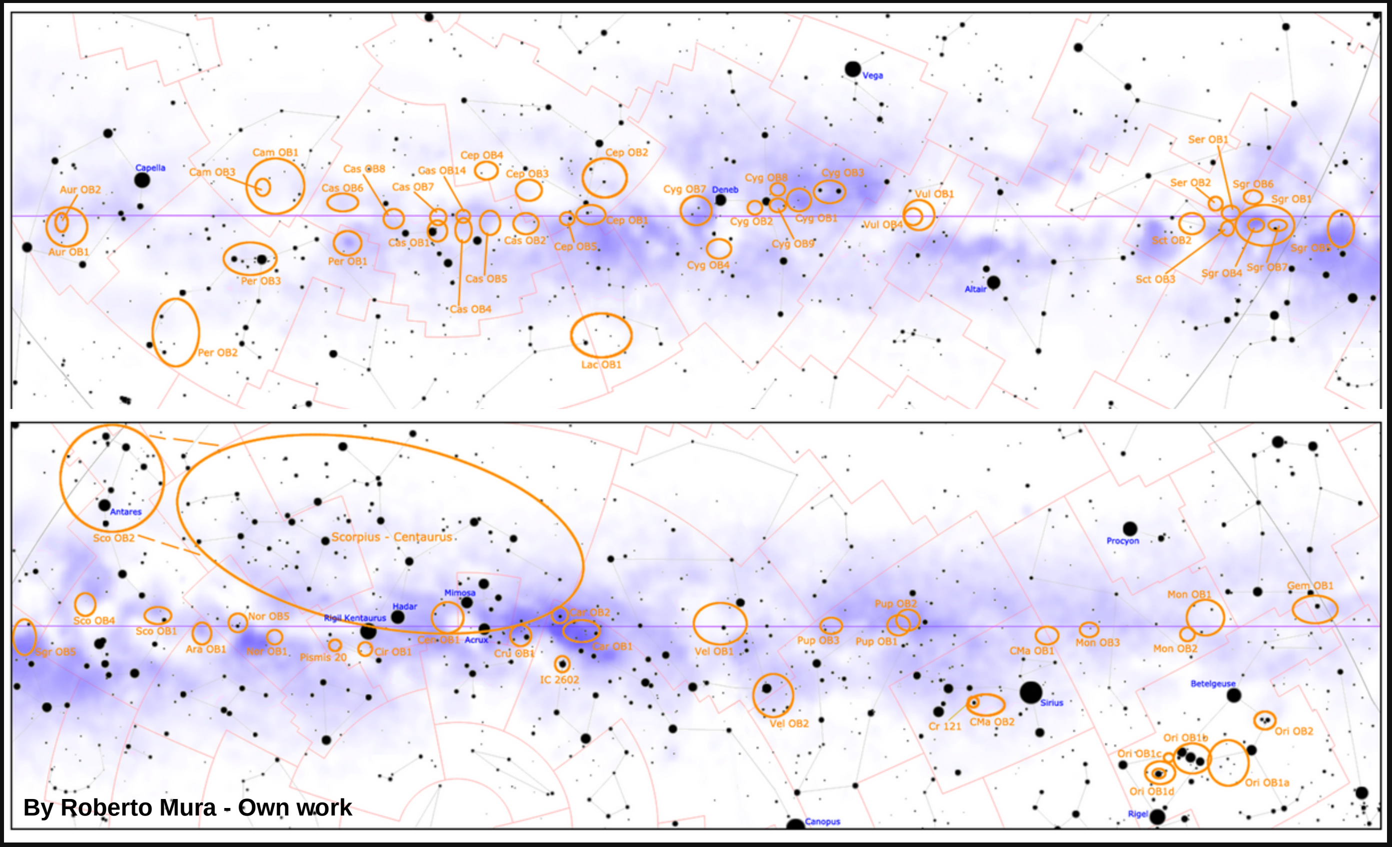
Massive stars in OB associations



Sara R. Berlanas

TOSCA- Topical Overview on Star Cluster Astrophysics

Siena, 31st October 2024

OB associations

OB associations are groups of young stars with a stellar density lower than that of the Galactic field and that are not strongly associated with interstellar matter (Wright et al. 2023)

- **Highly complex, with a high degree of spatial, kinematic and temporal substructure.**
- **Presence of subgroups with different ages and kinematics, young or open clusters, or bright central concentrations**

- **They originate as highly substructured systems without a linear star formation history, but with multiple clumps of stars that have since expanded and begun to overlap, producing the complex systems we observe today.**

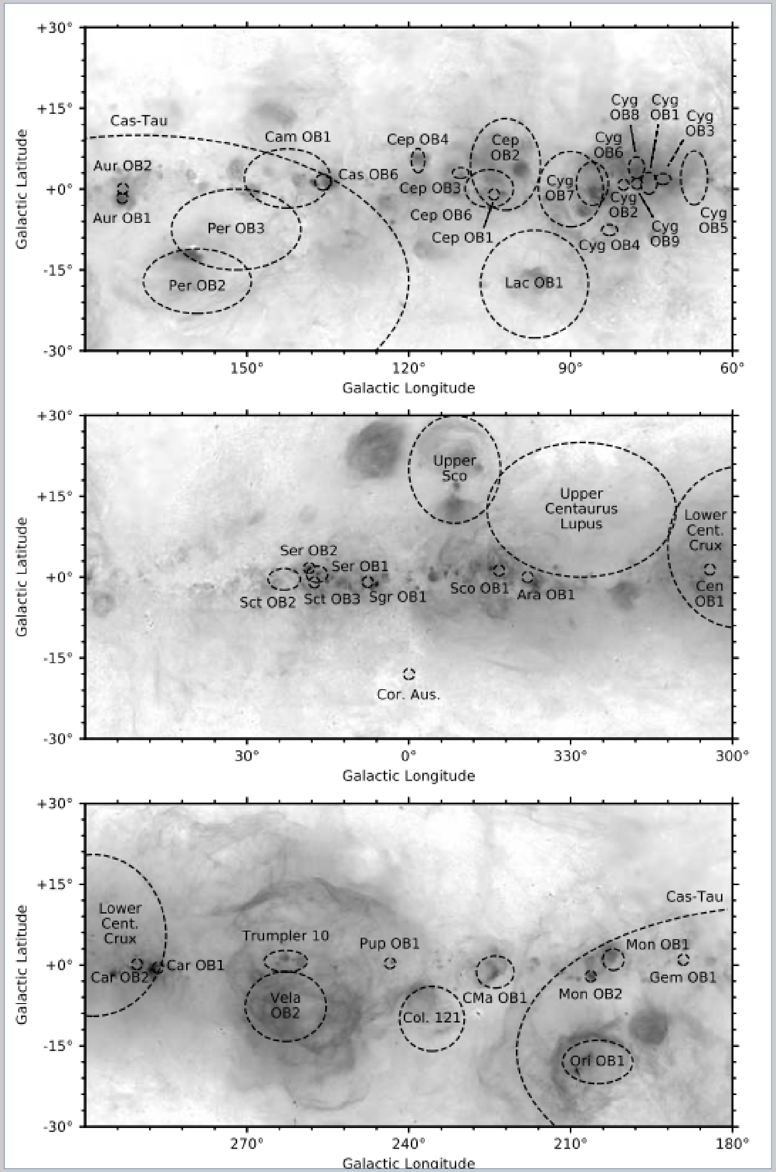
- **Globally unbound and expanding: evidence for clear expansion patterns in the association subgroups, suggesting the subgroups were more compact in the past.**

OB associations

Well studied OB associations

Name	l [deg.]	b [deg.]	Distance [pc]	Ref.	Age [Myr]	Ref.	Clusters	Nebulae
Well-studied OB associations:								
Sco-Cen: US	351.5	+20.0	143 ± 6	W18	10 ± 7	P16		
Sco-Cen: UCL	331.0	+12.5	136 ± 5	W18	16 ± 7	P16		
Sco-Cen: LCC	298.5	+5.5	115 ± 4	W18	15 ± 6	P16		
Ori OB1a	201.0	-17.3	~360	K18	8–12	B94	25 Ori	
Ori OB1b	205.0	-18.0	360–420	K18	2–8	B08	ϵ Ori	
Ori OB1c	211.3	-19.5	~385	K18	2–6	B08	NGC 1980, NGC 1981	
Ori OB1d	209.0	-19.5	~380	Z17	1–2	Z17	Orion Nebula Cluster	
Vela OB2	262.8	-7.7	411 ± 12	DZ 99	10–30	CG19	Gamma Vel, P Puppis	
Trumpler 10	262.8	+0.7	372 ± 23	DZ99	45–50	CG19		
Cyg OB2	80.2	+0.8	1350–1750	B19	1–7	W15		
High-confidence OB associations that have not been extensively studied:								
Ara OB1	338.0	0.0	~1100	M73	~2	A87	NGC 6193	
Aur OB1	173.1	-1.6	~1060	M17	11-22	T10	NGC 1912, NGC 1960	Sh2-227
Aur OB2	173.0	+0.1	~2420	M17	~5.5	T10	NGC 1893, Stock 8	IC 410, IC 417
Cam OB1	142.5	+2.0	~800	M17	7–14	S85	NGC 1502	S202
Car OB1	286.5	-0.5	2300 ± 50	S06	1–10	D01	NGC 3293, Tr 14–16	NGC 3372
Car OB2	290.4	+0.1	~1830	M20	~4	G94		
Cas OB6	135.9	+1.3	~1750	M17	~4	T10	IC 1805, IC 1848	W3, W4, W5
Cas-Tau	169.0	-16.5	125–300	DZ99	~50	DZ99		
Cen OB1	304.2	+1.4	~1920	M17	6–12	K94	Stock 16	RCW 75
Cep OB1	104.2	-1.0	~2780	M17	1–5	C11	NGC 7380	
Cep OB2	102.1	+4.6	~730	M20	5	DZ99	Tr 37, NGC 7160	IC 1396
Cep OB3	110.4	+3.0	~700	M17	5–8	J96	Cep OB3b	S155
Cep OB4	118.3	+5.3	~660	M17	1–6	M68	B59	S171
Cep OB6	105.1	+0.1	270 ± 12	DZ99	~50	DZ99		
CMa OB1	224.0	-1.3	~1200	Z20	1–10	S18	NGC 2353, NGC 2327	IC 2177, Sh2-296
Collinder 121	235.7	-10.0	543 ± 23	DZ99	5	DZ99	Collinder 121	Sh2-306
Cyg OB1	75.5	+1.1	~1460	M17	6–8	R08	NGC 6913, IC 4996	
Cyg OB3	72.9	+1.9	~1830	M17	2–12	R08	NGC 6871, NGC 6883	
Cyg OB4	82.8	-7.6	~800	M17	~8.3	U01		
Cyg OB5	67.1	+2.1	~1610	R66				
Cyg OB6	86.0	+1.0	~1700	R66				
Cyg OB7	89.0	0.0	~630	M17	1–13	U01, W13		Northern Coalsack
Cyg OB8	77.9	+3.4	~1830	M17	4–6	M15		
Cyg OB9	77.7	+1.9	~960	M17	2–4	M15		Sh2-108
Gem OB1	189.1	+1.0	~1210	M20	~9	T10	NGC 2175	IC 443
Lac OB1	96.7	-17.6	368 ± 17	DZ99	2–25	C08		S126
Mon OB1	202.1	+1.0	~580	M17	1–10	F99	NGC 2264	NGC 2264, Mon. Ring
Mon OB2	206.3	-2.1	~1210	M17	2–15	T76	NGC 2244	Rosette Neb.
Per OB2	159.2	-17.1	296 ± 17	DZ99	1–10	A15	IC 348, NGC 1333	
Per OB3	147.0	-5.5	175 ± 3	DZ99	50	DZ99	α Per	
Pup OB1	243.5	+0.3	~2010	M17	~4	H72	NGC 2467	S311
Sco OB1	343.3	+1.2	1560 ± 35	Y20	1–10	D18	NGC 6231, Tr 24	G345.45+1.50, Gum 55, IC 4628
Sct OB2	23.1	-0.4	~1600	M09	~6	S85	NGC 6705	
Ser OB1	16.7	0.0	~1530	M17	8–13	T10	NGC 6611	M16, M17
Ser OB2	18.2	+1.7	~1600	M17	~4.5	T10	NGC 6604	Sh2-54
Sgr OB1	7.6	-0.9	~1260	M17	5–8	S85	NGC 6530, Col. 367	M20

N. Wright 2020

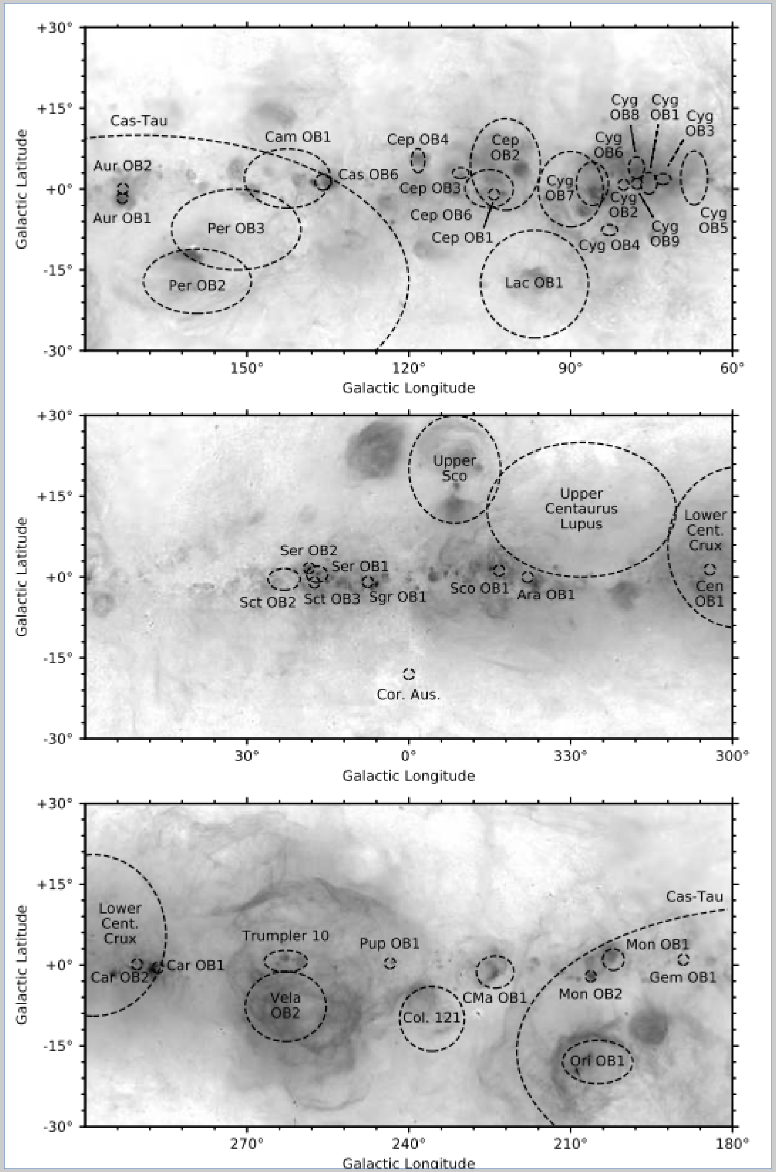


OB associations

High-confidence OB associations

Name	l [deg.]	b [deg.]	Distance [pc]	Ref.	Age [Myr]	Ref.	Clusters	Nebulae
Well-studied OB associations:								
Sco-Cen: US	351.5	+20.0	143 ± 6	W18	10 ± 7	P16		
Sco-Cen: UCL	331.0	+12.5	136 ± 5	W18	16 ± 7	P16		
Sco-Cen: LCC	298.5	+5.5	115 ± 4	W18	15 ± 6	P16		
Ori OB1a	201.0	-17.3	∼360	K18	8–12	B94	25 Ori	
Ori OB1b	205.0	-18.0	360–420	K18	2–8	B08	ϵ Ori	
Ori OB1c	211.3	-19.5	∼385	K18	2–6	B08	NGC 1980, NGC 1981	
Ori OB1d	209.0	-19.5	∼380	Z17	1–2	Z17	Orion Nebula Cluster	
Vela OB2	262.8	-7.7	411 ± 12	DZ 99	10–30	CG19	Gamma Vel, P Puppis	
Trumpler 10	262.8	+0.7	372 ± 23	DZ99	45–50	CG19		
Cyg OB2	80.2	+0.8	1350–1750	B19	1–7	W15		
High-confidence OB associations that have not been extensively studied:								
Ara OB1	338.0	0.0	∼1100	M73	∼2	A87	NGC 6193	
Aur OB1	173.1	-1.6	∼1060	M17	11-22	T10	NGC 1912, NGC 1960	Sh2-227
Aur OB2	173.0	+0.1	∼2420	M17	∼5.5	T10	NGC 1893, Stock 8	IC 410, IC 417
Cam OB1	142.5	+2.0	∼800	M17	7–14	S85	NGC 1502	S202
Car OB1	286.5	-0.5	2300 ± 50	S06	1–10	D01	NGC 3293, Tr 14–16	NGC 3372
Car OB2	290.4	+0.1	∼1830	M20	∼4	G94		
Cas OB6	135.9	+1.3	∼1750	M17	∼4	T10	IC 1805, IC 1848	W3, W4, W5
Cas-Tau	169.0	-16.5	125–300	DZ99	∼50	DZ99		
Cen OB1	304.2	+1.4	∼1920	M17	6–12	K94	Stock 16	RCW 75
Cep OB1	104.2	-1.0	∼2780	M17	1–5	C11	NGC 7380	
Cep OB2	102.1	+4.6	∼730	M20	5	DZ99	Tr 37, NGC 7160	IC 1396
Cep OB3	110.4	+3.0	∼700	M17	5–8	J96	Cep OB3b	S155
Cep OB4	118.3	+5.3	∼660	M17	1–6	M68	B59	S171
Cep OB6	105.1	+0.1	270 ± 12	DZ99	∼50	DZ99		
CMa OB1	224.0	-1.3	∼1200	Z20	1–10	S18	NGC 2353, NGC 2327	IC 2177, Sh2-296
Collinder 121	235.7	-10.0	543 ± 23	DZ99	5	DZ99	Collinder 121	Sh2-306
Cyg OB1	75.5	+1.1	∼1460	M17	6–8	R08	NGC 6913, IC 4996	
Cyg OB3	72.9	+1.9	∼1830	M17	2–12	R08	NGC 6871, NGC 6883	
Cyg OB4	82.8	-7.6	∼800	M17	∼8.3	U01		
Cyg OB5	67.1	+2.1	∼1610	R66				
Cyg OB6	86.0	+1.0	∼1700	R66				
Cyg OB7	89.0	0.0	∼630	M17	1–13	U01, W13		Northern Coalsack
Cyg OB8	77.9	+3.4	∼1830	M17	4–6	M15		
Cyg OB9	77.7	+1.9	∼960	M17	2–4	M15		Sh2-108
Gem OB1	189.1	+1.0	∼1210	M20	∼9	T10	NGC 2175	IC 443
Lac OB1	96.7	-17.6	368 ± 17	DZ99	2–25	C08		S126
Mon OB1	202.1	+1.0	∼580	M17	1–10	F99	NGC 2264	NGC 2264, Mon. Ring
Mon OB2	206.3	-2.1	∼1210	M17	2–15	T76	NGC 2244	Rosette Neb.
Per OB2	159.2	-17.1	296 ± 17	DZ99	1–10	A15	IC 348, NGC 1333	
Per OB3	147.0	-5.5	175 ± 3	DZ99	50	DZ99	α Per	
Pup OB1	243.5	+0.3	∼2010	M17	∼4	H72	NGC 2467	S311
Sco OB1	343.3	+1.2	1560 ± 35	Y20	1–10	D18	NGC 6231, Tr 24	G345.45+1.50, Gum 55, IC 4628
Sct OB2	23.1	-0.4	∼1600	M09	∼6	S85	NGC 6705	
Ser OB1	16.7	0.0	∼1530	M17	8–13	T10	NGC 6611	M16, M17
Ser OB2	18.2	+1.7	∼1600	M17	∼4.5	T10	NGC 6604	Sh2-54
Sgr OB1	7.6	-0.9	∼1260	M17	5–8	S85	NGC 6530, Col. 367	M20

N. Wright 2020

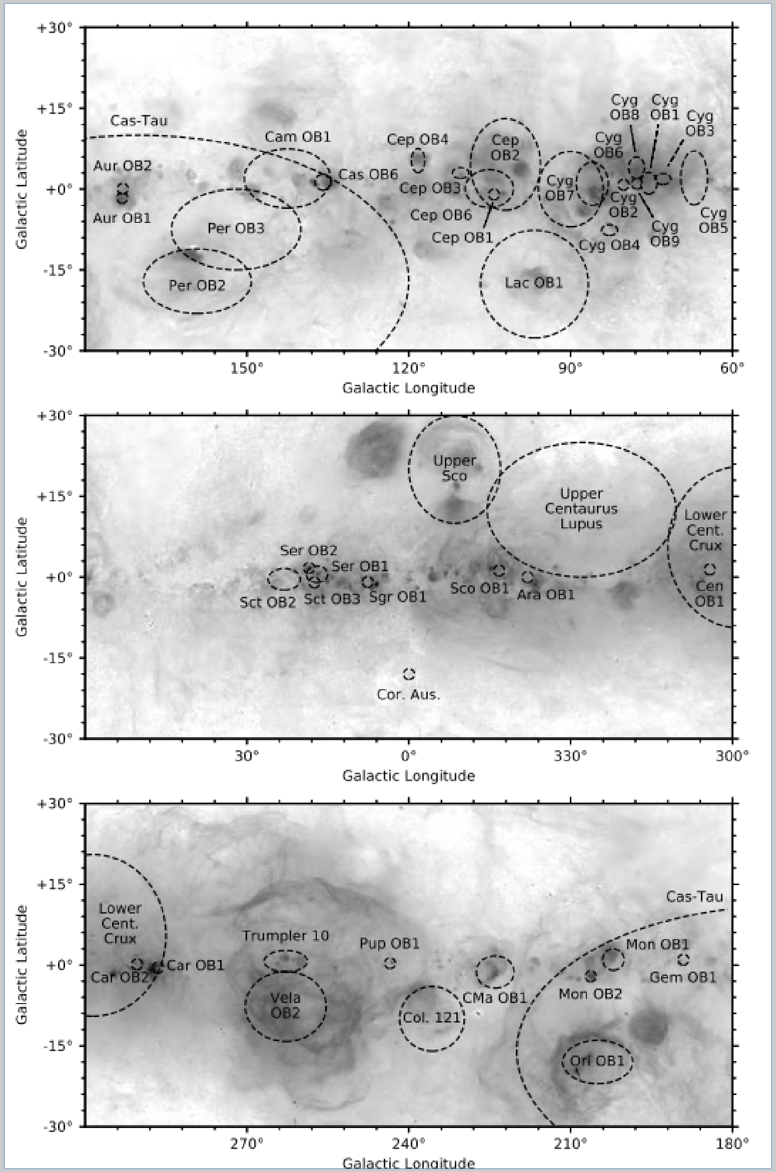


OB associations

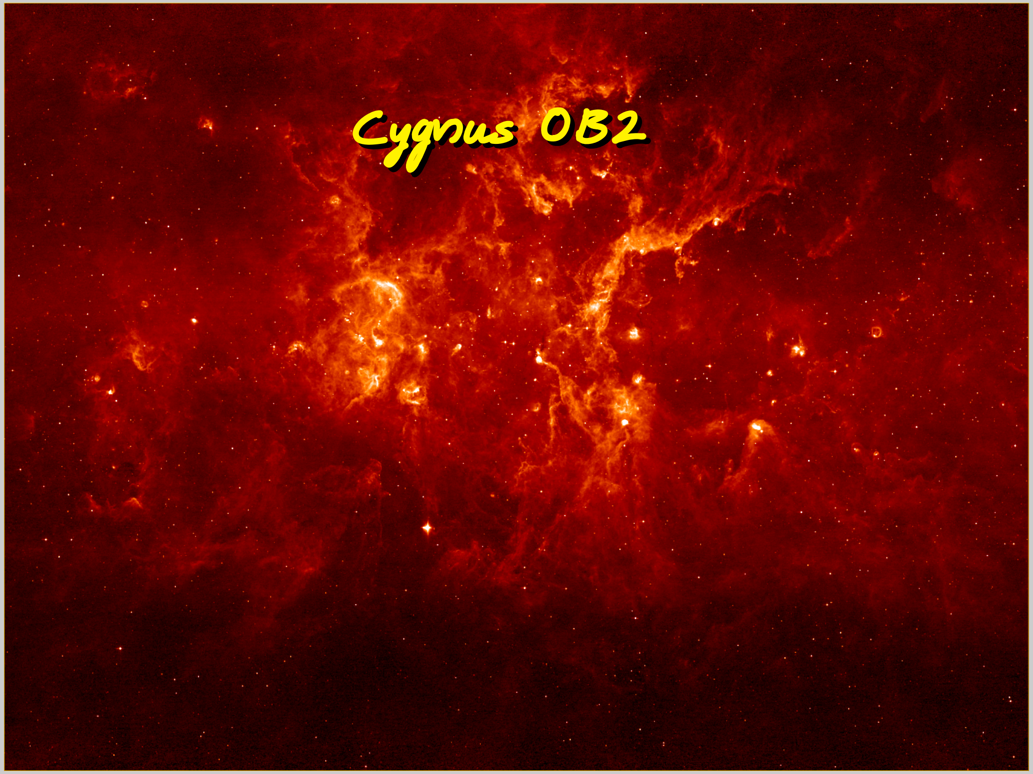
OB associations pending deeper exploration

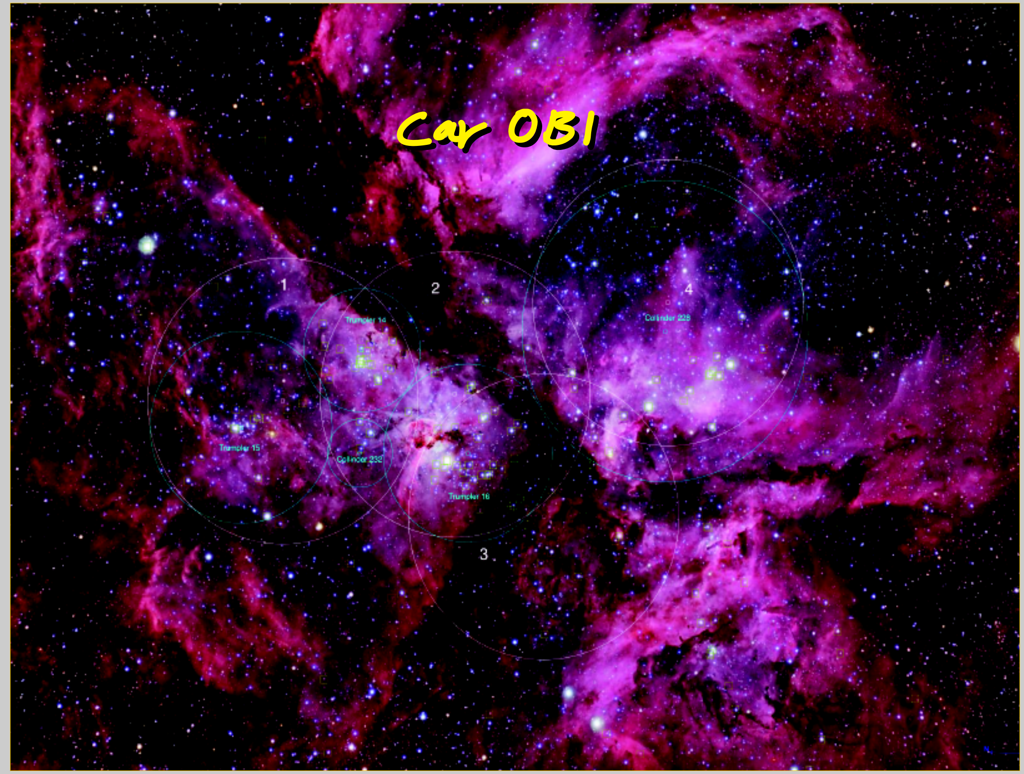
Name	l [deg.]	b [deg.]	Distance [pc]	Ref.	Age [Myr]	Ref.	Clusters	Nebulae
OB associations for which very little is known:								
Aql OB1 (?)	37.3	-0.6	~2750	R66				
Cam OB3	147.0	+3.0	~2650	M17	~11	T10	Alicante 1	
Cas OB1	124.1	-1.4	~2010	R66	~10	L86		
Cas OB2	112.0	0.0	~2100	M17	~10	L86		NGC 7538, Sh1-57
Cas OB4	120.1	-0.3	~2300	M17	~8	L86		
Cas OB5	116.2	-0.5	~2010	M17	6–8	S85		
Cas OB7	122.8	+1.2	~2010	M17	~8	L86		Sh2-180
Cas OB8	129.2	-1.1	~2300	M17	~20	T10	NGC 581, NGC 663	
Cas OB9 (?)	113.5	-2.5	~800	R66				
Cas OB10 (?)	130.8	-6.3	~3800	R66				
Cas OB14	120.4	+0.7	~880	M17	<10	T10		
Cen OB2	294.3	-1.0	~2100	R66	3–10	B14	IC 2944	IC 2948
Cep OB5	108.5	-2.8	~2090	H78	~10	L86		
Cir OB1	315.5	-2.8	~2010	M17			Pismis 20	
Cor. Aust. (?)	0.0	-18.0	~130	DZ99			Coronet cluster	NGC 6726, NGC 6729
Cru OB1 (?)	294.9	-1.1	~2010	M17	5–7	K94		IC 2944
Mon OB3	217.6	-0.3	~2420	M17	~7	T10		S287
Nor OB1	328.0	-0.9	~2780	M17				
Ori OB2 (?)	192.6	-11.6	~3240	R66				
Per OB1	134.7	-3.2	~1830	M17	8–11	M87	*h* and χ Persei (NGC 869 & 884)	
Pup OB2 (?)	244.6	0.7	~3180	M17	~2	H72	Ruprecht 20	
Pup OB3	254.0	0.0	~1460	M17	~4	W63		RCW 19
Sco OB4 (?)	352.4	+3.4	~960	M17				NGC 6334, Sh2-10
Sct OB3	17.3	-0.8	~1330	M17	~4.5	T10		Sh2-50
Sgr OB4	12.2	-1.0	~1920	M17	<10	T10		
Sgr OB5	359.9	-1.2	~2420	M20	6–12	S85		Sh2-15
Sgr OB6	14.2	+1.2	~1600	M17	<10	T10		
Sgr OB7	10.7	-1.5	~1390	M17	4–5	T10		
Vela OB1	265.0	-0.7	~1460	M17	~20	T79	NGC 2659	
Vul OB1	60.3	+0.1	~1600	M17	10–16	T10	NGC 6823	NGC 6820
Vul OB2 (?)	64.7	+1.8	~4130	R66				
Vul OB4	60.5	+0.5	~800	M17	~10	T80		

N. Wright 2020



Two of the youngest Galactic OB associations

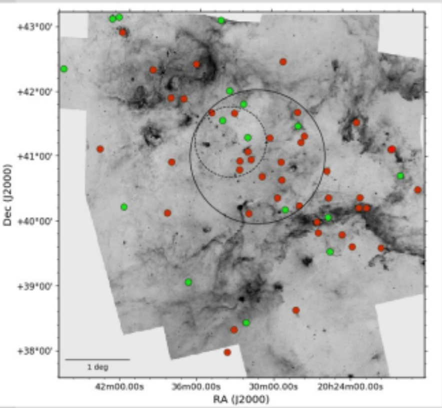




- They are **home to clusters and groups** with a large variety of massive stars, and are massive enough to contain O3 stars
- They are relatively **nearby** (at ~1.4-1.7 kpc Cyg OB2; ~3.2 kpc Car OB1) and contains hundreds of OB stars
- They are very **young**: age spread of 1 to 6 Myr in Cyg OB2; Car OB1 even younger
- In addition, ***Gaia*** **DR3** is providing accurate **parallaxes** to derive precise values of luminosity and also **proper motions**: Redefine associations; Runaways after SNe explosions; Runaways vs rotational velocities

Cygnus OB2

1. COMPLETING THE CENSUS OF OB MEMBERS

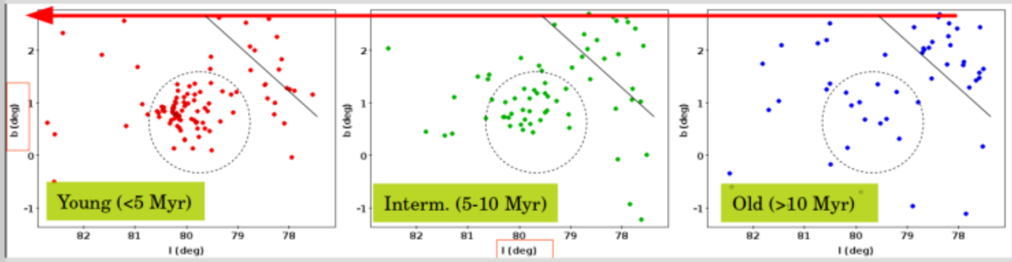


Spectral classification of new spectra: **42 new OB stars** (<B3V)

... but the magnitude cutoff in the selection criteria introduces an **incompleteness** which is important mainly for those **faintest and most obscured** late O-type members.

Age distribution

(T_{eff} from SpT calibrations + log L/L_{sun} assuming DM = 10.8)



Massive star formation has proceeded **from lower to higher Galactic longitudes**, from Cygnus OB9, continuing in the southern part of Cygnus OB2 and increasing in its northern part.

Berlanas et al. 2018a

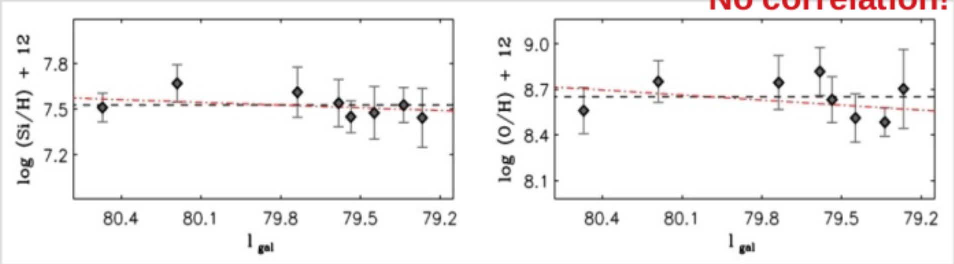
2. LOOKING FOR SELF-ENRICHMENT

Could the correlation between ages and Galactic longitudes be associated with a chemical composition gradient?

(that could evidence star formation from self-enrichment processes produced by pollution of the interstellar medium by successive generations of massive stars).

Si and O abundances for a sample of slow rotators

No correlation!



Our results indicate a **homogeneous** composition for our stellar sample, without evidence of a dependence on the Galactic longitude.

Test: O enrichment produced by stellar winds and SNe

The effect of self-enrichment by stellar winds and SNe is **small enough to be beyond the accuracy of our analyses.** We need to extend the sample and/or increase the quality of the spectra to detect it

Berlanas et al. 2018b

Cygnus OB2

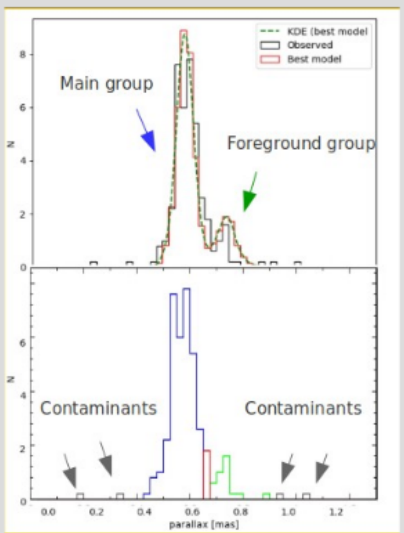
3. EXPLORING THE PARALLAX DISTRIBUTION

***Gaia* DR2 parallaxes** → unique opportunity to inspect the internal structure of Galactic young open clusters and relatively nearby massive OB associations.

Cygnus OB2: 200 OB-stars suitable for our analysis (RUWE < 1.4)

We created a **parametrized model** to reproduce the *Gaia* DR2 parallax distribution.

Compared to the parallax distribution using the MCMC ensemble sampler ***emcee***



We find two stellar groups superposed in Cygnus OB2 but separated by ~400 pc.

Main group ~1750 pc

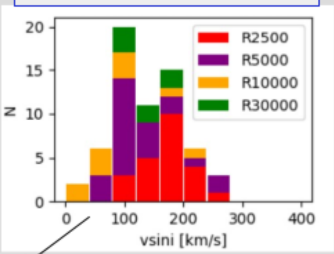
Foreground group ~1350 pc

Berlanas et al. 2019

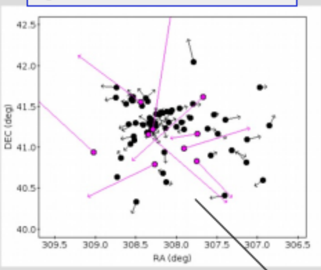
4. DETERMINING THE MAIN STELLAR PARAMETERS

We compiled new and already available spectra of the 77 O-type stars identified in Cygnus OB2: 63 are suitable for accurate spectroscopic analysis and 52 have reliable Gaia DR2 astrometry (RUWE < 1.4).

***vsini* distribution**



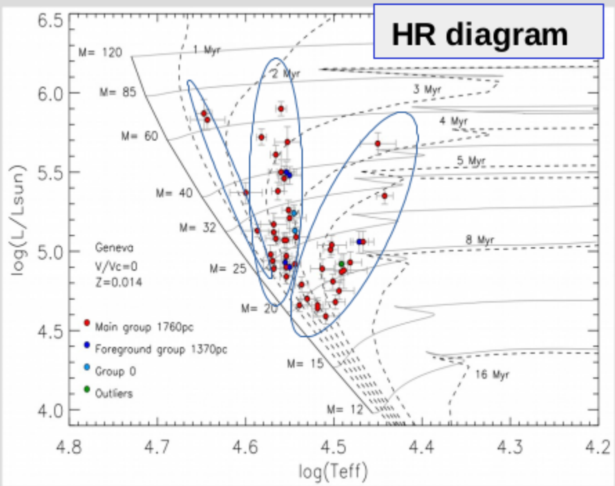
pm distribution



Similar to other distributions of O-stars except for the lack of very fast rotators

Runaway candidates!

HR diagram



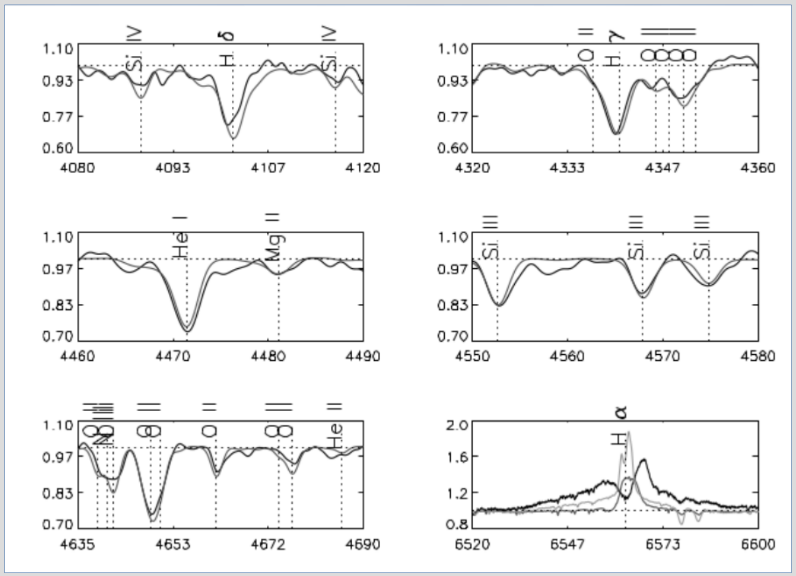
From spectroscopic parameters and *Gaia* distances we find star formation during the last 1–6 Myr, with two main bursts centred roughly at 3 and 5 Myr. A third smaller group of stars at ~1.5 Myr containing the hottest stars of our sample may be due to interactive binaries.

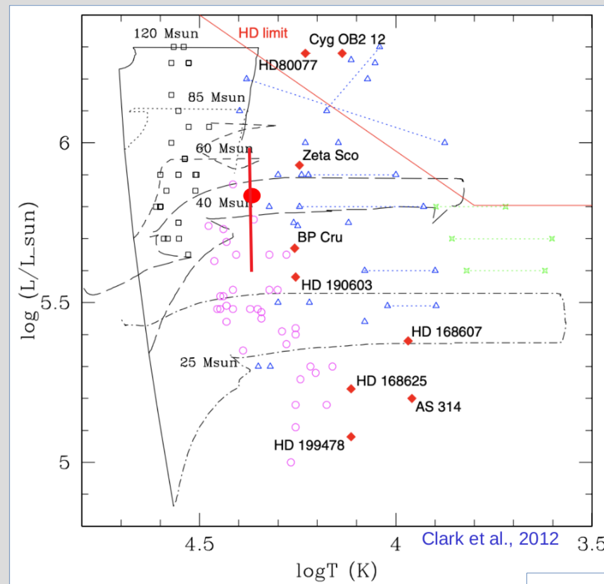
Berlanas et al. 2020

Cygnus OB2

5. IDENTIFICATION OF EXTREME LUMINOUS OBJECTS

J20395358+4222506 is a very luminous, highly extincted B1 Supergiant. It is one of the most luminous stars in the Milky Way (*Herrero et al. 2022*)

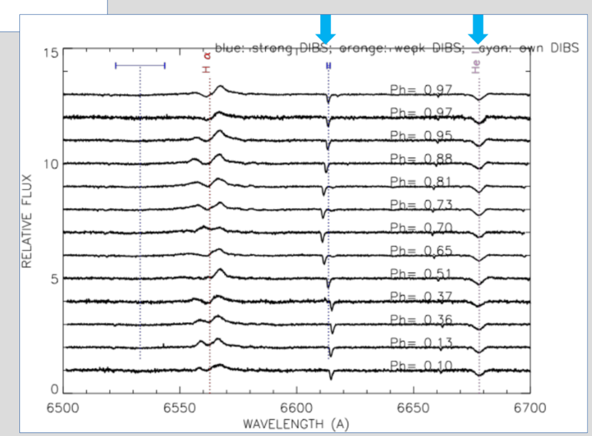




It has a very high
- mass-los rate
- terminal wind velocity
- rotational velocity

for its spectral type

It is in an advanced stage of evolution, probably close to become an early hypergiant (if not already so). It shows strong wind variability



J20395358+4222506 is an excellent **anchor object for stellar evolution and atmospheric modelling**

It has a mass of **~ 46 M⊙** but **it orbits around a companion with P~12.4 days and K ~ 90 km/s** (semi-amplitude)

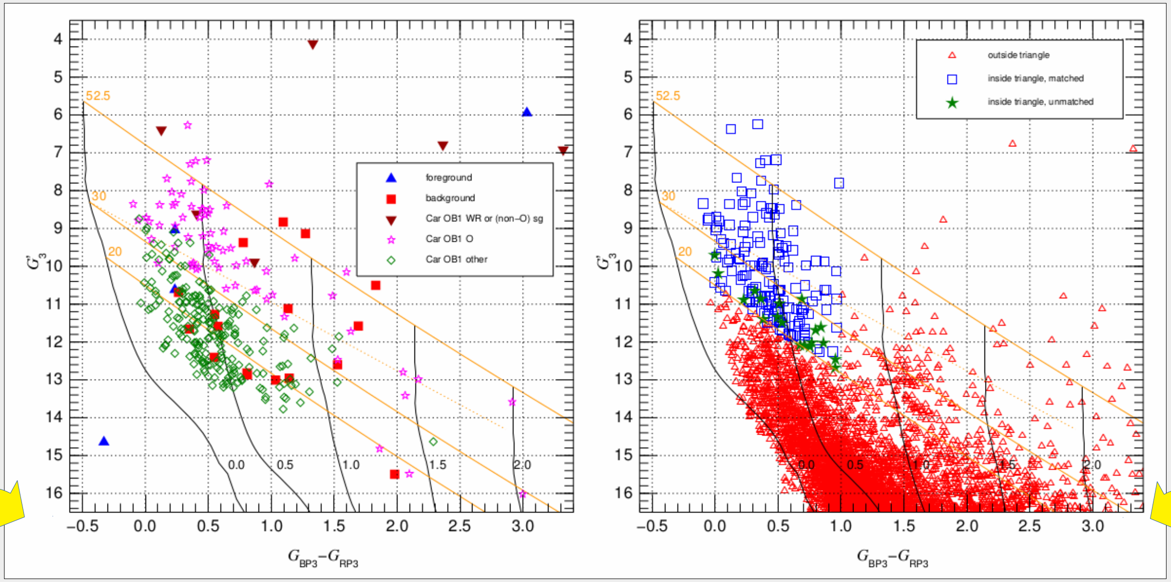
There is a high probability that the companion was the initial primary (and it may be a compact object) *(Herrero et al. 2024, in prep)*

Car OB1

1. CENSUS

The updated census contains a total of **316 stars**, being 18 of them in the background and four in the foreground. Of the 294 stellar systems in Car OB1, **74 are of O type (54 apparently single or SB1), 214 are of non-supergiant B type and 6 are of WR or non-O supergiant (II to Ia) spectral class.**

Within the sample, we identified **20 spectroscopic binary systems with an O-star primary and another 18 with a B-star primary.**



O and B stars are separated in the CMD, with the O stars mostly above the average age 30 kK extinction track for R_{5495}= 4.5 and the B stars below it.

This is an indirect confirmation of the quality of the spectral classifications.

We estimate that our sample is around 90% complete for low to moderate extinction O and early B systems.

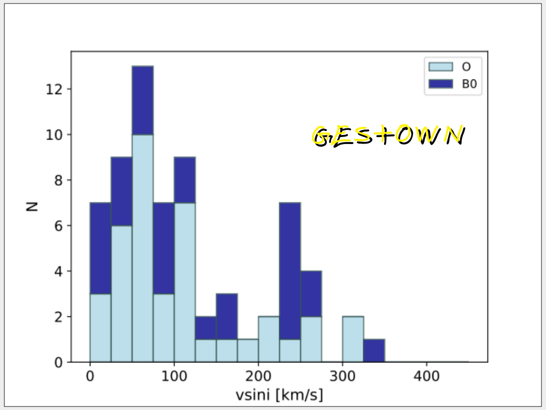
The location of the 19 green stars, all of them below the 30 kK extinction track, suggests that those missing objects are likely early-B stars.

Berlanas et al. 2023

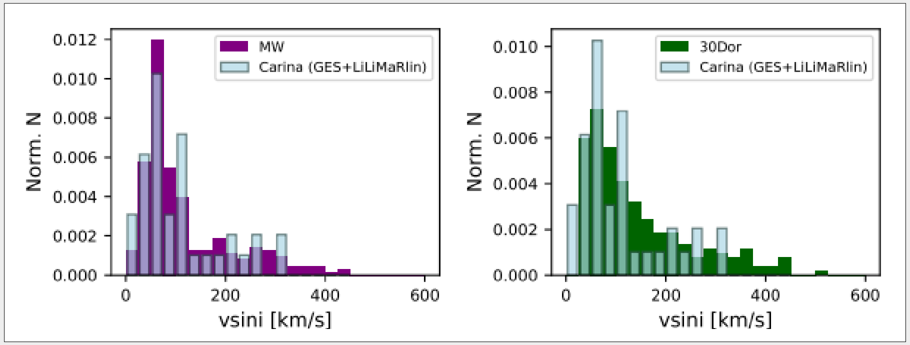
Car OB1

2. VSINI DISTRIBUTION

High-resolution spectroscopy for the maximum number of O stars in the census **is required to reach low rotational velocities and better disentangle the macroturbulence broadening: 38 O stars** (from 54)**.** This number represents a **70% fraction** of the total known population of 54 single O-type stars present in our census.



- **Low velocity peak at 60 km s⁻¹ and a tail of fast rotators above 200 km s⁻¹, as expected** from previous results in other surveys.
- Evident lack of stars in the 75-100 km s⁻¹ bin, but it is highly attenuated when adding the sample of B0 stars.



Similar to other distributions of O stars, showing a bimodal structure although a shorter tail of fast rotators is found. Possible reason: relative small size of our sample and the young age of Carina, which may imply insufficient time for binary interactions to produce such an extended tail of fast rotators

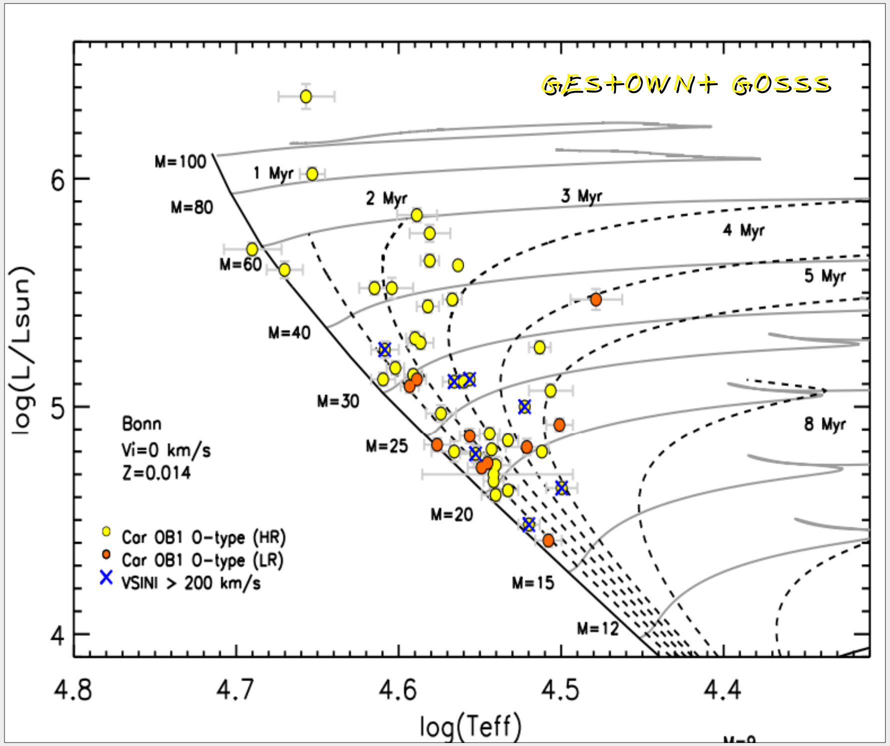
Similar trend in Cyg OB2!

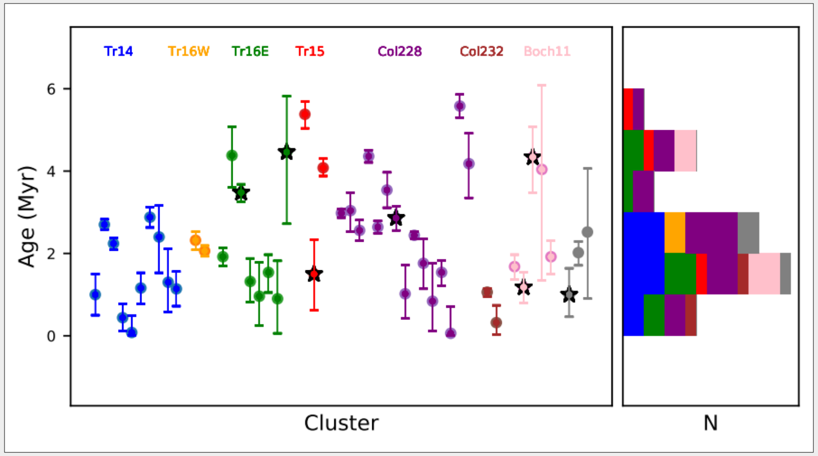
Berlanas et al. 2024 (imminent submission)

Car OB1

3. STELLAR PARAMETERS AND THE HRD

FASTWIND + **iacob-gbat** → main spectroscopic parameters from their H and He lines. Benefiting from ***Gaia*** **(DR3) and Molina-Lera et al. (in prep)** we used **group distances** to derive M_V for the sample of O stars in Carina → R,L, Msp. Using **BONNSAI tool**, we also derive Mev and Ages.





Age distribution peaking at 1 Myr. It confirms Car OB1, and specifically **Trumpler 14, as one of the youngest regions of the Galaxy**, as suggested by other authors.

Berlanas et al. 2024 (imminent submission)

Massive stars and large spectroscopic surveys

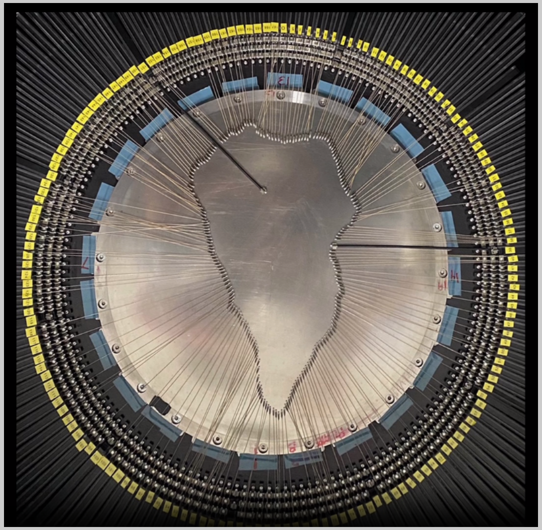
Massive stars and large spectroscopic surveys

But WEAVE and 4MOST are coming to complete (and improve) our view of Galactic massive stars!

WEAVE

	MOS fibres	Mini-IFUs (20)	LIFU
Diameter of field over which deployable (deg)	2.0	2.0	On-axis
Diameter of individual fibres (arcsec)	1.3	1.3	2.6
IFU field of view (arcsec)	-	11 x 12	90 x 78
Fibres per IFU (and filling factor)	-	37 (0.50)	547 (0.55)
Minimum separation on sky (arcsec)	60	60	-
Tumbler position (deg)	0 or 180	180	90
Configuration time (minutes)	55	<20	~ 1
Commissioning status	Ongoing	Ongoing	Complete
When available in open time	Not yet	Not yet	2023B

Three observing modes: **MOS** (multi-object spectroscopy), **mIFU** (mini integral-field units) and **LIFU** (large integral-field unit)

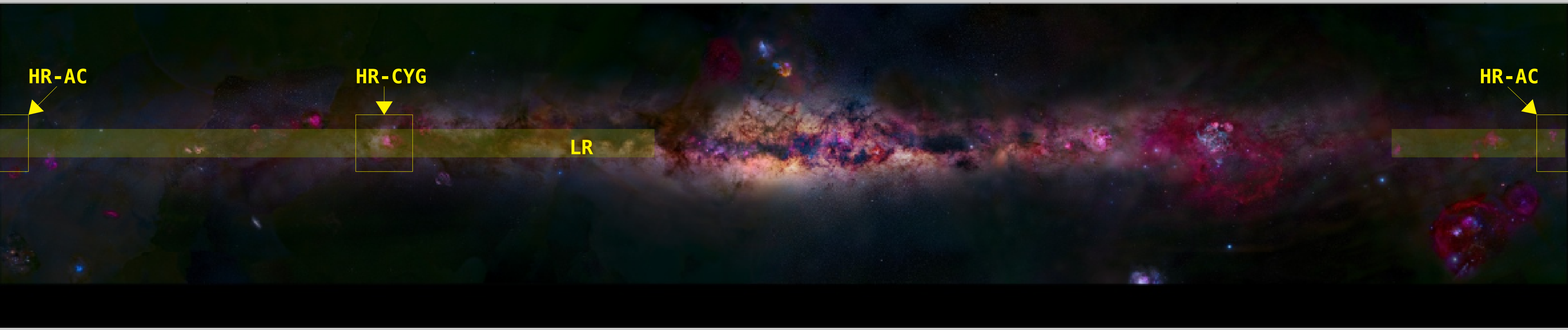


Mounted in June 2022 on the 4.2-m William Herschel Telescope, WEAVE is the **new wide-field multi-object spectroscopic** facility

	Low-resolution		High-resolution		
	Blue arm	Red arm	Blue arm		Red arm
Wavelength range (A)	3660-6060	5790-9590	4040-4650	4730-5450	5950-6850
Inter-CCD gap (A)	5491-5539	7590-7669	4525-4536	5302-5315	6412-6431
Spec. resolution for MOS, mIFUs	5000	5000	20000	20000	20000
Spec. resolution for LIFU	2500	2500	10000	10000	10000
Scale (A pixel^{-1})	0.30	0.48	0.076	0.090	0.11
WHT/WEAVE throughput (expected)	~ 0.25		~ 0.15 to 0.20		

Dual-arm (blue + red) spectrograph housed on one Nasmyth platform. It offers two possibles resolutions 5000 and 20000.

Stellar, Circumstellar and Interstellar Physics



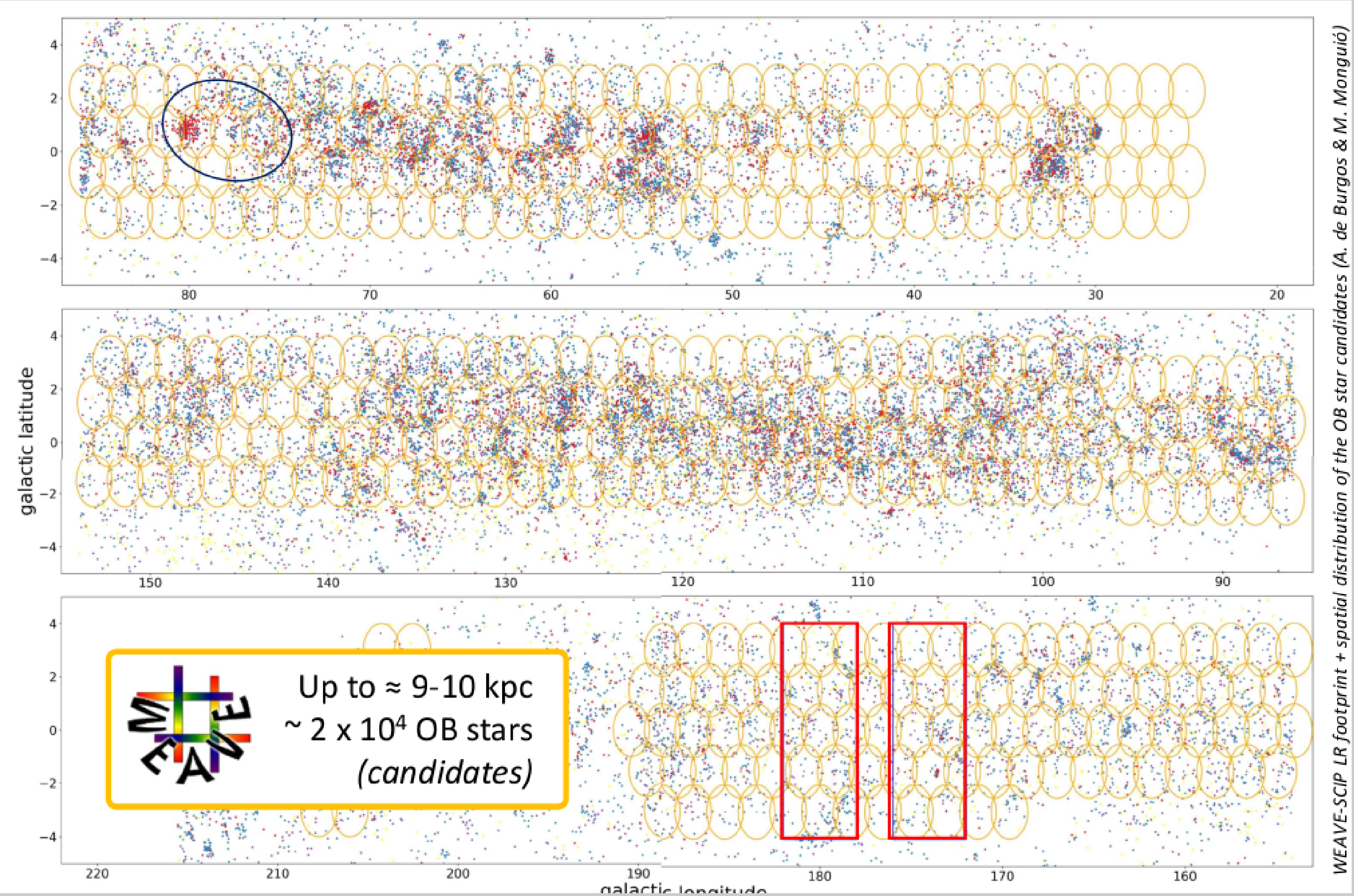
The SCIP program (**PI Janet Drew**) is divided into three components:

- a **LR survey (J. Drew) covering the northern Galactic plane:** 488000 fib/hour - 410 field centres, each to be observed once
- **two HR components** covering the **Anticenter (M. Monguió & Marc del Alcázar) and the Cygnus-X region** (**A. Herrero & S.R. Berlanas)**: 280000 fib/hour ~213 tiles, covering a much smaller sky areas but with many repeats

In addition there are **4 MOS-SV programs** associated to SCIP (**plus 1 mIFU and 1 LIFU programs**)

Aims
- Large stellar samples for young/old extremes of stellar evolution
- Interstellar medium
- 3D extinction, law variation

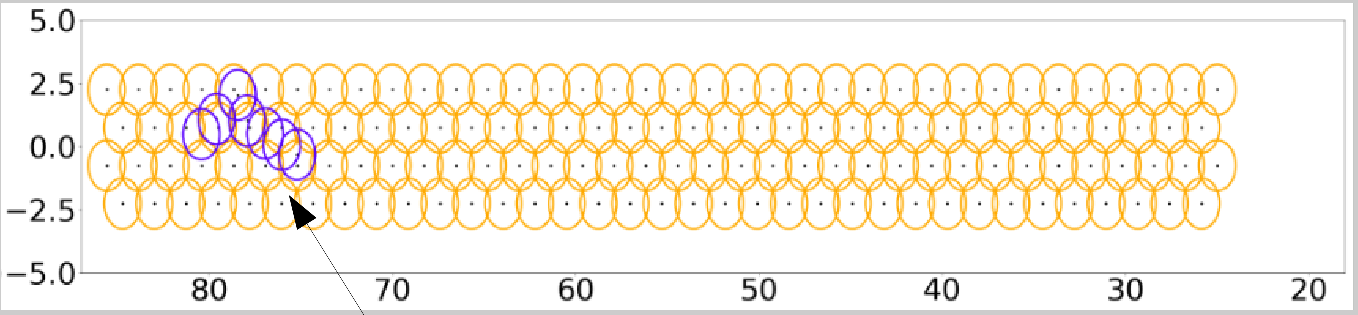
SCIP-LR-OB



Includes different type of targets:

- BA stars as Galactic probes
- **OB stars** to explore e.g. GAP close of the ZAMS
- Stellar evolution: OB stars BA, RSG, YSO, WD/IB, Be, CEP
- Poor seeing → PNe (LIFU)

SCIP-HR CYG



much smaller number of field centres,
with many repeats

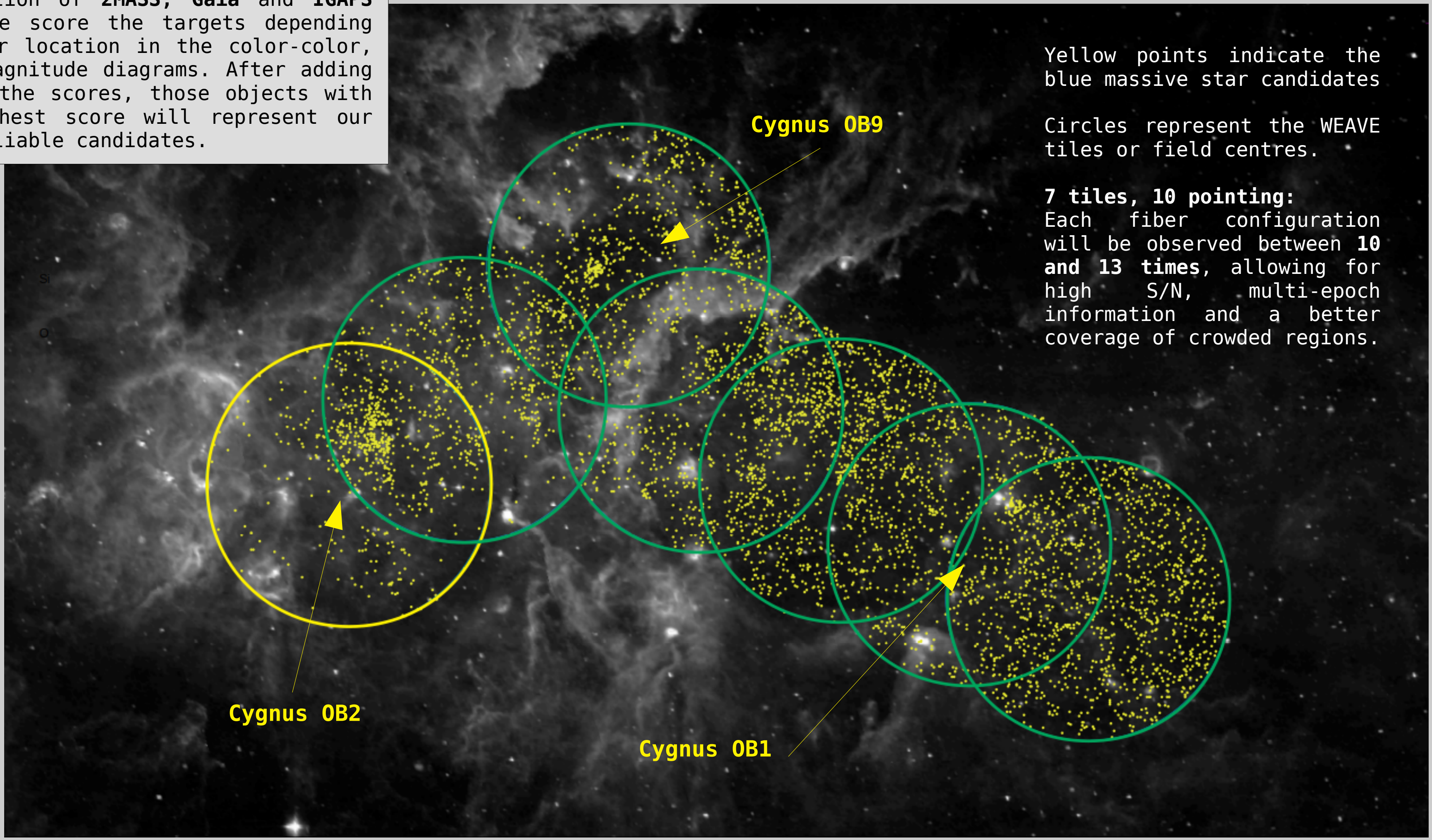
HR Cygnus-X (mainly OB stars)

- Obtain accurate **abundances and spatial abundance patterns** for OB stars in the region (*extending the work by Berlanas 2018b*)
- Obtain **rotational velocities** and their distributions, checking that obtained in previous works (*Berlanas 2020)* for Cygnus OB2
- Determine binary fractions and **stellar multiplicity** (multi-epoch observations!)
- Detect **peculiar objects** (like possible GW progenitors or extreme BSGs and study them in detail)
- Determine accurate **stellar parameters**, particularly gravity, improving those obtained from the LR survey and allowing more precise radii and masses with the help of **Gaia DR3** data (and forthcoming releases)
- Explore the **kinematical and dynamical** status of the stars in the region (*see Quintana et al. 2021,2022*)

SCIP-HR CYG

Our selection criteria are based on a combination of **2MASS, Gaia** and **IGAPS** data. We score the targets depending on their location in the color-color, color-magnitude diagrams. After adding up all the scores, those objects with the highest score will represent our most reliable candidates.

OB candidates



We will include **BAF** stars (age extensión, ZAMS anchor point, kinematics, dynamics, structure), **BA** stars (TAMS characteristics), **PMS** and **YSO** (kinematics, star formation activity), **ISM** (abundances, kinematics), Individual targets (**Cepheids, WDs, RSGs**)

Expected early science

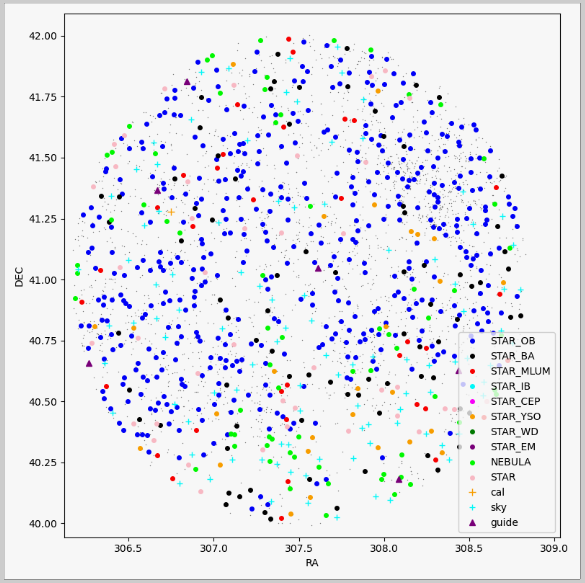
- **SV program focused on OB stars** (1LR+2HR MOS exposures in the same field centre: either Cygnus OB2 or the Rosette nebula)

→ OB selection criteria

→ saturation limits

→ LR vs HR (~30% OB candidates in common)

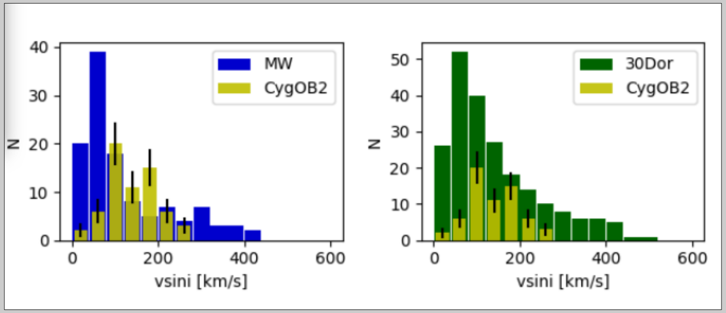
→ Fine-tuning of classification and analysis pipelines



- **Early science**

→ if Cygnus OB2: vsini distribution (lack of fast rotators?)

→ if Rossete: HRD of the complete OB star+YSO population

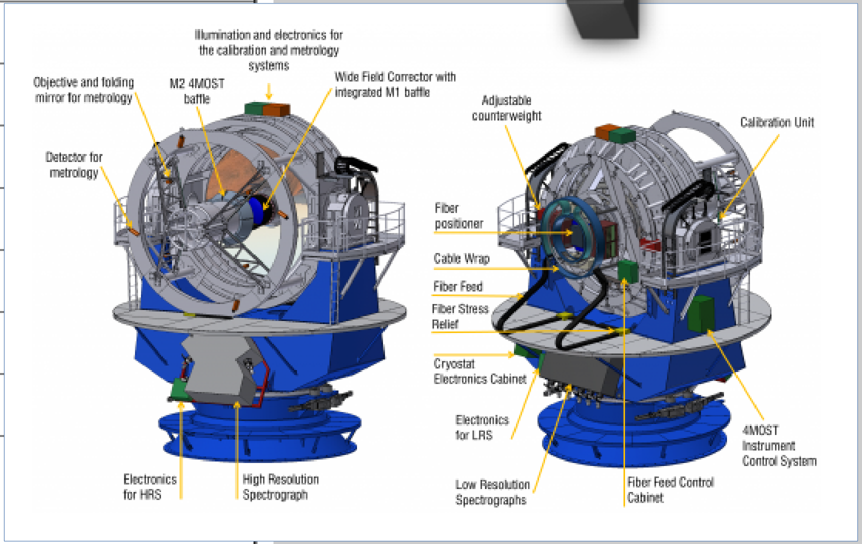


- **Commissioning test data**

4MOST will be a fibre-fed spectroscopic facility **on the VISTA telescope** with a large field-of-view to survey a significant fraction of the southern sky in a few years. 4MOST will have a high multiplex being able **to simultaneously obtain spectra for ~2400 objects**.

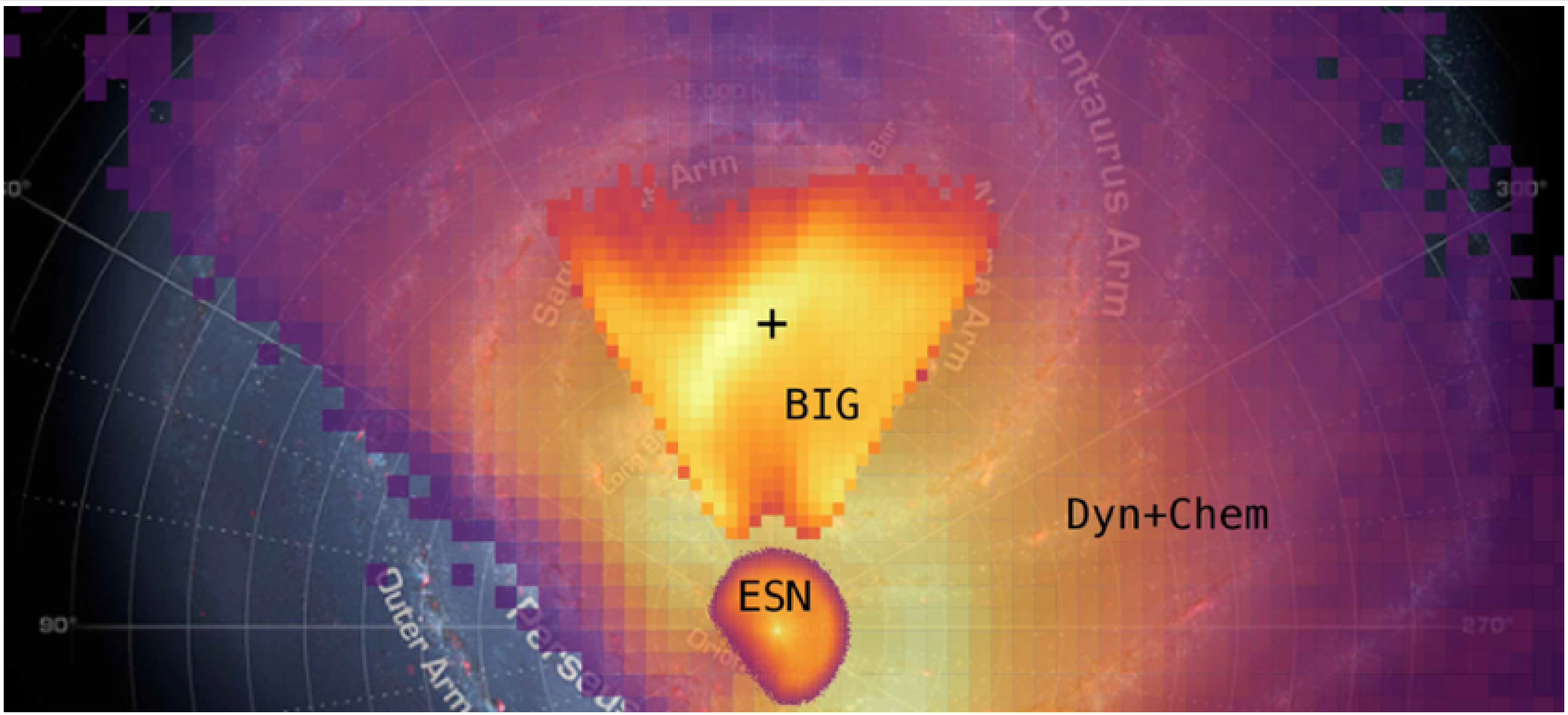
Baseline Specification

Requirement	**Baseline Specification**
Field-of-View in hexagon	4.1 degree^2
Fibre multiplex per pointing	2436
Smallest target separation	<17″
Low-Resolution Spectrographs (LRS)	
Fibre multiplex	1624
Spectral resolution	R>4000–7800
Wavelength coverage	370–950 nm
High-Resolution Spectrographs (HRS)	
Fibre multiplex	812
Spectral resolution	R>18,500
Wavelength coverage	392.6–435.5, 516–573 & 610–679 nm



4MOST Milky Way Disk and Bulge Low-Resolution Survey

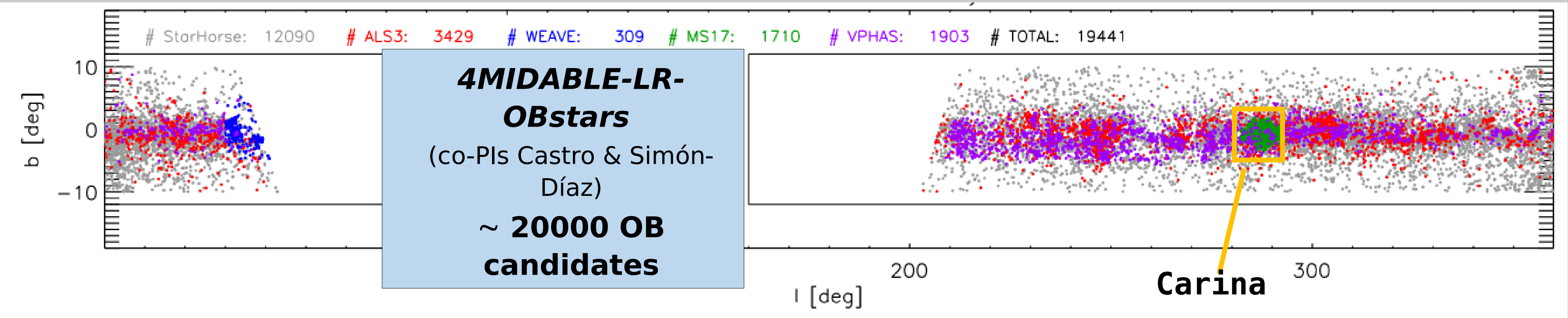
4MIDABLE-LR will provide the largest spectroscopic follow-up of Gaia (adding key information to the Gaia RVS) and thereby allow us to view the Milky Way as a whole stellar system by providing a detailed 3D chrono-chemokinematical map of the Milky Way stellar disk and bar-bulge (Project PIs Cristina Chiappini & Ivan Minchev)



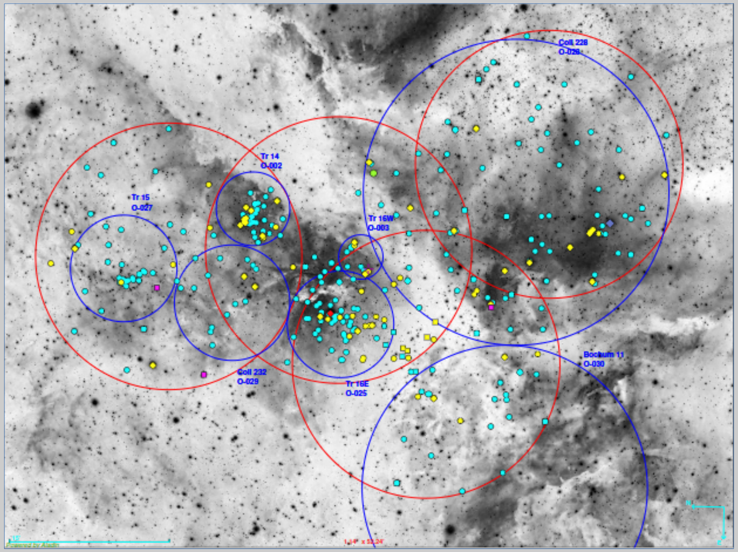
Credit: 4MIDABLE-LR-Team

4MIDABLE-LR-OB

OB sample included in 4MIDABLE-LR sub-survey, Co-IPs: S. Simón-Díaz & N. Castro



4MIDABLE-LR-OBstars
(co-PIs Castro & Simón-Díaz)
~ 20000 OB candidates



Gaia-ESO Survey: massive stars in the Carina Nebula
I. A new census of OB stars*

Gaia-ESO Survey: massive stars in the Carina Nebula
II. The spectroscopic analysis of the O-star population

The MEIGAS project

The MEIGAS project (PI S.R. Berlanas)**: *A multi-wavelength exploration of star-forming regions, young clusters and associations***

Conduct comprehensive studies in the major Galactic (and extragalactic) star-forming regions, young clusters and OB associations.

Gaia + spectroscopic data from large spectroscopic surveys (e.g., GES, WEAVE, 4MOST, XSHOOTU, BLOeM) + dedicated observing proposals at different wavelength ranges (IR, UV, gamma and X-ray regimes)

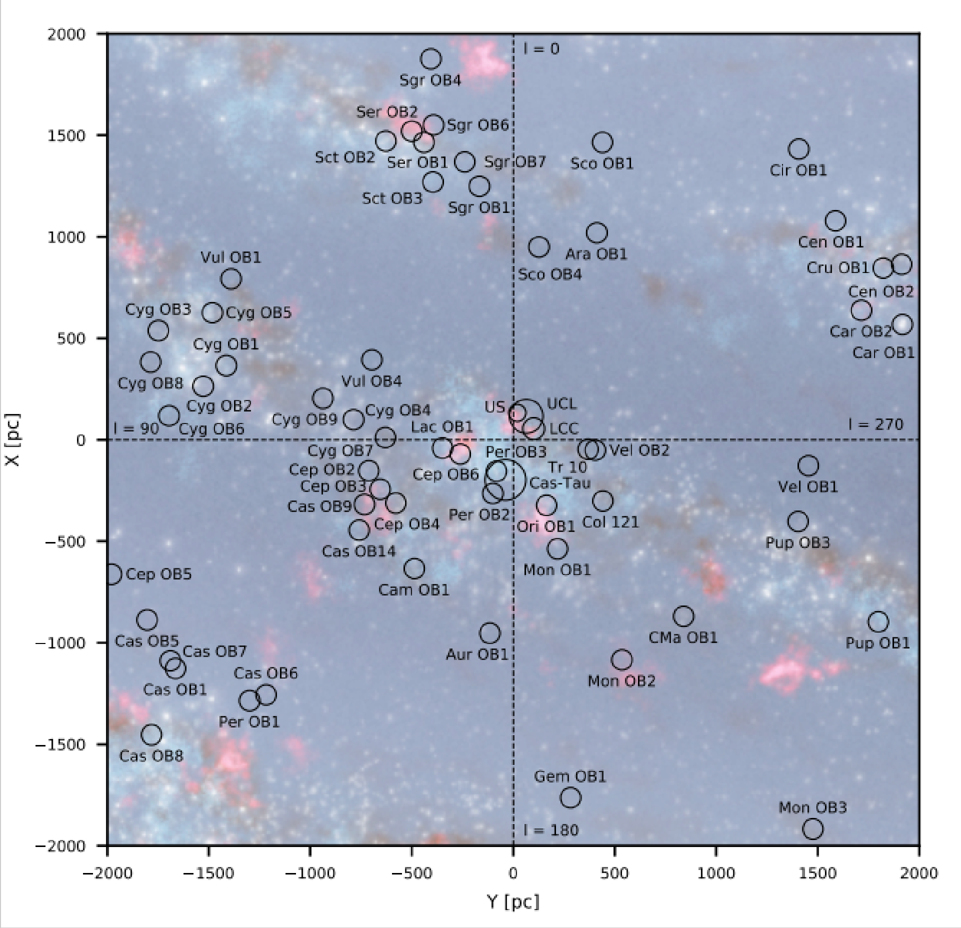
Achieve crucial and complementary information to adequately characterize these regions and their stellar content, something imperative not only to complete their stellar census but to improve our understanding of star formation and poorly known evolutionary pathways of massive stars.

I. The universality of the vsini distribution of massive OB stars

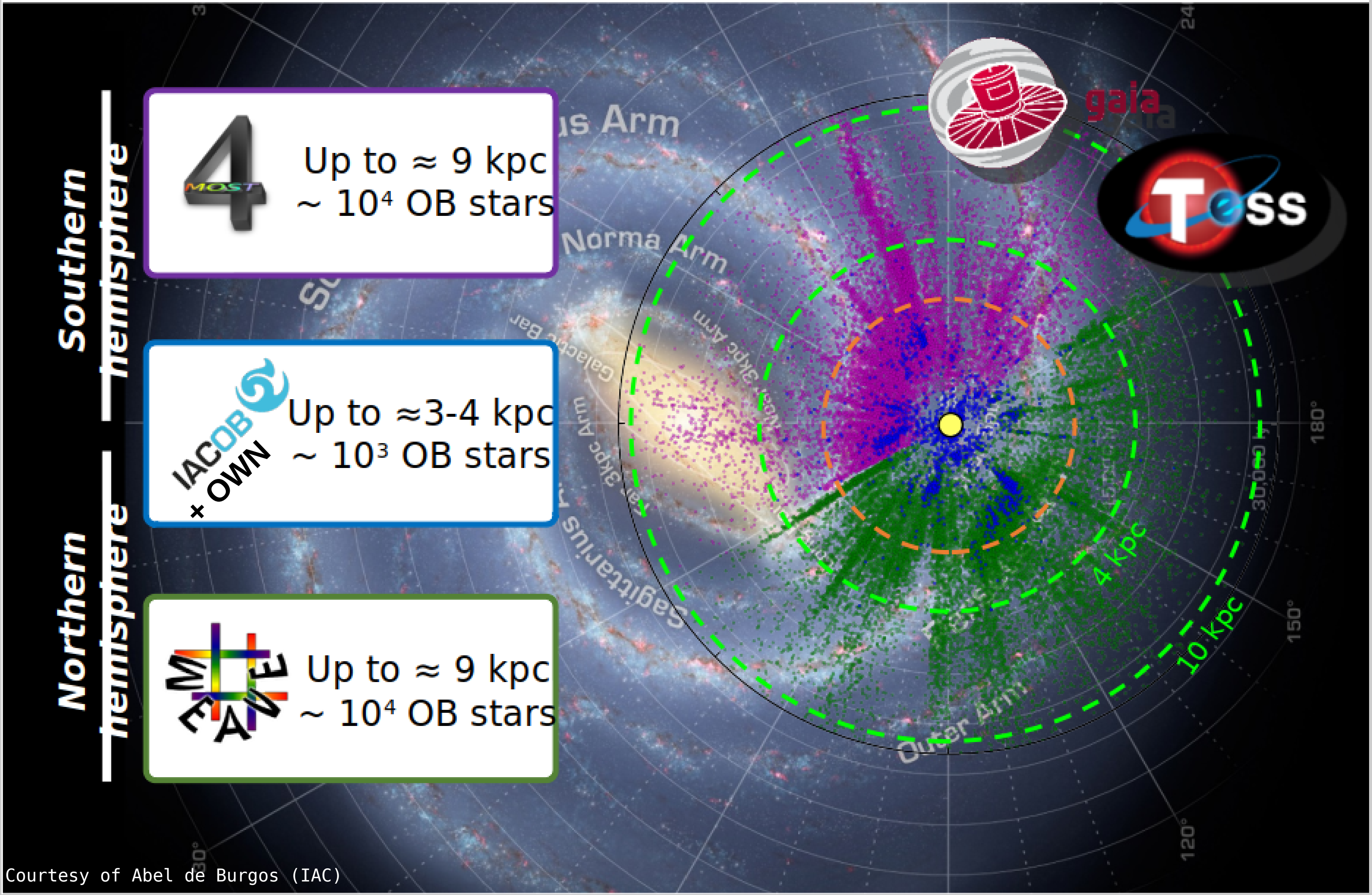
Optical and IR spectroscopy in the ***Cygnus-X complex*** and the ***Carina Nebula*** (WEAVE, 4MOST + confirmed own IR observations) + **SMC** and **LMC** (X-ShootU, BLOeM)

The MEIGAS project

MEIGAS is a long-term large program that aims to perform deeper explorations even in the less known Galactic OB associations and extend research to extragalactic regions



Synergies



Southern hemisphere
Up to ≈ 9 kpc
~ 10⁴ OB stars
IACOB + OWN
Up to ≈3-4 kpc
~ 10³ OB stars
Northern hemisphere
Up to ≈ 9 kpc
~ 10⁴ OB stars
Norma Arm
Sagittarius Arm
Outer Arm
Galactic Bar
4 kpc
10 kpc
gaia
TESS
Courtesy of Abel de Burgos (IAC)

Thanks for your attention!

TOSCA 2024

Questions -> srberlan@iac.es