SPACE TELESCOPE OBSERVATIONS OF NORMAL GALAXIES

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The subject of normal galaxies is much too large to cover even superficially in this paper, and I shall necessarily be giving a very limited and incomplete review. I shall tend to emphasize elliptical and peculiar galaxies at the expense of spirals, partly from personal interest, but largely because the Space Telescope will break more new ground in our knowledge of the former. Because we live in one, we have quite detailed knowledge about the structure and contents of at least one spiral galaxy. Therefore, the fact that the Space Telescope will allow us to study M31 in the same detail that the Magellanic Clouds can be studied from the ground, and to study spirals in the Virgo Cluster in the same detail that we have been able to study M31 is less important than, for example, the fact that we will be able to directly observe, for the first time, the stellar content of an elliptical galaxy.

Basically, I shall be discussing observations of the stellar content of galaxies, with a few detours to consider other interesting problems. In terms of observations, this divides into two parts: those objects near enough for us to observe individual stars, and those so distant that only their integrated light can be observed. Although the former may yield more information, I shall spend less time on it. This is partially because it is being discussed elsewhere, and partially because the observing programs are,in many cases,more obvious, being extensions to nearby galaxies of observations that have long been made in our own.

Before beginning to discuss particular problems, it might be worthwhile to consider for what types of observations of galaxies the Space Telescope will be most and least suited. Most important will be its greatly increased limiting magnitude as a panoramic detector and its ultraviolet capabilities. This will be an enormous gain in the photometry of individual stars and unresolved star clusters. The high resolution of the Space Telescope will permit observations in star fields too crowded to observe from the ground and will enable us to study the complex structure of regions of active star formation in moderately distant galaxies. A lesser improvement can be expected in spectroscopy

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of the same types of objects: even at the limiting magnitude of ground-based observations, the low photon flux from the faint objects is becoming the dominant factor. One area where the ST will not be of much use is in the study of faint extended objects, such as the halos of galaxies. The improved resolution does one no good here and the decrease in sky brightness will almost be offset by the smaller collecting area, compared to the largest ground-based telescopes.

1. NEARBY GALAXIES

By nearby galaxies I mean those in which a substantial fraction of the color-magnitude plane can be observed. This, in turn, depends on the nature of the observations. If we take 27 mag as a nominal limiting magnitude for photometry, we shall be able to observe stars at the main sequence turn-off of an old population out to a distance of 400 kpc and horizontal branch stars out to a distance of 1.5 Mpc. Thus, even from space, the number of "nearby" galaxies will be small. There are innumerable observations which can be made of these galaxies, but many of them really belong under the heading of studies of the interstellar medium, supernova remnants, star formation, etc. However, I would like to mention two subjects of particular interest to extragalactic astronomy.

The first concerns the formation history of galaxies. Elucidating this history could be an important acheivement of the Space Telescope and may produce some surprises. Although the history of our own galaxy may (or may not!) be fairly simple and well understood, we have no assurance that ours is typical. Indeed, even our nearest neighbors, the Magellanic Clouds, appear to be different. The cluster population of the clouds is certainly different, and there are some indications (Butcher 1977) that at least the LMC is younger, too. Also, contrary to our expectations for an elliptical galaxy, O'Connell (1979) has concluded, on the basis of detailed spectral synthesis, that the nearest typical elliptical, M32, had a significant amount of ongoing star formation as recently as a few billion years ago.

The data necessary to understand the history of star formation in nearby galaxies include kinematics, ages, elemental abundances and luminosity functions of various stellar subsystems. The most important information is ages and the most valuable data for this are photometry of stars at the main sequence turn-off. Unfortunately, for old populations, these will be easily obtainable only in companions of our own galaxy, even M31 and its satellites being too distant. This limits us to the Magellanic Clouds and a few dwarf spheroidals. The Clouds have distance moduli between 18.5 and 19, which means that the main sequence turn-offs of all populations are observable from the ground, and the Space Telescope is not needed. Most of the dwarf spheroidals are more distant, though, and one particularly straightforward question which the Space Telescope should be able to answer concerns their age. Was there only one epoch of star formation, and did it coincide with the

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epoch of formation of our own Galactic halo? The expected answer to both of these questions is "yes". A "no" answer to either would upset the conventional view of the almost-primeval nature of Population II.

If we wish to study a wider range of systems we will have to go to the distance of M31, M33 and their companions, which will not be easy. There are two possible approaches. One is to make the extra effort necessary to observe the 28th magnitude turn-off stars in these galaxies. I personally think this would be worthwhile, but the many astronomers with different interests competing for the very limited amount of observing time may not agree. The other approach is to only use observations of brighter stars. For example, the morphology of the giant branch and especially the horizontal branch are both rather sensitive to age. Unfortunately, they are even more sensitive to metallicity, which introduces complications to which we will return later.Similarly, if we can just reach the turn-off, we should still be able to obtain some information about the main sequence luminosity function, by comparing the integrated luminosity of the stellar sample to the sum of the light from all of the brighter post-main sequence stars which we can observe individually.

The other very important observation to be made in nearby galaxies is of the stellar content of elliptical galaxies. Unlike spirals, a few of which have been studied in some detail, our knowledge of the make-up of ellipticals is very slim indeed. Painstaking spectral synthesis of their integrated light has carried us one scant step beyond Baade's original insight into the similarity of the stellar population in M32 and the halo of our own galaxy. The prospects for much further progress from the ground are rather poor. Unfortunately, not even the Space Telescope will enable us to reach below the main sequence turn-off in the nearest ellipticals, but there are still innumerable observations to be made of the ages, metallicites and luminosity functions of stars in the dE companions of M31. The importance of the observations justifies, I think, the extra effort which will be required to reach at least the top of the main sequence in these galaxies. It is also unfortunate that there are no nearby giant ellipticals and no S0's, but it may be that we can at least infer something about the former by extrapolating the trends which emerge from dwarf spheroidals through the dwarf ellipticals.

On a related topic, much can be learned from a study of the peculiar dE NGC 205, in which star formation is still occurring. Besides the obvious interest in the young stellar populations themselves, we will here for the first time have an opportunity to study star formation in a spheroidal potential field rather than in a disk perturbed by spiral density waves. Detailed kinematic and structural studies of this process should be very relevant to understanding the early history of elliptical galaxies and the bulges of spirals.

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2. THE CONTENT OF DISTANT GALAXIES

2.1 Star Clusters

Beyond the local group, individual stars in galaxies are and will remain unobservable. In these more distant galaxies, star clusters provide the only samples of stellar populations free, we hope, of the complications of a range of metallicities and ages. Clusters, therefore, must be our main tool for unravelling the population structure and history of distant galaxies. The practical limits on how poor and how distant a cluster may be observed will obviously depend on the type of observations to be made. Where sufficient, photometry is much to be preferred over spectroscopy, because of the greater limiting magnitude, and especially because the panoramic detectors used will often permit one to photometer many clusters in a galaxy at one time. With a nominal limiting magnitude of 27 for photometry, the brightest globular clusters will be observable at least as far away as the Coma Cluster.

Using star clusters to study the stellar content of galaxies requires, however, that we be able to reliably determine the ages and metallicities of clusters from their integrated light. It is important, therefore, to consider how well we can do this and what, if any, the advantages of the ST over ground-based telescopes will be. First, to

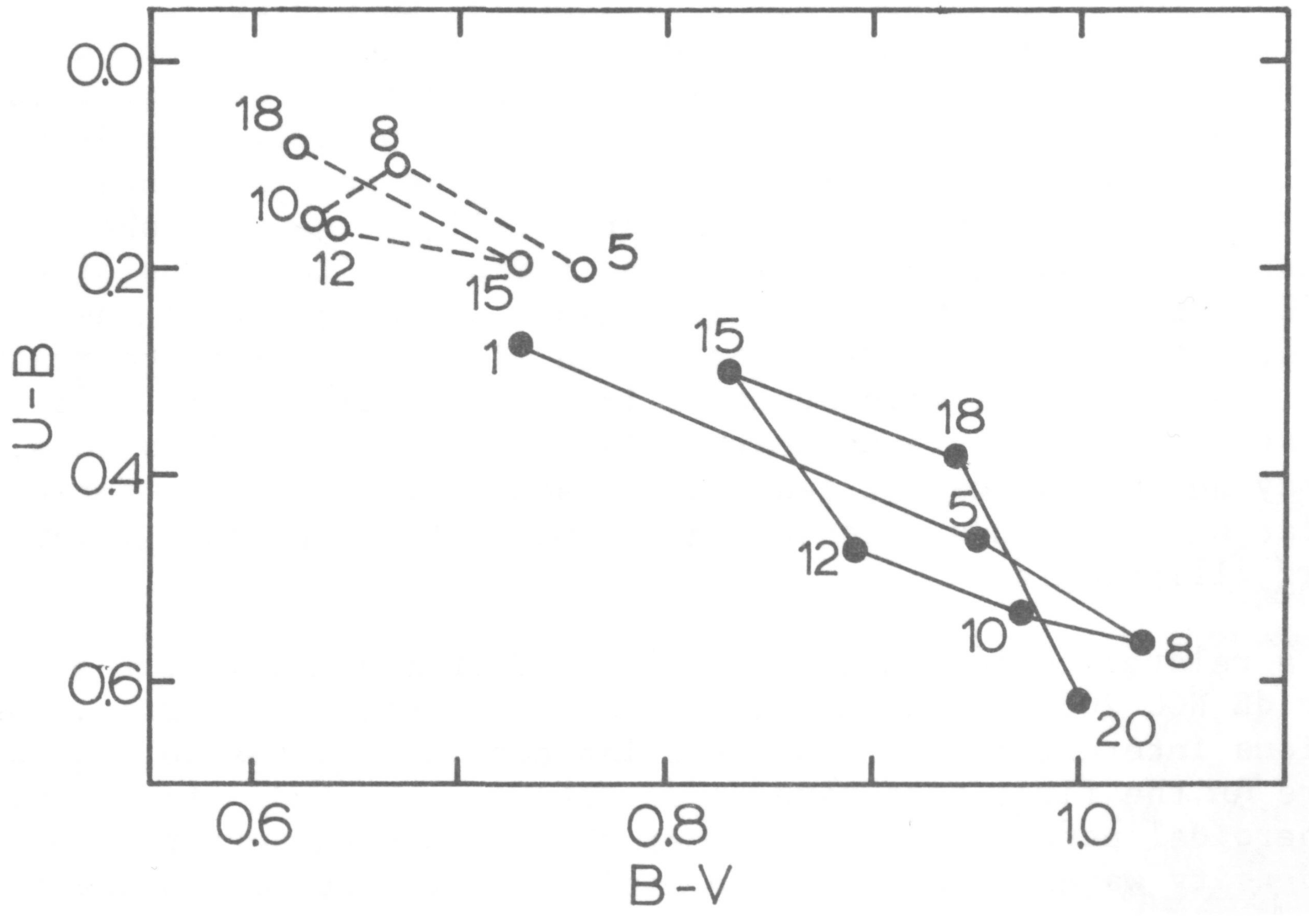

Fig. 1. Variation with age of the colors of two clusters, from Ciardullo and Demarque (1978). Open circles and dotted lines-metal poor($z=10^{-4}$) cluster. Filled circles and solid line-metal rich ($z=10^{-2}$) cluster. Numbers are the ages in billions of years.

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dispose of the obvious point, the Space Telescope will permit a gain in the faintness of the clusters that can be studied, assuming they are unresolved; but this, by itself, will not be revolutionary. A potentially more important advantage may be illustrated by considering the difficulties in simultaneously determining the age and metallicity of a cluster from its colors alone. Fig. 1 presents some calculations by Ciardullo and Demarque (1978) of the colors of high and low metal abundance clusters as a function of their age.

This is a very discouraging diagram because it shows that the age of a given cluster cannot be uniquely determined from its colors, and that the effects of age and metallicity are often indistinguishable. One possible source of hope, and one reason for discussing this subject here, is illustrated by some unpublished calculations, also by Demarque, presented in Fig. 2. These results for a metal rich cluster are only provisional because they are partially based on very early ultraviolet observations, but they should be qualitatively correct. The advantages of ultraviolet data are obvious.

The increased sensitivity to age in the UV is due mainly to changes in the blue end of the horizontal branch; (for younger clusters the main sequence turn-off is also important). But, of course, the horizontal branch is also very sensitive to metallicity (mainly CN). Therefore, it is not obvious how one separates the two effects. One possibility is

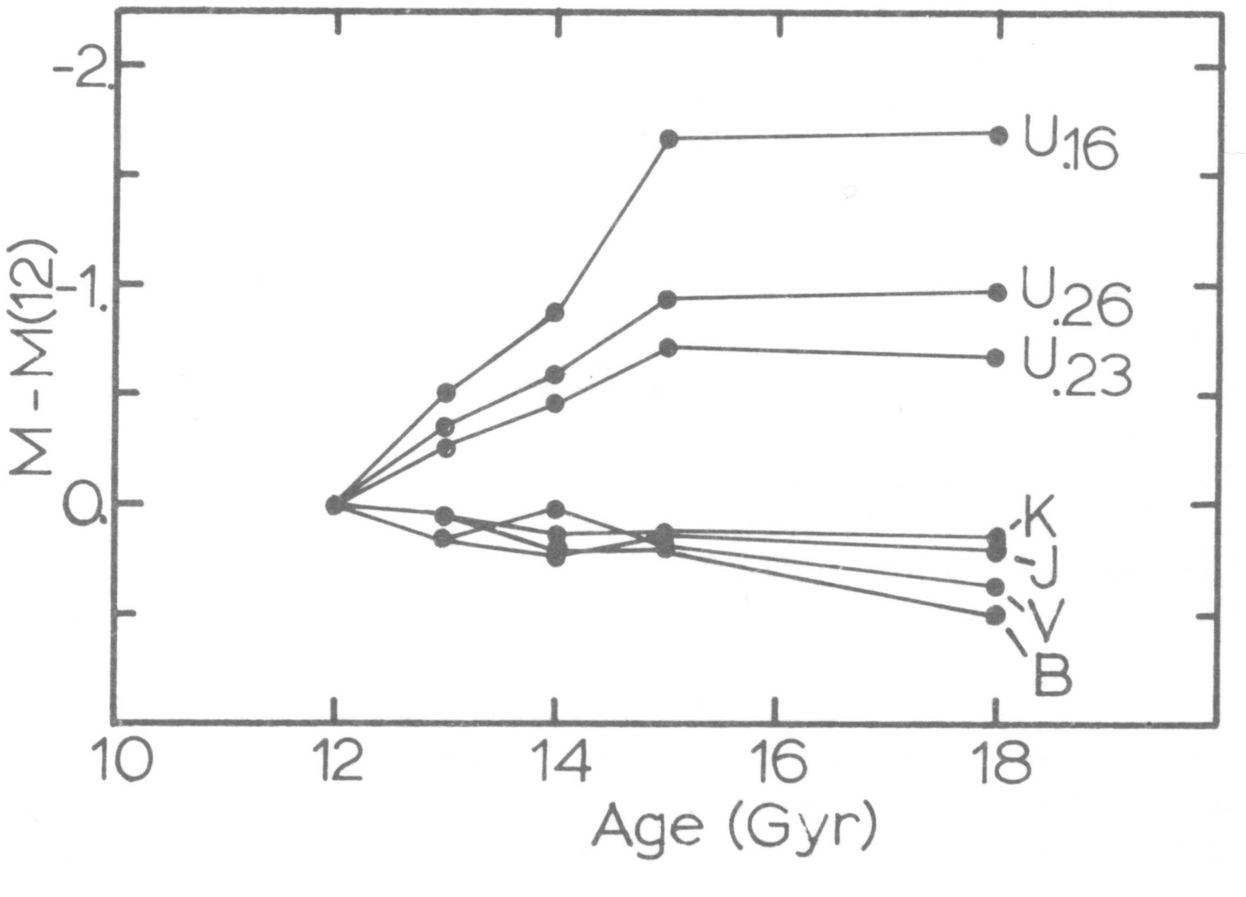

Fig. 2 Calculations by Demarque of a metal rich model cluster, showing the variation with age of the luminosity in various bands. Zero point of all bands is the luminosity at an age of 12 billion years.

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that line and band strengths in the red, where the light is dominated by the giants, may permit an independent determination of the metallicity. Other complications include blue stragglers and the UV bright post-horizontal-branch stars. The latter may be particularly troublesome: they are so bright and so rare that statistical fluctuations in the colors of even rich clusters may be large (Ciardullo and Demarque 1978). Unfortunately, much of the theoretical and observational work which would demonstrate (or refute) the practicality of these observations has not been done. It is crucial that they be done before the Space Telescope is launched.

In addition to their interest as individual objects, the properties of cluster systems in galaxies may tell us much about their history. For example, Hanes (1977) has shown that the number of globular clusters in elliptical galaxies in the Virgo cluster displays both intriguing regularities and irregularities. In most ellipticals, and some spiral bulges, the number of clusters is proportional to the galaxy's - or bulge's - luminosity.M87, on the other hand, has several times more clusters than one would expect from this trend. Also, Harris and Smith (1976) have shown that within at least one elliptical, the surface density of clusters is strictly proportional to the galaxy's surface brightness.

These results raise many questions which observations of more - and necessarily more distant - galaxies may answer. Do the globular clusters really constitute a fixed percentage of the mass of a spheroidal component? If so, may we use them to delineate quantitatively the Population II component of a galaxy? If not, does this percentage depend on the metallicity, mass, angular momentum or other physical properties of the galaxy? Why is M87 peculiar? Do other brightest cluster members, or X-ray galaxies, or galaxies with active nuclei display this same peculiarity?

Similar questions may be asked about the clusters in the disks of later-type galaxies. How does the ratio of young clusters of various masses to the present star formation rate depend on galaxy properties? The Magellanic Clouds contain young clusters as massive as the old globulars, but our own galaxy does not. Is this typical of Irr vs. Sbc galaxies? What about clusters in the disks of SO galaxies? The smooth potential should permit all but the poorest to survive. Are there such things?

Another intriguing but generally ignored question concerns the luminosity function of globular clusters. Most astrophysical objects - stars, galaxies, clusters of galaxies - have luminosity or mass functions which rise monotonically toward smaller objects, but that of globulars in our own and nearby galaxies is approximately gaussian, with a width of only about 1.5 mag. Are they preferentially formed at only one mass, a very significant fact if true? If so, is this mass a universal constant,

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or does it depend on the galactic parameters? Or has a more usual luminosity function been progressively truncated by the tidal disruption of the poorer clusters? Observations with the Space Telescope of globular clusters in a variety of environments should answer this question. (This is not the place to discuss it, but should the luminosity function turn out to be universal, its usefulness as a distance indicator is obvious.)

If the relationship between halo populations and globular clusters can be well established, clusters will provide a very effective probe of the extent and stellar content of ellipticals and the bulges of disk galaxies. I have mentioned above my skepticism about the suitability of the Space Telescope for observing the very low surface brightness outer parts of galaxies, but globular clusters may allow us to study these regions indirectly. It would be particularly interesting to study the extended envelopes of cD galaxies. The information that the globular clusters tell us about their composition may help us answer the question of the origin of these very massive envelopes.

2.2 The Contents of Early-type Galaxies

One of the most important aspects of galaxy studies to which the Space Telescope can be expected to contribute is the contents of elliptical galaxies. Because of the limited amount of data which will be obtainable even with the ST in nearby galaxies, observations of the integrated light of more distant ellipticals will be very necessary for this task. One obvious area in which ST observations will be useful is in improving spectral synthesis of the integrated light of galaxies. Most of what I discussed earlier about star clusters is equally relevant here. One may hope that the additional UV data will resolve ambiguities such as blue stragglers vs. early turn-off and age vs. metallicity, but we don't really know yet. In one way galaxies are easier than star clusters: the post-horizontal-branch stars, while still important, are at least present in sufficient numbers in these richer systems so that small number statistics are not a problem.

Another UV observation which may be informative is of the 2200 Å feature due to dust absorption. Dust is easy to observe in external galaxies if it is strongly clumped. However, if it is smoothly distributed it is very easy to miss, especially in poorly resolved galaxies. We are very familiar with dust in spiral galaxies, because it is confined to spiral arms in a thin disk. It is not at all obvious that the same amount of dust, if distributed rather smoothly throughout a spherical volume, would be visible in even the nearer ellipticals. A search for the 2200 Å feature in "normal" elliptical galaxies would be a valuable test of the conventional wisdom.

This brings us to the larger subject of the Population I content of elliptical galaxies. How well founded is our belief that they do not have any? They don't look like they do, but is that a very sensitive test? A list of all of the early-type galaxies within 10 Mpc, taken from the Second Reference Catalogue of Bright Galaxies (de Vaucouleurs, de Vaucouleurs, and Corwin 1976), is presented in Table I. The remarkable

Table I

Early-type Galaxies within 10 Mpc

Galaxy	Type	Galaxy	Type	Galaxy	Type
NGC 147	E	NGC 1428	S0	NGC 3115	S0
NGC 185	Ep	NGC 1705	S0p	NGC 4150	S0
NGC 205	Ep	NGC 2784	S0	NGC 5102	S0p
M32	E	NGC 3034	I0	NGC 5128	Ep
NGC 404	S0	NGC 3077	Ep/I0	NGC 5253	Ep/I0
NGC 1400	S0				

thing about this list is that, unlike the Catalogue as a whole, there are very few ellipticals which are not "peculiar", and their peculiarity is always related to the presence of Pop I material: gas, dust and young stars. Now, this may be a statistical quirk, but it may be due to the effects of distance usually hiding what is a common feature of most elliptical galaxies.

There are some hints that this may be so. Duus and Newell (1979) have obtained photometry of many dwarf E's in the Fornax cluster which shows that many are bluer than even the most metal poor galactic globular clusters. The implication of their data is that either all ellipticals are producing stars at a modest rate, thus shifting the entire color-magnitude relation to the blue, or that about one half of the dE's have a substantial amount of ongoing star formation. Oemler and Tinsley (1979) have recently concluded that the statistics of type I supernovae may be most easily explained if ellipticals are producing young stars at a rate sufficient to use up the gas lost by evolving stars.

A modest amount of star formation in any but the nearest galaxies would be easy to hide from ground-based observers. O'Connell (1976, 1979) has recently done very detailed spectral syntheses of a number of elliptical galaxies. He has concluded that star formation at several times the gas loss rate cannot be excluded by the observations. A very striking example of the invisibility of star formation in ellipticals is provided by NGC 1510. Its optical image provides only very slight

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hints that it is anything but a normal elliptical, but radio observations show that it contains a large mass of HI and its optical colors and spectra show that it is forming stars at a high rate (Disney and Pottash 1977). The Space Telescope offers two means of detecting star formation in ellipticals. Provided that the problems discussed earlier are solved UV spectrophotometry will be much more sensitive to young, hot stars than any ground-based observations. Equally important, the improved resolution of the ST will permit scrutiny of thousands of galaxies in the same detail with which the objects in Table 1 have been observed from the ground. If the same large fraction turn out to be"peculiar", we may have to revise our notions of what is "normal".

Another class of object about which the ST can be expected to tell us much are the peculiar galaxies. Among these I include the peculiar ellipticals , Irr II's, ring galaxies, blue compacts and interracting galaxies. Since each is different, there are as many questions one could ask as there are individual examples. In general, however, there are two types of data which would most help in understanding the origin of the peculiarity.

One type of data is the internal motions within the object. (In some cases this can be obtained from the ground, but often it cannot.) For example, a comparison of the motions of the gas and stars in Ep and Irr II galaxies can help decide whether the gas came from within or without the galaxy. The detailed motions inside the ring of a ring galaxy might distinguish between the various models of these objects. Motions within interracting galaxies can tell us much about the interraction.

The other important class of observations is of the stellar population in the peculiar galaxies. The Space Telescope should allow us to see the giant branch stars in enough galaxies to help decide whether the "intergalactic HII regions" have an old population, whether the material which has fallen into NGC 5128 was a gas cloud or another galaxy and perhaps whether there are remnants of a disk in the central holes of ring galaxies.

3. GALACTIC CORES

Spheroidal stellar distributions, whether ellipticals or the bulges of spirals, seem to possess several characteristic length scales which, if we knew how to interpret them, would tell us something about the formation processes of the system. One characteristic length is the core scale, a, in for example the Hubble law,

$$I \sim I_o \frac{1}{(r/a+1)^2} \tag{1}$$

or King's (1966) modified isothermal law

$$I \sim I_0 f(r/a,\ a/r_t). \tag{2}$$

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For a typical elliptical, a seems to be some fraction of a kiloparsec, which puts it, in most cases, beyond the resolving power of ground based observations (see, especially Schweitzer 1979). Thus, although there are some theoretical ideas around about the significance of the core size, there is little empirical data with which to compare them. One would like to know how core size depends on galactic mass, and whether other secondary parameters like metallicity or angular momentum are important. One would also like to know how core size evolves through mergers with other galaxies and whether the cores as well as the envelopes of cD galaxies show the effects of whatever processes have built these galaxies to their present enormous size.

On an even smaller scale than the cores are the almost point-like cusps found in the central light distributions of some galaxies. I shall leave the discussion of M87 and other active galaxies to Sargent, but less massive (and less active) mass concentrations exist in at least some normal galaxies. The example of M31 has been well studied. Stratoscope observations by Light, Danielson and Schwarzschild (1974) have shown the nucleus of M31 to be a distinct feature, with a scale length of $0\farcs28$ = 0.95 pc, superimposed on the bulge light distribution. Its dynamics are interesting, for the observed equality of nuclear and bulge velocity dispersion (Morton, Andereck and Bernard 1977) is not what is expected in the most straightforward models (Ruiz and Schwarzschild 1976). Tremaine, Ostriker and Spitzer (1975) have suggested that the nucleus has grown by the accretion of globular clusters from the bulge, but van den Bergh (1979) has disputed this because the nuclear colors are not consistent with this origin. Faber and French (1979) have recently reasserted Spinrad and Taylor's (1971) claim that the nucleus is dwarf enriched, a conclusion based on the strength of the Na I 8190 line. This would also be inconsistent with the Tremaine et.al. theory, but could explain the high nuclear velocity dispersion. The Space Telescope should help elucidate the nature of the M31 nucleus by permitting a more detailed study of its internal structure, dynamics, and, perhaps, luminosity function. It should also be possible to search for and study similar features in more distant galaxies; although their small scale will limit the number of galaxies which are accessible even from space.

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DISCUSSION

Jura: An important technique for studying dust with the Space Telescope is to look for polarisation away from the centre of a galaxy. If the grains are similar to those in our own Galaxy, there might be as much polarisation in the U-V as there is in the optical waveband. This would be particularly true if the grains are small because then the dominant source of opacity would lie in the ultraviolet waveband because of the λ^4 law.

Baum: Photometric ST imaging observations of regions in galaxies to distinguish stellar population differences involve some practical cautions and complications. Filter bands cannot be wide, because of the substantial wavelength dependence of the "flat-field" calibration of the CCD, and because of the high demand on photometric precision needed for detecting the presence of spectral features that indicate chemical composition differences. Another problem is that relatively narrow-band filters centered on specific features (examples, MgH, Hβ) have to have different central wavelengths for galaxies at differing redshifts (such as Local Group, Virgo Cluster, Coma Cluster, and beyond). This takes careful planning in the choice of filters and in the number of special filters required.

Van den Bergh: There is some direct evidence that tidal forces can and do destroy globular clusters. Globulars with small values of r_t/r_c are found to be ~ 5 times fainter than those with large values of this parameter. For 51 galactic globulars with $\log (r_t/r_c) \geq 1.25$, $\langle M_V \rangle = -7.96 \pm 0.13$ compared with $\langle M_V \rangle = 6.19 \pm 0.24$ m.e. for 11 clusters with $\log (r_t/r_c) \leq 1.00$. The best example of a dying globular is "E3" in which (presumably binary) blue stragglers outnumber evolved red giants.

The last object in your list, NGC 5253, is also one of the most exciting. A deep 4-metre plate shows this object to be embedded in a cloud of ~ 50 star clusters. These clusters probably provide fossil evidence for a violent burst of star formation that took place $\lesssim 10^9$ years ago. Possibly this activity was triggered by an encounter in which the ScI galaxy NGC 5236 dumped gas in NGC 5253. The high rate at which supernovae of type I occur in NGC 5253 is almost certainly due to the burst of star formation. The star clusters extend out to and beyond the distances at which the two supernovae in NGC 5253 occurred.

Oemler: The funny thing about that cluster is that all the early-type galaxies are peculiar which is odd considering how widely separated they are.

Ostriker: A couple of years ago Scott Tremaine and I investigated whether the form of the luminosity function of globular clusters could be due to dynamical effects. We concluded that it could not. This

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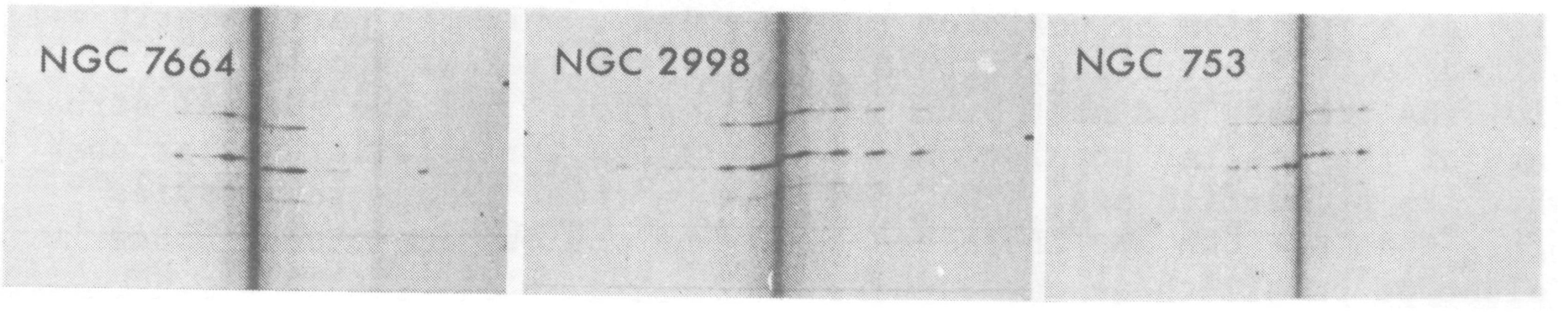
suggests that the shape of the luminosity function and the fact that there is a peak in it may be intrinsic. There is some evidence for this feature in the luminosity function of globulars in other galaxies but it needs checking for many more galaxies. The peak may provide a distance indicator. Two possible theories of its origin are either the standard Peebles-Dicke arguments or perhaps these are the kinds of gas clouds which are left over from an early phase of galaxy formation.

Freeman: I would like to make two comments. First, blue stars are needed in E galaxy population models. If these stars are like the UV-bright stars in globular clusters ($M_V \approx -3$), then they will be resolved in E galaxies out to the Virgo cluster with ST. Second, if galactic winds are responsible for keeping E galaxies almost gas free, then it may be possible to see these winds with ST by their UV absorption spectra against galactic nuclei.

Gallagher (Discussion leader): Let me re-emphasise some of the points raised by Oemler in his review. In the present discussion, we want to review the current physical state of affairs in a galaxy rather than evolutionary questions which will be dealt with after Dr. Tinsley's talk Among the things we want to know are (i) the distribution of mass as a function of radius, (ii) the metallicity and the dispersion in metallicity as a function of position in the galaxy, which is particularly well suited to UV spectroscopy with ST, (iii) the stellar population, (iv) the present and past birth rates of stars, (v) the spatial structure of the stellar populations and (vi) the interstellar matter and what its properties are. We need to know these things in galaxies other than our own and there are clear and obvious impacts of Space Telescope on all these endeavours.

Rubin: The high spatial resolution obtainable with the Space Telescope will permit the study of the dynamics of the central regions of spiral galaxies on a scale not presently possible. At M31, 1" = 3 pc; velocities for regions smaller than this can not now be studied. Only the Stratoscope observations (Light, Danielson, and Schwarzschild, Ap. J., 194, 257, 1974) reveal the nuclear structure with a resolution of 0.2 arcsec. In M31, individual stars will be resolvable very close to the center with ST. At the center of M31, the stellar density is 10^5 pc^{-3}, much like the densities in some globular clusters discussed today by Freeman. If the sun were viewed at the distance of M31 with infinite resolution, it would subtend an area of 10^{-15} pc^2. A comparison of the surface brightness for the central 1" in M31 with that of the sun indicates that only 10^{-10} of the available surface area in the central 1" is covered by stellar discs. Even at the finite (0.2 arcsec) resolution of ST, individual stars will be observable very close to the center of M31. For a very few spirals, studies of their central dynamics will be able to proceed star by star.

For spirals at larger distances, integrated nuclear spectra will be obtainable with ST, but at added resolution due to the higher spatial scale. Moreover, although low surface brightness may be a problem for many extragalactic programs, nuclear spectra will not be photon limited. For 21 Sc galaxies with a wide range of physical properties, we (Rubin, Ford and Thonnard) have obtained rotation curves. By their kinematic behavior out to nuclear distances of a few kpc, Sc's can be separated into two groups. Some galaxies, generally small and of low luminosity, have shallow initial velocity gradients, weak or absent stellar continua in the red, and Hα emission stronger than [NII], as in conventional HII regions. Other galaxies, most often large and of high luminosity, have steep nuclear velocity gradients, a strong red stellar continuum, and nuclear emission with [NII] stronger than Hα. All spatial and velocity details near the nucleus are lost in the inner few seconds of the galaxy spectrum; the observed velocity is high at the first measured position (2" or 3") off the center. For these galaxies, the nucleus is a black box which takes incoming velocities at V ∿ −250 km/s and sends them out at V ∿ +250 km/s. With the 10 times increase in scale from ST, we can hope to study some details of this phenomenon.



Three Sc galaxies with velocity discontinuities across the inner few seconds of the galaxy spectrum

The inner velocity gradient, V/R, is a measure of the inner mass and density, for $M \sim V^2R$, and $\rho \sim V^2/R^2$. For the nine galaxies in the Sc sample observed at 13-cm (Dressel and Condon, Ap. J. Suppl., 36, 53, 1978), there is also a correlation of 13-cm flux with central velocity gradient. Hence this gradient is also a measure of nuclear activity. For the largest galaxies in the sample, the mass within 1 kpc is $\sim 10^{10}\ M_\odot$; the distribution of this mass is unknown because of the lack of spatial velocity resolution. With the high spatial scale and UV spectra from ST, it should be possible to relate the kinematics to the nuclear abundances and history of the inner galaxy. For spiral galaxies at moderate distances, the increase in knowledge from ST nuclear spectra should be enormous.

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Humphreys: I will briefly discuss how observations with the ST can be used to study in some detail the structure, stellar content and even evolution of other galaxies by observations of individual member stars.

With imaging to $m_V \approx 28$ with the WFC we will be able to obtain magnitudes and colors for the Population I stars in galaxies as distant as the Virgo cluster and beyond ($\approx$ 100 Mpc). With the FOS spectra will be obtainable to $m_V \approx 22$-23, putting the very brightest stars in the Virgo cluster galaxies within reach of spectroscopic analysis.

Observations of this type will permit us to get a detailed picture of stellar evolution as a function of location in a galaxy. In our own Local Group of galaxies, stars on the main sequence will be observable. In more distant galaxies, such as the M81 group, M101 group and the Virgo cluster, the supergiants will be readily accessible. We will be able to study how stellar evolution, at least of Population I stars, depends on galactocentric distance and possible abundance gradients in the galactic disks. We may also ask if there are variations in the initial mass function with position in a galaxy and with galaxy type. Color-magnitude diagrams for associations of young stars in the spiral arms will allow us to age-date these stellar groups and discuss their evolution as a function of position in the arm - along and across a spiral arm. Such information may allow us to decide between various theories for the origin and maintenance of spiral arms - the density-wave theory and the stochastic formation process of Gerola and Seiden. If the radial velocities obtained with the FOS are sufficiently accurate we could also study the motions within the arms as well as their structure.

Some of these suggestions for the use of Space Telescope are illustrated by recent work on the stellar content of two Local Group galaxies M31 and M33 (see Humphreys, R.M., 1979. Ap. J., Dec. 15, Sandage and Humphreys, 1979. In preparation).

King: Dr. Oemler referred to a controversy about observed core radii of elliptical galaxies. This is based on a paper by Francois Schweizer that is in press. Schweizer notes that the core radii of M31 and M32 are so small that at the distance of Virgo they would be completely unresolved. He then convolves de Vaucouleurs profiles with seeing discs and gets results that closely resemble my dynamical models, but with apparent core radii that are much larger than the true cores. He therefore suggests that most of my "observed" core radii in Virgo might be quite fictitious, reflecting only seeing.

Schweizer and I are attempting to resolve our difference like gentlemen: instead of arguing, we have jointly secured better data and are analyzing it. If it turns out that I am right, then we know something about the cores of ellipticals. If Schweizer's right, we will have to wait for ST.

Burbidge: The mention of UV luminosity in nuclei of normal ellipticals and their luminosity profiles brings to mind a long-standing puzzle to me. Why are the two nuclei of the dumb-bell double elliptical NGC 4782/3 so different structurally? The galaxies are similar in total luminosity but one has a strongly concentrated nucleus and the other has a diffuse one. I wonder what the UV luminosities of the two are like - are they different? The WFC on ST could give this information.

Collin-Souffrin: A comment on Dr. Humphrey's talk: I would like to draw attention to the work of a group of astronomers working at the Observatoire de Marseille, France. From what I know of their extensive study of M33, it seems very similar to what Dr. Humphrey has described. In particular, they reach the same kind of conclusions concerning the asymmetry of the northern and southern arms in excitation, luminosity functions of stars, and kinematics.

Dr. Schwarschild has asked if there is a possibility of distinguishing between O stars and the nuclei of planetary nebulae, in the nuclei of galaxies. I think there is indeed one possibility: if gas is present, it is ionized by these hot stars. If the [OII] line λ 3727 and not the [OIII] line λ 5007 is present in the spectrum - as is generally the case in non-active nuclei - it is more likely that the ionizing stars are O stars and not nuclei of planetary nebulae, which are rarely colder than 35000 K.

Dr. Gallagher has discussed the importance of studying stellar populations in the nuclei of galaxies with ST. I would like to emphasize also the importance of performing stellar population syntheses in giant extragalactic HII regions, dwarf blue compact galaxies etc., which are in an active stage of star formation. Indeed, early type stars, such as A stars, would probably largely dominate the spectrum in the UV range. A detailed study, involving the comparison of the spatial distribution of ionized gas, its abundance and excitation, with the stellar population and eventually with kinematic properties, would certainly give us very interesting information concerning the process of star formation in bursts.

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