

The Scutum Complex

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Beijing
August 2012



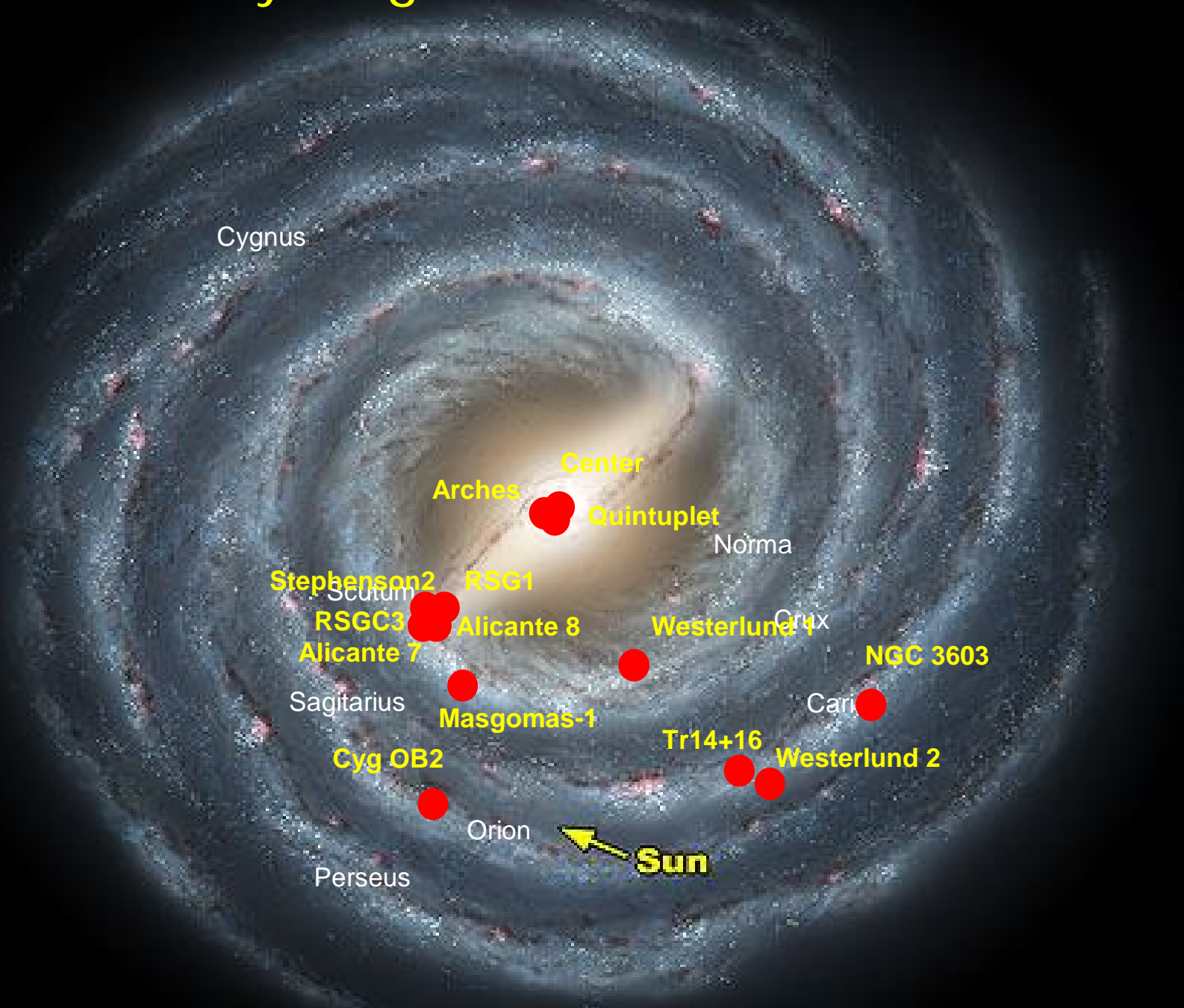
Collaborators

- **Ricardo Dorda,**
- **Carlos González-Fernández,**
- **Amparo Marco** (Universidad de Alicante)

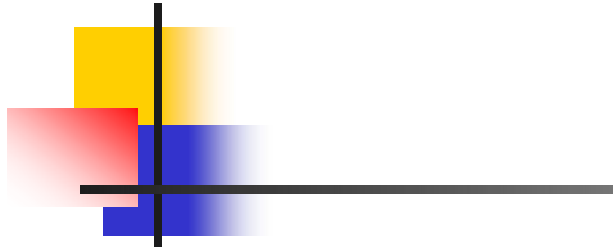
- **J. Simon Clark** (Open University)

- **Fran Jiménez-Esteban** (Spanish Virtual Observatory)

Distribution of young massive clusters in the Milky Way



A cluster with red supergiants

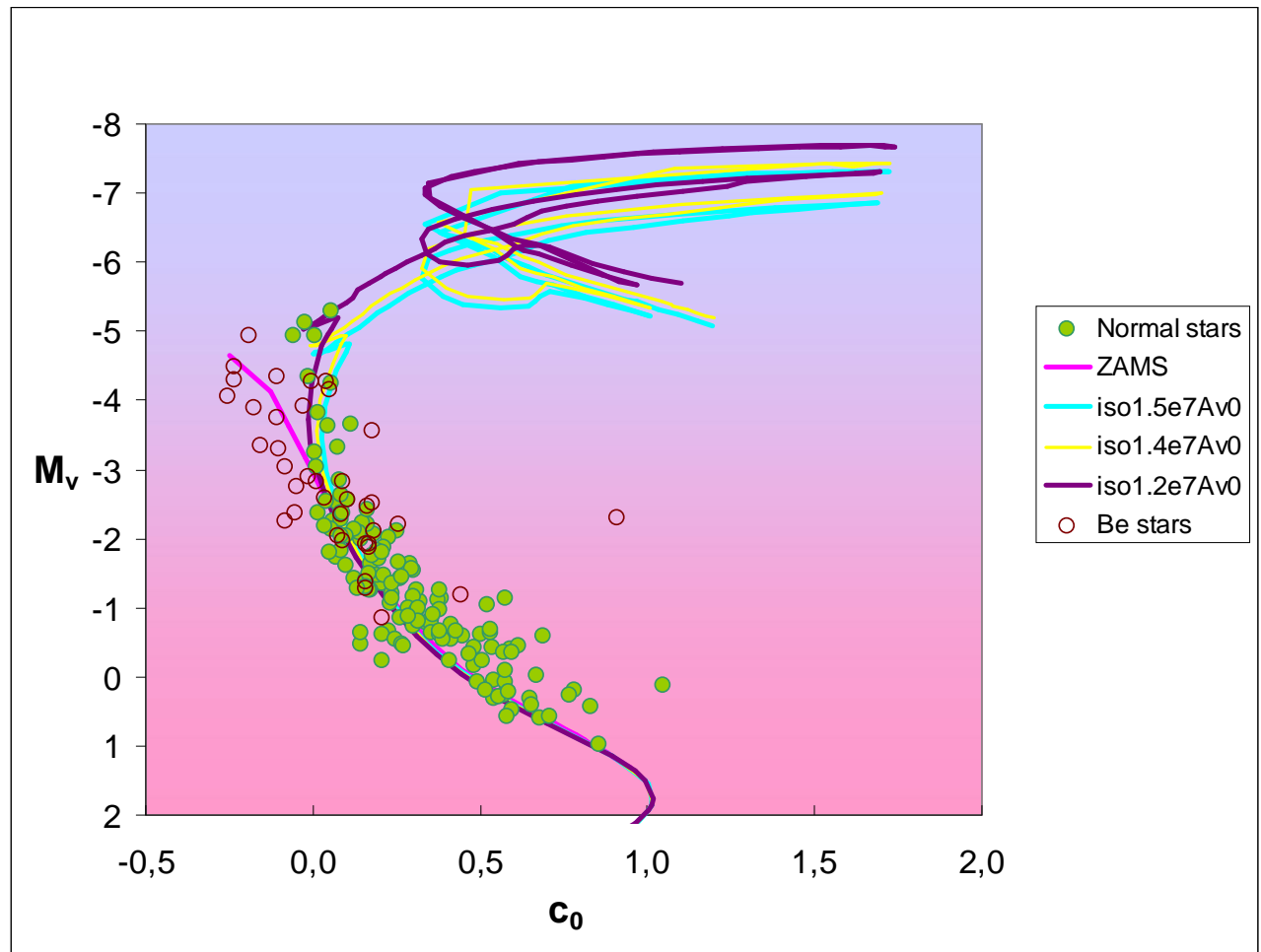


The open cluster
NGC 7419, observed
with the
NOT+ALFOSC,
October 2005.
False colours from
Strömgren *vby*
frames



A cluster with red supergiants

- Age 14 ± 2 Myr
- Mass of RSGs $\geq 15 M_{\odot}$
- Cluster mass $3-4 \times 10^3 M_{\odot}$
- Huge fraction of Be stars (about $\sim 40\%$ close to the turnoff)



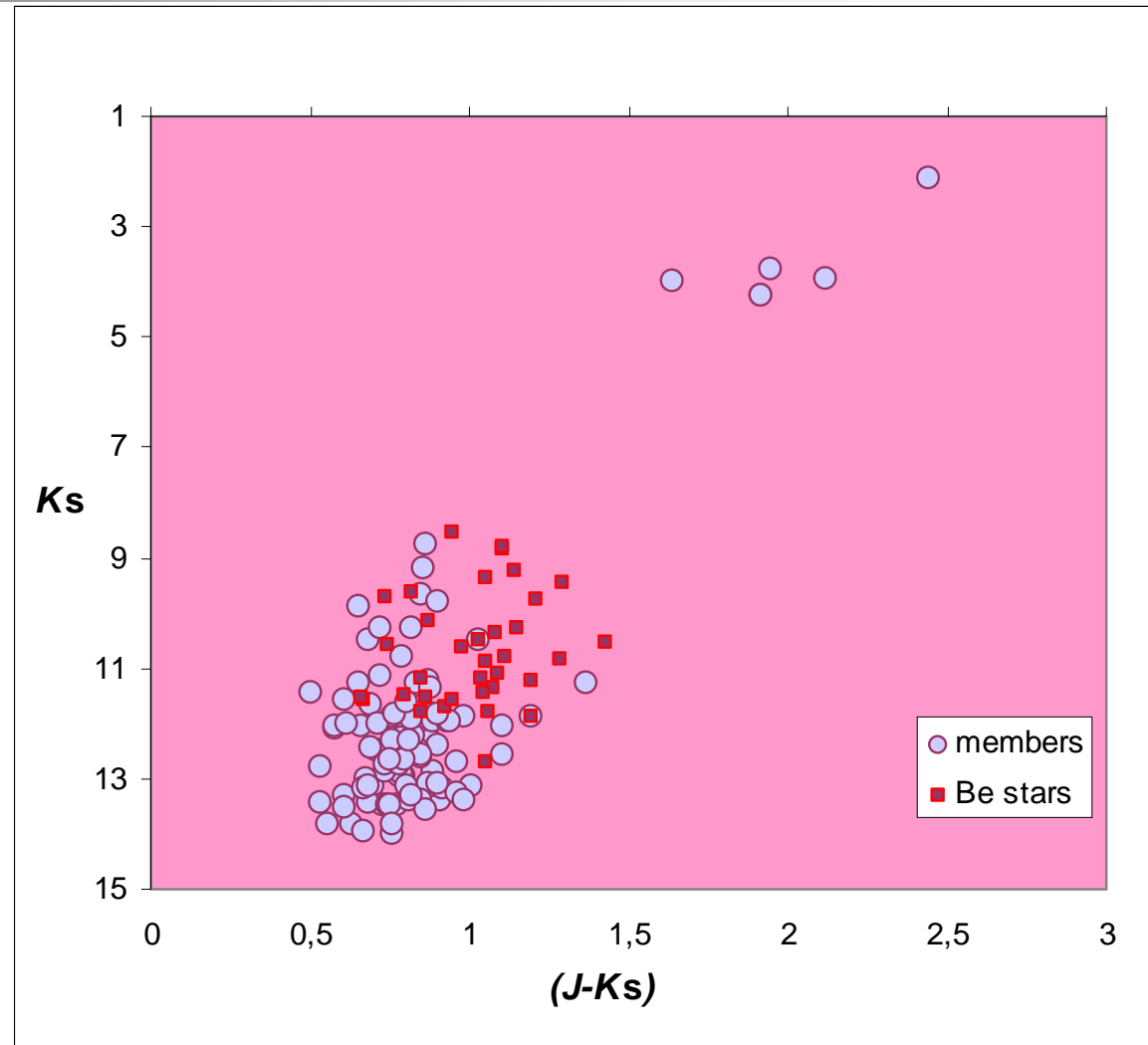
A cluster with red supergiants



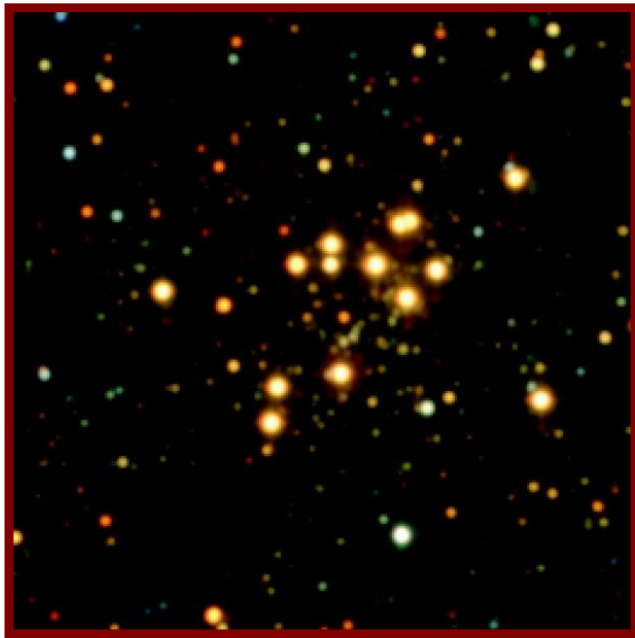
The open cluster
NGC 7419, from
the 2MASS
Showcase Gallery.
False colours from
JHK frames

A cluster with red supergiants

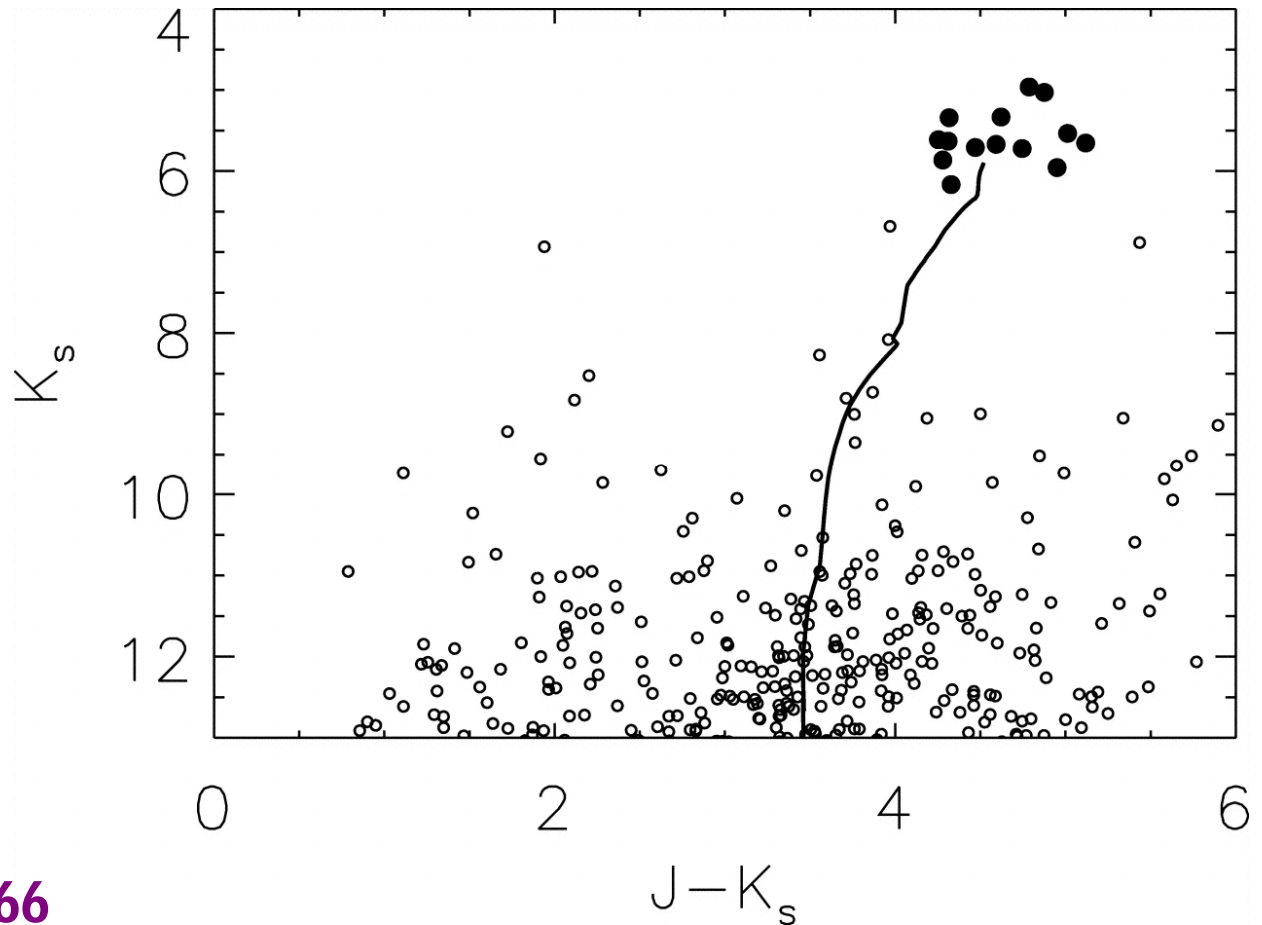
- Age 12 ± 2 Myr
- Mass of RSGs $\geq 16 M_{\odot}$
- Cluster mass $3-4 \times 10^3 M_{\odot}$
- Huge fraction of Be stars (about $\sim 40\%$ close to the turnoff)



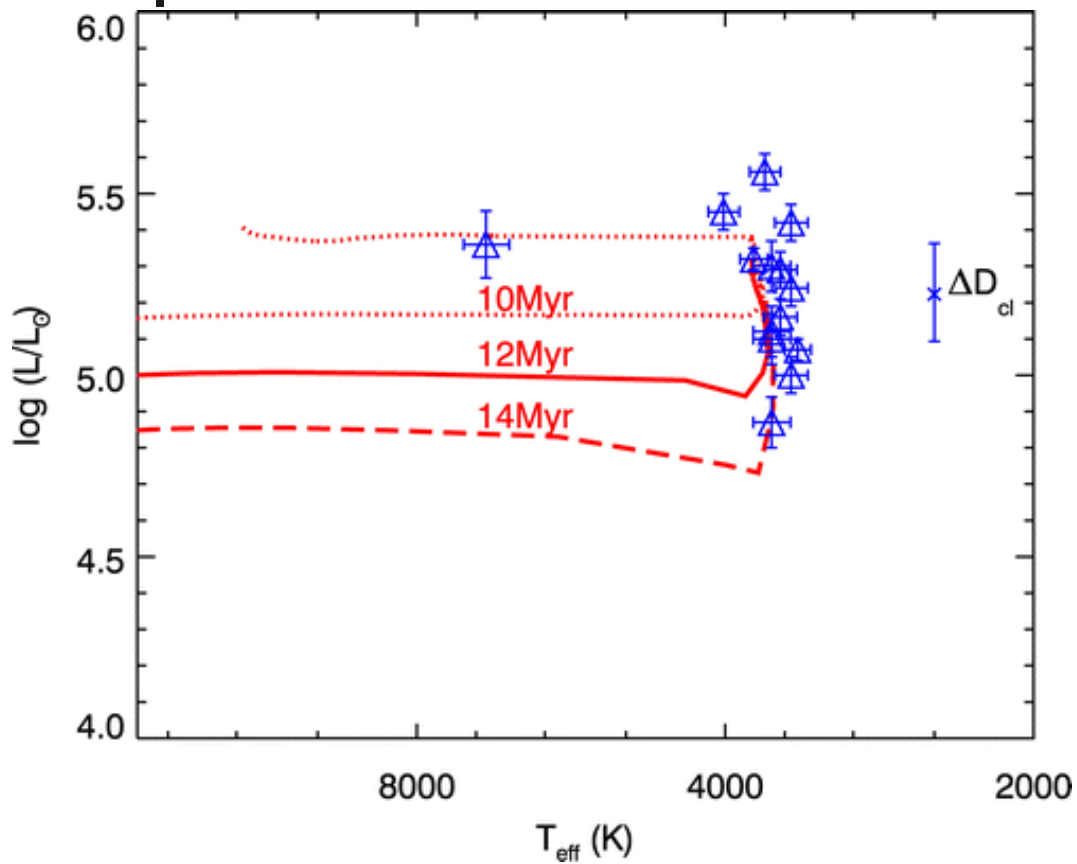
The clusters of red supergiants



**Red Supergiant
Cluster (RSGC) 1**

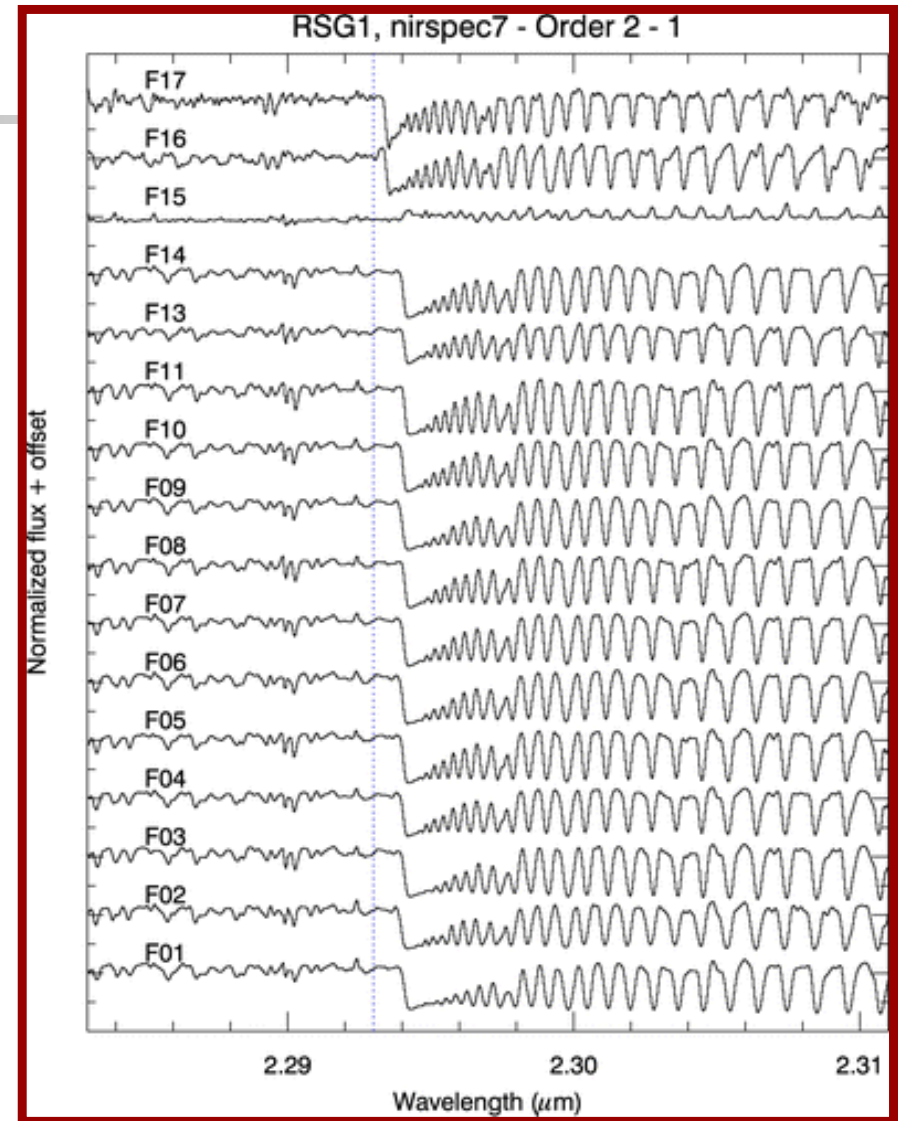


RSGC1



- Age 10-14 Myr
- Total mass $M \sim 3 \times 10^4 M_{\odot}$

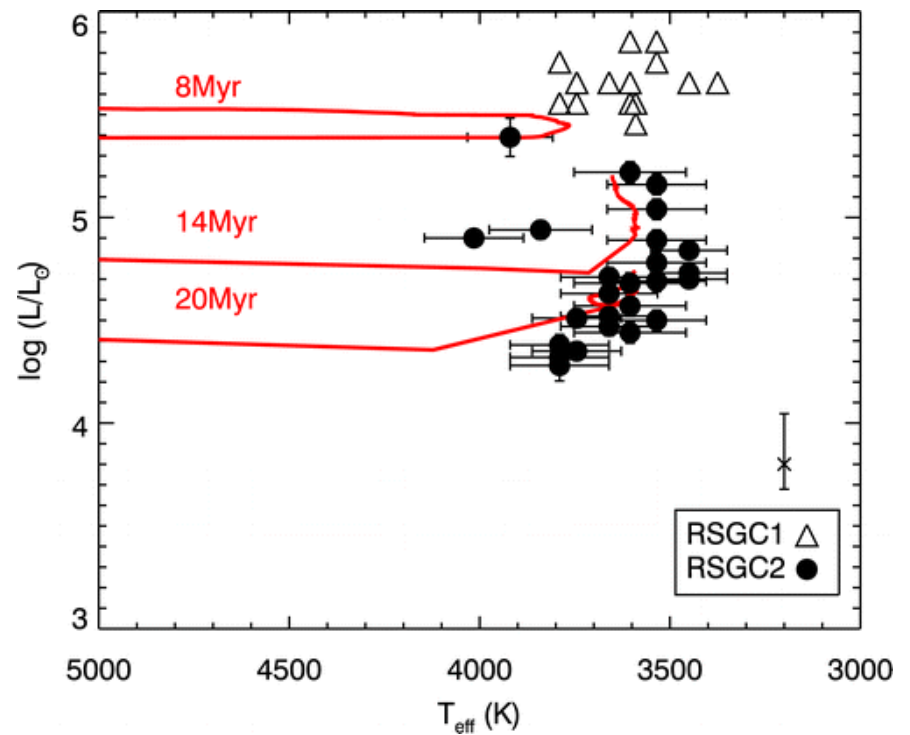
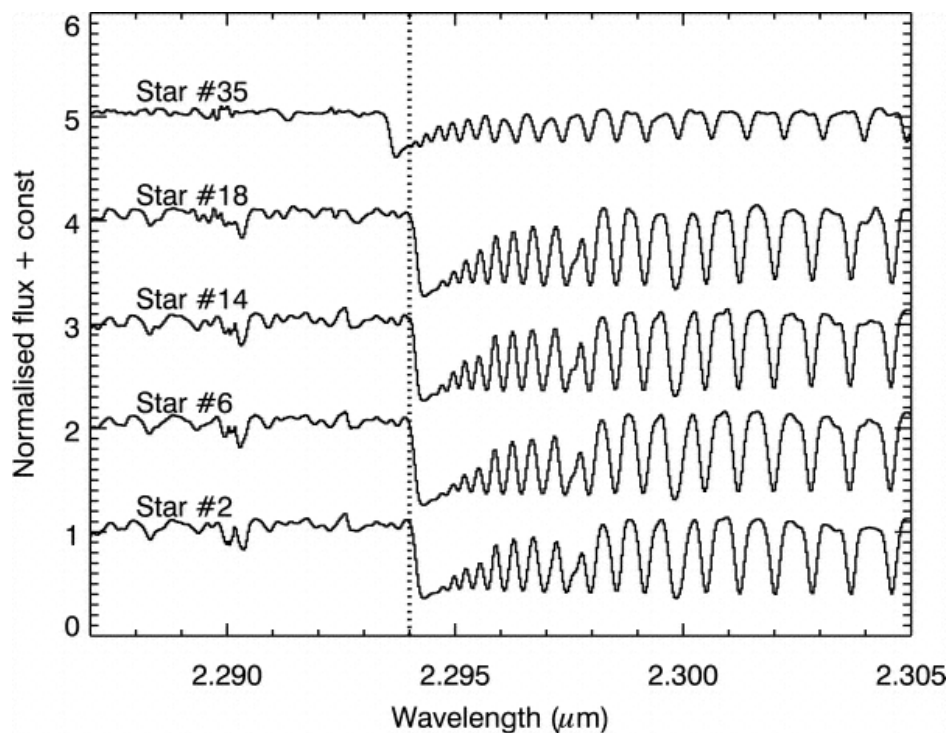
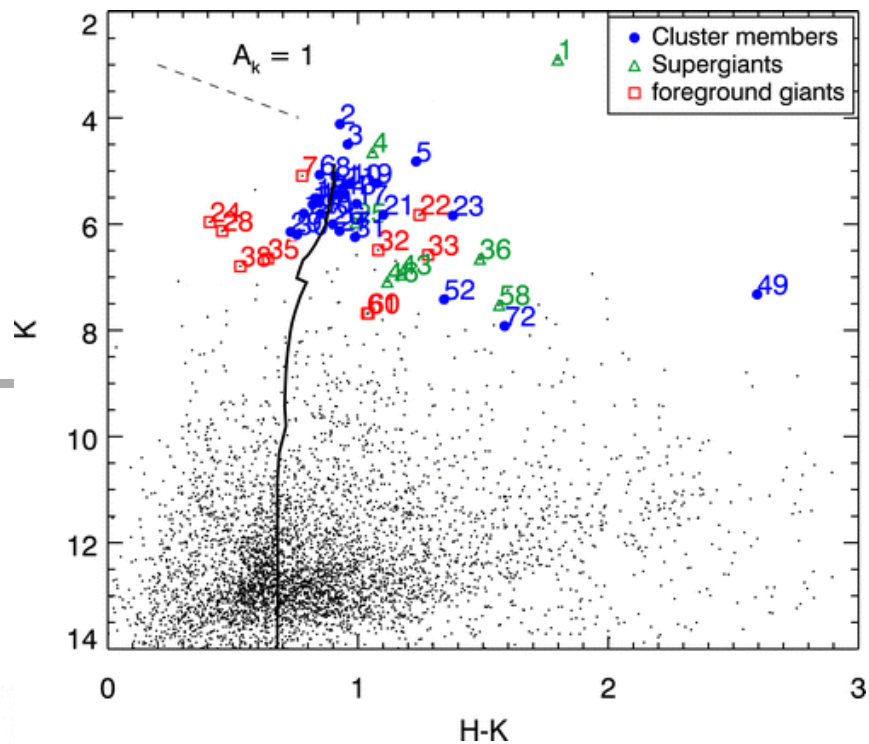
$$A_{K_s} = 2.6$$



Davies et al. 2008, ApJ 676, 1016

Stephenson 2 = RSGC2

- Age 15-20 Myr
- Total mass $M \sim 5 \times 10^4 M_{\odot}$



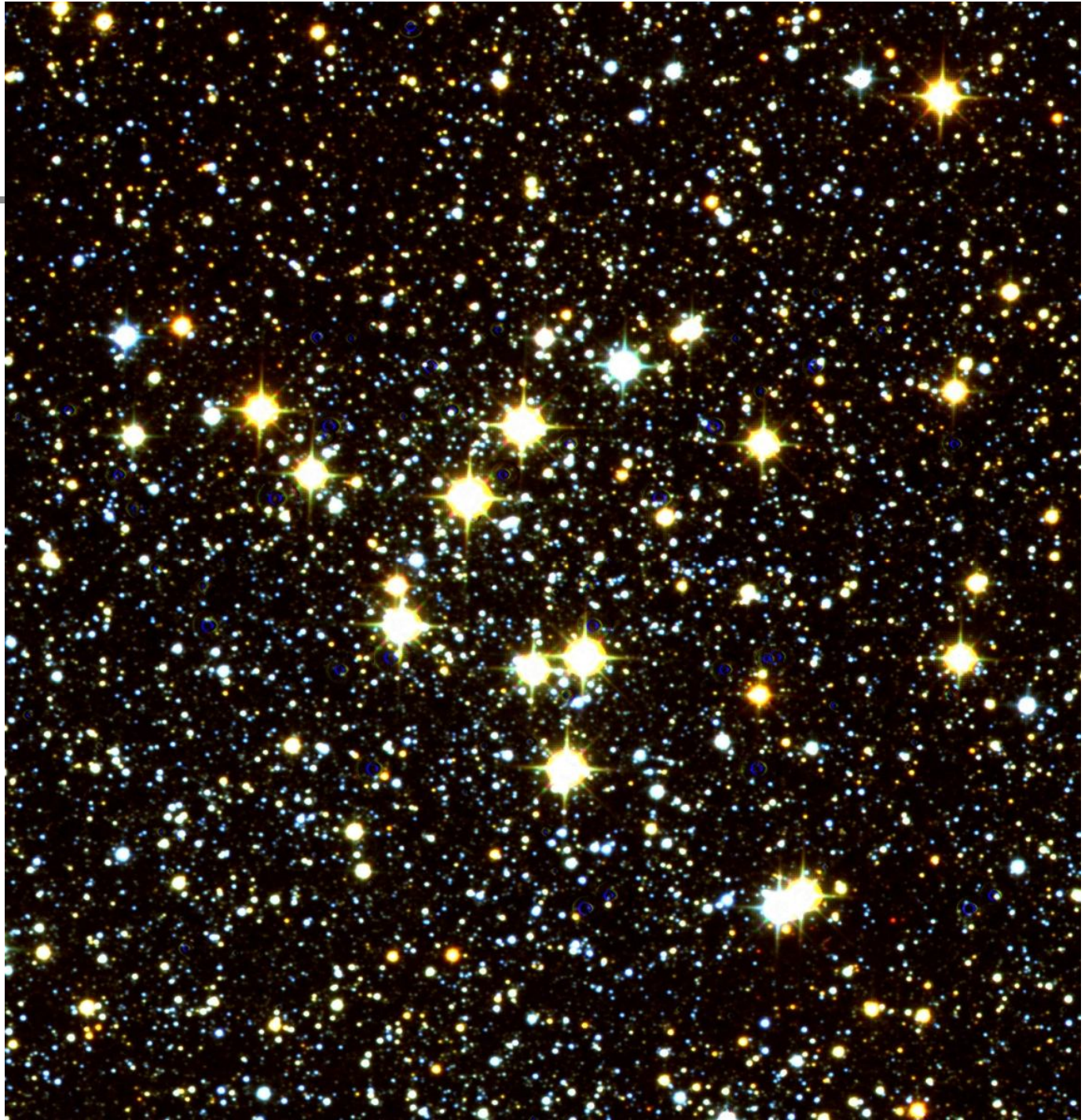
Davies et al. 2007, ApJ 671, 781

$$A_{Ks} = 1.4$$

The logo for RSGC3 features a stylized crosshair. The vertical bar is black and passes through a yellow square above and a blue square below. The horizontal bar is black and passes through a red square on the left and a blue square on the right. The text 'RSGC3' is written in a dark red, serif font to the right of the crosshair.

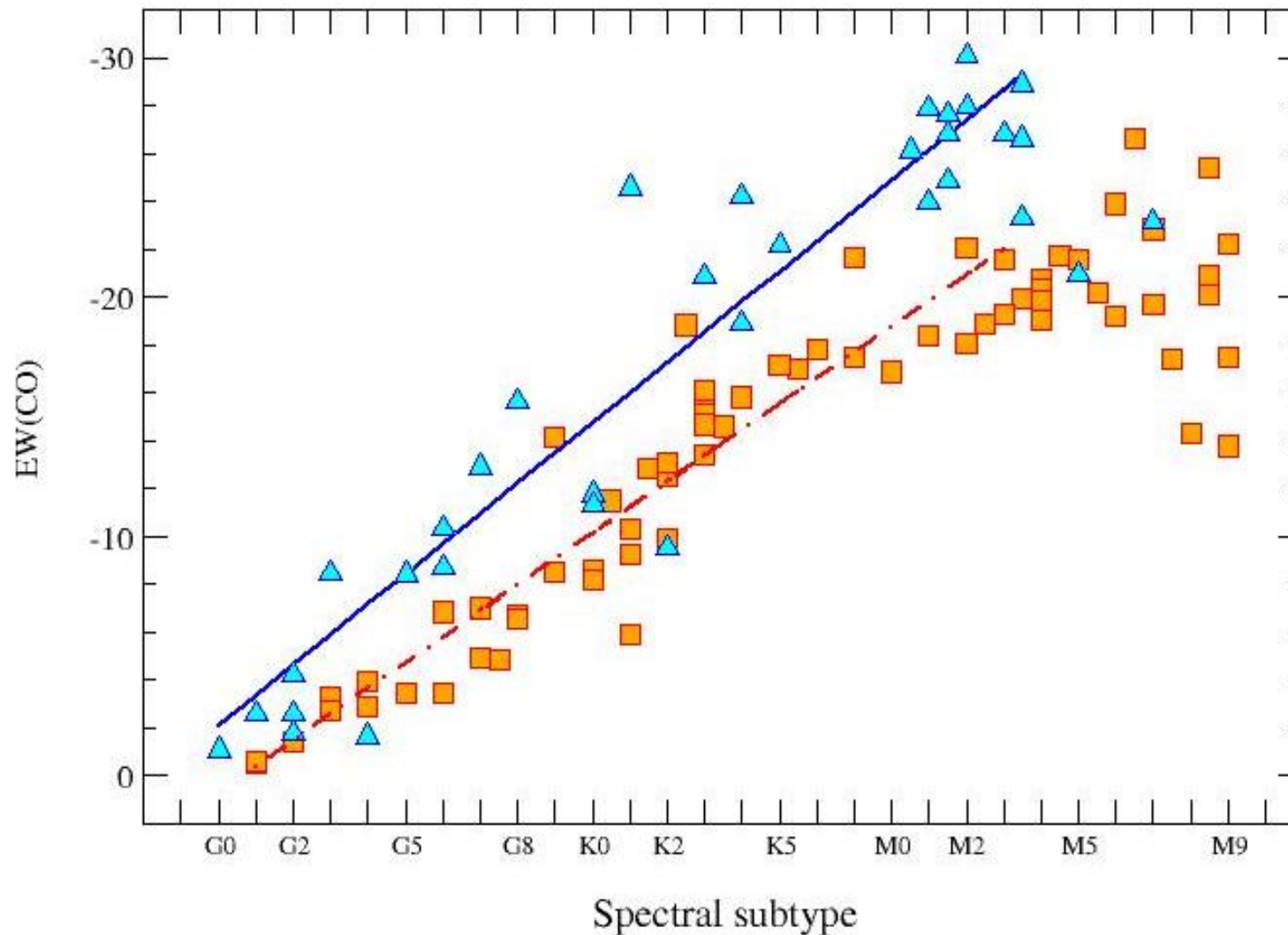
RSGC3

UKIDDS 3-colour
composite image (with
enhancements) of
massive cluster RSGC3

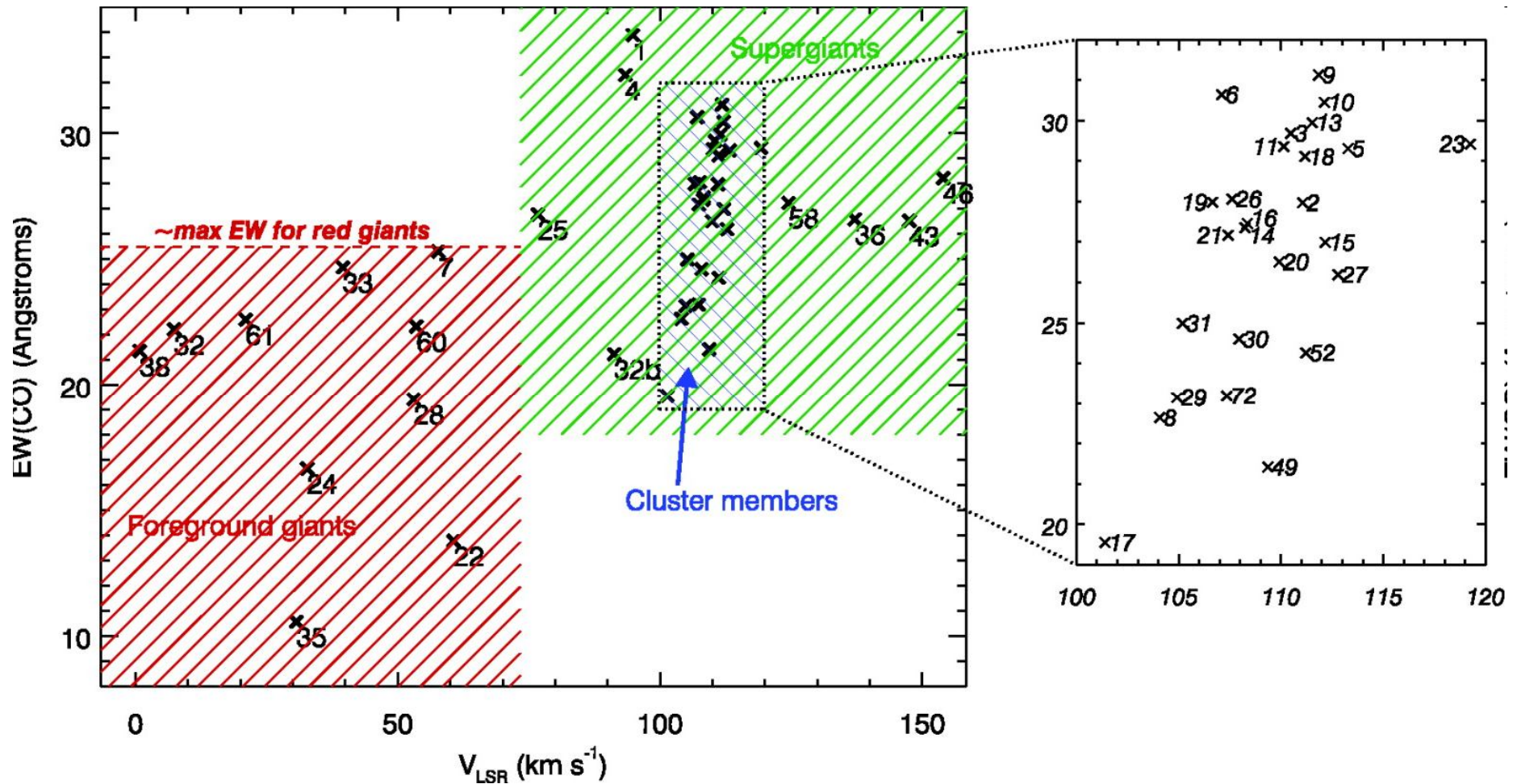


How do we know what they are?

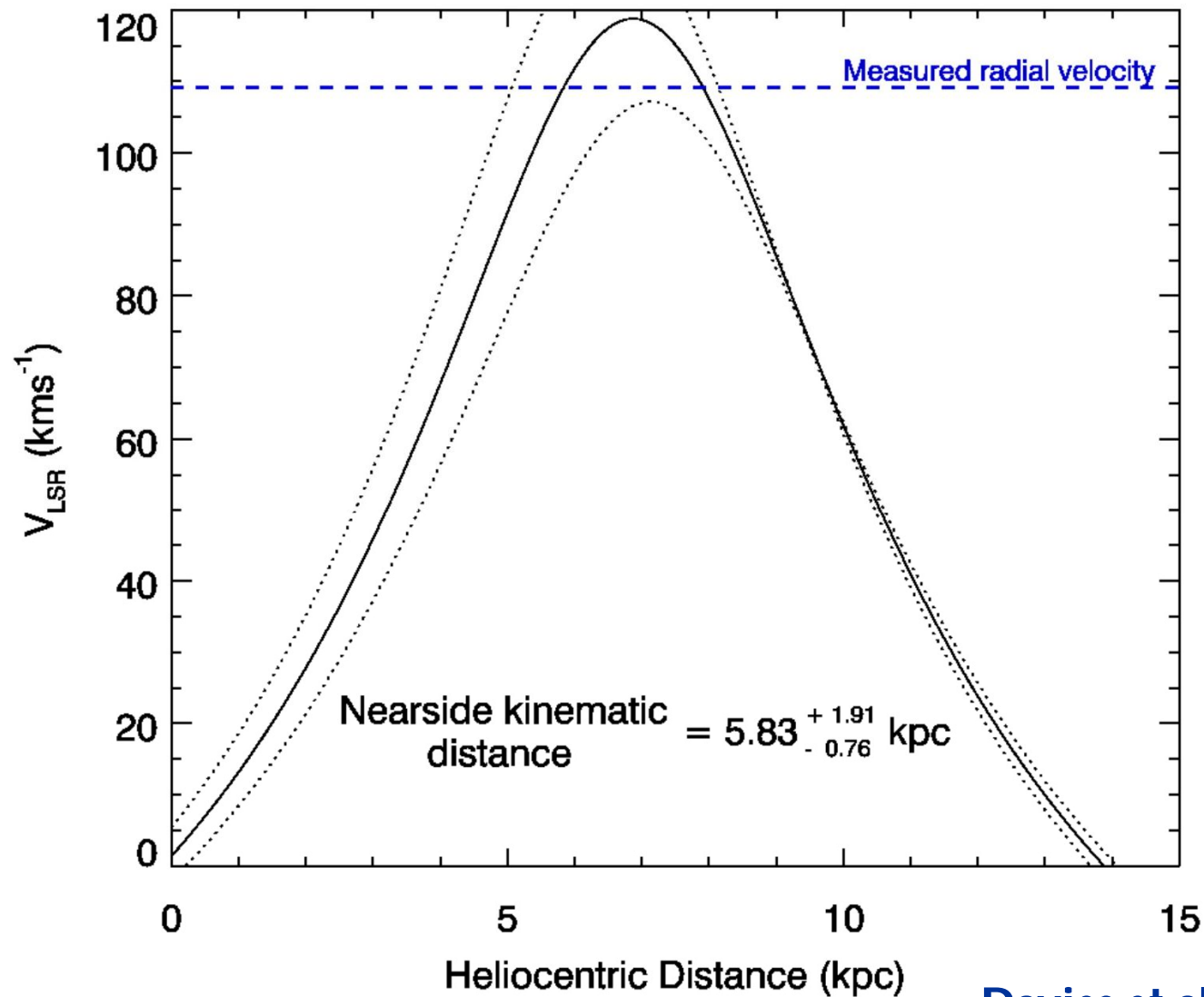
Negueruela et al. 2010, A&A 516, A78



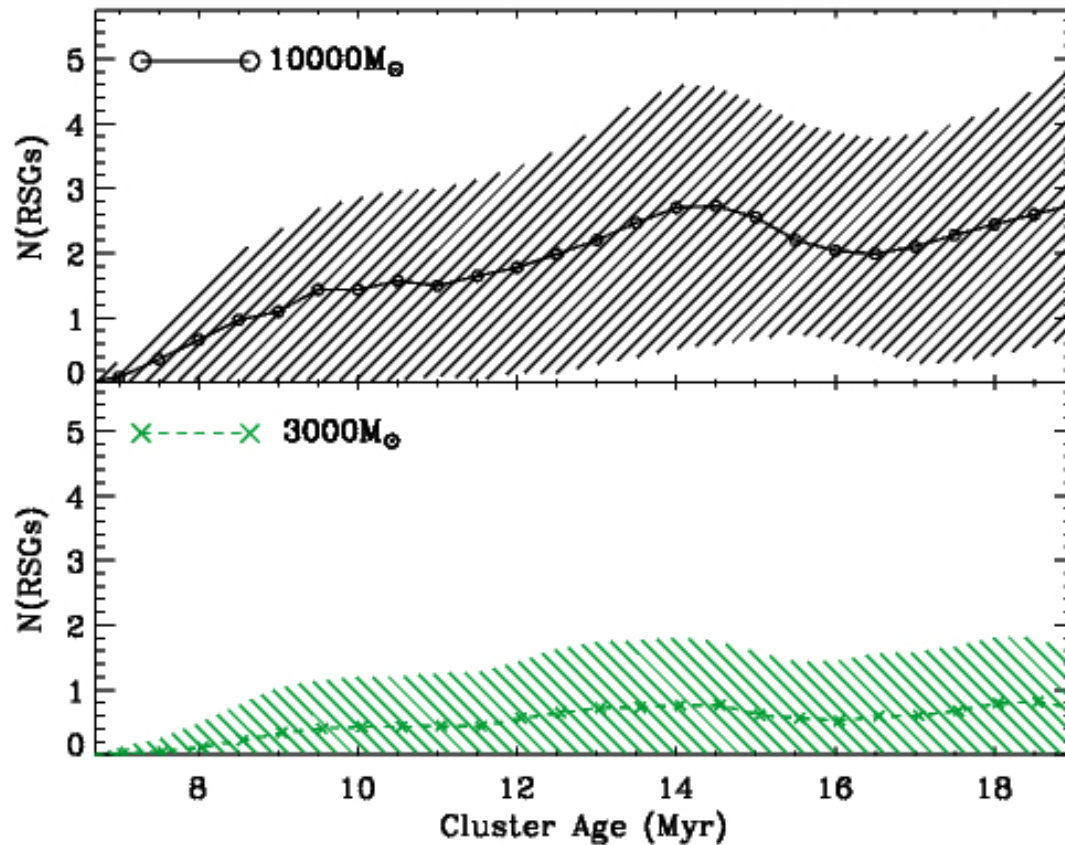
How do we know how big they are?



How do we know where they are?

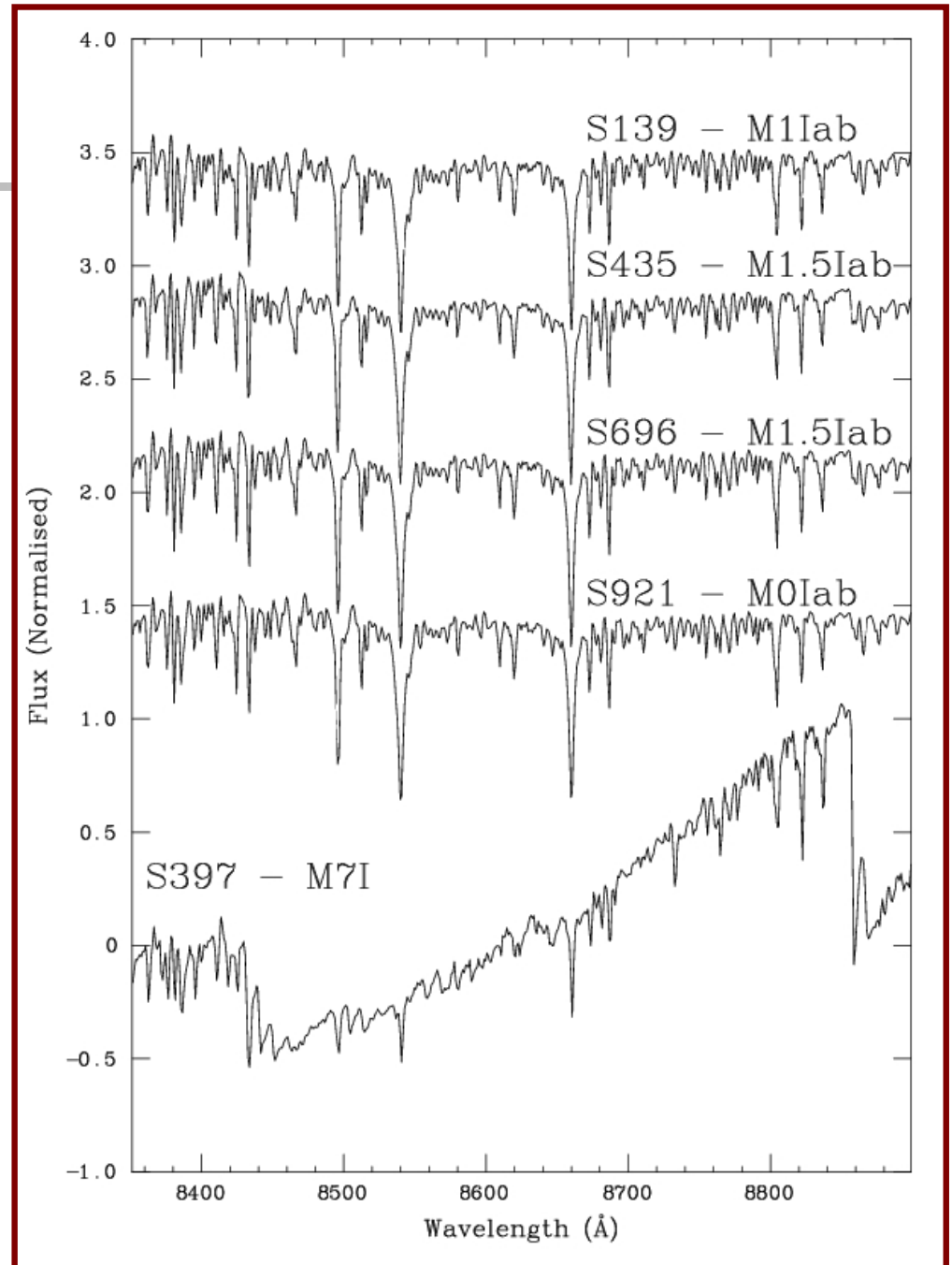


How do we know what's behind?



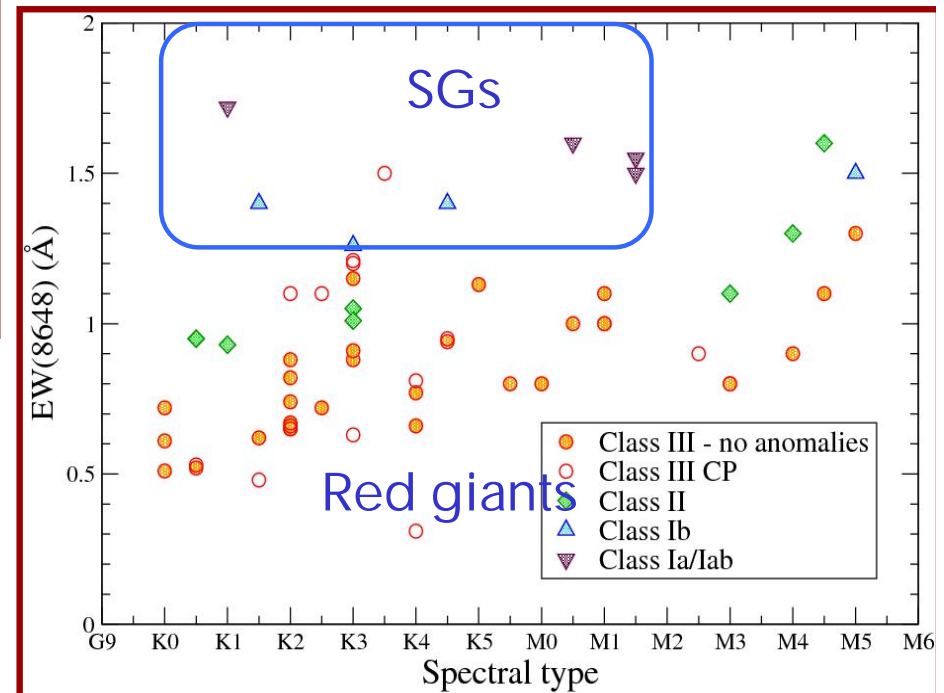
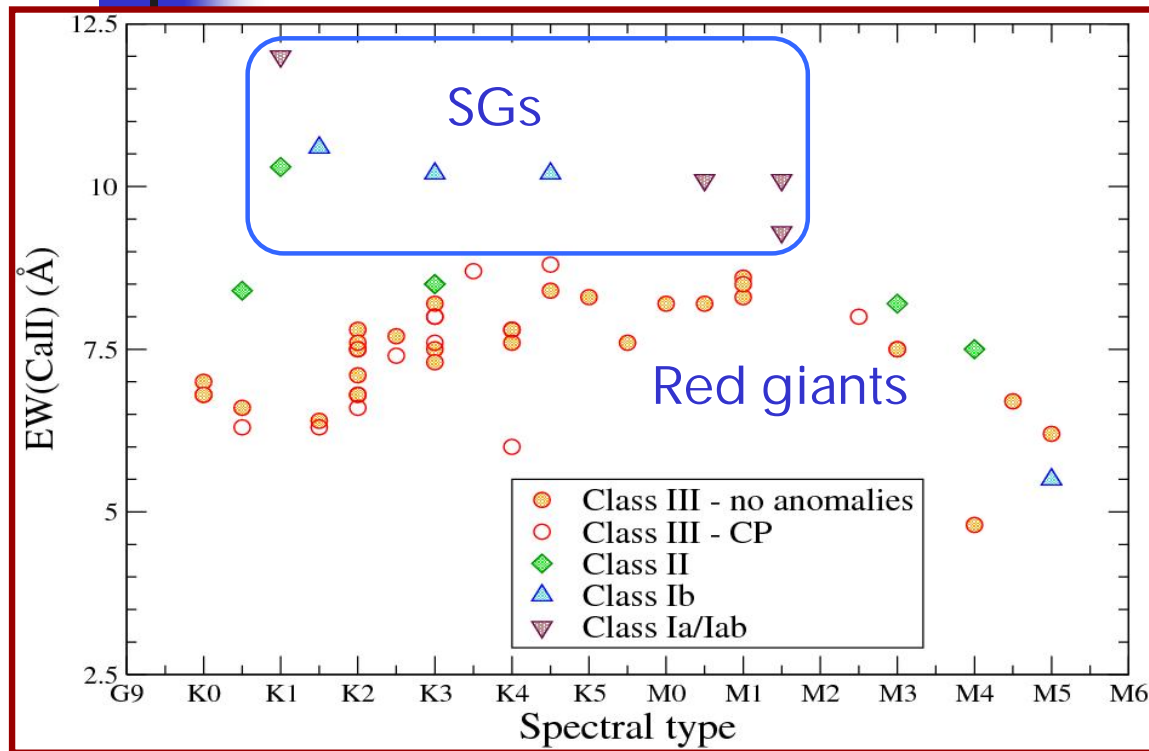
Montecarlo simulations of a stellar population with a standard Kroupa IMF

The I -band spectra



The I -band spectra

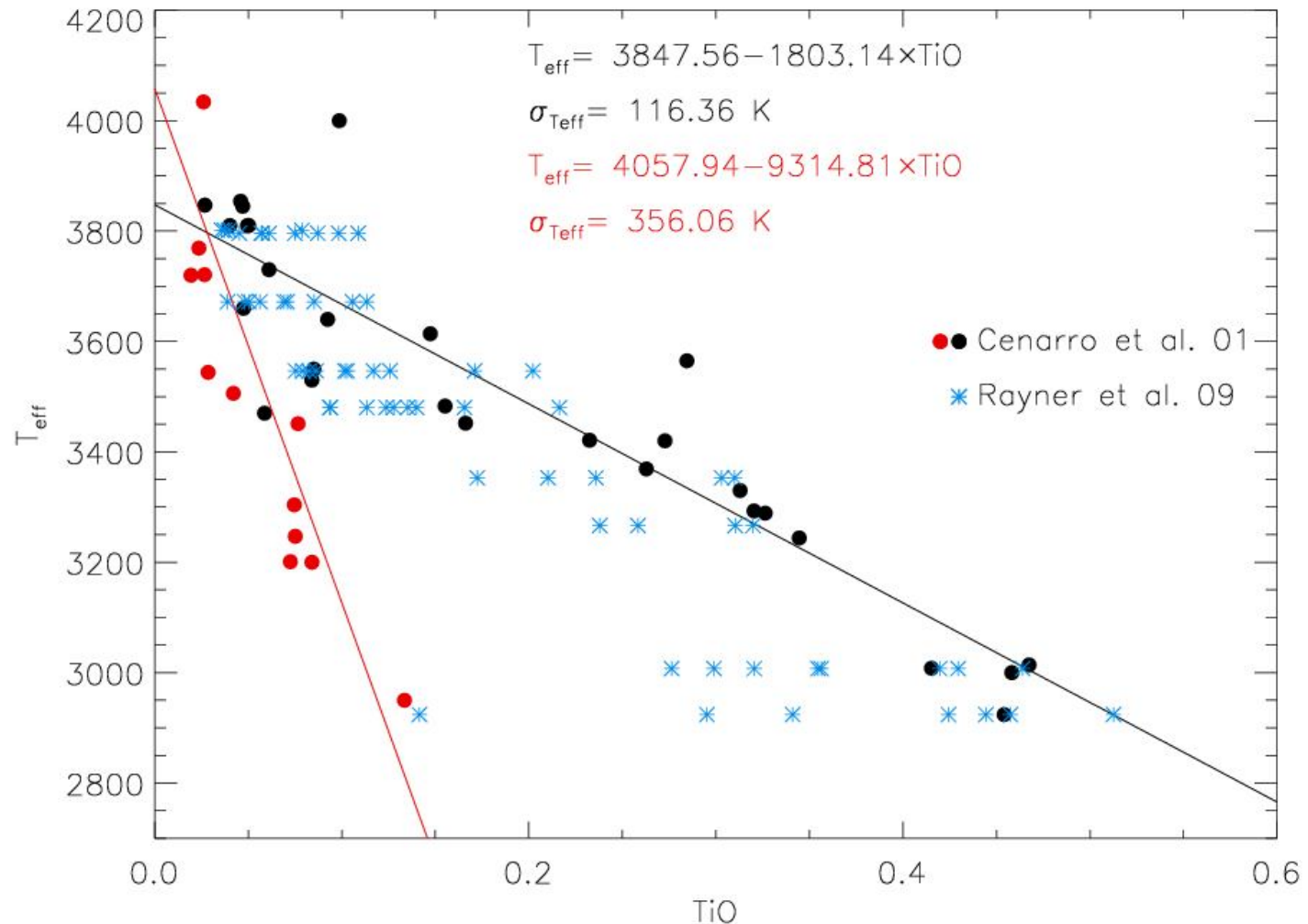
or using optical detectors to study obscured RSGs



The I -band spectra

or using optical detectors to study obscured RSGs

Calibration of the depth of the TiO bandhead at 8860Å against effective temperature.



Stephenson 2

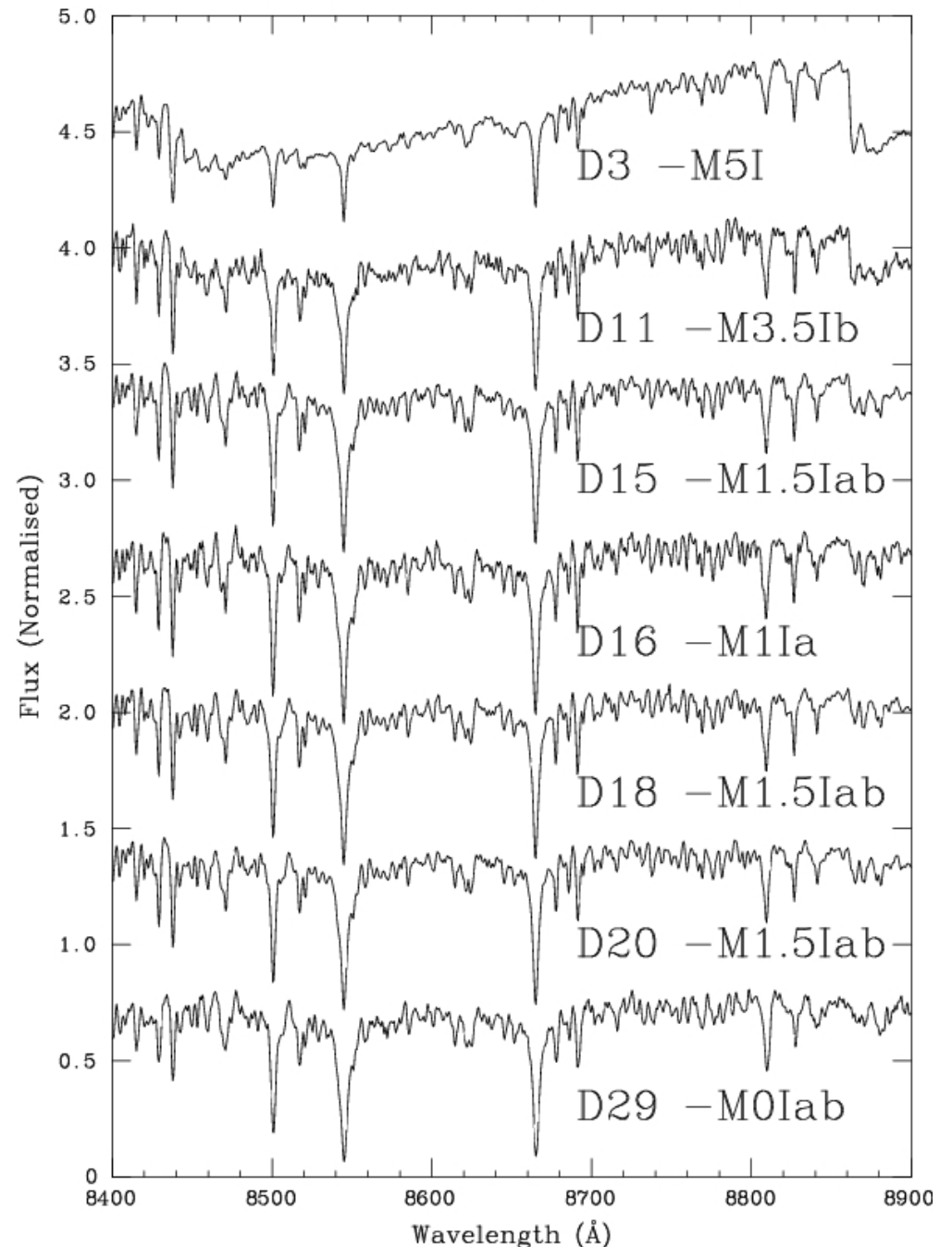
= RSGC2

- We confirm the nature of several RSGs.
- The CO bandhead spectral types are only approximate.
 - Average dispersion is ± 1 spectral subtype.
 - But a given star may easily be wrong by 3 subtypes

Calar Alto 3.5 m + TWI N, July 2009

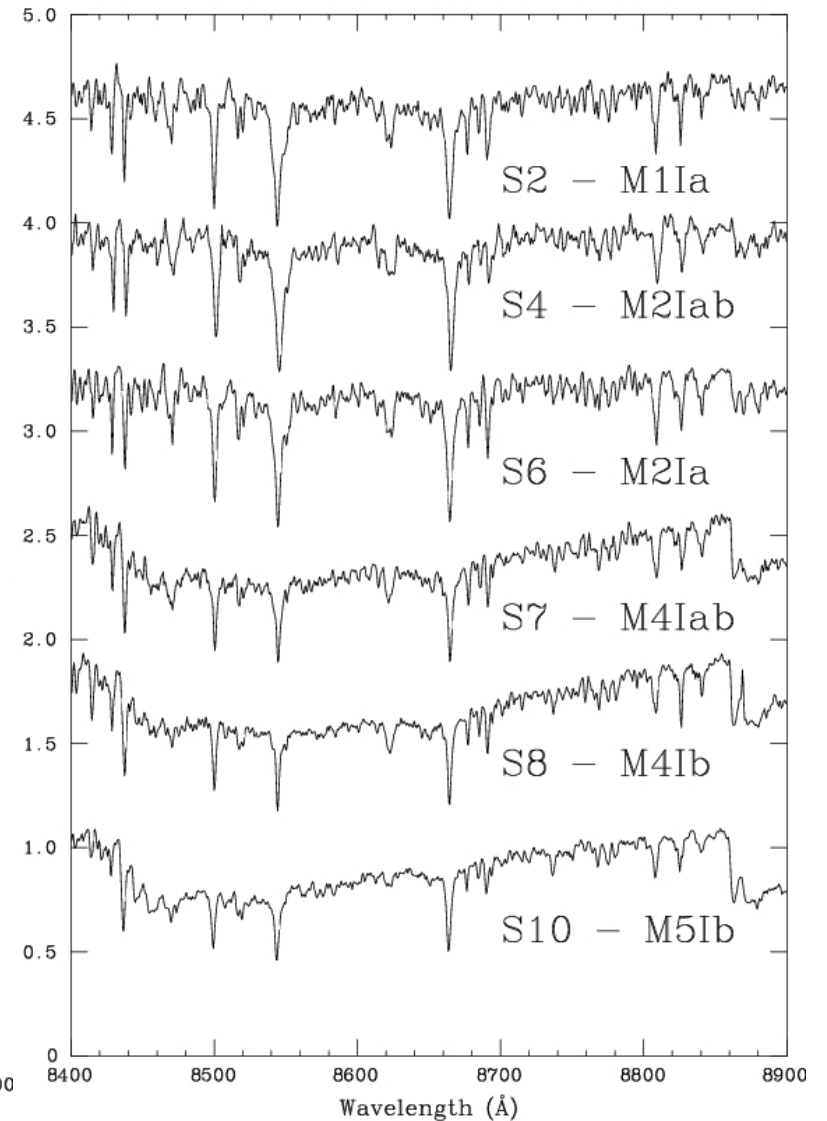
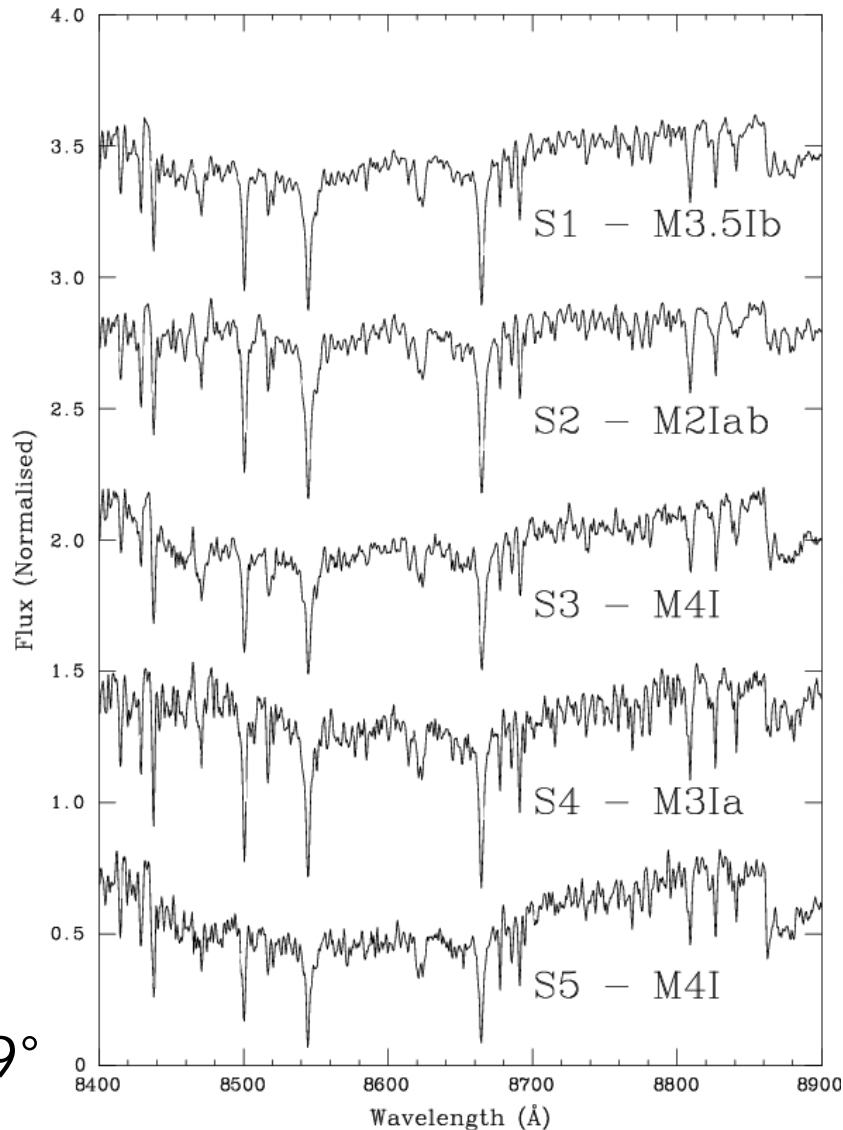
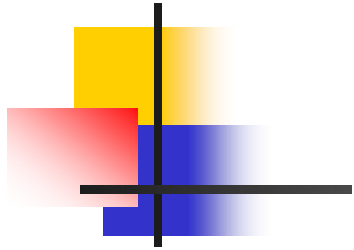
Around $\ell = 26^\circ$

Negueruela et al. 2011, A&A 528, A59



RSGC3

Alicante 7



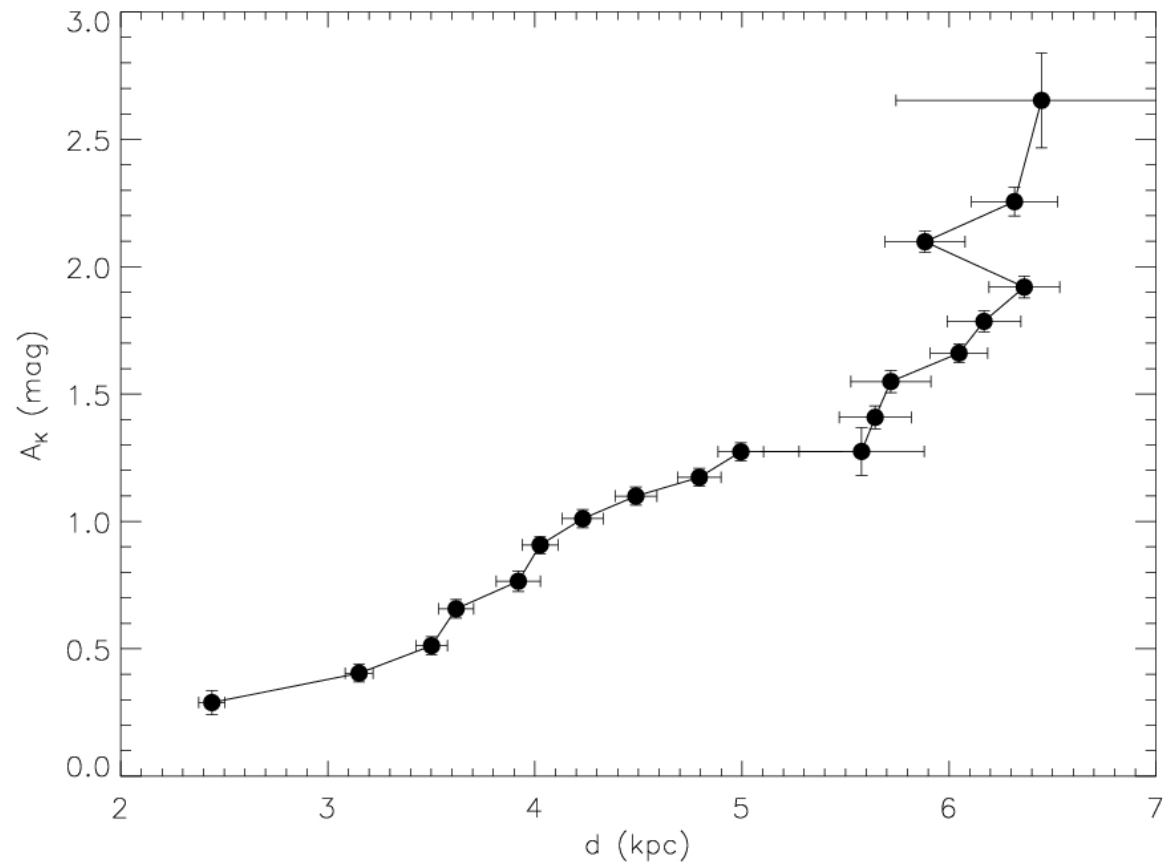
Around $\ell = 29^\circ$

Calar Alto 3.5 m + TWI N, July 2009

New cluster 16' away from RSGC3, Alicante 7 (nine likely RSGs)

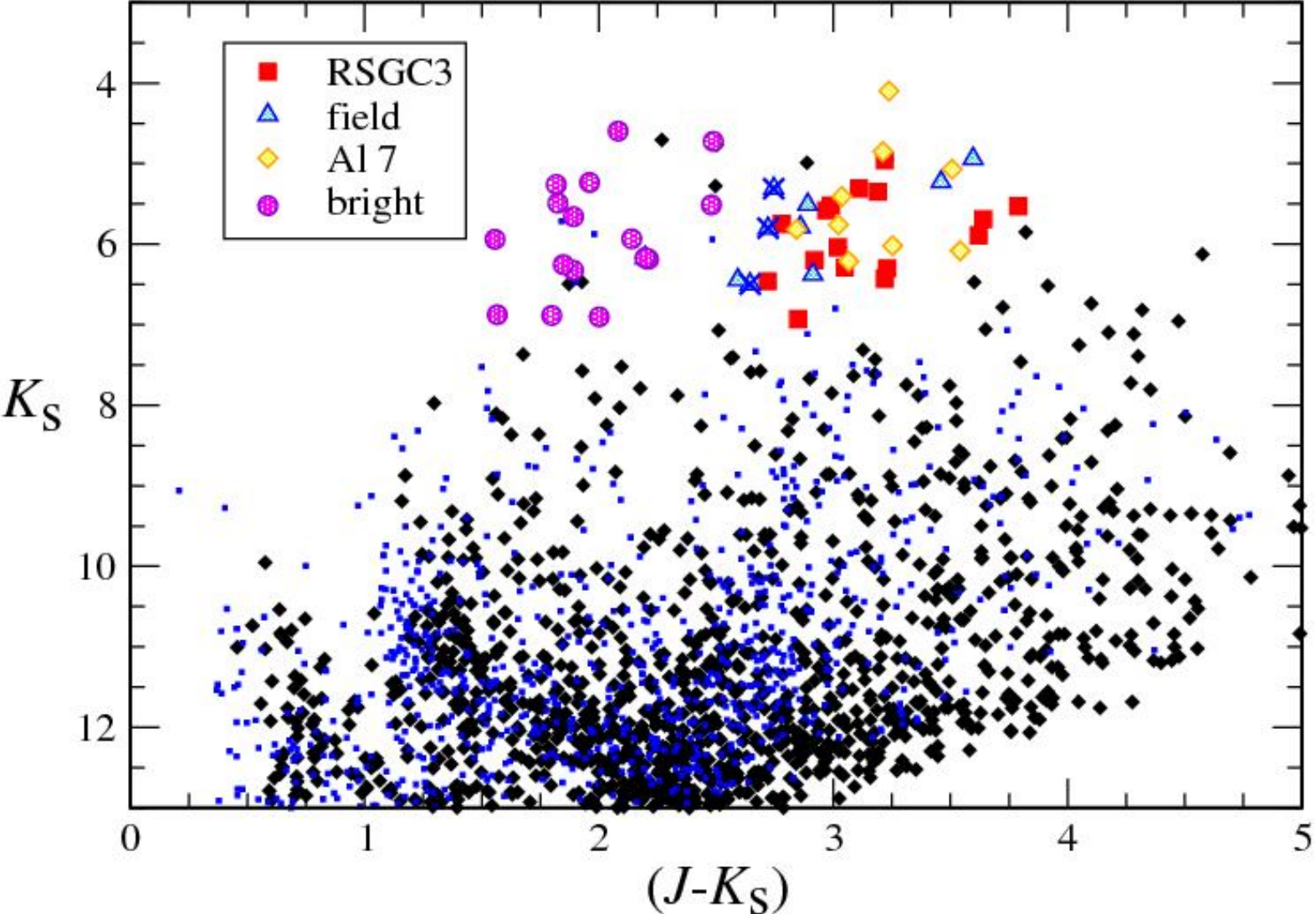
[Negueruela et al. 2011, A&A 528, A59](#)

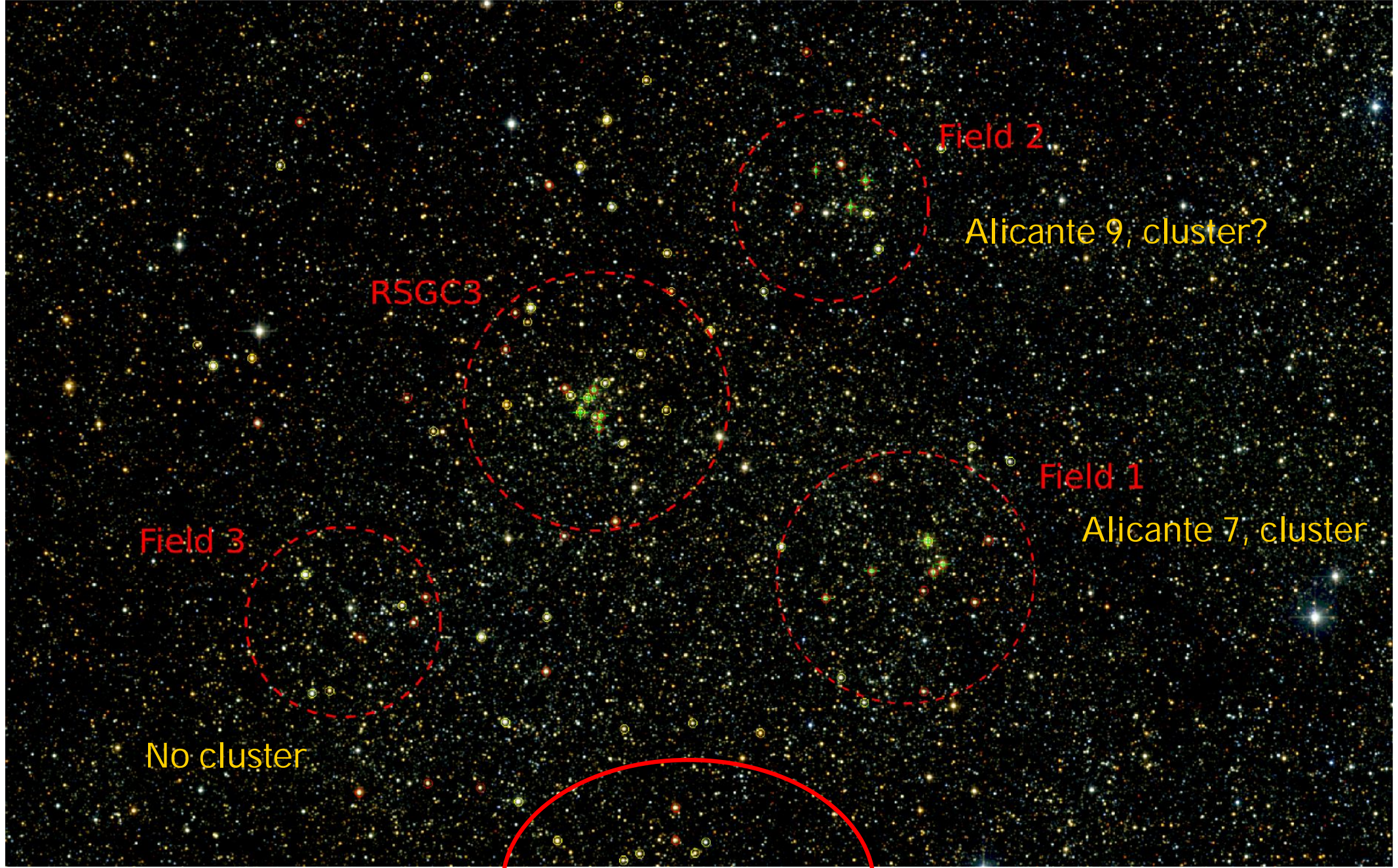
- Tight constraints on the distance from extinction in red clump giants.
- All RSGs at approximately same distance ~ 6 kpc.



Around $\ell = 29^\circ$

Extended association surrounding the clusters, with similar parameters





Field 2

Alicante 9, cluster?

RSGC3

Field 1

Alicante 7, cluster

Field 3

No cluster

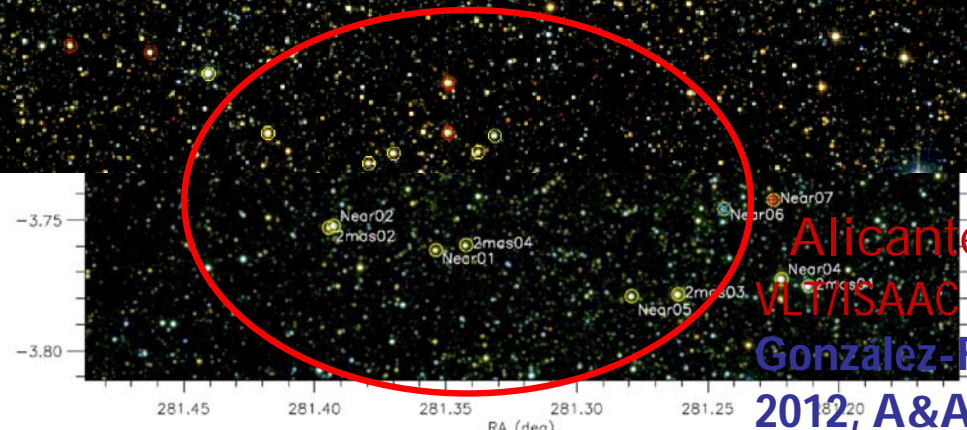
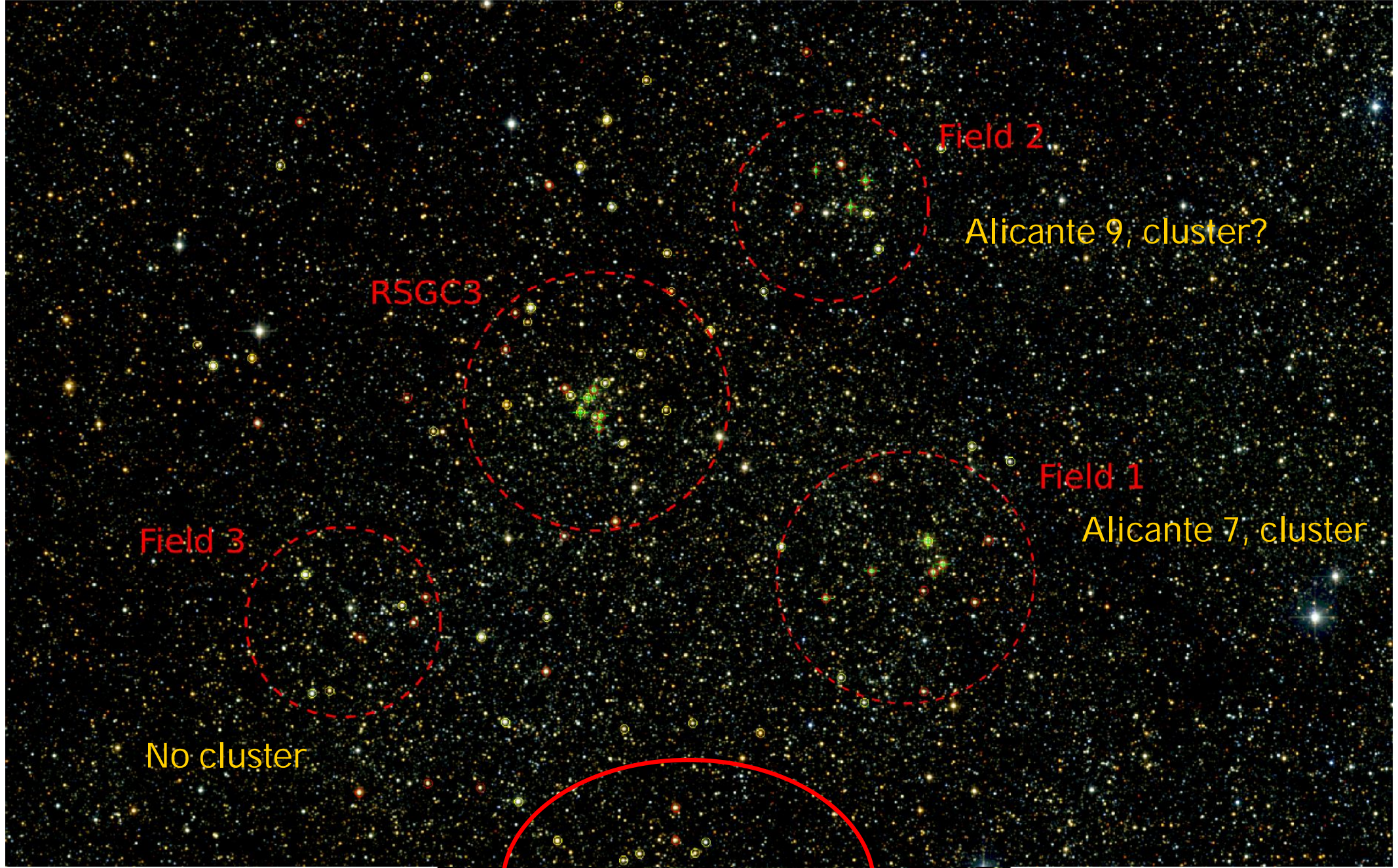


Alicante 10, cluster

VLT/ISAAC

González-Fernández & Negueruela

2012, A&A 539, A100



Alicante 10, cluster

VLTI/ISAAC

González-Fernández & Negueruela

2012, A&A 539, A100

Stephenson 2



Concentration of
> 26 RSGs

(Davies et al. 2007,
ApJ 671, 781)

Implied mass $\sim 5 \times 10^4 M_{\odot}$



False colour image from *JHK* UKIDSS frames



Multiplexing Stephenson 2

- We used WHT + AF2/WYFFOS in the summer of 2009.
- WYFFOS has intermediate/low resolution. We chose $R \sim 4000$.
- Circular field of view 1° across (40' without vignetting).
- Targets must be separated at least 25" (not good for compact clusters).
- There are 150 fibers, but we typically allocated 60.
- Observed surroundings of Ste 2 at different magnitudes and control fields.

WHT + WYFFOS, 2009

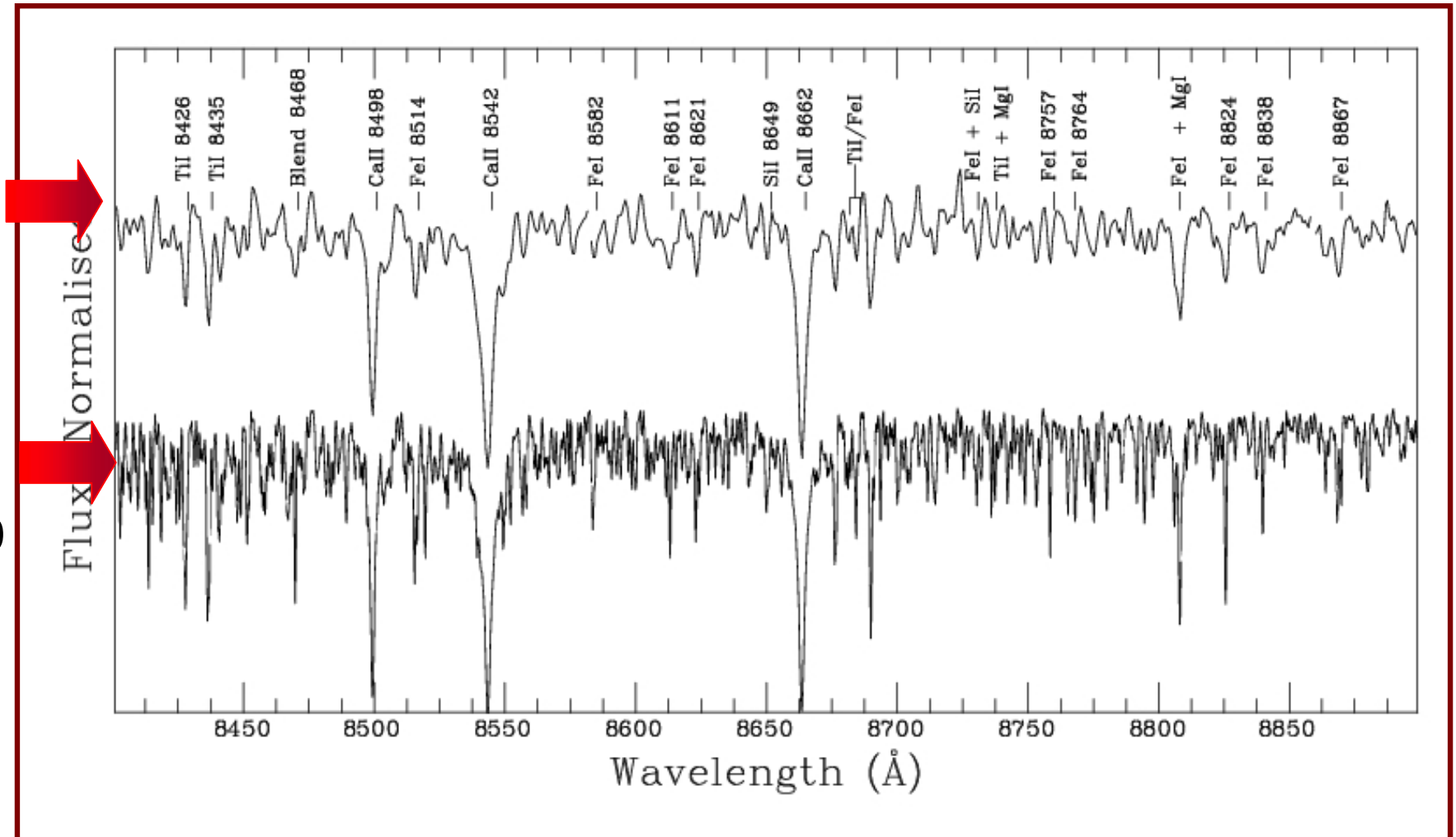
Around $\ell = 26^\circ$

[Negueruela et al. 2012, A&A, in press](#)

- Resolution is not ideal, but bench-mounted instrument gives high stability. We obtain accuracy of ± 4 km/s.
- We observed a few targets with WHT+ISIS at higher resolution to check for any undesired effects.

WYFFOS
R1200R
R ~ 4000

ISIS
R1200R
R ~ 16000





Multiplexing Stephenson 2

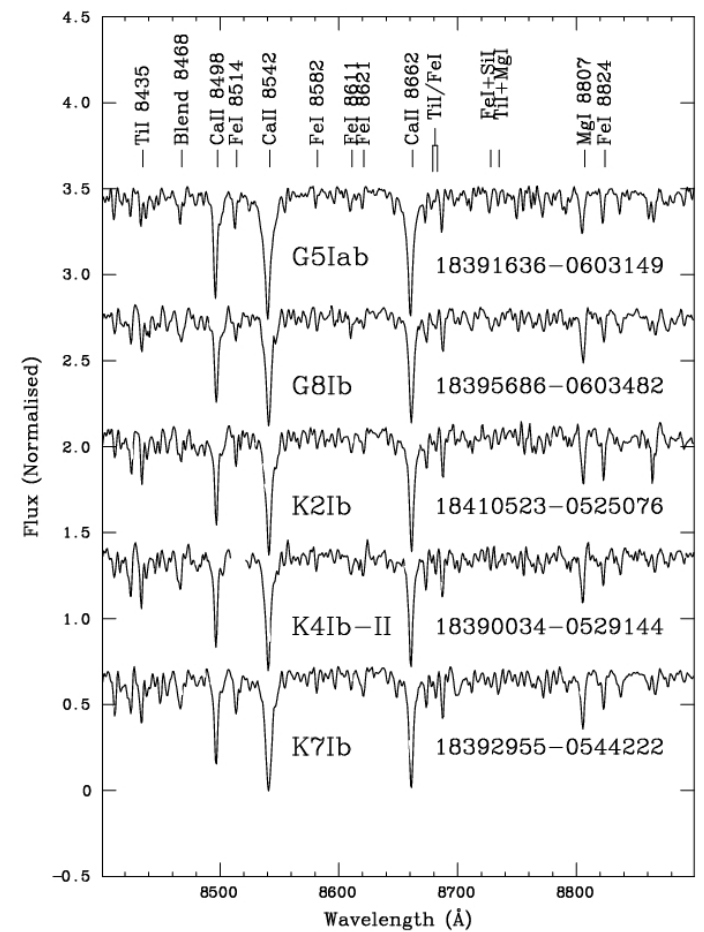
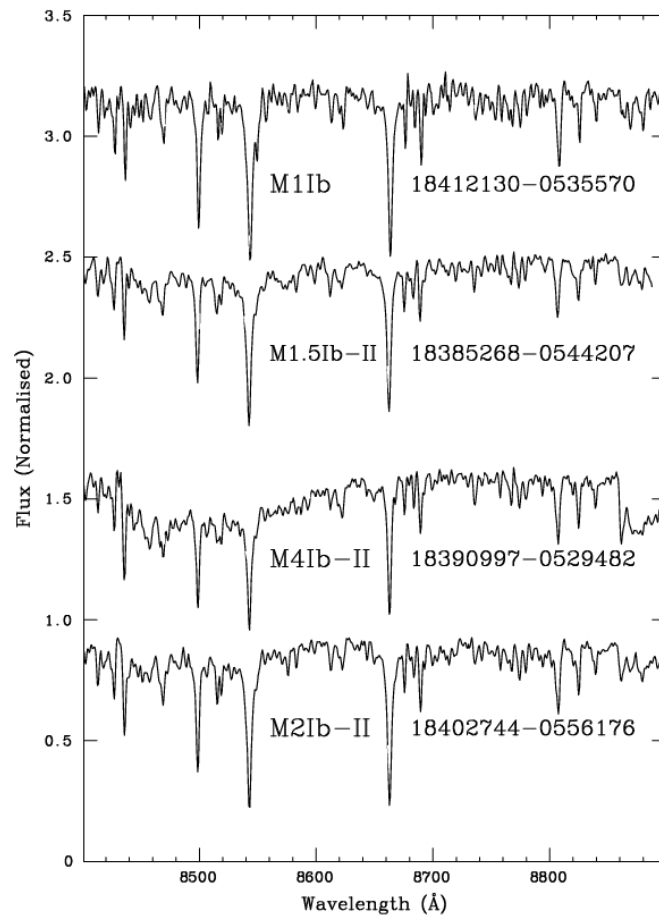
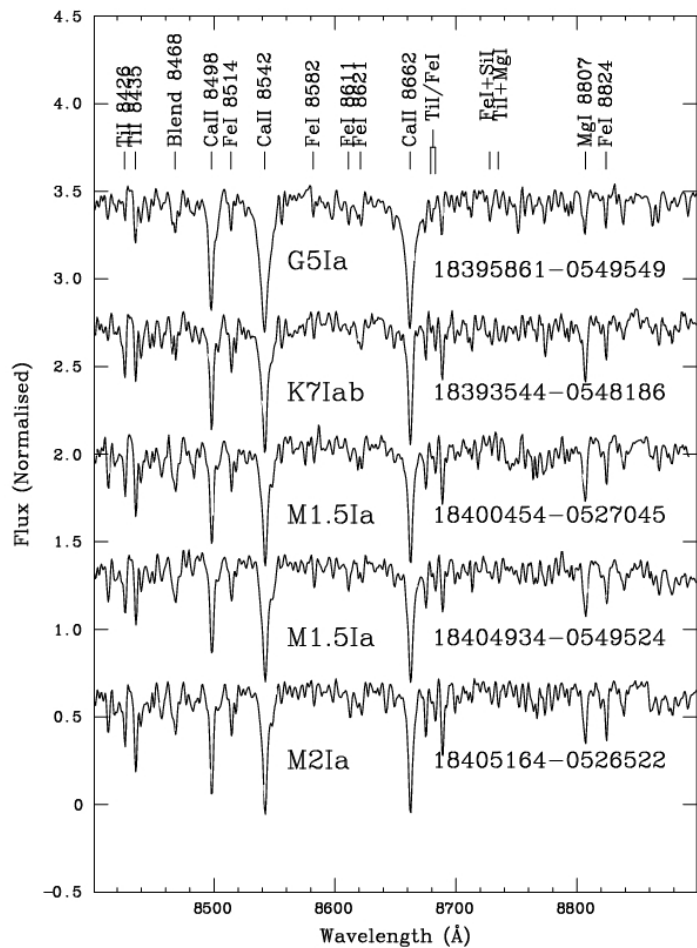
- Photometric criteria still detect only luminous red stars.
- About 230 unique objects observed.
- Intruders are always bright giants in the foreground or very late ($>M4$) giants.
- We observe ~ 35 RSGs with high v_{rad} (compatible with Ste 2) over the whole field (at distances $>50'$ from Stephenson 2).
- There are many RSGs with significantly different v_{rad} over the whole area.

WHT + WYFFOS, 2009

Around $\ell = 26^\circ$

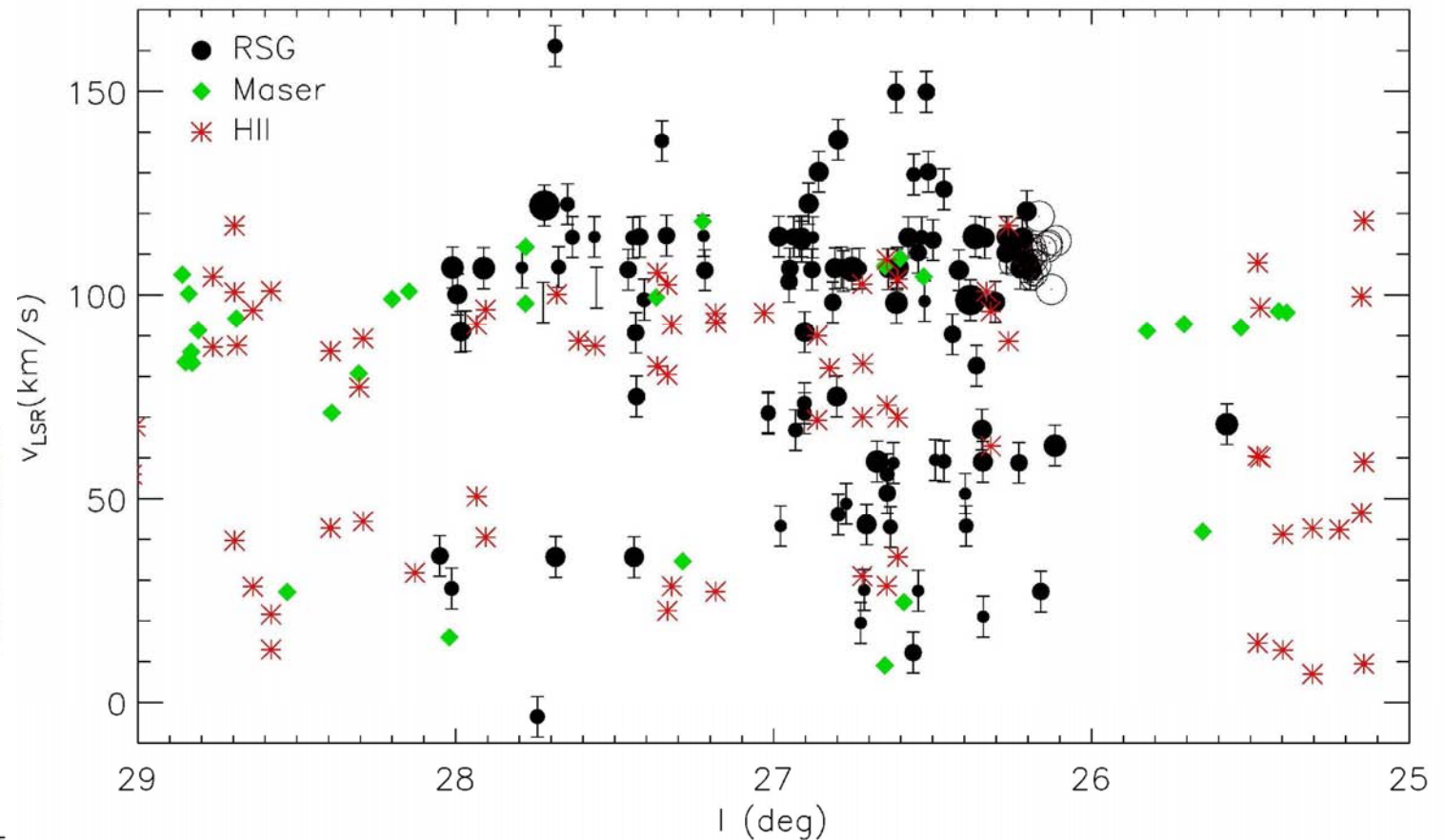
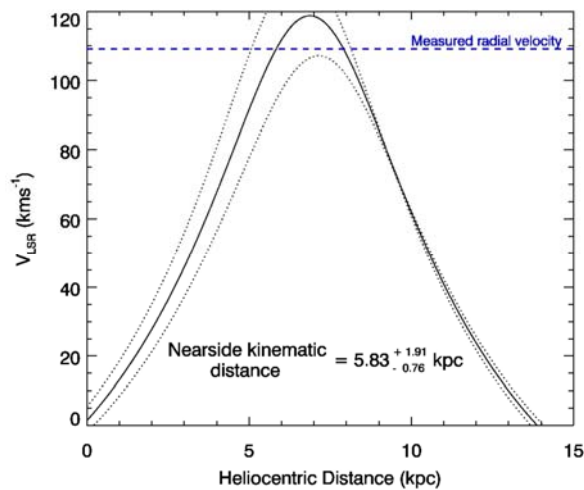
[Negueruela et al. 2012, A&A, in press](#)

RSGs of all tastes



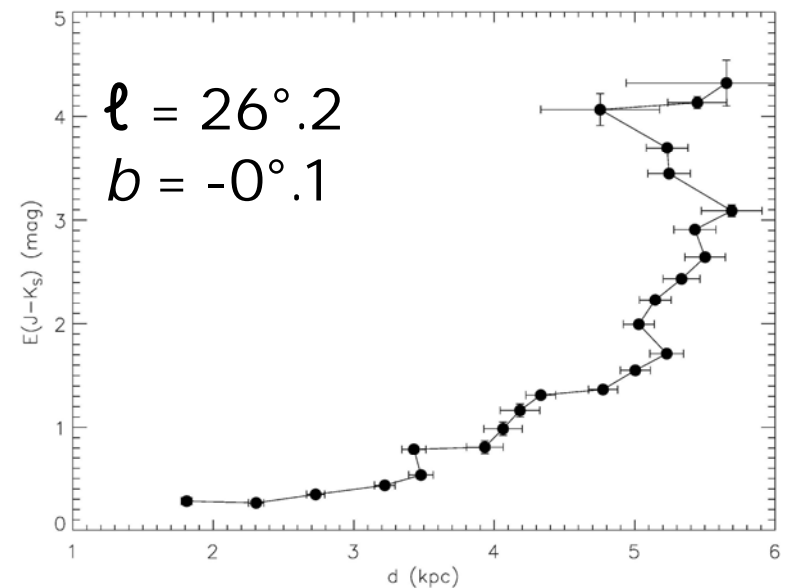
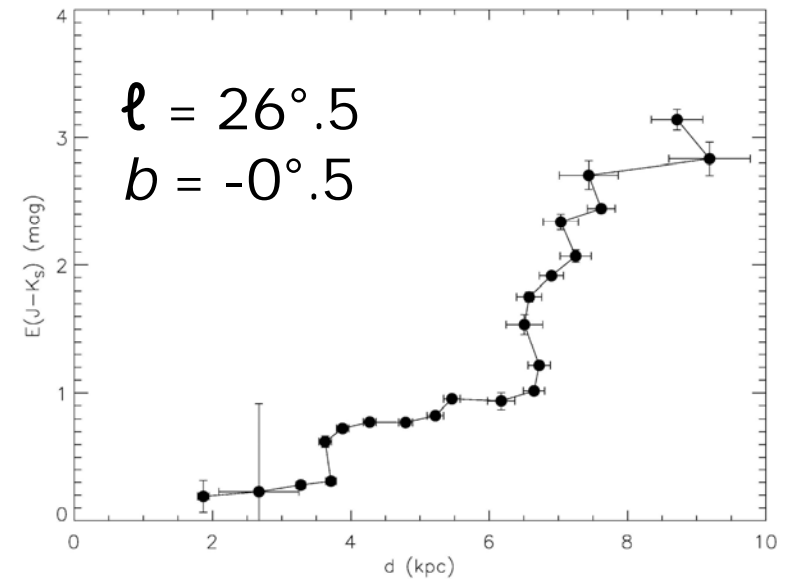
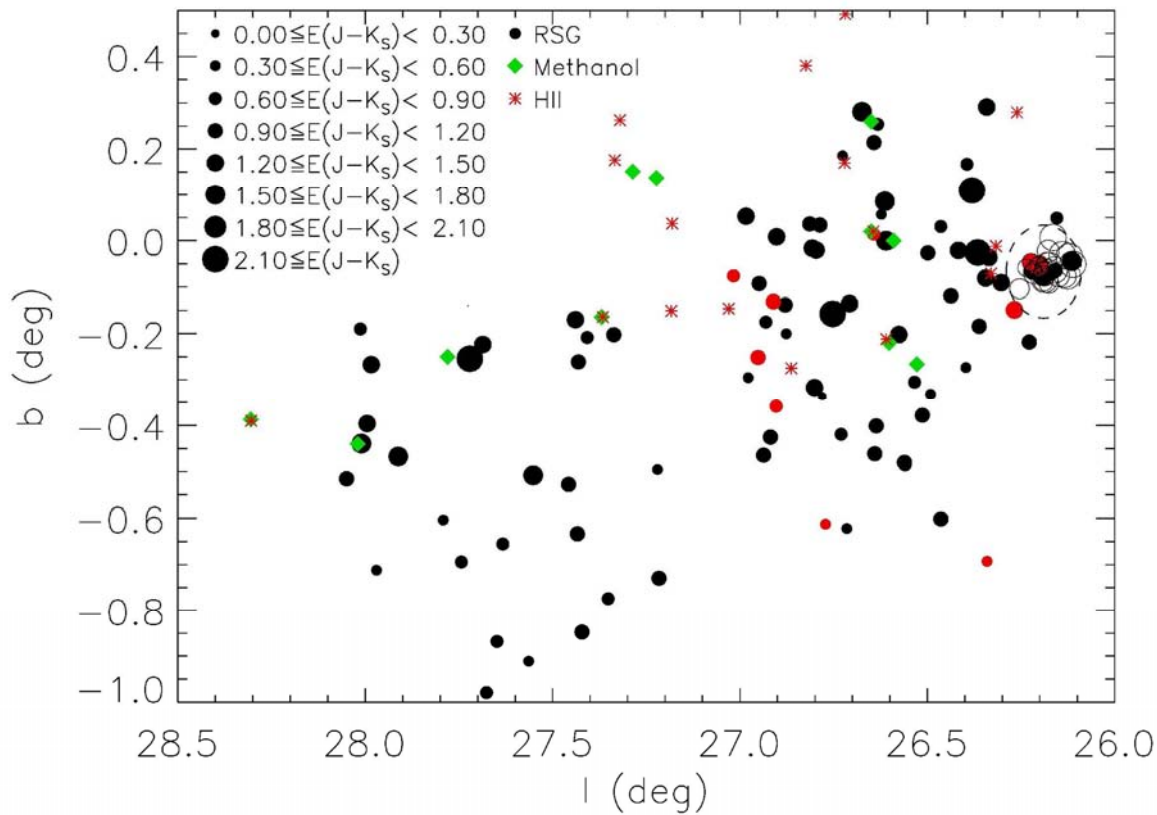
Tracers of Galactic structure

Masers \blacklozenge
HII regions \ast
RSGs \bullet



Tracers of Galactic structure

Negueruela et al., A&A, in press



Run of extinction calculated using the red clump giant method of Cabrera-Lavers et al. (2005)



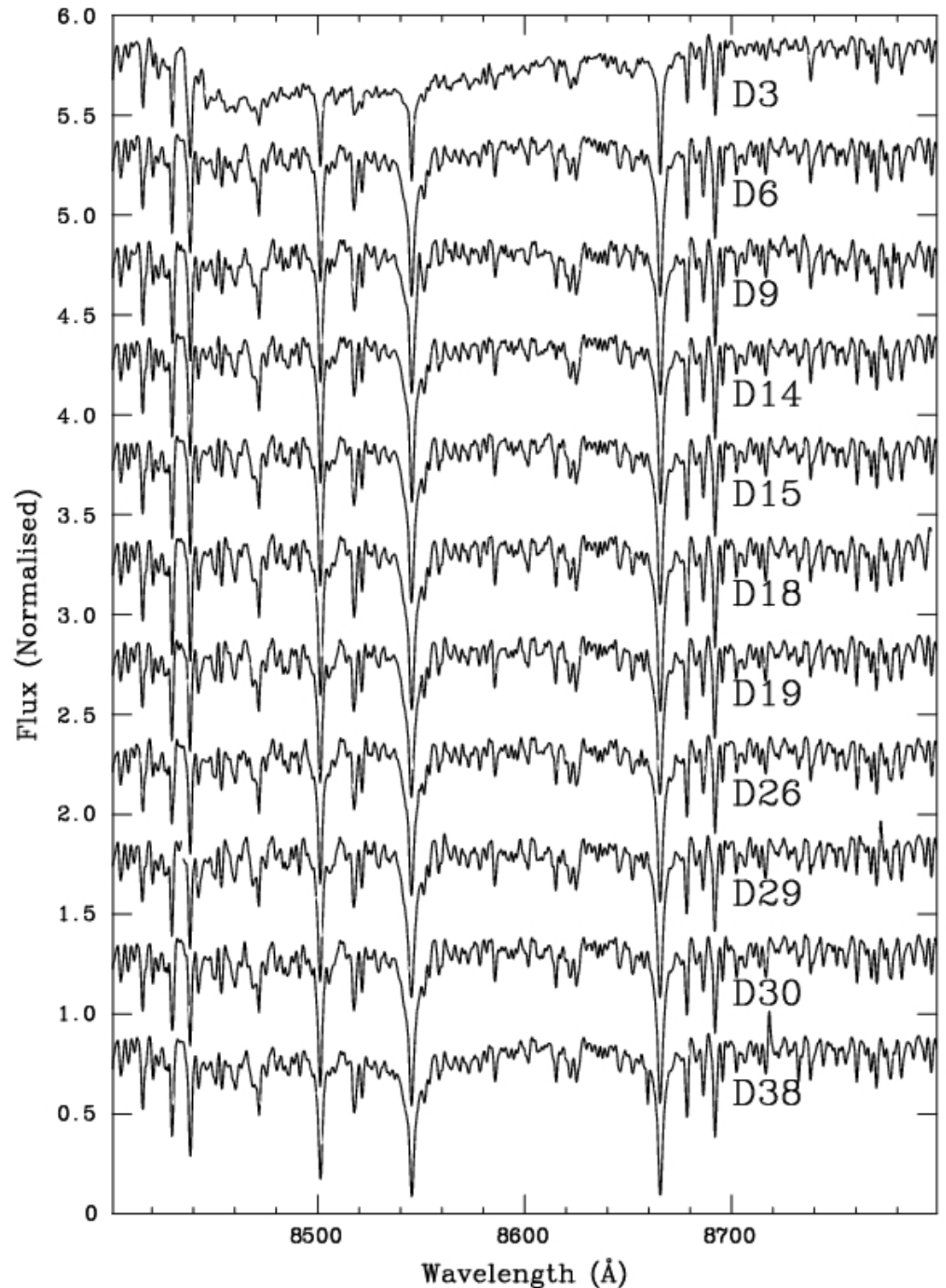
Multiplexing even more

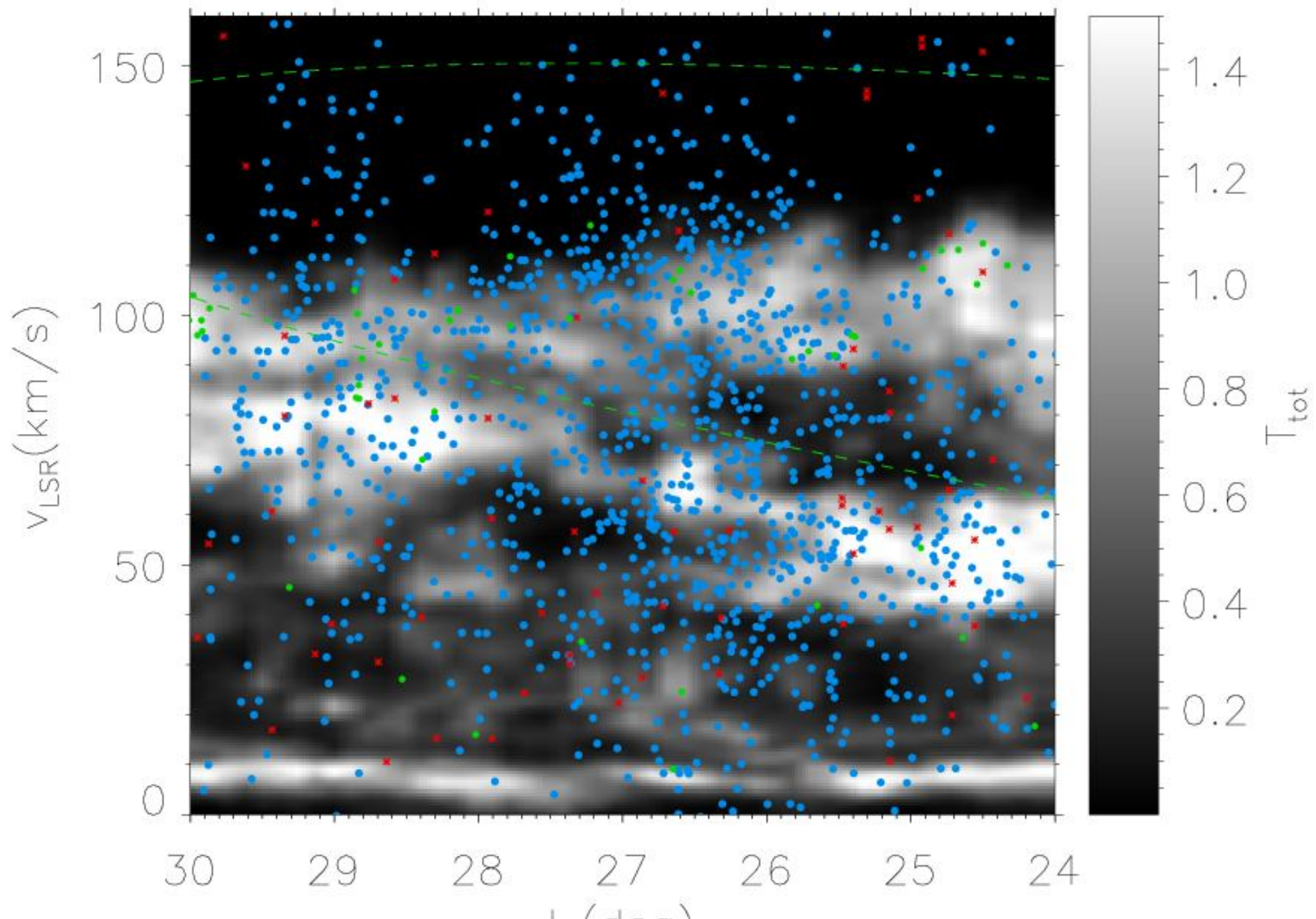
- We used AAT+AAOmega in August 2010 (poor results), July 2011 and July 2012.
- We used the high-resolution VPH grating giving $R \sim 10,000$.
- Circular field of view 2° across.
- Targets can be pretty close.
- There are 392 fibers, and we can typically allocate 300.
- We have observed ~ 1500 red luminous stars between $\ell = 24^\circ$ and $\ell = 30^\circ$

AAOmega data



- Much better access to cluster cores (22 RSGs in Ste 2 observed)
- Higher resolution
($R \sim 10\,000$)
gives accuracy of 2 km/s
(internal)



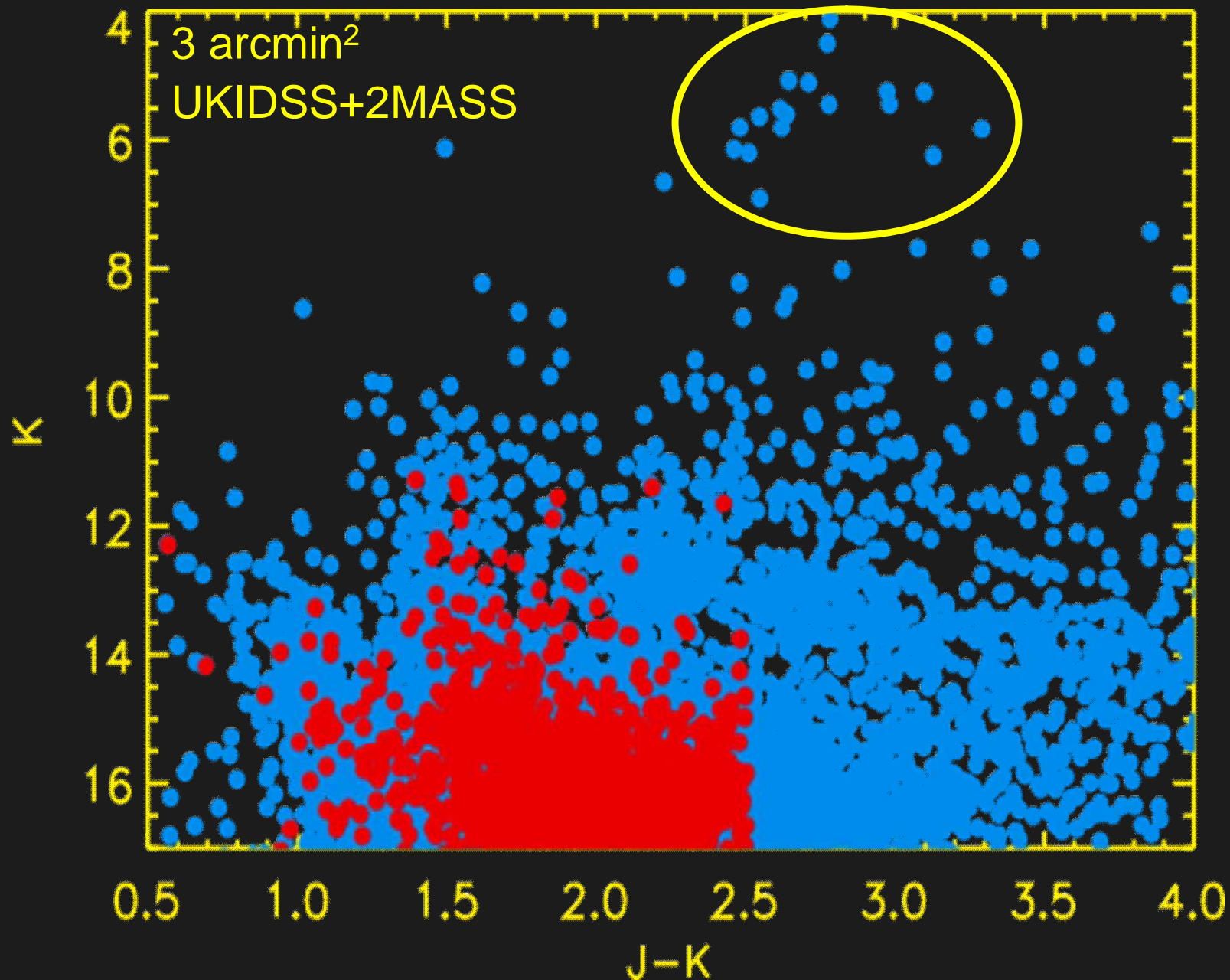


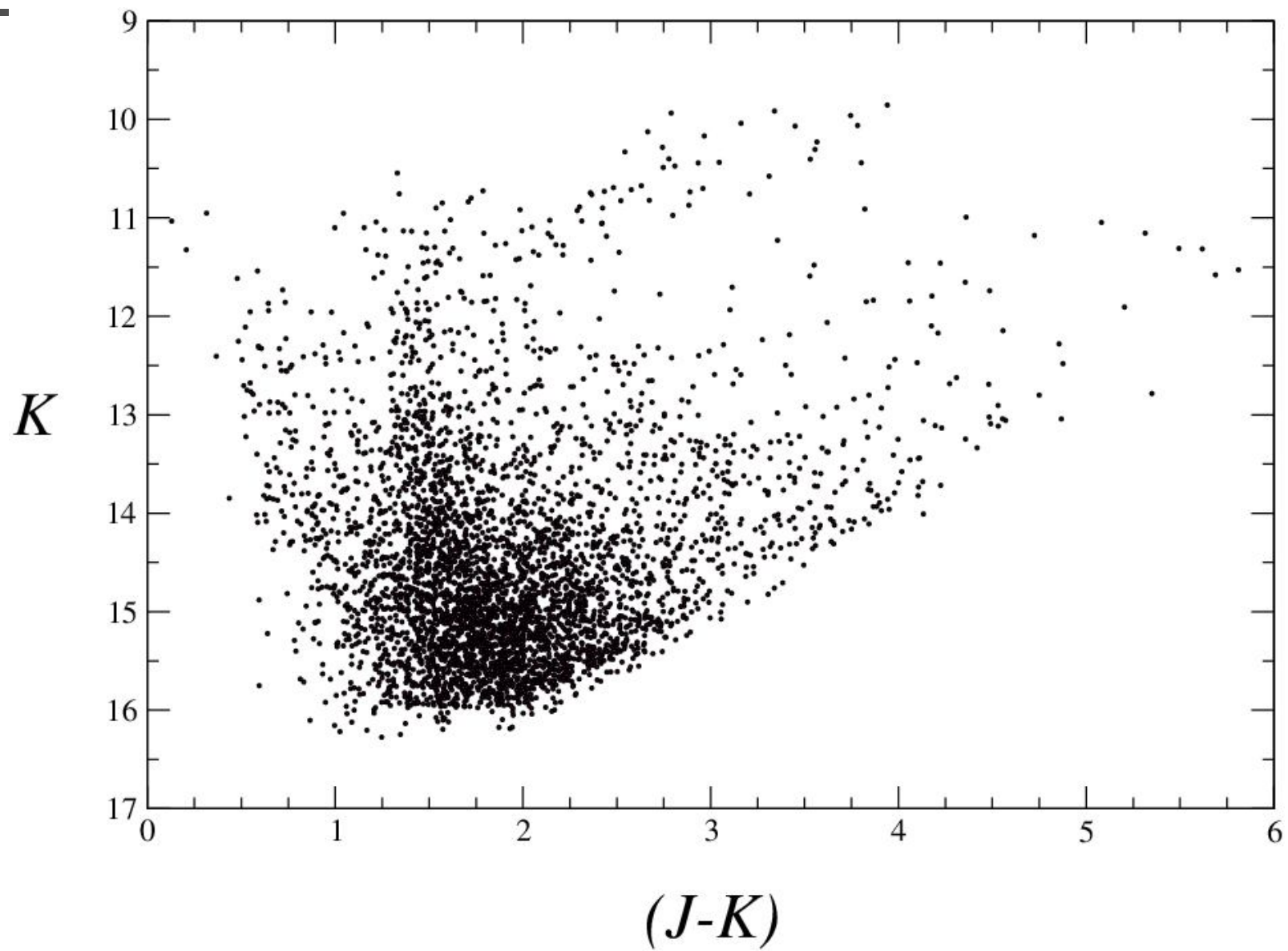
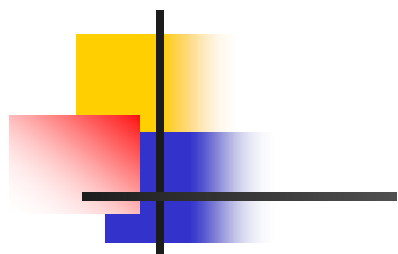


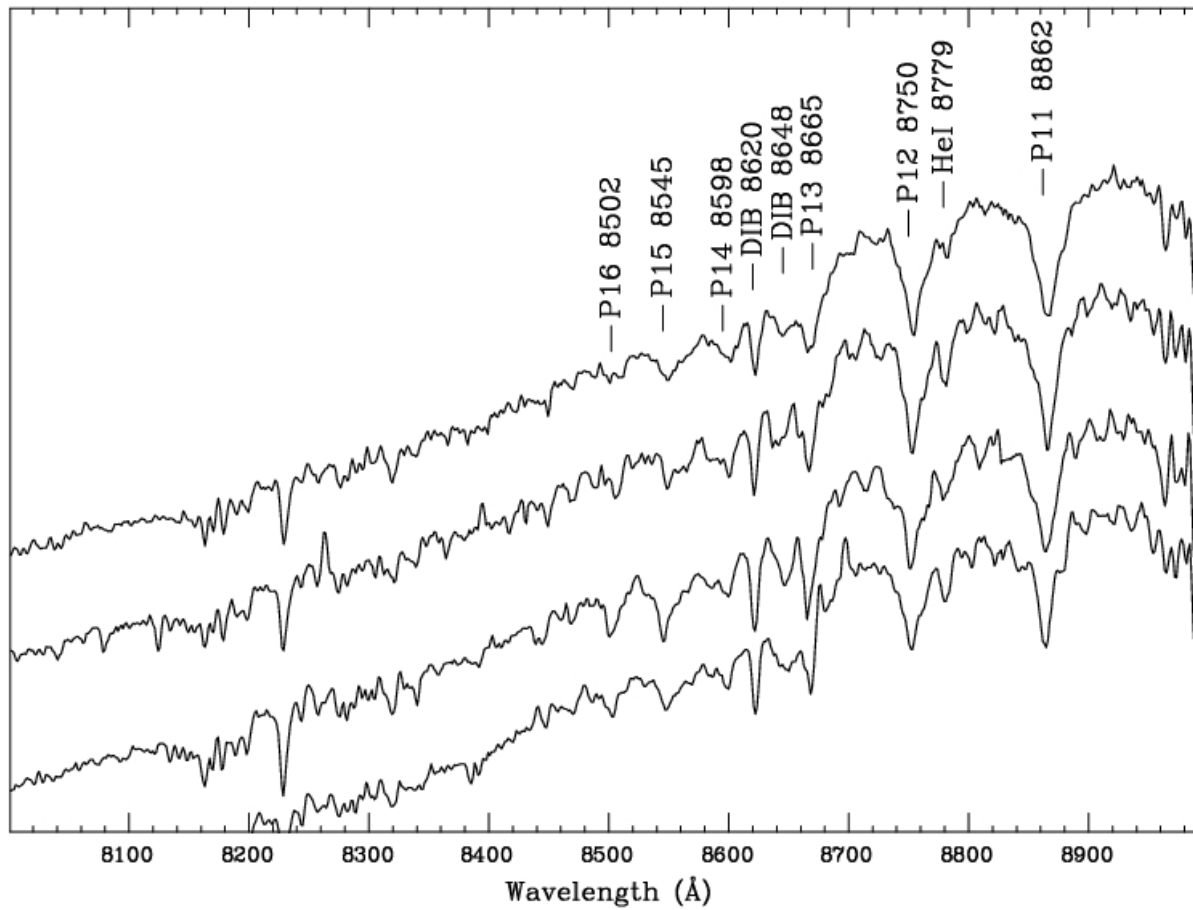
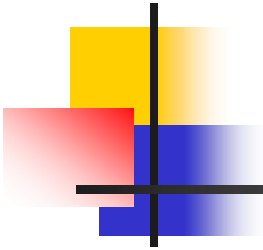
A preliminary picture ...

- RSGC3 is surrounded by an association wider than 1 degree.
- It contains at least three smaller clusters and includes ~ 100 RSGs ($\sim 2 \times 10^5 M_{\odot}$).
- Stephenson 2 consists of a compact core with 16-20 RSGs and an extended halo that mixes into a dense population of RSGs with almost identical v_{LSR} extending between $\ell = 26^{\circ}.4$ and $27^{\circ}.5$. There are ~ 150 RSGs in this region.

Do you see a cluster here?







- GTC + OSIRIS
- R2500I

- Early B giants
- $E(J-K) \approx 1.6$

So everything seems to agree.

But ...



- Do kinematic distances really follow the Galactic rotation curve? Our data show many features that make no sense in this view.
- Is the extinction law really similar to that in the Solar neighbourhood? Many recent papers have shown strong deviations towards the inner Milky Way due to:
 - Colour terms ([Stead & Hoare 2010, MNRAS 407, 923](#))
 - The extinction law itself ([Nishiyama et al. 2008, ApJ 680, 1174](#); [Gonzalez et al. 2012, A&A 543, A13](#); [González-Fernández, PhD Thesis](#))

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