Footprints of 'galactic immigration' uncovered in Andromeda galaxy

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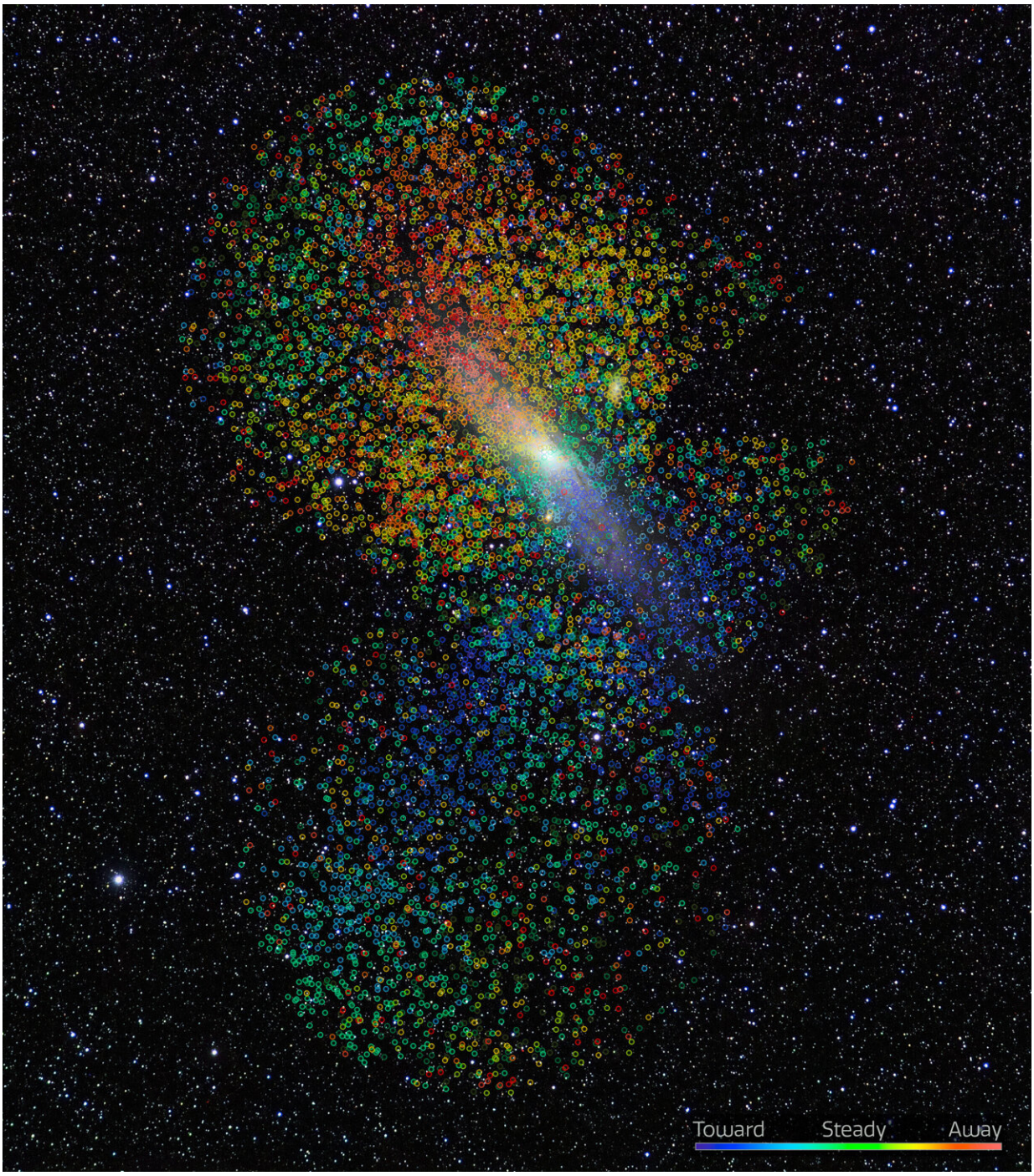

Striking new evidence for a mass immigration of stars into the Andromeda Galaxy has been uncovered by researchers led by astronomers at NSF's NOIRLab. The team used the DOE's Dark Energy Spectroscopic Instrument on the Nicholas U. Mayall 4-meter Telescope at Kitt Peak National Observatory, a Program of NSF's NOIRLab, to reveal intricate structures in this galaxy with

unprecedented detail and clarity. Each of the dots on this image represents an individual star in the Andromeda Galaxy, with the motion of the star (relative to the galaxy) color-coded from blue (moving toward us) to red (moving away from us). Credit: KPNO/NOIRLab/AURA/NSF/E. Slawik/D. de Martin/M. Zamani

Over the course of billions of years, galaxies grow and evolve by forging new stars and merging with other galaxies through aptly named "galactic immigration" events. Astronomers try to uncover the histories of these immigration events by studying the motions of individual stars throughout a galaxy and its extended halo of stars and dark matter. Such cosmic archaeology, however, has only been possible in our own galaxy, the Milky Way, until now.

An international team of researchers has uncovered striking new evidence of a large galactic immigration event in the Andromeda Galaxy, the Milky Way's nearest large galactic neighbor. The new results were made with the DOE's Dark Energy Spectroscopic Instrument (DESI) on the Nicholas U. Mayall 4-meter Telescope at Kitt Peak National Observatory, a Program of NSF's NOIRLab.

By measuring the motions of nearly 7500 stars in the inner halo of the Andromeda Galaxy, also known as Messier 31 (M31), the team discovered telltale patterns in the positions and motions of stars that revealed how these stars began their lives as part of another galaxy that merged with M31 about 2 billion years ago. While such patterns have long been predicted by theory, they have never been seen with such clarity in any galaxy.

"Our new observations of the Milky Way's nearest large galactic neighbor, the Andromeda Galaxy, reveal evidence of a galactic immigration event in exquisite detail," explained Arjun Dey, astronomer

at NSF's NOIRLab and the lead author of the paper presenting this research. "Although the night sky may seem unchanging, the Universe is a dynamic place. Galaxies like M31 and our Milky Way are constructed from the building blocks of many smaller galaxies over cosmic history."

"We have never before seen this so clearly in the motions of stars, nor had we seen some of the structures that result from this merger," said Sergey Koposov, an astrophysicist at the University of Edinburgh and co-author of the paper. "Our emerging picture is that the history of the Andromeda Galaxy is similar to that of our own Galaxy, the Milky Way. The inner halos of both galaxies are dominated by a single immigration event."

This research sheds light on not only the history of our galactic neighbors but also the history of our own galaxy. Most of the stars in the Milky Way's halo were formed in another galaxy and later migrated into our own in a galactic merger 8–10 billion years ago. Studying the relics of a similar, but more recent, galaxy merger in M31 gives astronomers a window onto one of the major events in the Milky Way's past.

To trace the history of migration in M31, the team turned to DESI. DESI was constructed to map tens of millions of galaxies and quasars in the nearby Universe in order to measure the effect of dark energy on the expansion of the Universe. It is the most powerful multi-object survey spectrograph in the world, and is capable of measuring the spectra of more than 100,000 galaxies a night. DESI's world-class capabilities can also be put to use closer to home, however, and the instrument was crucial to the team's survey of M31.

"This science could not have been done at any other facility in the world. DESI's amazing efficiency, throughput, and field of view make it the best system in the world to carry out a survey of the stars in the Andromeda Galaxy," said Dey. "In only a few hours of observing time,

DESI was able to surpass more than a decade of spectroscopy with much larger telescopes."

Even though the Mayall Telescope was completed 50 years ago (it achieved first light in 1973), it remains a world-class astronomical facility thanks to continued upgrades and state-of-the-art instrumentation. "Fifty years sounds like a long time, and naïvely one might think that's the natural lifetime of a facility," said co-author Joan R. Najita, also at NOIRLab. "But with renewal and reuse, a venerable telescope like the Mayall can continue to make amazing discoveries despite being relatively small by today's standards."

The research was carried out in collaboration with two Harvard University undergraduates, Gabriel Maxemin and Joshua Josephy-Zack, who connected with the project through the Radcliffe Institute for Advanced Study. Najita was a Radcliffe Fellow from 2021 to 2022.

The team now plans to use the unparalleled capabilities of DESI and the Mayall Telescope to explore more of M31's outlying stars, with the aim of revealing its structure and immigration history in unprecedented detail.

"It's amazing that we can look out at the sky and read billions of years of another galaxy's history as written in the motions of its stars—each star tells part of the story," concluded Najita. "Our initial observations exceeded our wildest expectations and we are now hoping to conduct a survey of the entire M31 halo with DESI. Who knows what new discoveries await."

The research is forthcoming in *The Astrophysical Journal*.

More information: DESI Observations of the Andromeda Galaxy: Revealing the Immigration History of our Nearest Neighbor, *The*

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