What would the Magellanic Clouds have evolved into, were they far from the Milky Way?

by Sarah Pearson, George C. Privon and Gurtina Besla.

Our close neighboring galaxies, the Magellanic Clouds (see Figure 1), are readily visible to the naked eye and have long been known to human civilizations across the southern hemisphere, playing important roles in their mythology and culture. The Large and Small Magellanic Clouds are classified as "dwarf galaxies", and they have a factor of ~20 and ~200 fewer stars than the Milky Way respectively. The two dwarfs have likely interacted with each other for several billion years, and are only now, for the first time, passing close by our Galaxy[1]. Several astronomers have modeled their evolution, but due to their close proximity to the Milky Way it has been difficult to disentangle their previous interaction history and ultimate fate. Studies of their motion through space indicate that the two dwarf galaxies won't remain bound as a pair after their close pass with the Milky Way[2], which can help explain why it's rare to observe Magellanic Cloud analogs around other Milky Way-type galaxies[3].

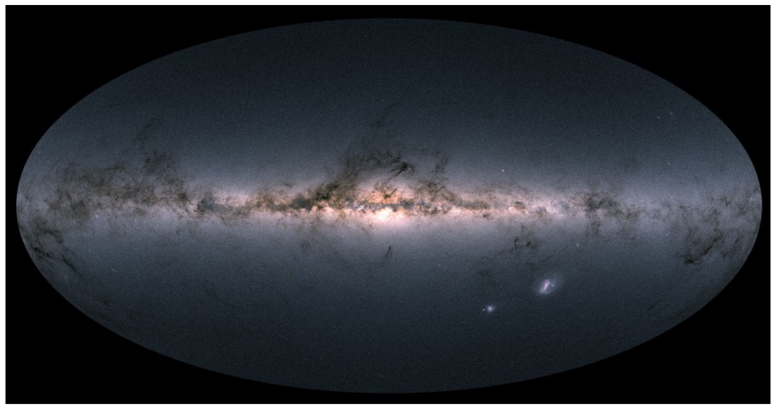

Fig 1: The Milky Way Galaxy as seen by the Gaia space telescope, along with the Large and Small Magellanic Clouds (see two bright galaxies, bottom right). Credit: Gaia Data Processing and Analysis Consortium (DPAC) / A. Moitinho / A. F. Silva / M. Barros / C. Barata (Univ. of Lisbon, Portugal) / H. Savietto (Fork Research, Portugal).

In a new article submitted for publication in the Monthly Notices of the Royal Astronomical Society[4], lead by Columbia University PhD student, Sarah Pearson, the authors investigate a pair of dwarf galaxies, NGC 4490 & NGC 4485 which are similar to the Magellanic Clouds, but far from any more massive galaxy. Their isolated environment enables the authors to investigate the single effect of the mutual interaction between two dwarfs. This allows them to ask: what would the Magellanic Clouds have evolved into, had they not been close to the Milky Way? Interpreting these types of interactions has important implications for understanding galactic growth in the early Universe, where galaxies are thought to build their mass by colliding with other galaxies and by accreting smaller systems. In fact, the Milky

Way is still devouring smaller galaxies at present day.

The NGC 4490 & NGC 4485 pair has a gaseous envelope extending more than 160,000 light years across in projection (see Figure 2) and resemble the Magellanic Clouds in that they have a similar mass ratio (the larger galaxy has roughly 8 times more stars than the smaller galaxy), they have a stellar and gaseous bridge connecting them, and they have a large amount of gas in their close vicinity.

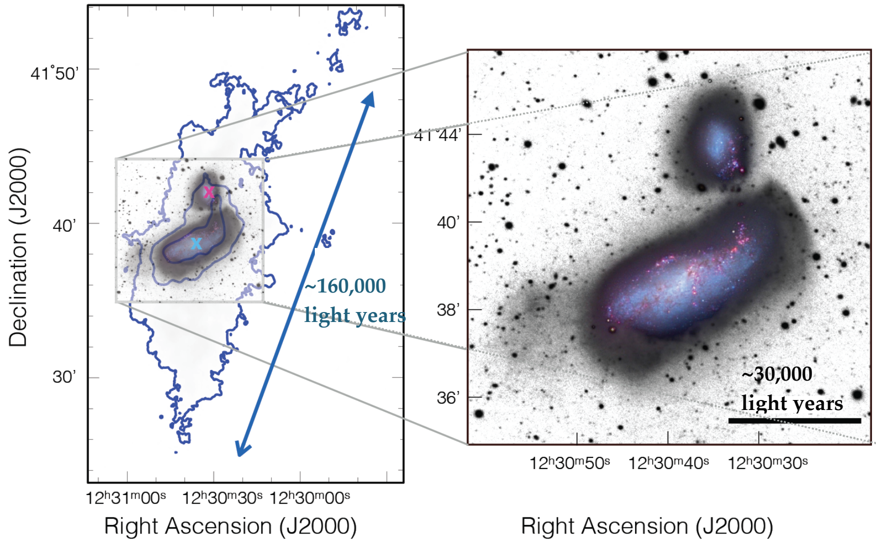

Fig 2: Left: Gaseous envelope surrounding the pair (blue) Right: stellar distribution of NGC 4490 (large) and NGC 4485 (small). Credit: Pearson et al 2018, MNRAS.

As galaxies collide a gravitational tidal interaction unfolds, leaving behind dynamical tracers that persist for several billion years. Using computer simulations (see Figure 3) of galaxy encounters and matching these to the velocity structures and distribution (morphology) of the actual gas in the data, the authors find that the smaller galaxy has plowed through the disk of the larger galaxy less than 300 million years ago, and that the two galaxies will fully merge and become one larger galaxy in only ~370 million years, which is quite a short time compared to galactic timescales. For comparison it takes the Sun roughly 200 million years to complete one orbit around our own Galaxy.

Simulation of a NGC 4490/85 type encounter showing ~2 billion years of evolution. Credit: Pearson et al. 2018, MNRAS.

This is the first match to observations of a galactic encounter between two isolated, interacting low mass galaxies, providing the authors the ability to constrain the pair's past interaction and future fate. With a model matched to an observed system, the authors investigated the timescales involved in cycling gas from the large extended gas envelope back into the galactic remnant. They find that the gas surrounding the two dwarfs is shed to large distances mainly from the small galaxy, due to its galactic disk spin being aligned with the orbital spin. Additionally, they find that the gas will remain extended for several billion years before most of it will return to the merger remnant potentially fueling new star formation.

The fact that the gas remains extended for several billion years, will allow the large gaseous envelope to be stripped very efficiently if the remnant were to fall into a more massive galaxy later in its lifetime. This scenario is exactly what astronomers believe has been the case for the Magellanic Clouds: the two galaxies likely had a very extended gas envelope prior to falling into the Milky Way, explaining the enormous amount of gas deposited to the Milky Way's halo[5,6]. A large percentage of dwarf galaxies appear to fall into more massive systems as pairs and groups[7], and if their gas is already extended due to their prior interaction[8], this can help astronomers explain why gas is stripped so efficiently from galaxies residing close to the Milky Way. Additionally, the long timescales can explain why astronomers observe isolated dwarf galaxies without companions far from anything else, with huge gas envelopes but not much star formation[9]. Maybe they had a merger in the past and are now slowly re-accreting the gas? The authors plan to model similar interactions in the future to build a statistical picture of dwarf-dwarf interactions.

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