NIR eyes to observe obscured & massive young stellar clusters

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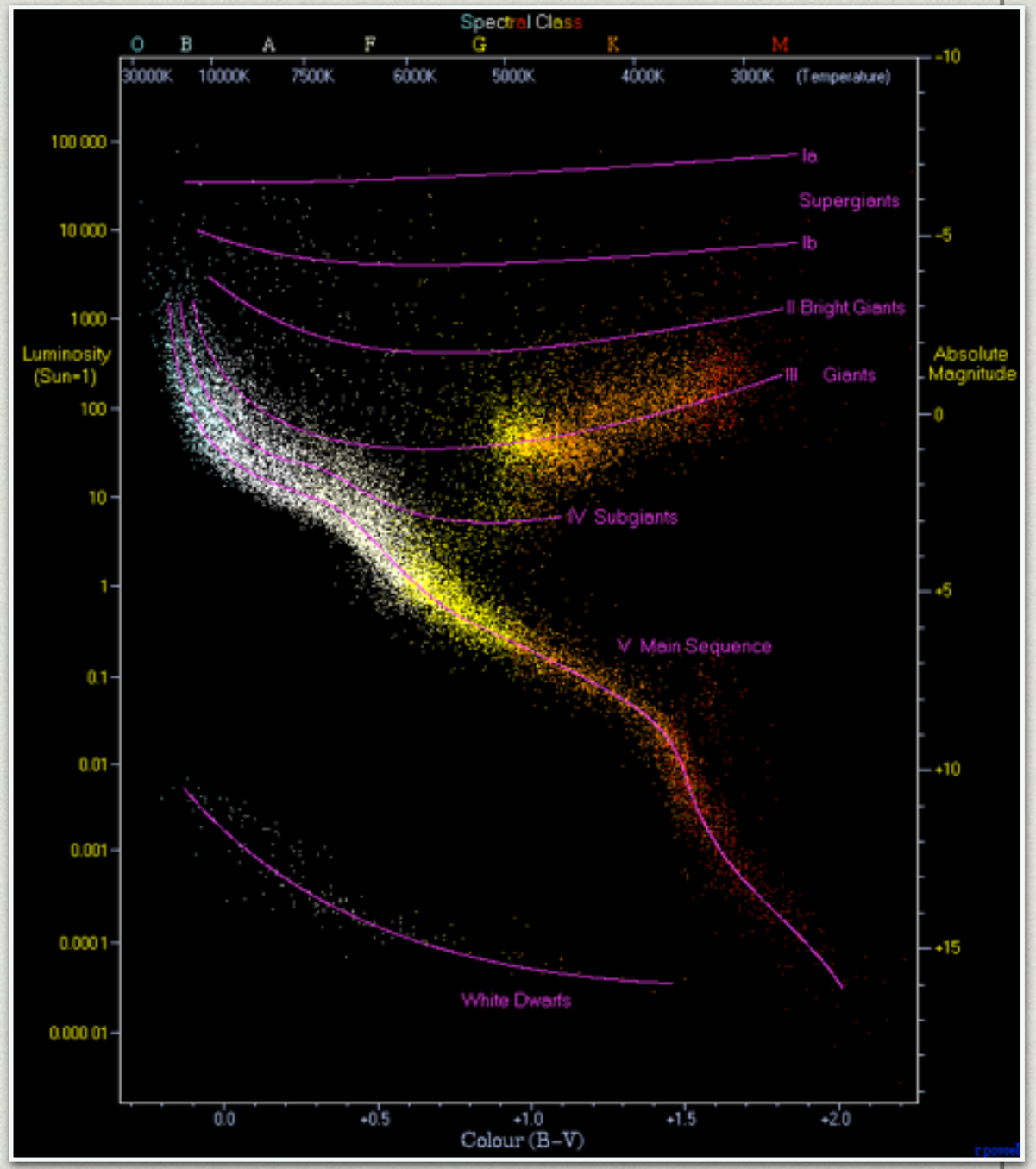
Massive stars

Definition: A star which ends its life with a supernova explosion. Initial mass ≳ 8 $M_\odot$ or spectral type earlier than B2-3 V (Cox, 2000)

Massive stars are rare objects (**10 massive every 100 solar mass** stars; Zinnecker & Yorke, 2007) and **evolve quickly** (2-10 Myr in the main sequence, versus ~10 Gyr expected for a solar type star).

They have a **strong influence in the galactic evolution**.



Massive stars

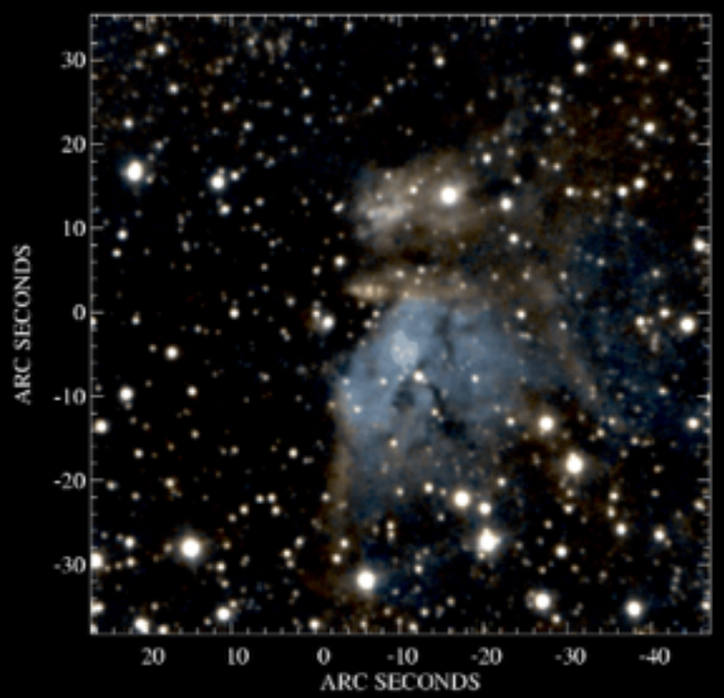
- Massive star formation must consider the powerful winds and radiation to accrete mass.
- **Observational hints for formation scenario: During formation in clusters, massive stars pass through four observational stages:**

1. **Dark IR clouds:** Spherical or filamentary structures, bright in far-IR.
2. **Hot molecular cores:** Massive protostar already formed; should present methanol and OH masers.
3. **HCH II** and **UCH II** regions.
4. **Compact H II regions:** Natal cloud finally disrupted

Dark IR clouds and hot molecular cores

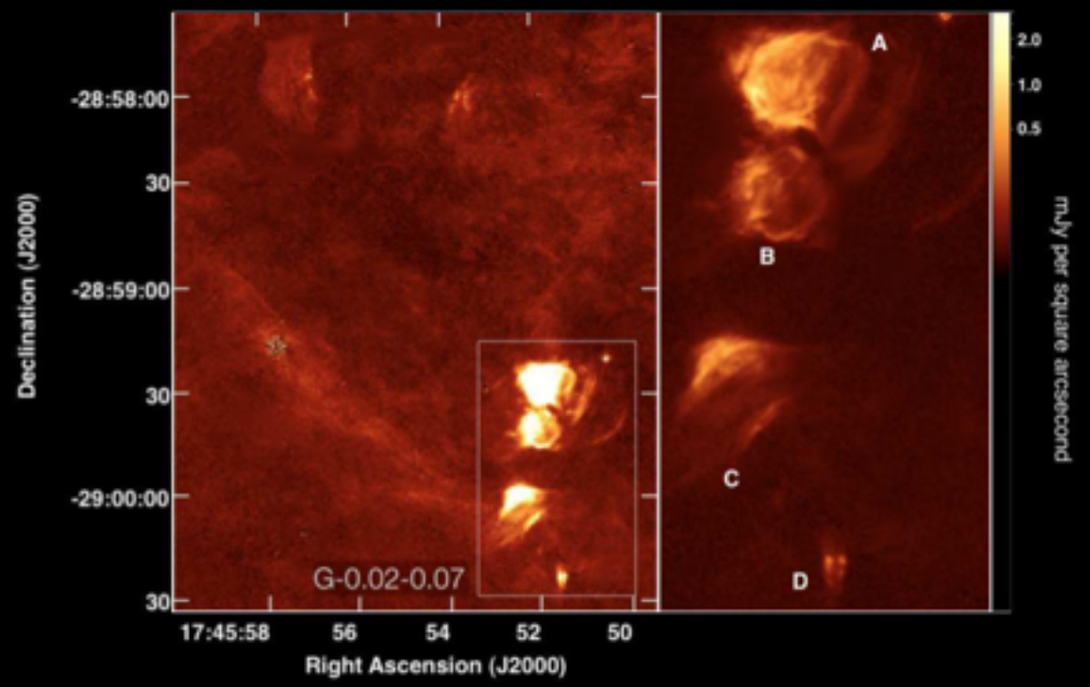
IRAS 18497+0022, Spitzer 8.0 μm

Hot molecular cores



G9.62+0.19 in the *K* narrow-band filters (Linz et al. 2005)

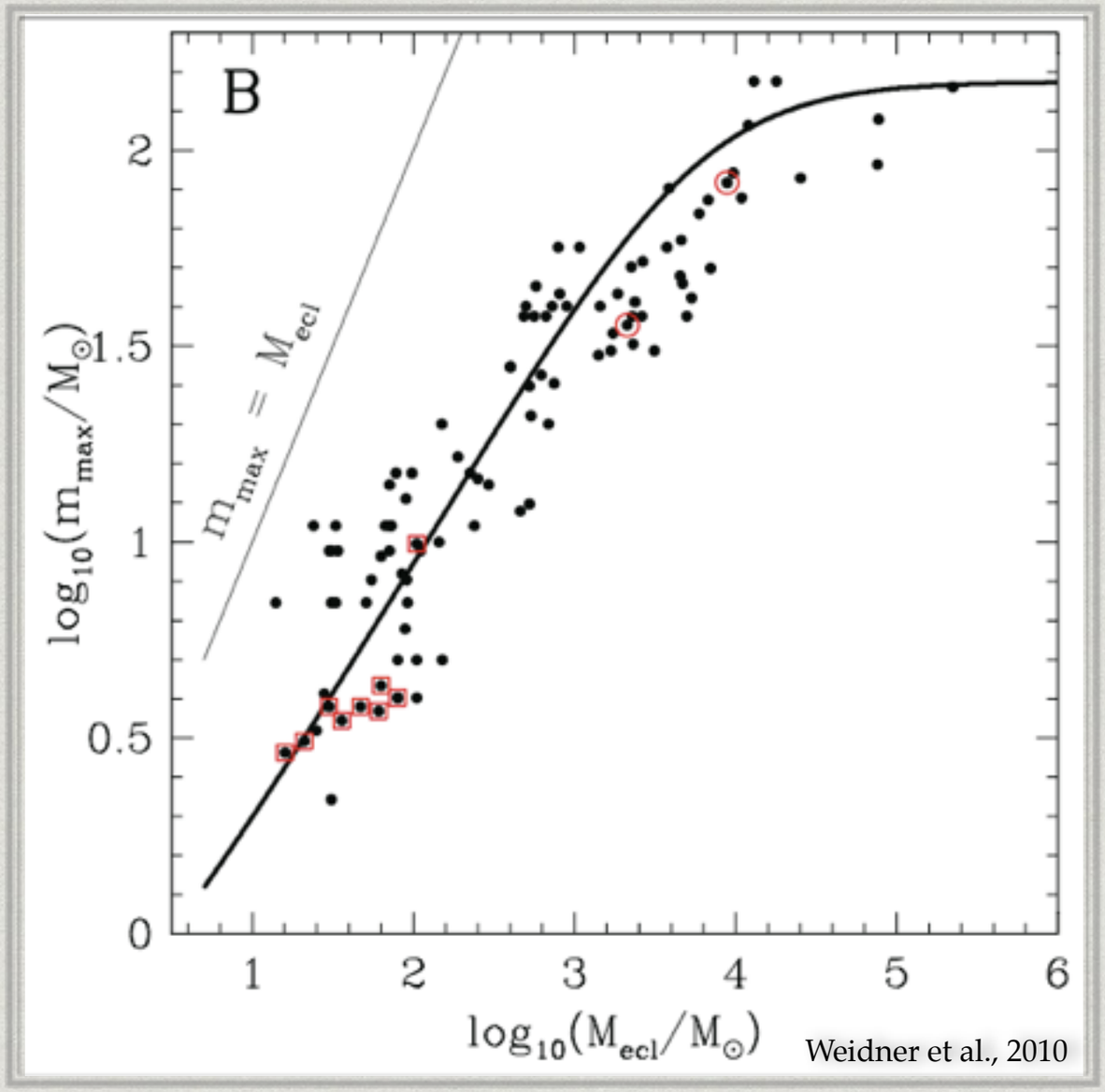
Compact HII and UCH II regions



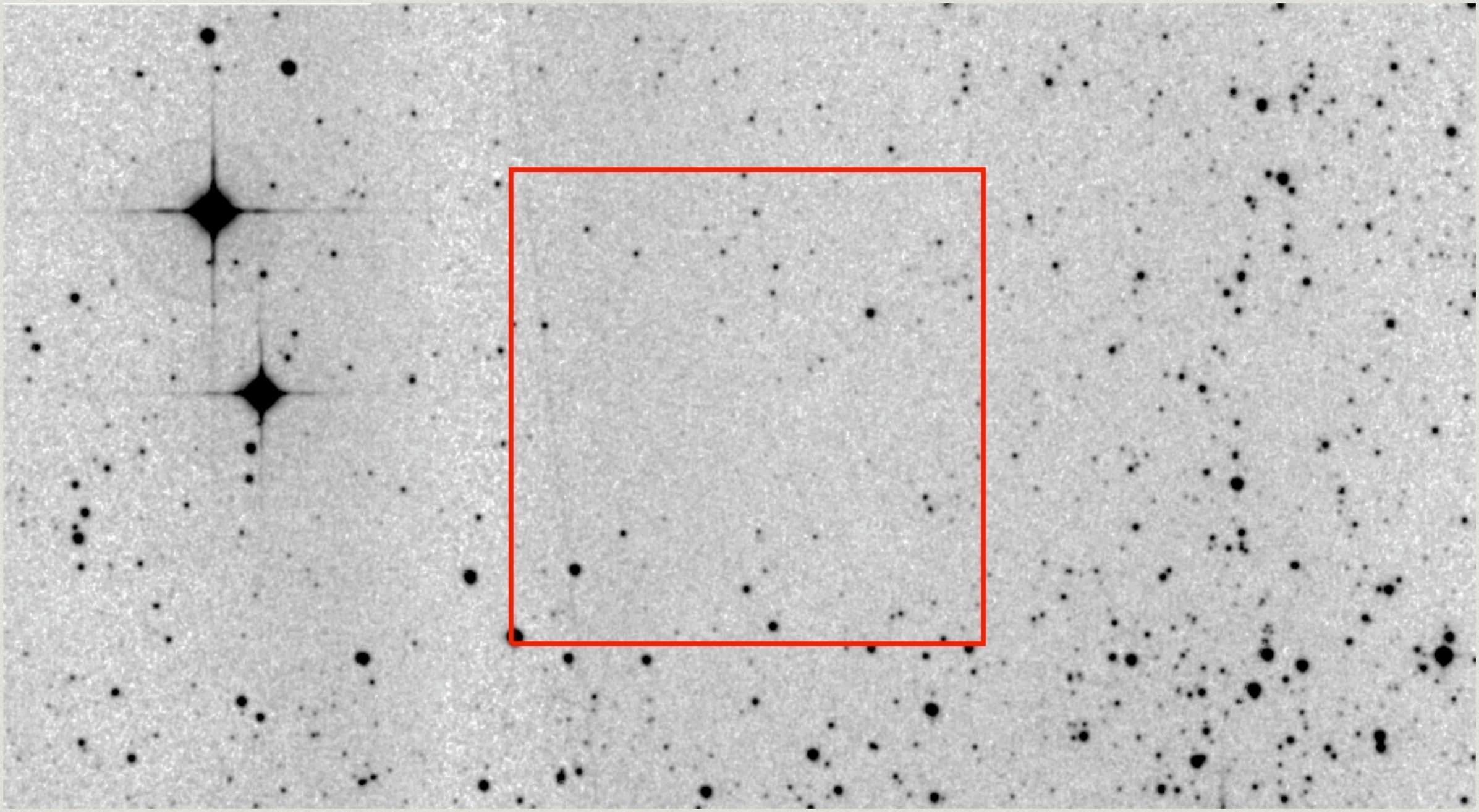
G-0.02-0.07 in the *Pa α* filter (Mills et al. 2011)

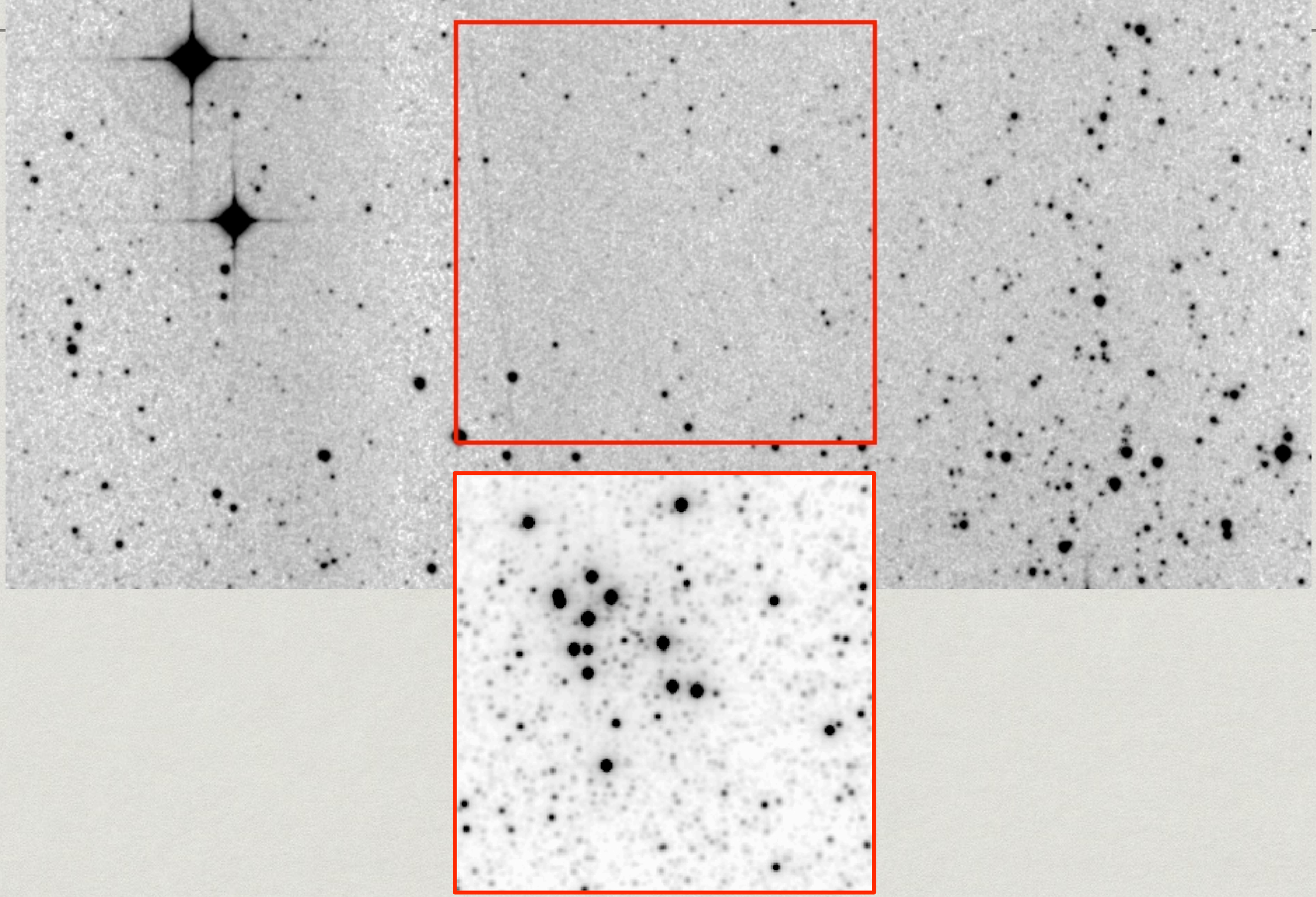
Massive clusters

- Clusters with a total mass over 10^4 $M_\odot$. These clusters may survive a dissolution phase (*infant mortality;* Portegies Zwart et al. 2010).
- Their massive population makes them ***young, massive*** and ***obscured*** objects.
- ***Poor census:*** Less than 20 massive clusters have been reported in the MW; but about 100 are expected to exist in the Galaxy (Hanson & Popescu, 2007)



Weidner et al., 2010





RSGC1 (Figer et al., 2006,
Davies et al. 2008)

Catalogues of cluster (candidates)

- Using NIR imaging to detect cluster candidates as over-densities.
  - 2MASS: Dutra & Bica (2001), Bica et al. (2003a, b); Ivanov et al. 2002, Borissova et al. 2003; Mercer et al. (2005), Kronberger et al. (2006), Koposov et al. (2008), Froebrich et al. (2013), Kamargo et al. (2015)
  - UKIDSS-GPS: Solin et al. (2012)
  - VVV: Borissova et al. (2011, 2014), Solin et al. (2014), Barbá et al. (2015) -> > 700 cluster candidates
- Some compilations: WEBDA (https://www.univie.ac.at/webda/catocl.html), Kharchenko et al. (2005), Morales et al. (2013).

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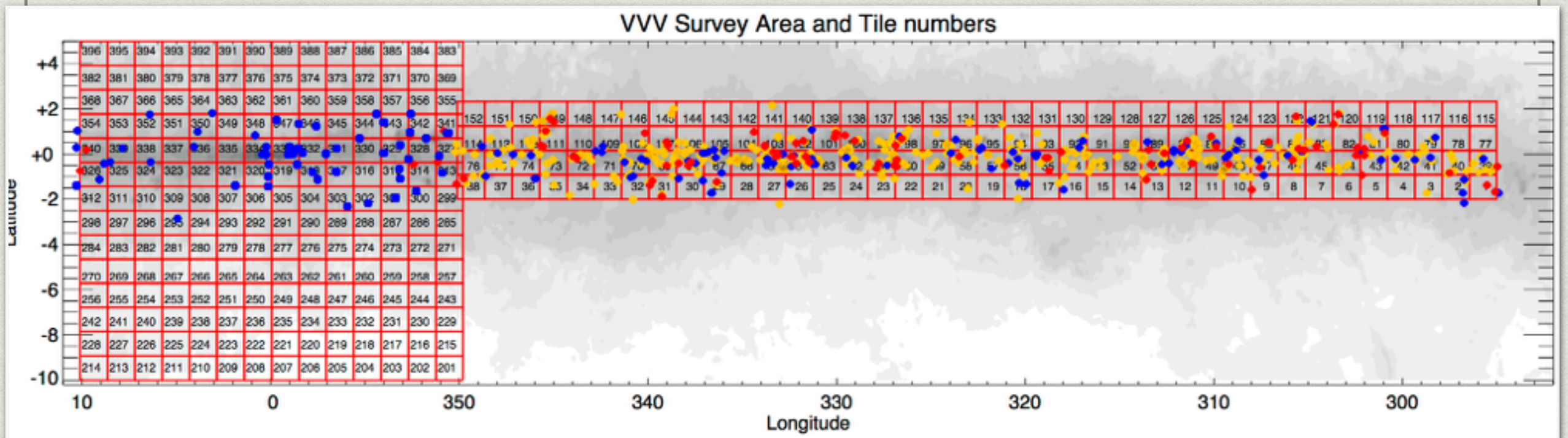

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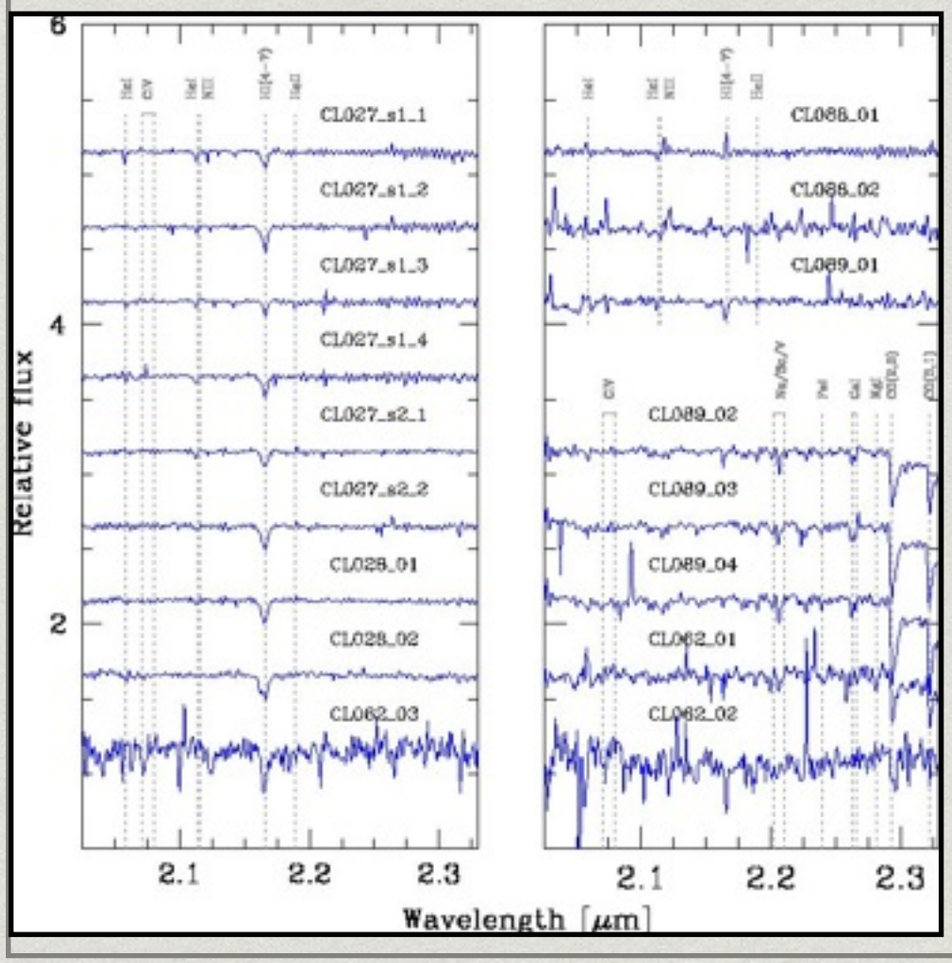
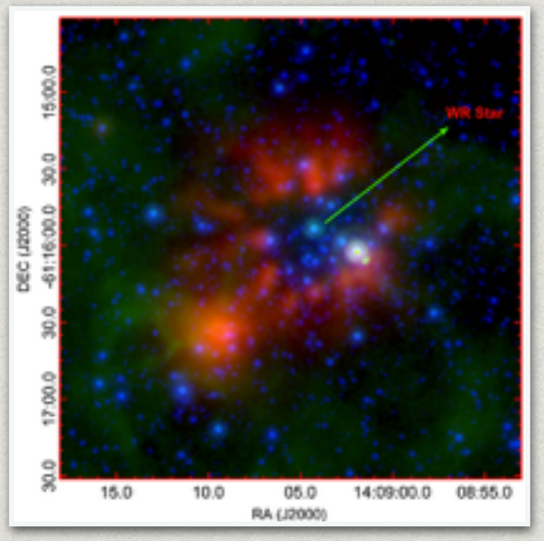
VVV clusters

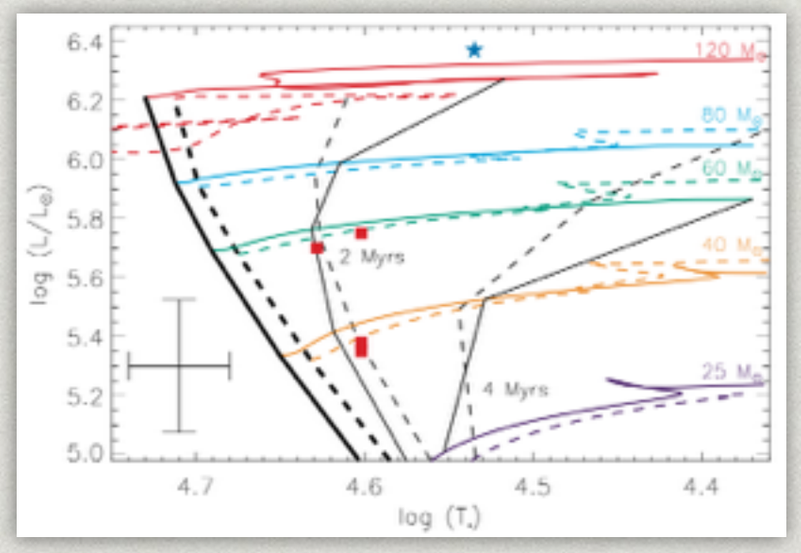
Clusters with OBs:

(Ramírez Alegría et al. 2014, 2016; Corti et al 2016)

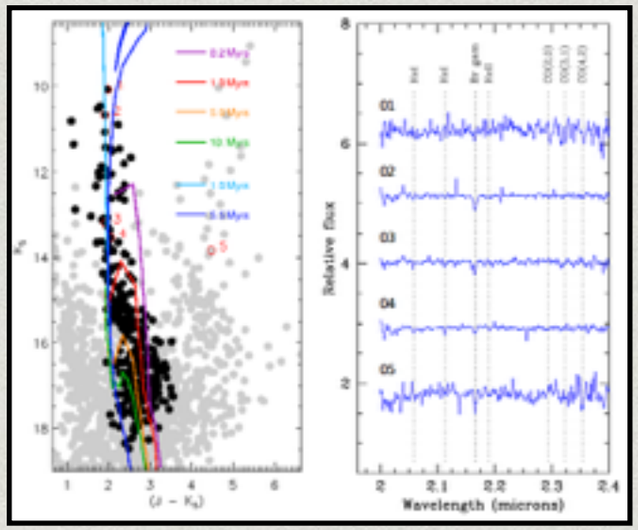




VVVCL036, hosting the WR60-6. Sub-mm APEX $^{12}CO(3\rightarrow2)$ observations allow to study the surrounding shell, and estimate a age of 28000 yr.



HR diagram for VVV CL041, with its O-stars (red squares) and WR (blue star) spectroscopically confirmed stars. Evolutionary tracks (Chieffi & Limongi 2013, colour) and isochrones (Ekström et al. 2012, black) are overplotted.



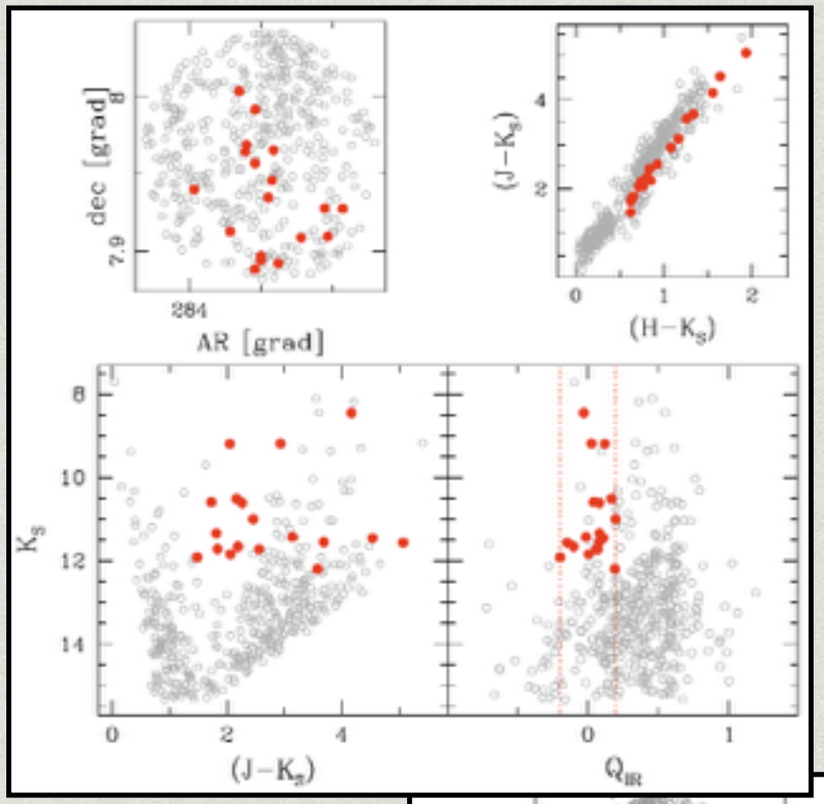
Clusters with WR:

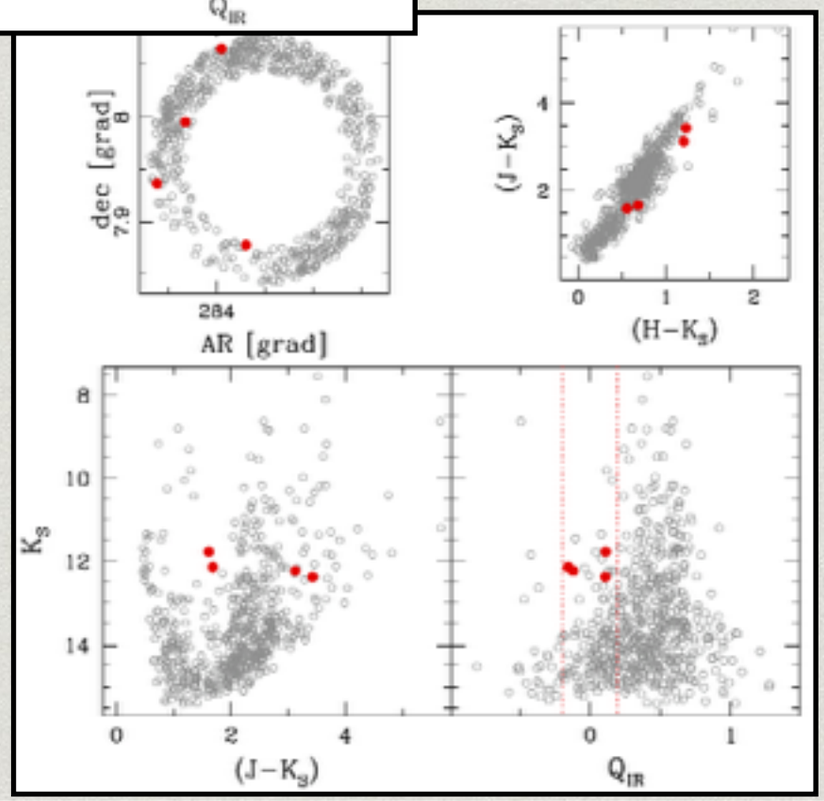
(Borissova et al. 2014b; Chené et al. 2013, 2015; Hervé et al. 2016; de la Fuente et al. 2016)

MASGOMAS project:
General description

- The **MA**ssive **S**tars in **G**alactic **O**bscured **MA**ssive cluster**S** (MASGOMAS) aims to discover and characterise massive clusters and their massive stellar population.
- First searches were focused on the direction of the close end of the Galactic Bar (*l*~35º).
- The candidate search is done using 2MASS photometry and the follow-up includes spectroscopy and imaging in near-infrared.
- First phase of the project, based on the Northern hemisphere.

MASGOMAS project: First candidates





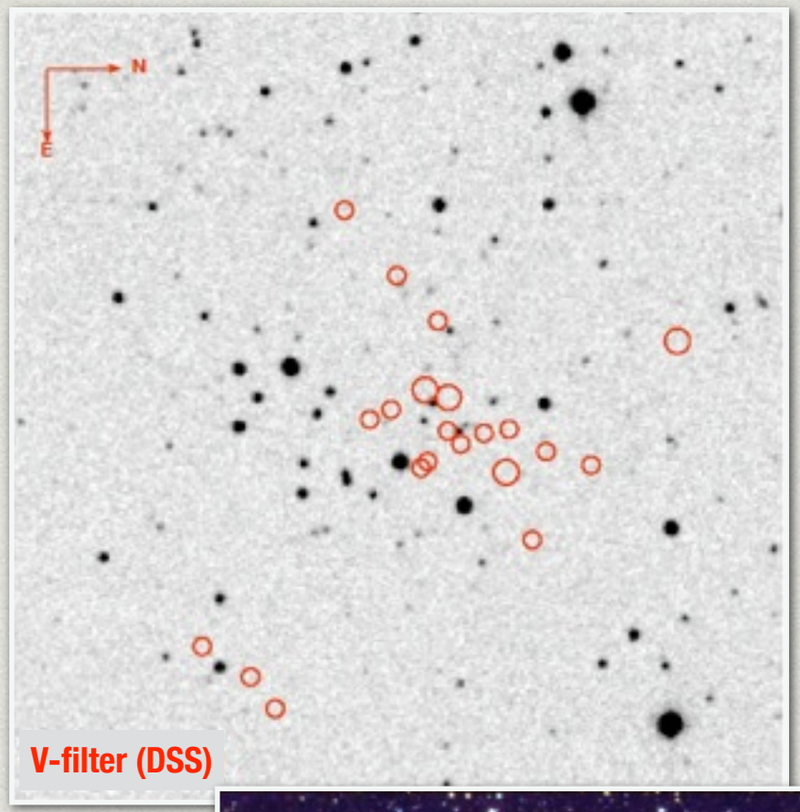
OB-type selection criteria:

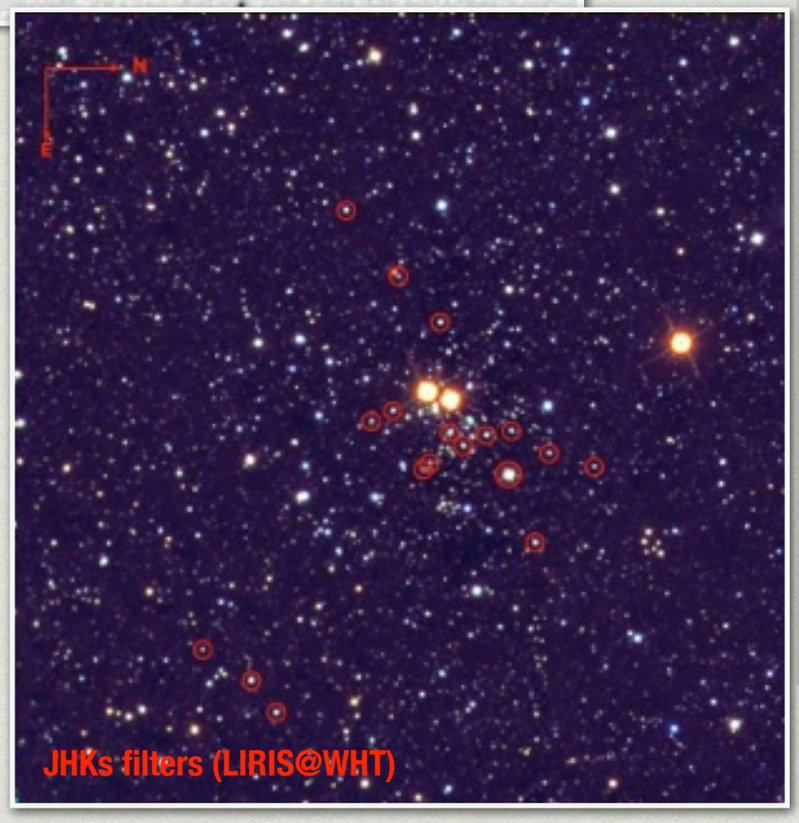
1. $K_S < 12$ mag
2. $(J\text{-}K_S) > 0.5—1$ mag
3. $-0.2 < Q_{IR} < 0.2$

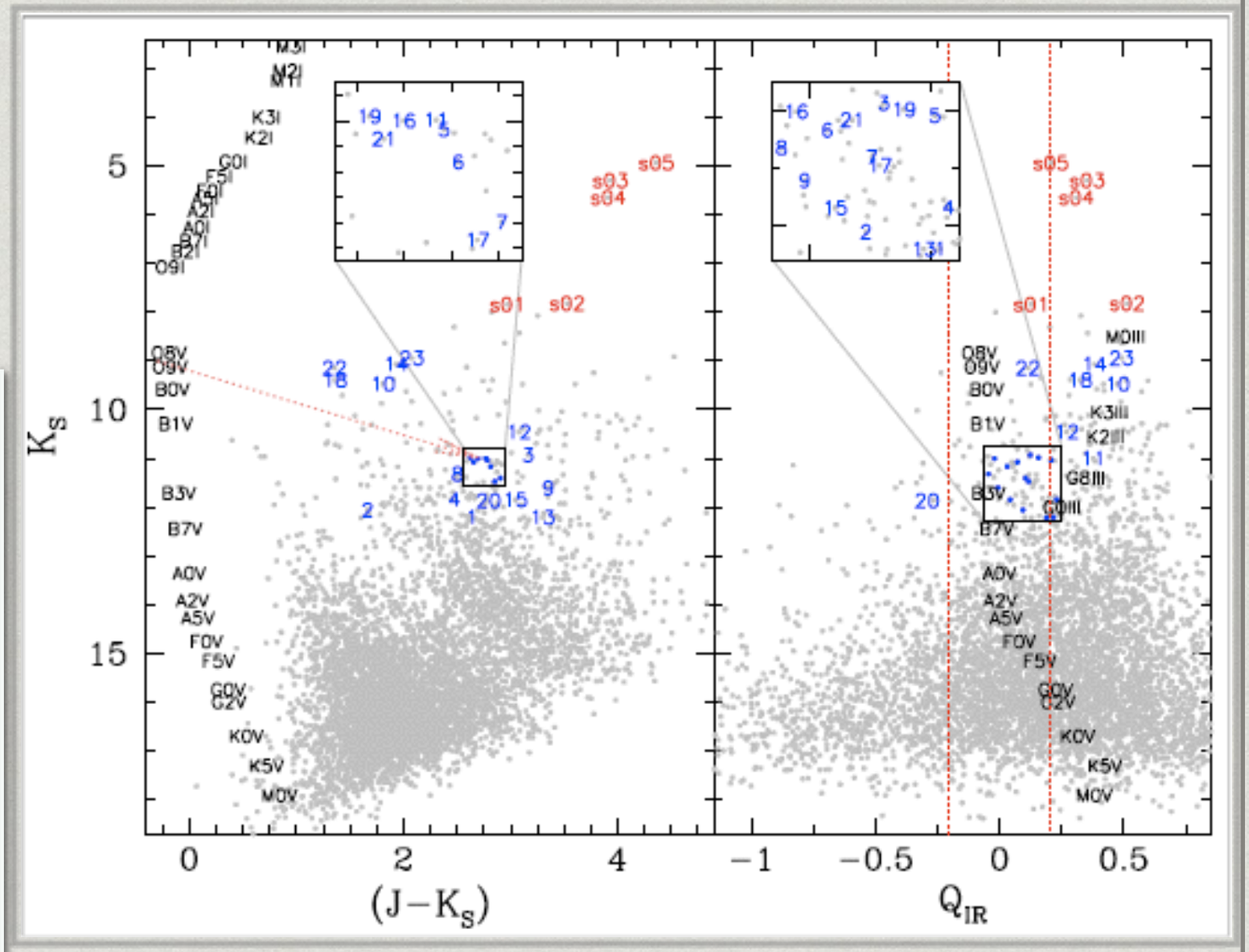
($Q_{IR} = (J\text{-}H)\text{-}\mathbf{1.8}\cdot(H\text{-}K_S)$; Comerón & Pasquali 2005)

—> look for over-densities of OB-type candidates

First candidates: Masgomas-1







Ramírez Alegría et al. (2012)

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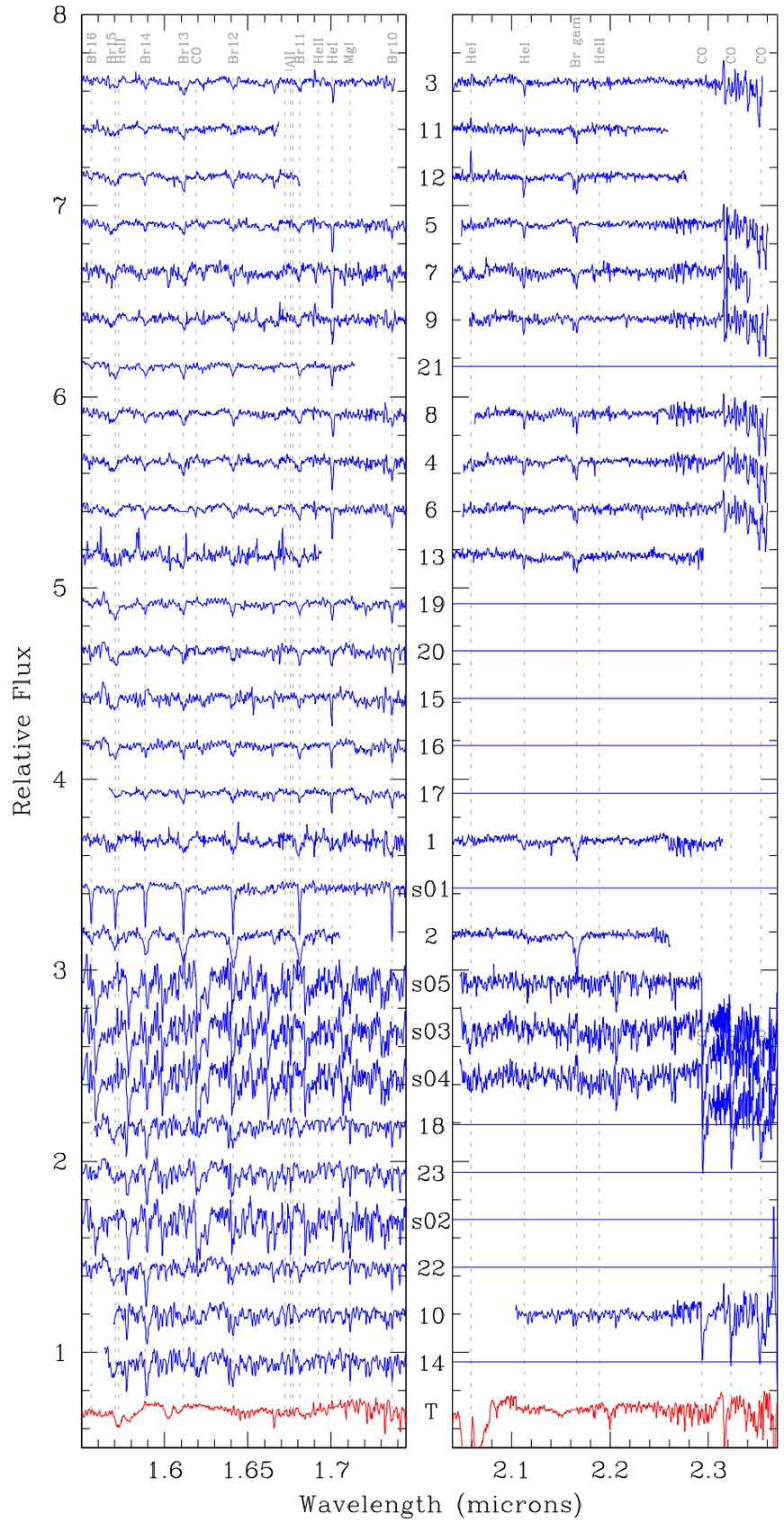
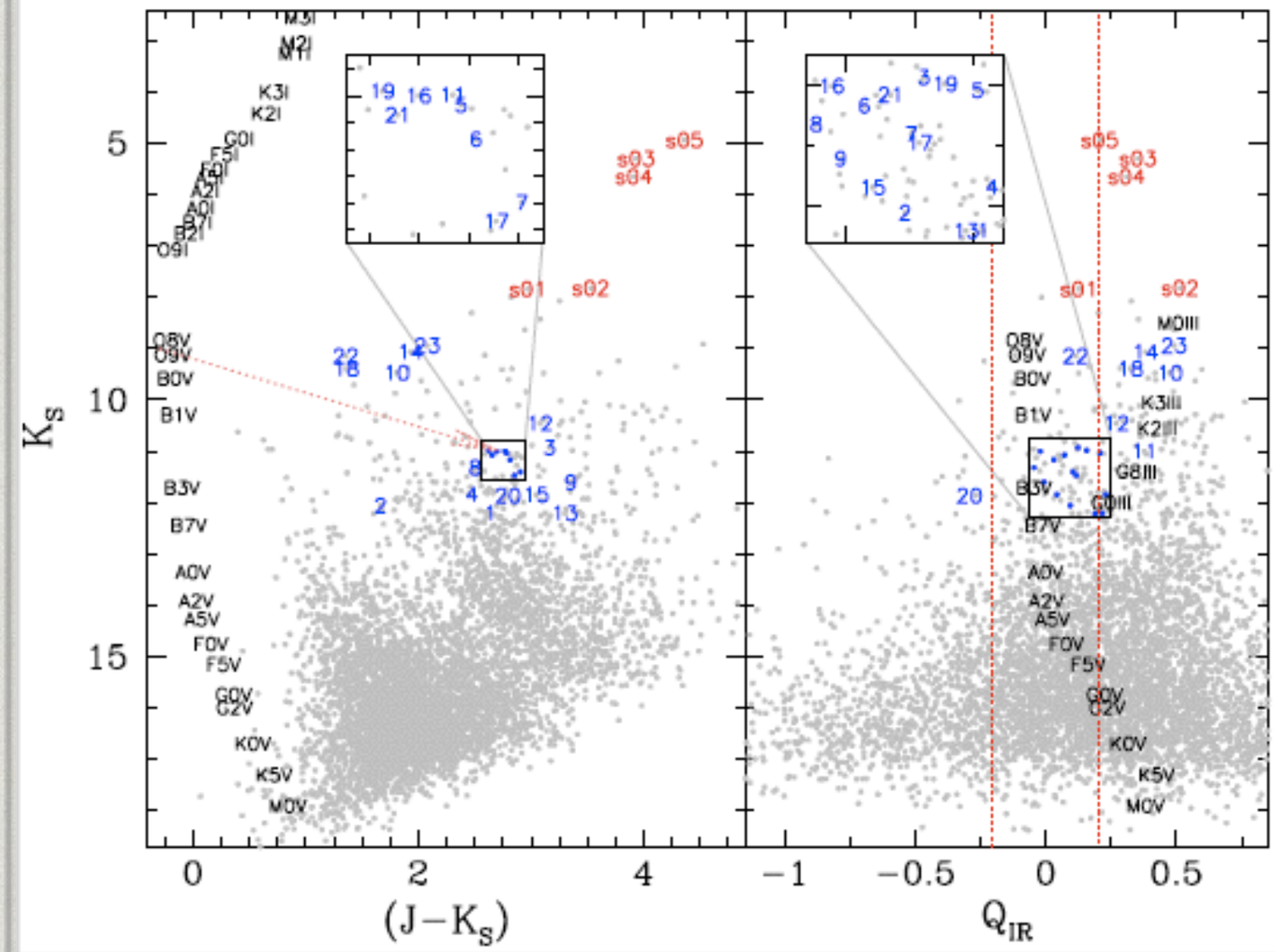
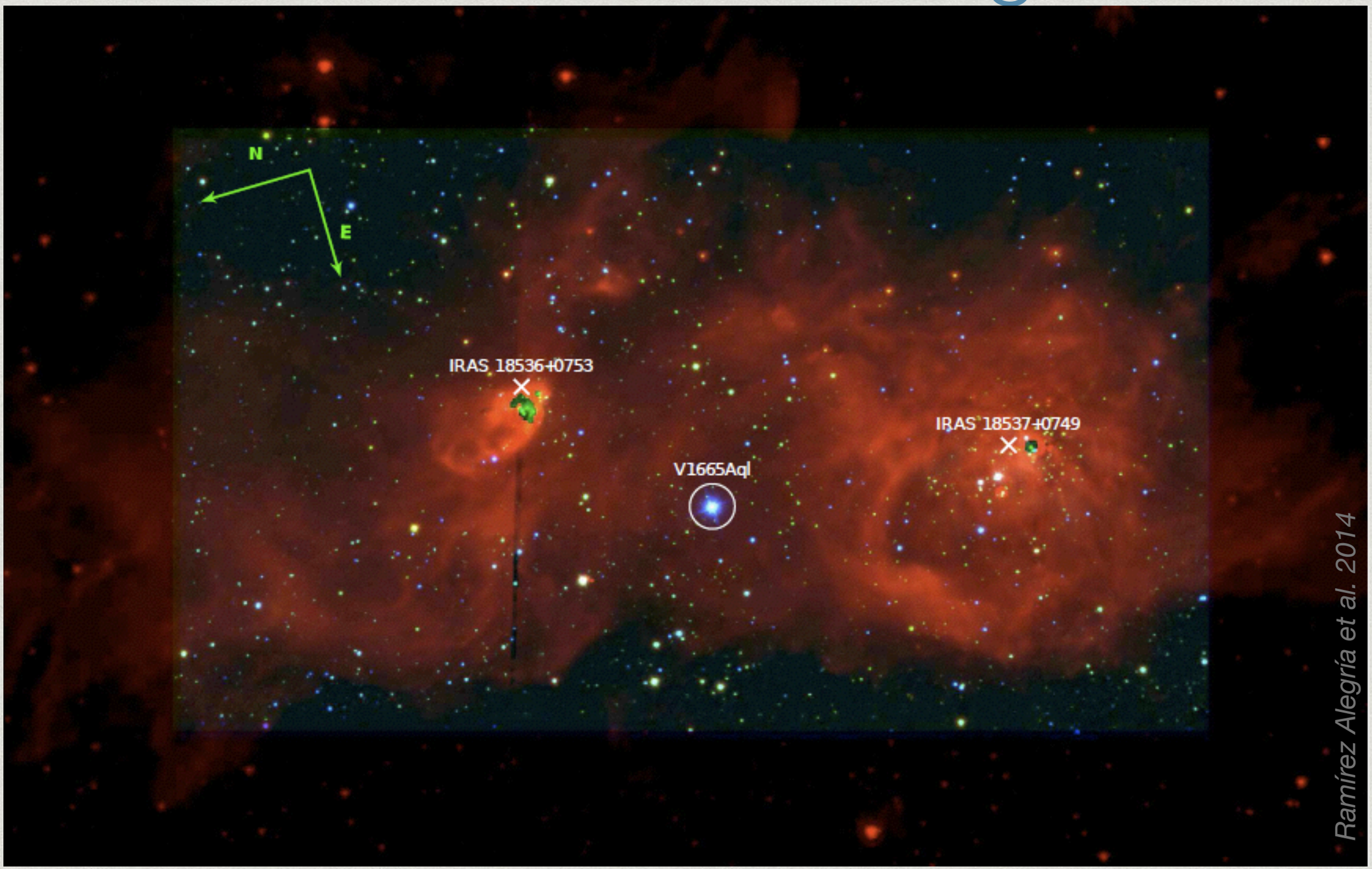


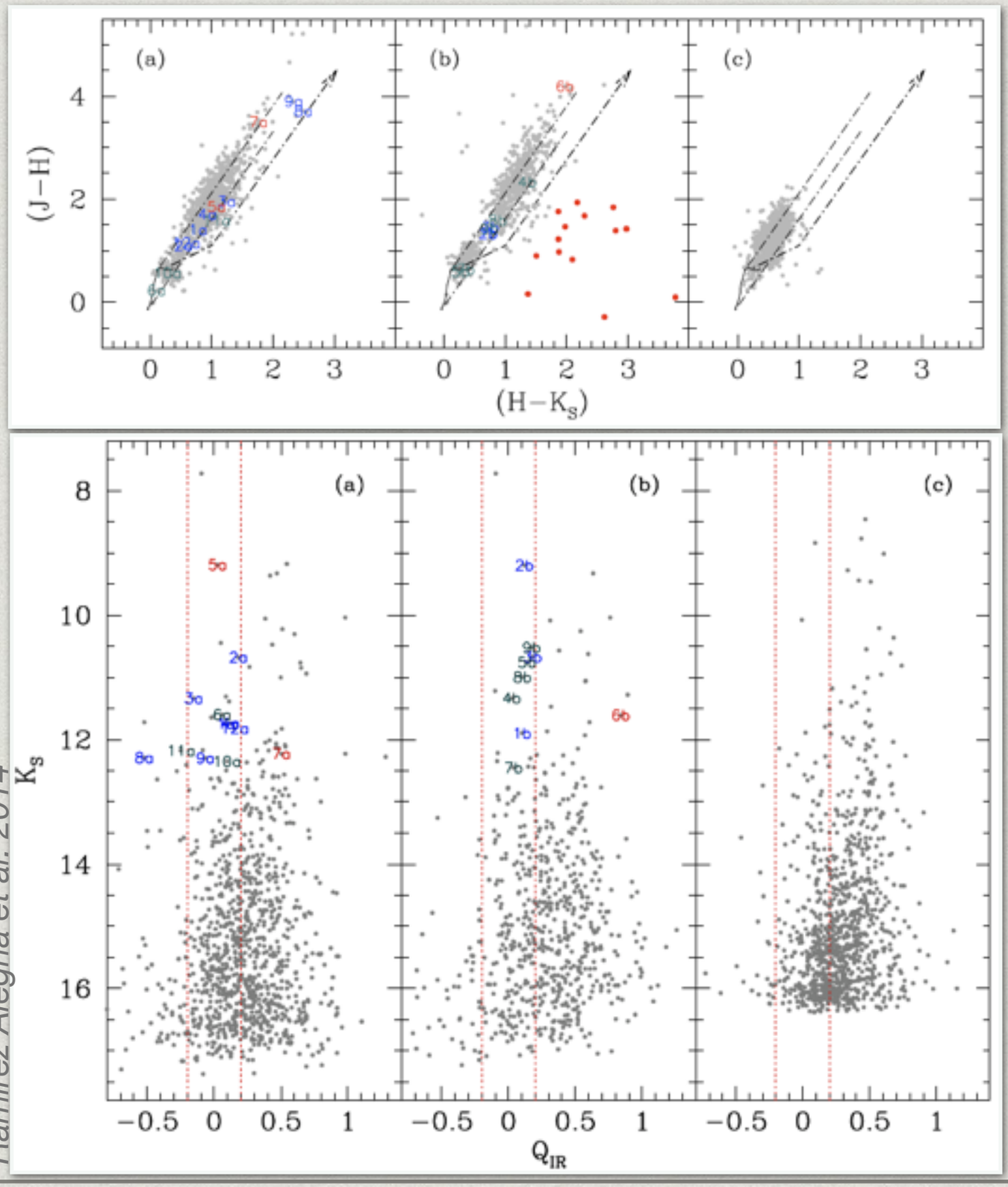


Ramírez Alegría et al. (2012)

First candidates: Masgomas-4



First candidates: Masgomas-4



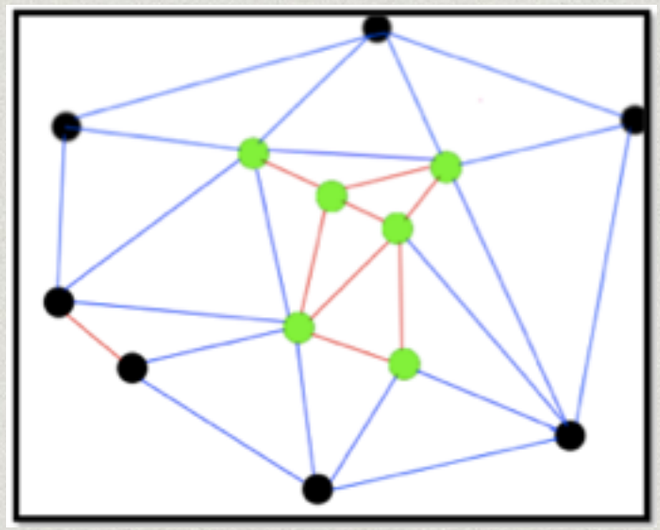
- Cores a & b share distance (~2kpc) but differ in the presence of YSO.
- Masgomas-4 is one example of embedded cluster, older than 3Myr (Pfalzner et al. 2016).

MASGOMAS project:
The systematic search

- With the same photometric criteria used to select OB-type candidates, we adapted the AUTOPOP code (García et al. 2011).

- The automatic search requires two values to consider an over-density as cluster candidate: distance $\mathbf{D_{opt}}$ and number of candidates $\mathbf{N_{min}}$.

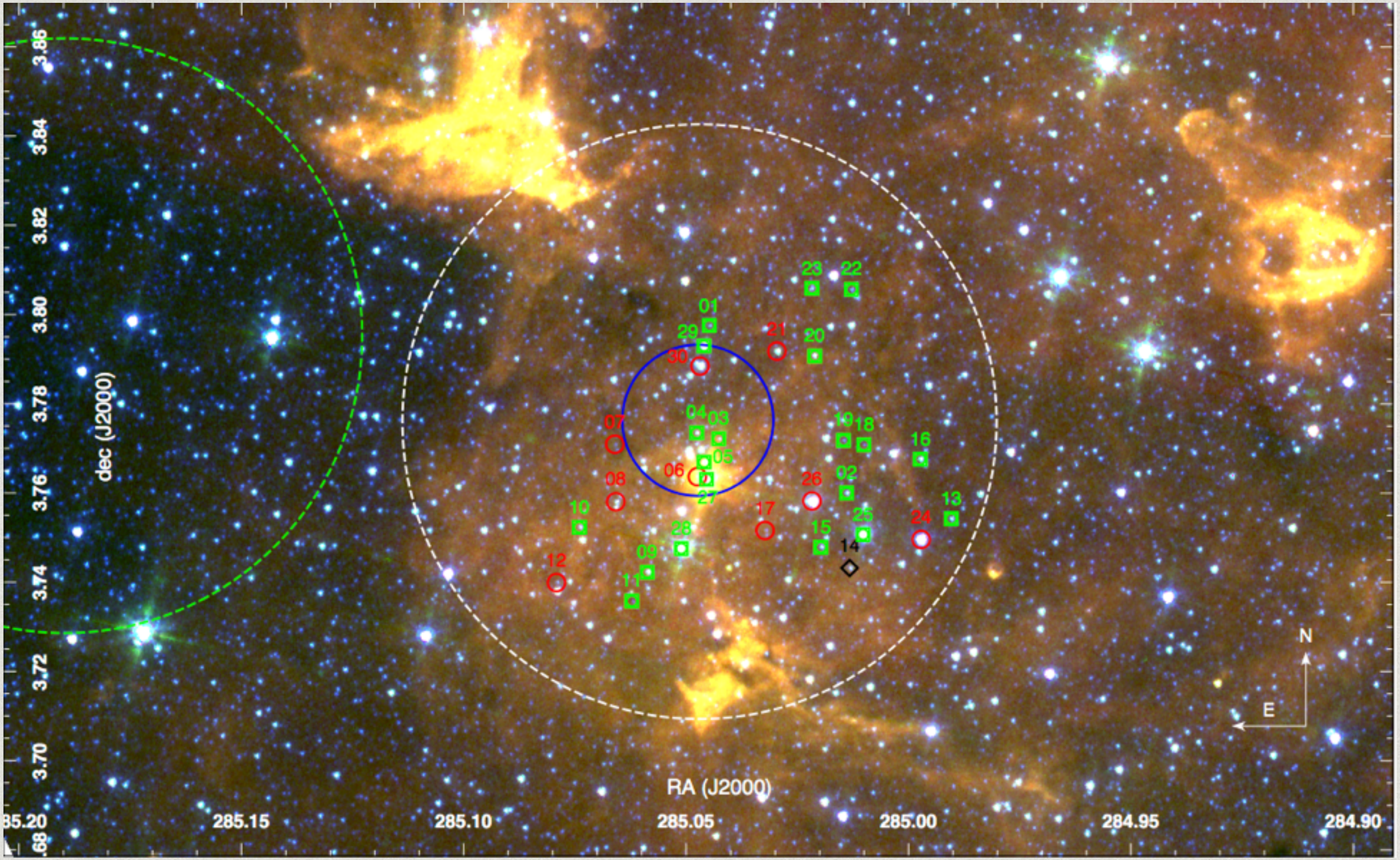
- If a group of at least $\mathbf{N_{min}}$ stars, have one or more companion at less than $\mathbf{D_{opt}}$, it is considered cluster candidate.



Herrero et al. 2017

AUTOPOP-b candidates: Masgomas-6

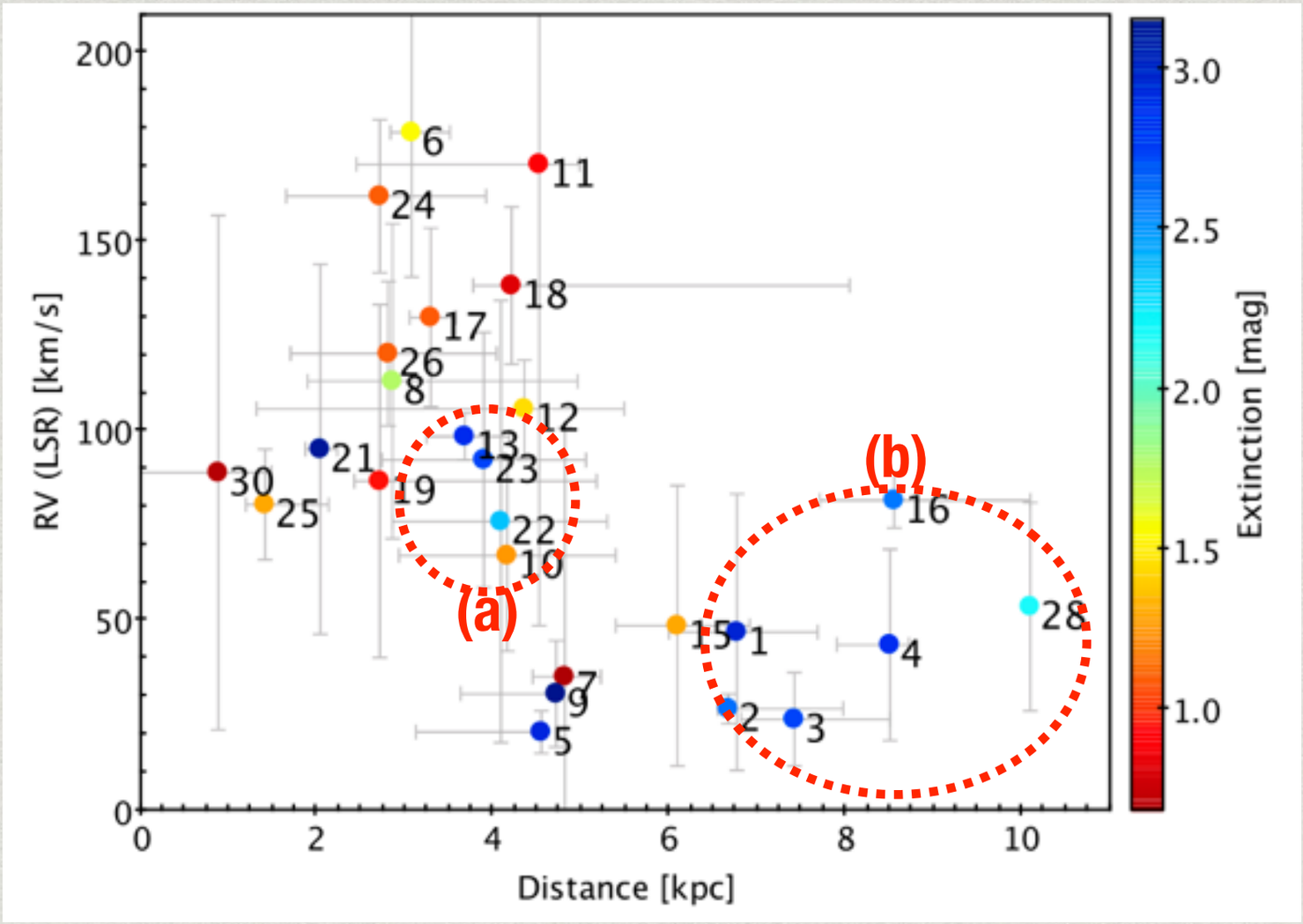
- First candidate with spectroscopic follow-up.
- 30 objects with *H*- & *K*-band spectra; 20 classified as massive stars (OB-dwarfs, giants and supergiants; LBV; WR; RSG).
- But the individual distance estimates ranges from 2-10 kpc.



Ramírez Alegría et al. 2017 (in prep.)

AUTOPOP-b candidates: Masgomas-6

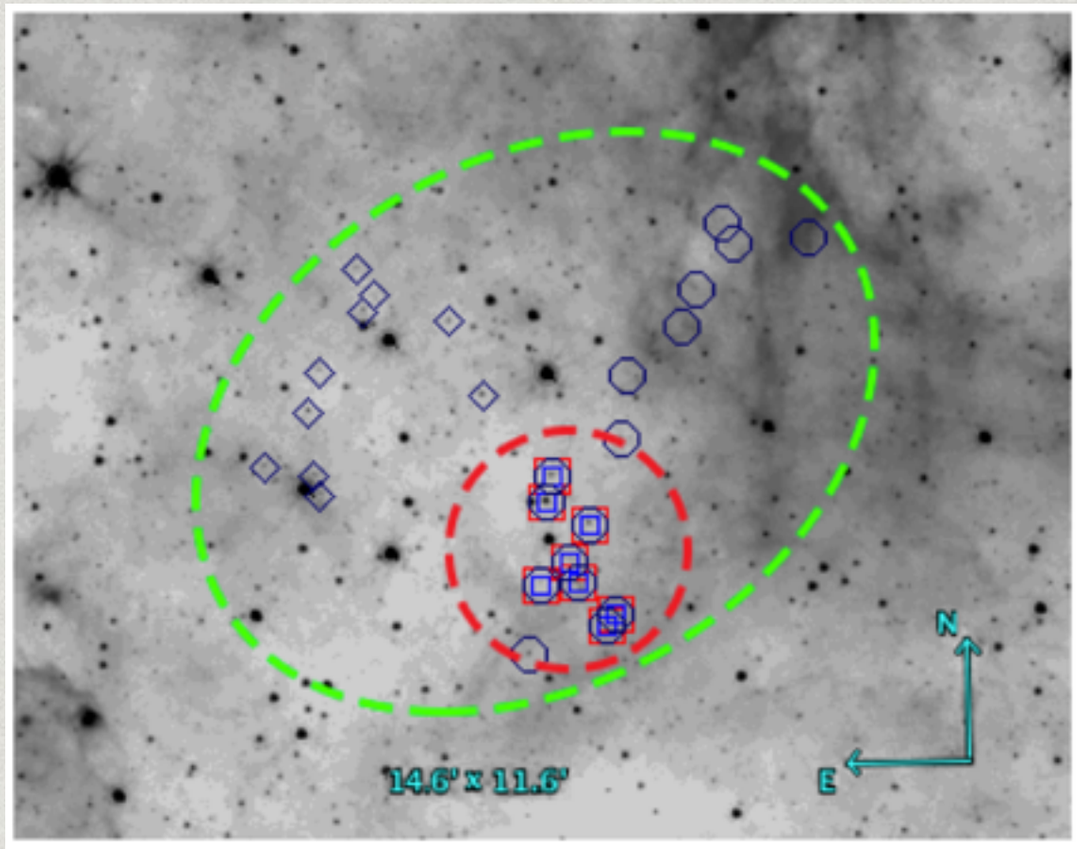
- But the individual distance estimates ranges from 2-10 kpc —> separating with RVs.

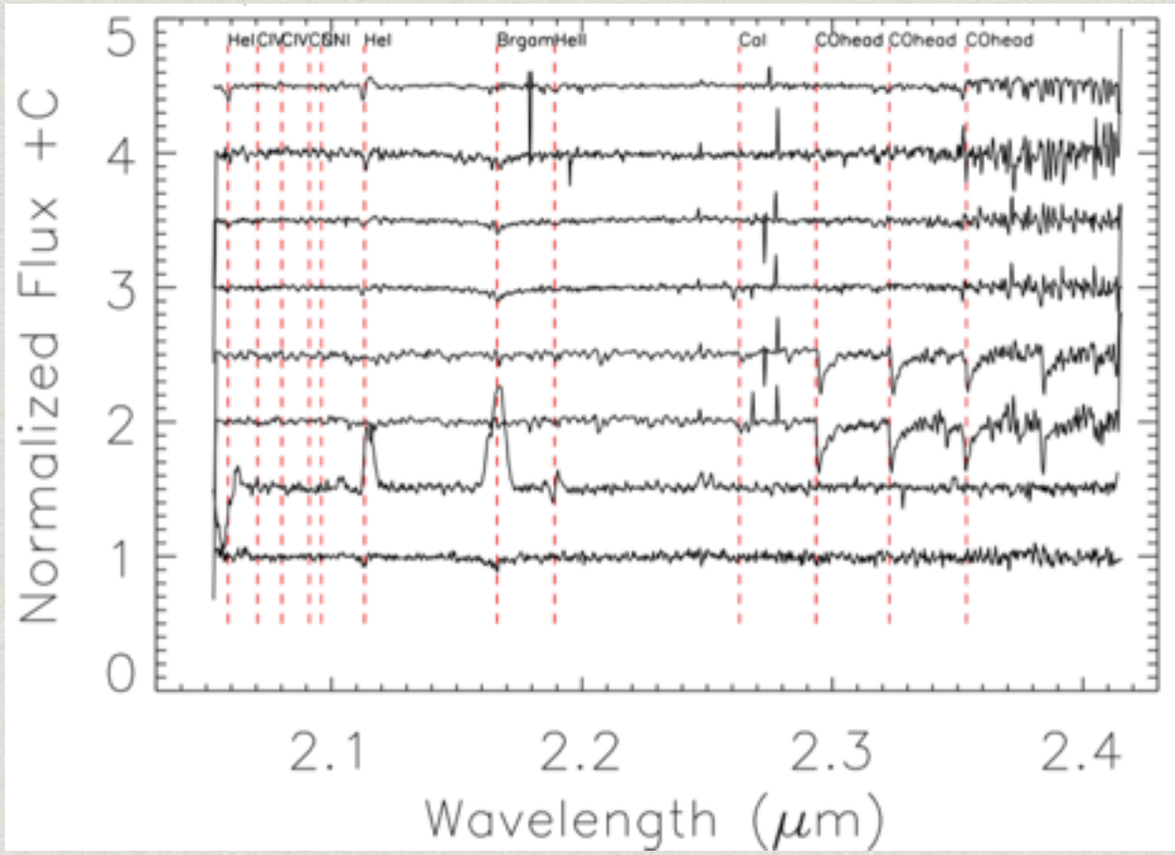


Ramírez Alegría et al. 2017 (in prep.)

AUTOPOP-b candidates: Masgomas-10

- Confirmed as massive cluster using LIRIS@WHT *K*-band spectroscopy.
- 8 early-type objects (including A0I & WN8).

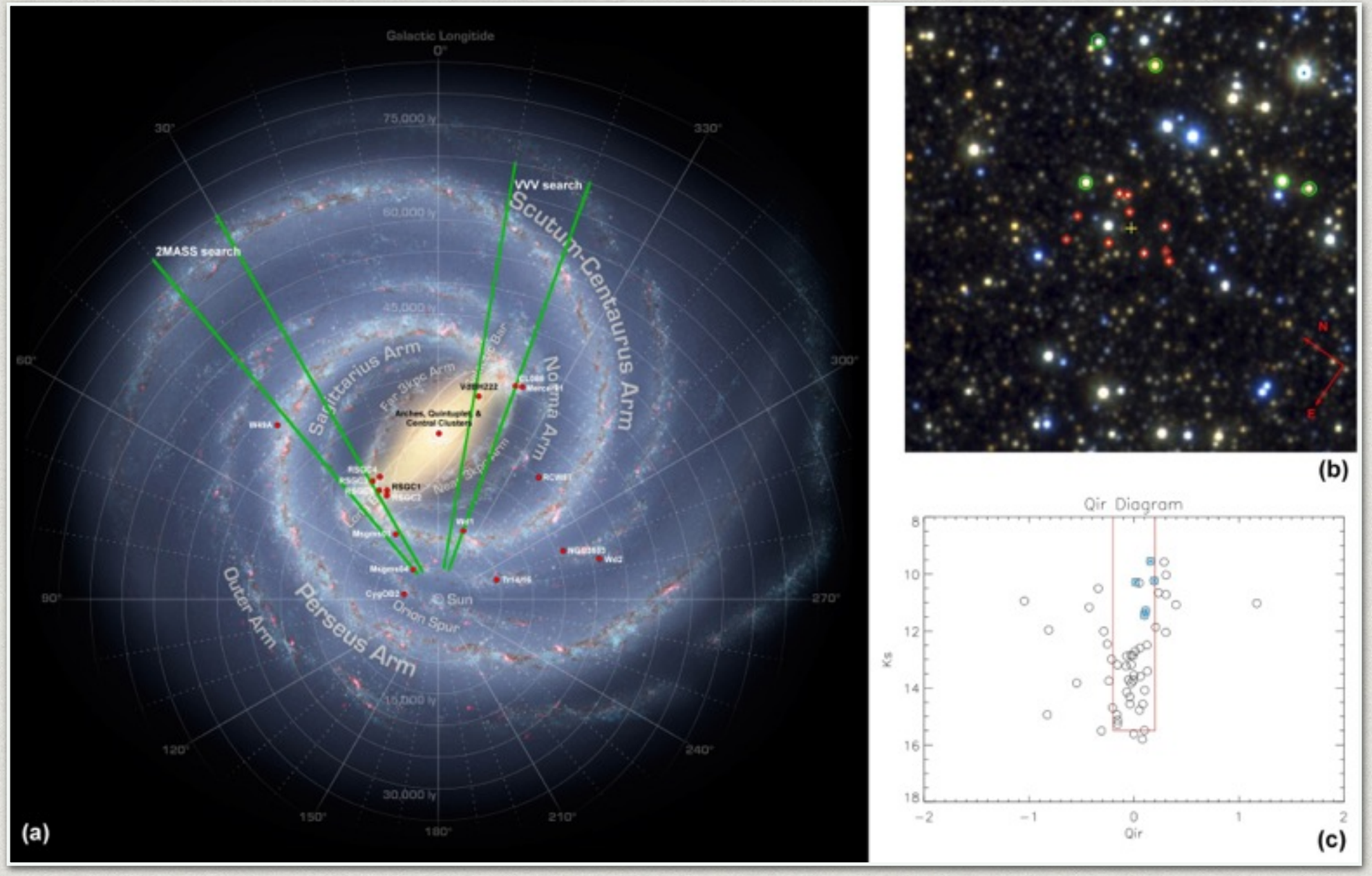




Herrero et al. 2017

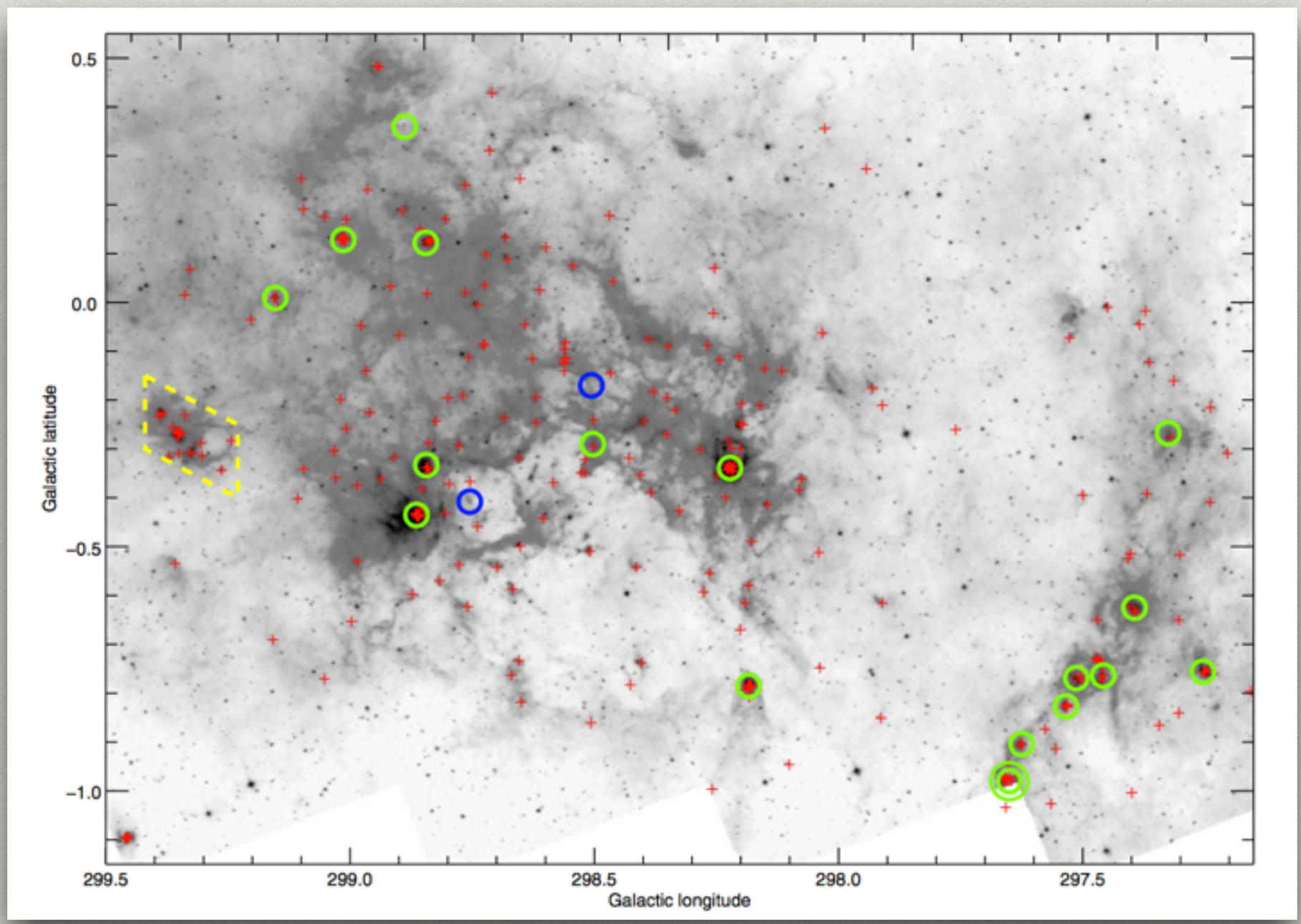
Next steps.

AUTOPOP-b candidates: Southern extension



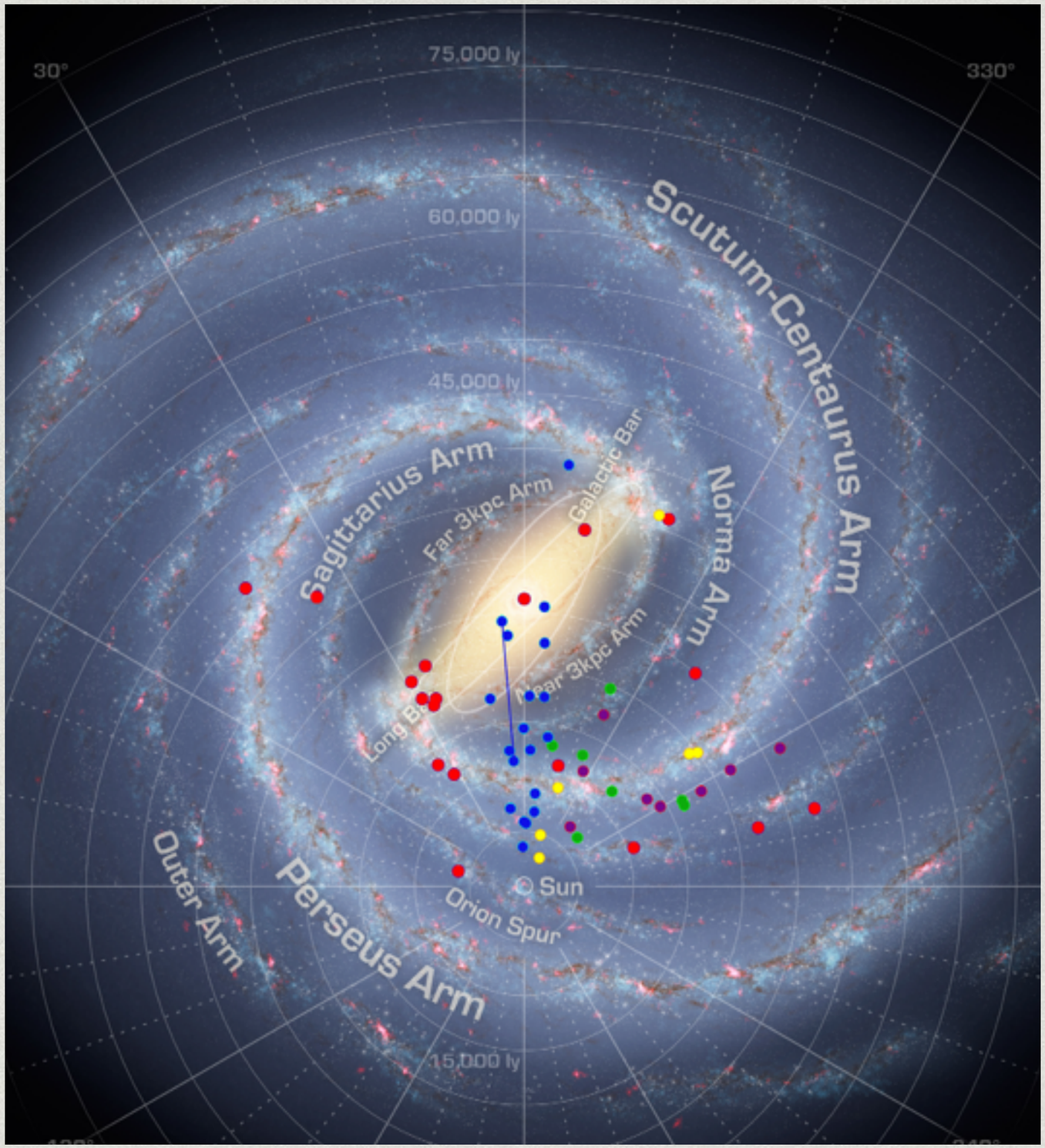
Studying the environment around clusters

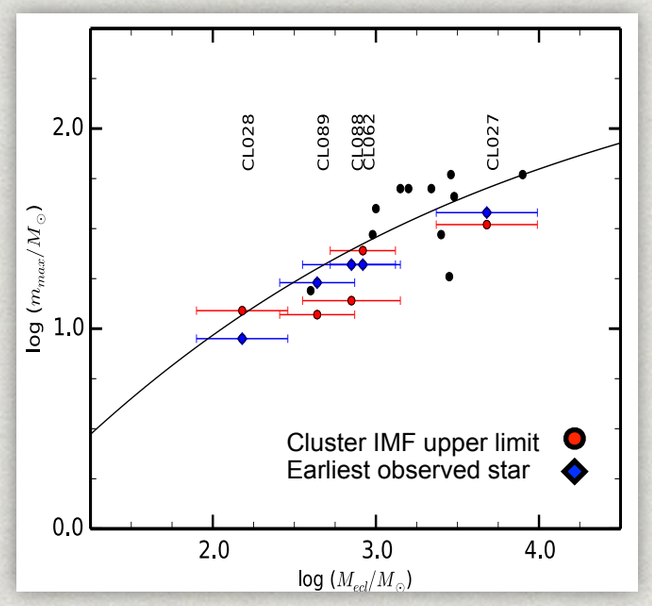
(Corti et al. 2016; de la Fuente et al. 2016)

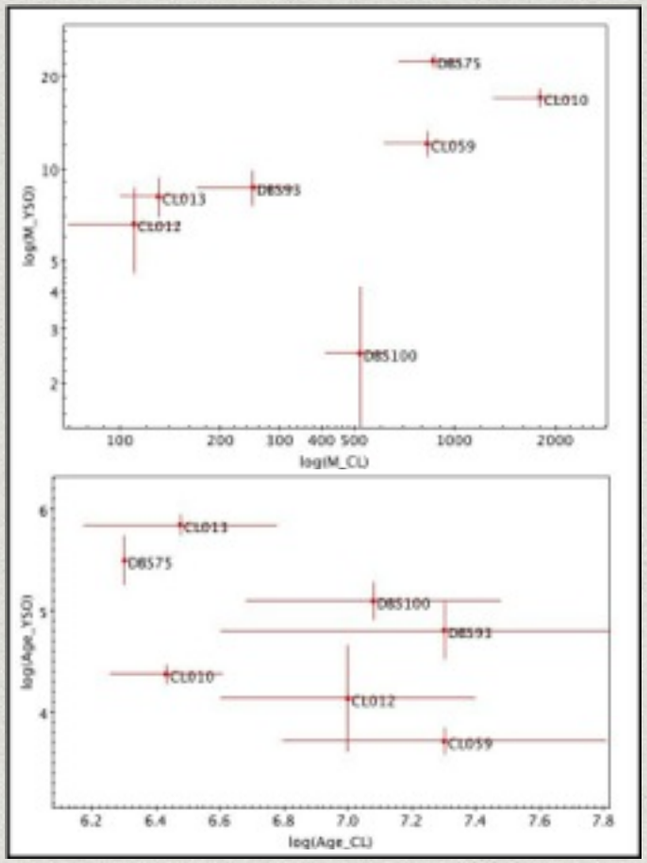


Mercer30 & the Dragonfish nebula
(de la Fuente et al. 2016)

Using the database of cluster parameters







Conclusions + open questions

- Near infrared surveys are a useful resources to find stellar cluster ***candidates.***
  - Spectroscopic confirmation required.
- The use of K_S-Q_{IR}-$(J-K_S)$ selection criteria is effective to find massive star cluster candidates (once the extinction law is well determined).
- Is a cluster always an over-density?
  In which (minimal) space (RA, dec, *UVB*+*Q*, *JHK*+Q_{IR}, MIR, sub-mm, PM, RV, …)?