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A NEAR-INFRARED VIEW OF THE NARROW LINE REGION OF AGN

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RESUMEN

Reportamos sobre el atlas espectral más completo de núcleos activos de galaxias en la región del infrarrojo cercano publicado a la fecha. El objetivo principal es construir una base homogénea de datos con una buena S/N y resolución espectral, que permita el estudio de las propiedades del continuo y de las líneas en fuentes individuales, y la comparación de éstas propiedades entre los diferentes tipos de AGN. Identificamos las líneas espectrales más importantes que fueron detectadas y confirmamos la utilidad del diagrama [Fe II]/Paβ vs H_2/Brγ para separar los diferentes objetos emisores de líneas de acuerdo al nivel de actividad nuclear. Encontramos que el NIR oferece información valiosa sobre las regiones emisoras de líneas anchas y estrechas, añadiendo restricciones importantes al modelaje de las propiedades físicas del gas emisor.

ABSTRACT

We report on the most complete spectral atlas of active galactic nuclei (AGN) in the near-infrared region (NIR) published to date. The main goal is to construct a homogeneous database at good S/N and spectral resolution allowing the study of the continuum and emission line properties of individual sources and the comparison of these properties among the different types of AGN. We identify the most important emission features detected and confirm the usefulness of the [Fe II]/Paβ vs H_2/Brγ diagram to separate emission line objects by their degree of nuclear activity. We found that the NIR offers valuable information for the broad and narrow line regions, adding important constraints to the 0 of the physical properties of the nuclear gas.

Key Words: H II regions — ISM: jets and outflows — stars: mass loss — stars: pre-main sequence

1. INTRODUCTION AND DATA SAMPLE

From the spectroscopic point of view, Active Galactic Nuclei (AGN) have been poorly studied in the near-infrared region (NIR). Indeed, just up to a few years ago, most published NIR spectra covered only individual lines or a limited wavelength interval within a band (Giannuzzi et al. 1995; Reunanen et al. 2002). Moreover, combined JHK spectra were usually obtained with different instruments using a variety of observing setups. Nowadays, the availability of cross-dispersed spectrographs allow the simultaneous observation of the 0.8–2.4 μm interval, free of seeing and aperture effects. Thus, large samples can be observed to study in detail line and continuum emission properties, providing a wealth of information that helps to better understand AGN, for instance, in a spectral region accessible from earth and less affected by extinction. This information can later be used as reference for classifying high-z sources and put constrains on current models, among other applications.

For all said above, the main goals of this work are: (i) to construct a homogeneous atlas of moderate resolution spectra of AGN in the NIR; (ii) to study and identify the most prominent emission lines, in particular, those not seen in the optical (i.e., H_2 and [Fe II]); (iii) investigate the continuum emission in a transition zone where the central engine no longer dominates whilst dust emission and young circumnuclear stellar emission start becoming important; (iv) get clues about the ionization structure of the NLR using NIR emission lines.

Spectra of 48 AGN (32 Type 1 and 16 Type 2) and 4 starbursts were obtained at the 3.1 m. NASA IRTF using SpeX (Cushing et al. 2004) at R $\sim$ 800. The integrated nuclear spectra cover, for most cases, the inner 200 pc. Resolved narrow line region spectroscopy, reaching distances of up to 500 pc from the nucleus, was also obtained for a sub-sample of objects. Figure 1 shows a sample of nuclear spectra of classical Seyfert 1 and 2 galaxies observed.

2. CONSIDERATIONS ABOUT THE CONTINUUM EMISSION

The NIR spectra of Type 1 sources (see Figure 1) are dominated by a featureless continuum with a strong blue rise and a clear “turning point” at $\sim$11000 Å. We interpret this latter feature as a

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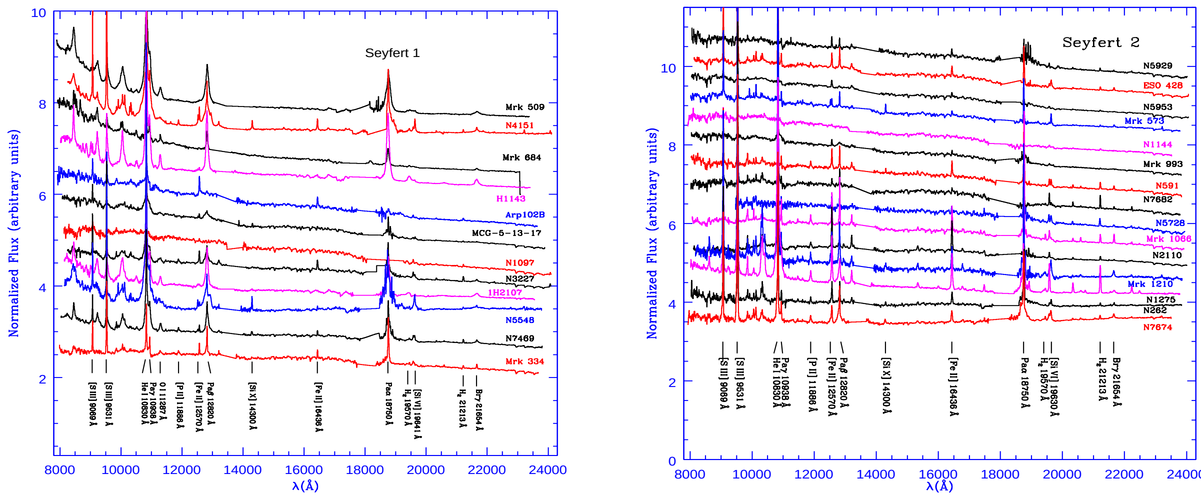

Fig. 1. Observed NIR spectra of classical Seyfert 1 galaxies (left) and Seyfert 2 galaxies (right). The spectra were flux normalized and displaced for displaying purposes. The most prominent emission lines are identified.

transition between the red end of the optical power-law continuum and the blue end of the warm dust continuum emission. This result is in perfect agreement with the findings of Glikman et al. (2006) for a sample of quasars. Mrk 1239, Mrk 478 and Mrk 766, in addition, display an excess of emission that peaks in the K-band. Rodríguez-Ardila & Mazzalay (2006) found that the excess in Mrk 1239 is well reproduced by a blackbody at a temperature of 1200 K. They interpreted it as a clear signature of host dust located near the central engine, probably associated to the Torus.

Few Type 1 sources show absorption features (the 2.3 μm CO bandheads, for example). This result implies that the observed continuum is emitted by the unresolved nucleus, which dilutes the features associated to circumnuclear stellar population. Even at the NIR, the nuclear continuum dominates.

None of the Type 2s studied display the blue rise of the continuum shortward of 1.1 μm observed in Type 1s. Moreover, all Type 2 except NGC 1275 and NGC 262 show prominent absorption lines and bands in H and K. Their NIR continuum is clearly stellar dominated. In J, most Seyfert 2s display an absorption band at 11000 Å, not reported before in AGN and which we associated to CN (Riffel et al. 2007).

3. NIR EMISSION LINE DEMOGRAPHY FOR THE SAMPLE

We describe below the most important lines observed in the interval 0.8–2.4 μm, with emphasis in the frequency which they are detected in the different types of AGN.

3.1. *Classical Seyfert 1 Galaxies*

Figure 1 shows that the stronger lines in the spectra are those of He I 10830 Å, [S III] 9531 Å and Paβ. Broad components of permitted lines, with FWHM reaching 5000 km s^{-1}, are detected. Other important features are Fe II and O I 11287 Å. The former is present in 35% of the Seyfert 1s, while the latter is observed in about 60% of the sources. Low ionization forbidden emission lines are also detected. The most common one is [Fe II] 12570 Å, present in 65% of the galaxies. H_2 21213 Å is observed in 75% of the sources. Coronal lines are conspicuous, with [Si VI] 19630 Å detected in 65% of the galaxies. [Si X] 14300 Å, which requires 351 eV for its production, is common to 40% of the objects.

3.2. *Narrow line Seyfert 1 galaxies*

Overall, the spectra of NLS1 are similar in shape to those found in classical Seyfert 1s. However, there are some differences. Indeed, the most conspicuous emission lines are He I 10830 Å, Paα and Paβ. The forbidden [S III] 9531 Å line is common to all the galaxies, but not as intense as in the classical Seyfert 1s. Other important lines are O I 11287 Å, present in more than 90% of the sources and the multiplets of Fe II, detected in more than 75% of the NLS1 objects. Interestingly, individual Fe II lines can be distinguished, contrary to what is observed in the optical region, where they are strongly blended, forming a pseudo-continuum. Narrow lines (forbidden and molecular) such as [Fe II] and H_2 are also present in 85% of the sources. Coronal lines are prominent, with [Si VI] 19630 Å and [Si X] 14300 Å observed in nearly 50% and 40% of the sources, respectively.

3.3. *Seyfert 2 Galaxies*

For Seyfert 2 galaxies (see right panel of Figure 1), we found that the strongest emission features are [S III] 9531 Å and He I 10830 Å, present in all objects.

The doublet [Fe II] 12570, 16436 Å was found in more than 80% of the galaxies. H_2 21213 Å is common to all spectra. Forbidden low ionization lines of phosphorus and carbon are also observed. At least one of the [P II] lines (λ 11460 Å or λ11886 Å) are detected in 53% of the Sy 2 spectra and [C I] is detected in 70% of the Sy 2's. The high ionization lines are found in some sources, with [Si VI] 19630 Å detected in more than 40% of the spectra and [Si X] 14300 Å common to less than 25% of objects. Statistically, these latter lines appear less frequently in Type 2 than in Type 1 objects.

4. A DIAGNOSTIC DIAGRAM IN THE NIR

Rodríguez-Ardila et al. (2004) showed that the line ratios H_2 21210 Å/Brγ and [Fe II] 12570 Å/Paβ were suitable to separate emission line objects according to their level of activity. Galaxies for which either one of the ratios were smaller than 2 were predominantly classified as Seyferts. Moreover, Starburst galaxies were preferentially located in the region with [Fe II]/Paβ and H_2/Brγ < 0.4, while LINERs were characterized by [Fe II]/Paβ and H_2/Brγ ratios < 2. However, few Seyfert 2 were included, preventing them to make definitive conclusions. Here, with an augmented sample, and most importantly, the inclusion of Seyfert 2s, it is possible to confirm the trends already observed.

Figure 2 shows the most recent version of the [Fe II]/Paβ vs H_2/Brγ diagram to date. It can be seen that the selected line ratios are suitable to separate emission line objects by their degree of activity in the NIR region. Although similar diagrams exists in the optical region Veilleux & Osterbrock 1987), clearly separating AGN from LINERs, starburst and H II galaxies, they fails for objects with $A_v \geq 3$, that is, for galaxies with buried AGN. Although one can argue that in the NIR AGN can be unambiguously distinguished from other emission line objects by the detection of coronal lines (i.e [Si VI] 19630 Å, [Ca VIII] 23210 Å), we have already seen that not all AGN display such high ionization lines (see § 3).

5. FINAL CONSIDERATIONS

The most completed NIR atlas of nuclear and extended emission line region of active galactic nuclei is presented and analyzed in terms of the continuum and line emission. The most important continuum feature observed in Type 1 sources is a turnover region that marks the red end of the optical power-law and the blue end of the continuum emitted by hot dust. Type 2 sources display a stellar dominated continuum. We identified a strong absorption band at 11000 Å due to CN. A diagnostic diagram useful to separate emission line objects by their degree of activity is confirmed as a suitable tool to identify AGN from large samples of objects. Overall, the NIR region provides a wealth of information complementing results gathered from optical data.

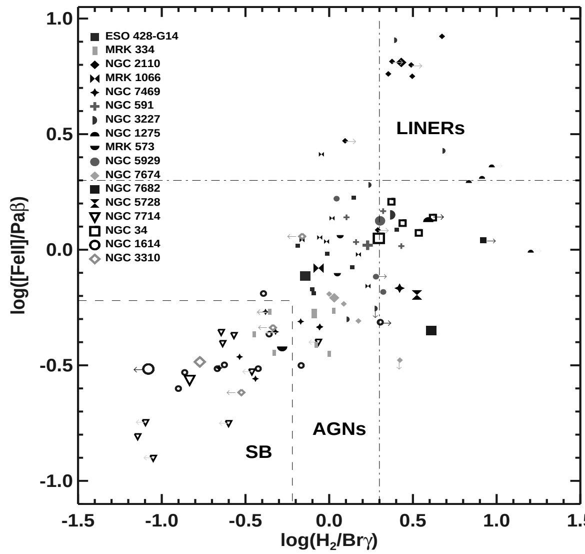

Fig. 2. The flux ratios H_2 2.12μm/Brγ vs ¿ [Fe II] 1.257μm/Paβ. Full symbols represent Seyfert galaxies (AGN) whilst open symbols are starburst (SB). The dashed line marks the boundary between AGN and SBs while the dot-dashed line separates AGN from LINERs. Large symbols refer to the unresolved nucleus. Smaller ones represent resolved NLR emission.

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