A census of OB stars within 1 kpc and the star formation and core collapse supernova rates of the Milky Way

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Why a new census of OB stars?

1) Mapping out age and distribution of young stellar groups

2) Identifying gravitational wave progenitors and targets for spectroscopic follow-up (e.g. WEAVE and 4MOST)

3) Bridging between catalogues of OBA stars and O & early B-type stars

4) High completeness enabled by combining *Gaia* and other photometric surveys, folding in evolutionary models to derive physical parameters

→ For this study: stars with T_{eff} > 10,000 K (main sequence O- and B-type stars + blue supergiants, hereafter OB stars)

How to build it?

1) *Gaia* DR3 catalogue

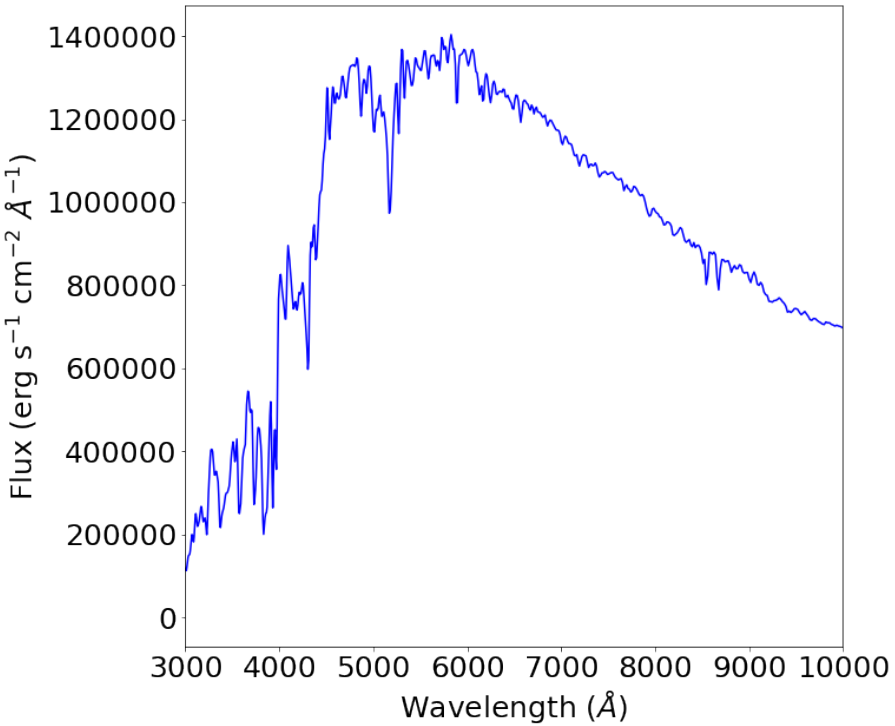
- ***Gaia* DR3 + 2MASS sources within** $\sqrt{(X^2+Y^2)}<1\,kpc$
- **Data quality cuts and filtering of contaminants**
- **195,266 candidate OB stars**

2) The Bright Stars catalogue (BSC)

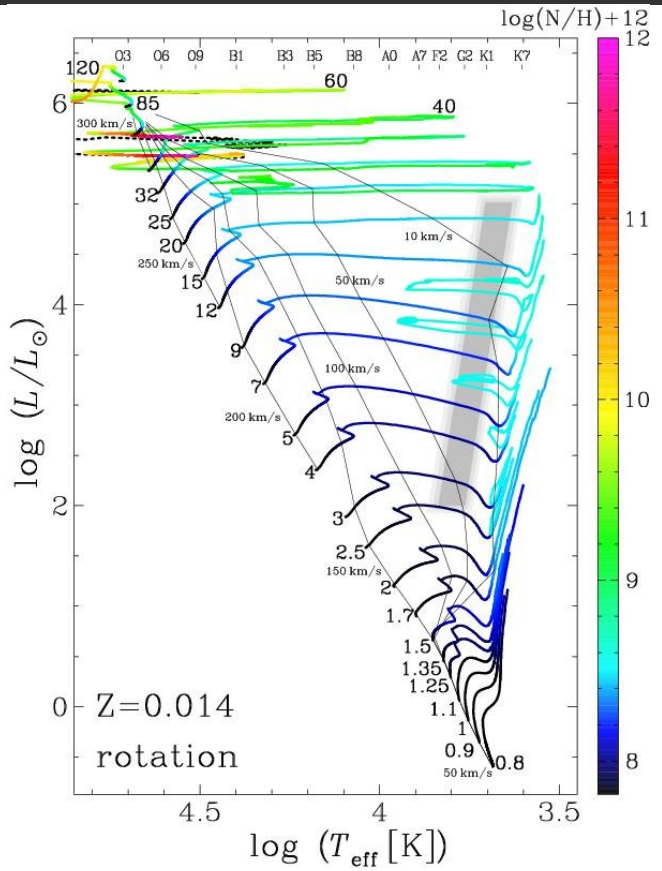
- ***Gaia* DR3 saturates for bright stars → Low density of OB stars around the Sun → Inclusion of the BSC containing the visually brightest stars**
- **385 missing OB stars from the BSC in the *Gaia* DR3 catalogue**
- **Combining *Gaia* and Hipparcos data**

→ 195,651 candidate OB stars in total

Model SEDs (1)

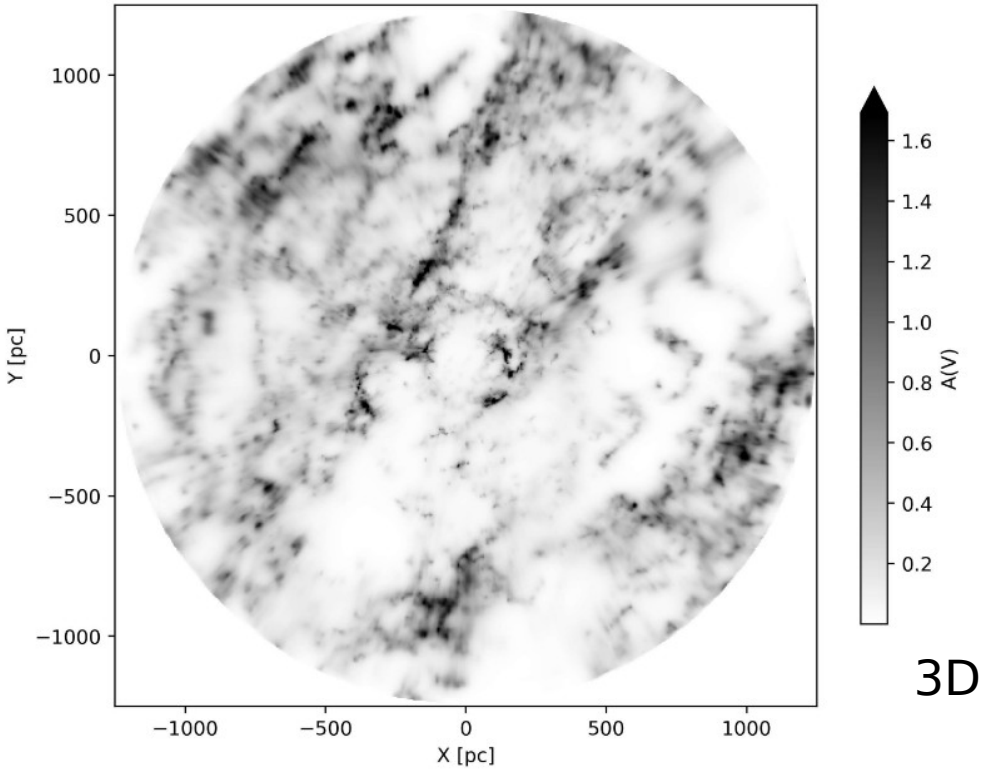


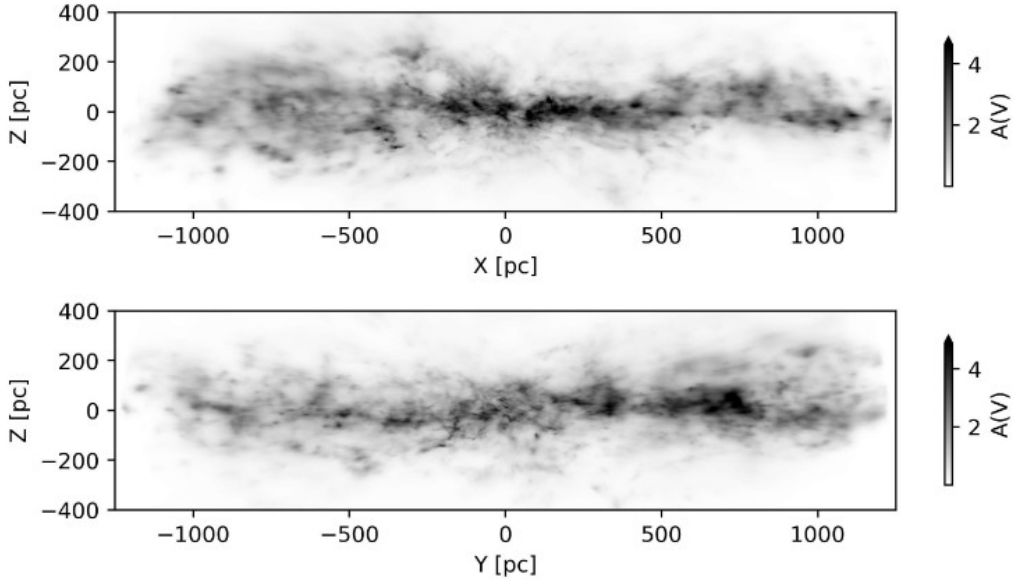
Convoluted stellar atmosphere models (here Kurucz at T_{eff} = 5000 K)



Rotating stellar evolutionary models from Ekström et al.(2012)
->
Interpolated

Model SEDs (2)



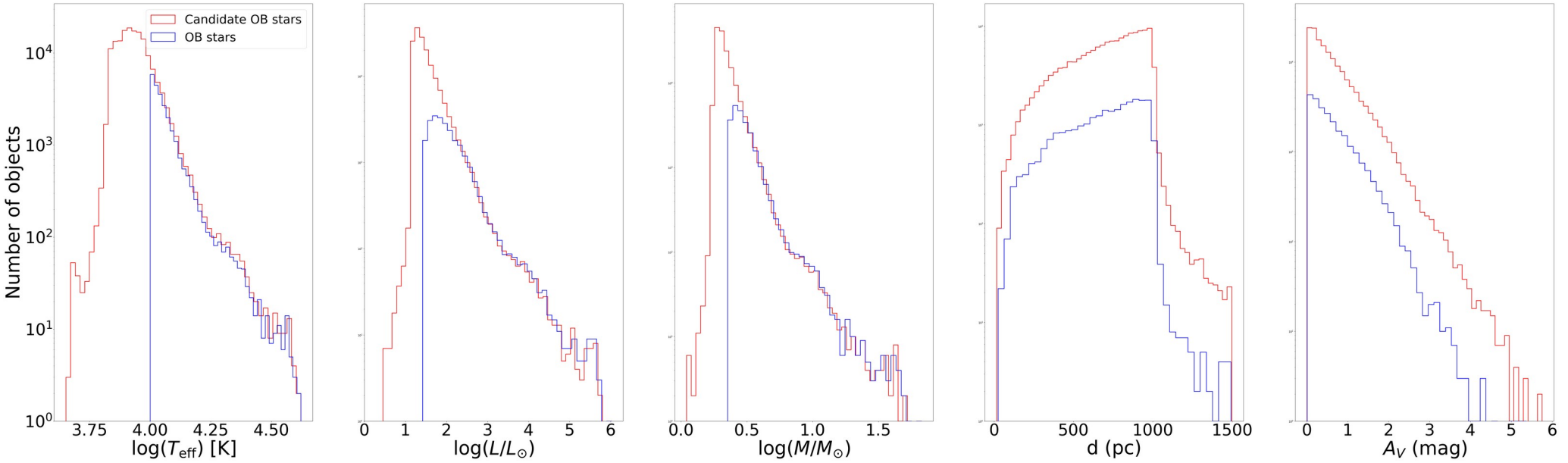


3D extinction map from Edenhofer et al. (2024)

SED fitter

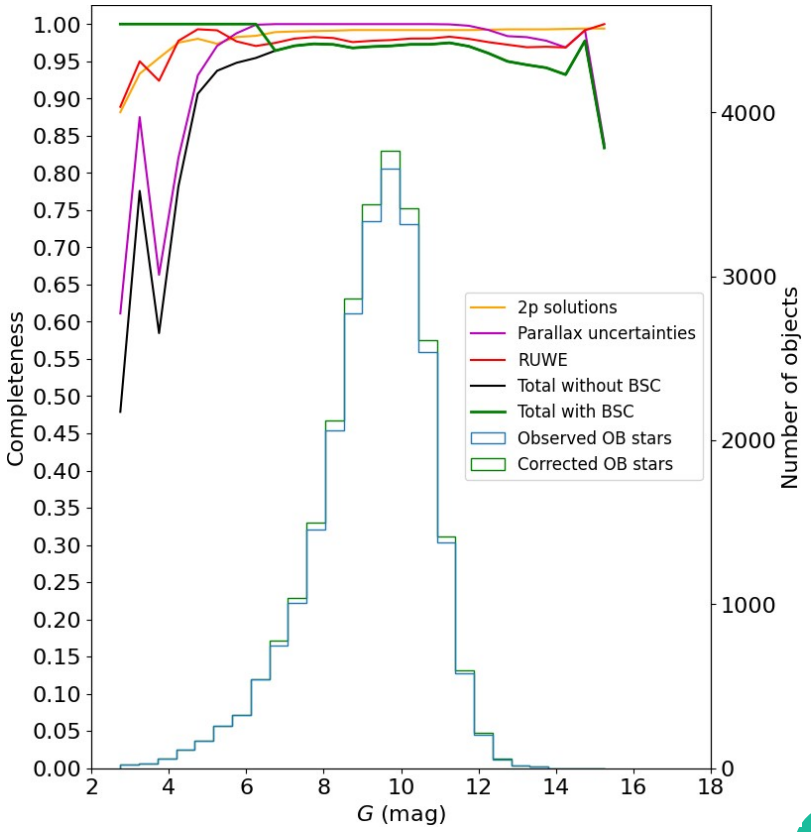
- **Observed SED: *Gaia* DR3 parallax + optical and NIR photometry (*Gaia,* 2MASS, IGAPS, VPHAS+)**
- **Fitting process using a Bayesian modelling and a maximum-likelihood test (Python *emcee* package)**
- **Derives stellar initial mass, age and distance, with effective temperature and luminosity as indirect products**

General results



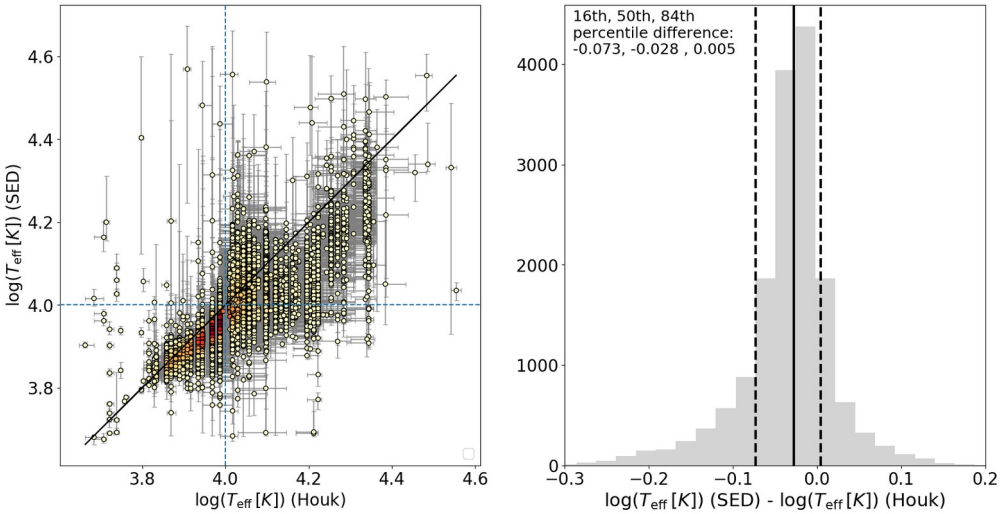
Completeness

- **Saturation towards the bright end compensated by the inclusion of the BSC**
- **Remaining source of incompleteness: bad *Gaia* astometry (e.g. WR stars)**
- **Overall completeness of 97.5%**

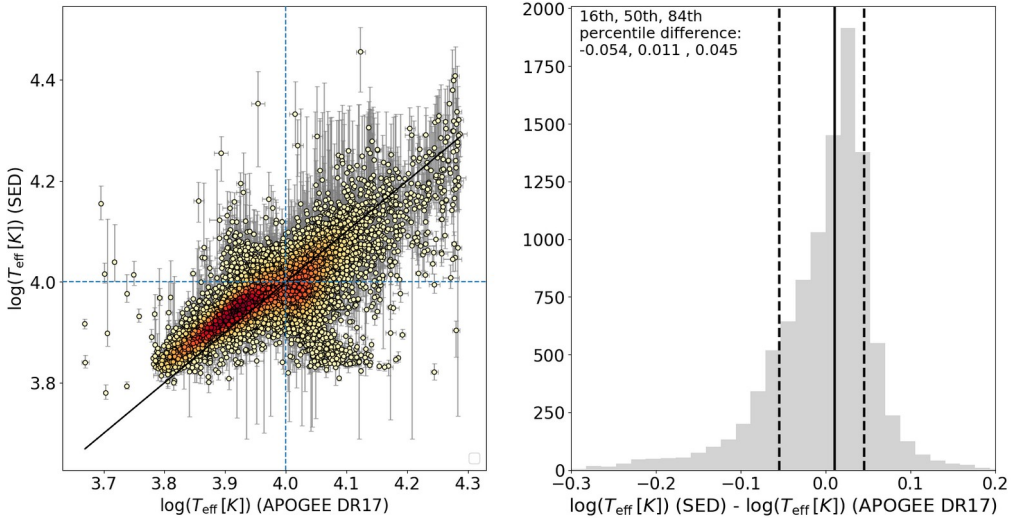


Comparison with spectroscopic temperatures (1)

Houk catalogues (1975-1999)

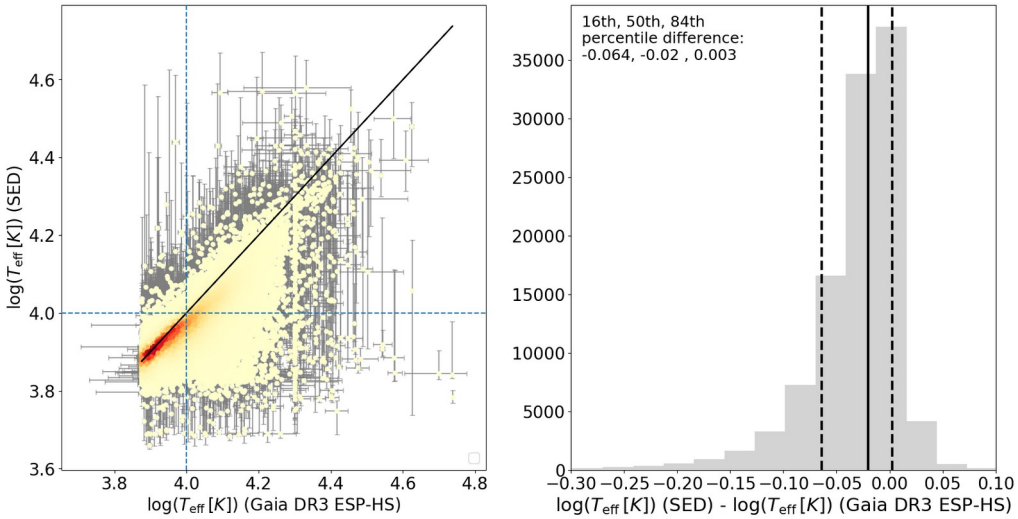


APOGEE DR17

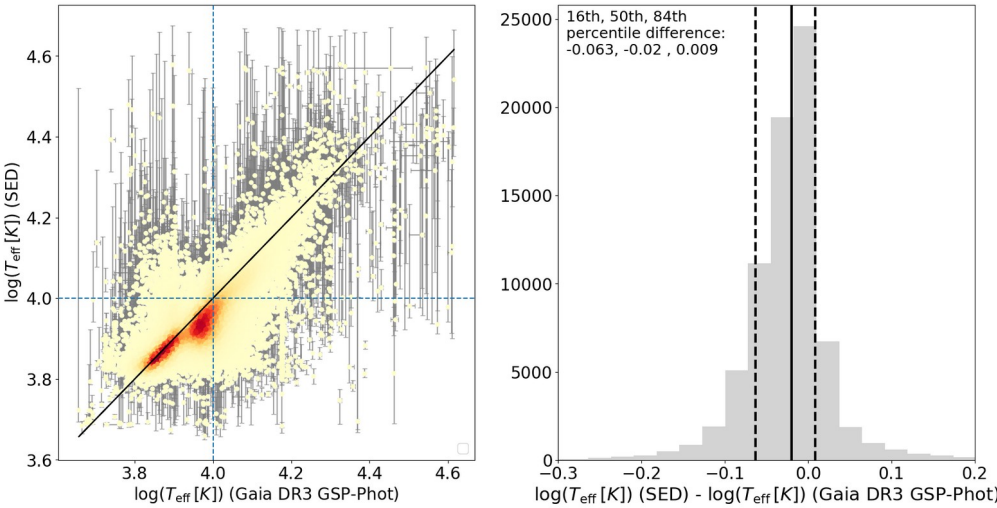


Comparison with spectroscopic temperatures (2)

Gaia DR3 ESP-HS

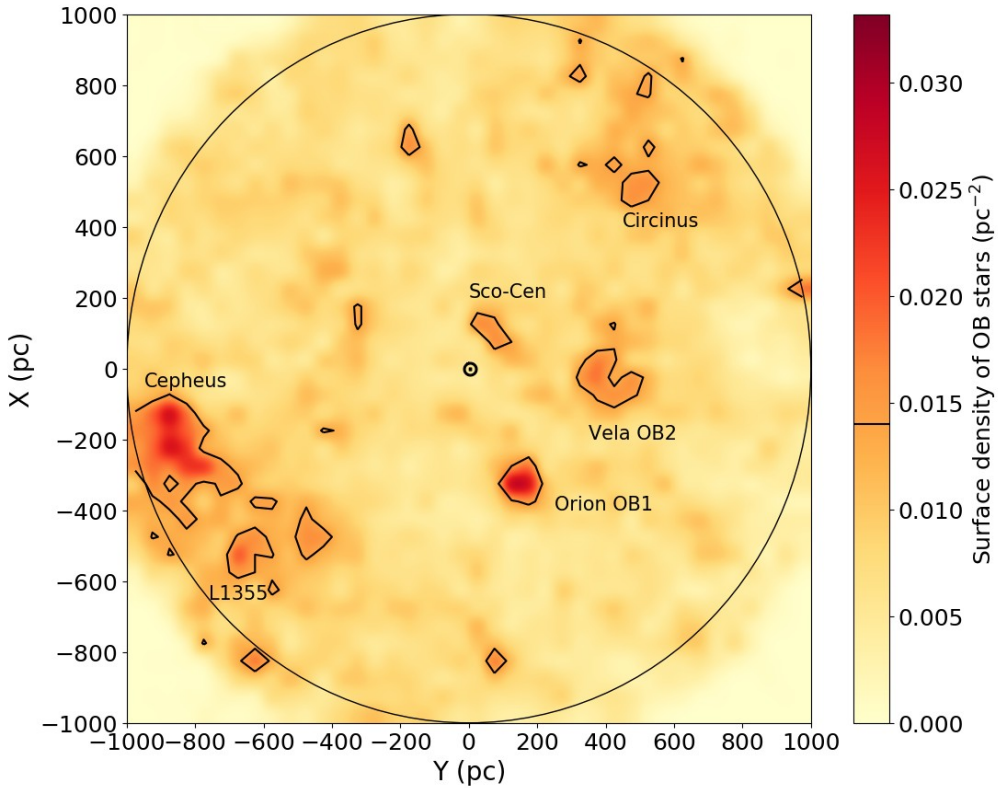


Gaia DR3 GSP-Phot

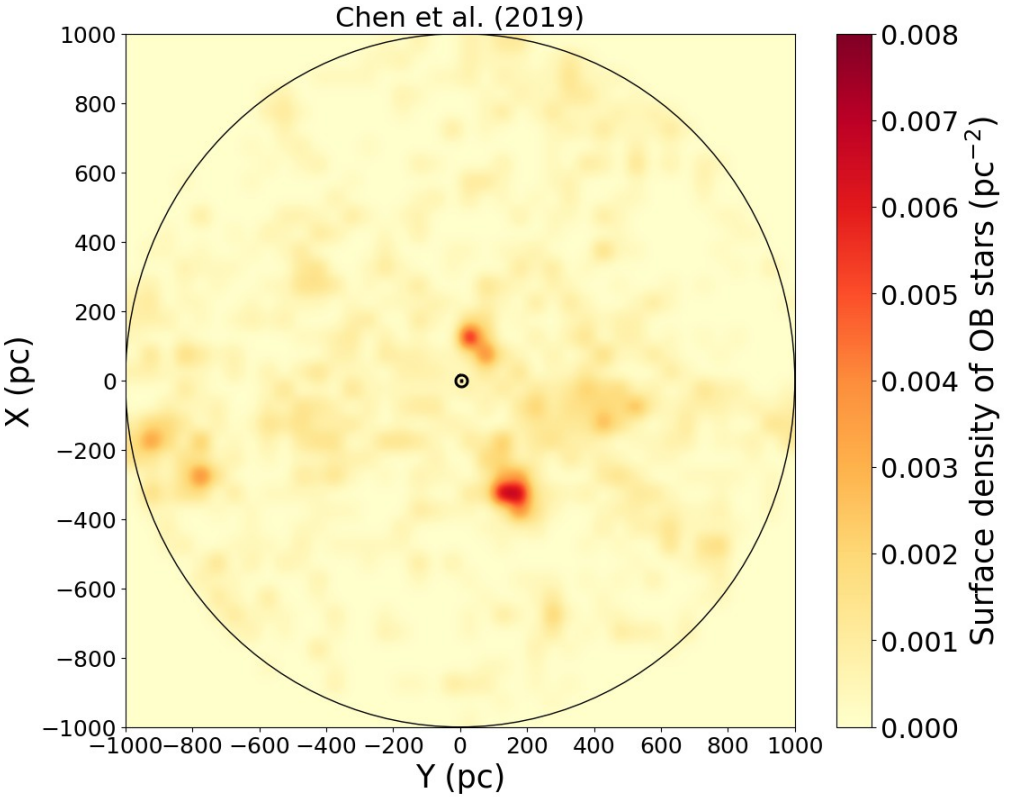


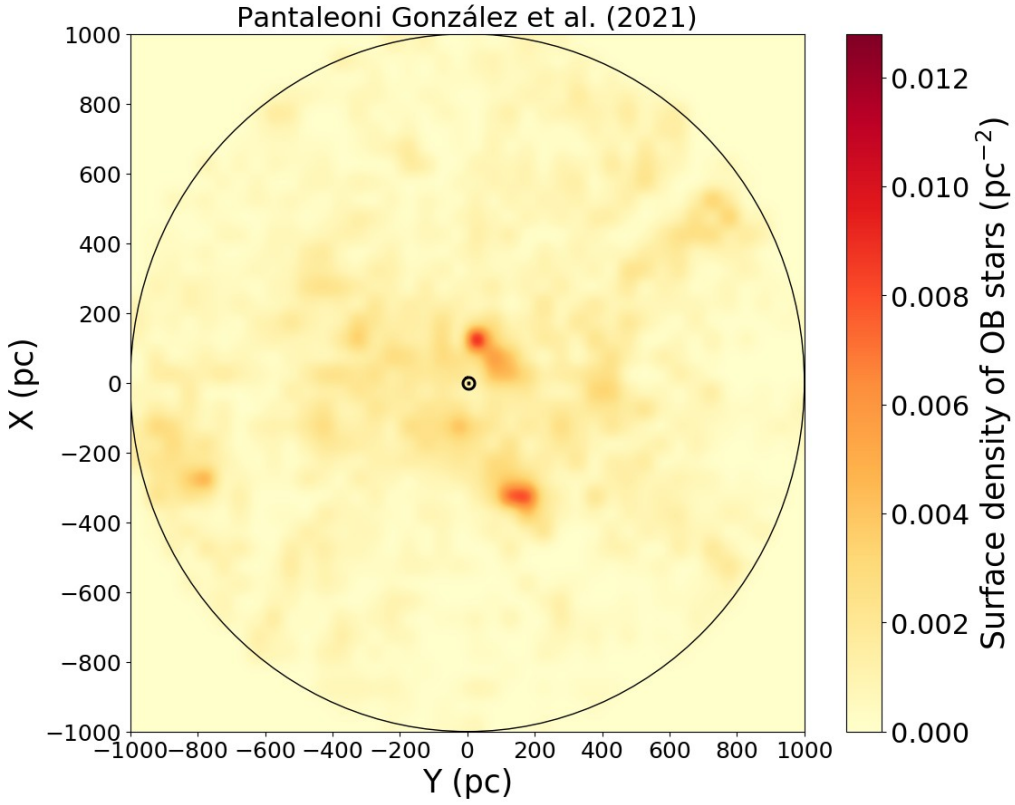
The census

- **24,706 SED-fitted O- and B-type stars within $\sqrt{(X^2+Y^2)}<1\,kpc$**
- **Surface density map unveils well-known OB associations and massive star-forming regions**
- **Hints of the Cepheus spur (see Pantaleoni González et al. 2021) and new overdensities**

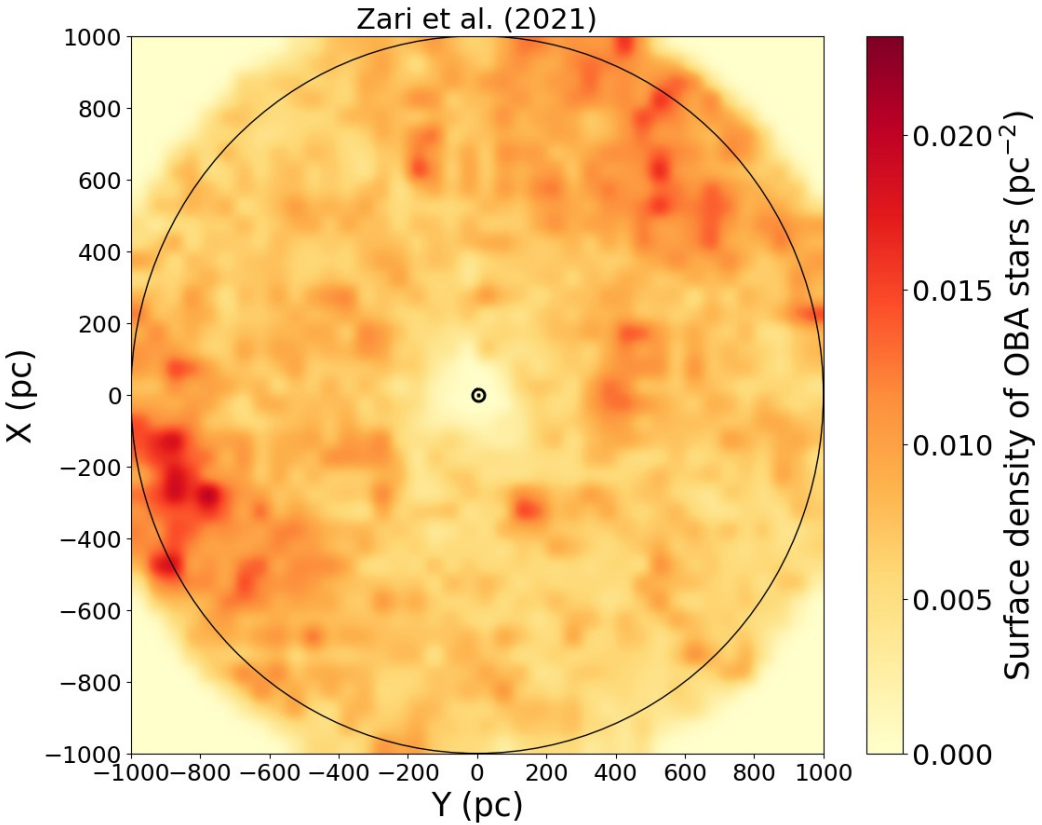


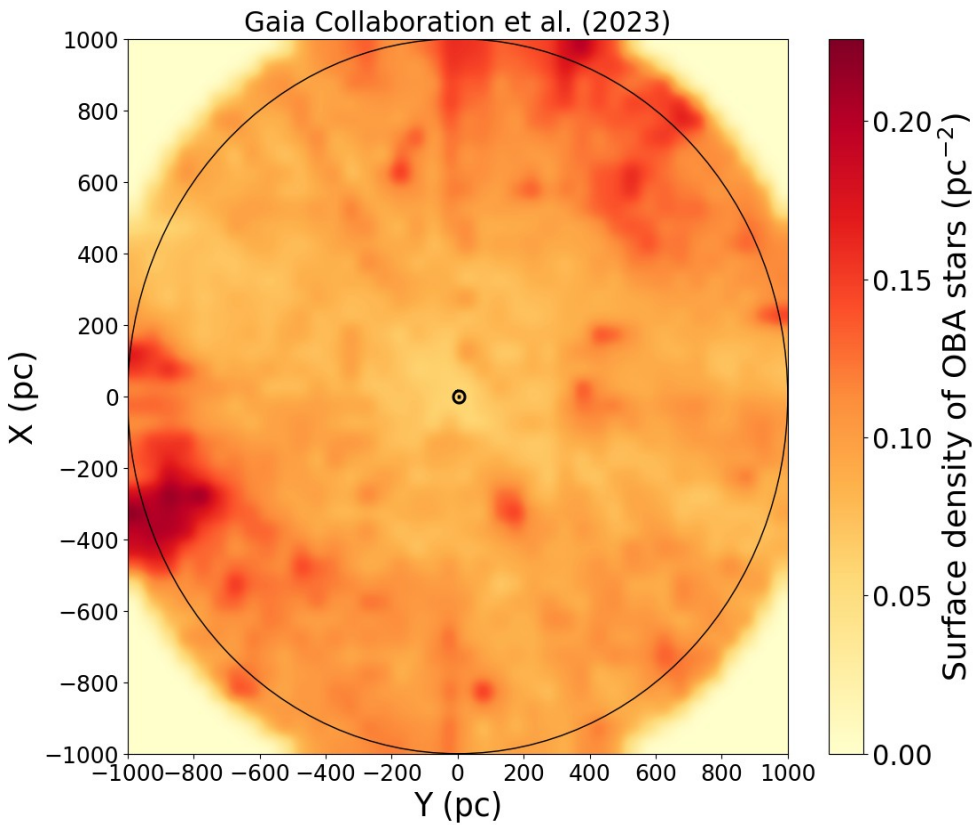
Comparison with catalogues of O and early B-type stars





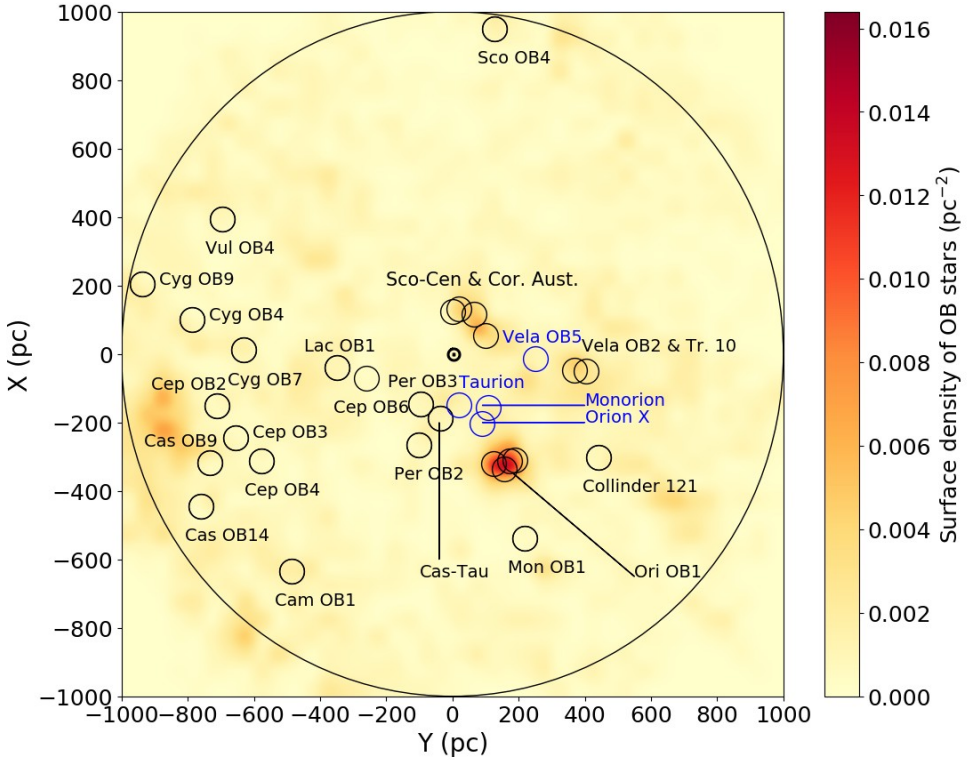
Comparison with catalogues of OBA stars



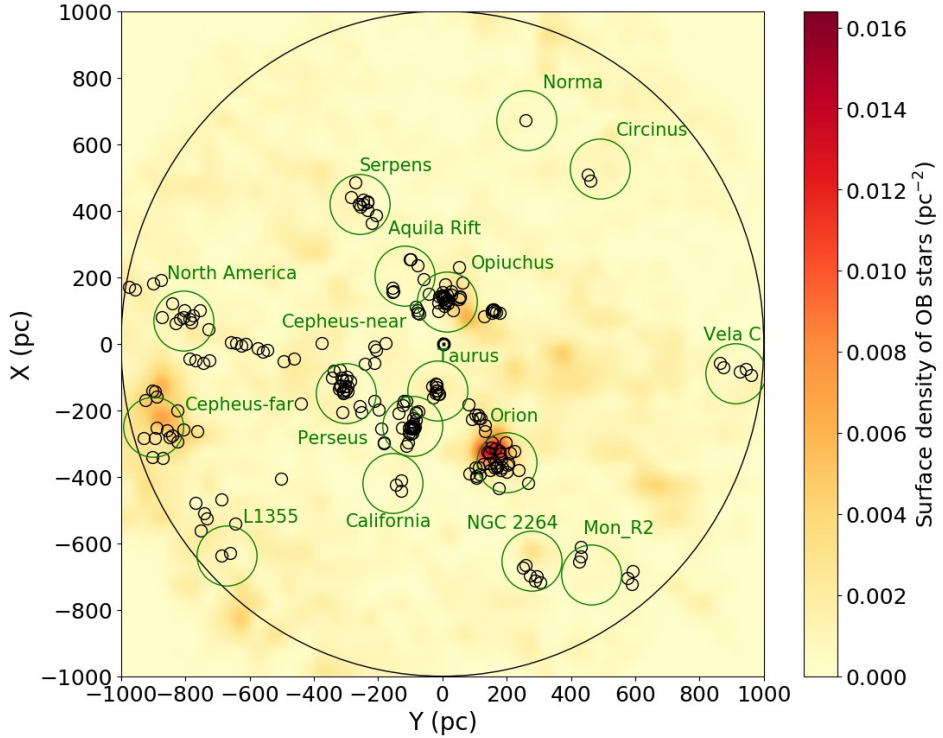


Comparison with OB associations and SFRs

Historical OB associations (Bouy & Alves 2015, Wright 2020)

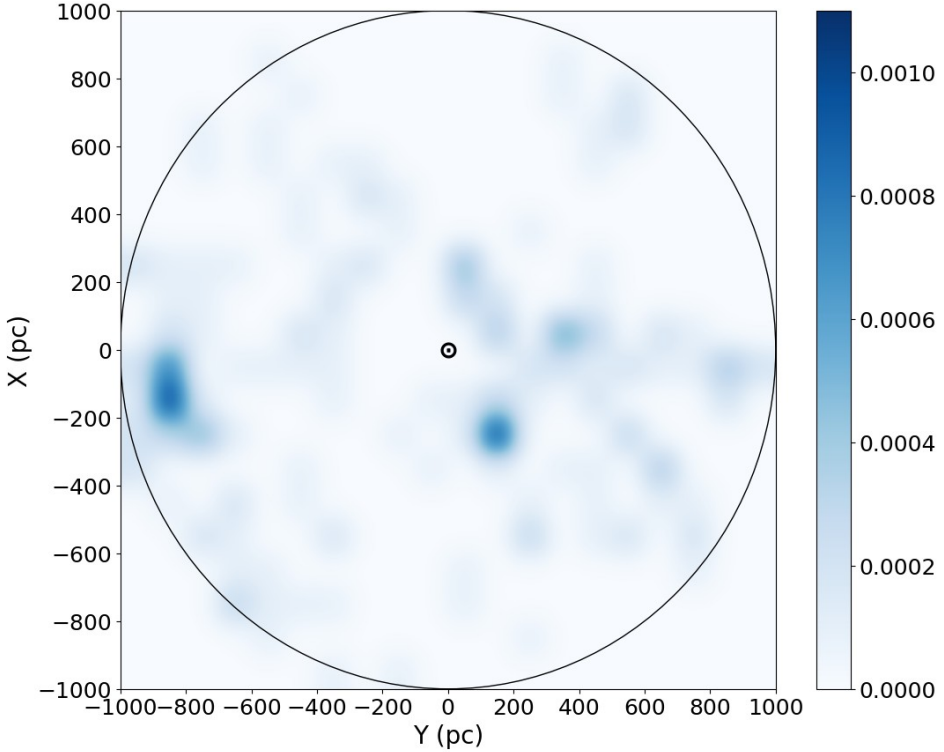


Molecular clouds and star-forming regions (Zucker et al. 2020)

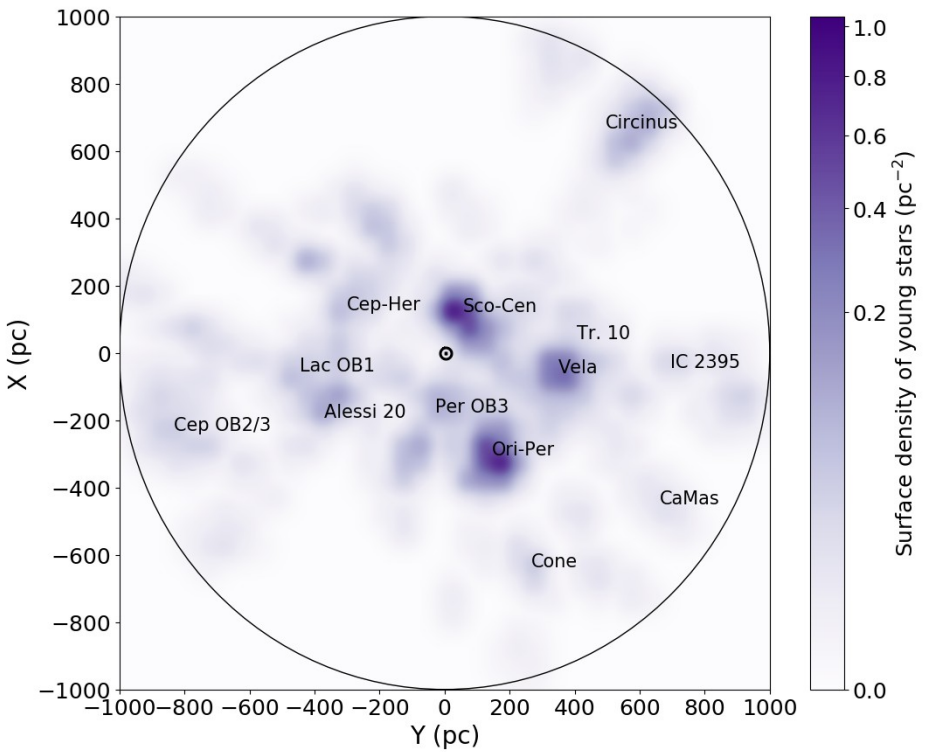


Comparison with open clusters and young stars

Young OCs (Hunt & Reffert 2024)

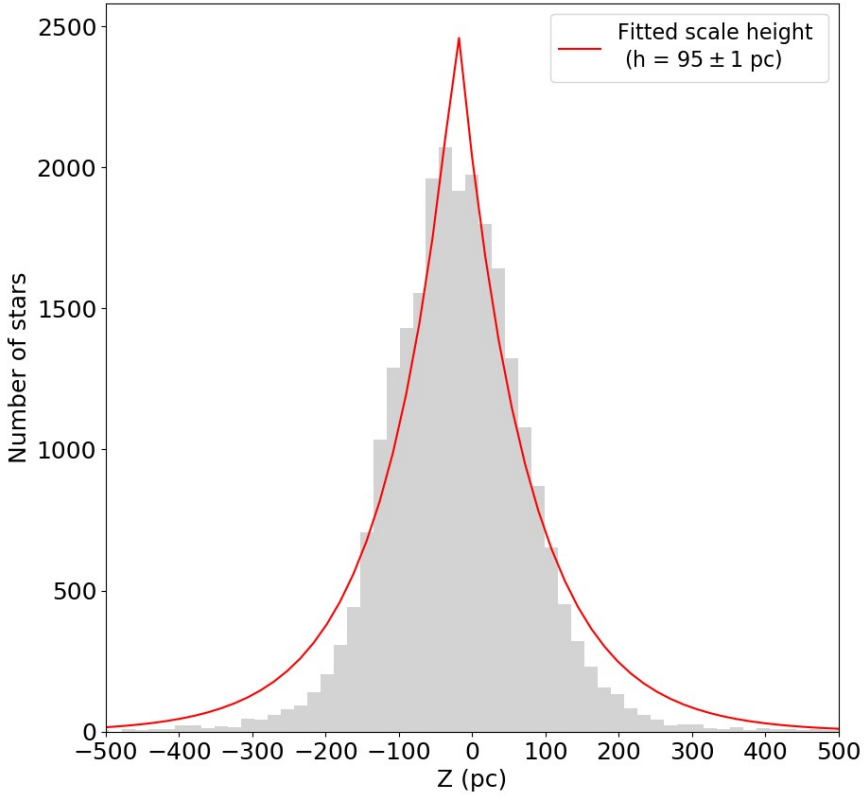


SPYGLASS IV (Kerr et al. 2023)



Star formation and supernova rates (1)

- **Simulated population of stars following the Maschberger (2013) IMF**
- **Local SFR and ccSN rate derived**
- **Extrapolated to Galactic values following the method from Reed (2005)**



Star formation and supernova rates (2)

- **Extrapolated Galactic values underestimated compared with previous estimates**
- **Typical values of 0.68 – 4.00 $M_\odot$ yr^{-1} for the Galactic SFR and 1-3 Galactic ccSN per century in the literature**

  → Improvements in the census of OB stars and evolutionary models

Parameter	Value	Units
Local SFR	2907^{+405}_{-1}	$M_\odot$ Myr^{-1}
Galactic SFR	$0.68^{+0.09}_{-0.01}$	$M_\odot$ yr^{-1}
Local SFDR	925^{+129}_{-1}	$M_\odot$ Myr^{-1} kpc^{-2}
Local ccSN_U rate	$16.5^{+7.0}_{-3.6}$	Myr^{-1}
Local ccSN_N rate	$20.4^{+8.4}_{-1.4}$	Myr^{-1}
Galactic ccSN_U rate	0.4 ± 0.1	$century^{-1}$
Galactic ccSN_N rate	0.5 ± 0.1	$century^{-1}$
Near-Earth ccSN_U rate	$1.6^{+0.7}_{-0.2}$	Gyr^{-1}
Near-Earth ccSN_N rate	$2.0^{+0.8}_{-0.3}$	Gyr^{-1}

Near-Earth supernova as mass killer

Estimated Near-Earth (<20 pc) ccSN rate of about 1 every 500 Myr

→ Consistent with the late Devonian and Ordovician extinction events

→ Possible scenario: nearby supernova explosion depleted the Earth's atmosphere, engendering a mass extinction event

Summary

- **New census of 24,706 O- and B-type stars within 1 kpc, >95% complete**
- **Noticeable overdensities in Sco-Cen, Orion, Vela OB2, Cepheus and Circinus**
- **Galactic SFR and ccSN rates slightly underestimated compared with previous estimates**
- **Near-Earth ccSN is a probable trigger of a past mass extinction event on Earth**

What’s next?

- **Producing a catalogue of runaway OB stars within 1 kpc from the Sun (Martínez García, Wright and Quintana, in prep.)**
- **Increasing the census of OB stars to larger distances (2 kpc, 3 kpc, …)**
- **Identifying kinematically-coherent OB associations with clustering algorithms**

More information

- **See Quintana, Wright and Martínez García (submitted to MNRAS)**
- **I am currently looking for a postdoc position**
- **Contact: alexis.quintana@ua.es and alexisquintana4@hotmail.com**