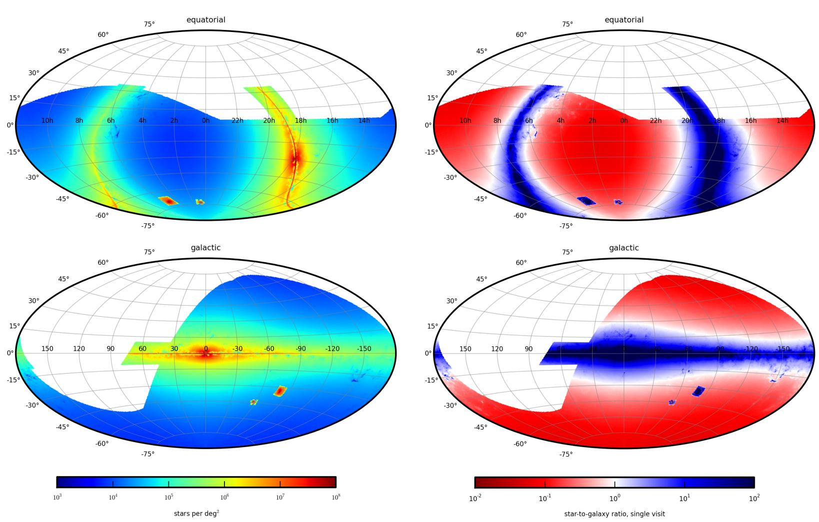

Figure 1: The sky area covered in present MW+MCs simulation, in an Aitoff projection. Each dot is a simulated HEALPixel with a 0.21 deg^2 area. Left: With the colorbar coding the logarithm of the simulated star counts down to $r = 27.5$ mag (the maximum depth, for the 10-yr coadd and ignoring the confusion limit). Right: The expected star-to-galaxy ratio, as an example of possible use of the simulations.

This initial simulation was ready by June 2018, and was being transferred to both UW and NOAO when a major system crash occurred. It interrupted the transfer for weeks and unfortunately corrupted a high fraction ($\sim 1/4$) of the output files. Given the instability of the system and the approach of the mini-surveys deadline, we decided not to recompute the missing area, but rather to produce some more basic numbers and maps that could be immediately useful for other people (see section 5, first item). The part of the simulation that was already transferred to NOAO, was recently made available as a NOAO Data Lab database (see section 5, second item).

Preparation for the next release. We are working on the preparation of the second version of this simulation. It is not yet clear where it will be computed (since the NCSA disks proved not to be reliable). Anyway now we know exactly the disk space required, and decided to limit future simulations down to a pre-computed crowding limit to keep the output files more manageable. Our population synthesis software, TRILEGAL [2, 3], is being constantly improved, with ongoing work to include interacting binaries, light curves of eclipsing binaries, long period variability, and fast rotating stars. We are also extending the libraries of evolutionary tracks and stellar model atmospheres (with e.g. updated post-AGB evolution and alpha-enhanced models), and performing extensive tests with present large photometric surveys (VVV, VMC, DES, Gaia DR2, etc.).

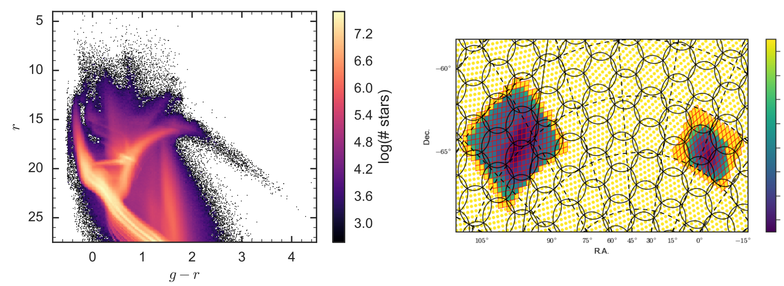

Figure 2: Left panel: a CMD with the expected stellar content for the SMC and LMC. Right panel: Estimated crowding limit, i.e. the r band magnitude that ensures 0.1 mag r.m.s. photometric errors for a seeing of 0.6 arcsec [cf. 4], in the central parts of the Magellanic Clouds, compared to the LSST field positions.

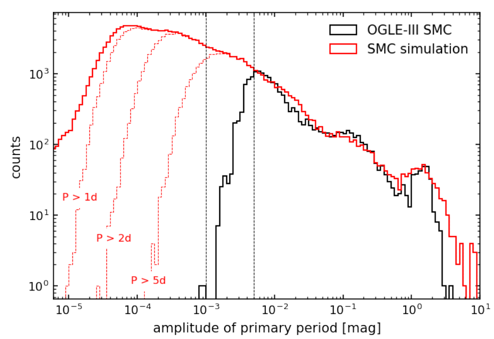

Figure 3: Distribution of I-band amplitudes of the primary period in the OGLE-III catalog of LPVs in the SMC (black line), compared to the expected distribution derived from our models (red line). Dashed red lines show the predicted distribution including only variables with periods larger than 1, 2, and 5 days. Vertical dashed lines mark the amplitude range where LSST is expected to detected a substantial number of new variables.

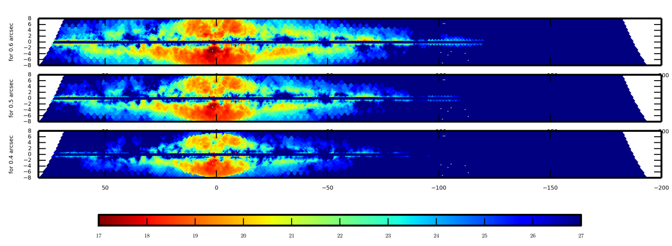

Figure 4: Estimated crowding limit in the LSST r band, for the Galactic Plane and Bulge areas, i.e. the magnitude that ensures 0.1 mag r.m.s. photometric errors for seeing values of 0.4, 0.5 and 0.6 arcsec, according to the formalism by [4]. The main uncertainty in these maps comes from the distribution of dust along the lines of sight.

5 Scientific and technical deliverables

Contributions to mini-survey white papers:
Numbers from our initial simulation were mentioned in the "Call for White Papers on the LSST Cadence Optimization" (Ivezic, Jones, & Ribeiro, Document-28382, section A3). We then contributed to 2 mini-survey white papers, within the Nov. 30th deadline:

- *Mapping the Periphery and Variability of the Magellanic Clouds (PIs Knut Olsen and Paula Szkody)* Two main aspects were contributed: (1) *On the crowding limit:* The deep stacked images will be severely crowded in the central LMC and SMC regions. Fig. 4 illustrates the crowding limit in r, at which photometric errors become larger than 0.1 mag for a constant seeing of 0.6 arcsec (other values were provided and used in the white paper). Such magnitudes are deep enough to reach the main-sequence turn-off of 2-Gyr old populations even in the densest parts of the LMC bar. CMD-reconstruction algorithms applied to the LSST data, as well as to the extended optical-near-infrared catalog obtained after cross-matching with VMC data [1], will allow improved maps of the star formation history, internal extinction, and distance distribution for the bulk of the MCs population. *On new expected variables:* The relatively shallow OGLE surveys (limited to $I \lesssim 21.5$ ABmag) have been a treasury trove for variability works. With its superior cadence and signal-to-noise, LSST can give us access to a multitude of new low-amplitude variables in the Magellanic Clouds. Fig. 4 shows the distribution of amplitudes in the OGLE database for the SMC, as compared to those derived from a population synthesis model (including the LPV models of [6]) of the same galaxy. They suggest that LSST will be able to uncover $\sim$6 times more variables than OGLE in the interval of amplitude 0.001–0.005 mag, where OGLE becomes incomplete. This regime of variability is particularly interesting as it corresponds to the overlap between LPVs and the solar-like oscillators extensively observed by Kepler in the MW.

- *The Plane's The Thing: The Case for Wide-Fast-Deep Coverage of the Galactic Plane and Bulge (PI: Jay Strader)* See `https://arxiv.org/abs/1811.12433`, [5]. From our simulations we prepared crowding limit maps for a few values of seeing and photometric errors (Fig. 4).

The NOAO Data Lab simulation:
Our first simulation was ingested as a database in the NOAO Data Lab, making use of a dedicated server (with adequate disk space) acquired by Knut Olsen's team especially for this goal. As of today, it is available for public access (`https://datalab.noao.edu/query.php?name=lsst_sim.simdr1`), but it is still missing part of the documentation, and lacks $\sim 1/4$ of the LSST possible observing area (especially some key areas of the Galactic Plane, because of the disk crash during the data transfer to NOAO). Despite these problems, the basic infractructure is already set, and the ingestion of a second version will certainly be much easier. We plan to offer a basic library of jupyter notebooks (built from the many available at the Data Lab) for the exploitation of this database.

6 Other information

Participation in LSST-related meetings: Here we list the conferences where we had LSST-related discussions. Just $\sim 1/3$ of our participation in these meetings were funded by LSST-Italy.

- “LSST TVS Workshop 2018”, INAF-OACN, Naples, Italy, April 9-11, 2018 – Talk by Trabucchi
- “2018 Spring Symposium: The 21st Century H-R Diagram: The power of Precision Photometry”, STScI, Baltimore, USA, April 23-26, 2018 – Girardi’s invited talk
- “VMC meeting”, Brussels, Belgium, May 30–June 1, 2018 – Girardi attended, included discussions about LSST Magellanic Clouds’ mini-survey.
- “LSST@Europe3”, Lyon, France, June 10–14, 2018 – talks by Trabucchi and Pastorelli, poster by Dal Tio; Girardi also attended.
- PHAT/M31+M33 meeting at Ringberg Schloss, Tegernsee, Germany, July 16–20, 2018 – Girardi, Pastorelli and Chen attended, included discussions of the LSST synergy with the WFIRST Nearby Galaxy Survey project (PI Ben Williams).
- “XXX IAU GA - Symposium 343: Why Galaxies Care About AGB Stars”, Vienna, Austria, August 20-23, 2018 – talks by Pastorelli and Trabucchi
- “A Revolution in Stellar Physics with Gaia and Large Surveys”, Warsaw, Poland, Sept. 3–7, 2018 – Girardi’s invited talk, and Dal Tio’s poster
- “Weighing Stars from Birth to Death: How to Determine Stellar Masses?”, Lorentz Center, Leiden, 19-23 Nov 2018 – Girardi attended, with discussions about asteroseismology with LSST data
- “Science with multi-object spectrographs: perspectives and opportunities for the Italian community”, Milano, 12-13 Dec – Girardi will attend

Plans and problems for 2019: We will start 2019 with the same team. The initial work is obvious: our priority goes to redoing (and improving) the LSST simulation and implementing it in a user-friendly way in the NOAO Data Lab. Some of the improvements will involve other LSST-Italy teams, more specifically: we will start the implementation of Cepheids and RR Lyrae in the models, in coordination with Gisella Clementini’ team at Bologne and Marcella Marconi + Ilaria Musella team in Naples.

Regarding the problems we met, it is clear that we need to solve the problem of ”computer unreliability” before performing the new simulations, while avoiding huge transfer times of the output data to Tucson+Seattle. One safe solution is to do simulations locally at OAPD, and then ship the disks to the US (with a total cost of a few hundreds of euro for the disks + shipping). But we are presently exploring other possible alternatives in the US.

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