Towards a holistic view of the star formation history of Orion

Alena Rottensteiner
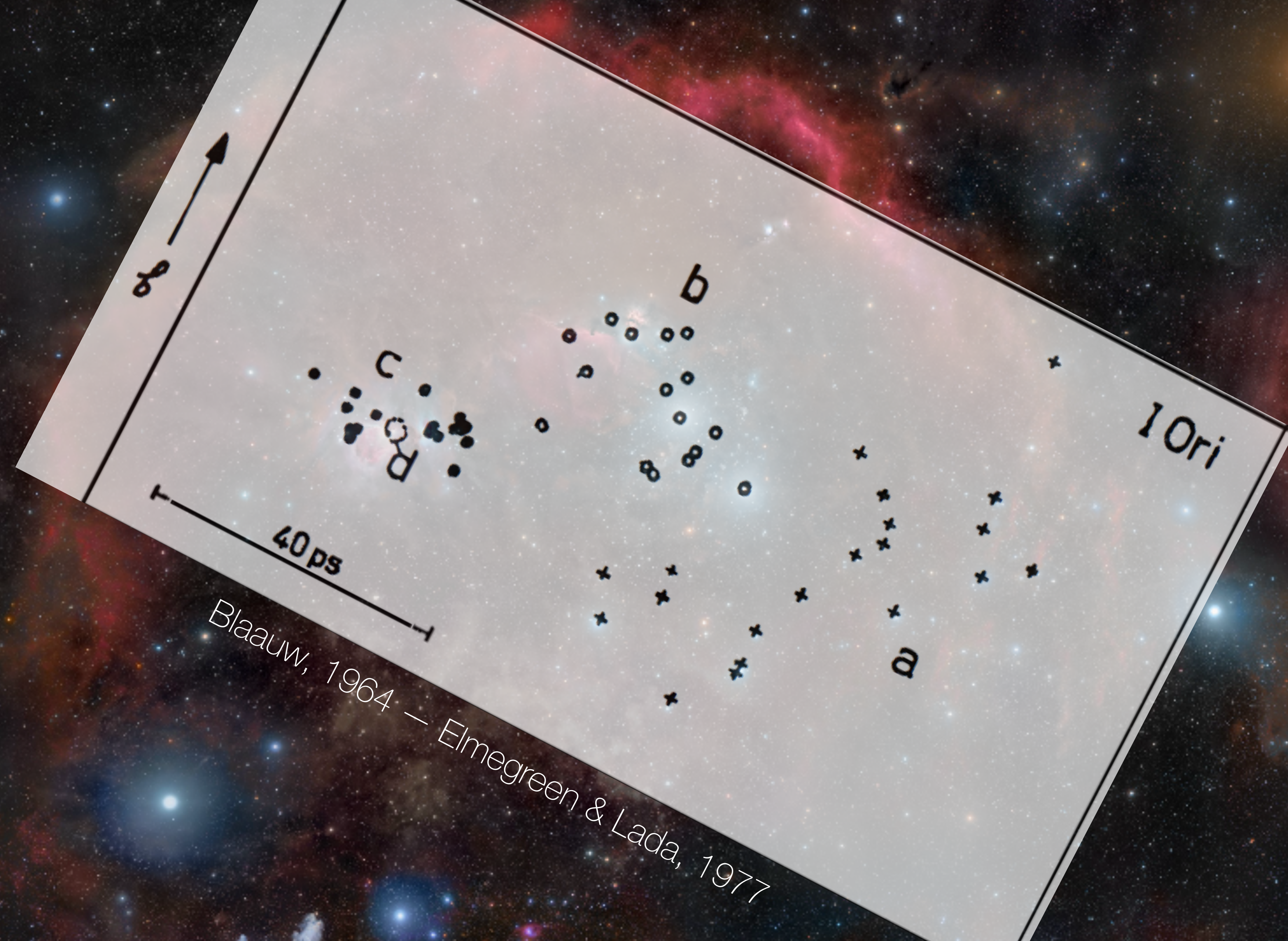
alena.kristina.rottensteiner@univie.ac.at

in collaboration with:

João Alves, Stefan Meingast, Monika Petr-Gotzens, Sebastian Ratzenböck, Núria Miret-Roig, **Josefa Großschedl**, Martin Piecka, Sebastian Hutschenreuter, Cameren Swiggum, **Laura Posch**, Efrem Maconi, Michelangelo Pantaleoni, Fabian Polnitzky, Isak Niederbrunner, Lilly Korman & David Hernandez
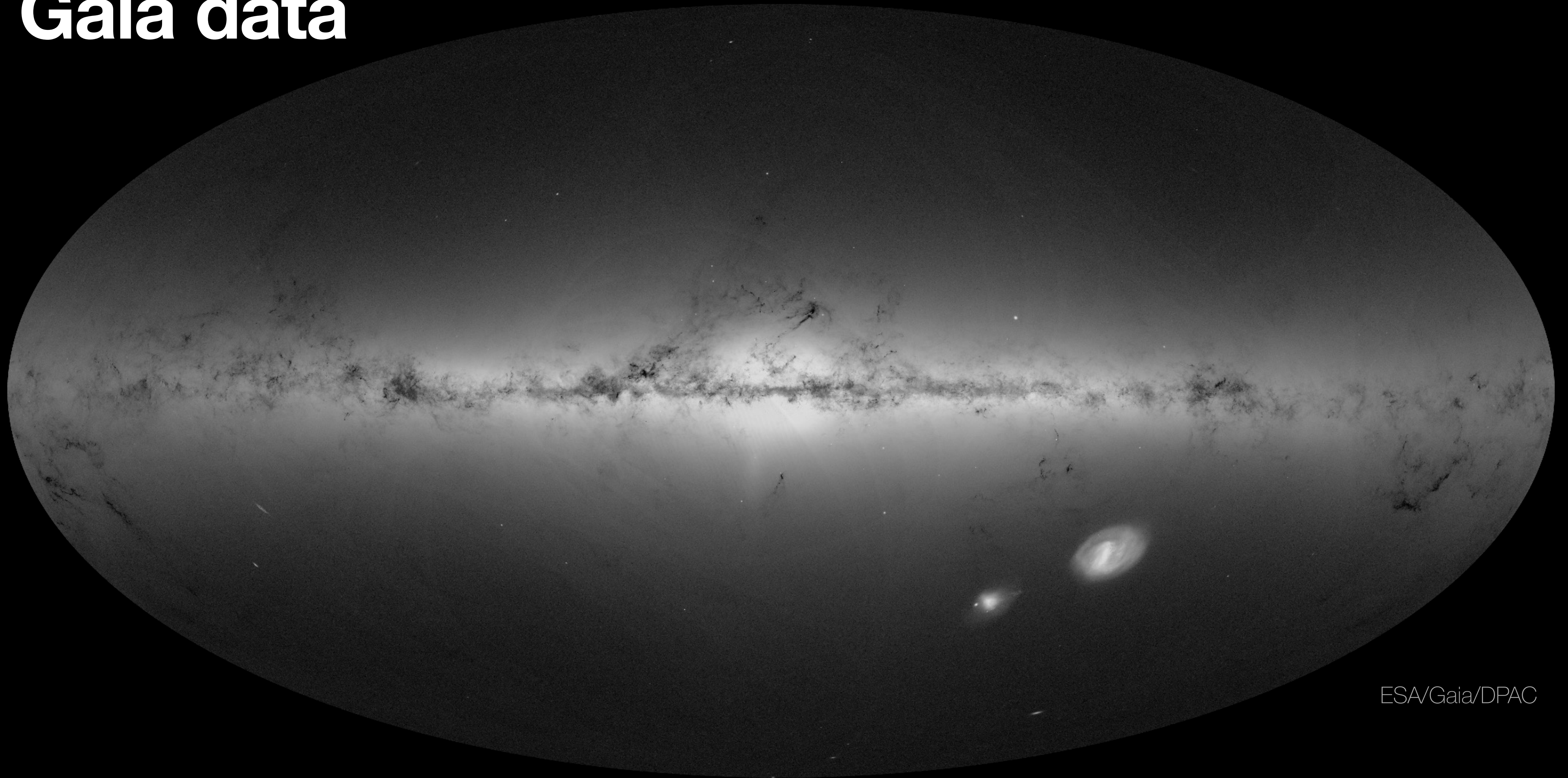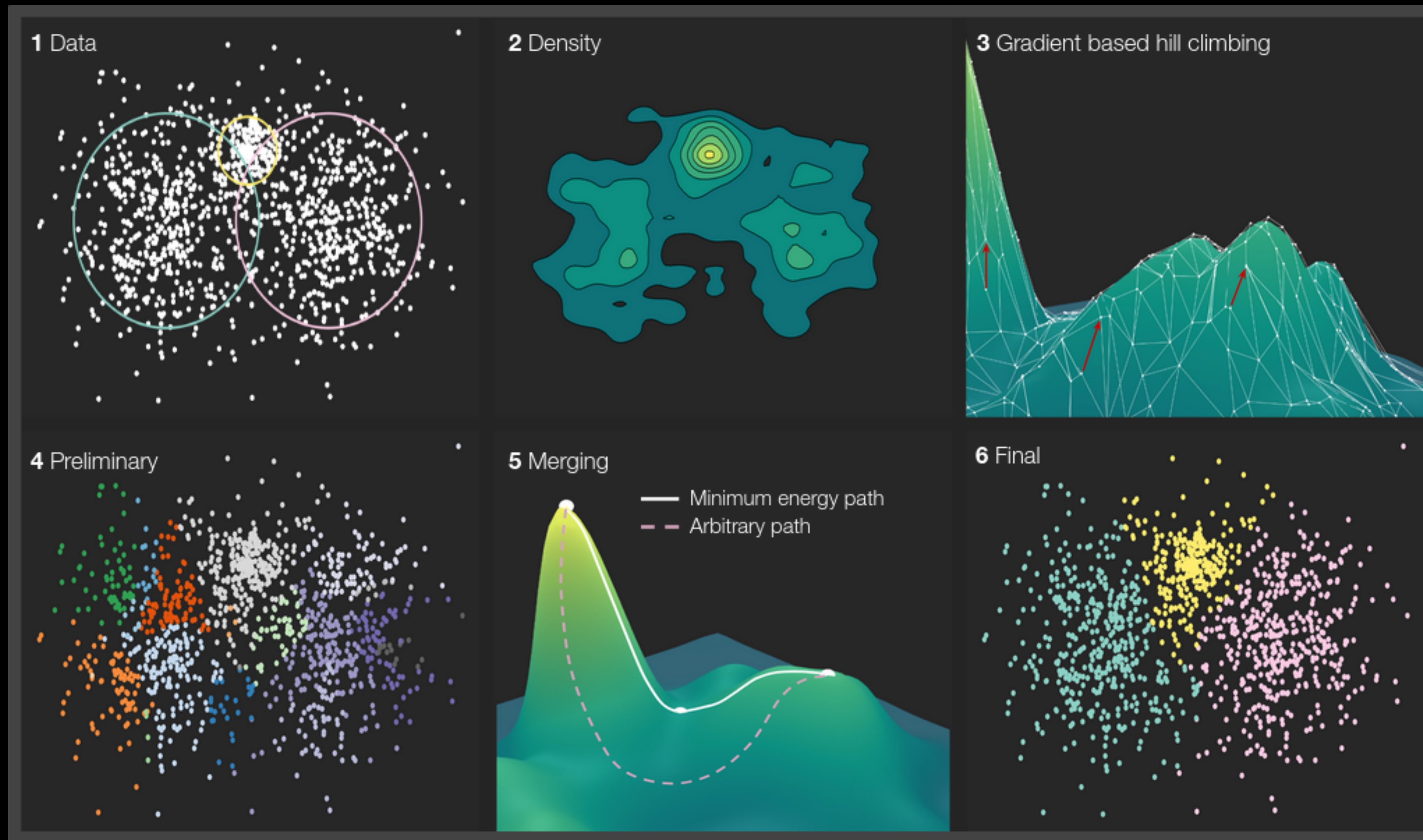
1 Ori

40 ps

Blaauw, 1964 — Elmegreen & Lada, 1977

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Gaia data

ESA/Gaia/DPAC

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SigMA in a nutshell

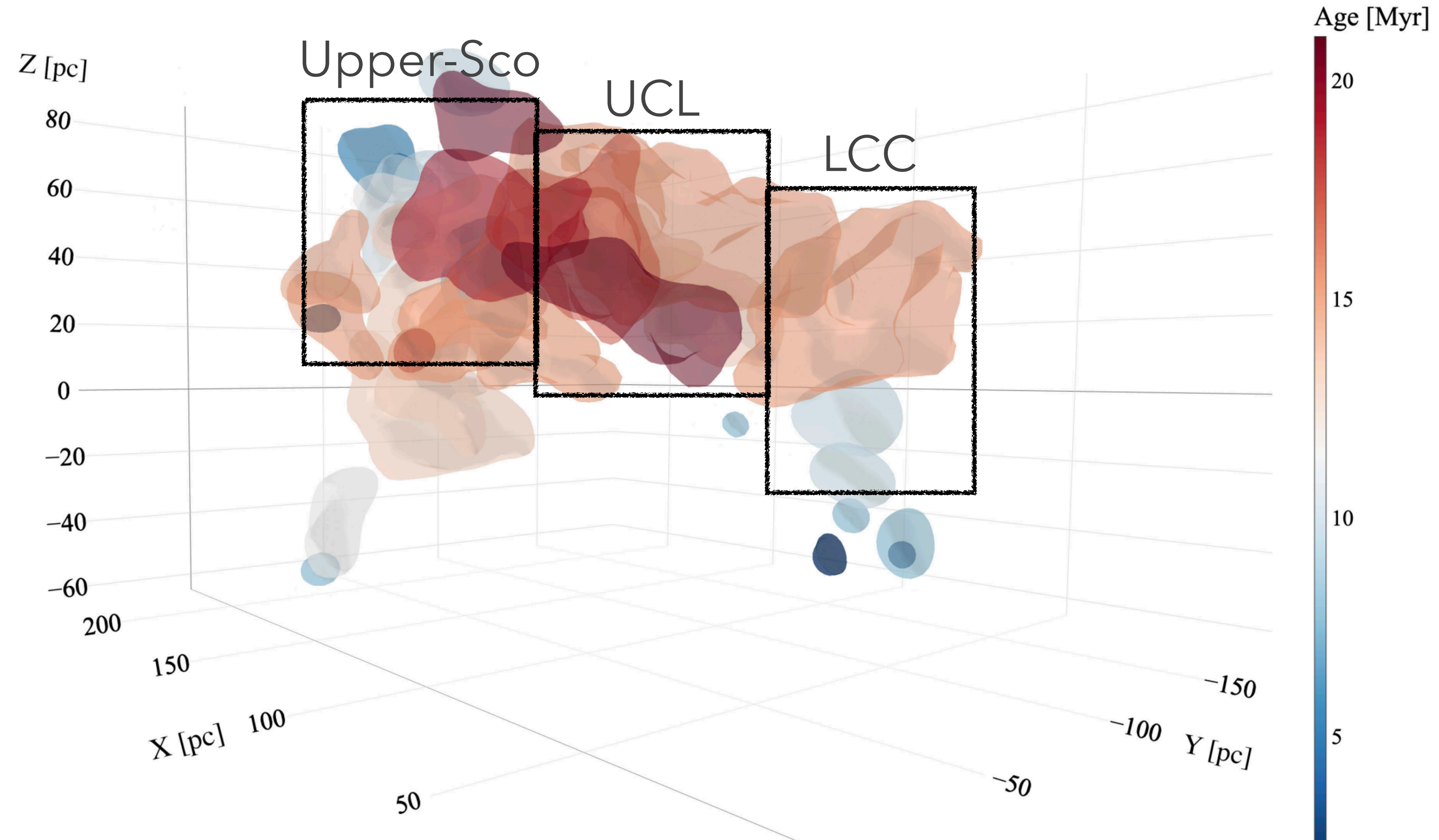Towards a holistic view of the star formation history of Orion   Alena Rottensteiner   Ballyfest 26.05.2025

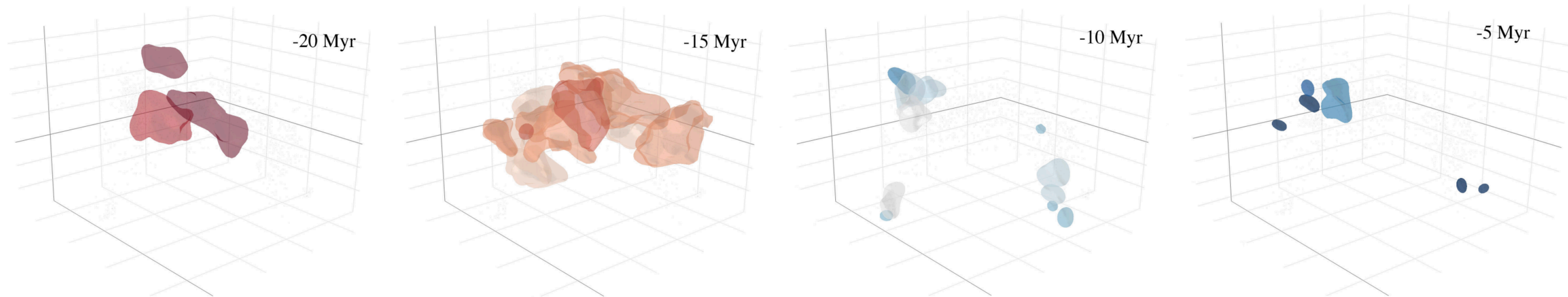# Sco-Cen
SigMA algorithm

Ratzenböck et al. 2023b

See also, Damiani et al. 2019, Schmitt et al. 2022, Zerjal et al. 2021, Squicciarini et al. 2021, Luhman 2021-2022, Miret-Roig et al. 2022, Briceño-Morales & Chanamé 2022

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High resolution star formation history

-20 Myr   -15 Myr   -10 Myr   -5 Myr

See talk by Laura Posch on Tuesday, 17:40:
Stellar feedback is driving sequential star formation in the Sco-Cen OB association
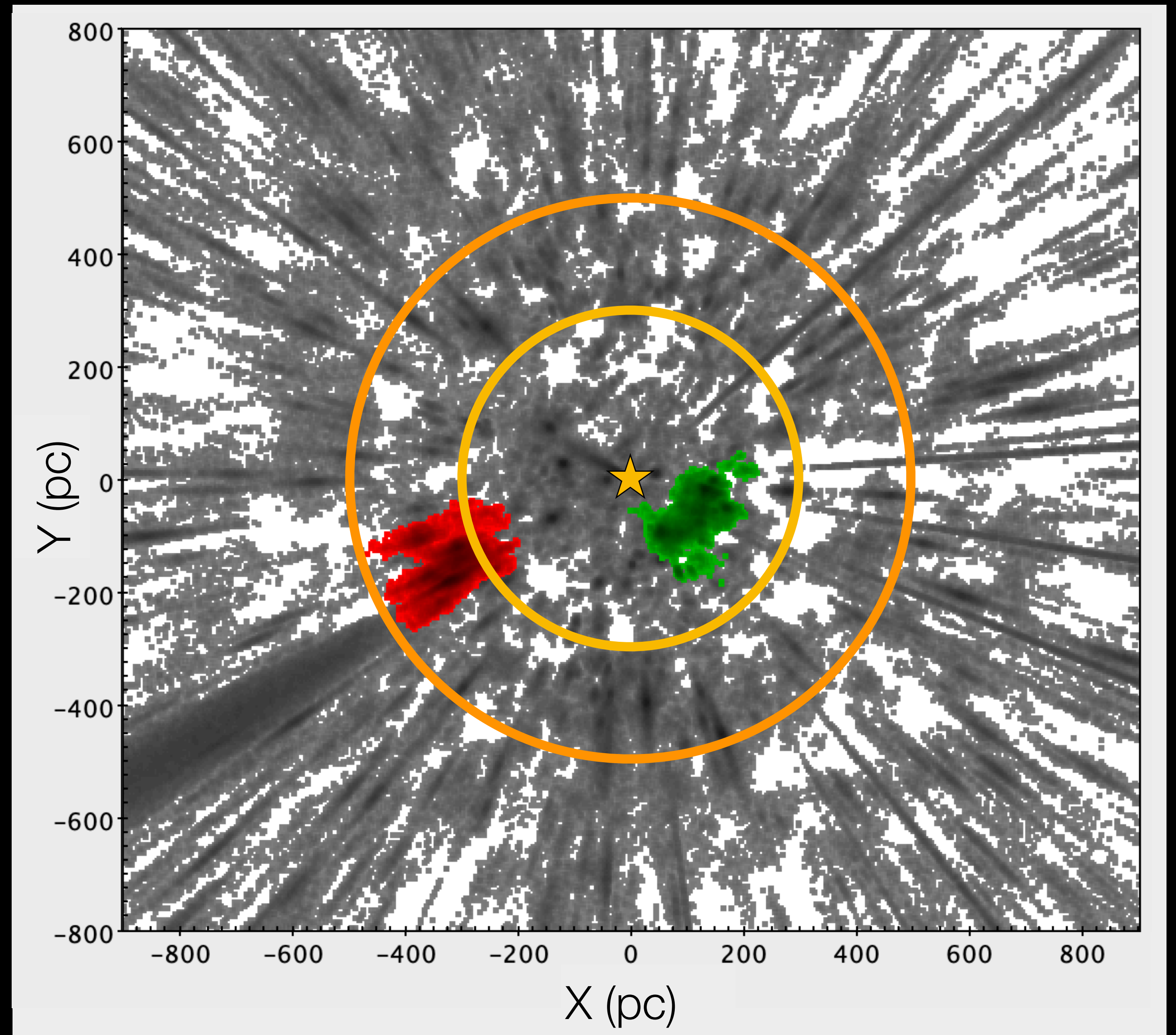
Ratzenböck et al. 2023b

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What does the picture look like in Orion?

Clustering at different distances

Clusters in the solar neighborhood

Hunt & Reffert 2023

300 pc   500 pc

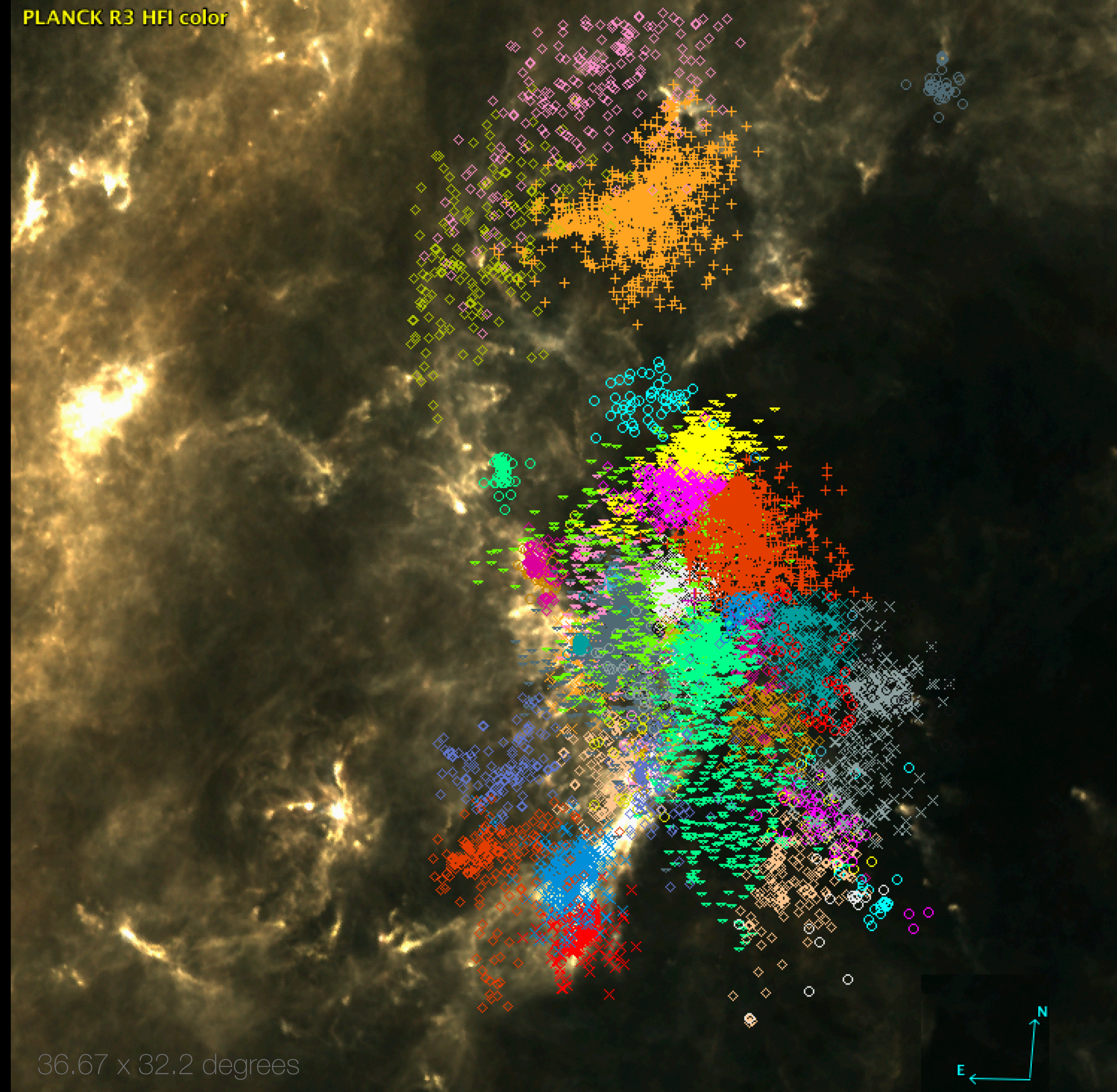Towards a holistic view of the star formation history of Orion   Alena Rottensteiner   Ballyfest 26.05.2025

Orion clusters
Characteristics

- More than **15,000 co-moving and coeval** young stars in Orion

- Roughly **40** individual groups identified

- SigMA finds more extended clusters - often with **50 - 100 % more stars**
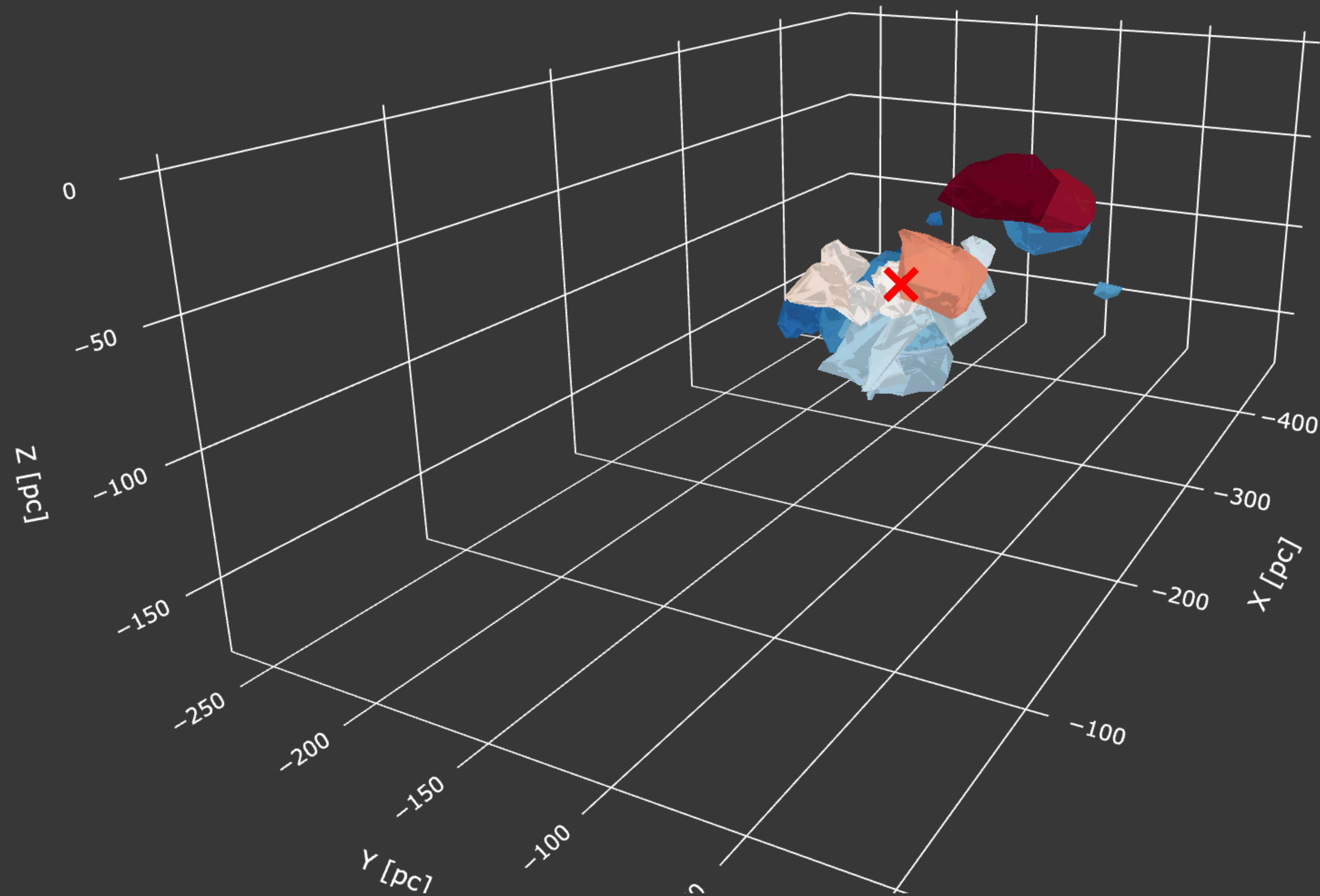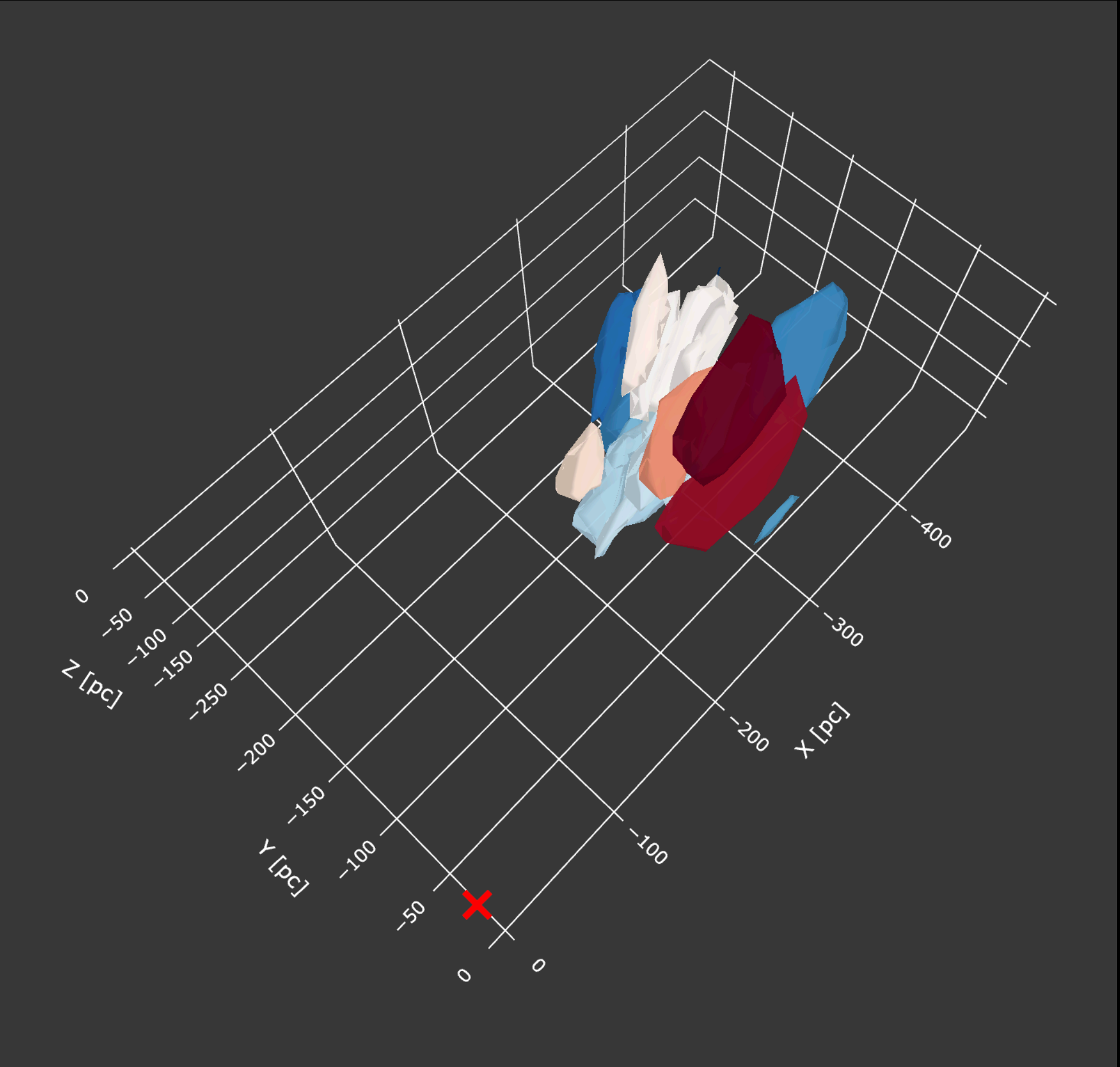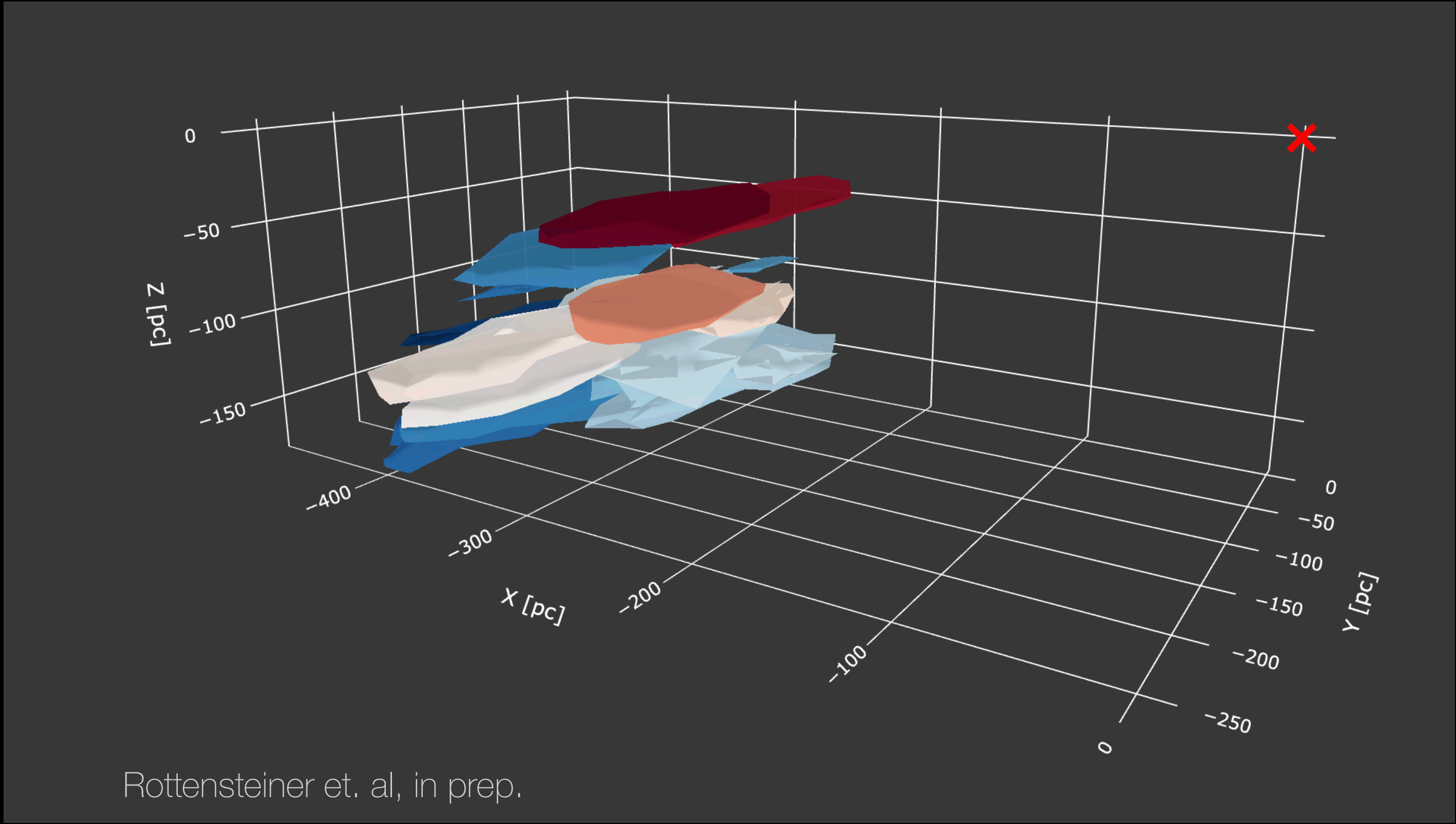
- **8** Previously unknown groups found

PLANCK R3 HFI color

36.67 x 32.2 degrees

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Preliminary

But what about 3D?

Rottensteiner et. al, in prep.

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Rottensteiner et. al, in prep.

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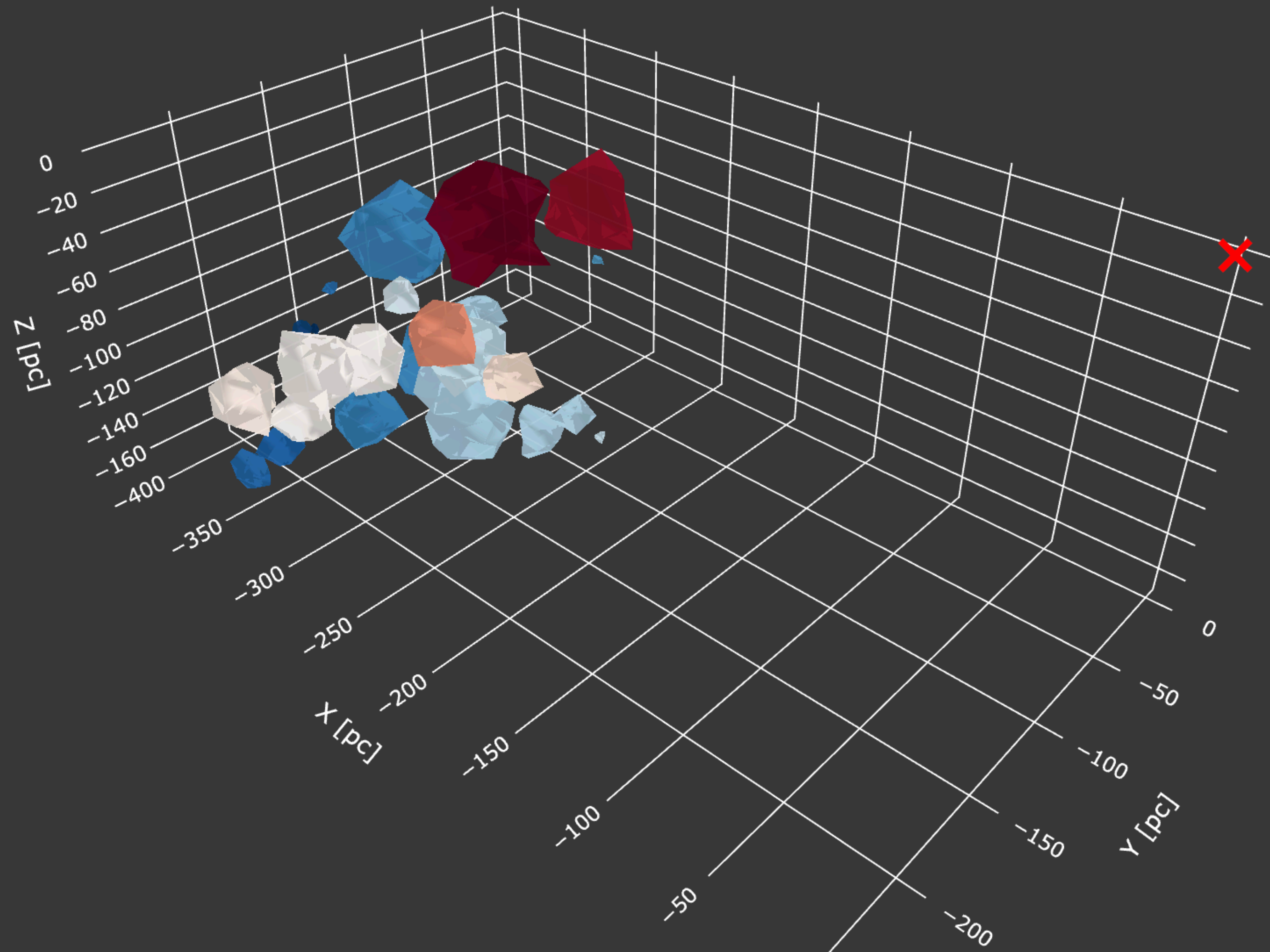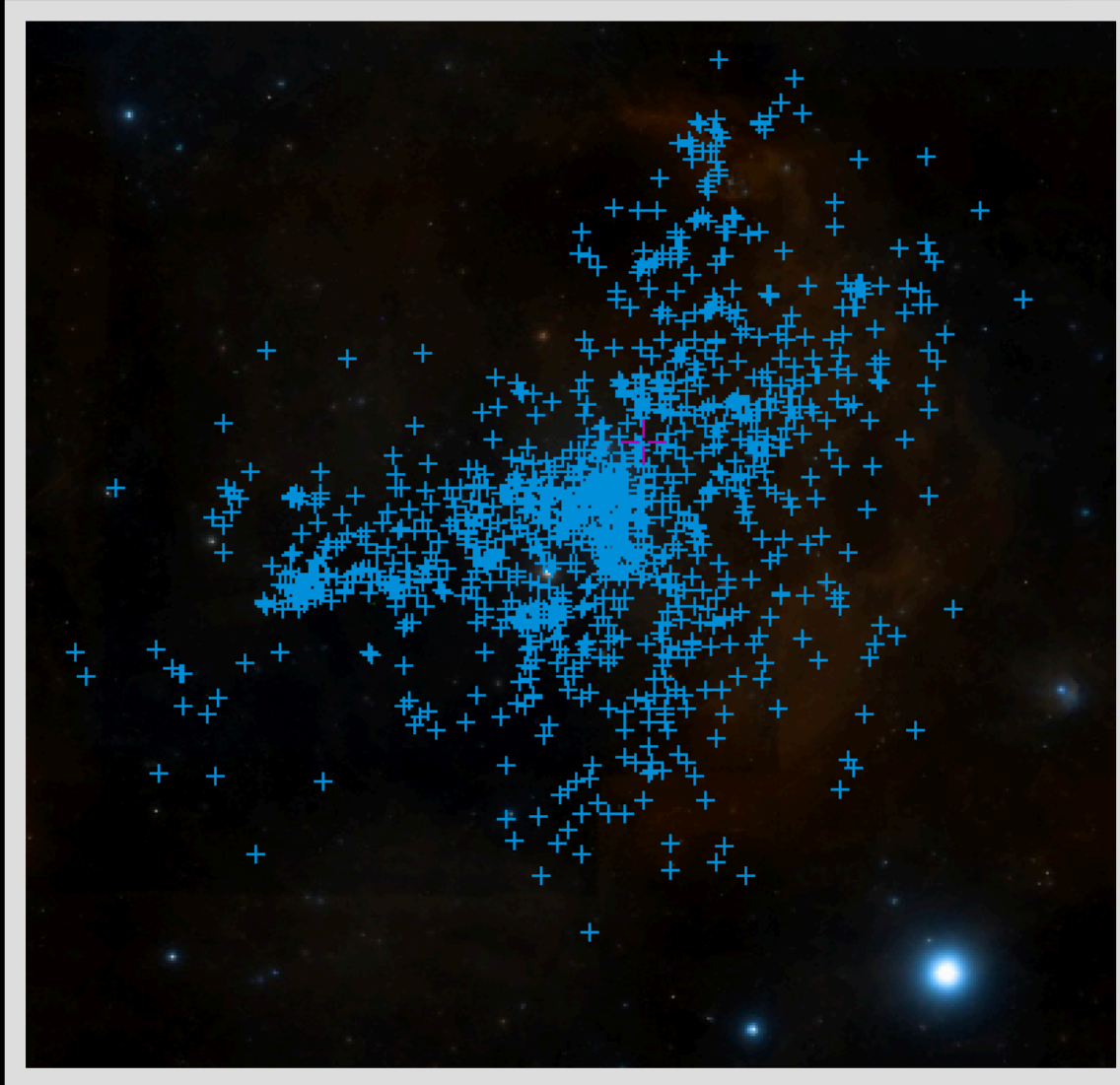
Lambda Ori ~ 6 Myr
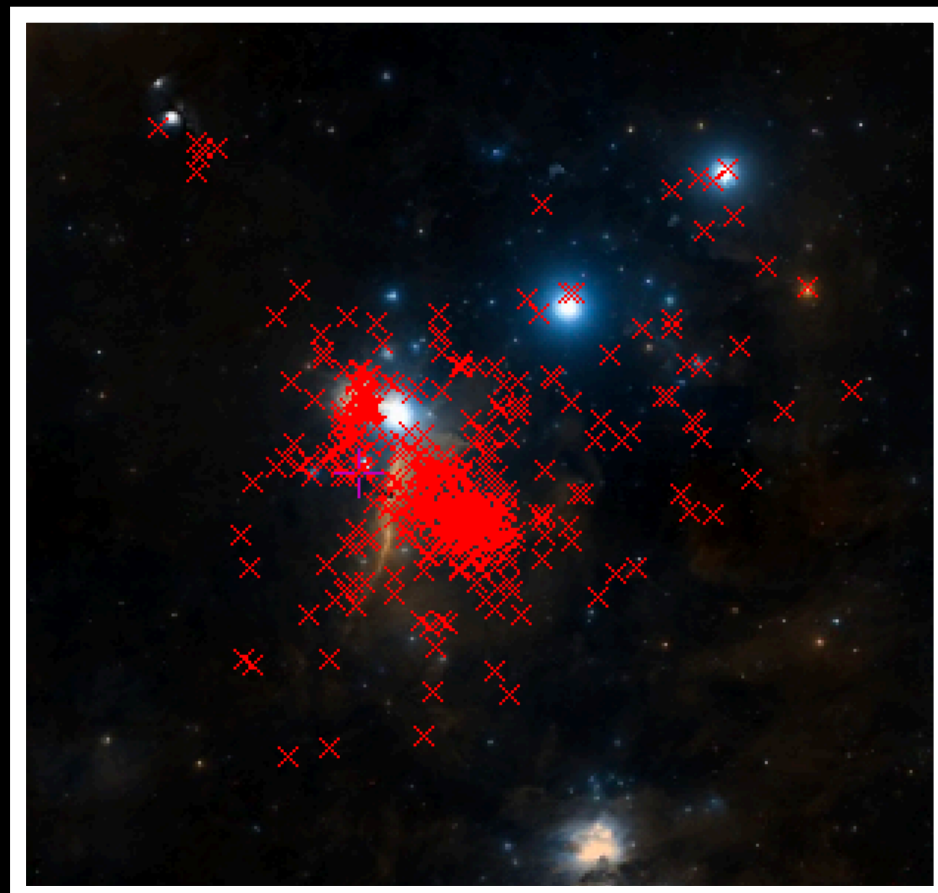
Briceno 1
~ 11-12 Myr

Preliminary

Sigma Ori ~ 3 Myr

ASCC 20 ~ 21 Myr

Z [pc]

0
−20
−40
−60
−80
−100
−120
−140
−160
−400

−350
−300
−250
−200
−150

X [pc]

Rottensteiner et. al, in prep.

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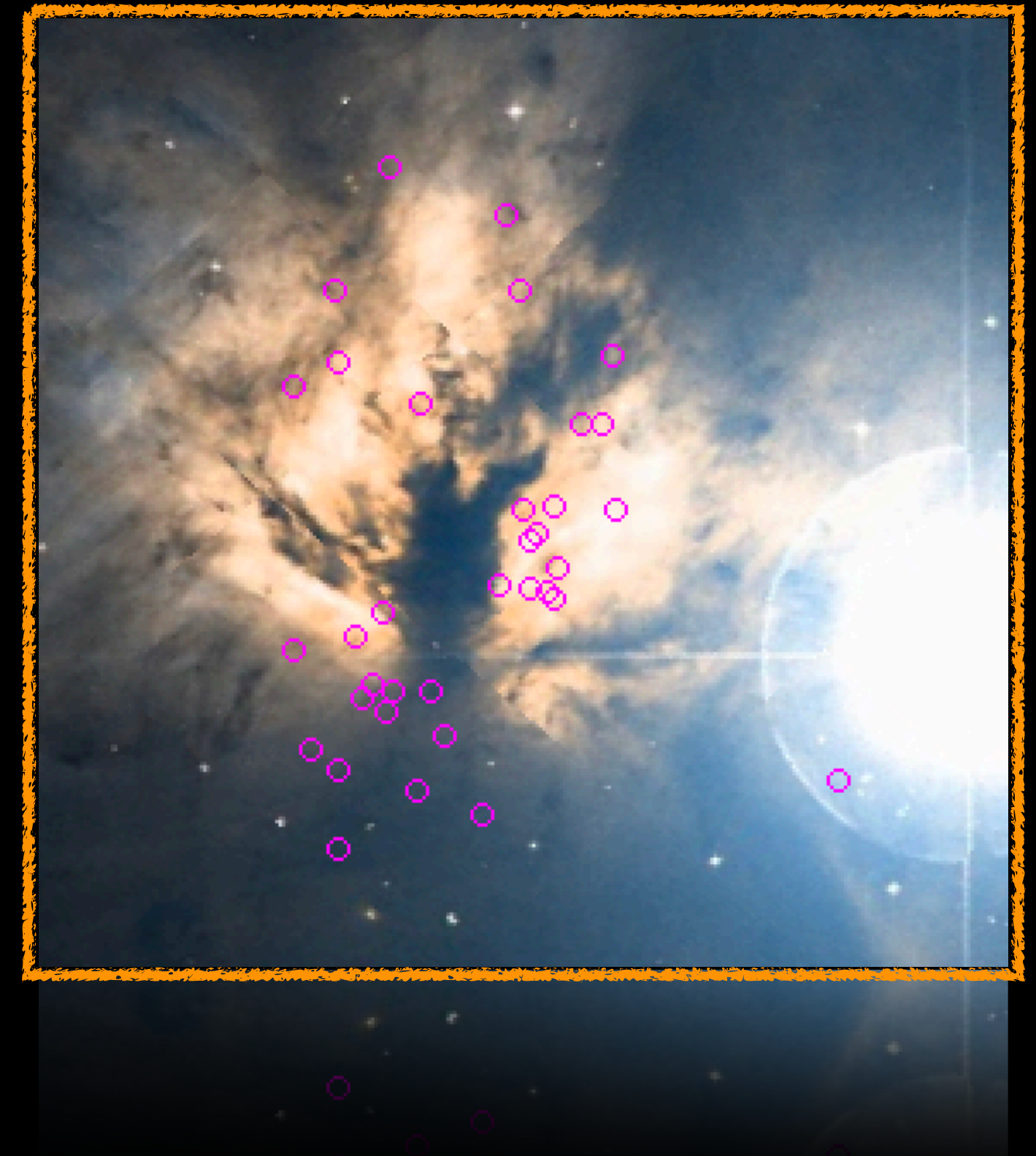UNIVERSITÄTSSTERNWARTE WIEN

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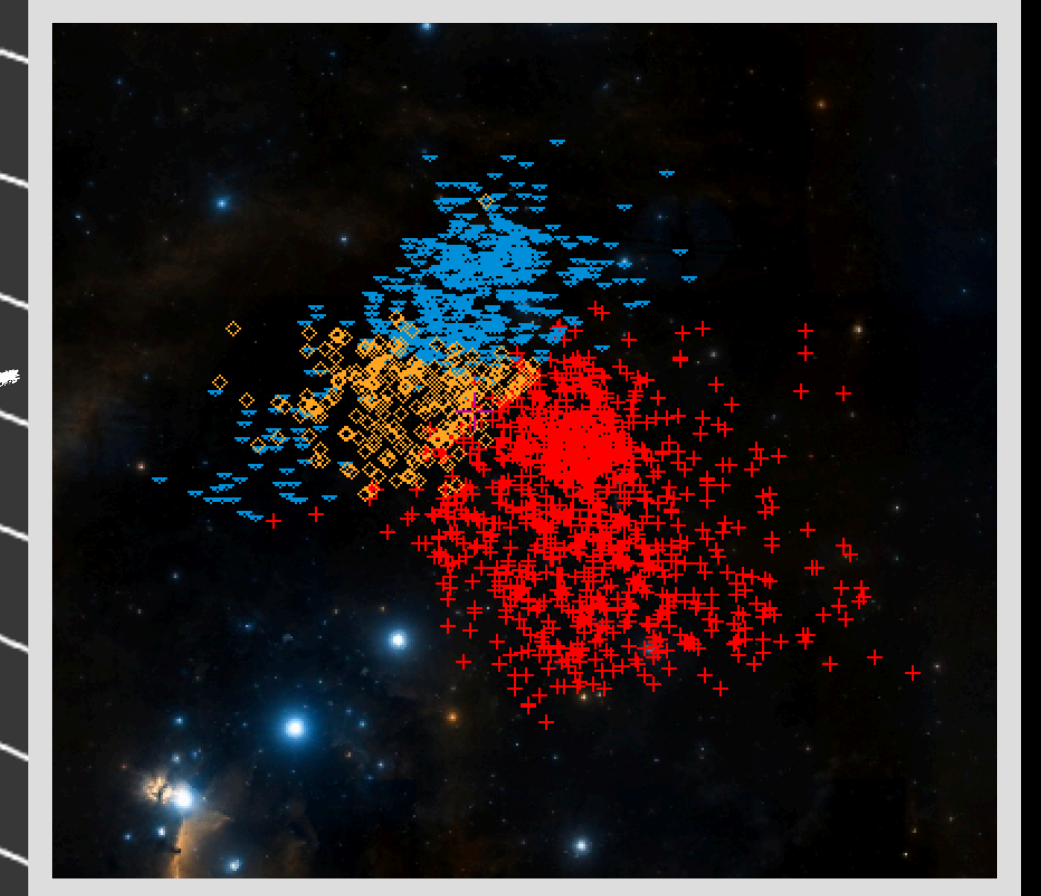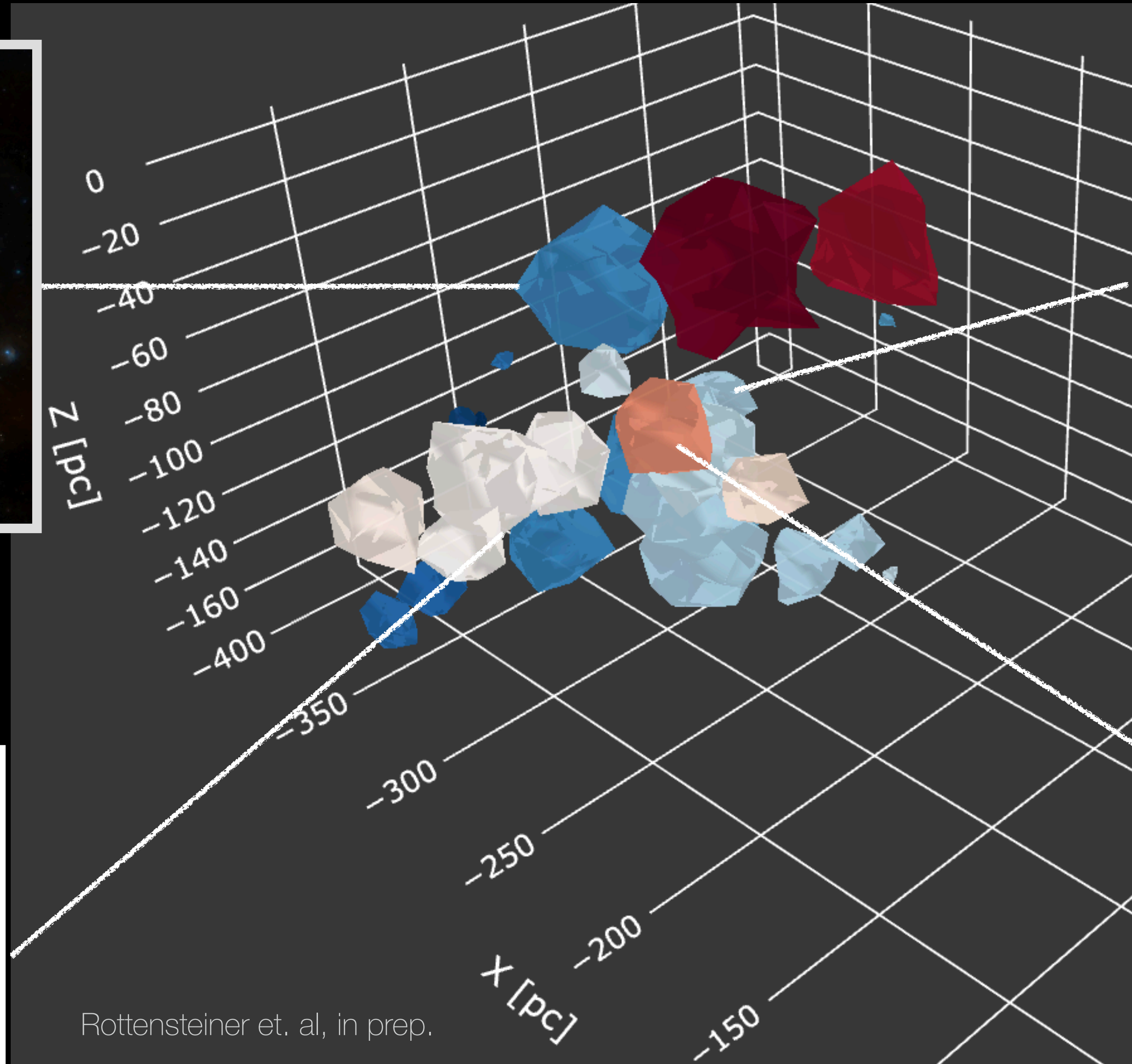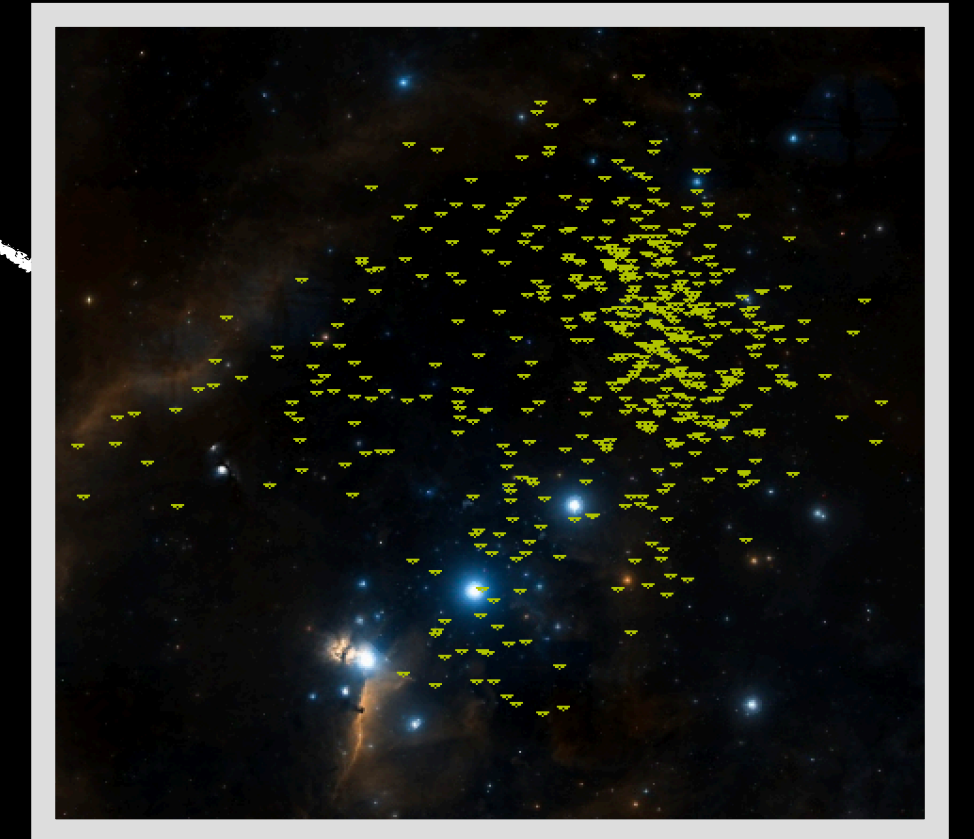
Cluster snapshots
Associated with bright stars, Rayleigh-Taylor Fingers and nebulas

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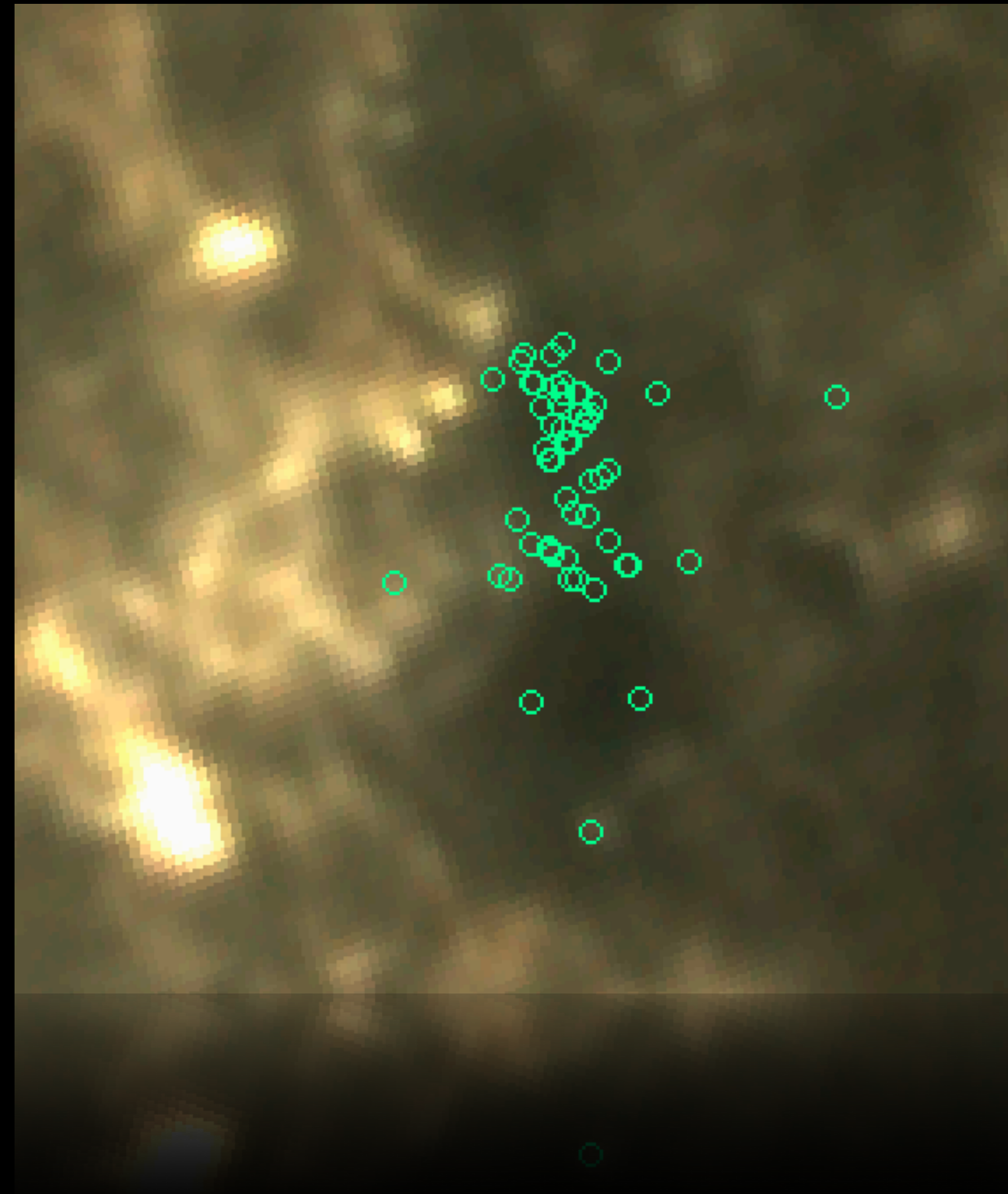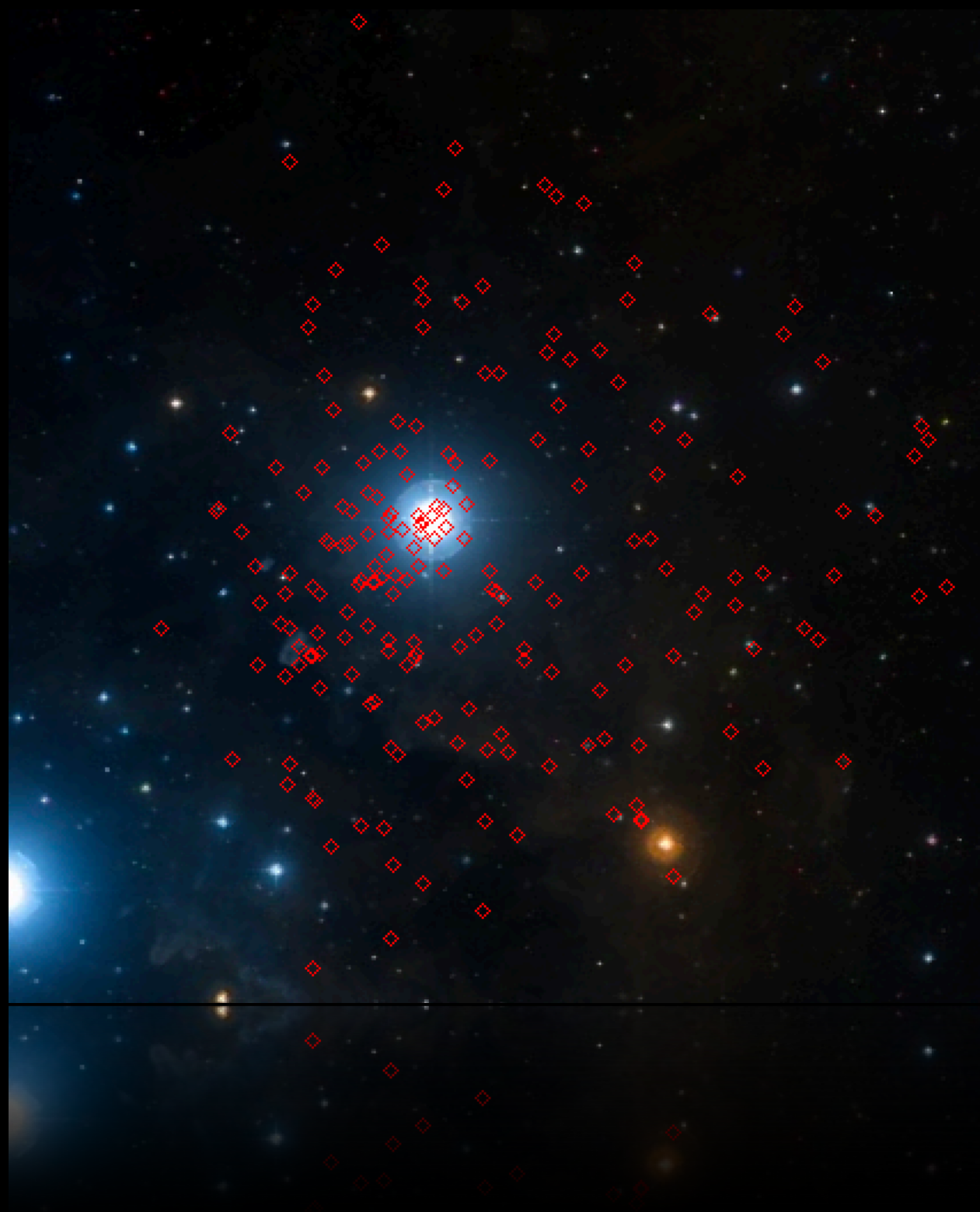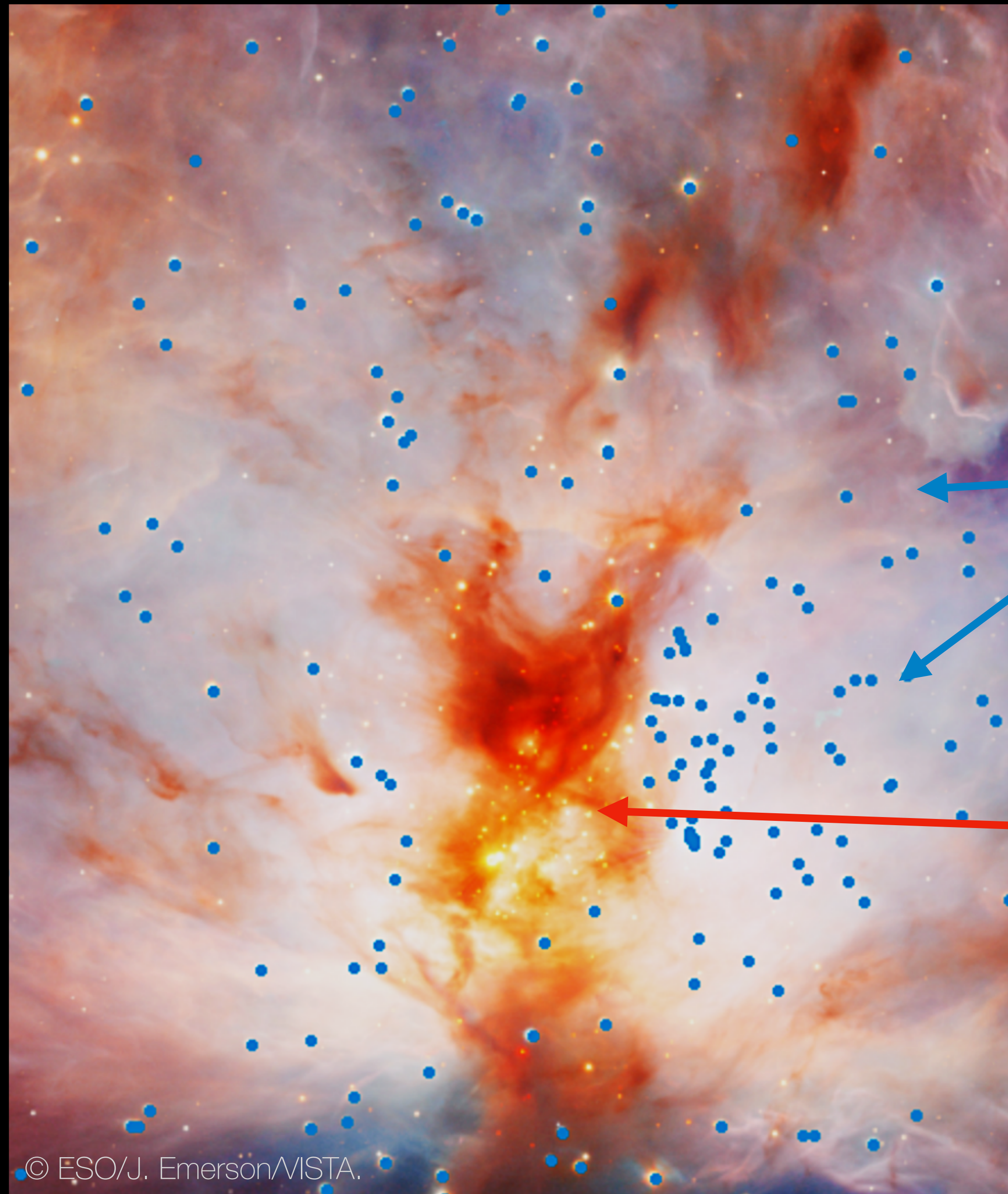
Star formation in active stellar nurseries

A pilot study in NGC 2024

Optically revealed stars <u>visible</u> to Gaia

Embedded stars <u>invisible</u> to Gaia

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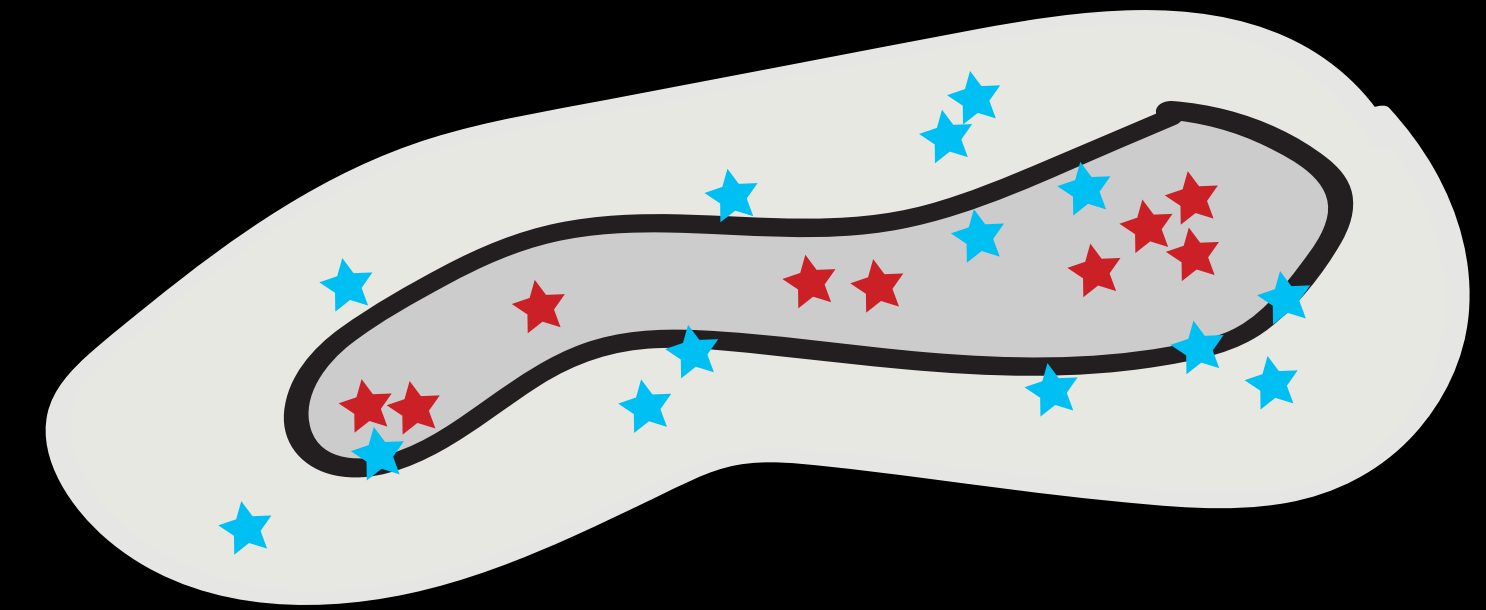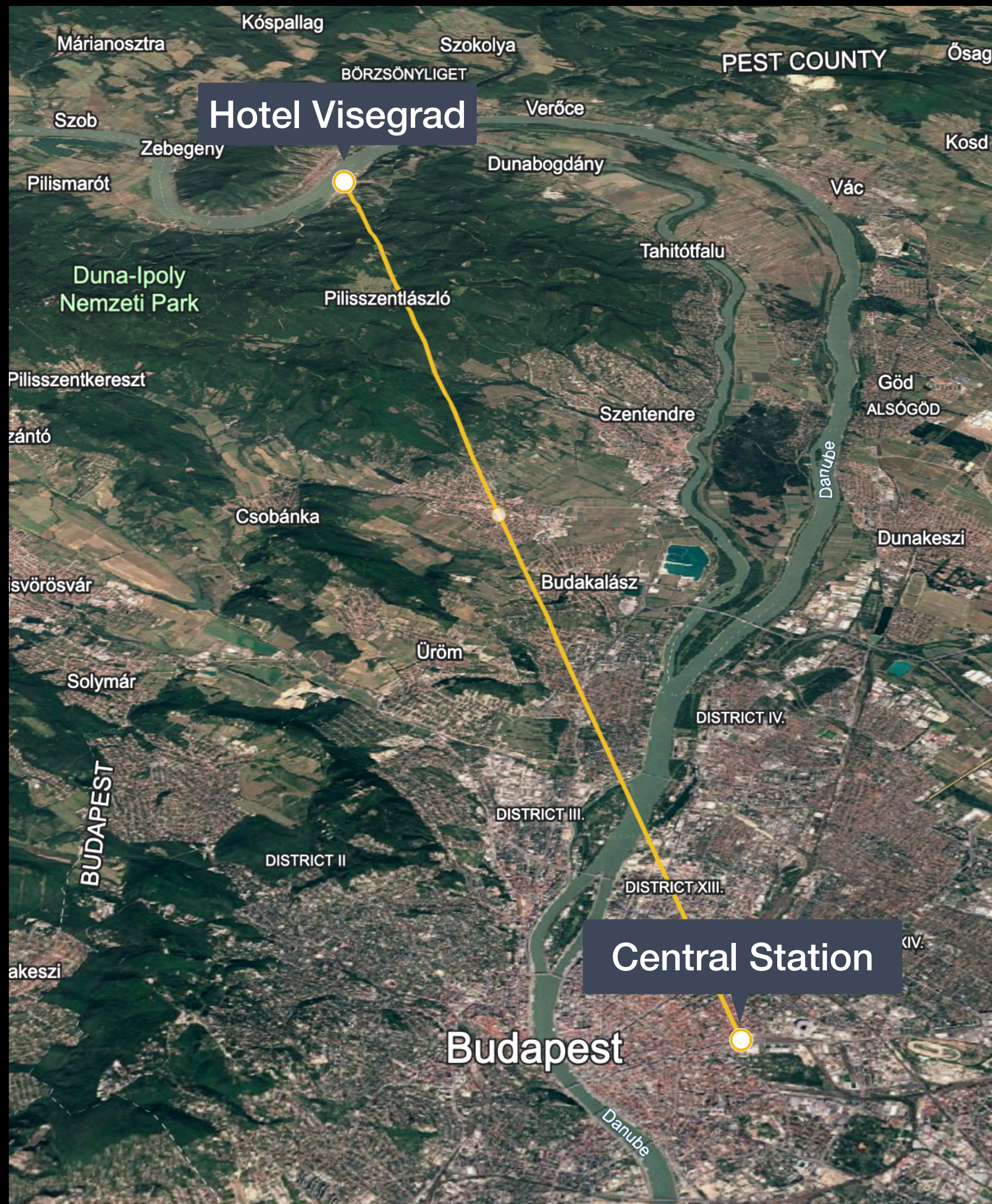
How precise do we need to be?

- Flame Nebula distance ~ 400 pc

- Proper motion of NGC 2024 sources ~ 1 mas/yr e.g., Zerjal et al. 2024

- Distance Hotel Visegrad - Budapest-Keleti station ~32.9 km

- Displacement of **~160 μm**

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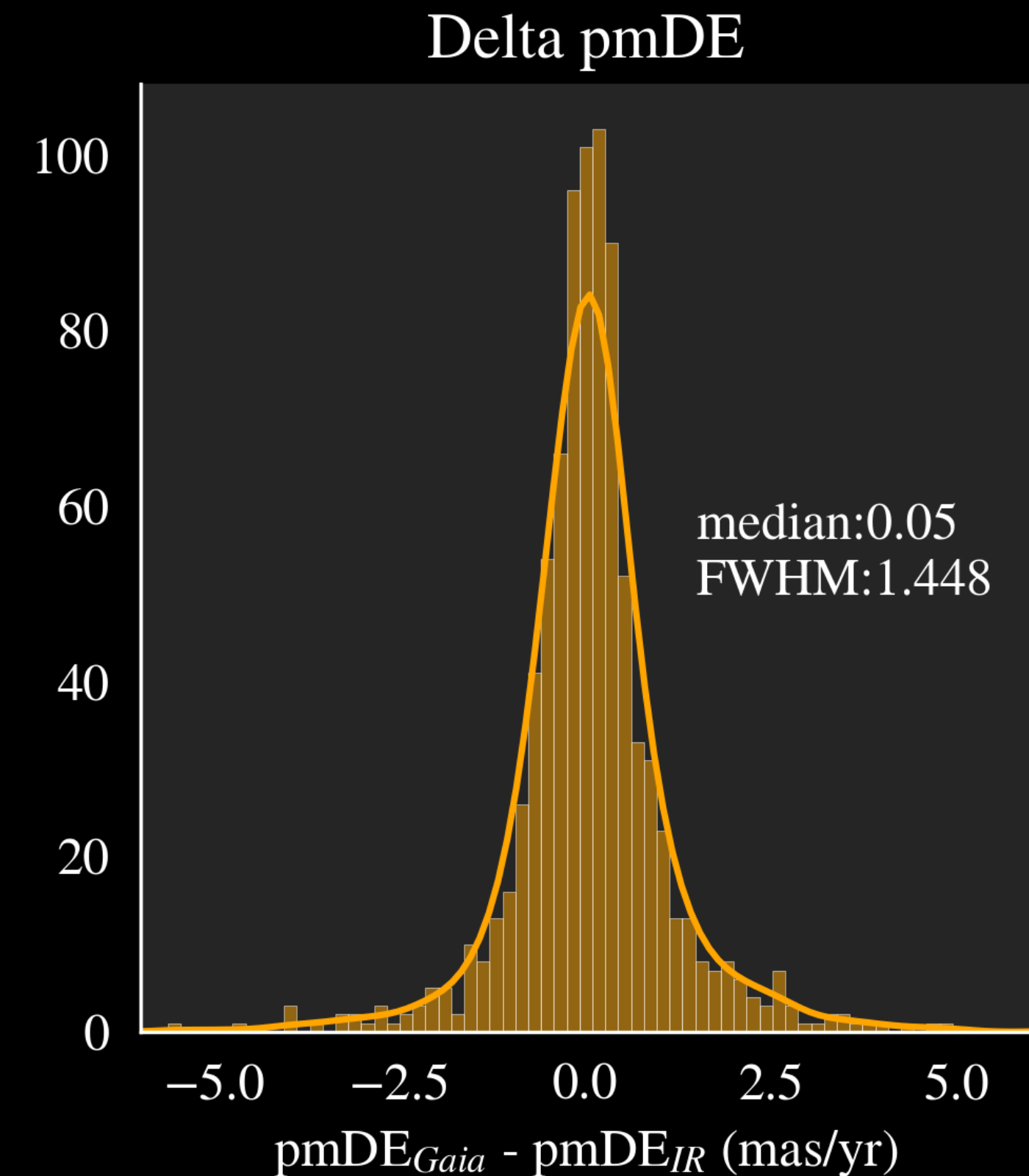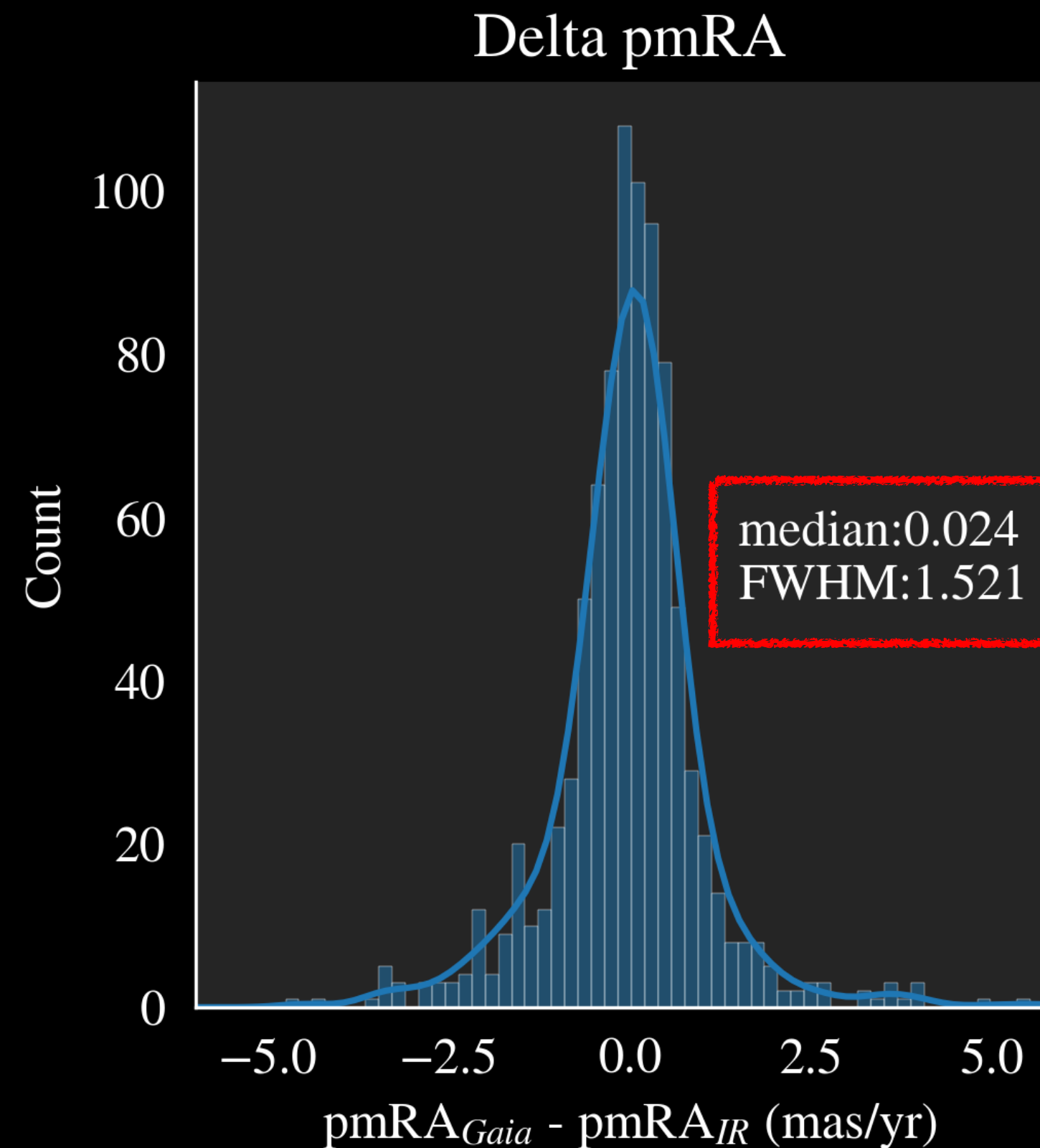UNIVERSITÄTSSTERNWARTE WIEN

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Proper motion catalog

Gaia comparison

Rottensteiner et. al, in prep.

- 6,769 sources

- 886 Gaia crossmatches

Very good agreement with Gaia

Delta pmRA

median:0.024
FWHM:1.521

Count

$pmRA_{Gaia} - pmRA_{IR}$ (mas/yr)

Delta pmDE

median:0.05
FWHM:1.448

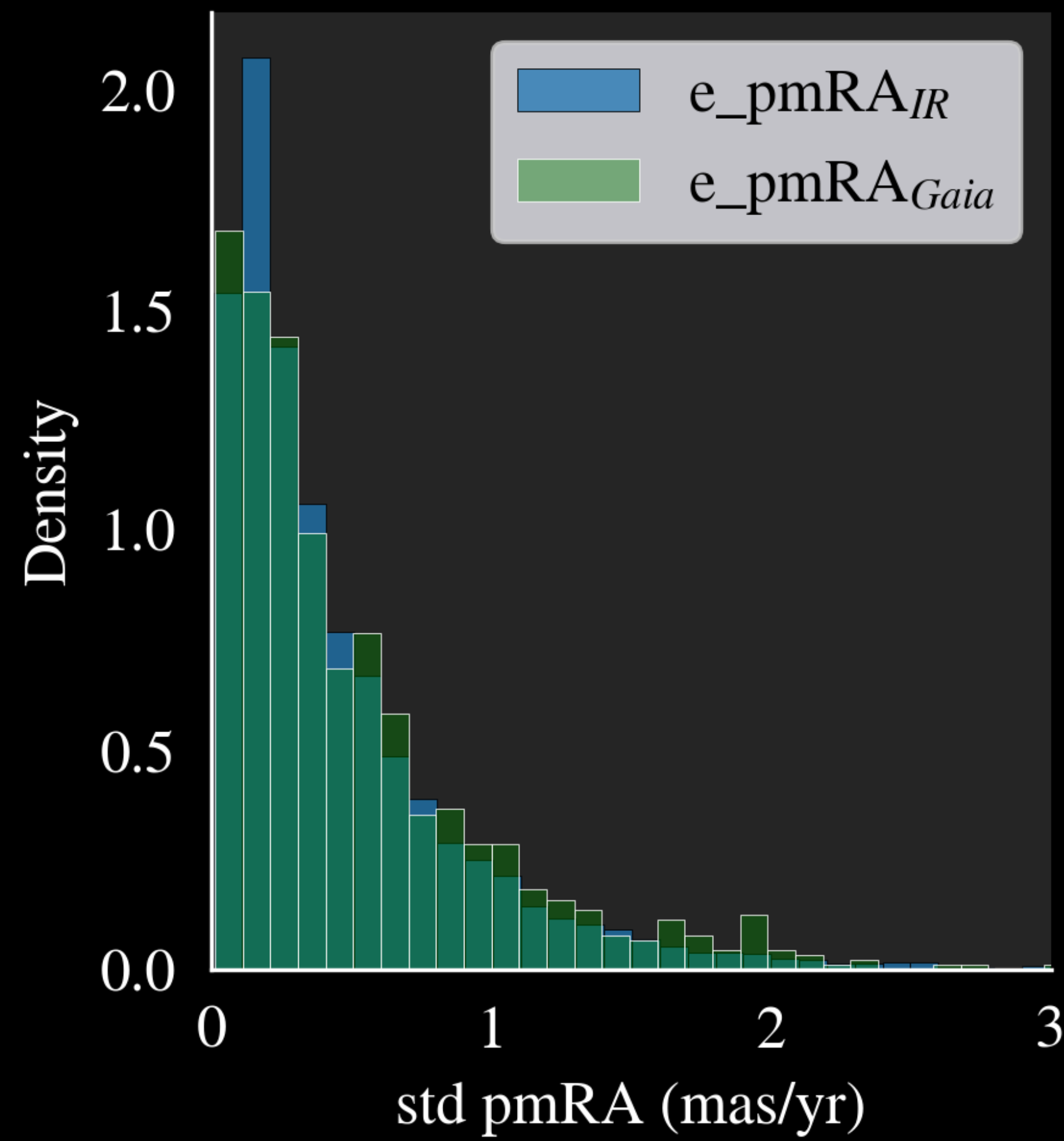$pmDE_{Gaia} - pmDE_{IR}$ (mas/yr)

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Proper motions - Errors are on par with Gaia
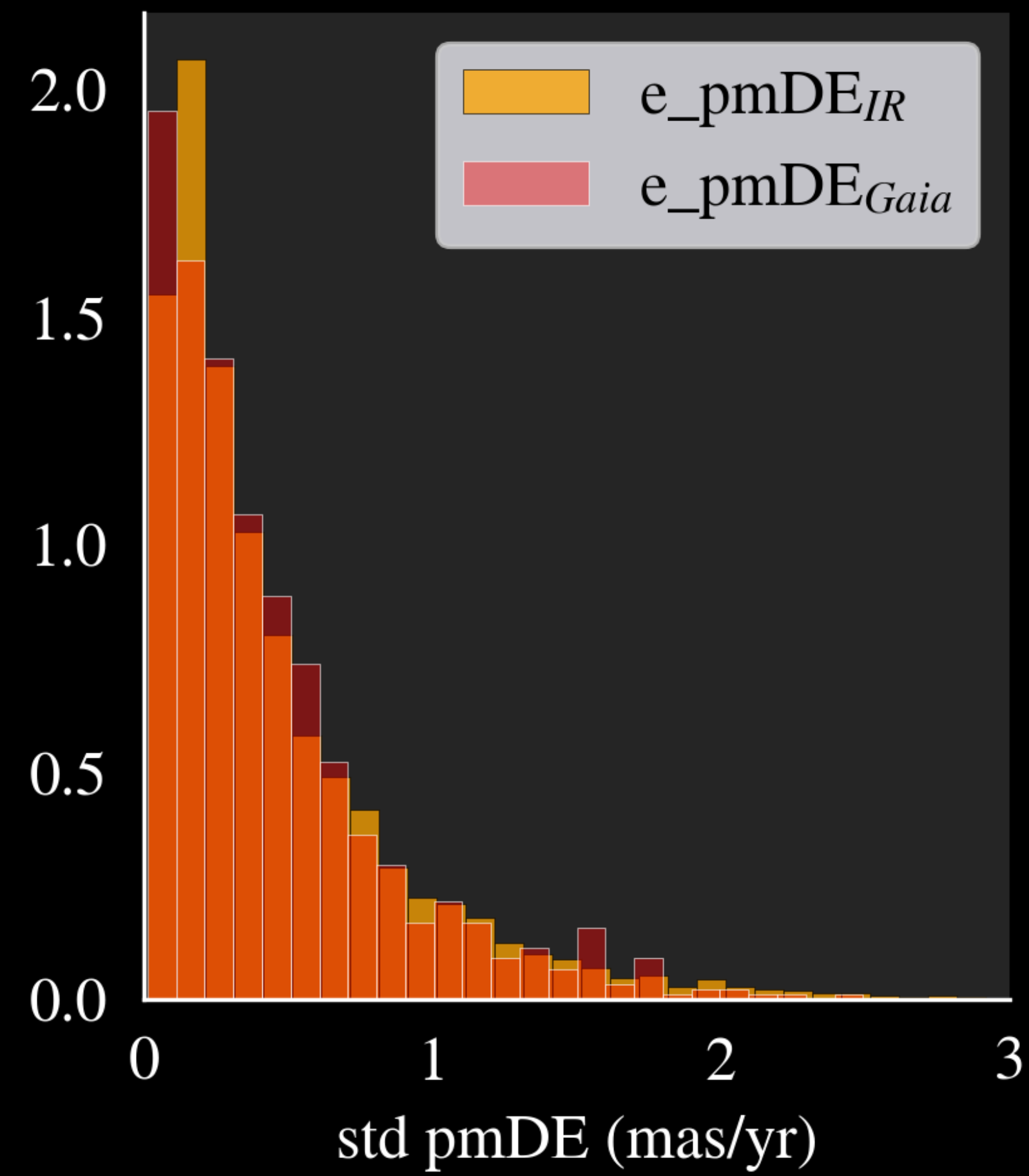
Rottensteiner et. al, in prep.

YSO population ~ 330 objects

Non-Gaia YSOs

Gaia YSOs

- ● Class I (48)
- ✕ Class II (166)
- ■ Flats (53)
- ✚ Class III (69)
- ◆ MS candidates
- ✦ Non-classified

Rottensteiner et. al, in prep.

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2D Velocity maps

Class I

Rottensteiner et. al, in prep.

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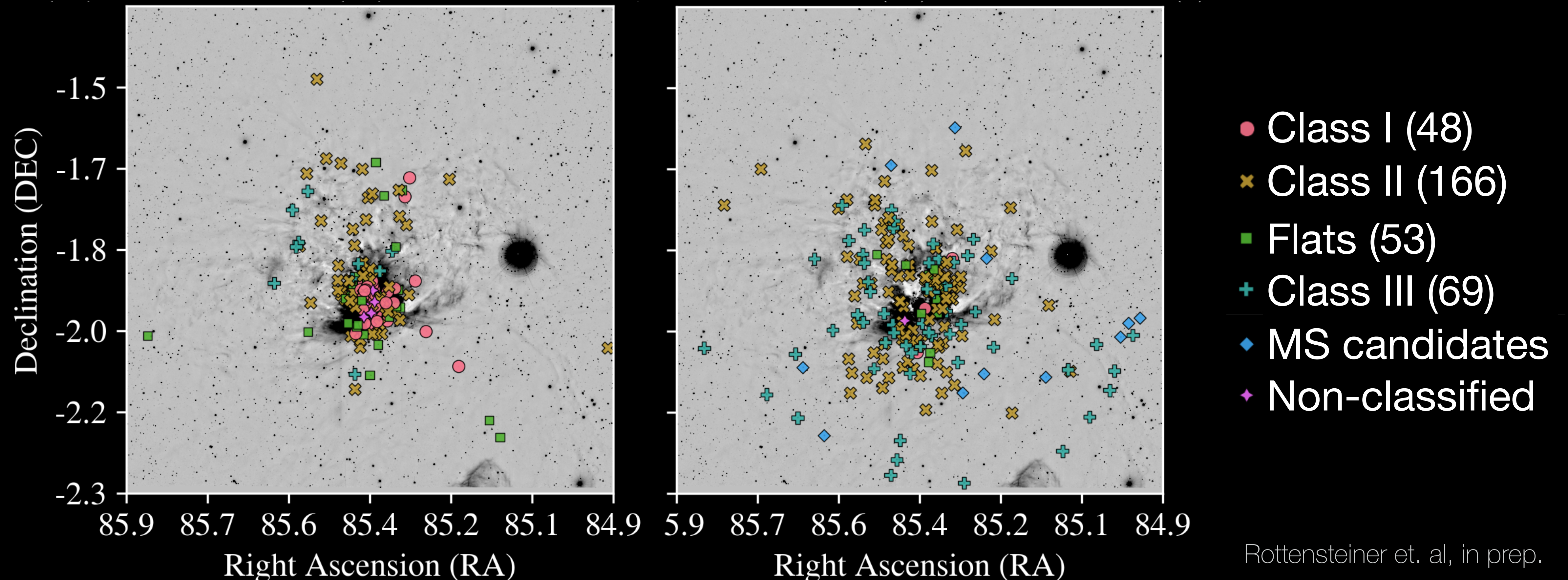
2D Velocity maps

2D Velocity maps
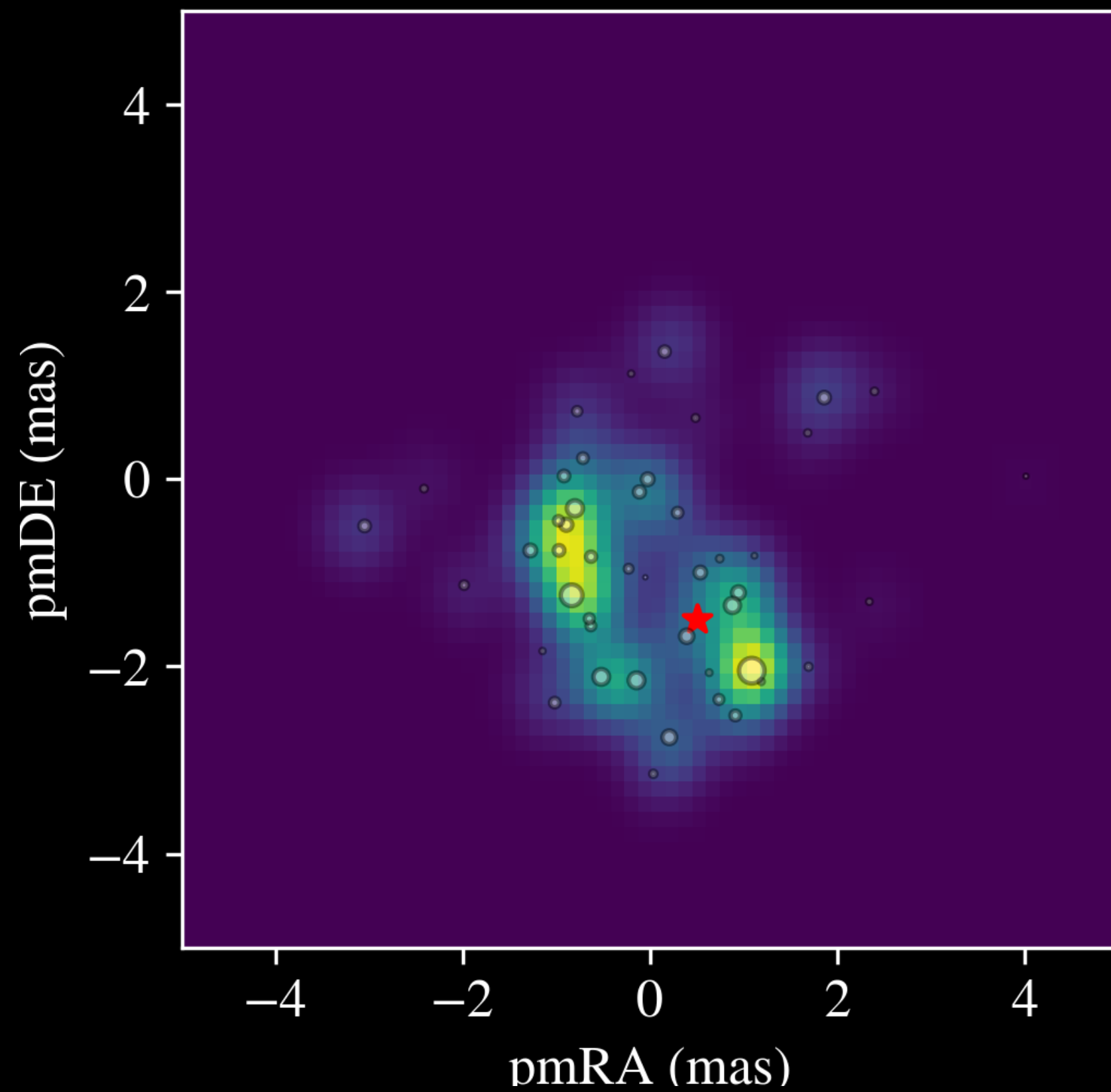
Class I | Class flat | Class II

Literature (Gaia)
NGC 2024 values

Rottensteiner et. al, in prep.

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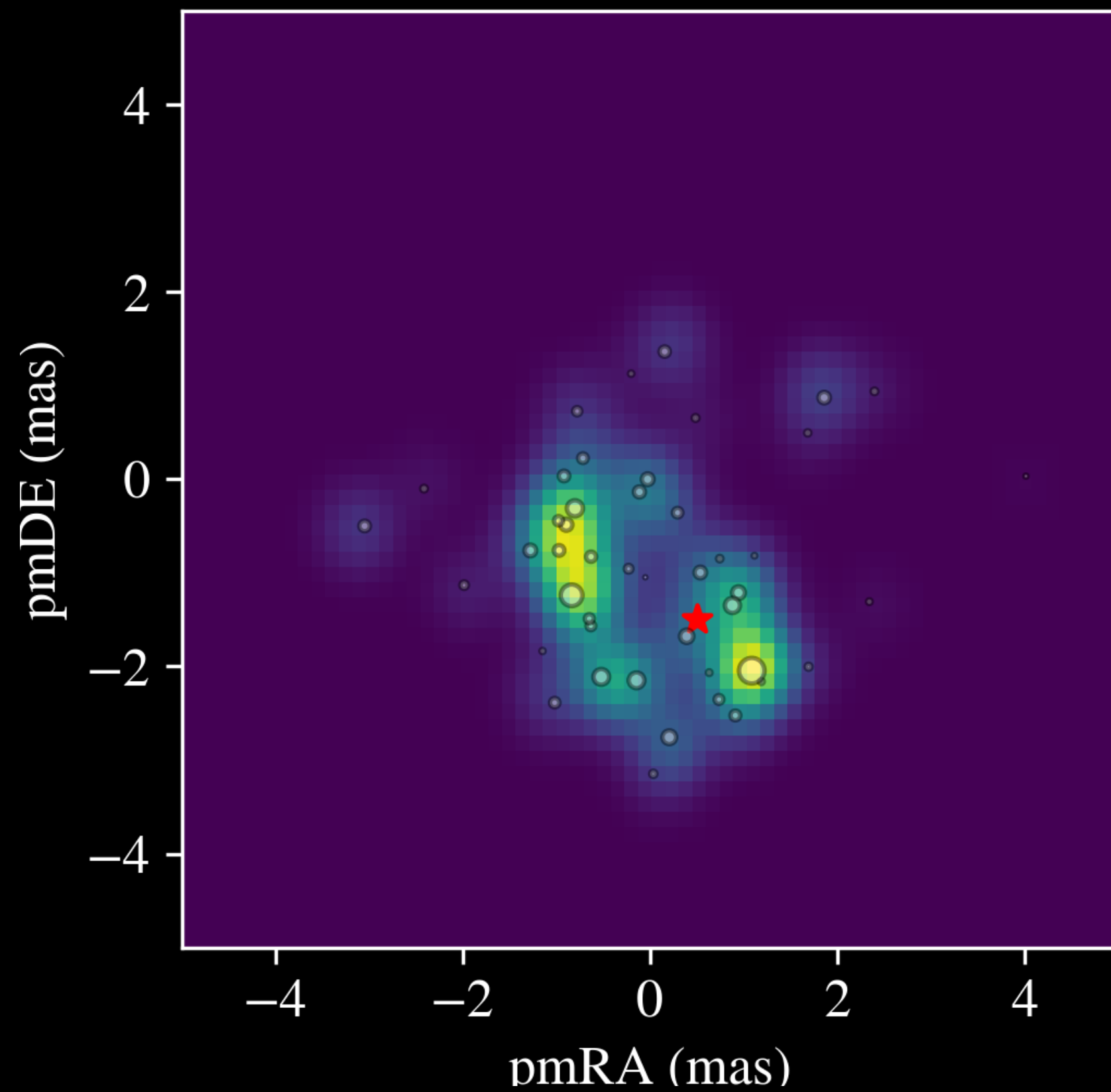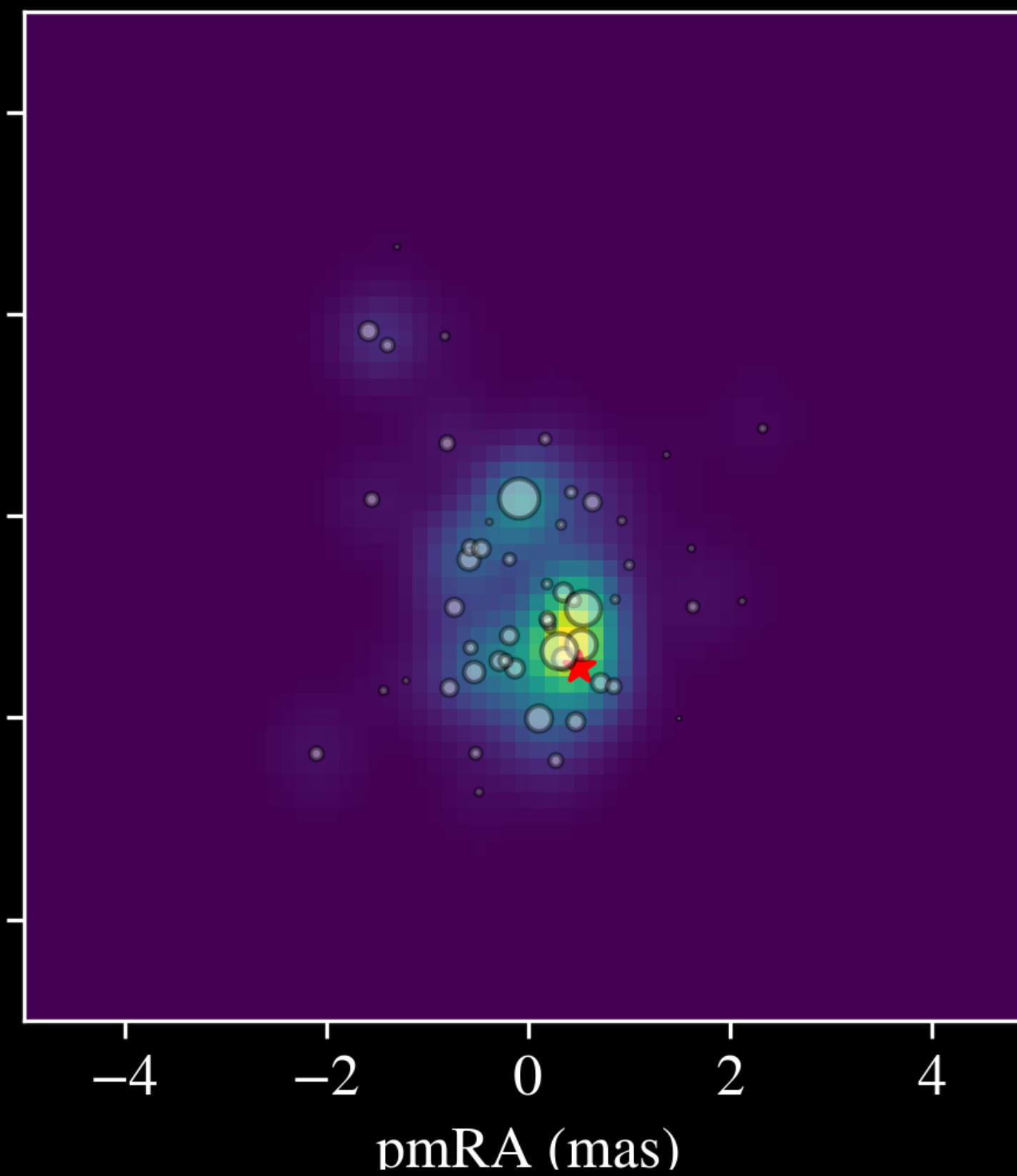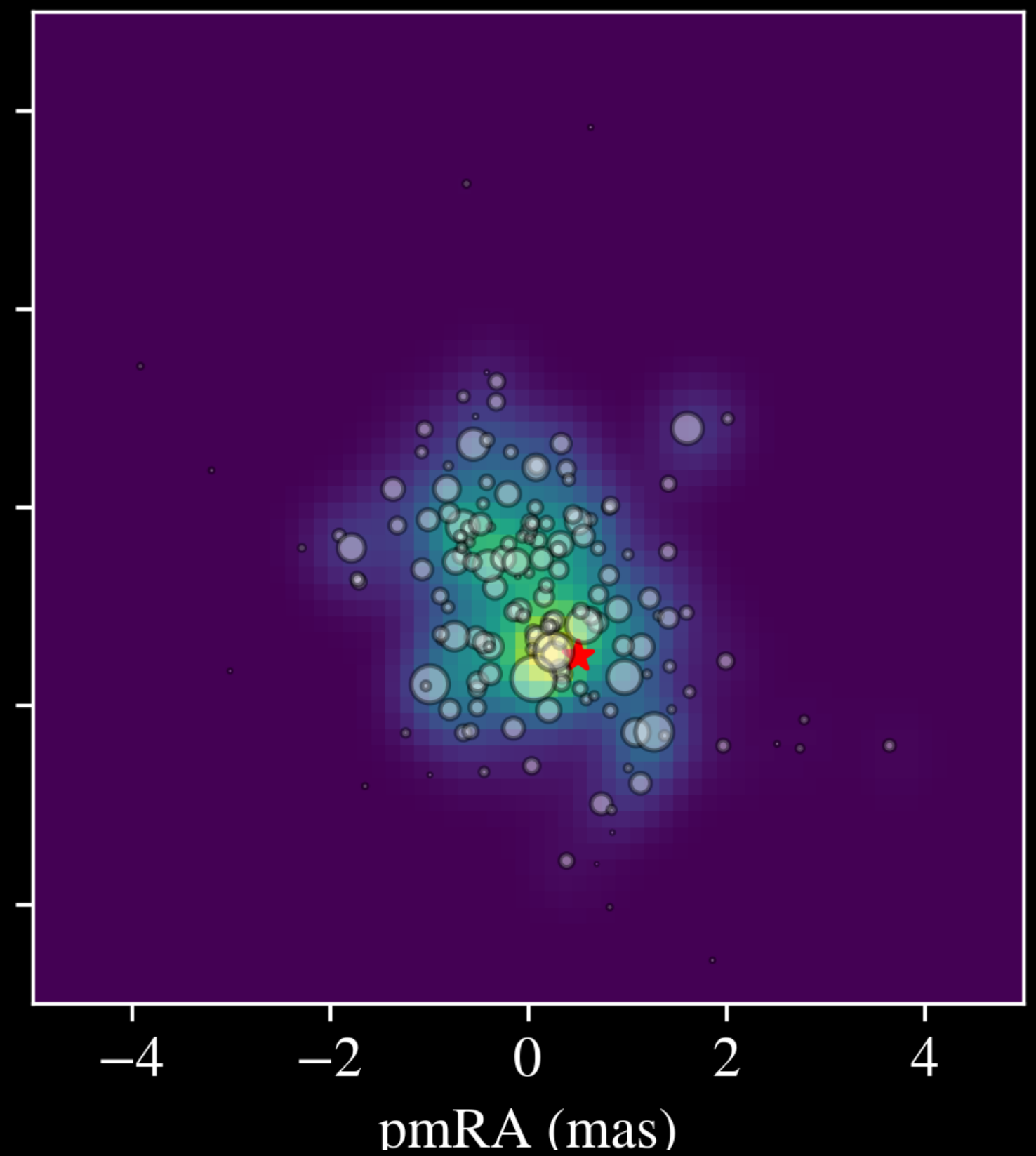
Coming back to the larger scale

Preliminary
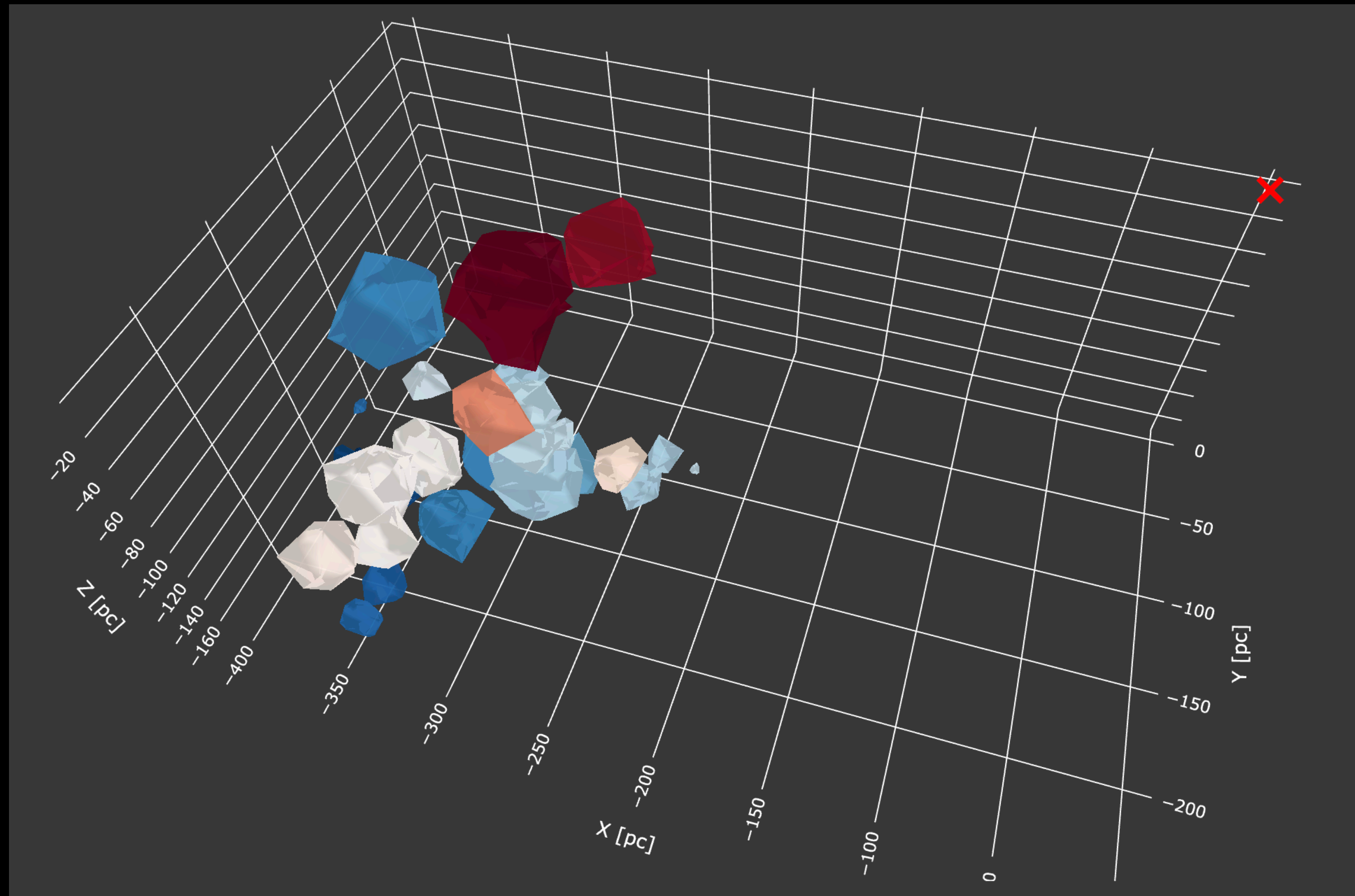
Age gradients? — It's complex

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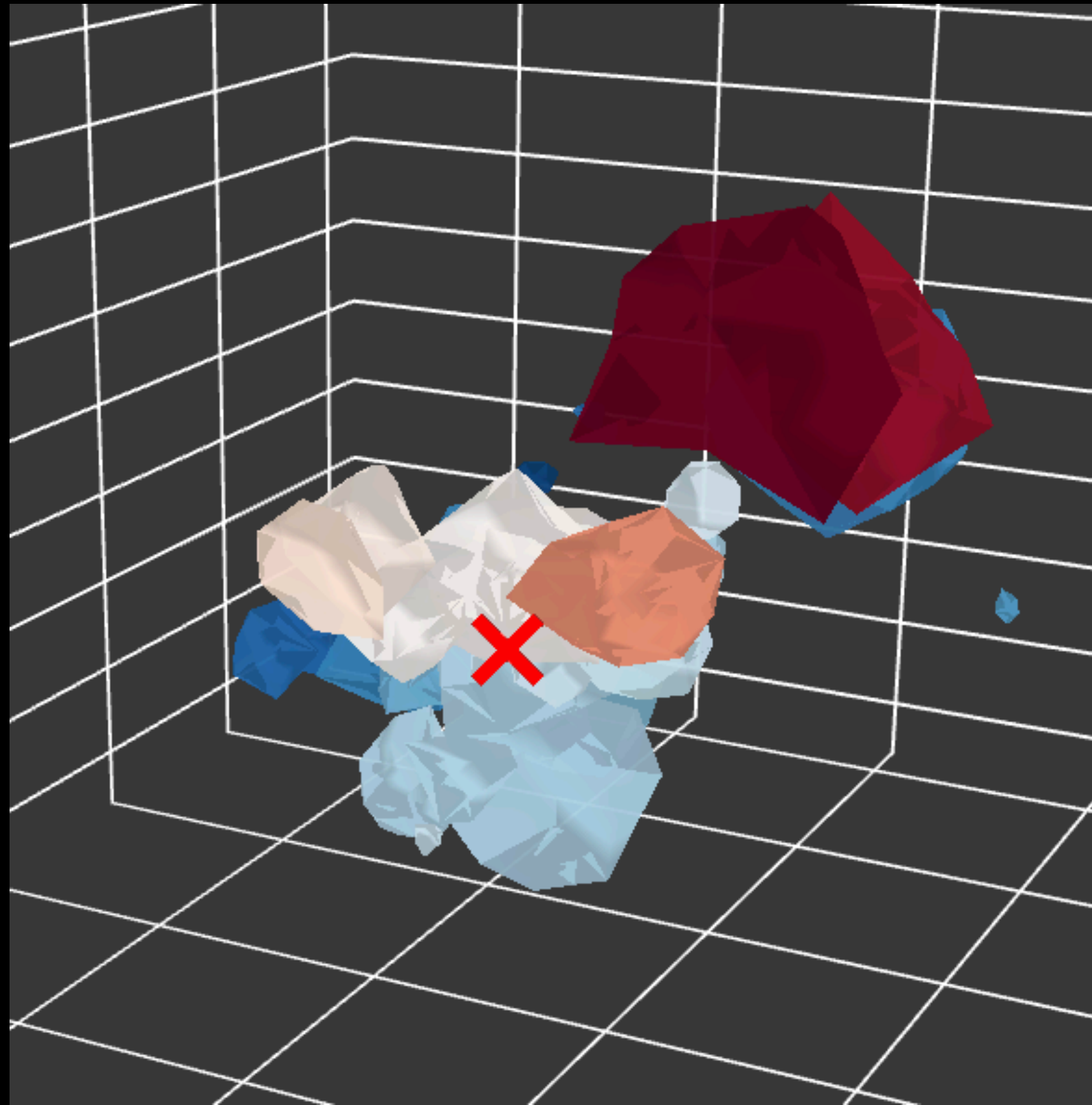
Line of sight view
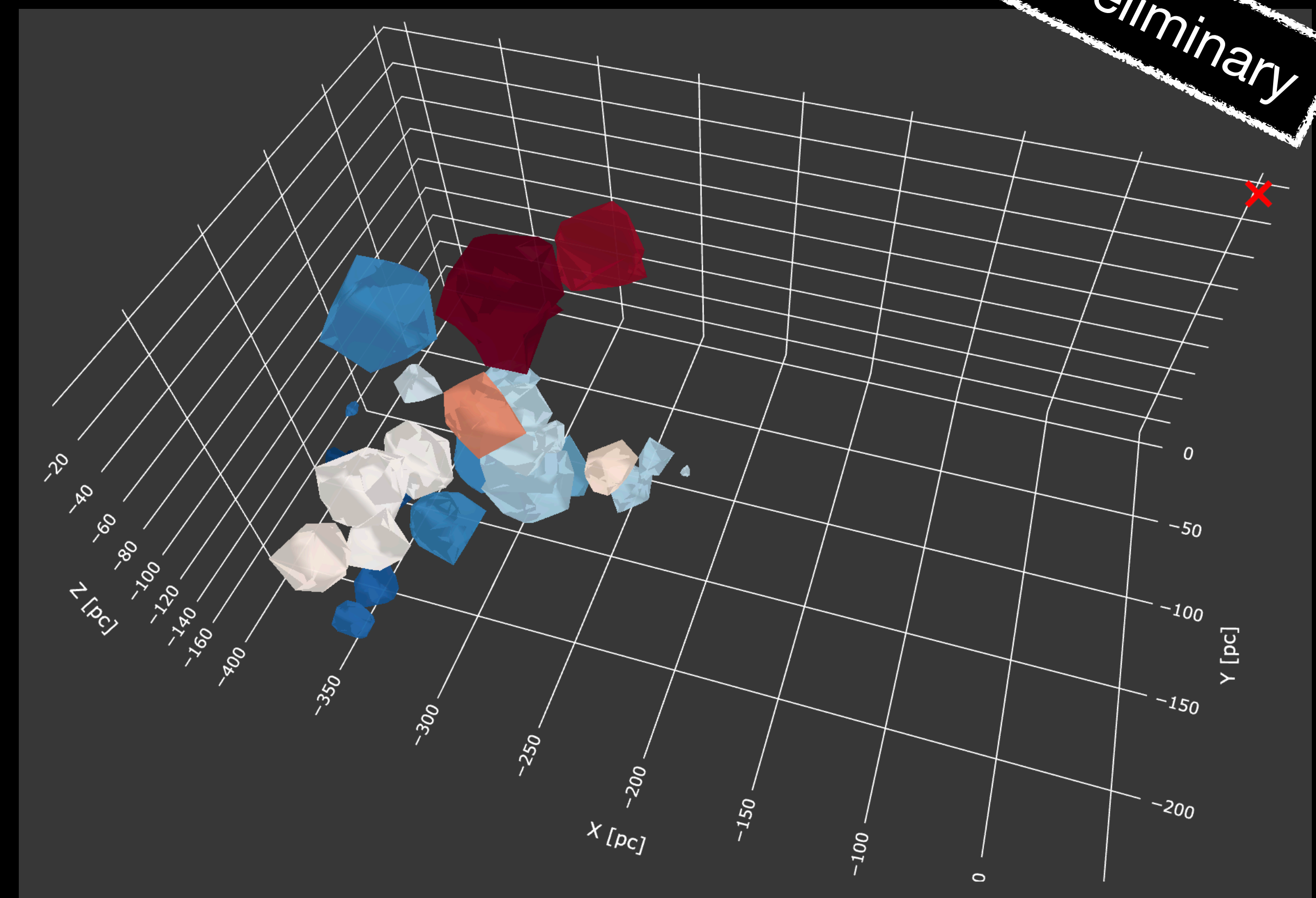
3D View

But we can see much more than in projection

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Summary

Successful application of the SigMA algorithm in Orion

- SigMA is finding **many more sources** for known clusters and **new clusters** over Chen et. al 2020

- Ages derived for preliminary solution show that **age structure is complex**

Pilot study on measuring proper motions in NGC 2024

- We measure precise **infrared proper motions** in good agreement with Gaia

- Tentative shift between optically revealed and embedded YSO motion

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