Galactic Plane Hα Surveys: New and Old Roles

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Hα as a tracer – received (20th century) wisdom:

As the highest emissivity, non-ground-state transition of the most abundant element in the cosmos

→ *the* tracer of ionised gas….

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

B. Point sources → CSM and winds of: large numbers of pre-main-sequence stars; smaller numbers of evolved stars and compact binaries

...much access via objective prism surveys

...point sources limited to R < 13 typically
The bequest from objective prism surveys:

*A view of the 2 halves of the Galactic Plane - Sanduleak/Stephenson, and Kohoutek/Wehmeyer compared.*

~first quadrant (S)
far less ‘active’ than
~fourth quadrant (N)
Hα surveys ‘current’ in 2005:
(adapted from Parker et al 2005)

<table>
<thead>
<tr>
<th>Survey</th>
<th>Coverage</th>
<th>Depth</th>
<th>Resolution</th>
<th>Field size</th>
<th>Filter FWHM</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(sq.deg.,region)</td>
<td>(Rayleigh)</td>
<td>(arcsec)</td>
<td>(degxdeg)</td>
<td>(Angstrom)</td>
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<tr>
<td>WHAM1</td>
<td>17000, δ&gt;-30°</td>
<td>0.15</td>
<td>3600</td>
<td>1</td>
<td>0.25</td>
</tr>
<tr>
<td>SHASSA2</td>
<td>17000, δ&lt;+15°</td>
<td>~2</td>
<td>48</td>
<td>13x13</td>
<td>32</td>
</tr>
<tr>
<td>VTSS3</td>
<td>&gt;1000, δ&gt;-20°</td>
<td>~2</td>
<td>96</td>
<td>10x10</td>
<td>17</td>
</tr>
<tr>
<td>SHS4</td>
<td>4000,</td>
<td>b</td>
<td>&lt;10° (δ –ve)</td>
<td>&lt;5</td>
<td>~2</td>
</tr>
<tr>
<td>IPHAS5</td>
<td>1800,</td>
<td>b</td>
<td>&lt;5° (δ +ve)</td>
<td>~3</td>
<td>&lt;1.7</td>
</tr>
</tbody>
</table>

The future? …a selection of mainly VISTA/VST photometric surveys:

Shown in Galactic Coordinates, with the Plane across the middle

Optical: IPHAS(r/i/Hα), UVEX (u/g/r), VPHAS+ (u/g/r/i/Hα), NIR: UKIDSS/GPS (J/H/K), VVV (z/y/J/H/K) ….Skymapper: Hα add-on?
I. \( \text{H} \alpha \) as a tracer of ionised gas

The WHAM picture of the northern hemisphere WIM:
Properties of the WIM (Warm Ionized Medium) traced by Hα, and backed up by radio dispersion measures:

- Concept of WIM scale height ‘challenging’, but 1 to 2 kpc
- Volume-averaged densities ~0.02 cm\(^{-3}\)
- WIM densities decline with z
- But filling factors \textit{increase} with z, until coronal conditions start to dominate at > 1 kpc
- Highly ragged and dynamic

\textit{(Haffner et al 2003, Gaensler et al 2008)}
SHS Hα montage of southern Galactic Plane

(less sensitive than WHAM – but much higher spatial resolution)

(from Parker et al 2005)
SHS benefits:

Significant update to census of Galactic PNe – MASH catalogue (*Parker et al 2006*) added 900 new, homogeneously collected nebulae.

For point sources – more limited outcomes, mainly due to non-linearity of photographic medium.

BUT e.g. some WR stars, including this WO star, WR 93b, dominated by C/O lines

(*Drew et al 2004*)
IPHAS – first ~arcsec resolution digital Hα survey, able to pick out emission line stars efficiently/comprehensively

|b| < 5°, complete northern Galactic Plane

IPHAS = *INT Photometric Hα Survey* of the northern Galactic Plane

‘simultaneous’ r’,i’, Hα to ~20th magnitude, ~15000 fields observed, covering area twice median seeing 1.1 arcsec

started 2003 – almost complete

*(IC 1396b, r’i’Hα N. Wright)*
Emission line stars in the northern Plane:

Automatic selection based on r’-Hα ‘excess’ (13<r’<19.5) across 80% of survey area

4853 objects, those in black r’>18

(Witham et al 2008)
Comparison between velocity-integrated HI data of Freudenreich et al 1994 and running median of emission-line star latitude

→ the Galactic disc warp in the north

note: typical classical Be star has $M_V \sim -3$

→ at 10 kpc, through $A_V = 5$

→ $r' \sim 16.5$
II. H\(\alpha\) as a marker for stellar intrinsic colour:

\(r'-H\alpha\) as a colour/‘excess’ measured to, now routine, photometric accuracy (~0.03 mags)

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

A0V: \(r'-H\alpha = 0.00\)  
G2V: \(r'-H\alpha = 0.23\)  
M4V: \(r'-H\alpha = 0.89\)

….and for nebulae (no continuum), \(r'-H\alpha \sim 3\)
IPHAS photometry, with $r'$, $i'$ and $H\alpha$

$r'-H\alpha$ 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 colour-colour plane

**Diagram:**

- **IPHAS data**
  - Unreddened MS
  - M giants
  - A dwarfs
  - WDs
  - Two Aquila Rift fields ($13 < r' < 20$)
  - 4199 in green
  - 4095 in blue (plotted second)

- **Synthetic tracks**
  - $E(B-V) = 0.0$
  - Early-A reddening line
  - MS tracks in black
  - Giant tracks in red
An earlier application of the same concept, with V-I as the broadband colour:

Digital photometry of NGC 2264:

R-H\(\alpha\), versus V-I

(Sung, Bessell & Lee 1997)

Darker symbols in this picture = PMS stars

Lighter symbols = ‘ordinary’ stars

…rising MS (in mauve)
Applications of this digital-survey capability:

(i) To studies of star clusters

(ii) To the construction of large spectral-type constrained samples

(iii) To Galactic disc structure problems (cf. Juric+, Ivezic+ SDSS papers)

(iv) 3D extinction mapping, for ISM studies and use in distance determination

Near MS A-star selection is particularly well-constrained, and easy to do…
Example application:
Searching out the near-MS early A stars in/around Cyg OB2:

Use IPHAS r ’i’ Ha magnitudes to identify, deredden and estimate distances to A stars within ~1 degree of cluster centre

→ evidence of appreciably larger, 5-7 Myr old cluster

→ present OB stars (in blue box) are a rejuvenation

...as seen in a number of associations

(Drew et al 2008)
Northern optical source densities (to ~20\textsuperscript{th} mag)

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

...more than half these can be ‘typed’ using r’-H\textalpha with a broadband colour
Conclusions:

A. The ‘old’ role for Hα as a tracer of ionized gas continues..

- important contributions from imaging of diffuse ISM and nebulae continue to be made
- emission line stars ‘en masse’ support studies of young clusters
- demographics of rare evolved objects being updated – extreme rarities uncovered (e.g. V458 Vul: a nova embedded in a PN)

B. The photometric precision achievable with digital detectors permits a ‘new’ role..

- r-Hα to ~0.03 mags precision → highly effective intrinsic colour discrimination → facilitating a variety of studies of larger stellar populations