RevMexAA (Serie de Conferencias), **40**, 72–73 (2011)

PHYSICAL CONDITIONS IN A SAMPLE OF SEYFERT AND STARBURST GALAXIES

M. Martínez,[1] M. Meléndez,[2] and C. Mendoza[1]

RESUMEN

En el presente trabajo hemos estudiado la relación entre las líneas de emisión de alta y baja ionización del [O IV] 25,89 μm (54,93 eV), [Ne III] 15,56 μm (40,96 eV), y [Ne II] 12,81 μm (21,6 eV) con el propósito de restringir la contribución del núcleo activo de galaxias (Active Galactic Nuclei, AGN) y la formación estelar en una muestra de 79 galaxias Seyfert del Universo local ($z < 0,08$) Weaver et al. (2010). Este estudio se llevó a cabo mediante la utilización del código de fotoionización CLOUDY de Gary Ferland (1996), el cual utilizamos para generar un conjunto de modelos de fotoionización con los cuales fue posible identificar parámetros físicos tales como la densidad de hidrógeno $n_{\rm H}$ y parámetro de ionización U asociados al AGN y la formación estelar. A partir de estos diagnósticos encontramos que los cocientes de línea de emisión observados en la región de línea estrecha (Narrow Line Region, NLR) de las galaxias Seyfert pueden ser reproducidos eficientemente por un modelo de dos zonas, el cual está formado por una zona de baja ionización y alta densidad y una de alta ionización y baja densidad. Un modelo similar fue utilizado para modelar las líneas de emisión observadas en las galaxias starburst, para las cuales se encontró que los cocientes observados eran mejor reproducidos mediante la combinación de una zona de baja ionización con una de alta ionización y densidades similares.

ABSTRACT

Active galactic nuclei (AGN) are thought to harbor massive black holes ($M_{\rm BH} \approx 10^6 - 10^8\ M_\odot$) surrounded by an accretion disk responsible for the enormous energy rates observed in their unresolved nuclei. Seyfert galaxies represent the most common type of AGN. Seyfert 1 galaxies have broad permitted (FWHM $\approx 1{-}5\times10^3$ km s^{-1}) and narrow (FWHM $\approx 5\times10^2$ km s^{-1}) permitted and forbidden lines and Seyfert 2 galaxies have only narrow permitted and forbidden line emission. According to the unified model of active galaxies, Seyfert 1 and Seyfert 2 galaxies are intrinsically the same, with their differences attributed to viewing angle. In Seyfert 2 galaxies, our line of sight to the broad line region (BLR) and the central engine is obstructed by an optically thick dusty torus-like structure, while in Seyfert 1 galaxies, our line of sight is not obstructed by the torus, allowing a direct view of the central regions of the active galaxy. In this work, we use photoionization models to fit the observed ratios between high and low ionization mid-infrared emission lines to separate the relative contributions of the AGN and star formation in the host galaxy. Overall, we found that the observed mid-infrared spectra can be reproduce by a two zone model defined by a radiation- and matter-bounded component.

Key Words: galaxies: active

1. INTRODUCTION

We have studied the relationship between the high-and low-ionization [O IV]λ25.89 μm, [Ne III]λ15.56 μm, and [Ne II]λ 12.81μm emission lines to constrain the active galactic nuclei (AGNs) and star formation contribution of a sample of 79 ($z < 0.08$) Seyfert galaxies (Weaver et al. 2010).

We used the [O IV] as a truly isotropic property of the AGN because given its high ionization potential (54.9 eV) is less affected by star formation and, also, [O IV] is significantly less affected by extinction than [O III]λ 5007 Å (Melendez et al. 2008). On the other hand, [Ne II] and [Ne III] can be readily produced by star formation. Moreover, [O IV], [Ne II] and [Ne III] are present in AGN, starburst, H II galaxies and have a wide range of ionization potentials and critical densities which allow us to study the connection between the active nucleus and star formation.

2. SEYFERT AND STARBURST GALAXIES: MODEL AND OBSERVATION

As we mentioned before, the ratios of high-ionization lines to low-ionization lines can reveal the relative contributions of the AGN and star formation. It is also known,that the most likely contributor to the [O IV] emission in starburst galaxies are

[1]Centro de Física, IVIC, Apartado Postal 21827, Caracas 1020A, Venezuela (mmariela@ivic.gob.ve).

[2]Department of Physics & Astronomy, The Johns Hopkins University, Homewood Campus, Baltimore, MD 21218, USA.

Wolf-Rayet stars (Luts et al. 2004). Therefore, [O IV] cannot be solely associated with the power of the AGN (see Weaver et al. 2010 for discussion). Figure 9 in Weaver et al. 2010 shows the observed [Ne III]/[Ne II] and [O IV]/[Ne III] ratios for different sources where it can be seen, (1) the BAT AGN branch; (2) below the BAT AGN are the starburst (SB) and HII galaxies which have an apparent [Ne II] excess; (3) above and to the left of the BAT AGN are the Blue Compact Dwarft (BCD), and (4) LINERs, which seem to follow a connecting path between AGN and SB/HII galaxies.

In order to study the physical conditions in the emission-line regions of active galaxies, starburst and composite systems (AGN+SB) we carried out extensive photoionization calculation using CLOUDY (Ferland et al. 1998). Our constant density and plane parallel calculations are designed to model the emitted spectrum of a slab of gas illuminated by radiation emitted by hot, young stars and the AGN, therefore, used two different spectral energy distributions (SEDs), one for each physical process. The star formation SED is designed to maximize the number of photons emitted above the Ne^{3+} ionization limit, while our AGN continuum is a broken power law as used by (Melendez et al. 2008) of the form $F_\nu \propto \nu^{-\alpha}$, with $\alpha = 0.5$ below 13.6 eV, $\alpha = 1.5$ from 13.6 eV to 1 keV and 0.8 at higher energies. We used solar and Orion abundances for the AGN and starburst model, respectively.

From this we generated a grid of models were we varied the hydrogen density, $n_{\rm H}$, between 10^2 and 10^7 cm^{-3}, and an ionization parameter U between $10^{-0.5}$ to $10^{-4.5}$, where the ionization parameter U is defined as:

$$U = \frac{1}{4\pi R^2 c n_{\rm H}} \int_{\nu_0}^{\infty} \frac{L_\nu}{h\nu} d\nu = \frac{Q({\rm H})}{4\pi R^2 c n_{\rm H}}, \quad (1)$$

where R is the distance to the cloud, c is the speed of light and Q(H) is the flux of ionizing photons.

3. RESULTS AND CONCLUSIONS

We used a single-zone AGN and starburst model to reproduce the physical conditions in a sample of galaxies. Assuming a total hydrogen column density of $N_{\rm H} = 10^{21}$ cm^{-2} we found that a single-zone model can only reproduced the observed [O IV]/[Ne III] and [Ne III]/[Ne II] ratio in a few sources in the AGN and starburst sample. This is probably due to the fact that we are comparing emission lines that

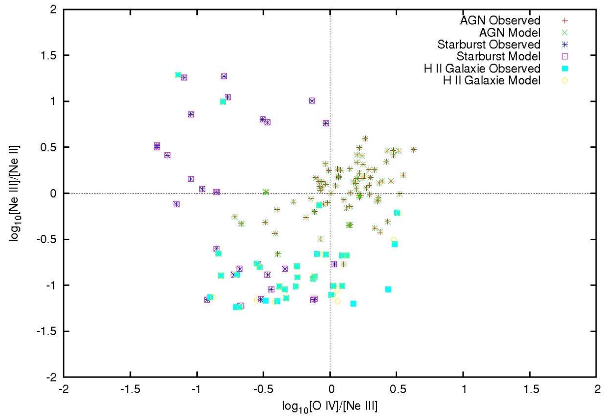

Fig. 1. Comparison between the [Ne III]/[Ne II] versus [O IV]/[Ne III] for a sample of BAT AGN, LINERs, starburst galaxies, HII galaxies and BCDs from (Weaver et al. 2010) and our two-zone models. The dashed lines represent a value of unity for the [Ne III]/[Ne II] and [O IV]/[Ne III] ratios.

have a wide range of ionization potentials and critical densities. Therefore, a more realistic model should included a combination of a radiation- and matter-bounded components. From this we constructed a two-zone model where we found that AGN can be fitted by a combining of two clouds, one at a low ionization ($U \sim 10^{-4}$) and high density ($n_{\rm H} \sim 10^6$ cm^{-3}) and another one at a higher ionization ($U \sim 10^{-1}$) and lower density ($n_{\rm H} \sim 10^3$ cm^{-3}), while starburst galaxies can also be fitted by combination of a cloud at a low ionization ($U \sim 10^{-4}$) and another cloud at a higher ionization ($\sim 10^{-1}$) with a hydrogen density roughly constant. Figure 1 shows the AGNs and starburst galaxies reproduced by our model of two-zone versus the observations.

REFERENCES

Ferland, G. J., Korista, K. T., Verner, D. A., Ferguson, J. W., Kingdon, J. B., & Verner, E. M. 1998, PASP, 110, 761

Lutz, D., Maiolino, R., Spoon, H. W. W., & Moorwood, A. F. M. 2004, A&A, 418, 465

Meléndez, M., Kraemer, S. B., Deo, R. P., Crenshaw, D. M., Schmitt, H. R., Mushotzky, R. F., Tueller, J., Markwardt, C. B., & Winter, L. 2008, ApJ, 682, 94

Weaver, K. A., Meléndez, M., Mushotzky, R. F., Kraemer, S., Engle, K., Malumuth, E., Tueller, J., Markwardt, C., Berghea, C. T., Dudik, R. P., Winter, L. M., & Armus, L. 2010, ApJ, 716, 1151