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INFRARED OBSERVATIONS OF ACTIVE GALAXIES

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RESUMEN

Se reportan observaciones espectroscópicas de resolución media para una muestra selecta de NAGs y galaxias Starburst, en el intervalo de 1.1 a 2.4 μm. Se han detectado intensas líneas en emisión de H I, He I, H_2 y [Fe II], así como trazas estelares, tales como las cabezas de banda del CO en las bandas H y K, y líneas de Si I, Na I y Ca I. Se discuten los mecanismos de excitación para el H_2.

ABSTRACT

We report medium resolution, spectroscopic observations of a selected sample of AGNs and Starburst galaxies, at wavelengths ranging from 1.1 to 2.4 μm. Strong H I, He I, H_2 and [Fe II] emission lines have been detected, as well as stellar features, such as the CO bandheads in both H- and K-band, and Si I, Na I, and Ca I lines. The excitation mechanisms for the H_2 emission are discussed.

Key Words: **GALAXIES: ACTIVE - GALAXIES: STARBURST - INFRARED: GALAXIES**

1. INTRODUCTION AND OBSERVATIONS

Near-IR imaging and spectroscopy have demonstrated to be excellent tools in the study of AGNs. The K-window offers several diagnostic spectral lines for studying the stellar populations of AGNs, like the deep CO band absorption long-ward of 2.3 μm arising from the atmospheres of late-type stars; in this window we also find the presence of many transitions of molecular hydrogen (H_2). The less studied J and H windows offer also the possibility of analyzing the stellar content of AGNs. The Si and CO lines detected in the H-Band are good tracers of red supergiants in AGNs (Marconi et al. 1994) as well as the nature of [Fe II] emission, still under debate. Here we present some preliminary results from medium resolution, spectroscopic observations of a selected sample of AGNs and Starburst galaxies, ranging from 1.1 to 2.4 μm.

Observations were made on December 1994, December 1995, August 1996, and March 1997, using the two-channel Gemini Camera at the 3.0 m Shane Telescope at Lick Observatory. Gemini employs a HgCdTe (J, H Bands) and a InSb (K Band) photovoltaic arrays made up 256×256, 30 μm square pixels. The optical design was driven by matching current 256×256 detectors to the W.M. Keck Telescope at f/15 with 0.25 arcsec pixels. The same design yields 0.7 arsec pixels on the Lick 3 m telescope (McLean 1994). In the spectroscopic mode Gemini was used inserting grisms into each beam in first order, providing spectral coverages of 1.1–1.35 μm, 1.45–1.8 μm, 1.8–2.4 μm respectively. A long slit of 180 pixels (126 arcsec) length was used. The dispersion in each band was 11.5, 16 and 19 Å per pixel and the final spectral resolution, as measured from the comparison arcs was 26, 30 and 38 Å i.e. 650, 545 and 520 km/s (FWHM) respectively. The resolving power $\lambda/\Delta\lambda$ in each band is thus $R_J = 460$, $R_H = 550$ and $R_K = 580$.

2. RESULTS AND DISCUSSION

We have detected, among others, the following emission lines: He I λ1.083, Pγ λ1.093, O I λ1.129, H_2 2-0S(0) λ1.189, [Fe II] $\lambda\lambda$1.257, 1.321, Pβ λ1.282, [Fe II] $\lambda\lambda$1.644, 1.677, He I λ 1.701 H_2 1-0S(2) λ2.033, 1–0S(1) λ2.122, 1–0S(0) λ2.223, 2–1S(1) λ2.248, Br$\gamma\lambda$2.165. The H I, He I, H_2 and [Fe II] emission lines are strong in both Starburst and Seyfert galaxies in the J and H bands, while in the K-band the emission lines are more prominent in Starburst galaxies only.

Stellar features such as the CO bandheads in both H- and K-band, Fe I 1.578, Si I 1.589, Na I 2.206, Ca I 2.263 are present in most of the spectra. In particular we have identified the complete CO $\Delta v = 3$ band on the spectrum of NGC 1052 (LINER), NGC 3079 (Starburst) and NGC 838 (Elliptical) in the H-Band. These CO features, as well as the other metallic lines, show that a significant fraction of the H continuum in these galaxies could have a stellar origin. In the K-band, the most prominent stellar features detected are the CO bandheads longward of 2.3 μm as well as the Na I 2.206 and Ca 2.263 lines. Weaker lines like Mg I 2.106 and Mg II 2.144 are also present in some objects. Comparing the measured equivalent widths of CO $\lambda\lambda$1.618, 2.296 μm with those obtained by Origlia et al. (1993) for a sample of K, M giants and supergiants stars, we found that all galaxies (Seyfert 2 and non-Seyfert) lie in a very restricted region of the [1.618, 1.618/2.296] diagram, confirming that Starbursts can not be reliably detected using these indices alone (Oliva et al. 1995).

A primary question about H_2 lines in AGNs is the source of their excitation. The main mechanism in star-forming regions is collisional excitation in the shock fronts created by expanding H II regions and by stellar winds. Active galaxies also present the possibility of fluorescent UV excitation (Black & van Dishoeck 1987). The strong UV flux should excite a significant amount of H_2. However, many of these galaxies display strong emission in the 1-0S(1) line (Goldader et al. 1997) but not in other H_2 lines, suggesting that collisional processes dominate over fluorescence. UV-excited H_2 is so difficult to detect because its energy is emitted in a huge number of lines, whereas thermally excited H_2 emits most of its luminosity in just a few. In a low density gas, fluorescent H_2 emits just 1.6% of its infrared luminosity in the readily observed 1-0S(1) line while thermally excited H_2 emits 9% of its infrared luminosity in this line (Engelbracht et al. 1998). Observationally, Puxley et al. (1988) report UV fluorescence in a sample of 7 starburst galaxies. On the other hand, Moorwood & Oliva (1990) have obtained negative results for another sample of galaxies, and concluding that this mechanism is not predominant in these objects. The table shows the comparison of the shocks and fluorescent UV models from Black & van Dishoeck with the relative fluxes of the stronger H_2 lines detected in our sample in the K band.

Object	1–0S(2) ($\lambda_{2.033}$)	1–0S(1) ($\lambda_{2.121}$)	1–0S(0) ($\lambda_{2.222}$)	2–1S(1) ($\lambda_{2.248}$)	Object	1–0S(2) ($\lambda_{2.033}$)	1–0S(1) ($\lambda_{2.121}$)	1–0S(0) ($\lambda_{2.222}$)	2–1S(1) ($\lambda_{2.248}$)
Shocks	0.37	1.00	0.21	0.08	Shocks	0.37	1.00	0.21	0.08
UV Fluor	0.50	1.00	0.46	0.56	UV Fluor	0.50	1.00	0.46	0.56
Mixed	0.44	1.00	0.34	0.32	Mixed	0.44	1.00	0.34	0.32
MRK 551	0.53	1.00	0.62	0.52	NGC 3690	0.60	1.00	0.39	0.39
UGC 2369	0.40	1.00	0.28	0.10	NGC 253	0.35	1.00	0.31	0.13
NGC 2992	0.54	1.00	0.39	0.26	NGC 7674	0.47	1.00	0.60	0.84
NGC 3079	0.42	1.00	0.29	0.13	NGC 231	0.22	1.00	0.19	0.30

We can see from the table that in MRK 551 and NGC 7674 the H_2 emission is apparently driven by UV fluorescence, but in general our observations are in better agreement with shock driven models.

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