PhD offer

Mapping of the Milky Way in 3D with the Besançon Galaxy Model from heterogeneous data

Supervision

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Description

Context

Accurately mapping the 3D structure of our galaxy, the Milky Way, is a key to understand its formation and evolution across the cosmic ages. However, our present knowledge of the Galactic structure remains limited both in terms of distance resolution and reach, especially for its interstellar component. During the last decade, many teams have published 3D maps of the Galactic interstellar medium (ISM). Most of them were based on measurements of the interstellar extinction of stellar light from stars with known distance, observed in the visible range. They were therefore affected by the strong interstellar extinction in this wavelength domain that limited their reach to a few kiloparsecs (kpc).

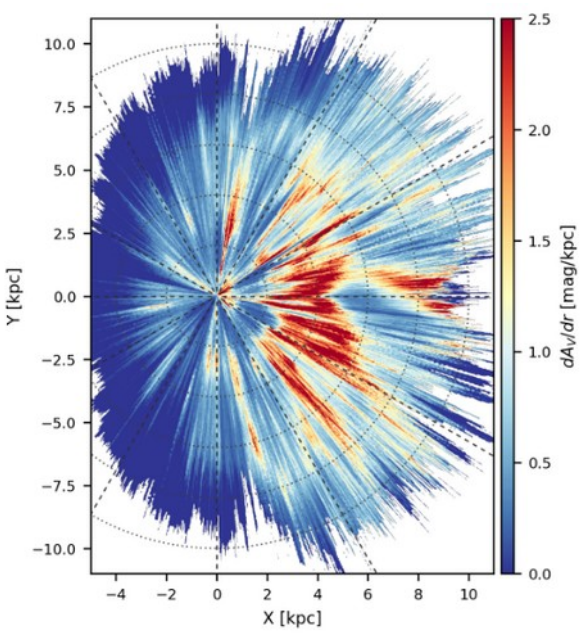

Figure 1: Galactic extinction map by Marshall et al. (2025). The Sun is at (X,Y)=(0,0), the Galactic center at (X,Y) = (8,0) kpc.

An original method was developed in Besançon that enables us to overcome some limitations of other methods and we have published the 3D extinction maps of the Milky Way plane with the best reach to date (~10 kpc) and a distance resolution of ~50-100 pc. This method is based on the statistical comparison between observed data and a stellar population synthesis model, the Besançon Galaxy model (BGM). The BGM summarizes the most up-to-date knowledge of this galaxy, making it possible to produce synthetic star catalogs with accurate statistical properties. Comparing these synthetic catalogs with observational ones enables us to further constrain the parameters of the model, and therefore to improve our understanding of the Galaxy's structure.

Our last step was to develop a user-friendly program, PyRedLine (Déforêt et al. 2026), that can easily combine various heterogeneous datasets from different surveys without cross-match. This approach opens the way to combining complementary datasets: photometry at various wavelengths (visible to mid-IR), parallaxes, proper motions, radial velocities, etc. So far we have used it to combine 2MASS near-IR photometry and Gaia visible photometry and parallaxes.

Aim

In this work, **we aim to push back the limits of our maps both in terms of reach and distance resolution: we aim for characterizing the ISM in the Galactic plane, with a particular attention to the region of the Galactic center and even to reach the far side of the Milky Way. To achieve this, we will take advantage of the variety of already available archival datasets, and of upcoming data**, such as those of the Nancy Grace Roman space telescope (hereafter Roman, launch planed in 2026).

Method
The PhD student will develop the BGM and PyRedLine to simulate archival datasets (the last data release of the Gaia mission with photometry, parallaxes and proper motion; the Glimpse survey mid-IR photometry; the VISTA Variables in the Via Lactea (VVV) survey in photometry and proper motion, Pan-STARRS 1 visible photometry) and to prepare the upcoming release of Roman data, planned for 2028.

This strategy is expected to provide 3D extinction maps both with a high resolution (<50 pc) at short distances in the Solar neighborhood and with a great depth of typically 10-12 kpc. Such a map will capture most of the volume sampled by the stellar surveys and therefore will make it possible to study the key features of the Galaxy like its spiral arms, the bar and the Galactic bulge.

Science team
The PhD student will be integrated in the Besançon ASTRO team that includes experts of Gaia, Roman, the BGM and PyRedLine, and benefit from their collaboration networks, especially with the 3D extinction experts in IRAP (Toulouse), Douglas Marshall and Barnabé Déforêt.

Bibliography
Robin et al. *A synthetic view on structure and evolution of the Milky Way*, A&A, **409**, 523 (2003)
Gaia Collaboration, Brown et al., *Gaia Early Data Release 3. Summary of the contents and survey properties*, A&A, **649**, A1 (2021)
Marshall et al. *Modelling the Galactic interstellar extinction distribution in three dimensions*, A&A **453**, 635, (2006)
Cornu et al. 2022, *3D extinction mapping of the Milky Way using Convolutional Neural Networks: Presentation of the method and demonstration in the Carina Arm region*, submitted to A&A, eprint arXiv:2201.05571

Expected candidate profile
The candidate should hold a master degree in astrophysics or in a related field, and have a taste for numerical simulations and data analysis.

Host institution and related opportunities
The PhD student will be integrated in the Besançon ASTRO team of the UTINAM institute (https://www.utinam.cnrs.fr/), which is hosted at the Besançon observatory. This institute depends on the Université Marie et Louis Pasteur and the Centre National de la Recherche Scientifique (CNRS) and has access to the opportunities provided by these organizations.
The UTINAM institute supports the *Physics and computational physics* master program. The PhD student will have the opportunity to teach and/or supervise science projects in this master program.

Important dates
Applications expected by March 13th
An interview will be requested by March 31st
Starting date : 1st October 2026

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