"Mr. Chairman, in the outskirts of this room it is difficult to follow the nuclear activity up front."

H. van Woerden in Discussion IV.2

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RADIO PROPERTIES OF THE NUCLEI IN ELLIPTICAL, SO AND SPIRAL GALAXIES

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When Heeschen (1968) found that the nuclear sources in the two elliptical galaxies NGC 4278 and NGC 1052 contained flat spectrum unresolved sources he conjectured that these might be weaker versions of the compact optically thick and strongly variable sources found in the quasar nuclei. This conjecture appears to be correct since these are both now known to have diameters <0.1 pc (Cohen et al. 1971) and to be variable on time scales of order one year. This variability has recently been confirmed by observations with the VLA (Heeschen, private communication).

From further surveys of elliptical and SO galaxies we now have about 20 more galaxies with similar flat spectrum compact nuclear sources. Furthermore, similar nuclear sources have also been found in many radio galaxies. Most of the elliptical galaxies that contain such nuclear sources also show optical emission lines in their central regions.

The radio properties of the nuclei of the elliptical galaxies are quite different from those just discussed by de Bruyn for the spiral and Seyfert galaxies. For example, almost all the radio sources in the nuclei of elliptical and SO galaxies are less than a parsec in size whereas most of the radio emission from the spiral and Seyfert galaxies usually comes from a region many hundred parsecs in size (Ekers 1977). There is also a clear difference between the spectral index distribution for the nuclei of elliptical and spiral galaxies (Ekers 1974). With the larger sample now available (de Bruyn 1976, Crane 1977, Ekers et al. 1978, Hummel private communication) we can make a finer division into Hubble types, as is shown in the Figure. We see a fairly smooth trend from the elliptical galaxies which have mostly flat spectrum nuclear sources to the late-type spirals with only steep spectrum nuclear sources.

A new intriguing correlation is suggested by the observation of HI gas in the two prototype elliptical galaxies with radio core sources: NGC 4278 and NGC 1052 (Gallagher et al. 1977, Knapp et al. 1977, Fosbury et al. 1977). This point has been checked further by comparing the radio continuum data (Hummel private communication) for six elliptical galaxies

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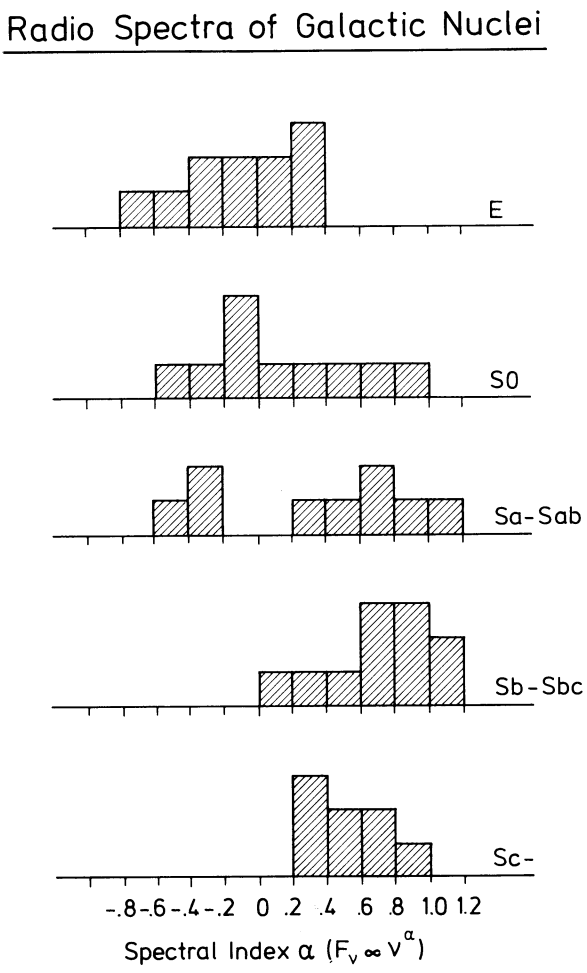

Figure: Distribution of radio spectral index, α ($F_\nu \propto \nu^\alpha$), for galactic nuclei subdivided by Hubble type.

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with detected HI with that for a comparison sample consisting of the six elliptical galaxies with lowest HI limits in the literature. While four of the six elliptical galaxies with HI detected also have flat spectrum nuclei, none of the comparison sample do.

In conclusion, we see a striking change in the properties of the nuclei of galaxies of different Hubble type indicating that the overall morphology of a galaxy is very relevant to the state of the nucleus. There are various ways to interpret these results: perhaps the gas in a spiral galaxy absorbs the radio emission from the compact nuclei or perhaps it extinguishes the radio source by overfeeding the nuclear engine. Alternatively, it may be that greater sphericity of the ellipticals lets material sink deeper into the nucleus making a more compact source. We might also contemplate the opposite situation in which some property of a seed nucleus determines whether a spiral or an elliptical galaxy is formed in the beginning.

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DISCUSSION FOLLOWING PAPER IV.2 GIVEN BY R.D. EKERS

VAN DER LAAN: Two remarks connected with your hints relating Hubble types to the presence and spectrum of nuclear radio sources. (1) I think it is instructive when discussing these phenomena to distinguish "engine power" and fuelling rate. A large range of engine powers seems possible among elliptical galaxies, but in spirals big engines seem not to be found. Possibly the galaxy formation process is responsible for this difference. (2) If there is a lot of gas, a nuclear engine may not remain visible through the radio window. Not only synchrotron self-absorption but especially free-free absorption may hide activity in late spirals' nuclei. Possibly these can be uncovered by hard-X ray experiments planned for Spacelab II.

DE BRUYN: I would like to point out that the distributions of radio power and sizes of the (Markarian) Seyferts are considerably broader than the one Dr. Ekers has shown us. Therefore I am not sure whether

the gap between Seyferts and radio galaxies in the diagram is real.

WELIACHEW: Is there a correlation between the presence of compact radio sources and the presence of the λ3727 lines of [OII] in elliptical galaxies?

EKERS: Yes, there is a very good correlation: about 80% of the ellipticals with compact sources have emission lines, usually λ3727. However, the optical sample of spectrographs should be made more complete.

BARTEL: What is the range of the spectral index variations in NGC 1052 and what is known about the physical processes that trigger the spectral variations?

HEESCHEN: I don't know the cause of the spectral index variations in NGC 1052. They are similar to those seen in some quasars and radio galaxies, and may have a similar cause, perhaps that suggested some time ago by Kellermann and van der Laan. The range of spectral index variation is at least ± 0.2 at a given wavelength, say around 1 cm - 10 cm.
[see Discussion I.5 for HI in NGC 1052 and 4278]

KERR: COMPACT COMPONENTS IN ACTIVE SPIRAL AND SEYFERT GALAXY NUCLEI AND GALAXY INTERACTIONS

In an interferometric study made by J.B. Carlson, University of Maryland, of 61 active spiral and Seyfert galaxy nuclei, compact nuclear components as small as 0.1 arcsec were found in 26 cases. Some of the highly compact sources are of the order of parsecs in size or less. Two-point spectral indices calculated between 2695 and 8085 MHz show that compact sources tend to have flat, positive or complex spectral indices, whereas more extended sources (> 100 pc diameter) tend to have indices clustering around -0.7.

No discernible differences were found between Seyferts and active spirals on the basis of nuclear radio properties alone, but Seyferts tend to have greater nuclear radio luminosities and greater total optical luminosities. Active Irr II galaxies also have high centimeter-wavelength nuclear radio luminosities, for a given total optical luminosity. No correlation was found to exist between the nuclear radio properties of spirals or Seyferts and the Hubble type or stage.

All but two of the 26 active galaxies in the present sample are probable members of small groups, are members of interacting pairs, or show evidence of tidal disturbance according to the DDO classification system (i.e. they have "n", "*", or "t" DDO designations). Attention is called to interacting systems such as NGC 3623/3627/3628, NGC 4631/4627/4656 and NGC 3031/3034/3077, for which high-resolution neutral hydrogen studies are available as well as data on the nuclear radio properties. These systems have been found to contain intergalactic bridges, streamers and clumps of HI and the constituent galaxies contain active compact (radio) nuclei.

It is suggested that the activation of "excited" galactic nuclei is

externally initiated by interaction with another galaxy, leading to tidal disruption or similar effects. In this hypothesis, the interaction process feeds fresh gas into the nuclear region which could yield the observed nuclear activity by initiating a burst of star formation, or perhaps accretion on a black hole.

VAN ALBADA: What is the most extreme mass ratio for galaxies in a pair in which a nuclear source has been excited in at least one galaxy of that pair?

KERR: The members of a pair tend to have about equal mass.

ALLEN: Several years ago, before it was fashionable to feed the gas-eating monsters which are supposed to lurk in the nuclei of some galaxies, Ekers, Burke, Miley and I published a short paper in Nature in which we examined the correlation between total radio emission and interaction for a small sample of objects from Arp's atlas. We concluded then that, when the sample was compared with a sample of normal non-interacting galaxies there was no clear evidence either for an increased frequency of occurrence or for an increased intensity of the radio emission from the individual members of an interacting system. This conclusion was corroborated with a larger sample of interacting and non-interacting systems surveyed later by Wright with the Parkes telescope. Could you comment on the difference of your results with these?

KERR: Perhaps your statement referred to the total flux of the galaxies, while ours is very definitely for the small diameter component at the center.

EKERS: Do you know if these are really nuclear sources, or just compact emission from somewhere in the system?

KERR: They are nuclear sources because we have got positions that quite accurately coincide with the optical ones.

VAN DER KRUIT: Since the Westerbork survey of interacting galaxies by yourself and others the 5 GHz survey of Sramek and of Sulentic have appeared. We can see now that you happen to have selected some of the radio faintest Arp interacting pairs detected by them.