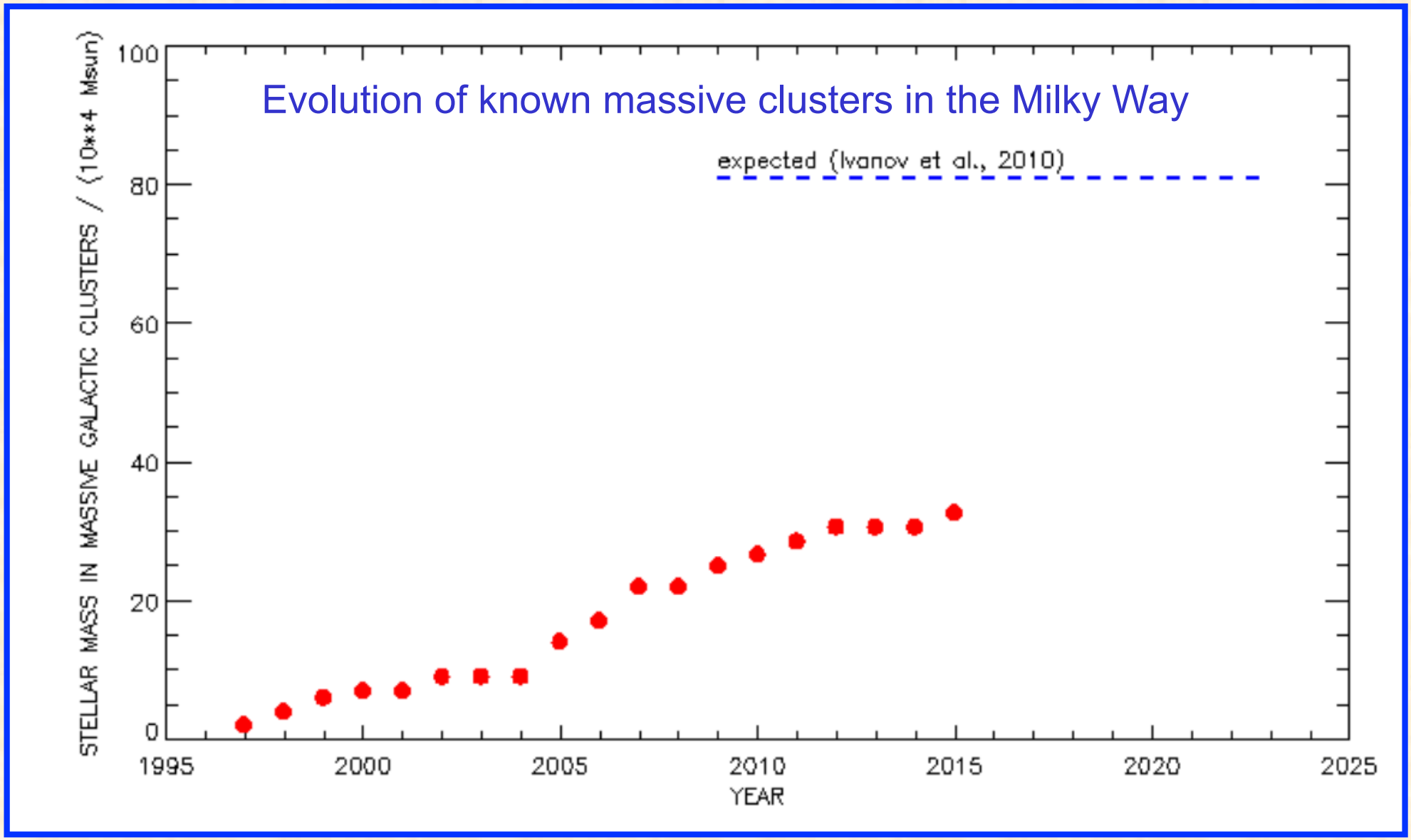
Obscured massive stars in the Milky Way with EMIR



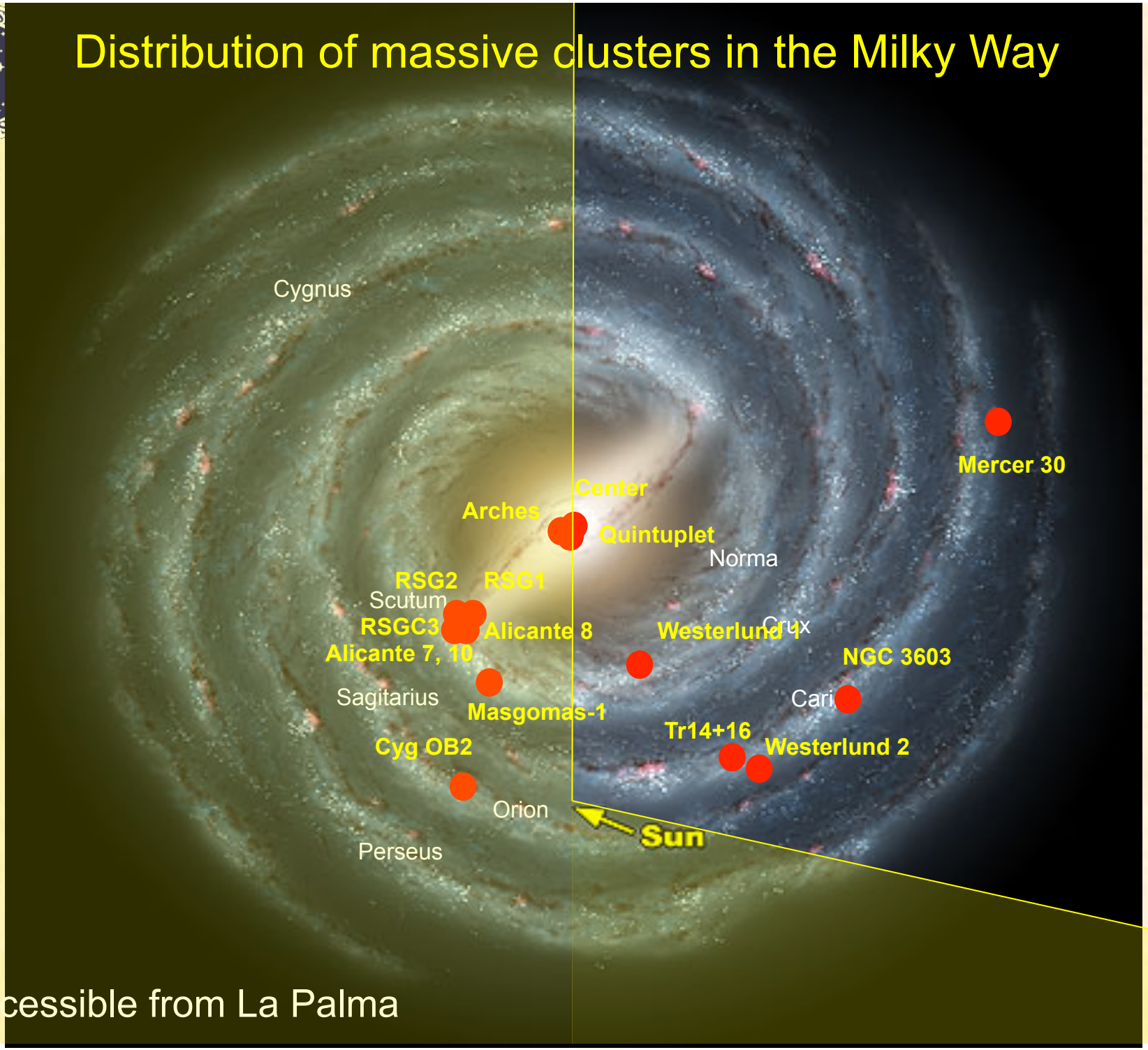
Artemio Herrero (IAC)
Klaus Rübke (IAC)
S. Ramírez Alegría
M. Garcia (CAB)
L. Patrick (IAC)
A. Marín Franch (CEFCA)

RIA-EMIR Workshop
Cádiz, November 24th, 2017

Massive clusters in the Milky Way



Distribution of massive clusters in the Milky Way



Accessible from La Palma

MASGOMAS

(**MA**ssive **S**tars in **G**alactic **O**bscured **MA**ssive cluster**S**)

A project initially started as a preparation for EMIR@GTC

Search for OB obscured clusters

Identify OB stars for follow-up spectroscopy

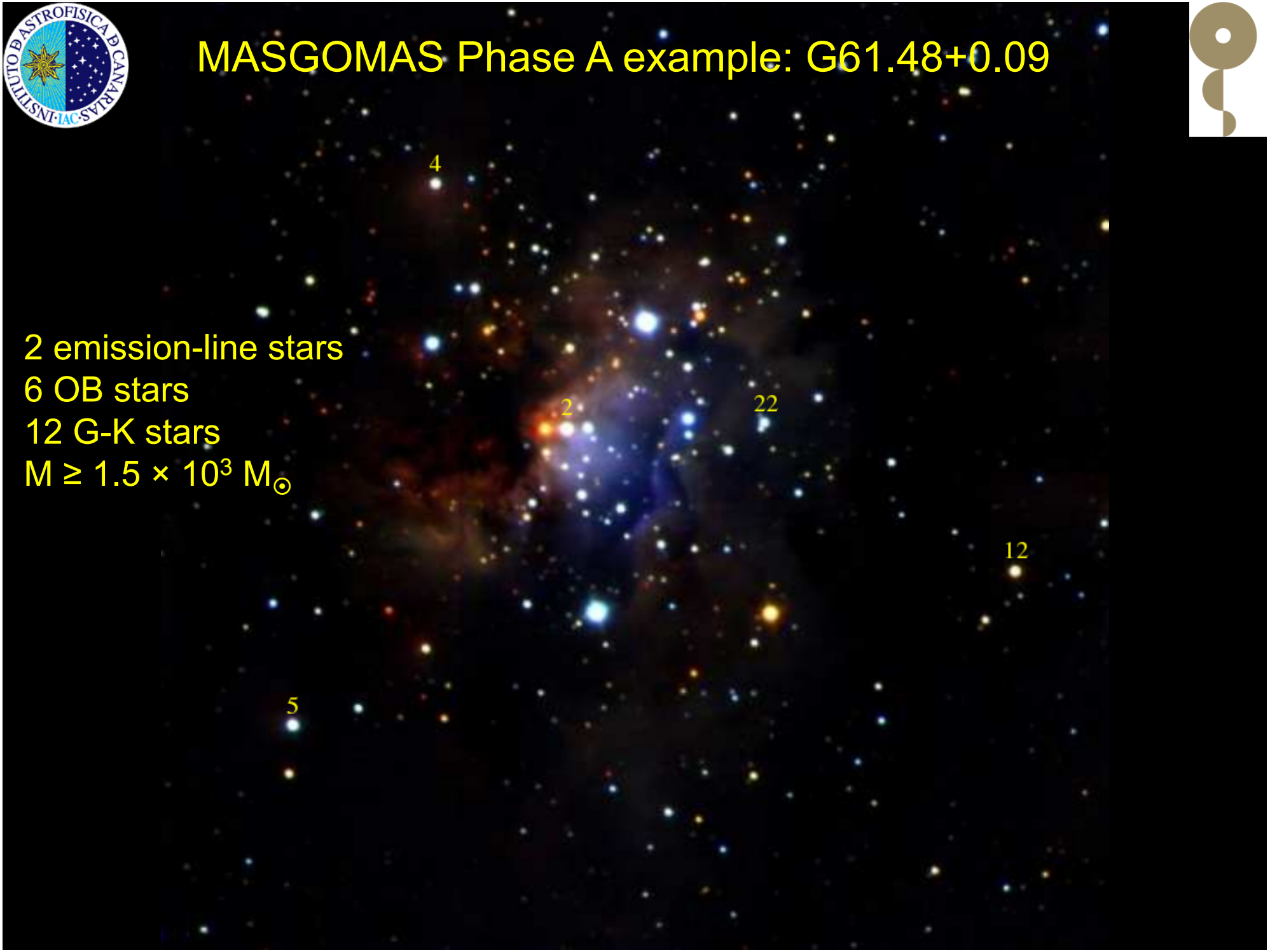
•Phase A: Selection by appearance from the 2MASS catalogue

•Phase B: Selection based on 2MASS photometry and color cuts to search for overdensities of OB star candidates

•Phase C: Automatic search for overdensities with AUTOPOP (friends of friends algorithm)

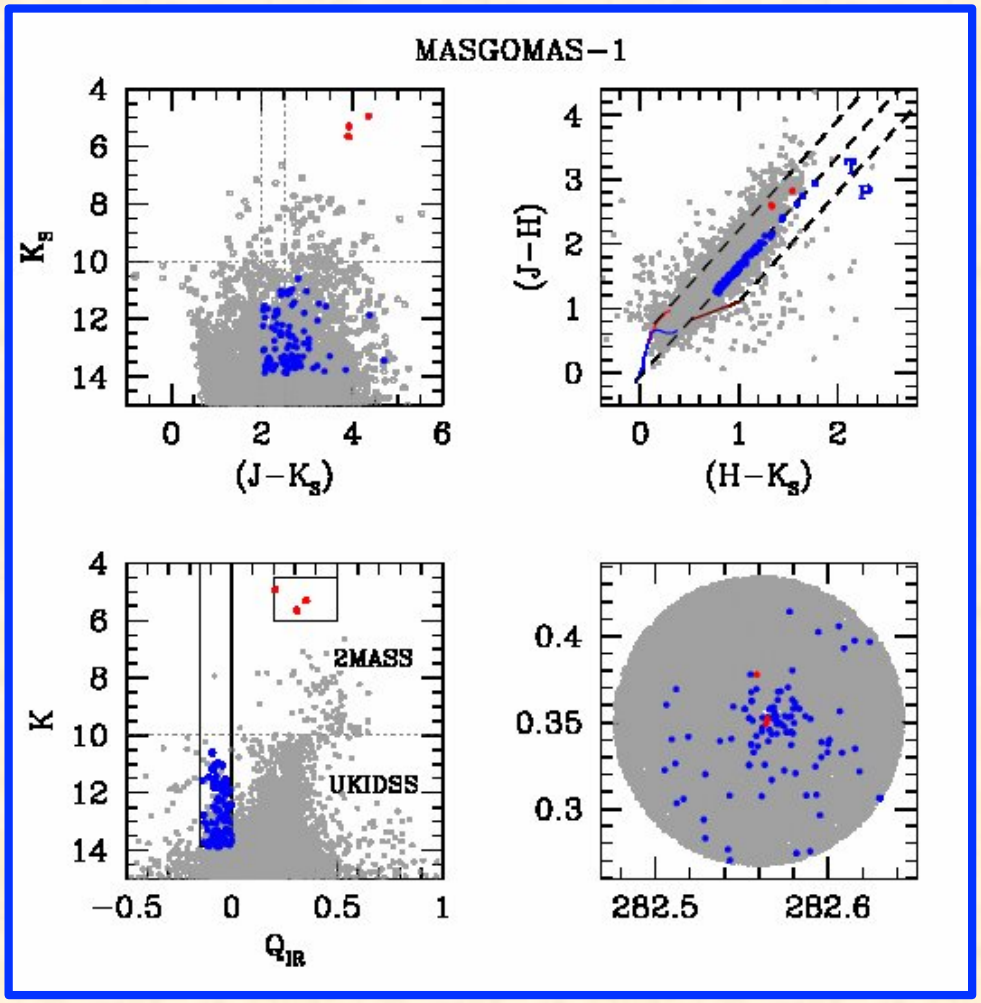
Cluster	Phase	Characteristic	Reference	Notes
G61.48+0.09	A	Known clusters	Marín-Franch et al. 2009	
NGC 7538			Puga et al. 2010	
Sh2-152			Ramírez Alegría et al. 2011	
MASGOMAS–1	B	Automatic star selection;	Ramírez Alegría et al. 2012	$1.94 \times 10^4 M_\odot$
MASGOMAS–4		cluster candidates	Ramírez Alegría et al. 2014	$2.19 \times 10^3 M_\odot$
		selected by eye.		
MASGOMAS–6	C	Automatic cluster	Ramírez Alegría et al., in prep.	Presented in this work.
MASGOMAS–10		candidate selection.	Rübke et al., in prep.	Presented in this work.

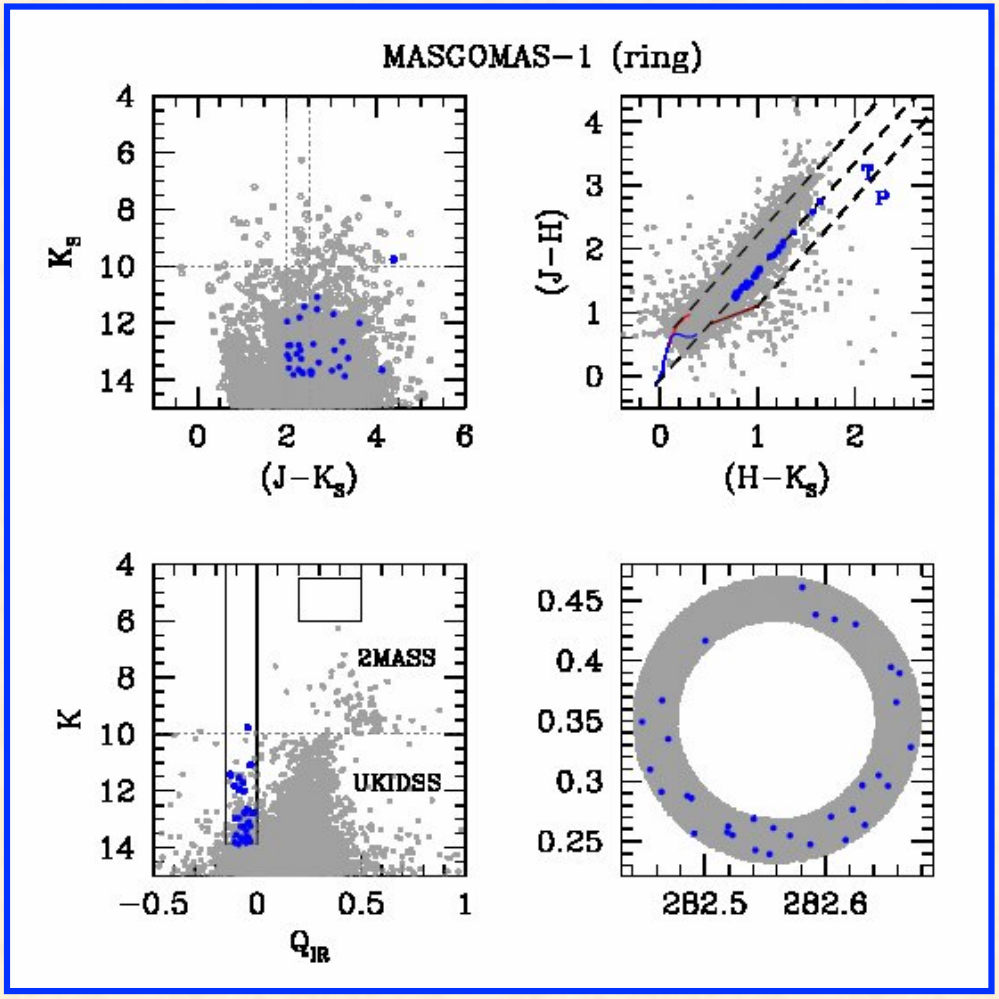
MASGOMAS Phase A example: G61.48+0.09



2 emission-line stars
6 OB stars
12 G-K stars
$M \geq 1.5 \times 10^3 M_\odot$

MASGOMAS Phase B example: MASGOMAS-1

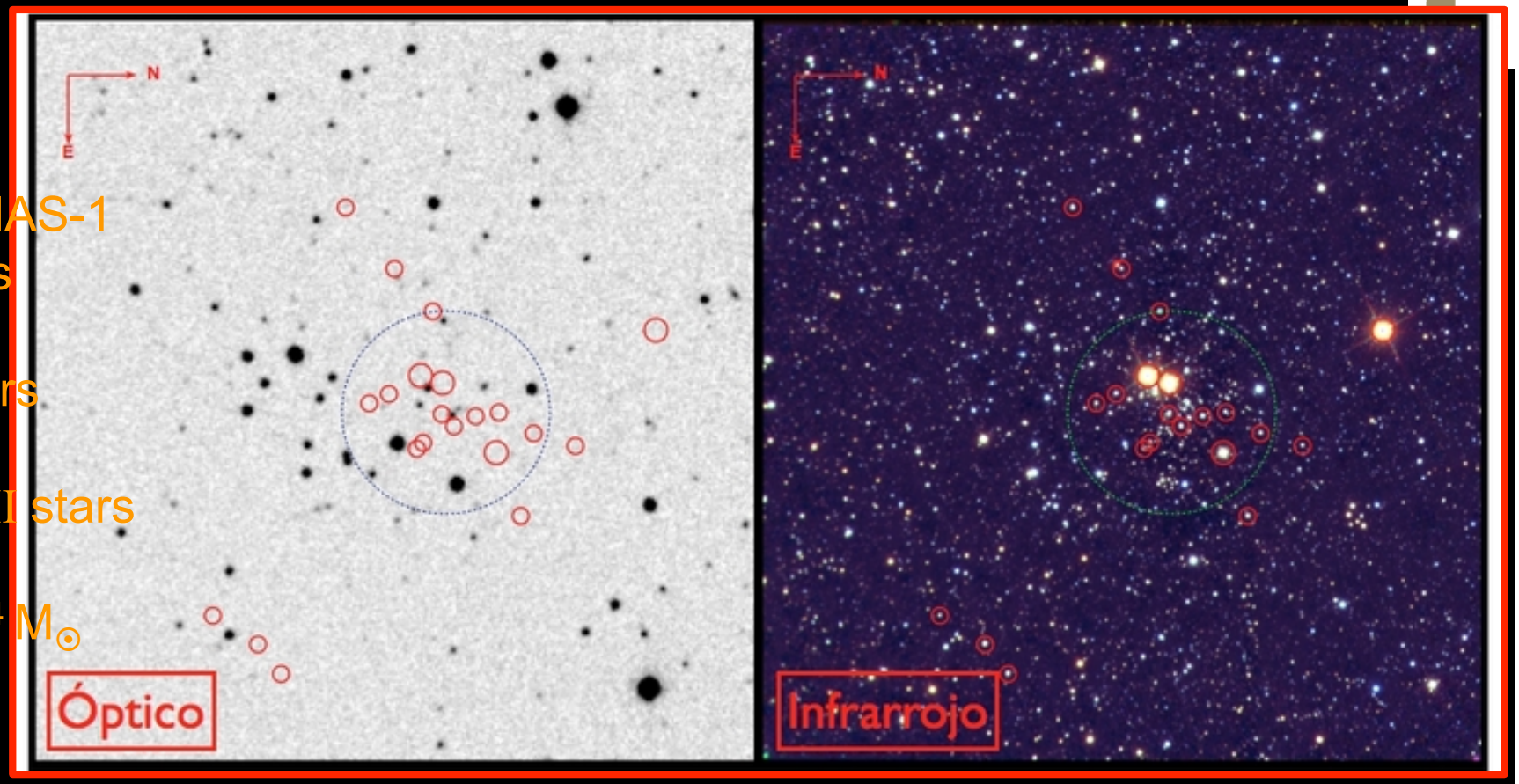


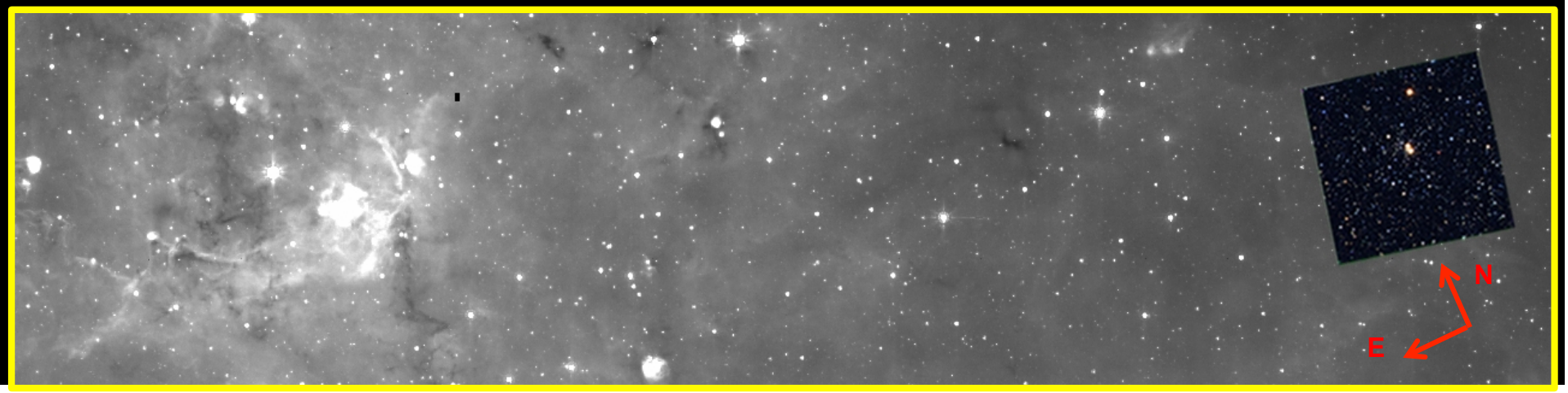


MASGOMAS Phase B example: MASGOMAS-1

MASGOMAS-1
3 M I stars
1 A I star
17 OB stars
1 A V star
6 G-K V-III stars

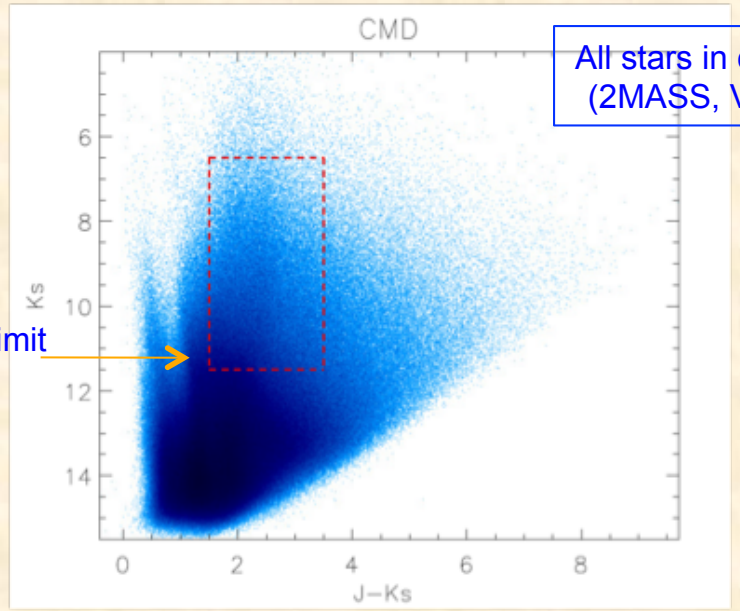
$M \geq 2 \times 10^4 M_\odot$





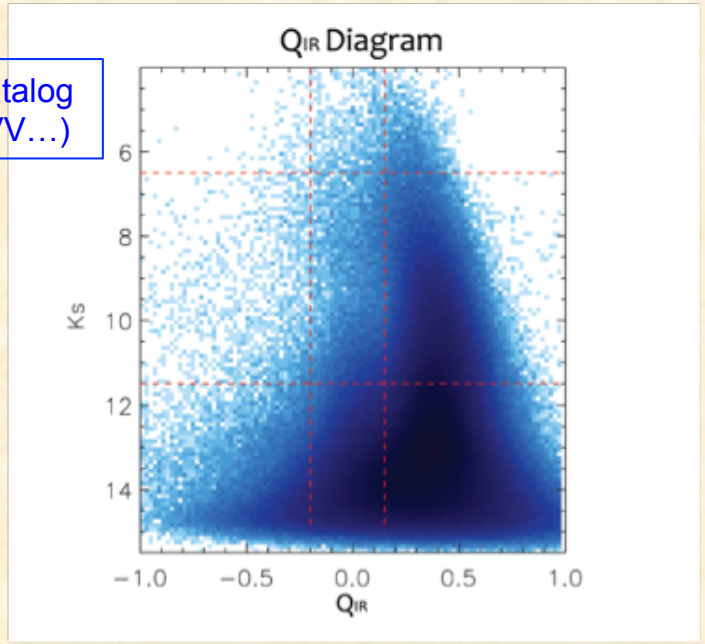
MASCA 1.0: MASGOMAS Automatic Search of Clusters Algorithm

Photometric cuts



All stars in catalog (2MASS, VVV…)

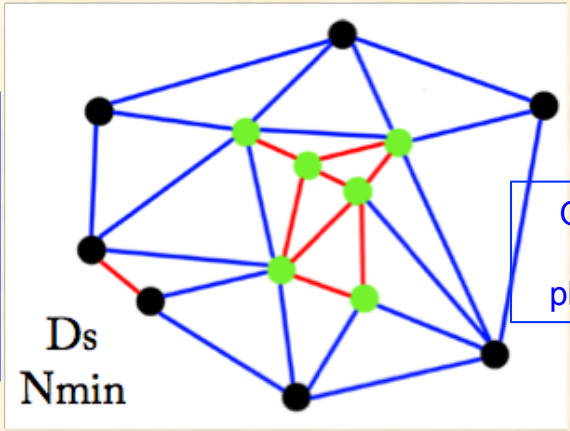
LIRIS limit



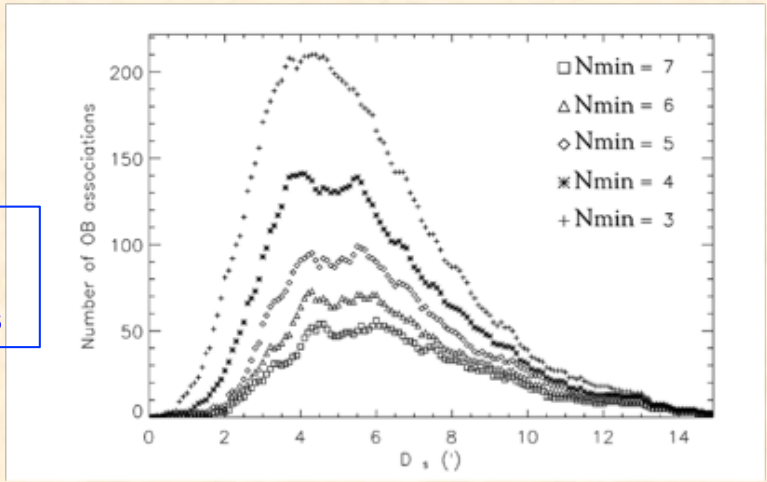
K	6.5 -11.5
J-K	1.5-3.5
Q	-0.2,0.15

Friends Of Friends Algorithm (FOFA), ex AUTOPOP (Garcia et al. 2009)

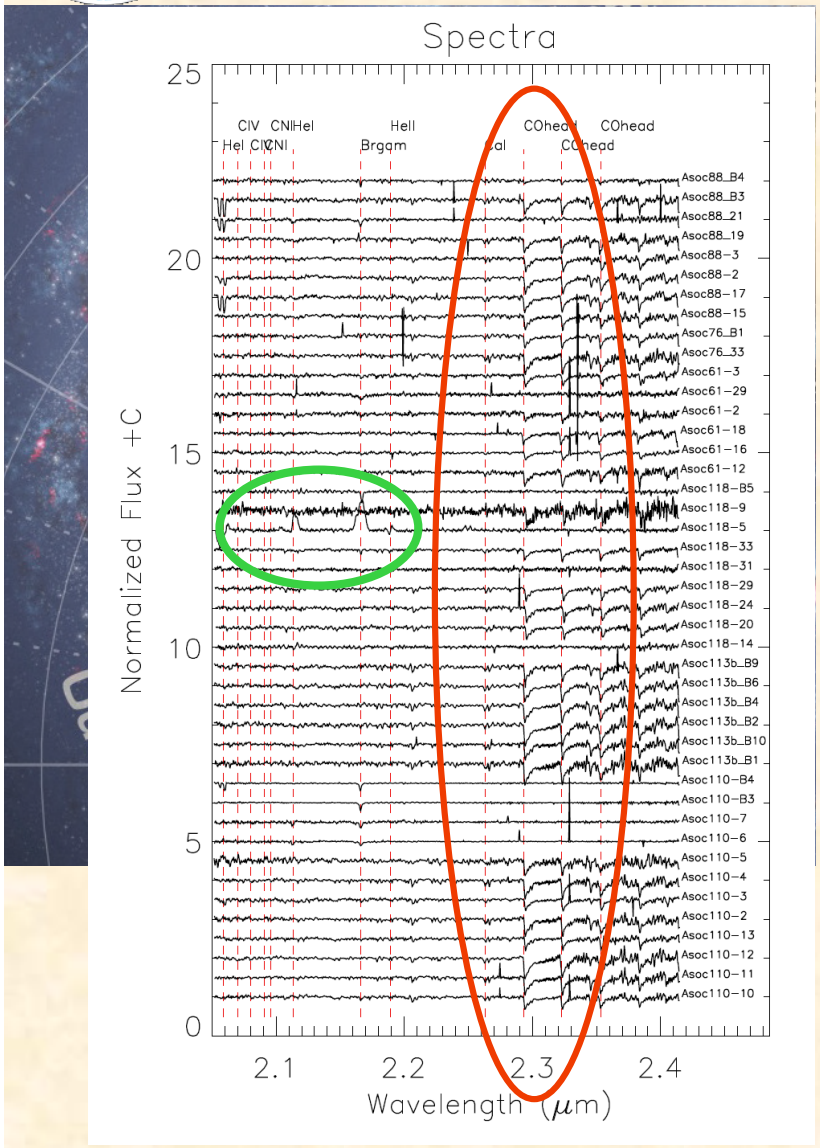
D_s and N_{min} are arbitrary parameters

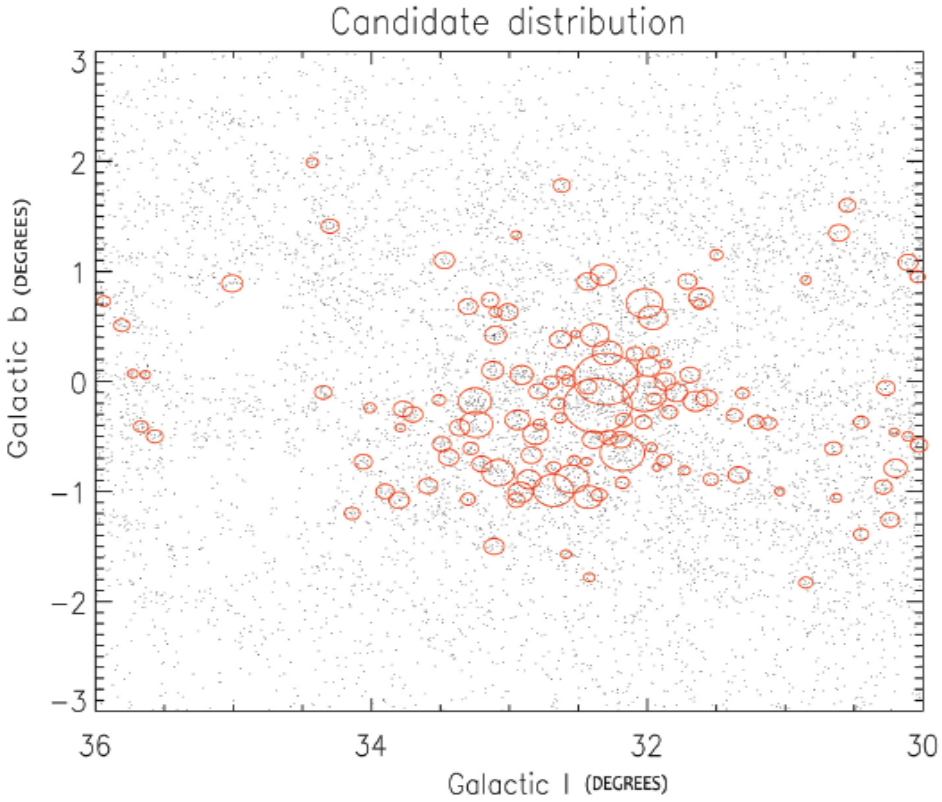


Only stars that passed the photometric cuts



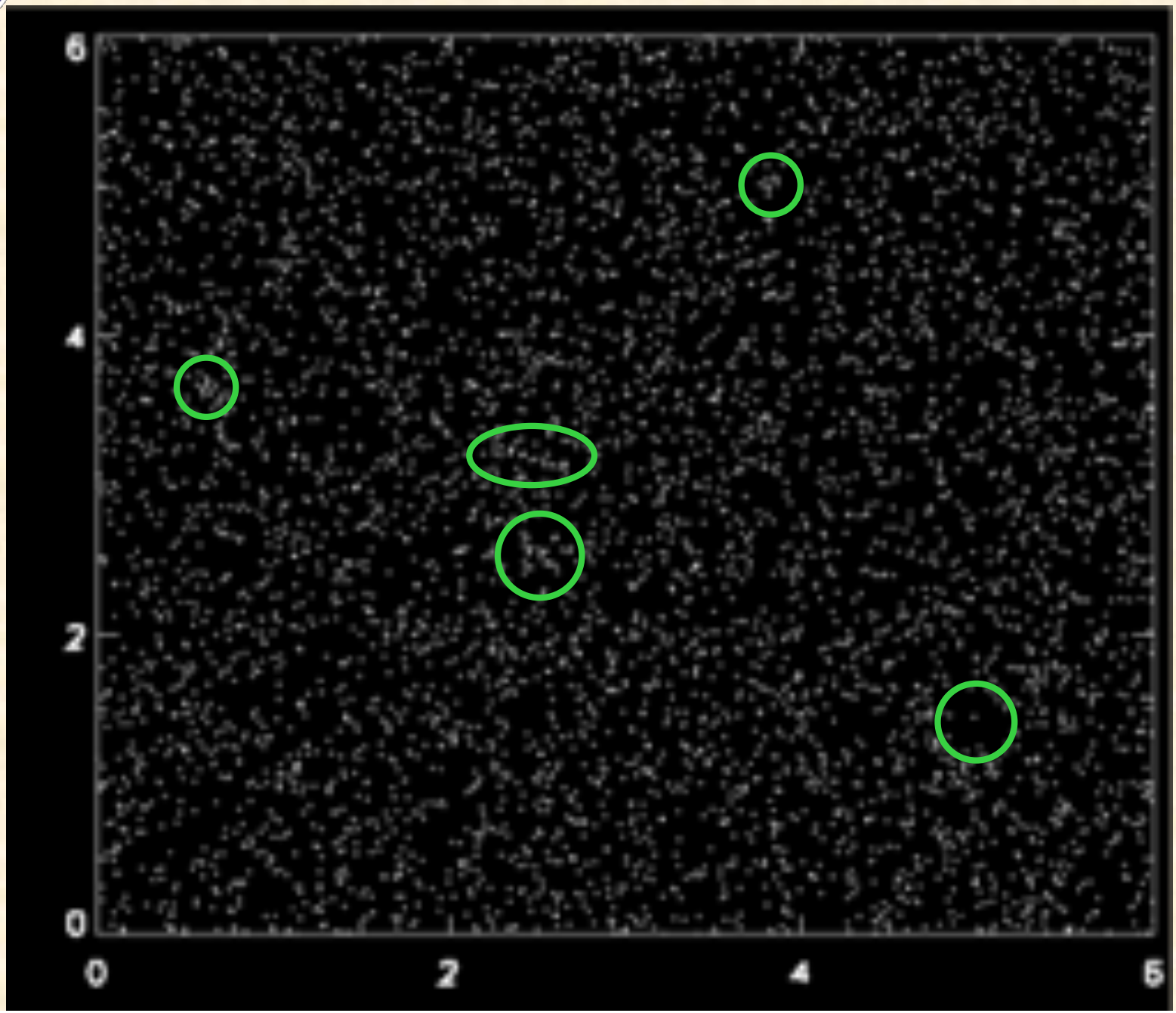
MASCA 1.0: MASGOMAS Automatic Search of Clusters Algorithm





Association candidate	l	b	Ncand	Radius["]
Assoc61	32.022	-0.111	35	577
Assoc76	32.361	-0.222	90	889
Assoc88	32.287	0.256	29	395
Assoc110	32.627	0.381	17	279
Assoc113	32.909	0.063	31	304
Assoc118	33.247	-0.183	44	430

MASCA 2.0: MASGOMAS Automatic Search of Clusters Algorithm



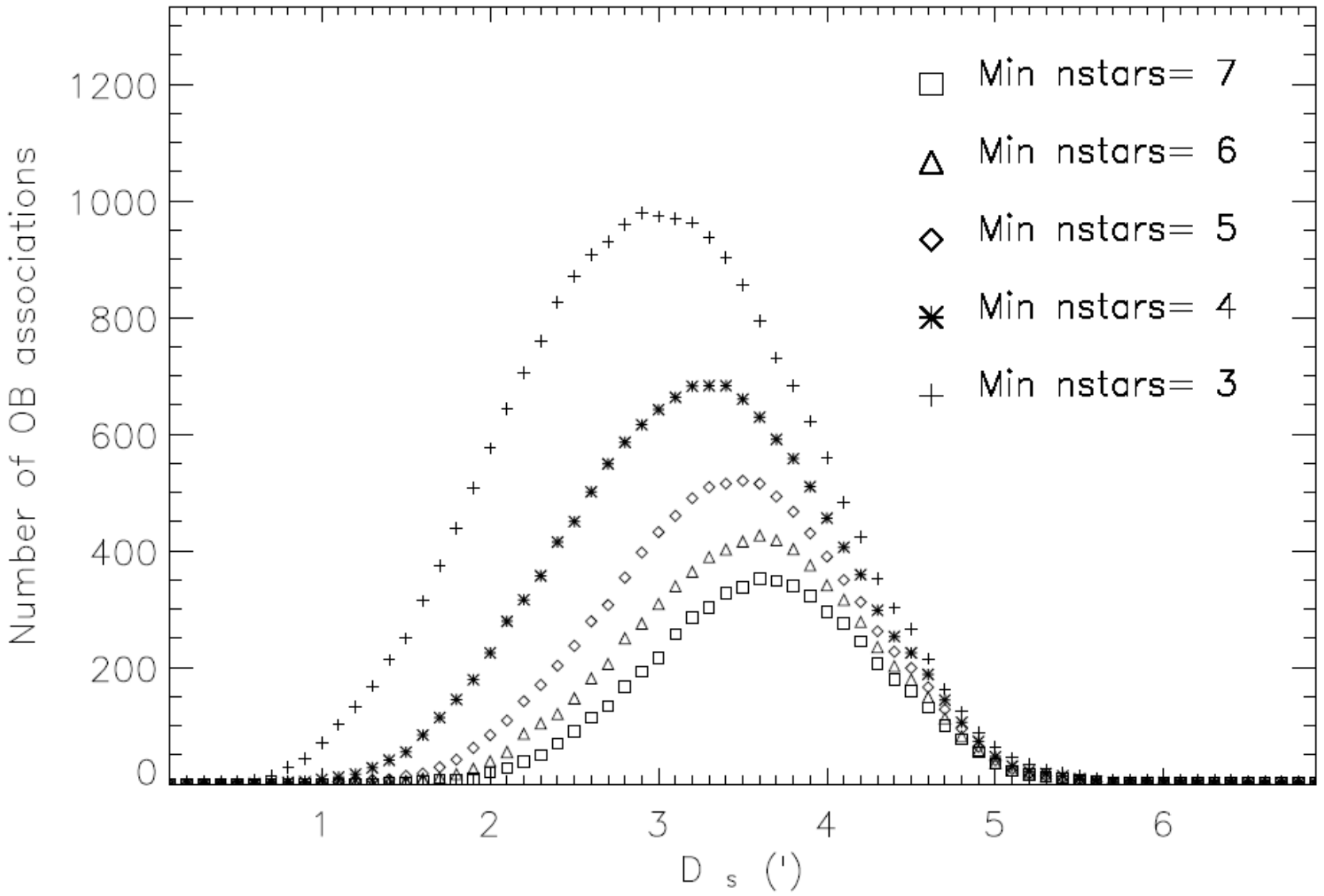
MASCA 2.0: MASGOMAS Automatic Search of Clusters Algorithm

1. Generate random fields with different stellar densities (10x for each density)
2. For a given density, search for apparent clusters with different (D_s , N_{min})
3. For each density and N_{min} determine the largest D_s for which no apparent cluster is found

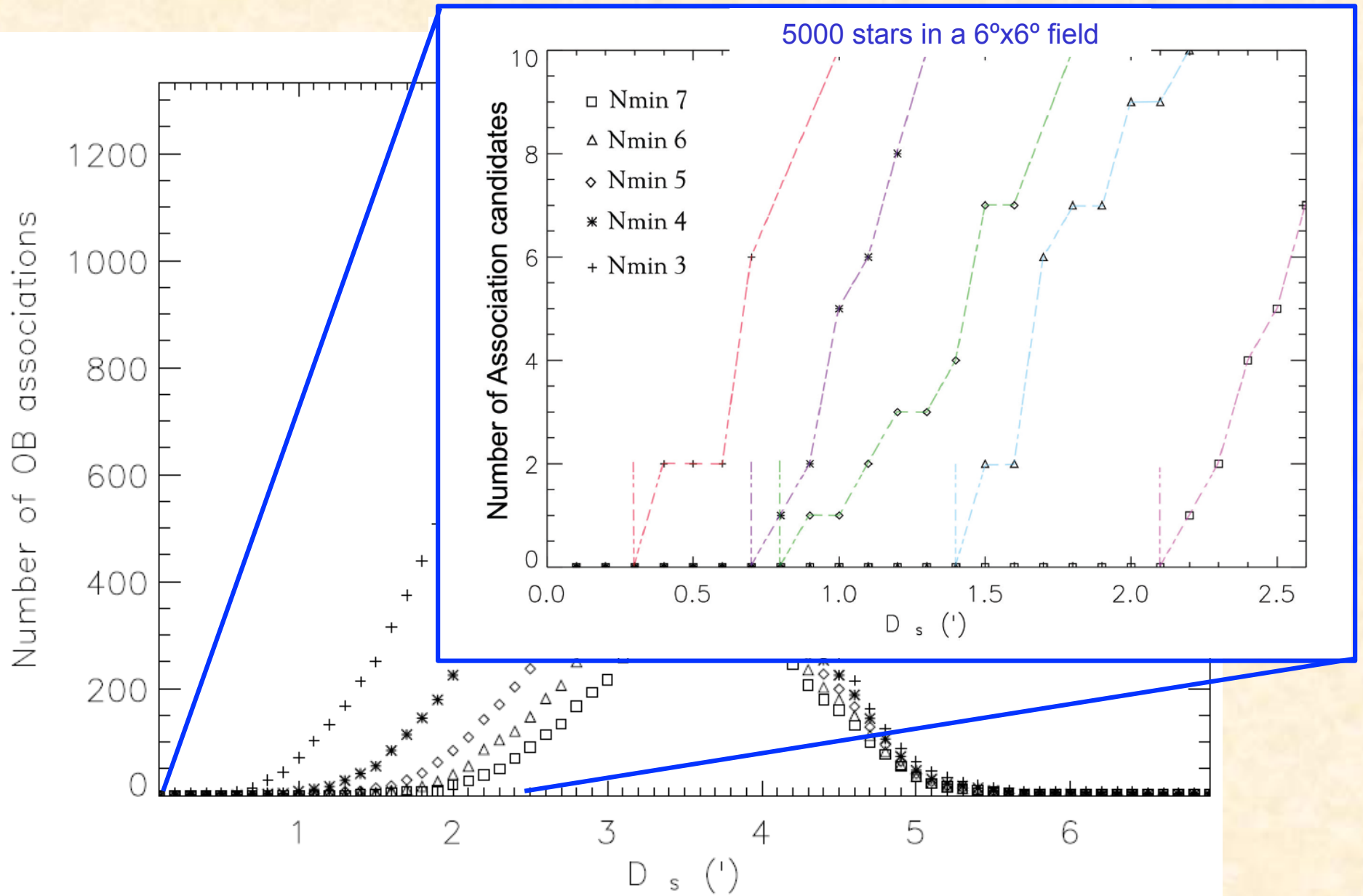
4. Determine the stellar density of the observed field
5. Use different combinations of (D_s , N_{min}) to search for cluster candidates
6. Select those candidates that appear for more than one (D_s , N_{min}) combinations

MASCA 2.0: MASGOMAS Automatic Search of Clusters Algorithm

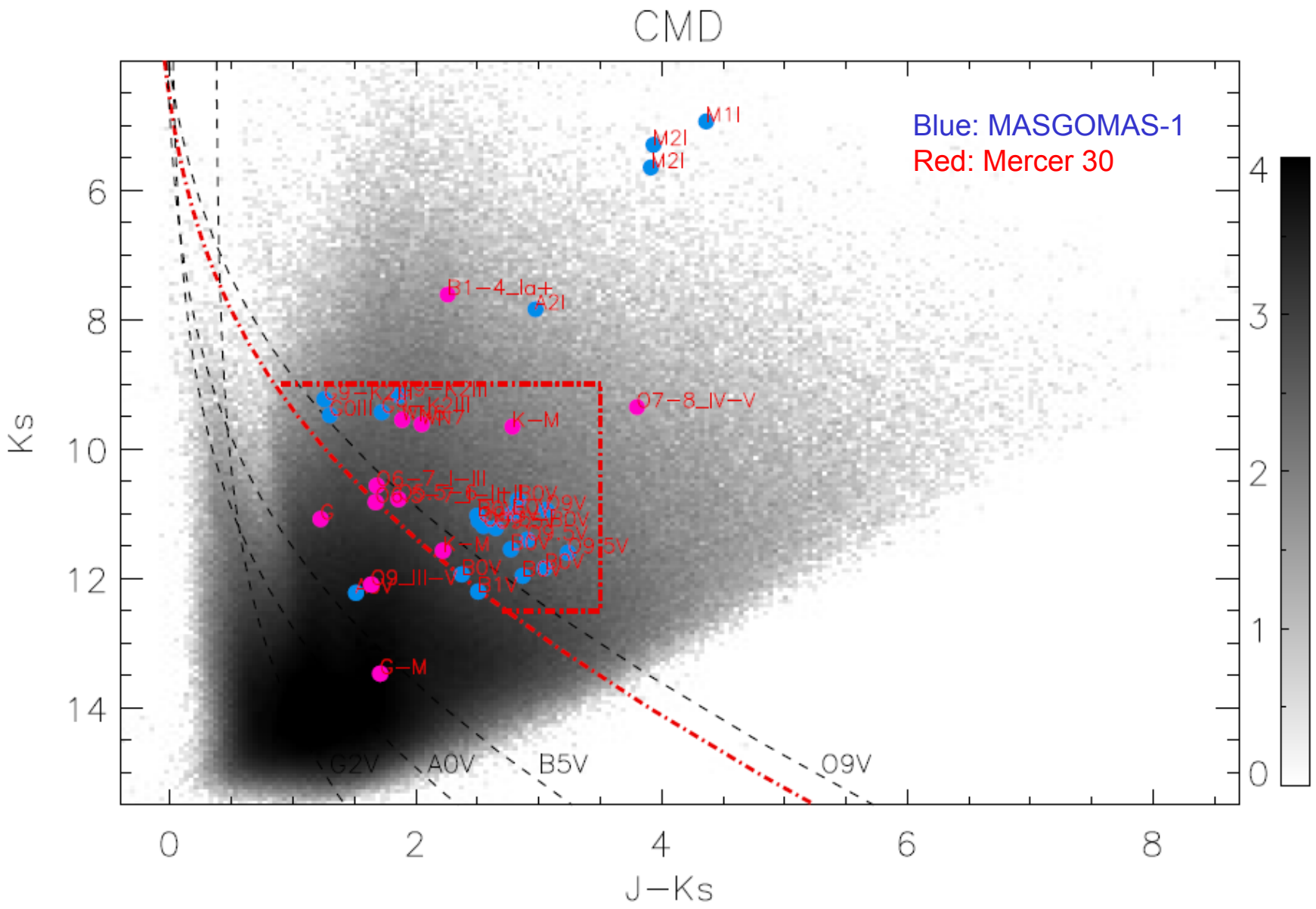
8000 stars in a 6ºx6º field



MASCA 2.0: MASGOMAS Automatic Search of Clusters Algorithm

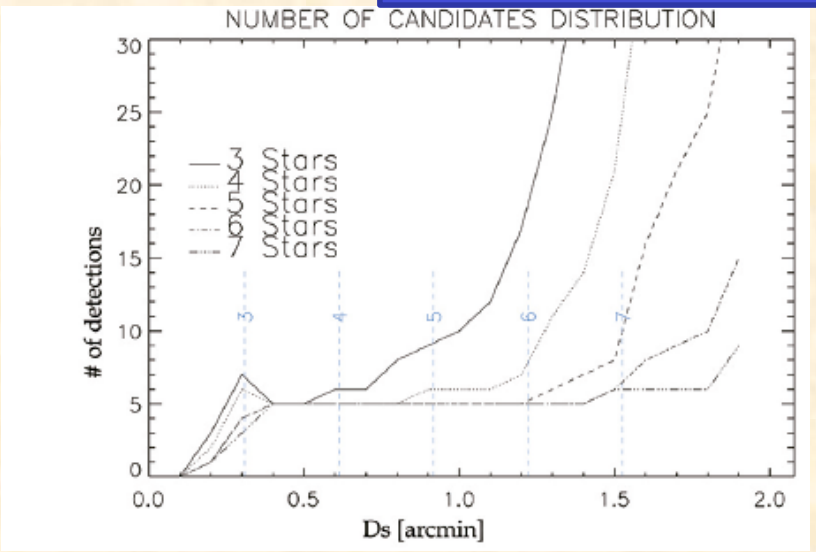


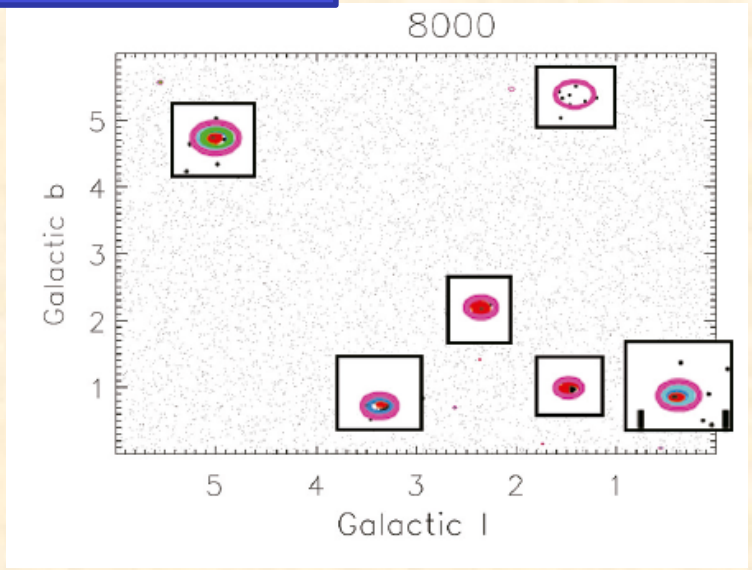
MASCA 2.0: MASGOMAS Automatic Search of Clusters Algorithm



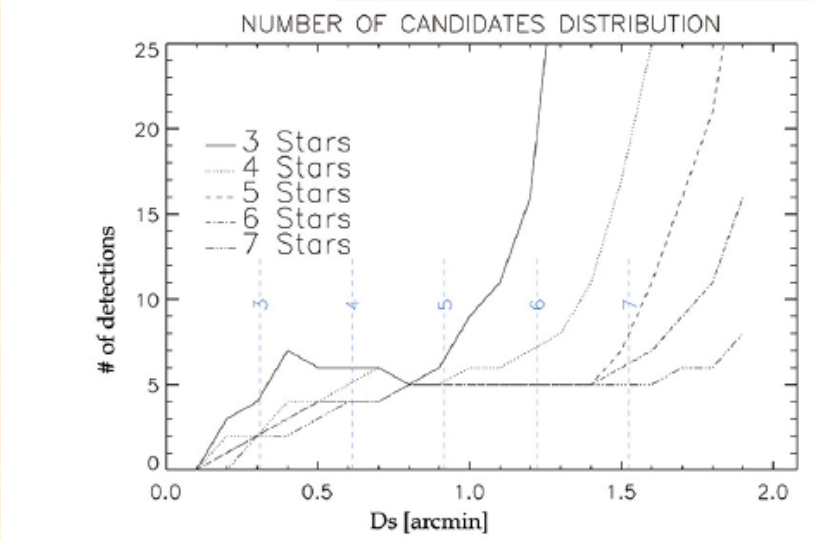
MASCA 2.0: MASGOMAS Automatic Search of Clusters Algorithm

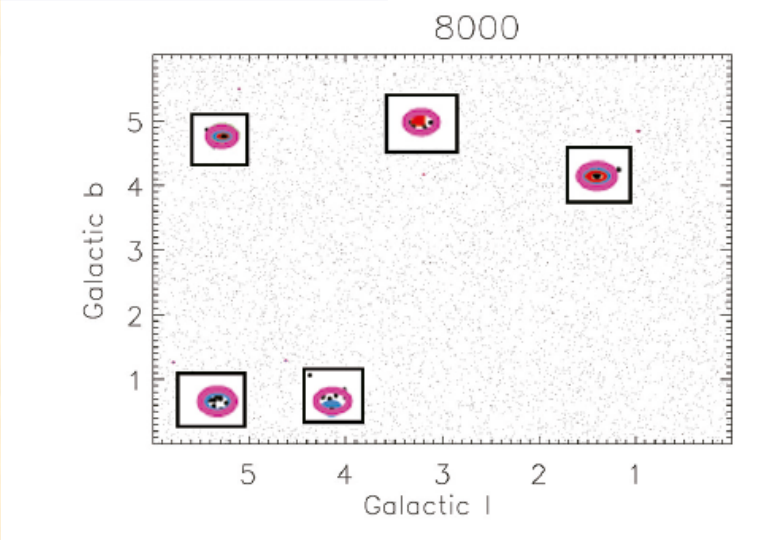
Test I: simulated MASGOMAS-1 clusters



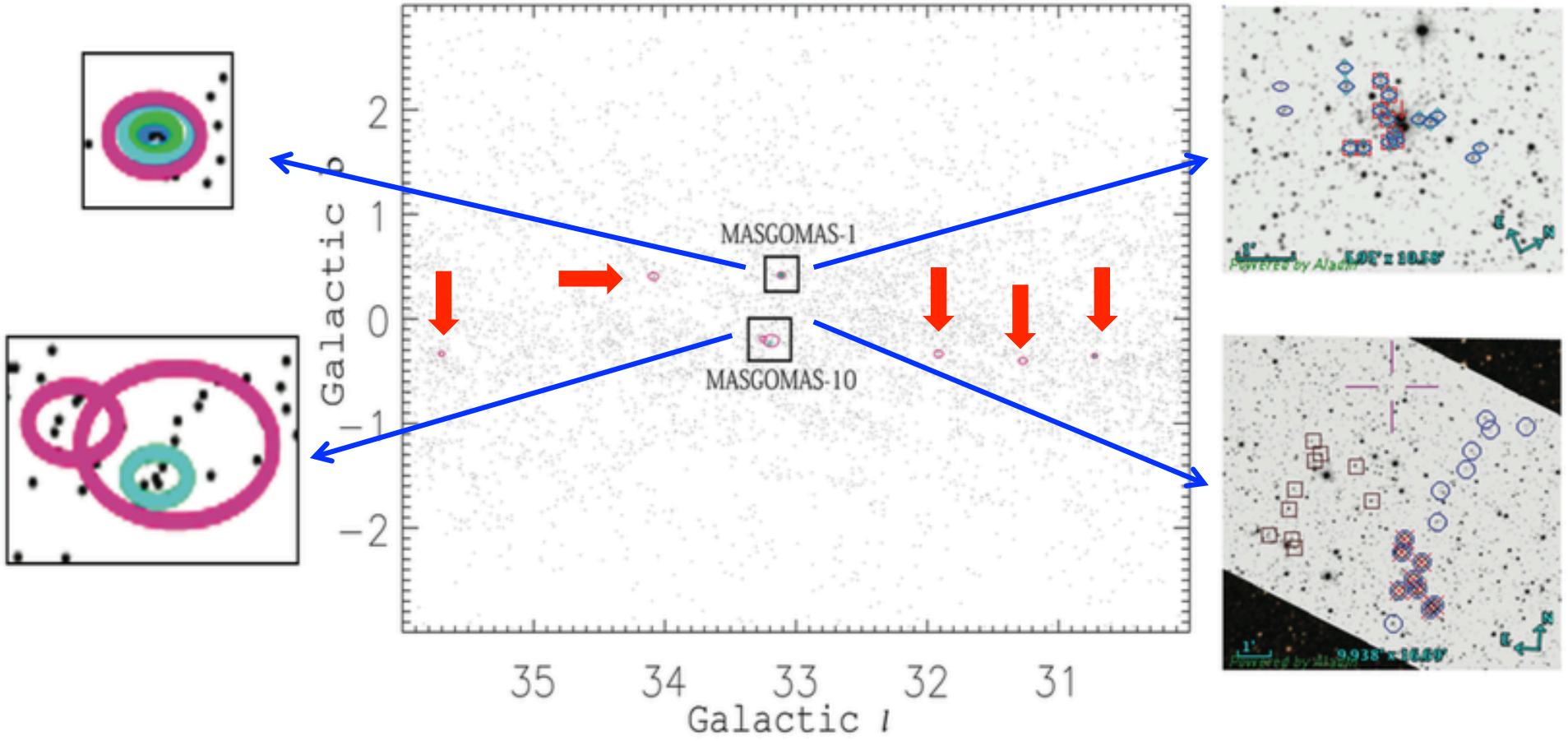


Test II: simulated clusters with different densities

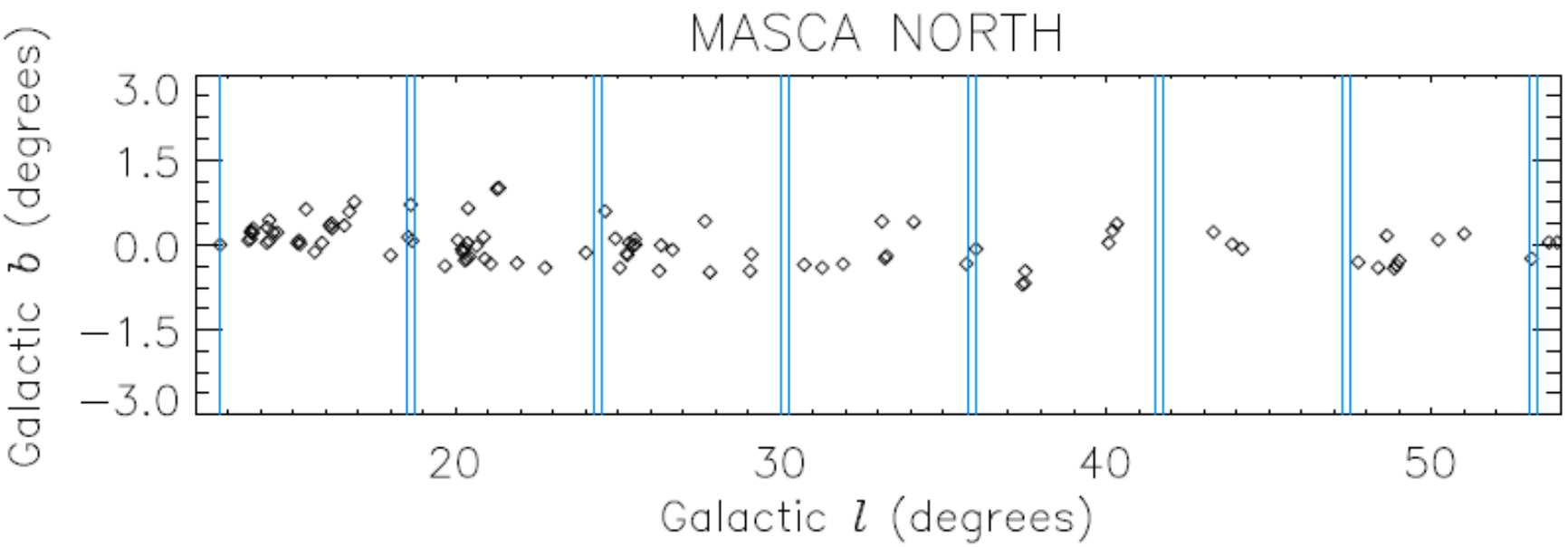


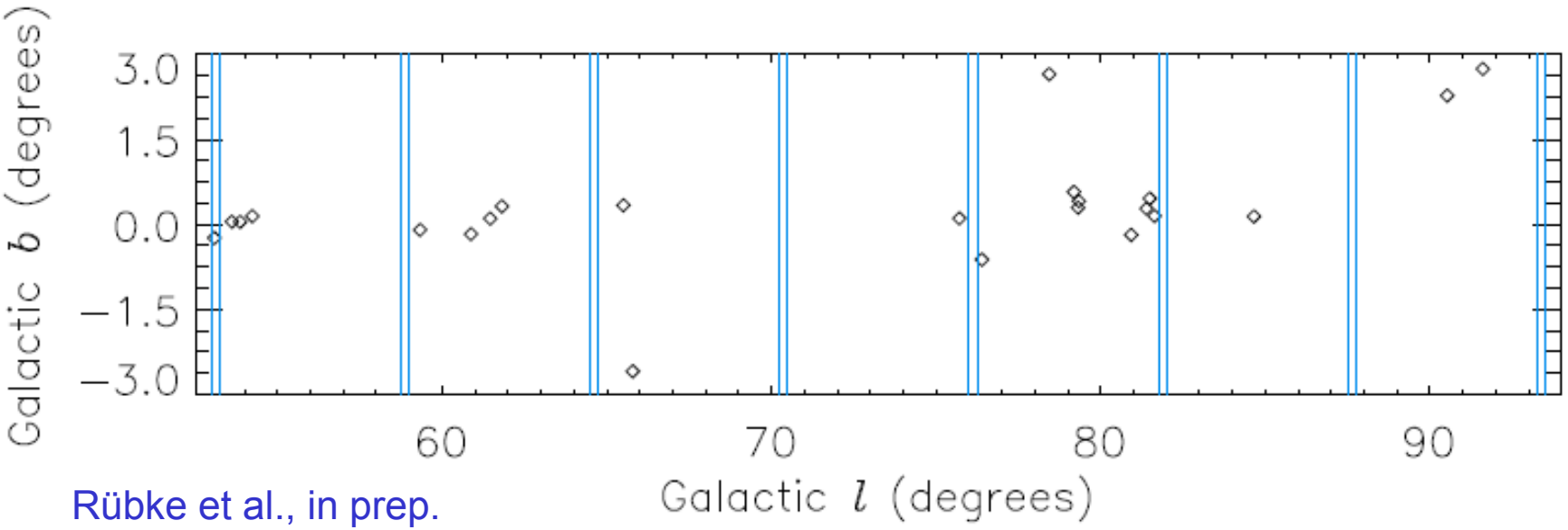


MASCA 2.0: MASGOMAS Automatic Search of Clusters Algorithm



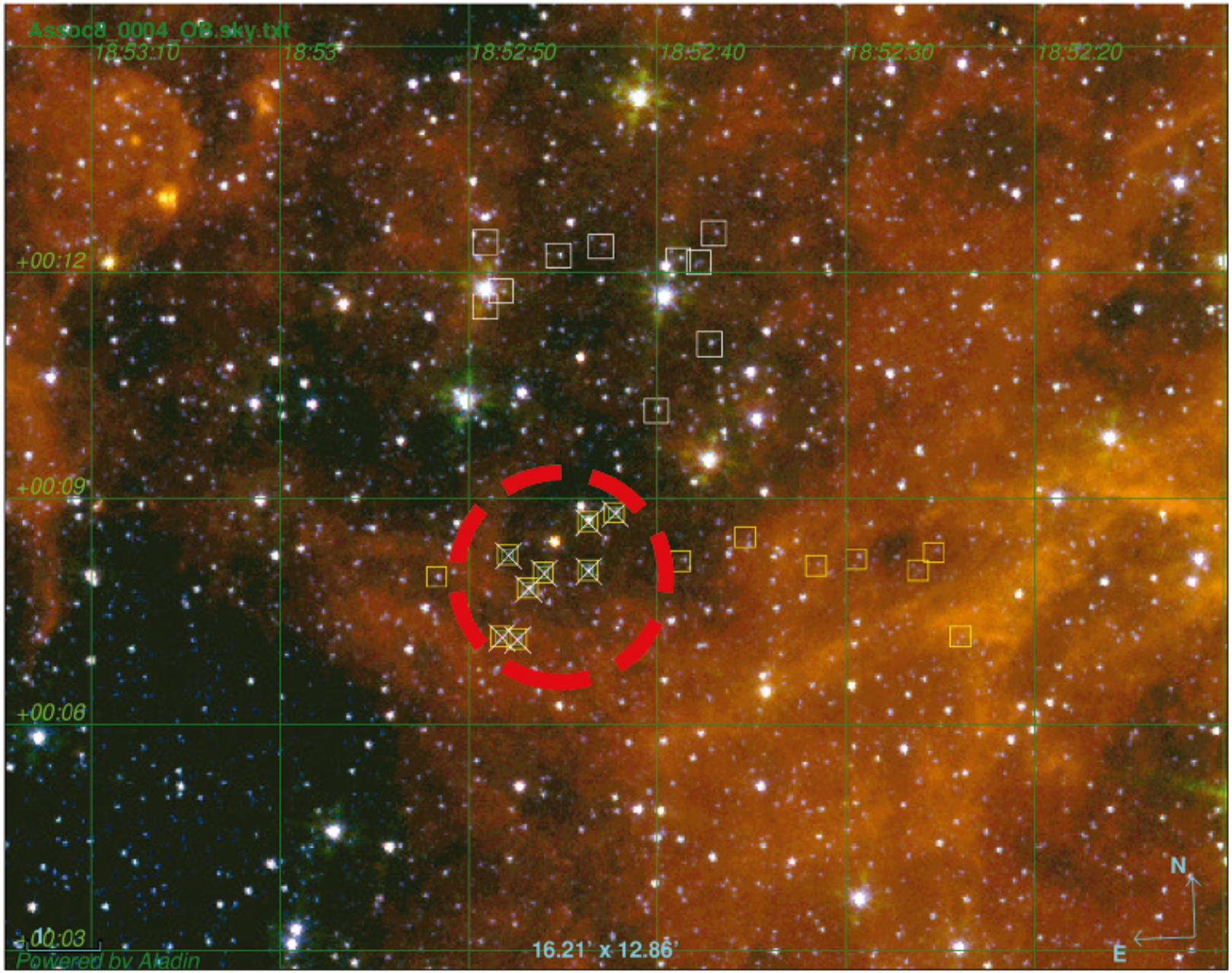
MASCA 2.0: MASGOMAS Automatic Search of Clusters Algorithm





Rübke et al., in prep.

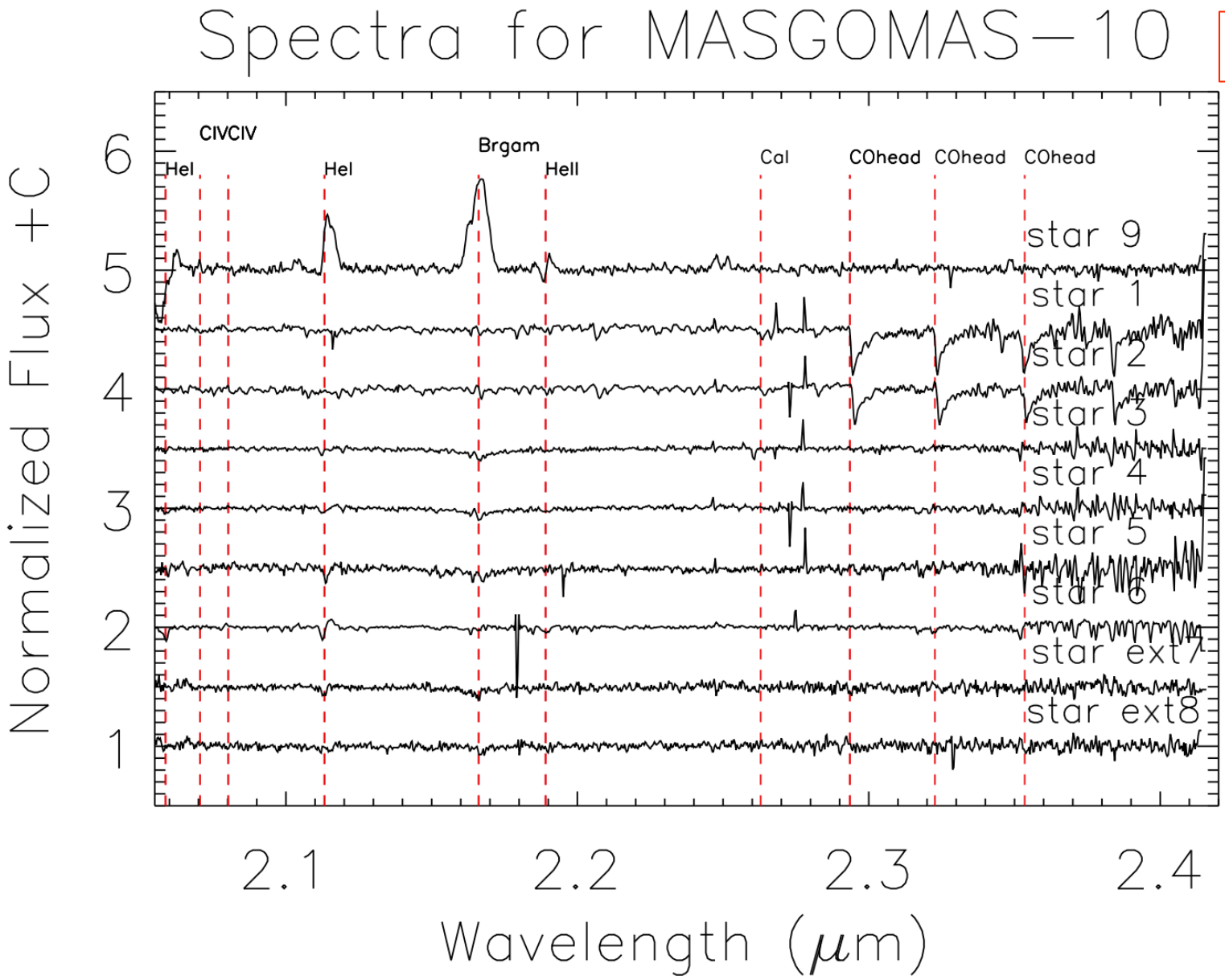
MASGOMAS-10



DEC (J2000.0)

RA (J2000.0)

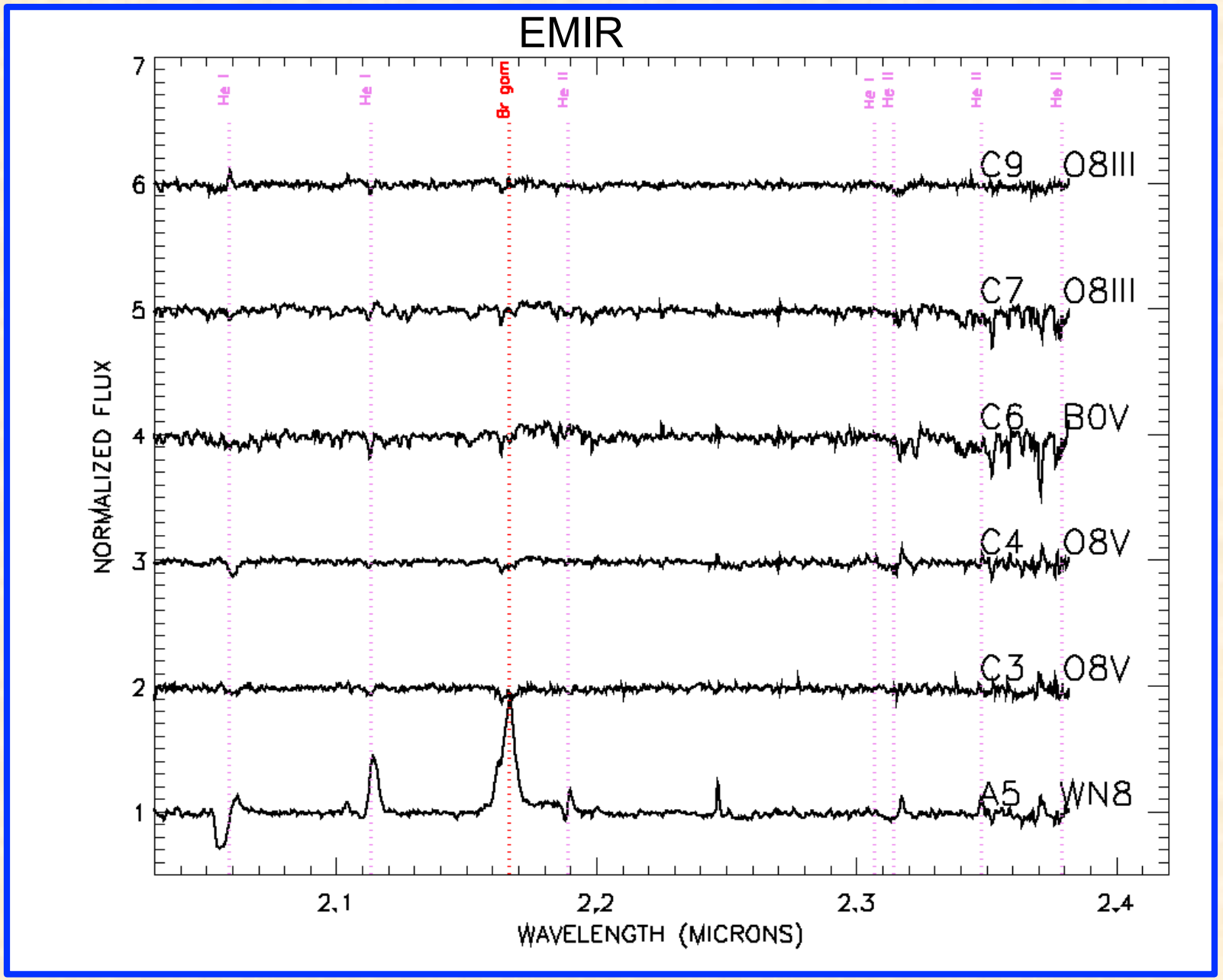
MASGOMAS-10


Spectra for MASGOMAS−10
LIRIS
Normalized Flux +C
Wavelength (μm)
CIVCIV
HeI
HeI
Brgam
HeII
CaI
COhead
COhead
COhead
star 9
star 1
star 2
star 3
star 4
star 5
star 6
star ext7
star ext8
1
2
3
4
5
6
2.1
2.2
2.3
2.4

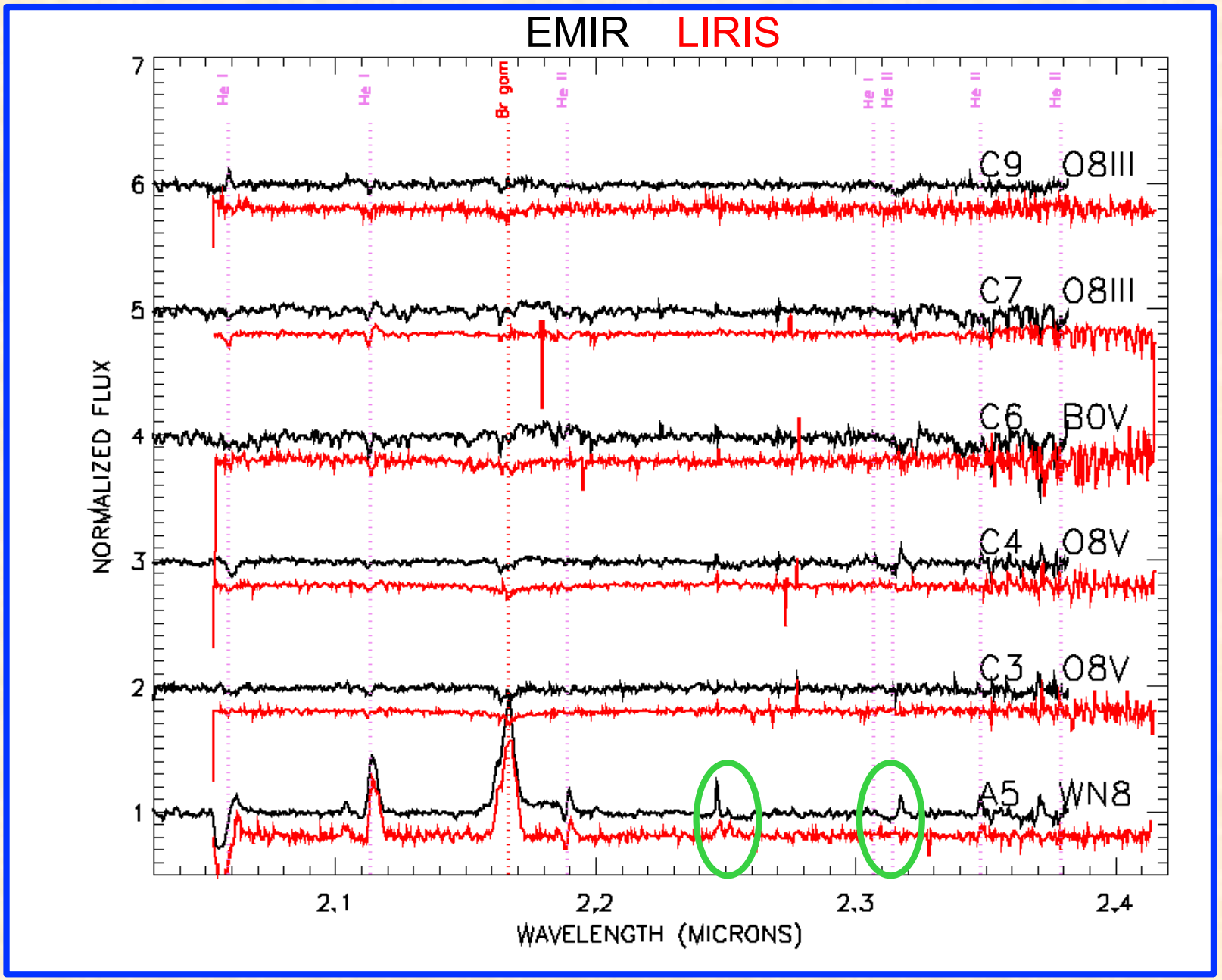
MASGOMAS-10

0.8” slit
R≥ 3000

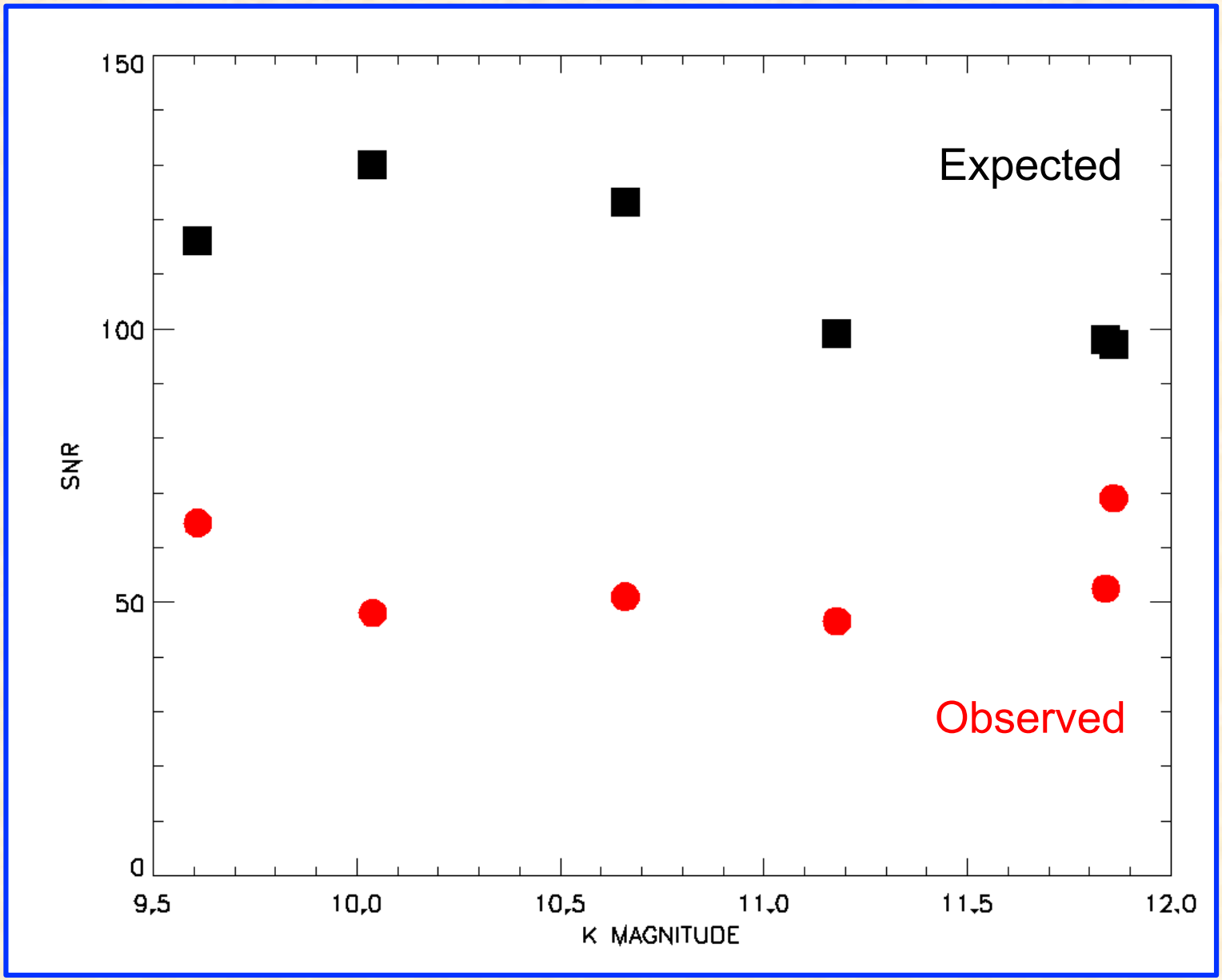
Texp= 4.2h



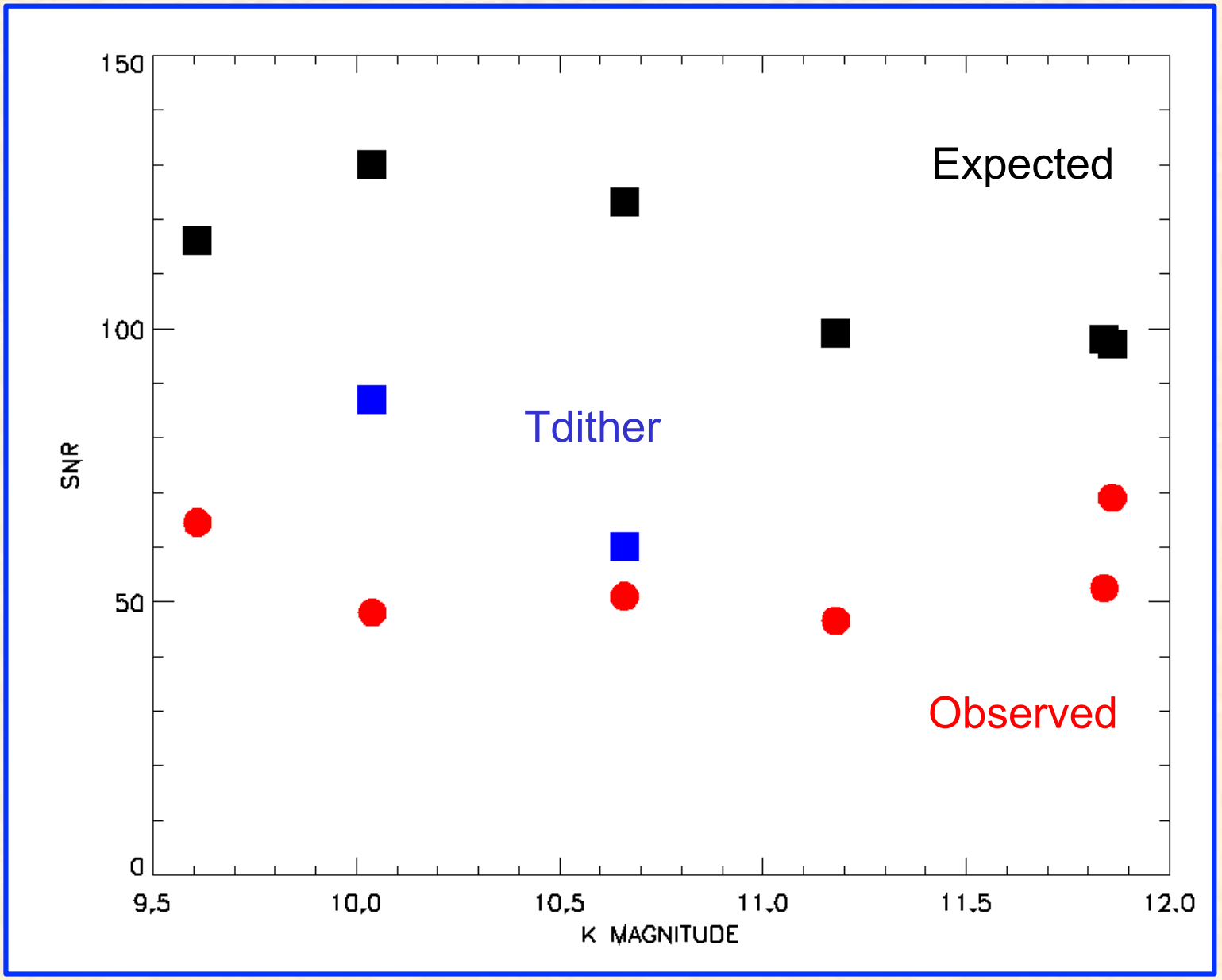
MASGOMAS-10


EMIR
LIRIS
He I
He I
Br gam
He II
He I
He I
He II
He II
C9 O8III
C7 O8III
C6 B0V
C4 O8V
C3 O8V
A5 WN8
NORMALIZED FLUX
WAVELENGTH (MICRONS)
2.1
2.2
2.3
2.4
1
2
3
4
5
6
7

MASGOMAS-10


150
100
50
0
SNR
9,5
10,0
10,5
11,0
11,5
12,0
K MAGNITUDE
Expected
Observed

MASGOMAS-10


150
100
50
0
SNR
9,5
10,0
10,5
11,0
11,5
12,0
K MAGNITUDE
Expected
Tdither
Observed

Future Work

- Finish the reduction of MASGOMAS-10 (H-band!)
  - Clarify the cause for the relatively low S/N
  - Check the variability seen in some spectra
- Confirm MASGOMAS-1 nature
  - Is it really a very massive cluster/association ?
- Explore in detail MASGOMAS-4 and MASGOMAS-6
- Explore the cluster candidates in the MASGOMAS North catalog