SO AND SMOOTH-ARM Sa's WITHIN THE HUBBLE SEQUENCE

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ABSTRACT

SO and smooth-armed Sa galaxies are generic to the Hubble sequence, not formed by environmental stripping.

I. INTRODUCTION

Because SO galaxies are flattened disks without spiral arms, speculation began already in the 1950's (Spitzer and Baade 1951) that they are formed by the secondary processes of gas stripping from parent spirals, leaving the daughters inert. The clearest statement of environmental formation is given by van den Bergh (1976) where he extends Baade's (1963) suggestion that SO's and other "anemic" spirals form a parallel sequence with normal gas-rich spirals, differing from their "parent" spirals only in their gas and dust content.

This view has received wide attention, and a large school of galaxy strippers has arisen. If true, a major revision in the Hubble sequence would be required.

The contrary view (Sandage, Freeman, and Stokes 1970, SFS) is that SO and smooth-armed Sa galaxies naturally form the early terminus of the disk systems. SO's are earlier than Sa types and are a transition to the flattened E galaxies (Hubble 1936; Sandage 1961), initially placed at that point in the sequence by the extreme values of some distributed parameter (eg., density or specific angular momentum). Evidence in support of this generic viewpoint is discussed in the next sections.

II. SURFACE BRIGHTNESS DISTRIBUTIONS

That SO and smooth-armed Sa's cannot be stripped Sb and Sc galaxies is seen by looking through a telescope, an archaic activity evidently not now practiced by strippers.

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In work related to the Revised Shapley Ames Catalog (Sandage and Tammann 1981) photographs of all listed galaxies were taken with the Mount Wilson, Palomar, and Las Campanas reflectors. To check the telescope setting, most fields were visually inspected. The fact, known generally to old visual observers, was rediscovered that Sd and Sc galaxies were extremely difficult to see with large scale reflectors, Sb's easier, Sa's still easier, whereas all SO and E galaxies stand like beacons in the focal plane.

This progressive change of surface brightness with Hubble type is shown quantitatively in Figures 1a and 1b where the average $V_{\text{mag}}$ surface brightness within a photoelectric blocking diaphragm $A/D(0)$ is plotted for various Hubble types. The photoelectric data are taken from standard literature sources (e.g., de Vaucouleurs and de Vaucouleurs 1961; Sandage 1975; Sandage and Visvanathan 1978; Griersmith 1980). The shape of the line is from integrating the standard growth curve (Sandage 1975, Table B1), but forced through the E plot.

The E and SO galaxies have nearly the same surface brightness distribution. However, as soon as evidence of arms appears (i.e., in SO/a types), the average surface brightness at any $A/D(0) > 0.1$ decreases. That dust is not a problem is shown in panels 4 and 5 of Fig. 1a by dividing the Sa's into dust-free and dust-present systems.

![Fig. 1a. The surface brightness in $V_{\text{mag}}$ for E through Sab galaxies, averaged over the area inside a radius of $A/D(0)$, where $D(0)$ is $\approx 0.3$ of the Holmberg radius. The mean line for E galaxies is repeated in every panel.](image-url)