VPHAS+: surveying the southern Galactic Plane

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Credits:

The consortium:

Core functions:
University of Hertfordshire (PI institution);
University of Cambridge (pipeline);
University of Graz (software oversight)

Other member institutions:
Radboud University Nijmegen, IAC, Warwick University, University College London, Tautenburg Observatory, Imperial College London, University of Manchester, Southampton University, Armagh Observatory, Macquarie University, Harvard-Smithsonian CfA, ESO, ESTEC, University of Valencia

Key individuals: Geert Barentsen, Romano Corradi, Jochen Eisloeffel, Hywel Farnhill, Boris Gaensicke, Robert Greimel, Eduardo Gonzalez-Solares, Paul Groot, Mike Irwin, Danny Steeghs, Jeremy Walsh

This talk is:-

An initial word on the EGAPS surveys…

(i) A progress report on VPHAS+
- What has been done since January
- Emergent issues and some good news

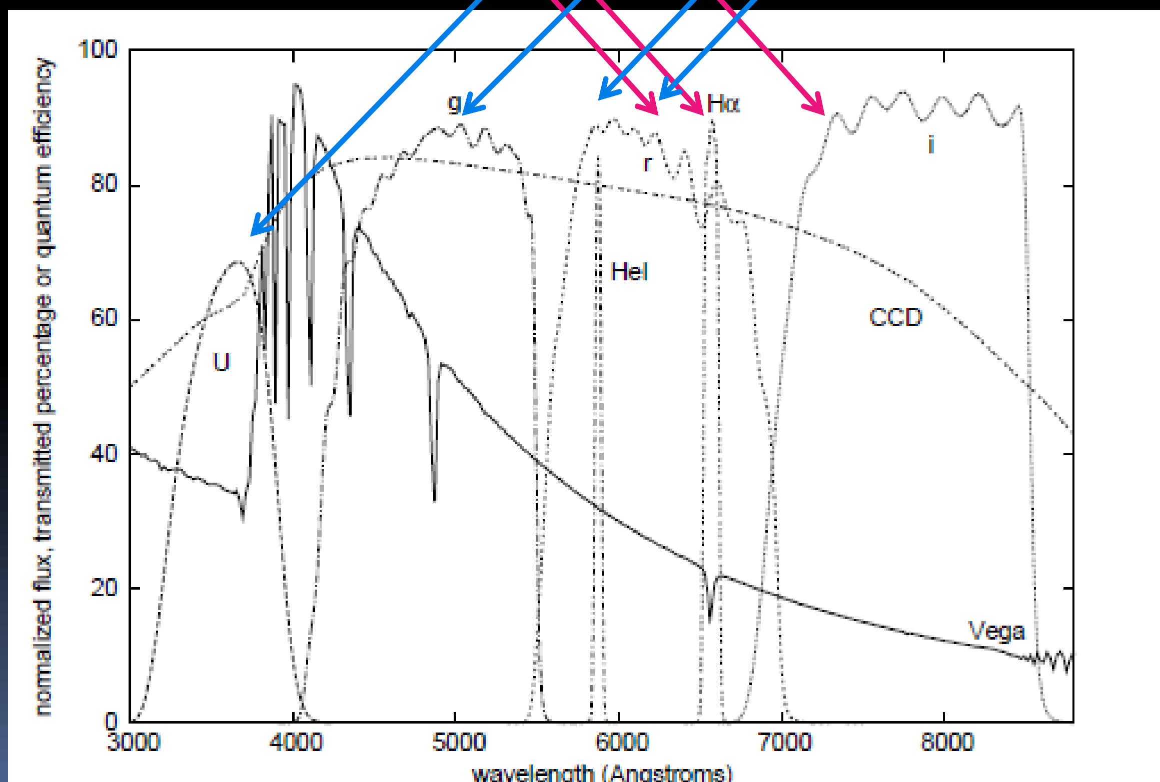
(ii) Examples to illustrate what a survey like this enables
- …one looking back (IPHAS)
- …one looking forward (VPHAS+)

(iii) "Here's one we prepared earlier"
- Finishing a Galactic Plane survey (IPHAS)

European Galactic Plane Surveys: 2 northern surveys (1 red with Hα, 1 blue); 1 merged red+blue survey in the south

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

5 filters (all except HeI)



(Spectrum of Vega, with filter transmission profiles on top -- from Groot et al 2009)

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

Primary 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….

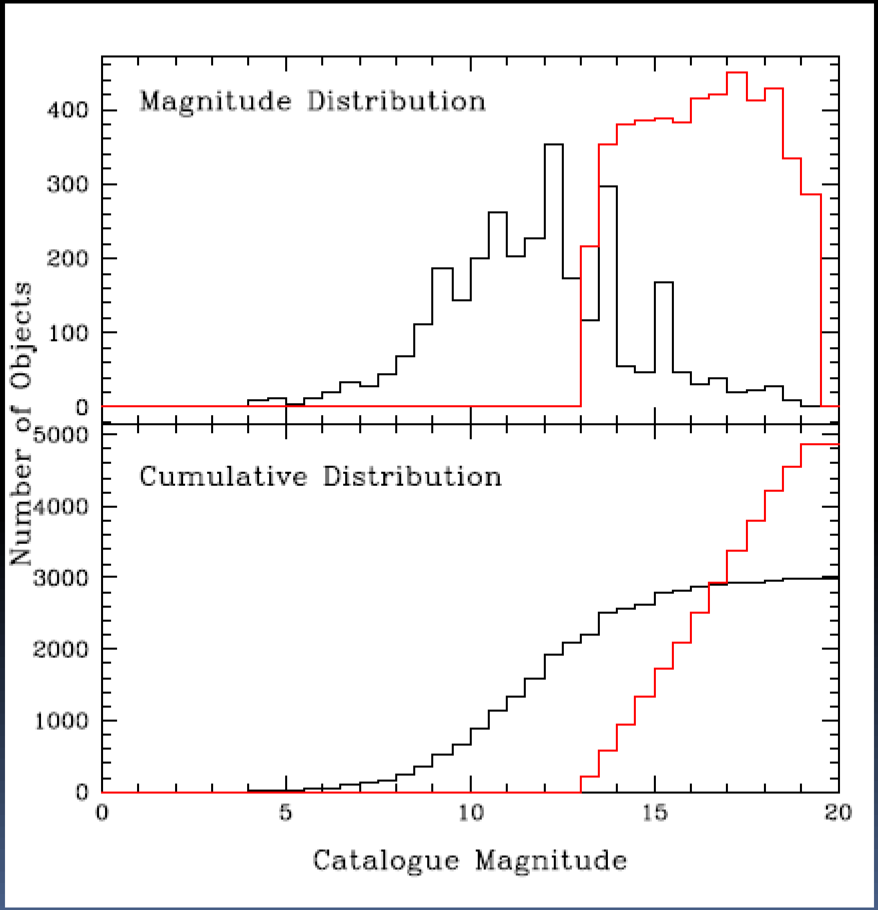
Spatially resolved imaging → detection of HII regions, bubbles/chimneys, planetary nebulae and supernova remnants

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)

Narrowband Hα picks out short-lived/important phases of stellar evolution

- In 2003: few emission line stars known below ~13th magnitude



On the way to being fixed in the north by IPHAS

Figure: comparison of Kohoutek & Wehmeyer catalogue, in black, with conservatively-selected Witham et al 2008 IPHAS catalogue, in red (80% of survey footprint).

2004-5 UVEX came into being as an INT survey:

- U, g, r and narrowband HeI
- Same footprint and 'double-pass' strategy as IPHAS

→ To seek out UV-excess objects – compact binaries of all kinds, hot WDs, massive stars…

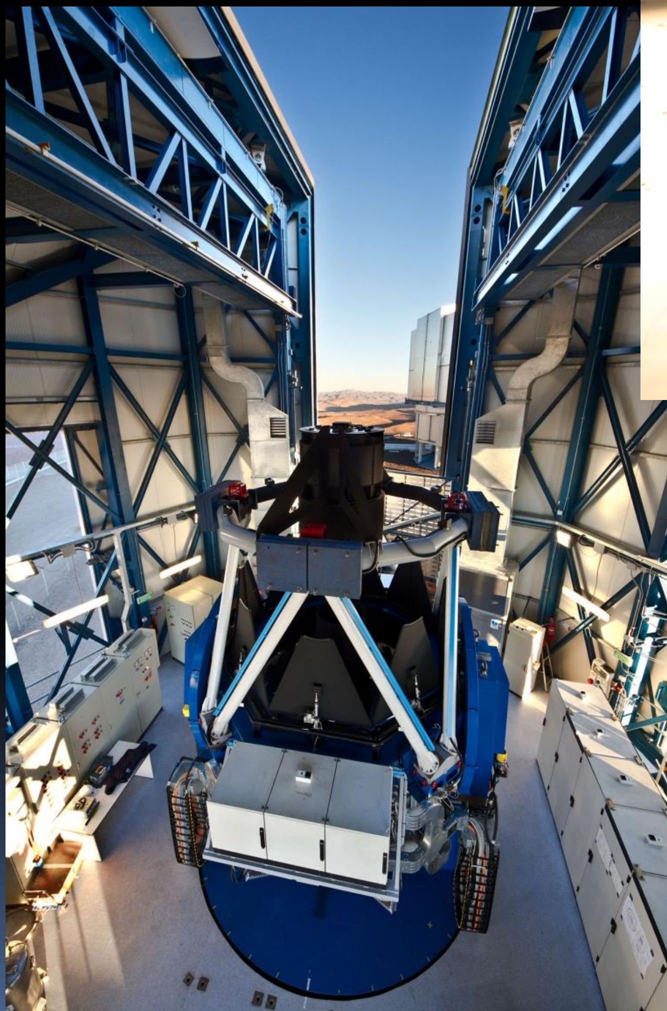
In parallel, VPHAS+ for the VST had been proposed and approved as a merger of VPHAS (Hα, r, i) and UVEX-S (u, g, r)

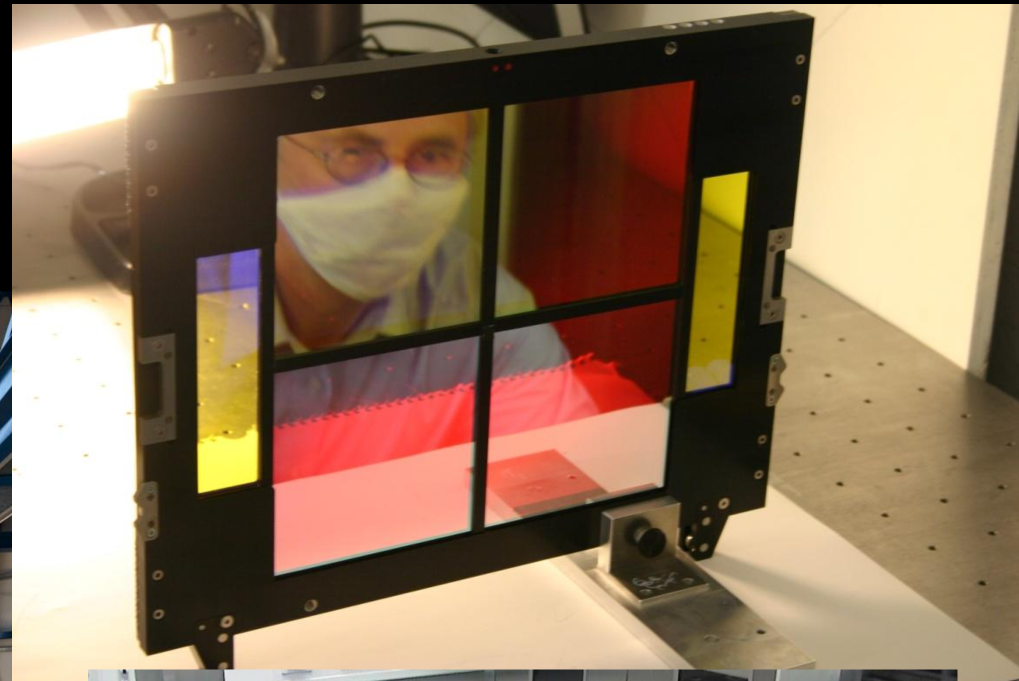
- Contemporaneous u,g,r,i and Hα across the southern GP
- 'Double-pass' strategy again
- Order placed for narrowband Hα filter for VST

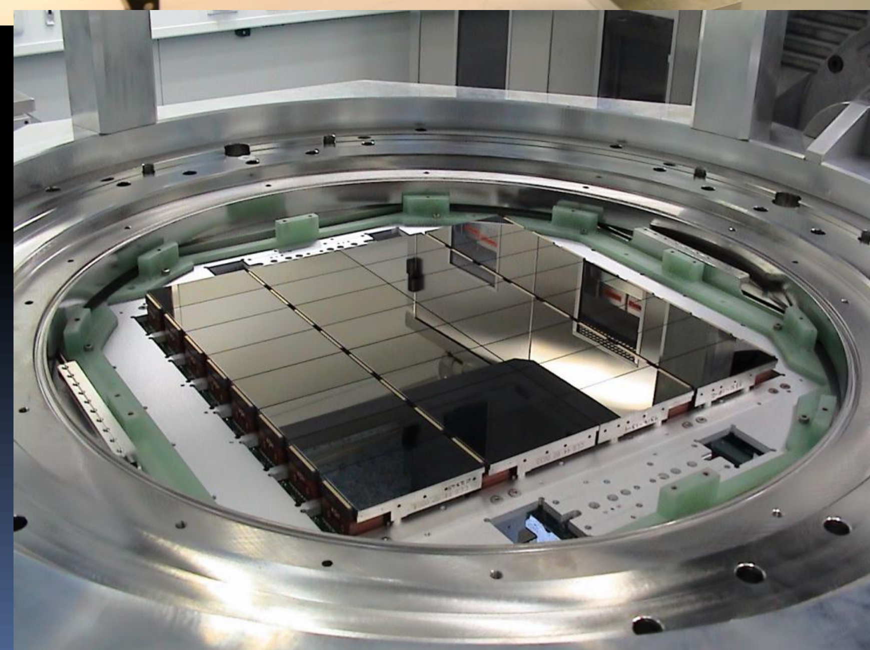
2009 Filter delivered and tested
2010 Bulge added to VPHAS+ footprint

VPHAS+ underway by beginning 2012

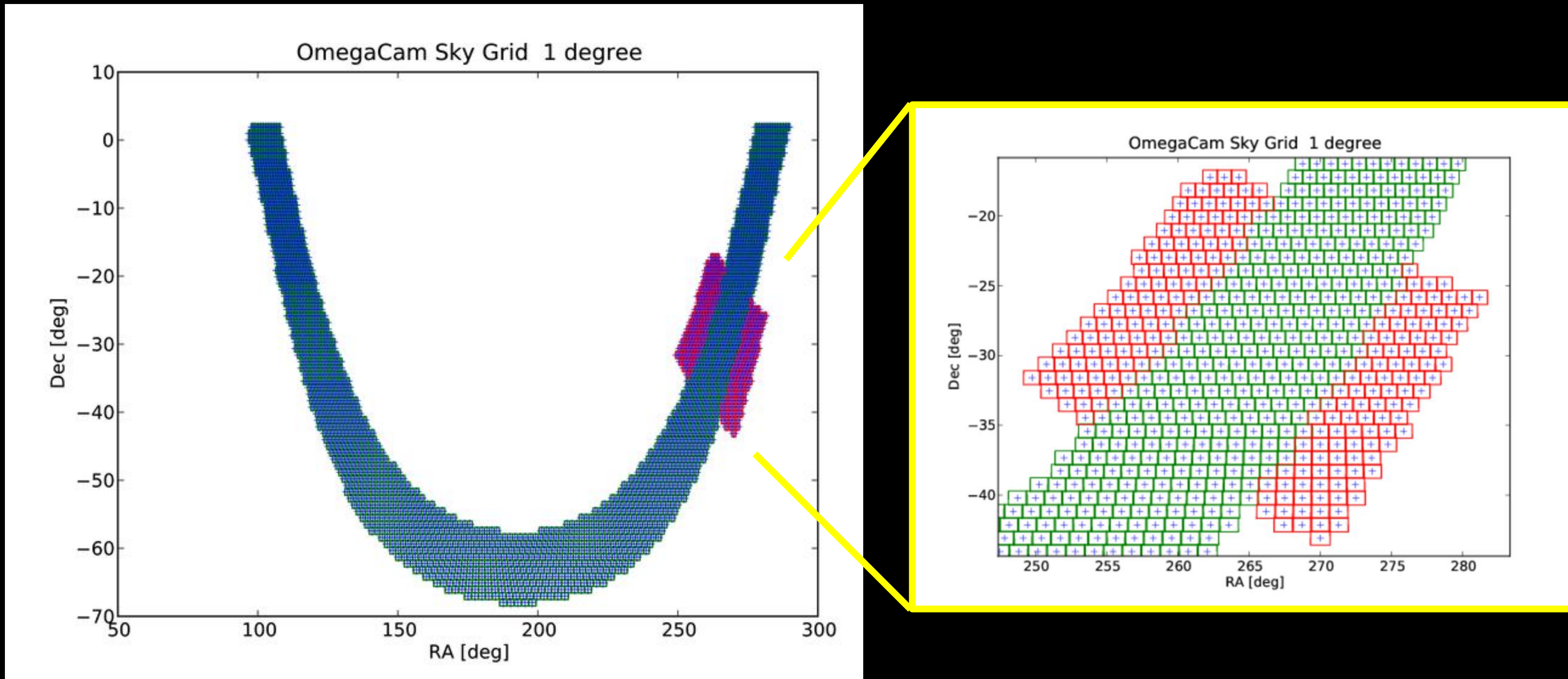
And now at Paranal: VST







VST Photometric Halpha Survey (www.vphas.eu)



* 1800 sq.deg, |b| < 5°, plus small overlap at celestial equator, ~2000 fields

- And also 200 sq.deg to cover Galactic Bulge, ~220 fields

* VPHAS+ began in survey mode 2011/12 New Year

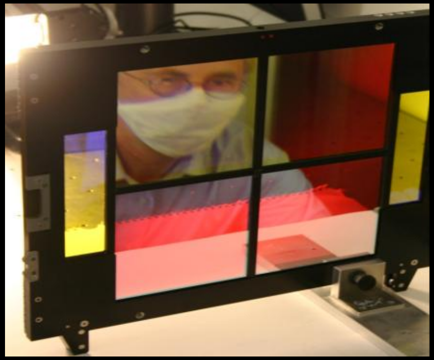
...split into u/g/r and Ha/r/i concatenations for operational reasons

Hα Filter

* Segmented

* λ ~ 6588 ± 8 Å

* FWHM ~ 102 ± 2 Å



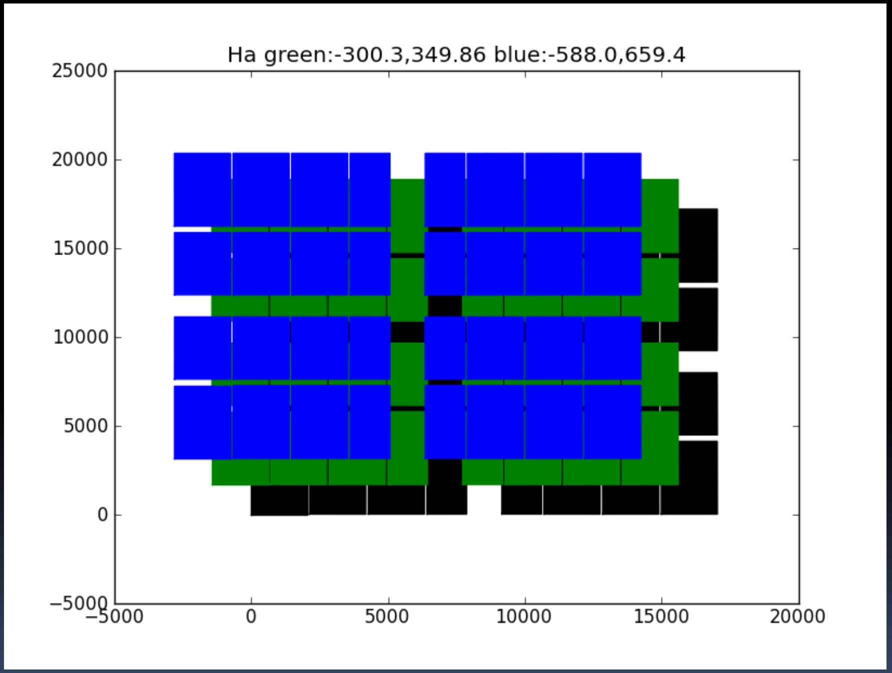
Exposure times (secs)

Hα, r, i   concatenations

3 fields x (3x120, 2x25, 2x25)

u, g, r   concantenations

3 fields x (2x150, 2x30, 2x25)



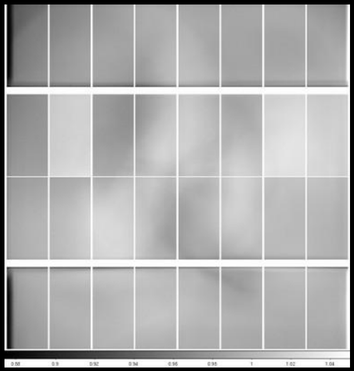
10σ Limiting magnitudes

* ~20 mag for a single exposure

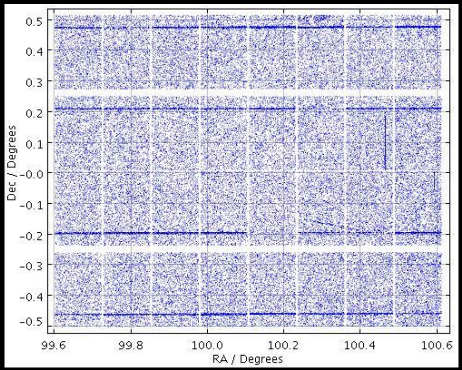
....NO GUIDING – AT ALL....

New telescope – new problems being solved

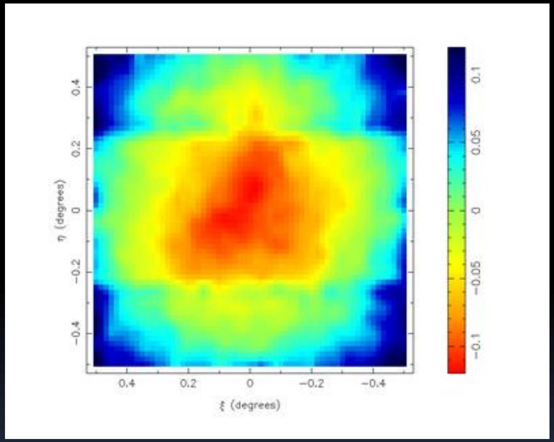
- CCD gain variation
- pickup noise
- illumination correction
- stray light
- **...... and it varies!**



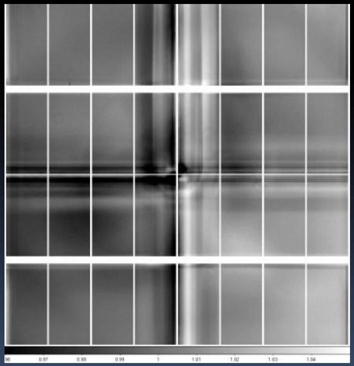
Source: CASU, i flat ratio



i source distribution



Source: CASU, r scattered light



Source: CASU, Ha flat ratio

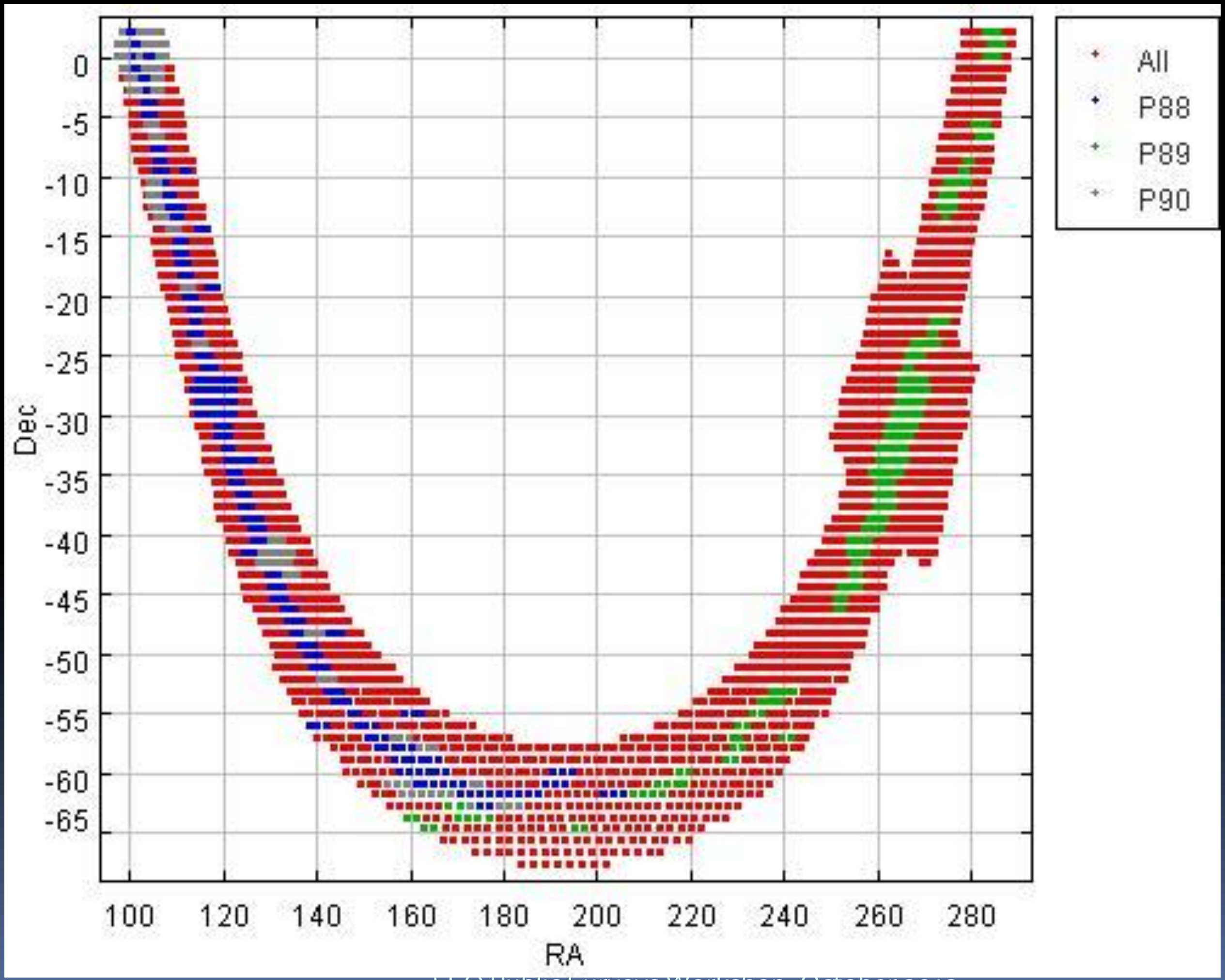
For science with image data, stray light remains as the significant issue (~10-20% variations present)

VPHAS P88 and P89 Phase 2 submitted fields:

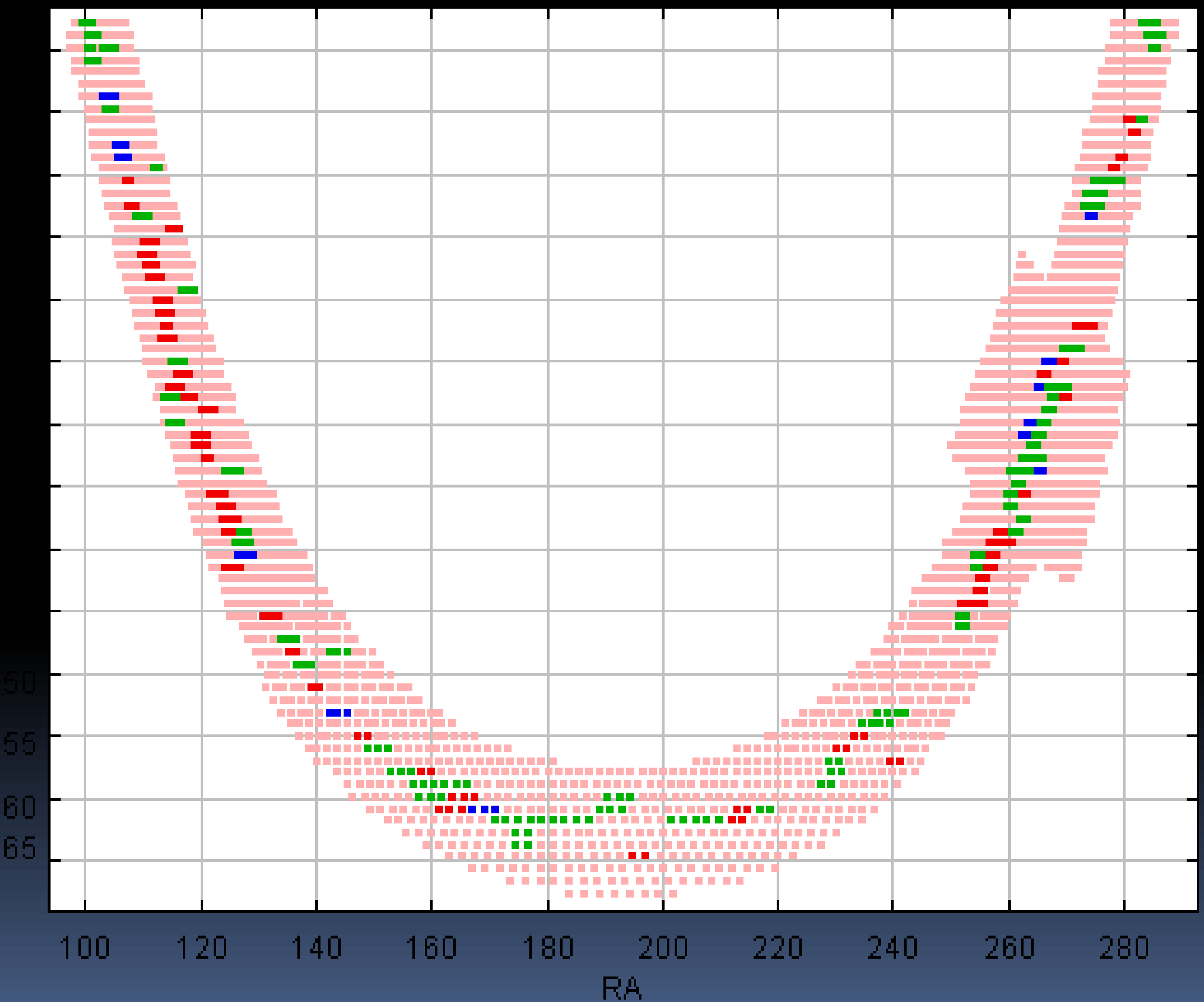
P88, 140 hrs allocated – 248 fields submitted

P89, 145 hrs allocated – 194 fields submitted (increased overheads)

P90, 64 hrs allocated – 114 fields submitted (adding to carry-over)



VPHAS+ Status at the end of August 2012

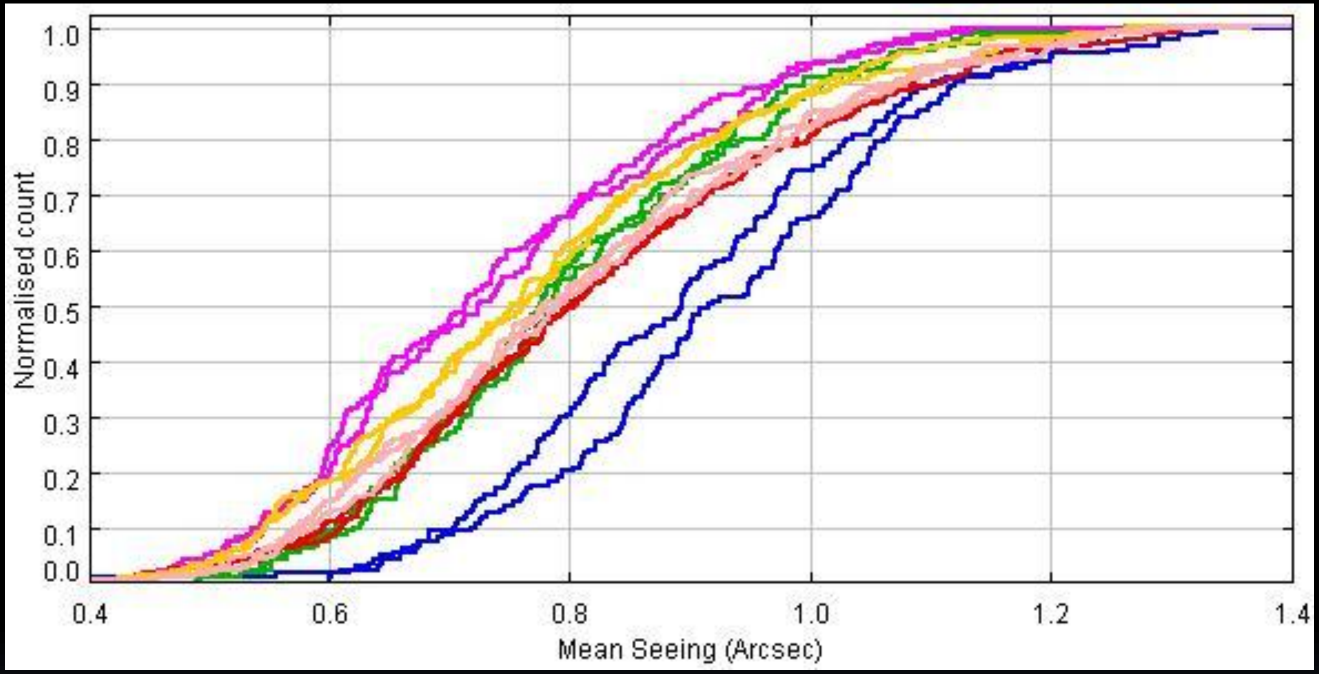


Hα/r/i (red):
307 fields

u/g/r (blue):
204 fields

All filters (green):
172 fields

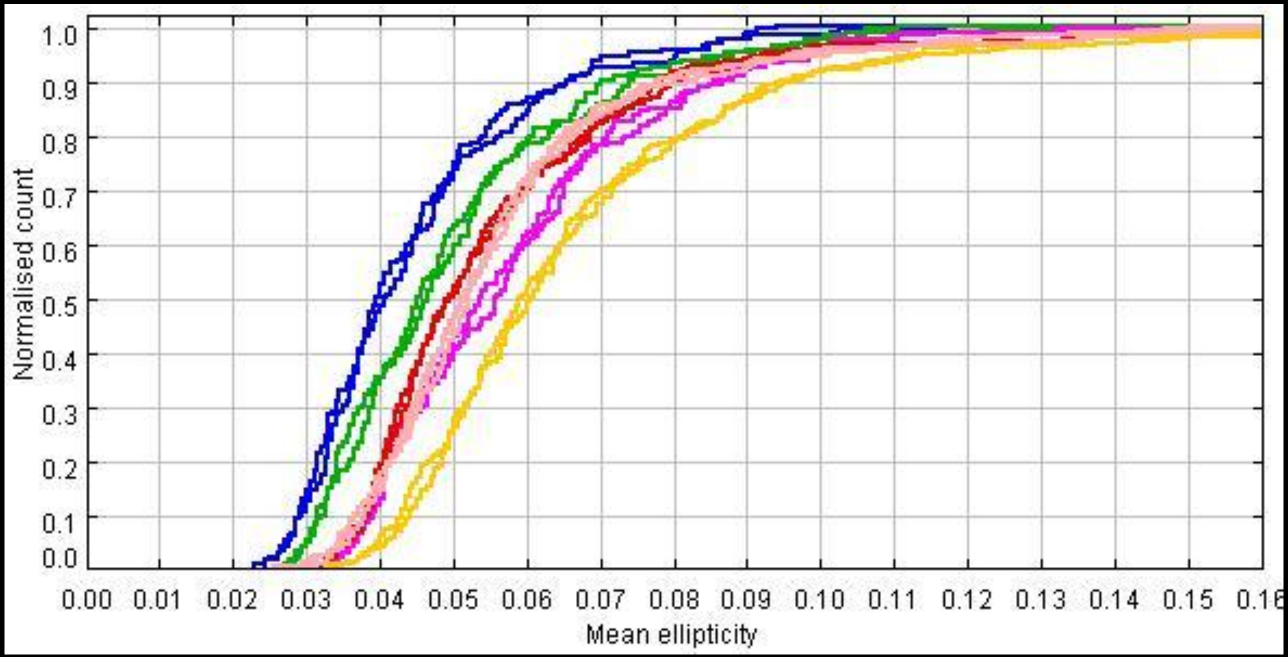
(Running well below time allocation:
cf. request of 442 fields in P88 and P89)



Mean seeing data (A,B graded concatenations)

u: blue
g: green
r : mauve (blue concat)
r: red (red concat)
i: deep yellow
Ha: pink

Constraints set:
1.2 arcsec mainly, except for some 'dense' fields where it is
0.9 (red concats),
1.0 (blue concats)



Ellipticity data (A/B graded data)

Colour scheme as previous slide

Generally better than 0.1
-- even without guide

Using unguided exposures has significantly improved efficiency – and the tracking is good enough to permit this.
(Even for dense fields, where VST operations requested guide to be taken off – as autoguider becomes unreliable)

Note:

At this point in the talk, Dr. Henry Joy McCracken interrupted from the floor – apparently to assert that the evidence of good ellipticity might be bogus and that guiding was clearly necessary to prevent e.g. small jumps in pointing that would create double images (with little ellipticity).

It transpired that this comment was based on his personal experience with UltraVISTA on VISTA (different survey, different telescope)

This unfortunately interfered with the essential important point here that for most of the time VST is tracking well without guiding. Yes, glitches will occur occasionally and will have to be identified and offending data replaced. HOWEVER – it is clearly important that, in the general run, overhead on survey data-taking is squeezed out as much as possible.

Happily, not guiding now appears viable as a survey strategy. If image analysis can be sped up, the level of overhead may yet fall to the level estimated in the original VPHAS+ proposal.

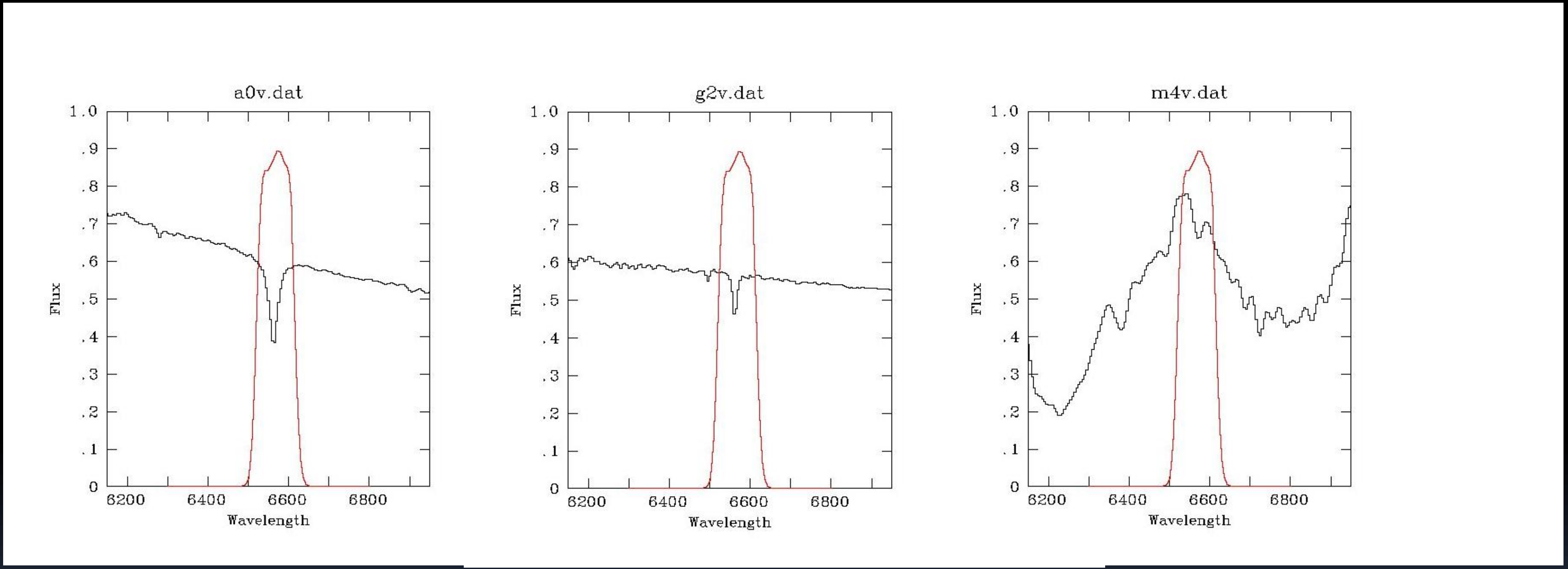
EGAPS/VPHAS+ example applications

1: narrowband Hα as a pointer to intrinsic stellar colour – to supplement OIR broad bands

The role of Hα: as a marker for stellar intrinsic colour:

r'-Hα as a colour 'excess' measured to - now routine - photometric accuracy (~0.03 mags)

→ *quantitative indicator of stellar intrinsic colour (~spectral type)*



A0V: r'-Hα = 0.00 G2V: r'-Hα = 0.23 M4V: r'-Hα = 0.89

….and for nebulae (no continuum), r'-Hα ~ 3

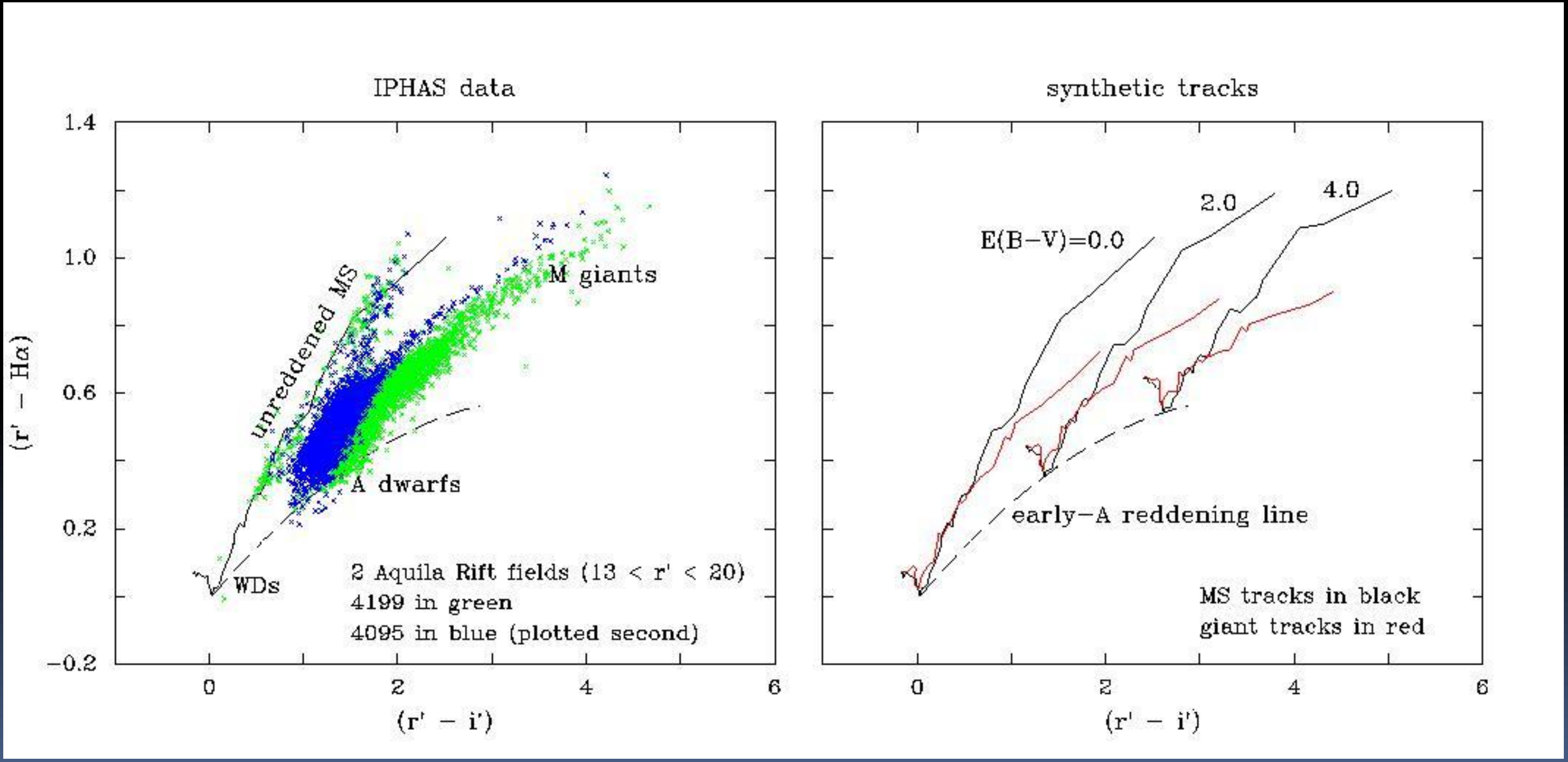
The other function of narrowband Hα photometry

r'-Hα is overwhelming sensitive to spectral type

r'-i' carries a strong reddening dependence

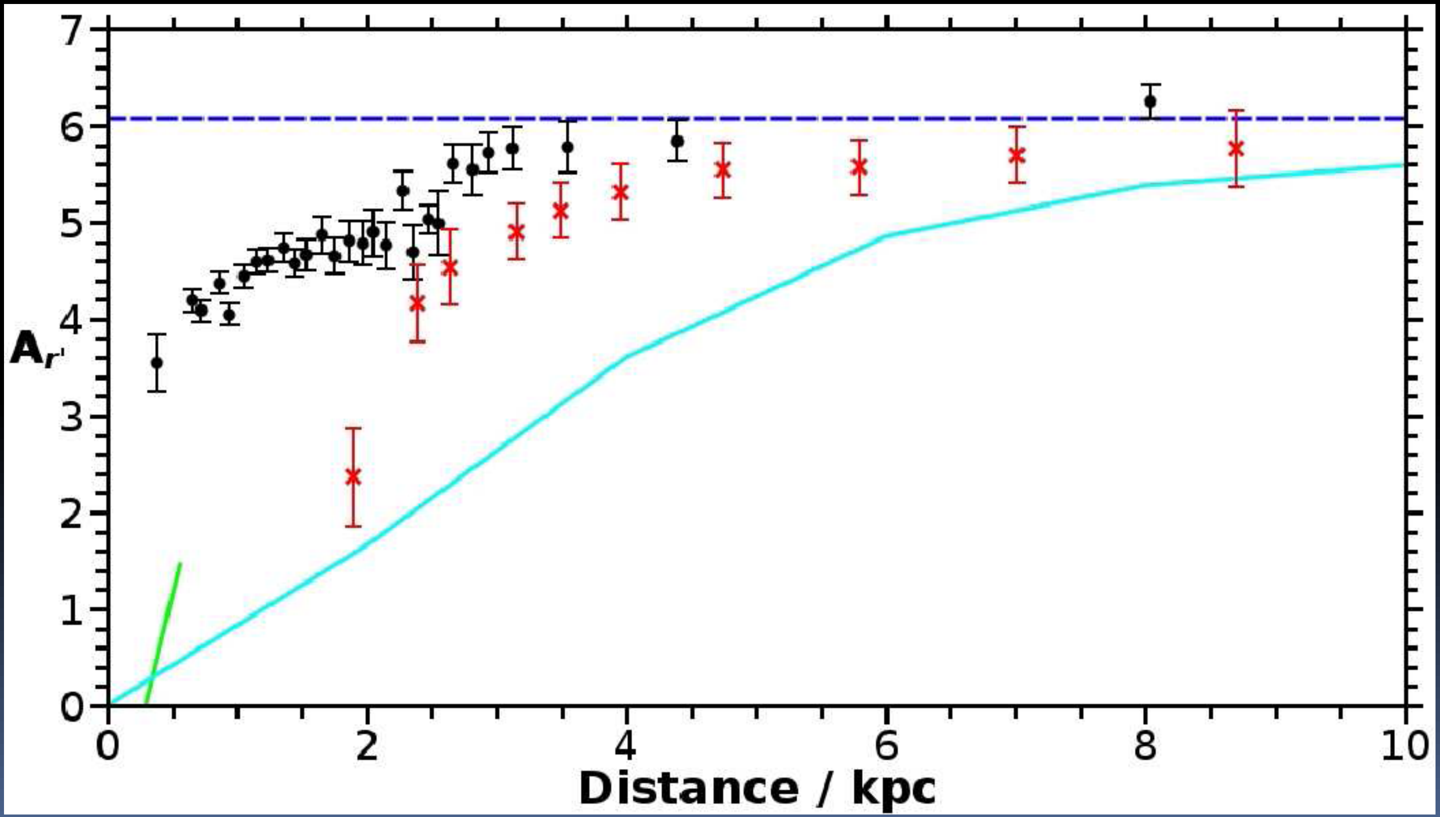
When combined: temperature sequences sweep out area as they are reddened
→ can assign (type, reddening) to each location in the colour-colour plane

→ allows dust distribution to mapped in 3D



3D extinction mapping – a worked example: line of sight into the Aquila Rift/Sagittarius Arm (Sale et al 2009)

Below …how extinction, A(r), rises with distance – deduced from IPHAS photometry (black data points) compared with earlier results



Moving the 3D extinction mapping on:

H-MEAD (Sale 2012) compared with the reddening/sp'scopic parallax of a Perseus/Outer Arm classical Be star (from Raddi et al sample, submitted)

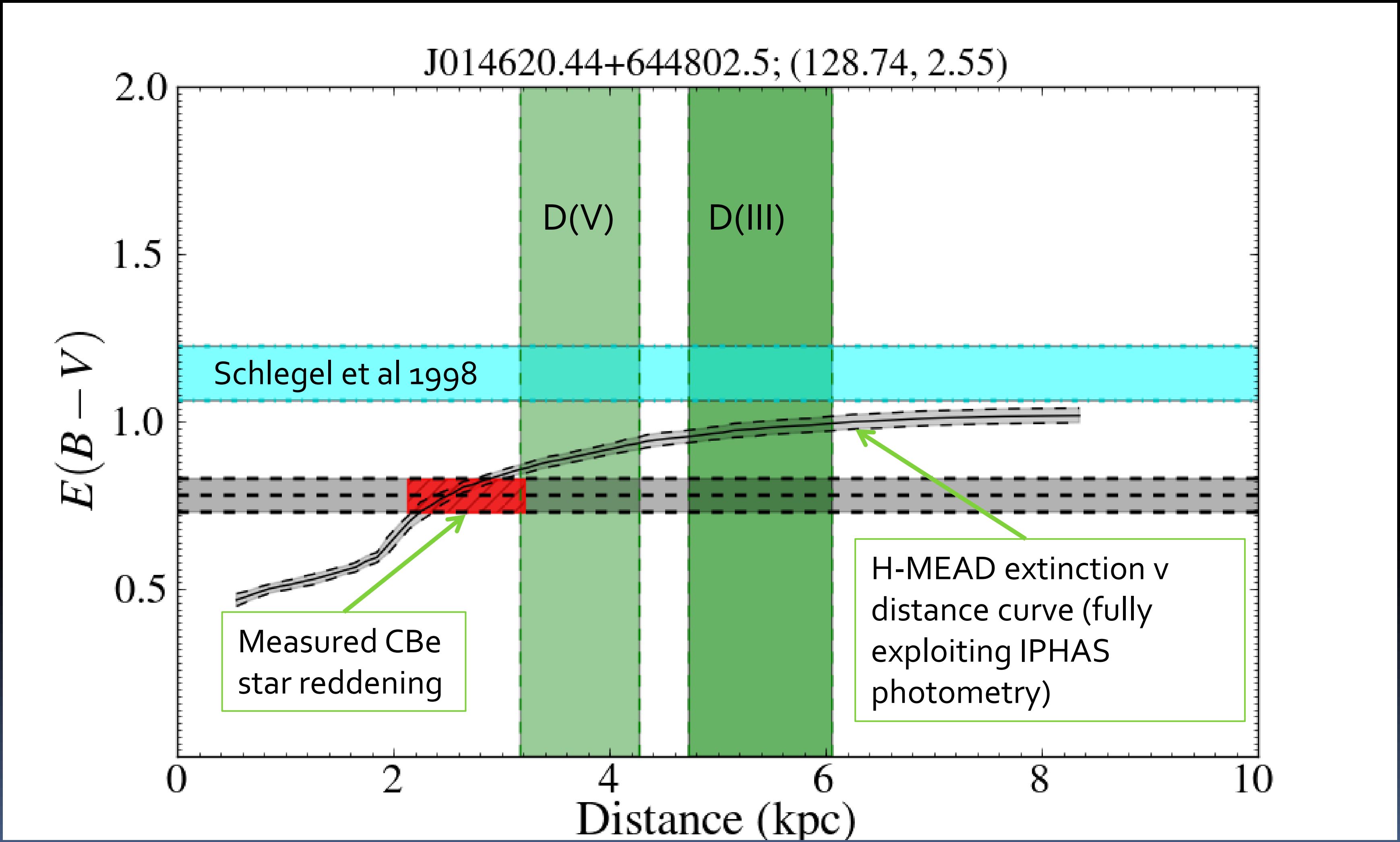
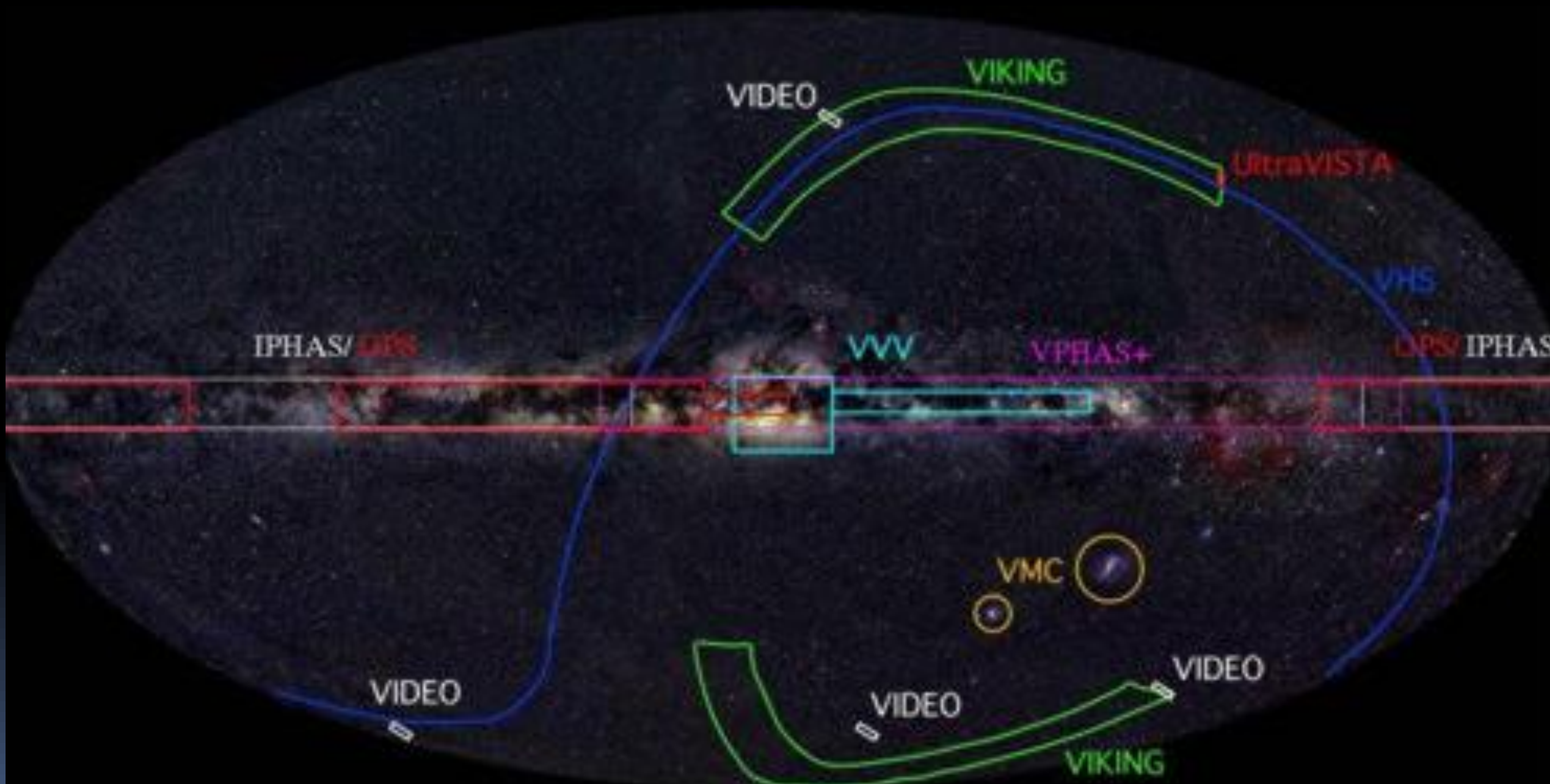


Figure: Roberto Raddi

To extinction map, and determine a few hundred million stellar reddenings to a useful precision
→ use wide wavelength grasp: from optical/blue – to NIR (JHK)

IPHAS/UVEX/VPHAS will deliver the optical with Hα, and other filters
...but deep NIR Galactic Plane surveys miss: 20 percent of N, ~40 percent S



EGAPS/VPHAS+ example applications

2: multicolour photometry of clusters in the wide field

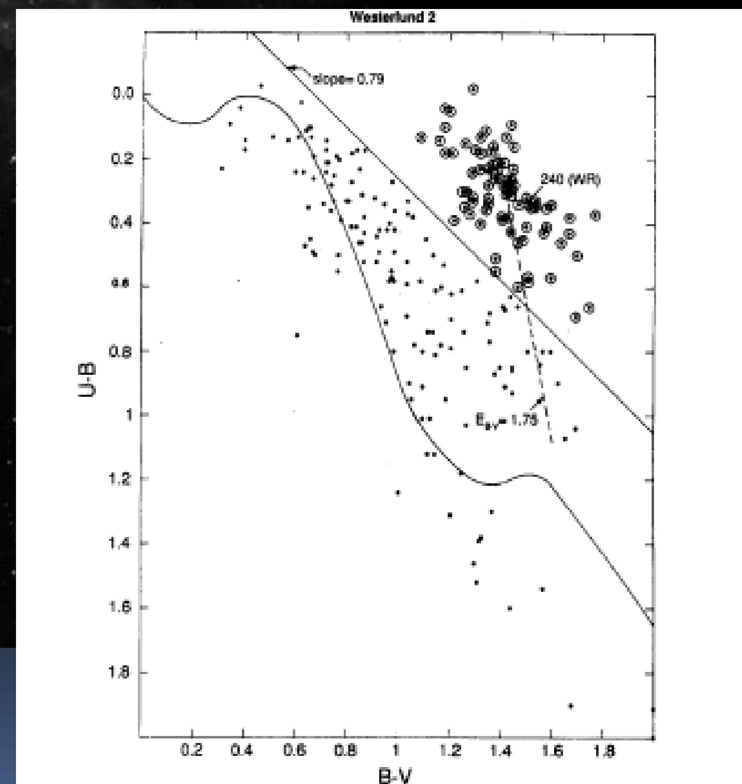
NOTES:
P88/P89 VPHAS+ pointings have prioritised GES clusters – 35 of which lie within the VPHAS+ footprint

Data exchange to support GES target selection has begun

VPHAS+ consortium cluster interest group has formed and is beginning to examine the same and other cluster data.

An example: Westerlund 2 in Carina (A_V ~ 5-6, distance 6+ kpc)

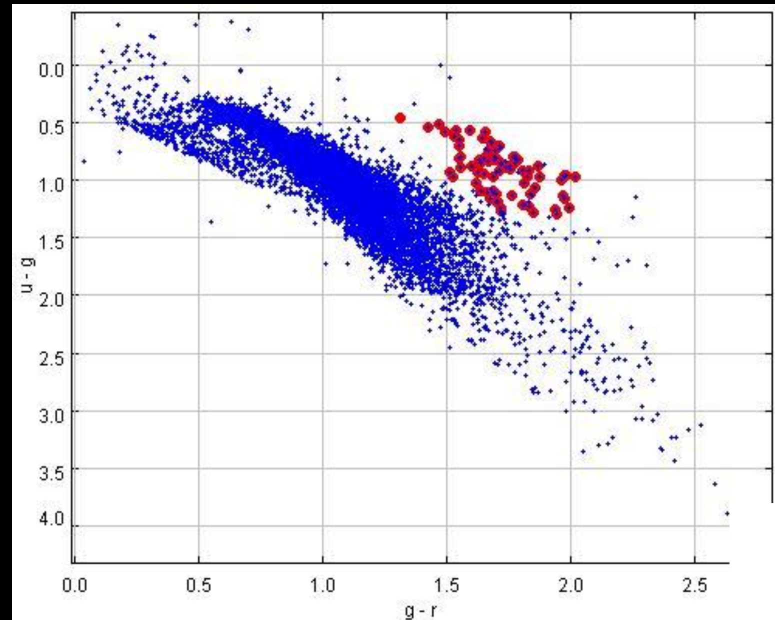
From Moffat et al 1991:
(U-B,B-V) selection of OB stars

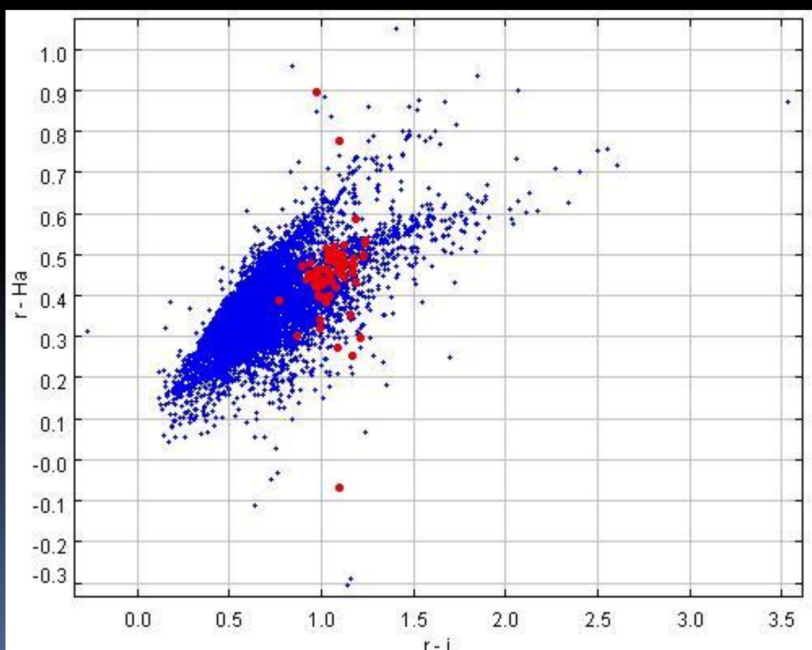


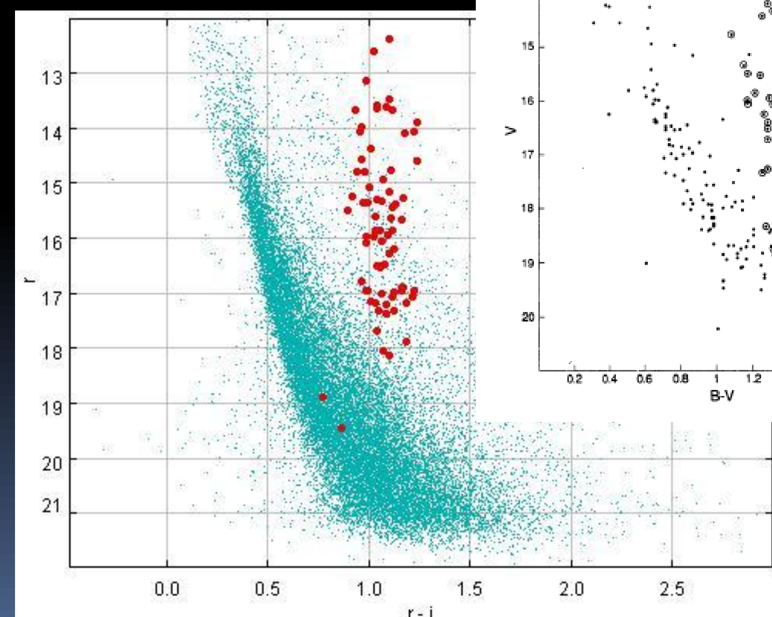
Above, in colour -- Chandra data in 8x8 arcmin2 box, in grey scale Spitzer IR data

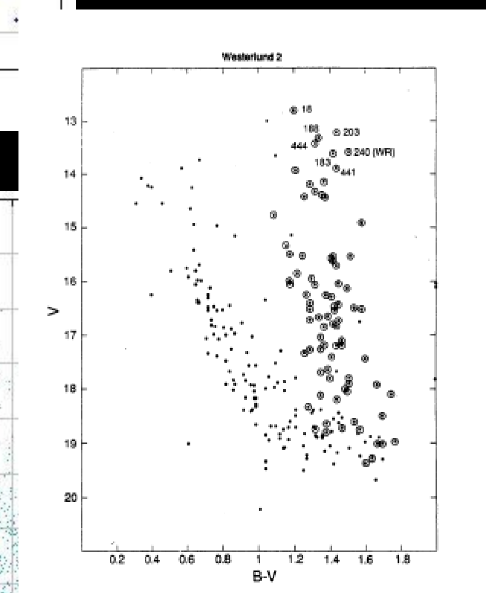
Right: make a u-g, g-r selection of candidate reddened OB stars

Below …replot selection on
r-Ha, r-i diagram (left), and on r,r-i CMD (right)

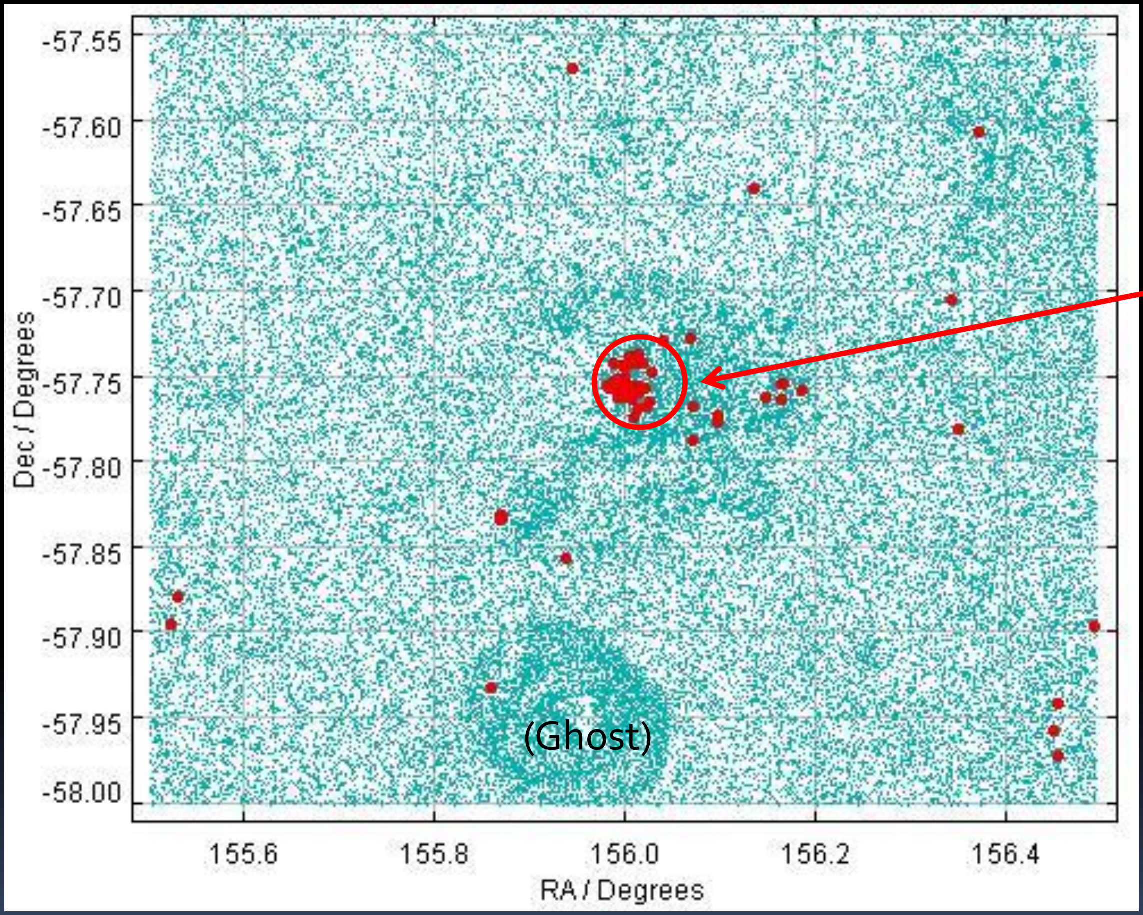








The spatial distribution of the selected sources (30x30 arcmin² cutout):



Moffat et al's cluster (roughly)

...runaways , and other interesting objects revealed → to be automated.

“One we prepared earlier” ...finishing a Galactic Plane survey (IPHAS)

Global calibration
→mapping the northern Plane in r
→ getting out an (almost) complete catalogue

→Submission for publication Dec 2012 – and CDS catalogue to go with it

work in progress at Herts by Hywel Farnhill, Janet Drew, Geert Barentsen, Brent Miszalski (now SAAO), Christine Ruhland – with Robert Greimel, U of Graz

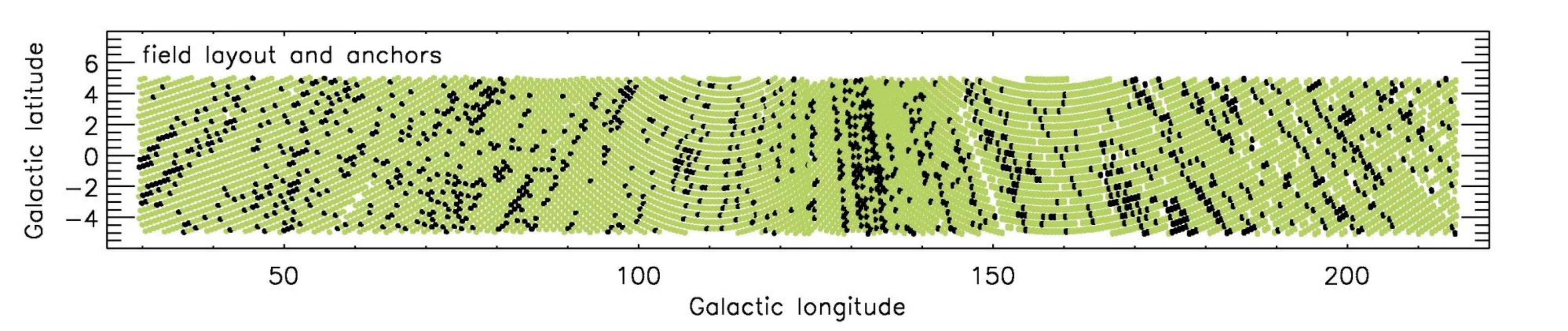
IC 1396b: r,i,Ha (N Wright/IPHAS)

Global Calibration

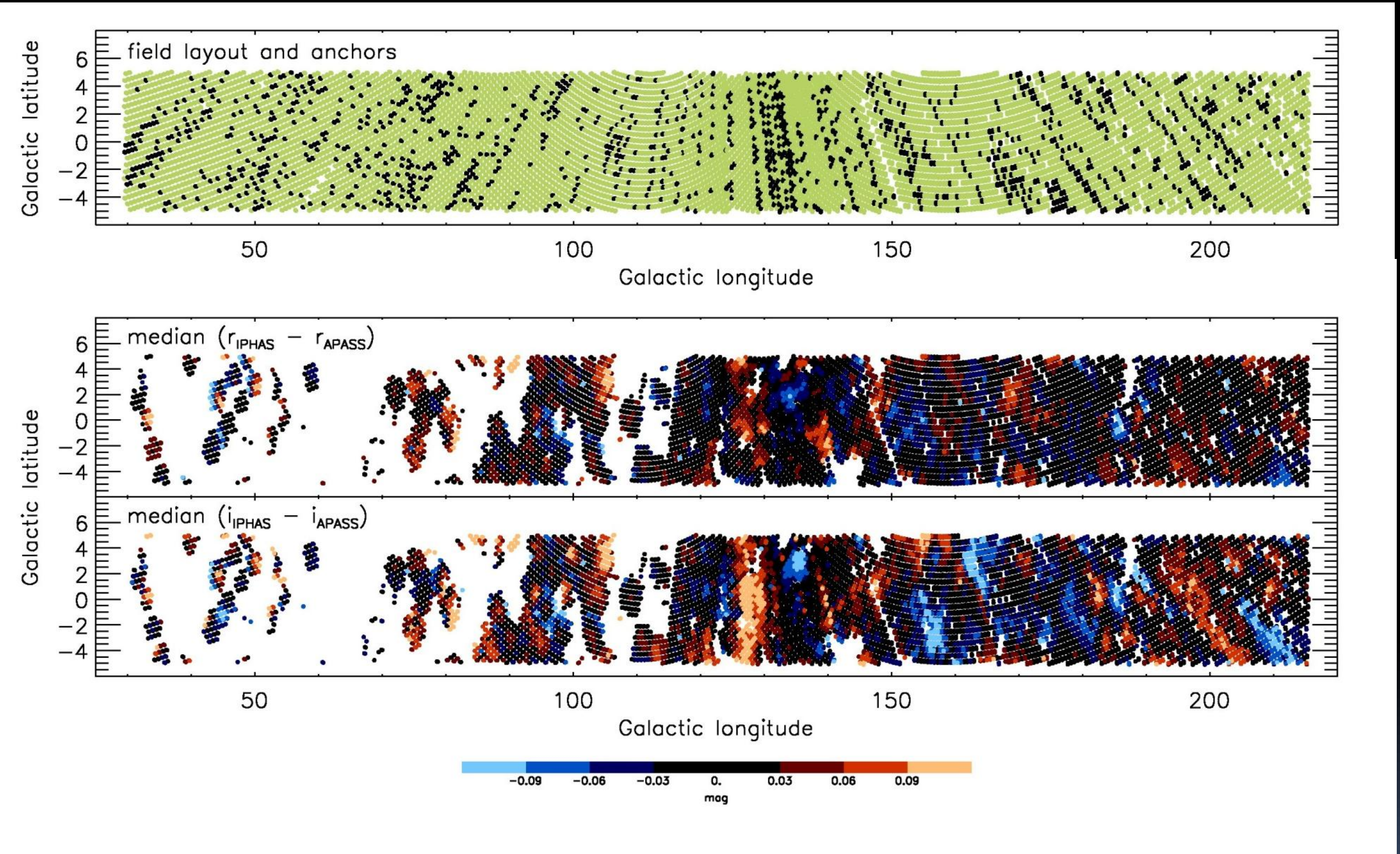
IPHAS = 15000+ images spanning 1800 sq deg, twice.   Data taken in a range of weathers – pipelined with a nightly calibration

→ Globally calibrate by
(i) Setting up a system of anchor fields obtained in photometric conditions
(ii) Solving system of 7500+ equations representing overlaps between field pairs (method of Glazebrook et al 1994)

→ Check by comparing with e.g. APASS (r and i only – no Ha options!)
scatter in r differences: σ = 0.031 (anchors only 0.029)
" " i " : σ = 0.043 (" " 0.039)



Comparison with APASS



Notes: (i) APASS incomplete in northern plane, (ii) scatter consistent with both surveys' estimated external error, and can be improved.

Stellar density mapping in r band
Counting IPHAS r point sources is non-trivial

Challenge:

- the L-shaped camera footprint and its many/various overlaps
  → sources turn up 1, 2 ...and more times

n=1　　n=2　　n=3　　n=4

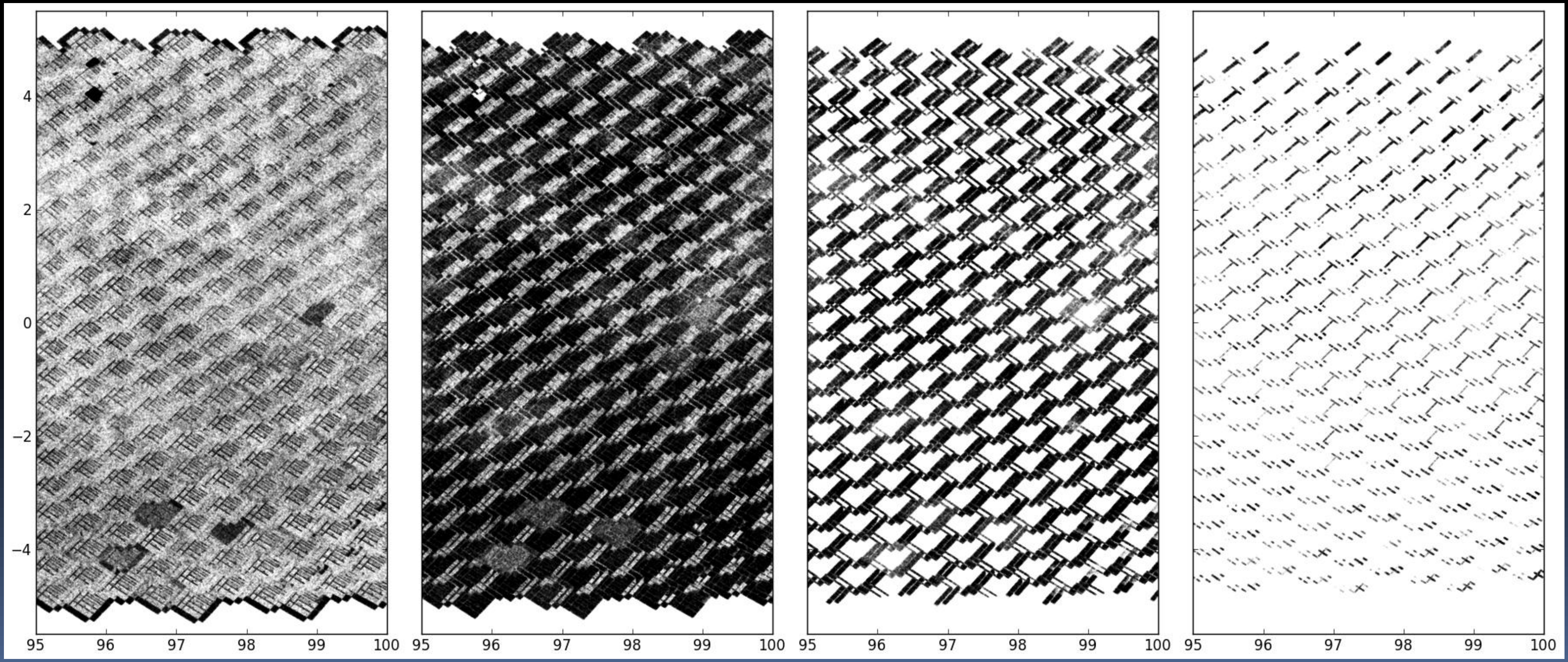


Figure: H Farnhill

By longitude – the probability that point sources are detected once, twice, thrice....

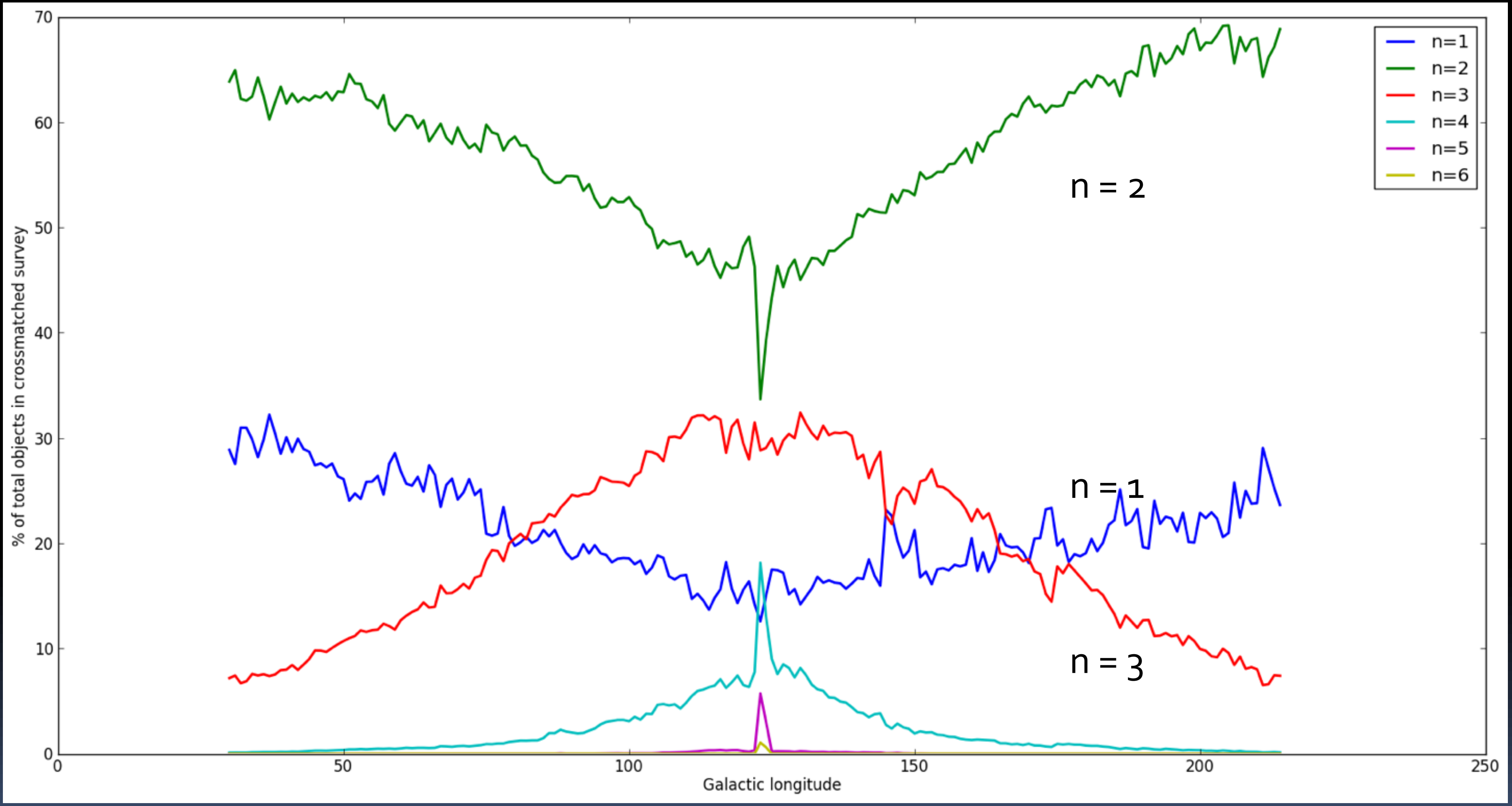
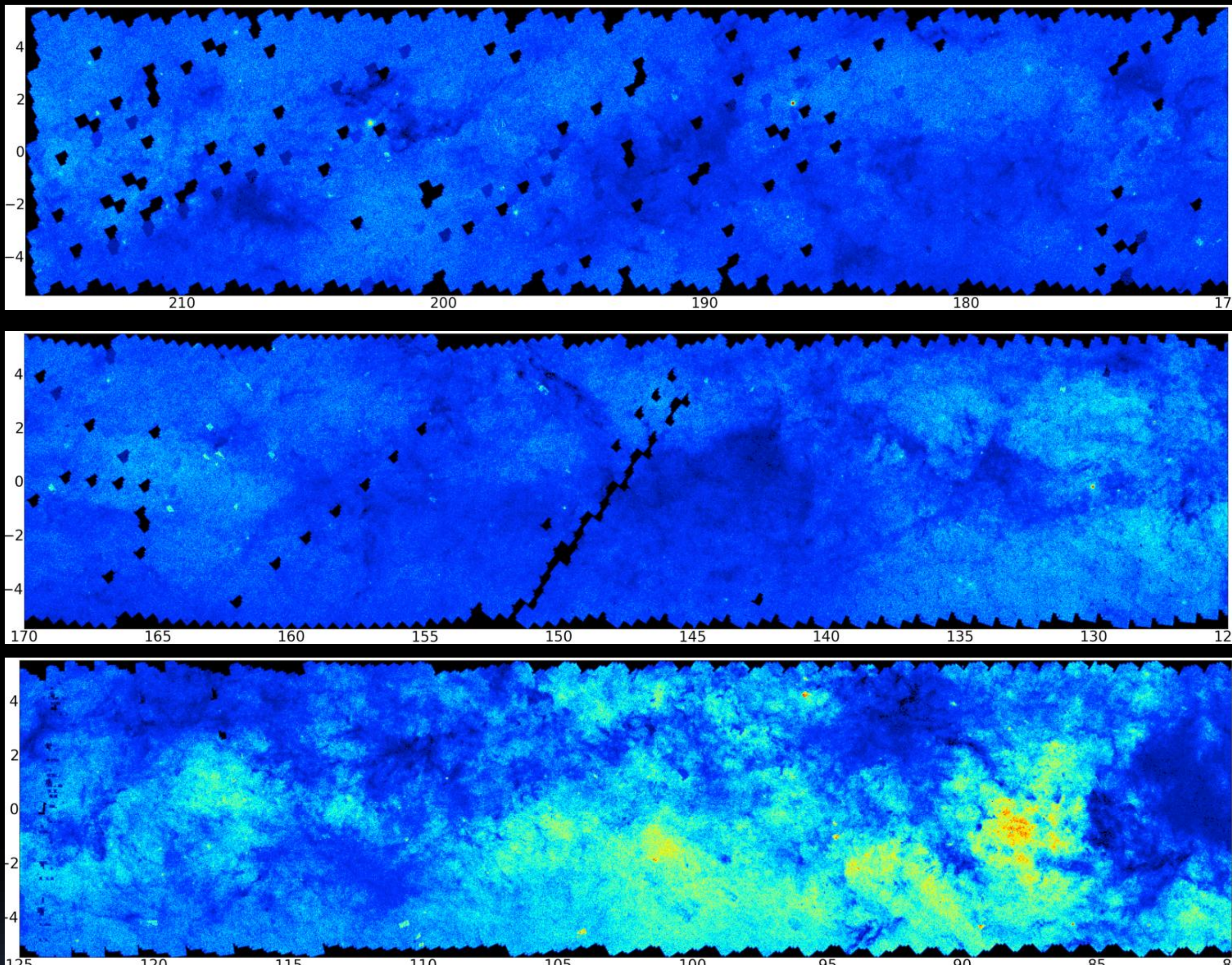
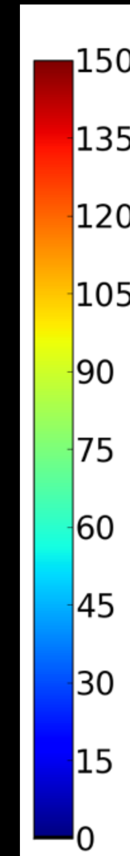


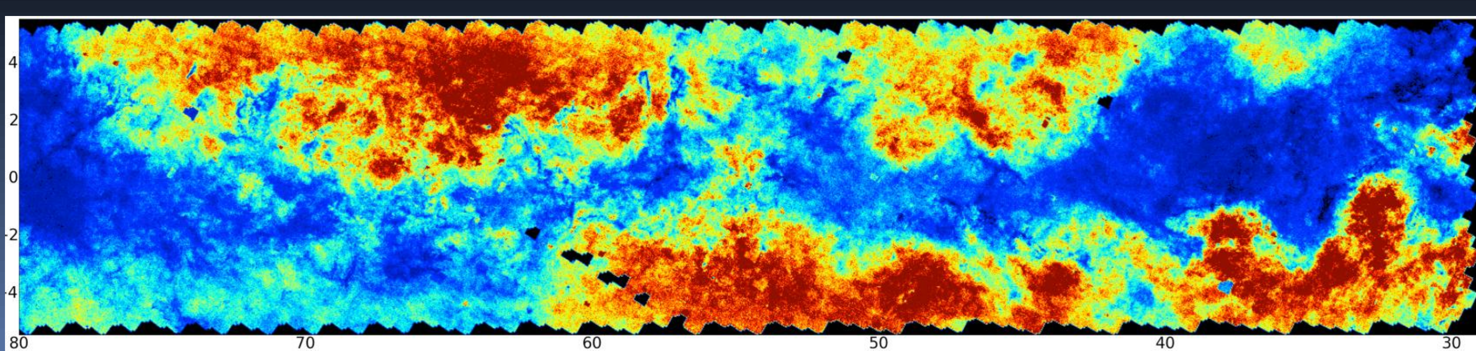
Figure: by Hywel Farnhill



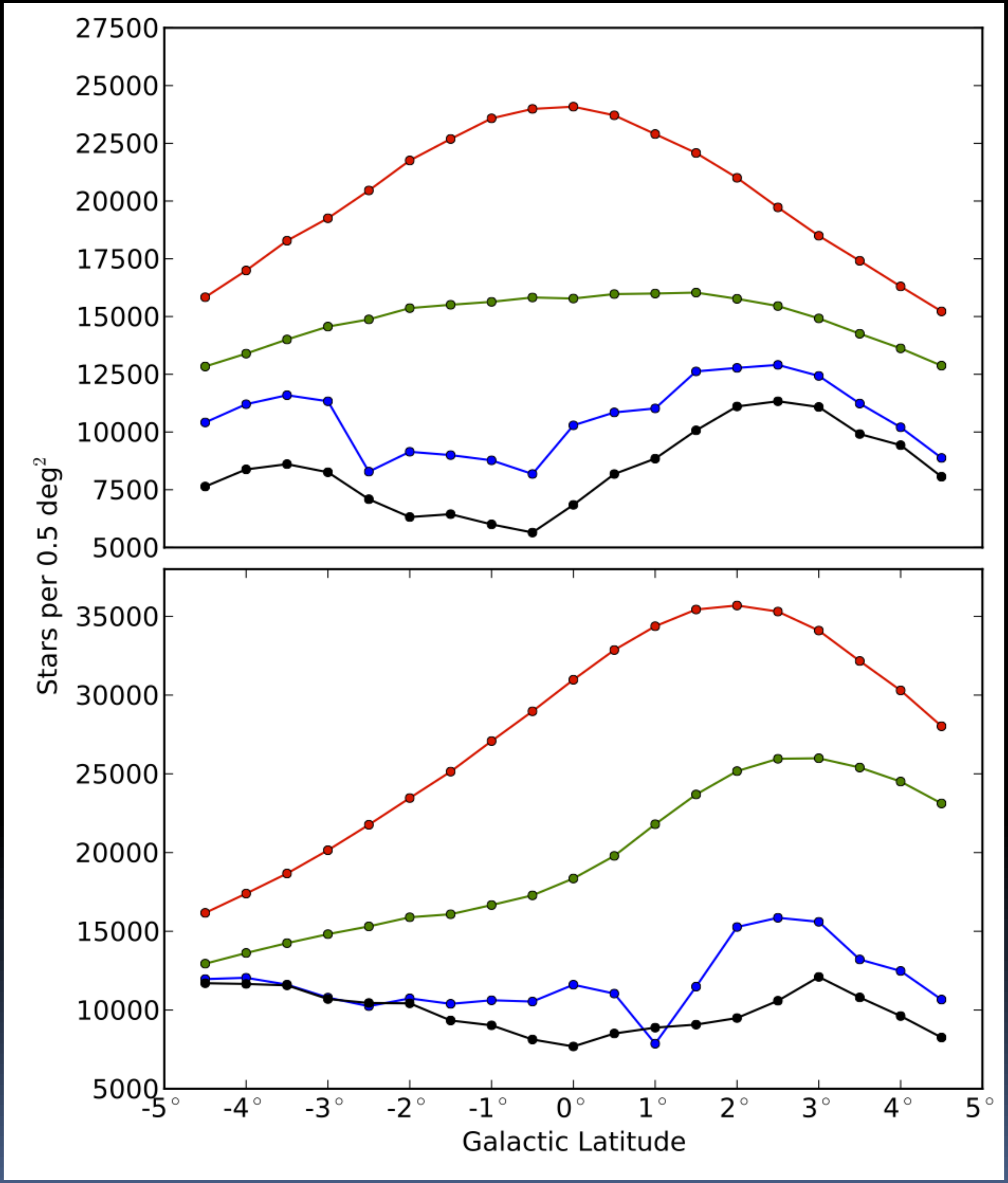


The 2D view of point source densities (r < 19) across the northern Plane …and of remaining bad data! (by H Farnhill)

(# per 2x2 arcmin^2)



Anticentre INT mop-up This November!



And finally – some science with the r –band stellar density maps:
the real disk outside the solar circle compared with the Besancon model

Top: 176 < long. < 180
Bottom: 135 < long. <140
Red – Besancon model, no extinction
Green – Besancon with default extinction model added
Blue – Besancon with all SFD98 extinction in Perseus Arm
Black – IPHAS observation

→ Place some extinction locally (i.e. ...need a good 3D model)

In conclusion – the EGAPS surveys, with VPHAS+ to complete the set:

- The first optical digital ~1 arcsec resolution surveys of the entire Galactic Plane within |b| < 5 …and inner Bulge
  - compiling u,g,r,i broadband information, enhanced by narrowband Hα, for point sources to 20th magnitude.
  - → massive update of Hα emission line stars – young and evolved – in the Milky Way disk
  - → opportunities to map the disk: notably the 3D dust distribution, and its properties
  - → will bring the wide field to bear on star-cluster studies
  - → a significant complementary resource for the Gaia revolution coming

Thank You