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Project Title: Probing ionizing mechanisms in nearby massive galaxies using SALT Slit Mask Integral Field Unit

1. Background

The efficiency of star formation in a galaxy is found to be a strong function of its mass. While star formation efficiency peaks at Milky Way sized galaxies, both lower and higher mass galaxies demonstrate significatly more inefficiency. The strongest contributing factor in regulating star formation is the feedback generated by the process itself. The hot ionized gas is a particularly important tracer of star formation feedback. Although we understand the process heuristically, the detailed physics behind this process is not well understood. Among several feedback types, HII bubbles, galactic fountains, shocks and diffused ionized gas (DIG) are found to be important candidates for such study.

The DIG is distributed in a much thicker layer compared to the star-forming disc. Such distribution is found to be typical, as seen in several edge-on late type galaxies. DIG regions have emission-line flux ratios that are distinct from star forming regions as well as AGN. While the gas itself likely comes from a confluence of star-formation-region fountains (outflows) from disc midplanes, in-situ mass-loss from evolved stars in thick discs, and infall from high-velocity clouds, the ionization mechanisms are debated.

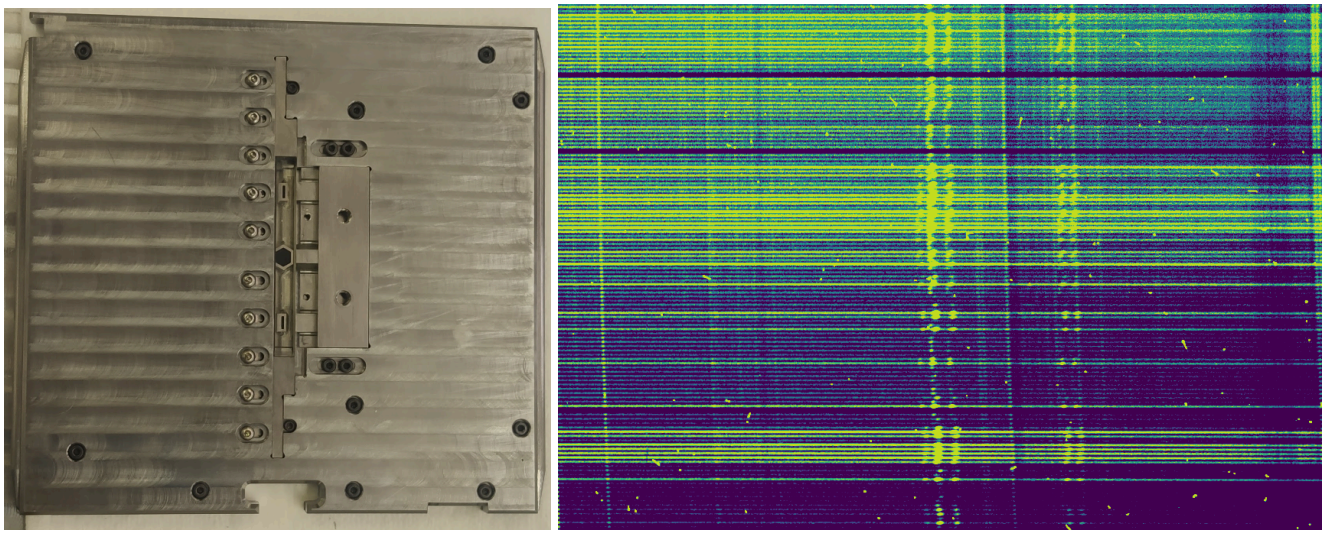

Figure: Left: The fully assembled SMI-200 instrument. Right: Spectra of a star-forming galaxy through several fibers of SMI (each individual horizontal trace is spectra from a fiber). The vertically misaligned zig zag blobs are Hydrogen-alpha (brightest), doubly ionized Nitrogen and Sulphur emission lines.

2. Aims and objectives of the project

2.1. Science: Study of diffused ionized gas

While there are efforts (such as AMASE with its 26 arcsec sampling IFU) underway to fine-sample the lighter end of the stellar mass function in local galaxy groups, the same method is difficult to implement for the massive end. This is partially because instruments optimized for smaller local group galaxies would provide too coarse a sampling for farther massive galaxies. Observing nearby massive galaxies with the Slit Mask IFU on board the Southern African Large Telescope would enable us to sample the physical scales of star forming regions at high spectral resolution to deduce even the minute effects of ionization mechanisms.

One way to probe the physics is by observing ionization structures at (i) varying distances from star-forming regions and at (ii) varying heights about the mid-plane with known gradients in evolved stellar populations. By examining the trends in ionization conditions in the HII region distance and mid-plane height, including line diagnostics sensitive to shock heating, we will be able to determine uniquely the contributions from different sources of ionizations.

The first version of the Slit Mask Integral Field Unit (SMI-200) has recently gone through a successful engineering commissioning run on the Southern African Large Telescope. The SMI-200 is a front end module for the visible arm or Robert Stobie Spectrograph (RSS) on board SALT. The module reformats an 18"x23" sky patch sampled at 0.9" onto the spectrograph slit input using optical fibers. The elongated hexagonal shape of SMI is ideal for observing galaxies over a range of inclination angles, and can be used to map more extended objects. Using the SALT data from SMI-200, we aim to probe the source of ionization of DIG and shock regions from emission line identifiers.

The science section would consist of two thirds of the doctoral thesis.

2.2. Instrumentation: Development of second generation SMI-200

Although the first generation of SMI-200 has been commissioned, the instrument throughput can be further enhanced via minor modifications. The astrophotonics research lab at SAAO is one of the few facilities across the globe dedicated towards developing state of the art astronomical fiber based instrumentation. The SAAO astrophotonics group is currently involved in developing multiple instruments for telescopes hosted by SAAO. The group consists of professor, astronomer, post-doctoral fellow, and engineer members from SAAO and University of Wisconsin.

We aim to use the existing facilities and inputs from partner collaboration to perform design, fabrication, assembly and performance validation of the second generation of SMI-200. The detailed objectives are following:

- **2.2.1.** Understand focal-ratio-degradation in multi-mode fibers. Using the understanding develop fiber sorting mechanism in order to stress relieve fiber. This involves study of fiber properties and defining the requirements towards design of such mechanisms.
- **2.2.2.** Develop and perform opto-mechanical assembly of fibers at the telescope end as an integral field unit.
- **2.2.3.** Develop and perform opto-mechanical assembly of fibers at the spectrograph end as a slit assembly.
- **2.2.4.** Characterization of fiber performance after assembly followed by on-sky commissioning.

The instrumentation effort would amount to one thirds of the thesis content.

3. Potential impacts of the project

The origin of diffused ionized gas around the star forming disk has drawn many theoretical models for prediction of its observable state. These models have been unable to provide an intricate understanding of the forming processes behind DIG and shock influenced regions. We aim to use observation to validate these models. SMI-200 would provide the avenue to observe massive nearby galaxies where the effects of photoionization can be caught in the act with fine details. In addition, the project would provide commissioning of an improved version of SMI-200 for SALT.

4. Requirements

The student would require a basic grasp of any software language. Having taken a course on galaxy evolution and basics of astronomy is desired but not necessary. However, a keen interest and willingness to learn and apply the knowledge for solving practical problems would be important.