Large Synoptic Survey Telescope (LSST) Facility Paper

For the mid-term review of the Australian Astronomy Decadal Plan

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Science overview

The Large Synoptic Survey Telescope (LSST) is an 8.4-metre optical imaging telescope under construction on Cerro Pachon in Chile by the US NSF & DoE agencies. It was the first-ranked facility in the 2010-2020 US astronomy Decadal Survey. Commissioning the telescope will start in 2021 with a 10-year science survey starting in 2023. The main "wide, fast, deep" survey will use 80% of the time to observe the whole southern hemisphere sky 50-200 times over 10 years in each of 6 optical bands (*ugrizy*) to great sensitivity. The remaining 10-20% of time will observe deep-drilling fields.

LSST will be the apex optical imaging facility for the next decade and more. It will be transformative for a large number of science cases from understanding dark energy and galaxy evolution to detecting exoplanets, finding ultrafaint Milky Way satellite galaxies (LSST Science Book, arXiv:0912.0201), and it will open up a new discovery space for transient science. As with the shallower Sloan Digital Sky Survey, LSST will play a crucial role in the preselection of samples for targeted multi-wavelength studies of our Universe, including the rapid localization of transients.

How does this science connect with the priorities set out in the Decadal Plan?

The science that LSST undertakes will contribute to each of the six key research questions raised in the 2016-2025 Australian Decadal Plan. Within these research questions, LSST will revolutionize many research areas of interest to Australia. These include:

LSST will increase the data sets of rare transient objects such as luminous red novae by factors of 100 or more. Such a uniform, deep, wide survey with characterisable selection effects will allow for a level of statistical analysis across this and other science cases that has not previously been possible.

LSST will be the key facility for finding Milky Way streams and satellite dwarf galaxies over the next decade. Australia is expert in robustly identifying these systems and their member stars in order for targeted physical analysis, in this case with 30-m class telescopes.

LSST will provide much-needed optical identifications for ASKAP-detected continuum, spectral line and transient point sources. With ASKAP surveys covering the whole southern hemisphere, LSST will significantly enhance multi-wavelength studies of a vast range of astronomical objects."

LSST will find 100,000 galaxy clusters and 1 million groups to redshift~1. For the first time it will allow the quantitative study of the amount, origin and growth rate of the ultrafaint diffuse intracluster light, providing a new test of galaxy evolution.

What are the current issues and key risks?

The existing Australian arrangement with the LSST is the form of an MOU, negotiated by CAASTRO, and subsequently novated to AAL. This MOU provided for LSST access for 10 Australian PIs (each with 4 junior scientists); the number limited by the funding Australia could secure for the project. In May 2019, LSST, together with the US agencies DoE and NSF, announced that they are changing the model for international contributors to an in-kind contribution model. Australia has much that could form a strong in-kind contribution, and crucially, could increase the PIs with access to LSST.

There are currently 35 members of faculty at 13 Australian institutions who have expressed an interest and would require PI status to access LSST data. This number of PIs would allow for up to a

total of 175 Australian researchers to engage with LSST science. Through the current agreement of 10 PIs, a total of 43 researchers have been able to join LSST Science Collaborations.

LSST's construction is well underway and the target survey start date of 2023 is not expected to slip.

What are the synergies with other Decadal Plan priorities?

LSST will provide valued information for sources (e.g. photometric redshifts and stellar masses) found with ASKAP surveys. It will find exciting sources for follow-up with 30m-class telescopes.

What is the best engagement model likely to be?

Access to the LSST for international researchers is gained through in-kind contributions, to be negotiated with LSST and the US agencies DoE and NSF, and which must be of benefit to the facility and/or the US community more broadly.

What are the approximate costings - a) for the remainder of the decade; b) 2025+?.

The LSST main survey will run from 2023 to 2033. Negotiations around Australia's in-kind contribution to the project will occur in the next year. Australia could offer a range of facilities, including optical, radio and data processing, as well as providing the US community with added value through researchers undertaking preparatory work for the LSST Science Collaborations.

Australia's geographical location provides a unique capability to the LSST partnership. No facilities comparable to those of Australian observatories are available in the southern hemisphere in the temporal window provided by our longitude.

To get an idea of the instrumentation that would be most useful, the LSST Dark Energy Science Collaboration (whose interests extend from transient objects through galaxies to strong lensing) have made an inventory of the additional facilities they would value in order to advance their science. These include *multi-object spectroscopy* on a 4m telescope (for photometric redshift training and calibration); *single-object spectroscopy* (classifying candidate SNe Ia); daily *gri imaging on a 2m telescope* (transient cadence monitoring), *IFU spectra* of SN Ia host galaxies; and *radio observations* (to find AGN and determine radio properties).

As such, the most obvious in-kind option would be to offer AAT time to the US community. There is already a demand from the US for access to the AAT, with two programs securing significant time on the facility through its paid time scheme. Using the AAT as an in-kind contribution to the LSST also opens consideration of funding opportunities to continue operations of the AAT beyond its current funding allocation to June 2022.

For the AAT option, a rate of ~1PI to ~1 AAT night/year could be considered reasonable. With an anticipated ~35 Australian PIs, we would be expecting to offer 35 nights on the AAT/year. In addition, sufficient support, data processing and archiving resources would need to be available.

As can be seen from the science interests above, having the 2dF instrument continuing to perform over the first few years of the agreement will be invaluable. VELOCE is also of particular interest to the US community, for follow up of transient candidates. A new single-object spectrograph for transient-follow-up could also be explored using, for example, an ARC LIEF bid.

Should we offer broader access to the Siding Spring Observatory facilities, e.g. Skymapper (for rapid photometric follow-up of brighter objects) and the ANU 2.3m telescopes (WiFES integral field spectrograph), those would require additional funding to be found. In addition, the Taipan wide-field spectroscopic survey facility also offers an opportunity for spectroscopic follow up of transient hosts.