PLANETARY NEBULAE WITH MASSIVE NUCLEI

R. Tylenda
Laboratory for Astrophysics, Copernicus Astronomical Center,
Chopina 12/18, 87-100 Torun, Poland

Massive central stars ($M > 1\ M_{\odot}$) of planetary nebulae burn nuclear fuel on a time scale of hundreds or tens of years which is shorter than the recombination time in a typical planetary nebula. Consequently the ionization and thermal structure of a nebula with such a nucleus is expected to be far from equilibrium conditions. The greatest chance of observing such a nebula is when the central star cools down to the white dwarf region. Time-dependent photoionization models suggest the following non-equilibrium effects to be expected at this stage. Firstly, the nebula shows a double shell structure, i.e. a bright, inner ring is surrounded by a faint, extended halo best seen in the HI lines and infrared lines from low-ionization species, such as [Ne II] 12.8 μ. Secondly, the low-excitation emission ([O II], [Ne II], [S II]) is enhanced relative to the high-excitation ([O III], [Ne III], [S III]). Thirdly, different modifications of the Zanstra method result in significantly different temperatures for the central star with a general rule that $T_{HI} > T_{HeII} > T_{HeII/HI}$. The He II Zanstra method gives the most reliable result. Fourthly, the electron temperature derived from the [O III] lines is appreciably higher than that obtained from the [N II] lines. It is suggested that NGC 7027 and NGC 2440 possess massive central stars and that the above time-dependent effects are currently observed in these nebulae.

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