But because of the comparative nearness of the Seyferts it is to be expected that definite clues will be forthcoming as the observational material accumulates.

Because of the many similarities between Seyferts and quasistellars, such clues may also prove vital to the understanding of the latter.

46. Concluding Remarks: Spectroscopic Problems

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It seems to me that the observations show there are quite extreme density fluctuations or density condensations in the Seyfert galaxies with a very wide range of density. Different forbidden lines indicate electron densities in the range of $10^4$ to $10^5 \text{ cm}^{-3}$ and there are probably variations above and below those values. There must be spatial variations in temperature, too, caused by differences in heating and cooling rates, both of which depend on radiation field, ionization, and density in a complicated way.

As to the source of ionization, I agree with Dr. Woltjer that there are very severe objections to the mechanism of ionization by fast particles. Dr. Parker and I were led to test this mechanism because of the observational evidence that there is an intimate mixture of neutral material and highly ionized material in NGC 1068. We thought that this condition is impossible under conditions of ionization by ultraviolet radiation, because of the sharpness of the boundary of the Strömgren spheres. However, we realized later that our thinking was entirely based on experience with calculations assuming blackbody radiation, which falls off exponentially at high frequency, Dr. Williams' later calculations, however, showed that with synchrotron radiation, that is, with a power-law spectrum for the radiation, it is possible that a mixture of ions with high and low ionization potentials, and even of neutral material can coexist. This result must be true not only for a power-law spectrum but for any kind of spectrum that extends far into the ultraviolet. The argument that Dr. Woltjer and Madame Souffrin described, that under conditions of collisional ionization the forbidden lines should be much stronger with respect to the hydrogen lines than is observed, seems quite conclusive to me.

Therefore we must assume photoionization by a source with a spectrum extending far into the ultraviolet. This radiation source may be a single object, such as a small nucleus or a massive star, but I think we should also keep in mind the possibility that it might be distributed over a considerable part of the nucleus of the Seyfert galaxy. There may be synchrotron emission occurring over fairly large regions, and this emphasizes the importance of observational information about light variations, which will certainly have to be taken into account in setting a limit to the sizes of the emitting regions.

The hydrogen lines pose a real problem. The Balmer decrement, at least in NGC 1068, just does not agree with any kind of theoretical calculation that exists at the present time. Dr. Parker and I, when we wrote our paper, had the hope (which was nothing more than a hope and therefore was relegated to the Appendix) that there might be sufficient population in the $2p$ state of hydrogen caused by Ly-$\alpha$ scattering, so that large optical-depth effects in the Balmer lines might conceivably give the observed decrement. However, we had no quantitative calculations that demonstrate this, and as we have heard at this conference, Williams' and Weymann's calculation show that there is not a sufficient population in the $2p$ state to cause significant optical-depth effects.

Interstellar reddening should be considered quantitatively to see if it can help to match the observed Balmer decrement. Of course, we have to remember that in a Seyfert galaxy the situation is a bit different than the typical case of interstellar reddening of a star, for interstellar extinction occurs mostly by scattering. If the albedo were exactly unity, then scattering by dust mixed in the nucleus of a Seyfert galaxy would not effect the decrement at all, because no photons would be absorbed and in the steady state all of them would ultimately escape. Only the absorption component of the reddening affects the decrement in a situation in which the sources of emission and of excitation are intimately mixed and are observed as a unit. We have the observational possibility of measuring both the Paschen and Balmer lines, and trying to use whatever information we can thus gain on the interstellar absorption curve to see whether it can match the observed decrement. Again there is the problem that Dr. Woltjer mentioned: If the interstellar absorption affects the Balmer decrement significantly, it must also affect the continuum radiation significantly, and the Seyfert nuclei must then be understood as even more luminous objects.

If there actually is interstellar obscuration due to dust, it may have some connection with the infrared excess. Several people have suggested that the infrared excess in the planetary nebula NGC 7027 is connected with the conversion of high-energy photons (perhaps Ly-$\alpha$) into thermal radiation by the dust, and this also may be a possibility for Seyfert galaxies. The similarity of the spectra of NGC 7027 and of NGC 1068 has been mentioned several times. But until we do understand the Balmer decrement quantitatively, we cannot be sure that some important physical process has not been omitted, and we therefore really do not have a complete picture of Seyfert galaxies.
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