

3D extinction mapping of the Milky Way with the Besançon Galaxy Model in the Gaia era

Barnabé Déforêt¹

Supervisor: Julien Montillaud¹ and Annie Robin¹

¹Université de Franche-Comte, Institut UTINAM

24th May 2023



Our Galaxy



Type of galaxies



Spiral



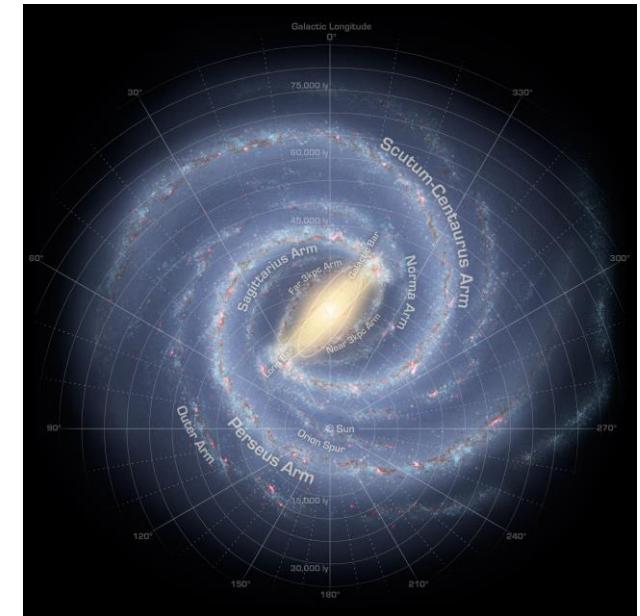
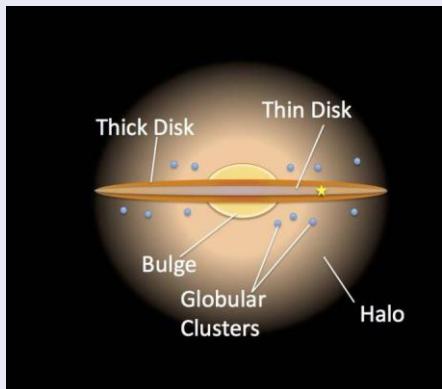
Elliptical



Irregular

Components

- 4 major arms
- 4 stellar populations



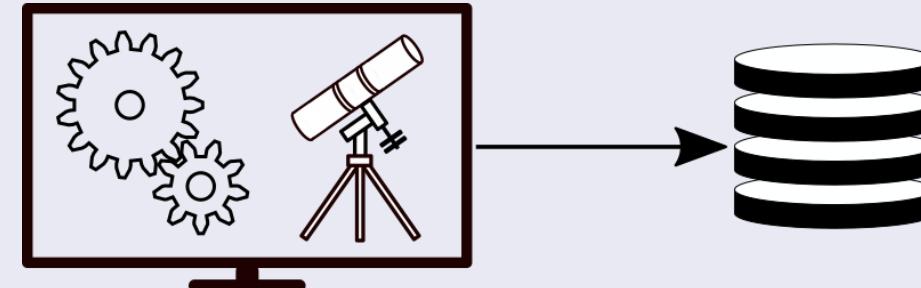
The Besançon Galaxy model



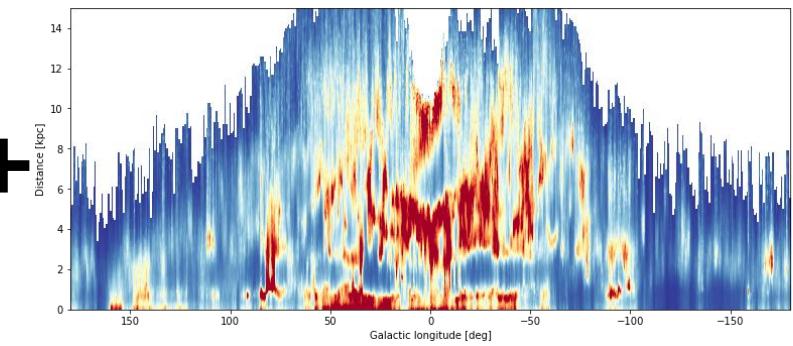
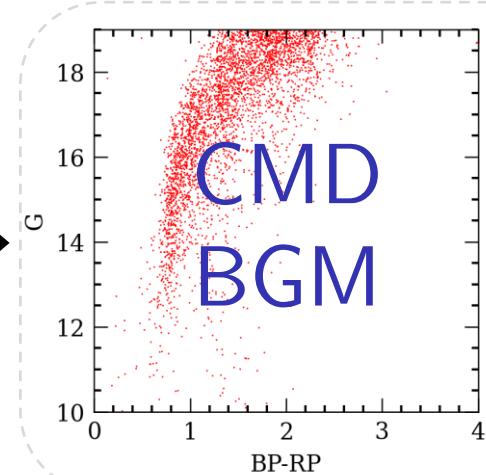
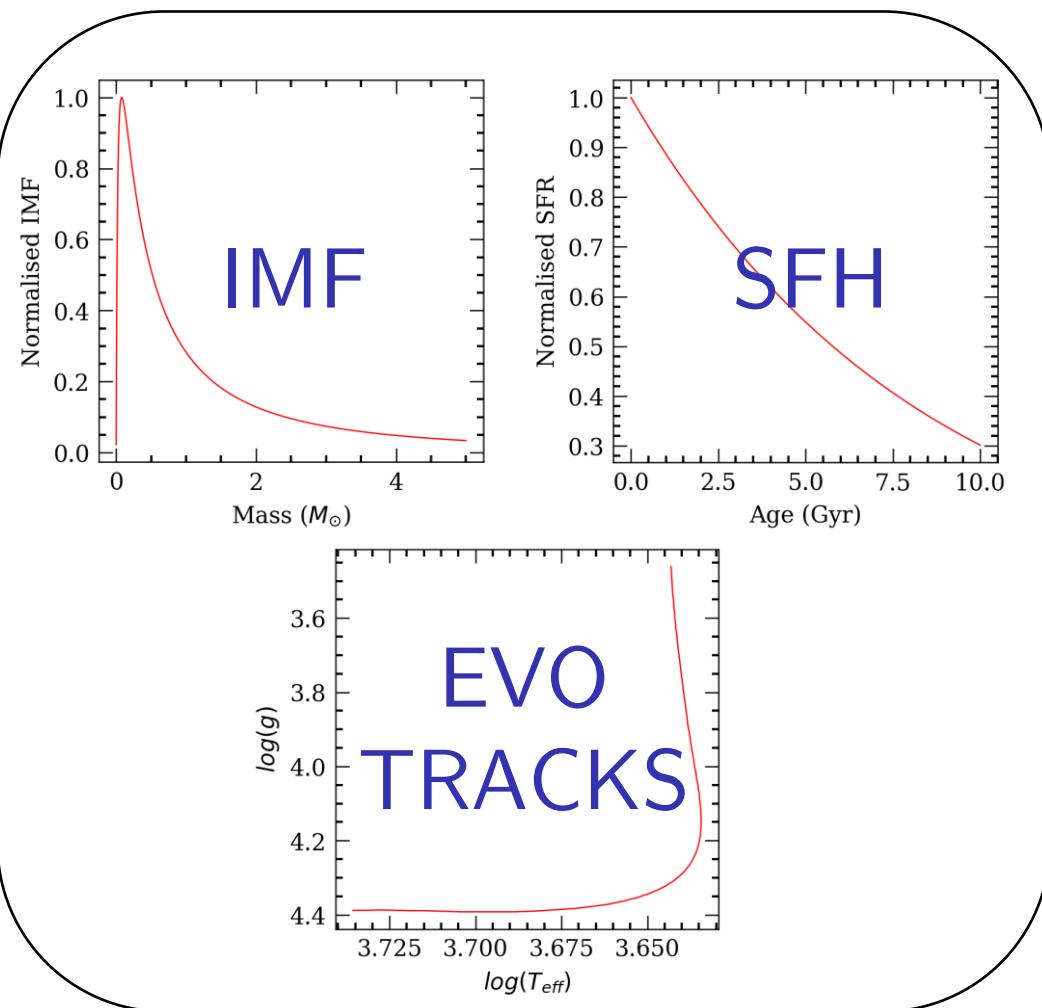
History

- Developed by Robin et al. (2003)
- Improved by Marshall et al. (2006) (3D extinction map)
- Improved by Czekaj et al. and Robin et al. (2014) (new evolutionary tracks, SFH and IMF)
- Improved by Lagarde et al. (2017) (new population synthesis code)
- Improved by Robin et al. (2022) (fully self-consistent gravitational potential)

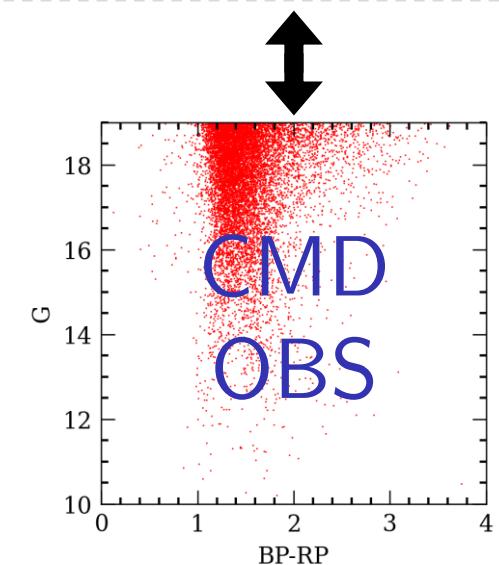
Use



Details on the BGM

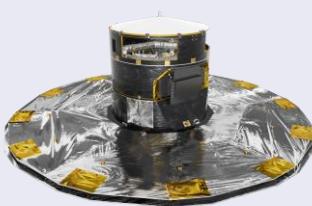
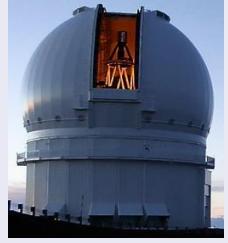


mag/kpc

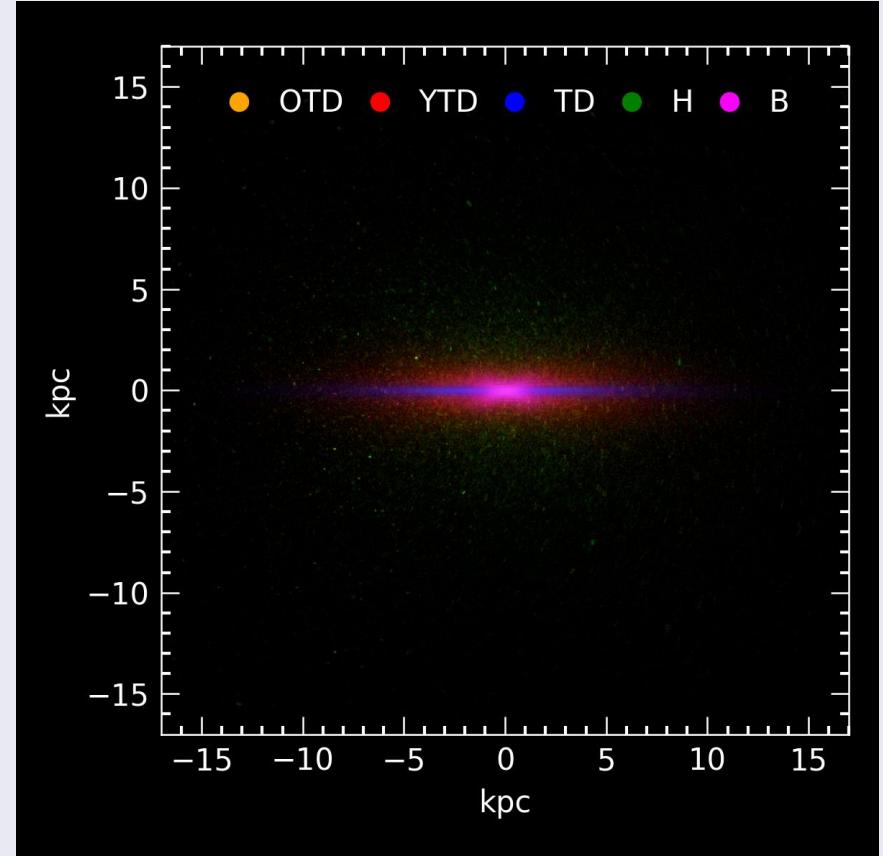
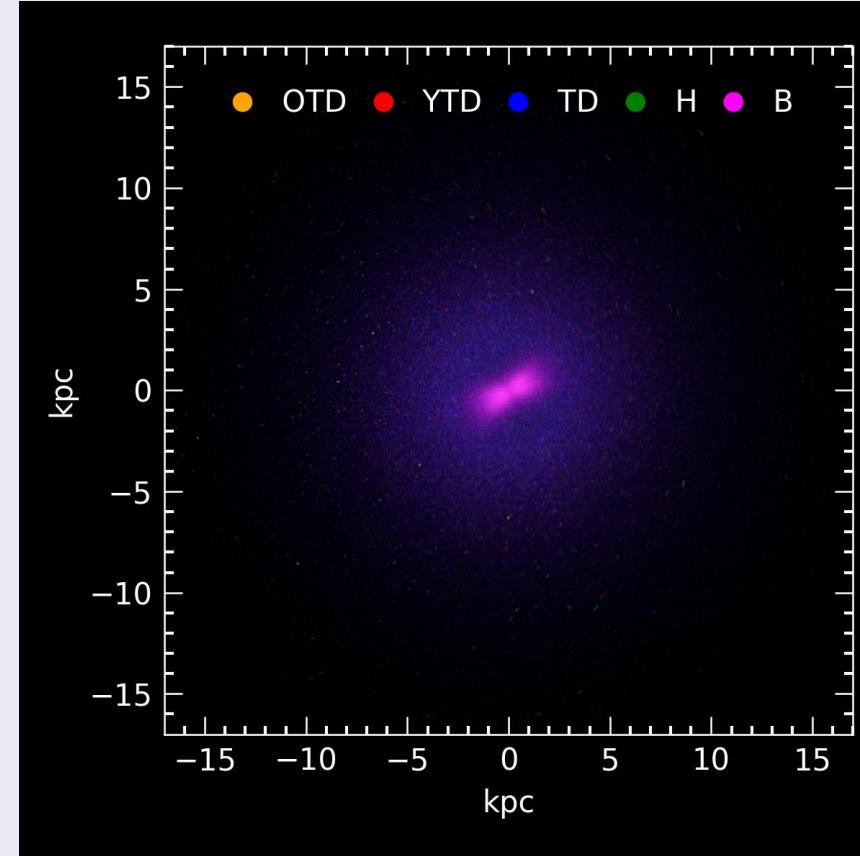


Specificities

Photometric systems



Five stellar populations

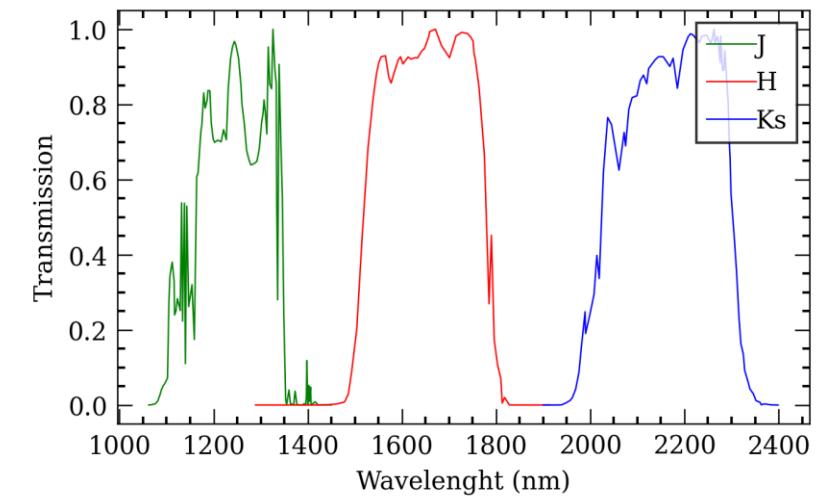
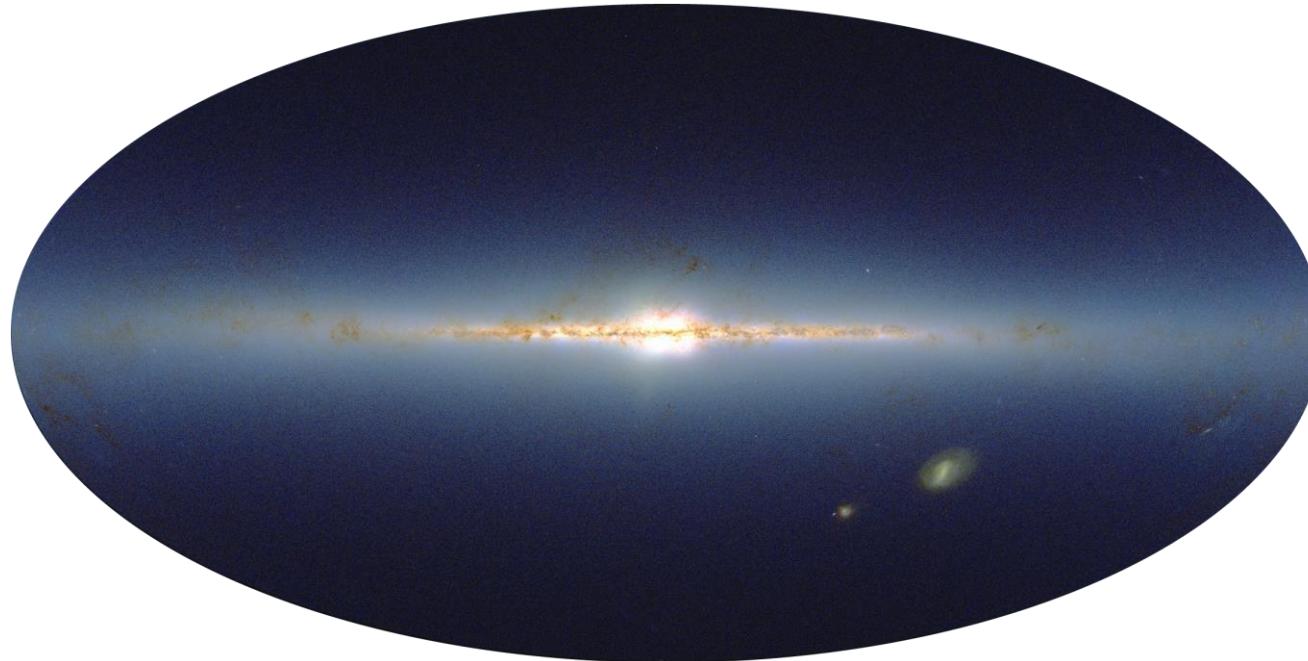


2MASS

The 2MASS mission



- From 1997 to 2001
- 3 photometric bands:
 - J: 1235 nm
 - H: 1662 nm
 - Ks: 2159 nm



All-sky release

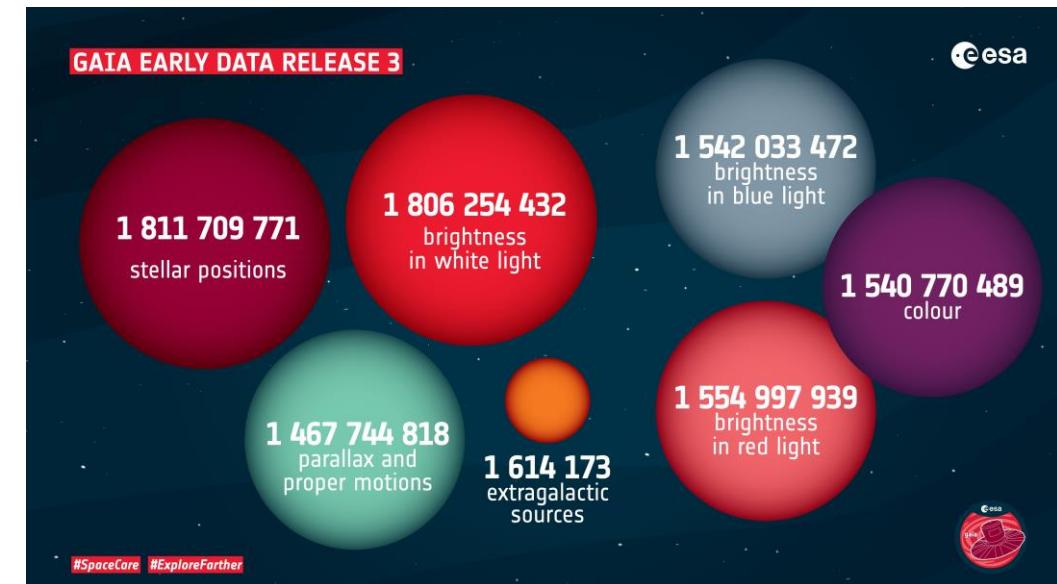
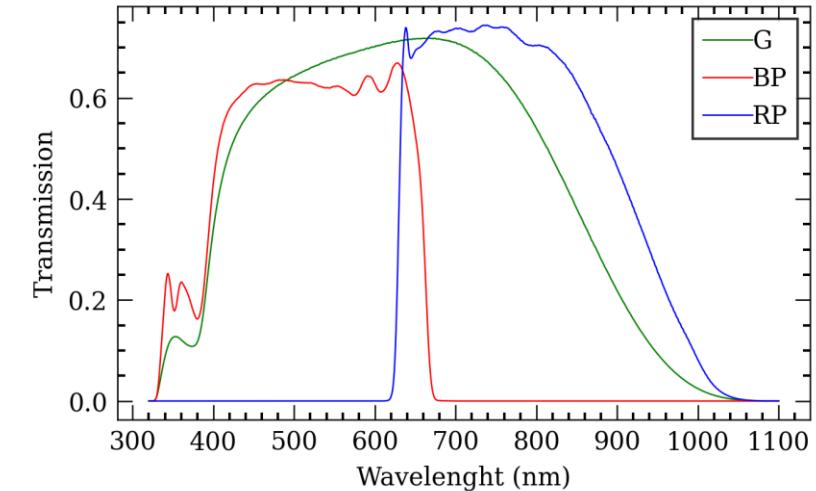
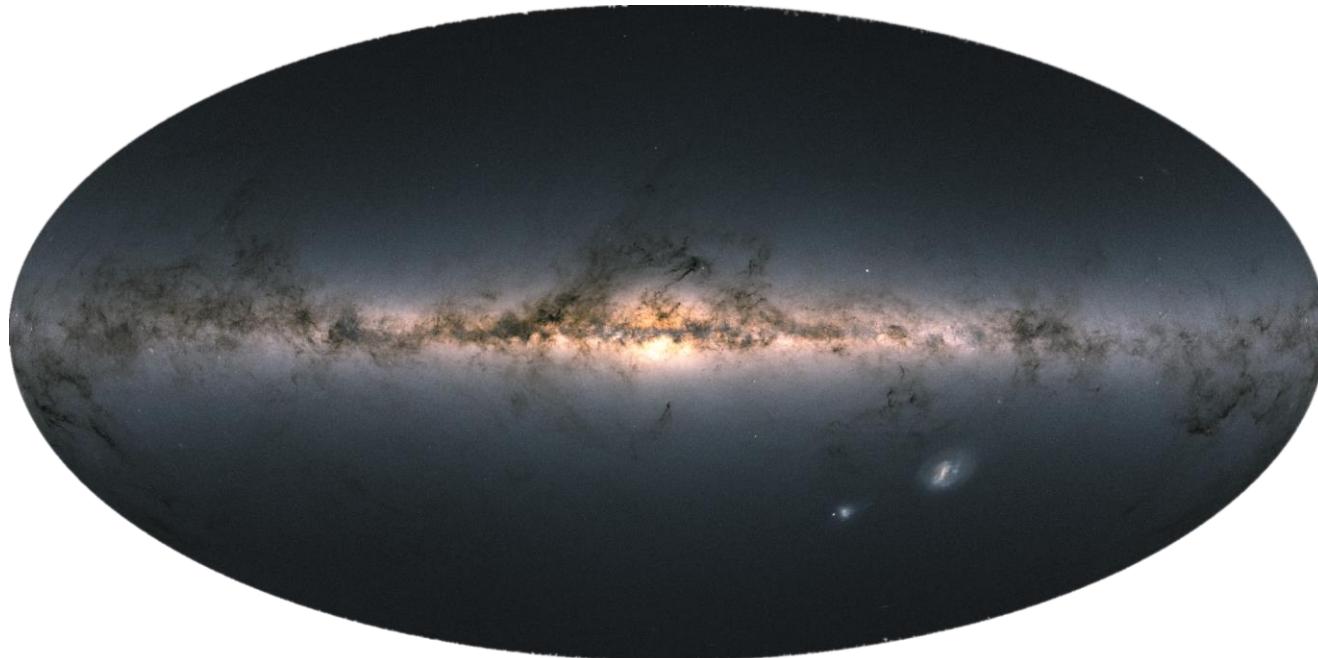
Point Source Catalog: 470 992 970 sources
Extended Source Catalog: 1 667 599 sources

Gaia

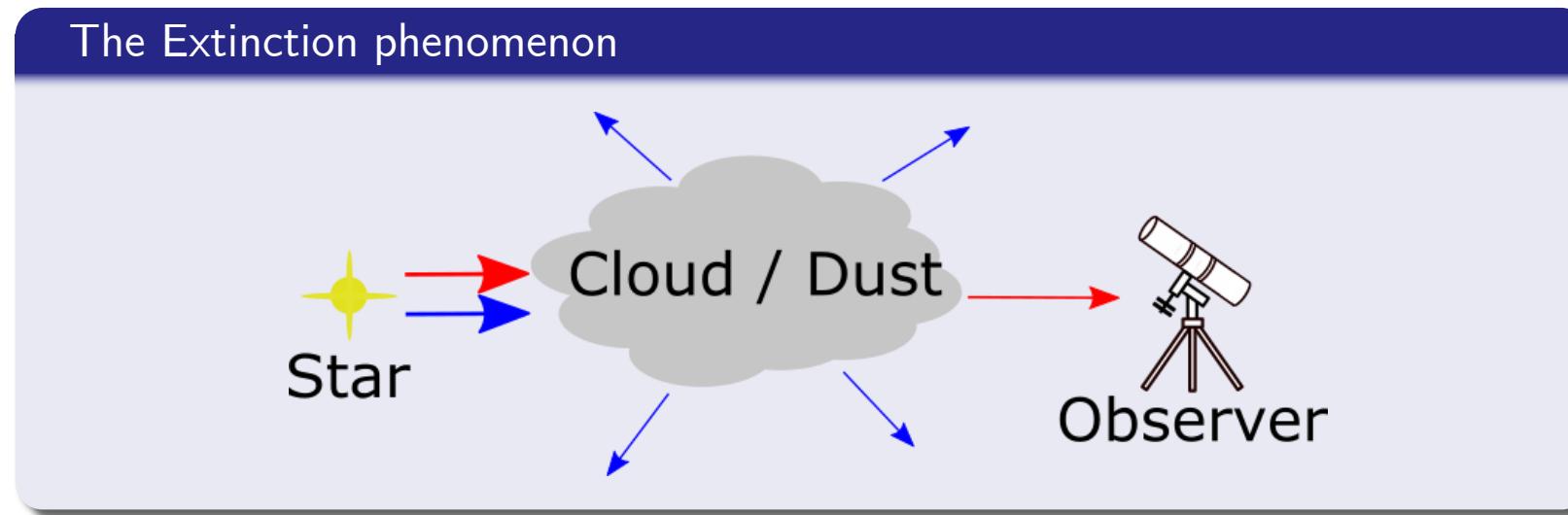
The Gaia mission



- From 2014 to now
- 3 photometric bands:
 - BP: 511 nm
 - G: 622 nm
 - RP: 777 nm

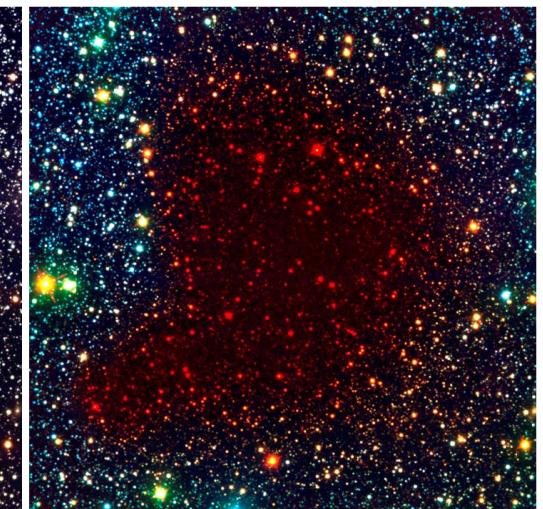


3D extinction map



Why 3D maps?

- MW structures identification
- Extinction in stellar population synthesis models
- ISM objects characterisation:
Distance to Molecular clouds, etc.



Barnard 68

3D extinction map

Different methods

Paper	Method	Depth	Resolution
Marshall et al. (2006)	Bayesian	7 kpc	15'
Chen et al. (2019)	Random Forest regression (ML)	4–6 kpc	6'
Guo et al. (2021)	SED fit	5 kpc	6'9 – 27'
Lallement et al. (2022)	Hierarchical Bayesian inversion	3 kpc	25 – 500 pc
Cornu et al. (2022)	Convolutional neural network (ML)	10 kpc	30'

Deriving extinction: main idea

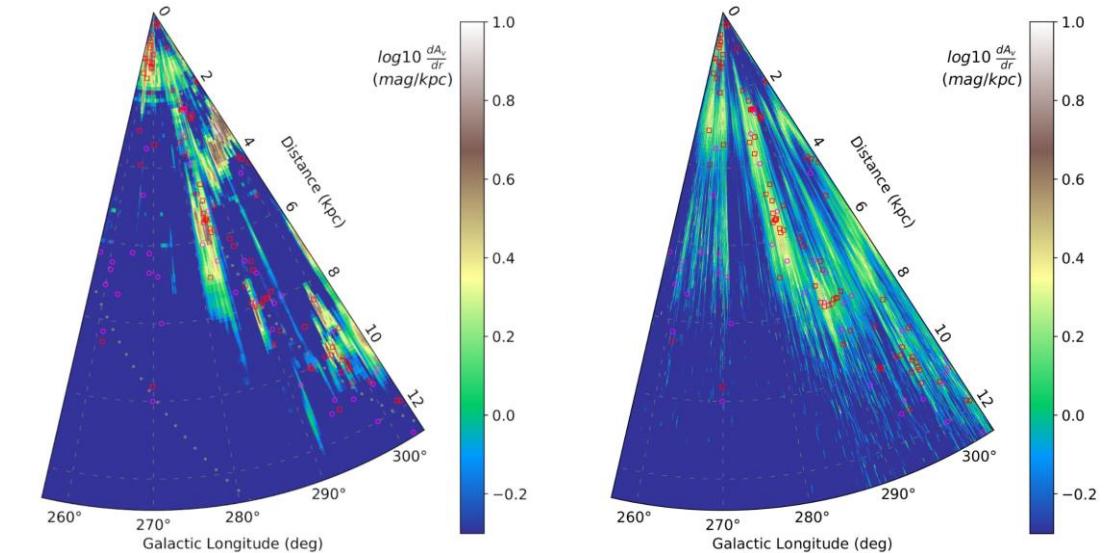
Observations – Simulations = Extinction

Stars + Extinction – Stars = Extinction

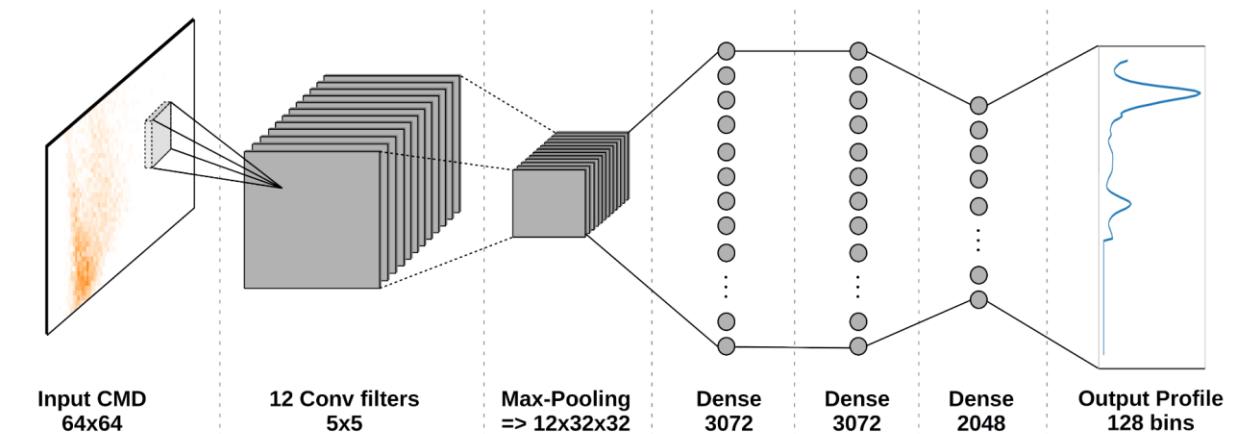
CIANNA

CIANNA

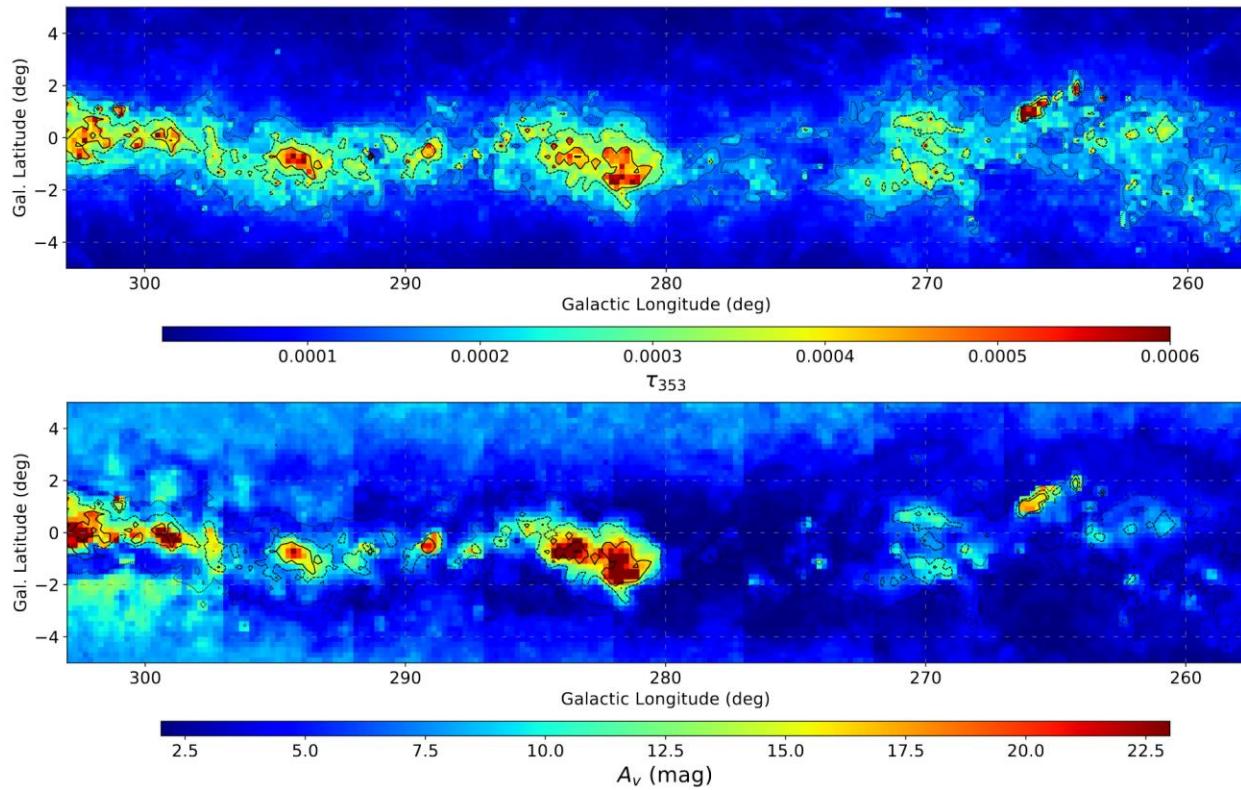
- CIANNA: Convolutional Interactive Artificial Neural Networks by/for Astrophysicists
- Developed by Cornu et al. (2022)
- Supervised training of CNNs
 - Trained using BGM
 - Used on 2MASS observations
- Possibility to combine multiple surveys without crossmatch



IANNA



CIANNA



Limitations

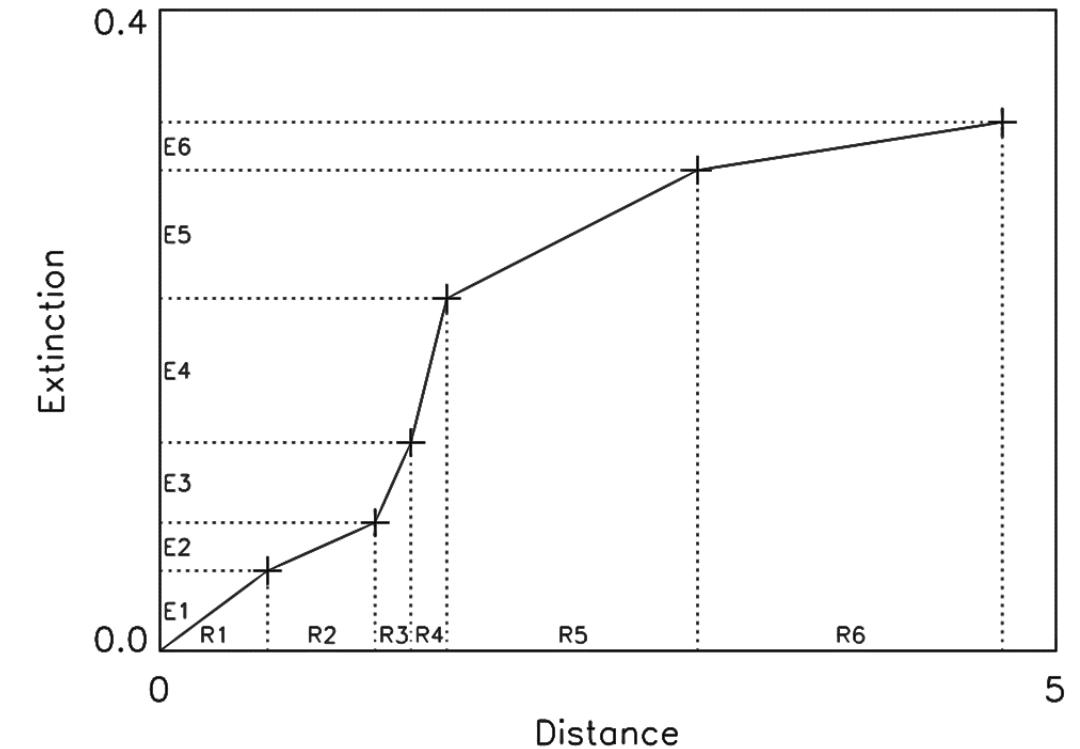
- Very Heavy training (time and storage)
- Need realistic training datasets
- Tiling effect
- Longitude dependence
- Only a small sky area was tested
- BGM dependent

RedLine

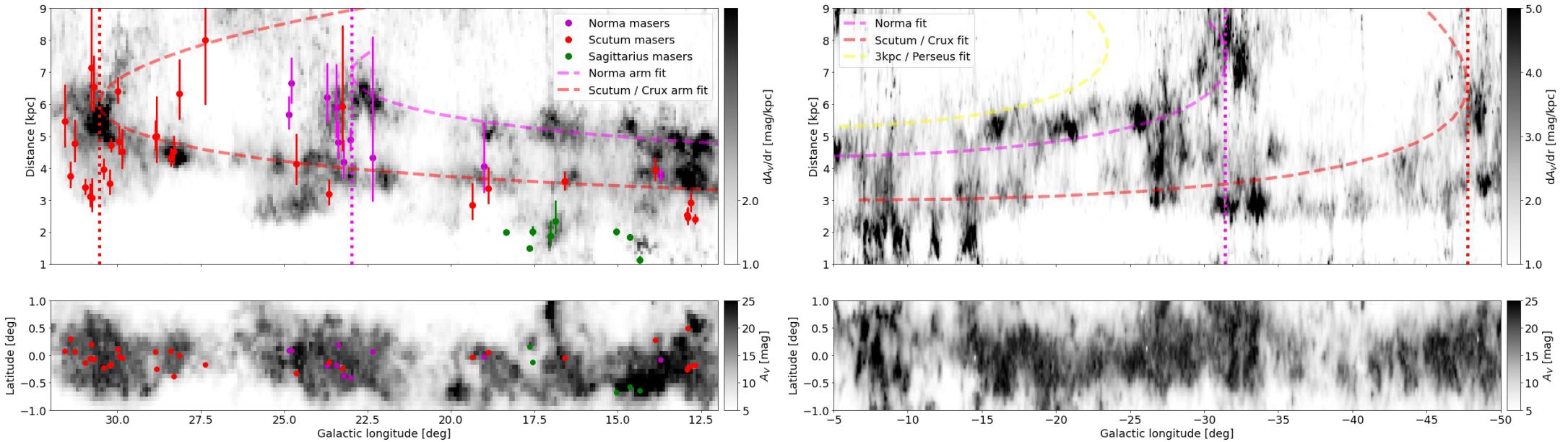
RedLine

RedLine

- Developed by Marshall et al. (in prep)
- Based on a Markov Chain Monte Carlo (MCMC) + Bayesian inference
- Use of BGM + 2MASS
- Could theoretically be used on other type of survey

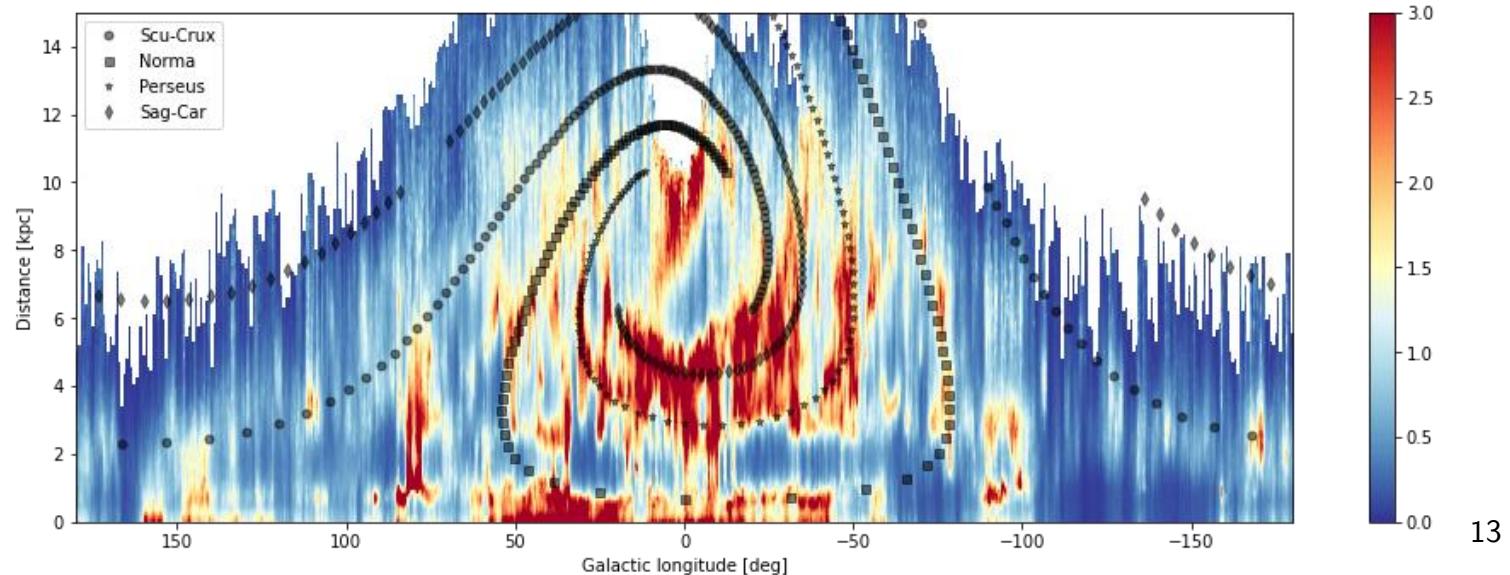


RedLine



Limitations

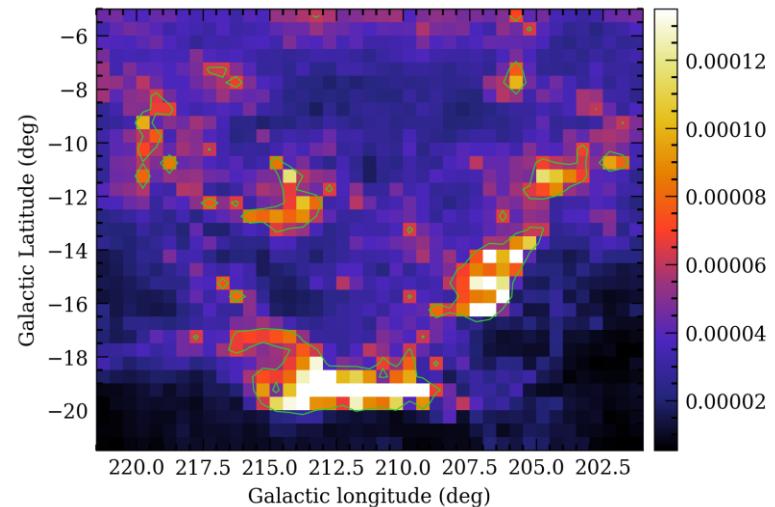
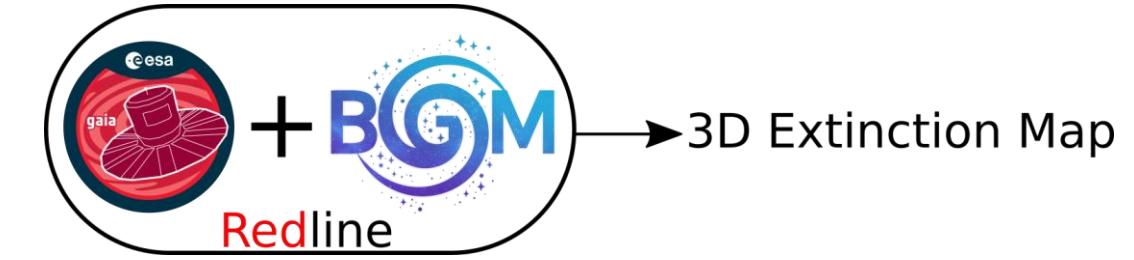
- Tested mainly on 2MASS
- Latitude dependence
- “Fingers of god” structures
- BGM dependent



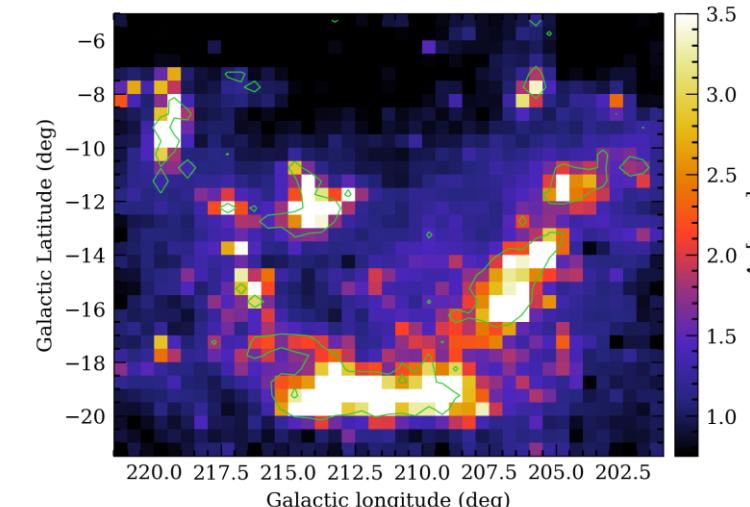
Gaia in RedLine

Method

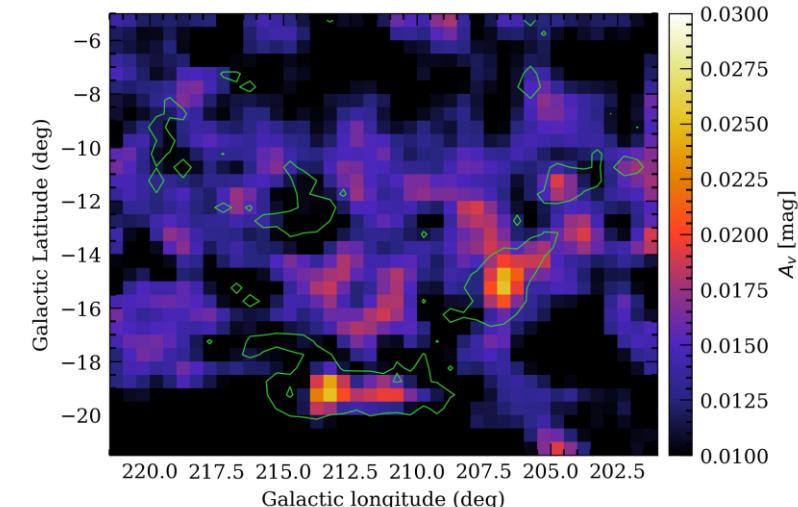
- Data: BP-RP and parallaxes from Gaia DR3
- Focus on:
 - Orion (400pc)
 - Taurus (125pc)
 - Monoceros (700pc)
 - Rosette (1.4 kpc)



Planck opacity at 353 GHz

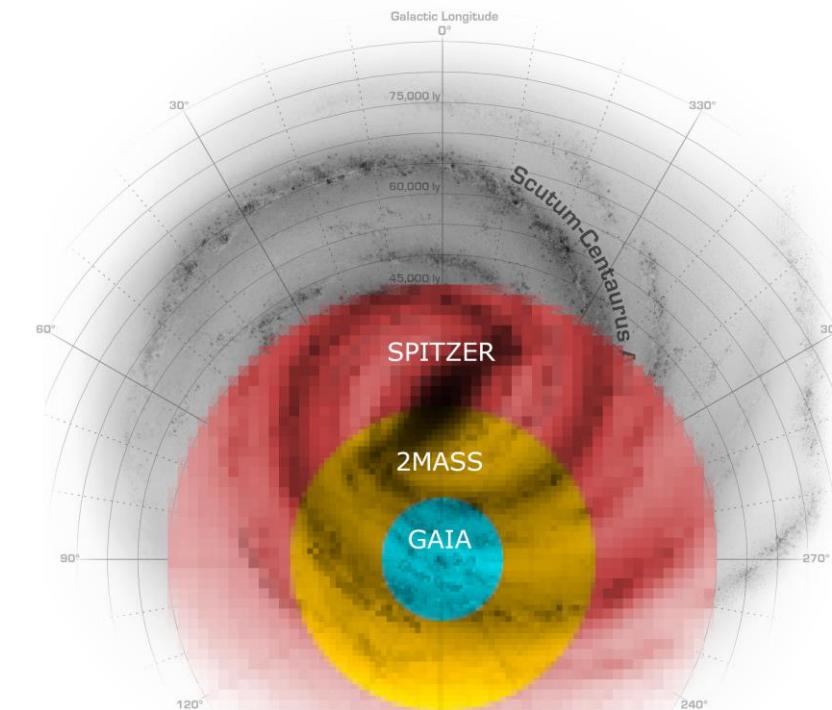
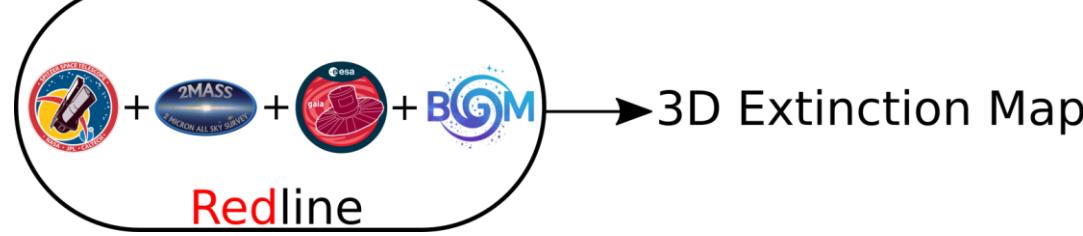
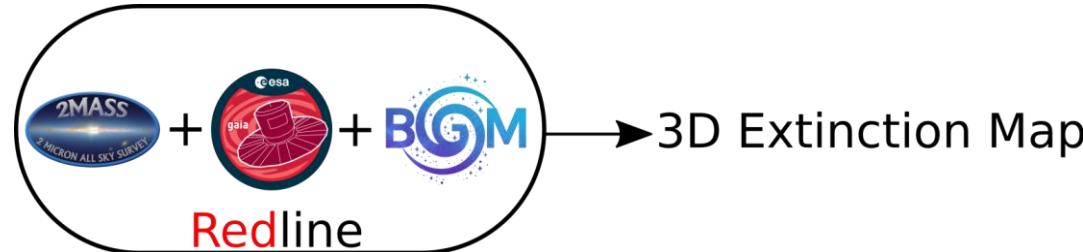
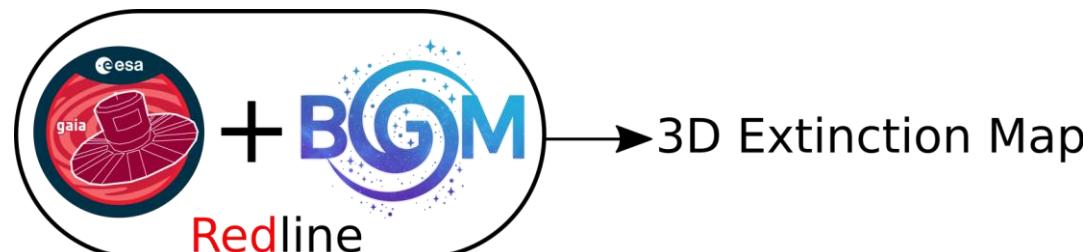


2MASS Integrated extinction map



GAIA Integrated extinction map

Goals



Long-term Goals

- 3D extinction map of the whole Galaxy
- Use of CIANNA

Reference

-  Robin, A. C. et al. (2003). "A synthetic view on structure and evolution of the Milky Way". In: *A & A* 409, pp. 523–540. DOI: [10.1051/0004-6361:20031117](https://doi.org/10.1051/0004-6361:20031117).
-  Marshall, D. J. et al. (2006). "Modelling the Galactic interstellar extinction distribution in three dimensions". In: *A & A* 453.2, pp. 635–651. DOI: [10.1051/0004-6361:20053842](https://doi.org/10.1051/0004-6361:20053842).
-  Robin, A. C. et al. (2014). "Constraining the thick disc formation scenario of the Milky Way". In: *A & A* 569, A13. DOI: [10.1051/0004-6361/201423415](https://doi.org/10.1051/0004-6361/201423415).
-  Lagarde, N. et al. (2017). "Population synthesis to constrain Galactic and stellar physics: I. Determining age and mass of thin-disc red-giant stars". In: *A & A* 601, A27. DOI: [10.1051/0004-6361/201630253](https://doi.org/10.1051/0004-6361/201630253).
-  Robin, A. C. et al. (2022). "A self-consistent dynamical model of the Milky Way disc adjusted to Gaia data". In: arXiv:2208.13827. arXiv:2208.13827 [astro-ph]. URL: <http://arxiv.org/abs/2208.13827>.
-  Marshall, D. J. et al. (in prep.). "Spiral and non-spiral structure of the plane of the Milky Way". In.
-  Cornu, D. 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". In: arXiv:2201.05571.