Large Synoptic Space Telescope

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1 Introduction

Telescopes have been at the heart of astronomy since their first use for this purpose by Galileo Galilei (not invented, a common misconception). It is safe to say that we have come a long way from his first telescope of 8 times magnification. That does not mean, however, that telescope technology has peaked. Current ground telescopes have reached astounding magnifications, but that generally comes with the trade-off of a much shorter field of view. Thus, even though we can save observational data to process it later, many times even by people not part of the organisation which owns the telescope, it can take a single telescope a year to observe the entire night sky of its hemisphere. Seems rather slow, right?

This is where the Large Synoptic Survey Telescope (LSST) comes in. A part of the Legacy Survey of Space and Time (also LSST), it aims to survey the entire southern night sky from Cerro Pachon in northern Chile every few nights. According to their estimates, the LSST (the telescope) will be able to complete a survey of the sky every 3 nights, starting from 2022. This doesn't just mean faster collection and eventually faster processing of data, but the increased frequency can be used for making entirely different types of scientific observations and inferences.

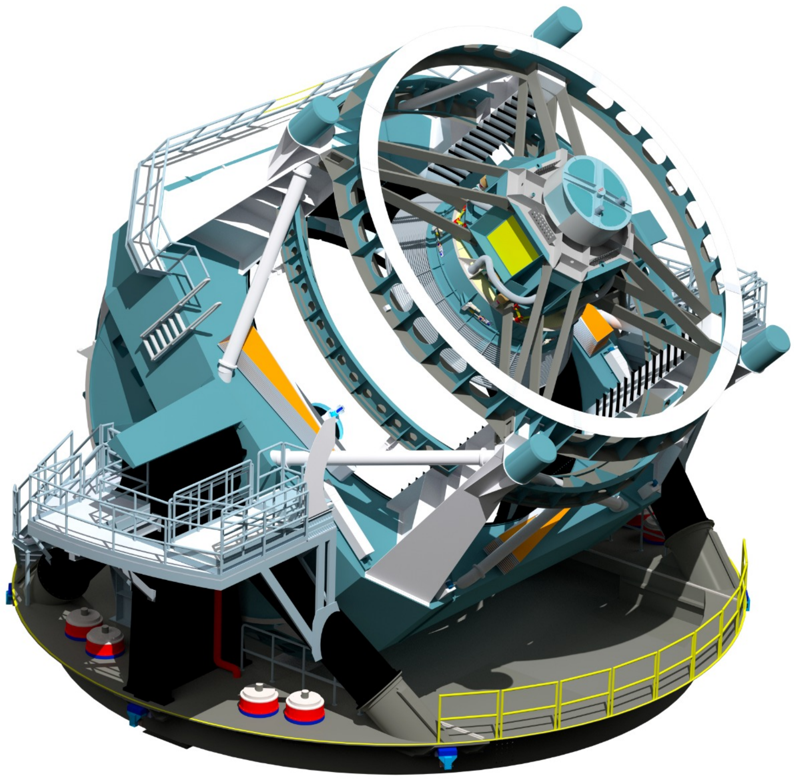

Figure 1: An artist's rendition of the LSST. Credits: LSST Project/NSF/AURA

2 Prospects

The LSST aims to investigate four main areas of scientific observations:

- Understanding Dark Matter and Dark Energy: Supernovae are some of the largest explosions in the universe and are bright enough to be seen from billions of light years away, at times out-shining whole galaxies. This property of type Ia supernovae allows astronomers to test whether dark energy exists, as over such long distances the effect of dark energy becomes distinctly visible.
  The 2011 Nobel Prize in Physics [2] was awarded to Saul Perlmutter, Adam Riess and Brian Schmidt "for the discovery of accelerating expansion of the universe through observations of distant supernovae". By looking at the discrepancy, if any, in the observed and expected brightnesses of these explosions we can find out the rate of acceleration of the expansion of the universe and thus find the dark energy content in it. Dark energy is

currently an unsolved mystery and taking lots of observations of supernovae will definitely help us pin down its effects exactly and make further predictions about its nature.

- Looking out for Hazardous NEOs and remote objects in the solar system: The current catalogue of near-earth objects (NEOs), according to some, is grossly incomplete, as the number of these detected every year is still quite large. It is not only important to detect objects which are near the earth now, but also ones which might be potentially hazardous in the future, so that action could be taken if needed. This requires precisely calculating their trajectory, which takes multiple observations over a short period of time. Thus, the LSST is a great candidate to help study these as it will be able to detect $60-90\%$ of all potentially hazardous asteroids. Besides NEOs, the LSST could also detect remote objects in the solar system and observe their nature, giving us further insight into the formation of the solar system.

- Observing the Transient Optical Sky: A transient event is a short duration event, by astronomical standards, lasting from a few seconds to several years. Some examples of such events are novae, supernovae, gamma ray bursts and gravitational lensing. The LSST is considered to be one of the best ground-based telescopes to detect the optical counterparts of gravitational wave detections made by LIGO due to its wide field of view, quick reaction times and low downtime.

- The Formation and Structure of the Milky Way: Being able to provide data on large portions of the sky on a frequent basis, the LSST will increase our knowledge about the stars in our galaxy and also their velocities. Based on the current locations, velocities and type of stars we would be able to make better simulations on the formation, structure and evolution of our galaxy. The LSST's capabilities will help it map more than 10 times the volume of past surveys.

3 The Build of the Telescope and Systems

Clearly, the LSST wishes to focus on the dimension of time more than the dimension(s) of space. To achieve this, it uses a combination of cutting-edge technology, engineering ingenuity and optimised software. The details of these are as follows:

- Optics: It has a large 8.4 m primary mirror and the world's largest camera lens spanning 1.57m in diameter as a part of its 3 lens – 3 mirror optical assembly. It consists of an active optics system which allows a computerised system to change the shape of the mirrors constantly to correct for atmospheric interference due to variable density of winds.

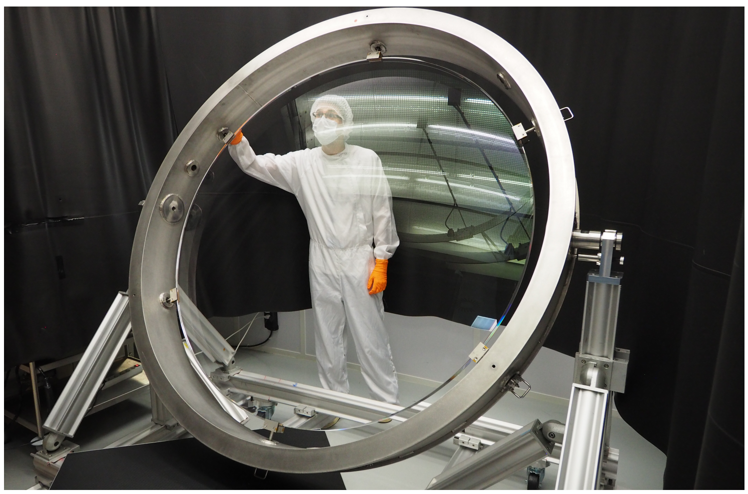

Figure 2: L1 Lens, the largest camera lens in the world. Credits: SAFRAN

- Camera: It will house the largest digital camera sensor in the world. At 1.65m by 3m, this CCD is roughly the size of a small car and weighs almost 2800 kg. The detector format employs a mosaic of 189 16-megapixel silicon detectors arranged on 21 "rafts" to provide a total of about 3.2 gigapixels. It can observe light in the near ultraviolet to near infrared (0.3 - 1 μm) range of the electromagnetic spectrum. This massive sensor will allow the telescope to take images that cover 40 times the area of the moon in a single exposure. The camera is designed to provide a 3.5-degree field of view, with its 10 m pixels capable of 0.2 arcsecond sampling for optimized pixel sensitivity vs pixel resolution. The telescope will also have 6 filters to observe through and a completely computerised mechanism to quickly and efficiently change between them.

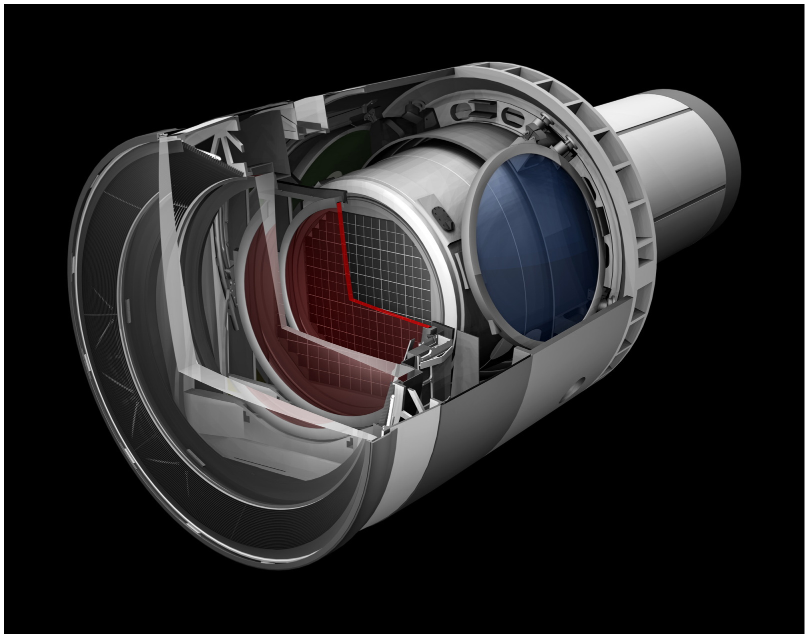

Figure 3: The camera's rendition with filters. Credits: SLAC / LSST Project Office

- Data Management: It will produce about 20 terabytes of raw image data each night of operation. Over 10 years of operation, it is expected to reach 60 petabytes. Processing such a large amount of data and converting the raw images into a faithful representation of the universe is a big challenge, and thus the team has devised a 3 layer data management system.
  The first is an infrastructure layer consisting of the computing, storage, and networking hardware and system software. The second is a middleware layer which handles distributed processing, data access, the user interface, and system operations services. The third is an applications layer which handles the data pipelines and maintains the archives of science data. The applications layer is organised around the data being produced.
  The pipelines are divided into a nightly data release output which highlights the difference between two exposures and highlights the community of interesting transient events taking place, within 60 seconds. The second major data release pipeline is intended to produce a complete picture with properly analysed data which measures faint objects of interest over longer periods of time. Each year it will add to the complete set of data of the map of our galaxy and the universe, and much more.
  It is safe to say this will require a lot of computing power, but the team aims to optimise processing speeds so as to not push the expected tech-

nology to the limit to maintain reliability standards.

4 Summary

The LSST is Large with its 8.4 m primary mirror, a 3.2 GP camera and a field of view of moons. It is Synoptic, the Greek word for looking at all aspects of something, as it views the sky in 6 colours and with its frequency of observation will help form the first motion picture of our universe. It will help us take a Survey of the entire southern night sky every few nights for a decade, allowing us to identify changes in near real time and collect tens of petabytes of data. Finally, it is more than a telescope - it is an observing facility comprised of a telescope, camera, and data management system whose ultimate deliverable is the fully reduced data. It truly will live up to its name.

References

[1] *Official website of LSST*. URL: https://www.lsst.org/.

[2] Saul Perlmutter, Brian P Schmidt, and Adam G Riess. "The Nobel Prize in Physics 2011". In: *AG Riess, My Path to the Accelerating Universe, Nobel Lecture* (2011).