Hα + [N II[jet and *not* the well-known radio jet as in all other cases.

The nuclear spectra also show a complex structure: the Hα and two [N II] emission lines are multiple with at least three observable components. This is probably due to flows of gas in other directions, e.g. towards the north where other emission can be seen in Figure 1. The [O III] (5007 Å) emission line is double peaked in the core. This can be clearly seen in Figure 4. The emission lines then merge at about r = ± 2", reminiscent of an expanding shell of gas. The velocity of expansion is measured to be about 300 km s^{-1}.

In summary, the jet nature of the Hα + [N II] emission-line feature seems well established. The origin of the entire Hα + [N II] gas is not. Moreover, of particular interest is the alignment of the [O III] core emission with this jet since it is not seen in any other radio galaxy with emission-line activity. This gas and other species will merit more detailed study in the future.

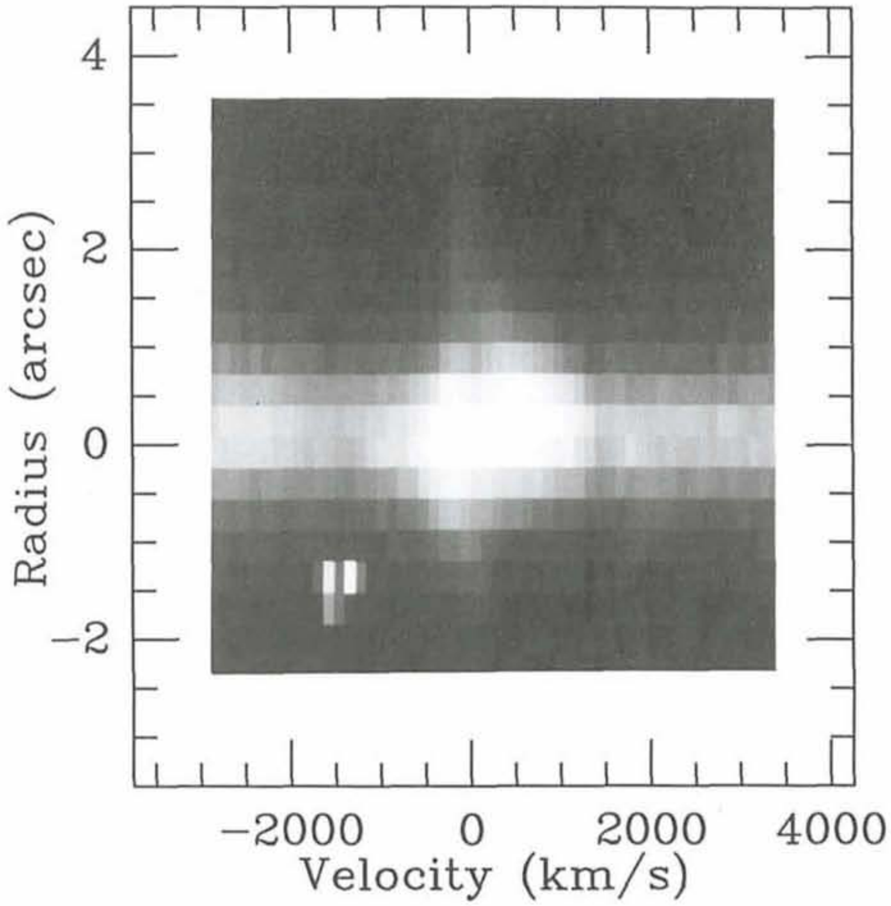

Figure 4: *The [O III] (5007 Å) emission line in the core of M87. Note the double peak at the centre.*

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Infrared Coronal Lines in Active Galaxies

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1. Introduction

Coronal lines are forbidden fine-structure emission lines from highly ionized heavy metals. Although the best known are probably those of [Fe VII]–[Fe XIV], which fall in the visible, many more coronal lines from a large number of elements fall in the infrared spectral range but have received little attention so far. These include transitions of [Ca VIII], [Al V], [Al VI], [Si VI], [Si VII], [Mg VIII], [Al IX], and [Si IX] at wavelengths between 1.96 and 3.92 μm which, although mostly falling in regions of poor atmospheric transmission, have now been observed from the ground in several novae. Discovery of these lines in novae was completey unexpected and their identification was controversial for some time until confirmed by subsequent work.

The [Si VI] ($^2P_{1/2}$–$^2P_{3/2}$) 1.96 μm and [Si VII] ($^3P_1$–$^3P_2$) 2.48 μm lines are also present in spectra of the extremely high excitation planetary nebula NGC 6302 and represent the highest ionization stages (ionization potentials of 167 eV and 205 eV respectively) observed in PN.

2. Infrared Lines

As further evidence that infrared spectroscopy is still in its exploratory phase, the first reported measurement of an infrared coronal line in an extragalactic object was our somewhat serendipitous detection of the [Si VI] 1.962 μm line in the Seyfert galaxy NGC 1068 while using IRSPEC at the ESO 3.6-m telescope to explore bright galaxies in previously unobserved portions of their infrared spectra lying outside the high transmission 'window' regions (Oliva and Moorwood 1990).

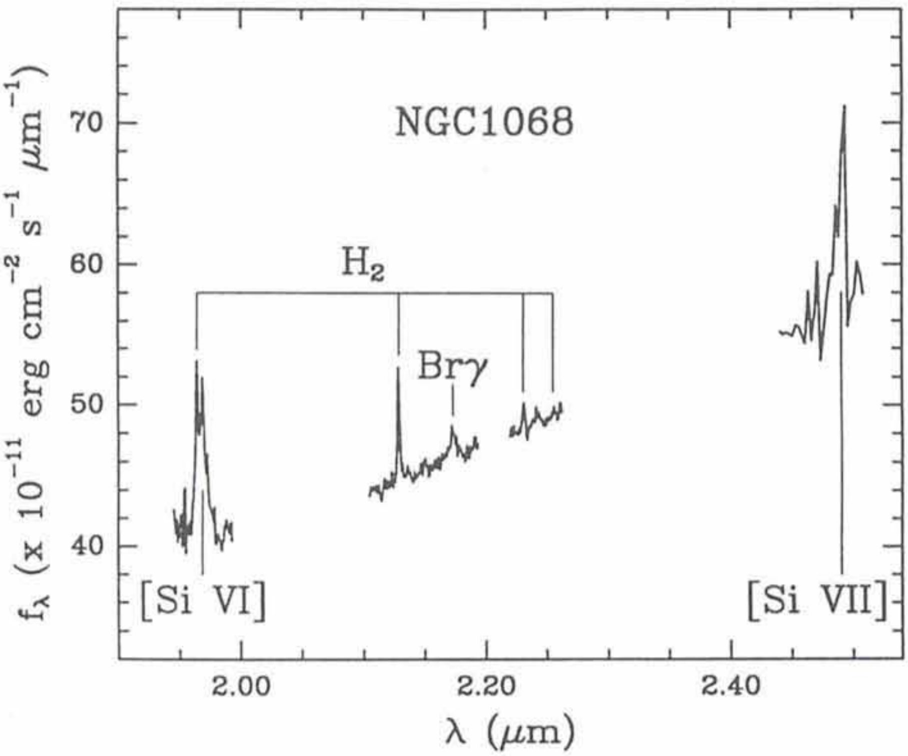

Figure 1: *Discovery spectrum of the [SiVII] 2.48 μm line in the Seyfert galaxy NGC 1068 obtained with IRSPEC at the NTT plotted together with the previously obtained spectrum at the 3.6-m telescope showing [SiVI] 1.962 μm blended with the H_2 1-0S(3) line. Residual noise in the [SiVII] spectrum is dominated by imperfect cancellation of strong atmospheric absorption lines in this region of the spectrum which lies to the long wavelength side of the K band window.*

Following this discovery we have subsequently searched specifically for the [Si VI] line in several other galaxies with detections in the Seyfert galaxies A1409-65, NGC5506 and IC4329A and, as anticipated, no evidence for this line in several starburst nuclei included for comparison.

Following the transfer of IRSPEC to its new home at the NTT in October 1990 we have also now observed the [SiVII] line at its expected rest wavelength of 2.48 μm in NGC 1068 to confirm the line identifications and obtain additional diagnostic information. Apart from their potential as a new technique for investigating the origin of coronal lines, simply the presence of these lines is of considerable interest as potential infrared tracers of Seyfert activity and their intensities should provide a valuable check on models now being used to predict the likely strengths of longer wavelength coronal lines which are unobservable from the ground but should be accessible to the spectrometers to be flown on the ESA Infrared Space Observatory scheduled for launch in 1993.

Both lines exhibit extremely large equivalent widths as can be seen in Figure 1 which shows the calibrated spectrum of NGC1068 around [SiVII] plotted together with our previously published discovery spectrum of [SiVI]. Estimated fluxes are ~7.5 and $9.0 \cdot 10^{-13}$erg. $cm^{-2}.s^{-1}$ in a 6 × 6 arcsec aperture for the [SiVI] and [SiVII] lines respectively, although accurate determinations are difficult because the [Si VI] line is blended with the H_2 1-0S(3) line and lies shortward of the K(2.2 μm) window, where the transmission is poor and varies rapidly with wavelength, while the [Si VII] line lies in an even worse atmospheric region longward of the K window. This line, being broad (~1000 km/s), is clearly visible in the raw spectra. In order to improve cancellation of the many strong and narrow H_2O absorption features, however, the spectrum shown was obtained by combining spectra measured with the 32-pixel array at four grating positions selected to yield a 128 point spectrum with half pixel spacings which was then re-binned over four pixels (~300 km/s) before dividing by interleaved measurements of a nearby standard star treated in the same way. The resulting noise is, nevertheless, still dominated by imperfect cancellation of these lines.

3. Origin of the Lines

As infrared coronal lines result from transitions between low lying levels, they are easy to excite collisionally even in relatively low temperature gas. Formation of the ions themselves, however, requires a highly energetic process and is generally attributed to collisional excitation in hot (~10^6K) gas or photoionization by UV/X-ray photons. The relative importance of these mechanisms in active galaxies is still a matter of debate as is the actual location and density of the coronal line gas.

Initially, therefore, it appeared highly significant that both the ratios [SiVI]/Br_γ ~ 6 and [SiVII]/[SiVI] ~ 1.2 measured for NGC 1068 are almost exactly as predicted very recently for photoionization of the low density interstellar medium by the central continuum source in active galaxies (Korista and Ferland, 1989 and results presented in the ISO Long Wavelength Spectrometer Consortium GT Proposal obtained using the same code). Accepting the apparent support for this model at face value, however, would imply that the Br_γ emission within the central 6×6 arcsec region observed is dominated by the coronal line gas which appears improbable. Following conventional reasoning, the fact that the [SiVI] and [SiVII] lines are broader than other forbidden lines of lower excitation, e.g. [FeII] have widths comparable to the He I 1.083 μm line, also indicates an origin in high- rather than low-density gas.

Comparison of our results for NGC 1068 with those obtained on novae and the planetary nebula NGC 6302 also reveals the more perplexing fact that, whereas the [SiVII]/[SiVI] ratio should be sensitive to details of the ionization mechanism, its measured values are essentially identical in all the objects so far measured.

In novae, the coronal lines are believed to arise in relatively high density gas (< 10^6 cm^{-3}) excited by both photoionization and collisions in hot gas and the remarkable similarity in conditions implied by the constancy of the [SiVII]/[SiVI] ratio in the four novae in which this has been measured has already been drawn attention to by Greenhouse et al. (1990). In the planetary nebula NGC 6302 it appears to be consistent with lower density (10^4 cm^{-3}) gas photoionized by a central star at T ~ 5.10^5K (Ashley and Hyland, 1988) and the same ratio now observed in NGC 1068 is consistent with photoionization of low density gas by an active nucleus. At the moment the detailed implications of this result are not clear.

As the [Si] line critical densities are similar and much higher (~2.10^8 cm^{-3}) than the model densities considered in NGC 6302 and NGC 1068 their line ratios should exhibit a relatively weak density dependence and the similarity of the observed ratios may simply reflect the fact that the ionizing spectrum of a star as hot as that invoked in the planetary nebula does closely mimic an active nucleus (thus at least providing support for photoionization rather than collisional excitation in active nuclei). The more difficult problem is accounting for the similarity whith novae if collisional excitation really does play an important role in these objects.

As the other galaxies mentioned above which show the [SiVI] line have not been observed around [SiVII], the constancy of this ratio in galaxies cannot yet be tested. These and other galaxies for which [SiVI] upper limits have been obtained do, however, appear to exhibit lower [SiVI]/Br_γ ratios (≤ 2) except perhaps for the Seyfert 1 galaxy IC4329A (≥ 1.7). The [SiVI]/[FeVII] line ratio in this galaxy is also larger than in NGC1068 – consistent with higher excitation conditions as already indicated by its larger [FeX]/[FeVII] ratio. Further tests of the correlation between [Si] and [Fe] lines are of interest but presently limited by the small sample of galaxies observed to date and uncertainties in the extinction corrections to be applied to the visible lines.

Following the planned upgrade of IRSPEC with a 2D array detector, it is now hoped in the near future to be able to extend our observations of the [Si] lines to a larger sample of galaxies; to utilize the new long-slit capability to measure their spatial distribution and to search for coronal emission from other species in order to investigate further the location and excitation of these lines.

Acknowledgement

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New NTT Discoveries on Distant Galaxies and Gravitational Lensing

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Since the discovery of the double lensed QSO 0957+561 by Walsh et al. (1979), gravitational lensing effects are being identified in a steadily increasing number of sources. Indeed, detector improvements in the 1980s have led to the detection of features as faint as a few thousandths of the sky signal. This has resulted in the identification of radio galaxies at high-z, which are much more numerous than QSOs and also potentially affected by gravitational lensing.

We know today about 50 radio galaxies at $z > 1$, and these sources are likely to be affected by gravitational lensing, because they lie at the bright end of the Radio Luminosity Function (RLF). This is the steepest part of the RLF – the slope is equal to –3.5 – and hence is strongly subjected to statistical gravitational lensing. Let us recall that the latter influences much more steeper luminosity functions than the normal galaxy luminosity function which, with a slope equal to –1, cannot be statistically affected by lensing. We have predicted (Hammer and Le Fèvre, 1990; Hammer and Wu, in preparation) that there should be 5 to 10 times more bright radio sources behind rich lensing clusters of galaxies than in the rest of the sky and therefore, maybe that all 30 known high-z galaxies are part of the 3CR catalog because their radio luminosity has been sufficiently mag-

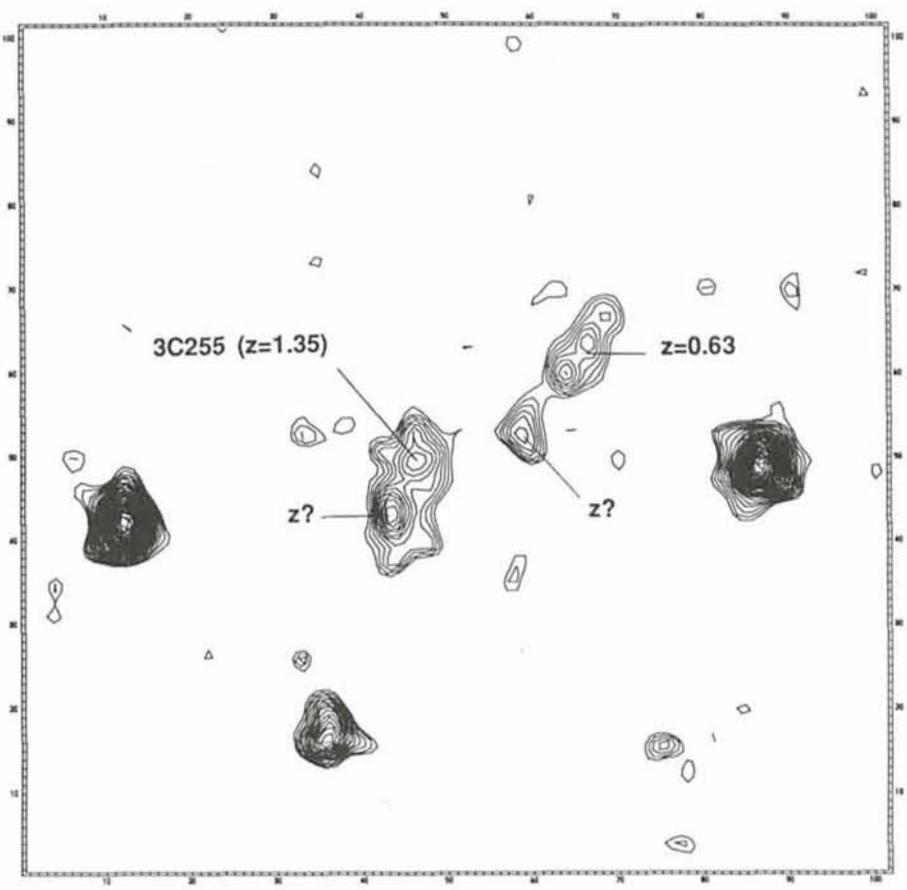

Figure 1: *3C255 (z=1.35), R, FWHM=0.″9, CFHT prime focus. The field is 20 × 20 arcsec, North is up and East to the left.*