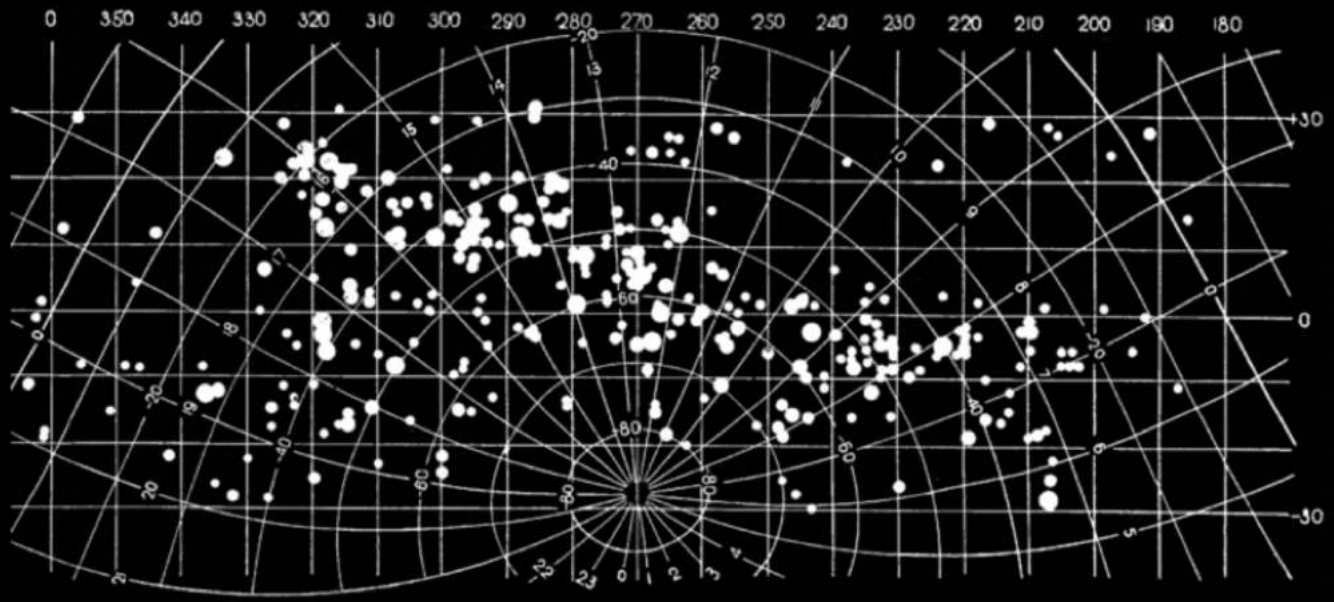
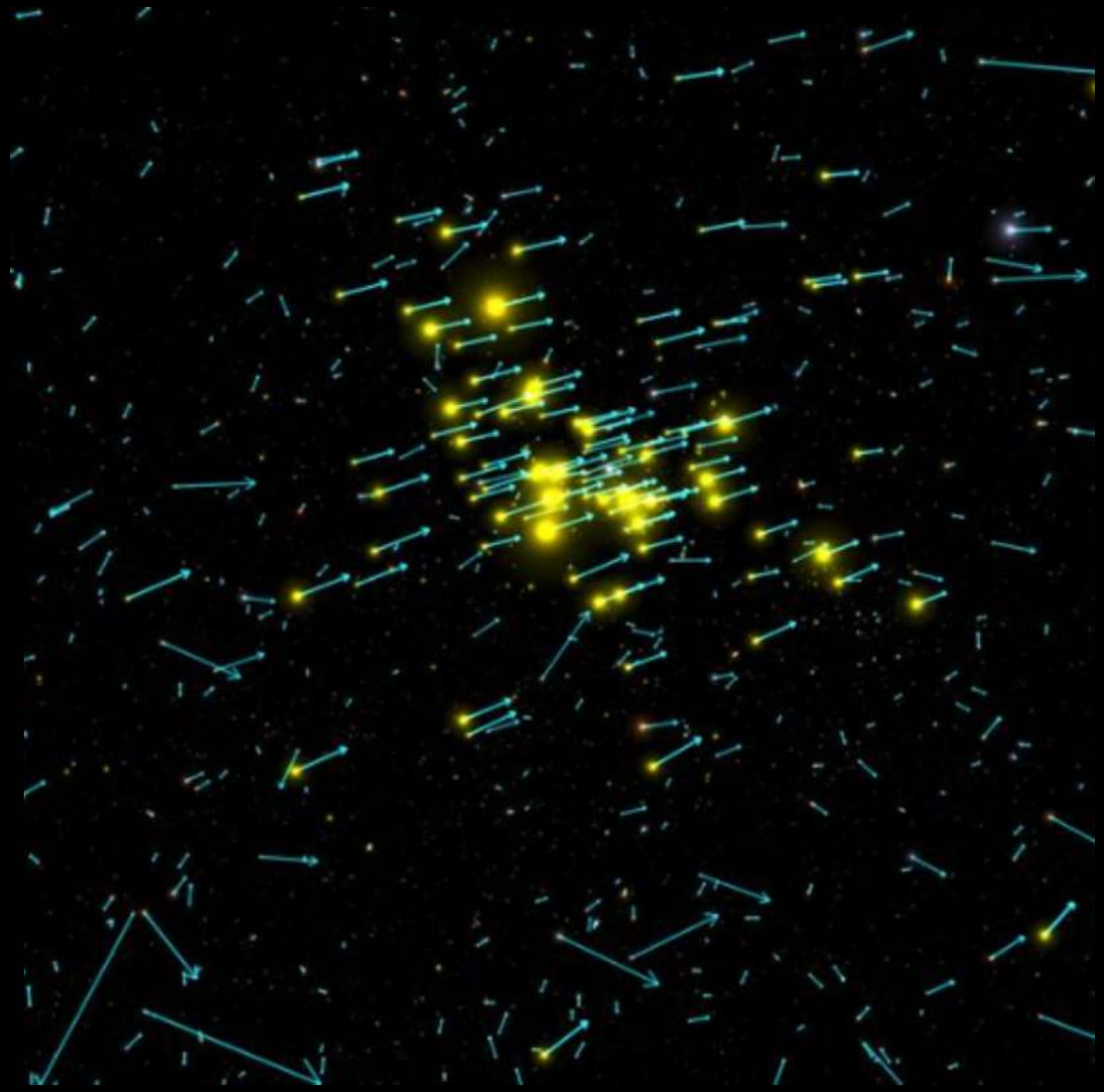
Star clusters and the Galactic mid-plane





Tristan Cantat-Gaudin

Max-Planck-Institut für Astronomie
Heidelberg

Science and technology roadmap for µas studies of the Milky Way – Lund – 18-20 July 2023

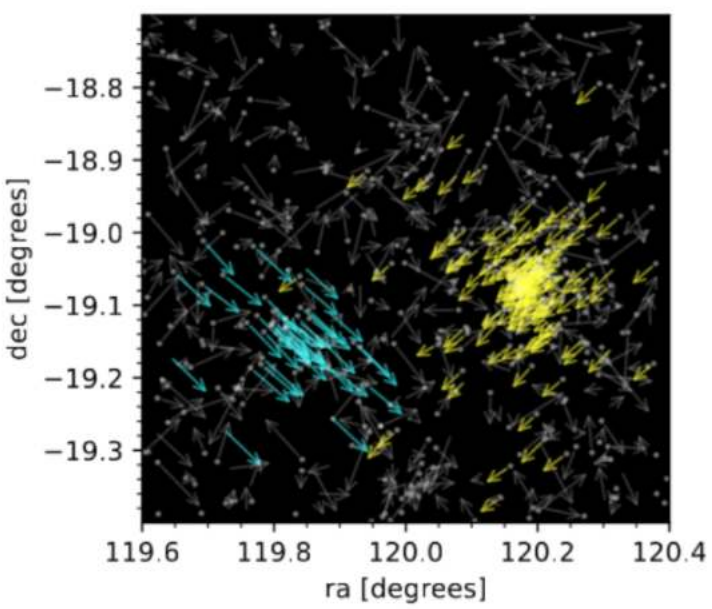
Gaia offers a 5D characterisation of stars: ideal data set to identify clusters as overdensities.

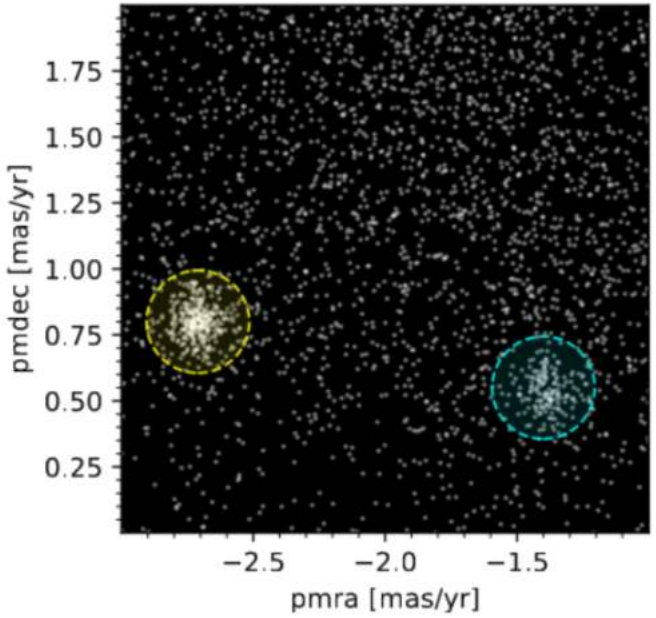
Here NGC 2509 (discovered late 18th century) and LP 589 (Liu & Pang 2019 with Gaia DR2).

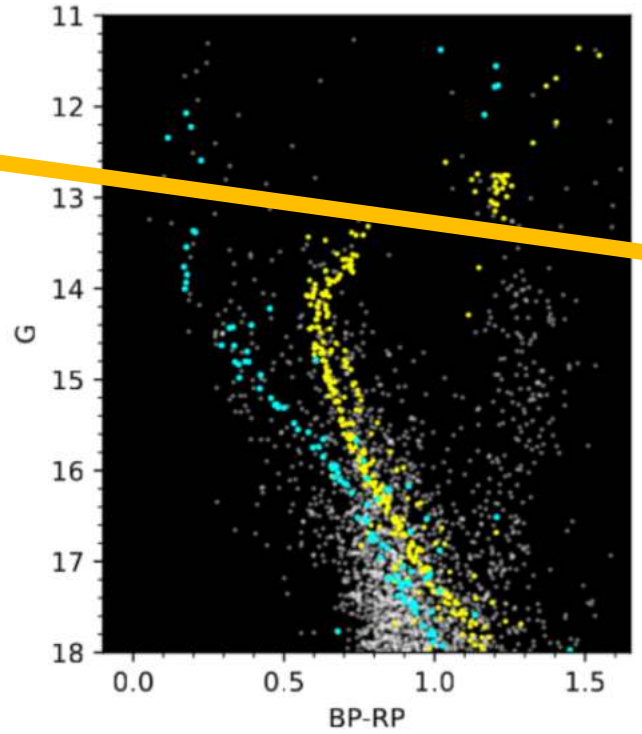
The parallaxes allow for precise distance estimates, especially within a few kpc

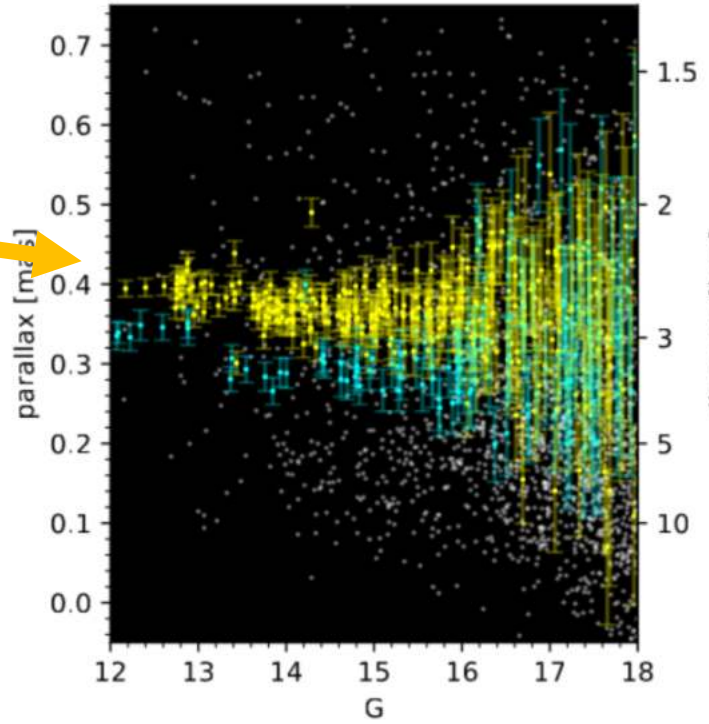
distances to NGC 2509 in the literature:

1.1 kpc (1918)
3 kpc (1930)
2.8 kpc (1931)
2 kpc (1955)
0.9 kpc (2003)
1.7 kpc (2013)
2.9 kpc (2007)



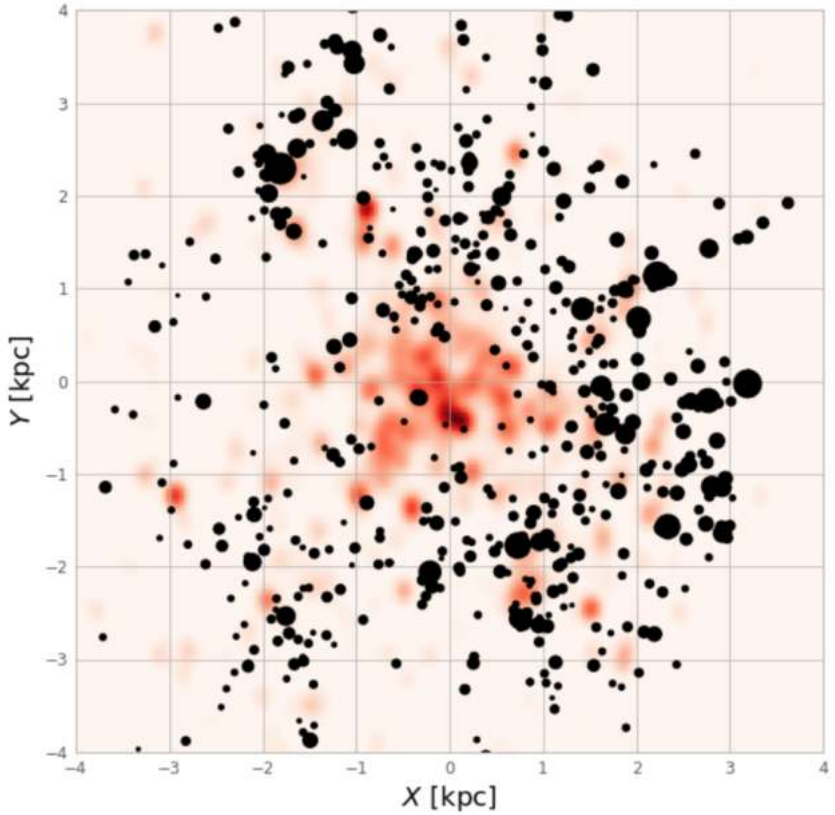




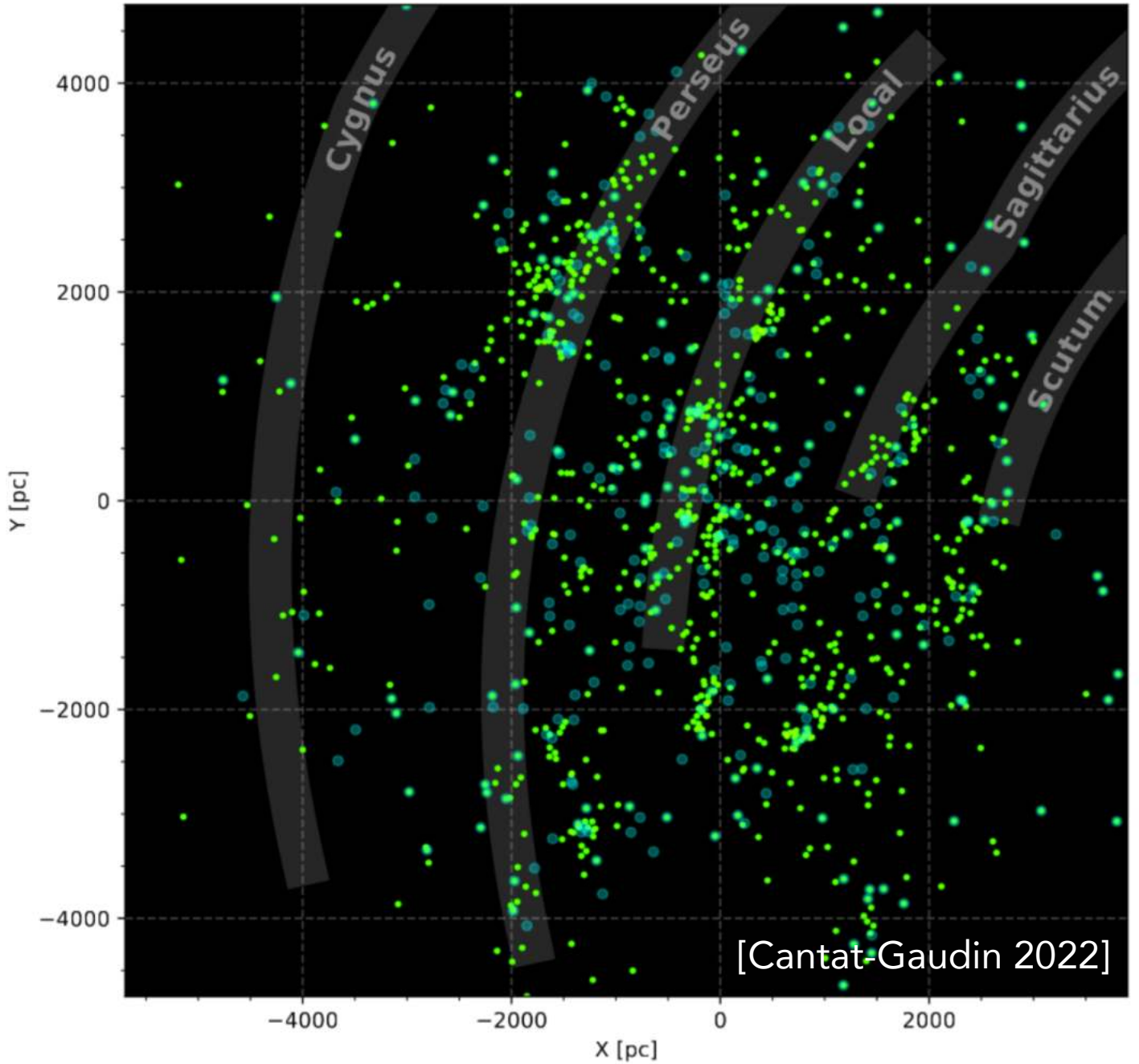


Hundreds of newly discovered clusters

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



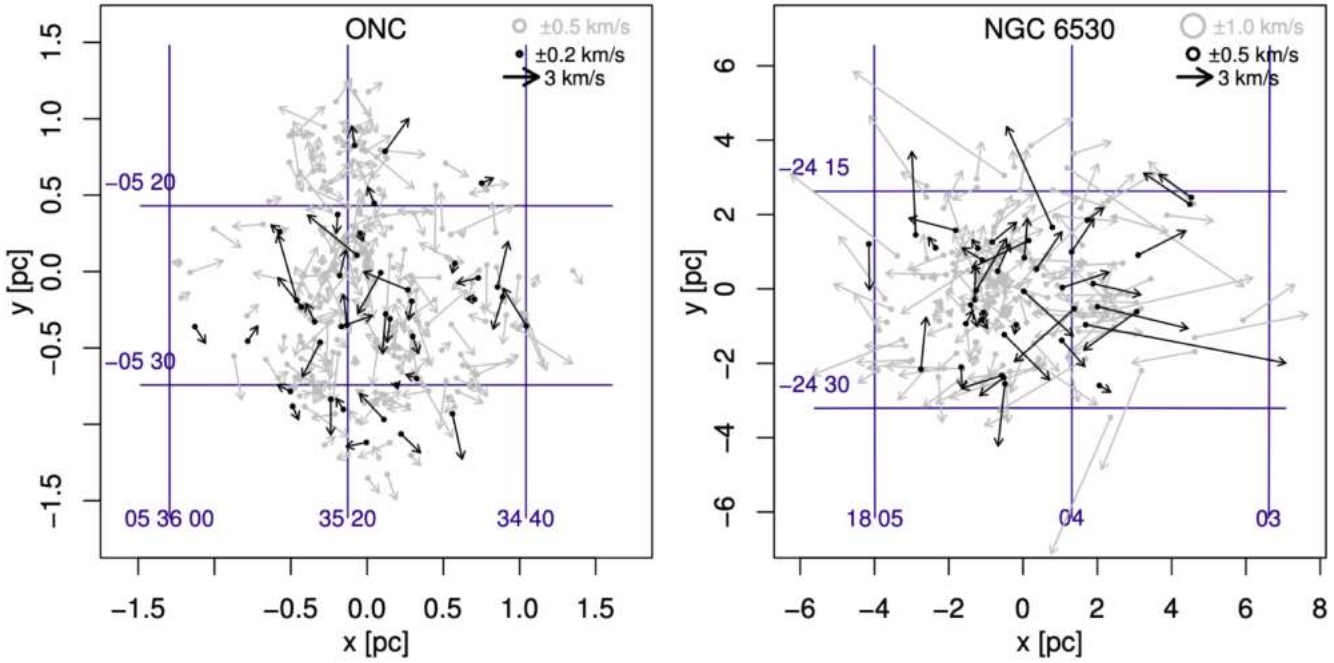
[Castro-Ginard et al. 2020]



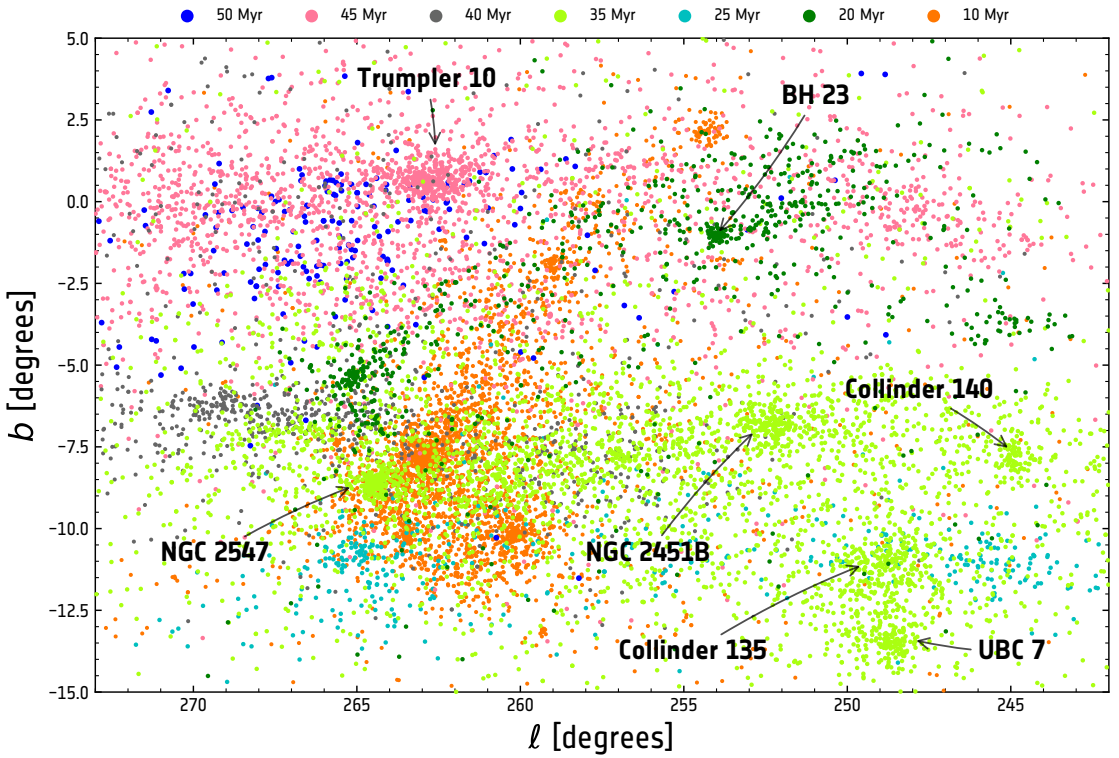
clusters younger than 60 Myr (green) and 60 to 100 Myr (cyan)

Gaia questions the distinction between clusters and associations

Many young “clusters” are in fact dense (but slowly expanding) clumps within sparse complexes of young stars.



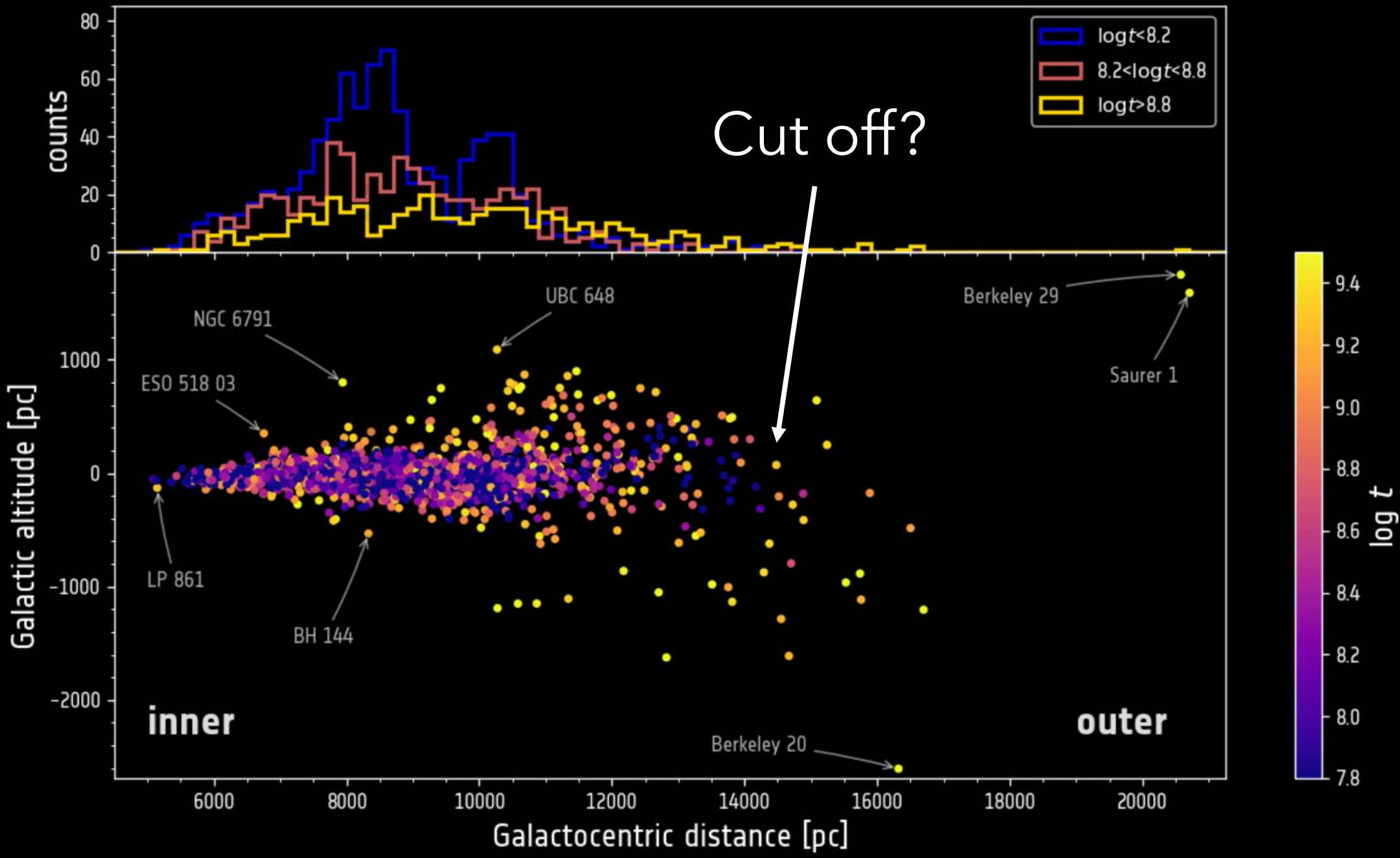
Kuhn et al. (2019)

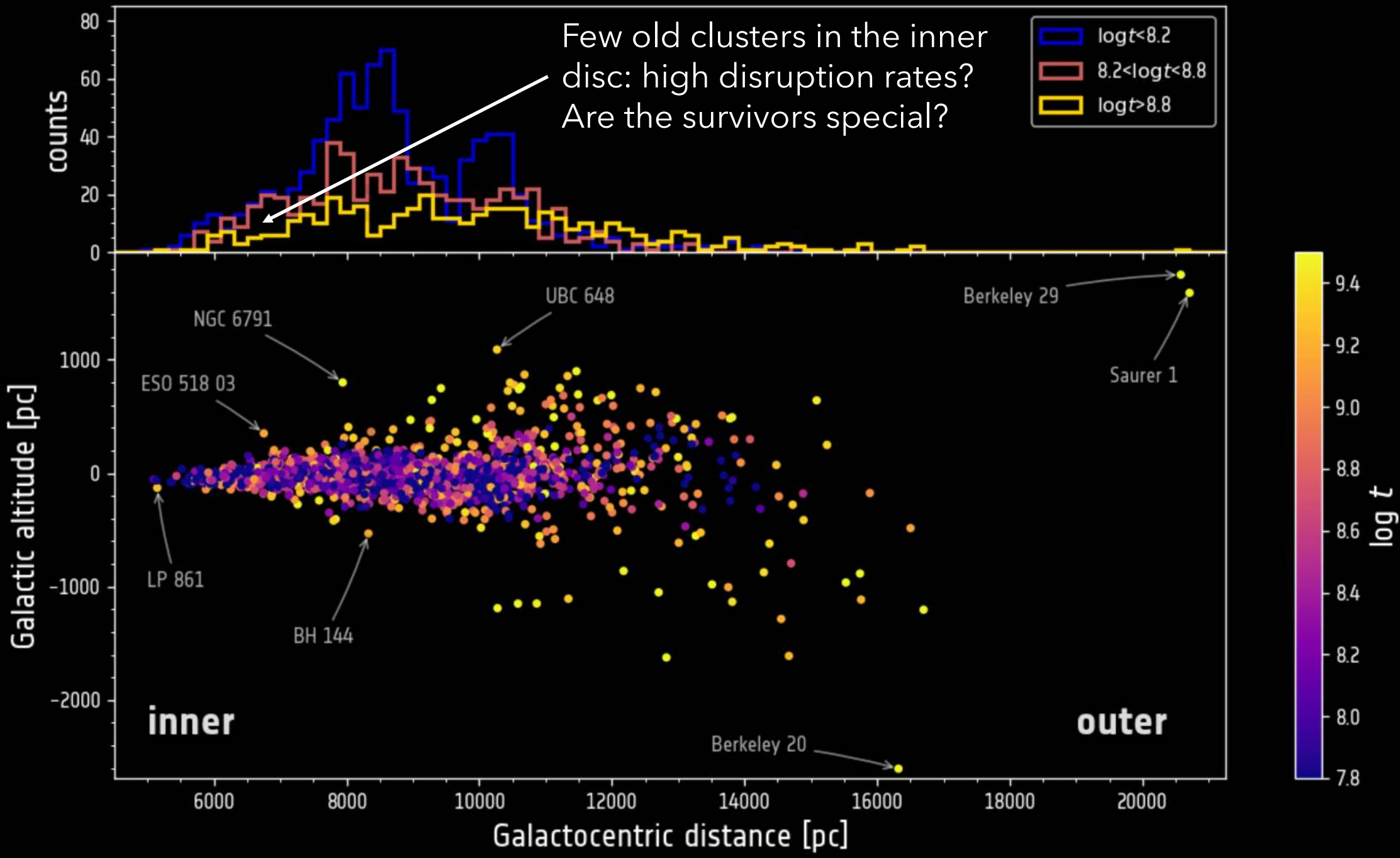


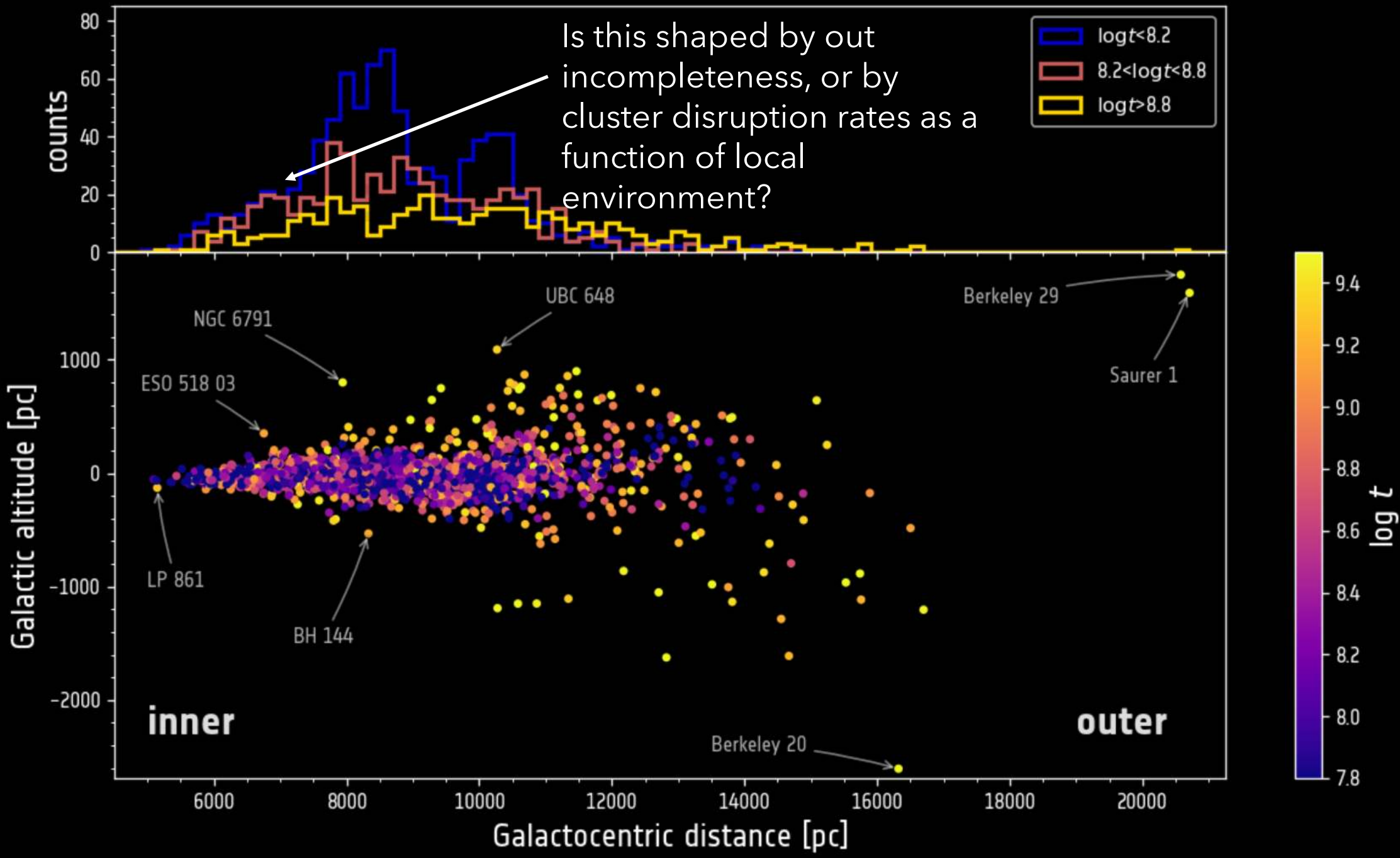
Cantat-Gaudin et al. (2019)

None of the large regions of recent star formation (Orion, Scorpius-Centaurus, Vela-Puppis) seems to have formed gravitationally bound clusters

Anders et al. (2021): only 10-20% of all stars born in the solar neighbourhood form in bound clusters


Cut off?
logt<8.2
8.2<logt<8.8
logt>8.8
counts
80
60
40
20
0
UBC 648
NGC 6791
ESO 518 03
Berkeley 29
Saurer 1
LP 861
BH 144
Berkeley 20
inner
outer
Galactic altitude [pc]
1000
0
−1000
−2000
6000
8000
10000
12000
14000
16000
18000
20000
Galactocentric distance [pc]
9.4
9.2
9.0
8.8
8.6
8.4
8.2
8.0
7.8
log t


Few old clusters in the inner disc: high disruption rates? Are the survivors special?
logt<8.2
8.2<logt<8.8
logt>8.8
counts
80
60
40
20
0
UBC 648
NGC 6791
Berkeley 29
Saurer 1
ESO 518 03
LP 861
BH 144
Berkeley 20
inner
outer
Galactic altitude [pc]
1000
0
-1000
-2000
6000
8000
10000
12000
14000
16000
18000
20000
Galactocentric distance [pc]
9.4
9.2
9.0
8.8
8.6
8.4
8.2
8.0
7.8
log t


Is this shaped by out incompleteness, or by cluster disruption rates as a function of local environment?
logt<8.2
8.2<logt<8.8
logt>8.8
counts
80
60
40
20
0
UBC 648
NGC 6791
Berkeley 29
Saurer 1
ESO 518 03
LP 861
BH 144
Berkeley 20
inner
outer
Galactic altitude [pc]
1000
0
-1000
-2000
6000
8000
10000
12000
14000
16000
18000
20000
Galactocentric distance [pc]
9.4
9.2
9.0
8.8
8.6
8.4
8.2
8.0
7.8
log t

No supermassive young clusters in the Solar neighbourhood

(see talk by Ignacio Negueruela)

All those massive young open clusters are well within the Solar circle

Idea:

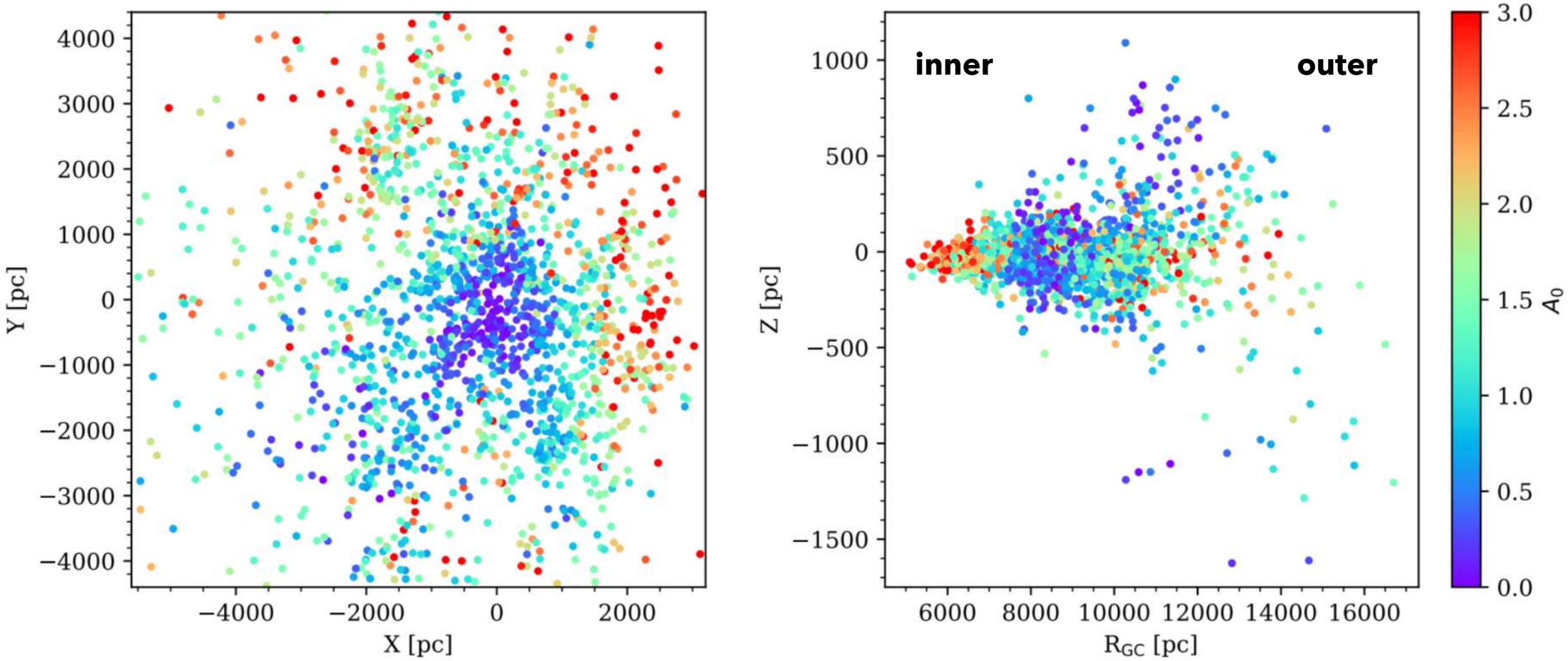
- The higher densities of the inner disc lead to star formation happening in denser, more massive clumps. But they are quickly dispersed.

- In the Solar neighbourhood/outer disc, the lower density makes star formation happen in sparser complexes that dissipate slowly.

Observationally: we should observe a continuity between these two regimes, but we don't.

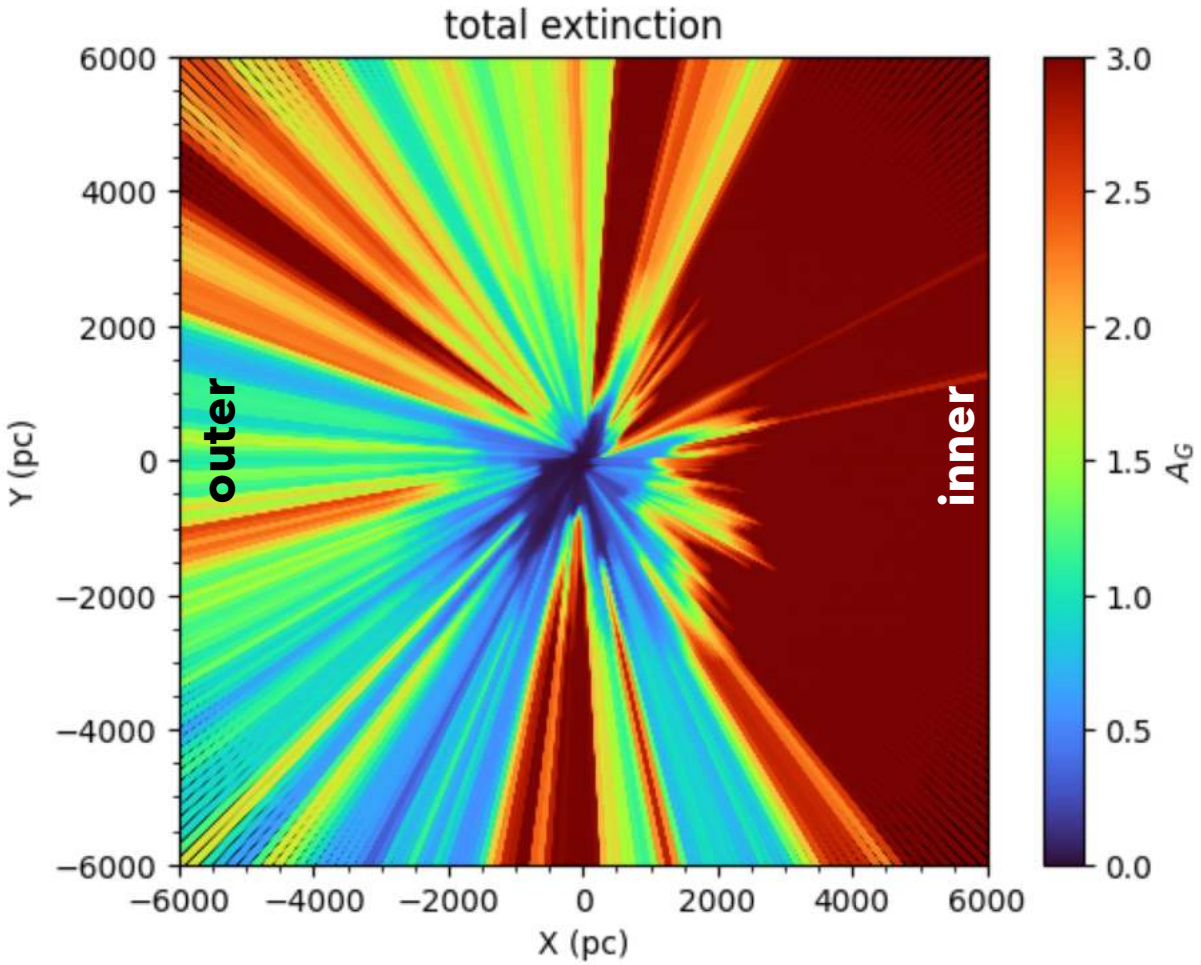
Our view of the inner disc is limited by extinction

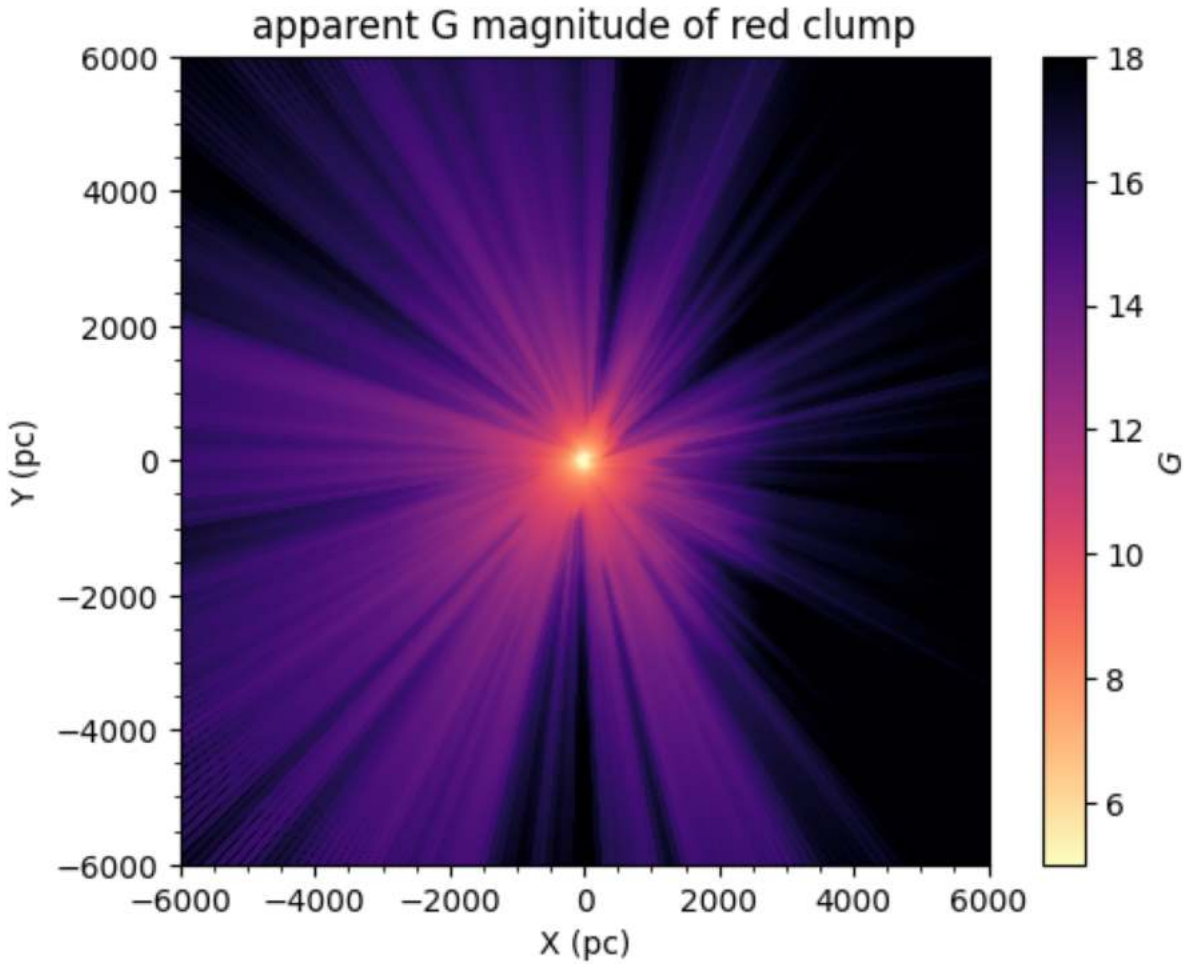
The view of the outer disc is much less affected.



Our view of the inner disc is limited by extinction

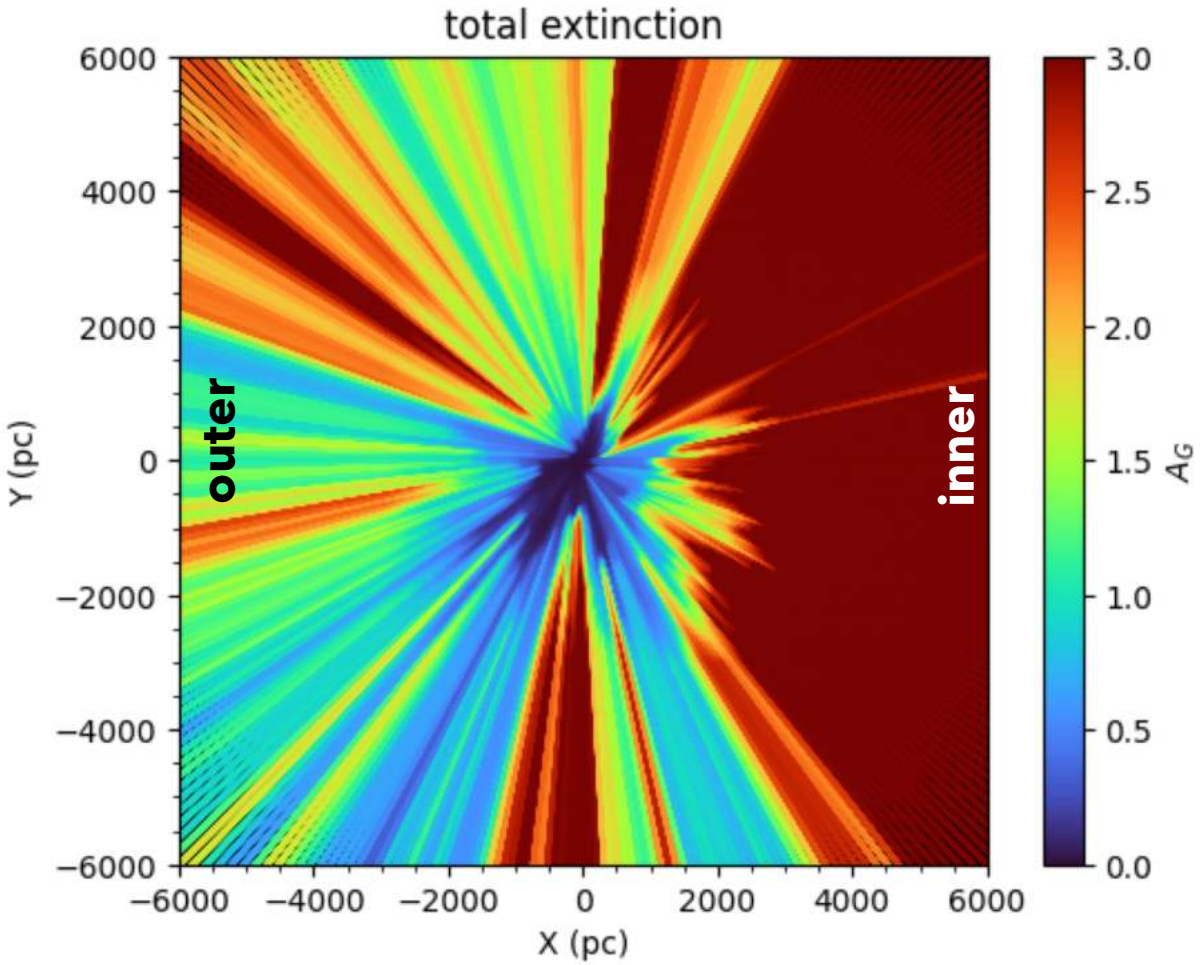
3D extinction map from Lallement et al. (2022)

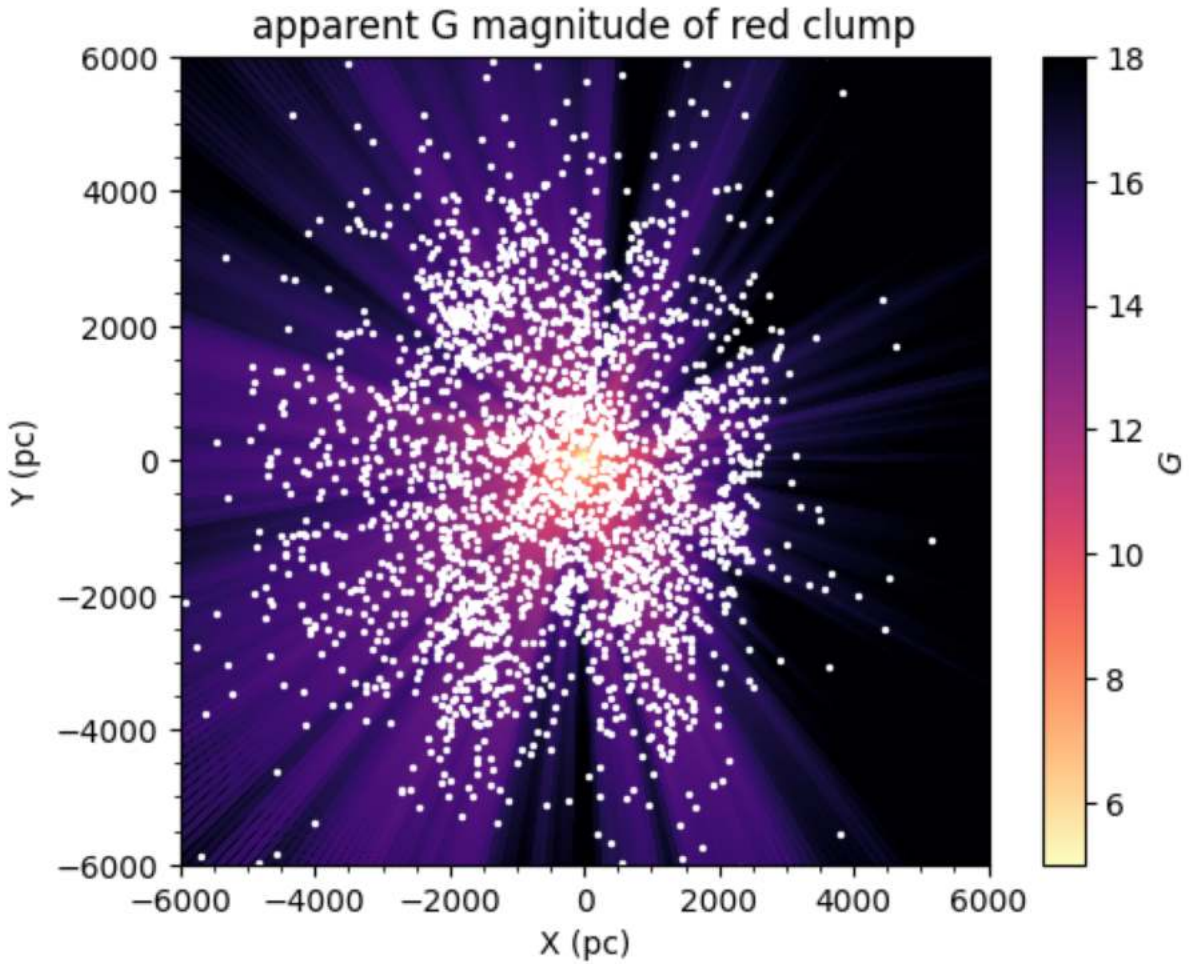




Our view of the inner disc is limited by extinction

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





JASMINE: Near-Infrared Astrometry and Time Series Photometry Science

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

It is also likely that a few open clusters will be discovered in this field. There is at least one star cluster (UBC335) in the new *Gaia* DR2 star cluster catalogue (Castro-Ginard et al. 2020) in the *JASMINE* GCS field. These cluster data would be useful for the calibration of asteroseismic ages, as proposed in an ESA M7 mission candidate, *HAYDN* (Miglio et al. 2021b). *JASMINE* can provide a proof of concept study for *HAYDN* in terms of asteroseismology in dense stellar fields.

My expectation from extrapolating the local density: between zero and three new clusters per additional kpc of depth

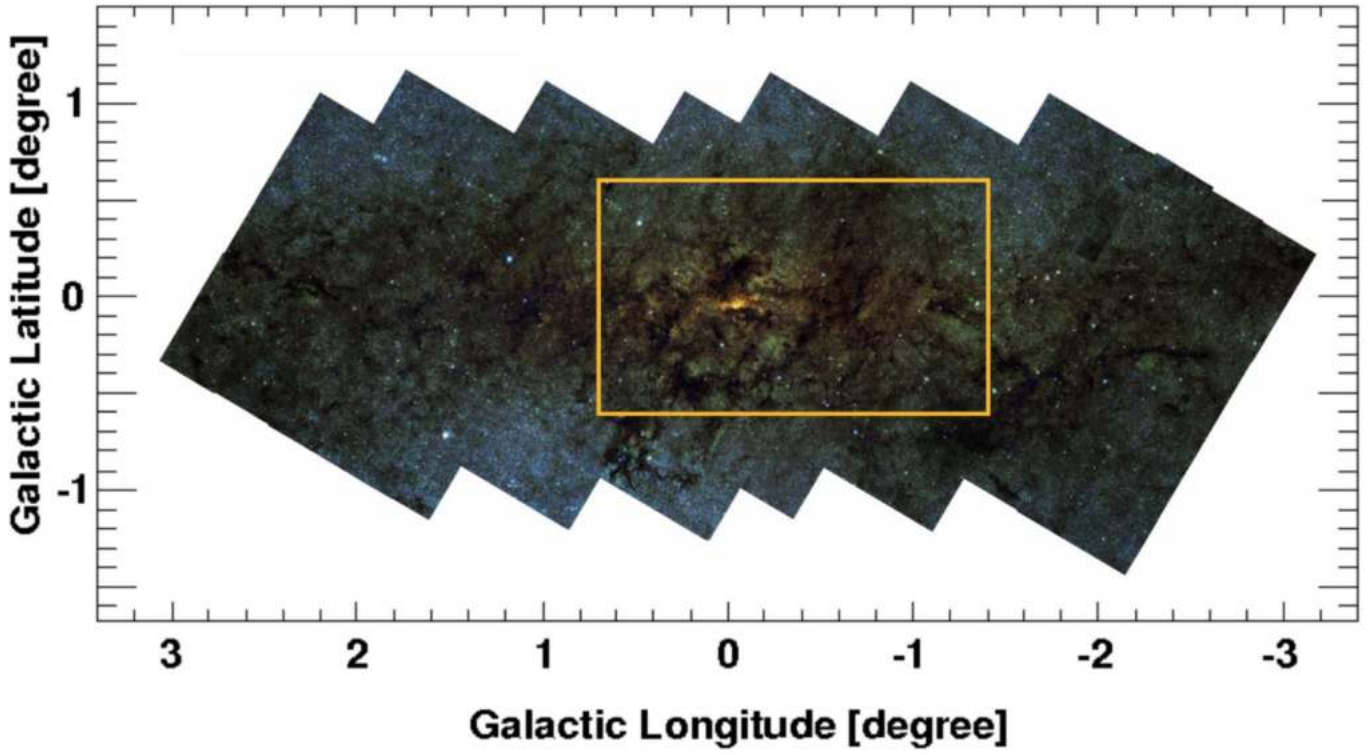
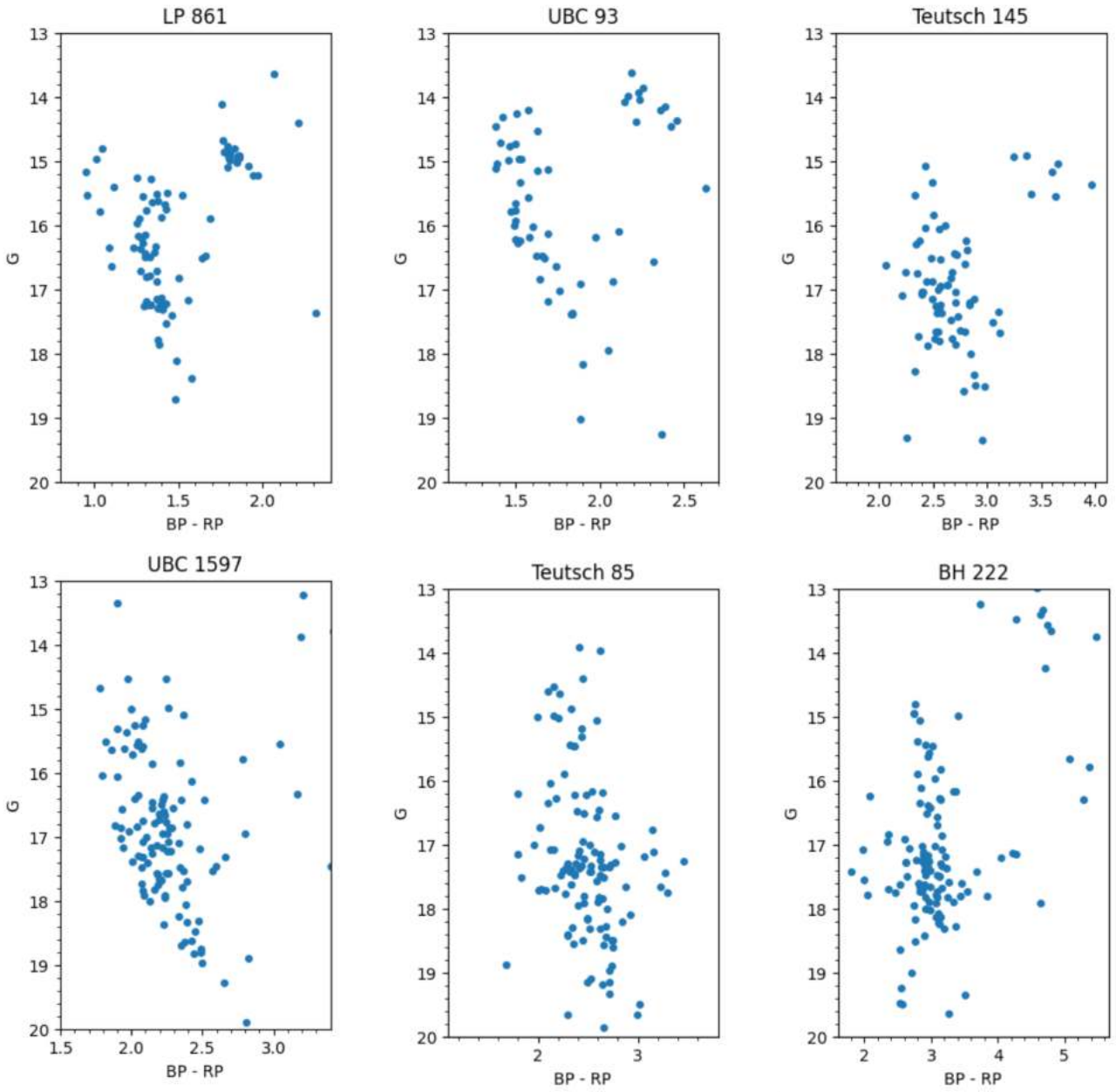


Fig. 2. The planned survey area of the *JASMINE* GCS program (highlighted with a yellow open square) overlaid on an the image of the SIRIUS survey (Nishiyama et al. 2006).

Six of the innermost clusters...

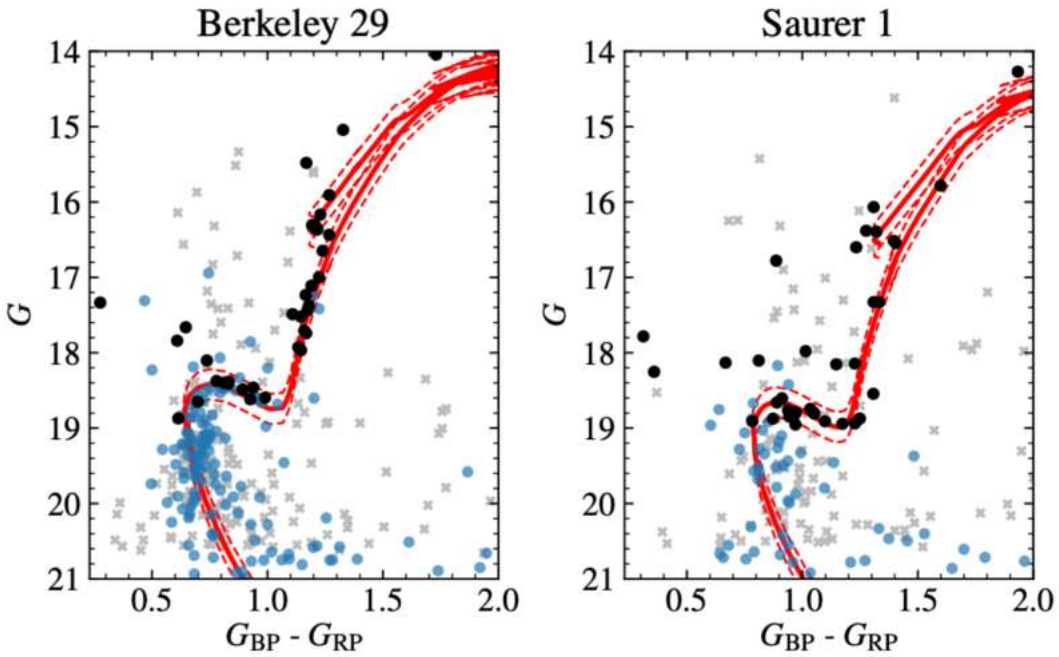


extinction makes the CMDs of inner-disc clusters blurry

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

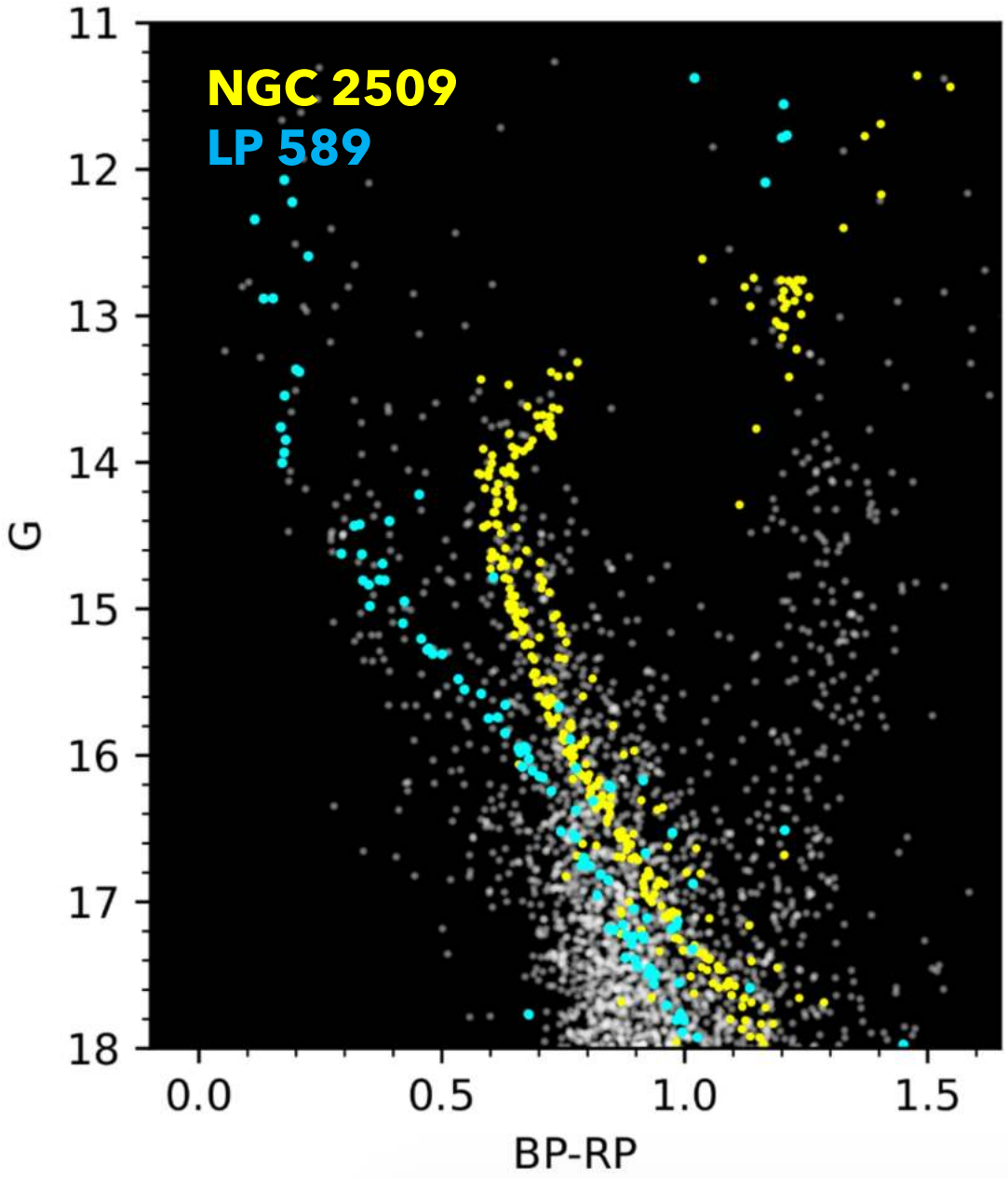
the fainter members have G~18-19

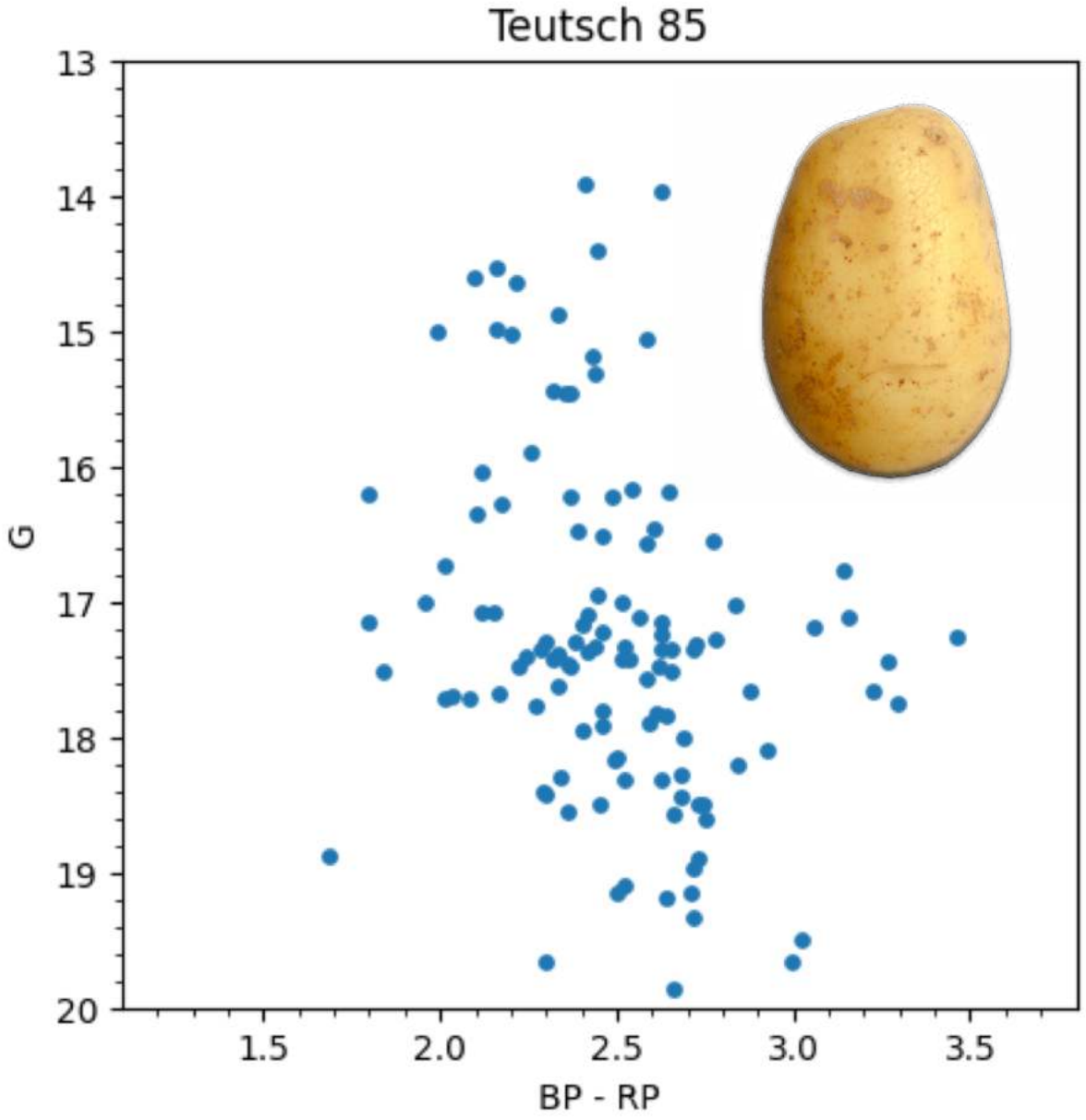
...vs two outermost clusters



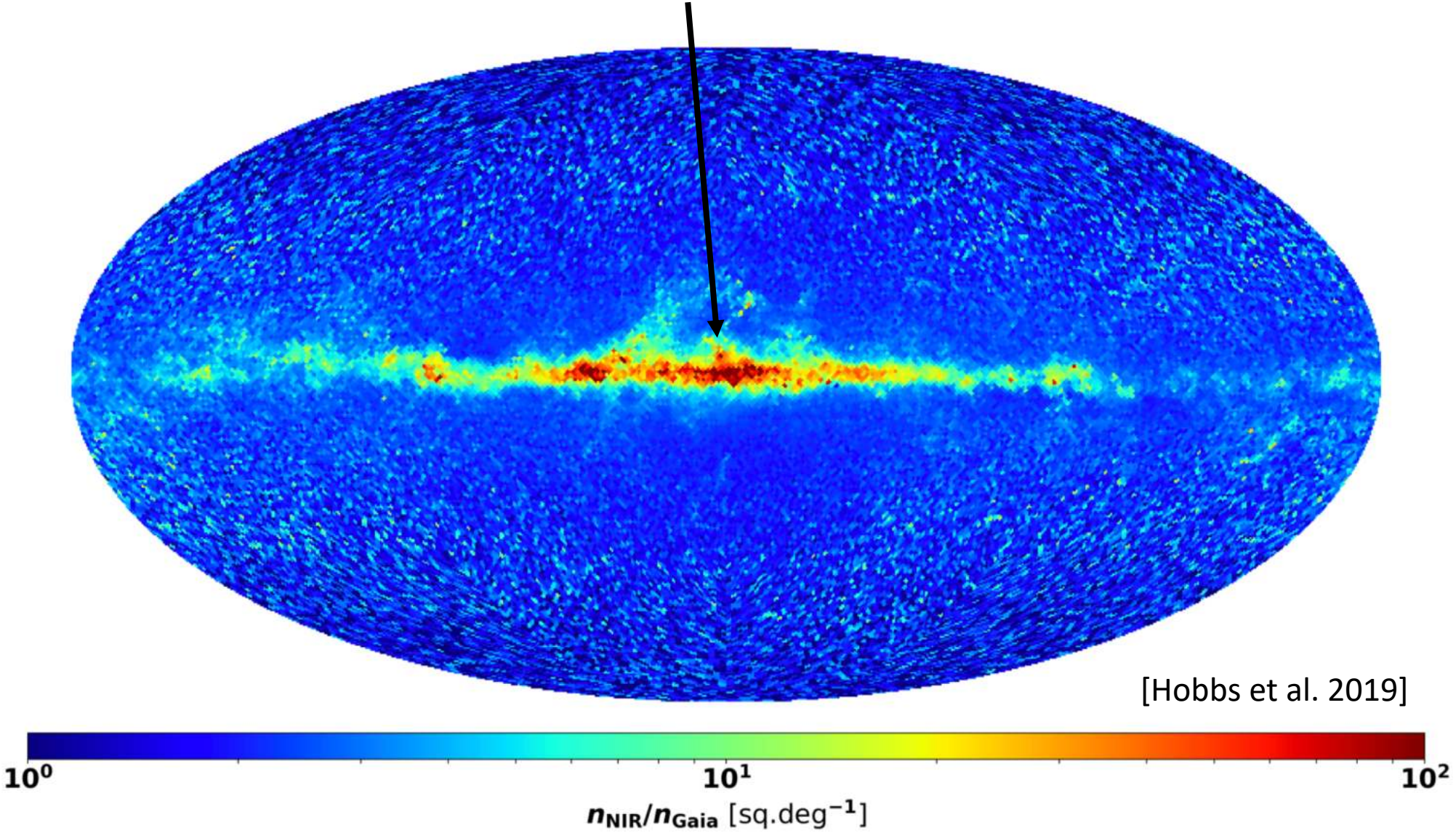
[Gaia collaboration, Antoja et al. 2021]

Optical CMDs are easily blurred by extinction

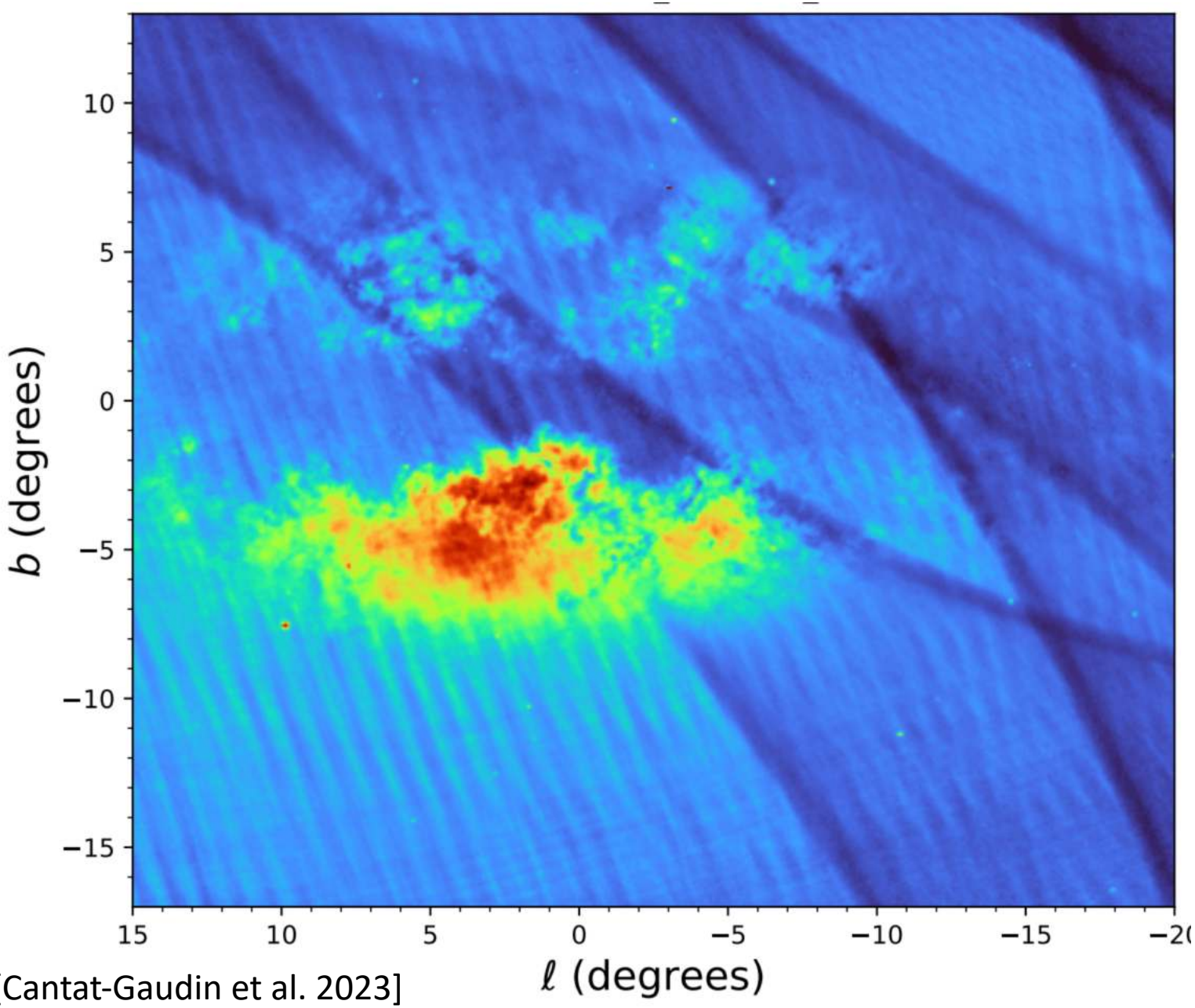




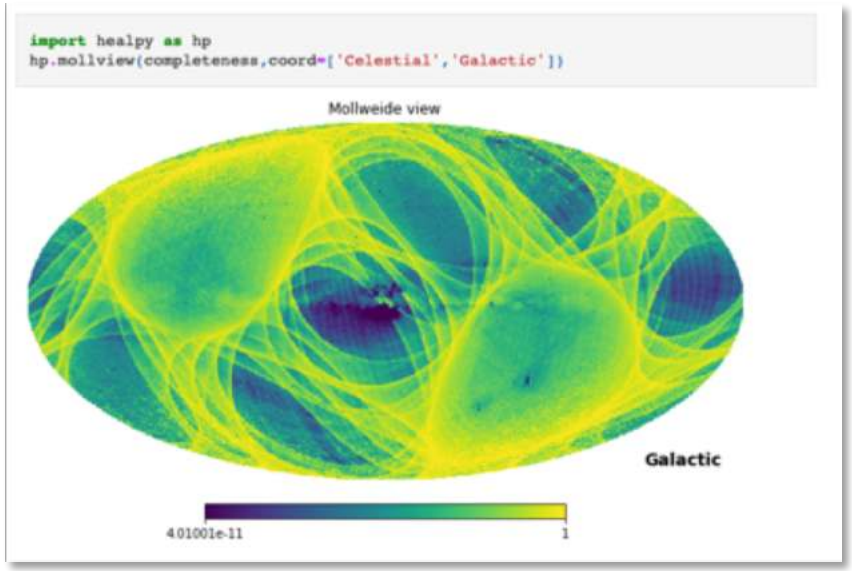
If inner regions contain 100 times more stars in GaiaNIR than in Gaia, we are going to need **very precise proper motions** to pick up the signal of a compact cluster



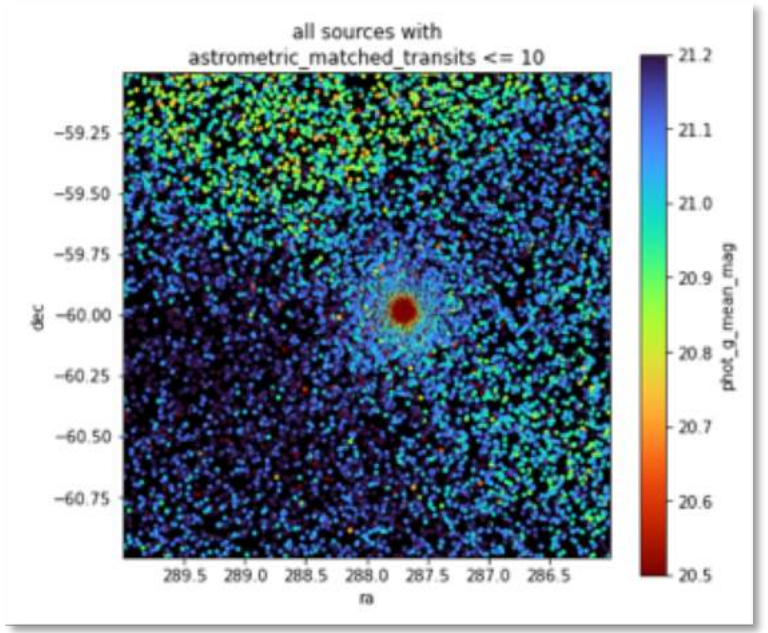
GaiaUnlimited – Gaia completeness and selection function

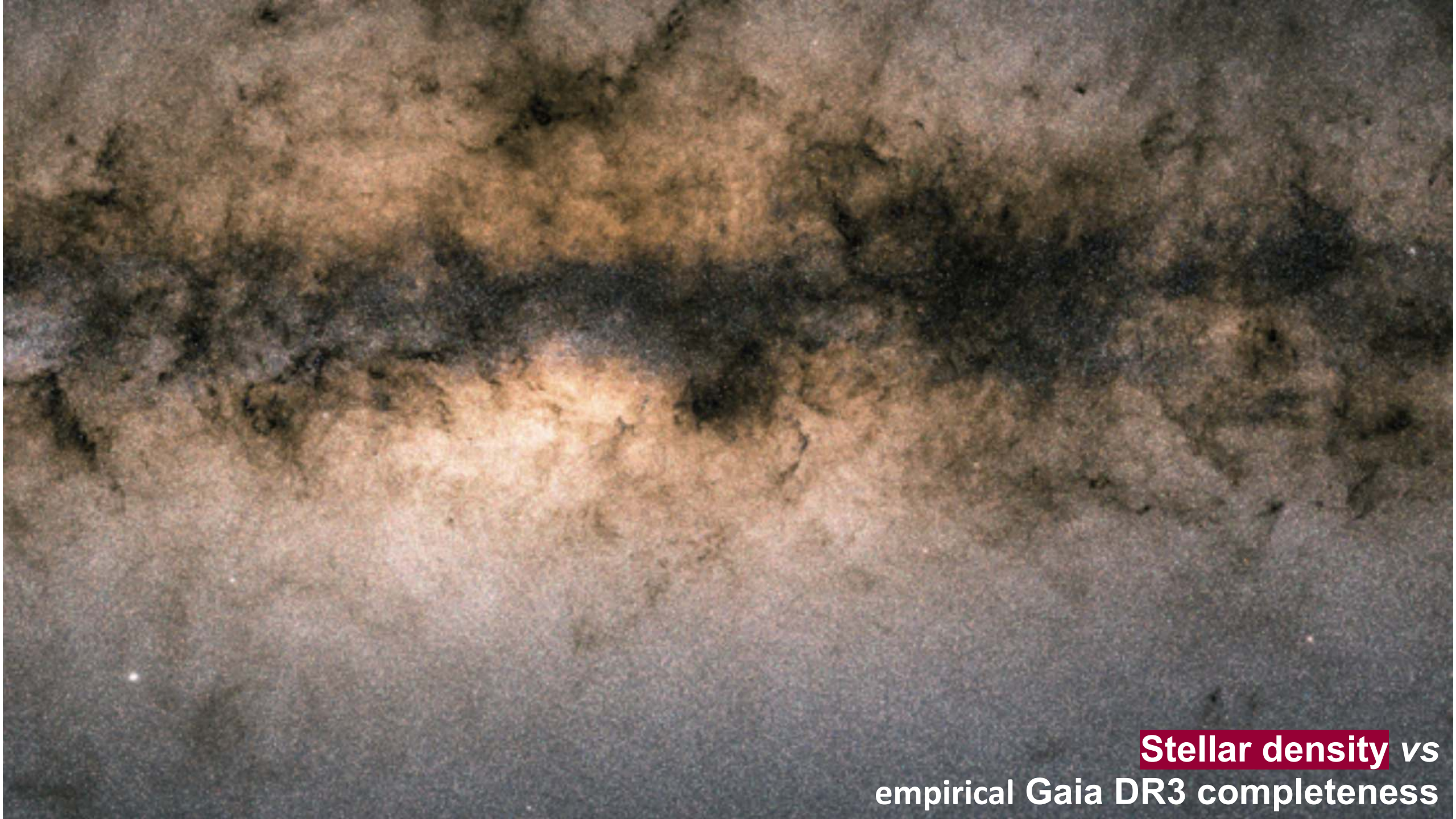


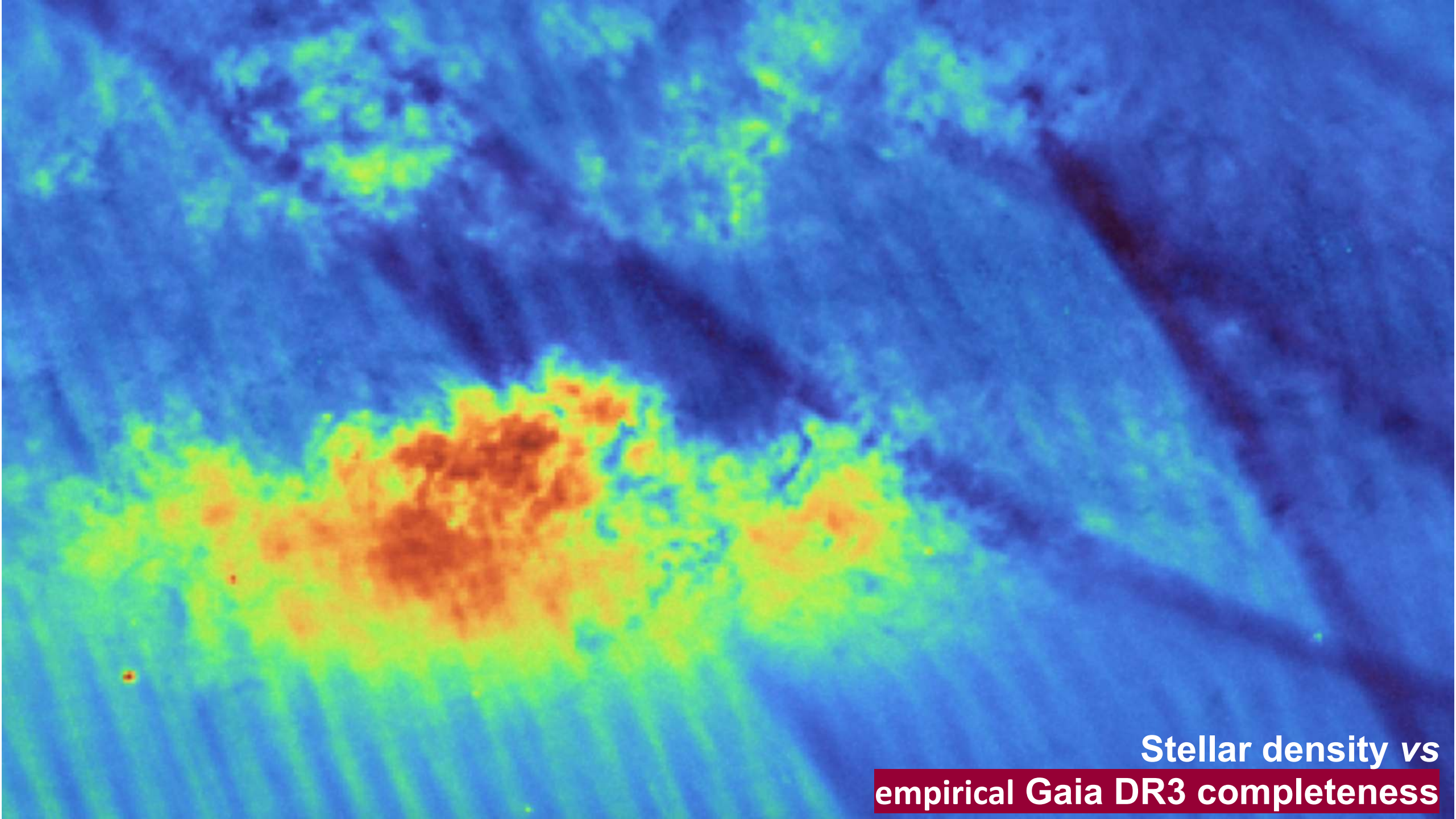
[Cantat-Gaudin et al. 2023]



https://github.com/gaia-unlimited/gaiaunlimited




Stellar density *vs*
empirical Gaia DR3 completeness


Stellar density *vs*
empirical Gaia DR3 completeness

Summary

- Gaia revolutionised cluster studies in the Solar neighbourhood/outer disc.
- The inner disc and its strange population of massive young clusters is not easy to probe with Gaia alone
- A more transparent Milky Way would help
- Improved proper motions would help A LOT