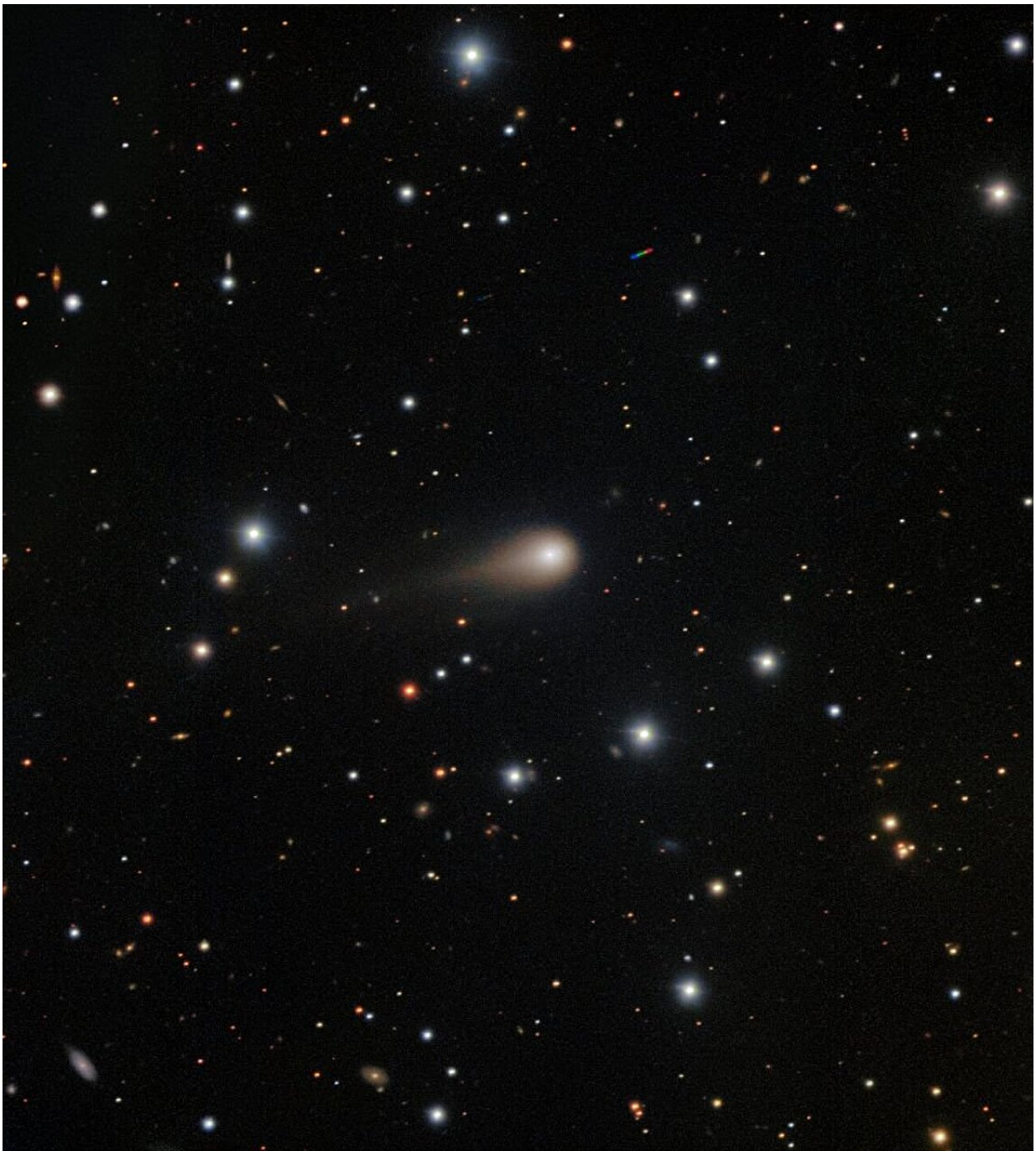
Where did the interstellar comet 3I/ATLAS come from?

September 12 2025, by Evan Gough



The Gemini South Observatory captured this image of the interstellar comet 3L/ATLAS on August 27th. It shows the object's fuzzy coma and tail, made of volatiles released by the sun's heat. Credit: International Gemini Observatory/NOIRLab/NSF/AURA/Shadow the Scientist, CC BY 4.0

Comet 3I/ATLAS is the third ISO ever detected. It was discovered by the Asteroid Terrestrial-impact Last Alert System (ATLAS) station on 1 July 2025. It's traveling through the inner solar system at about 220,000 km/h and will make its closest approach to the sun in late October.

Multiple telescopes have observed it, including the JWST, and will continue to observe it. Interplanetary missions like the Jupiter Icy Moons Explorer (JUICE) and Mars Express will also get a crack at it in the future. NASA's Juno may even observe it from its mission to the Jovian System.

None of these observations, as important as they are, will reveal where 3L/ATLAS came from. But another mission, now ended, might be able to illuminate the path it took to reach us: Gaia.

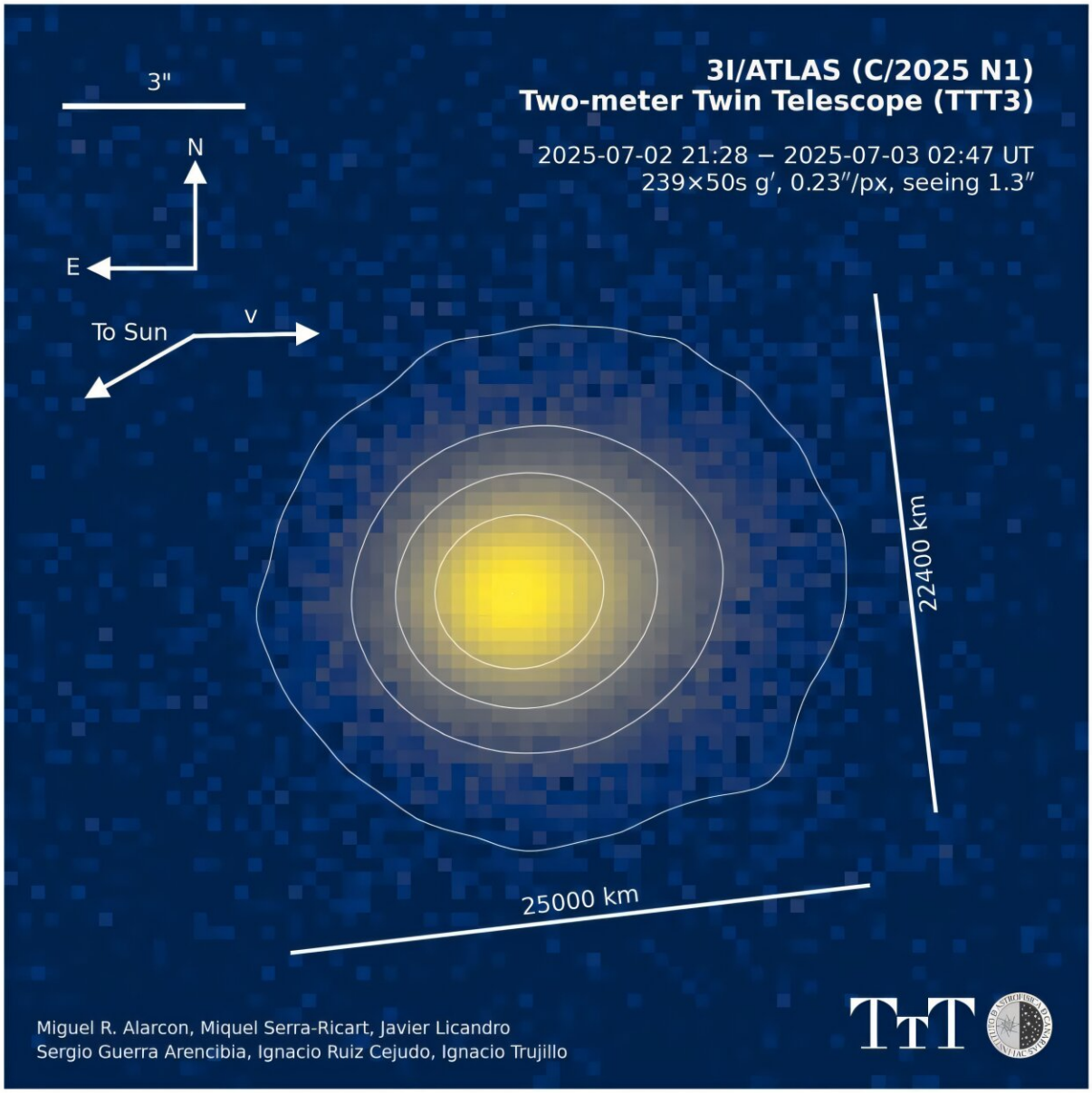
In new research submitted to the *Astrophysical Journal Letters*, researchers from Spain and Sweden used data from the ESA's astrometry mission Gaia to try to understand if encounters with stars altered its trajectory toward our solar system.

It's titled "3I/ATLAS: In Search of the Witnesses to Its Voyage," and a pre-print version is available on the server, *arXiv*. The lead author is Xabier Pérez Couto, from the Department of Computer Science and Information Technologies at the Universidade da Coruna in Spain.

"3I/ATLAS is the third interstellar object discovered to date, following 1I/'Oumuamua and 2I/Borisov," the researchers write in their paper. "Its unusually high excess velocity and active cometary nature make it a key probe of the galactic population of icy planetesimals."

Its active nature, meaning that volatiles are released during close approach to the sun and form a comet and a tail, gives clues to its composition. The outgassing and its contents are a direct sample of the

materials the comet formed from elsewhere in the Milky Way. It's like nature is delivering a sample directly to us.



Scientists used the Two-meter Twin Telescope to image comet 3I/ATLAS from July 02 to July 03, 2025. Credit: Miguel R. Alarcon, Miquel Serra-Ricart, Javier Licandro, Sergio Guerra Arencibia, Ignacio Ruiz Cejudo, and Ignacio Trujillo

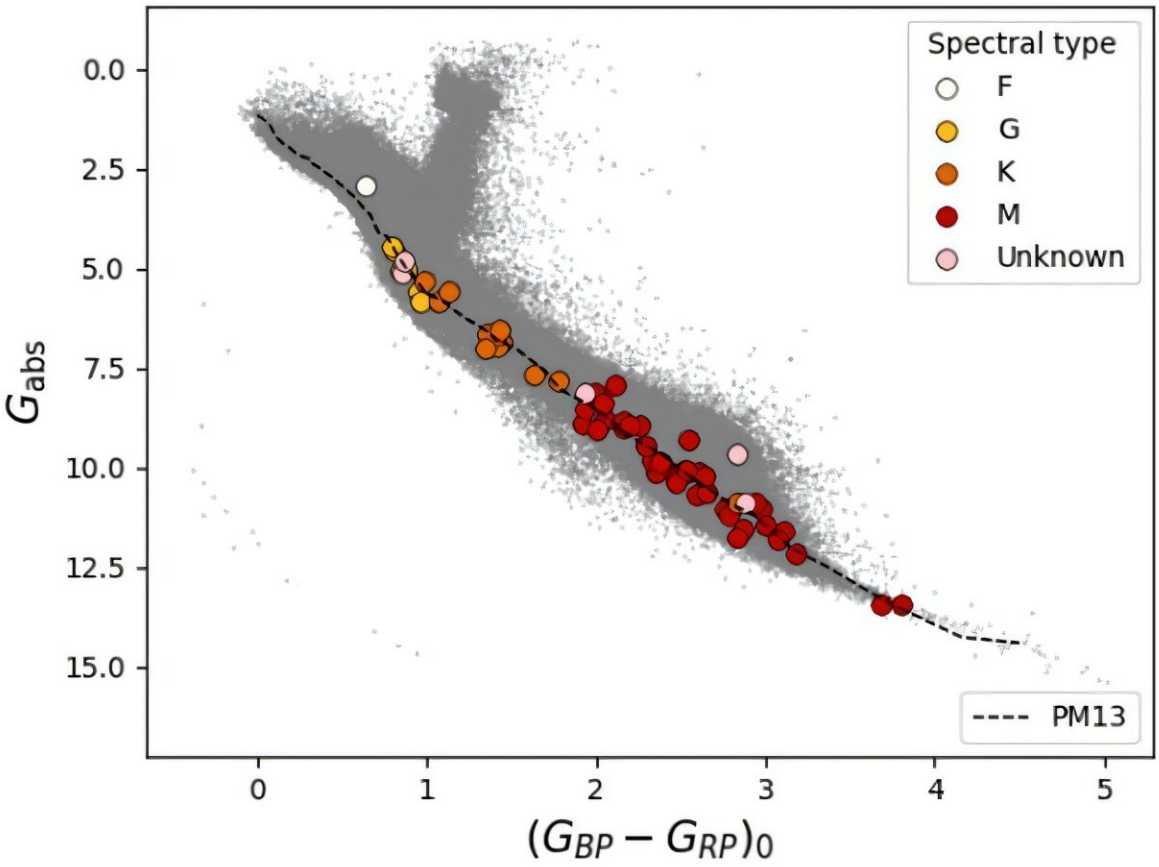
But the comet's coma and tail can't tell us what path it took to reach us.

"Kinematics is the key to identify interstellar objects (ISOs), since their trajectories provide the most direct evidence of an extrasolar origin," the authors write.

Previous research into the kinematics show that 3L/ATLAS likely originated in the Milky Way's thick disk, home to ancient stars. Its high velocity and steep angle support this. If it did come from there, then it could be older than the sun. But its kinematics could've been altered by encounters with stars.

The authors explain that they can understand the comet's origin and journey in more detail by tracing its past trajectory through the Milky Way. They can use Gaia data to find possible stellar encounters it had during its journey that could help explain its origins or if its trajectory was perturbed.

"We integrated the orbit of 3I/ATLAS backward in time for 10 Myr, together with a sample of Gaia DR3 stars with high-quality astrometry and radial velocities, to identify close passages within 2 pc," they write.



This figure from the research shows the positions on the Gaia colour-magnitude diagram of the stars that experienced a close encounter with 3I/ATLAS. All of these stars are on the main sequence. Credit: Couto et al. 2025

The researchers found 93 stellar encounters between 3I/ATLAS and stars, 62 of which they consider to be high-confidence encounters.

All 62 were with main sequence stars. The fact that they were all main sequence stars is noteworthy. It could reveal an observational bias in the Gaia data, and main sequence stars tend to dominate stellar surveys. The absence of evolved stars like white dwarfs and neutron stars is problematic, because they could create far stronger perturbations than

main sequence stars.

However, the study is still valuable and the results informative.

The strongest encounter occurred about 72,000 years ago. The star in that event is called HD 187760. It's about 84 light years away and is about 70% as massive as the sun.

That encounter did affect the velocity and trajectory of 3L/ATLAS, but only by a negligible amount. "Such a small perturbation indicates that 3I/ATLAS has not been significantly influenced by encounters with stars with known kinematics over the past 4.27 Myr," the authors write.

They explain that 4.27 Myr is the epoch of the earliest encounter identified in their work. "We conclude that 3I/ATLAS has not experienced any stellar flybys within the past 4 Myr, among the stars contained in Gaia DR3, that could account for its present trajectory nor its origin," they write.

This work is about more than just 3L/ATLAS. We're going to detect more and more interstellar objects in the future, especially with the Vera Rubin Observatory. Scientific predictions say it could find one or two each year, or about 15 during its Legacy Survey of Space and Time.

Observations of all of these objects will give us a better understanding of ISOs as a class of objects. Collectively, they could tell us a lot about how planetary material is spread around the galaxy.

"The emerging picture from recent studies is that interstellar objects are a heterogeneous population that provide rare observational constraints on planetary system evolution across the galaxy," the authors explain.

But the big question is "Where did it come from?"

"Together, all data indicate that while 3I/ATLAS follows a thin-disk orbit in the solar neighborhood, it may nonetheless be an old object, consistent with ejection from a primordial planetesimal disk in an early-formed system, or from an exo-Oort cloud, and is most likely associated with the transition region between the thin and thick disk, although its origin remains undisclosed," the researchers conclude.

More information: X. Pérez-Couto et al, 3I/ATLAS: In Search of the Witnesses to Its Voyage, *arXiv* (2025). DOI: 10.48550/arxiv.2509.07678