Facilities for Follow-up Observations in the LSST Era

M. Virginia McSwain (Lehigh University), Lou Strolger (STScI), Federica Bianco (New York University), Will Clarkson (University of Michigan, Dearborn), Suvi Gezari (University of Maryland), Melissa Graham (University of Washington), Henry Hsieh (Planetary Science Institute), Bryan Miller (Gemini Obs.), Dara Norman (NOAO), Travis Rector (University of Alaska), Steve Ridgway (NOAO), Abi Saha (NOAO), Marcelle Soares-Santos (Brandeis University), and Kathy Vivas (NOAO)

Following guidance from the NSF, NOAO is developing the LSST Community Science Center (LCSC) to provide support and infrastructure for community science with LSST. The LCSC Working Group (WG) was formed to study the goals, requirements, and aspirations for community science with LSST, and to recommend priorities for the essential functions of the LCSC. Additional information can be found in the October 2017 NOAO Newsletter (https://www.noao.edu/noao/noaonews/oct17/116news.pdf), 'Preparing for Community Science with LSST' on page 11. This white paper outlines facilities for LSST follow-up that should be pursued over the next 10 years.

LSST will have a great deal of mission overlap with WFIRST and Euclid on deep-field survey science, and these surveys will be greatly benefited by GSMT-aperture facilities. There remains, however, a great deal of science to be done in targeted follow-up of newly discovered objects and phenomena. As detailed in Najita et al. (Maximizing Science in the Era of LSST, see Chapter 11), the facilities needed to maximize LSST science must be broadly diverse and provide a multitude of opportunities for developing "workhorse" facilities for, as well as other contributions to, the LSST enterprise. The LCSC should be a community advocate for the facilities and instrumentation necessary for effective source follow-up.

Static and transient follow-up with spectroscopy

The majority of LSST sources will vary by 1% or less and therefore will not be classified as variables. Follow-up on these "static" sources will not be time critical, but it would benefit from spectroscopic facilities in the Southern Hemisphere that provide a range in capabilities from wide-field multi-object instruments spanning the broad O/IR wavelength range at low resolution, to targeted single-object spectroscopy at high resolution, and the various combinations in between.

Low resolution, low S/N spectroscopy will be useful for characterizing new static sources, and this can be can be achieved with current or developing instrumentation at existing < 10m facilities. Deeper spectroscopic follow-up, especially at higher resolution of R > 20,000 or requiring higher S/N, will require a larger aperture of 10-m or even 25-

m. There are some modes (mostly in single-object or small FOV spectroscopy) at Gemini, Blanco, and SOAR that will be useful for static source follow-up. However, the truly wide-field multi-object spectrographs, such as the PFS on Subaru and DESI on the Mayall, are only available in the Northern Hemisphere and will not have time available to the entire US community. Possible approaches are to negotiate with the Japanese community for a share of time on Subaru, or request a share of fibers on the Mayall's DESI spectrograph, so that the US community has access to these instruments for additional spectroscopic follow-up opportunities. There are no existing southern "survey" multi-object spectrographs available to the broad US community, despite the very high demand for decades now. This capability will require a substantial investment in a new facility.

Variable stars with known periodicities can be integrated into the same scheduling routine as static sky objects, just with extra time constraints. However, spectroscopic follow-up of truly transient sources of unknown duration will require target-of-opportunity (ToO) interruptions of the observing queue. These are likely to be done more efficiently with 4-m and 8-m single-slit spectrographs or IFUs. In the grander scheme of facility coordination, it is probably not advantageous to have this facility be the same as that used for static-sky and time constrained phenomena, as there are likely to be a great number of triggers per night to vet and measure. Existing facilities such as SOAR, Blanco's Cosmos, and Gemini are ideal for this role.

Static and transient follow-up with imaging

Non-LSST imaging cadences and alternate filter sets will be very important to several science areas. The community can contribute unique narrow-band filters for specialized projects. 4-m facilities will be an appropriate aperture size for many imaging follow-up needs. The reactivity of the scheduling queue will be the main factor in choosing to insert ToOs into observing schedules. The DECam on Blanco satisfies many of these criteria, with a wide field of view and broad- and medium-band imaging, and the possibility of remote observing capabilities and queue observing, as is done with Gemini. Gemini, SOAR and other facilities may also be useful for more targeted follow-up on small numbers of objects. NOAO (NCOA) should consider developing partnerships as needed.

Summary

While much of this discussion has focused on existing instrumentation at NOAO facilities, there is clearly a need to develop new facilities (in the case of >25 meter telescopes, and a dedicated approx. 10-m with wide-area MOS) and to deploy new and upgraded instrumentation (in the case of high-resolution single- and multi-object spectrographs). NOAO and the LCSC should continue to advocate for the development of new instrumentation on behalf of the community, as well as leverage telescope time for co-development with external groups.