RevMexAA (Serie de Conferencias), **9**, 324–325 (2000)

THE CORONAL LINE SPECTRUM OF THE BRIGHTEST SEYFERT GALAXIES AS SEEN BY *ISO*

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RESUMEN

Se analiza el espectro de líneas coronales observado con *ISO*, en una muestra de las galaxias Seyfert más brillantes que se conocen. Las observaciones contienen líneas de [O IV] 25.9 μ, [Ne V] 14.3 μ, [Mg VIII] 3.02 μ y [Si IX] 2.58 μ. La relación entre estas líneas y el continuo ionizante entre 50 y 300 eV es el objetivo de este trabajo. Los modelos con pura fotoionización reproducen los cocientes de líneas y dan límites estrictos al parámetro de ionización y la profundidad óptica de las nubes de emisión. Los datos no permiten distinguir entre una ley de potencia o un cuerpo negro para el continuo UV ionizante en estas galaxias. La excepción pueden ser las galaxias más brillantes: NGC 1068, Circinus y NGC 4151, en las que un cuerpo negro parece ajustar mejor al continuo ionizante.

ABSTRACT

The *ISO* coronal line spectrum of a sample of the brightest known Seyfert galaxies is presented and modeled. *ISO* observations of [O IV] 25.9 μ, [Ne V] 14.3 μ, [Mg VIII] 3.02 μ and [Si IX] 2.58 μ lines are presented; their relationship with the ionizing spectrum from 50 to 300 eV is investigated. Pure photoionization models reproduce the line ratios, setting ranges for the ionization parameter and the optical depth of the emitting clouds. On the basis of the available data alone it is not possible to distinguish between a power-law or a blackbody as the intrinsic shape of the UV ionizing spectrum. However, for the brightest Seyferts analyzed, NGC 1068, Circinus and NGC 4151, a blackbody UV continuum is favored.

Key Words: **GALAXIES: SEYFERT— INFRARED: GALAXIES — LINE: FORMATION**

1. INTRODUCTION

Coronal lines are particularly suitable for deriving information about the UV to the soft X-ray region of the ionizing spectrum, as they require photon energies above 50 eV. These lines are unique for tracing the pure AGN power mechanism. Important coronal lines, particularly from Fe, are present in the optical spectrum of some bright AGNs. However, the larger extinction in the optical and the fact that reliable detection of those lines requires medium to high spectral resolution make the number of detections scarce. The IR region is less affected by extinction and proves to be ideal for detecting a wide range of coronal species. The availability of *ISO* allowed us to make a systematic search for such coronal lines in Seyferts galaxies. The brightest Seyferts from the CfA sample were selected for observations with the SWS spectrometer on board *ISO*. All those sources

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that were detected with *IRAS* at 12 μ were selected. *ISO* SWS spectra of the coronal lines [O IV] 25.9 μ, [Ne V] 14.3 μ, [Mg VIII] 3.02 μ and [Si IX] 2.58 μ were collected for all of them. The sample includes the prototypes NGC 1068 and NGC 4151, and the Southern very bright Circinus galaxy. The detailed description of the sample and the *ISO* observations is in Viegas & Prieto (2000).

2. *ISO* RESULTS AND MODELING CORONAL LINES

The two more relevant observational results are as follows:
(1) For all the galaxies in the sample, the emission lines [O IV] 25.9 μ and [Ne V] 14.3 μ are strong features in the Seyfert spectra regardless of their type. On the other hand, [Mg VIII] 3.02 μ and [Si IX] 2.58 μ are systematically weaker in all cases.
(2) When comparing the coronal lines relative to [O IV] 25.9 μ ([Ne V]/[O IV], [Mg VIII]/[O IV] and [Si IX]/[O IV]) with the ionization potential (IP) that gives rise to the corresponding ion (Ne^{4+}, Mg^{7+} and Si^{8+}, respectively), a trend of decreasing line ratios with the IP is found for all the galaxies in the sample.

To test the ionizing continuum shape, the ratio of the coronal lines relative to [O IV] 25.9 μ were compared to pure photoionization model predictions. The simulations were obtained with the photoionization code Aangaba (Gruenwald & Viegas 1992). The basic assumptions considered in the models were plan-parallel symmetry, solar abundances, and a composite ionizing spectra (blackbody plus an X-ray power law, or two power-laws). For the X-ray component, we adopt the canonical power-law index for AGN $\alpha_X = -0.7$. We discuss the results for two types of UV continuum: a 2×10^5 K blackbody and a power-law with index $\alpha_{UV} = -2$. In both cases, the UV spectrum matches the X-rays at E $\simeq$ 100 eV. The two parameters in the models that were left free to vary were *the ionization parameter U* (the ratio of the number density of ionizing photons to gas particles), and the *cloud optical depth* at the Lyman limit, τ_{ly}. The results are:
(1) Within a reasonable range of values for U (0.2 to 0.006) and τ_{ly} (0.2 to 30), both type of UV ionization continua appear indistinguishable on the basis of these data alone.
(2) However, some constraints on the ionization parameter and the cloud optical depth can be derived. Independent on the UV continuum model selected, values of U below 0.1 are required to account for the low [Si IX]/[O IV] ratios. The optical depth is more UV-continuum dependent but values of about 1 or larger are required for most sources: τ_{ly} varies from optically thin to optically thick in the case of a power law, whereas optically thick clouds are required in the case of a blackbody.
(3) For the brightest Seyfert in the sample, Circinus, NGC 1068 and NGC 4151, with accurate measurements of the coronal lines, a more clear pattern arises. Our best approximation to the decreasing line ratios vs IP pattern in these sources is obtained by assuming a blackbody with a cutoff in the 100 − 120 eV range. Furthermore, U values below 0.01 and τ_{ly} larger than 1 are required. In fact, low U values coupled to large values of τ_{ly} favor the presence of low ionization ions such as O^{+3} compared to Si^{+8}, decreasing the [Si IX]/[O IV] ratio. In addition, if the cloud is optically thick, the volume emitting [O IV] is larger, and the [Si IX]/[O IV] ratio is even lower as seen in NGC 4151. Other facts are also expected to contribute. First, these line ratios depend on the abundance ratios and only solar ratios are here assumed. Second, a reliable determination of the ionizing radiation spectrum could only be obtained if a mixing of clouds with different U and τ_{ly} is chosen to fit more emission-line intensities.

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Astrophysical Plasmas: Codes, Models, and Observations (Mexico City, 25-29 October 1999)
Editors: Jane Arthur, Nancy Brickhouse, & José Franco