After SDSS-IV: A Wide Field Near-Infrared Spectroscopic Survey

Michael Pierce (PI), Michael Brotherton, Daniel Dale, Hannah Jang-Condell, Chip Kobulnicky, and Adam Myers (University of Wyoming)

We propose to develop a unique wide-field, near-infrared spectrograph for AS4 that would extend the legacy of SDSS I-IV to fainter near-infrared targets. The instrument design concept would provide simultaneous, near-infrared spectroscopy of up to 2800 targets over the full 3-degree field of view of the SDSS telescope. The design builds upon the robotic fiber positioners developed for DESI (also see the Huehnerhoff et al. white paper) but with additional optics that couple the fibers to the telescope pupil to allow near-infrared operation. This capability would be unique and would directly complement the next generation of large telescopes that will be coming on line in the 2020s and enable rapid response to an LSST trigger. Such an instrument would truly revolutionize the science capabilities of SDSS and greatly extend its research capabilities.

Technical Overview of the Instrument

The instrument we hope to propose would make use of an array of seven near infrared dewars arranged in a hexagonal format mounted in place of the current SDSS "cassettes." Each of these dewars would contain up to 400 robotic fiber positioners operating at cryogenic temperatures and make use of the FBPI infrared transmitting fibers from Polymicro. The "cable" would be thermally shielded within a copper jacket with multi-layer insulation within a vacuum hose that would connect each focal plane dewar to one of 7 separate but identical infrared spectrographs located below the telescope. Each focal plane and instrument dewar would have its own cryogenic cooler to cool both the positioners and the spectrograph optics. The fibers would radiatively cool against the copper jacket that is cooled from both ends via the focal plane and instrument cryo-coolers. The spectrograph design would be similar to that of FLAMINGOS and the NIIS spectrograph developed by the PI at the University of Wyoming. It would feature a Hawaii2-RG focal plane array and a set of VPH grisms mounted within a rotating turret providing a resolution of > 3200 within each of the near-infrared bands. This resolution is sufficient to work between the strong near-infrared skylines. The resulting instrument would provide up to 2800 positioners over the full 3-deg field of view of SDSS and result in a unique wide field, near infrared spectroscopic capability for decades to come.

Collaborative Science with the New Instrument

The new infrared AS4 capability would enable a broad range of collaborative science. This includes access to the H-β and [OIII] lines in $z > 1$ quasars. The clustering of these quasars are poorly constrained at these redshifts due to systematic velocity offsets of up to 500 km/s in the rest-frame UV lines such as C IV when compared with the forbidden [OIII] lines that better match the host redshifts. Similarly, the H-β line would provide the most unbiased black hole masses determined via reverberation mapping.

The new spectrograph would provide access to the H-α line for $z > 0.5$ emission line galaxies. H-α is typically 6 times stronger than [OII] allowing the redshifts of emission line galaxies to be acquired at higher redshifts. At the same time H-α also provides a better estimator of their star formation rates than does [OII] and complement DESI. The new capability would therefore allow the star formation and mass assembly of galaxies to be more accurately determined and the luminosity and environmental dependencies to be fully characterized back to the epoch of peak assembly.

The new instrument would greatly impact our understanding of the star formation within local galaxies. It could be used to explore star formation on galaxy scales through the brightest accessible lines, e.g., [Fe II] 1.257 μm, [Fe II] 1.644 μm, Pa-β 1.282 μm, H_2 2.122 μm, and Br-γ 2.166 μm. The multi-fiber aspect would enable the probing of a large number of nearby galaxies that span a range of morphological types, luminosities, metallicities, and infrared-to-optical ratios. These data would constrain the characteristics of the star-forming regions, including their strength, maturity, spatial variability, metal (Fe) content, and extinction. Near-infrared spectroscopy is imperative since the sample will include very dusty LIRGs and ULIRGs.

The new instrument could be used to conduct spectroscopy of heavily obscured star forming regions within the Milky Way Plane. Infrared spectroscopy is needed to identify and measure the masses, velocities, and temperatures of rare classes of evolved stars in hard-to-catch phases of evolution, especially at the end of their lifetimes when they shed many solar masses of atmosphere in just a few thousand years. Infrared spectroscopy is also the key to identifying young stars in their very earliest evolutionary phases when they are still enshrouded in their natal molecular clouds. The survey capabilities of SDSS combined with the multiplexing capabilities of the new instrument would enable some of the first truly long-term (time domain) infrared surveys of these key objects on Galactic scales.

The new instrument would greatly contribute to our understanding of the formation of young protostars and their planets. The process is complex but it is clear that as the primordial disk dissipates, an inner cavity becomes evacuated of dust and an inner disk rim or wall forms, the geometry of which determines which portions of the outer disk are shadowed—shielded from the central radiant source—thus determining the temperature distribution in the disk. A cold outer disk may be accompanied by an ionized inner disk, where gas is channeled by magnetic field lines to a polar accretion hotspot. This means that models fit to broadband spectral energy distributions are hopelessly degenerate. Accretion and excretion activity is also notoriously variable, begging for time-series spectrophotometry to identify the physical drivers of this process.

Data Acquisition and Management

The new instrument would enable both survey and targeted, time-domain operation (e.g. Green et al. white paper). We also expect that a TOO capability would be incorporated to allow for rapid follow-up of transient events. The data would be processed using a modified version of the SDSS pipeline and merged into the existing SDSS archive.