Milky Way very young low mass stars unveiled by machine learning and Gaia EDR3

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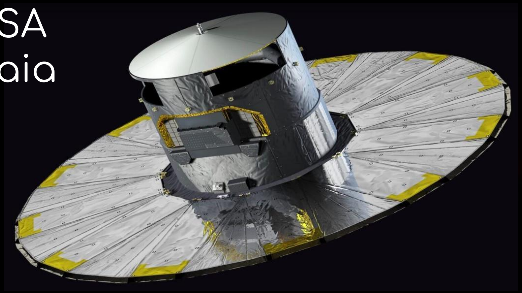
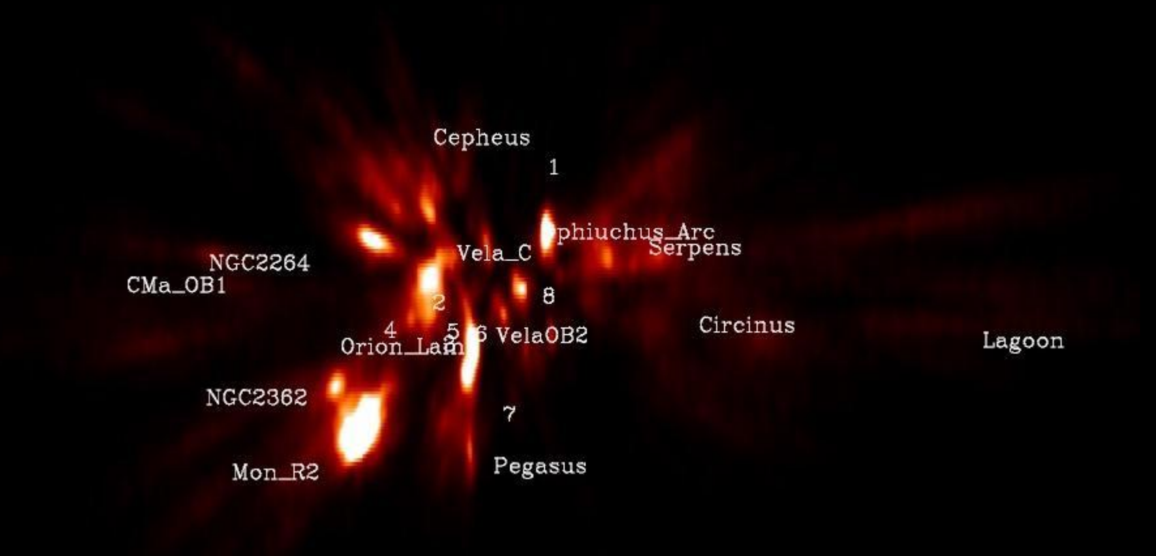
gaia





Loredana Prisinzano INAF Osservatorio Astronomico di Palermo

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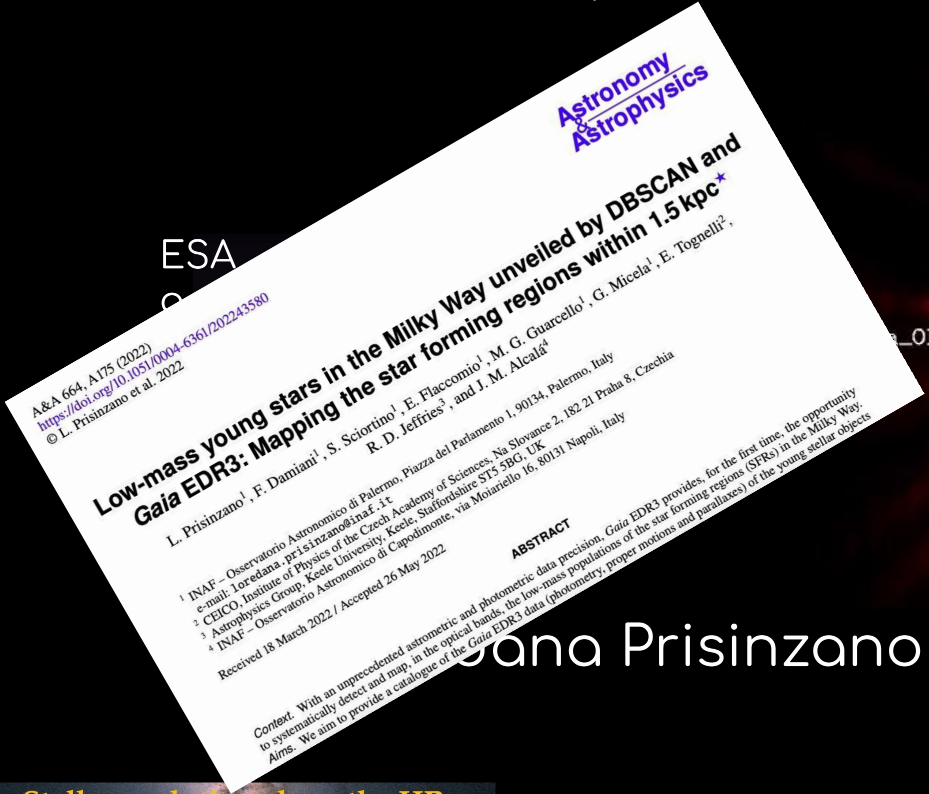
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Astronomy & Astrophysics

Low-mass young stars in the Milky Way unveiled by DBSCAN and Gaia EDR3: Mapping the star forming regions within 1.5 kpc*

L. Prisinzano[1], F. Damiani[1], S. Sciortino[1], E. Flaccomio[1], M. G. Guarcello[1], G. Micela[1], E. Tognelli[2], R. D. Jeffries[3], and J. M. Alcalá[4]

[1] INAF – Osservatorio Astronomico di Palermo, Piazza del Parlamento 1, 90134, Palermo, Italy
e-mail: loredana.prisinzano@inaf.it
[2] CEICO, Institute of Physics of the Czech Academy of Sciences, Na Slovance 2, 182 21 Praha 8, Czechia
[3] Astrophysics Group, Keele University, Keele, Staffordshire ST5 5BG, UK
[4] INAF – Osservatorio Astronomico di Capodimonte, via Moiariello 16, 80131 Napoli, Italy

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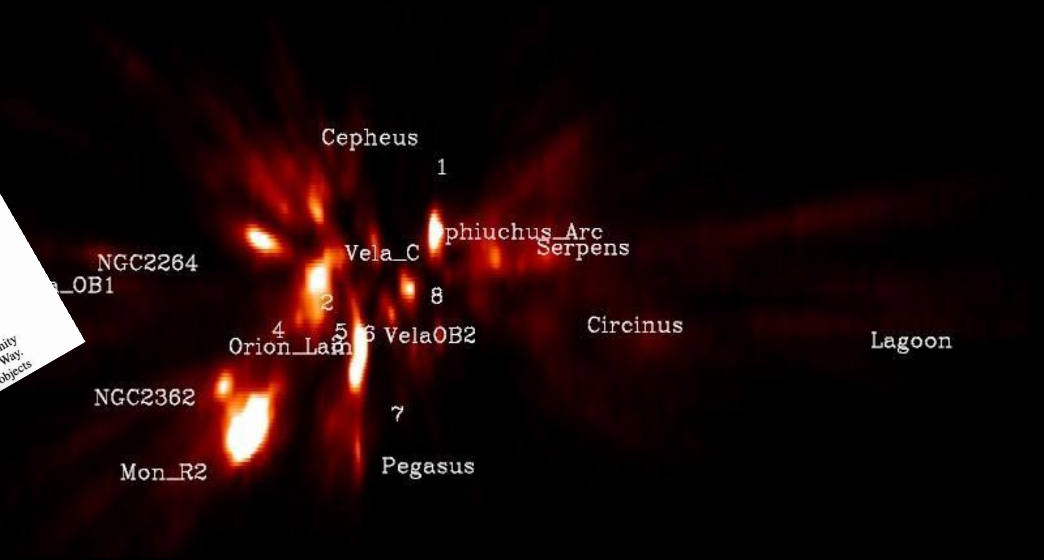
ABSTRACT

Context. With an unprecedented astrometric and photometric data precision, *Gaia* EDR3 provides, for the first time, the opportunity to systematically detect and map, in the optical bands, the low-mass populations of the star forming regions (SFRs) in the Milky Way.
Aims. We aim to provide a catalogue of the *Gaia* EDR3 data (photometry, proper motions and parallaxes) of the young stellar objects



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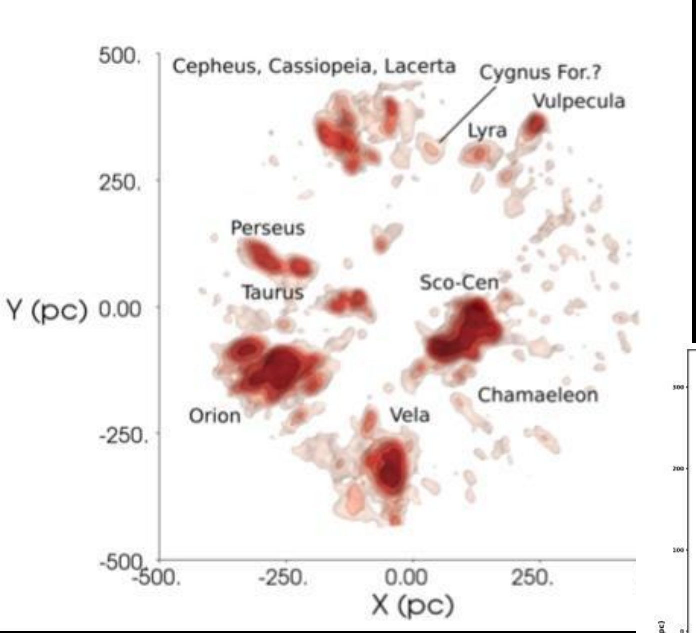
Why should we study young low mass stars?



Zari et al. 2018
Gaia DR2, 500 pc
t< 20 Myrs

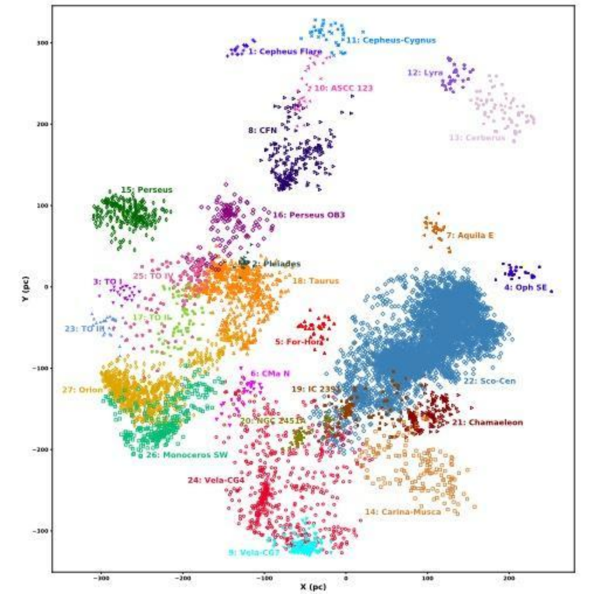
Stars form in Star Forming Regions (SFR) in the Galactic Disk

- Spiral Arms characterization
- cluster IMF, dynamics, Star Formation History
- planet and star formation

Why young low mass stars?

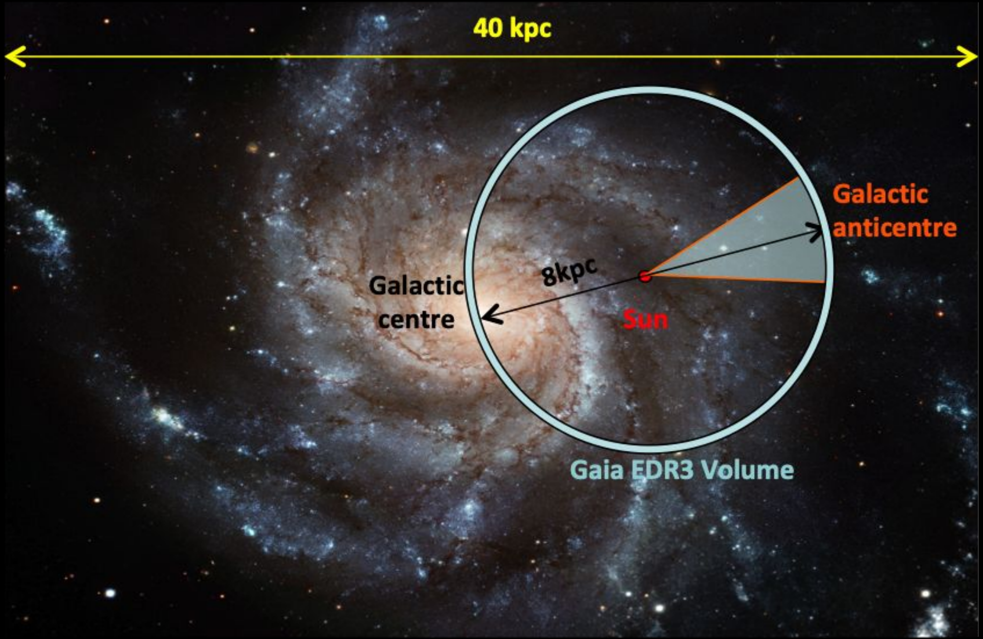
they represent the bulk of the SFR

(>80% only M-stars, Lada+08)



Kerr et al. 2021
Gaia DR2, 333 pc
t<50 Myrs

Gaia EDR3 data: a revolutionary understanding



Our census is extended up to 2kpc

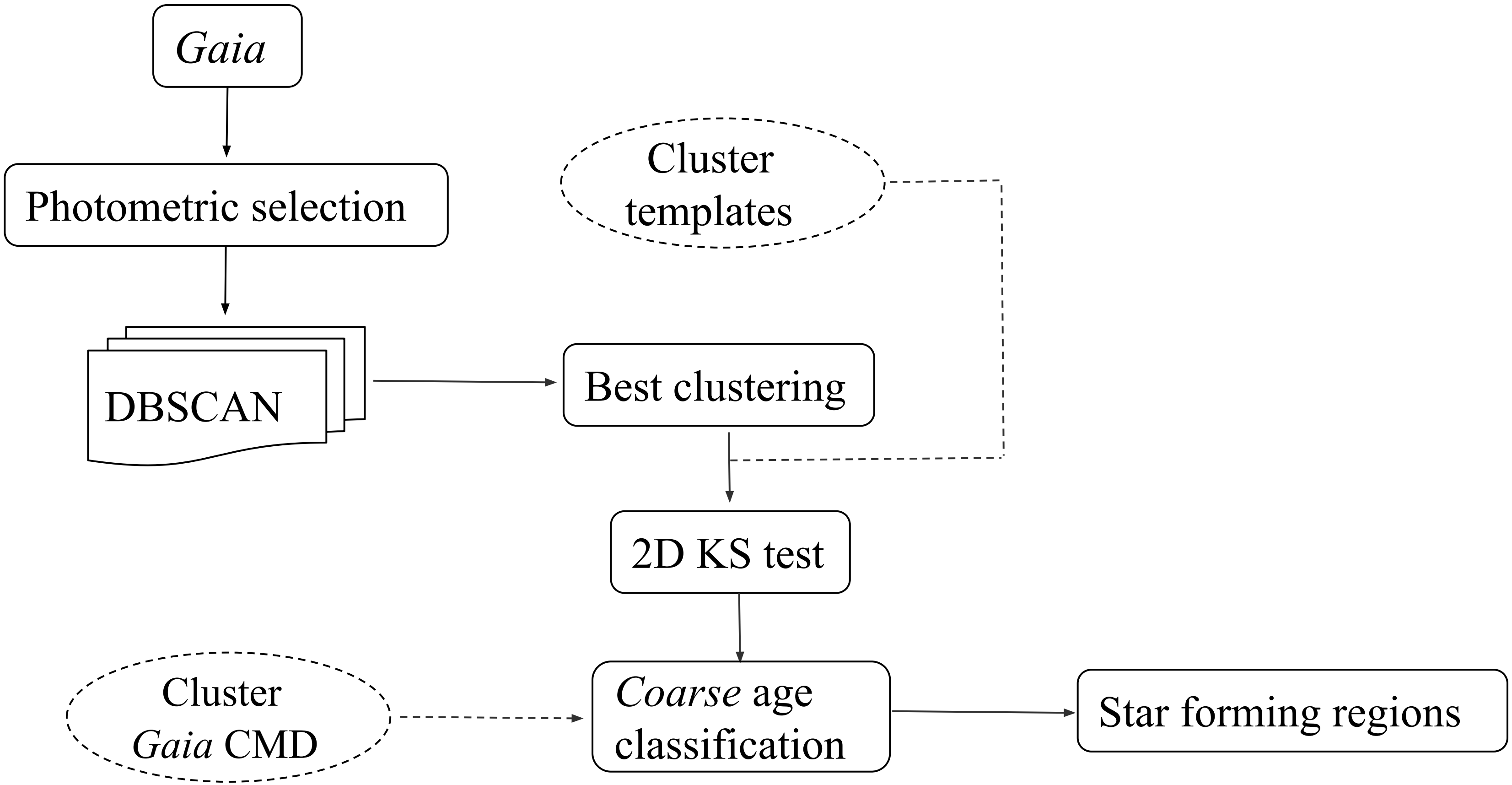
Low mass young star detection is very challenging:

- ➢ faint and reddened
- ➢ hard selection in optical bands
- ➢ biased membership criteria (IR, X-rays, spectroscopy)

Excellent Gaia photometry & astrometry allow us a systematic and homogeneous detection of very young stars.

No biases towards WTTS or CTTS stars (at least when they emit in the optics)

Method: finding star forming regions



Method: finding star forming regions

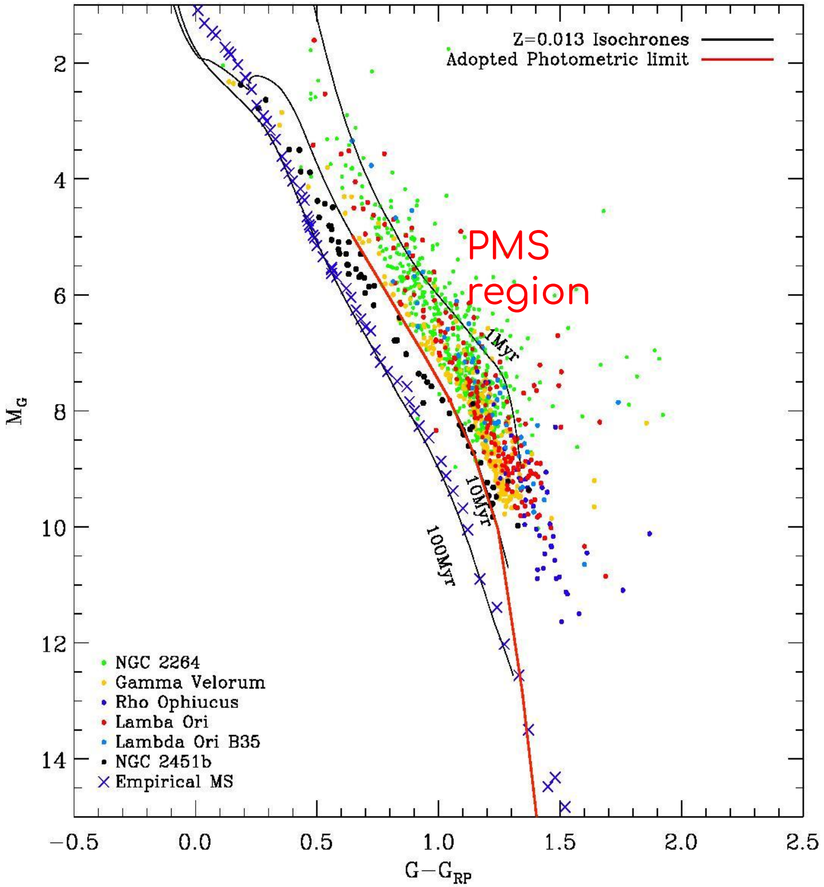
Gaia

↓

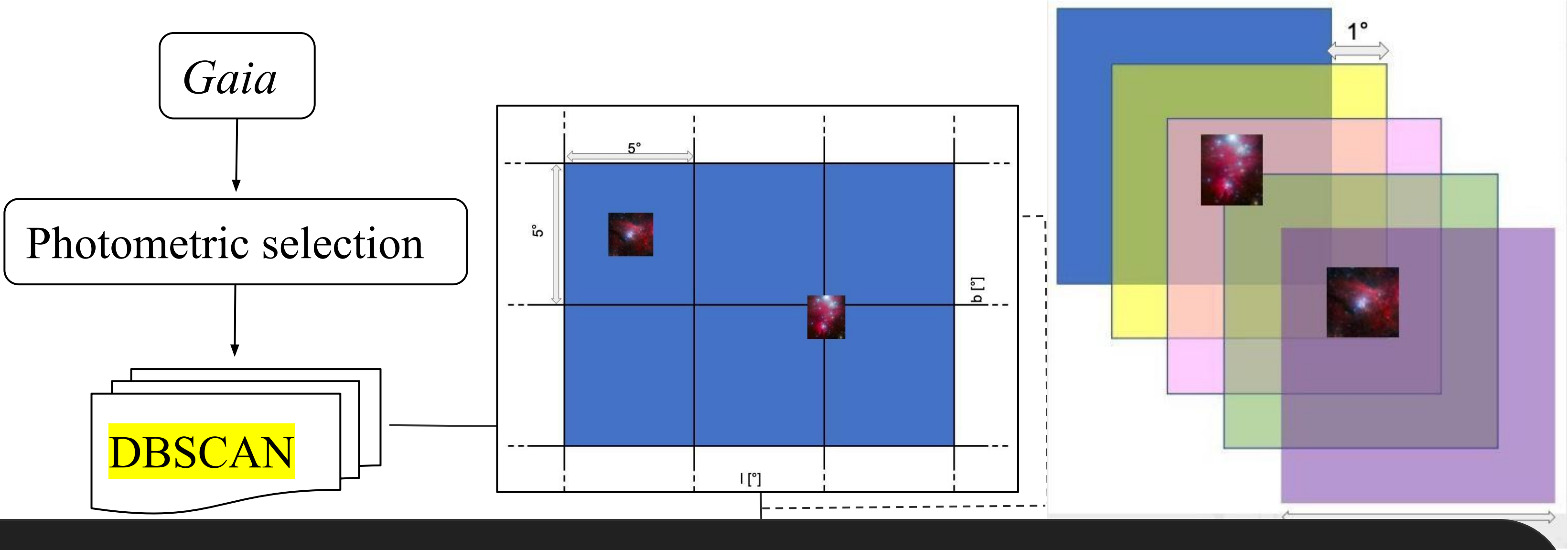
Photometric selection

all-sky (|b<30|) Gaia data in the M_G vs. $G-G_{RP}$ region compatible with PMS stars (ages t<10 Myr)

no reddening correction applied



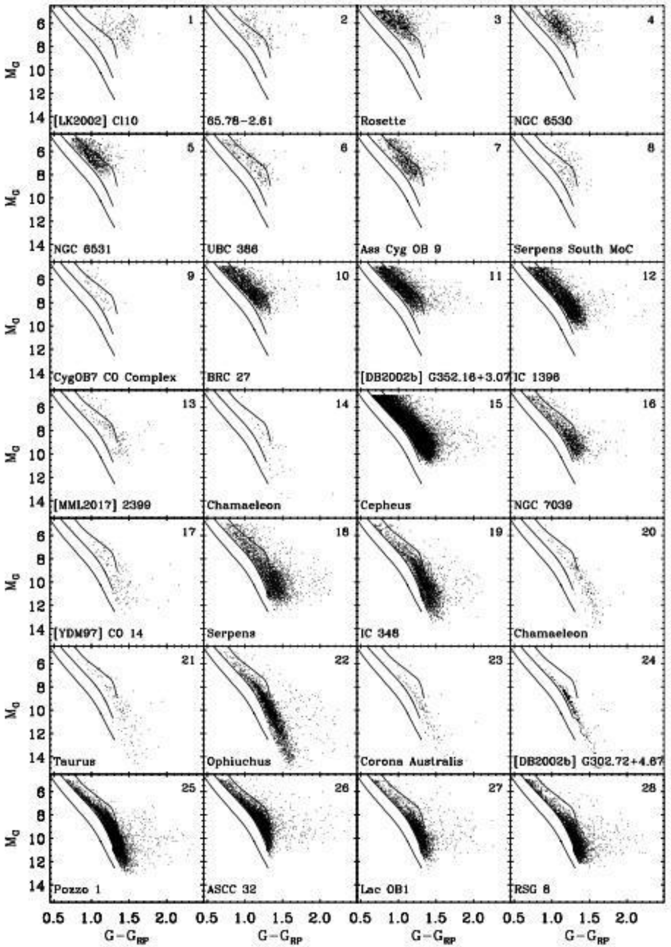
Method: finding star forming regions



DBSCAN = *Density-Based Spatial Clustering of Applications with Noise*

- Unsupervised Machine Learning clustering algorithm: **over-densities in 5D (*l*, *b*, π, μ_α, μ_δ)**
- ALL-SKY Multiple GRID of 5° x 5° boxes shifted by 1°
- parameters: ε={0.1,0.2, 0.3, …,9.0} distance threshold
  minPts={5, 10, 15, …,50} min. # objects

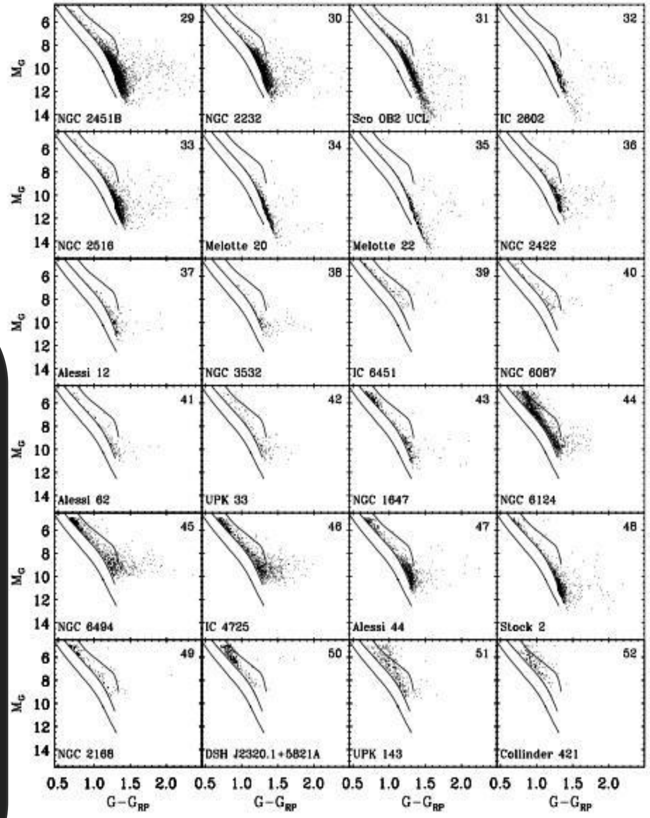
Method: finding star forming regions



Cluster templates

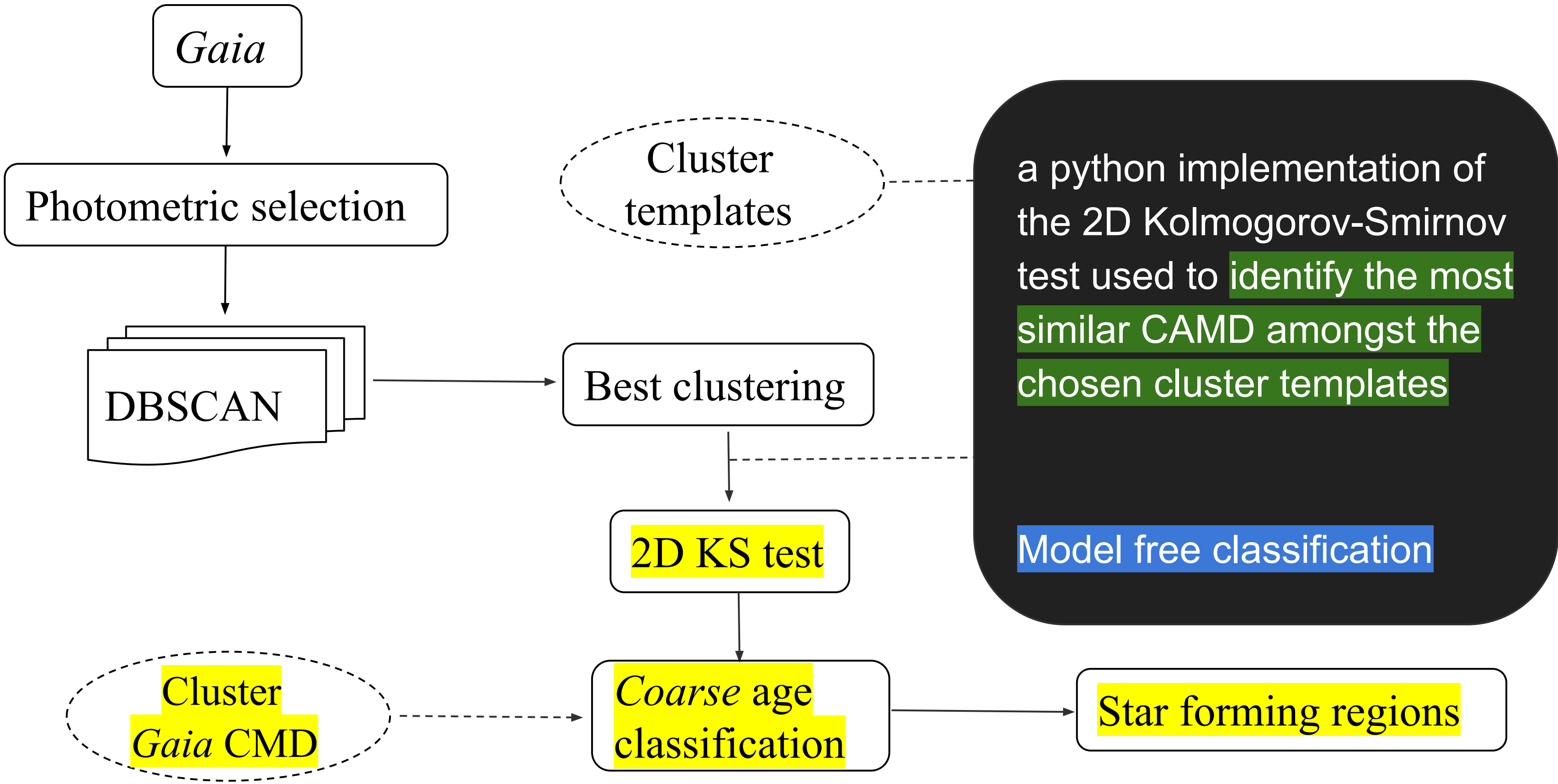
observed CAMD of 52 known clusters used as templates for cluster validation and age classification

28 SFRs t<10 Myr
8 OCs 10Myr<t<100Myr
16 OCs t>100 Myr



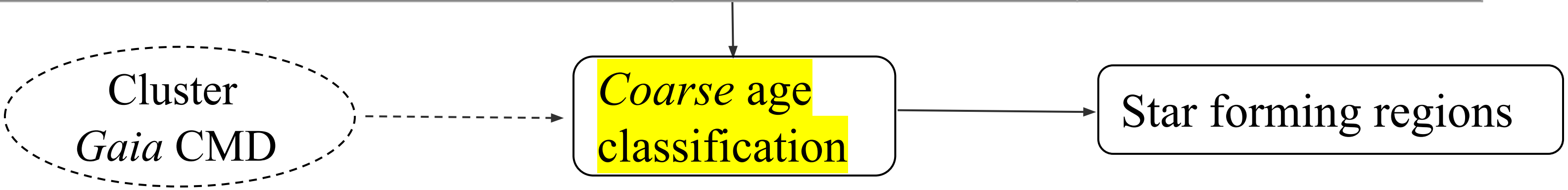
old clusters partially included for the photometric selection (reddening effects, G-RP colors)

Method: finding star forming regions

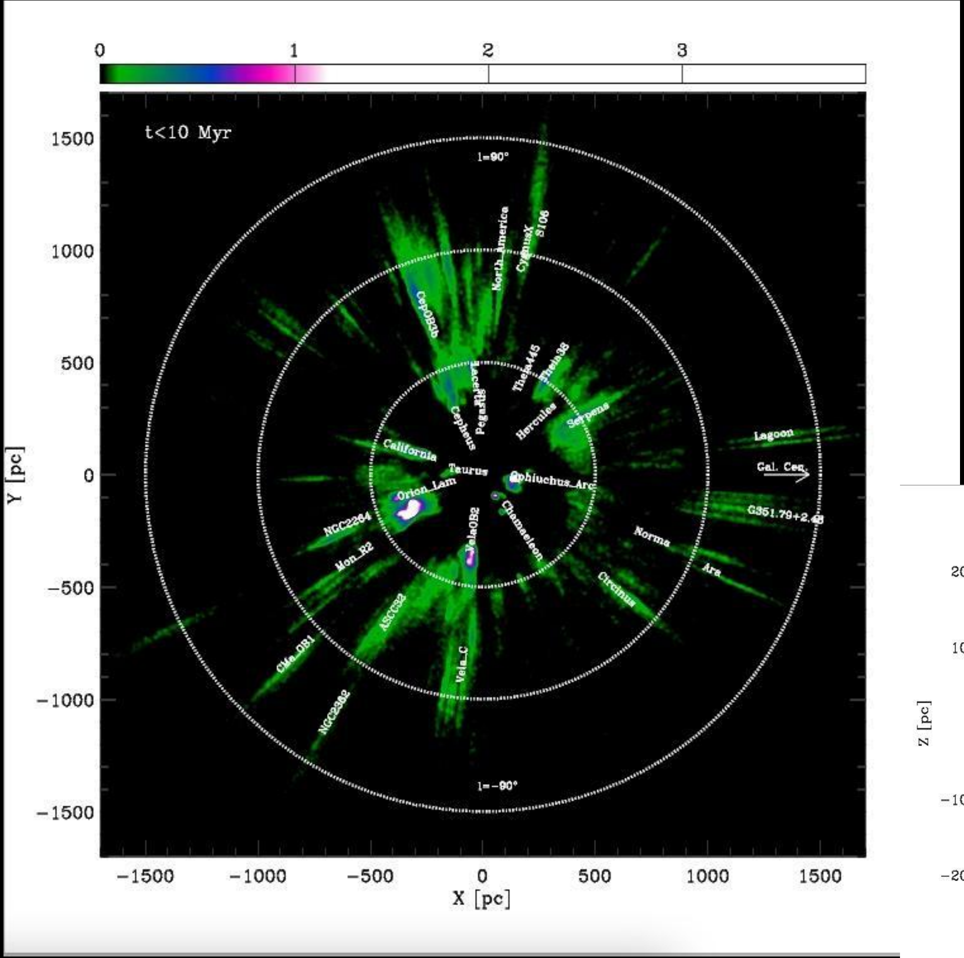


Results: finding star forming regions

Classification	#Stars	#Clusters	Flag
t< 10 Myr	**124 440**	**354**	1 - 28
10 Myr < t < 100 Myr	**65 863**	**322**	29 - 36
t > 100 Myr	43 936	524	37 - 52
Phot. unphysical aggregates	68 491	250	< 0
Unclassified	147 119	5 887	<0



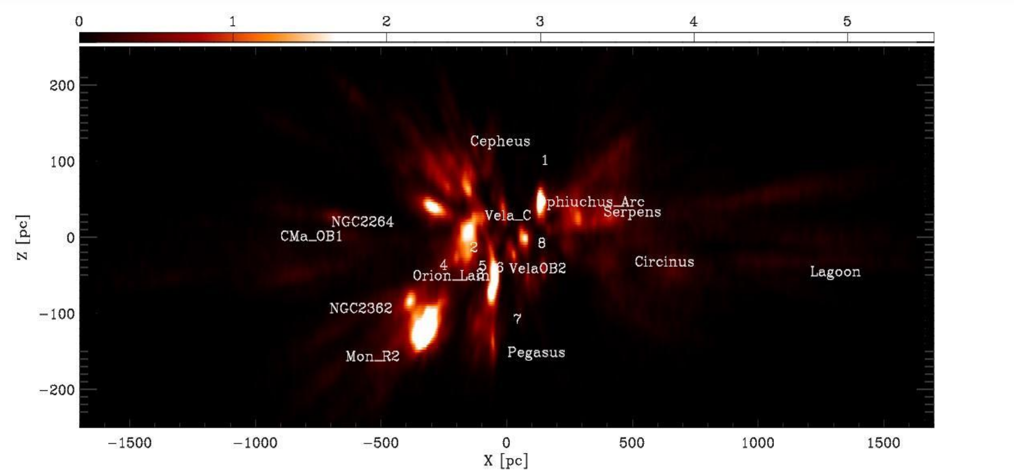
Results: Density map of the SFRs



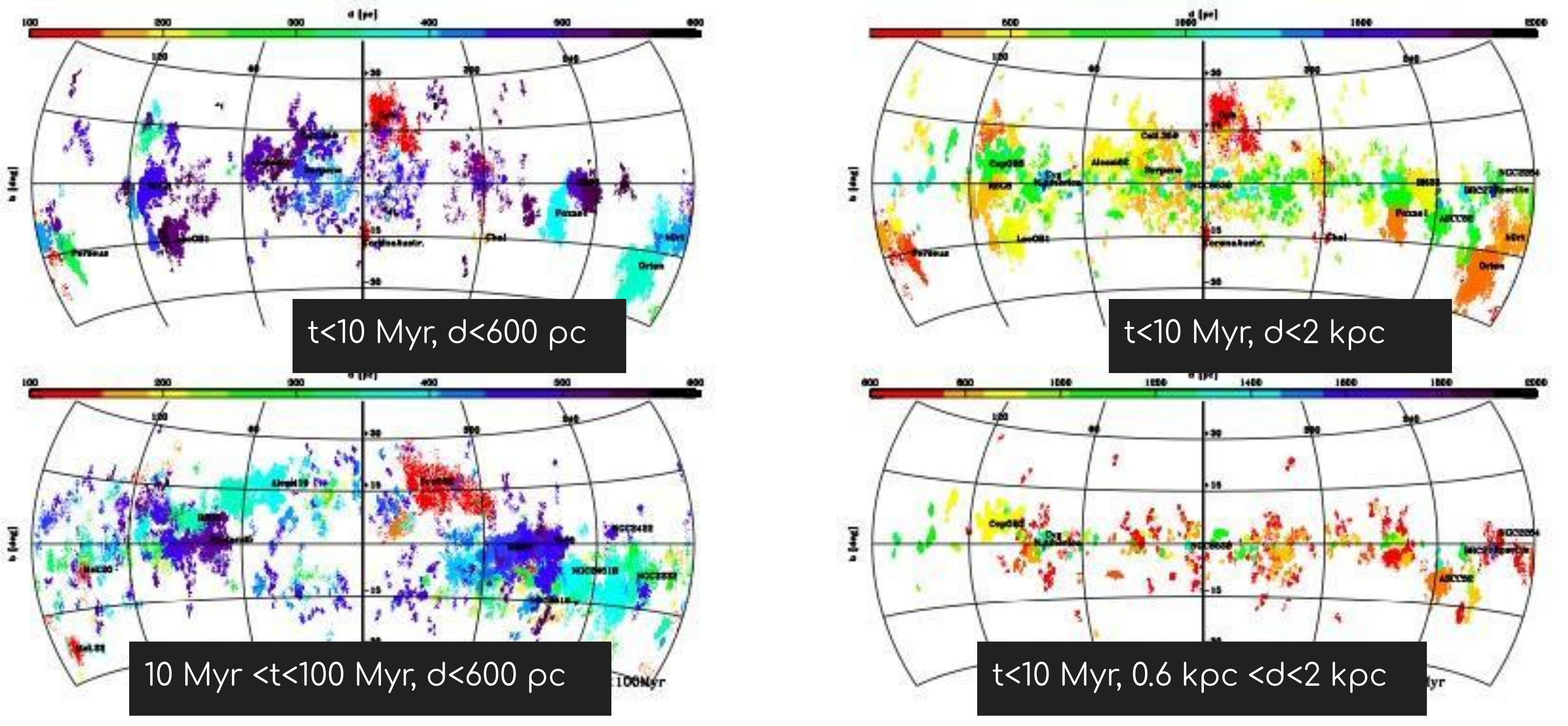
face on and edge on projections on the Gal. Plane

first map of stars younger than 10 Myrs
up to ~1.5-2 Kpc from the Sun with Gaia EDR3

peripheral regions of known SFRs included!
→ cluster dynamics, IMF and SF History
overview of the solar neighborhood Galactic structure

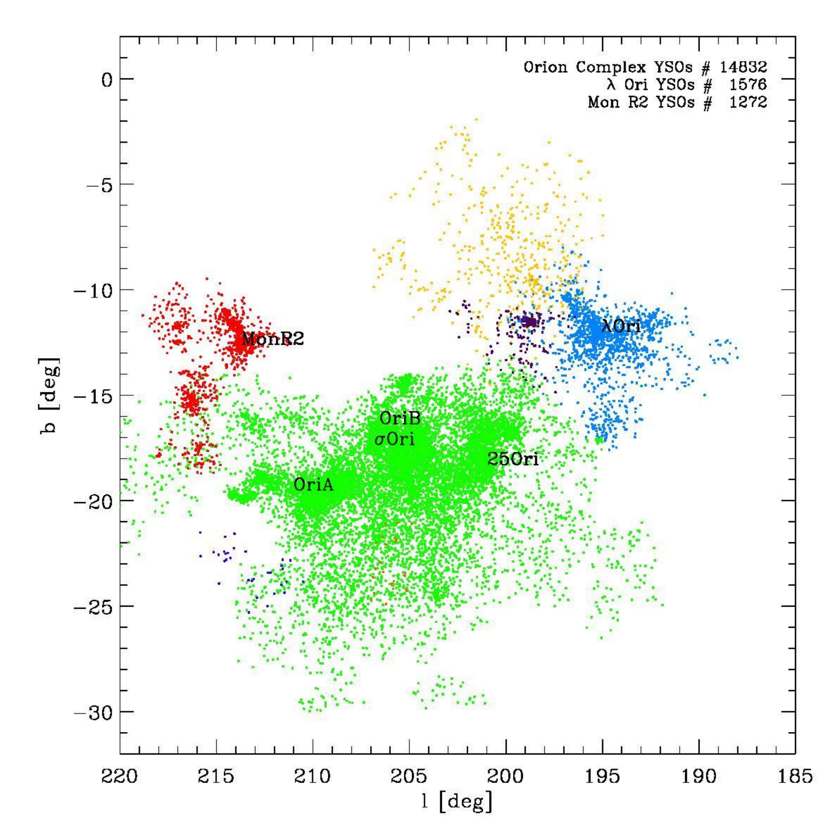


Aitoff projection in Galactic coordinates

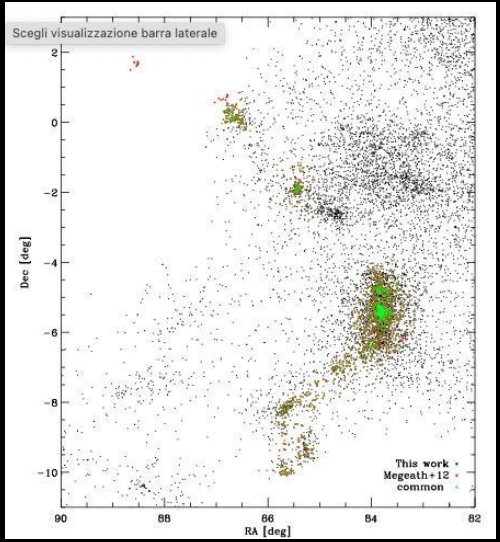


The Orion complex case

This work



Megeath et al. 2012



Spitzer Space Telescope Survey of Orion A and B Mol. clouds: 3479 YSOs

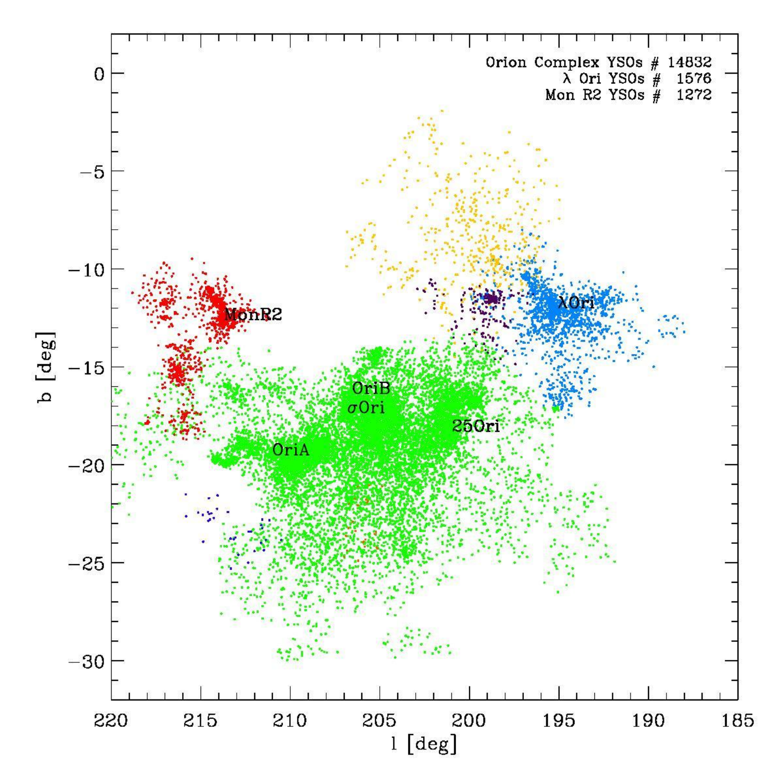
2612 in Gaia DR3 (75%)

among those compliant with our photometric selection, 94% are in our catalog

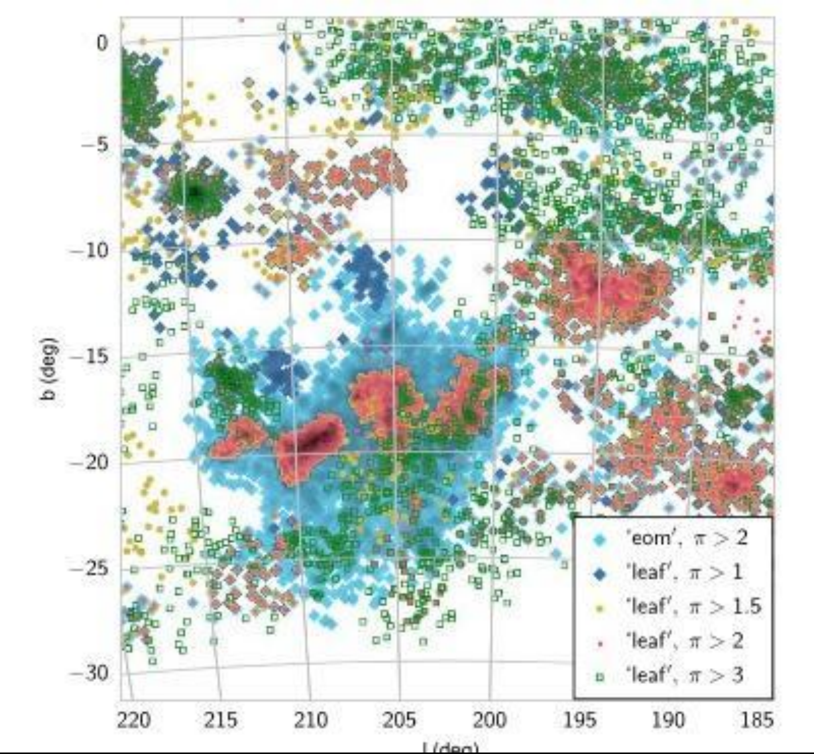
High efficiency of Gaia data

The Orion complex case

This work

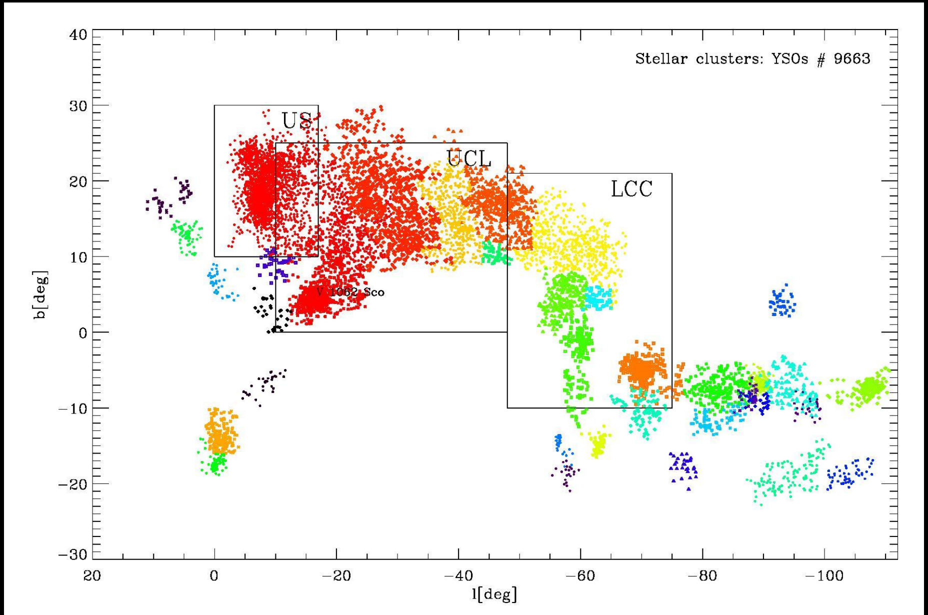


Gaia DR2 and HDBSCAN (Kounkel et al. 2019)

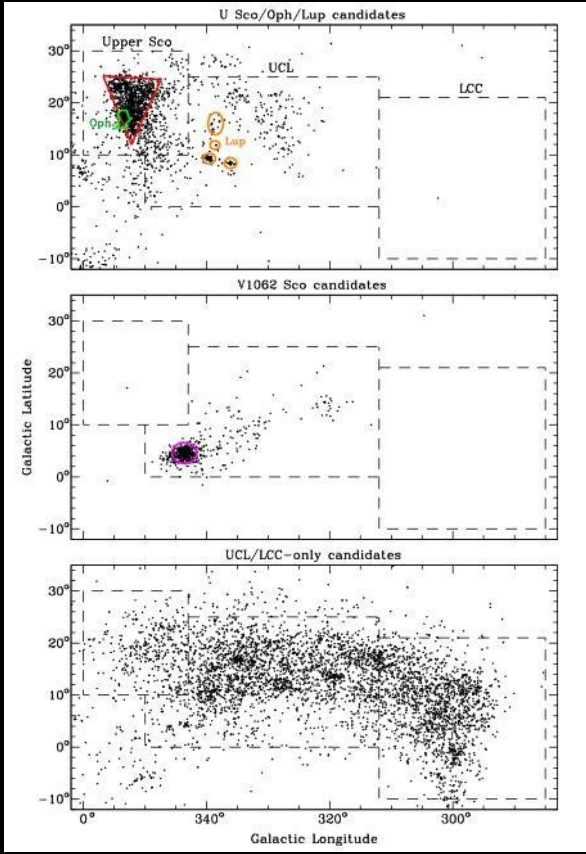


Our results suggest DBSCAN more suitable than HDBSCAN to retrieve SFRs

Example 2: the Sco-OB2 complex - 20-30 Myr old



This work



~86% of YSOs in common with Luhman 2022

Luhman 2022, Gaia EDR3

Conclusions

We performed a blind search of SFRs using *Gaia* EDR3 data

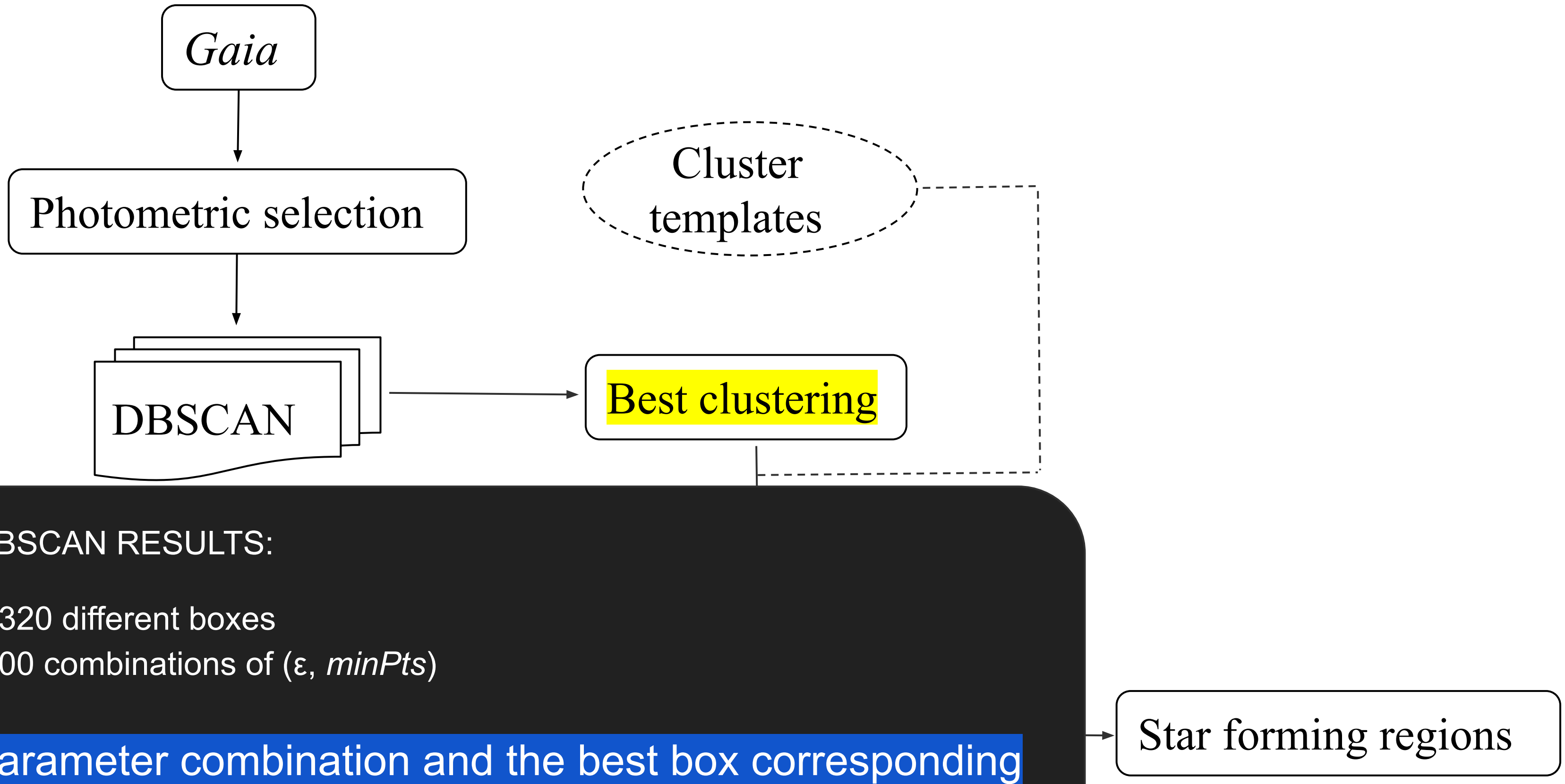
- 124 440 YSOs within 354 SFRs (distance ≤ 2Kpc)
- 65 863 YSOs in clusters with 10 Myr<t<100 Myr (distance ≤ 500 pc)

crucial for future studies on Star Formation History, cluster dynamics, IMF detailed studies of circumstellar disk evolution, targets for direct imaging of young giant planets

- Census completeness: >85% in very rich and concentrated clusters; ~50% in very low density clusters (e.g. Taurus-Auriga)
- Binarity: at distances ~100, 200 pc, a loss of ~35% is estimated due to the RUWE selection

- The overall distribution of YSOs in SFRs with *d* <600 pc traces a complex 3D pattern
- Evidence of a projected inclined structure, traced by the Orion, Vela OB2 and Rho Ophiuchi, Serpens, Lacerta OB1 and Perseus
    - Such structure is broadly consistent with the Alves et al. (2020) findings
    - We confirm that the space distribution of < 10 Myr low-mass stars is more structured than the Gould Belt

Method: finding star forming regions



DBSCAN RESULTS:

- 4320 different boxes
- 900 combinations of (ε, *minPts*)

best parameter combination and the best box corresponding to the cluster with the maximum number of members