Classifying and interpreting marginally resolved or unresolved detections in HI surveys

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Section A: Overview of the Research Project Proposal

1. Title of the research project:

Classifying and interpreting marginally resolved or unresolved detections in HI surveys

2. Broad field of research:

Astrophysics

3. Academic level of the research project:

PhD

4. Research project abstract/summary:

Traditionally, the physical interpretation of HI spectra of unresolved or marginally resolved galaxies is restricted to utilize the systemic velocity, the velocity widths, the amplitude and the integrated total flux. Here we aim to add two elements: (1) the shape of the integrated galaxy HI spectra (e.g., Westmeier et al. 2014) and (2) the HI mass - diameter relation of galaxies (Wang et al. 2016). The latter can be used to derive the expected galaxy HI diameter and therefore the number of resolution elements, facilitating the analysis of HI position-velocity diagrams. Furthermore, by using ancillary data (e.g. optical images), which do not even have to have an extremely high quality, stellar properties can be used to inform the galaxy orientation and morphology, shape and amplitude of the rotation curve, all of which contribute to the shape of the integrated HI spectra. In this PhD project, the student will investigate the possibility to physically interpret the spectral shape of HI detections, as well as to statistically maximise the scientific output when interpreting marginally resolved HI detections.

5. Primary supervisor's details

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Section B: Details of Research Project

1. Scientific merit

Future blind and targeted HI surveys with MeerKAT, and other SKA progenitor surveys will provide a large amount of resolved detections of galaxies in the HI emission line, for which a detailed analysis of the rotation curve, the orientation of the disk, and other parameters is possible. The vast majority of the detected galaxies, however, will be unresolved or marginally resolved, having diameters less than two resolution elements.

While the basic parameters, the line width and the total flux already allow to investigate the rotational amplitude (in combination with ancillary data) and the HI mass, the data contain, at least on a statistical basis, much more information. For example, the shape of the rotation curve determines whether the profile is centrally peaked (for e.g. solid-body rotation curves) or whether it has the typical double-horn shape (for flat rotation curves). At the same time, the shape is also influenced by other parameters, physical and geometrical, for example the warping of the outer HI disk. The centrally peaked profile would also turn up for a single rotating ring (a physical property) or for a more face-on orientation (a purely geometrical property). These parameters are hence correlated.

It should be possible to infer more information about these systems and break these degeneracies using ancillary data (the optical luminosity, e.g., will also inform about the rotational amplitude via the Tully-Fisher-Relation, which can be used to gain information about the shape of the rotation curve). Also, if more than one resolution element is available, this could be used to break degeneracies even better.

The candidate will have the task to investigate and catalogue how much information truly can be extracted from integrated HI spectra and marginally resolved data cubes. The analysis will involve simulated data from one of our simulation tools (TiRiFiC, PyFAT) as well as available data of well-resolved galaxies which will be degraded to marginally resolved. This allows an accurate study of degeneracies between galaxy parameters (describing well-resolved galaxies) when interpreting spectra. Once this is accomplished, we will turn to real surveys with MeerKAT and other telescopes (MALS, WALLABY, to which we have direct access, but also other MeerKAT publicly available data) to interpret the spectra of marginally resolved galaxies in those surveys.

This is a project for a candidate who is familiar with statistical methods and has experience in writing software programs. If successful, it can be applied to a vast number of detections in future surveys.

2. Feasibility and resources

The spectral line data needed for this Ph.D. project are partly being gathered as part of MALS, a MeerKAT Key Science Project (Co-supervisor Gupta is co-PI of MALS). With 400 pointings already observed in L-band we will have observed sufficient pointings to finalise the project. The recent publications in the context of MALS (see https://mals.iucaa.in/) show that science quality data will be available for the project. See Gupta et al. 2016 for a description of MALS HI emission line survey.

RATT/RARG is in possession of several high-performance compute clusters and sufficient storage, such that there are sufficient resources to analyse the data. While a data cube as produced by MeerKAT can be very large, only a small fraction of it will be used for the proposed analysis.

IUCAA is in possession of a compute cluster VROOM to process MALS data. The student will also have access to this cluster if required.

3. SARAO research priority areas

This project is addressing the following SARAO priority areas, ordered by relevance, from top to bottom:

- Data projected to be available by 2021-22 from key existing radio astronomy instruments located in South Africa, with MeerKAT having the highest priority: this is a MeerKAT project.

4. Student academic abilities / skills required

The student should have the ability to write Python scripts and be proficient in Physics. Some experience with the analysis of radio astronomical data, in particular data cubes is highly recommended. Experience in the kinematical and dynamical analysis of galaxies is welcome.