Morphological Classification of New Candidate PNe in an IPHAS Sample

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Summary. We are currently undertaking a systematic search of new Galactic planetary nebulae (PNe) in the IPHAS (INT Photometric H-Alpha Survey) data. We employ two methods to search for PNe of different sizes: a visual search through continuum subtracted r'–Hα mosaics for extended PNe and a (point) source catalog based search for small diameter PNe. We have completed the search at the RA = 18-20h region of the northern Galactic Plane and found a total of 389 objects, including 100 known PNe in that area. Here we present a morphological study for the 133 new candidate PNe for which the available images allow this study to be carried out.

Key words: planetary nebulae, morphology

1 Introduction

1.1 IPHAS survey

IPHAS is currently mapping 1800 degrees^2 of the Northern Galactic Plane (a band between b= –5 to +5 degrees) in three filters using the INT Wide Field Camera at the Observatorio del Roque de los Muchachos (La Palma, Spain). The survey is an international collaboration of 15 institutes led by J. Drew at Imperial College (London, UK). IPHAS observing started in August 2003 and will be completed by the end of the 2007, with an estimated total of 30 observing weeks (mostly bright nights). A narrow-band Hα and two Sloan filters (r' and i') are used for matched 120, 30, and 10 s exposures, respectively, spanning the magnitude range r'=13 to 20 mag for point sources. Each IPHAS field is observed twice at two closely overlapped pointings. IPHAS is the first fully-photometric Hα survey of the Galactic Plane. It will discover many thousands of new emission-line stars, including young stars

(T Tau, Herbig AeBe stars, etc.), evolved stars (post-AGB, LBVs, etc.) as well as binaries (CVs, symbiotic stars, etc.), in addition to extended nebulae such as PNe, H-H objects, H II regions, SN remnants, etc. More information about the survey can be found in [2] and on the official survey website, http://www.iphas.org/.

1.2 Planetary nebulae and IPHAS

As shown in the Fig. 1, there is a clear lack of PNe detections in the Galactic Plane. This is expected considering the amount of extinction at the plane and the confusion with other objects in this crowded region. An immediate precursor of IPHAS and a prompt for the need of a northern survey is the Anglo-Australian Observatory UK Schmidt Telescope (UKST) narrow-band Hα survey of the Southern Galactic Plane and Magellanic clouds. The full description of this survey can be found in [5]. The survey was completed in 2003 and discovered about 1000 new PNe in the southern Galactic Plane. IPHAS is expected to find about the same amount of northern plane nebulae.

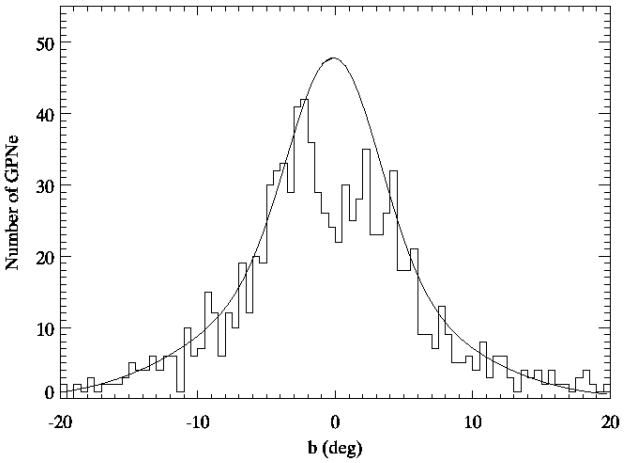

Fig. 1. Numbers of known disk PNe binned by Galactic latitude. The image is adapted from [7].

2 Search techniques

We are currently conducting a systematic search for new PNe from IPHAS data. We use two search techniques: visual search to find extended PNe and semi-automatic technique to find compact/small PNe.

2.1 Extended PNe search

The extended PNe are searched visually from IPHAS mosaics. We use two pixel binning values: $15'' \times 15''$ to find extended and/or faint nebulae and $5'' \times 5''$ for intermediate sized nebulae. Results from the two methods overlap making the search more complete.

2.2 Small/compact PNe search

The compact/small nebulae are searched automatically from the IPHAS catalogs. Fig. 2 presents the loci of known PNe in the IPHAS two-color diagram. Only those nebulae which had good magnitude measurements available for the whole nebula, or for the central parts (i.e. in general compact/small PNe) are included in the graphic. Presented are also the theoretical tracks for main sequence stars (see [2]). The PNe occupy the region from r' - Hα=1 to 3 and are nicely separated from the stellar locus in this diagram. So, the first criteria for PN candidate selection is that they should show an Hα excess similar to the known PNe. The cut shown as solid line in Fig. 2 (r' - H$\alpha \geq 0.25$(r' - i') + 0.55) is selected to exclude the normal (main sequence and giant) stars, to include the area where all the known planetaries are located, and to be roughly parallel to the reddening vector.

From the selected objects those being too close to the borders of the CCDs or to areas of bad pixels are filtered out, as well as those which are not classified as stars or nebular objects. We also require that the object must be detected at least in Hα and r' filter and at least twice in both filters. To get rid of the faintest objects, where the quality of the IPHAS photometry decreases, we require the objects to be brighter than 19.5 magnitudes in Hα.

So far, we have completed the area between RA = 18-20h. After the automatic selection described above we were still left with 56314 objects in this area. Of these about 90% are optical binaries which are not resolved in Hα but in r' yes, and thus cause a detection of an "Hα emitting" object. A separate algorithm was developed to get rid of these contaminants. The final selection was made visually, inspecting the IPHAS images, in the following way: at the part of the diagram where most of the known PNe are concentrated, all the objects were studied, and at an area below, which still includes some known PNe, only the brightest Hα emitters were selected (m(Hα) ≤ 17.5), the cuts used are shown as dashed lines in Fig. 3. The area closest to the main sequence tracks which does not include any known PNe was omitted.

The semi-automated small/compact PN search presented here overlaps with the previously presented visual searches. So, our PN search is complete up to the limiting magnitude of IPHAS.

3 Search results

So far we have completed the PN search at the IPHAS 18-20h region for all the three search methods described above. A small fraction ($\sim 5\%$) of this area of the sky has not been observed by IPHAS yet, and these fields will be studied in the future. Combining our three search methods, we selected a total of 389 objects, of which 100 were known PNe and the rest, 289 new candidate PNe. Of the candidate

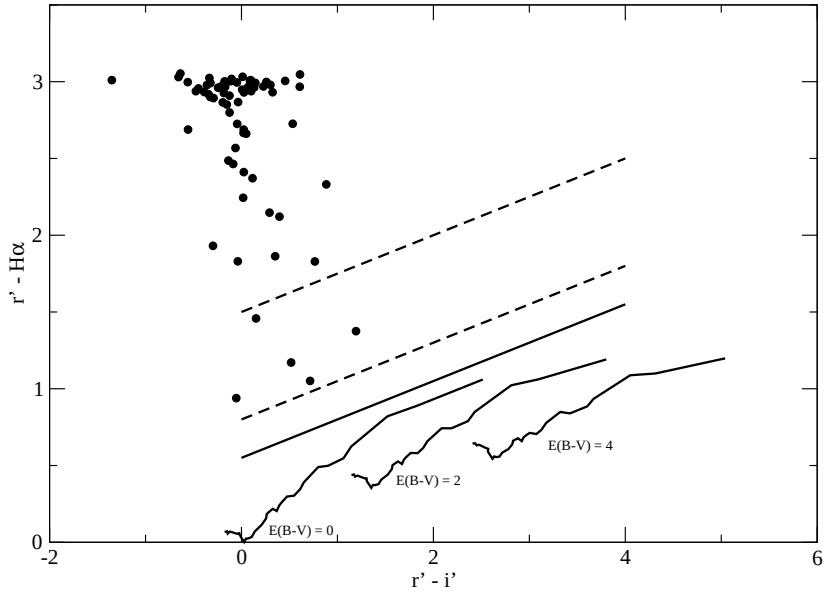

Fig. 2. The known PNe in the IPHAS two-color diagram (filled circles). Shown are also the synthetic tracks for main sequence stars with different reddenings [2]. The straight solid line is the first cut made to search for compact PNe candidates and the dashed lines show the cuts used in the final (visual) candidate selection (see text).

PNe 37 are unresolved or barely resolved (size around 1″) and 119 present 'unclear' morphology meaning that we either can not say what the morphology is from the existing images or we cannot be convinced about the genuine PN nature of the object before a spectroscopic study. For the remaining 133 objects we carried out a preliminary morphological classification.

4 Morphology of the IPHAS candidate PNe

4.1 Introduction to PN morphology

PNe present various morphologies: elliptical, bipolar, point-symmetric, irregular, stellar, etc. [6]. There is not yet available any standard classification scheme and the classes used are author dependent. There is observational evidence that the PN morphology is connected to its chemical abundances so that for example bipolar nebulae are overabundant in He and N [1]. With respect to Galactic distribution,

[4] found that the median Galactic latitude of the PNe increases from bipolars to ellipticals and to rounds. Also the central star properties are related to the morphology so that bipolar nebulae have more massive progenitor stars [1]. All these facts should be explained theoretically. So, the PN morphology study constraints the theories.

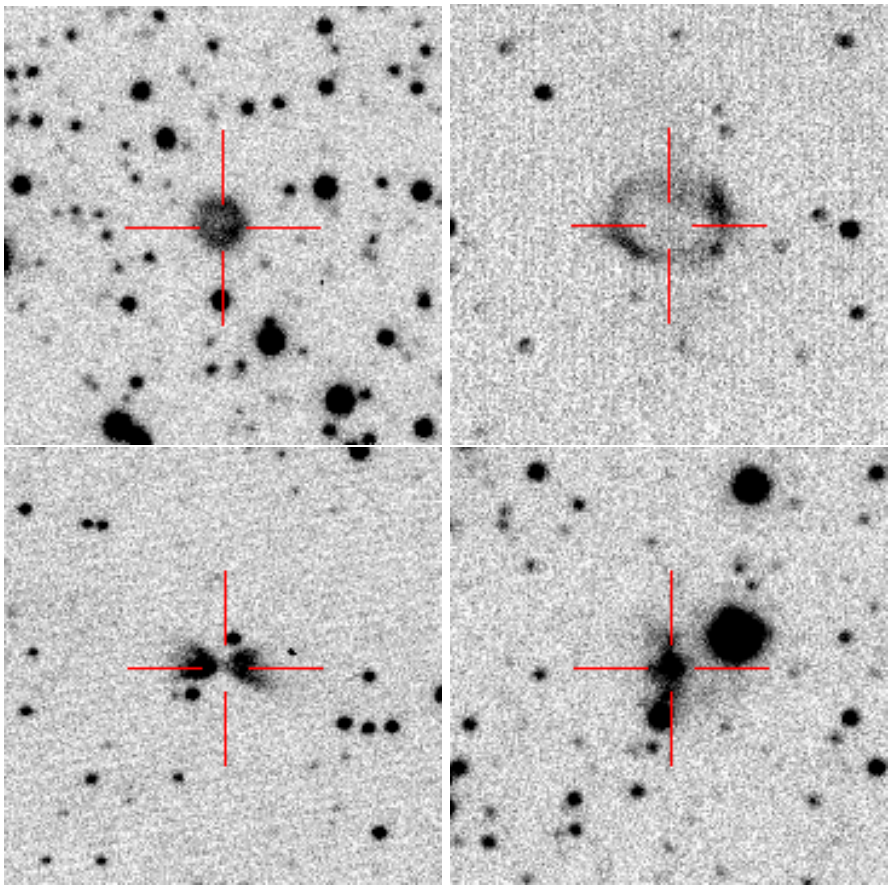

Fig. 3. Examples of different morphologies of IPHAS candidate PNe. From top right to down left: round, elliptical, bipolar and irregular PN candidate. The images sizes are $1' \times 1'$, North is up and East is to the left.

4.2 Properties of the IPHAS sample in the RA 18-20h region

Our sample includes 133 *candidate* PNe in the Northern Galactic Plane. Being just candidates, there exists the possibility that some of the objects might not be genuine PNe. However, considering the fact that we have discarded the unresolved/barely

resolved candidates as well as candidates with less 'PN-like' morphology, we can assume the sample to be quite clean. Before IPHAS, these objects have escaped from detection, often due their faintness. So, in general our sample represents a *low surface brightness* PNe population in the Galactic Plane.

4.3 The candidate PN classification

We classified our sample of 133 PN candidates based on their IPHAS Hα images into five morphological classes: round, elliptical, bipolar, point-symmetric, and irregular. We did not consider the stellar-like objects for this study as before spectroscopic confirmation the danger of 'contamination' by emission line stars is high. We found that the majority, 46%, of them are rounds, 20% ellipticals, 20% irregulars, 14% bipolars, and none turned out to be point-symmetric. We compared first our result with the morphological study of 359 southern PNe by [1]. They do not separate round and elliptical PNe, thus we also combined these two groups. The result is shown in Table 1. The percentage values of different morphological groups in these two studies are almost identical. This is somehow surprising considering that our sample is concentrated on the Galactic Plane (where most of the bipolars are expected to be found) while the sample of [1] includes PNe from all southern Galactic latitudes. Second, we compare our results with those from [4]. They divide their sample of 255 northern PNe in only three groups: round, elliptical, and bipolar, and we compared their classification with our corresponding sample (106 candidate PNe). The results are shown in Table 2. The percentage of round PNe is clearly higher in our study as compared to [4] results. So, it seems that we are finding a new, round, faint PN population in the Galactic Plane.

Table 1. Comparison between the morphological classification of our candidate PNe and the classification of a sample of southern PNe by [1].

	elliptical	bipolar	irregular	point-symmetric
our study	66%	14%	20%	0%
Corradi & Schwarz	64%	14%	18%	4%

Table 2. As in 1 for a sample of Galactic Plane PNe by [4].

	round	elliptical	bipolar
our study	58%	25%	17%
Manchado et al.	28%	59%	13%

5 Discussion

From our preliminary morphological study of candidate PNe in the RA 18-20h region of the Galactic Plane we can derive two main conclusions: 1) the relative amount of bipolar PNe is not higher in our Galactic Plane sample (of generally faint PNe) as compared to the sample of [1] including PNe at a wide latitude range. 2) The amount of round PNe is clearly higher in our (faint PN) sample than in a Galactic Plane sample of [4].

As a matter of fact [8] argues that most of the faint undetected PNe would be spherical. Our results support this idea. However, to directly compare with [8] predictions, a PN should be considered as spherical only if both its outer and inner structures are spherical. In our study (as in [3]) if the inner structure is visible, the outer structure defines the shape. However, in most of our faint spherical candidate PNe, there is no inner structure visible.

However, before deriving firm conclusions, some caution should be taken. The morphological classifications in the studies compared here are made visually and from images taken with different instruments, observing conditions, filters, etc. Visual inspection is always subjective and the PN appearance can vary at different wavelengths and with the deepness of the image. As a first step, to make the comparison IPHAS (faint) PNe – known PNe more robust, the classification of the known Galactic Plane PNe should be redone using the IPHAS images, and then compared to the new PN candidate sample. This is left for a future work.

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