

PLANETARY NEBULAE DISCOVERED AND CONFIRMED BY AMATEUR ASTRONOMERS

P. Le Dû¹, Q.A. Parker², O. Garde³, T. Demange⁴, R. Galli⁴, T. Petit⁴, J. P. Cales¹, S. Chareyre¹, L. Ferrero¹, L. Huet¹, L. Mulato¹, N. Outters¹, T. Prestgard¹, G. Sun¹, H. Tan¹, M. Vanhuysse¹ and S. Zoll¹

Abstract. Unreferenced objects from the sky are regularly discovered by amateur astronomers from their own images or from professional images. Following the example of the Deep Sky Hunter list (DSH), thanks to the initiative of Agnès Acker and Pascal Le Dû [1][5], a list of planetary nebulae (PN) candidates is maintained in France and regularly published in the Société Astronomique de France (SAF) journal (*L'Astronomie*) and then in VizieR at the Strasbourg Astronomical Data Center (CDS). Recently, amateur astronomers specialising in spectroscopy have managed to observe the spectra of some of these candidates to confirm their nature.

Keywords: planetary nebulae, imaging, spectroscopy

1 Detections of planetary nebulae

1.1 Discoveries from amateur images

The detections are mainly made from instruments of small diameters with low f/D ratio, using efficient cameras with large, sensitive detectors, equipped with H α , [OIII] and [SII] narrow-band filters (Acker et al. 2012) (Fig. 1).

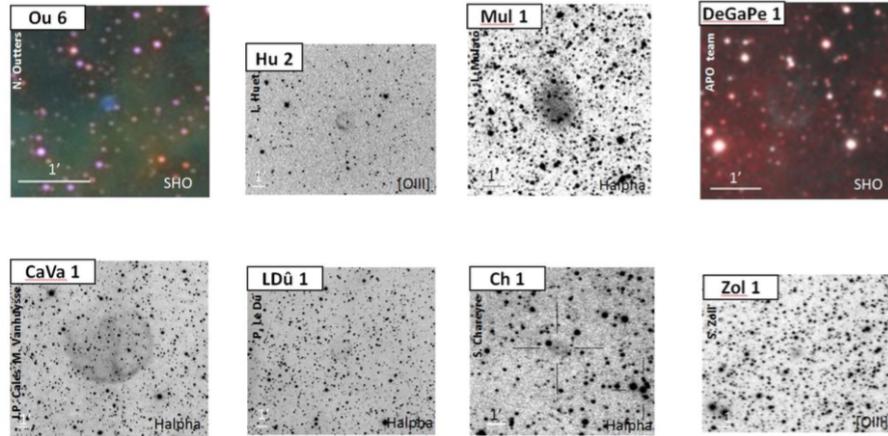


Fig. 1. PN candidates discovered from amateur images

¹ Deep Sky Hunter Collaboration (DSH)

² Department of Physics, University of Hong Kong, China

³ Tourbière Observatory, on behalf of the PNST team (S. Charbonel, P. Dubreuil, P. Le Dû, T. Lemoult, A. Lopez and O. Garde)

⁴ APO Team

1.2 Discoveries from professional images

Professional surveys at different wavelengths are easily accessible from advanced tools like Aladin from the CDS (Fig. 2). Objects are searched in the visible (DSS, DECaPS ...) but also in the medium infrared (WISE ...) (Jacoby et al. 2010; Parker et al. 2012; Kronberger et al. 2013) (Fig. 3).

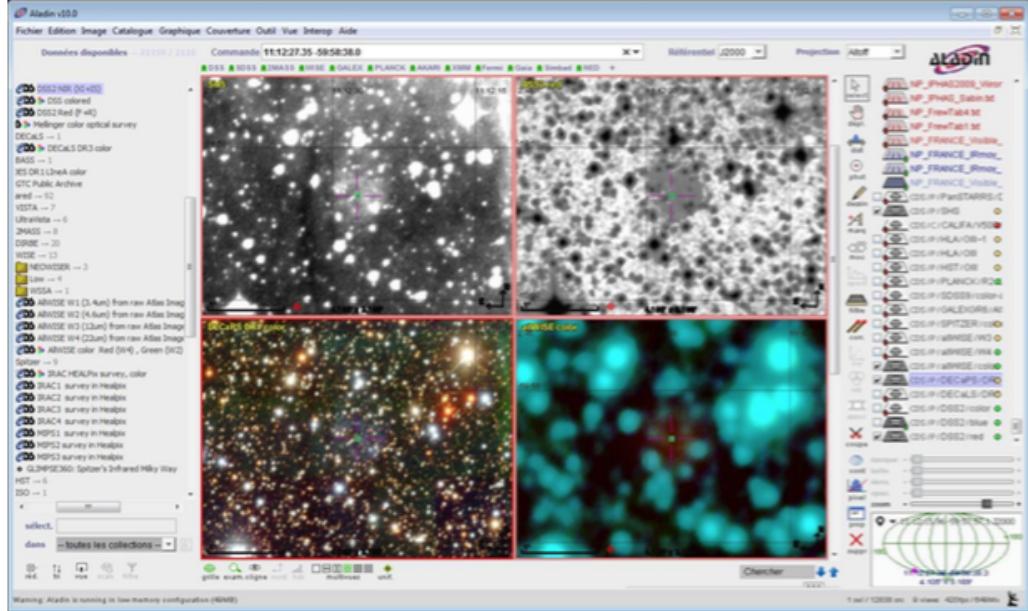


Fig. 2. Interactive sky atlas Aladin (CDS)

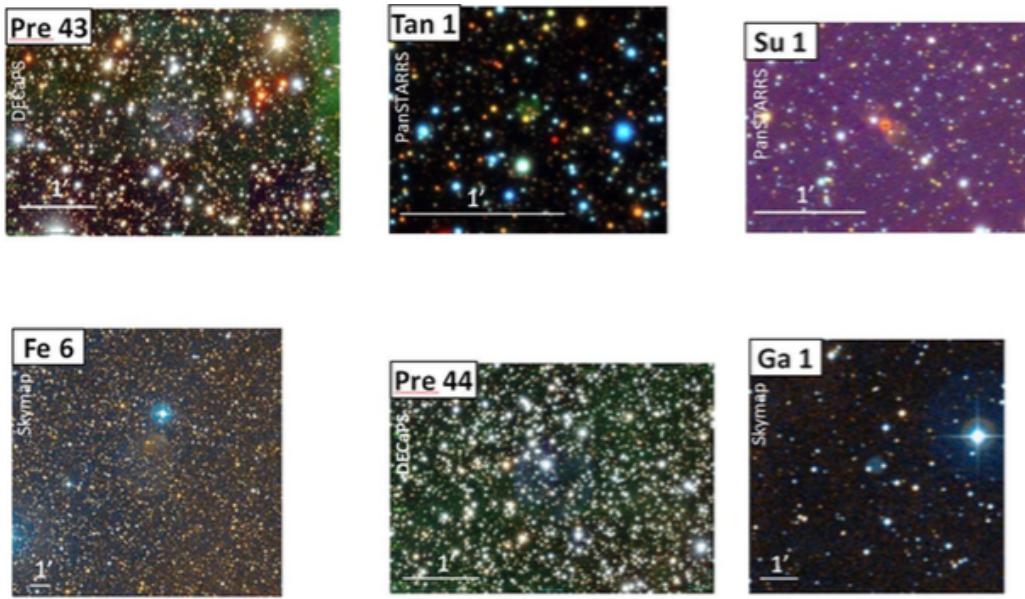


Fig. 3. PN candidates discovered from professional images

1.3 Planetary nebulae candidates

The French list of PN candidates contains 320 objects and 57 objects of unknown nature listed in a second table (Fig. 4).

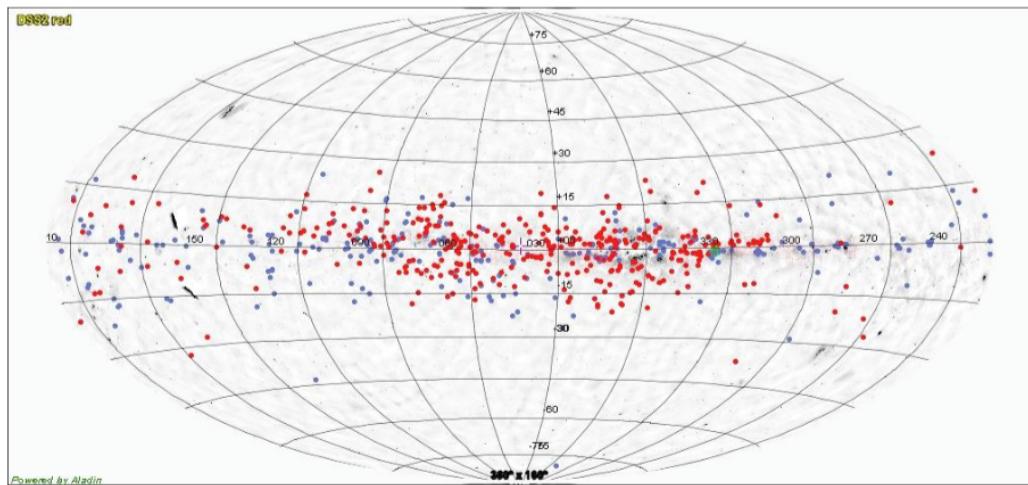


Fig. 4. PN Candidates from DSH list (blue) and French list (red).

2 Spectroscopic confirmations

2.1 Instruments and teams

The spectra of some candidates were acquired with modest instruments from 0.09 m to 0.2 m diameter (Fig. 5). Specific missions have allowed amateur teams like the PNST to use larger telescopes from 0.5 m (AstroQueyras) to 1 m diameter (Calern C2PU) (Fig. 6). The spectrographs used are at low resolution at $f/D = 5$.

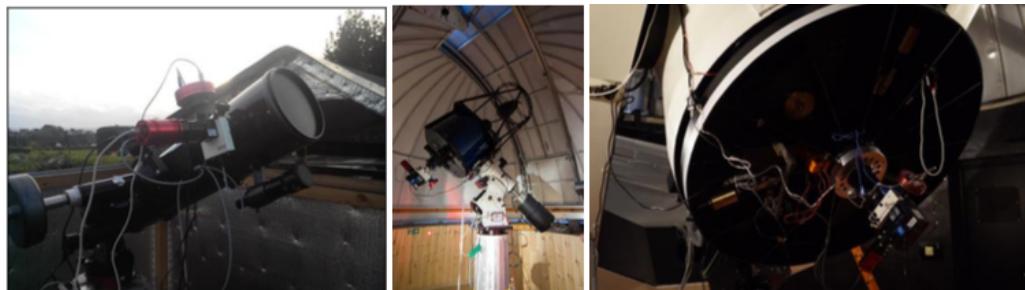


Fig. 5. Instrument used for spectroscopic confirmation



Fig. 6. Members of the PNST installing a spectrograph at the AstroQueyras Observatory

2.2 Some observed candidates

More than 50 PN candidates spectra showing nebulae lines have been observed by amateur (Table 1).

Candidate	RA (J2000)	DEC (J2000)	Place	Instrument	Observer	Emission lines
Ou 4	09:50:48.00	-28:01:51.60	OHP (04)	85mm/LISA	C. Buil	[OIII] (5007)
Ou 5	21:14:20.00	+43:41:35.00	Castanet (31)	200mm/ALPY	C. Buil	HeII (4686), H β (4861), [OIII] (4959/5007), H α (6563), [NII] (6583)
Ra 1	18:54:45.77	+36:30:12.00	OHP (04)	130mm/LISA	PNST (1)	HeII (4686), H β (4861), [OIII] (4959/5007), [NII] (6583), H α (6563)
Mul 5	19:49:53.70	+18:40:15.10	Castanet (31)	200mm/ALPY	C. Buil	[OIII] (4959/5007), H α (6563)
LDû 18	21:29:52.51	+50:54:19.18	AstroQueyras (05)	508mm/LISA	P. Le Dû	H β (4861), [OIII] (5007), H α (6563)
Zol 1	20:53:49.60	+46:46:47.00	Piera (Espagne)		J. Guarro	[OIII] (4959/5007), H α (6563)
KnFe 1	20:38:09.15	+61:55:05.00	Porspoder (29)	200mm/ALPY	P. Le Dû	[OIII] (4959/5007), H α (6563)
Fe 8	02:10:10.64	+65:25:15.30	Porspoder (29)	200mm/ALPY	P. Le Dû	[ArIV] (4711), [NII] (6548/6583), H α (6563)
Ra 5	21:02:38.00	+44:46:42.00	OHP (04)		PNST (2)	H β (4861), [OIII] (4959/5007), [NII] (6548/6583), [SII] (6716/6731), H α (6563)
LDû 1	21:36:06.35	+50:54:04.80	AstroQueyras (05)	508mm/LISA	PNST (3)	[OIII] (5007), [NII] (6548/6583), H α (6563)
Pre 8	01:26:36.00	+18:51:19.80	AstroQueyras (05)	508mm/LISA	PNST (3)	[OIII] (5007), H α (6563)
Ra 3	19:12:10.00	+16:46:33.00	AstroQueyras (05)	508mm/LISA	PNST (3)	H β (4861), [OIII] (4959/5007), [NII] (6548/6583), H α (6563)
Mul-Ir 19	20:34:26.20	+31:18:33.12	AstroQueyras (05)	508mm/LISA	PNST (3)	HeII (4686), H β (4861), [OIII] (4959/5007), H α (6563), [NII] (6583)
Mul-Ir-14	19:16:21.40	+16:56:36.60	AstroQueyras (05)	508mm/LISA	PNST (3)	H β (4861), [OIII] (4959/5007), H α (6563), [NII] (6583), HeI (7065), Ar[III] (7136), [OII] (7320/7325)
Ra 4	20:44:13.00	+36:07:38.00	AstroQueyras (05)	508mm/LISA	PNST (3)	[OIII] (5007), [NII] (6548/6583), H α (6563)
LDûPa 1	19:11:56.23	+15:25:25.20	AstroQueyras (05)	508mm/LISA	PNST (3)	[OIII] (5007), H α (6563)
Mul 4	20:10:17.90	+36:13:09.00	AstroQueyras (05)	508mm/LHIRES3	A. Brémond, P. Bazart	H α (6563), [NII], [SII] (6716/6731)
Ra 10	20:50:13.00	+46:55:18.00	AstroQueyras (05)	508mm/LHIRES3	A. Brémond, P. Bazart	[OIII] (4959/5007), H α (6563), [NII] (6583)
Ou 6	20:03:53.54	+35:22:50.40	AstroQueyras (05)	508mm/LHIRES3	A. Brémond, P. Bazart	[OIII] (5007), [NII] (6548/6583), H α (6563)
LDû 14	03:04:21.70	+62:18:01.30	AstroQueyras (05)	508mm/LHIRES3	A. Brémond, P. Bazart	[OIII] (5007), [NII] (6548/6583), H α (6563)
Hu 2	00:33:57.40	+74:18:40.00	Porspoder (29)	200mm/ALPY	P. Le Dû	H β (4861), [OIII] (4959/5007), H α (6563)
Ga 1	05:25:56.63	+07:48:21.70	Porspoder (29)	200mm/ALPY	P. Le Dû	H β (4861), [OIII] (4959/5007), H α (6563), [NII] (6583)
CaVa 1	06:52:52.59	+09:04:22.70	Porspoder (29)	200mm/ALPY	P. Le Dû	HeII (4686), [OIII] (4959/5007), H α (6563), [NII] (6548/6583)
Pre 35	18:20:14.30	-22:30:14.10	Armidale, Australie		T. Bohlsen	H β [NII] (6548/6583), H α (6563)
Ra 24	19:37:40.00	+20:35:47.00	CALERN (06)	1 m/LISA	PNST (4)	H β (4861), [OIII] (4959/5007), H α (6563), [NII] (6583)
Ch 1	19:57:15.56	+34:47:18.80	CALERN (06)	1 m/LISA	PNST (4)	[OIII] (4959/5007), [NII] (6548/6583), H α (6563)
DeGaPe 32	05:17:57.10	+07:26:24.70	CALERN (06)	1 m/LISA	PNST (4)	H α (6563)
Pre 24	04:25:53.60	+39:49:10.40	CALERN (06)	1 m/LISA	PNST (4)	H β (4861), [OIII] (4959/5007), H α (6563), [SII] dcalage des raies
Ra 11	18:25:15.00	+00:02:03.00	CALERN (06)	1 m/LISA	PNST (4)	[OIII] (4959/5007), H α (6563)
Hu 1	20:54:14.00	+58:51:20.40	Porspoder (29)	200mm/ALPY	P. Le Dû	[OIII] (5007), H α (6563), [NII] (6583), [SII] (6716)
LDû 31	06:13:51.03	+19:37:09.00	Porspoder (29)	200mm/ALPY	P. Le Dû	H α (6563), [NII] (6548/6583)

PNST (1) : T. Lemoult, P. Le Dû

PNST (2) : O. Garde, P. Le Dû, S. Charbonnel

PNST (3) : O. Garde, P. Le Dû, T. Lemoult

PNST (4) : O. Garde, P. Le Dû, P. Dubreuil, A. Lopez

Table 1. Some PN candidates observed by spectroscopy

2.3 PN candidates spectra

The instrumental response of each spectrum is determined using an observation made on a naturally non-reddened type A or B reference star ($E(B - V) \sim 0$) that is located near the target. Calibration is performed with Argon-Neon lamps.

The data analysis software generally used is ISIS. (<http://www.astrosurf.com/buil/isis-software.html>). The spectral data are recorded with observation sheets and are transmitted to Quentin Parker (Fig. 7 - 8).

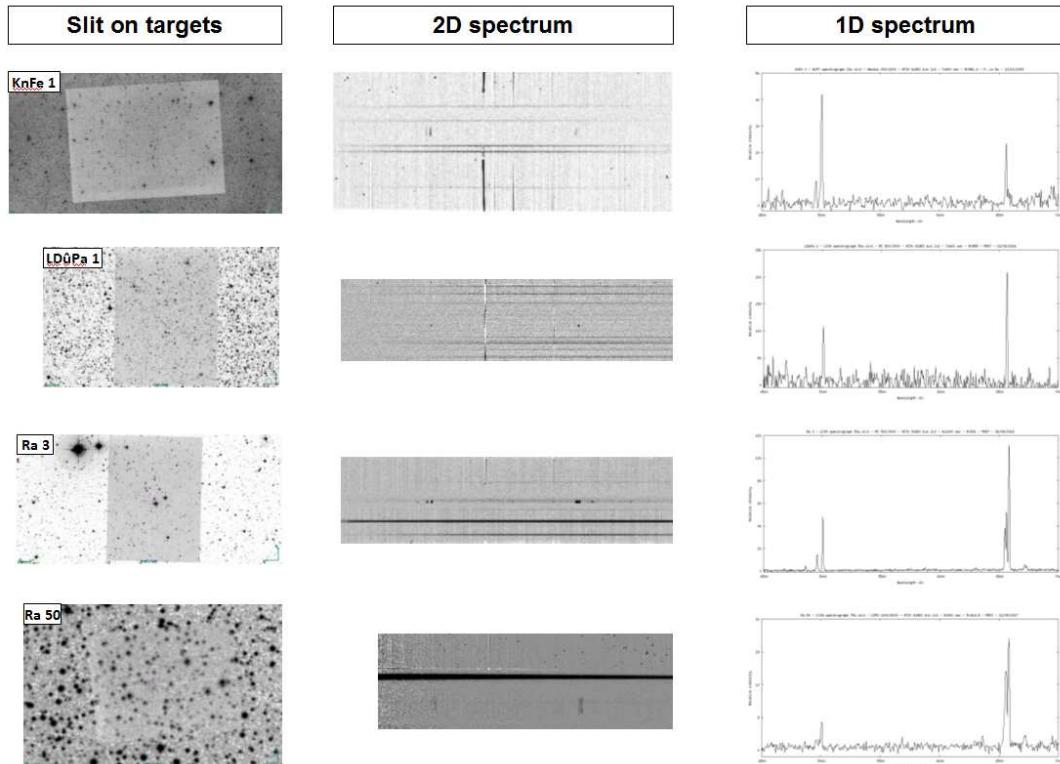


Fig. 7. PN candidates spectra

FICHE D'OBSERVATION SPECTROSCOPIQUE

Identification objet		Détails prises de vue	
Objet	Ra 3	Remarque générale	Opérateurs : Olivier Garde, Thémy Lemoult, Pascal Le Du
Type d'objet	Candidate nébuleuse planétaire	Pointage cible	
Classification	Possible	Superposition images :	Automatique / DSS2 Blue
Coordonnées J2000	19 12 10.00 +16 46 33.00	Autoguidage	Poses de 3 sec. Corrections AD: 0.7 Dec: 0.7
Images	Origine : DSS2 et SDSS9	Images brutes	6 poses de 20 minutes
		Spectre 2D brut	
		Etoile de référence	HD196544 11 poses de 10 sec.
		Dark	Réalisés le 10/08/2016 : 6 poses de 20 minutes
		Offset	Réalisés le 03/08/2016 : 30 poses de 0.01 sec
		Flat	21 poses de 7 sec en fin d'observation après images Néon étoile de référence
		Néon-Argon	3 poses de 6 sec après les poses unitaires de l'objet
Résultat après Traitement			
Réponse Instrumentale étoile de référence	HD196544 Etoile de type A2V		
Spectre 2D traité	120 min de pose. Filtage bruits et râles atmosphériques. Rases [OIII] Haéba et [NII] visibles. Calibration avec lampe Néon		
Graphe	Résolution : 531 Graphe sans correction de flats.		
Commentaires	Principales rases nébulaires bien visibles		
Résultat	Objet qui présente toutes les caractéristiques d'une nébuleuse planétaire. Une première analyse en utilisant les rases [NII] 6581 et Haéba montre une vitesse radiale estimée à -107 km/s à +/- 10 km/s	<p>Version : ISIS V5.5.2</p> <p>Date du traitement : 30/08/2016 21:15:00 Correction vitesse radiale : 0</p> <p>Facteur de binning en sortie : 1</p> <p>Indicatif du mode d'étalonnage : 20</p> <p>Nom de l'objet traité : Ra3</p> <p>Nom complet du fichier de l'objet traité : _Ra3</p> <p>Chemin de sauvegarde : c:\astronomie\pc_\queyras_automatique\travail</p> <p>Position X de référence : 754</p> <p>Instrument : AstroSib 500/3000</p> <p>Résolution : 531</p> <p>Site : AstroQueyras</p> <p>Observateur : Garde-Lemoult-LeDu</p> <p>Delta heure : 0</p> <p>Ciel Y1 : 25</p> <p>Ciel Y2 : 8</p> <p>Ciel Y3 : 15</p> <p>Ciel Y4 : 40</p> <p>Largeur de la zone de binning : 8</p> <p>Binning optimisé : oui</p> <p>Coefficient de rejet des cosmiques pour le binning : 50</p> <p>Zone de normalisation [Lambda 1 - Lambda 2] : [6630 - 6645]</p> <p>Sommation standard des profils individuels</p> <p>Interpolation : bilinéaire</p> <p>A4 : 0</p> <p>A3 : 6.99579211198992E-09</p> <p>A2 : 4.44304310657076E-06</p> <p>A1 : 2.55708812875062</p> <p>A0 : 4011.53296196175</p> <p>Date de prise de vue : 28/08/2016 21:04:10</p> <p>Durée de prise de vue : 7211.0</p> <p>Durée de prise de vue décomposée : 6 x 1200 s</p> <p>Date de milieu de prise de vue : 28.920/08/2016</p> <p>Jour Julian géocentrique du milieu de prise de vue : 2457629.4196</p> <p>Pouvoir de résolution : 531.4</p> <p>RMS de l'étalement spectral : 1.02590</p>	

Fig. 8. Spectroscopic observation sheets

3 Publications and dissemination of works

3.1 Société Astronomique de France (SAF)

The articles published in the SAF magazine report on new discoveries of planetary nebulae candidates (Acker & Le Dû 2014, 2015, 2016; Le Dû 2017, 2018) (Fig. 9). The techniques used by the discoverers are described and advice is given to avoid confusing PN candidates with other objects that may resemble them.



Fig. 9. Articles published in journal of the SAF, L'Astronomie (2014–2018).

3.2 VizieR

PN candidate tables are easily searchable using the VizieR tool of the Strasbourg Astronomical Data Center (CDS) (Le Dû 2018), for example <http://vizier.u-strasbg.fr/viz-bin/VizieR-3?-source=J/other/LAstr/114.54/table1&-out.max=50&-out.form=HTML%20Table&-oc.form=sexu> (Fig. 10).

Full	Name	GLON	GLAT	R _{J2000}	D _{J2000}	Dim	WISE	Image/Sp
		deg	deg	hh:mm:ss	dd:mm:ss	arcsec		
1	App 1	101.80	-11.622 49.20.13	+46 07 38.40	0.90		Sp (GLDL)	
2	App 2	95.10	0.921 30 45.12	+52 41 48.10	1.00			
3	Bea 1	237.80	13.508 28 03.29	-14 58 54.60	0.30			
4	CaV 1	205.00	4.406 52 52.59	+09 04 22.70	7.90		Halipa (JP Cales M. Valuyse), Sp (P. Le Du)	
5	Ch 1	70.80	3.0 19 57 15.56	+34 47 18.80	1.00		Sp (GLDL)	
6	Ch 2	70.70	3.0 19 56 53.55	+34 44 55.40	0.90		[OIII] (S. Chareyre)	
7	Ch 3	103.20	-0.2 22 19 41.44	+56 43 48.40	1.30		[OIII] (S. Chareyre)	
8	DeGaPe 1	262.40	-1.9 08 35 40.69	-43 48 30.60	1.00		[OIII] (DGP)	
9	DeGaPe 2	267.40	-0.3 09 00 17.70	-46 40 40.60	1.70 W4		[OIII] (DGP)	
10	DeGaPe 3	266.10	-1.1 08 51 59.00	-46 10 50.80	0.10		[OIII] (DGP)	
11	DeGaPe 4	291.70	-0.2 11 16 58.00	-61 05 35.40	0.10		[OIII] (DGP)	
12	DeGaPe 5	338.10	-1.4 16 46 11.80	-47 37 05.40	0.10 W3 W4		[OIII] (DGP)	
13	DeGaPe 6	338.50	-2.0 16 50 32.40	-47 42 29.30	0.10 W3 W4		[OIII] (DGP)	
14	DeGaPe 7	337.70	-1.6 16 45 45.10	-47 59 22.90	0.10		[OIII] (DGP)	
15	DeGaPe 8	337.70	-1.5 16 45 31.30	-47 57 44.70	0.10		[OIII] (DGP)	
16	DeGaPe 9	305.40	-0.5 13 13 40.40	-61 20 44.10	0.10		[OIII] (DGP)	
17	DeGaPe 10	337.60	-2.7 16 50 27.70	-48 50 37.00	0.10		[OIII] (DGP)	
18	DeGaPe 11	337.20	-2.7 16 49 01.70	-49 07 01.00	0.10 W4		[OIII] (DGP)	
19	DeGaPe 12	337.10	-2.1 16 45 38.30	-48 45 09.00	0.10 W3 W4		[OIII] (DGP)	
20	DeGaPe 13	336.20	-1.8 16 40 34.60	-49 19 22.90	0.10		[OIII] (DGP)	

Fig. 10. PN Candidate table in VizieR.

3.3 HASH PN database

The HASH (Hong Kong/AAO/Strasbourg Halpha) planetary nebula database (Parker et al. 2016) is a database of all known planetary nebulae, whether candidate or confirmed. Each object is associated with images at different wavelengths and spectra, if available (Fig. 11). This SQL database and research platform is the result of a collaboration between the University of Hong Kong, the Astronomical Observatory of Australia and the Astronomical Observatory of Strasbourg. It is maintained by Quentin Parker and Ivan Bojičić in Hong Kong and is open to the public recently.

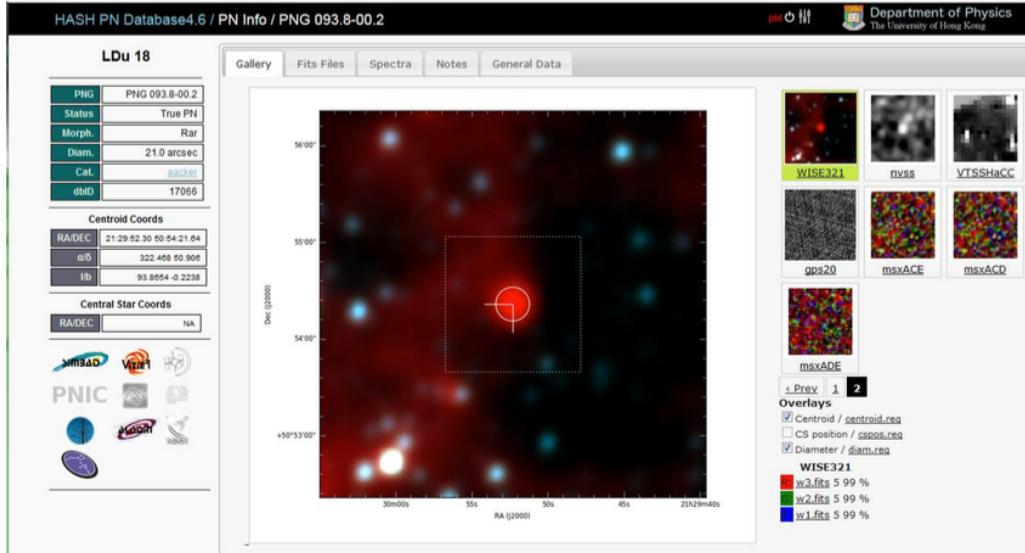


Fig. 11. PN LDu 18 in the HASH PN database.

The table of candidates discovered by amateur astronomers is regularly transmitted to Hong Kong.

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