Characterizing the Physical State of Neutral Hydrogen in the Milky Way and Magellanic System using GASKAP-HI

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Atomic neutral hydrogen (HI) is a key component of the interstellar medium (ISM) as it provides the raw fuel for star formation, which ultimately drives galaxy evolution. HI is thermally bi-stable, meaning two distinct phases exist at the same thermal pressure: the cold neutral medium (CNM) with kinetic temperatures ~100 K and a warm neutral medium (WNM) with temperatures ranging from 5000 K to 8000 K. The relative fraction of CNM to WNM, which is traced by conjoined analysis of HI emission lines and HI absorption, is an important ISM property since regions with high CNM fractions trace the dense cold conditions needed for the gravitational collapse of gas to form stars. However, the spatial distribution of the CNM fraction has historically been difficult to measure due to the need for strong background continuum sources to provide the radiation for intervening CNM clouds to absorb that also are serendipitously placed behind areas of strong HI emission.

The HI component of the Galactic ASKAP Survey (GASKAP-HI) is producing high-resolution, high-sensitivity, and wide-field (~25 deg^2) maps of the distribution of HI in the nearby Magellanic System and our own Milky Way. The high sensitivity is only possible due to the 36 simultaneous, electronically formed primary beams that expand the field-of-view (FoV) of ASKAP to approximately 25 deg^2. This large FoV captures many necessary background continuum sources in each field, facilitating detailed studies into the spatial distribution of the CNM fraction. It also enables long integration times to provide the preeminent view into how gas dynamics (e.g., accretion and cloud-to-cloud interactions) and ISM turbulence influence star formation and shape the overall ISM lifecycle.

Pilot observations of several fields centered on the Small and Large Magellanic Clouds (SMC and LMC, respectively), Magellanic Bridge, and Galactic Plane were undertaken in 2022. In addition to showcasing the latest high-resolution and high-sensitivity images of HI emission from these pilot observations, this article summarizes several early science results including the detection of the cold neutral medium out to Galactic radii of ~40 kpc [1] and revised CNM fractions in the SMC [2].

The proximity of our science targets results in extended emission that crosses the boundaries of multiple primary beams. Thus, to ensure accurate reconstruction of the large-scale emission, we require a joint deconvolution approach wherein visibilities from all 36 beams are gridded unto the same large-scale grid before continuing to deconvolution to remove typical instrumental artifacts (e.g., sidelobe structure in the point spread function) known to afflict interferometric images. In addition to the science results, this paper will also summarize the imaging pipeline that is designed to run on a generic computing cluster to address the technical challenges of imaging visibilities from 36 simultaneous beams with joint deconvolution. Tackling these technical challenges before the next generation of arrays, such as the Square Kilometre Array and Next Generation Very Large Array, is essential to avoid potential bottlenecks in generating science quality data products.

References

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