SURP Project

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It is believed that stars form by gravitational collapse of dense and cold structures located in molecular clouds. However, the process that leads to the formation of these over-densities is still unclear. Radiative condensation of the diffuse warm neutral medium (WNM) is a plausible mechanism for producing the cold neutral medium (CNM), and in turn the CNM, being denser, is thought to be a critical initial step leading the atomic-to-molecular (HI-to-H_2) transition. Huge efforts have been made to understand the formation of molecular gas, but the step that led to the formation of the cold HI still remains unclear. Numerical simulations abound. Furthermore, a large amount of data has been collected over the last decade and so we now have access to arcmin spatial resolution observations to study the transition.

Among these data sets, the GHIGLS 21-cm line survey at 10' resolution covers over 1000 deg^2 and gives us the possibility to look at different environments of the Galaxy. Some large areas of this have been studied at 1' resolution in the DHIGLS survey. The first goal of this admittedly open-ended project is to analyze the multiphase structure of intermediate latitude HI fields in these surveys.

In particular, to get started Mukesh will focus his work on analyzing GHIGLS data for "the Spider" and/or the URSA Major region ("UMA"), HI structures located at the disk halo interface that hint at and/or show the formation of molecular (H_2) gas.

As a very first step **specifically related to the computing course**, Mukesh will have the opportunity to probe the phase transition in HI by making use of the ROHSA multi-Gaussian decomposition code. This step will familiarize him with handling archival HI spectral data stored in data cubes, extracting spectra, and manipulating spectra (integrals, moments, etc.), as well as visualization. It will also introduce him to the ROHSA optimization tool for inverse problem solving applied to astrophysical observations such as the 21-cm line. **Specific tasks, the elements of "the assignment for the course," will be mapped out in separate documentation (see next page).**

In later steps, it will be possible to start a comparison with other tracers of the interstellar medium, such as the thermal emission by dust grains seen by the `Planck` and `Herschel` satellites. Among the many interesting questions for enquiry is the following: Does the thermal condensation shaping the neutral interstellar medium reveal any signature of a change in the properties of this dusty fluid (for example, an evolution of the dust emissivity)?

Through this scientific investigation, Mukesh will contribute to original research on some interesting astrophysical questions and will acquire a wide range of skills, from new statistical tools (ROHSA) to new programming languages (LaTeX, python) and management tools (GitHub, Overleaf).

Develop a python notebook for the following.

1. Download the cube for the designated field
2. Load the cube.
3. Extract one spectrum. Plot it. Make sure that it has both low and intermediate velocity gas (2 main peaks). Otherwise, find another that does! (here, something like a cube previewer might help – please consult).
4. Compute the first three (velocity) moments. Express the integral in units of HI column density.
5. Like 4, but first divide the spectrum into two sensible velocity ranges for which the moments make more sense.
6. Measure the noise from the “end channels.”
7. Using a least-squares curve fitter (from python library), fit two Gaussians, one for each velocity range. Plot the fitted curve and the residual spectrum (data - model).
8. Understand (derive) the relation between the dispersion of the Gaussian and the FWHM. Express the FWHM of the Gaussian in units of temperature rather than km/s.
9. Extract a small section of the cube, say 20 by 20 pixels across the face. Compute and plot the average spectrum.
10. What is the noise in the average spectrum comapred to a single spectrum?
11. Repeat 7 and 8 for the average spectrum.
12. Use ROHSA to decompose the spectra across this small region. Use 2 or more components as needed.
13. Visualize the ROHSA output using the standard plotting tools (e.g., in the sample ROHSA notebook).