PROBING THE PHYSICAL CONDITIONS IN THE CIRCUMNUCLEAR REGION OF NGC 4151

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ABSTRACT

We present a study of high resolution HST images of the Seyfert 1 galaxy NGC 4151 in the emission lines [OII]λ3727Å and [OIII]λ5007Å. These images were used to study the ionization structure of the gas in the Narrow Line Region (NLR), through the emission line ratio [OIII]/[OII]. We find that gas located along the region perpendicular to the torus axis has much lower ionization than the gas located along the torus axis. This result, indicates that the gas along the torus equator is being ionized by radiation filtered through its outer regions. This scenario is consistent with the detection, by X-ray observations, of a high column density along the line of sight, corroborating the previously suggested nuclear geometry of this AGN.

Key words: Emission Lines; Seyfert; NGC 4151.

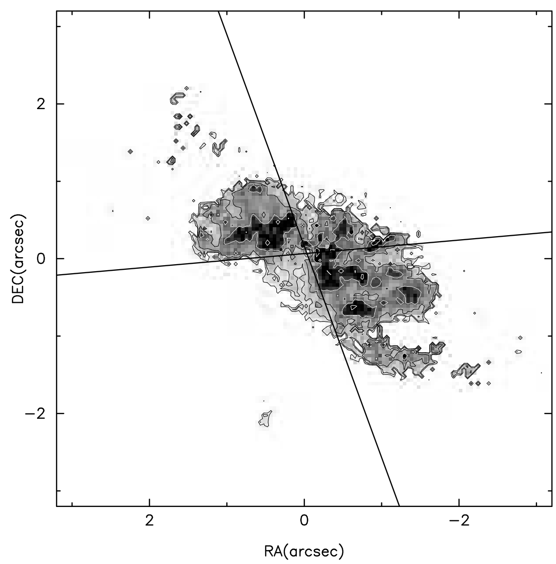

Figure 1. The [OIII]/[OII] ratio image of NGC 4151. The solid lines highlight the ionization bi-cone described by Evans et al. (1993), which has a projected opening angle of 75°, aligned along PA= 60°. The range of values covered by the image goes from [OIII]/[OII]=0.5 in the lighter regions, low ionization, to 8 in the darker ones, high ionization. The contour levels correspond to [OIII]/[OII]=0.5, 1, 2, 4 and 8.

1. INTRODUCTION

NGC 4151 is a nearby Seyfert 1 galaxy that has been extensively studied throughout the electromagnetic spectrum. Narrow band images of this galaxy (Evans et al. , 1993) show that the [OIII] emission has the shape of a bi-cone with the axis aligned along PA= 60°. The bi-cone is caused by the shadowing of the nuclear radiation by the circumnuclear torus, postulated by the unified scheme Antonucci (1993). Based on the orientation of the NLR relative to the host galaxy and the radio jet, Evans et al. (1993) suggested a geometry where the nucleus of this AGN is observed through the torus wall. Although this geometry would suggest that NGC 4151 should be classified as a Seyfert 2 object, our line of sight to the nucleus may pass only through regions of the torus that are mostly ionized, or have a small dust content. Support for this interpretation comes from previous X-ray studies with ASCA and Chandra (e.g. George et al. 1998), which detected a high column density of ionized gas in front of the nucleus of this galaxy, with column densities in the range $2-5\times10^{22}$ cm^{-2}.

Here we present further evidence in favor of the geometry proposed by Evans et al. (1993), based on high resolution HST images. We used narrow-band images centered on the emission lines [OIII] and [OII], observed with the planetary camera on WPFC2. The images were reduced, calibrated and continuum subtracted using standard procedures. In order to study the ionization of the NLR gas we clipped the continuum free images at the 3σ level and created a [OIII]/[OII] image (Figure 1). This image shows the ionization bi-cone seen in the single emission line images, with the high ionization gas located along the bi-cone axis. A feature of particular interest in this Figure is the wedge of low ionization gas along the direction perpendicular to the bi-cone axis (PA 150).

The difference in the ionization state of the gas along the bi-cone axis and in the perpendicular direction can be seen better in the radial profiles presented in Figure 2. In the case of the profile along PA$= 221°$, we can do a direct comparison to the STIS long slit spectrum presented by Nelson et al. (2000). We find a good agreement between the two measurements, with the strongest [OIII]/[OII] located close to the nucleus, indicating higher excitation, decreasing toward to outer regions of the NLR. On the other hand, the profile along the direction perpendicular to the bi-cone axis (PA$= 150°$) confirms that [OIII]/[OII] is lower along this direction, particularly toward the SE, where it reaches a factor of $\sim$5 lower than along the bi-cone axis. The emission toward the NW has slightly higher values, but still lower then the ones seen in the cone. Notice that this ratio should actually be considered an upper limit, since the effect of reddening is strong in [OII], which suggests that the excitation of the gas can be even lower along this direction.

The result presented in Figures 1 and 2 can be understood in the geometry proposed by Evans et al. (1993). A natural consequence of this scenario is that the torus filters part of the ionizing radiation, resulting in the low [OIII]/[OII] seen along PA$= 150°$ (torus equator). Further confirmation of this model comes from the comparison between the predictions from simple photo-ionization models with the [OIII]/[OII] along this direction. We find that the observed line ratios can be explained if the continuum ionizing this gas is first absorbed by a column density of $\sim 10^{21}$ cm^{-2}.

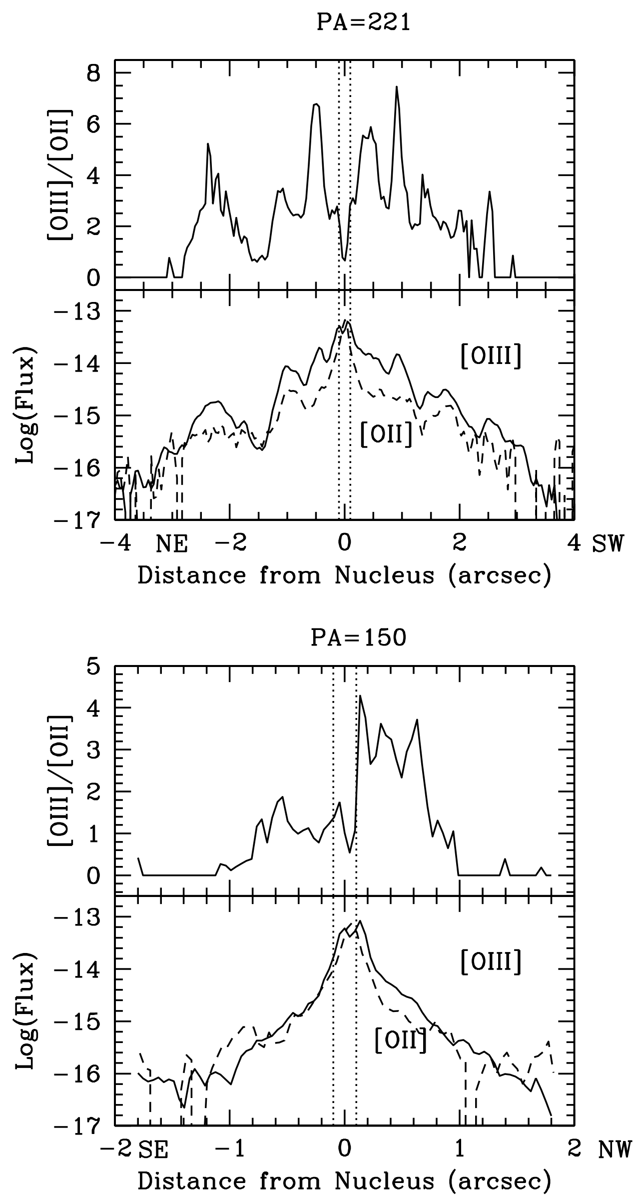

Figure 2. Radial profiles along PA$= 221°$ (top panels), corresponding to the direction along the bi-cone/torus axis, and along PA$= 150°$ (bottom panels), corresponding to the direction along the torus equator. Top panel shows the [OIII]/[OII] ratio and the bottom one shows the [OIII] (solid line) and [OII] (dashed line). The vertical dotted lines show the region around the nucleus that should be disregarded because of image saturation. Profiles were extracted by adding 3 pixels ($\sim 0.14''$) along the direction perpendicular to the one being studied.

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