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Synchronizing stellar clocks reveals new insights into star formation and dispersal

A systematic "error" between two age dating techniques for stars might not be an error after all and could offer a new window into the early development of baby stars

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A team from the University of Vienna and Centro de Astrobiología (CAB), INTA-CSIC, has discovered an age discrepancy between two of the most reliable methods to measure stellar ages, isochronal and dynamical tracebacks. Their results find dynamical traceback ages to be consistently younger by about 5.5 million years. This key finding suggests that the dynamical traceback 'clock' starts when a star cluster begins to expand after it leaves its parental cloud, while the isochronal 'clock' starts ticking from the moment of star formation. This result has significant implications for our understanding of star formation and stellar evolution, including planet formation and the formation of galaxies. With it, existing models can be tested to offer a new perspective on the chronology of star formation. These results will be published in Nature Astronomy.

Stellar ages are a fundamental parameter in astrophysics, however, they are one of the hardest measurements to make. The best estimations are for star clusters, i.e., groups of co-eval stars with a common origin. Numerous techniques are used to estimate stellar ages, but they often show conflicting results. Are the age differences between different techniques caused by uncertainties in models and observations? Or, can we profit from this age puzzle to learn something about the star formation process?

David Barrado, co-author and researcher from the Instituto Nacional de Técnoca Aeroespacial (INTA) at CAB, qualifies: "Determining the ages of any cosmic process is a fundamental problem. This work lays a very firm foundation for the search for global solutions. The ESA's PLATO space telescope, which will be launched at the end of 2026, will be the key to a complete resolution.

Núria Miret-Roig, the first author of this study and researcher at the University of Vienna, indicates that "*Astronomers have been using isochronal ages since we understood how stars work, but these ages depend on the particular model we use*. *The high-quality data from the Gaia satellite allows us to measure ages dynamically, independently of stellar models, and we were excited to synchronize the clocks, meaning, to test the different models. We found a consistent and puzzling difference between the two age methods. We got to the point where we could not blame the discrepancy on observational errors anymore, so the two clocks are most likely measuring two different things."*

"*This age difference between the two methods constitutes a new and much needed tool to quantify the earliest stages in a star's life*" says João Alves, co-author and professor at the University of Vienna. "*It allows us to measure how long baby stars take before leaving their nest*".

Such a constraint is pivotal in advancing our comprehension of the early life of stars and the evolution of stellar clusters. The researchers analyzed six nearby (<150 pc), young (<50 Myr) clusters and showed that the timescale of the embedded phase is 5.5±1.1 Myr, and could depend on the cluster mass and amount of stellar feedback. The application of this new technique to other young clusters in the solar neighborhood, where the observational precisions are best, will provide new insights into the star formation and dispersal process.

This work has been possible thanks to the excellent astrometry of the *Gaia* special mission combined with ground-based radial velocities (such as the ones from the APOGEE catalogue), which allow the precisions in the 3D velocities to trace the positions of stars back in time to their birth site. New and coming spectroscopic surveys such as WEAVE, 4MOST, and SDSS-V will make this study possible for the entire solar neighborhood.

As Miret-Roig puts it, "*Our work paves the way for future research in star formation, offering a clearer picture of how stars and clusters evolve. It's a significant step in our quest to understand the formation of the Milky Way and other galaxies.*"

About CAB

The Centro de Astrobiología (CAB) is a joint research centre of INTA and CSIC. Created in 1999, it was the first centre in the world specifically dedicated to astrobiological research and the first non-US centre associated with the NASA Astrobiology Institute (NAI), currently the NASA Astrobiology Program. It is a multidisciplinary centre whose main objective is to study the origin, presence and influence of life in the universe through a transdisciplinary approach. The CAB was distinguished in 2017 by the Ministry of Science and Innovation as a Unit of Excellence "María de Maeztu".

The CAB has led the development of the REMS, TWINS and MEDA instruments, operational on Mars since August 2012, November 2018 and February 2021, respectively; as well as the science of the RLS and RAX Raman instruments, which will be sent to Mars at the end of this decade as part of the ExoMars mission and to one of its moons in the MMX mission, respectively. It is also developing the SOLID instrument for the search for life in planetary exploration. The CAB is also co-leading, together with three other European institutions, the development of the PLATO space telescope, and participates in different missions and instruments of great astrobiological relevance, such as MMX, CARMENES, CHEOPS, BepiColombo, DART, Hera, the MIRI and NIRSpec instruments on JWST and the HARMONI instrument on ESO's ELT.

Scientific paper:, *Nature Astronomy*.
https://www.nature.com/articles/s41550-023-02132-4

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