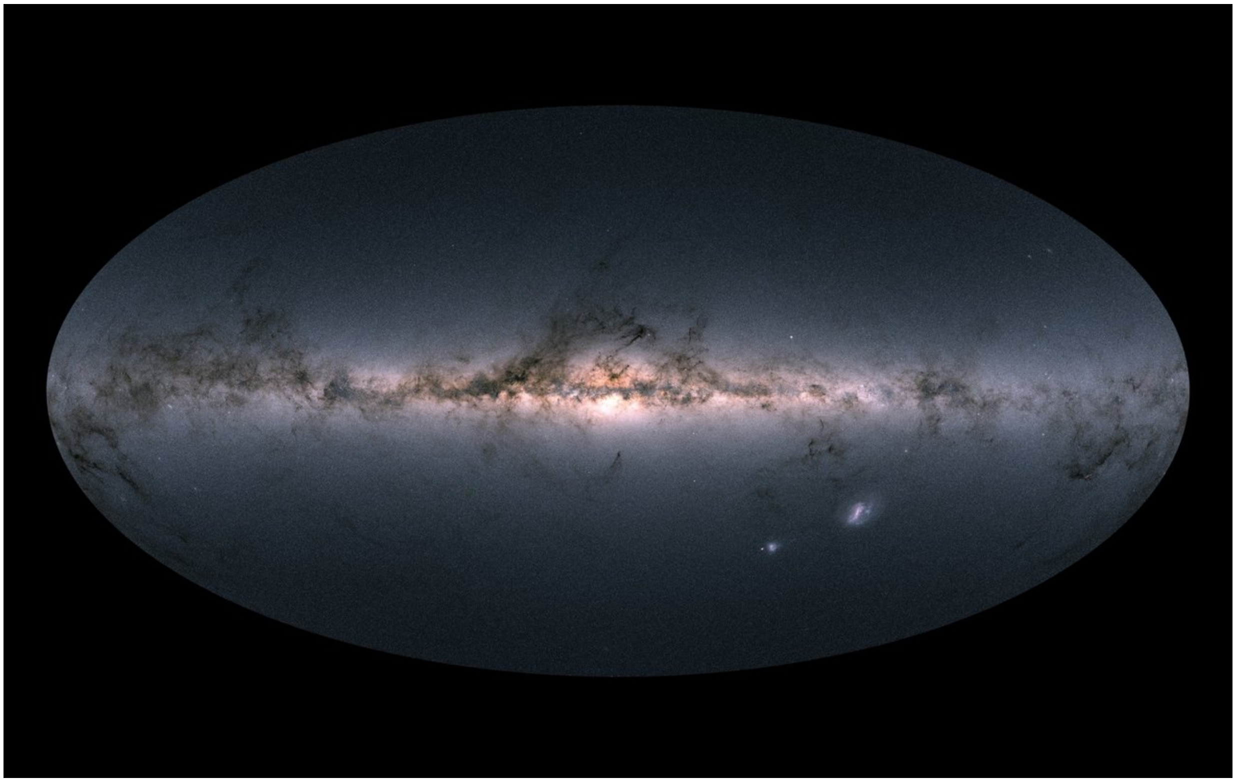
Narrowing down the mass of the Milky Way

September 21 2018



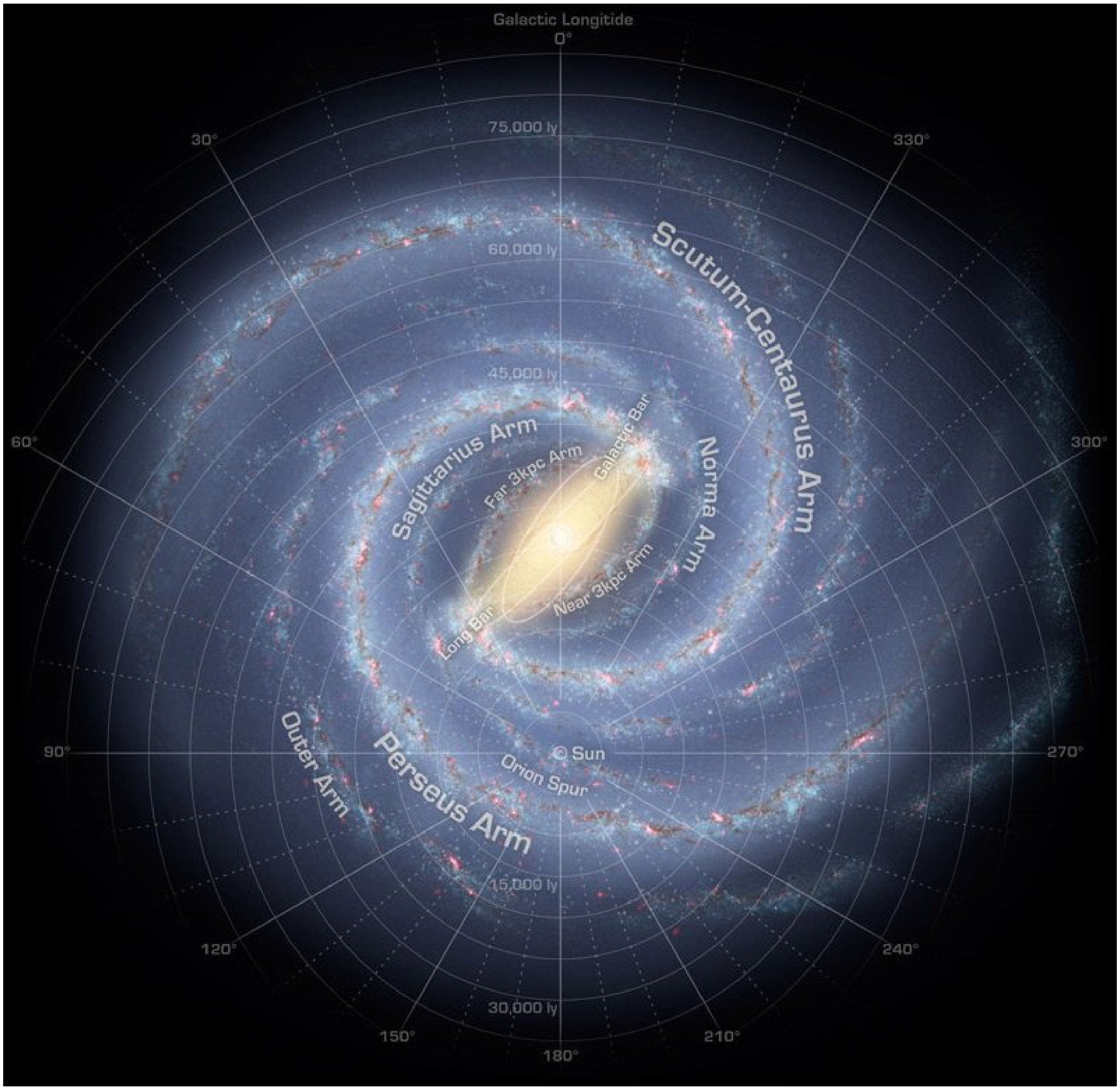
Credit: NASA

Since the birth of modern astronomy, scientists have sought to determine the full extent of the Milky Way galaxy and learn more about its structure, formation and evolution. At present, astronomers estimate that it is 100,000 to 180,000 light-years in diameter and consists of 100 to 400 billion stars – though some estimates say there could be as many as 1 trillion.

And yet, even after decades of research and observations, there is still much about our galaxy astronomers do not know. For example, they are still trying to determine how massive the Milky Way is, and estimates vary widely. In a new study, a team of international scientists presents a new method for weighing the galaxy based the dynamics of the Milky Way's satellites galaxies.

The study, titled "The mass of the Milky Way from satellite dynamics," recently appeared in the *Monthly Notices of the Royal Astronomical Society*. The study was led by Thomas Callingham from the University of Durham's Institute of Computational Cosmology, and included members from the Massachusetts Institute of Technology (MIT), the Heidelberg Institute for Theoretical Studies, and multiple universities.

As they indicate in their study, the mass of the Milky Way is fundamental to our understanding of astrophysics. Not only is it important in terms of placing our galaxy into the context of the general galaxy population, but it also plays a major role when addressing some of the greatest mysteries that arise from our current astrophysical and cosmological theories.



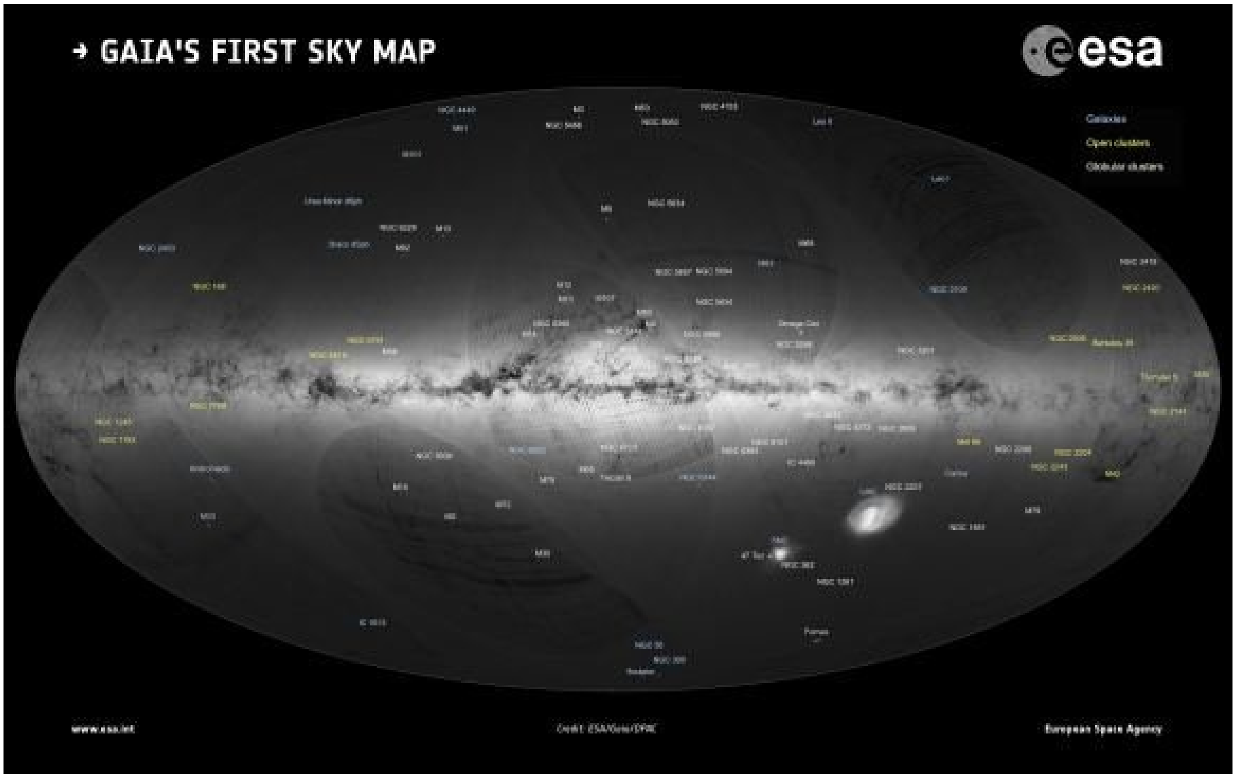
Artist's impression of the Milky Way Galaxy. Credit: NASA/JPL-Caltech/R. Hurt (SSC-Caltech)

These include the intricacies of galaxy formation, discrepancies with the current Lambda Cold Dark Matter (Lambda CDM) model, alternative theories on the nature of dark matter, and the large-scale structure of the universe. What's more, previous studies have been hampered by a number of factors, which include the fact that the Milky Way's dark matter halo (which makes up most of its mass) cannot be observed directly.

Another major issue is the fact that it is difficult to measure the extent and mass of the Milky Way because we are within it. As a result, previous studies that have attempted to infer the mass of our galaxy resulted in mass estimates ranging from about 500 billion to 2.5 trillion times the mass of our sun (solar masses). As Callingham explained to universe Today via email, refined approach was needed:

"The majority of the galaxy is in its dark matter halo, which cannot be directly observed. Instead, we infer its properties through observations of various dynamical tracers that feel the gravitational effects of the dark matter – such as stellar populations, globular clusters, steams and satellite galaxies. Most of these lie at the center of a our galaxy in the the galactic disc (within ~10kpc) and the stellar halo (~15kpc) which can give good mass estimates of the inner region. However the DM halo reaches ~200kpc, and for this reason we chose to focus on satellite galaxies, as one of the only tracers that probe these outer parts of the galaxy."

For the sake of their study, the team relied on data from the Gaia satellite's second data release (DR2 release) to place better constraints on the Milky Way's mass. The Gaia mission, which has provided more information than ever before about our galaxy, includes the position and relative motions of countless stars in the Milky Way – including those that are in satellite galaxies. As Callingham indicated, this proved very useful for constraining the mass of the Milky Way:



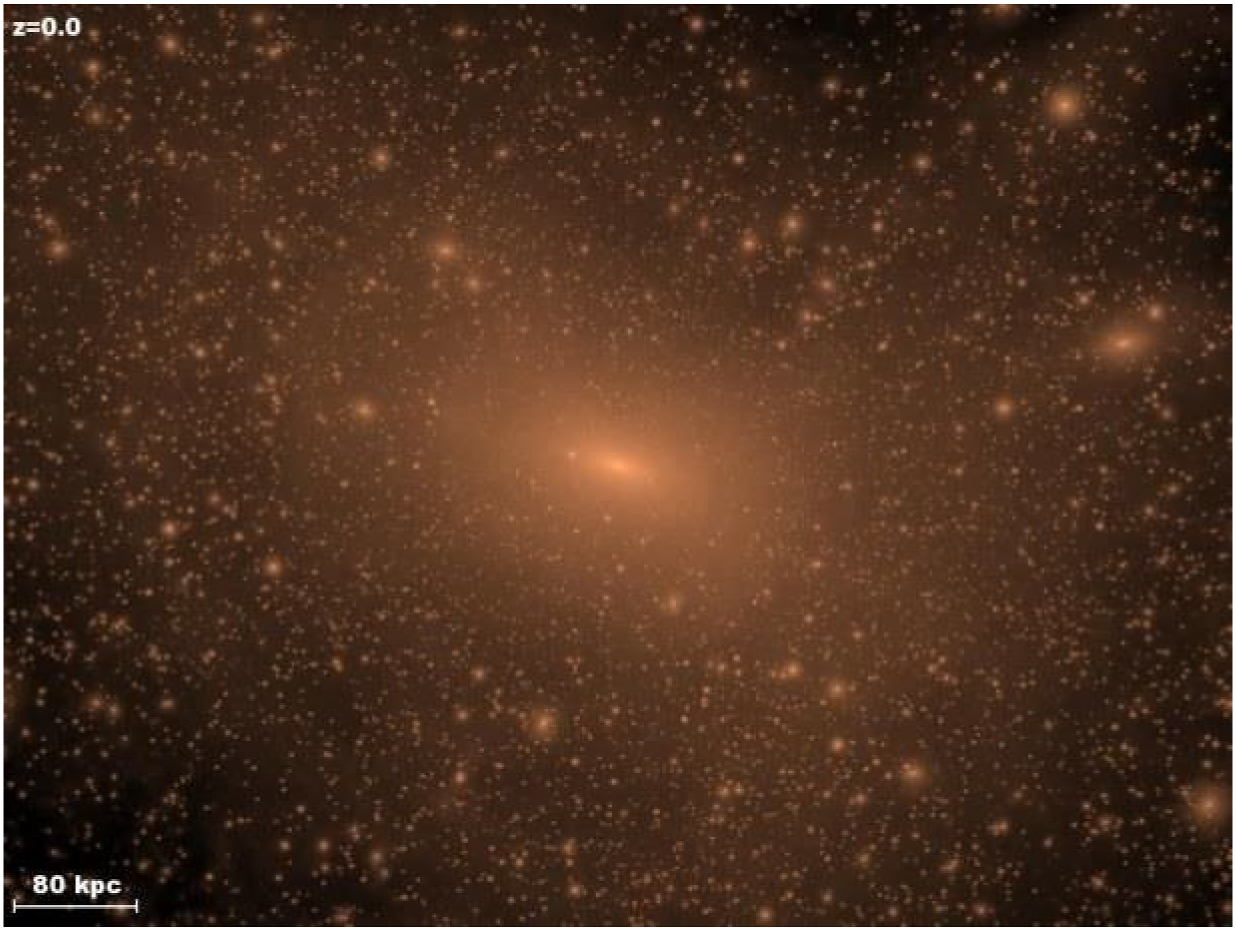
The Gaia mission’s first sky map. Credit: ESA / Gaia / DPAC / A. Moitinho & M. Barros, CENTRA – University of Lisbon.

"We compare the orbital properties Energy and Angular Momentum of the MWs satellite galaxies to those found in simulations. We used the latest observations of the MWs satellites from the recent Gaia DR2 dataset and a sample of suitable galaxies and satellite galaxies from the EAGLE simulations, a leading simulation ran in Durham with a large volume and full hydrodynamical baryonic physics."

The EAGLE software (Evolution and Assembly of GaLaxies and their Environments), which was developed by Durham University's Institute of Computational Cosmology, models the formation of structures in a cosmological volume measuring 100 Megaparsecs on a side (over 300 million light-years). However, using this software to infer the mass of the Milky Way presented some challenges.

"A challenge to this is the limited sample of MW size galaxies in EAGLE (or indeed any simulation)," said Callingham. "To help this we use a mass scaling relation to scale our total sample of galaxies to be the same mass. This allows us to effectively use more from our dataset and greatly improves our statistics. Our method was then rigorously tested by finding the mass of simulated galaxies from EAGLE and the Auriga simulations – an independent suite of high resolution simulations. This ensures that our mass estimate is robust and has realistic errors (something the field sometimes struggles with due to analytic assumptions)."

From this, they found that the total halo mass of the Milky Way was about 1.04 x 1012 (over 1 trillion) solar masses, with a 20 percent margin of error. This estimate places much tighter constraints on the Milky Way's mass than previous estimates, and could have some significant implications in the fields of astronomy, astrophysics and cosmology. As Callingham summarized:



All galaxies are thought to have a dark matter halo. This image shows the distribution of dark matter surrounding our very own Milky Way. Image credit: J. Diemand, M. Kuhlen and P. Madau (UCSC)

"A tighter mass estimate can be used in many ways. In galaxy modelling, the DM halo is the backdrop on which stellar components are fit. Many methods to probe the nature of DM, such as the structure of the DM halo, as well as the density of DM on Earth for direct detection purposes depend on the mass of the MW. The mass can also be used to predict the number of satellite galaxies around the MW that we expect."

In addition to providing astronomers with refined measurements of the

Milky Way's mass – which will go a long way towards informing our understanding of its size, extent, and satellite galaxy population – this study also has implications for our understanding of the universe as a whole. What's more, it is yet another groundbreaking study that was made possible through Gaia's second data release.

The third release of Gaia data is scheduled to take place in late 2020, with the final catalog being published in the 2020s. Meanwhile, an extension has already been approved for the Gaia mission, which will now remain in operation until the end of 2020 (to be confirmed at the end of this year).

More information: The mass of the Milky Way from satellite dynamics. arxiv.org/pdf/1808.10456.pdf

Source Universe Today

Citation: Narrowing down the mass of the Milky Way (2018, September 21) retrieved 26 April 2024 from https://phys.org/news/2018-09-narrowing-mass-milky.html