Near–infrared spectroscopy of Seyfert galaxies

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Abstract. Results from near-infrared 1.5 – 2.5 μm long-slit spectroscopy of 14 nearby Seyfert galaxies are presented.

1. Introduction

In the AGN unified models (Antonucci 1993), a molecular torus obscures the nucleus and the BLR in Seyfert 2 (S2) galaxies, while in Seyfert 1 (S1) galaxies they are directly visible. Adequate spatial resolution to search for the molecular torus, with predicted size < 100 pc (Pier & Krolik 1993) can be achieved in the near-infrared (NIR). However, such NIR spectroscopic studies have so far been made at only moderate spatial resolution and/or only along the radio or [O III] axis (Veilleux et al. 1997; Winge et al. 2000). We present NIR 1.5 – 2.5 μm long-slit spectroscopy of 14 nearby (0.002 < z < 0.010) Seyferts (3 S1s, 2 intermediate Seyferts and 9 S2s), both parallel and perpendicular to the ionization cone. For full discussion, see Reunanen, Kotilainen & Prieto (2002a, b).

2. Results

The strongest emission line is Brγ 2.166 μm in 2 S1s, 2 intermediate Seyferts and 2 S2s; [Fe II] 1.644 μm in 3 S2s; H2 1-0 S(1) 2.122 μm in 1 S1 and 1 S2; and a coronal line ([Si VI] 1.964 μm or [Si VII] 2.483 μm) in 3 S2s.

Broad Brγ is detected in 9 Seyferts, of which 5 are optically classified as S2s. The detection of broad Brγ in more than half of the S2s is due to the lower nuclear extinction in the NIR. This extinction is unlikely to be related to the molecular torus, as its optical depth is likely to be high enough to obscure the BLR. The extinction is more likely caused by foreground dusty material in the form of star forming (SF) clouds, which frequently coexist with the AGN.

Spatially resolved nuclear [Fe II] emission was detected in 8 Seyferts (1 S1, 2 intermediate Seyferts, and 5 S2s). The extended emission is patchy and follows closely the SF complexes as [Fe II] is correlated with Brγ. The nuclear [Fe II] emission in a few Seyferts is consistent with X-ray excitation in the NLR, but appears predominantly to be shock-excited.

The nuclear H2 surface density is higher in S2s than in S1s. This quantity is, however, correlated with the detection of broad Brγ, indicating extinction
effects. The H$_2$ emission is extended in 11 Seyferts. In a few Seyferts (NGC 1097, NGC 1386, NGC 4945) off-nuclear H$_2$ emission regions are detected, associated with the SF rings, but in most Seyferts, the extended molecular disc-like gas declines smoothly with radius. The spatial extent of the nuclear H$_2$ emission is larger perpendicular to the cone than parallel to it in only 6/11 galaxies, in only moderate agreement with the unified models and the existence of a molecular torus. Thus a larger sample and/or higher spatial resolution data is required to search for the molecular material associated with the torus. Only in 5 Seyferts, nuclear H$_2$ 2–1 S(1) 2.248 $\mu$m emission was detected and the 2–1 S(1)/1–0 S(1) ratios are inconsistent with significant fluorescent excitation, and agree with thermal excitation by X-rays or, more likely, by shocks.

Four coronal lines were detected: [Si vi], [Al ix] 2.043 $\mu$m, [Ca viii] 2.321 $\mu$m and [Si vii]. Of these, [Si vi] was detected in 7, [Al ix] in 3, [Ca viii] in 4 and [Si vii] in 7 Seyferts. At least one coronal line was detected in 8 Seyferts (1 S1, 1 intermediate Seyfert and 6 S2s), substantially increasing the number of Seyferts with NIR coronal line detection. Interestingly, in all three Seyferts with spatial information (NGC 1068, NGC 3081 and ESO 428-G14), the coronal line emission is extended parallel to the cone, indicating an anisotropic radiation field. Due to the high ionization potential of the coronal lines, the extended emission is mainly produced by shocks interacting with the interstellar medium.

3. Work in progress: stellar populations

The NIR spectra contain many stellar and nebular features (He i 2.058 $\mu$m and Br$\gamma$ emission lines, Si I 1.588 $\mu$m and CO (6-3) 1.619 $\mu$m absorption lines, and the $^{12}$CO and $^{13}$CO absorption bandheads longward of 2.29 $\mu$m). The He i and Br$\gamma$ emission lines are related to the number of ionizing UV photons from massive stars, while the CO lines measure the stellar kinematics, light-to-mass ratio, and recent SF (Oliva et al. 1995). In Seyferts, the central CO emission is often diluted by hot dust emission heated by the AGN.

We are currently studying the stellar population content of the Seyferts (Reunanen et al., in prep.). Stellar emission and absorption features probe the age and SF properties of the stellar population in the nucleus and as a function of radius. Comparison of these properties between Seyferts and a matched sample of spirals, for which we have obtained similar NIR spectra, will assess any relationship of SF with the nuclear power.

References

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