IPHAS, UVEX and VPHAS+: Galactic Plane Open Clusters

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with contributions from U of Hertfordshire colleagues:

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And the EGAPS consortia:- R Greimel, M Irwin, E Gonzalez-Solares, P Groot, R Corradi, A Mampaso, M Barlow, J Drake, J Eisloeffel, B Gaensicke, C Knigge, R Morris, Q Parker, T Prusti, L Sabin, S Sale, D Steeghs, J Vink, J Walsh, N Walton, A Zijlstra

World of Clusters, Padova, 25/09/13

The European galactic plane surveys at optical wavelengths:

- IPHAS (INT/WFC photometric Hα survey of the Northern Galactic Plane), began 8/2003
- UVEX (UV-excess survey, INT also) started in 2006, covers blue bands
- VPHAS+ (VST photometric... Southern Galactic Plane and Bulge) began 12/2011

Three surveys with a common strategy, reaching to ~20th magnitude at ~1 arcsec spatial resolution – covering the Galactic Plane within $-5^o < b < +5^o$ and Bulge

Survey papers:
IPHAS: Drew et al 2005, followed by the Initial Data Release (IDR) Gonzalez-Solares et al 2008
UVEX: Groot et al 2009; VPHAS+: Drew et al – under construction

Status of the surveys:

IPHAS (r,i,Hα in the north):

- data taking now limited to essential repeats
- IDR was in 2008 (~60% of footprint, nightly calibration)
- DR2 merged source catalogue (93% of footprint, global calibration) exists and is in last checks
- DR3 will be the final version (~100%, improved calibration)

IPHAS sets the data-product model for UVEX and VPHAS+

UVEX (U,g,r and partial HeI, north)

- About two-thirds done – no public releases yet

VPHAS+ (u,g,r,i,Ha in the south)

- Public survey → release of P88/P89 single-band catalogues has already happened
- ~a quarter done ...including all GES cluster fields fed in early, at high priority

Where EGAPS began:- Back in 2003, with IPHAS on the Isaac Newton Telescope – Hα, backed up by r,i

Original motivation:

Hα = the highest emissivity, non-ground-state transition of the most abundant element in the cosmos – usually excited by recombination

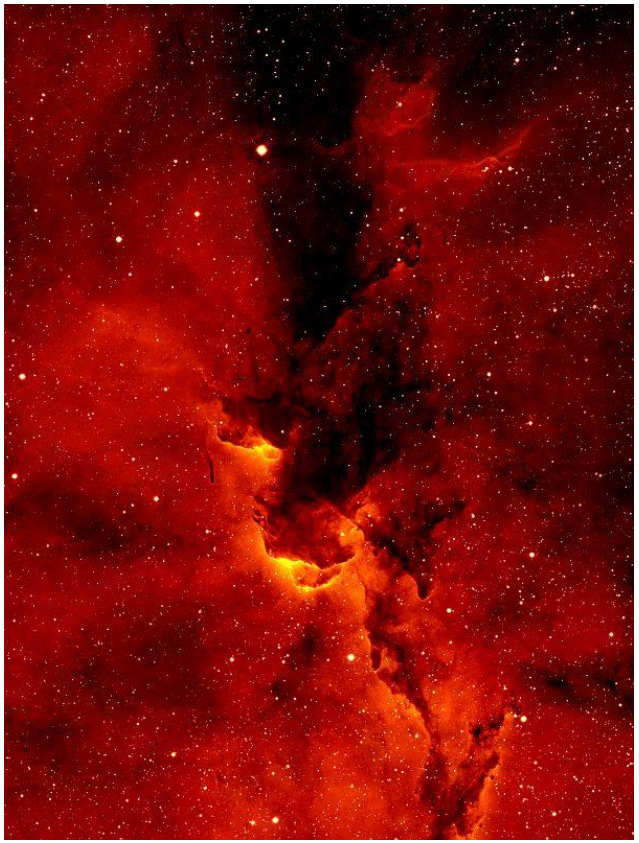
→*the* tracer of ionised gas….

Spatially resolved imaging → detection of HII regions, bubbles/chimneys, planetary nebulae and supernova remnants

Point sources → disks and winds of large numbers of Be and pre-main-sequence stars – and many different types, of evolved stars and compact binaries

...we do not understand any of these object classes adequately (samples usually too small or too incomplete)

IPHAS (www.iphas.org) – first ~arcsec resolution digital Hα survey, able to pick out emission line stars reliably/comprehensively



(IC 1396b, r'i'Hα, N. Wright)

WFC footprint ~0.25 sq.deg

'simultaneous' r',i', Hα data to ~20th magnitude, obtained each pointing

~15000 pointings, covering 1800 sq.deg area twice

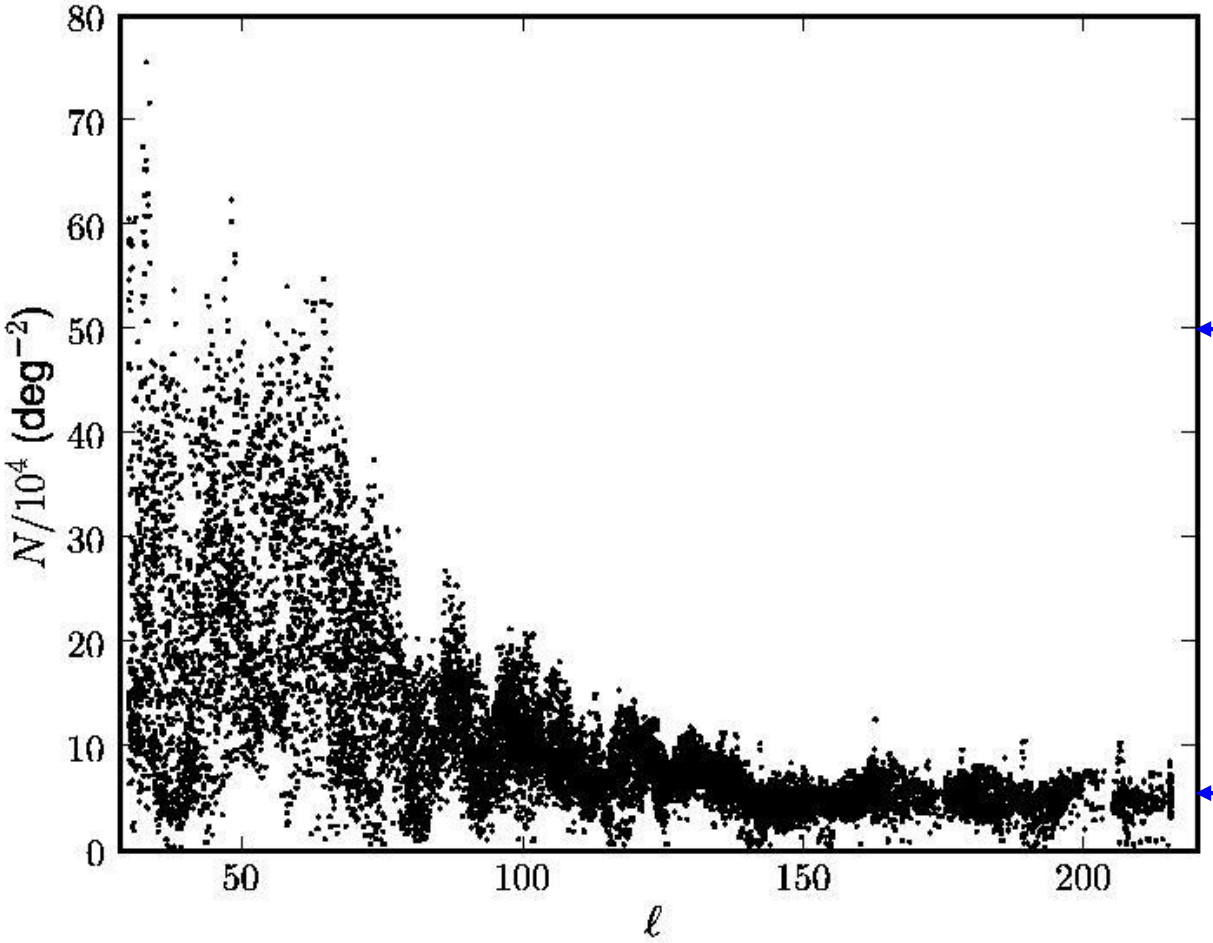
pointings are paired → basic data unit is : 2 offset positions x 3 filters, on each field, to: deal with CCD gaps; aid calibration

median seeing: 1.1 arcse

data pipelined at CASU (reduced images and aperture photometry)

Northern optical source densities (to ~20th mag)

IPHAS IDR catalogued object densities per sq. degree: each data point is an IPHAS field. (figure from Gonzalez-Solares et al 2008)



500000/sq.deg

50000/sq.deg

Above ~200000/sq deg, confusion is an issue... affecting limiting mag and completeness (evaluation by artificial source recovery scheduled for DR3).

Properties of the IPHAS DR2 integrated source catalogue (alpha version built by G Barentsen):

220 million unique objects with SNR > 5, in one band (i usually)
109 " " " " , in all three bands and not de-blended

Sources extracted by aperture photometry (default 3.3 arcsec aperture), and cross-matched using a 1 arcsec matching radius limit

84-column catalogue, borrowing ideas from UKIDSS
In most instances, 2 contemporaneous sets of globally-calibrated r,i,Hα magnitudes will be provided

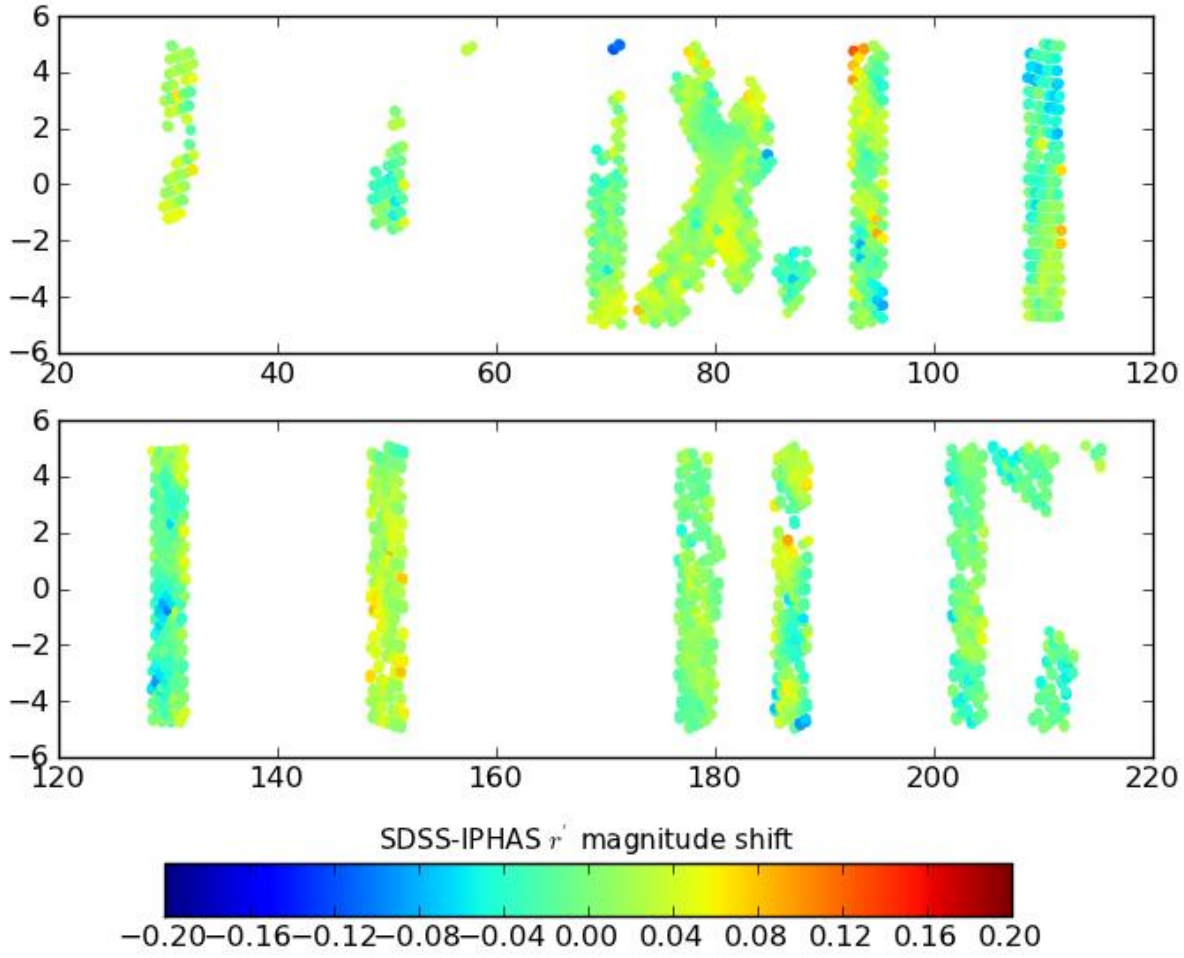
Agreement in place to give catalogue of IPHAS2 sources to CDS, when linked paper (Farnhill et al) is accepted for publication

***Vega magnitudes are used** – not AB*

DR2 global calibration: based on anchor selection + minimising overlap magnitude shifts + comparison with APASS photometry

IPHAS v APASS reference
→ External error of 1% in r and i

IPHAS v SDSS validation
→ External error of 3% in r and i



Hα calibration:

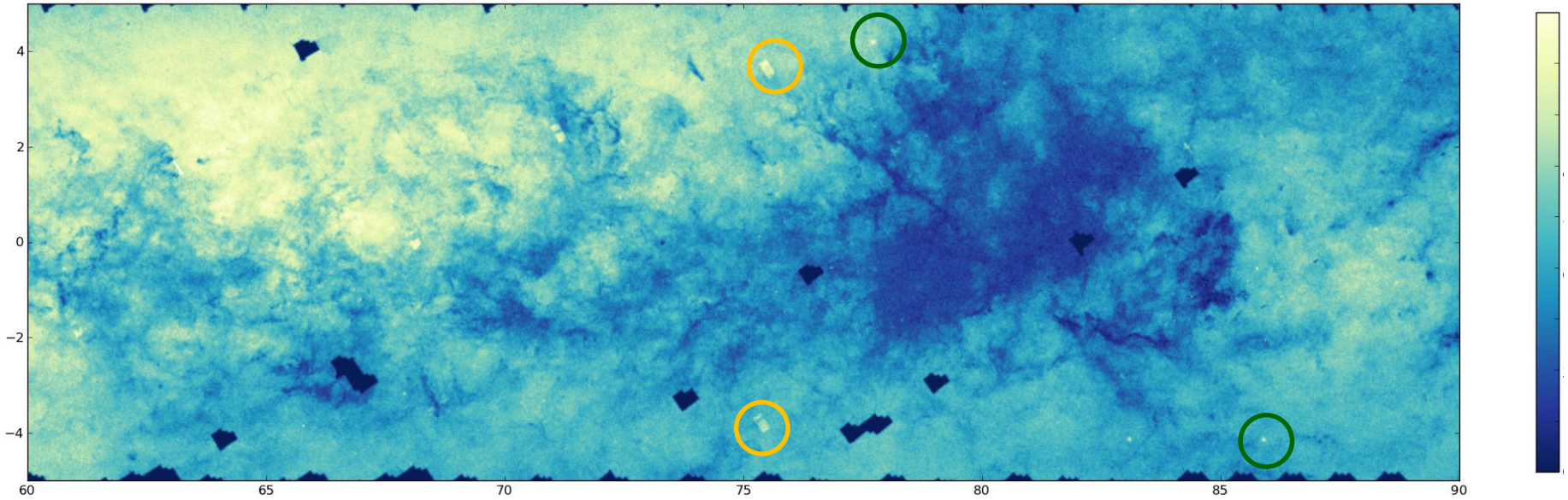
Dense anchoring wrt r, + overlap minimisation (then checked, by eye)

Catalogue science verification

IPHAS stellar density maps – a cut-out covering 60º < *l* < 90º, and -5º < b <+5º (built by H Farnhill, for DR2 paper)

To 19th magnitude, star counts per 2x2 arcmin^2 'pixel' – peak counts,cream, are 150000 in r, 290000 in i (square root scale used)

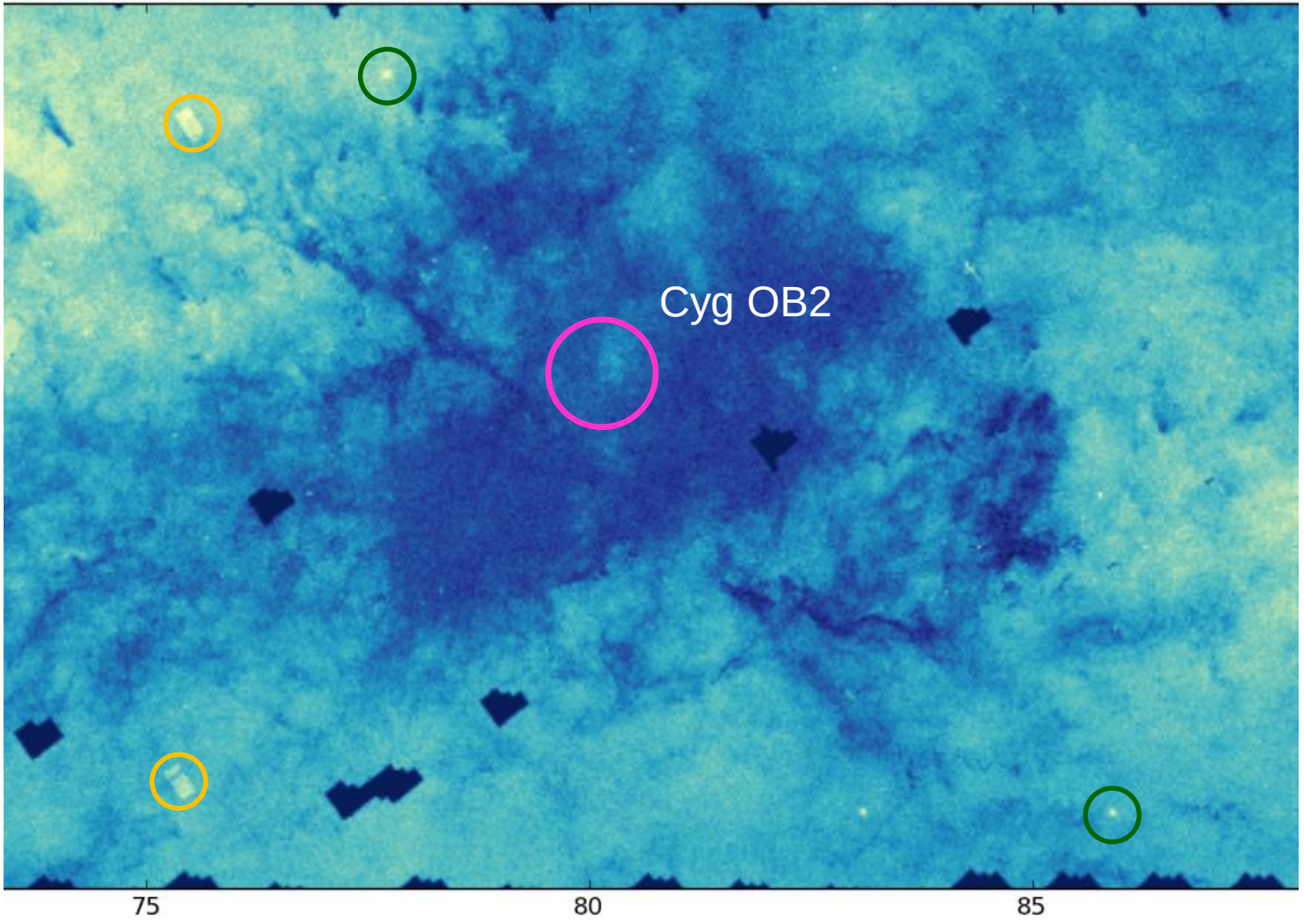
rimap

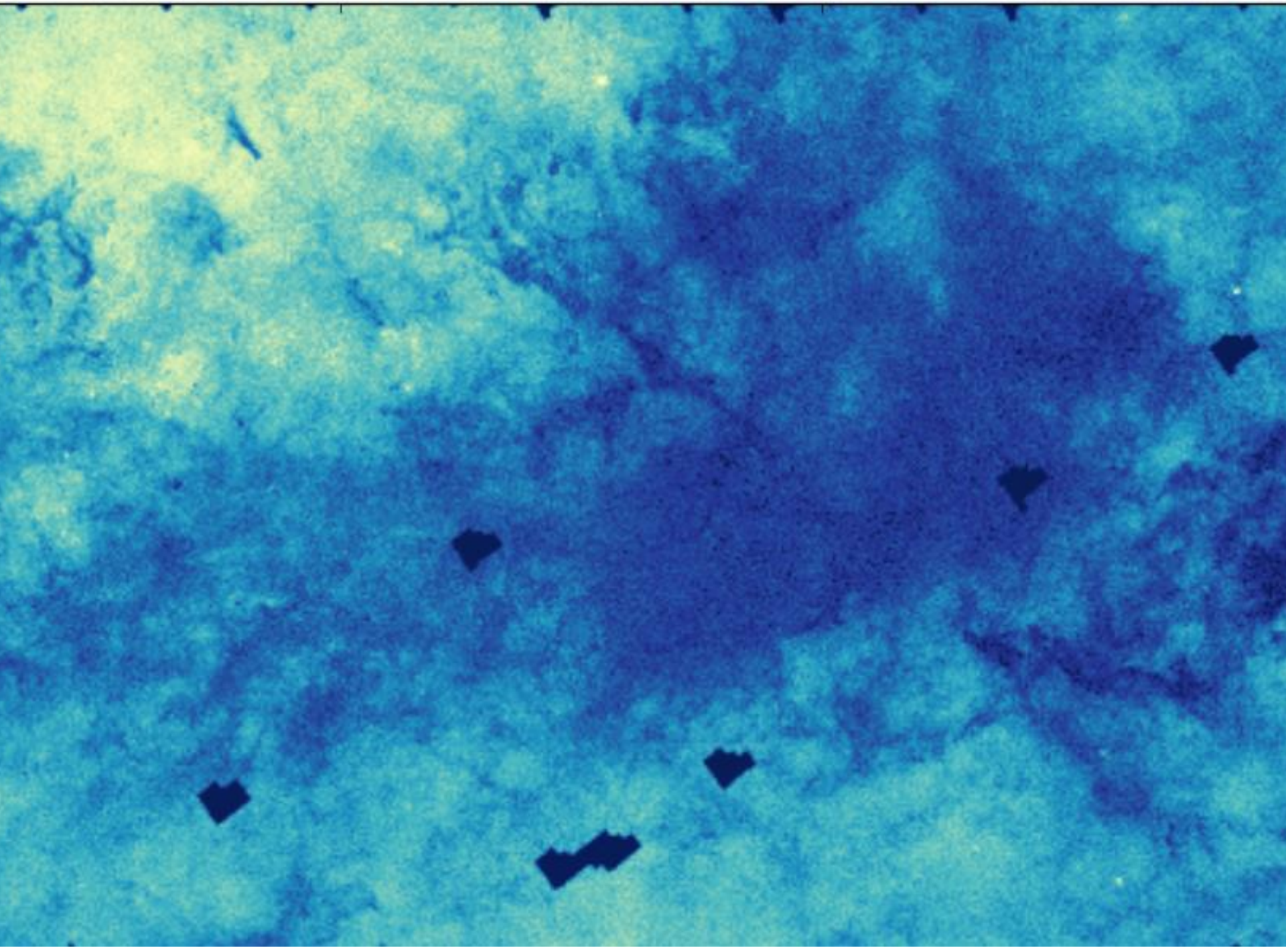


Astrometry problem! *Open cluster (IC 1311, NGC 7044 picked out)*

Dark cut outs are rejected fields awaiting replacement

...zooming in to the Cygnus Rift:





A simple catalogue application

Uniform characterisation of optically-detected open clusters across the northern Plane

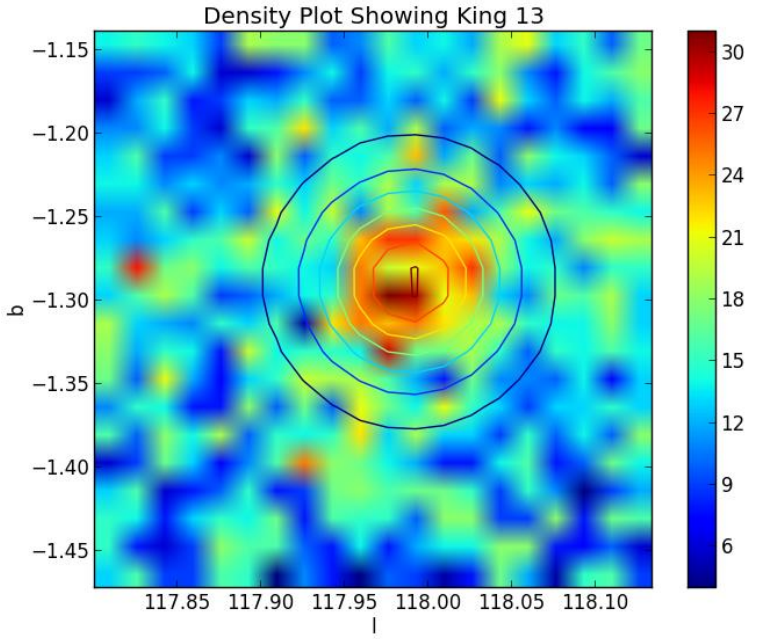
-- student summer project (J Westcott) to work through all the northern Dias catalogue clusters in the Plane, running automated fits of:

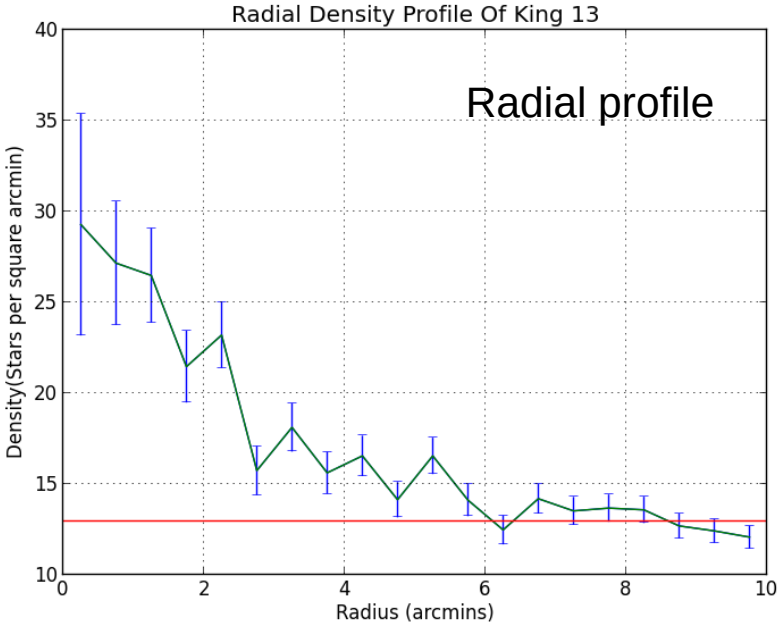
cluster positions; radial profiles; gaussian FWHM in r and i

Stars brighter than 20th collected – counts binned to 1.6' x1.6' – background computed...

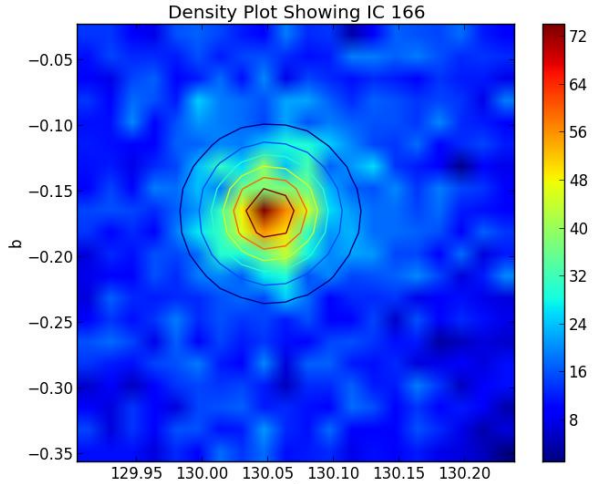
e.g.
King 13
r band

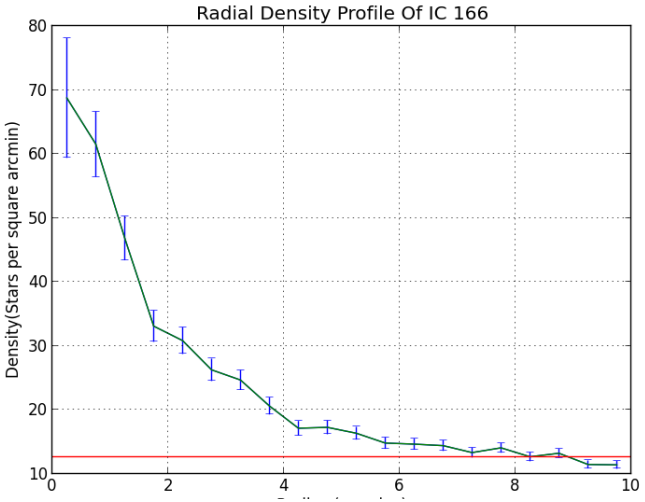
Left:
10x10
sq.arcmin
density
plot

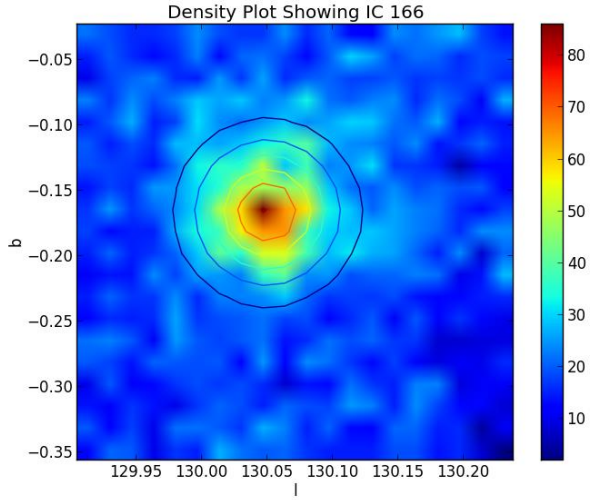


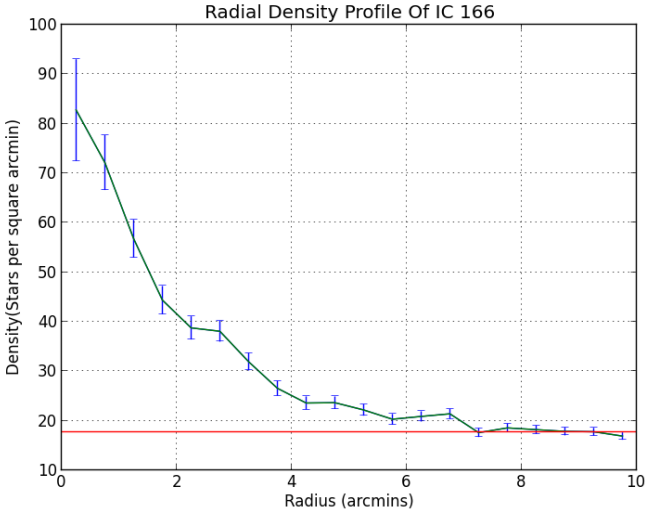


IC 166: r (top), and i(bottom)









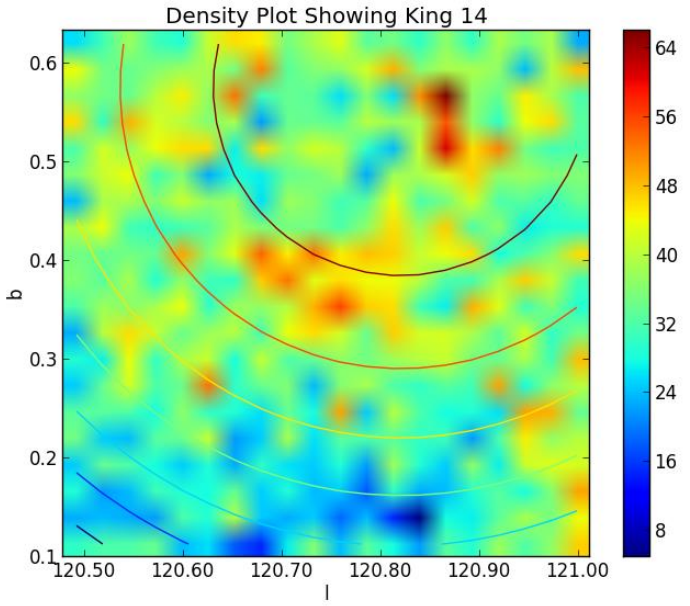
...catalogued position off a bit;
in i band, IC 166 is a bit larger and more populous (not a surprise).

And there are total failures:

e.g. King 14
Fits in r and i – both a mess!

- distinctly non-circular cluster?
- against a density gradient?
- interesting/distracting nearby density peaks?

...early days – tuning needed.



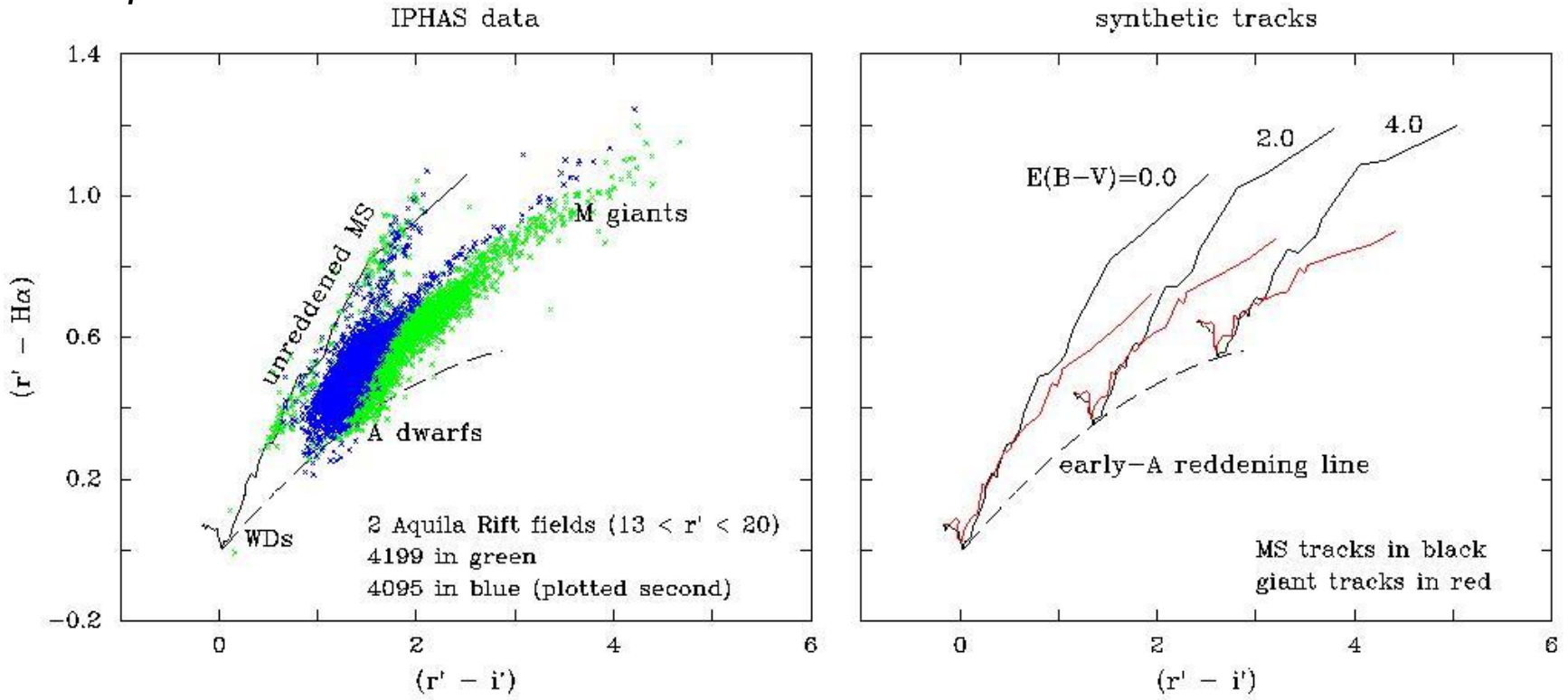
Brief interlude: the crucial added value of Hα narrowband

r'-Hα is overwhelming sensitive to spectral type/intrinsic colour

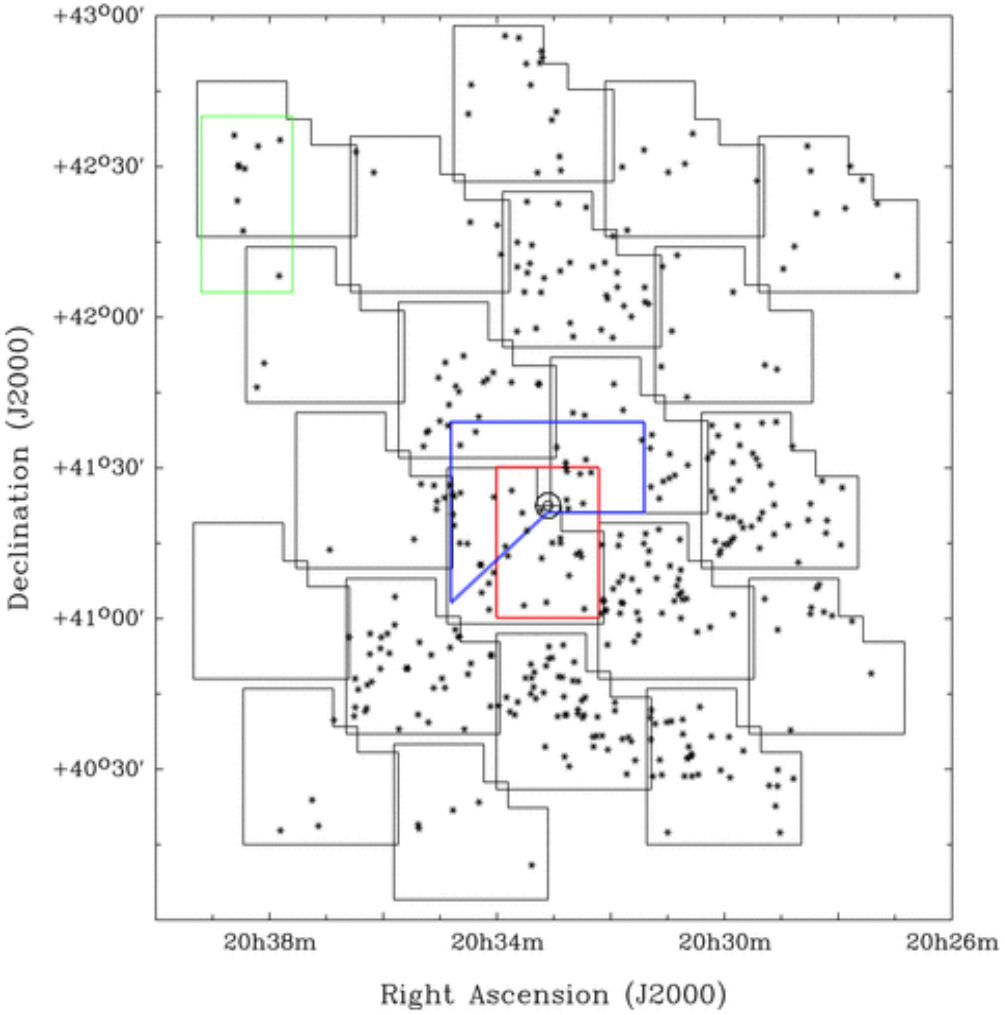
r'-i' carries a strong reddening dependence

When combined: temperature sequences sweep out area as they are reddened

→ can assign (sp.type, reddening) to each location in the colour-colour plane



Selecting, dereddening and mapping the A stars in/around Cyg OB2:



Left: the ~2 x 2 sq.deg region explored around Cyg OB2

O stars mainly fall inside blue outline; Knodlseder's 2MASS Cyg OB2 peaks in red box; DR21 in green

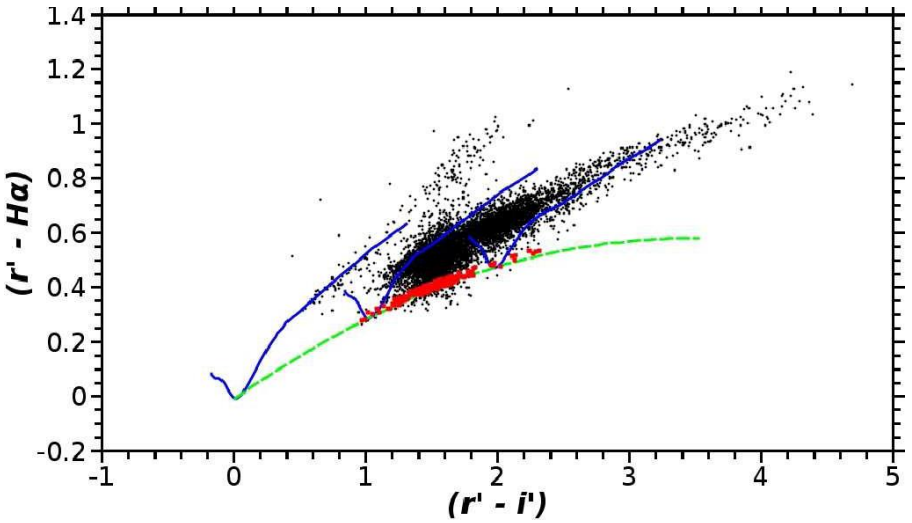
A stars marked in black – selected and dereddened using IPHAS photometry .

- only at the right distance (1.4-1.5 kpc) **if** 5-7 Myrs old
- O stars are 1-3 Myrs old
- evidence of mixed ages in Cyg OB2.

Drew et al 2008

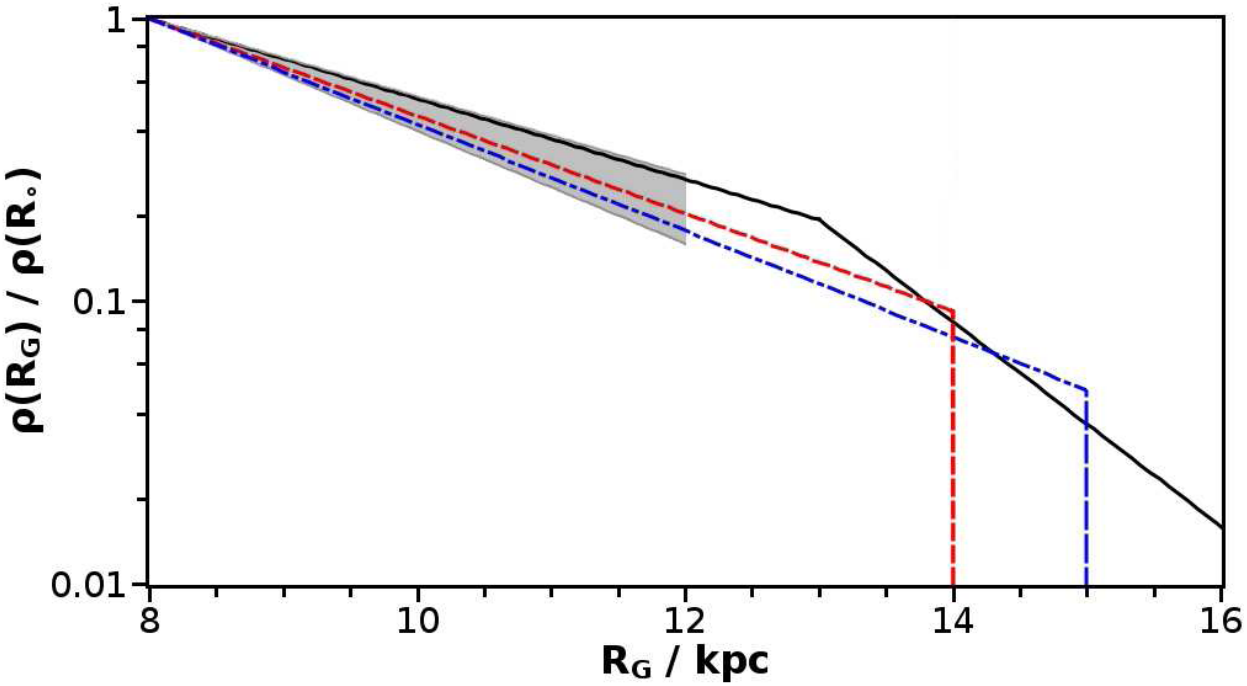
The stellar density gradient in the outer thin disc – as portrayed by A stars

(Sale et al 2010, using ~40000 extinction-corrected A stars: 160 < ℓ < 200, |b| < 1)



~100 Myr-old A stars (black line) hint at longer scale length than SDSS K/M stars (shaded area).

DENIS sharp cut-off (broken lines) updated.

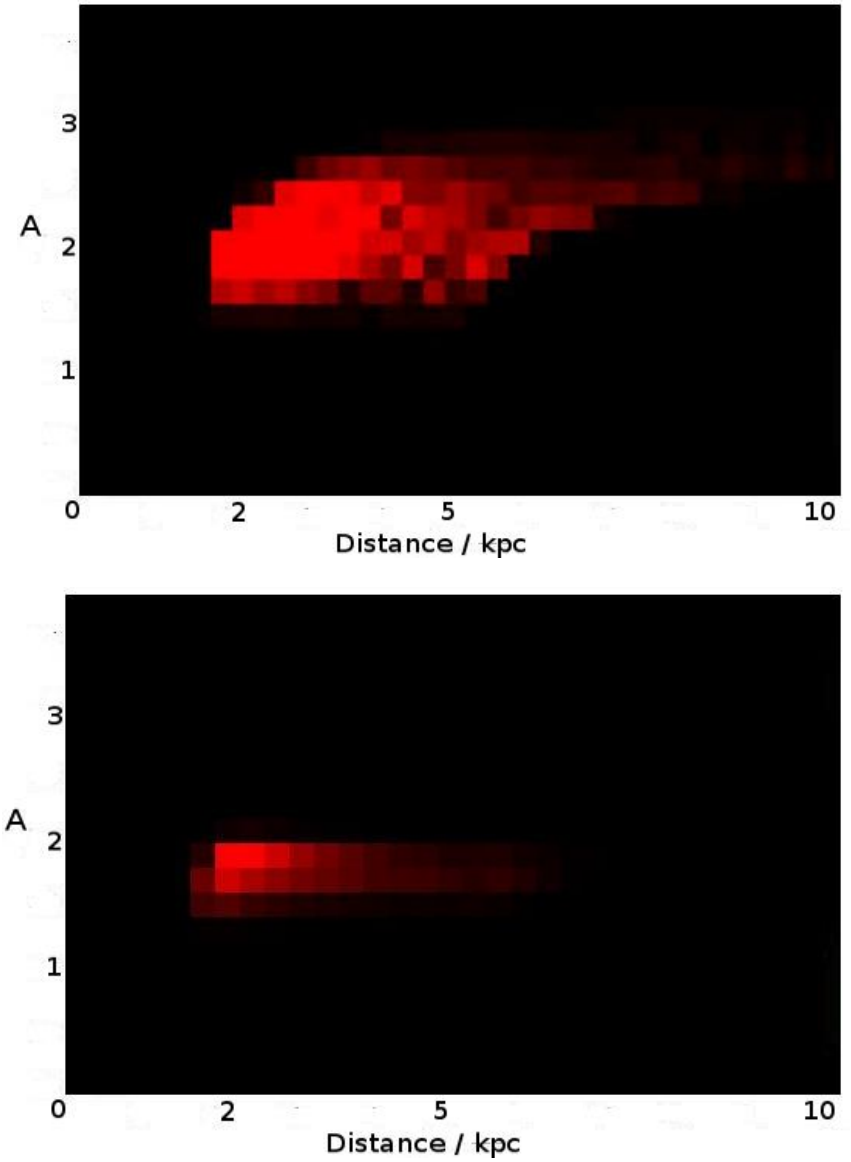


And Hα is a great band to support 3D-extinction mapping...

Right:-

Sale 2012, in presenting H-MEAD, a Bayesian algorithm for 3D extinction mapping, simulated and compared: broadband-only data (top) with broadband + Hα (bottom) for recovery of stellar parameters ...and hence extinction+distance

Object fed in was at 2kpc, and A(V) of 2.



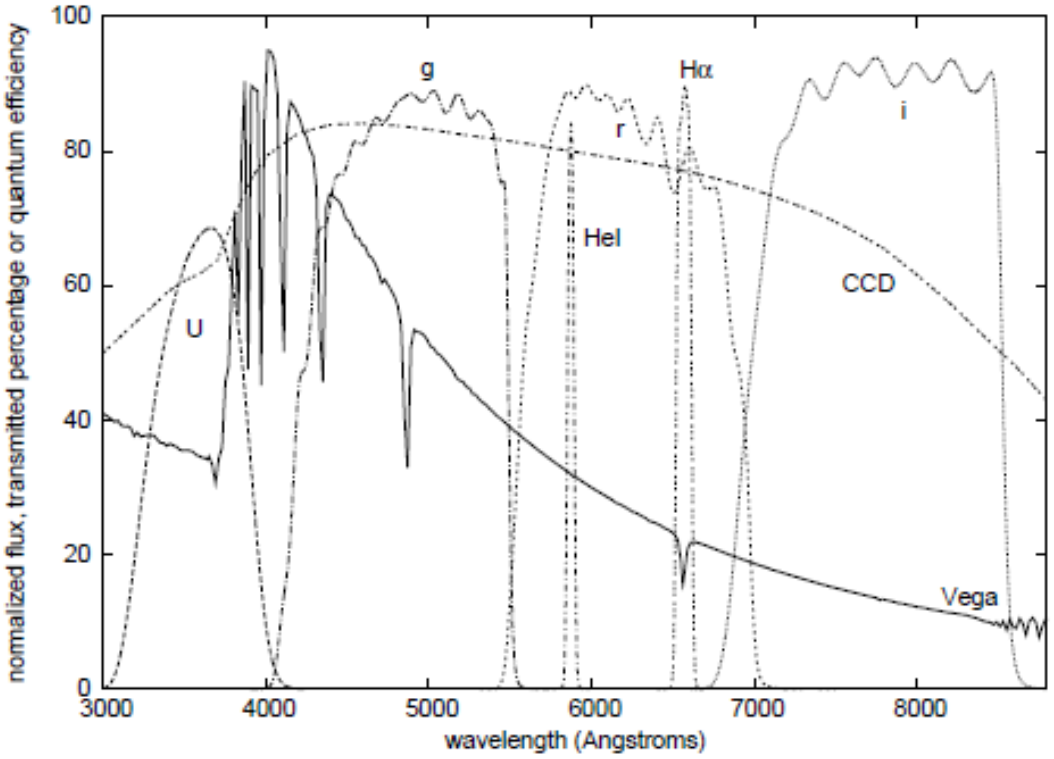
UVEX: UV excess survey of the northern Galactic plane

Covers U,g,HeI bands, and repeats r:

Started in 2006 ...following IPHAS on at 3+ yr delay – on purpose (for PMs)

Over 2/3 complete See e.g. Verbeek et al papers

Will be merged with IPHAS, ultimately



The UVEX+IPHAS filter set, and Vega
(because we work in Vega magnitudes)

ESO press release 18/09/13
(IC 4628)

VPHAS+ (www.vphas.eu) is an ESO public survey
...based on IPHAS/UVEX, but it has become more complicated...
...winding up more like IPHAS/UVEX than intended!

Filter set has had to be split into two for queue-scheduling reasons:

- *u (150 sec),g (40 sec),r (25 sec) are obtained together*
- *r (25 sec),i (20 sec),Ha (120 sec) " " "*

No time link between them is feasible

3 fields are observed within the same observing block to minimise filter-change overhead.

Filter split allows better tailoring of observing constraints (red data can be obtained during brighter moon)

Split loses contemporaneity – repeat of r is there to ease bringing the filter sets together again at the cataloging phase

u,g,r,i,Hα filter set split into two: u,g,r and r,i,Hα.
The less demanding red filters win the scheduling software lottery more often:

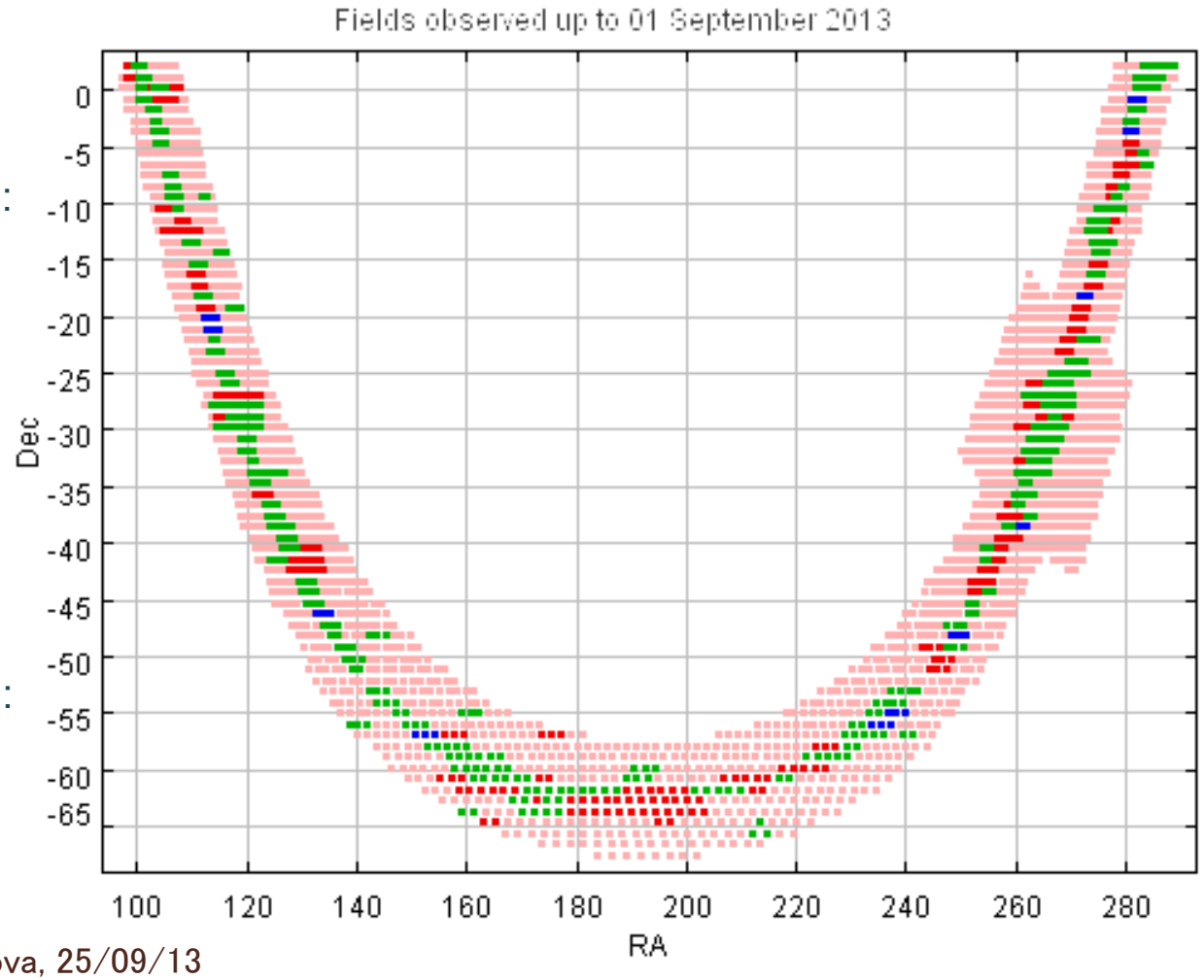
VPHAS+ progress to date:

Survey footprint, in pink

Red filters, Hα/r/i :
622 fields

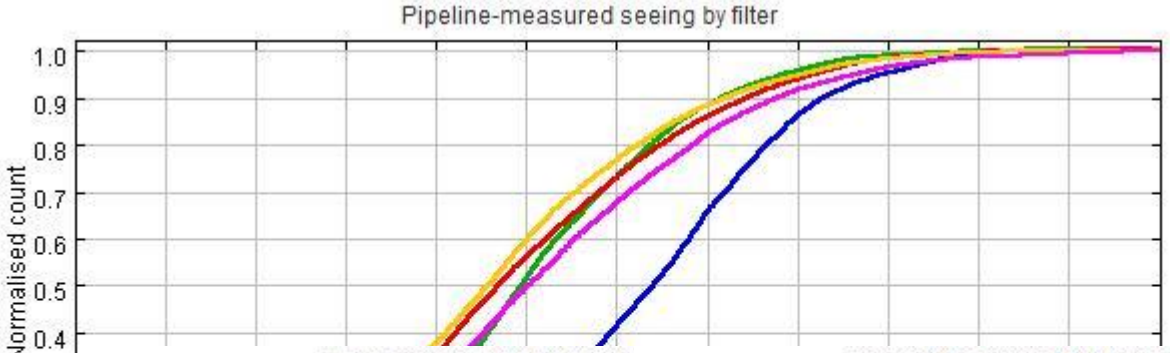
Blue filters u,g,r:
429 fields

All filters (shown in green):
399 fields

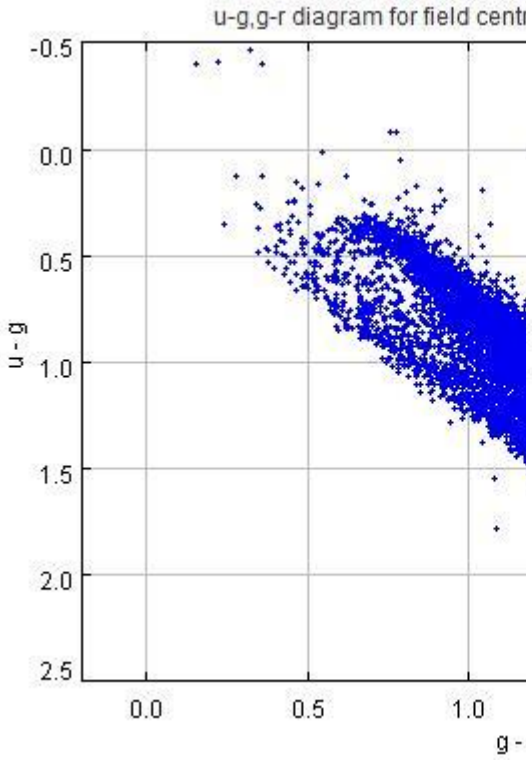


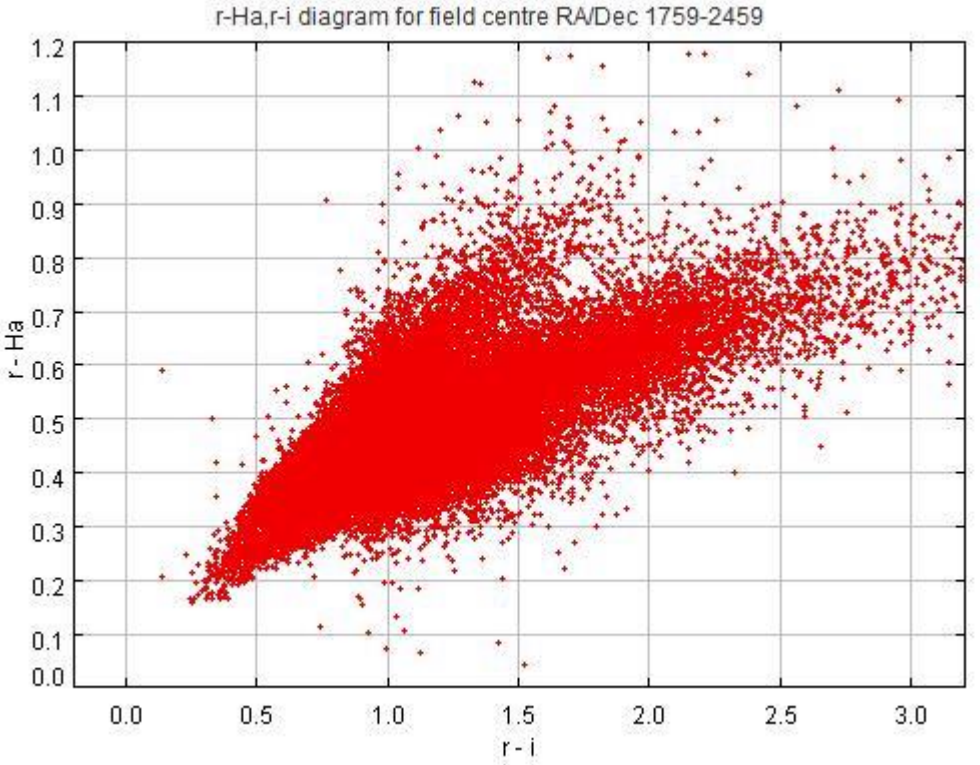
OmegaCam data quality – good and consistent across 1 sq.deg field

(plots from DR1 description)

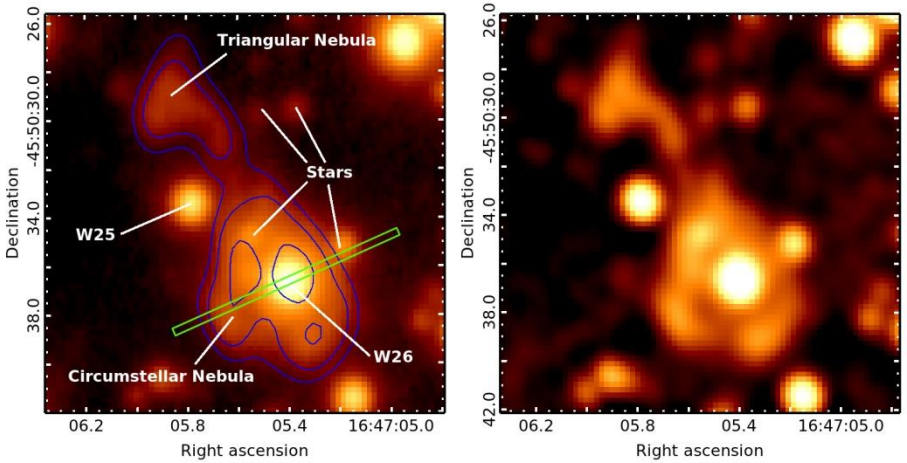


Median seeing in g,r,i,Ha is < 0.8”, ~0.95 in u

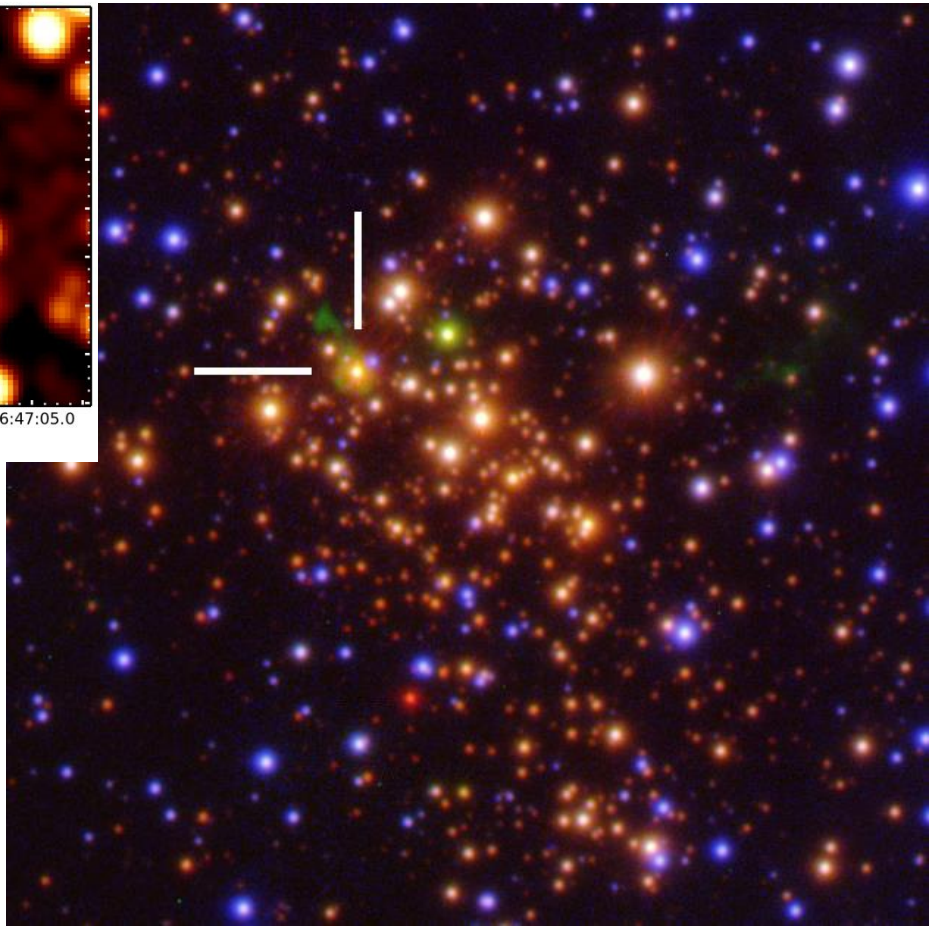




A first piece of VPHAS+ science from Westerlund 1: just resolving the externally-ionized wind of W26, an M supergiant



VPHAS+ u,g,Hα combined cut-out



An exotic first.

Ionised Hα flux, compared with radio → extinction law needs to be mildly anomalous (R ~3.7) to recover A(V) ~ 12.

(Wright et al, in press)

Concluding remarks

EGAPS
EUROPEAN GALACTIC PLANE SURVEYS

✓ These surveys, collectively, will provide a uniform multi-band digital reference set of ~half a billion Galactic Plane sources (in a few years). They complement Gaia G and BP/RP, in the crowded Plane. ...they complement NIR surveys.

✓ IPHAS/UVEX/VPHAS+ seeing is at least comparable to PanSTARRS ...better than Skymapper.

✓ *The presence of narrowband Hα is a game-changer ...the cheapest form of spectroscopy conceivable, as well as mapping ionized circum- and interstellar gas.*

✓ Many science opportunities – for star clusters, among others.

✓ A coming one-stop shop for reliable wide-field MOS target selection – seeing some use already for GES.