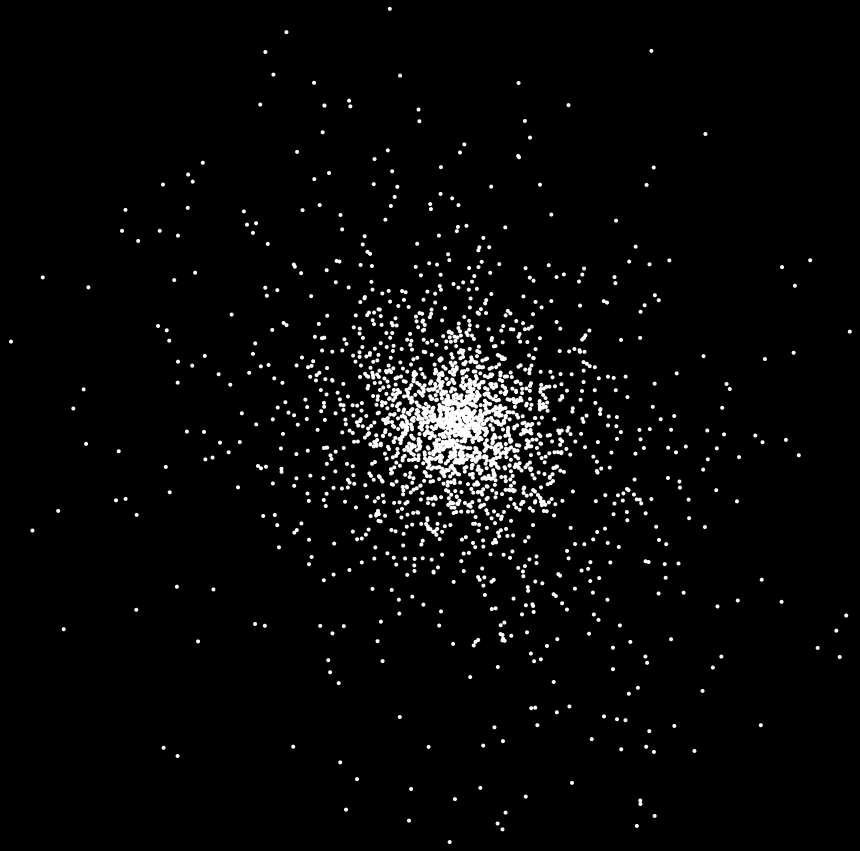
GAIA, EXTINCTION, AND THE GALACTIC MID-PLANE

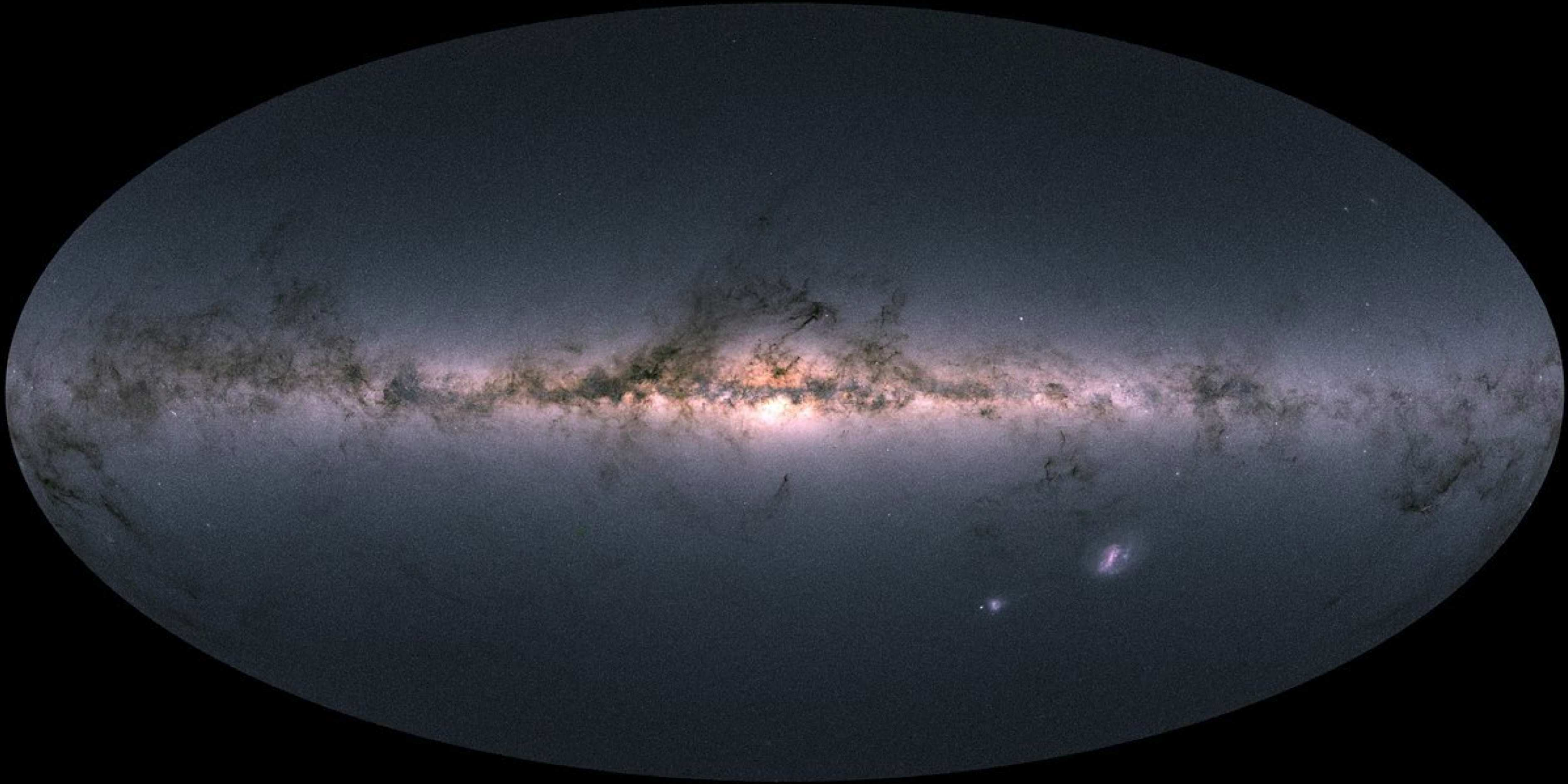


Tristan Cantat-Gaudin

Max-Planck-Institut für Astronomie, Heidelberg

From Star Clusters to Field Populations, Firenze – 2023/11/20


Jérôme Obiols

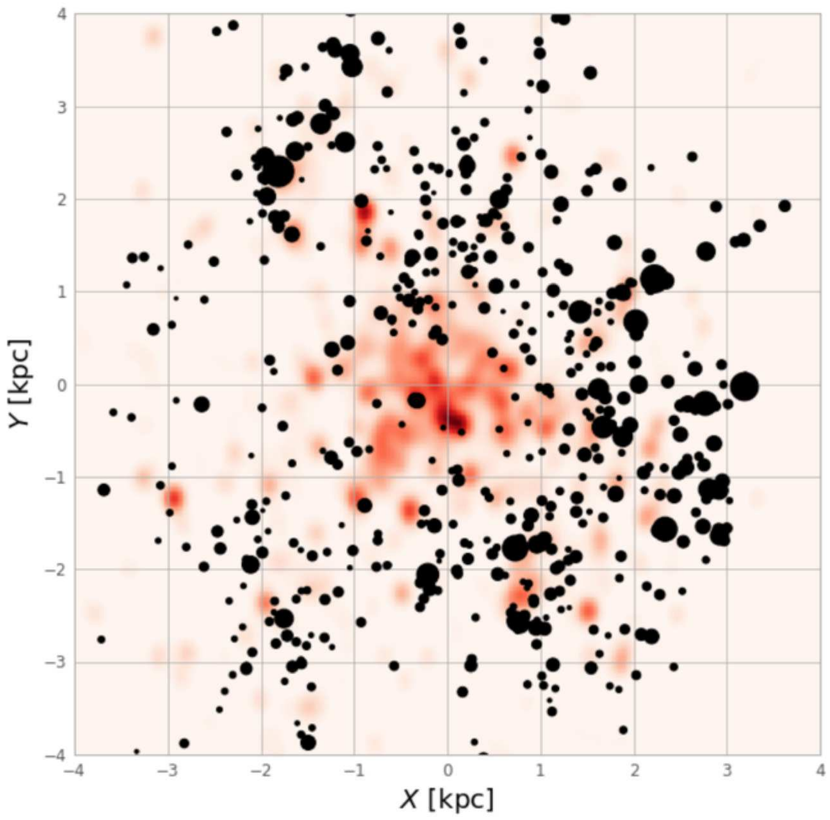


The Milky Way is a spiral galaxy

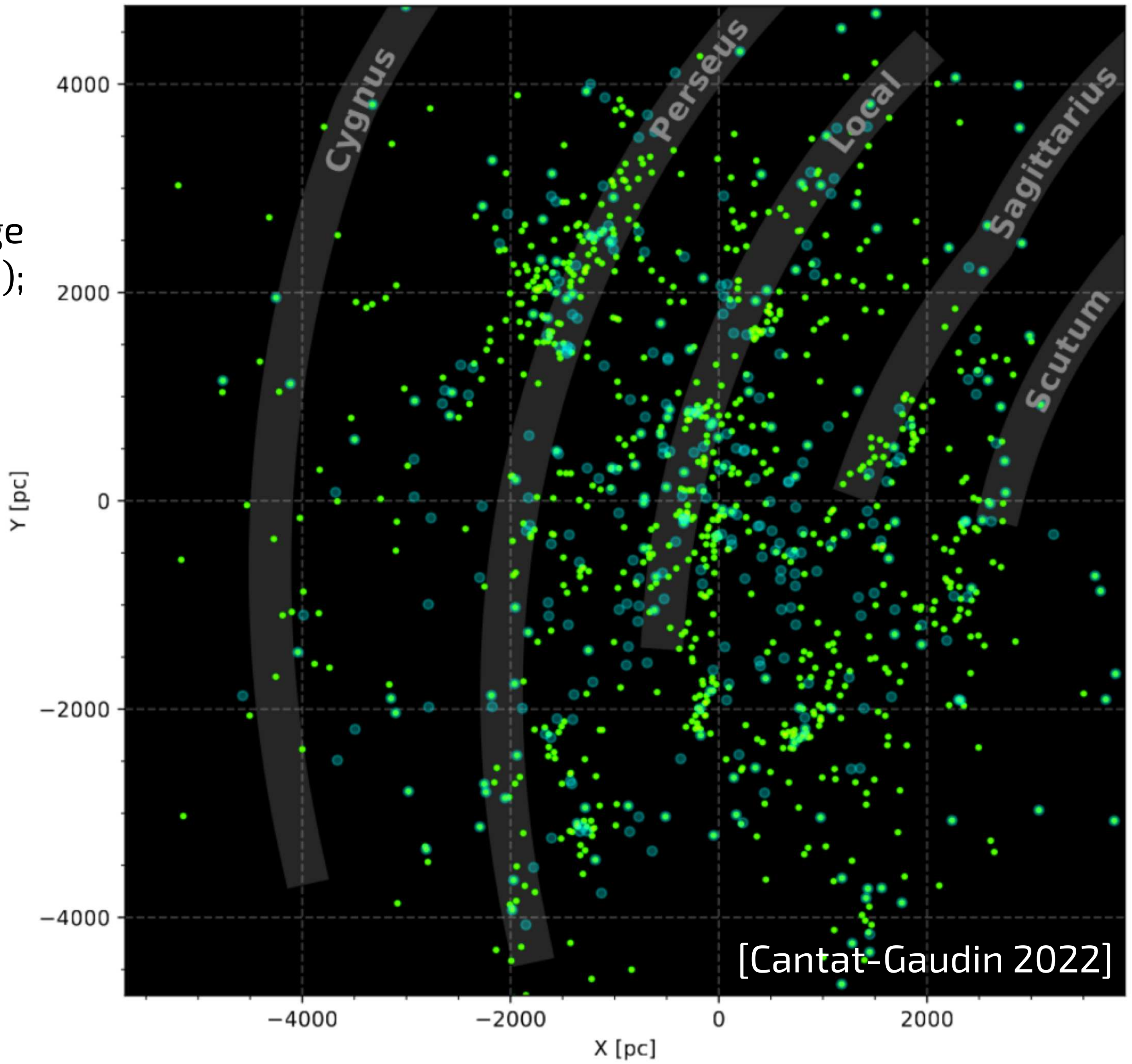
Since we live inside it, we actually know a lot less about its structure than we know about other, distant galaxies.

Hundreds of Gaia-discovered clusters

and automated methods to estimate ages for large batches of objects. e.g. Cantat-Gaudin et al. (2020); Cavallo et al. (2023); Hunt & Reffert (2023)

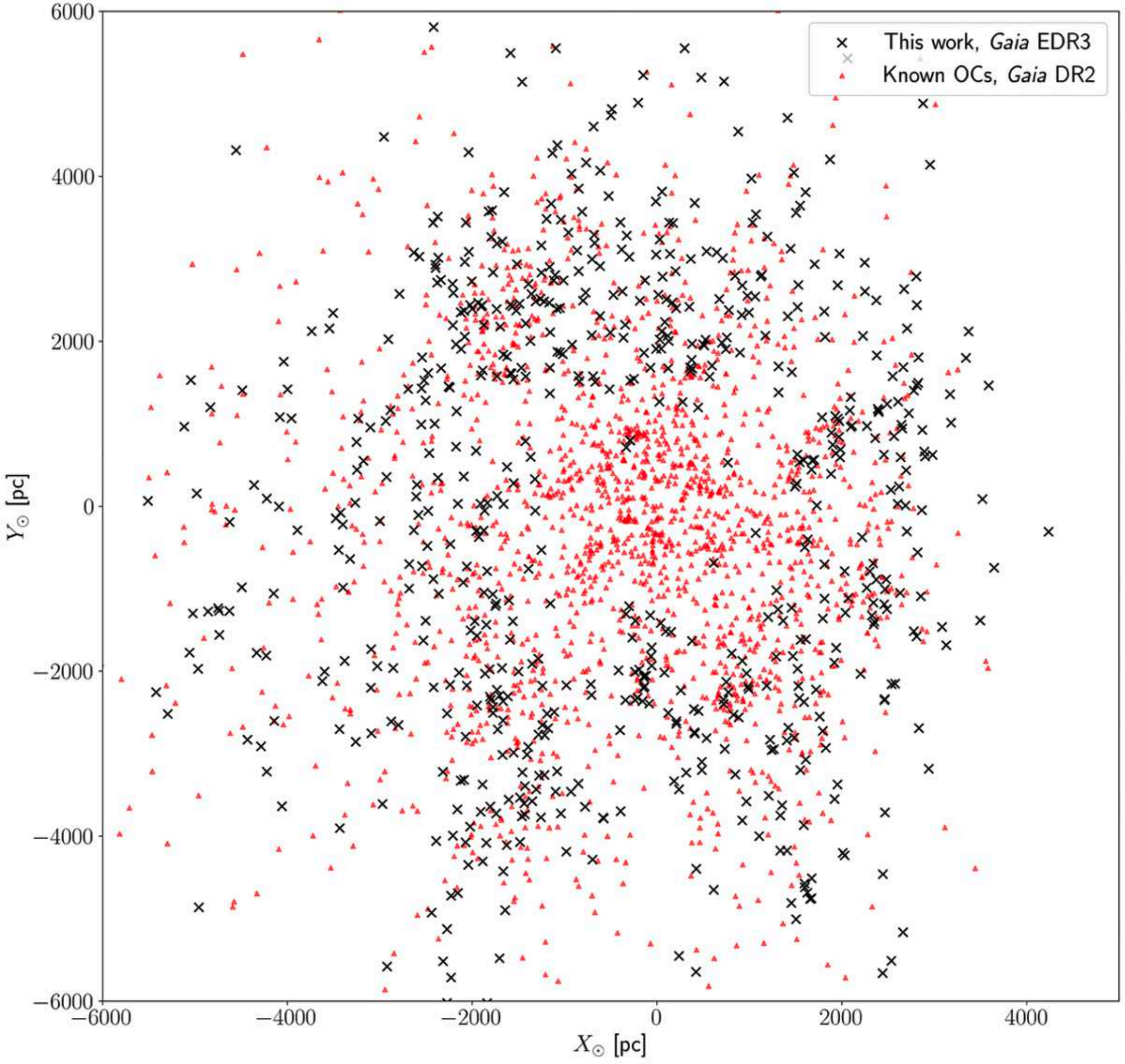


[Castro-Ginard et al. 2020]



clusters younger than 60 Myr (green) and 60 to 100 Myr (cyan)

Hundreds of Gaia-discovered clusters



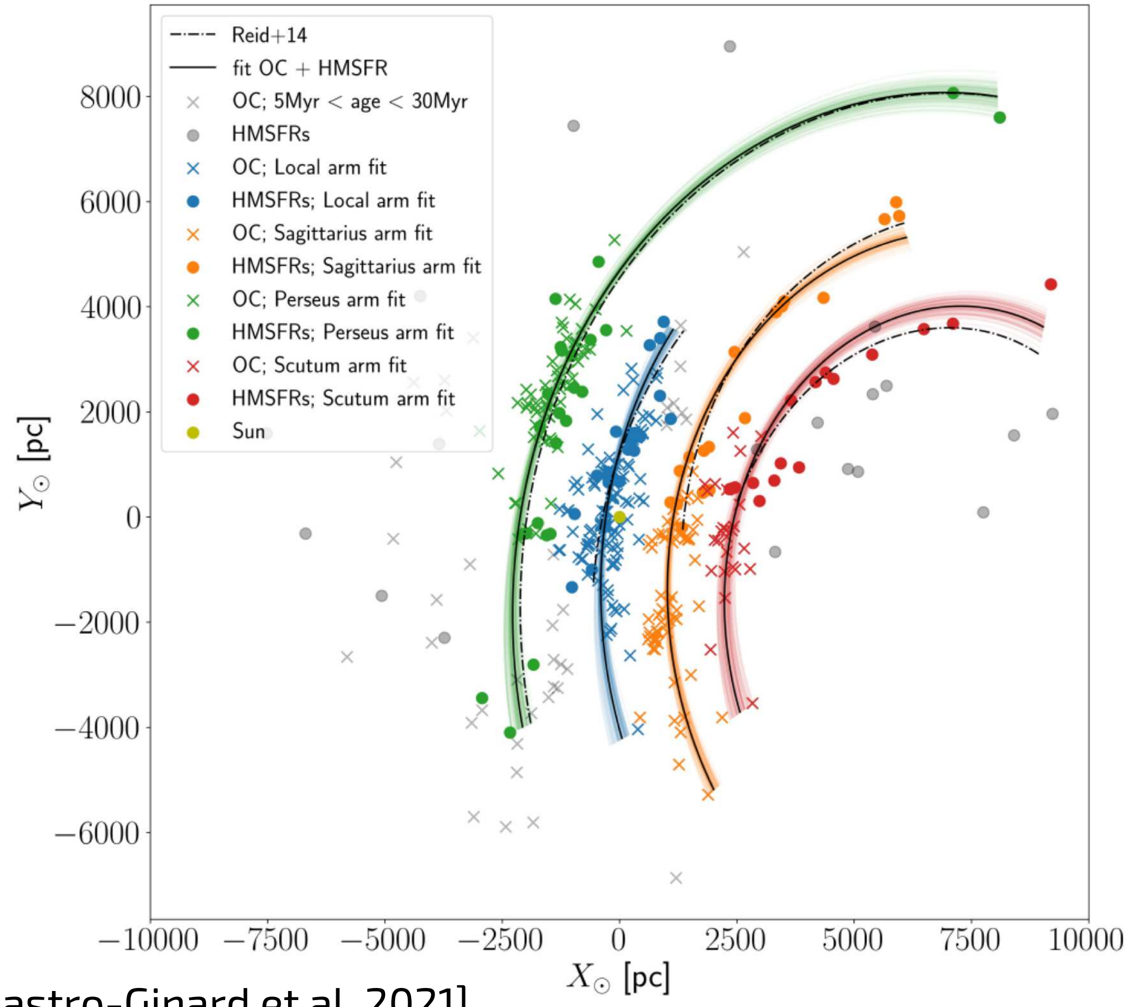
Castro-Ginard et al. (2022)

[Perren et al. 2023]

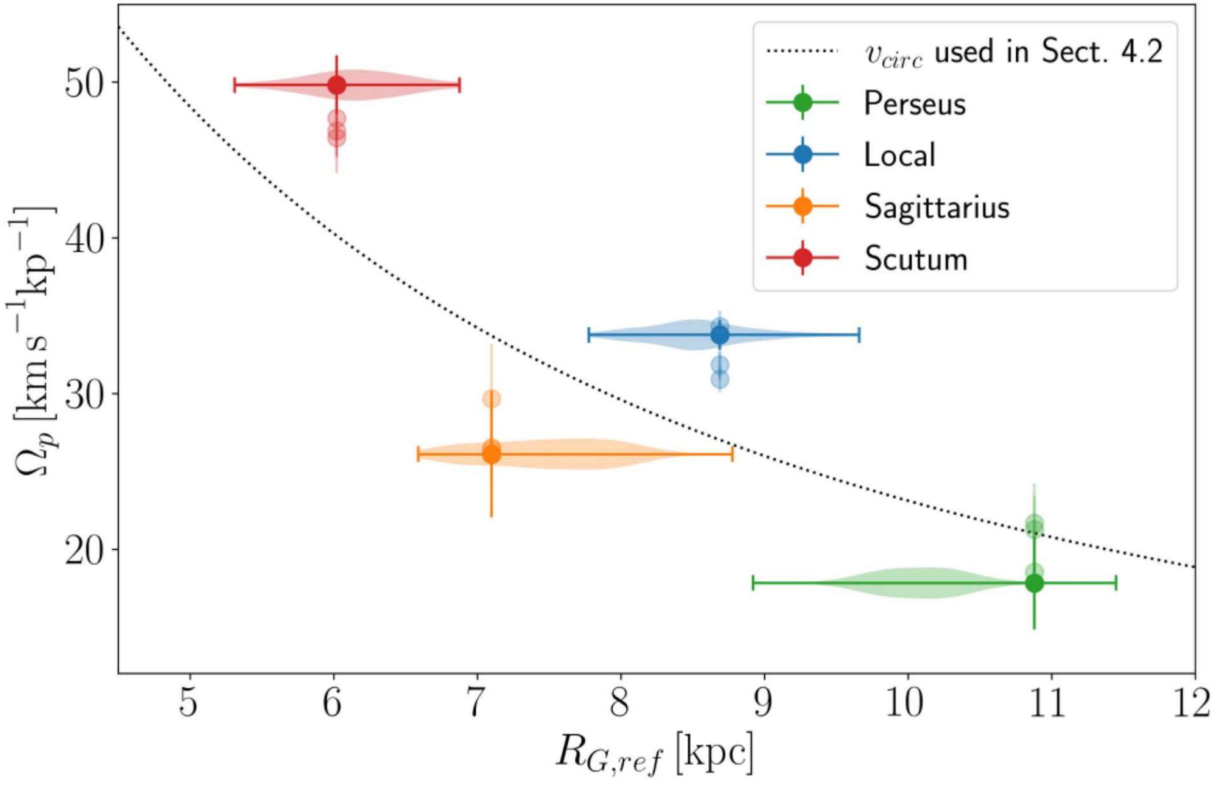
Table 1. List of all the catalogues cross-matched in this article to generate the UCC database. Columns ID and N are the denomination used for new candidate OCs, and the total number of OCs taken from each work, respectively.

Reference	ID	N
Kharchenko et al. (2012)	–	2854
Loktin & Popova (2017)	LP	1050
Castro-Ginard et al. (2018)	UBC	23
Bica et al. (2019)	Bica	3555
Castro-Ginard et al. (2019)	UBC	53
Sim et al. (2019)	UPK	207
Liu & Pang (2019)	FoF	76
Ferreira et al. (2019)	UFMG	3
Castro-Ginard et al. (2020)	UBC	570
Ferreira et al. (2020)	UFMG	25
Cantat-Gaudin et al. (2020)	–	2017
Hao et al. (2020)	HXWHB	16
Ferreira et al. (2021)	UFMG	34
He et al. (2021)	HXHWL	74
Dias et al. (2021)	–	1742
Hunt & Reffert (2021)	PHOC	41
Casado (2021)	Casado	20
Jaehnig et al. (2021)	XDOCC	11
Santos-Silva et al. (2021)	CMa	5
Tarricq et al. (2022)	–	467
Castro-Ginard et al. (2022)	UBC	628
He et al. (2022a)	CWNU	541
He et al. (2022b)	CWNU	836
Hao et al. (2022)	OC	703
Li et al. (2022)	LISC	61
He et al. (2023b)	CWNU	1656
Hunt & Reffert (2023)	HSC	6272
Qin et al. (2023)	OCSN	101
Li & Mao (2023)	LISC	35
Chi et al. (2023b)	CWWL	46
Chi et al. (2023a)	LISC-III	82
Chi et al. (2023c)	CWWDL	1179
Number of OCs in all the catalogues		24983
Number of unique OCs after cross-matching		13684

The Milky Way doesn't seem to be a classical grand-design spiral galaxy



[Castro-Ginard et al. 2021]

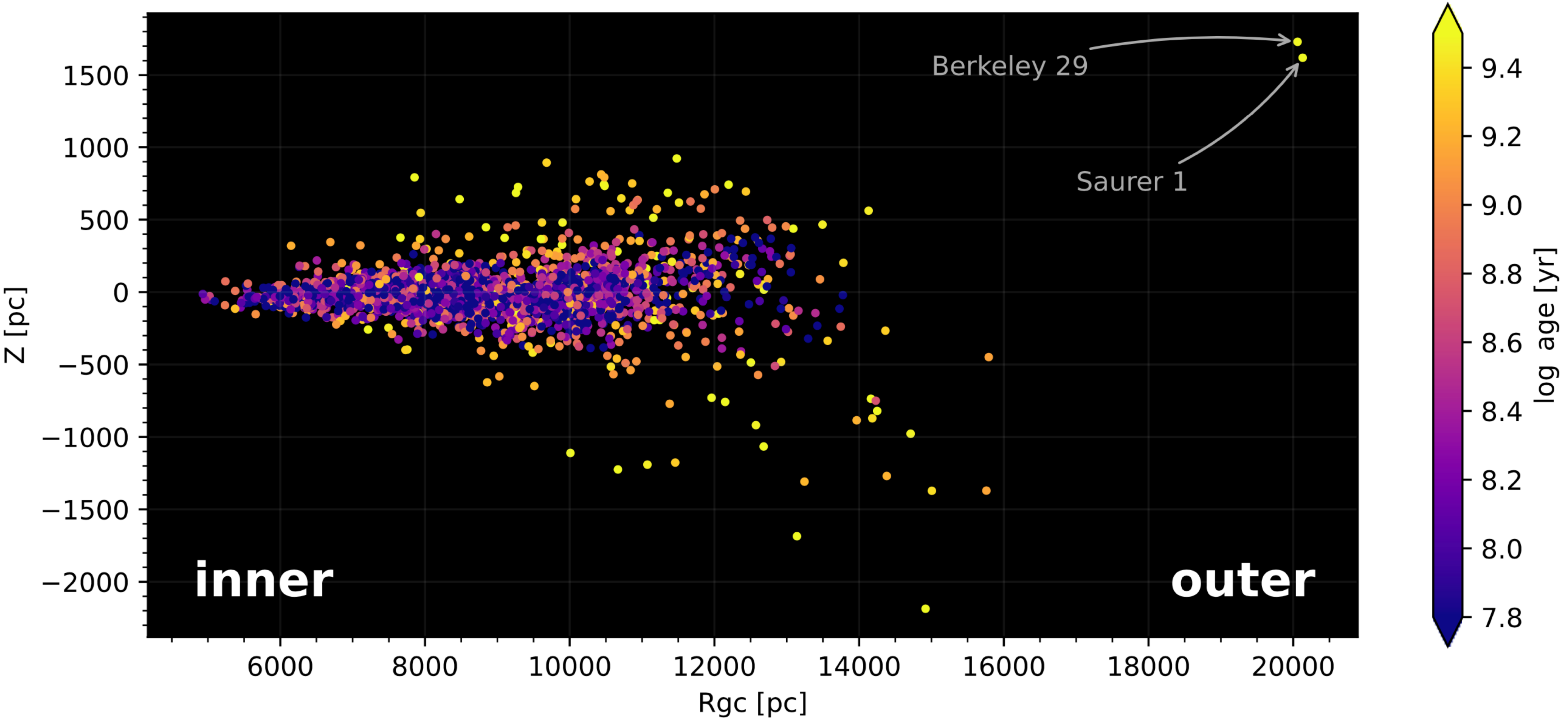


The arms all have independent pattern speeds, which are close to the rotational velocity of circular orbits.

They are probably transient features, not stable density waves

The radial and vertical structure of the Milky Way

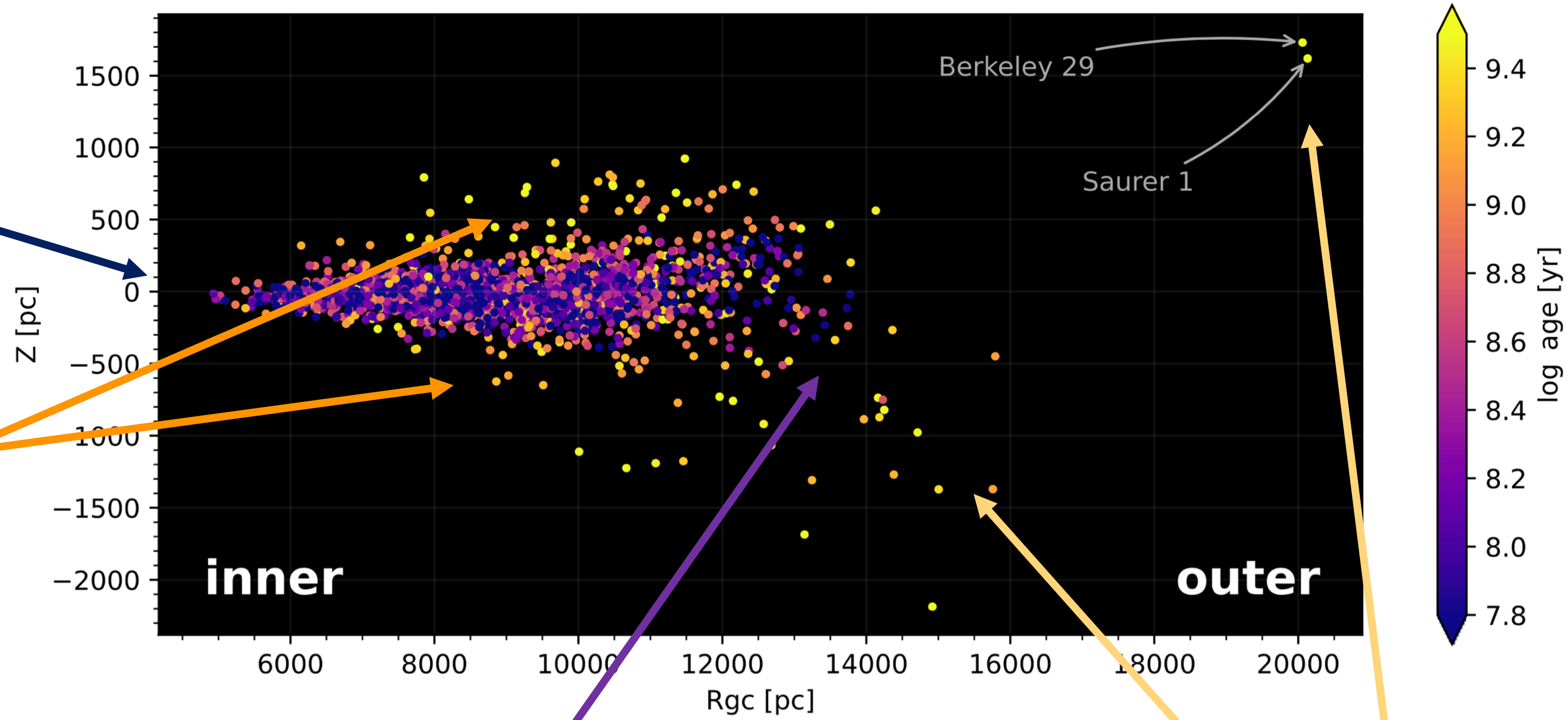
(traced by clusters)



The radial and vertical structure of the Milky Way

few old clusters in the inner disc

older clusters can be found further from the Galactic mid-plane



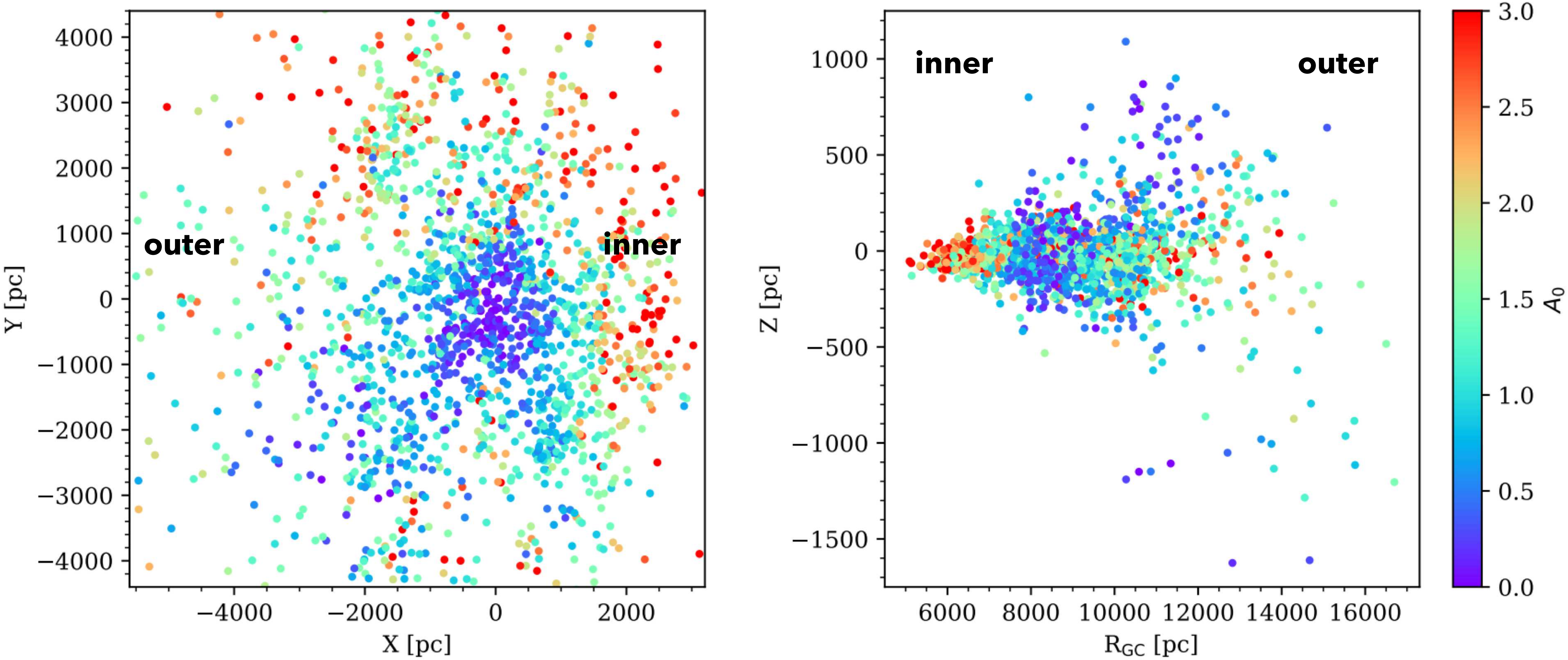
no star formation beyond ~ 14 kpc?

visible flaring: increase of scale height with Galactocentric distance

radial migration: old clusters can be found at large Galactocentric distances

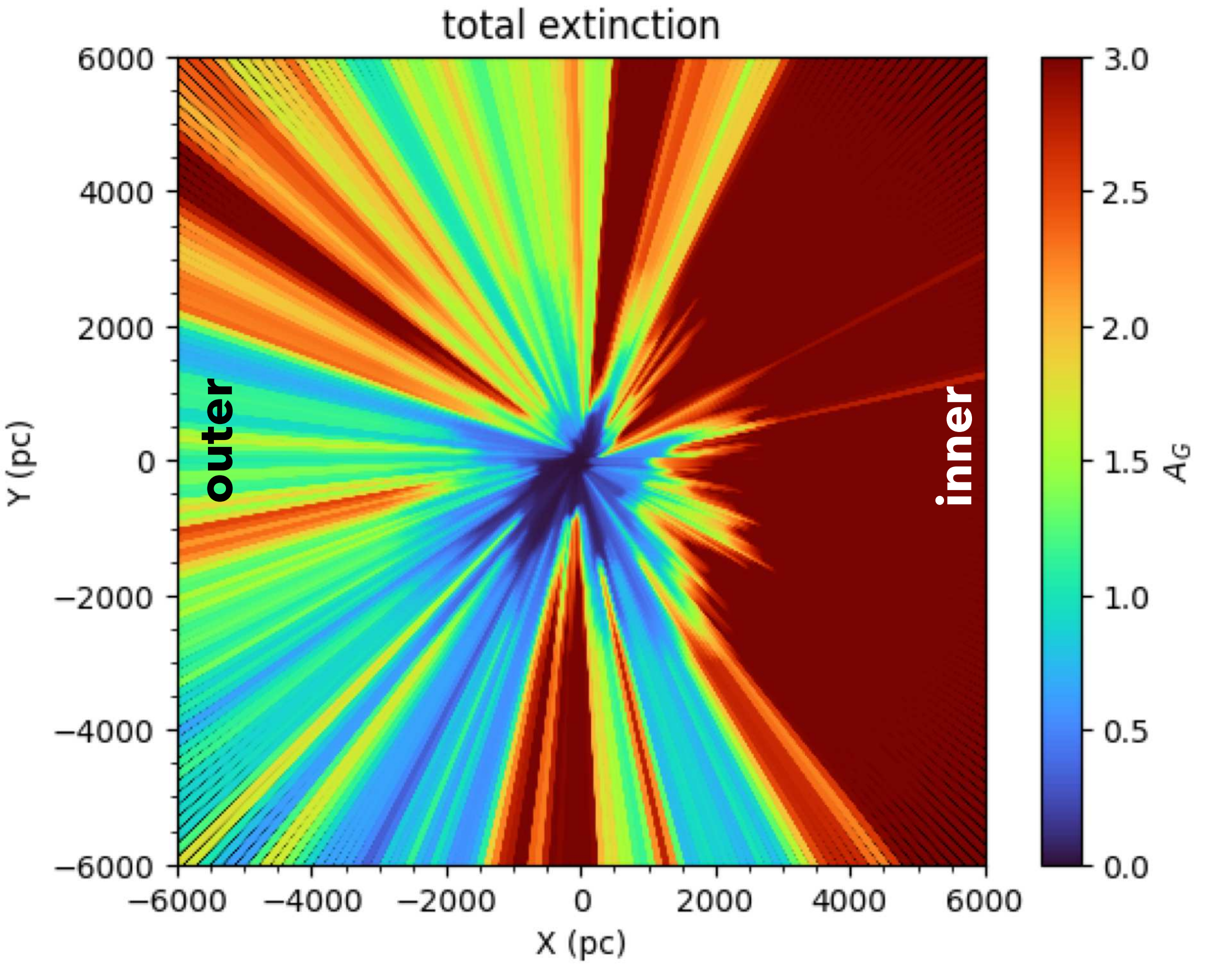
Our view of the inner disc is limited by extinction

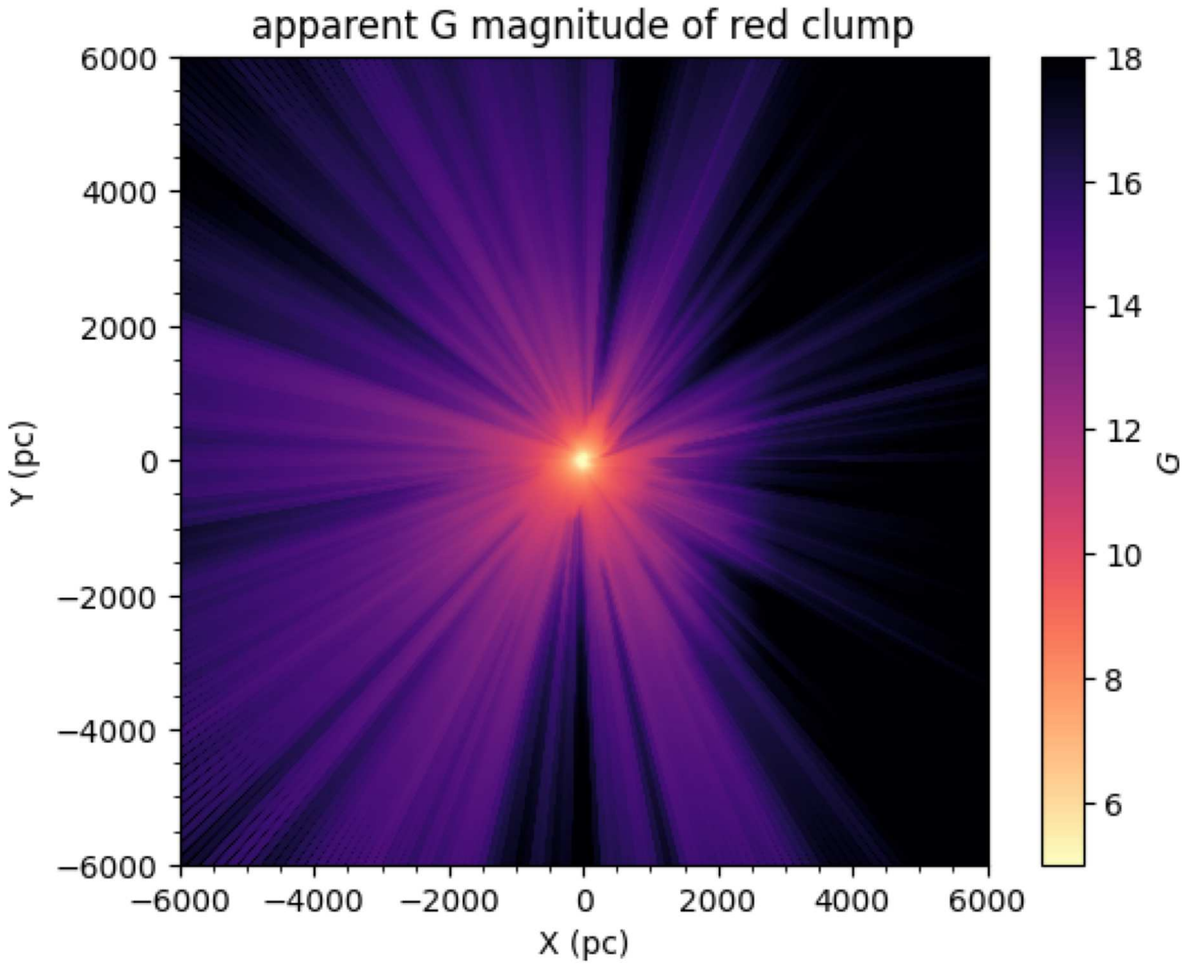
The view of the outer disc is much less affected.



Our view of the inner disc is limited by extinction

3D extinction map from Lallement et al. (2022)





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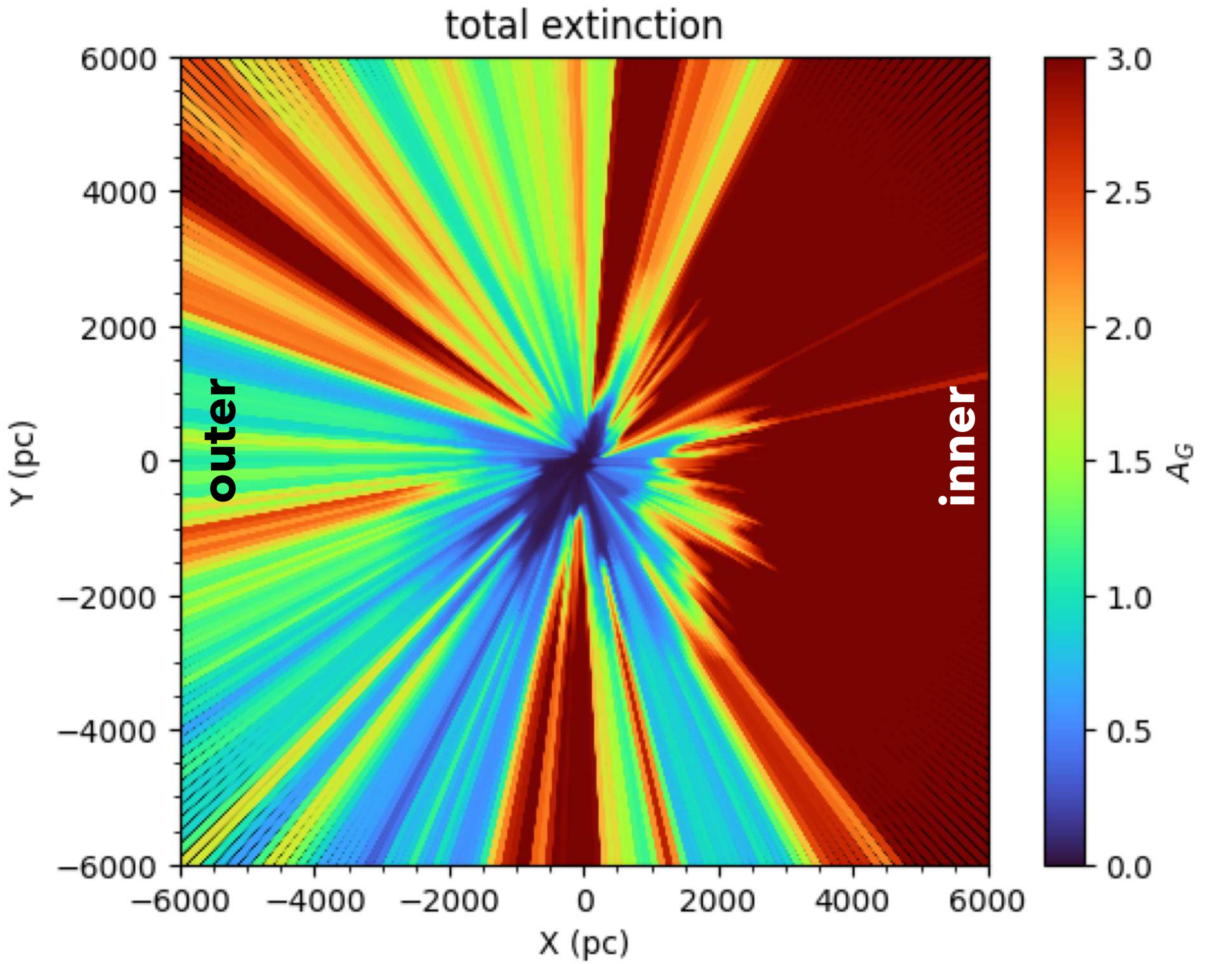
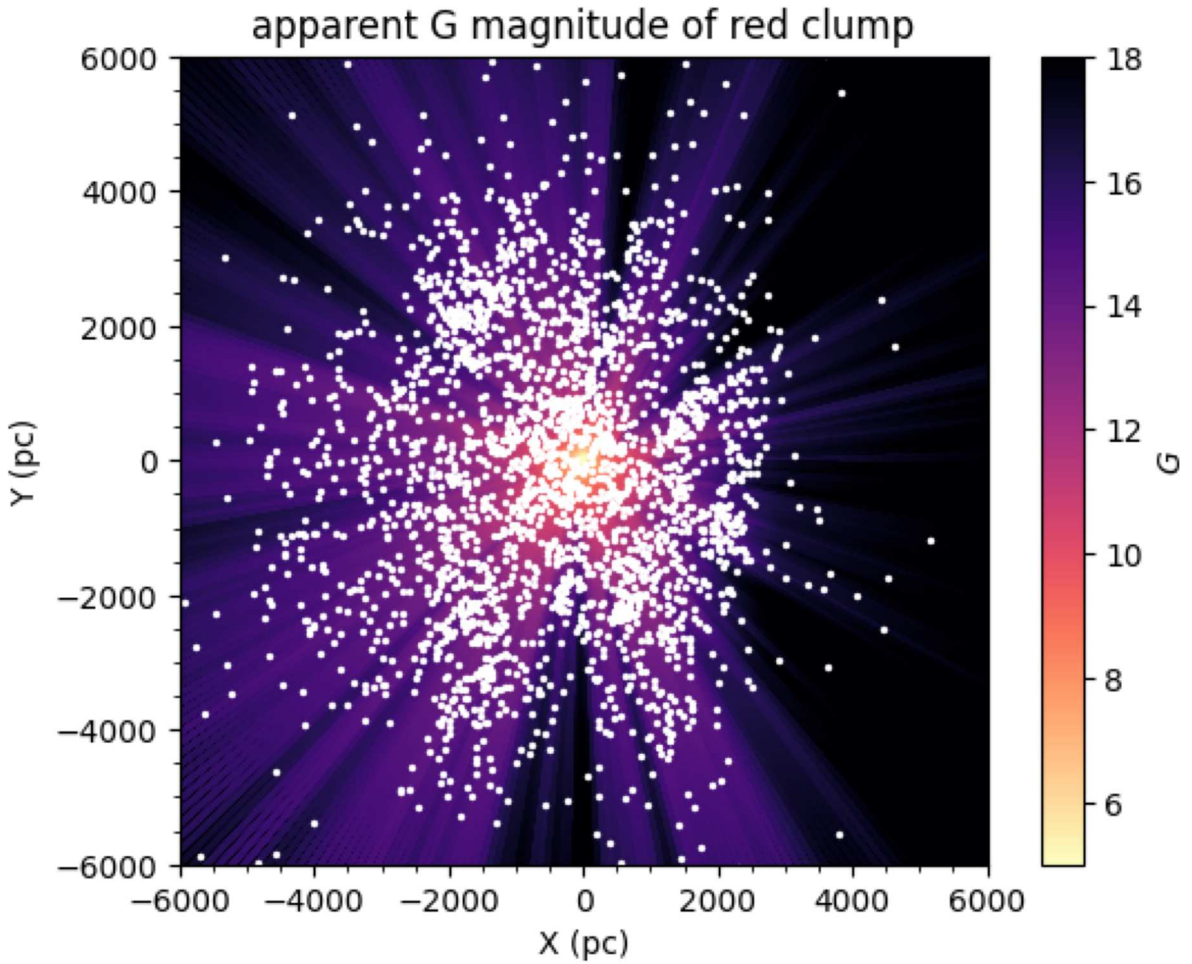
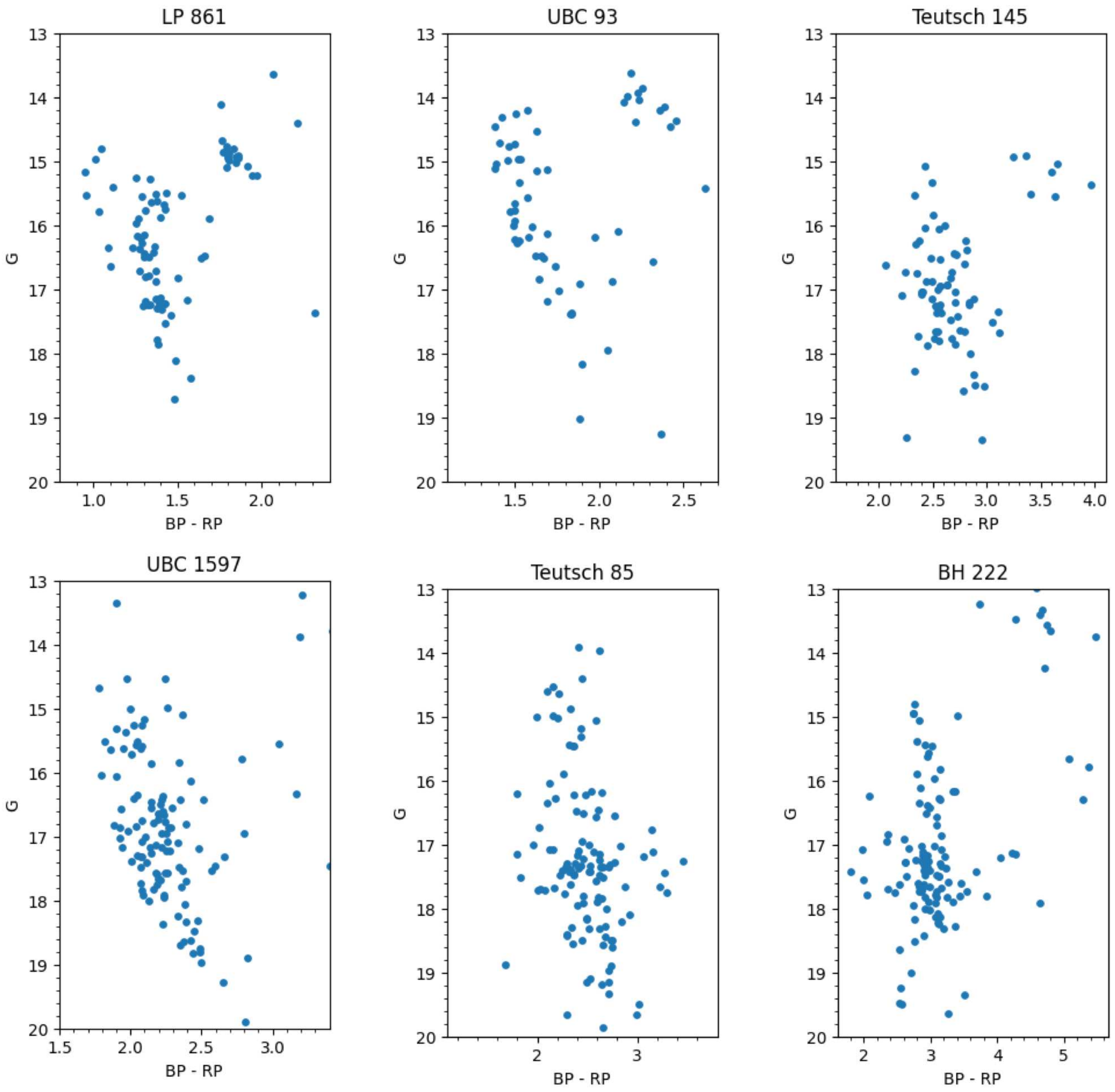




Six of the innermost clusters…

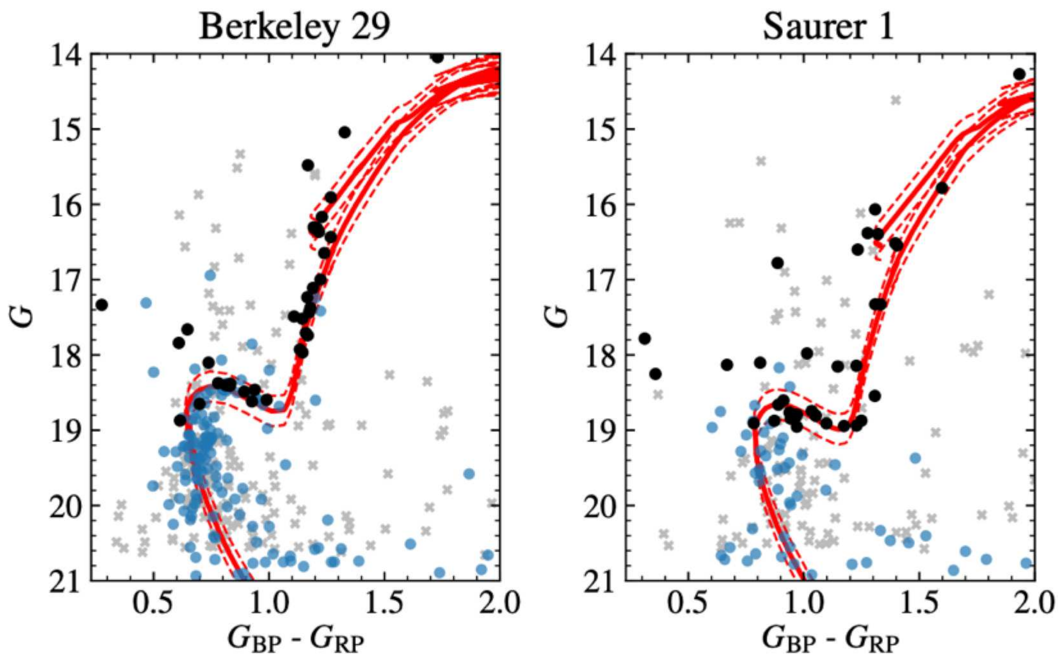


extinction makes the CMDs of inner-disc clusters blurry

red clump apparent magnitude G~14-15
(the cluster/field contrast is poor in the inner disc)

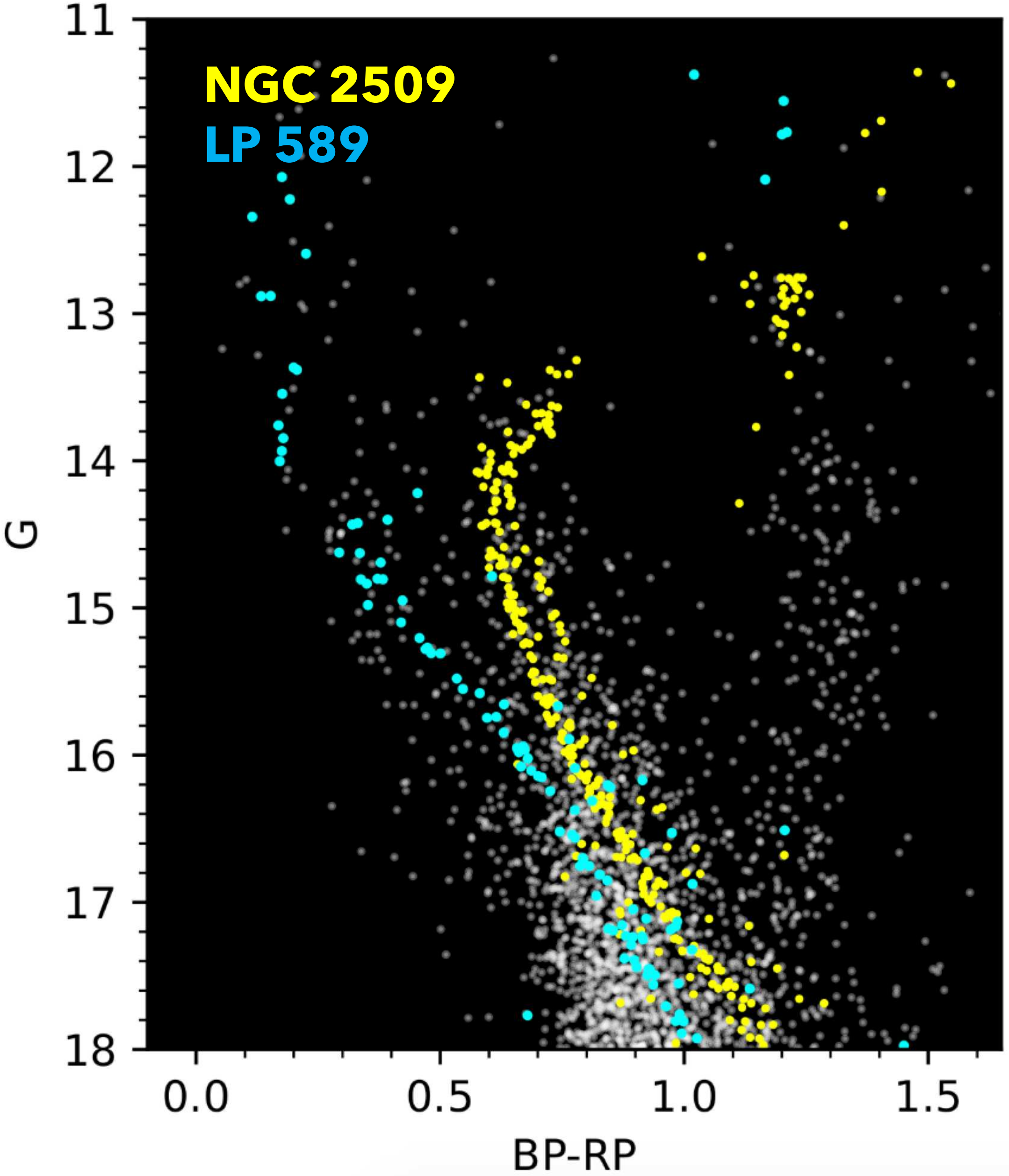
the fainter members have G~18-19

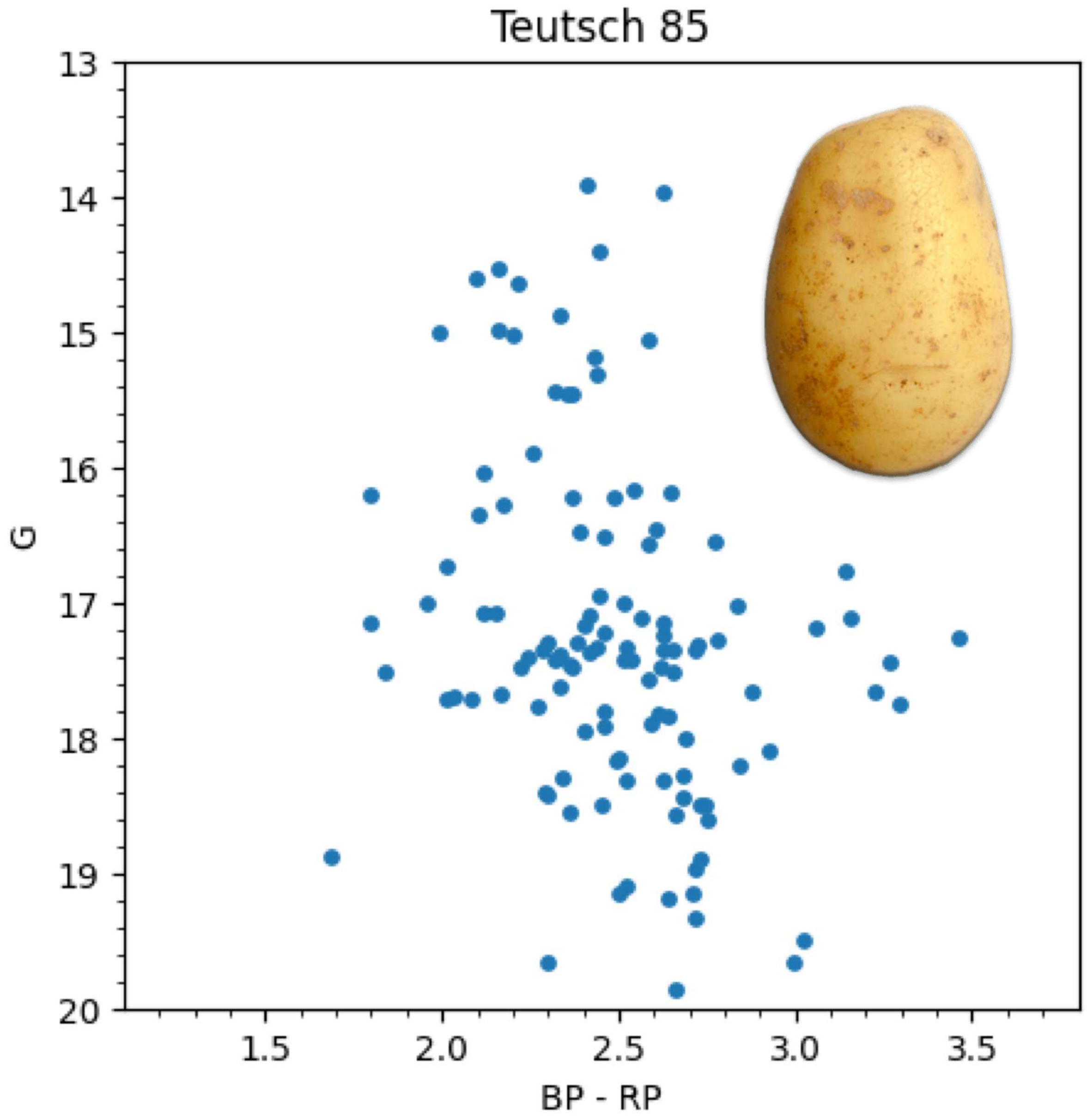
…vs two outermost clusters



[Gaia collaboration, Antoja et al. 2021]

Optical CMDs are easily blurred by extinction





Near-infrared astrometry to probe the inner disc

2028:

JASMINE: **Near-Infrared Astrometry and Time Series Photometry Science**

Daisuke Kawata[1,2,*], Hajime Kawahara[3], Naoteru Gouda[1,4], Nathan J.

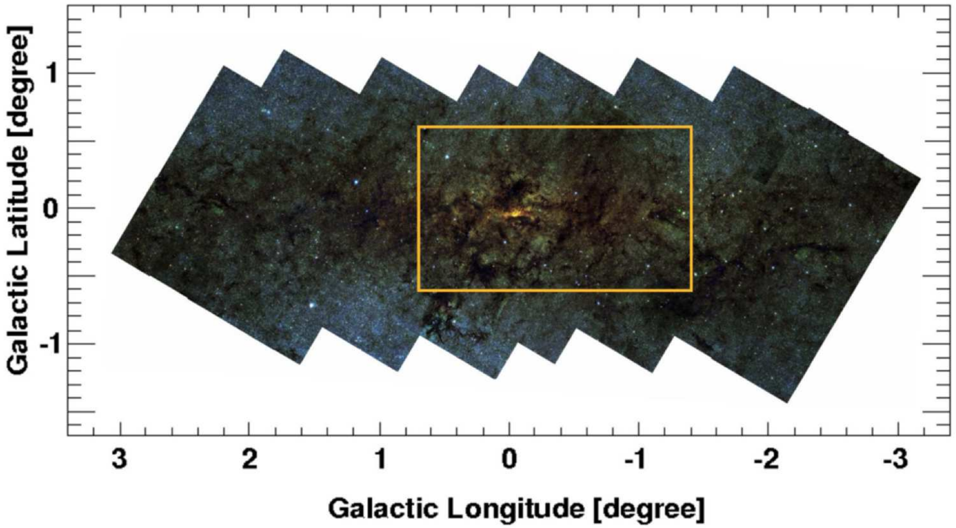


Fig. 2. The planned survey area of the *JASMINE* GCS program (highlighted with a yellow open square) overlaid on an the image of the SIRIUS survey (Nishiyama et al. 2006).

~2045: GaiaNIR

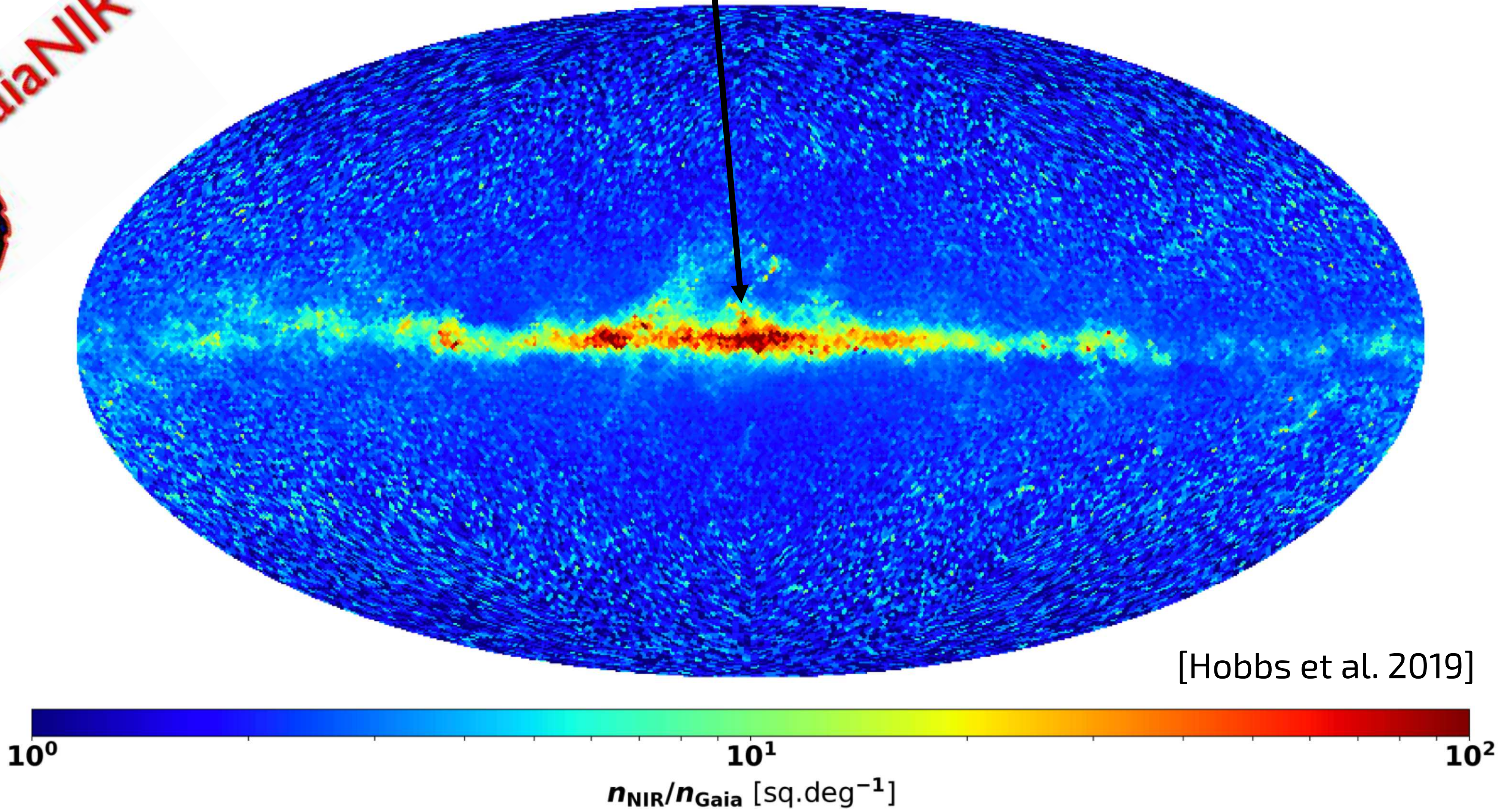
A near-infrared version of Gaia would probe the inner disc and the faint end of the mass function (K,M, brown dwarfs...)

Combining Gaia and GaiaNIR would improve proper motions by a factor of 20.

Mission still in project: if you want to help look up

"Register your interest in GaiaNIR"

If inner regions contain 100 times more stars in GaiaNIR than in Gaia, we are going to need **very precise proper motions** to pick up the signal of a compact cluster

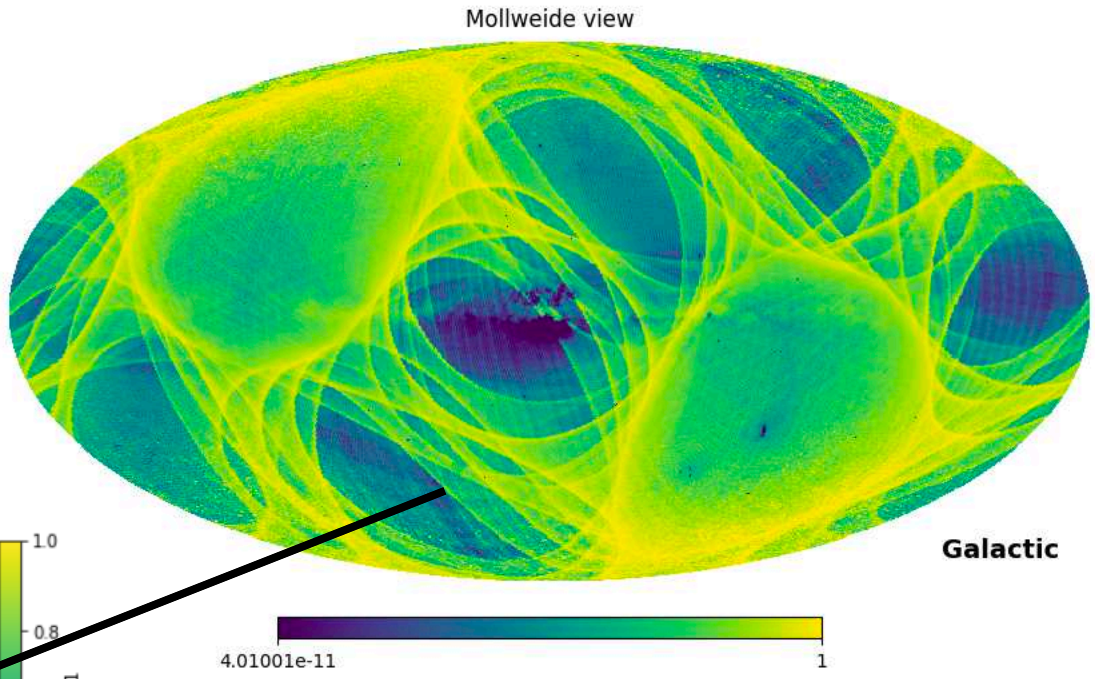


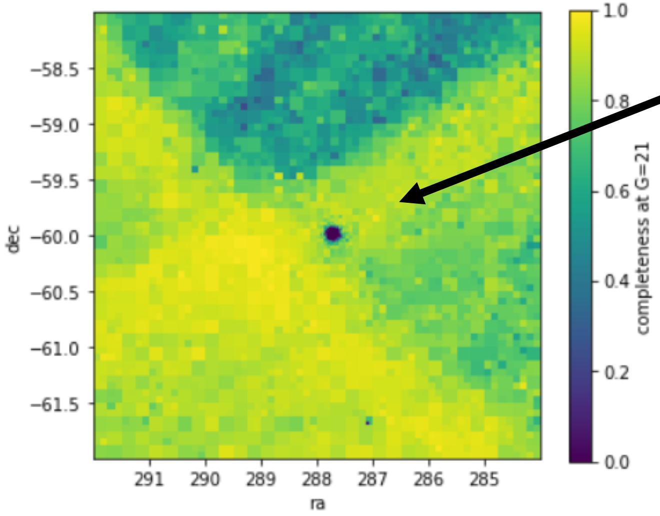
[Hobbs et al. 2019]

Modelling the Milky Way with incomplete samples

All astronomical catalogues have completeness limits. For Gaia the limit is around G~21 but this varies with position on the sky due to the scanning law, and to crowding effects.

Any subset of Gaia data (e.g. good parallaxes, astrophysical parameters) has its own selection function.





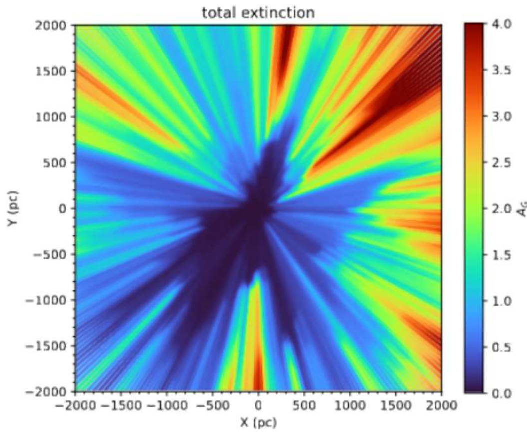
The GaiaUnlimited Python package helps you construct selection functions

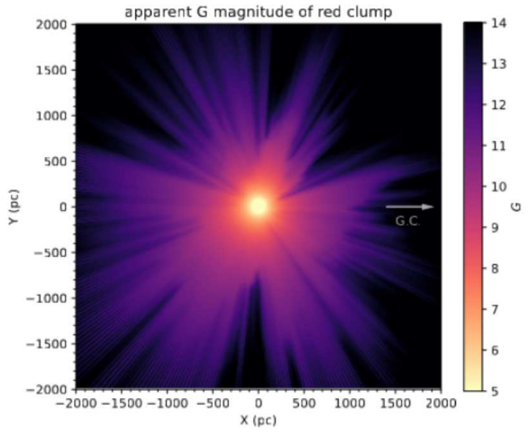
Gaia DR3 completeness at G=21
[Cantat-Gaudin et al. 2023]

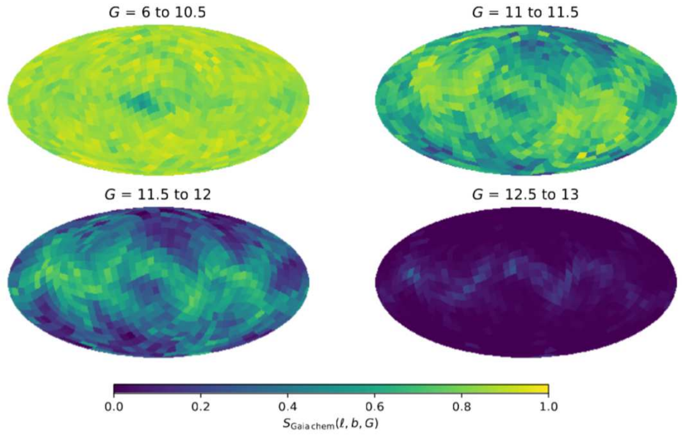
Modelling the Milky Way with incomplete samples

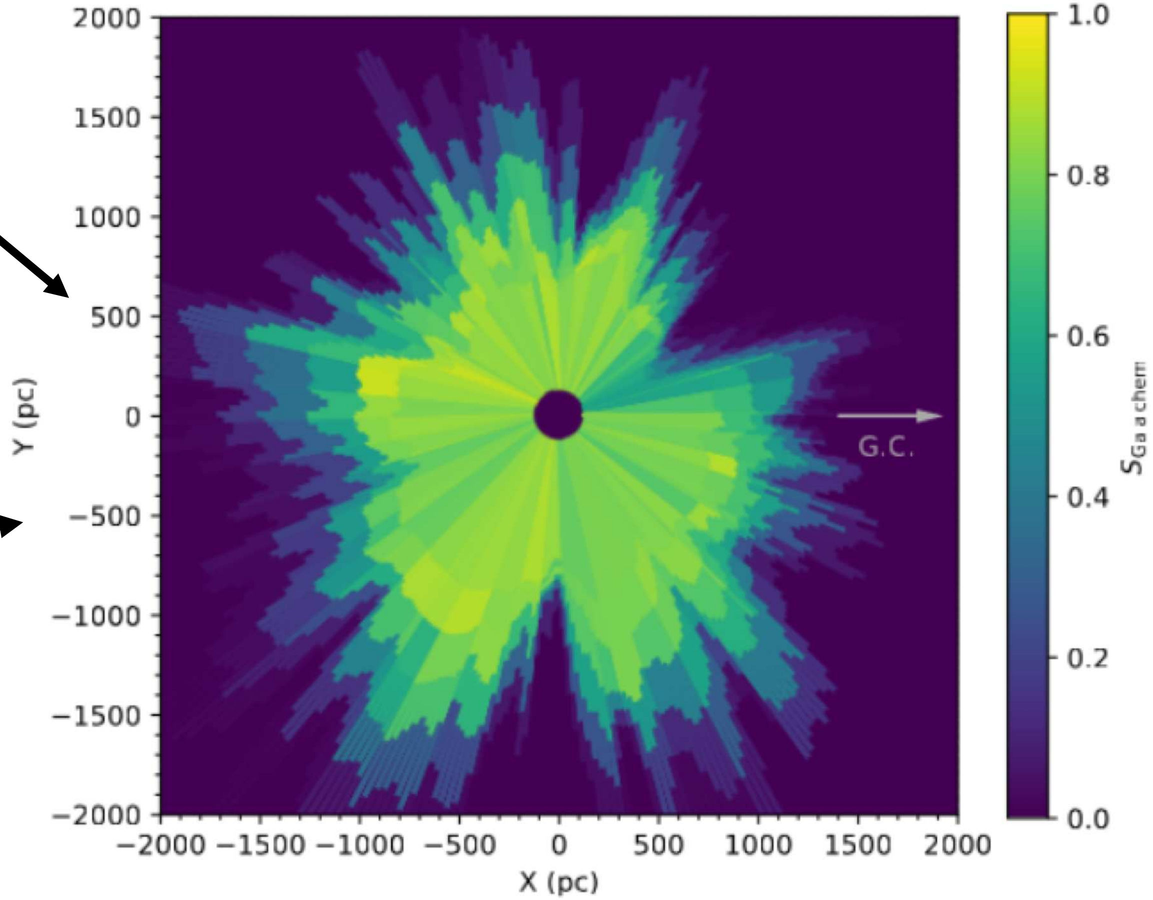
Cantat-Gaudin et al. (submitted)

Selection function for Gaia red clump stars and 3D modelling of the density distribution of mono-abundance populations.









Future work: a catalogue of Gaia clusters with a well-defined selection function

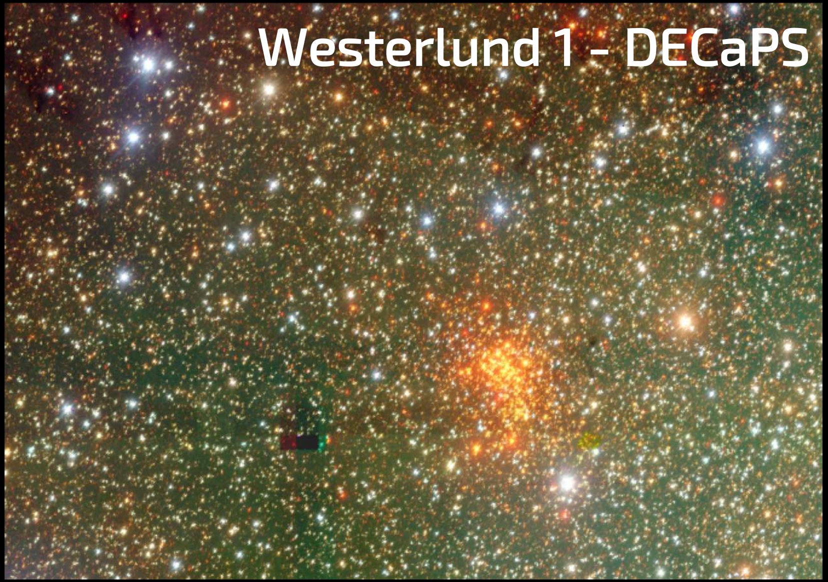
Clusters are easier to detect:

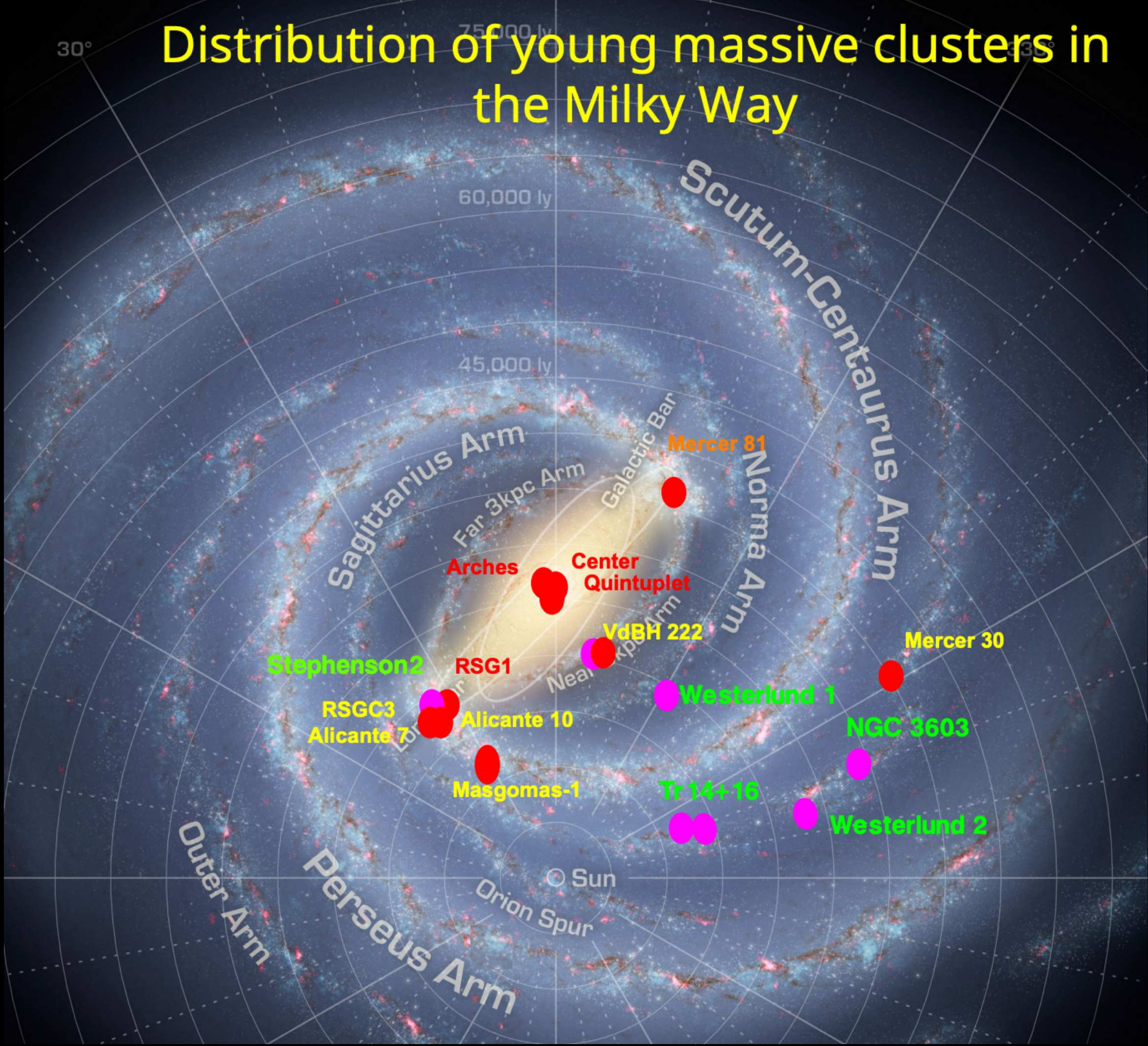
- against a sparse background
- if they have more stars
- if they have bright stars
- if their motions are different from the surrounding stars

Making meaningful quantitative comparisons between models and observed catalogues requires a selection function, which describes the completeness of the sample as a function of **position, distance, age, orbital parameters**, etc.

Massive Young Clusters

- tens or hundreds of thousands of solar masses
- ages of few Myr
- found in the Magellanic Clouds or in the inner Milky Way
- embedded in dust





(from I. Negueruela)

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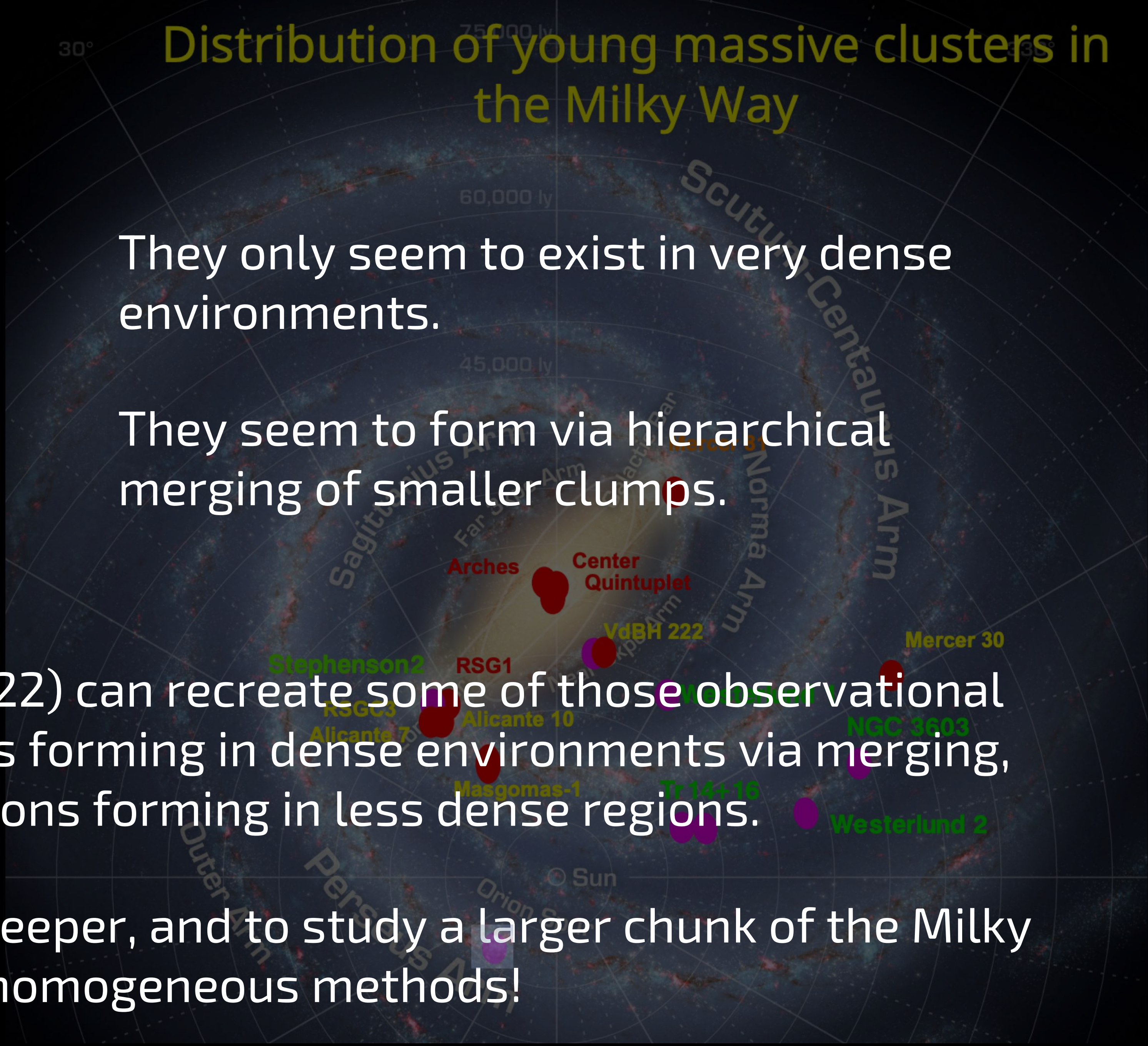
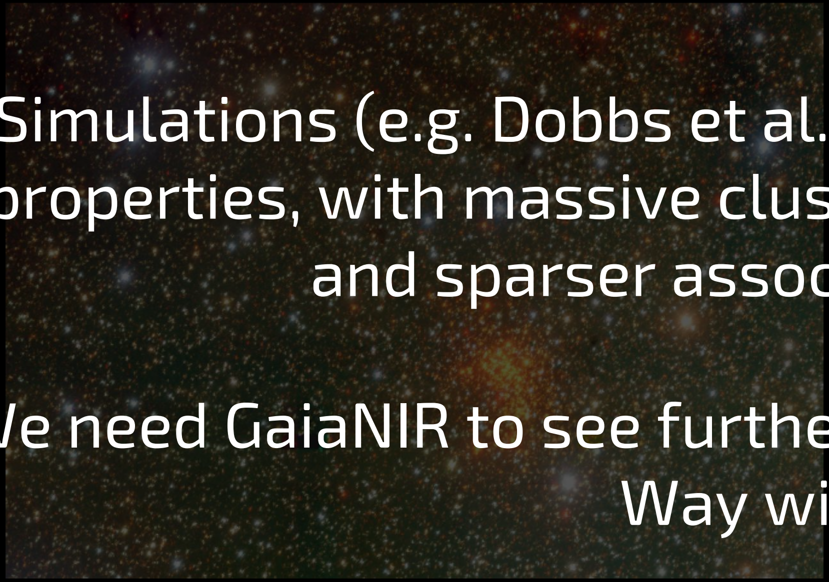


They only seem to exist in very dense environments.

They seem to form via hierarchical merging of smaller clumps.



Simulations (e.g. Dobbs et al. 2022) can recreate some of those observational properties, with massive clusters forming in dense environments via merging, and sparser associations forming in less dense regions.

We need GaiaNIR to see further, deeper, and to study a larger chunk of the Milky Way with homogeneous methods!

Summary

- We see fragments of spiral arms, but not over very large distances.
- We are probably not extinction-limited in the outer disc, but Gaia definitely hits an extinction wall in the inner disc.
- Studying the difference between inner- and outer-disc clusters (formation processes, survival rates) requires near-infrared photometry and astrometry.
- We can do a lot of science with incomplete samples, **as long as we know the selection function**: for cluster it is still a very tricky question!