Supervisor: Dr. Sabyasachi Chattopadhyay (SAAO)
Email address: sabyasachi@saao.ac.za
Registration University: Any
Type: PhD
Potential Co-supervisor: Prof. Matt Bershady (SAAO/UCT), Dr. Petri Vaisanen (SAAO/UCT), Prof. Ilani Loubser (NWU)

Project Title: Probing ionization feedback in sub parsec scale through AMASE

1. Background:

South African Astronomical Observatory (SAAO) is going to develop the fiber instrument cable for the Affordable Multiple Aperture Spectroscopy Explorer (AMASE) survey. AMASE is a planned project that will pair 100 identical multi-fibre spectrographs with a large array of telephoto lenses to achieve a large area integral field spectroscopy survey of the sky at the spatial resolution of half an arcminute and a spectral resolution of R=15,000, covering important emission lines in the optical for studying the ionised gas in the Milky Way and beyond. AMASE spectrographs will cover major optical emission lines, including Halpha, Hbeta, [NII] 6548,6583 A, [SII] 6716,6731 A, [OIII] 5007 A. AMASE will also cover [OI] 6300 A and HeII 4686 A. From these emission line maps of star-forming regions of the Milky way and local group of galaxies in sub-pc to sub-kpc resolution, AMASE will try to understand the physics of galaxy evolution via star formation and its feedback through measurements of emissivity profile, dust extinction, metallicity, ionization parameter, kinematic temperature and turbulence etc. among many others.

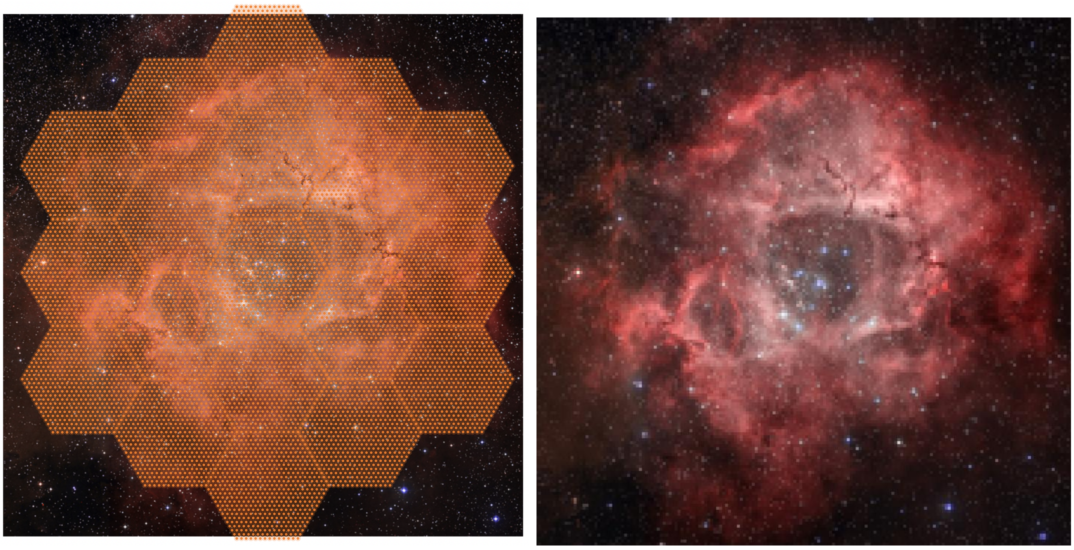

Figure 1: Left: AMASE-P footprint overlaid on the Rosette nebula. With 3 spectrographs, AMASE is going to cover the area with just 7 pointings including three dither positions per pointing. Right: Each pixel would provide separate spectra by AMASE.

2. Aims and objectives of the project

a. Instrumentation: Development of AMASE fiber instrument feed

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. SAAO astrophotonics group is currently involved in developing multiple instruments for telescopes hosted by SAAO/SALT and UCT. The group consists of professor, astronomer, post-doctoral fellow, and engineer members from SAAO and University of Wisconsin.

Two prototype demonstration versions of AMASE would be developed through the collaboration and installed in China and South Africa, namely AMASE North and AMASE South. SAAO astrophotonics group will be developing the fibre instrument cable (FIC) for both the AMASE North and South in collaboration with Chinese University of Hong Kong (CUHK). We aim to use the existing facilities and inputs from partner collaboration to perform design, fabrication, assembly and performance validation of the FIC. The detailed objectives are following:

i. 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.
ii. Develop and perform opto-mechanical assembly of fibers at the telescope end as an integral field unit. This involves fiber cleaving/polishing, fiber packing and glueing.
iii. Develop and perform opto-mechanical assembly of fibers at the spectrograph end as a slit assembly. This involves fiber cleaving/polishing, fiber packing and glueing.
iv. Design and assembly of fiber routing from telescope to spectrograph. This involves fiber sorting and fabricating minor tools using the existing 3D printer.
v. Characterization of fiber performance after assembly. This involves mapping of fibers and analysis of fiber optical properties via simple python or similar scripting language.

b. Science: Origins of the warm/diffuse ionized gas

The Wisconsin Hα Mapper (WHAM) mapped the Milky Way in Hα wavelengths, uncovering areas of star formation as well as warm, diffuse ionized gas (DIG), referred to as the Reynolds Layer. 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. Leakage of ionizing photons from mid-plane star-formation is one possibility, while in situ photo-ionization from hot evolved stars (metal-poor blue horizontal-branch or pAGB stars) is another. Shocks may be another ionization source.

AMASE will be able to discriminate between these ionization sources by targeting DIG regions at (i) varying distances from star-forming regions and at (ii) varying heights about the mid-plane with known gradients in evolved stellar populations. These lines of sight will be carefully chosen to be outside the solar circle where velocity information yields unique velocity-to-distance transformation. By examining the trends in ionization conditions in the DIG with HII region distance and mid-plane height, including line diagnostics sensitive to shock heating, we will aim to determine uniquely the contributions from different sources of DIG ionization.

The student would get to participate in defining the survey strategy to cover this science goal in the AMASE prototype survey and use proprietary data. The task would be to reduce and analyse the data to measure kinematics and understand the physics of ionization in sub-parsec scales by accurately modelling the strong emission lines.

3. Potential impacts of the project

Several astronomical research bodies including ESO, NASA are encouraging large dedicated surveys to use niche capabilities of instrumentation development to bridge the gap in our understanding of the universe. Along this line of exploration, AMASE survey would greatly advance our understanding of the physics of star formation. Some of the scientific impacts would include but not limited to:

a. Understanding of the source of warm/diffuse ionized gas
b. Better constraining the input spectral energy distribution leading to emission mechanism
c. Advancement of edge buttable 2D area spectrograph
d. Demonstration of small multi-mode fiber application in astronomy

4. Requirements

The student would require a basic grasp of any software language. Understanding of photonics or optical fiber is not necessary and will be built over the duration of the project. However, a keen interest and willingness to learn and apply the knowledge for solving practical problems would be important.