

## STELLAR POPULATIONS AND HUBBLE TYPE

Sidney van den Bergh  
Dominion Astrophysical Observatory  
Herzberg Institute of Astrophysics  
Victoria, B.C.

Men are more apt to be mistaken  
in their generalization than in  
their particular observations.

Machiavelli

### I. INTRODUCTION

It was already realized by Hubble (1936) that galaxy morphology and stellar content were correlated. He pointed out that resolution into stars increases along the classification sequence Sa-Sb-Sc. Simultaneously the colours of spirals become bluer and their integrated spectral types become earlier as one proceeds from Sa to Sc. Baade (1944) speculated that the red stars in ellipticals and in the nuclear bulges of spirals were identical to those in globular clusters. He suggested that stars in galaxies belong to two distinct populations: young metal-rich stars of Population I which inhabit the disc and spiral arm regions of spirals, and old metal-poor stars of Population II which dominate the light of elliptical galaxies and the nuclear bulges of spirals. Subsequently Baade (1950) emphasized the strong correlation between the occurrence of gas and dust and the presence of young stars. As Baade put it so succinctly "No dust, no Population I". Belief in a clear cut dichotomy between Population I and Population II was strengthened by the differences in their radial luminosity distributions. The surface brightness of Population I in spirals is well represented by an exponential disc, whereas the surface brightness of Population II stars in ellipticals and the bulges of spirals may be described by an  $r^{1/4}$  law (de Vaucouleurs 1959).

Subsequent work was to modify Baade's simple two population scheme in two important respects. Firstly, it rapidly became clear (cf. O'Connell 1958) that the division of all stars into two stellar populations was a gross oversimplification. In the Galaxy one can clearly distinguish halo Pop. II, intermediate Pop. II, disc population, older Pop. I and extreme Pop. I. Secondly, observations by

Morgan (1959) showed that the integrated spectra of the nuclear bulges of the Galaxy and of M 31 were strong-lined, *i.e.* their light was not dominated by metal-poor, globular cluster-like stars.

## II. ELLIPTICAL GALAXIES.

According to Hubble (1936) elliptical galaxies differ only in their apparent axial ratios. We now know that ellipticals are, in fact, not monotonously similar. Baum (1959) first showed that the integrated colours of dwarf ellipticals are almost as blue as those of halo globular clusters whereas supergiant elliptical galaxies are quite red. Baum correctly surmised (Faber 1973) that this result implied that dwarf ellipticals consist of old metal-poor stars, whereas the light of giant ellipticals is dominated by old metal-rich stars. An unexpected complication is that flattened E galaxies are, in the mean, bluer than are more nearly spherical ellipticals (van den Bergh 1979). The physical reason for this effect is not yet understood. Spectrophotometry by Terlevich *et al.* (1981) confirms that the observed dependence of colour on axial ratio is due to the fact that spherical ellipticals have stronger metal lines than do flattened E galaxies of the same luminosity.

Observation shows (*e.g.* de Vaucouleurs and de Vaucouleurs 1972) that ellipticals usually exhibit pronounced colour gradients with galactic nuclei generally being redder than their envelopes. This indicates that the average metallicity of stars in ellipticals exhibits a strong radial gradient. At any radius the mean colours of globular clusters are, however, found to be bluer than those of the underlying galaxy (Forte, Strom and Strom 1981). This is consistent with conventional scenarios in which globular clusters were formed earlier than the bulk of the stellar population at all radii.

Finally, Harris and van den Bergh (1981) find significant differences between the specific globular cluster frequencies in different ellipticals. A possible interpretation of this observation is that the relative intensity of early, intermediate and late phases of star formation differed significantly from galaxy to galaxy. The globular cluster observations of Harris and van den Bergh indicate that these differences may correlate with environmental factors. They find that Virgo E galaxies are more globular-cluster prone than are the ellipticals in small clusters and in the field. Environmental influences might also account for the apparent differences between the intrinsic colours of dwarf ellipticals in the Local Group, the Virgo cluster and the Coma cluster (Sandage 1972).

If environmental factors are, in fact, important then the stellar populations in the central cD galaxies in rich clusters might differ significantly from those in normal supergiant E galaxies. In particular, Fabian, Nulsen and Canizares (1982) and Sarazin and O'Connell (1982) suggest that the high pressure dust-free gas flowing into cD galaxies at the centres of rich clusters might form a huge

population of low-mass stars. Such low-mass stars might be marginally detectable with presently available observational techniques.

### III. SPIRAL GALAXIES.

By and large the nuclear bulges of spirals exhibit the same characteristics as do elliptical galaxies. Observations by Nassau and Blanco (1958), which demonstrated that the galactic nuclear bulge contains a larger fraction of late M giants than does the solar neighbourhood, provided the first indication that stars near the galactic nucleus might be "super metal-rich". This suspicion has since been confirmed by the spectrophotometry of Frogel and Whitford (1982).

The first evidence for a radial composition gradient within the disc of our own galaxy was derived from the radial decrease in the mean period of Cepheids of Population I (van den Bergh 1958). Numerous subsequent photometric and spectroscopic observations have confirmed the reality of such composition gradients in the Galaxy and in the discs of many other spirals. Much less information is, however, available on population differences along the Hubble classification sequence of spirals.

Ever since the Hubble classification system was first introduced it has been known that the spiral arms of Sc galaxies are much more highly resolved than are those of Sa spirals. It is usually assumed that this difference is entirely due to the fact that gas-rich Sc's are forming stars much more vigorously than do Sa's. In fact there is some evidence which indicates that the upper limit to the luminosity of individual young stars in Sa galaxies is lower than it is in spirals of type Sc. Intercomparison of CTIO 4-m plates of M 100 in the Virgo cluster and M 104 (= the Sombrero), which are located at similar distances, show a dramatic difference in resolution. The Sc spiral M 100 contains numerous huge H II regions, whereas the Sa galaxy M 104 contains only a few much less luminous Strömgren spheres (van den Bergh 1976, Schweizer 1978). Such differences are most easily accounted for by assuming that the mass spectrum of star formation in Sa galaxies is deficient in massive O-type stars with  $M > .15 M_{\odot}$ . Kormendy (1977) has drawn attention to the fact that Sb galaxies of the NGC 2841 subtype, which contain many short spiral arcs, are less resolved and contain fewer H II regions than do two-armed spirals. This suggests a correlation between the mass spectrum of star formation and the strength of density waves in galactic discs.

An entirely different class of problems relates to the nature of the stellar populations in smooth-armed spirals (Wilkerson 1979), gas-rich spirals with low surface brightness arms (Gallagher 1979), galaxies with low surface brightness discs (Romanishin, Strom and Strom 1982) and star-burst galaxies (Weedman *et al.* 1981). Investigation of the stellar populations in these types of objects would appear to be a particularly fruitful field for future study.

Finally, investigation of stellar populations in S0 and anaemic galaxies might provide us with a deeper understanding of the nature and evolutionary history of these objects.

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