The After Sloan-V (AS5) Survey

Executive Summary

The After Sloan-V (AS5) Survey is a next-generation, dual-hemisphere spectroscopic program designed to address fundamental questions in astrophysics by combining full sky coverage, time-domain sampling, and multi-wavelength spectroscopy. Leveraging a unique suite of existing and newly deployed instrumentation, AS5 will provide optical to near-infrared spectroscopy across a broad range of spectral resolutions and spatial scales. Its design enables both high-cadence monitoring and long time-baseline observations, making it uniquely suited to study dynamic astrophysical processes alongside the structure and evolution of galaxies.

In particular, AS5 will:

- Spectroscopically characterize time-variable and transient phenomena across the sky
- Map the structure and evolution of the central and far side of the Milky Way
- Resolve the interplay between stars and gas in the Milky Way and nearby galaxies
- Uncover the origins of the chemical elements

To achieve these ambitious aims, AS5 is organized into four complementary survey components—Dynamic Universe Explorer (DUE), Hidden Galaxy Explorer (HGE), Local Volume Mapper 2 (LVM2), and Atomic Genesis Explorer (AGE)—each tackling a distinct but interconnected set of scientific goals. Together, these components form a cohesive program aimed at linking time variability, stellar and galactic evolution, and chemical enrichment into a unified understanding of the Universe.

The Dynamic Universe Explorer (DUE) will conduct spectroscopic observations of variable sources, both stellar and extragalactic, using the existing dual hemisphere 2.5m class telescopes with low resolution (R~2,000) optical and moderate resolution near infrared (R~22,000) spectrographs. DUE will:

- ***Perform rapid spectroscopic follow-up for 1000s of photometric transients.*** DUE will classify and characterize new transients with prioritization set by the Collaboration members. DUE will advance understanding of SMBH accretion physics and circumnuclear dynamics (tidal disruption events, AGN turn-on events), late-stage and/or binary stellar evolution (supernovae, cataclysmic variables), and phenomena at the intersection of stars, compact objects, and high-energy astrophysics. DUE is the only wide-field multi-object spectral program up to the challenge posed by modern time-domain surveys and will serve as a large-scale “spectroscopic clearing house” for transient searches in programs like LSST and LS4, among others.

- ***Obtain spectra of >10^6 variables to enable the discovery of atypical classes and refine the understanding of known classes***. For stellar variables, improved spectroscopic parameters would allow a better understanding of their properties, thereby improving, e.g., the calibration of Period-Luminosity-Metallicity relationships. For extragalactic variables, it enables a deeper understanding of “normal” and “extreme” AGN variability (i.e., extremely variable and changing-look AGN) and its relation to SMBH properties.
- ***Conduct regular monitoring for many variable sources.*** DUE produces time series observations that would enable measurement of changes in spectroscopic properties. This would enable mapping the circumnuclear gas and measuring SMBH masses of AGN, analyzing the spot properties for young stars across the entire orbital cycle, performing astroseismology of luminous giants across their pulsation patterns, and more.

The Hidden Galaxy Explorer (HGE) will investigate the chemistry and dynamics of the Milky Way’s unexplored regions. HGE will use the dual hemisphere APOGEE (near infrared, R~22,500) spectrographs mounted on 2.5m class telescopes. HGE is complementary to major space- and ground-based facilities (e.g., NASA *Roman’s* Galactic Plane Survey and Galactic Bulge Time Domain Survey). HGE will enable us to transform our understanding of the Milky Way. HGE will:

- ***Provide systematic mapping of the chemistry and kinematics on both sides of the Galactic center.*** Leveraging red giant stars on the far side of the Galaxy, HGE will test whether the Milky Way disk and bar are globally symmetric or exhibit large-scale asymmetries. This has implications for physics that drive internal evolution inside of the Milky Way (including bar and stellar dynamics, and chemical evolution).

- ***Explore disk–halo interaction and satellite impacts in the interior region of the Milky Way.*** The Sagittarius stream and the massive Magellanic Clouds are expected to induce warps, waves, and kinematic asymmetries in the (far) disk and HGE will be able to observe the predicted features for the first time.
- ***Open the doors to new discoveries.*** The far side of the Galaxy remains a promising region for the discovery of new stellar clusters, satellite systems, and chemically distinct substructures.

The Local Volume Mapper 2 (LVM2) — will map stars and gas at star-formation scales across Local Group galaxies. LMV2 will use the dual hemisphere Local Volume Mapper Instrument (optical, R~4,000, IFU) mounted on both small 0.16m (south) and 2.5m class (north) telescopes. LVM2 aims to characterize the stellar and ionized gas components of Local Group galaxies in unprecedented detail. LVM2 will:

- ***Constrain physics of stellar feedback and chemical enrichment in a wide range of environments and map the stellar populations in Local Group galaxies.*** The Northern component of LVM2 will provide high physical-resolution (~10 pc resolution for M31) extremely wide field IFU spectroscopy for M31, M33 and local, star-forming dwarf galaxies out to 5 Mpc. LVM2 will be a rich legacy dataset that will provide the necessary information to constrain the physics of stellar feedback and chemical enrichment processes and map the stellar populations in these systems. LVM2 will complement the legacy Hubble Space Telescope imaging in M31 (PHAT+PHAST) and M33 (PHATTER). LVM2 will also map additional low-metallicity, star-forming dwarf galaxies within 5 Mpc at spatial resolutions of ~50 pc or better. LVM2 is designed to probe the role mass and/or metallicity in stellar feedback processes.

- ***Explore the physical processes in ionized nebulae in the Milky Way.*** LVM2 will drill down on samples of Galactic ionized nebulae at very high physical resolution (< 0.1 pc) to obtain three times deeper and higher fidelity data than SDSS-V LVM, and will produce the first comprehensive spectral characterization of spatially resolved Auroral lines and metal recombination lines in HII regions in our Galaxy, therefore enabling high-fidelity nebular physics measurements not accessible with existing datasets.
- ***Linking stars and gas across diverse environments.*** LVM2 will provide a legacy dataset that links the Galactic and extragalactic regimes spectroscopically with unprecedented spatial resolution and uniformity. This connects stars to gas across a wide range of physical conditions, local environments, and star formation histories.

The Atomic Genesis Explorer (AGE) will probe the key nucleosynthetic pathways that produce the elements of the periodic table using optical high-resolution (R>50,000) spectroscopy by targeting stars using prior information for each object (e.g., stellar parameters, metallicity, and age). AGE will:

- ***Produce a legacy sample for Galactic chemical evolution for > 30 elements*****:** AGE will provide a high-fidelity optical spectroscopy that provides insight into multiple nucleosynthetic pathways. Building on the legacy of *Gaia*, APOGEE, and *Kepler*, AGE will uniformly sample across metallicity and age enabling insight into detailed enrichment history in the Galactic disk. AGE will measure > 30 elemental abundances at 0.01–0.05 dex precision, including a comprehensive set of neutron-capture elements (e.g., Rb, Sr, Y, Ba, Zr, Ru, Ce, La, Dy, Sm, Pr, Mo, Nd, Eu). This delivers the combined high precision age–chemistry mapping to constrain the delay-time distributions of some of the most poorly understood, physically interesting nucleosynthetic events in the Galaxy.
- ***Disentangle nucleosynthetic fingerprints of stars.*** AGE will reveal the astrophysical sites of nucleosynthesis by revealing the nucleosynthetic patterns in red giants selected in a narrow evolutionary state and uniformly in metallicity. Using > 30 elements that sample multiple astrophysical processes, AGE will uncover element production pathways, identify their metallicity dependence., and place constraints on yields from a diverse ensemble of astrophysical sites.
- ***Build an enrichment chronology in the Milky Way.*** Using asteroseismic ages, AGE provides an age-resolved view of chemical evolution capable of constraining delay-time distributions for nucleosynthetic events in the Galaxy

and identifying the transition points between the dominant processes for elements produced through multiple nucleosynthetic pathways.
- ***Reveal the interior workings of stars.*** Isotopic ratios (e.g., C, Mg). AGE will provide insight on internal stellar mixing processes that drive changes in isotopic ratios, as well as inferring nucleosynthetic yields and evolutionary pathways.
- ***Test if chemical tagging can work to recover co-natal stars.*** AGE will test whether chemical tagging can recover co-natal stars by observing open cluster stars. AGE will provide the precision to compare open cluster members to field populations and establish whether stellar birth environments can be reconstructed from chemical signatures alone.

AS5's scientific power is enabled by its comprehensive observational infrastructure, which includes:

- Dual-hemisphere, wide-field optical spectrographs at low resolution (R~2,000) for large-scale surveys
- Dual-hemisphere, wide-field near-infrared spectrographs at moderate resolution (R~22,500) for probing dust-obscured regions of the Milky Way
- Dual-hemisphere optical ultra-wide-field IFUs enabling moderate resolution (R~4,000) for spatially resolved spectroscopy
- High-resolution (R>50,000) echelle spectrograph(s) for precision abundance measurements

This combination allows AS5 to operate across multiple regimes—temporal, spatial, and spectral—within a single coordinated program. The survey will build upon existing data reduction pipelines and infrastructure developed in previous generations of SDSS, minimizing technical risk. Most required hardware is already in place, with only modest upgrades and/or instrumentation builds needed, enabling a phased start beginning in early 2027.

AS5 is designed as a collaborative, open scientific enterprise with a strong commitment to community engagement and data accessibility building off the existing SDSS legacy, which has been an inspiration for projects across astronomy. Regular public high-quality data releases, accompanied by high-quality documentation, will ensure the survey's high impact in the broader astronomy community.