



Correlation Between Nitrogen and Oxygen Content in Planetary Nebulae Morphology

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Abstract

Planetary nebulae are the result of stars' deaths and are beautiful cosmic spectacles. All planetary nebulae form in the same manner and from similar stars. Despite these facts, planetary nebulae form into many different shapes (morphologies) as the clouds of gas expand into space. The purpose of this experiment was to determine what may be one cause of the many different morphologies. Possible causes relate to the composition of the nebulae or possibly the temperature or size of the progenitor star that created it. Our hypothesis was that if the visible light spectra (3500-7000Å) of a sample of planetary nebulae of two different morphologies (polar and spherical) are taken and analyzed, then the spherical nebulae would contain more Oxygen, and the polar nebulae would contain more Nitrogen. This hypothesis is based off the behavior of these two gases when exposed to a magnetic field, which is produced by planetary nebulae. The spectral data was acquired using the B&C Visible Light Spectrometer, and this data was reduced and analyzed by Imaging Reduction and Analysis Facility software. After the data was reduced, the wavelength of each spectral line was measured, and the percent composition of the light emitted from each nebula was determined. When the %composition of the two gases, Oxygen and Nitrogen, were compared between the two groups of planetary nebulae, the results appeared to support the hypothesis. The polar group averaged 16.6% more nitrogen than the spherical group, and averaged 17.8% less oxygen. Based on this, it appears as if the amount of these two gases in a planetary nebula may affect the shape it takes as it forms and interacts with magnetic fields.

Introduction

Planetary nebulae form when a star of less than four solar masses, usually less than two, dies. When a low mass star approaches the end of its life, it expands and turns into a red giant. A helium-flash occurs in

the core of the star, and the outer layers of the star become unstable and are ejected out into space at high speed. The stellar winds from the hot core push the gases out into space, and the gases are ionized². It is known that the cores of these stars create fairly strong magnetic fields, and it is also known that certain gases react to magnetic fields in certain ways³. Oxygen tends to flow along magnetic fields and surrounds the magnetic source, and Nitrogen tends the flow from the point of lowest to highest magnetic intensity⁴. However, the reason why there are so many different morphologies of these nebulae is not known. Theories range from stellar winds to the perspective we view the nebulae from. Previous studies have shown that there are magnetic fields present around the central stars of planetary nebulae, but no exact connection has been identified between the morphology and the composition, and the way which the gases may react with central star magnetic fields. It would make sense that the amount of the gases, which are reactive to magnetic fields, present in a nebula would change the behavior of the nebula as it expanded out into space, and through a magnetic field. The more we learn about how these objects form, the better we will understand our sun and what will happen to it in the future.

Materials and Methods

The first thing that was done was the selection of the planetary nebula to examine, and the separation of them into two categories based on shape (spherical and polar). The nebulae chosen were high in the sky at the time, to minimize any atmospheric emission that could interfere with the data, were fairly low in magnitude (higher surface brightness), and were not close to any very bright stars, which could corrupt the data. Five nebulae were chosen which were spherical in shape. These were NGC 7027, NGC 6210, NGC 6905, M97 and Abell 39. Five other nebulae were chosen which were polar in shape. These were NGC 7026, NGC 6720, IC 4593, NGC 6765 and NGC 6445. Because there really is no measurement for shape, you could argue that one nebula belongs in the other category,



it is based on the viewer's definition (Figure 1a,1b). To reduce variability, simple measurements were taken for each nebula (x and y axis measurements), and they were separated into based on eccentricity. Minkowski 2-9 (Figure 1b) was added to the pool as a definite polar nebula, just for reference. Ten hours of observation time were reserved at the University of Arizona's 90inch Bok telescope at Kitt Peak National Observatory. This telescope's large mirror and its spectrograph were used to take exposures of each nebula. The spectrograph separates the light coming from the nebulae into its principle parts, were you can determine what elements and in what amount are present. This involves uses a computer to control the exposure time, and the part of the nebula where the light was being gathered from. Once the Right Ascension and Declination (coordinates of objects on the celestial sphere) of each object were entered into the telescope's computer, the telescope was slewed to the target location. A camera fixed to the prime-focus of the telescope, which could be switched out with the spectrograph remotely, was set to take pictures of the field every few second. This allowed for slight adjustments to the alignment of the field's center to the target object. Once the target was centered in the field, the plate to which the camera and spectrograph were fixed was rotated to align the spectrograph's slit with the major axis of each nebula. Stars within the field of view of the nebulae were avoided when the spectrograph slit was aligned with the target. An exposure was taken for each nebula, ranging from 6 to 15 minutes depending on the size and magnitude of the target. The exposure was adjusted to avoid saturation of any emission line (5007Å, OIII was often very strong), but also to insure that all emission lines detected were strong enough to measure accurately. With the computer, the newly collected spectra were calibrated instantly with the light from a helium-argon lamp (which has known spectral lines) which was located inside the telescope and could be turned on and off as needed. The data was run through IRAF (image reduction and analysis facility) to reduce it to a usable, graph form. IRAF allowed the wavelength and intensity of each emission line to be calculated (Figure 2). From there, IRAF was used a gain to eliminate the data points from the central star and all other stars in the field of view to leave only the data that came

directly from the nebulae itself. The intensity of the light from each element was compared respectively to the total visible light output from the nebulae.



Figure 1a. Abell 39 (Most Spherical) NOAO photo



Figure 1b. Minkowski 2-9 (Most Polar) Hubble photo

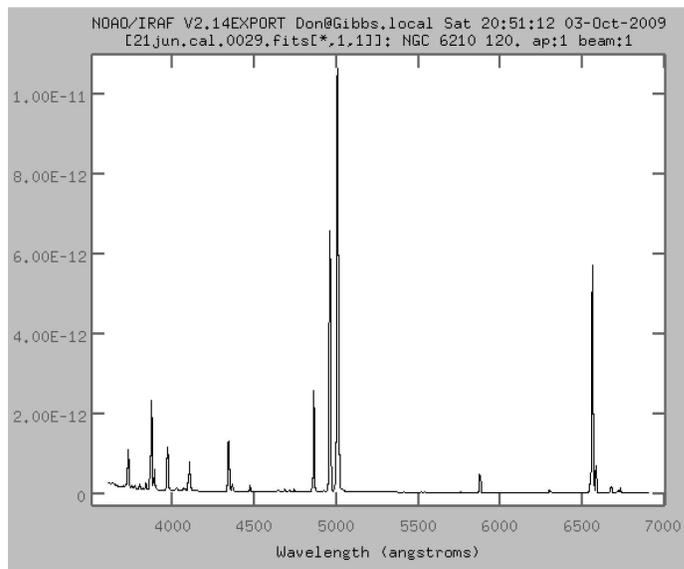
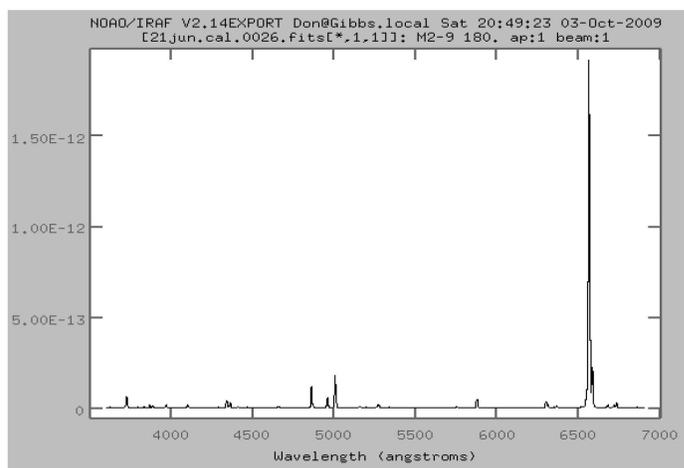


Figure 2. Sample IRAF Graphs of NGC 6210 (top) and M2-9 (bottom).



Results

The results in table 1 are the total results from all of the spectra analysis. They nebulae are in the general order (from top to bottom) from most spherical to most polar. The exact order may change depending on the way morphology is measured, but the top five are spherical, and the bottom six are polar in shape. All elements that were observed are included in the data table, although not all were detected in all nebulae. Besides Nitrogen and Oxygen, Fluorine, Neon, Sulfur, Carbon and Argon were all detected. The only elements concerned in this experiment are Oxygen and Nitrogen, so these were placed in figure 3. Again, the nebulae are in general order from left to right of most spherical to most polar. If the hypothesis was correct, then the expected trend for Oxygen would be decreasing left to right. Although the data doesn't follow this trend perfectly, there is an obvious difference between the spherical and polar groups. There was an average of 17.8% more light emitted by Oxygen in the Spherical group member nebulae than those in the polar group. The expected trend for Nitrogen would be increasing from left to right in figure 3. There was an average of 16.6% more light emitted by Nitrogen in the Polar group nebulae than in the spherical group. Neon, Sulfur, Hydrogen and Helium were also graphed in order to show that trends weren't found in other elements observed (Figure 4,5).

Table 1. Chart of all elements found in Planetary Nebulae observed and their %compositions

		Nitrogen	Oxygen	Fluorine	Neon	Sulfur	Carbon	Chlorine	Argon
Abell 39	1	1.1	72	0	1.1	0	4.2	1	0
M 97	2	4.6	60.5	0.6	10.2	0	1	0.9	0.1
NGC 6905	3	0.9	60.8	0	5.8	0.4	0	0	0.5
NGC 7027	4	8.8	58.7	0	1	0.8	0	0	0.4
NGC 6210	5	3.6	51.9	0	9.1	0.6	0	0.2	0.4
IC 4593	6	2	43.2	0	0	0.2	0	0	0
NGC 6765	7	17.4	49.2	0	2.9	6.2	0	0.15	0
NGC 7026	8	16	44.2	0	2.7	3.1	0	0	0.8
NGC 6720	9	16.4	46.95	0	6.1	3.3	0	0	0
NGC 6445	10	27.5	48.9	0	1.9	1.1	0	0.3	0.6
Mink 2_9	11	25.35	10.9	0	1	2.1	0	0	0.6

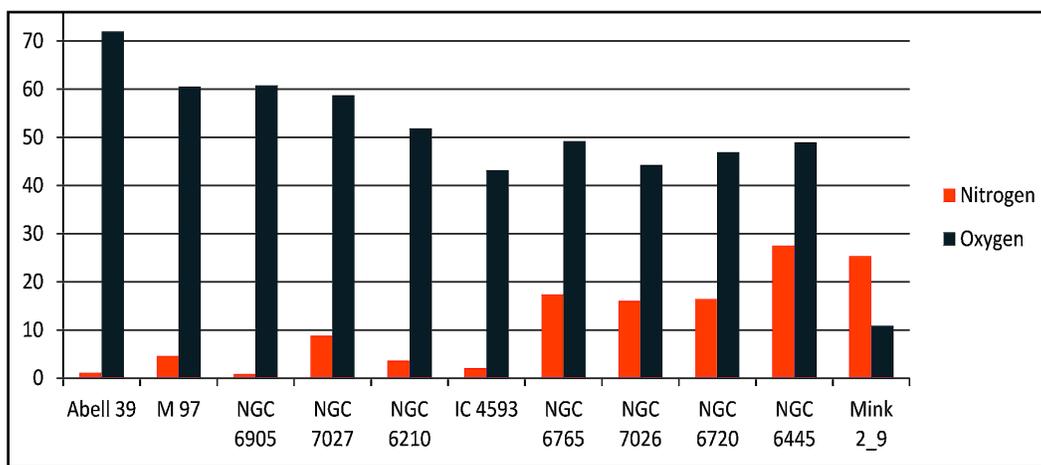


Figure 3. This is the data from the table above in bar graph format. Only the figures for oxygen and nitrogen were graphed here, because these were the only gases with known reactions to magnetic fields, and were the only gases which were hypothesized to have an effect on the morphology of the nebulae.

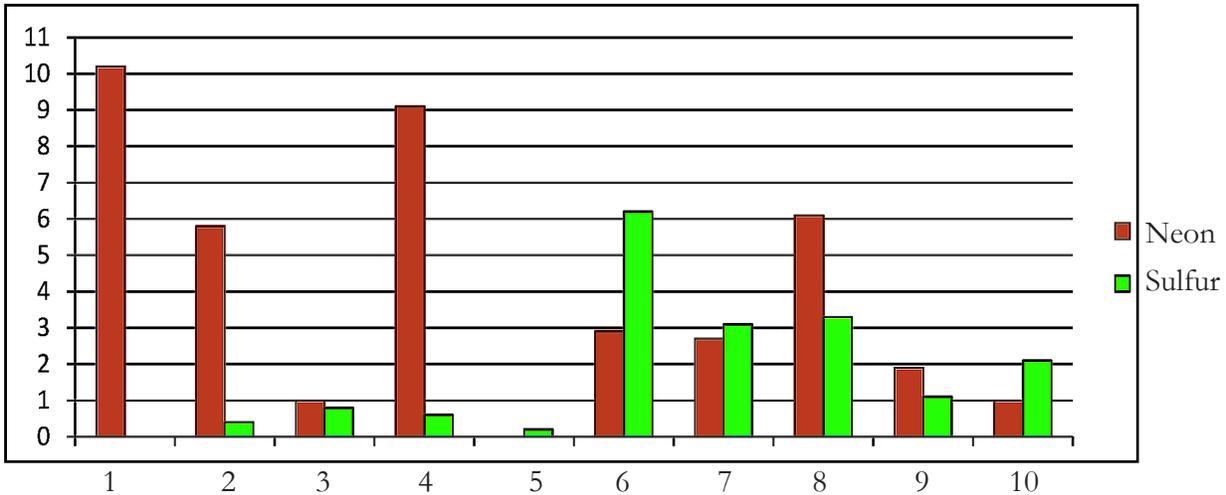


Figure 4. This chart represents the nebulae in the same order as before (most spherical to most polar from left to right), but with two other elements, neon and sulfur.

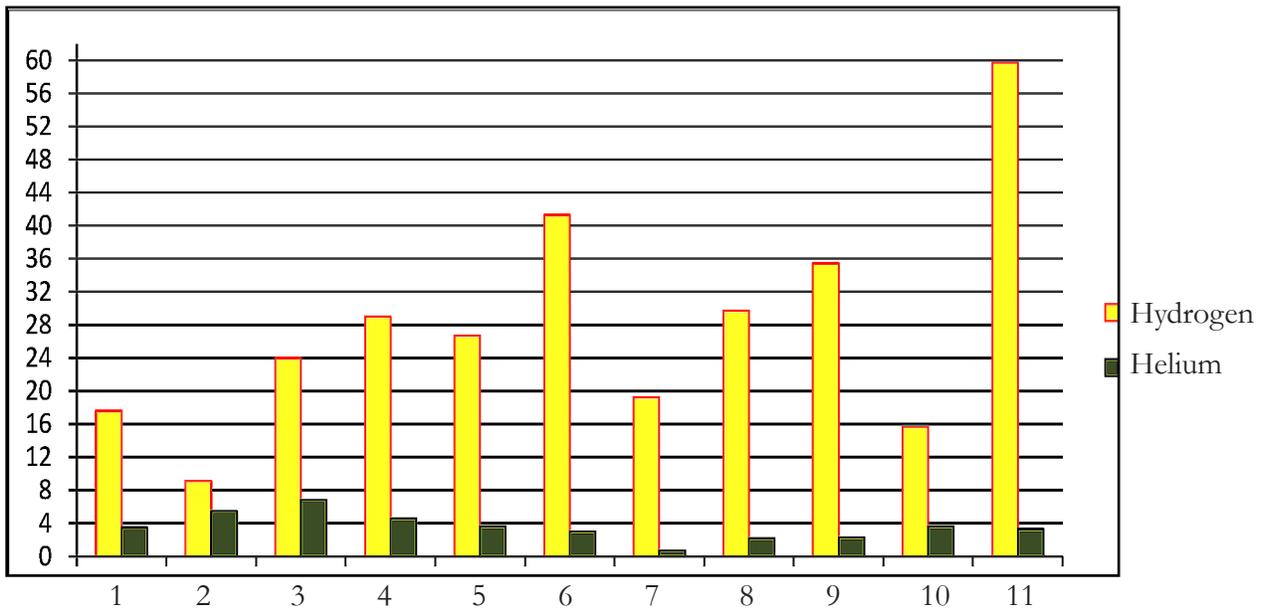


Figure 5. This chart represents the nebulae with two other elements, hydrogen and helium. The purpose of this and the other chart above is to show that there was no other trend found between morphology and other elements found in the 11 nebulae observed.

Discussion

This group of 11 planetary nebulae makes a very small sample size, and it is difficult to say with any certainty that the data from this experiment is representative of a large group. However, some trends and patterns are evident within this data.

When looking only at the percent (light) composition data for oxygen and nitrogen, especially when a trend line is added to the data points, a split can be seen between the two morphology groups. For nitrogen, the difference between the polar group

and the spherical group is huge, with the spherical group averaging over 16% higher light intensity from nitrogen molecules. The Spherical group averaged more than 17% higher light intensity from oxygen. It is important to address that the %composition measured in this experiment does not represent the composition by volume or mass, but only by the amount of light produced by each nebula, and by each element. When the amounts of other elements found in these nebulae are analyzed, no pattern connected to morphology is evident.



Discussion

It is well known that no two planetary nebulae look exactly alike; this is not hard to see. But the reason for this is harder to explain. Why does an event that happens in the same way under the same types of conditions produce such a different result (in morphology)? Our hypothesis was that the cause of the different morphologies in planetary nebulae was the magnetic fields of the central stars interacting with the nebular gases as they are pushed out into space. Because it was assumed that these gases would behave in the same way on a large scale as in a laboratory setting, we hypothesized that the amount of oxygen and nitrogen present in the nebulae will affect the shape of the nebulae as it forms. Based on the data collected in this experiment, it does appear as if this hypothesis is supported. It is important to address that oxygen and nitrogen were the two gases found in the highest intensity. The polar nebulae, which are closer to the configuration that nitrogen takes in a magnetic field in a vacuum, produced more light in the wavelengths of nitrogen than oxygen. What this shows is not that there is more nitrogen present than oxygen in these nebulae, but that more of the light emitted, and therefore more of the visible surface area of the nebula, is produced by ionized nitrogen. The spherical nebulae, which are closer to the configuration that oxygen takes in the conditions listed above, produced more light in oxygen wavelengths. What this suggests is that the area of the nebulae which emit light in visible wavelengths do match with the expected behavior if their shape was dictated by magnetic fields.

Overall, the hypothesis is supported by the data. However, this is a small sample size. The next step in this experiment would be to replicate the same experiment but with a larger sample size of 50 nebulae or more. Also, it would be useful to do the same tests, but analyzing the light in other wavelengths, such as infrared or microwave, to see if the trend continues even in areas that we can't see in visible light.

References

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