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LSST & SERBIAN SCIENCE

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Abstract. We briefly review characteristics and current status of the Large Synoptic Survey Telescope (LSST). A group of Serbian astronomers formally joined the LSST project in November 2013. Our contribution to the project is building a simulator of a stream of alerts AlertSim. It will be used in commissioning and early operation phase of the survey. We expect many exciting developments in the next twenty years, influencing not only astronomy but physics, informatics and Big Data science in general

1. INTRODUCTION

LSST will be a large, wide-field ground-based optical telescope system designed to obtain multiple images covering the sky that is visible from Cerro Pachón in Northern Chile. The current baseline design, with an 8.4m (6.7m effective) primary mirror, a 9.6 deg^2 field of view, and a 3.2 Gigapixel camera, will allow about 10,000 square degrees of sky to be covered every night using pairs of 15-second exposures, with typical 5σ depth for point sources of r $\sim$24.5 (AB). The system is designed to yield high image quality as well as superb astrometric and photometric accuracy. The total survey area will include $\sim$ 30,000 deg^2 with $\delta < +34.5^o$, and will be imaged multiple times in six bands, ugrizy, covering the wavelength range 320$-$1050 nm.

The artistic impression of the telescope and its future housing on Cerro Pachón is shown in Fig1.

About 90% of the observing time will be devoted to a deep-wide-fast survey mode which will uniformly observe a 18,000 deg^2 region about 1000 times (summed over all six bands) during the anticipated 10 years of operations, and yield a coadded map to r$\sim$ 27.5. These data will result in catalogs including over 38 billion stars and galaxies, that will serve the majority of the primary science programs. The remaining 10% of the observing time will be allocated to special projects such as a Very Deep and Fast time domain survey.

[2]LSST Serbian Technical group consists of the scientist funded through the project III44002:Astroinformatics application of IT in Astronomy and close fields

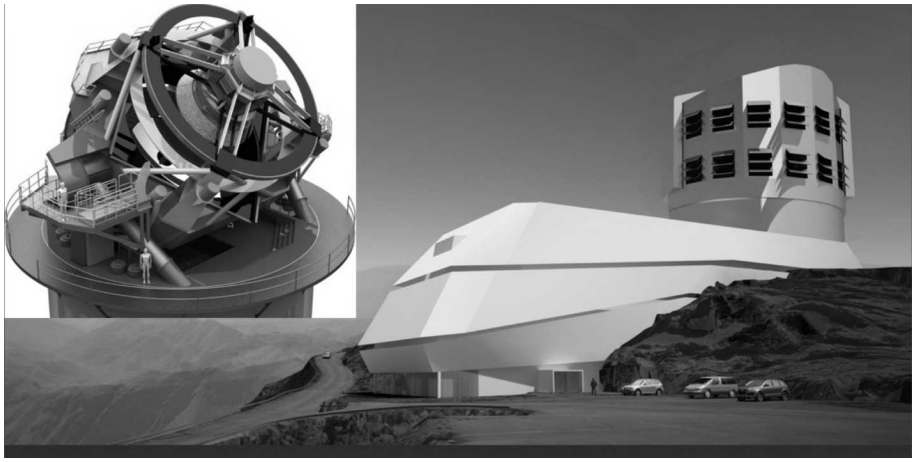

Figure 1: LSST telescope and future building on Cerro Pachón (artistic render).

The LSST is designed to achieve goals set by four main science themes:

1. Probing Dark Energy and Dark Matter;
2. Taking an Inventory of the Solar System;
3. Exploring the Transient Optical Sky;
4. Mapping the Milky Way.

The main science drivers are used to optimize various systems (Ivezić et al. 2014).

The LSST will be operated in fully automated survey mode. The images acquired by the LSST Camera will be processed by LSST Data Management software to a) detect and characterize imaged astrophysical sources and b) detect and characterize temporal changes in the LSST-observed universe. The results of that processing will be reduced images, catalogs of detected objects and the measurements of their properties, and prompt alerts to "events" { changes in astrophysical scenery discovered by differencing incoming images against older, deeper, images of the sky in the same direction (templates)}. Measurements will be internally and absolutely calibrated.

The project is scheduled to begin the regular survey operations at the start of next decade. In the beginning of August of 2014 the US National Science Foundation started a new phase of the project namely Major Research Facilities and Equipment Construction (in short Construction). The current expected time-line of the project is shown in Fig.2

2. SERBIAN ASTRONOMY AND LSST

There are two main institutions, carrying research in astronomy in Serbia; namely the Astronomical Observatory in Belgrade and the Department of Astronomy, Faculty of Mathematics, University of Belgrade. Astronomy in Serbia is almost exclusively funded by the Serbian government through the projects/grants. At the moment there are eight projects, which have a significant astronomical content. Out of eight, six projects supported the Serbian involvement in the LSST:

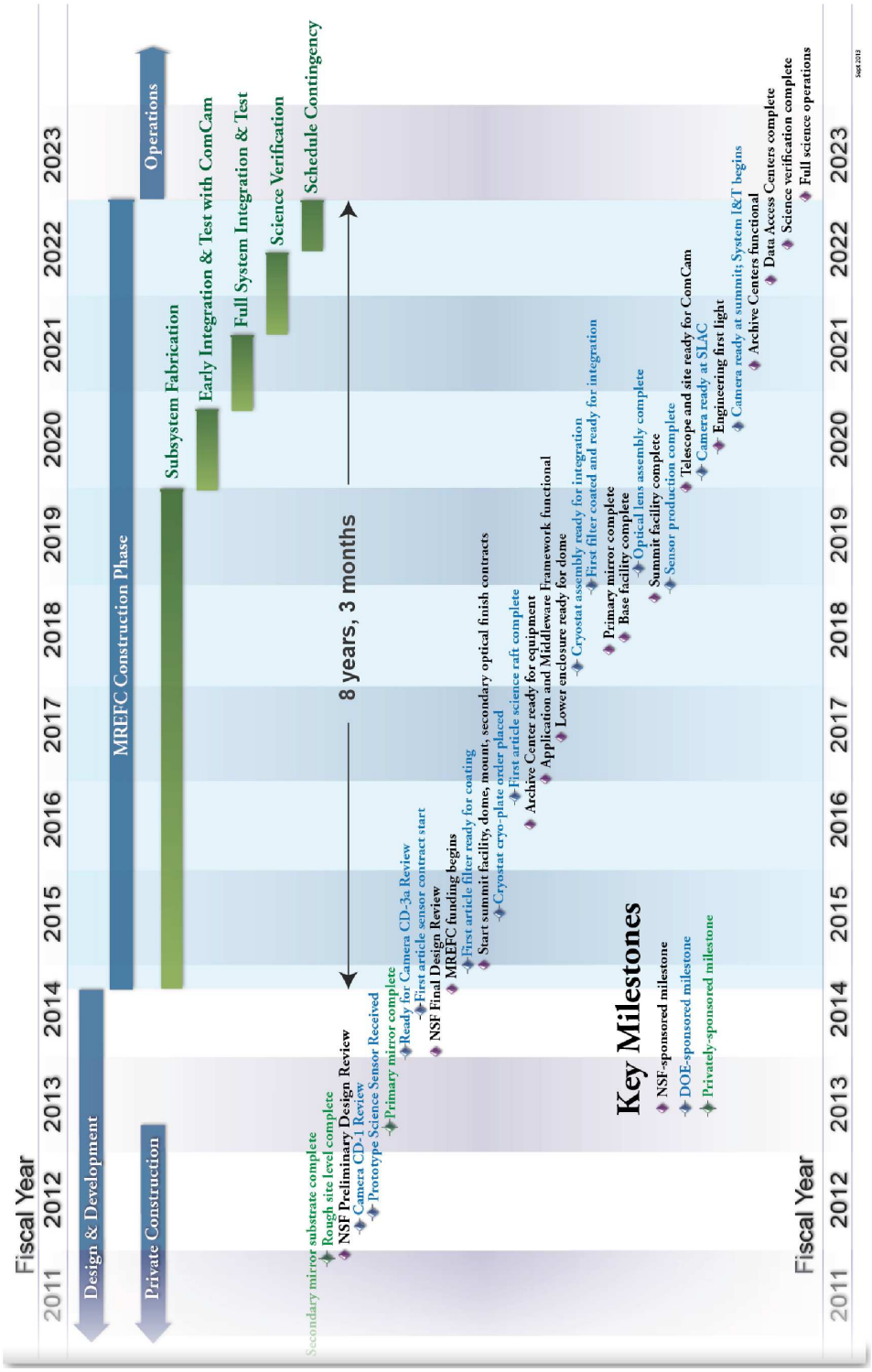

Figure 2: The integrated schedule of LSST.

- Astrophysical Spectroscopy of Extragalactic Objects (led by Luka Popović)
- Gravitation and the large scale structure of the Universe (Predrag Jovanović)
- Emission nebulae: structure and evolution (Dejan Urošević)
- Influence of collisions on astrophysical plasma spectra (Milan Dimitrijević, Zoran Simić)
- Dynamics and kinematics of celestial bodies and systems (Zoran Knežević, Rade Pavlović)
- Astroinformatics: application of IT in astronomy and close fields (Darko Jevremović)

From the scientific point of view, Serbian astronomers have interest in the following subjects:

- Variable phenomena
- Variable stars
- AGN variability
- Gravitational micro-lensing
- SNR & Planetary nebulae
- Small solar system bodies (orbits, elements...)
- Development of astroinformatics
- Development of algorithms, software

2. 1. INTERNATIONAL INVOLVEMENT IN LSST

The LSST is essentially a US project with the standard Chilean share (in exchange for providing the telescope site). In 2011 LSST solicited the Letters of Interest from the global astronomical community. The main reason was an estimate that some additional funds (contributions) would be necessary for the smooth operation of the Survey over ten years. France and Serbia have the special status because of the very early involvement (before the Decadal Survey in 2010) in the project, and got an opportunity to do some of the contributions as in kind support. France is involved in camera and software development, while Serbian contribution is described in the next section.

Sixty eight institutions from 25 nations outside US and Chilean Community have expressed their interest in being involved in LSST. Geographical distribution is shown in Fig.3 (from Hand 2012)

Since 2012 the international involvement in the LSST is measured in PI's. PI (principal investigator) is a senior scientist who can have a group of up to four students/postdocs. PI has essentially all the rights as someone from the US or Chilean community (access to documentation, software, data etc.) In exchange to that he/she

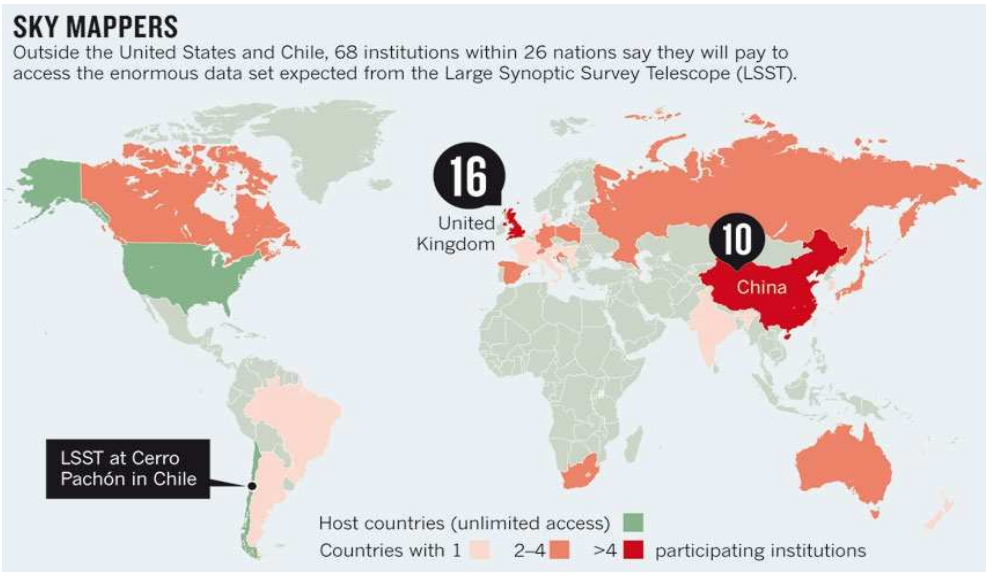

Figure 3: The world wide distribution of institutions committed to the LSST Hand (2012).

is expected to contribute 20k$/year toward the costs of the operations. For example China committed to fifty PI's, Great Britain to up to 120, France 50+50, Australia 25, Germany around 100, Hungary 3 etc. Serbia at the moment is committed to 2+2 PI's. Funds for two PI's are approved and for other two we are developing small suite of software as in kind contribution.

2. 2. ALERTSIM: SERBIAN IN KIND CONTRIBUTION TO THE LSST

Here we transmit parts of the document which defined Serbian in kind contribution and was part of the negotiations (Jurić et al 2013)

As a part of its nightly operations, LSST is expected to generate a transient alert stream of 10,000 events/visit. That stream is planned to be forwarded a) unfiltered, to a number of public event brokers, and b) to an internal simple transient filtering service designed to support the end-users (per the Science Requirement Document, Section 3.5 Ivezić et al. 2011). It is anticipated that due to bandwidth constraints only a limited number of public brokers (on order of $\sim$2 to $\sim$4) will be able to connect directly to LSST. Memorandums of Understanding (MOU's) will be signed with their operators, defining the technical and policy aspects within which they will be expected to operate.

Given the limited number of external brokers that will serve as the primary delivery mechanism of LSST transient data to the public, it is important to assure they are capable of receiving and processing the LSST event stream, both initially and throughout operations. An inefficient or buggy event broker results in opportunity loss for the LSST user community, and in helpdesk/technical support costs to LSST. To achieve the projected return of investment for LSST transient science, it is important to initially validate each external broker's capability, continually monitor it, and

have the tools and support personnel to understand and resolve any issues as they arise.

The LSST MREFC Construction budget includes all work items needed to generate the transient alerts, transmit them to external brokers, build and operate the simple filtering service, and perform acceptance for all LSST-provided transient alert services. The LSST Operations budget anticipates the need for additional software development to validate and assess the performance of external brokers, develop capabilities for their continuous validation and troubleshooting, and monitor their performance. Furthermore, the LSST Operation budget anticipates the need for helpdesk and technical personnel to assist in troubleshooting external broker connectivity/functionality issues. The work provided by the SPG, defined below, is aimed to reduce these operation costs. In order to do so, the SPG will develop and contribute, in time for LSST Early Operations, a transient alert stream simulator and event broker validation suite ("AlertSim"). This software package will:

1. Be capable of generating realistic streams of LSST transient alerts, at data rates expected of LSST.

2. Be capable of simulating various failure or exceptional/extreme operation modes, including:

   a) Unexpectedly large numbers of spurious detections
   b) Unusually large numbers of detections, simulating observations of high-density fields
   c) Disruptions in the event stream (such as due to forced termination of difference image processing due to exceeding the 60-second maximum)
   d) Corruption of the event stream (e.g., due to software errors)
   e) Network connectivity interruptions and "bursty" transfer modes

3. Provide facilities to ease troubleshooting of problems with broker end-points (e.g., logging, VO Event packet inspection)

4. Be configurable, automated, and capable of keeping provenance information.

5. Be written following all applicable LSST software standards, conventions, and development processes, and executable on LSST Data Access Center hardware.

6. Be developed in coordination with and leveraging capabilities provided by the LSST Simulations Group.

This contributed package is expected to reduce LSST Operations cost by:

I. Delivering functionality early, that is currently planned to be developed in Operations.

II. Reducing the need for help desk and technical support personnel by automating the validation/troubleshooting activities and increasing this aspect of staff productivity.

III. Further reducing potential down-time and troubleshooting personnel costs by providing the capability for full characterization of the behavior of connected public brokers in the full suite of exceptional/extreme operation modes that may occur in Operations, but are unlikely to occur with real data in Commissioning.

The work on AlertSim will be done by the Serbian Technical Group(STG). This group is open for the suggestions, contributions and of course new members.

2. 3. OTHER SERBIAN SCIENCES, EDUCATION AND PUBLIC OUTREACH AND LSST

There is a potential of further involvement of Serbian scientists in LSST especially from the field of fundamental physics - namely Cosmology and new 'Dark Energy Science'. Also, the development of 'Big Data science' is very important and significant part will be in the development of algorithms, methods and visualization tools. Mathematicians, software engineers and scientists from many other fields which (will) have a significant Big Data component might find collaborating with LSST-STG very fruitful.

The important part of the project is the Education and Public Outreach. The target audience consists of general public, students and teachers, formal/informal venues and of course amateur astronomers. Goals of the program can be summarize as:

- Actively engage audience Citizen Science
- Increase public awareness of scientific research
- Contribute to Science Technology Engineering and Math education
- Enhance 21 st century workforce skills

3. CONCLUSIONS

We reviewed the current status of the Large Synoptic Survey Telescope and the Serbian involvement in the project. As a main conclusion we would like to point that international collaborations are probably the only way for a small country (with limited resources) to get involved in the top level science especially in the expensive disciplines such as an astronomy, particle physics etc.

Acknowledgements

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