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Physical parameters of point-symmetric planetary nebulae

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Abstract. We present a systematic observational study of 32 PNe that present point-symmetric structures, multiple bipolar outflows or other related features.

Keywords. planetary nebulae: general

Most of the images have been obtained with the 1.5 m and 2.1 m UNAM telescopes (OAN-SPM), and the 1.5m OSN telescope. Some images were also taken from the literature and the MAST-HST archive. Long-slit spectroscopy has been obtained with the 2.1 m UNAM telescope (OAN-SPM), using the Boller & Chivens spectrograph for low dispersion spectroscopy and the Manchester Echelle Spectrograph for high dispersion spectroscopy. The radio continuum data were obtained from the VLA archive.

Physical parameters are summarized in Table 1. *Low dispersion data*: left-hand values refer to point-symmetric structures, right-hand values refer to the main nebula. *High dispersion data*: left-hand values refer to observed radial velocity of the point-symmetric features, right-hand values refer to the expansion velocity of the main nebula.

Preliminary results indicate that, in general, (1) point-symmetric features have a lower electron density than their corresponding main nebula, and (2) point-symmetric features and the main nebula share a common velocity field. Other parameters do not present a clear systematic behavior and deserve a deeper analysis.

Different formation scenarios as well as a morphologically biased selection of the sample may account for the different cases of point-symmetry and related morphologies. Models for this kind of structures should predict not only the observed morphology but also the physical parameters.

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Table 1. Physical parameters obtained from optical spectra and VLA radio continuum.

	Low dispersion						High dispersion		Radio continuum	
Name	T_e[O III] (K)		T_e[N II] (K)		N_e[S II] (cm^{-3})		V_r ($km\,s^{-1}$)	V_{exp} ($km\,s^{-1}$)	n_e (cm^{-3})	M(H II) ($M_\odot$)
J 320	14 200	13 350	—	—	6460	2840	20	30	1100	0.20
IC 2149	7400	9400	11 000	12 400	10 000	> 10 000	0	25	1700	0.01
M 3-1	11 100	10 500	10 900	10 400	560	1250	17	23	580	0.29
NGC 2371	13 850	13 370	—	9400	440	1100	93	67	100	0.10
NGC 2440	14 000	13 000	—	—	8000	4000	150	22	3200	0.03
NGC 2452	11 200	12 250	10 600	13 900	1200	1300	27	36	490	0.32
NGC 3242	10 950	11 500	—	—	3850	1000	18	31	400	0.09
NGC 3587	13 000	10 200	—	—	50	50	20	40	50	0.28
NGC 4361	15 100	18 300	—	—	—	—	30	26	220	0.40
IC 972	12 300	11 360	10 100	10 100	60	50	12	20	40	0.16
Me 2-1	11 400	12 950	—	—	1080	1780	34	33	1200	0.11
IC 4593	8700	9000	—	—	1360	> 10 000	10	31	250	0.60
NGC 6210	10 200	10 300	—	10 300	1740	2970	45	34	3200	0.06
IC 4634	10 640	9830	10 600	—	2660	> 10 000	27	20	5340	0.02
NGC 6309	—	12400	—	10 700	1830	2300	20	15	1400	0.18
Sa 2-237	12 790	12 900	9400	9250	1200	1300	161	50	50	0.15
NGC 6445	15 000	11 000	—	—	200	1000	40	36	150	0.58
NGC 6543	8120	9800	8900	9300	7400	3100	28	25	3500	0.07
Cn 3-1	—	—	9120	9260	5700	7200	2	14	4000	0.04
PC 19	12 400	11 300	—	—	7000	1830	32	33	4500	0.07
Pe 1-17	13 000	12 500	10 900	10 900	1580	810	26	27	40	0.01
Hu 2-1	—	—	—	—	—	> 10 000	48	23	5900	0.036
NGC 6765	15 200	13 700	—	1160	70	230	23	42	50	0.24
He 2-429	10 500	9 700	—	—	5500	7550	2	30	120	0.14
He 1-1	—	—	10 200	9 900	1400	1400	45	34	100	0.01
NGC 6818	11 900	11 020	9200	9400	1300	1200	30	32	3500	0.33
M 2-48	—	10 850	—	10 700	100	1260	15	25	40	0.03
IC 5217	—	—	—	14 200	—	4300	27	21	3400	0.03
NGC 7354	9700	10 600	—	—	1040	1780	30	24	710	0.22
KjPn 8	—	—	—	8000	100	550	230	50	320	0.002
NGC 7662	—	—	—	—	1460	3070	34	27	1550	0.04
NGC 6369	14 900	9300	14500	10 700	1200	2100	54	46	700	0.01

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