PROFILE OF A KEY PROGRAMME

A Redshift Survey of Galaxies with $z \lesssim 0.6$ Using Multi-Object Spectroscopy

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Through the steady acquisition of redshifts of galaxies, our understanding of the large-scale galaxy distribution has evolved drastically during the past decade. Most recently, the Centre for Astrophysics (CfA) redshift survey ($B \leq 15.5$) has suggested a new picture of the galaxy distribution: galaxies appear to be distributed on thin shells surrounding vast regions with diameters between 20 and 50 h^{-1} Mpc (H_0 = 100 h km s^{-1} Mpc^{-1}) devoid of bright galaxies (de Lapparent, Geller, and Huchra 1986). This new interpretation of the galaxy distribution is consistent with the detection of a 60 h^{-1} Mpc void in Boötes (Kirshner et al. 1981) and with the alternation of peaks and ~ 100 h^{-1} Mpc wide valleys in deep pencil-beam probes (Koo, Kron, and Szalay 1987). Shell-like structures are also detected in redshift surveys of H I galaxies (Haynes and Giovanelli 1986).

Although the CfA redshift survey is unique in its combination of large angular coverage and depth, it does not represent a fair sample of the universe: the size of the largest coherent structures (~ 50 h^{-1} Mpc) is comparable to the spatial extent of the survey (~ 100 h^{-1} Mpc). Deeper redshift surveys are therefore necessary for measuring the mean statistical properties of the large-scale clustering. Deep surveys can constrain the size and frequency of the shells, and thus complement nearby wide-angle surveys which provide information about the details of the galaxy distribution within the shells. In an attempt to satisfy the need for deep surveys, we have designed a redshift survey programme ~ 15 times deeper in velocity than the CfA redshift survey.

Our programme aims at the acquisition of a complete galaxy catalogue to $R \sim 20.5$, with BVR photometry and low-resolution spectroscopy ($\Delta\lambda$ ~ 10 Å). We will start the observations on the 3.6-m using the ESO Faint Object Spectrograph and Camera (EFOSC; Buzzoni et al. 1984) for both imaging and spectroscopy. We will take full advantage of the multi-object spectroscopy capability of EFOSC provided by the Punching Machine (PUMA), which allows real time drilling of multiple slits into aperture plates (Fort et al. 1986). At $R \leq 20.5$, there are on the average ~ 8 galaxies per ~ 3.'5 × 5′ field of EFOSC, and the slit spectra of ≤ 10 galaxies can be obtained simultaneously (as demonstrated during two previous observing runs). When the ESO Multi-Mode Instrument (EMMI; D'Odorico et al. 1986) becomes available on the NTT with the multi-slit mode (1990), we will switch to the NTT. The larger field of view planned for EMMI (7′ × 10′ with a new-generation CCD) will result in a time gain of a factor ~ 3 for the photometry and a factor ~ 2 for the spectroscopy. The total observing time (60 nights) will be spent in the proportion of ~ ⅛ for imaging and ~ ⅞ for spectroscopy.

We will survey a strip with a total area of 0.4 deg^2, in a region near $\alpha \simeq 22^h$ and $\delta \simeq -30°$, located at high galactic latitude (b^{II} ~ −50°). Measurement of the redshifts of the ~ 700 galaxies in the survey region will provide a unique data base for studying the clustering on very large scales. With its effective depth of z ~ 0.6 (~ 1400 h^{-1} Mpc with q_0 = 0.1), our survey could intercept along the line of sight ~ 45 shells with mean diameter 30 h^{-1} Mpc. The size of the projected area surveyed by the strip at 1400 h^{-1} Mpc, ~ 6 × 45 h^{-2} Mpc^2, can be compared to the characteristic scales for the structures in the CfA redshift survey (mean separation of galaxies in the shells – a few h^{-1} Mpc –, and diameter of the shells). This comparison suggests that the deep survey will sample the structures with a sufficient spatial coverage for delineation of the individual shells.

The deep redshift survey will indicate whether the nearby voids are typical in size, and whether larger inhomogeneities exist. The contribution of large voids dominates the uncertainty in the mean number density of galaxies. This uncertainty in turn introduces a large scatter in the determination of the two-point correlation function (de Lapparent, Geller, and Huchra 1988), an important tool for constraining the power spectrum of primordial fluctuations at large-scale (Peebles 1980). In addition, the survey will provide information on the spectrum of shell diameter, and therefore, will tightly constrain the N-body models for the formation of large-scale structure (Melott 1987; White et al. 1987; see also Ostriker and Vishniac 1986). The large number of individual structures sampled by the survey will also allow to put direct limits on evolution in the large-scale clustering with redshift.

The other major goal of the programme is to examine the spectrophotometric evolution of field galaxies. Catalogues of distant clusters of galaxies (Butcher and Oemler 1978; Butcher and Oemler 1984; Dressler, Gunnn, and Schneider 1985; Lavery and Henry 1986) suggest a significant evolution at z ~ 0.5 in the "blue" population of clusters. Deep galaxy counts suggest a similar effect in the field at $B \gtrsim 24$ (Koo 1986; Tyson 1988), suggesting UV excess from massive star formation in galaxies at z ~ 1–3. The availability of redshifts for the galaxies in our survey will allow to recover their intrinsic colours and thus distinguish evolution from cosmology. We will then be able to estimate the fraction of intrinsically "blue" galaxies [$(B-V)_{intr} \lesssim 0.7$] per redshift interval. Examination of the spectral features will yield information on the nature of these "blue" galaxies (see Dressler and Gunn 1983), and thus will provide a test for the interpretation of the "blueing" trend as originating from extensive star formation. A study of the variations in the fraction of "blue" galaxies with the local galaxy density might also provide some insight into the influence of the environment on the process for galaxy formation.

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PROFILE OF A KEY PROGRAMME

Towards a Physical Classification of Early-type Galaxies

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Hubble was the first who succeeded in classifying galaxies within a scheme of some physical meaning. Although it soon became clear that Hubble's *tuning fork* does not represent an evolutionary sequence, this essential diagram has proven to be a powerful tool especially for the understanding of late-type galaxies. On the other hand, the "early-type" sequence of elliptical (E) and S0 galaxies is less satisfying, because it does not seem to reflect a unique sequence of physical properties. The S0 class, although conceived to bridge the gap between disk- and disk-less galaxies, has often been abused to host ellipticals exhibiting peculiarities incompatible with their definition as structureless objects. For the elliptical galaxies themselves, "ellipticity" has been found to be essentially meaningless with regard to their angular momentum properties, and shows little, if any, correlation with other global parameters. This fact became apparent after the first stellar kinematical measurements of luminous ellipticals (Bertola and Capaccioli 1975, Illingworth 1977): E galaxies are not necessarily flattened by rotation and may have anisotropic velocity dispersions (Binney 1978).

A first step towards a physical classification of early-type galaxies was the investigation of the correlations between the classical global parameters (luminosity, scale length, projected central velocity dispersion, central density, and metallicity/colour). These parameters were found to form a plane in the parameter space ("the fundamental plane"). More specifically, each of these global parameters can be given as a function of two independent parameters, namely in general the central velocity dispersion and the mean surface brightness. The fundamental plane corresponds to the cooling diagram plane of modern theories of galaxy formation, which are based on the self-regulation of the dissipative collapse of protogalaxies (Silk 1983, Blumenthal et al. 1984).

In contrast to the "global" parameters, those describing the detailed shape and kinematics of early-type galaxies (ellipticity gradients, isophotal twists, trends of radial light profiles, velocity anisotropies, etc.) do not correlate with the fundamental plane. This lack of correlations has instilled further suspicion that even the Hubble E class alone is not physically homogeneous (Capaccioli 1987). Indeed, while all ellipticals share roughly the same morphological appearance, they may nonetheless belong to genetically distinct families (see Bender et al. 1988, Nieto 1988, Prugniel et al., 1989). The consequences of this hypothesis are more dramatic than having the E galaxies populate a "2 + N" parameter space (e.g. Djorgovski and Davis 1987, Dressler et al. 1987) since a physical segregation of E types would bear directly on our understanding of the formation/evolution of the different species of galaxies.

An effective tool for separating E galaxies into at least two physically distinct classes has been recently identified with a simple and direct observational parameter which measures the lowest-order axisymmetric deviation (a_4) of the galaxy isophotes from perfect ellipses (Bender 1987). This parameter, easily extracted from good S/N images by Fourier analysis, discriminates between "boxy" ($a_4 < 0$) and "pointed" ($a_4 > 0$) isophotes (e.g. Lauer 1985, Bender and Möllenhoff 1987, and Jedrzejewski 1987).

Bender et al. (1988, 1989) and Nieto (1988) found that these two "shape-classes":
(a) contain ≈ 80 % of all Es, and
(b) isolate objects with distinct physical properties.

More specifically, boxy ellipticals are frequently radio-loud (the power being a function of the mass) and permeated by gaseous "halos" (as inferred from their X-ray emission), while ellipticals with pointed isophotes are usually undetected in the radio and X-ray bands (Fig. 1). There is also a clear segregation of the kinematical properties between these two classes: in most cases boxy ellipticals are flattened by anisotropic velocity dispersion while "pointed" E's are rotationally supported (Bender 1988a, Nieto et al. 1988; see Fig. 2).

The nature of "pointed" E's is easily understood if one assumes (Nieto et al. 1988) that they are internally structured

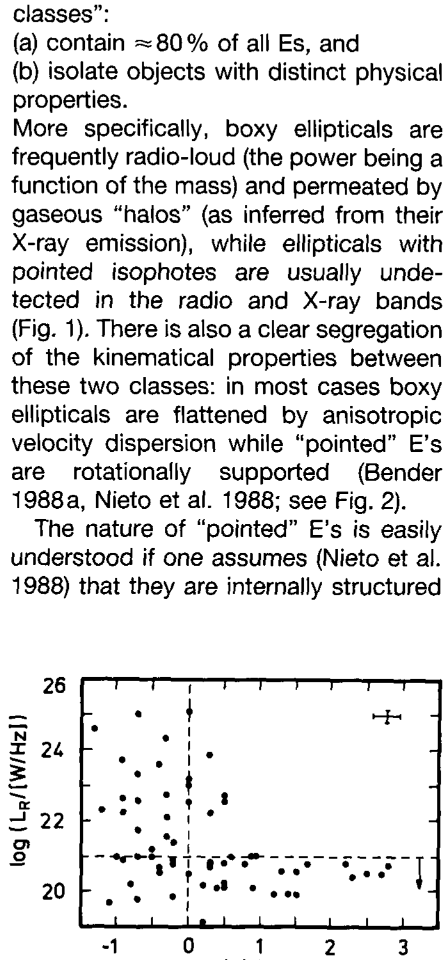

Figure 1: *Logarithm of radio luminosity at 1.4 GHz against isophotal shape parametrized by a(4)/a (a(4)/a < 0 indicates boxy isophotes, a(4)/a > 0 disky isophotes). Below the dashed line most symbols indicate upper limits (Bender et al. 1989).*