Unveiling galaxy evolution in the group environment and the diffuse intragroup medium

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We propose to map the HI content of a dark matter halo mass- and volumetrically-complete set of 100 galaxy groups with ALPACA to gain the most complete census of the diffuse intragroup medium (IGM) to date. Galaxy groups are an important site of environmentally driven galaxy evolution where a variety of physical mechanisms act to both stimulate star formation within galaxies, and to remove the cold gas reservoir from galaxies thereby quenching it. As the environment in which the majority of galaxies live, groups are also where they undergo the majority of their evolution. The neutral atomic hydrogen (HI) component of galaxies is a critical tracer of these environmental interactions: deep HI observations reveal ongoing gravitational and hydrodynamic interactions through appearance of tidal tails, intragroup HI clouds, and signatures of starvation or ram pressure stripping. However, little is known about the frequency of interactions between galaxies in groups, how the frequency and importance of these processes vary with dark matter halo mass, or what the fate of the gas is in these interactions--for example the survival rate of HI clouds in the IGM. Recent studies show that large HI tails and intragroup clouds may be more common in the group environment than has previously been recognized (e.g. Leisman et al 2016; Hess et al 2017; Oosterloo et al 2018) and that they may survive longer than predicted by analytic arguments (Hess et al 2017). GBT observations have further suggested a diffuse HI component exists in groups that has been missed by interferometric studies (e.g. Borthakur et al 2010). Thus, deep HI observations are critical to understanding the role of the group environment in shaping the galaxy populations we see today.

The recently completed Apertif HI survey with the upgraded Westerbork Synthesis Radio Telescope is the first wide-area survey to provide a resolved view of HI in galaxy groups across a broad range of group dark matter halo mass ($10^{12\text{-}14.5}$ M_{Sun}) and group dynamical age, achieving HI column densities of a ~10^{20} cm^{-2} over thousands of square degrees. While Apertif provides an unbiased census of HI *in* galaxies across a range of environments, observations with ALPACA are required to achieve the surface brightness sensitivity to gain a full census of HI in groups and the signatures of environmental interactions. Apertif has mapped the HI content in ~100 known galaxy groups, which we propose to target with ALPACA. We aim to map regions ~2x2 deg^2 around each group to 5x10^{17} cm^{-2} at the 5 sigma level over 25 km/s. A single group will take ~4.3 hours with ALPACA, and allow the detection of extended HI tails and diffuse HI clouds in the IGM, linking them with group members and ongoing environmental processes. Achieving these depths for a statistically significant number of groups over a range of dark matter halo masses and dynamical states, will provide the most complete understanding of the baryonic cycle and the dynamic lives of galaxies in the group environment to date, and allow us to fully quantify the amount of intragroup HI for the first time. ALPACA will make this possible with only ~430 hours of observing. These ALPACA+Apertif HI maps, combined with future X-ray observations of the hot IGM by Athena, and observations of AGN sightlines from COS on HST will give us a complete view of the baryonic cycle between galaxies and the circumgalactic and intragroup mediums.