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# Spectral Classification of Emission-line Galaxies

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## ABSTRACT

A revised method of classification of narrow-line active galaxies and H II region-like galaxies is proposed. It involves the line ratios [O III] $\lambda5007/H\beta$, [N II] $\lambda6583/H\alpha$, [S II] ($\lambda\lambda6716+6731$)/ $H\alpha$, and [O I] $\lambda6300/H\alpha$. These line ratios take full advantage of the physical distinction between the two types of objects and minimize the effects of reddening correction and errors in the flux calibration. Large sets of internally consistent data are used including new previously unpublished measurements. Predictions of recent photoionization models by power-law spectra and by hot stars are compared with the observations. The classification is based on the observational data interpreted on the basis of these models.

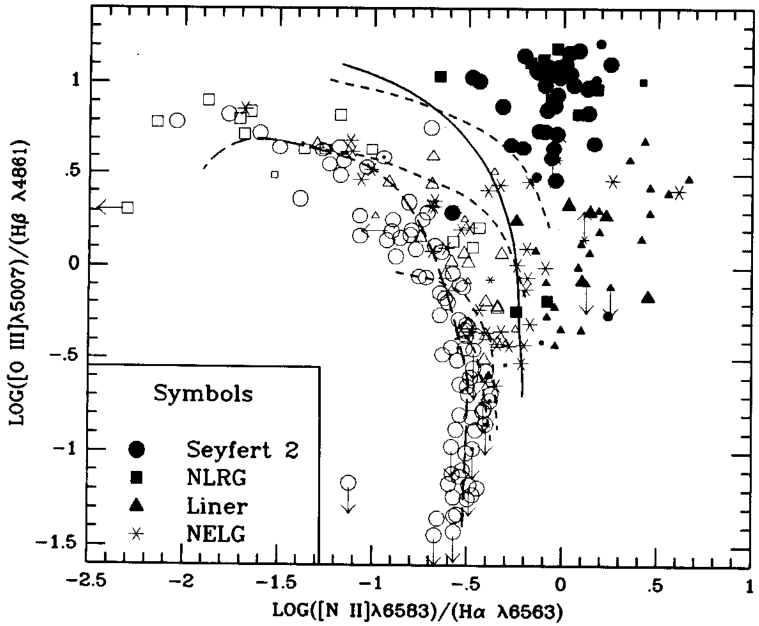
## I. Introduction

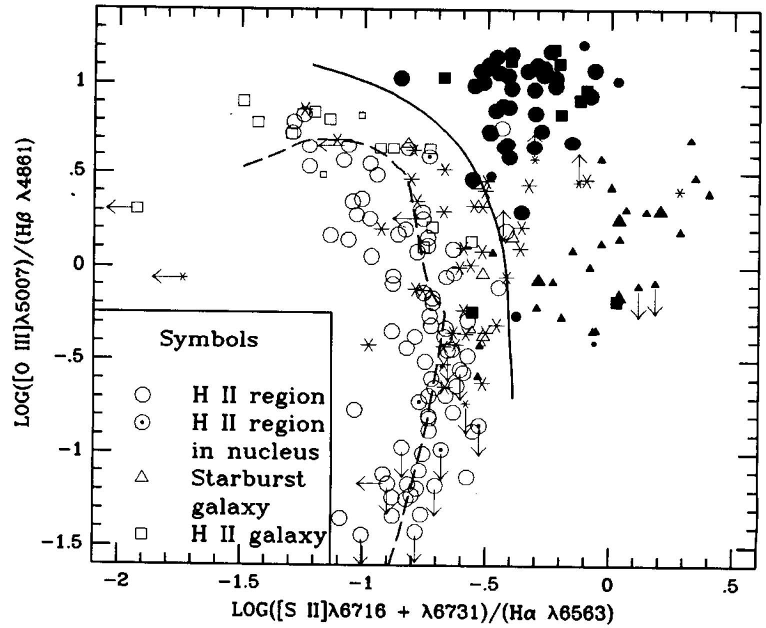
Possibly the best way we have to test our understanding of the different mechanisms responsible for the ionization in emission-line galaxies is to consider a large sample of these objects with well measured spectra, and try to determine which spectral features differentiate objects in which the photoionization is by hot OB stars from objects in which the photoionization is due to a "non-thermal" or "power-law continuum". We know that H II region-like galaxies can be distinguished from Seyfert 2 galaxies by the weakness of low-ionization lines like [N II] $\lambda6583$, [S II] $\lambda\lambda6716,6731$, and especially [O I] $\lambda6300$. It is the basis of the classification scheme of Baldwin, Phillips, and Terlevich (1981, BPT).

In the present discussion we propose a revised method of classification of narrow-line AGNs and H II region-like galaxies based on line ratios involving [O III] $\lambda5007$, [N II] $\lambda6583$, [S II] $\lambda\lambda6716,6731$, [O I] $\lambda6300$, and the Balmer lines. It excludes reddening-sensitive line ratios such as [O II] $\lambda3727$/[O III] $\lambda5007$ used by BPT. Since that paper appeared, large sets of data on emission-line galaxies have been published by Keel (1983) and Balzano (1983). These and other recent data will be included in our analysis. Our theoretical understanding of emission-line galaxies has also improved considerably during the past five years. Important publications of photoionization models by power-law spectra and by hot stars will be discussed as they can help discriminate between the two classes of objects.

## II. Results and discussion

The reddening corrected line ratios of the objects in our sample are presented in figures 1-6. In these figures, NLRG stands for narrow-line radio-galaxy and NELG for narrow-emission-line galaxy (Shuder and Osterbrock 1981). In figures 1, 2, and 3 the four short dashed lines are H II region models of Evans and Dopita (1985) for



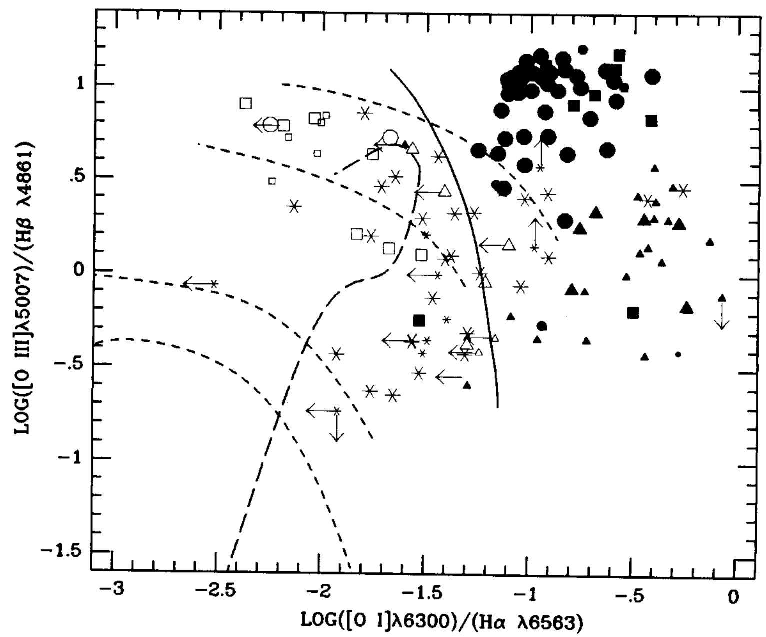




**Figure 1 (above); Figure 2 (top right); Figure 3 (right)**

**Distribution of narrow-line active galaxies, narrow-emission-line galaxies, starburst galaxies, H II region-like galaxies and H II regions. The intensity ratios are expressed in logarithms. The size of each symbol gives an indication of its uncertainty. Arrows on data points indicate lower or upper limits. The meaning of the curves is discussed in the text.**

$T_e$= 56 000 K, 45 000 K, 38 500 K and 37 000 K from top to bottom, respectively. The long dashed curve is the H II region model of McCall, Rybski, and Shields (1985).

In figures 4, 5, and 6 the short dashed curves are power-law models of Ferland and Netzer (1983) for solar and 0.1 solar abundances (upper and lower respectively). The ionization parameter varies along each curve from $10^{-1.5}$ to $10^{-4}$. The long dashed line is the composite, two-component ($N_e = 10^2$ and $10^6$ $cm^{-3}$) model of Stasinska (1984). The ionization parameter varies along the curve from $10^{-2}$ to $10^{-4}$. The shock models of Shull and McKee (1979) are presented as the dot-dashed curve. Shock velocity increases along the curve from less than 80 km $s^{-1}$ to 130 km $s^{-1}$.

In all six figures the solid curve divides narrow-line AGNs from H II region-like objects. A clear separation between the two classes of emission-line galaxies is apparent, especially in figures 3 and 6. The distribution of NELGs however, is not like the distribution of either class of objects. Instead some NELGs are clearly H II region galaxies while others are narrow-line AGNs.

Finally, a few objects in our sample (half-filled circles in figures 4-6) fall in the region of H II region galaxies in some diagram(s) but in the region of AGNs in some other diagram(s). Many of these objects have uncertain line ratios; others are "transition objects" where both ionization mechanisms might be operating. The "outstanding" NLRG in the first three figures was thought to be 3C 178 by Costero and Osterbrock (1977). However, a more recent accurate radio position determined by Haschick *et al.* (1980) shows that the object Costero and Osterbrock observed is not the radio galaxy 3C 178. The object they observed is an H II region galaxy that is by no means exceptional, while 3C 178 is presumably a much fainter and still unidentified quasar. This is a striking confirmation of the classification scheme.

This method of classification of emission-line galaxies is discussed in greater details in Veilleux and Osterbrock (1986).

## References

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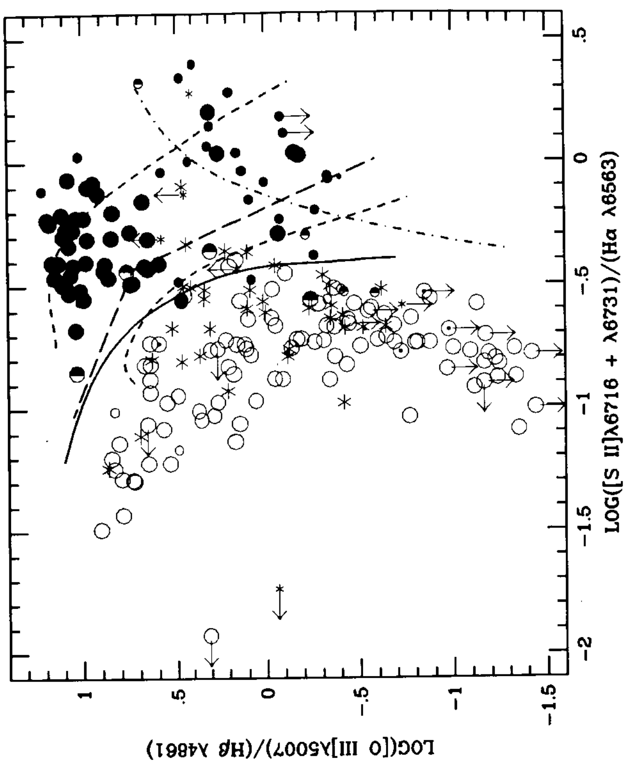


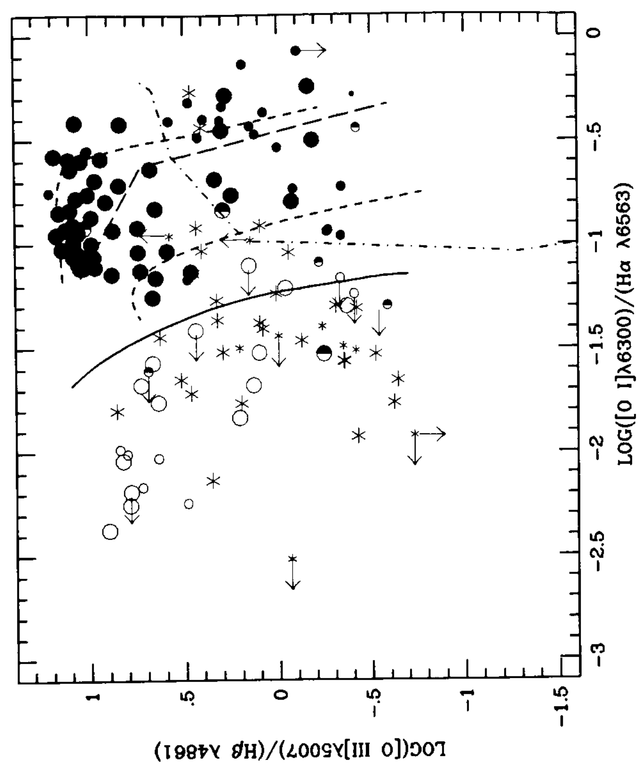


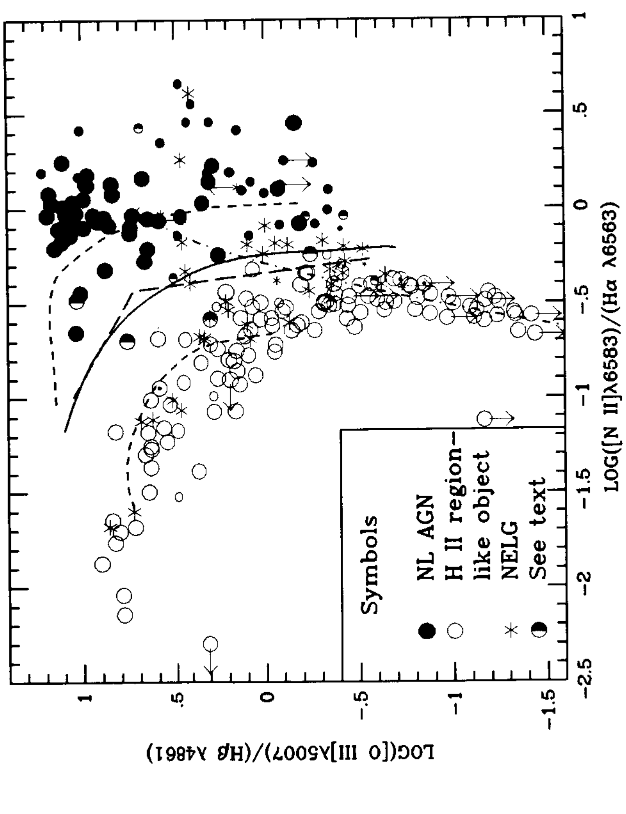


**Figure 4 (above); Figure 5 (top right); Figure 6 (right)**

Distribution of narrow-line active galaxies, narrow-emission-line galaxies and H II region-like objects. The intensity ratios are expressed in logarithms. The size of each symbol gives an indication of its uncertainty. Arrows on data points indicate lower or upper limits. The meaning of the curves is discussed in the text.