

## Eloisa Poggio



### Title

Evidence of a dynamically evolving Galactic warp

### Abstract

In a cosmological setting, the disk of a galaxy is expected to continuously experience gravitational torques and perturbations from a variety of sources, which can cause the disc to wobble, flare and warp. Specifically, the study of galactic warps and their dynamical nature can potentially reveal key information on the formation history of galaxies and the mass distribution of their halos. Our Milky Way presents a unique case study for galactic warps, thanks to detailed knowledge of its stellar distribution and kinematics. Using a simple model of how the warp's orientation is changing with time, we measure the precession rate of the Milky Way's warp using 12 million giant stars from Gaia Data Release 2, finding that it is precessing at  $10.86 \pm 0.03$  (statistical)  $\pm 3.20$  (systematic) km/s/kpc in the direction of Galactic rotation, about one third the angular rotation velocity at the Sun's position in the Galaxy. The direction and magnitude of the warp's precession rate favour the scenario that the warp is the result of a recent or ongoing encounter with a satellite galaxy, rather than the relic of the ancient assembly history of the Galaxy. Using N-body simulations, we analyse the vertical response of the Galactic disc to the repeated impacts of a satellite similar to the Sagittarius dwarf galaxy, finding that the instantaneous vertical pattern speeds in the disc have a constraining power in the context of a Milky Way-satellite interaction.

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## RESEARCH INTERESTS

E. Poggio's main scientific interests include the structure, kinematics and chemistry of the disc of the Milky Way, with particular focus on the warp, the local arm and the spiral structure. She is also interested in Galaxy formation and evolution. E. Poggio joined the Gaia mission as a member of the CU3 team in 2017.

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## RESEARCH EXPERIENCE

**CNES post-doctoral fellow** *November 2020 - present*  
Université Côte d'Azur, Observatoire de la Côte d'Azur (OCA)  
Laboratoire Lagrange, France  
Project: "Understanding the out-of-equilibrium evolution of the Milky Way"  
Collaborator: A. Recio-Blanco (OCA)

**Post-doctoral researcher** *December 2018 - October 2020*  
INAF-Osservatorio Astrofisico di Torino (OATo), Torino, Italy  
Project: "Galactic dynamics with Gaia data"  
Collaborators: R. Drimmel, M. G. Lattanzi, R. L. Smart, A. Spagna (OATo)

**Visiting researcher (1 month)** *September 2019*  
Center for Computational Astrophysics (CCA), Simons Foundation,  
Flatiron Institute, New York, U.S.A.  
Project: "Evolution of the Milky Way disc: N-body simulations vs. Gaia data"  
Collaborator: K. V. Johnston (CCA, Columbia University)

**Research fellow** *June 2018 - November 2018*  
INAF-Osservatorio Astrofisico di Torino (OATo), Italy  
Project: "Kinematics of disk stellar populations  
for the study of the Galactic warp based on the Gaia catalogue"  
Collaborators: R. Drimmel, M. G. Lattanzi, R. L. Smart, A. Spagna (OATo)

**Visiting researcher (1 month)** *March 2017 - April 2017*  
Max Planck Institute for Astronomy (MPIA), Heidelberg, Germany  
Project: "Bayesian inference applied to the Galactic warp"  
Collaborators: R. Andrae, C. A. L. Bailer-Jones, M. Fouesneau (MPIA)

**Summer fellowship (3 months)** *April 2012 - June 2012*  
Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany  
Project: "The cosmic rays energy spectrum"  
Collaborators: A. Haungs, D. Kang (KIT)

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## EDUCATION

**Ph.D. in Physics and Astrophysics** *November 2014 - October 2018*  
Università degli Studi di Torino (UniTo), in collaboration with  
INAF-Osservatorio Astrofisico di Torino (OATo), Torino, Italy  
Thesis: "The kinematic signature of the Galactic warp in the Gaia era"  
Supervisors: R. Drimmel, A. Spagna (OATo)

**Master degree cum laude in Physics** *October 2012 - July 2014*  
Università degli Studi di Torino, Torino, Italy  
Thesis: "Identifying cosmic structures with the Minimal Spanning Tree"  
Supervisor: A. Diaferio (UniTo)

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**Bachelor degree in Physics***October 2009 - October 2012*

Università degli Studi di Torino, Torino, Italy

Thesis: “The cosmic rays energy spectrum”

Supervisors: M. E. Bertaina (UniTo)

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**HONORS AND GRANTS**

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**CNES Post-doctoral Grant***November 2020*

Centre National d'Études Spatiales (CNES), Paris, France (EUR 30000)

**Travel Grant***September 2019*Center for Computational Astrophysics, Simons Foundation,  
Flatiron Institute, New York City, U.S.A. (\$ 4000)**“Giuseppe Lorenzoni” Prize of the Italian Astronomical Society (SAIt)***May 2019*for the best scientific article published by a young researcher  
between 2016 and 2018 (EUR 2000)**IAU Travel Grant***April 2017*330 Symposium of the International Astronomical Union (IAU),  
Nice, France (EUR 430)**Travel Grant***October 2016*Gaia Sprint, Center for Computational Astrophysics, Simons Foundation,  
Flatiron Institute, New York City, U.S.A. (\$ 1400)

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**PRESENTATIONS**

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| 06/2020 | Talk    | Meeting of the European Astronomical Society (EAS 2020),<br>Session: “Gaia: The (two) billion star galaxy census: The promise of (E)DR3<br>and ground-based synergies”, Leiden, The Netherlands (Virtual Meeting) |
| 06/2020 | Poster  | Meeting of the European Astronomical Society (EAS 2020),<br>Session: “The Local Group in Context: Galaxies in the Local Volume<br>as a Testbed of Cosmology”, Leiden, The Netherlands (Virtual Meeting)           |
| 04/2020 | Seminar | Max Planck Institute for Astronomy (MPIA),<br>Heidelberg, Germany (Virtual Seminar)   |
| 12/2019 | Talk    | Workshop Gaia WG4: “A dynamical view of the sky”,<br>Observatoire de la Côte d'Azur, Mont Gros site, Nice, France   |
| 09/2019 | Seminar | Department of Astrophysics, Rose Center for Earth and Space,<br>American Museum of Natural History, New York City, U.S.A.   |
| 05/2019 | Poster  | LXIII Congresso della Società Astronomica Italiana, Rome, Italy   |
| 04/2019 | Talk    | 53rd ESLAB Symposium: “The Gaia Universe”, ESTEC/ESA,<br>Noordwijk, The Netherlands   |
| 01/2019 | Talk    | Conference: “Galactic Archaeology in the Gaia Era”,<br>Sexten Center for Astrophysics, Sesto, Italy   |
| 08/2018 | Poster  | IAU Symposium 348: “21st Century Astrometry: crossing the dark and<br>habitable frontiers”, Wien, Austria   |
| 06/2018 | Talk    | Conference: “Gaia day”, Agenzia Spaziale Italiana (ASI), Rome, Italy  |
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- 04/2017    Talk    IAU Symposium 330: “Astrometry and Astrophysics in the Gaia sky”,  
Nice, France
  - 01/2017    Talk    Conference: “Beyond the Solar Neighborhood: Entering into the Gaia Era”,  
Sexten Center for Astrophysics – Sesto, Italy
  - 07/2016    Talk    Conference: “European Week of Astronomy and Space Science” (EWASS),  
Athens, Greece
  - 01/2016    Talk    Conference: “Galactic surveys: new results on formation, evolution,  
structure and chemical evolution of the Milky Way”,  
Sexten Center for Astrophysics, Sesto, Italy
  - 06/2015    Poster    Conference: “European Week of Astronomy and Space Science” (EWASS),  
Tenerife, Spain

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### SCHOOLS AND WORKSHOPS

- 06/2019    International School of Space Science: “Space Astrometry for Astrophysics”,  
L’Aquila, Italy
- 02-03/2018    International School for Young Astronomers: “Scientific exploitation of Gaia data”,  
Paris, France
- 10/2016    Workshop: “Gaia Sprint”, Simons Center for Computational Astrophysics,  
New York, U.S.A.
- 09/2016    IMPRS Summer School: “Astrostatistics and Data Mining”, Heidelberg, Germany
- 06/2015    Summer School in Statistics for Astronomers - Penn State University,  
Pennsylvania, U.S.A.
- 06/2015    PhD School of Astrophysics “F. Lucchin”, Populonia, Livorno, Italy

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### SCIENTIFIC OUTREACH

- 2020    Interview on national television (“TG Leonardo”) on our paper Poggio et al. 2020  
<http://gallery.media.inaf.it/main.php/v/video/inafintv/Rai3/20200305-tg-leonardo-warp-poggio.mp4.html>
- 2019    Outreach article on our paper Poggio et al. 2018 at the invitation of the journal  
“Giornale di Astronomia” for the Lorenzoni Prize
- 2014/2015    Scientific communicator at INFINITO Planetarium, Museo dell’Astronomia  
e dello Spazio, Pino Torinese, Italy
- 2013    Scientific communicator (1 month) at the exhibition “Fate il nostro gioco”,  
Bolzano, Italy

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### REFEREEING

Astronomy & Astrophysics, The Astrophysical Journal

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### PROGRAMMING SKILLS

IDL, Python, R, C++, C

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### LANGUAGE SKILLS

Italian (mother tongue), English, German, French

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## PEER-REVIEWED PUBLICATIONS

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1. L. Lindegren, S. A. Klioner, J. Hernández, and 94 co-authors (incl. **E. Poggio**), *Gaia Early Data Release 3: The astrometric solution*, 2020, accepted for publication in A&A
2. Gaia Collaboration, S. A. Klioner, F. Mignard, and 414 co-authors (incl. **E. Poggio**), *Gaia Early Data Release 3: Acceleration of the solar system from Gaia astrometry*, 2020, accepted for publication in A&A
3. Gaia Collaboration, R. L. Smart, L. M. Sarro, and 420 co-authors (incl. **E. Poggio**), *Gaia Early Data Release 3: The Gaia Catalogue of Nearby Stars*, 2020, accepted for publication in A&A
4. Gaia Collaboration, X. Luri, L. Chemin, and 417 co-authors (incl. **E. Poggio**), *Gaia Early Data Release 3: Structure and properties of the Magellanic Clouds*, 2020, accepted for publication in A&A
5. Gaia Collaboration, A. G. A. Brown, A. Vallenari, T. Prusti, and 422 co-authors (incl. **E. Poggio**), *Gaia Early Data Release 3: Summary of the contents and survey properties*, 2020, accepted for publication in A&A
6. M. Crosta, M. Giammaria, M. G. Lattanzi, **E. Poggio**, *Testing CDM and geometry-driven Milky Way rotation curve models with Gaia DR2*, 2020, MNRAS, 496, 2107
7. **E. Poggio**, R. Drimmel, R. Andrae, C. A. L. Bailer-Jones, M. Fouesneau, M. G. Lattanzi, R. L. Smart, A. Spagna, *Evidence of a dynamically evolving Galactic warp*, 2020, Nature Astronomy, 4, 590
8. P. Giacobbe, M. Benedetto, M. Damasso, A. Sozzetti, J. M. Christille, M. G. Lattanzi, P. Calcidese, A. Carbognani, D. Barbato, M. Pinamonti, **E. Poggio**, A. F. Lanza, A. Bernagozzi, D. Cenadelli, L. Lanteri, E. Bertolini, *Photometric rotation periods for 107 M dwarfs from the APACHE survey*, 2020, MNRAS, 491, 5216
9. Gaia Collaboration, L. Eyer, L. Rimoldini, and 453 co-authors (incl. **E. Poggio**), *Gaia Data Release 2: Variable stars in the colour-absolute magnitude diagram*, 2019, A&A, 623, A110
10. **E. Poggio**, R. Drimmel, M. G. Lattanzi, R. L. Smart, A. Spagna, R. Andrae, C. A. L. Bailer-Jones, M. Fouesneau, T. Antoja, C. Babusiaux, D. W. Evans, F. Figueras, D. Katz, C. Reylé, A. C. Robin, M. Romero-Gómez, G. M. Seabroke, *The Galactic warp revealed by Gaia DR2*, 2018, MNRAS, 481, L21
11. T. Antoja, A. Helmi, M. Romero-Gómez, D. Katz, C. Babusiaux, R. Drimmel, D. W. Evans, F. Figueras, **E. Poggio**, C. Reylé, A.C. Robin, G. Seabroke, and C. Soubiran, *A dynamically young and perturbed Milky Way disk*, 2018, Nature, 561, 36
12. Gaia Collaboration, D. Katz, T. Antoja, M. Romero-Gómez, R. Drimmel, C. Reylé, G. M. Seabroke, C. Soubiran, C. Babusiaux, P. Di Matteo, F. Figueras, **E. Poggio**, A. C. Robin, D. W. Evans, and 440 co-authors, *Gaia Data Release 2: Mapping the Milky Way disc kinematics*, 2018, A&A, 616, A11
13. L. Lindegren, J. Hernández, A. Bombrun, S. Klioner, U. Bastian, and 85 co-authors (incl. **E. Poggio**), *Gaia Data Release 2: The astrometric solution*, 2018, A&A, 616, A2
14. Gaia Collaboration, A. G. A. Brown, A. Vallenari, T. Prusti, and 450 co-authors (incl. **E. Poggio**), *Gaia Data Release 2: Summary of the contents and survey properties*, 2018, A&A, 616, A1
15. Gaia Collaboration, C. Babusiaux, F. van Leeuwen, M.A. Barstow, and 449 co-authors (incl. **E. Poggio**), *Gaia Data Release 2: Observational Hertzsprung-Russel diagrams*, 2018, A&A, 616, A10
16. Gaia Collaboration, A. Helmi, F. van Leeuwen, P.J. McMillan, and 450 co-authors (incl. **E. Poggio**), *Gaia Data Release 2: Kinematics of globular clusters and dwarf galaxies around the Milky Way*, 2018, A&A, 616, A12

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17. Gaia Collaboration, F. Mignard, S. A. Klioner, L. Lindegren, and 449 co-authors (incl. **E. Poggio**), *Gaia Data Release 2: The Celestial reference frame (Gaia-CRF2)*, 2018, A&A, 616, A14
  18. Gaia Collaboration, F. Spoto, P. Tanga, F. Mignard, J. Berthier, and 450 co-authors (incl. **E. Poggio**), *Gaia Data Release 2: Observations of solar system objects*, 2018, A&A, 616, A13
  19. **E. Poggio**, R. Drimmel, R. L. Smart, A. Spagna, M. G. Lattanzi, *The kinematic signature of the Galactic warp in Gaia DR1. - I. The Hipparcos subsample*, 2017, A&A, 601, A115

## OTHER PUBLICATIONS

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1. **E. Poggio**, *Tra le pieghe della Galassia*, 2019, Giornale di Astronomia della Società Astronomica Italiana, 45/4, 80
2. R. Drimmel & **E. Poggio**, *On the solar velocity*, 2018, Research notes of the AAS, 2, 210
3. **E. Poggio**, R. Drimmel, R. L. Smart, A. Spagna, M. G. Lattanzi, *Search for Galactic warp signal in Gaia DR1 proper motions*, 2017, Proceedings of IAU Symposium 330: “Astrometry and Astrophysics in the Gaia sky”, 330, 185

## REFERENCES

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### **Dr. Ronald Drimmel**

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