# OPTICAL SPECTRA OF RADIO-LOUD AND RADIO-QUIET ACTIVE GALACTIC NUCLEI

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Many radio galaxies have strong emission lines in their optical spectra. The fraction with such lines is much larger than in "normal" galaxies. Radio galaxies generally also have very bright nuclei; thus those with strong emission lines are similar in both respects to Seyfert galaxies. Hence radio and Seyfert galaxies are both generally considered to be similar physical objects: active galactic nuclei. Their observational properties show they are closely related to quasars (quasi-stellar radio sources) and (radio-quiet) QSOs. A short table of the space density of these objects, culled from many sources, chiefly Schmidt (1978) and Simkim, Su and Schwarz (1980) is given below. Although all the numbers are quite uncertain, there is no doubt that the radio-loud objects are relatively rare. With less certainty, it appears that the ratio of numbers of radio galaxies to Seyfert galaxies is about the same as the ratio of numbers of quasars to QSOs.

Table 1. Approximate Space Densities Here and Now

| | |
|---|---|
| Field Galaxies | $10^{-1}$ $Mpc^{-3}$ |
| Luminous Spirals | $10^{-2}$ |
| Seyfert Galaxies | $10^{-4}$ |
| Radio Galaxies | $10^{-6}$ |
| QSOs | $10^{-7}$ |
| Quasars | $10^{-9}$ |

Many of the strong radio sources are broad-line radio galaxies (BLRG), having H I emission lines with widths from 5000 to 30,000 km $s^{-1}$ in their optical spectra. They are mostly extended double radio sources. They tend to have a greater fraction of their radio luminosity concentrated in a central compact component than the narrow-line radio galaxies do (Hine and Longair 1979). The optical spectra of the BLRG also show very strong featureless continua with approximately power-law forms. These featureless continua apparently extend to high frequencies in the ultraviolet and provide the source of ionizing photons



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responsible for much of the observed optical emission. Nearly all the BLRG are N galaxies in form.

The corresponding radio-quiet objects are Seyfert 1 galaxies. They are observed to have dense broad-line emission regions much the same as the BLRG. However the Seyfert 1 galaxies are mostly spirals or related to spirals, often barred or having companions.

There are differences in the optical broad emission-line spectra of the BLRG and Seyfert 1's. Each class contains a wide range of objects, but on the average the BLRG have much weaker Fe II/Hβ emission-line ratios and stronger Hα/Hβ ratios. The radio galaxies' line profiles often appear to be more irregular and flatter than the Seyfert 1 galaxies' line profiles. The same correlation, that the Fe II optical emission lines tend to be weak, holds up for most but not all radio-loud quasars, while the few radio-quiet QSOs observed in the optical region tend to have strong Fe II optical emission, like Seyfert 1 galaxies (Phillips 1978a and unpublished private communication; Peterson, Foltz and Byard 1981). Those quasars that do have strong optical Fe II emission are mostly compact radio sources (Miley and Miller 1979).

The Fe II emission thus must contain a clue as to the difference in structure between radio-loud and radio-quiet active galactic nuclei. Physically, Fe II is a very low stage of ionization. Analysis of the observations shows that the Fe II resonance lines in the ultra-violet must have very large optical depths, but the dimensions are reasonable in terms of our knowledge of active galactic nuclei (Phillips 1978b; Collin-Souffrin et al. 1979). The optical spectra of quasars with large redshifts show they do have strong Fe II emission in the ultra-violet, indicating that some but not as much Fe II is present as in the radio-quiet objects (Wills et al. 1980; Gaskell 1981; Grandi 1981). The relative intensities of the Fe II lines show that $T \approx 10^4$K in the dense region in which they are emitted. The excitation is probably collisional. The source of ionization of the partly ionized region in which the Fe II arises is still controversial, perhaps primary photo-ionization by hard photons followed by Auger and collisional ionization (Netzer 1980), perhaps mechanical heating (Collin-Souffrin et al. 1980).

What then is the significance of the relative weakness of the Fe II emission in the radio-loud BLRG? One possibility is that there is not as much gas in the dense broad-line regions of BLRG, so that there is only a small partly ionized region. Another possible interpretation would be that the gas is present, but that the extended region of low ionization does not exist. On the photoionization mechanism this would mean that there is a lack of hard ionizing photons in the spectrum of the central sources of the BLRG. There is no evidence to support this from X-ray measurements, nor from the observed optical lines emitted by the outer narrow-line region. On the mechanical input hypothesis the BLRG would differ from the Seyfert 1's in having less mechanical input of heat, presumably from dissipation of mass motions or magnetohydrodynamic waves.

The narrow-line active galactic nuclei are narrow-line radio galaxies (NLRG) and Seyfert 2 galaxies. Members of both classes generally have weaker featureless continua than BLRG and Seyfert 1's. The narrow-line objects are not as "active." Perhaps they are not as close to the critical Eddington luminosity, and gas is not ejected from their accretion disks or turbulence is not generated by some instability within them. There is no major observed difference in the optical spectra of NLRG and radio-quiet Seyfert 2 galaxies (Cohen and Osterbrock 1981), although in form the former are mostly cD, D, and E galaxies, while the latter are mostly spirals. There is a strong correlation between the strength of the narrow lines with radio emission. All BLRG have relatively strong forbidden lines, more like Seyfert 1.5 galaxies than like Seyfert 1's. Among the Seyfert galaxies that have been detected as weak radio sources, Seyfert 2 galaxies on the average have much stronger radio emission. The few so-called Seyfert 1 galaxies that have been detected as radio sources are in fact mostly Seyfert 1.5 galaxies. This correlation suggests that the escape of the radio plasma from its source, presumably at the center of the active nucleus, occurs along the same channels as the escape of the ionizing photons out into the narrow-line region. The interaction of the plasma with the ionized gas in radio galaxies must produce some effects which might be most easily observed in the form of heating effects; it will be worthwhile to look for them observationally.

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