The Sagittarius stream with Gaia data

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The in-fall of the Sagittarius Dwarf Spheroidal (Sgr) has possibly been responsible of important perturbations on the Milky Way (MW) disk. Yet, with only some thousand of line-of-sight velocities and very few astrometric measurements, there are still many open questions regarding its orbit and stellar content, which hinders our ability to constrain its effects on the MW. We present the largest sample of Sagittarius dwarf and stream stars available to date, obtained entirely by searching in the Gaia DR2 proper motions. Thanks to a smart use of the Gaia Archive combined with the Wavelet Transform to detect substructure, we have unveiled the stream and its proper motion in an almost 360º of its path on the sky, being the more extended and continuous proper motion sequence ever measured for a stream. We have also obtained a sample of RR Lyrae in the stream for which we gain access to the distances and, therefore, to the tangential velocities for the first time. We show the main kinematic and population characteristics of the stream derived in our study. A first comparison with one of the most successful models of the stream shows significant kinematical differences with the data. Our data will allow us to study the detailed the populations of Sgr, obtain the best possible fit to the MW potential from its orbit and, in turn, constrain its impact on our Galaxy.

https://services.fqa.ub.edu/sagittarius

Context

- The Sagittarius (Sgr) dwarf galaxy (Ibata+94) is the closest dwarf galaxy to the Sun not fully disrupted yet
- A large fraction of its stars have left the progenitor and form a prominent stellar stream that fills the whole sky (Mateo et al., 1996; Totten & Irwin, 1998; Majewski et al., 2003)
- Such a nearby massive satellite can perturb significantly the disc, but disentangling its effects from others (Galactic bar, transient arms, dark matter sub-halos) requires a detailed knowledge of its orbit and bound mass
- Current models cannot reproduce the kinematics (radial velocity) of the stream nor some of its features like a stream bifurcation (Belokurov et al., 2006; Koposov et al., 2012)
- Only few proper motions had been measured for this system with the Hubble space telescope (Sohn et al., 2015).

No purely *Gaia* study had been yet performed

We present the studies:

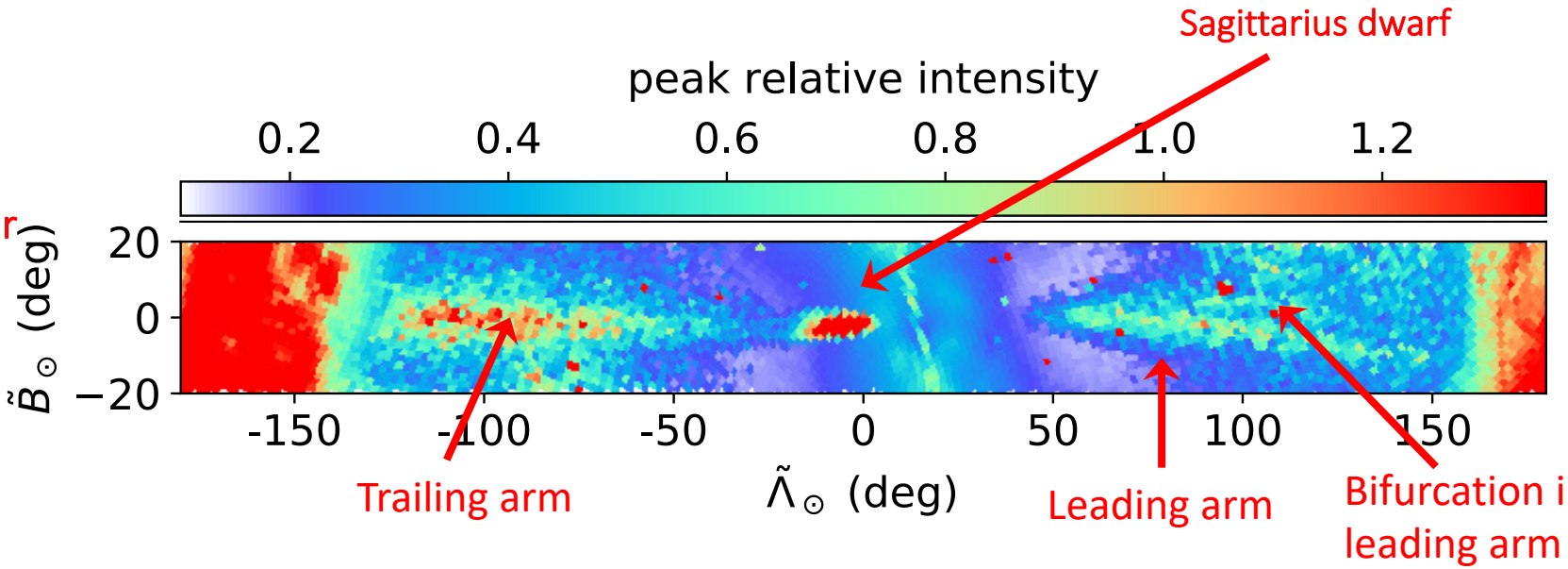
- An all-sky proper-motion map of the Sagittarius stream using Gaia DR2, A&A, 635, L3, 2020
  Antoja, T.; Ramos, P.; Mateu, C.; Helmi, A.; Anders, F.; Jordi, C.; Carballo-Bello, J. A.
- Full 5D characterisation of the Sagittarius stream with Gaia DR2 RR Lyrae A&A, 638, A104, 2020
  Ramos, P.; Mateu, C.; Antoja, T.; Helmi, A.; Castro-Ginard, A.; Balbinot, E.; Carrasco, J. M.

Data and Methods

Kinematic 4D sample:

- We select distant *Gaia* stars with parallax-parallax_error < 0.1 mas & bp_rp > 0.2 mag
- We download the proper motion histogram at each sky region (HEALpix) from the *Gaia* Archive and apply the Wavelet Transformation to detect significant over-densities in proper motion
- We select the kinematic structure created by the Sgr stream in the sky

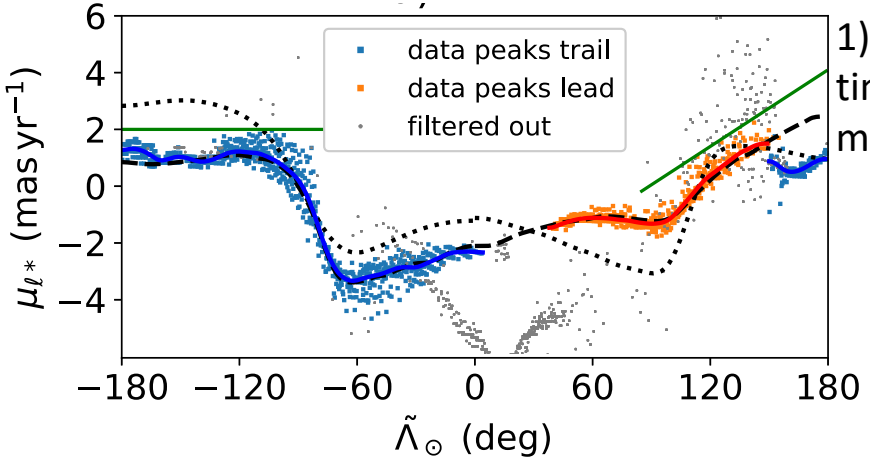
Sagittarius stream in our detection in the coordinates of its orbital plane



RR Lyrae 5D sample:

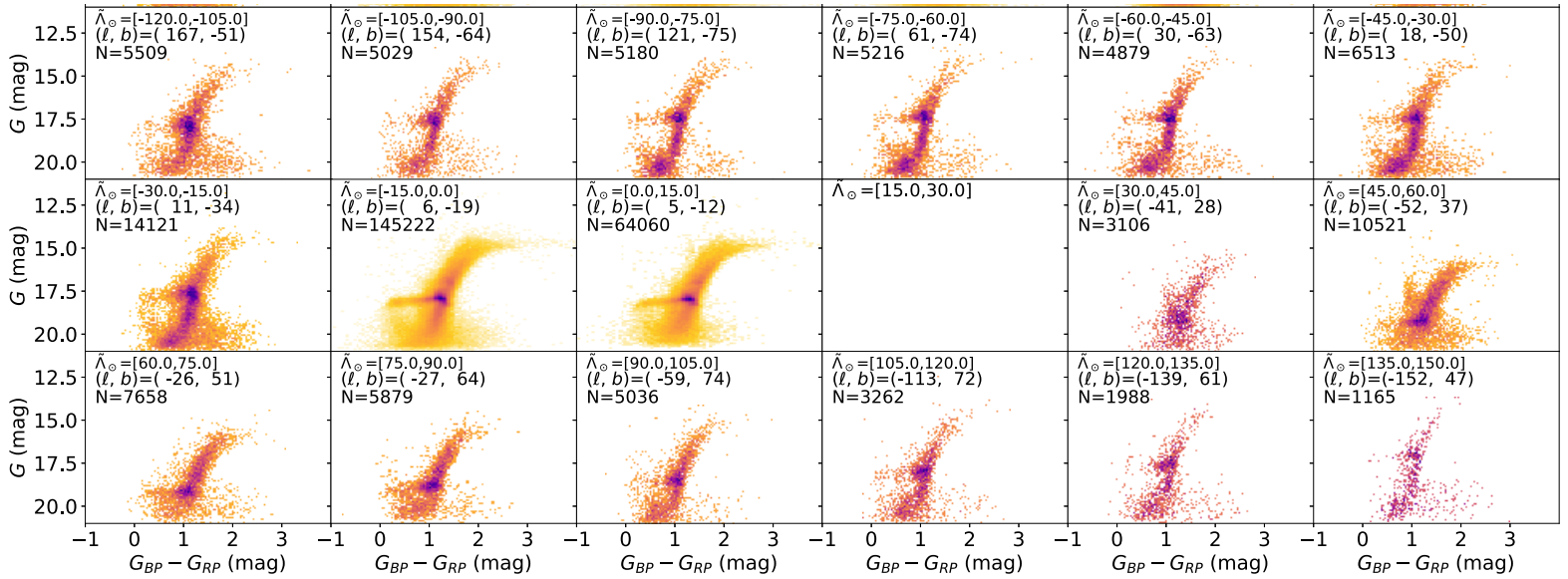
- We use the *Gaia* catalogue of RR Lyrae stars (Holl et al., 2018; Clementini et al., 2019, Sesar et al., 2017) that have proper motions in *Gaia*
- We present two samples selected in proper motion and distance: 1) Strip: more complete sample, but more contaminated, by selecting stars closer than 20º to the orbital plane, 2) nGC3: a purer sample, at the cost of completeness, by applying the Pole Count method (Abedi et al., 2014)

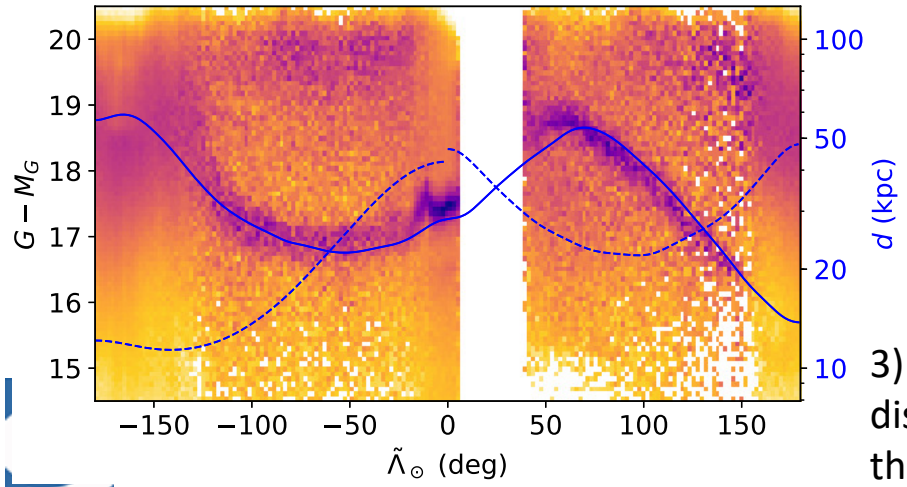
Results: 4D sample (~200k stars in the dwarf + ~100k in the stream)



1) We measure the proper motion along the full first turn of the Sgr stream for the first time (blue and red dots). We note significant differences with the Law & Majewski 2010 model (dashed)

2) We study the variations in the CMD along the stream. To zero-order, the position in this diagram is dominated by the distance gradient, but we have now enough data to study in detail the population mix at different positions

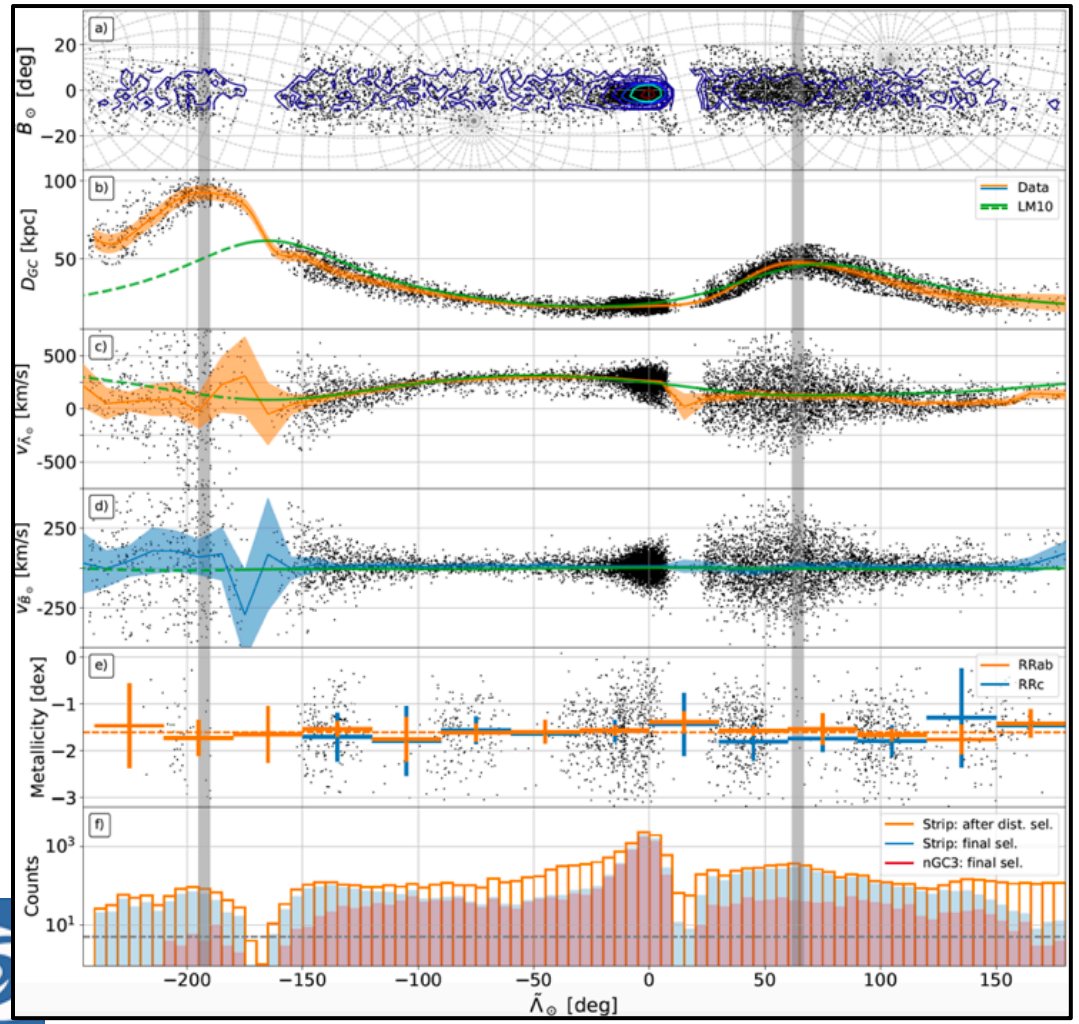




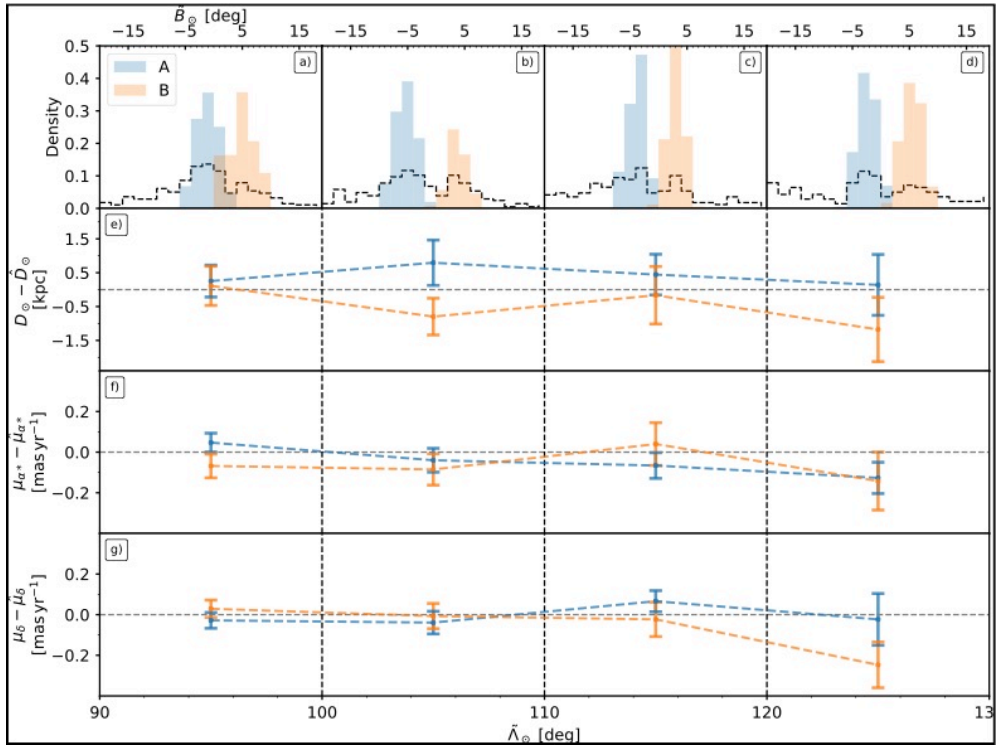
3) The distribution of apparent magnitudes as a function of angular distance of our sample is dominated by the Red Clump, which reveals the distance gradient of the stream

Results: 5D sample (~11k RR Lyrae)

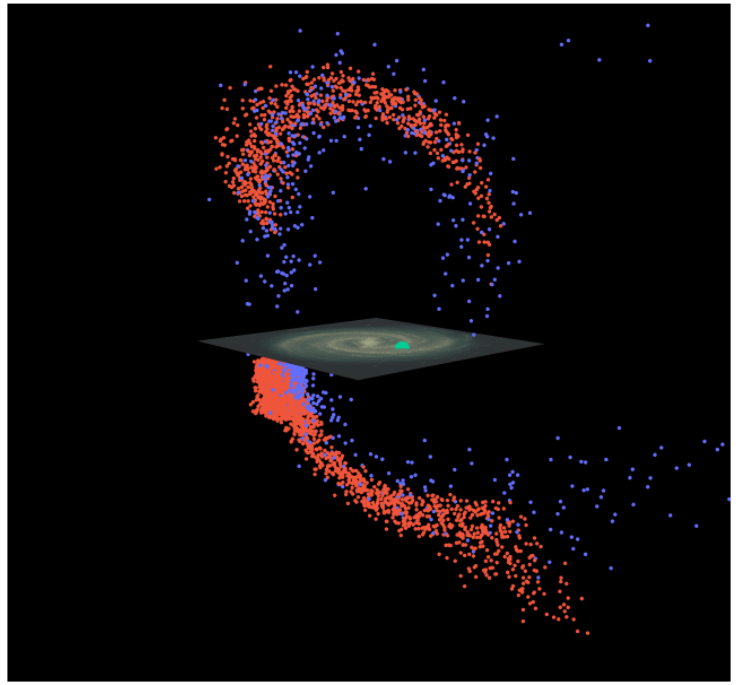
1) By combining positions and proper motions we have, for the first time, quantified the tangential velocity trends along Sgr. We report significant deviations from the Law&Majewsky2010 model in distance and velocities, and no measurable metallicity gradient



2) We detect the bifurcation at the leading arm also in this sample of old stars, with no significant separation between the two branches in distance or proper motions



Conclusions and prospects



1. This work is the first look into the proper motions of the stream across the whole sky thanks to Gaia
2. We have compiled the largest sample of candidate stars of the Sgr stream: ~300 000 stars of mixed populations and ~11 000 of RR Lyrae stars
3. Even the most successful model for the Sgr orbit (Law&Majewski 2010) **cannot** reproduce the measured proper motion, tangential velocity nor distance trends
4. We detect the bifurcation in the leading arm for all the samples, indicating that is not sensible to the age of the stars. There is no significant phase-space difference between branches
5. The new observational constrains provided will allow for a precise determination of the Sgr in-fall history using its full 6D phase-space information and for a much better measurement of the Milky Way potential
6. It is also now possible to study the differences in population along the stream and relate this to a particular mass-loss and star formation history
7. With the improved proper motions of EDR3 the sample size will grow and the uncertainties reduce, allowing for a better determination of the trends and a rigorous comparison between the young and old stars in the stream