Discovery of a neutral hydrogen halo surrounding the Whale galaxy

BY A/PROF. JING WANG (PEKING UNIVERSITY) AND PROF. LISTER STAVELEY-SMITH (ICRAR)

Observations with China's Five-hundred-metre Aperture Spherical Telescope (FAST) have helped to shed new light on the process that forms galaxies from diffuse gas.

A team led by scientists at Peking University combined the FAST observations with data from the Westerbork Synthesis Radio Telescope (WSRT) in the Netherlands in the study. The results have been published in The Astrophysical Journal.

By combining the sensitivity of FAST with the resolution of the WSRT, they were able to image vast amounts of diffuse gas surrounding the galaxy group known as NGC 4631, and observe a previously unseen "halo" component that may have resulted from cooling of the ionised gas widely surrounding galaxies.

Galaxies like our Milky Way were not built in a day. Instead, they had been growing gradually by accreting surrounding hydrogen gas to form stars. Yet most of the hydrogen, as the basic chemical element, still floats in the vast Universe in the form of gas. A fundamental question in astronomy is why and how does this hydrogen gas accrete onto galaxies, and what are the obstacles limiting the rate of accretion?

To answer this question, the hydrogen gas needs to be traced on extremely large scales – the size of a dark matter halo that provides most of the gravity to form galaxies – to much smaller ones, comparable to a star-forming gaseous clump.

Neutral hydrogen (HI) can provide crucial clues on both scales. On the scale of dark matter halos, HI observations strongly constrain the temperature and pressure conditions of gas accretion, while on sub-galactic scales, the observations constrain the physical conditions within the galactic disks where stars are formed.

Traditional interferometric radio telescopes (which use multiple antennas acting as one telescope) have been very helpful in mapping the neutral hydrogen in nearby galaxies with a resolution sufficient to resolve star-forming clumps, but they struggle to simultaneously capture the more diffuse and extended neutral hydrogen. This is because interferometers have less sensitivity at large spatial scales, where the signals are confined to the very shortest baselines.

The SKA telescopes, with many antennas in the core and short baselines between them, will be able to simultaneously resolve structures of many sizes. In the meantime, the most promising way is using large single-dish radio telescopes, in conjunction with interferometers, to fill in the "gaps" and detect and resolve the large-scale missing hydrogen.

The image below highlights a successful effort in this direction, combining data from the currently largest single-dish telescope, FAST in China, with the deepest interferometric data so far from the HALOGAS survey taken by the WSRT.

The combined data reveals a newly detected neutral hydrogen halo in dark blue around the dense neutral hydrogen disk in light blue of the galaxy NGC 4631, also known as the Whale. The neutral gaseous halo, which previously has mostly been seen only in numerical simulations, marks a possible transitional stage between the hotter, ionised halo gas and the cool, neutral disk gas. This halo-like shape suggests that the hydrogen gas does not abruptly shift between the two phases, at least in this system, but first enters a "warm" state which has not been observed before.

This finding suggests a new world to be discovered in galactic neutral hydrogen science with the ongoing efforts of building new radio instruments, including the SKA telescopes.

BELOW: *A false colour image demonstrating the NGC 4631 group and its HI gas. On top of the optical image, the blue-coloured halo shows the diffuse gas imaged by FAST, while the light-blue finer structures are denser gas previously detected in the WSRT HALOGAS (Heald et al. 2011) observation. Credit: Jing Wang*