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Citation: AIP Conference Proceedings **804**, 7 (2005); doi: 10.1063/1.2146213
View online: http://dx.doi.org/10.1063/1.2146213
View Table of Contents: http://scitation.aip.org/content/aip/proceeding/aipcp/804?ver=pdfcov
Published by the AIP Publishing

# Detection of New Planetary Nebulae by IPHAS, the Hα Survey of the North Galactic Plane

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**Abstract.**
IPHAS is an ongoing Hα imaging survey of the North Galactic plane. When completed, it is expected to discover several hundred new Galactic planetary nebulae, in addition to a huge number of Hα emitters.

We present here the project, the methods used to search for compact and extended ionized nebulae, and some preliminary results about the ∼100 new candidate planetary nebulae identified so far.

## THE IPHAS SURVEY

The INT Photometric Hα Survey (IPHAS) is an international collaboration which involves 13 different institutes, mainly from the UK, Spain and The Netherlands. The aim of this imaging survey is to produce a complete, fully photometric, and spatially detailed Hα map of the part of the Galactic Plane between latitudes $-5°$ and $+5°$ that is visible from the Northern hemisphere. When complete, it will thus cover a total of 1850 square degrees of sky. The survey started on August 2003 and we expect to finish observations by the end of 2006, with an estimated total of 22 observing weeks of clear time (mostly during bright moon).

The IPHAS observations are done using the Wide Field Camera (WFC) at the 2.5m Isaac Newton Telescope (INT) at the Observatorio del Roque de los Muchachos on La Palma, Spain. The WFC is installed at the prime focus of the telescope and consists of a mosaic of four 2k×4k EEV CCDs, providing a field of view of $34\times34$ arcmin$^2$ with a sampling of $0''.33$ per pixel.

The IPHAS images are taken through three filters: a narrow-band Hα ($\lambda_c$ = 6568Å; FWHM = 95Å) and two broad-band Sloan *r*, *i* filters, with matched 120, 30, and 10 s exposures, respectively. In this way, the magnitude range $13 \leq r \leq 20$ (the fainter end at $10\sigma$) is covered for point sources.

Pipeline data reduction and data distribution are handled by the Cambridge Astronomical Survey Unit (CASU, see `http://archive.ast.cam.ac.uk/`).

IPHAS is the first fully-photometric Hα survey of the North Galactic plane, and will complement the recently completed AAO/UKST photographic survey of the South Galactic plane (see Parker, these proceedings, and `http://www-wfau.roe.ac.uk/sss/halpha/`). The IPHAS sensitivity is matched to that of the AAO/UKST survey, but offers the advantage of CCD dynamic range and linearity, and a better spatial resolution.

An extrapolation of our presently limited knowledge of the population of the Hα emitters in the Milky Way leads to the estimate that IPHAS will detect around 50000 new emission-line stars, including young stars (T

CP804, *Planetary Nebulae as Astronomical Tools*, edited by R. Szczerba, G. Stasińska, and S. K. Górny

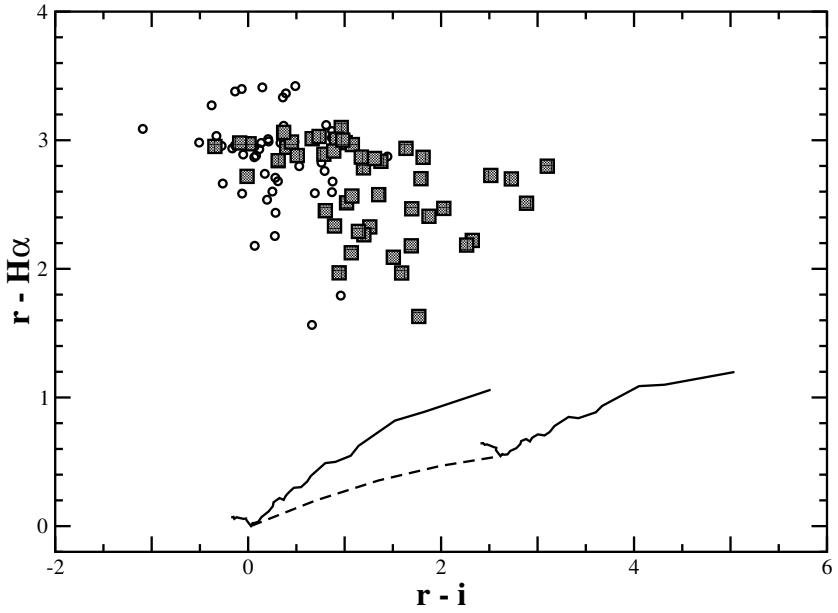


**FIGURE 1.** The IPHAS colour-colour diagram. New candidate PNe extracted from the IPHAS photometric catalogue are represented by the filled squares, while circles indicate previously known PNe falling in IPHAS fields. At the bottom, the inclined continuous lines indicate the locus occupied by normal stars: the line at left is the unreddened main-sequence, the parallel one at right is the main-sequence for E(B-V)=4, and the dashed line indicate the reddening line for A0V stars (see Drew et al. 2005 for more details).

Tau, Herbig AeBe stars, etc.), evolved ones (post-AGB, LBVs, etc.), different classes of interacting binaries (cataclysmic variables, symbiotic stars, etc.) in addition to thousands of extended ionized nebulae such as planetary nebulae, HII regions, SN remnants, H-H objects, etc.

The IAU-registered nomenclature adopted by IPHAS for point sources is *IPHAS JHHMMSS.ss+DDMMSS.s*, encoding the J2000 object coordinates into the name, and *IPHASX JHHMMSS.ss+DDMMSS.s* for extended nebulae.

Further information on the IPHAS collaboration, its scientific objectives, products, and first results can be found in Drew et al. (2005) and in the survey Web site at `http://astro.ic.ac.uk/Research/Halpha/North/`.

## IPHAS AND PLANETARY NEBULAE

It is expected that IPHAS will significantly contribute to improve our knowledge of the population of planetary nebulae (PNe) in the Galaxy. In terms of surface brightness, the Hα detection limit of IPHAS (at S/N=3) is $2.5\,10^{-16}$ erg cm$^{-2}$ s$^{-1}$ arcsec$^{-2}$ at full spatial resolution (no pixel binning, spatial sampling of $0''.33$), and $10^{-17}$ erg cm$^{-2}$ s$^{-1}$ arcsec$^{-2}$ for $15\times15$ pixel binning ($5''$ sampling).

Based on the recent results of the AAO/UKST Southern survey (see Parker, these proceedings), which has a similar detection limit for extended objects, it is estimated that IPHAS will discover several hundred new Galactic PNe. The combination of the two surveys will then allow us to perform surface-brightness-limited PNe counts in the solar vicinity and throughout the disk of the Galaxy, a figure which is intimately related to our understanding of the PN density per unit luminosity in spiral galaxies, the stellar death rate, the PNe lifetimes, their absolute luminosities, etc. (e.g. Buzzoni et al. 2005).

In addition, a number of the PNe discovered by IPHAS will be located along very interesting line of sights, like the direction toward the Galactic anti-centre, providing new targets to probe stellar properties and the chemistry of the interstellar medium at large galactocentric distances.

### Searching methods and first results

In order to achieve the objectives above, substantial effort is dedicated within the IPHAS collaboration to the systematic search of PNe and other ionized nebulae. Two searching techniques are used:

1. Compact ionized nebulae are searched in the photometric catalogue which is automatically created

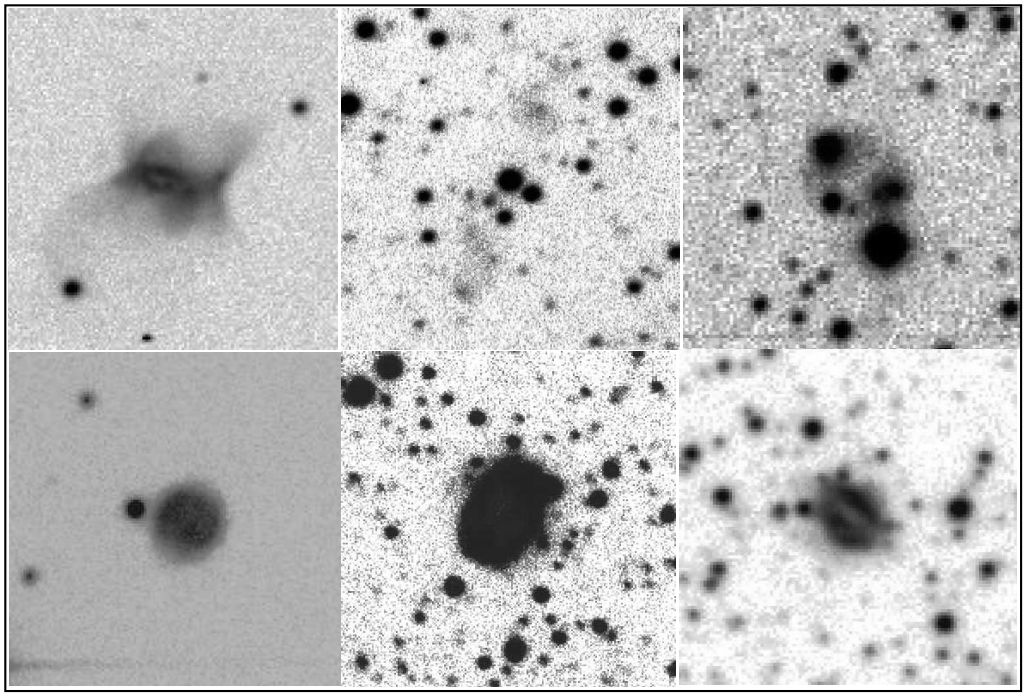

**FIGURE 2.** Some examples of compact nebulae identified in the IPHAS photometric catalogue.

by the IPHAS data reduction pipeline for point-like and compact objects. We select those sources that have a strong H$\alpha$ excess in the IPHAS $r - H\alpha$ vs. $r - i$ colour-colour diagram (see Drew et al. 2005). The analysis of the IPHAS data obtained under good seeing conditions until July 2004 has already identified 66 good PN candidates. They are displayed in Figure 1 as filled squares, while small circles are genuine PNe in the IPHAS fields listed in the Acker et al. (1992) catalogue. In the figure, the tracks of normal main-sequence stars of different spectral types are indicated by the lines at the bottom of the plot, and are clearly separated from PNe which, as expected, show a large $r$–H$\alpha$ colour (they can be considered as 'pure' H$\alpha$ emitters with very little continuum emission even in the broad $r$ filter).

The images of some of the new candidate PNe, which display different kind of morphologies, are shown in Figure 2.

2. Much larger nebulae, that are not detected by the automated photometry, are searched by visual inspection of the IPHAS images. In particular, the CASU data reduction pipeline includes the possibility of producing mosaics, of a chosen size and pixel binning, of continuum-subtracted H$\alpha$-$r$ images.

   In searching for extended nebulae, we are presently adopting a spatial binning of 15×15 pixels (5×5 arcsec$^2$). These mosaics are visually inspected by independent collaborators, and any extended nebula with a symmetrical, regular, or even peculiar morphology is registered.

   Only a tiny fraction (a few square degrees) of the total area covered by IPHAS has been inspected in this way so far. Nevertheless, some 20 new candidate PNe have been found. Some of them are shown in Figure 3 along with other nebulosities.

## FOLLOW-UP SPECTROSCOPY

The obvious step following the detection of new candidate PNe (and any other object selected by IPHAS) is to secure their spectroscopy to confirm their nature and derive information on their physical and chemical properties.

We have started such a programme at different telescopes worldwide, as for instance the 4.2m WHT+ISIS at the ORM and the 2.1m OAN telescope at San Pedro Mártir (México). The results for two of the first PNe discovered by IPHAS, both located at very large galactocentric distances, can be found in Mampaso et al. (this conference), and Mampaso et al. (2005). Wareing et al. (2005) present the study and modelling of the interaction of an evolved PN, Sh 2-188, with the interstellar medium, making use of IPHAS images. Many more results will be coming in the future.

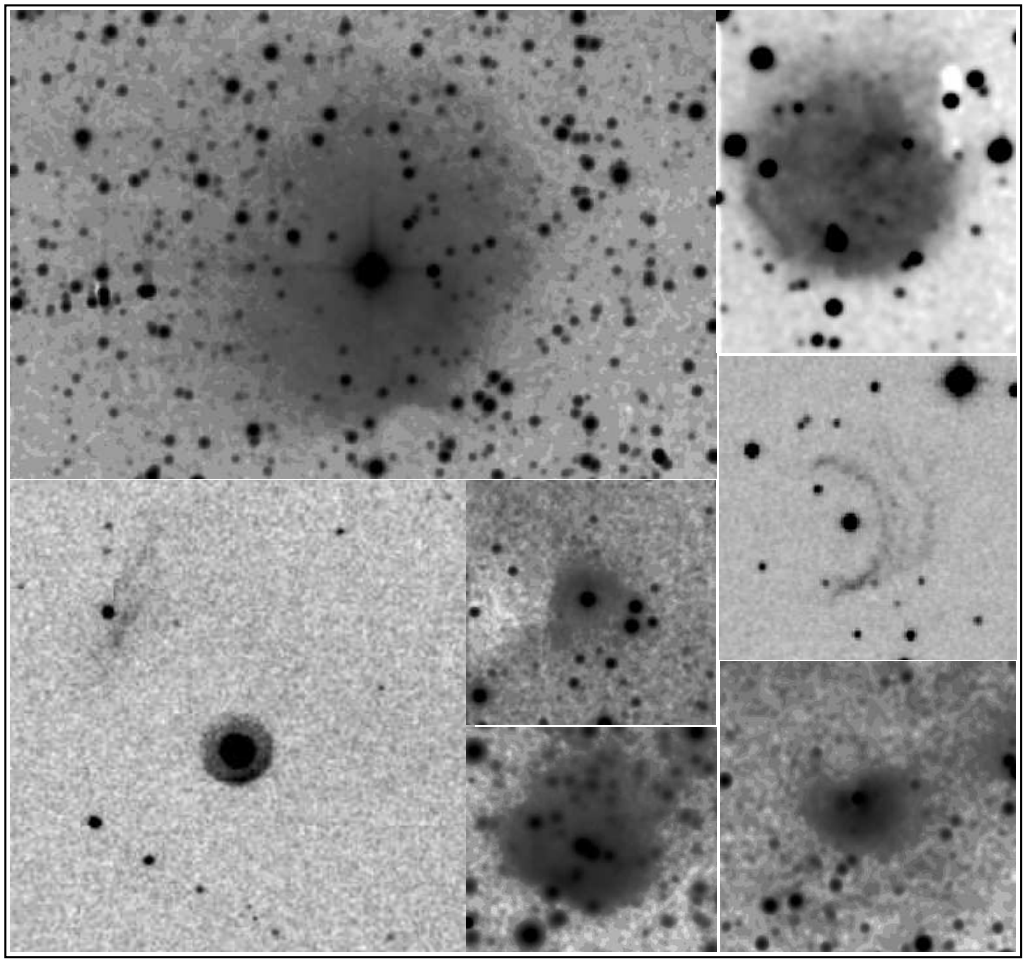

**FIGURE 3.** Some extended ionized nebulae visually identified in the IPHAS continuum-subtracted Hα mosaics.

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