PREPRINTS

OF THE

STEWARD OBSERVATORY

THE UNIVERSITY OF ARIZONA
TUCSON, ARIZONA

No. 8

ENERGY DISTRIBUTION IN SPECTRA OF SEYFERT GALAXIES AND QUASISTELLAR SOURCES

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MAY 1967

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(Presented at IV Texas Symposium on Relativistic Astrophysics, New York City, January 1967)

May, 1967

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The detection of strong infrared radiation from Seyfert galaxies (Pacholczyk and Wisniewski, 1967) was followed by investigations of these objects at millimeter and micron wavelengths (Epstein, 3.4mm; Low 1.6, 5, 10 and 20 μ). The results of these observations are giving more evidence for a possible relationship between Seyfert galaxies and quasistellar sources, discussed some time ago by Burbidge, Burbidge and Sandage (1965) and Shklovskii (1965). The purpose of these remarks is to discuss the gross distribution of energy in the spectrum of a Seyfert galaxy and of a quasi-stellar source. These remarks will necessarily be very conjectural in nature and should be considered as working hypotheses aimed at the setting up of future observational programs rather than conclusions based on existing statistics of these types of extragalactic objects.

The distribution of energy in the entire range of frequencies from 10^6Hz to 10^{15}Hz is known only for a very few objects. The relatively best known object (in this sense) is the quasistellar source 3C 273 (Fig. 1). A few other quasars do have fluxes measured at millimeter wavelengths and in the infrared. Among Seyfert galaxies, NGC 1068 is the most thoroughly investigated (Fig. 1); infrared radiation has been measured also for NGC 4151 and there are many centimeter observations of NGC 1275 and some of other Seyfert galaxies. Several normal and peculiar galaxies (some of which are strong radio sources) were investigated in the infrared (Johnson 1966). In all cases, however, the wavelength range between 20 μ and 1mm is still entirely inaccessible to measurements.

Fig. 1 summarizes all existing observations of the Seyfert galaxy NGC 1068 and of the quasistellar source 3C 273. The list of sources of data for

3C 273 is very long and is therefore omitted, the data on NGC 1068 are taken from Howard and Maran (1965), Kellermann and Pauliny-Toth (1966), Pacholczyk and Wisniewski (1967) and the preliminary measurements by Epstein are also included (private communication).

Four major components exemplified in Fig. 1 in two cases of very complex spectra can be distinguished in the overall spectrum of an extragalactic object:

Component I: Present in a vast majority of extragalactic radio sources, characterized by a power-law dependence on frequency with the synchrotron radiation of relativistic electrons in magnetic fields, usually exhibiting some curvature at higher frequencies probably due to electron energy losses, sometimes curved at lower frequencies presumably because of ionization losses, electron energy cut-off, or synchrotron self-absorption. No variability detected.

Component II: Conjectured to be a feature of "flat spectrum" quasars and of some Seyfert galaxies, with the location of the lower frequency curvature in the spectrum depending on parameters characterizing a source; variable at frequencies higher than that of the maximum intensity of this component; rather difficult to explain in terms of synchrotron radiation in case of 3C 273 (Fig. 1) component II appears to be more or less flat, in other cases it does have a pronounced curvature.

Component III: Conjectured to be a distinctive feature of "flat spectrum" quasars and of some Seyfert galaxies; has a more or less

power-law form with an exponent of around -2.5; contains most of the radiative energy of a source (in the case of NGC 1068 the luminosity in this component is of the order of 10^{44} ergs/sec, the luminosity of 3C 273 at cosmological distance is of the order of 10^{47} ergs/sec); variable in quasars in optical region; possibly variable for Seyfert galaxies which are currently being monitored for variability at Steward Observatory of the University of Arizona; rather unlikely to be caused by free-free emission or by synchrotron radiation in the case of 3C 273 at cosmological distance.*

*At this Symposium Colgate suggested a mechanism involving enhanced scattering of photons by unstable plasma oscillations which could explain component II and III.

Component IV: Of stellar origin; its presence in spectra of quasistellar objects is a wide open question; observations aimed at the detection of an underlying galaxy in 3C 273 are being carried out at the University of Arizona (Taylor and Weymann).

For a number of objects excess ultraviolet or infrared radiation was observed, presumably of nonstellar origin. For some objects this excess radiation could be due to component I extending to the infrared and possibly the ultraviolet. For other objects (quasars, Seyfert galaxies) the ultraviolet excess could be connected with the extension of component III (e.g., through inverse Compton scattering) or would constitute a separate component V.

Among extragalactic objects, galaxies are characterized by component IV, while radio galaxies have in addition component I. The "flat spectrum"

quasars and some Seyfert galaxies show the presence of components II-III in their spectra. The statement that some of the Seyfert galaxies are weak radio emitters (NGC 3227, 4051) or are not radio sources (NGC 5548) (Heeschen and Wade, 1964) is based on radio observations at longer wavelengths, i.e., observations of component I. Available data on radio sources do not indicate any relationship between the intensity of radiation of components I and II or III.

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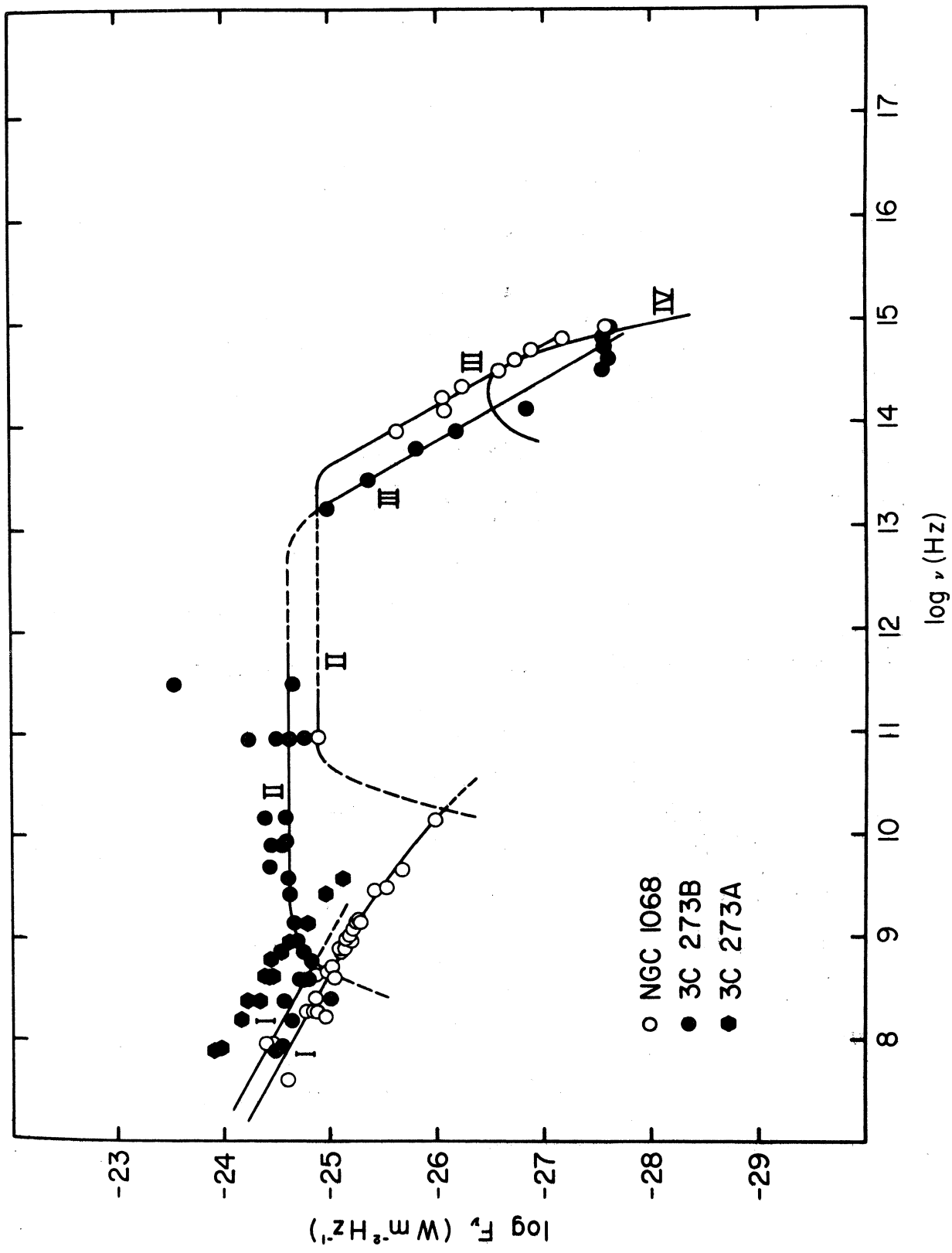

Fig. 1. Observed spectrum of the Seyfert galaxy NGC 1068 compared with the spectrum of the quasistellar source 3C 273.