

## DISCOVERY OF NEW FAINT NORTHERN GALACTIC PLANETARY NEBULAE

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### RESUMEN

Presentamos el descubrimiento de 6 objetos nebulares realizado por astrónomos aficionados. Cuatro de estos objetos son claramente nebulosas planetarias, uno es posiblemente también una nebulosa planetaria, y el último es probablemente una región H II. La nebulosa bipolar Ou4 tiene la extensión angular más grande hasta ahora encontrada: más de un grado en el cielo! Consideramos varios escenarios para explicar este objeto. Ou4 podría ser una de las nebulosas planetarias más cercanas, aunque su naturaleza como tal debe aún ser confirmada.

### ABSTRACT

We present the discovery of 6 nebular objects made by amateur astronomers. Four of these discoveries are clearly planetary nebulae (PNe), one is a possible PN, and another is a likely H II region. The bipolar nebula Ou4 presents the largest angular extent ever found: over one degree on the sky! We consider various scenarios that could explain such a nebula. Ou4 could be one of the nearest PNe known, though its possible PN nature will need confirmation.

*Key Words:* planetary nebulae: general — surveys

### 1. INTRODUCTION

According to the most generally accepted paradigm, planetary nebulae (PNe) represent the luminous transitory phase of the end of the life of low and intermediate mass stars (0.8 to 8  $M_{\odot}$ ). About 2,850 PNe have been detected so far in the Galaxy, according to the new consolidated database of PNe (Miszalski et al. 2012), which gather the PNe listed in the Strasbourg catalogue (Acker et al. 1992), the PNe discovered in the Southern Hemisphere by the AAO-UKST H $\alpha$  Surveys (MASH; Parker et al. 2006; Miszalski et al. 2008), and in the northern IPHAS Survey (Drew et al. 2005; Viironen et al. 2009; Sabin et al., in preparation).

However, the expected Galactic PN population is estimated to be between 6,000 and 25,000 or more

(Frew & Parker 2006; Jacoby et al. 2010), depending on the possible role of binaries in forming PNe. Moe & De Marco (2006) argued, based on population synthesis, that only  $\sim 20\%$  of low- and intermediate-mass stars produce a PN, with the remainder transiting between the AGB and white dwarf phases with invisible, or under-luminous nebulae. Soker & Subag (2005) predicted that deep searches could find the brightest among these underluminous PNe and that they would be spherical. This prediction has only been partly borne out by the MASH surveys mentioned above that doubled the fraction of spherical PNe from  $\sim 10\%$  to  $\sim 20\%$ , and by the Deep Sky Hunters survey that found a similar fraction (Jacoby et al. 2010). It is thus necessary to try to find many more faint PNe, so as to clearly establish the necessary observational framework to compare with theory.

In this paper, we present the detection of 4 new PNe and one possible new faint PN from deep multi-colour images obtained by amateur astronomers, in addition to one H II region as an example of a “tricky” object. The paper is organised as follows: in § 2, we present the imaging programmes that led

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to the discoveries, while § 3 presents spectroscopy for two of the brightest of the newly found objects. Finally, § 4 looks into each object for more detail.

## 2. SEARCH METHODS

As mentioned above, a group of amateur astronomers named the Deep Sky Hunters (Kronberger et al. 2006) have been methodically scanning the digital sky survey (DSS), thereby visually identifying dozens of faint PN candidates in the Galactic plane. Most objects were confirmed by spectroscopy or through narrow-band CCD imaging. The discovery of 60 faint PNe using this method is reported in Jacoby et al. (2010). This sample is notable for the large proportion of spherical PNe at high latitudes, a trait first seen in MASH-I and MASH-II PNe (Parker et al. 2006; Miszalski et al. 2008).

Visual searches of all-sky plates are much less sensitive to compact PNe which may be an important complement at high latitudes, where distant halo PNe are expected to reside. Miszalski et al. (2011) introduced the Extremely Turquoise Halo Object Survey (ETHOS) and its first discovery, ETHOS 1 (PN G068.1+11.0), which is a compact PN that hosts a pair of jets and a close binary central star ( $P = 0.535$  d). The ETHOS takes a similar approach to MASH-II by processing the catalogue photometry from Hambly et al. (2001) in search of new PN candidates and thereby explores a complementary parameter space to that of Jacoby et al. (2010).

There is, however, another way in which amateurs can help in discovering new, faint PNe. Since about 10 years ago, amateur astronomers have been equipped with CCD imagers with high sensitivity and  $\sim 1$  arcsec resolution, allowing them to obtain images with high resolution and contrast, and with unprecedented depth, using narrow-band filters. The most impressive example so far is without doubt the “Soap Bubble” that measures  $\sim 260''$  across and features a  $B_J = 19.45$  mag central star as measured by the SuperCOSMOS catalogue. Discovered by Dave Jurasevich (2009), it was then painstakingly confirmed as being a planetary nebula (Ju 1, PN G075.5+01.7; J2000  $20^h 15^m 22^s .2$ ,  $+38^\circ 02' 58''$ ). It is noteworthy that, relating his discovery in a popular magazine, Jurasevich recognised the difficulty of reporting it in an IAU Central Bureau Electronic Telegram, which is not really equipped to handle discoveries of objects of a non-transient nature such as PNe.

Here we report on the use of similar deep narrow-band imaging to find new PNe that was performed by amateur astronomers F. Alves, N. Outters and

P. Le Dû in the vicinity of various H II regions (Sharpless 1953) and PN G080.3–10.4 (MWP1; Motch, Werner & Pakull 1993). The high sensitivity, exclusive telescope time and large field of view of their setup greatly contributed to their discoveries.

To confirm their discoveries, we cross-checked the candidate objects on POSS-I and POSS-II images to guard against plate defects (Parker et al. 2006). Then, we checked whether the object was not already cataloged (e.g., in SIMBAD or in the PN catalogues of Acker et al. 1992, 1994; Parker et al. 2006; Miszalski et al. 2008). Additional digitised photographic  $B$ ,  $R$  and  $I$  images (Hambly et al. 2001) and  $H\alpha$  images from the IPHAS survey (Drew et al. 2005; González-Solares et al. 2008) were then retrieved. The former allow for faint blue central stars to be identified, while the latter allow the nebula morphology to be assessed.

Table 1 presents the characteristics of the 6 newly discovered objects. The following information is provided:

- Lines 1 and 2: the usual name (truncated author’s name) and the PN G denomination.
- Lines 3 and 4: the J2000 coordinates, and the angular size.
- Line 5: the CSPN identification and magnitude, if available. The  $B_J$  and  $R_F$  magnitudes correspond to the ones determined by the Second Palomar Sky Survey (Reid et al. 1991) made available by Hambly et al. (2001).
- Line 6: the name of the discoverer, and the discovery date.
- Lines 7 and 8: the technical details concerning the telescope and CCD camera, and the exposure times using different filters.
- Line 9: the exposure time and date of the spectroscopy, if any.
- Line 10: details on other images of the object available.
- Line 11: the name of objects observed near the newly discovered object.

The observations were made using a 200mm F/D 3.7 Newtonian telescope (Alves), and a Takahashi FSQ106-F/D 5 telescope (Le Dû and Outters), with commercially available cooled CCD cameras (Fingerlake and Sbig with KAF6303e, QSI and Fingerlake with KAF8300). The narrow-band filters are centred

TABLE 1  
CHARACTERISTICS OF THE NEWLY DISCOVERED NEBULAE

OBJECT	Out1	Out2	Out3	Out4	IDu1	Alv1
PN G	Possible PN? or small H II region?	120.4-01.3	059.2+01.0	098.5+07.9 (TBC)	094.5-00.8a	079.8-10.2
Position J2000	04 07 21.6 +51 24 22	00 30 56.8 +61 24 34	19 38 17.5 +23 45 49	21 11 48.2 +59 59 12	21 36 05.5 +50 54 10	21 15 06.6 +33 58 18
Size	75" × 55"	80"	92"	1°9'24" × 19'48"	132"	270"
CSPN magnitude	$B_J = 19.38$ $B_J - R_F = -0.60$	$B_J = 19.58$ $B_J - R_F = -0.26$	$B_J \sim 21$	unclear (see text)	$B_J = 21.64$	$B_J = 18.22$ $B_J - R_F = -0.40$
Discoverer	Outters N.	Outters N.	Outters N.	Outters N.	Le Dú P.	Alves F.
Discovery date	2007-2009	Nov 2010	Nov. 2009	June 2011	Aug. 2011	Nov. 2009
Instrument Optic CCD camera	F SQ106 F/5 FLI img6303e	F SQ106 F/5 SbigSTL6303e	F SQ106 F/5 FLI img6303e	F SQ106 F/5 SbigSTL6303e KAF6303e	F SQ106 F/5 QSI 583wsg KAF8300	8" ASA astrograph F/3.7-FLI Microline
Exposure time	9h H $\alpha$ 9.5h S[II] 5.5h O[III]	20.5h H $\alpha$ 5.6h BVR	11h H $\alpha$ 11.5h S[II] 13.5h O[III]	18h H $\alpha$ 8h S[II] 12.5h O[III]	18h20 H $\alpha$ 13h40 S[II] 11h40 O[III]	14.1h H $\alpha$ 8.6h O[III] BVR
Spectrum (exp. time) date	- -	40 min 23-26/08/11	- -	40 min 23-26/08/11	- -	- -
Other images	-	IPHAS WISE W4 (22 $\mu$ m) POSS2/UKSTU	IPHAS	-	IPHAS Pöpsel & Binnewies	POSS-II DSS red
Object nearby	NGC 1491	Sh2-173	NGC 6820	Sh2-129 HR 8119	Sh2-124 PN G094.5-00.8	MWP1

TABLE 2  
EMISSION LINE INTENSITIES  
(UNCORRECTED FOR INTERSTELLAR  
REDDENING) OF OU2 AND OU4

Line	Ou2 (H $\beta$ =100)	Ou4 (H $\beta$ =100)
He II 4686	100	
H $\beta$ 4861	100	100:
[O III] 4959	362	462
[O III] 5007	1153	1533
H $\alpha$ 6563	453	227:
[N II] 6583	trace	
[Ar III] 7135	trace	

For Ou4, the H $\beta$  detection is very uncertain and the quoted value is only an upper limit. The H $\alpha$ /H $\beta$  line ratio leads to a visual extinction constant,  $\text{CH}\beta = 2.84 \log((\text{H}\alpha/\text{H}\beta)/2.86)$ , equal to 0.6 for Ou2 and about 0 for Ou4.

on 656 nm (H $\alpha$ ), 672.5 nm ([SII]), and 500.7 nm ([OIII]), respectively. Alves used filters of the brand Astronomik, whose widths were 6 nm for H $\alpha$  and 12 nm for [OIII], while Le Dû and Outters used filters from Astrodon. These have a FWHM of 5 nm, except the [OIII] filter used to observe Ou4, which had a FWHM of 3 nm. The various narrow-band images were digitally combined, so as to produce colour images.

### 3. SPECTROSCOPY

We obtained spectra for the two brightest of the six candidates, i.e. Ou2 and Ou4. The observations were performed by one of us with the 2.1 m telescope at the San Pedro Mártir Observatory (OAN-SPM<sup>9</sup>) equipped with a Boller & Chivens spectrograph and a Marconi 2 CCD (2048  $\times$  2048 pixels with a spatial resolution of 1.22''/pixel). The long slit had a length of 5' and a width of 200  $\mu\text{m}$  (about 2''). A position angle of 90 degrees was adopted as well as an exposure time of 2400 seconds. Due to the faintness of the targets we also took great care while positioning the slit, making sure it also contained enough sky for background subtraction. For Ou4, the slit was placed on the brightest part of the nebula, i.e. on the eastern edge of the southern lobe. The observations took place between 23–26 August 2011. A 400 l/mm grating was used in order to cover the range  $\sim 4330$ – $7530$  Å with a resolution of  $\sim 5$  Å (FWHM). We used

<sup>9</sup>The Observatorio Astronómico Nacional at the Sierra de San Pedro Mártir (OAN-SPM) is a national facility operated by the Instituto de Astronomía of the Universidad Nacional Autónoma de México.

a  $2 \times 2$  binning to increase the signal. The observing conditions were variable during the run with thin meandering clouds and therefore non-photometric sky. The data were bias subtracted, flatfielded, and wavelength calibrated using a copper-argon lamp. The flux calibration was done using the spectrophotometric standard star BD+284211, which was observed with a wide slit of 1200  $\mu\text{m}$ . The reduction was performed using standard routines in IRAF.

Figure 1 presents the reduced flux-calibrated spectra of Ou2 and Ou4. The spectrum of Ou4 was extracted by adding the brightest 25'' of emission and subtracting an adjacent sky region of the same size. Due to the very low surface brightness only the strongest emission lines can be seen. Table 2 gives the measured line intensities. In both cases the reddening is very low, but difficult to accurately measure.

These spectra were taken for classification purposes and therefore only the brightest nebular lines are measurable. The remaining apparent peaks are sky subtraction residuals: no emission is visible for the lines of [SII]-6717/32, and [NII] 6584 is just detectable for Ou2. This is a known situation: for most classical bright PN, the [SII]-doublet total intensity is very low (and can be about 150 times fainter than H $\alpha$  or not measurable), and a similar situation is observed for [NII]-6584 (see the line intensities of galactic PN in Acker et al. 1992). Note that in the case of shocked excited nebulae, the [SII] lines could be as intense as H $\alpha$  and [OI]-6300 lines.

### 4. ANALYSIS OF THE 6 PN CANDIDATES

For the four objects Alv1, IDû1, Ou2 and Ou3, their round morphology and blue CSPN are convincing evidence that they are fairly old PN. The object Ou4 presents an extended bipolar morphology and is of great angular extent. We discuss it extensively in § 4.6. The Ou1 candidate is most likely an H II region.

#### 4.1. *Alv 1 – PN G079.8-10.2*

A faint PN candidate was serendipitously discovered during an imaging session of the exotic planetary nebula MWP 1 (PN G080.3–10.4) with a wide field of 60' by 80' centered on MWP1. Optical observations were performed remotely at the CROW observatory in Portalegre, Portugal, during several observing runs. Images were taken using a 60 Å wide H $\alpha$  filter and a 120 Å wide [O III] filter, as well as wide-band *BVR* images. Exposure times ranged from 600 s to 1800 s using  $1 \times 1$  or  $2 \times 2$  binning

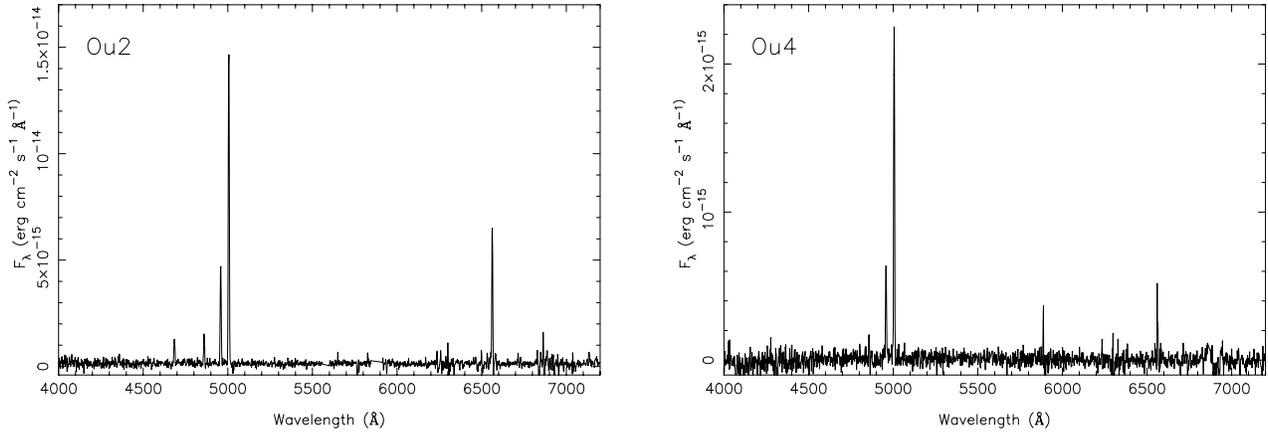


Fig. 1. SPM spectra of Ou2 (left) and Ou4 (right).

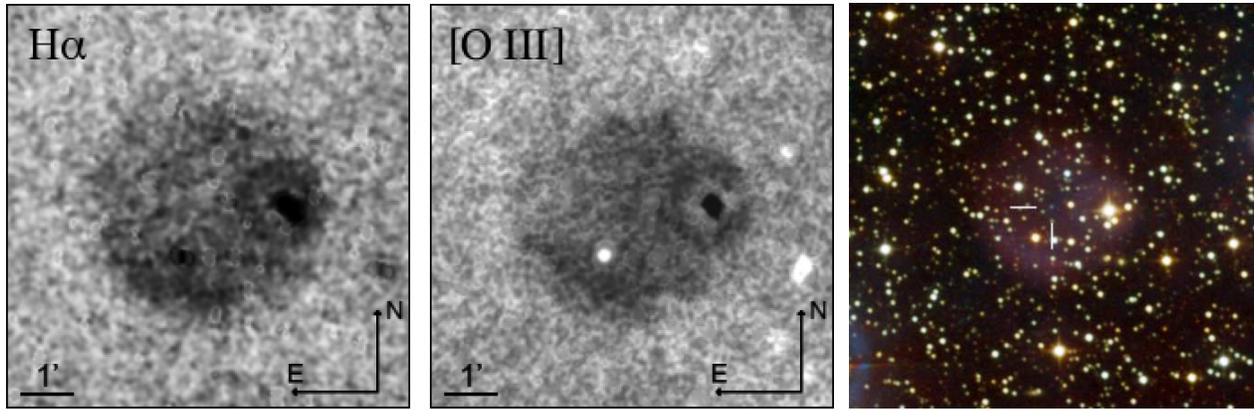


Fig. 2. Images of Alv1. Left:  $H\alpha$  and  $[O\ III]$  plates with continuum subtracted. Right: Location of the very blue candidate central star. The color figure can be viewed online.

depending on seeing and weather conditions. Exposures were later properly calibrated (i.e., debiased and flat-fielded), aligned and co-added.

Images taken during about 23 hours with the wide-band Astronomik  $R$  and  $V$  filters were used to subtract the continuum from the  $H\alpha$  and  $[OIII]$  plates respectively; convolutions were applied in order to homogenize the PSFs between plates, and subtraction weights were found empirically to remove the stars. Figure 2 (left) shows the final images obtained for Alv1.

By overlaying the broadband  $BVR$  plates on our image, a very blue star (Figure 2 right) of  $B \sim 18.2$  is found approximately  $12''$  away from the geometrical centre of the nebula, and could possibly be the central star of this object, thereby increasing the possibility of it being a PN. We note that it is not unusual to find a slightly offset central star: this could be related to ISM-wind interaction, high proper motion

of the central star, the presence of a binary system at the centre, or simply some asymmetry of the nebula itself. An extensive kinematical study would be necessary to assess the reason for this, but such a study is beyond the scope of the current paper.

#### 4.2. $lD\hat{u}\ 1 - PN\ G094.5-00.8a$

Three small round nebulae were found in a  $90' \times 50'$  field around the H II region Sh2-124 in July and August 2011. Two of them are known PNe, and the other is a much fainter new nebula (Figure 3). 43.3 hours of observations with  $H\alpha$ ,  $[SII]$ , and  $[OIII]$  filters were accumulated to confirm that this is a new PN with a very faint central star, also seen on previous images from the IPHAS Survey (Figure 3 bottom).

#### 4.3. $Ou2 - PN\ G120.4-01.3$

Accumulating 41 hours of observations in  $H\alpha$  of the field around the H II region Sh2-173, a small

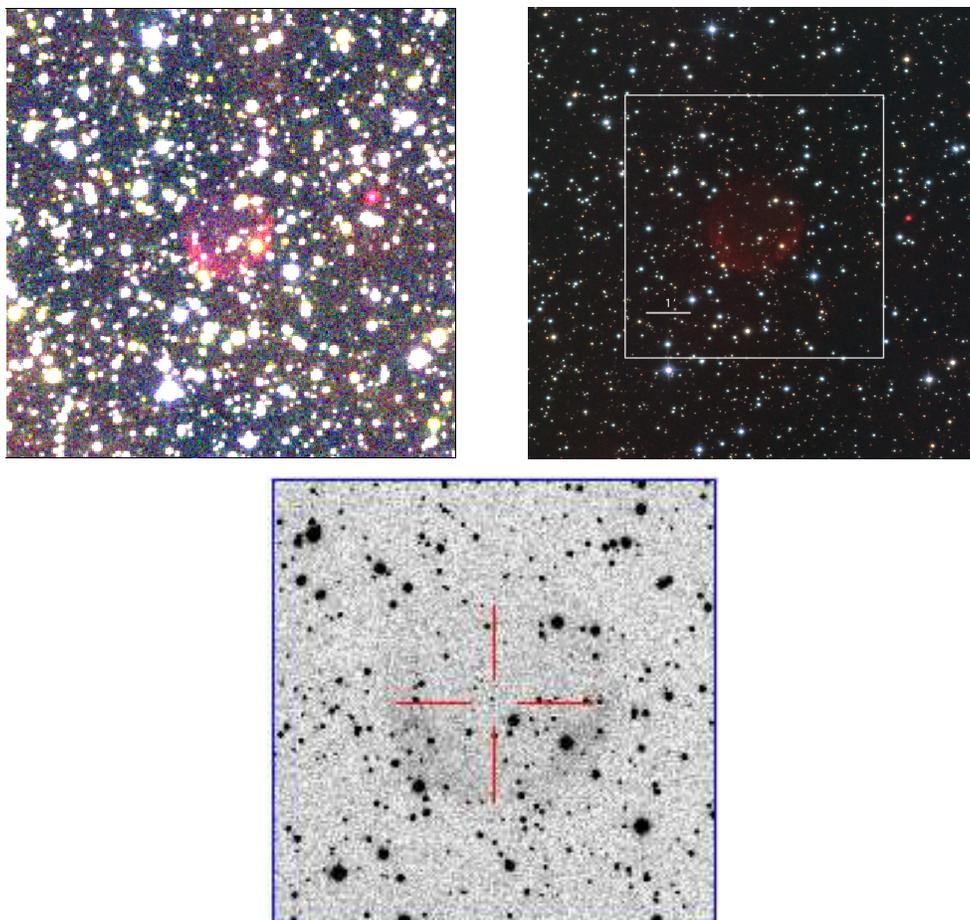


Fig. 3. Top left: Zoom onto IDu 1, together with the nearby ( $208''$ ) known compact PN K 3-83 (PN G094.5–00.8). The  $10.25' \times 10.25'$  image is made from  $H\alpha$  (red), [SII] (green) and [OIII] (blue). Top right: zoom on IDu1, with the small PN K3-83 at right (image  $H\alpha$ RGB composite, by Josef Pöpsel, Stefan Binnewies, Capella Observatory, 9h exposure). Bottom:  $H\alpha$ + [N II] image of the PN from the IPHAS survey ( $150 \times 150$  arcsec<sup>2</sup> and  $1.33''$ /pixel). North is up, east to left in all images. The color figure can be viewed online.

round object ( $1.5'$  in diameter) was discovered, with a central star appearing very blue on the  $B$  image. The PN is visible on previous IPHAS images (Figure 4).

The spectrum (Figure 1) is dominated by the green [OIII] doublet and the high intensity of the He II 4686 line (see Table 2). This implies a very high excitation, and a very hot CSPN.

#### 4.4. *Ou3* – PN G059.2+01.0

This object was discovered on a narrow-band image of the field around the H II region NGC 6820, after exposing for 36 hours. As shown on Figure 5, a double ring is well detected on the [OIII] image, with a diameter of about  $1.8'$ . A very faint nebula around a possible CSPN appears on the corresponding IPHAS image (Figure 6).

#### 4.5. *Ou1* – A non-PN but H II region?

Studying in detail the region surrounding the H II region NGC 1491, a faint nebula of about  $1.2' \times 1'$  extension was discovered in the field. Exposures of 10-min each were accumulated over 4 consecutive nights for a total of 24 hours of observations with Astrodon  $6 \mu\text{m}$ -wide  $H\alpha$ , [SII] and [OIII] filters. The final image was composed using the *Ccdautopilot3* software (Figure 7). A very blue star lies roughly at the centre of the nebula and is certainly responsible for the observed nebula seen in the [OIII] image.

The asymmetric morphology of *Ou1* bears strong resemblance to that of A35, a PN distorted by interaction with the interstellar medium due to its high proper motion (Acker et al. 1998). But in *Ou1*, the star is very close to the centre and not located near the compressed zone. Given its very close proximity

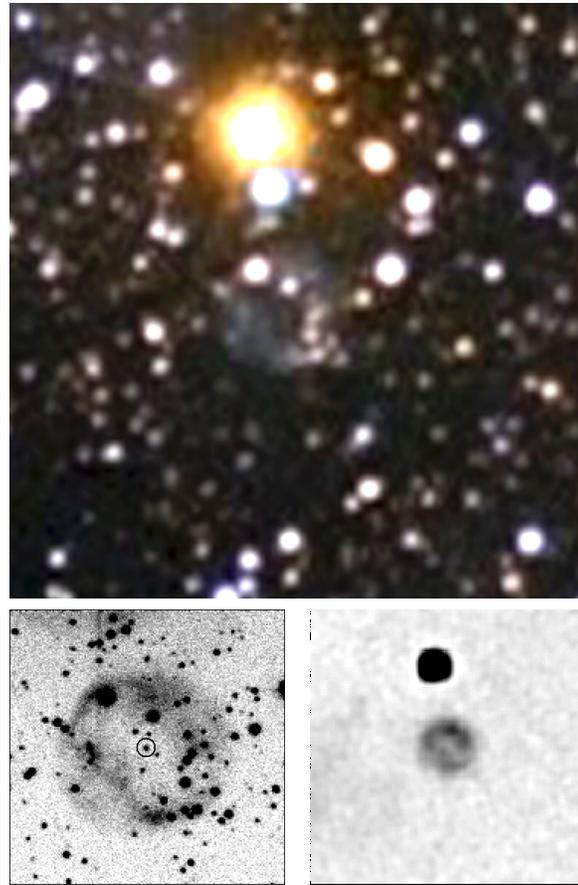


Fig. 4. Top: Composite  $H\alpha$ RGB image showing the new PN Ou2 ( $6 \times 6$  arcmin). Bottom left:  $H\alpha + [N II]$  image from the IPHAS Survey ( $120 \times 120$  arcsec) with the central star candidate circled. Bottom right: *WISE* W4 ( $22 \mu\text{m}$ ) image ( $6 \times 6$  arcmin) that has had a small amount of unsharp masking applied. North up, east left. The color figure can be viewed online.



Fig. 5. Field around the nebula NGC 6820 (composite  $H\alpha$ RBV), with the object Ou3 shown in  $[O III]$  in the  $6' \times 6'$  insert. The color figure can be viewed online.

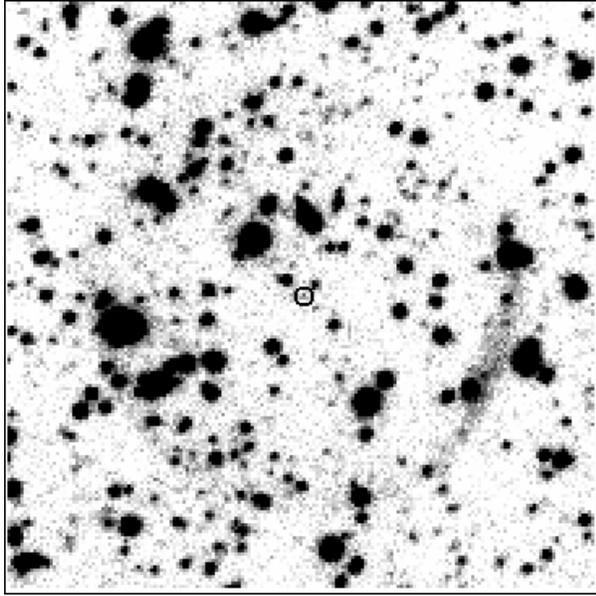


Fig. 6.  $H\alpha+[NII]$  image of Ou3 from the IPHAS Survey (North up, East left).

to another H II region and its patchy  $H\alpha$  morphology unlike other PNe, we classify Ou1 as a likely H II region rather than a PN. Ultimately a spectrum of the  $B_J = 19.38$  mag ionising star will decide between the two possibilities.

#### 4.6. *Ou4* – PN G 098.6+07.9 (TBC)

While observing Sh2–129, a strange object was discovered inside this large nebula: with the narrow [OIII] filter, a bipolar nebula appears (Figure 8). Its shape is similar to well-known bipolar PNe, such as Mz3 (Santander-García et al. 2004), M2–9 (Corradi, Balick, & Santander-García 2011), and KJPN8 (López et al. 2000).

The morphology appears as a complex addition of two components: a small central disc-like structure and two elongated opposite lobes – comparable to the large faint “chakram” and the relatively short lobes of Mz3, both being seen in  $H\alpha+[NII]$  light (Santander-García et al. 2004, Figure 1).

The spectrum of Ou4 (Figure 1 and Table 2) is dominated by the green [OIII] doublet, whose total intensity is about 20 times larger than that of  $H\beta$ . Such a high excitation class is coherent with a very hot CSPN.

The very bright star lying in the central part of the nebula is HR 8119 ( $\alpha = 21^h 11^m 48^s .18$ ,  $\delta = +59^\circ 59' 09''$ ), of spectral type B0 II or B0 V, depending on the authors (see below). The star is thought to belong to the Cepheus OB2 massive star association,

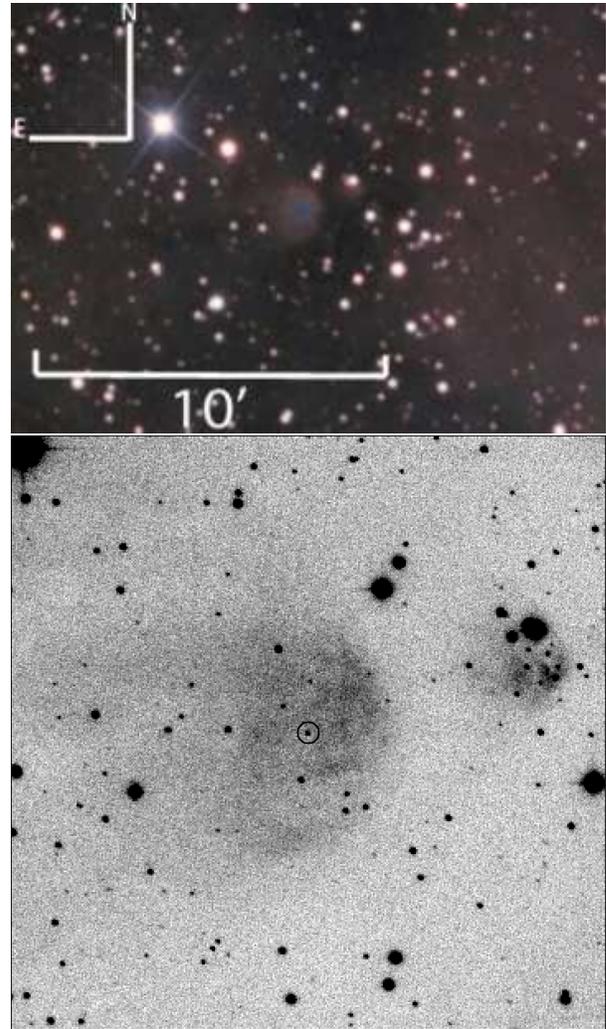


Fig. 7. Top: Discovery colour-composite image of Ou1 in [SII],  $H\alpha$ , and [OIII]. Bottom:  $H\alpha+[NII]$  image from the IPHAS survey. The circle indicates the position of the likely central star. The color figure can be viewed online.

the Sh2–129 H II region, or the Trumpler 37 cluster, and is variable ( $V = 5.51$  to  $5.57$ ). The star belongs to a triple system (Eggleton & Tokovinin 2008), with the following configuration in magnitude-spectrum and separation for the brightest components: Aa: 6.17-B0 II + Ab: ?; separation of  $0.06''$ , and B: 6.78; separation AB of  $1.035''$ . Using speckle interferometry, Mason et al. (2009) derived the following parameters for the triple system:

- stars AaAb: position angle =  $124.5^\circ$ , separation =  $0.045''$ ,  $\Delta V = 0.6$
- stars AB: position angle =  $212.5^\circ$ , separation =  $1.013''$ ,  $\Delta V = 0.3$ .

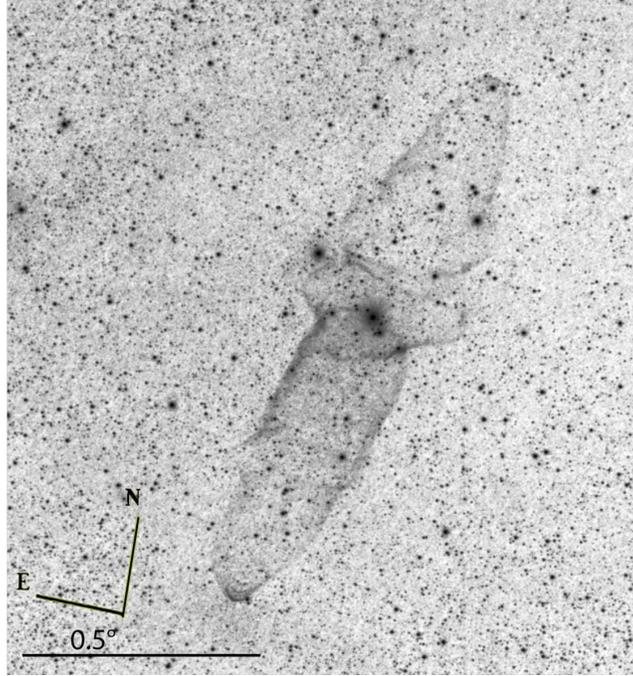


Fig. 8. Ou4 image obtained by 25 exposures of 30 min with a [OIII]-3 nm filter.

We may thus attribute the following magnitude values for the components: star Aa: 6.17, star Ab:  $6.17+0.6\sim 6.8$ ; star B:  $6.17+0.3\sim 6.5$ . Could the unknown faint component Ab of the B0 II star be a CSPN? We consider this and the opposite in the following.

We have also to take into account another characteristic of the system of HR 8119: the ROSAT all-sky survey includes the source 1RX J211148.9+595920, at about the same position than HR 8119 with a  $14''$  uncertainty. The source is found to have a flux of about  $10^{-13}$  erg cm $^{-2}$  s $^{-1}$  and a count rate of  $0.033 \pm 0.008$  counts s $^{-1}$ .

(a) *Is Ou4 connected with HR 8119?* Using the relation between the strengths of the interstellar Ca lines in the, assumed, B0 II star spectrum, and the distances to early-type stars, Megier et al. (2009) estimated a distance of  $1032 \pm 144$  pc, in agreement with the (poorly determined) parallax measured by Hipparcos ( $1315 \pm 726$  pc). Tetzlaff, Neuhäuser, & Hohle (2011) consider, on the other hand, that HR 8119 is a  $37.2 M_{\odot}$  young B0 V star, located in the Trumpler 37 cluster, at a distance of 835 pc. If we adopt a realistic absolute magnitude for such a B0 V star, i.e.  $M_V = -3.6$  (Walborn 1972), with an apparent magnitude of 6.1 (component Aa), we would find a distance of  $\sim 870$  pc, compatible with

the result of Tetzlaff et al. (2011). Note that the H II region Sh2-129 is closer than HR 8119: its kinematic distance is estimated as  $400 \pm 130$  pc (Brand & Blitz 1993).

We examine different possibilities based on the association of Ou4 and HR 8119.

If we assume that a PN emerges from the physical companion to HR 8119, we would of course be faced with two major problems. First, the young age of the system would preclude the evolution of a star up to the PN stage. And obviously a massive star cannot be a CSPN. Second, the large angular dimension ( $1^{\circ}10'33'' \times 19'54''$ ) would lead to an extension of the nebula of about 20 pc at a distance of about 1 kpc – much too large for a PN! As a comparison, the bipolar PN Mz3 (covering  $1.5'$  on the sky) extends only 0.5–1.2 pc, depending on the estimated distance (1 to 2.5 kpc; Santander-García et al. 2004).

Could Ou4 be a shell recently ejected by a nova associated with the X-ray source, as was for example seen for V445 Puppis (Woudt et al. 2009)? A priori, such a X-ray source could be associated with a close binary with an accreting white dwarf in the centre of Ou4, in agreement with the high excitation class of the nebular spectrum. However, if the object were located at the distance of 800–1000 pc, its intrinsic luminosity would be too high for a cataclysmic variable. We would thus have to assume it is even further

away, which makes it then difficult to reconcile with the extent of the nebula on the sky.

Another possibility is that Ou4 is some other kind of nebulosity related to HR 8119. Recently, Angeloni et al. (2011) discovered a giant, highly collimated jet from Sanduleak’s star in the Large Magellanic Cloud, with a physical extent of 14 pc. Sanduleak’s star shows an optical emission-line spectrum reminiscent of a dusty-type symbiotic star, including the presence of the Raman bands at  $\lambda\lambda 6825, 7082$ . Clearly this is not the case for HR 8119. However, its mere existence proves that large outflows of such nature are possible.

It seems that Ou4 is probably not associated with the distant B0 star HR 8119.

*(b) Is Ou4 a nearby PN?* One intriguing possibility would be that it is a highly excited PN, with a very hot CSPN, seen in the same direction as HR 8119, and, hence, seen as an optical companion (wrongly identified as Ab thus – see above), but without any physical link with the B0 star. A distance could be estimated by comparison with Mz 3: a typical extent for such PN would be 0.5–1 pc, which given the angular size of Ou4 would translate into a distance of  $\sim 25$ –50 pc. We note that the distance seems to be relatively small because the blue part of the spectrum (Figure 1 and Table 2) shows negligible extinction. If this were confirmed, Ou4 would be the nearest PN discovered to date! At such a distance, the corresponding absolute magnitude of the optical companion Ab ( $V \sim 6.8$ ) to HR 8119 would be 3.5–4.9, which is compatible with typical values for CSPNe.

Note that detections of diffuse X-ray emission were reported for more than 20 PNe, in particular BD+30°3639 (count rate  $0.242 \pm 0.004$  counts  $s^{-1}$ , Flux  $6.8 \times 10^{-13}$  erg  $cm^{-2} s^{-1}$ , Kastner et al. 2000), and Mz 3 (count rate  $0.0022 \pm 0.0003$  counts  $s^{-1}$ , Flux  $7.0 \times 10^{-15}$  erg  $cm^{-2} s^{-1}$ , Kastner et al. 2003), an emission associated here with the bow-shocks of the fast collimated outflows. As claimed by Guerrero, Chu, & Gruendl (2000), PNe are key to assessing the action of fast stellar winds and collimated outflows in the formation and evolution of PNe near the end of the AGB phase. However, the X-ray source observed here is based on extremely shallow all-sky measurements and clearly consistent with the B0 type star HR 8119.

At this stage, we are thus led to conclude that the nature of Ou4 is controversial: it could be a massive collimated outflow but without relation to the B0 star as it would produce an extremely large nebula considering the distance to the star. Or it could be a

PN which is  $\sim 0.5$ –1 pc across and  $\sim 25$ –50 pc away, in agreement with the absence of extinction. Ou4 should certainly become the target of many studies to come.

## 5. DISCUSSION AND CONCLUSIONS

In this paper, we have presented 6 newly discovered nebulae, obtained through very deep narrow-band imaging by amateur astronomers. Four of them (Ou2, Ou3, IDû1 and Alv1) are round, fairly evolved PNe, and correspond to the missing population of such PNe that is thought to exist. Such PNe are most easily discovered by the patient and dedicated work of amateur astronomers rather than by automatic surveys, most efficient at discovering small, compact objects. The example of IDû1, located just next to the small PN K3-83 discovered in 1972 by Kohoutek is very revealing in this respect. The detection of new PNe by experienced amateur astronomers will thus be an excellent support to improve the completeness of the Galactic planetary nebula census.

The fifth object is quite remarkable. Ou4 is a very large bipolar nebula, with a central “chakram”, opposite tubular lobes emerging from an invisible, hot central star. If confirmed as a PN, Ou4 may be the nearest PN known to date, with a possibly identified central star. If on the other hand, it is located at a distance of 800 pc to 1 kpc, it would be one of the largest bipolar nebulae discovered. Whatever its final nature, the complex shape and amazing properties make it an object of choice for further studies.

Most sources are located near the Galactic plane where many star forming complexes, H II regions, and molecular clouds are present, and there is a high probability of a candidate being nearby in projection, or physically associated, with one of those regions: it is the case of Ou4 (related to Sh2–129), and of Ou1 associated with a nearby H II region. The new PNe near the galactic plane are smaller (mean size of  $110''$  for 3 PNe) than those at higher latitude ( $70'$  and  $270''$ ). This could be related to the decreasing ISM density, although any shock caused by the ISM would make the PN much brighter than they are observed.

N. Outters observed 49 fields, whose sizes vary between  $24' \times 16'$  and  $180' \times 119'$ , and found three candidate PNe. P. Le Dû found four PNe –among which one new candidate– after observing 11 fields, of sizes between  $80' \times 60'$  and  $116' \times 88'$ . Compared to the number of PNe already known in these regions of the sky, this amounts to an increase of about 10% in the number of PNe. This is still far from the factor 10 we are looking for, as predicted.

We are, however, convinced that the contribution of amateur astronomers to the discovery of relatively nearby PNe inside the Milky Way will increase in the coming years. This could provide essential clues regarding the final number of PNe in the Galaxy and their origin. In particular, we stress the important role amateur astronomers could play in the less explored high galactic latitude regions, outside current professional H $\alpha$  surveys.

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