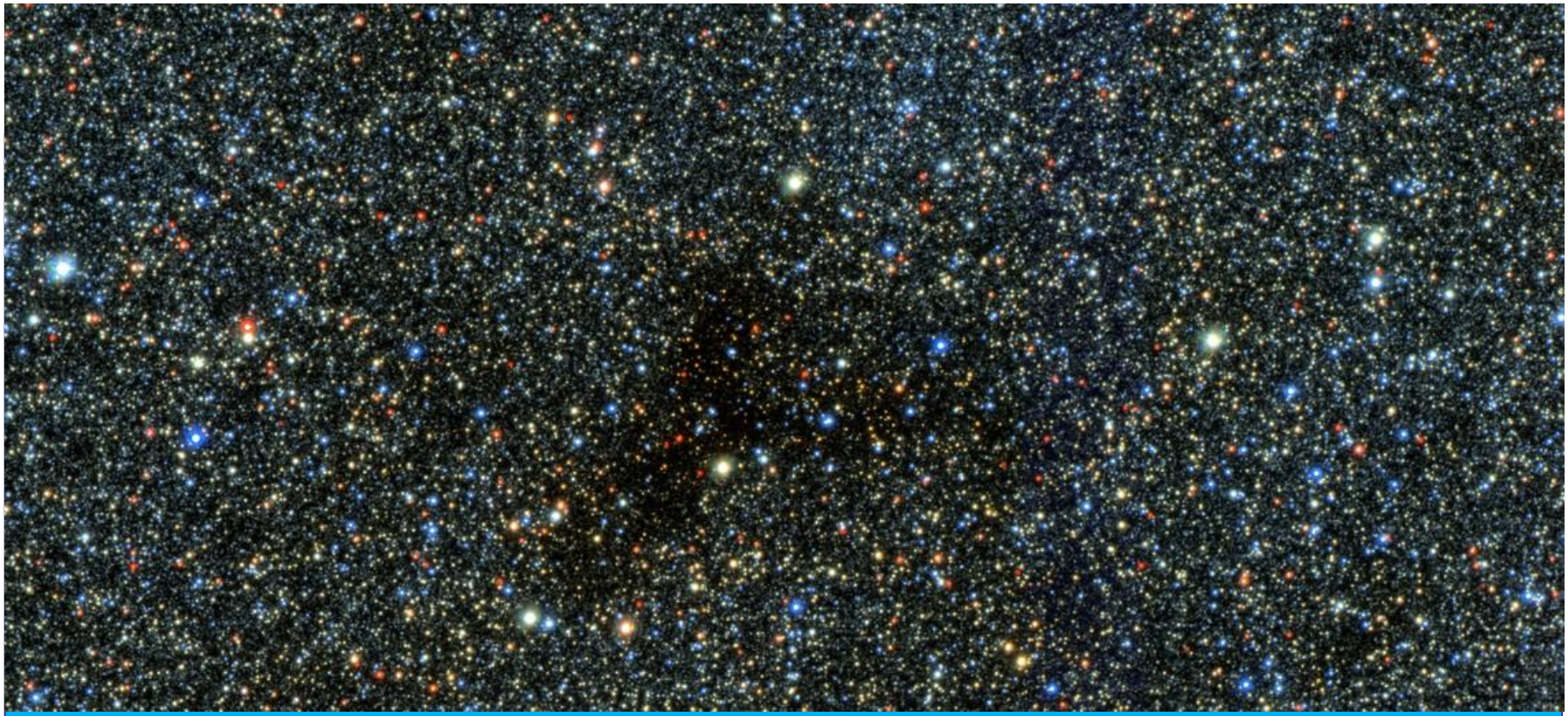


(15’ x 7.5’ , in Baade’s Window, VST/VPHAS+)

Deep searches for early-type stars in the Galactic Plane

Janet Drew[1], Juan Fabregat[2], Leonardos Gkouvelis[2], Mike Mohr-Smith[1]

[1]University of Hertfordshire, [2]Universidad de Valencia

The previous talks this session → why massive stars are scientifically important

Here:

- how optically-based spectroscopy following up optical photometry across the wide field finds and characterises them
  - Hα excess → the emission line population
  - blue excess → the non-emission stars

- some words on using these intrinsically-luminous stars to open up the 3D Galactic ISM on a grand scale

Source materials: the EGAPS surveys to ~20th magnitude, ~1” resolution

The Northern Galactic Plane, $-5^o < b < +5^o$

IPHAS: r,i,**Hα**, INT since 2003 www.iphas.org

survey description – Drew et al 2005
DR2 on Vizier and iphas.org – Barentsen et al 2014
3D extinction map – Sale et al 2014
deep r,i star counts – Farnhill et al, in prep

UVEX: **u**,g,r, INT since 2006

survey description – Groot et al 2009

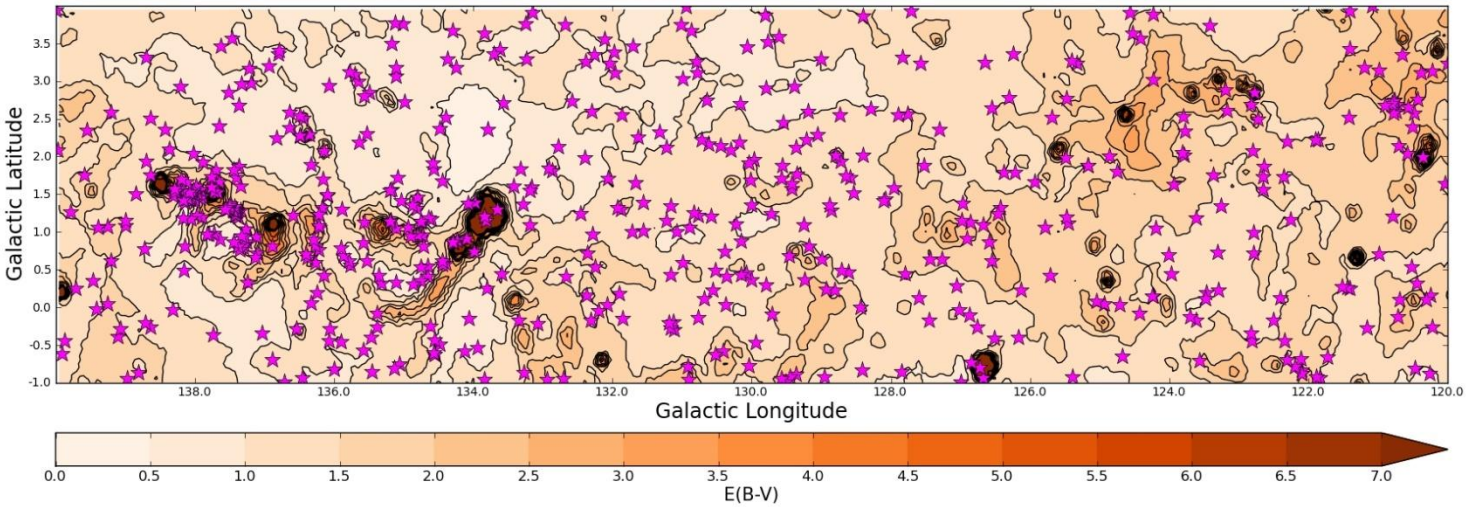
The Southern Galactic Plane, and Bulge

VPHAS+: **u**,g,r,i,**Hα**, VST since 2012 www.vphas.eu

survey description – Drew et al 2014

IPHAS + UVEX + VPHAS+ = EGAPS
EUROPEAN GALACTIC PLANE SURVEYS

1. Emission Line Stars



Emission line stars towards Perseus Arm ($120^o < l < 140^o$) – Raddi et al 2015

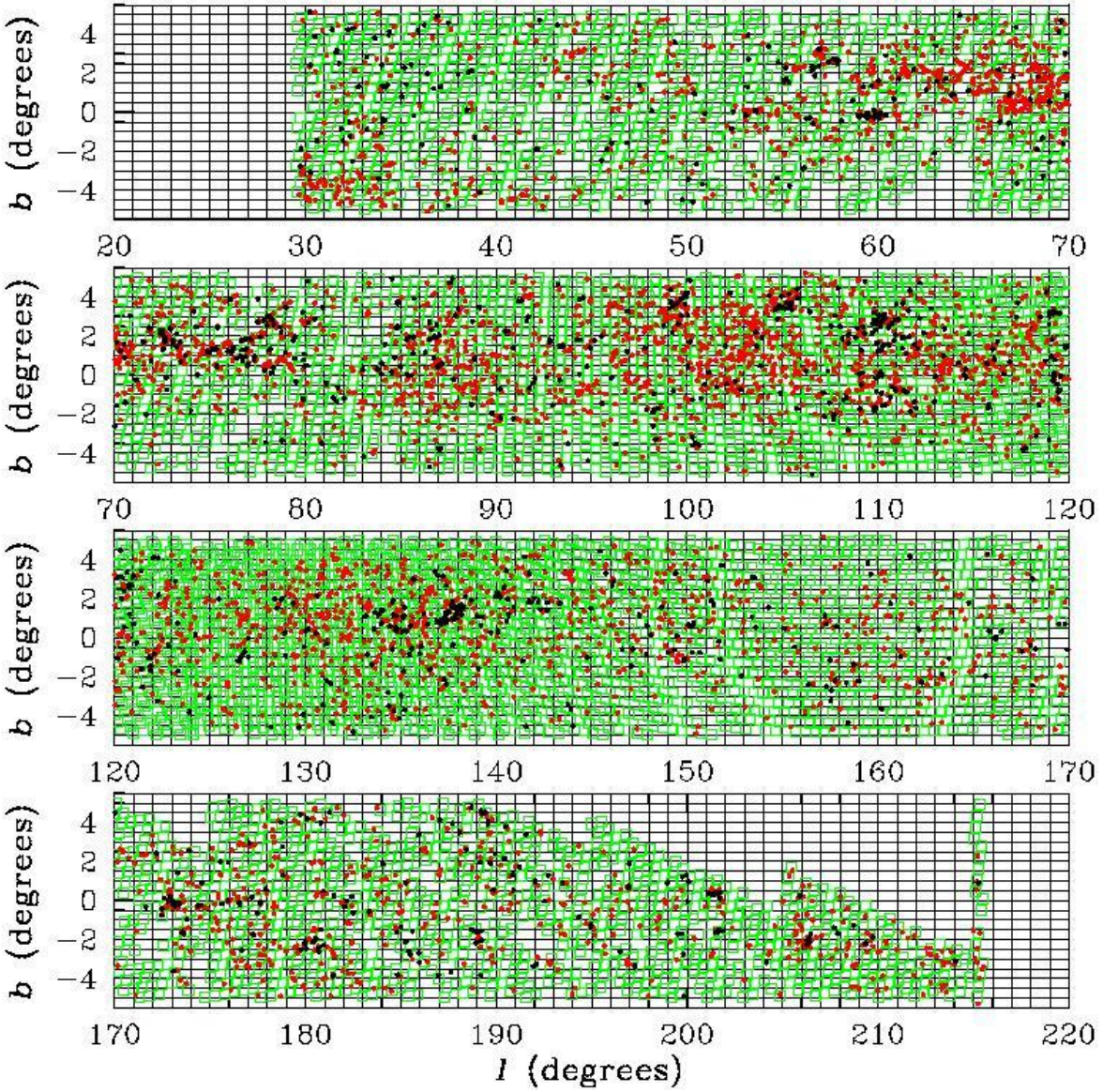
Emission line stars in the northern Plane:

Automatic selection based on r'-Hα 'excess', with 13<r'<19.5

4853 objects *(from Witham et al 2008)*

→FAST spectrum of every listed object to r ~16.5

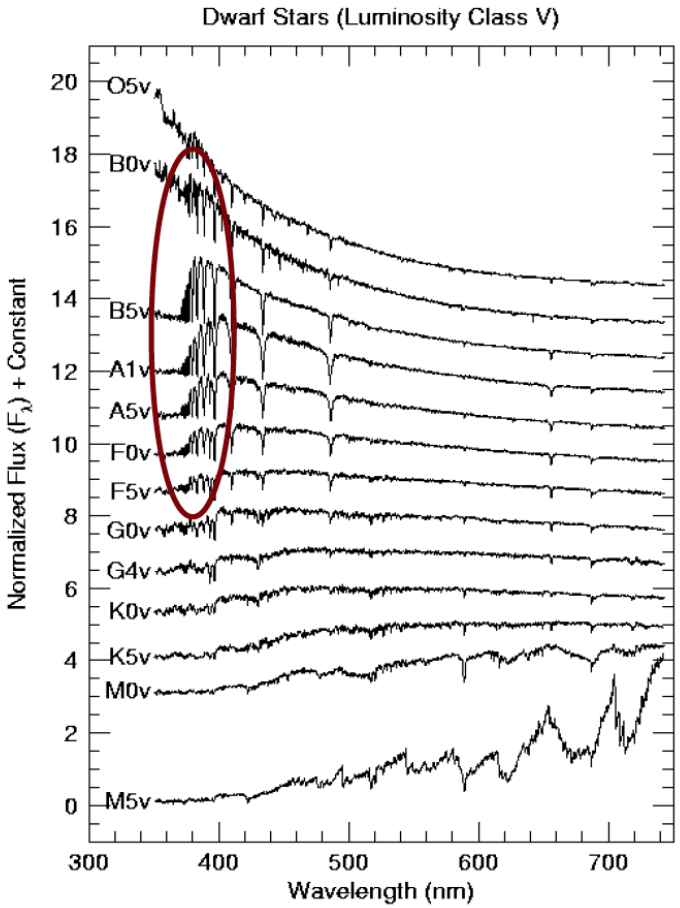
→Around 70% are classical Be stars



BCD classification system

- Developed by Barbier, Chalonge & Divan from early 1940s
- Uses measures of the Balmer discontinuity (BD) near 3700 A
- Shape/contrast of BD depends on spectral type and luminosity class

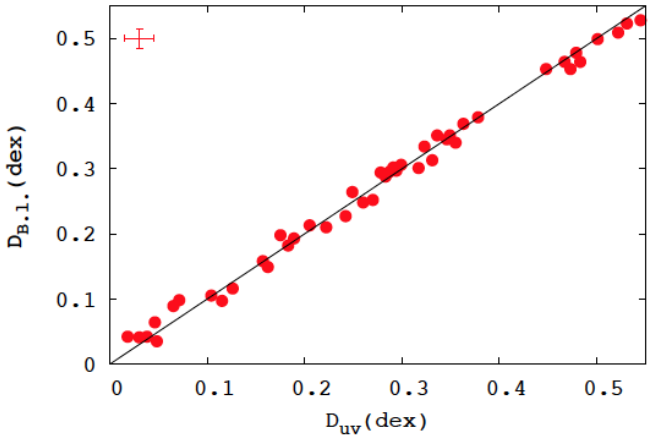
...now automated.

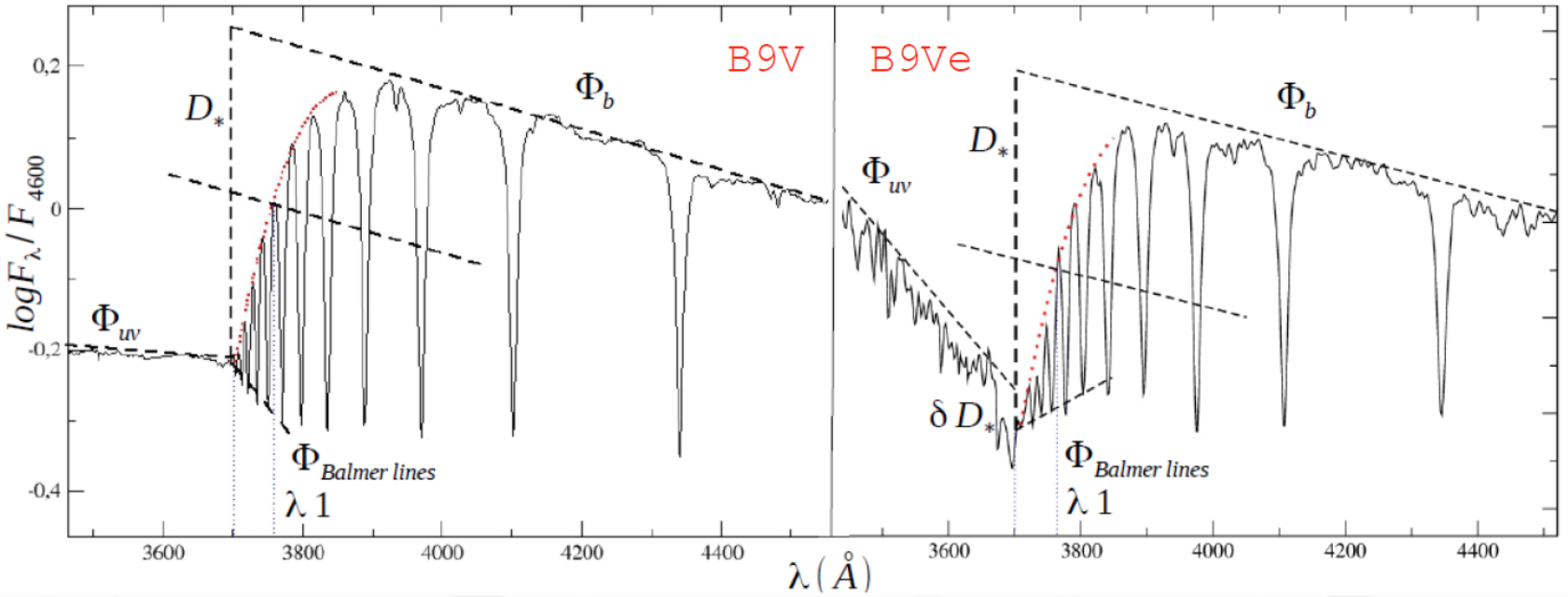


BCD classification system

The basic parameters that describe the energy around BD are:

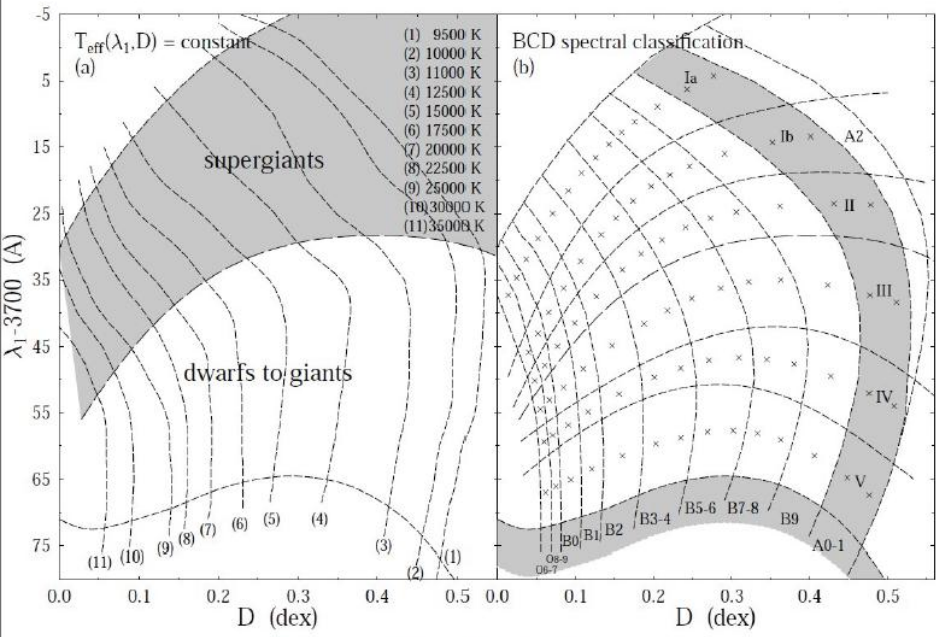
- D, the Balmer jump depth(dex), an effective temperature indicator.
- λ1, the average position of the BD, given as the difference λ1-3700Å, very sensitive to log g.
- ϕ_b, the color gradient, which is the continuum near the BD.
- ϕ_{uv}, the slope of the Balmer continuum.



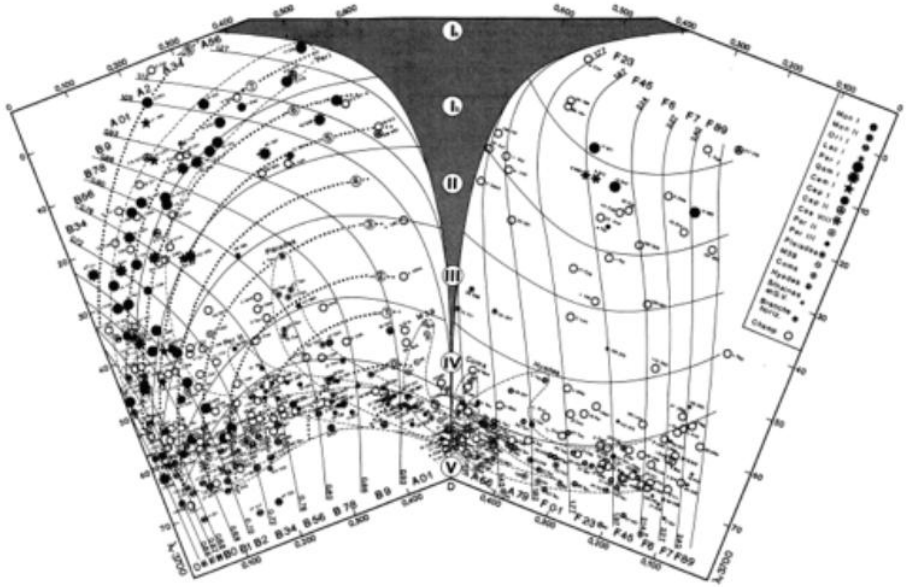


BCD classification system

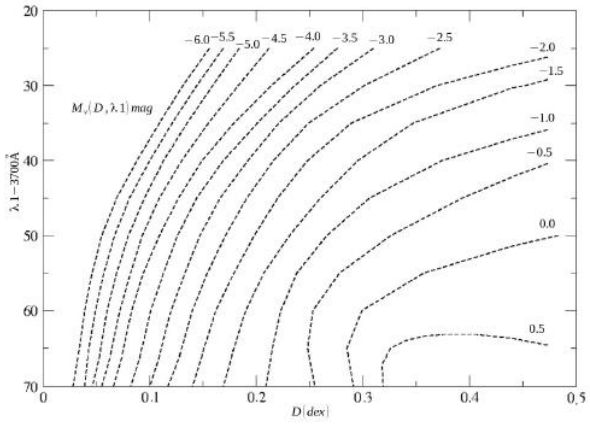
Each star is defined by a unique point (D, λ_1, ϕ_b)



(Zorec J. et al. 2009)

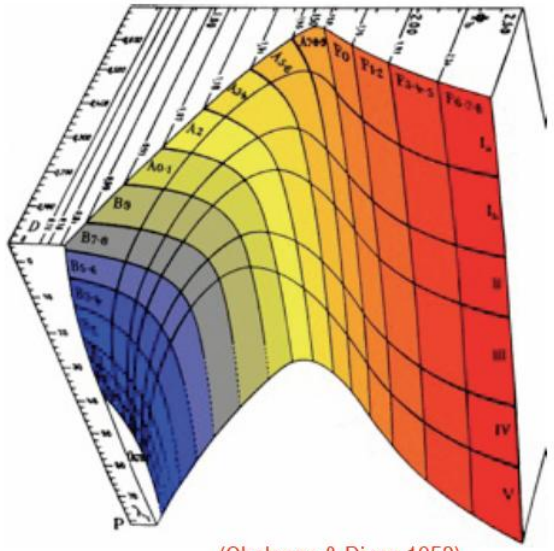


(Chalonge & Divan 1973)



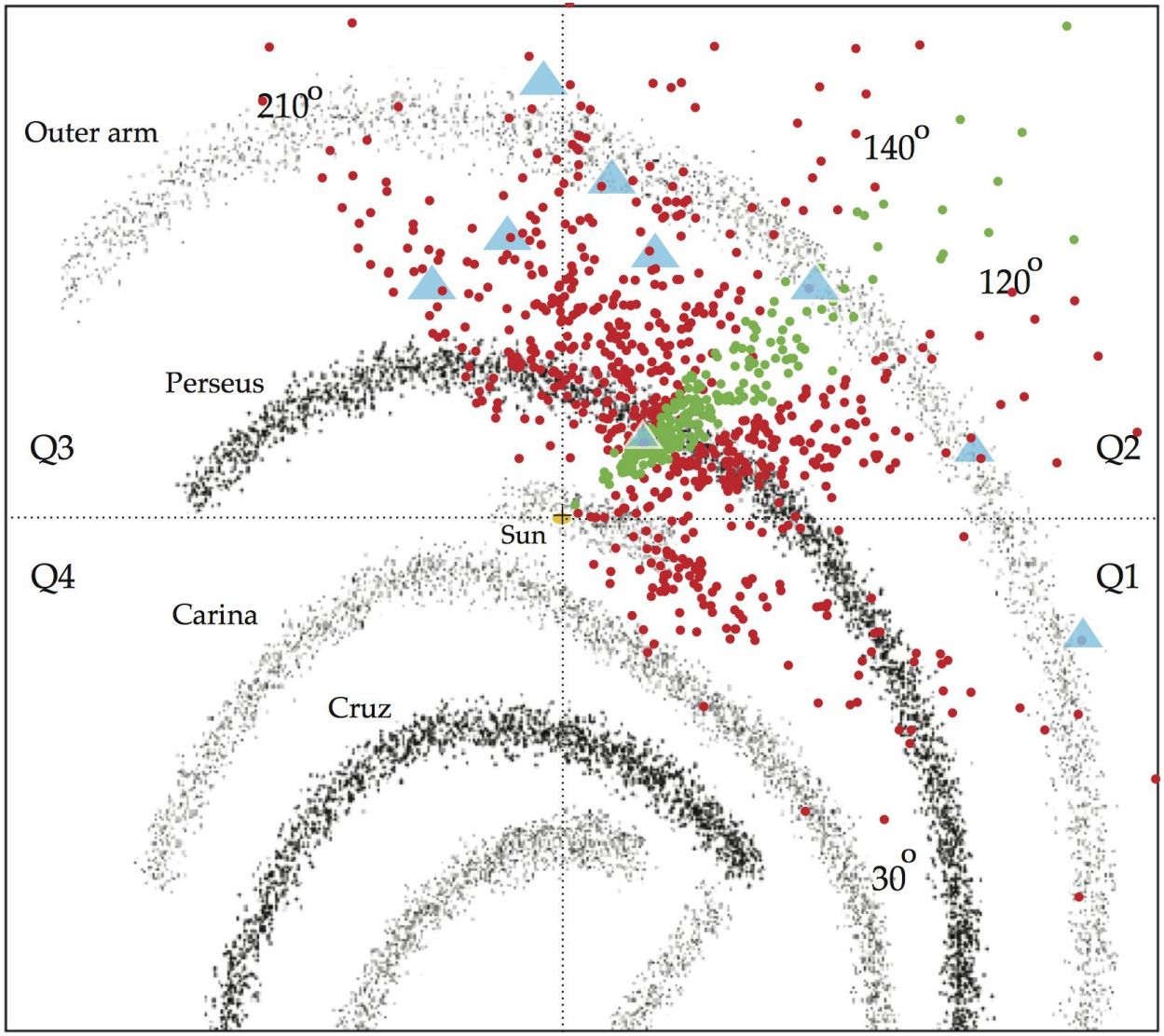
(Zorec J. et al. 1991)

- The normal stars are near the Σ surface.
- Metal-poor stars are behind the Σ surface.
- Metal-rich stars are in front of the Σ surface.



(Chalonge & Divan 1953)

Northern Plane distance mapping of brighter CBe (using automated BCD spectroscopic parallax)

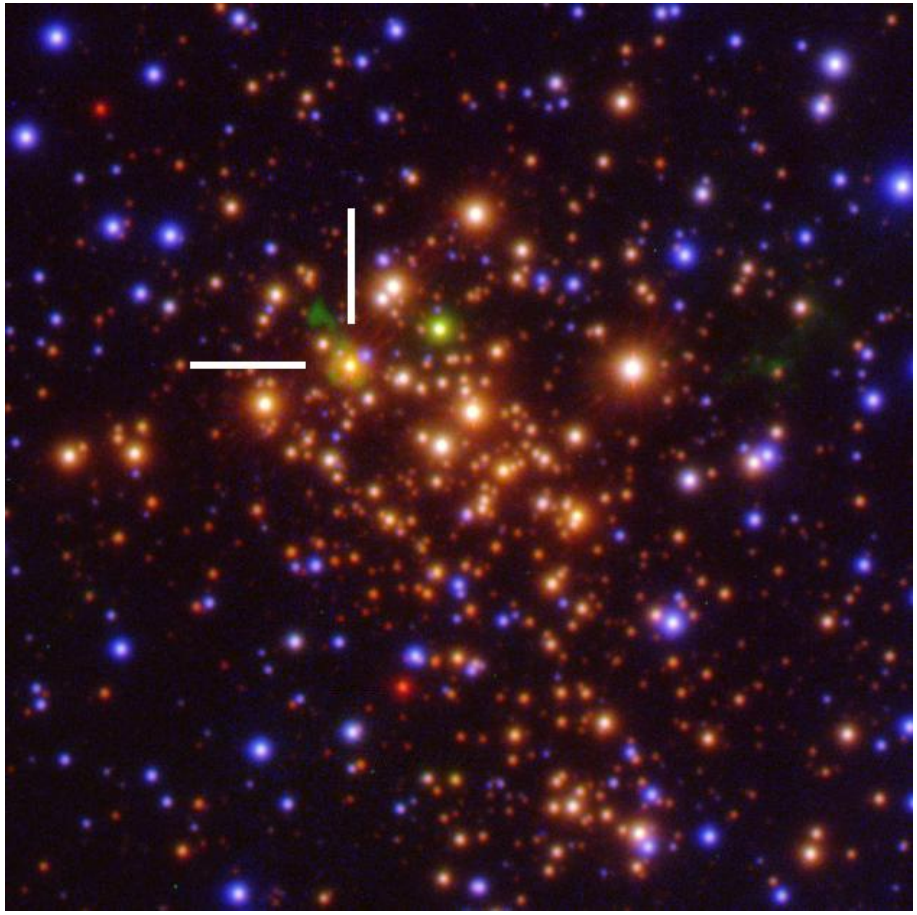


IPHAS-selected CBe stars to r ~16.5:

- from Gkouvelis et al in prep.
- from Raddi et al 2013,2015

(Triangles are masers)

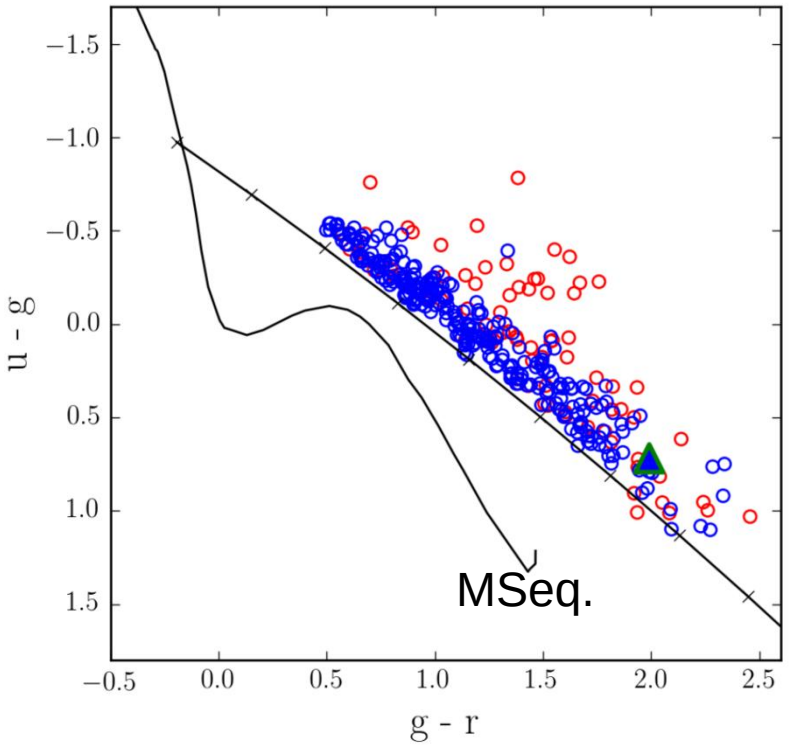
2. Non-emission line OB stars



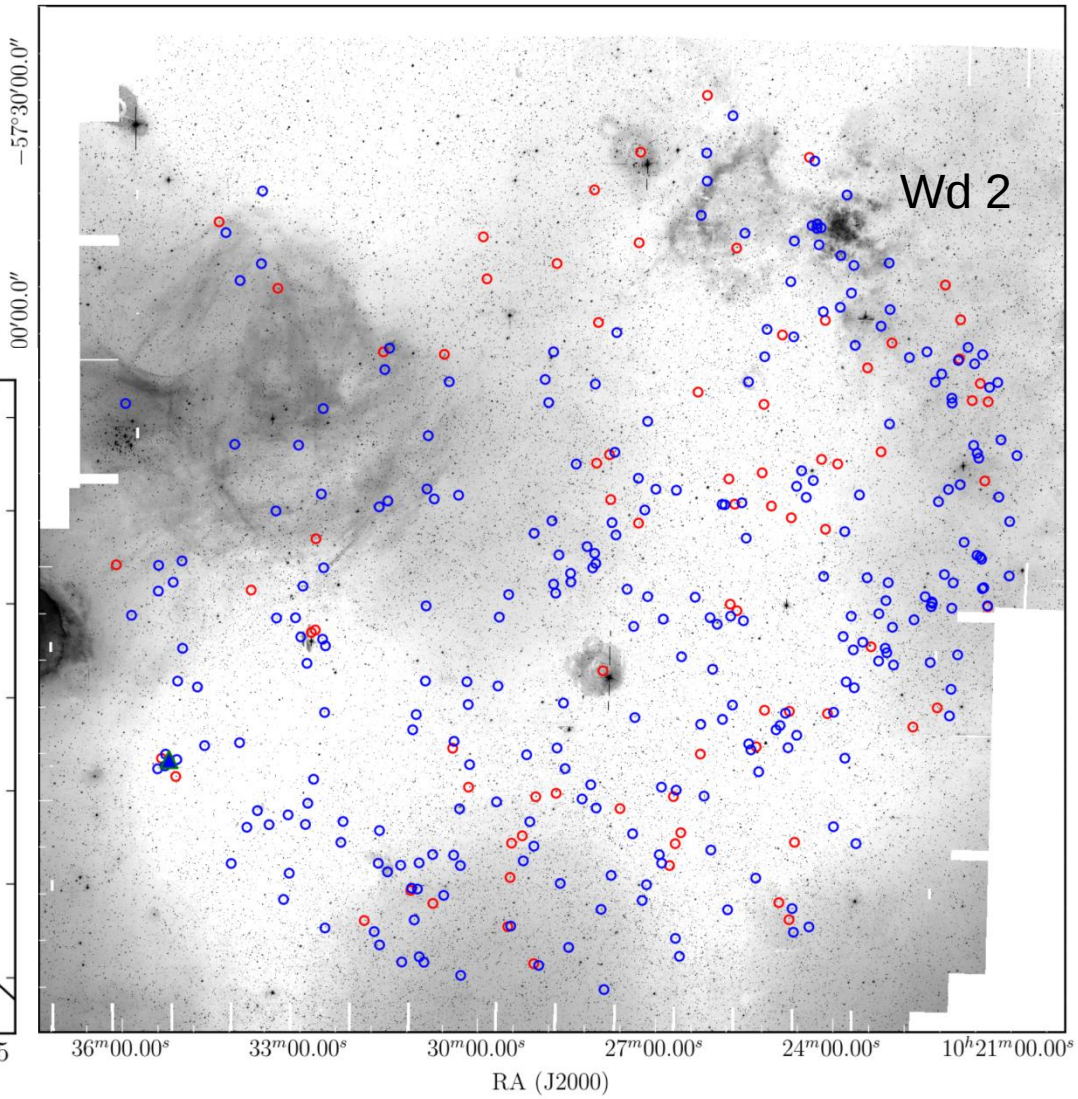
(W26 in Westerlund 1, Wright et al 2014)

A trial of VPHAS+ photometry in the Carina Arm:

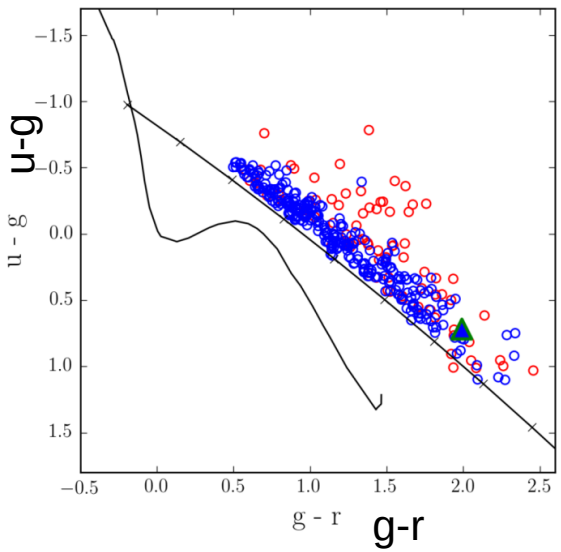
First step: select candidate O/early-B stars from the u-g, g-r diagram, above B3 reddening line:

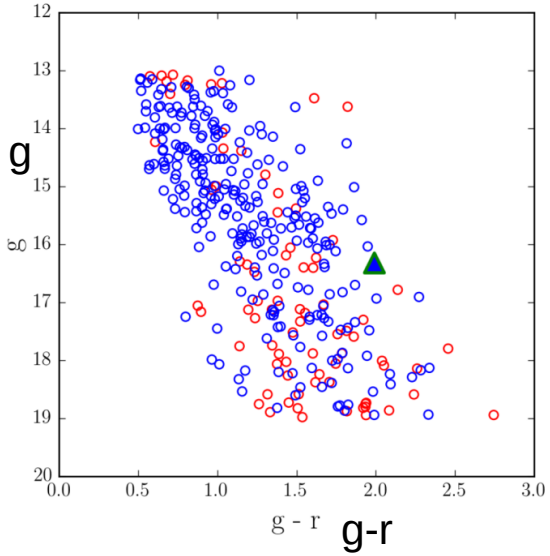


(AAOmega targets, on VPHAS+ Hα image)

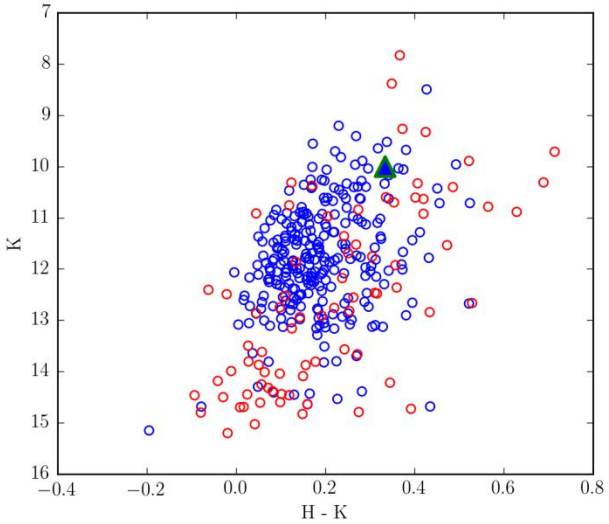


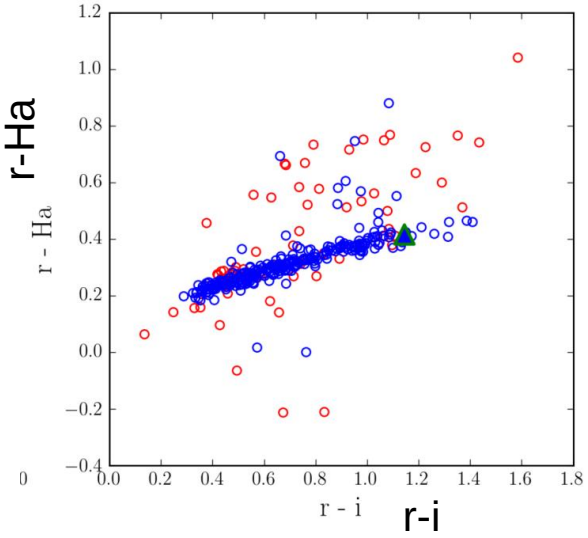
Optical diagrams



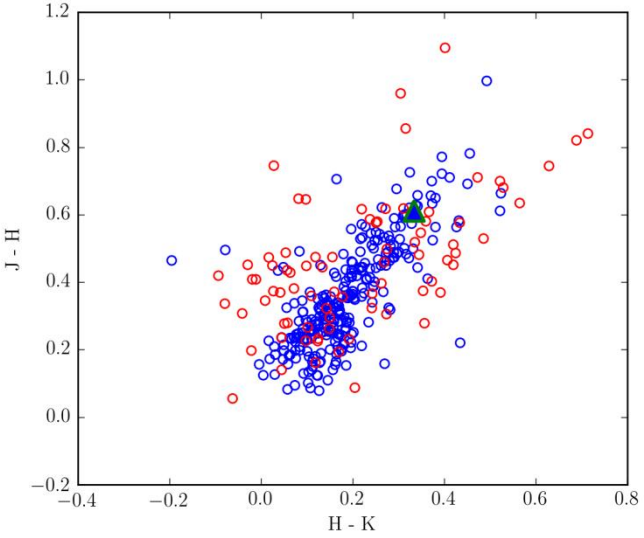


NIR diagrams

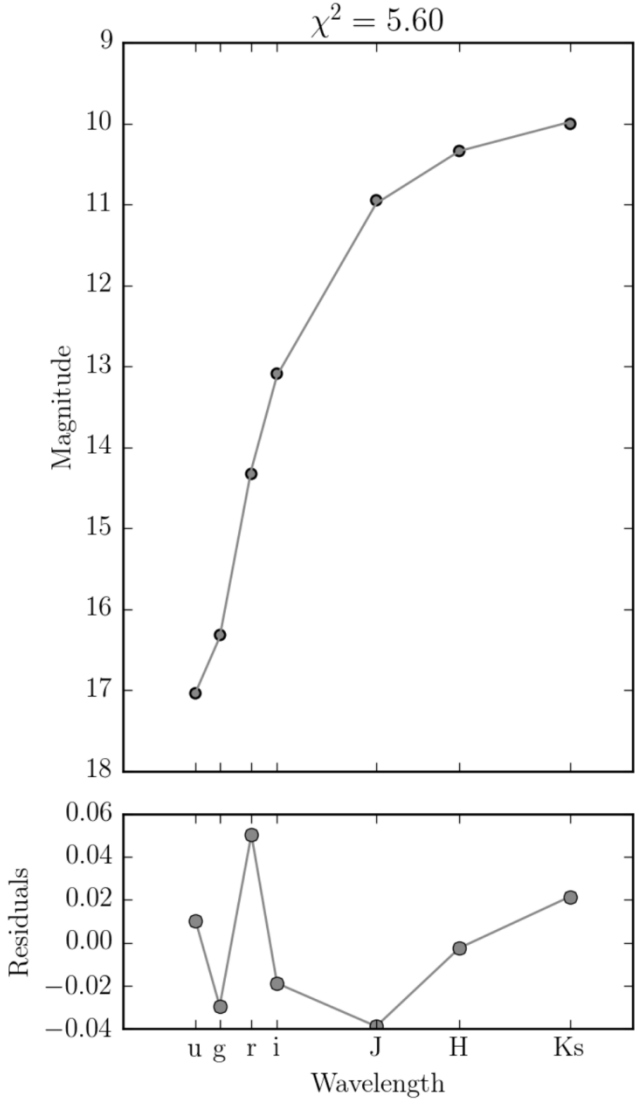


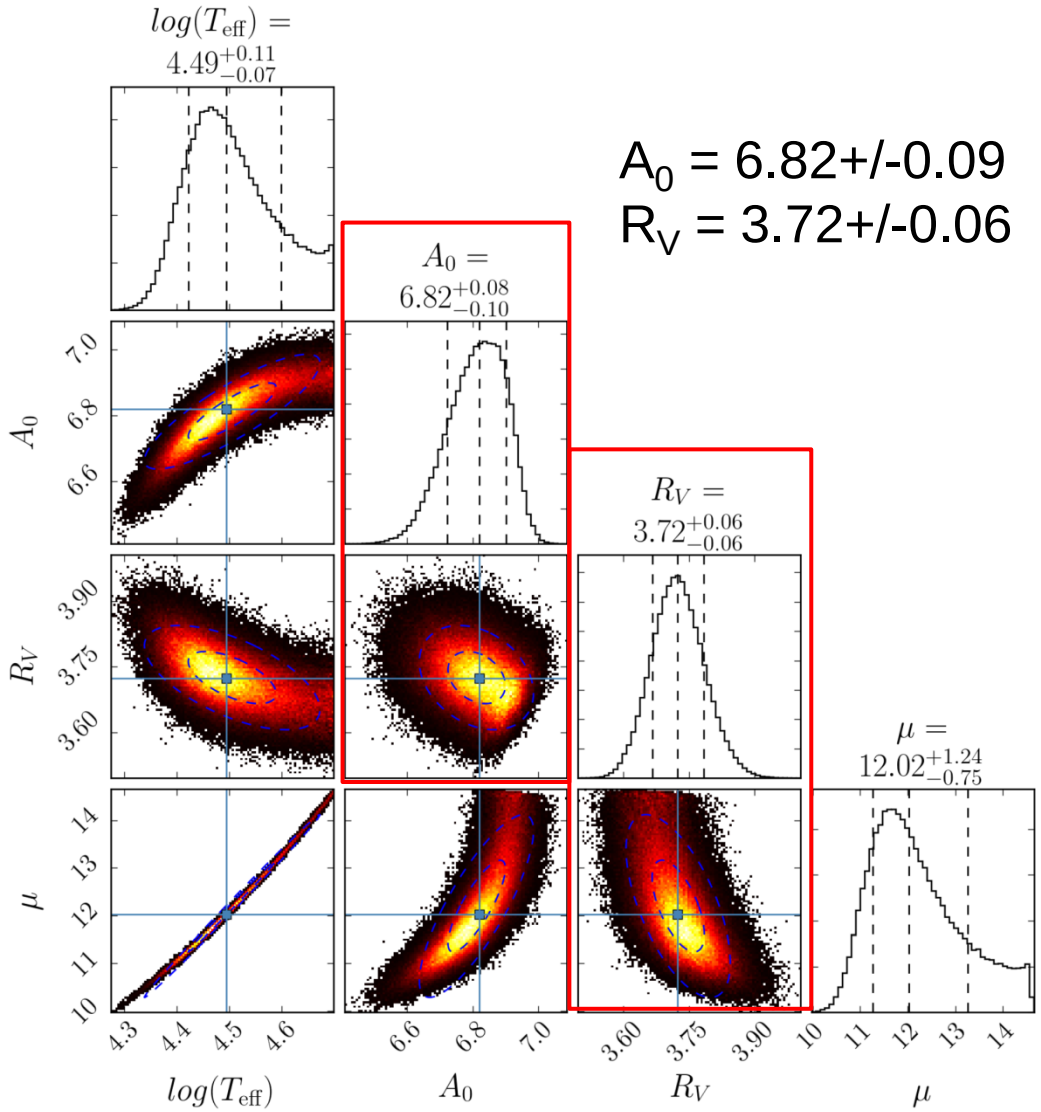


Optical colours pin down O/early B types well – even in the field



Second: fit u,g,r,i,J,H,K → OB status gains support
→ measure extinction parameters, A_0 and R_V, well





A_0 = 6.82+/-0.09
R_V = 3.72+/-0.06

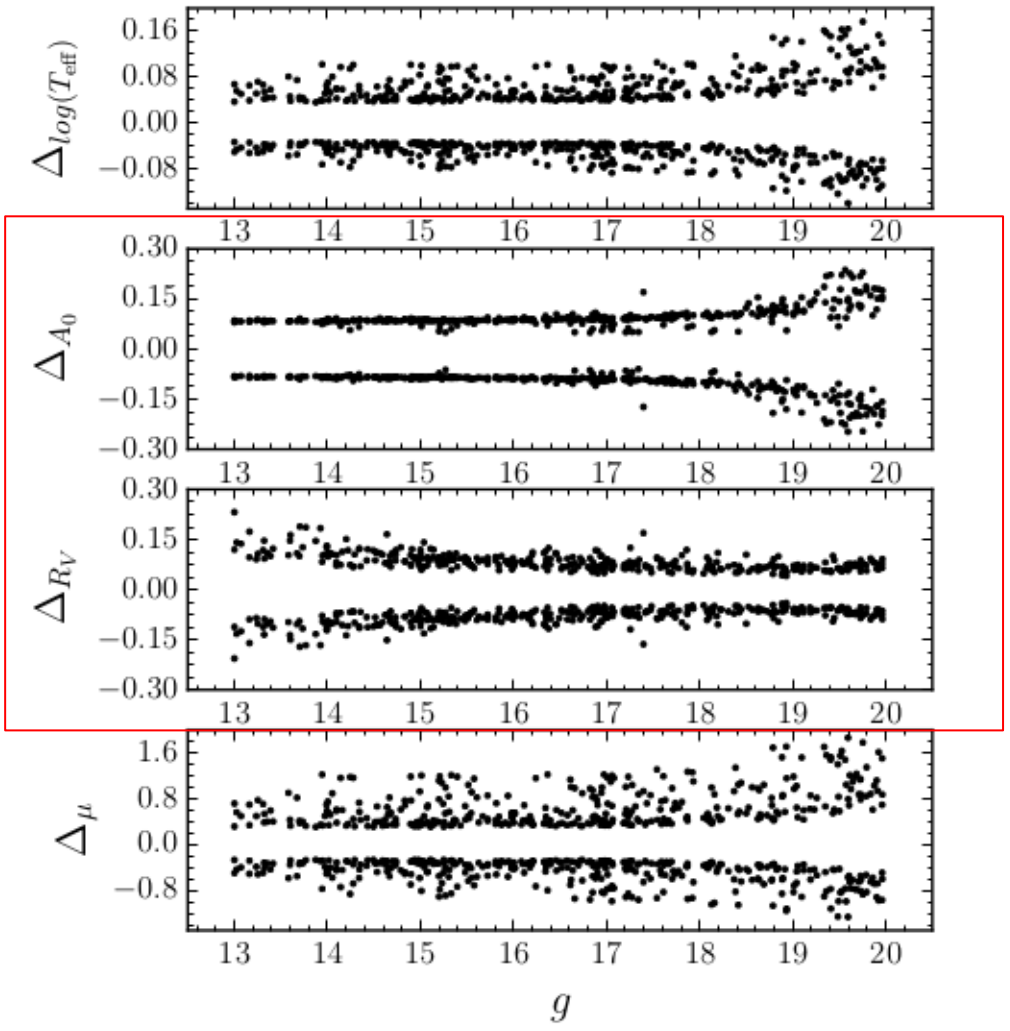
As near-Rayleigh-Jeans objects in the optical:

O and early-OB OIR SEDs – very weakly dependent on effective temperature

→O/early-B SEDs are favoured for probing extinction laws.

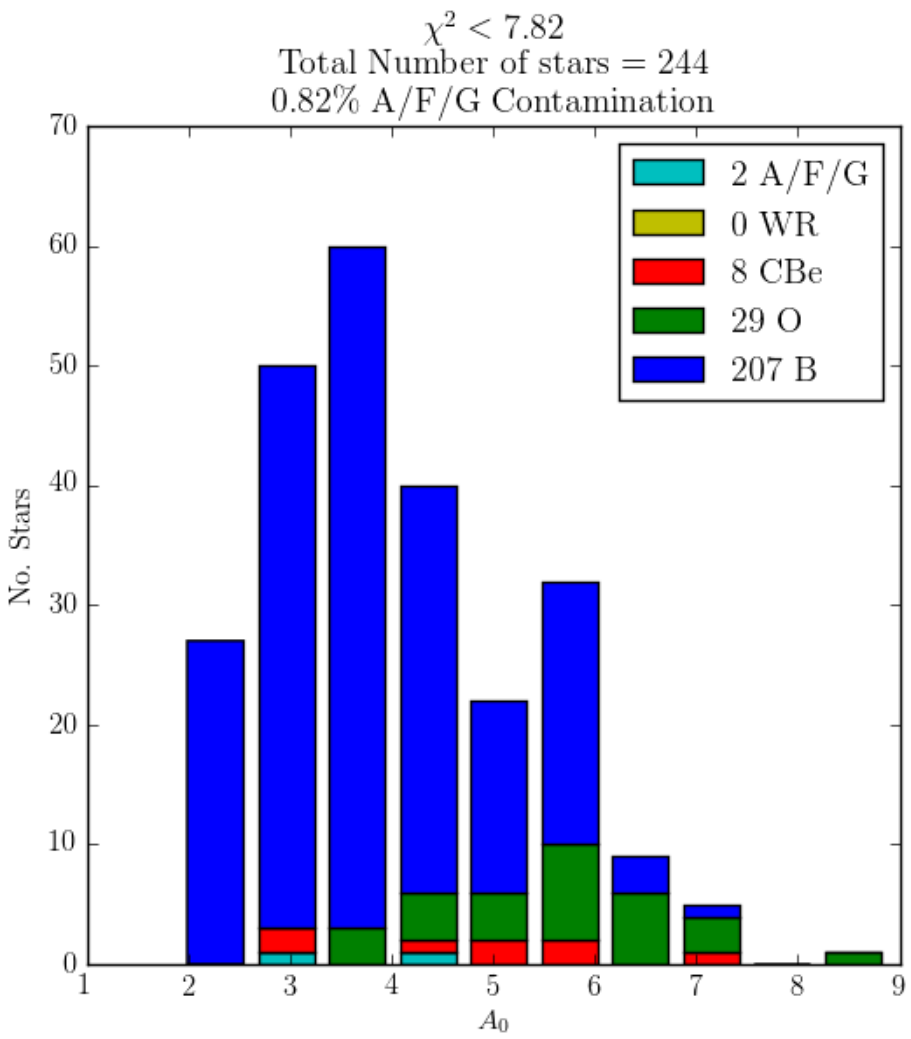
→ grip on extinction gets **even tighter** if stellar parameters are measured separately via spectroscopy (see e.g. Maiz-Apellaniz et al 2014)

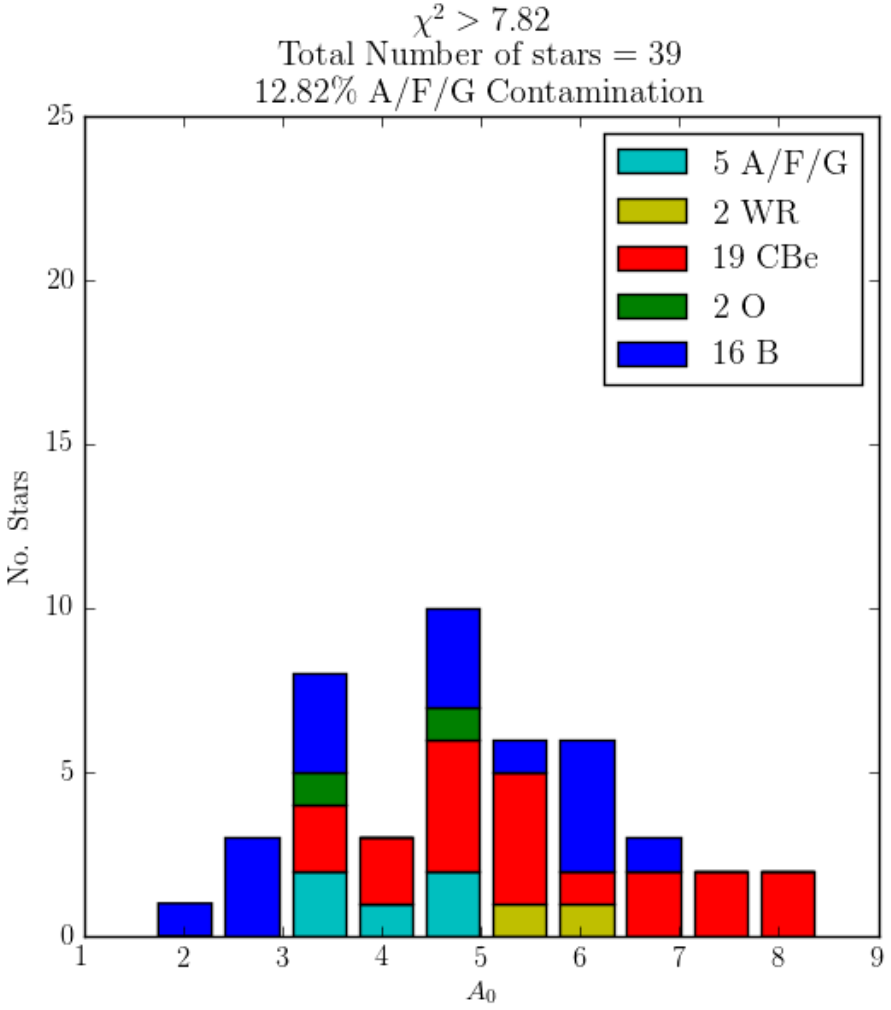
Right: VPHAS+/Carina Arm OB-star parameter errors: ΔA_0 *and* $\Delta R_V < 0.1$



Third step – take spectra, and determine success rate

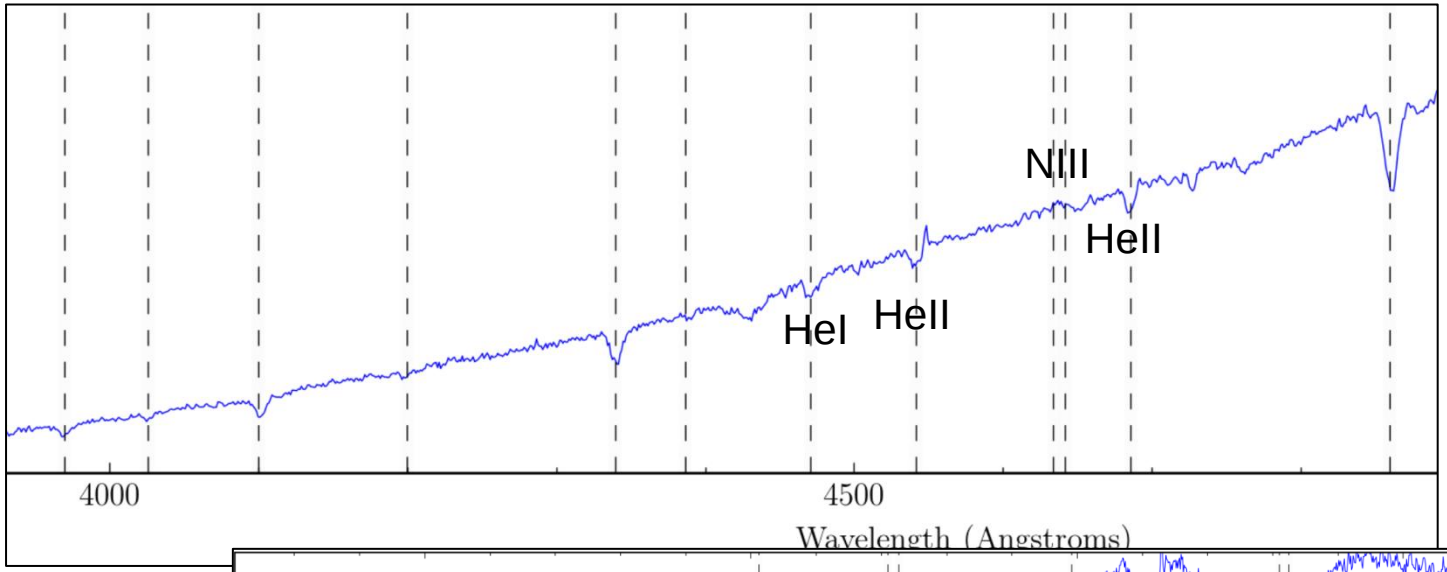
Results of AAOmega trial: **very high** conversion rate – poorer fit sources (right panel) still scientifically interesting!

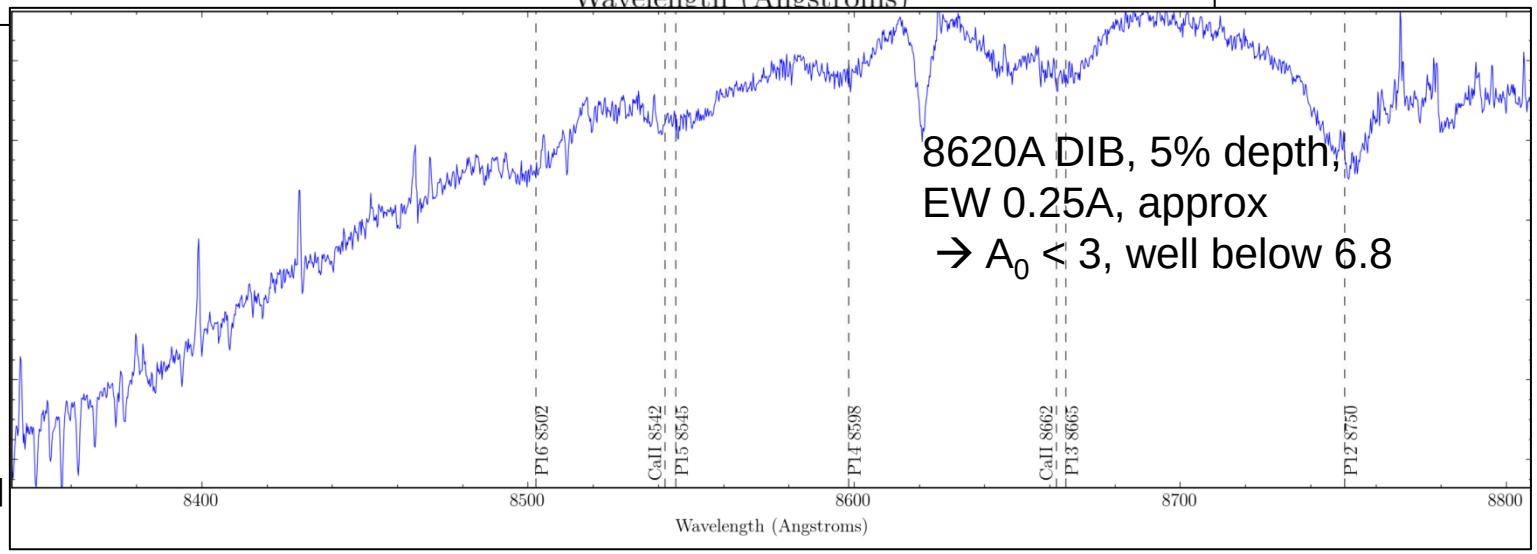




Top: blue spectrum (AAOmega 580V, R = 1300)→ O7V-III

Bottom: CaT region (AAOmega 1700D, R = 10000) ...less informative





(highly suppressed Zero)

The Milky Way's r >14 OB stars from EGAPS surveys:

A. Wide-field spectroscopic follow-up can confirm and characterise early type stars to $A_0 \sim 9$

→ numbers of optically-accessible undiscovered O and (all) B stars, from 14th to 19th mag exceed 0.5 million

- R=5000 optical spectroscopy → well-suited to measuring key stellar parameters, kinematics
- no bias to detection in clusters → settle the in-situ/runaway debates ...true relation to spiral arm shocks (and other MW structures)
- well-positioned, and needs to exploit Gaia astrometry from 2017

B. ...fabulous resource to inform 3D ISM models to 5-10kpc distances across the Galactic Plane

- stellar parameters → to better exploit photometric fitting
- wealth of detected interstellar absorption features
- with relative flux calibration ...even **more** power to delineate extinction law variety

Thank You