THE SHOCKING TRUTH ABOUT SOME "PROTO-PN"

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ABSTRACT. A small number of bipolar planetaries -including M2-9, M1-91, GL 618, and M2-56- exhibit very strong emission lines of low ionization species such as [O I], [N I], [N II], and [S II]. Most previous authors have attempted to analyze the spectra of these objects assuming that they are photoionized by their central stars. Closer examination, however, suggests that a different excitation mechanism may be at work -that of shock heating.

In the relatively high excitation objects M2-9 and M1-91 the ratio of [O III] λλ4959, 5007 to λ4363 may be used to define an [O III] temperature, T([O III]). Similarly, [N II] λλ6548, 84/λ5755 defines a [N II] temperature, T([N II]). Under the assumptions of photoionization and low density we find that T([O III]) for the wings of M2-9 and M1-91 is typically 4 times larger than T([N II]). This is typical of shocks, where the [O III] comes from the high-T region just behind the shock and the [N II] arises from cooler gas further downstream. On the other hand, T([O III]) in the cores is undefined, indicating that there, at least, the λλ4959, 5007 lines are collisionally deexcited, indicating $N_e \sim 10^6$ cm^{-3} in the [O III] region. However, this high electron density would almost completely quench the [N I], [N II], and [S II] lines, and these lines are already unusually strong in these nebulae. Hence there must exist two phases of gas at very different densities. ([N II] λ5199 has a critical density of only 2000 cm^{-3}). Previous models have not taken this into account, but in any case still would have difficulty reproducing the strengths of the low ionization species relative to Hβ.

The low-ionization objects GL 618 and M2-56 have no [O III] lines, so the excellent shock discriminant T([O III]) is not available. However, the relative line intensities of these two objects compare rather well with the spectra of HH 43C and HH 43N. It is now accepted that HH objects are shock heated, and we may infer by analogy that GL 618 and M2-56 are also shock heated. Further detailed modeling is currently under way.

Clearly care must be exercised in interpreting the spectra of these objects, and it is likely that we will require more sophisticated models than are usually used for PN.

S. Torres-Peimbert (ed.), Planetary Nebulae, 447.