SCIENCE

IPHAS: Surveying the Northern Galactic Plane in Hα

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Hα emission is ubiquitous in our Galaxy. It traces ionised gas of assorted nebulae such as HII regions, planetary nebulae, Wolf-Rayet nebulae, and supernova remnants. It is a strong signature of active stars, interacting binaries, very massive stars (especially supergiants, Luminous Blue Variables and Wolf-Rayet stars), Be stars, post-AGB stars, pre-main-sequence stars and so on. These objects represent important evolutionary phases which are generally short lived, and are therefore few in number and difficult to find. Their discovery is therefore well worth the effort of a concerted programme and in August 2003 a major new survey project was started using the Wide Field Camera (WFC) on the Isaac Newton Telescope (INT) to do just that. It is called the INT Photometric Hα Survey of the Northern Galactic Plane, or IPHAS for short.

Figure 1. The crescent nebula, NGC6888, which surrounds the Wolf-Rayet star PPM 84423, seen in Hα emission by IPHAS. Colour image courtesy of Jonathan Irwin.

IPHAS is a collaborative UK/NL/ES venture led by Janet Drew in UK, Paul Groot in The Netherlands, and Antonio Mampaso in Spain. Its goal is to conduct an Hα survey of the entire northern Galactic Plane in the latitude range $-5° < b < +5°$, a sky area of 1800 sq. deg., covering the magnitude range $13 < r' < 20$. That such a survey is needed can be deduced from Figure 2, and when complete it will represent an enormous improvement over previous work. For example it is expected that in excess of 10,000 new emission line stars alone will be discovered, an order of magnitude increase on known sources.

Survey Details

The 1800 square degrees will be tiled with 7635 pointings of the WFC, each of which is paired with a second pointing at an offset of 5 arcmin W and S. The purpose of the offset field is to ensure that we cover stars in the gaps between detectors, but also means that the majority of sources are observed at least twice. Each field is to be observed with the Sloan r' and i' filters, plus a narrow band Hα filter, with exposure times of 30s, 10s and 120s respectively. The use of a guide star is not necessary for such short exposure times and is dispensed with to save on overheads, while for each Hα–r'–i' sequence at a given pointing the CCD readout, filter movements, and final telescope movement, are overlapped for additional savings. Finally, human

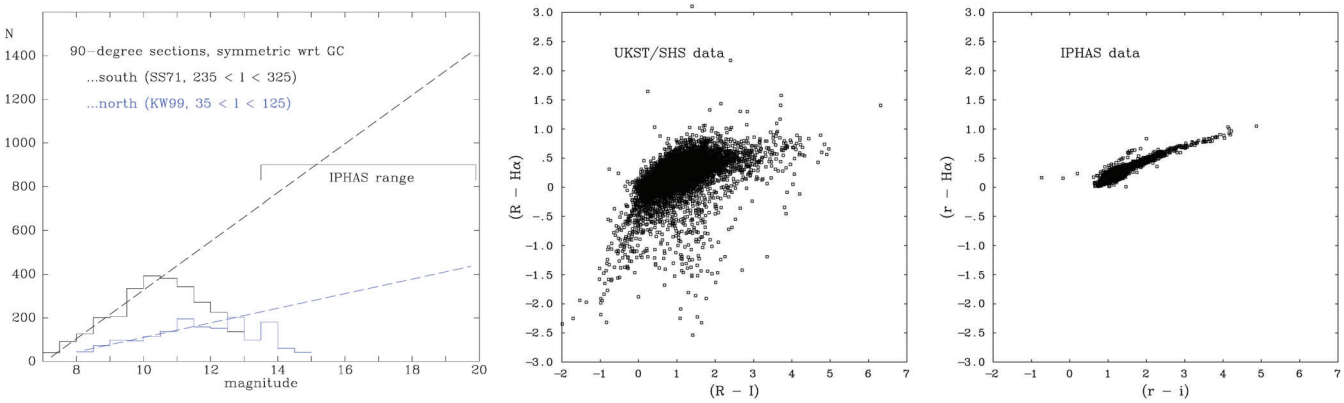

Figure 2. The left-hand panel illustrates the effect of a simple extrapolation of numbers of catalogued emission line stars from previous Hα surveys of Kohoutek & Wehmeyer (1999) in the north, and Stephenson & Sanduleak (1971) in the south. Based on a rough extrapolation of these earlier surveys it is estimated that of order ~10^4 emission line stars will be discovered. The central and right-hand panels compare the quality of the current IPHAS colour-colour diagrams with those for the same sky area taken from the UK Schmidt southern Hα photographic survey. Notice the superb delineation of the field population of normal stars and M dwarfs in the IPHAS data (cf. Figure 3).

interaction is avoided as much as possible by the use of automatic observing scripts, which typically run for about 3 hours, broken only to take standard star observations.

All data are transferred using external discs to the Cambridge Astronomical Survey Unit (CASU) where they are processed using the CASU pipeline; calibration steps consisting of bias correction, flat-fielding, de-fringing, astrometric solution, flux calibration and object catalogue generation (see the article by Irwin et al. on WFS in this issue). Work is progressing on the construction of a unified object catalogue and flux calibration for the complete survey, with an expected first data release of final data products expected in early 2006. It is hoped that completion of the full survey will occur during 2006, with the full data release coming during 2007.

Some Expected Science

Strong Hα emission line stars are of course reasonably easily selected from the sample since they are well separated from the bulk population in the (r'–i', r'–Hα) diagram. Indeed an initial blue selection of such objects has already been made using the 2003 data and some subsequent follow-up spectroscopy has revealed the vast majority of these to be Be-like stars, with a sprinkling of CVs, compact PN, potential luminous blue supergiants and the odd QSO (Figure 3).

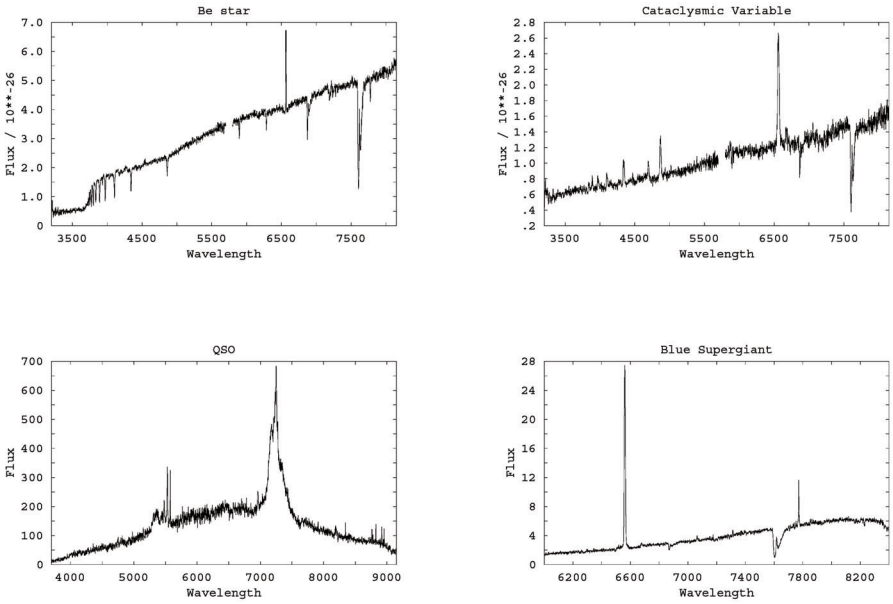

Figure 3. Sampling the Hα zoo as discovered by IPHAS. Clockwise from top left; a typical Be star, a cataclysmic variable, a potential luminous blue supergiant in Cygnus and a low redshift QSO (the QSO was detected as a peculiar outlier in the colour-colour plane).

Not all emission line objects are as easily discovered however and it is crucial that effort is put into understanding the IPHAS colour-colour plane so that future object selections can be made with some confidence. This problem has been attacked on two fronts; through the construction of synthetic photometry using a library of observed flux-calibrated stellar spectra, and by conducting spectroscopic surveys of selected fields as a visual check on predicted spectral types. Figure 4 illustrates the result of this process for a sample field in Cygnus. Several thousand spectra in a number of selected fields have now been amassed using Hectospec on the MMT and AF2 on the WHT. In general this demonstrates that the synthetic photometry is well matched to the observations, although detailed studies of this field, and additional test fields indicate that some further investigation of the calibration for very red objects is required.

IPHAS is also producing new discoveries of nebulae, one of the first to be discovered has been named after the wedding of Su Alteza Real El Príncipe de Asturias Don Felipe de Borbón with Doña Letizia Ortiz Rocasolano which took place around

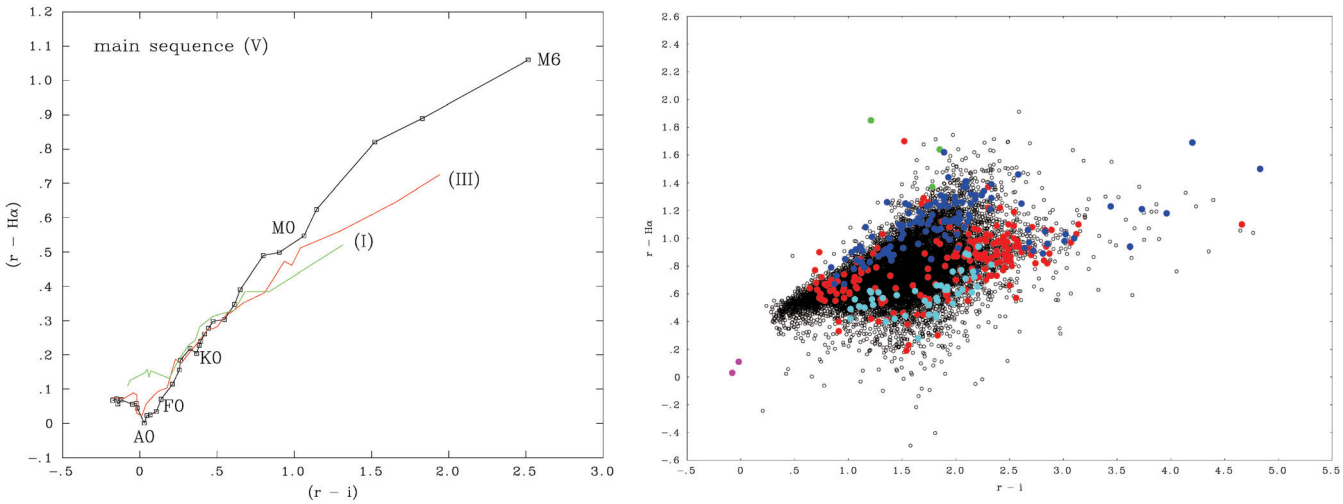

Figure 4. Left-hand panel shows the simulated positions of the unreddened main sequence (black), giant (red) and supergiant (red) stars in the (r'–i',r'–Hα) plane according to spectral type. The right-hand panel shows the observed sources in a field in the Cygnus region (black points), with some spectroscopically determined spectral types overplotted in colour; light blue points are early-type stars, red points are mostly G and K stars, while dark blue points are M stars. The magenta points are strong Hα absorbers, in fact they are white dwarfs, while the green points are emission line stars, in fact Be stars. Note that the trend from early-type to late-type stars is well reproduced by the synthetic colours (there is a zero point offset due to extinction which drives stars diagonally upward and to right this diagram). The central gap in the spectroscopic sample is simply a selection effect due to the algorithm used to select targets for follow-up. All spectroscopy for this field was carried out using Hectospec on the MMT.

the time of the PN's discovery. PNG 126.62+1.32 is a rare quadrupolar nebula, and it was spectroscopically confirmed as a PN in 2004 using the WHT. A deeper image, compared to the discovery image, is shown in Figure 5, which illustrates the initially undetected faint lobes of the nebula.

Besides looking for new nebulae, IPHAS has proved to be exceptionally useful for taking a new look at previously known nebulae; ING users will be familiar with the image of the Wolf-Rayet NGC6888 which adorned the ING Christmas card in 2004 (Figure 1). However Figure 6 shows the spectacular 5°×3.5° mosaic of images covering the supernova remnant S147. Bear in mind that this image, which is binned for the purposes of this article, has immense detail on the arcsecond scale.

To date the survey is approaching its half-way point in terms of completed fields. However as we look forward to the completion of the northern hemisphere survey it's clear that we are already seeing new discoveries, and generating additional exciting ideas for follow-up science and data mining. For example the colour-colour plane morphologies across the Galactic Plane will provide useful insights into the structure of the northern Milky Way, while linking IPHAS photometry with *JHK* survey data from 2MASS and the UKIDSS Galactic Plane Survey will add further powerful diagnostic capabilities.

We thank the many observers who have contributed to this programme. Finally, for more complete details interested parties should refer to the first survey paper which is currently in preparation (Drew et al., 2005, to appear in *MNRAS*), and to the IPHAS home page at `http://astro.ic.ac.uk/Research/Halpha/North/`. ¤

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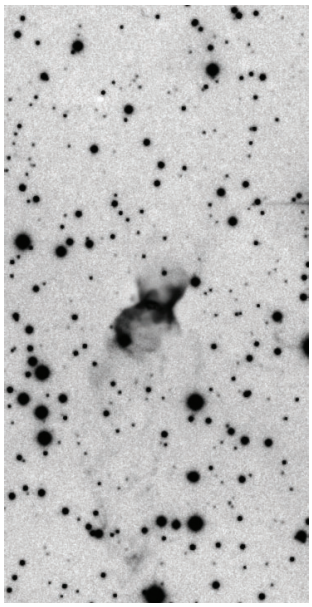
Survey area: ~1800 sq deg in 2×7600 overlapping pointings
Region: $-5° < b < +5°$, $25° < l < 225°$
Depth: $13 < r' < 20$
Seeing: < 1.7 arcsec
WFC pixel size: 0.33" × 0.33"
WFC field size: ~0.25 sq deg in four 2k×4k CCDs
Filters: r': λ_c=6420Å, FWHM = 1347Å, t_{exp}=30s
i': λ_c= 7743Å, FWHM = 1519Å, t_{exp}=10s
Hα: λ_c=6568Å, FWHM= 95Å, t_{exp}=120s
IPHAS Home: `http://astro.ic.ac.uk/Research/Halpha/North/index.html`

Table 1. IPHAS essentials.



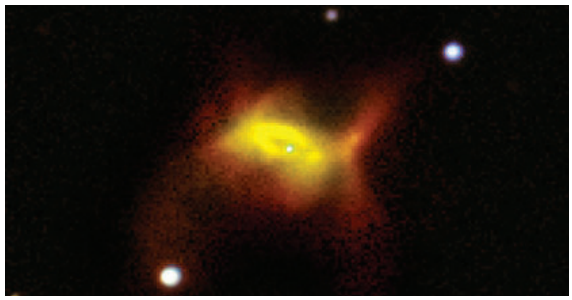


Figure 5. Left: The newly discovered Planetary Nebula PN 126.62+1.32, the 'Prince of Asturias' is a rare quadrupolar nebula (central region), with extended fainter lobes extending over 16 arcminutes from the central star. Top: Publicity version of the discovery image.

Figure 6 (next two pages). A 5°×3.5° mosaic of the supernova remnant S147 in Hα. North is to the top and East to the left. Courtesy of Albert Ziljstra and Jonathan Irwin.