THE DISTRIBUTION OF MOLECULAR HYDROGEN IN PLANETARY NEBULAE

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ABSTRACT. A correlation has been found between strong molecular hydrogen emission and the morphological type of a planetary nebula. Those with an equatorial toroid and bipolar extensions have H_2 1-0 S(1) stronger than Brackett γ. H_2 maps of several objects, and NGC 2346 in particular, are consistent with a fast stellar wind interacting with an anisotropic medium.

The first detection of infrared lines of molecular hydrogen from a planetary nebula was made in 1975 in NGC 7027. Since that time, some 35 planetaries have been searched for in H_2 at various detection levels, and most planetaries have revealed a detectable emission of H_2. The ratio of this emission to ionized gas content may vary over many orders of magnitude.

We propose that planetary nebulae with very strong H_2 emission belong to one morphological class. These are characterised by a dominant equatorial toroid, and bipolar extensions. Planetaries of this form predominantly fall into a class called Type I. Type I planetaries are distinguished by their bipolar structure as well as a high N and He abundances, and some, but not all, have a pronounced equatorial toroid plus less dense extended polar lobes. To test our hypothesis we chose a series of Type I planetaries to be observed in H_2 on the Anglo-Australian Telescope. Each nebula was mapped at 2.12 μm and spectra taken of any bright points to confirm that H_2 was the main contributor. NGC 2346, NGC 2818 and NGC 2899 were chosen as satisfying our morphological class, while NGC 3699 and He 2-111 were chosen as members of type I which do not fall into this class.

In Table 1 all the measurements that we are aware of have been listed, together with information on the ratio of the H_2 S(1) line at 2.12 μm, to Brackett γ at 2.16 μm and on whether the object belongs to the class of Type I planetaries. There is a definite correlation between Type I planetaries and those with a positive detection of H_2. The correlation is particularly strong for the group with H_2 S(1) stronger than Brackett γ.

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The H_2 image of NGC 2346 shows an equatorial ring slightly outside the optical ring, plus delicate bipolar extensions coincident with the optical ones. This structure may indicate the presence of a strong fast stellar wind emanating from the central star. The wind interacts with the dense, previously ejected equatorial disc-shaped cloud, which is rich in molecules. The anisotropic density distribution leads to the development of polar cavities with standing shocks at their inner edges (Canto, Konigl). The resulting shocks excite the H_2 causing it to emit in the infrared and delineate the fronts, and a structure just like that observed in NGC 2346 is expected. The images of the other planetaries observed conform with this scheme and indicate how the kinematic evolution of such nebulae will proceed.

Table 1. PLANETARY NEBULAE FOR INFRARED H_2 EMISSION.
a) Positive detection.

Object	Ref	H_2 S(1)/Br γ	Type	Object	Ref	H_2 S(1)/Br γ	Type
J900	3	0.21		M2-9	5	0.02	
NGC 2346	8	5	I	NGC 6302	4	0.01	I
NGC 2440	1,3	0.16	I	NGC 6720	2	3.2	
NGC 2818	6,8	35	I	BD+30°3639	2	0.06	
NGC 2899	8	3	I	NGC 7027	7	0.05	
NGC 3132	6,8	10.5	I-II	M1-78	3	0.16	
He 2-111	8	1	I	IC 5117	3	0.12	
IC 4406	6	1.4	I	NGC 7293	6	4.5	I
NGC 6072	6	6.2	I	NGC 7662	3	0.13	
NGC 6210	3	0.05		HB 12	2	0.11	

b) No detections.

Object	Ref	Type	Object	Ref	Type
NGC 246	6		NGC 3699	8	I
NGC 1360	6		Me 2-1	6	
NGC 1535	6		NGC 6153	6	
IC 418	6		H 2-3	6	
IC 2149	3		NGC 6572	2,3	
IC 2165	3		NGC 6790	2	
NGC 2792	6		NGC 6884	3	
NGC 3195	6	I	IC 4997	2	
NGC 3242	6				

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