

# Galactic Surveys with VST and VISTA

Janet Drew

CAR/STRI, University of Hertfordshire, UK

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(IPHAS image of the Rosette:  
N. Wright UCL)

# Talk Outline

- Introductory remarks – the Sloan/2MASS revolution
- VISTA/VVV and VST/MPHAS+: goals and definition
- Insights from the northern hemisphere trailblazers: IPHAS and UKIDSS/GPS
- The photometry – spectroscopy link
- Closing remarks

## Large-area surveys: where we have come from

*Large-area astronomical surveys, from the ground (that included the Galactic Plane), prior to ~2000 were photographic*

*...mainly conducted using Schmidt telescopes giving a large image plane (e.g. UK Schmidt in Australia, Oschin Schmidt in California)*

*...only photographic plates or film big enough to serve as detectors*

Huge database built up and digitised

→ all still accessible

→...but non-linear response and small dynamic range = crude calibration

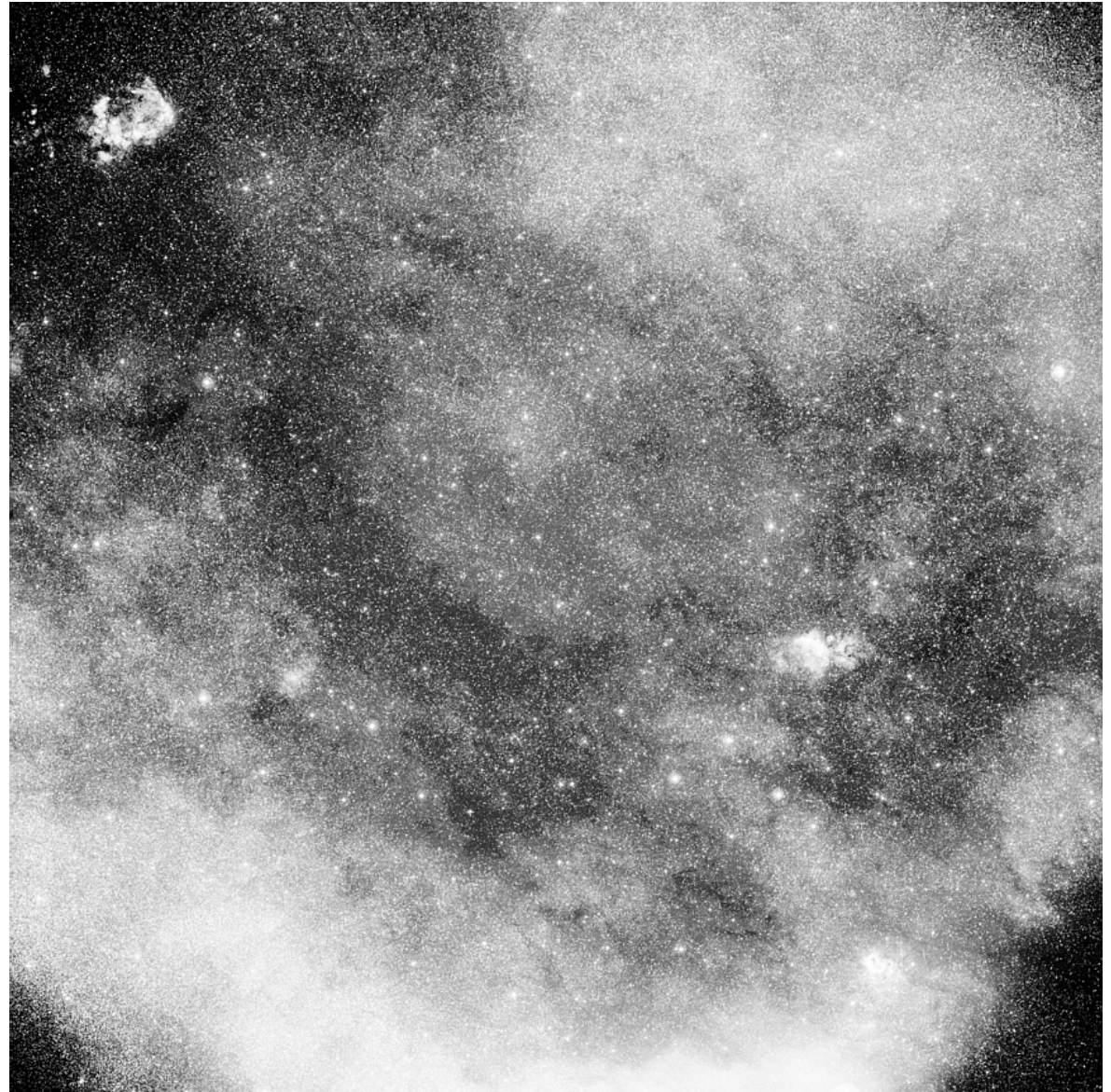
*Change stimulated by (i) availability/deployment of mosaic CCD detectors, (ii) growth in IT capabilities ...Sloan and 2MASS led the way.*

An example of a  
UK-Schmidt  
photographic  
image:

From the SHS at  
ROE, H $\alpha$  film 223  
covering a 6-  
degree diameter  
field

(still a *big* field...)

(and among the last  
to be obtained before  
photographic imaging  
abandoned ~2003)

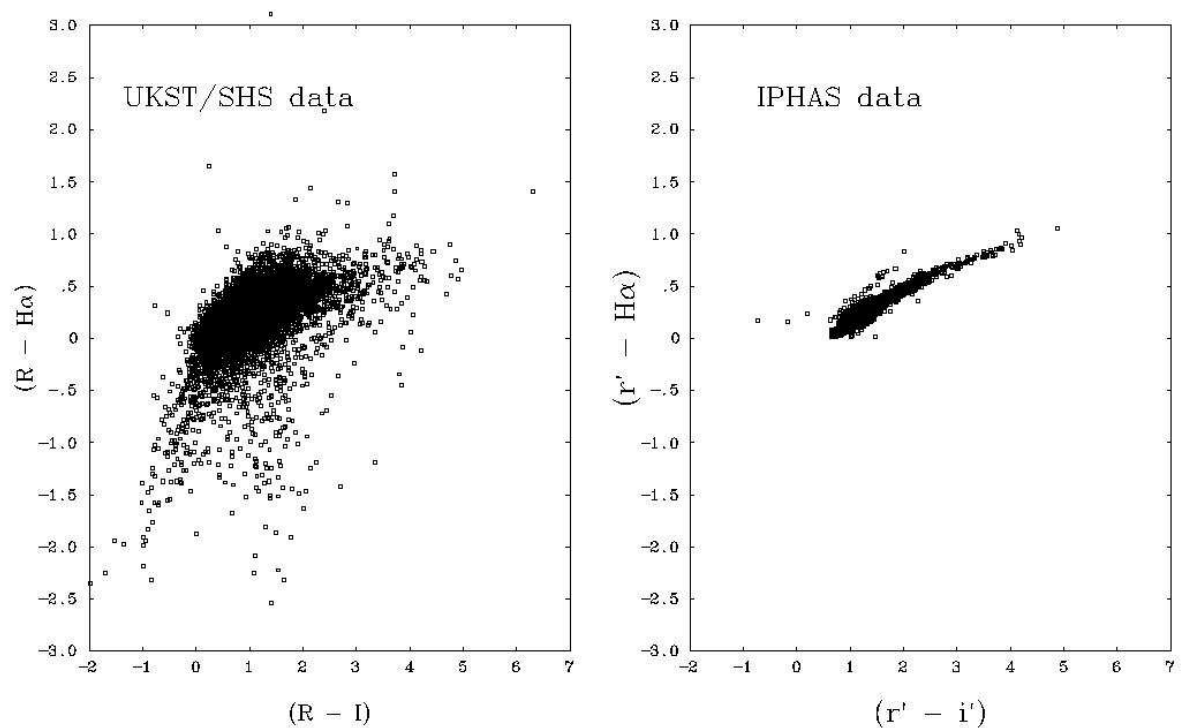


(Parker et al 2005)

# What the change to digital has meant:

Photographic and digital diagnostic colour-colour diagrams directly compared (SHS versus IPHAS for same star field)

In this example, a narrowband excess ( $r - H\alpha$ ) is plotted as a function of broadband colour ( $r' - i'$ , or  $R - I$ )



# *OIR Comprehensive Digital Galactic Plane Surveys:*

## *Optical:*

IPHAS:  $r'$ ,  $i'$ ,  $H\alpha$  across the northern Plane (all but complete)

UVEX:  $u'$ ,  $g'$ ,  $r'$  -- same area as IPHAS (underway)

VST/MPHAS+:  $u'$ ,  $g'$ ,  $r'$ ,  $i'$ ,  $H\alpha$  across the southern Plane (public survey – start in 1 year?)

## *Near Infrared:*

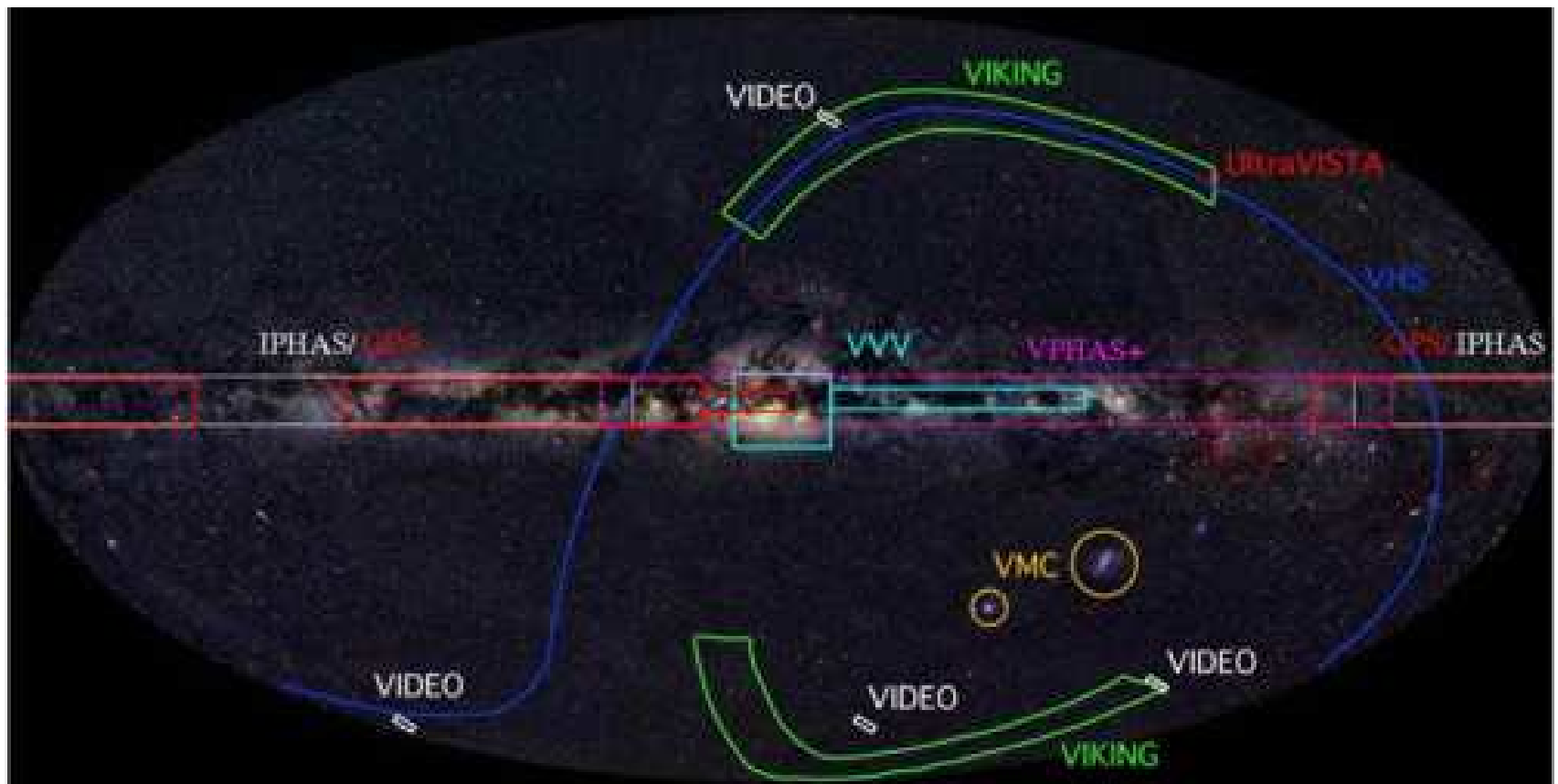
UKIDSS/GPS: J, H, K, mainly across northern Plane (underway)

VISTA /VVV: z, Y, J, H, K (public survey – about to start)

A selection of surveys – mainly to come

Shown in Galactic Coordinates, with the Plane across the middle (which IPHAS, VPHAS+, UKIDSS/GPS VVV capture)

UVEX (u/g/r) – covers the same area as IPHAS



## What are these new digital Galactic Plane surveys for?

to clarify on all possible scales (clusters → spiral arms) how the Galactic bulge and disk are organised

*(high and rapidly varying dust extinction + bright survey limits have been a major problem until now)*

- to get a head start on mapping the stars as well as the gas (CO, HI) has been already: e.g. the Galactic rotation law is so far a description of gas motions
- to provide comprehensive photometric samples of a range of special object types
- to provide an underpinning resource for the world community that will support work on Milky Way structure, star formation and stellar evolution



## Definition of VPHAS+:

*VPHAS+ = VST Photometric H $\alpha$  Survey of the Southern Galactic Plane (PI Drew)*

Telescope/instrument: VST/OmegaCam -- detector area 1 deg<sup>2</sup>, 0.21 arcsec pixels

Survey area: all southern Plane longitudes; latitude range  $-5^\circ < b < +5^\circ$  (1800+ sq deg) ...catches the warp, overlaps IPHAS/UVEX

Magnitude limit ( $10\sigma$ ): AB mag ~22 (all bands)

Exposures:

H $\alpha$  (120 s), Sloan u' (120 s), g' (30 s), r' (30 s) and i' (30 s)

at 2 overlapping pointings ( $\rightarrow$  5 x 2 x 1800+ images, ~100N)

Seeing specification: 0.8-1.2 arcsec

Photometric precision: to within ~0.03

## Definition of VVV:

*VVV = VISTA Variables in the Via Lactea (PI Minniti)*

Telescope/instrument: VISTA/WFCAM -- detector area  
1.5 deg<sup>2</sup>, 0.2 arcsec pixels

Survey area: the Galactic Bulge; plus the GLIMPSE strip  
sampling the inner Plane across to longitude 300° (520  
sq.deg)

Magnitude limits ( $10\sigma$ ): ~18 (at K) to ~22 (z)

Exposures – highly multi-epoch (>100) in K, aiming to use  
variables as standard candles

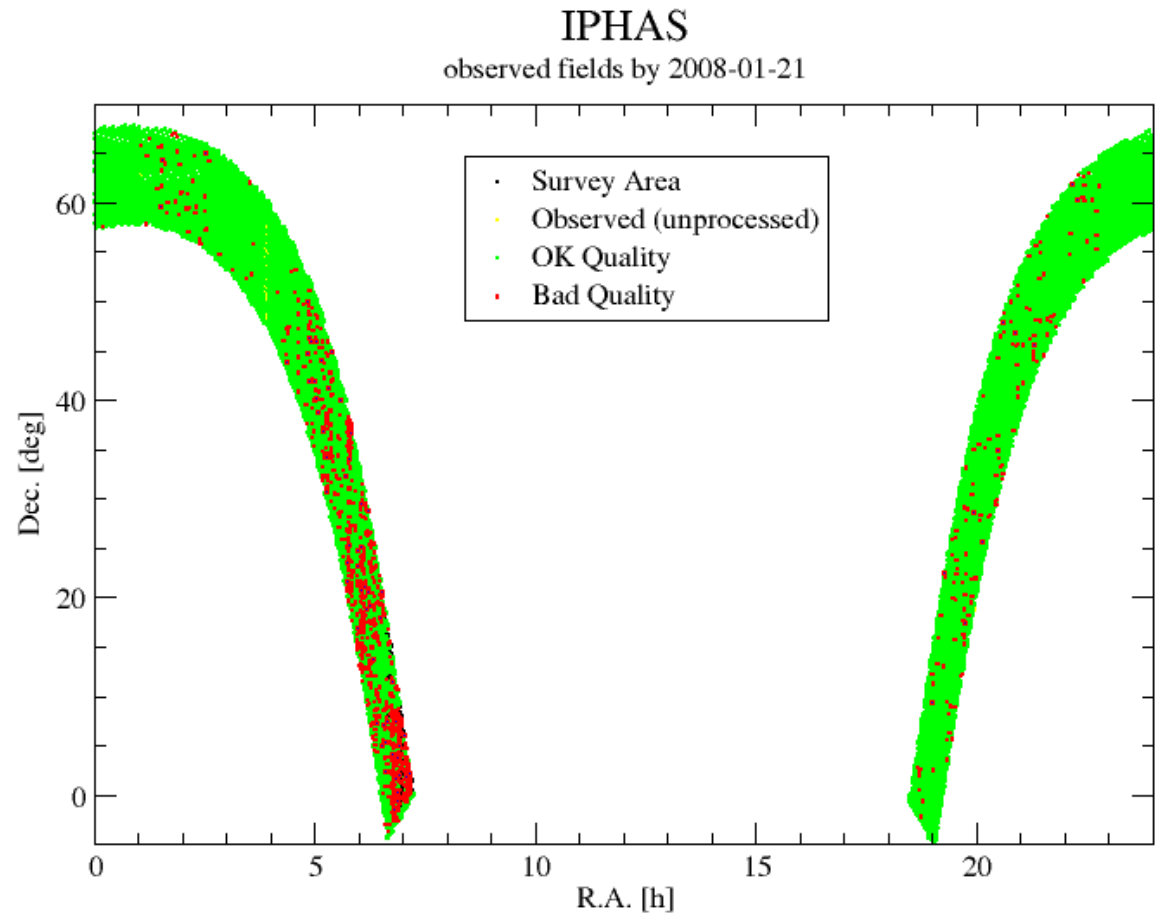
z', Y, J, H, K filter observations

Seeing: < 0.8 arcsec for initial multi-band survey season

(Absolute photometric precision – as VPHAS+)

What we can expect – and improve on (a bit)

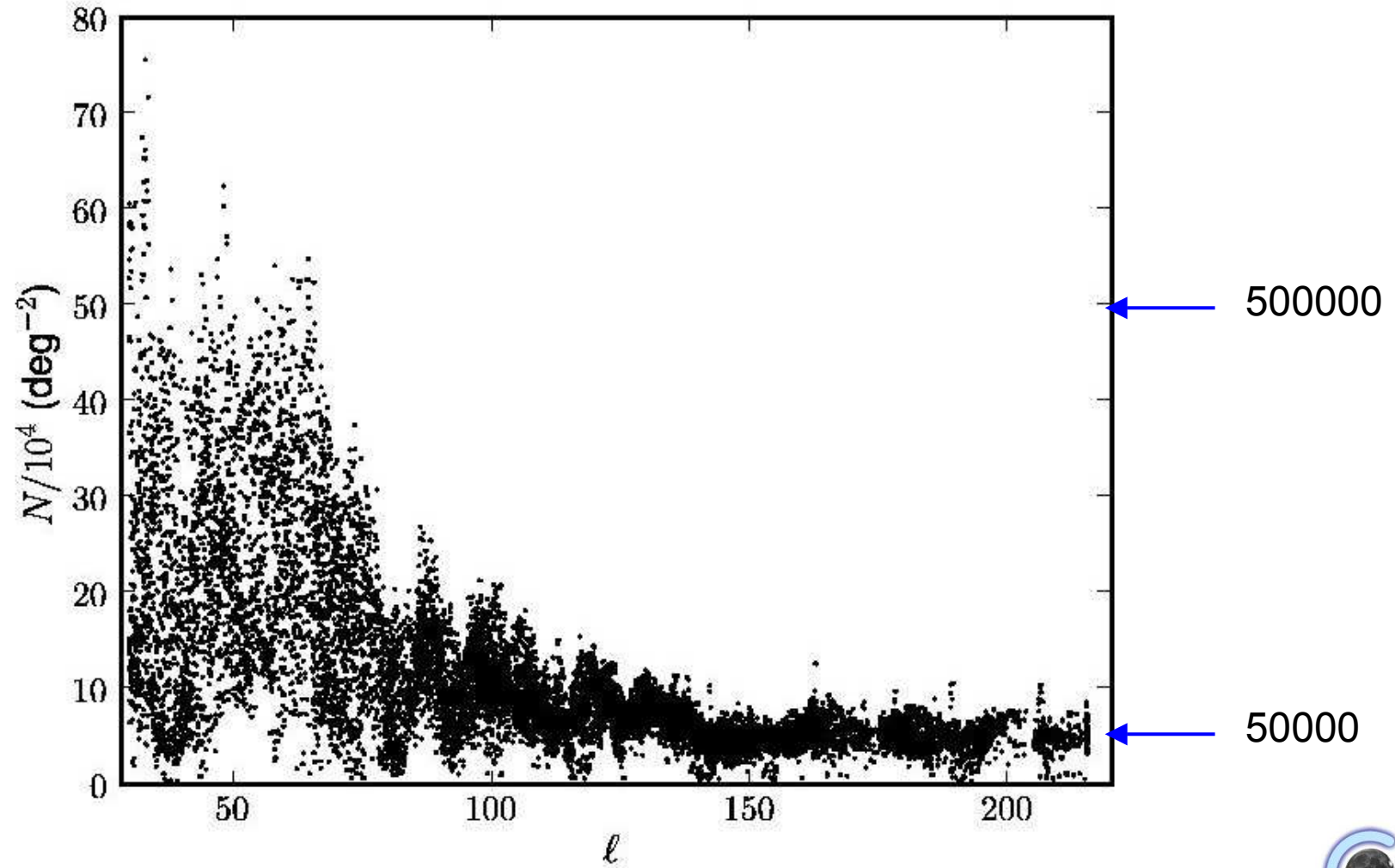
Insights from IPHAS and UKIDDS/GPS in the north:



IPHAS status end 2007: winter end of the plane (4-7 hrs) incomplete

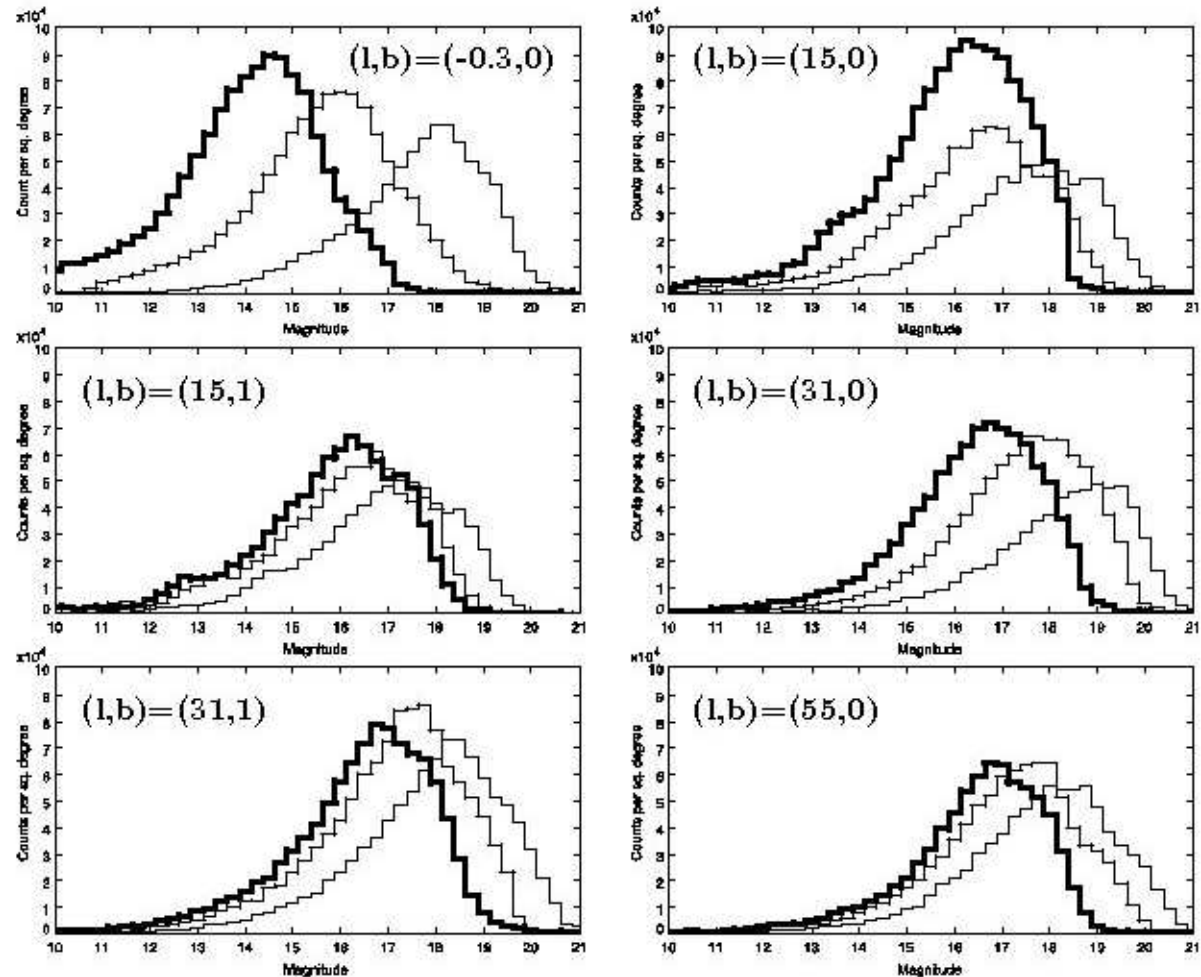
## Source densities

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



# UKIDSS/GPS catalogued object histograms:

vertical scale (0 – 100000) is object count per 0.25 magnitude bin per sq.deg; darkest line is K-band count



*GPS K-band  
object densities =  
1-5x IPHAS  
densities, where  
direct comparison  
possible*

*Figure from Lucas  
etal 2008*

# Decoding the photometry:

How new capabilities act to shift the boundary  
between photometry and spectroscopy

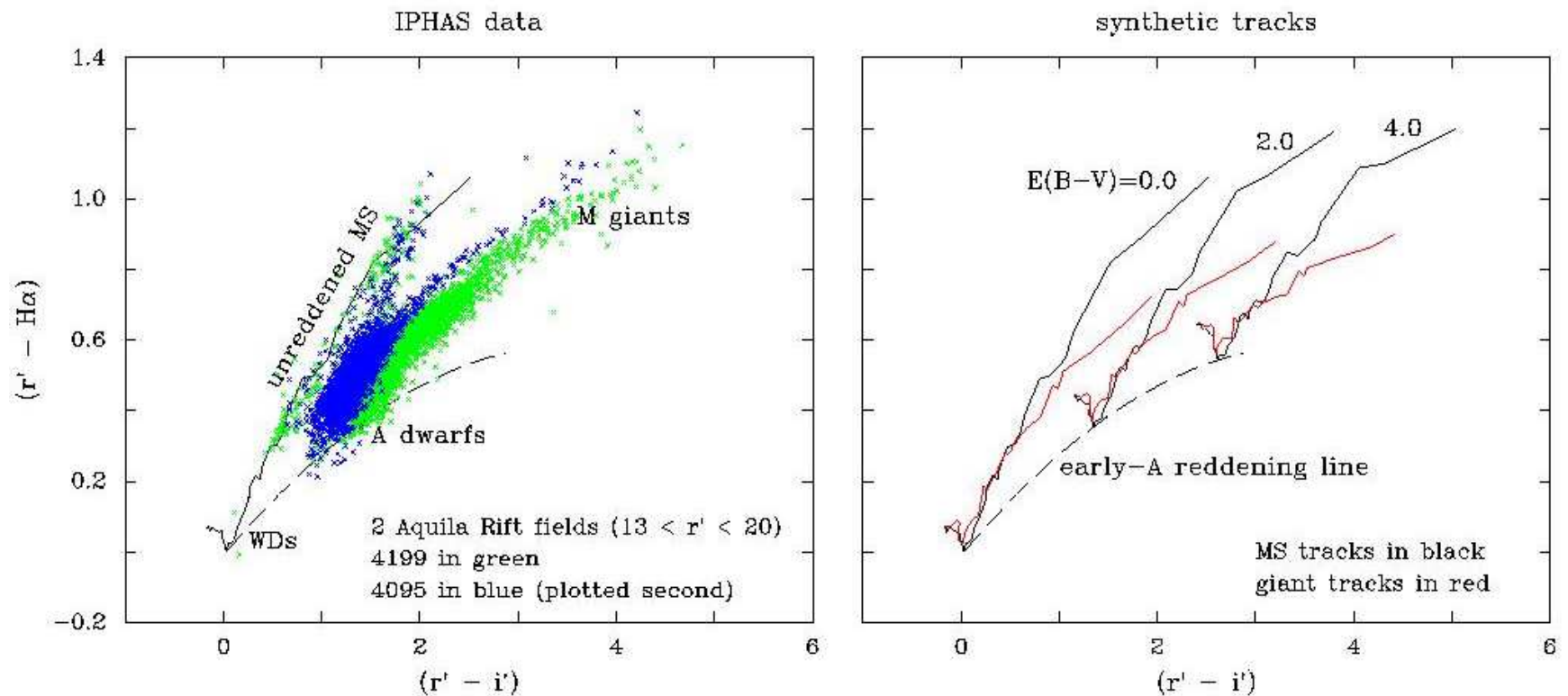
- (a) The new role for narrowband  $H\alpha$
- (b) Brief return to NIR capability

IPHAS photometry: the value of introducing the  $H\alpha$  narrowband

$r'-H\alpha$  is overwhelming sensitive to spectral type

$r'-i'$  carries a strong reddening dependence

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



## Easily separated object classes

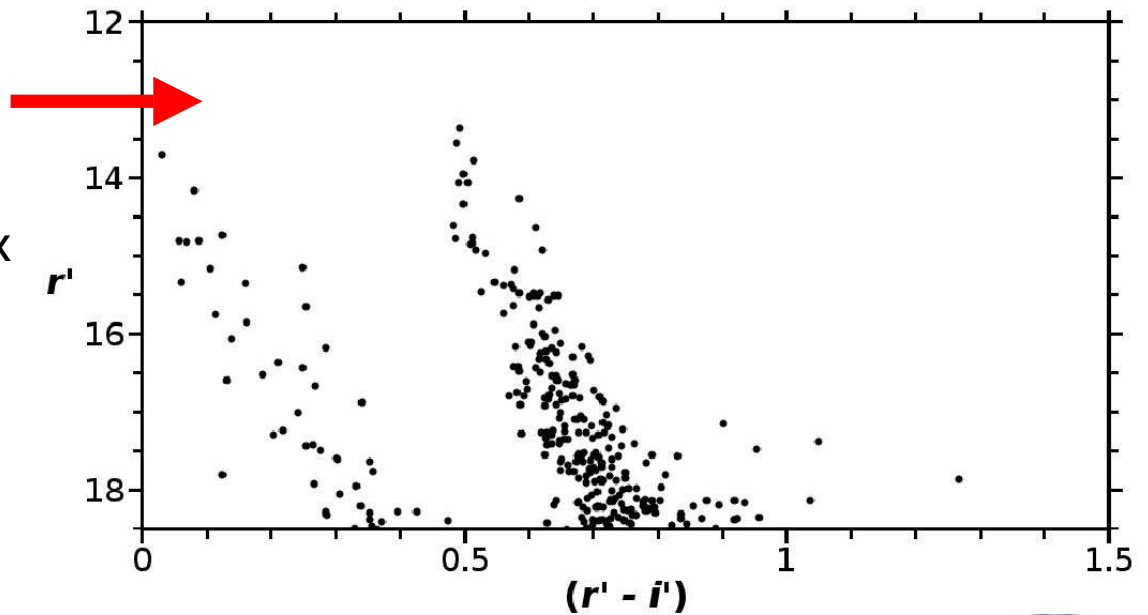
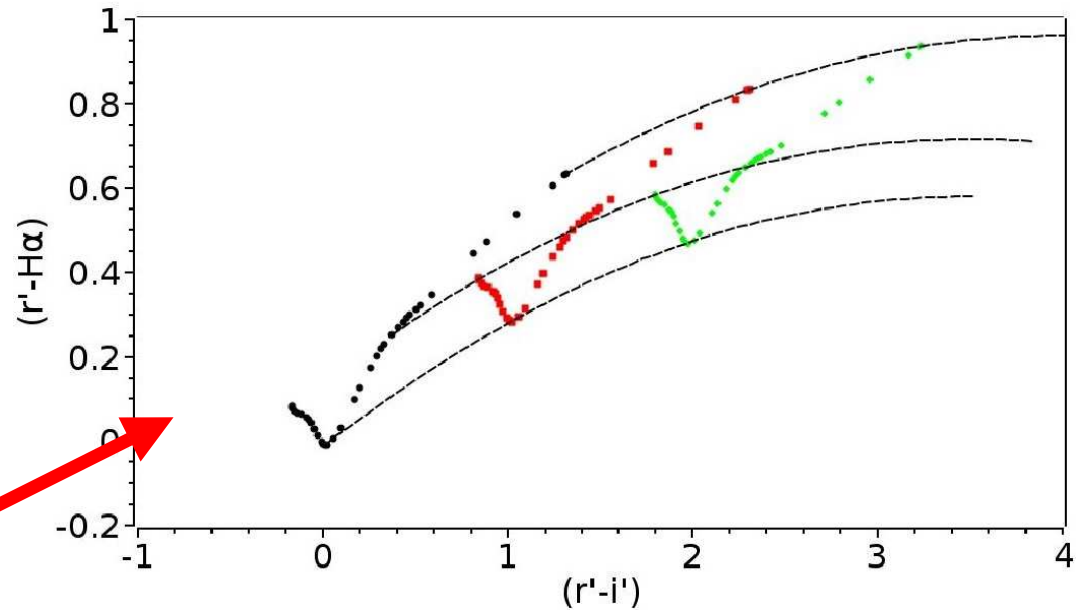
- Emission line stars/compact nebulae above main stellar locus in the colour-colour plane:
  - Classical Be stars, visible to many kpc
  - (Generally clustered) fainter YSOs
  - PNe and symbiotic nebulae (at  $r'-H\alpha > 2.5$ )
  - Evolved stellar exotica ...often interacting binaries
- M dwarfs as extension of ~unreddened main sequence
- M giants angle off reddened main sequences to  $r'-i' \sim 6$
- (C, S stars below the main M-giant sequence)
- White dwarfs – blue objects, often with strong  $H\alpha$  absorption
- A dwarfs, tracing lower edge of main stellar locus – visible to  $R_G \sim 20$  kpc



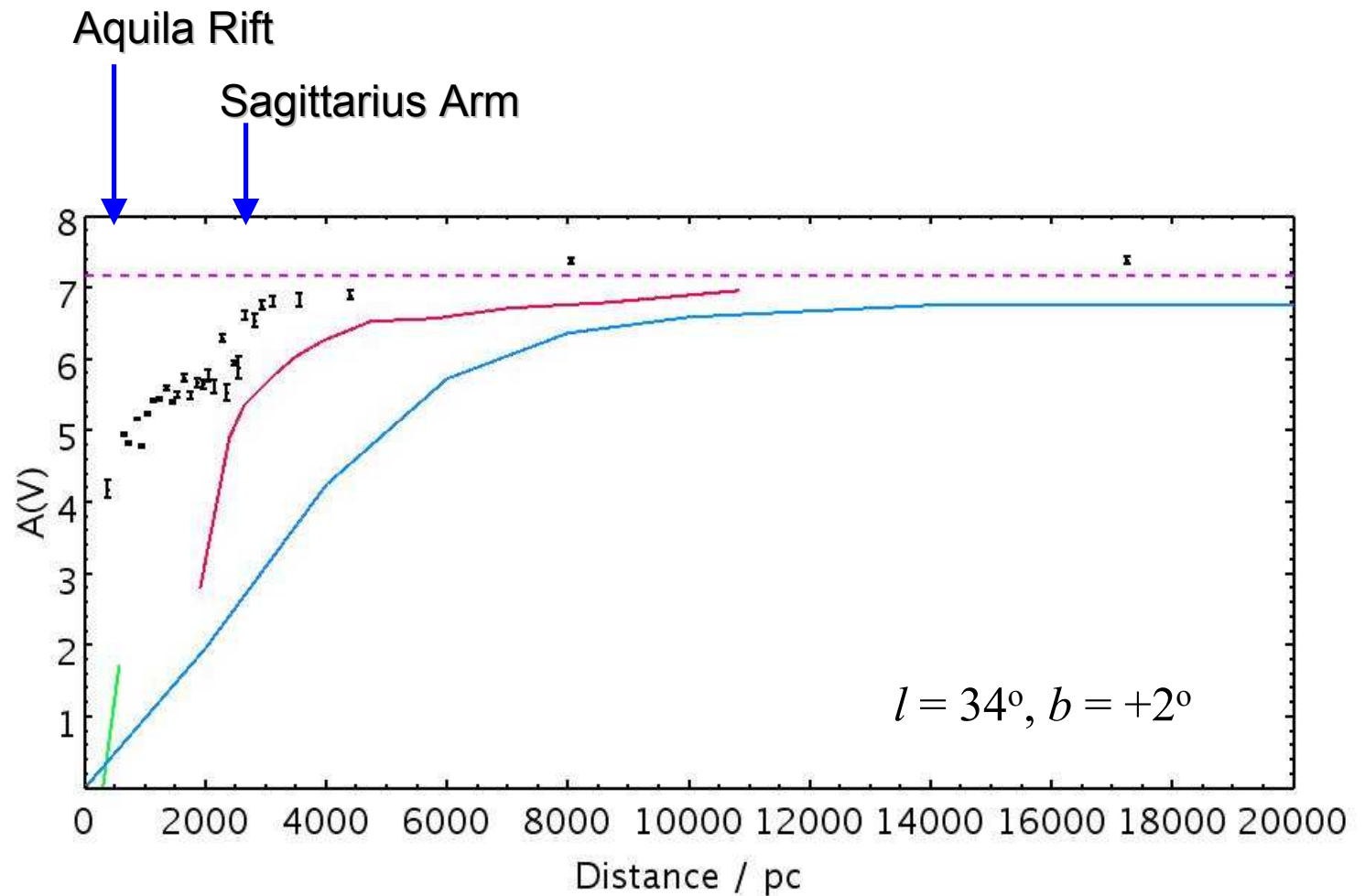
# 3D extinction mapping from the IPHAS filters (alone):

- (i) Select for spectral type (intrinsic colour), first from colour-colour plane
- (ii) Then separate luminosity classes using colour-magnitude plane
- (iii) Photometric parallax + deduced reddenings = 3D extinction map

(Sale et al 2009 – mid F stars shown right)

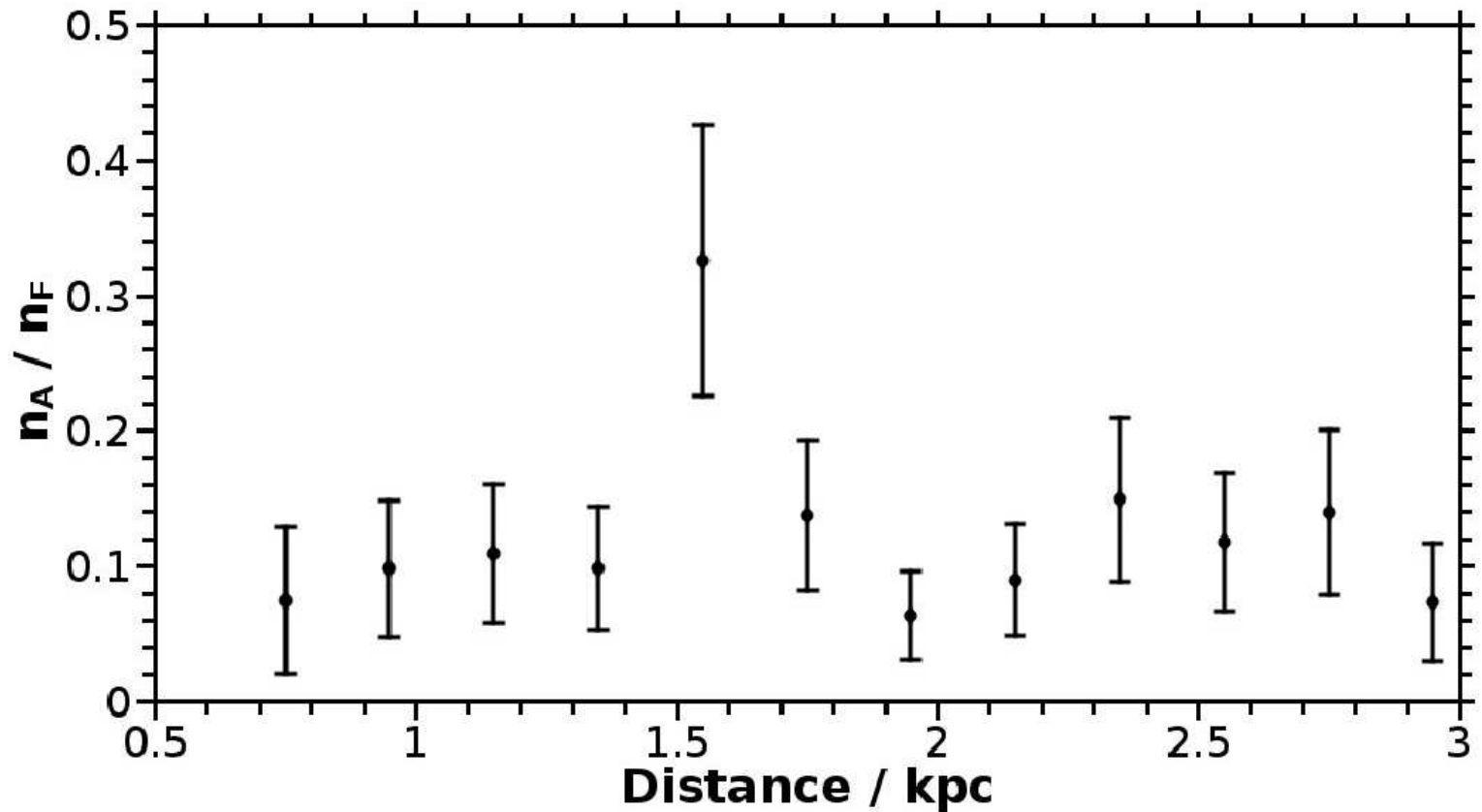


Extinction mapping and spiral arm structure: IPHAS photometry from 10x10 arcmin<sup>2</sup>, compared with previous descriptions (Marshall et al 2006, 30x30 arcmin<sup>2</sup> – red; Drimmel et al 2003 – blue, Neckel et al 1980 – green, and Schlegel et al 1998 total Galactic extinction – purple/dashed )



Can use  $r'$ - $H\alpha$  spectral-type sensitivity in other ways

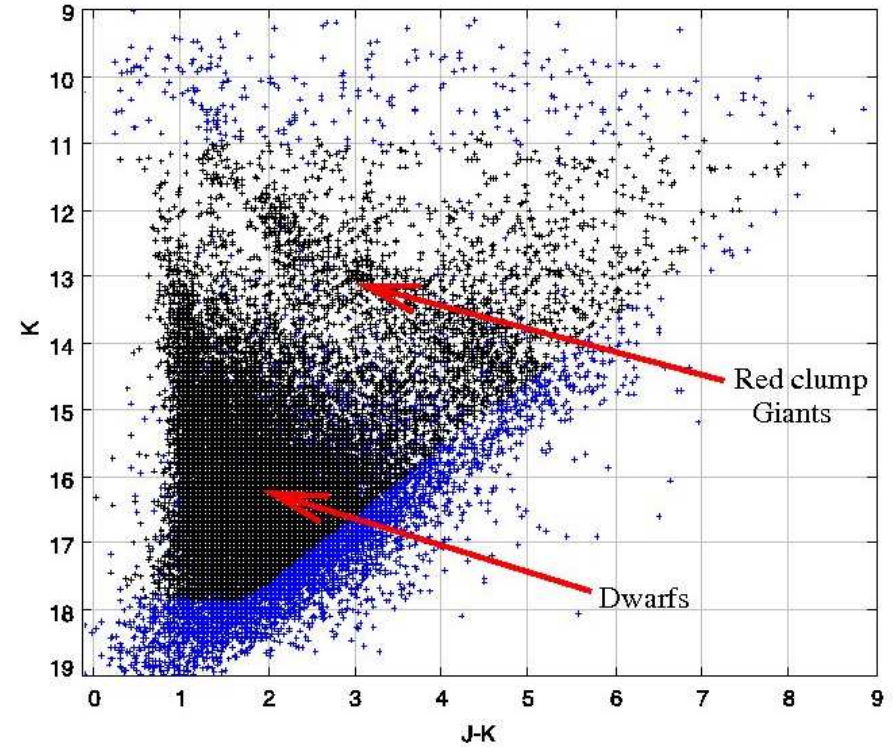
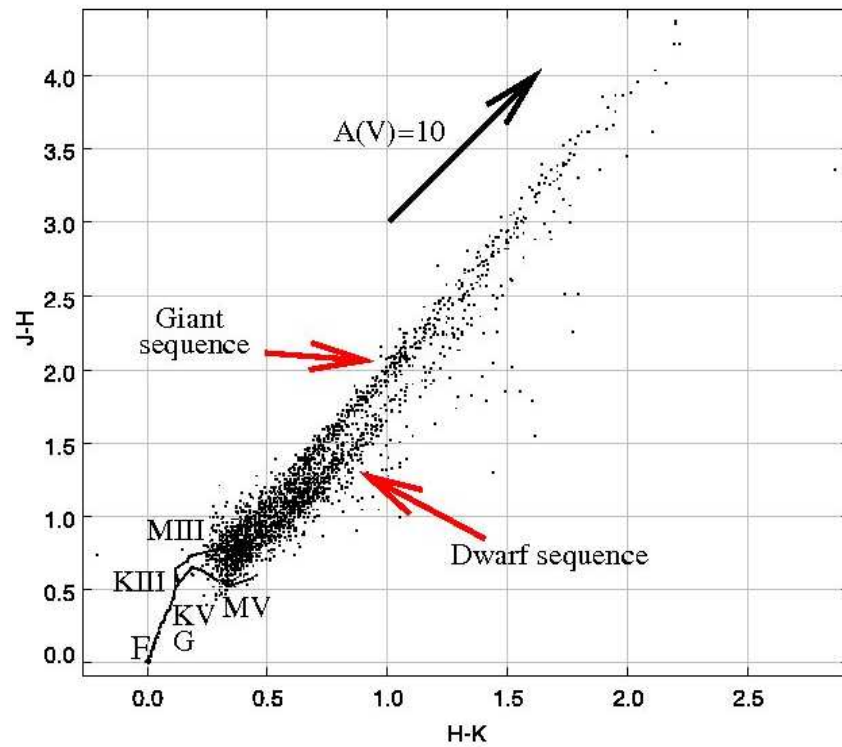
Here: relative A-star enhancement along line of sight picks out Cyg OB2 against older background (Sale et al 2009)



# UKIDSS/GPS photometry

4-5 mags fainter than 2MASS, and precision transformed.

Left: J-H,H-K plane; Right: K,J-K CMD



(from Lucas et al 2008)

VVV will mainly access structure through its identification of variables and extensive monitoring in K band:

### The Bulge: RR Lyrae stars and type II Cepheids

→ trace out the bar(s), characterise the old populations within/outside clusters and tease them apart

...33 known globular clusters, and the Sgr dwarf in the region to be surveyed

### The inner Plane: Pop I Cepheids

→ pick out young populations of the inner plane and establish distances/structure.

...trace the as-yet poorly defined transition from Bulge to disk?

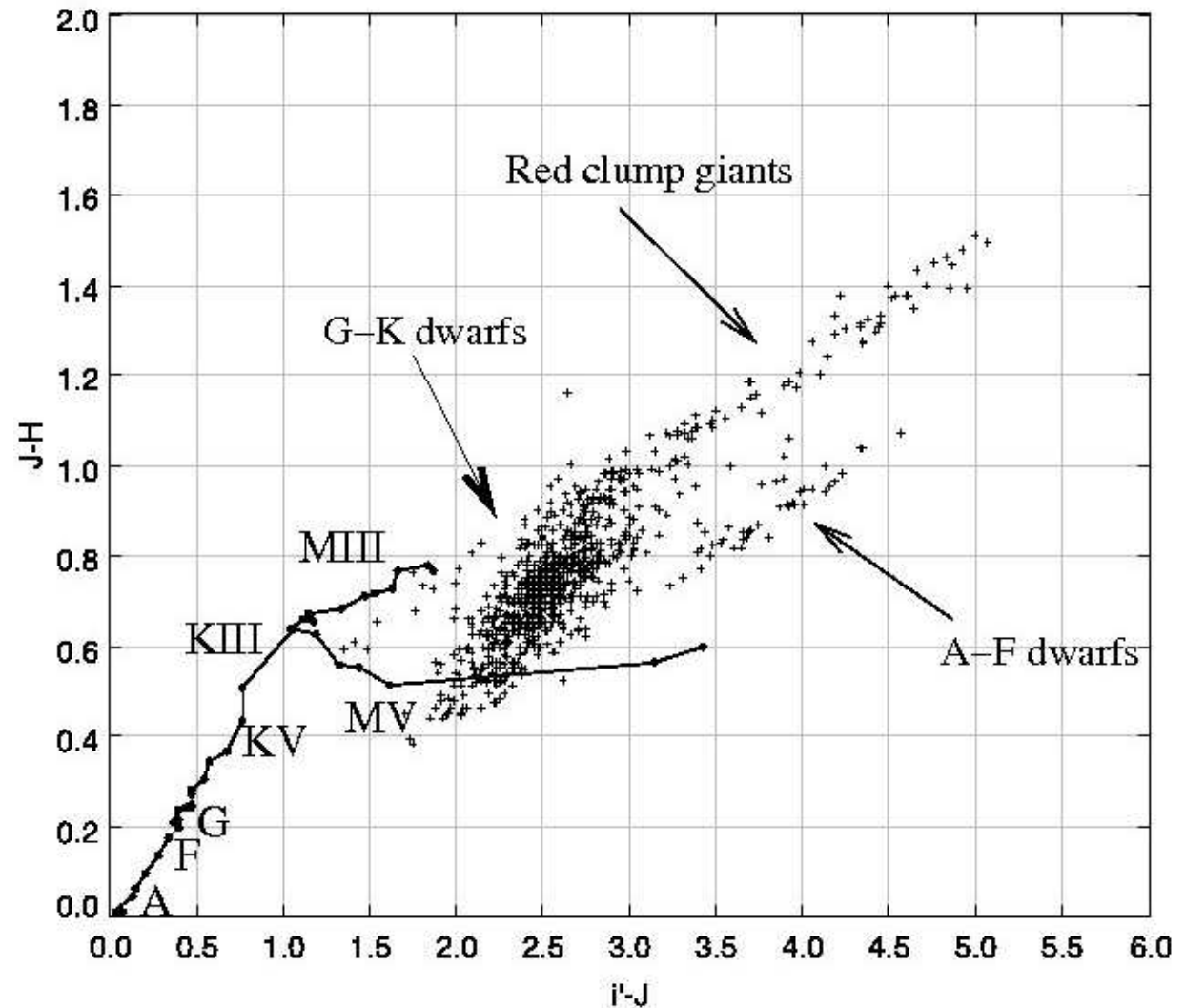
(Will also map large numbers of SF regions in NIR by a mix of methods, using multi-band data)

Still awaiting  
significant  
exploitation –  
inter-survey  
synergies

e.g. increase  
the wavelength  
baseline, and  
gain extra  
diagnostic  
power

(*IPHAS i'* and  
*UKIDSS/GPS J,H*  
used together

*Lucas et al 2008)*



## Spectroscopic follow on from the photometry:

*Digital photometry highly capable for general ID work, when supplemented by narrowband  $H\alpha$ , and/or multiple epoch data (variability, proper motions)*

These surveys generate well-controlled samples of objects well outside the solar neighbourhood (...into Bulge, and to 'edge' of disk)

→ greatly reduced spectroscopic ID failure rates

→ conditioned input to kinematic and abundance studies on just about any angular scale.

BUT ...metallicity discrimination not so easy ...can be assisted by u'g' data → ID spectroscopy likely to remain a necessity to search for EMP stars in the Plane (where most stars are)

# Closing summary/remarks

- In the northern hemisphere, optical and NIR digital surveys of the Galactic Plane to  $\sim 20^{\text{th}}$  mag are well underway
- In the southern hemisphere, VISTA/VVV takes on the Bulge and GLIMPSE Plane in NIR
- VST/VPHAS+ takes on the whole southern Plane at optical wavelengths
- gaps in NIR coverage remain (north and south)
- The precision/calibration of digital photometry confers increased diagnostic power (especially with narrowband  $H\alpha$ )  $\rightarrow$  efficiency of spectroscopic target selection much improved.
- These surveys are very flexible as sources of target lists.
- ...can never replace spectroscopy for kinematics and abundances