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THE SEARCH FOR GHOSTS OF MERGERS PAST WITH GAIA

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RESUMEN

Presentamos los resultados de nuestro trabajo produciendo catálogos simulados de Gaia para Halos tipo Vía Láctea y utilizando nGC3, un método de conteo de estrellas en círculos máximos, para la búsqueda de corrientes estelares utilizando información de posición y movimientos propios. Nuestros diez catálogos Gaia simulados fueron producidos a partir de los halos de galaxias de masa similar a la Vía Láctea de las simulaciones cosmológicas Aquarius y HYDRO-zooms y reproducen la función de selección y errores observaciones de Gaia para dos trazadores estelares: gigantes K y RR Lyrae. La diversidad de órbitas y de progenitores en las simulaciones nos permiten caracterizar la completitud y límites de detección del método nGC3 en un escenario realista. Mostramos que el método nGC3 tiene una frontera de detección bien definida, cuya ubicación está dada únicamente en términos de observables. Estimamos que *un total de 4–13 corrientes estelares producidas por galaxias enanas sean detectables con Gaia+nGC3, con gigantes K y RR Lyrae en conjunto* y estimamos una eficiencia superior al 80% dentro de la frontera de detección. Los progenitores exitosamente recuperados se encuentran en el rango de masa de las galaxias esferoidales enanas clásicas, con masas tan bajas como $\sim 10^6 M_\odot$, que hayan sido acretadas tan temprano como $z \lesssim 3$.

ABSTRACT

We present our work producing Milky Way Halo mock Gaia catalogues and using nGC3, a great-circle cell counts method, to search for tidal streams using positional information and proper motions. Our ten Galactic Halo mock catalogues were made from Milky-Way-mass haloes from the Aquarius and HYDRO-zoom cosmological simulations, and reproduce the Gaia selection function and observational errors for two stellar tracers: K giants and RR Lyrae stars. The diversity of orbits and progenitors in the simulations allow us to characterize the nGC3 methods completeness and detection limits in a realistic setting. We show the nGC3 method has a well-defined detection boundary, whose location can be predicted based on direct observables alone. We expect *a total of 4–13 tidal streams produced by dwarf galaxies to be detectable with Gaia+nGC3 with K giant and RR Lyrae stars combined*, and estimate a detection efficiency >80% inside the boundary. Successfully recovered progenitors are in the mass range of classical Milky Way dwarf satellites, with stellar masses down to $\sim 10^6 M_\odot$, and may have been accreted as early as $z \lesssim 3$.

Key Words: dark matter — galaxies: dwarf — methods: data analysis

1. INTRODUCTION

The study of tidal streams is one of the key science drivers for the Gaia mission, given their widely recognised usefulness in the inference of the Galactic accretion history and the Galactic potential (e.g. Johnston et al. 2008; Helmi et al. 2011; Price-Whelan & Johnston 2013; Sanderson 2016).

Although it is expected that Gaia will discover many new stellar streams in the Galactic Halo, no forecasts of the number of dwarf galaxy streams that are expected to be found with Gaia were available to date.

In this work we have used mock Gaia catalogues of Milky-Way-mass haloes together with the nGC3 great-circle method (Mateu et al. 2011; Abedi et al. 2014) to conduct a systematic and automated search for tidal streams, with the aim of predicting how many dwarf galaxy streams are to be detected with Gaia and to characterize the detection method's selection function and overall efficiency. Our work and results are described in detail in Mateu et al. (2016). In what follows we present a short summary.

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2. GAIA MOCK CATALOGUES AND STREAM SEARCH

We produced ten mock Gaia catalogues built from two suites of cosmological simulations of Milky Way-mass galaxies: five from the Aquarius dark matter only simulations combined with semi-analytic prescriptions(Cooper et al. 2010); and five from the HYDRO-zooms (Font et al., in prep.), a set of gas-dynamical simulations with initial conditions from the EAGLE simulation (Schaye et al. 2011).

The mock catalogues were produced for two stellar tracers: K giants and RR Lyrae stars. The Gaia selection function, including the effect of extinction, and end-of-mission observational errors were simulated using the `Gaia-errors` software from Romero-Gómez et al. (2015), which implements prescriptions from Rygl et al. (2014). We assume photometric distances will be used for these tracers and simulate them with constant (Gaussian) errors of 7% for RR Lyrae stars, and 20% for K giants (see Mateu et al. 2016).

The automated stream search was performed using nGC3, a great circle cell counts method from the mGC3 family described in Mateu et al. (2011) and Abedi et al. (2014), which uses proper motions and positional information to find overdensities of stars concentrated along great circles in the 'celestial' sphere as seen from the Galactic center.

2.1. *Publicly available resources*

All codes used and mock catalogues produced in this work are publicly available for the community at the following repositories:

- The Gaia mock catalogues are available at the GitHub repository in `https://cmateu.github.io/Cecilia_Mateu_WebPage/Gaia_Halo_Mocks.html`. K giant mocks are available for the Aquarius and HYDRO-zoom haloes, the RR Lyrae mocks are currently available for the Aquarius haloes alone.

- Mercè Romero-Gomez's `Gaia-errors` software, which simulates the Gaia selection function and latest post-launch observational errors, is available at the GitHub repository in `https://github.com/mromerog/Gaia-errors`.

- The Python module `PyMGC3` provides an implementation of the mGC3 family of methods with utilities to compute and plot pole count maps, and is available at `https://github.com/cmateu/PyMGC3`.

3. RESULTS AND CONCLUSIONS

- The nGC3 method is capable of identifying realistic tidal streams produced in cosmological simulations, even in the presence of a background of in situ stars as in the case of the HYDRO-zoom gas dynamical simulations.

- The nGC3 method, and all great circle methods in general, have a well-defined detection boundary in the plane of angular width (perpendicular to the stream's orbital plane) versus ratio of observable stars to pole count map background stars. *This boundary is parameter-free and can be predicted based on observables alone.*

- The median efficiency inside the detection boundary is 86% and 80% for streams detected with K giants and RR Lyrae respectively, up to angular widths $\Delta\theta \sim 15^\circ$.

- A total of 4 to 13 streams, depending on the accretion history, are expected to be recovered successfully with Gaia+nGC3 when results from K giants and RR Lyrae stars are combined.

- Progenitors are recovered down to the same stellar mass limit of $\sim 10^6 M_\odot$ (luminosities down to $\sim 4 \times 10^5 L_\odot$) and the same infall redshift range $z \lesssim 3$ with either tracer, RR Lyrae or K giants.

- The best efficiency ($> 80\%$) in the recovery of streams is achieved in the distance range from ~20 to ~90 kpc, *with both tracers*, showing that RR Lyrae stars probe *the same effective volume as K giants for partially unbound progenitors.* For fully bound progenitors, K giants probe a larger volume reaching out to ~130 kpc.

REFERENCES

Abedi, H., Mateu, C., Aguilar, L. A., Figueras, F., & Romero-Gómez, M. 2014, MNRAS, 442, 3627
de Bruijne, J. H. J. 2012, Ap&SS, 341, 31
Cooper, et al. 2010, MNRAS, 406, 744
Helmi, et al. 2011, ApJL, 733, L7
Johnston, et al. 2008, ApJ, 689, 936
Mateu, et al. 2011, MNRAS, 415, 214
Mateu, et al. 2016, arXiv, astro-ph/1609.08653
Price-Whelan, A. M. & Johnston, K. V. 2013, ApJL, 778, L12
Romero-Gómez, M., Figueras, F., Antoja, T., Abedi, H., & Aguilar, L. 2015, MNRAS, 447, 218
Rygl, K. L. J., Molinari, S., Prusti, T., Antoja, T., Elia, D., & de Bruijne, J. 2014, EAS Publications Series, 67, 397
Sanderson, R. E. 2016, ApJ, 818, 41
Schaye, et al. 2015, MNRAS, 446, 521