Using the hydrogen recombination spectrum to probe nebular physical conditions

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Abstract

The hydrogen recombination spectrum, which includes continuum and line emission, is important in the study of nebular physical conditions. We present a method to simultaneously determine electron temperatures and densities of planetary nebulae (PNe), using the observed hydrogen recombination spectrum near the Balmer jump at 3646 Å. The method has been applied to spectra of 48 Galactic PNe.

Comparison between electron temperatures and densities derived from the hydrogen recombination spectrum and those derived from collisionally excited line (CEL) ratios provides an excellent probe to investigate temperature and density variations within nebulae. Electron temperatures derived from the hydrogen recombination spectrum [hereafter $T_{\rm e}$(Bal)] are found to be systematically lower than those derived from the [O III] $\lambda4959/\lambda4363$ and the [O III] $(88\mu{\rm m} + 52\mu{\rm m})/\lambda4959$ ratios [hereafter $T_{\rm e}([{\rm O\,III}]_{\rm na})$ and $T_{\rm e}([{\rm O\,III}]_{\rm fn})$]. And electron densities determined from the hydrogen recombination spectrum are found to be systematically higher than those derived from the [O II] $\lambda3729/\lambda3726$, [S II] $\lambda6731/\lambda6716$, [Cl III] $\lambda5537/\lambda5517$, [Ar IV] $\lambda4740/\lambda4711$ and [O III] 88μm/52μm ratios. These results suggest that temperature and density variations are generally present within nebulae. However, not all the observed temperature disparities can be attributed to the presence of temperature and density variations, especially in some extreme nebula where the temperature disparities are particularly large. Detailed mutliwave band studies of these extreme PNe have shown that temperature and density variations fail to explain the very large temperature disparities and the known discrepancy between the ionic abundances of heavy elements derived from CELs and those derived from recombination lines. Rather, they point to the presence of new gas component, cold and H-deficient material

embedded in diffuse nebula,

We find that He/H abundances of PNe are positively correlated with the difference between $T_e([\mathrm{O\,III}]_{\mathrm{na}})$ and $T_e(\mathrm{Bal})$, indicating that He/H abundances might have been overestimated in general because of the possible existence of cold H-deficient material. The discrepancies between $T_e([\mathrm{O\,III}]_{\mathrm{na}})$ and $T_e(\mathrm{Bal})$ are found to be anti-correlated with electron densities derived from various density indicators, suggesting that temperature discrepancy is a phenomenon related to nebular evolution, in the sense that temperature discrepancy increases as the nebula expands and ages.

Details of these results are given in astro-ph/0403371.