Continuity of Spectroscopic Properties from Nearby Active Galaxy Nuclei to Intermediate Redshift Quasars.

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What are quasars? Astronomers have wondered ever since their discovery, more than 15 years ago, as a class of highly enigmatic astronomical objects. Now, however, a better understanding of the physical processes in their interiors is slowly emerging, thanks to improved observations, and it appears more or less confirmed that (most of the known) quasars are actually rather similar to the nuclei of nearby, active galaxies. Correlations between strengths of emission lines and absolute magnitude have been found. Drs. Jacqueline Bergeron and Daniel Kunth of the ESO Scientific Group in Geneva are presently studying the important question of radio-strong vs. radio-quiet quasars and report some extremely interesting observations with the 3.6 m telescope.

The physical properties of the broad-line regions (BLR) of the active galaxy nuclei may be derived from correlations between emission-line ratios or line equivalent widths (EW) and luminosities.

In the past the observed broad emission lines in nearby active nuclei were only those of hydrogen and helium. For these objects, the lack of variation of EW (Hβ) with the absolute magnitude M_v (however with large scatter) found by Searle and Sargent (1) in 1968 favours optically thick, photoionized models for the BLR.

Shortly after the first report of the presence of FeII emission in the spectrum of the quasar 3C273 by Wampler and Oke (2) (1967), it was widely recognized that FeII emission had been overlooked in the optical spectra of Seyfert galaxies for many years. The chief reason was that the bulk of emission does not arise from one individual line, but is spread into many distinct multiplets. Moreover, synthetic spectra produced to fit the observed ones could show unambiguously that the intrinsic width of each line is as large as the broad Balmer lines. These reasons all together explain why FeII emission was difficult to detect on uncalibrated photographic plates.

Subsequent investigations of Seyfert 1 galaxies by Osterbrock (3) have shown that all the known Seyfert 1 indeed have broad FeII emission features.

The FeII Emission Lines

What does FeII emission tell us about the BLR? We know from its atomic structure that Fe^{+}-ions can only exist in regions that are well shielded from the near UV-continuum source. Therefore the FeII emission is characteristic of regions of very large absorbing column density and high optical depth in the UV.

For quasars, Baldwin (4) derived, from surveys *involving different redshift ranges,* a composite spectrum assuming a continuity of spectroscopic properties between low and high redshift quasars. He could predict relative intensities of optical and UV lines, in particular a ratio Lyα/Hβ around 2–6, one order of magnitude smaller than expected from pure radiation recombination origin.

This continuity was confirmed by UV observations of active nuclei and low redshift quasars (5) and IR data of distant quasars (6).

However, from existing observations a difference was suggested by Philipps (7): although optical FeII emission is characteristic of Seyfert 1 galaxies, it was uncommon in his survey of 20 quasars of low redshift (at $z < 0.70$).

We had the feeling that some observational bias in the sample selected by Philipps was at the origin of this difference. His observed quasars were strong radio sources, similar in some way to nearby broad-line radio galaxies. The weakness of optical FeII emission in a large fraction of these radio galaxies, known since the observations of Osterbrock et al (8), rather suggests a continuity between the *broad-line radio galaxies* and the *radio quasars.*

Observations of nearby *radio-quiet* quasars thus appear necessary to investigate the continuity between Seyfert galaxies and radio-quiet quasars. We therefore decided to observe a fair sample of quasars known to be radio-quiet at the limit of detection of the Parkes survey; unfortunately no large optical surveys have been carried out for the redshift range we were interested in. Objects do exist however; most of them come from the Haro-Luyten catalogue or from the recent R. Green survey of bright QSOs.

Bergeron (9) and Kunth and Sargent (10) found a well-defined (increasing) upper limit of EW (FeII) versus M_v. This trend is different from the constancy of EW (Hβ) and points towards the existence of different mechanisms for Hβ and FeII emissions. For high-redshift, radio-flat quasars (high luminosity objects) the correlation between EW (CIV) and the UV luminosity (11) is inverse to that found for FeII. It favours an optically thin emission region for the higher excitation lines. Nearby radio quasars of high luminosity as 3C 273 (5) follow this relationship, but lower luminosity, active nuclei such as NGC 4151 or 3C 390.3 have substantially lower values of EW(CIV) than predicted by the quasar relationship.

Our quasar survey would allow to study the relationship between EW (FeII) and M_v at higher luminosities and to check whether a break in the FeII correlation occurs between nearby active nuclei and radio-quiet quasars, as it seems to occur from the broad-line radio galaxies to the radio quasars for the CIV correlation.

To extend the relation between EW (Hβ) and M_v is also of great interest. If the lack of correlation between EW (Hβ) and M_v is valid in the luminosity range where the CIV holds, then CIV and Hβ emission would not arise predominantly in the same parts of the BLR.

3.6 m Observations and Preliminary Results

The observations were performed at the 3.6 m telescope at La Silla, August 1979, with the IDS attached to the Boller and Chivens spectrograph. Preliminary observations on one object in March 1979 led us to select a 600 l/mm grating, giving 114 Å/mm dispersion. The same grating was used for the blue range λλ3700–5900 Å and the red range λλ5500–7700 Å. Direct sky subtraction can be performed on

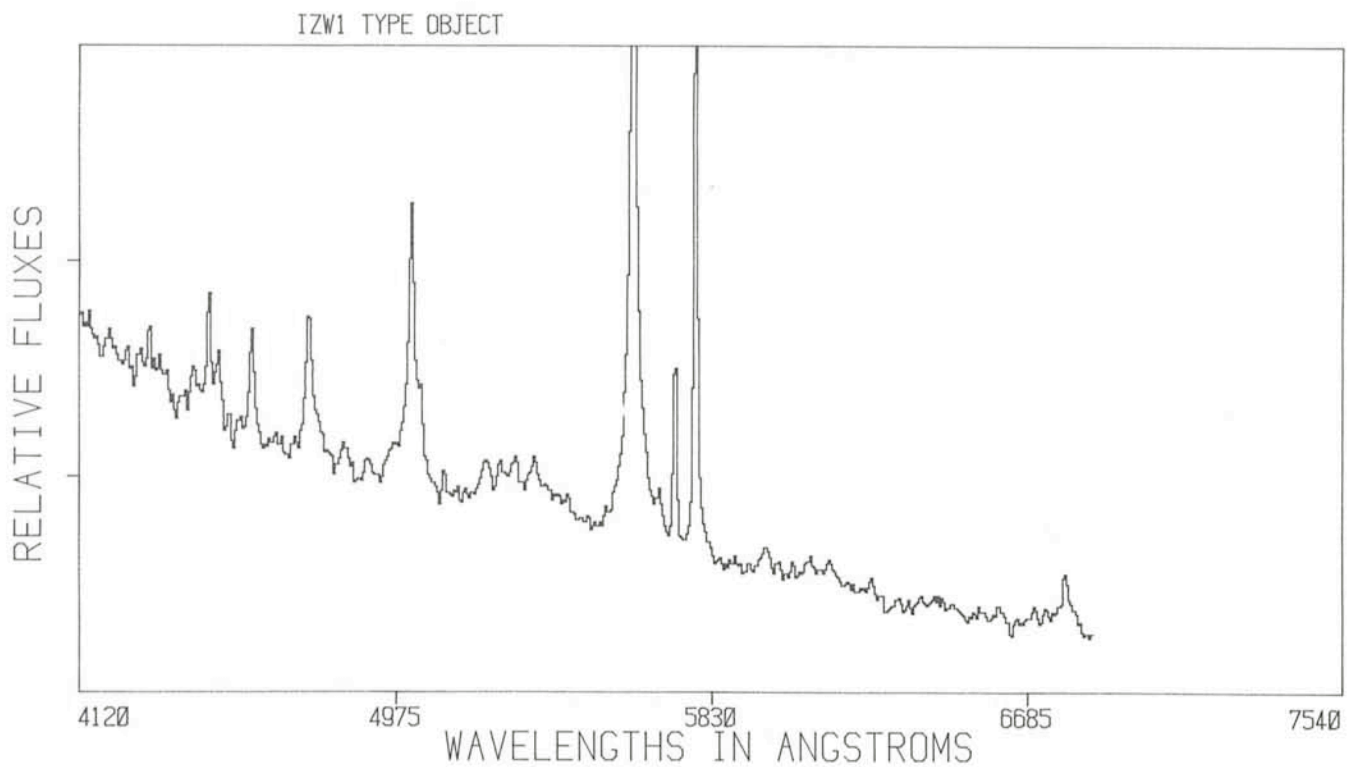

Fig. 1: *The spectrum of one of the quasars that were recently observed with the 3.6 m telescope and the IDS. Note the strong lines of [O III] and Hβ in emission (near centre of figure) and the numerous, much weaker Fe II emission peaks on either side of these three lines.*

the IDS and it is therefore quite suitable when one looks for faint, broad features of low contrast against the continuum. Hopefully, these observations will allow to answer some of the questions mentioned above.

From a preliminary look on the data we can already now foresee some new results. We wish however to stress that some of the numbers given below are only approximate and may be somewhat changed after complete reduction of our data.

Contrary to Philipps' (7) conclusions, we find that a large fraction of the quasars from our sample (23 objects) are FeII emitters. For the radio-quiet quasars the proportion is very high (9 out of a total of 11), and the strongest observed FeII emissions are found among them. For the radio quasars the ratio is still important (6 out of 12), with at least half of the FeII emitters being flat radio sources. This trend should be confirmed on a larger sample, since some strong radio-flat quasars do not show any substantial emission.

These results strengthen the link between Seyfert 1 galaxies and radio-quiet quasars and give further support to the identification of radio-quiet quasars with spiral galaxies, since most (if not all) Seyfert 1 galaxies are spiral galaxies (12).

One of our objects has a typical Seyfert 1 spectrum, yet with small line widths. The FeII multiplets are well resolved as shown in figure 1. This occurs only rarely in Seyfert galaxies. A comparison with I Zw1, the most studied Seyfert 1 "narrow-line" galaxy, will allow to estimate the variability among the FeII multiplets (in particular multiplets 27 and 28 relatively to the other multiplets). This may help to identify the FeII exciting agent.

Correlations

Only very rough statements can yet be made on possible correlations involving equivalent widths. Our range of absolute luminosities overlaps with Baldwin's (8) survey of radio quasars and with our studies (6) (7) of FeII in Seyfert galaxies.

The lack of correlation between EW(Hβ) and M_v found for Seyfert galaxies seems to extend towards larger luminosities.

Among the radio-quiet quasars, we have found 3 objects with very strong FeII emission. We will thus be able to extend the relationship EW (FeII), M_v at larger luminosities, but cannot say yet whether a break in the relationship occurs or not.

The spread of full-width half maximum (FWHM) for the permitted lines is large. Only a small fraction of our objects have very large FWHM. Furthermore, the larger the line, the more asymmetric is the profile. There does not seem to appear any trend of increase of the line width with increasing luminosity as suggested by A. Wilson.

More observing runs are necessary in particular to extend our preliminary relations to higher luminosities and to improve the statistics of the radio FeII emitters QSOs.

It will also be interesting to fill the gap and to try to find a unique property valid on a large-z sample.

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