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THE MORPHOLOGICAL CLASSIFICATION OF GALAXIES

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ABSTRACT. Much of what is known about galaxies began with a simple classification of their forms as seen on direct blue-light plates. This classification continues to be useful at a time when galaxies have never been better understood. The reason for this is that morphology contains information on the dynamics and evolution of galaxies in spite of the fact that the features dominating the appearance may include only a small fraction of the total mass. In this article I briefly review the important classification systems in use today and highlight classification as an art having significant discriminating ability and at the same time serious limitations. I also summarize recent developments in this field from a morphologist's point of view.

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1. INTRODUCTION

Galaxy classification is one of those enjoyable aspects of galaxy research that few of us consider ourselves specialists in. Most of us obtain the morphological information we require from the large catalogues or lists provided by a few respected "morphologists", and rarely attempt to improve on those types by re-inspecting the galaxies ourselves or by carrying out an imaging survey. Though we may on occasion question a catalogue type in individual cases, especially if better image material becomes available, published morphological types provide an important starting point for most extragalactic research. This is as true today as it was 66 years ago when Hubble published his famous classification system. There can be little doubt now that nature and nurture play a role in determining the morphology of galaxies. The main questions are to what degree have each of these processes influenced present-day morphology, and how do we recognize these influences. Morphology alone cannot answer these questions, so a confrontation between theory and observation is essential. It is thus fitting to begin this conference with a review of the morphological classification of galaxies, since this provides the background for the nature vs. nurture controversy. Due to space limitations, the discussions are necessarily brief.

2. REVIEW OF CLASSIFICATION SYSTEMS

Though the nomenclature was very simplistic, the morphological classification of galaxies can be traced back to the time of the Herschels (1781-1847), whose telescopes were large enough to allow visual recognition of distinct differences in the large-scale characteristics of the so-called "white nebulae". Different degrees of central concentration, apparent flattening, and mottling were clearly distinguishable. More complex structure was seen in a few of the brighter cases, but it was Lord Rosse who, in 1845, added the attribute "spiral" to some members of the Herschels' white nebulae. This is when morphology began to get interesting.

The advent of photography in astronomy at the end of the 19th century firmly established the reality of the spiral morphology. Photography also provided a greater appreciation of the complexity and range of galaxy morphology that must have proved almost daunting to anyone wishing to understand how the different forms are related to one another, if at all. As the number of good quality images grew in the first part of the 20th century, different classification schemes were naturally attempted. An excellent review of the steps which led to the recognition of the main types is provided by Sandage [45], who gives all of the early references as well as references to a number of classification systems which fell into early dis-use. Examples of most of the main types were already known by 1920.

The classification systems in use today are all in some way related to that described in Hubble's [34] paper. This system, which originally included only ellipticals, spirals, and irregulars, focused on a few basic characteristics and ordered galaxies in a manner that was eventually found to correlate with some basic measured parameters. The sequence was best defined for spirals since three classification criteria were available: the relative strength of the bulge, the openness of the arms, and the degree of resolution of the arms. Van den Bergh [62] commented that the firm establishment and later addition of the SO class by Hubble [35] destroyed the "simple beauty" of the original system. It is interesting also that in spite of a great deal of recent research, there have been no firm correlations found between ellipticity and other properties of E galaxies, leaving the value of this criterion as part of the "sequence" in doubt (e.g., Tremaine [59]). The later division of irregulars into two subclasses, "Irr I" and "Irr II", was proposed by Holmberg [33].

Hubble's final revision to his system is illustrated and described by Sandage [44]. No other classification system has ever been so beautifully illustrated. This was complemented recently by the *Atlas of Galaxies Useful for the Cosmological Distance Scale* by Sandage and Bedke[46], and by the published "mini-atlases" of Dressler and Sandage [27], Sandage and Brucato [48], Sandage, Binggeli, and Tammann [50] and the Revised ShapleyAmes Catalogue [49] (=RSA).

De Vaucouleurs [18, 19, 20] presented a personal revision of Hubble's system that provides a better description of what a galaxy looks like without being too complicated. The system uses the concept of a classification volume, rather than a simple multi-pronged "tuning fork", and is recognized mainly for its addition of stages *later* than Sc, called Sd and Sm, and for the notation (SA, SAB, and SB) used to denote continuity of the bar characteristic. These revisions to Hubble's system have been largely accepted by most astronomers. The Sm class is particularly important because it recognized the Magellanic Clouds not simply as "irregulars" but as very late spirals with no spheroidal component [25, 43].

The classification system proposed by Morgan [40] (see also Morgan, Kayser, and White [41]) was designed as a means of tying galaxy morphology to the then current ideas of stellar populations. The degree of central concentration was used to define a one-dimensional spectral classification system (population group) based on form alone. Secondary dimensions, defined by the "form family" and the tilt index, tied the system in an indirect way to Hubble's system. Morgan also introduced some types not recognized fully by Hubble. The best known of these was the cD class, although its discovery is claimed by Vorontsov-Velyaminov [67]. The Morgan system has recently been used in a study of the spiral-to-elliptical galaxy ratio in two nearby galaxy clusters [70]. However, it has not been used in any recent major catalogues.

One limitation of Hubble's system was recognized by van den Bergh [60, 61], who demonstrated the existence of luminosity effects on the contrast and development of spiral arms. He assigned not only modified Hubble types to galaxies, but also luminosity classes symbolized in a manner similar to stellar luminosity classes. The luminosity classes were originally applied to Sb, Sc, and Irr galaxies, but the latter objects, lacking spiral structure, had to have their luminosity classes estimated from surface brightness alone. Van den Bergh's modified Hubble system was later drastically changed; he disagreed with Hubble's placement of SO's in the "transition region" between ellipticals and spirals for reasons related to flattening and bulge-to-disk ratio. He instead proposed placing SO's in a sequence parallel to spirals [62] (RDDO system). The two sequences use bulge to disk ratio as a classification criterion, and he identified transition cases between SO's and normal spirals which appeared to be spirals with little star formation in the arms. These were given the term "anemics", and were assumed to be gas-poor.

Because the RDDO system builds around the expected evolutionary scenario in clusters that stripping can deplete spirals of the gas needed for ongoing star formation, nurture is explicit: galaxies which may once have been spirals evolved to a completely different type called SO's owing to an interaction with the cluster environment. SO's may not be born, but are made by this interaction. This is a controversy that has not yet been resolved. A primary problem, noted by Burstein [9], is that there are as yet no known examples of SOc galaxies, i.e., galaxies of the SO type which have a bulge-to-disk ratio as small as those seen in many Sc galaxies. Another problem, noted by van den Bergh [64], is that the SO class is a mixed bag of possibly unrelated types of objects.

Vorontsov-Velyaminov [67], referring to his work on the Morphological Catalogue of Galaxies (MCG) in the 1960's, has held steadfastly to the view that galaxy morphology is too complicated to be represented adequately by any of the available Hubble or Hubblelike systems. He developed in the MCG a purely descriptive classification with symbols geared to almost every detail of morphology. This makes for a complex symbolism but is still useful because it allows the isolation of specific categories of objects that the broad Hubble classes do not adequately represent.

3. CLASSIFICATION AS AN ART

It is one thing to know the various classification systems, but quite another to apply these to real galaxies. As an art, galaxy classification has many stringent requirements as well as limitations. For instance, a system is usually defined by a set of standards or prototypes as they appear on a selected type of image material. Thus, reproducibility and consistency will depend on different observers using similar material to classify other objects. For Hubble's system, this image material included prime focus and other bluelight plates taken with 1.5-5m class telescopes. In general, telescope focal length and ratio, image resolution, and the depth of exposure, in addition to the characteristics of a given galaxy itself, all play a role in determining what information is available for classification.

However, there are important problems, such as high inclination, and the fact that large-scale plates or digital images, ideal for classification, are available for less than 15% of the approximately 25,000 galaxies having a standard isophotal diameter $\geq$ 1'. This means that *for most galaxies, morphology is judged from small-scale sky survey plates, prints, and films*. The pitfall of the sky survey images, in addition to the much smaller image scale than is typical of Cass or prime focus large reflector images, is frequent overexposure, making it difficult to see the crucial inner regions where high surface brightness bars, rings, lenses, etc., may be present. Distinguishing E and SO galaxies on such image material, for example, can be difficult [48]. On the other hand, the pitfall of large reflector plates in the past has often been underexposure, causing very low surface brightness disks, rings, arms, etc. to be completely missed. (In fields with significant galactic extinction, these same details can still be lost even on deep SRC-J plates.) Thus, *it is important when using published morphological types to know where the types came from and their limitations*.

The standard Hubble classification system can also simply be difficult to apply to certain kinds of galaxies. Some of the worst offenders can be early-type ringed, barred galaxies, where the bulge can be relatively small in spite of the fact that a spiral pattern is tightly wrapped and not highly resolved [44, 15]. Particularly interesting and important in my view also are what Vorontsov-Velyaminov [67] calls "double or triple stage spirals", which refers to those spirals which exhibit distinct sets of spiral structure on different scales. The use of one pattern could lead to a different type from the other. A good example is NGC 3504 in the Hubble atlas, where a well-resolved oval and bar dust lanes lead to a classification of Sb in the RSA, but a fainter, larger, and smooth outer pseudoring with almost zero pitch angle would clearly warrant a type of Sa. De Vaucouleurs [20] compromises on a type of Sab for this one. The classification of galaxies with hierarchical spiral structure is an interesting problem hardly discussed in the literature, but this kind of structure plays a selective role in the application of Hubble's system [44].

Perhaps the most serious problem with galaxy classification is that it is still largely a subjective visual exercise. The human eye is very good at pattern recognition, and is capable of integrating the information in an image quite quickly. However, a morphological type is not a measured quantity even if it is coded on a numerical scale. De Vaucouleurs [23] emphasized that in spite of the subjective nature of classification, such classification is a time-honored tradition in astronomy that has been largely successful. This has been recently demonstrated very definitively by the extensive analysis of published type (T) and luminosity (L) classifications that provided the coded types given in the *Third Reference Catalogue of Bright Galaxies* [26] (=RC3). From this analysis, which is based mainly on sky survey (PSS or SRC-J) classifications, the average uncertainty in both of these parameters is $\approx$ 0.9 step, where one step represents a difference such as Sb to Sbc, Sa to Sab, etc. Classifications based on large-scale reflector plates, or for large face-on galaxies based on sky survey images, axe generally considerably better than this.

4. TYPE CORRELATIONS

Several studies have quantified two aspects of the spiral sequence that determine the Hubble classification: the bulge to disk ratio and the pitch angle of the arms. Kennicutt [37] showed that objectively measured pitch angles correlate on average with RSA type, but with a large scatter; a rough correlation of pitch angle with Morgan concentration class was also found. Simien and de Vaucouleurs [57] used bulge/disk decompositions to illustrate how the bulge-to-total luminosity ratio varies with Hubble type. A smooth variation with type was found, but most importantly, this study found no support for van den Bergh's belief that SO's form a sequence parallel to spirals. The bulge contribution for SO's is generally intermediate between pure spheroidal systems and spirals, thus supporting Hubble's placement of SO's as transitions between E's and SO's.

The above correlations are expected because they underlie the classification system. But what really makes the Hubble system important are the correlations with other parameters that were not part of the system. It has been known for a long time that

Hubble types, especially de Vaucouleurs revised Hubble types, also correlate very closely with objective measures of color, surface brightness, and HI content [22], [11]. Late-type galaxies are bluer, have more hydrogen, and generally lower surface brightnesses than early-type galaxies. Intermediate types have intermediate properties between these extremes. These correlations are illustrated with new RC3 data and revised galactic extinction and tilt corrections in Figure 1. They are remarkable, at least for spirals, SO's, and irregulars, and they suggest that the revised Hubble sequence has physical significance [21]. Possible scenarios for the origin of the Hubble sequence are discussed by Larson in this volume.

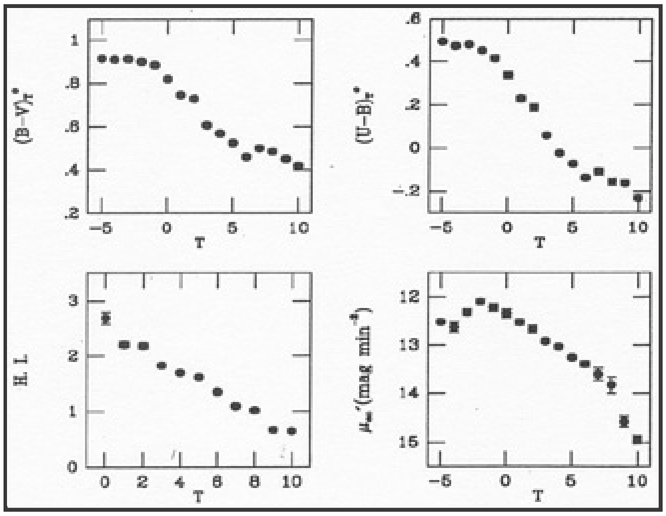

Figure 1: Dependence of several photometric parameters on the coded numerical stage in de Vaucouleurs system. The top two panels illustrate the correlations for colors, while the lower panels show the correlations for hydrogen index H. I. and mean effective surface brightness μ'_{eo}, all as defined and corrected in the introduction to RC3.

5. RECENT DEVELOPMENTS IN CLASSIFICATION AND MORPHOLOGY

Recent developments in this field have been concerned with (1) new major catalogues of standard Hubble types; (2) slight modifications to existing classification systems; (3) the identification of new types of galaxies and improved understanding of older types; (4) identification of the major orbit resonances in grand design spirals and ringed galaxies; (5) widespread application of electronic detectors with high quantum efficiency to large numbers of galaxies of many types, and over a wide range of passbands; and (6) computer classification.

Major catalogues with morphological data continue to be produced. These are summarized in reviews by Corwin [17] and Buta [13]. The RC3 combined several of these catalogues and other smaller lists into the largest database of Hubble morphological type information ever compiled. The 17,700 types given in this catalogue are based solely on photographic sources and are on the classification system of de Vaucouleurs [19]. Other major catalogues include the Virgo Cluster Catalogue [5] and the RSA; these give types on Hubble's revised system [44], with additions and revisions, some described below.

No major new classification systems have been proposed since 1976, though modifications to existing systems have been suggested. For example, Kormendy [38] suggested that tenses be distinguished from rings using their own notation within the framework of the de Vaucouleurs revised Hubble system. He suggested denoting inner lenses by (1) and outer lenses by (L) in the same classification positions where inner and outer rings would be specified. Kormendy also suggested a different approach to morphology, the idea of characterizing galaxies in terms of a small number of "distinct components" (bars, rings, etc.) rather than a large number of morphological "cells". The objective of the approach is to make deductions concerning secular evolution from the ways these components might be expected to interact (see Table 1 of Kormendy [39]). Kormendy suggested that such an approach leads to the possible conclusion that bars are not permanent features of galaxies but may evolve under certain circumstances to a lens. Whether this evolution actually takes place or not is still uncertain.

Another revision to the classification systems is the recognition of "dusty E's." The misclassification of these objects as S0's is a noteworthy problem of catalogues emphasized by Ebneter, Djorgovski, and Davis [28] (and references therein; =EDD). The presence of such "features" in a type of galaxy which was by definition featureless led EDD to suggest a more physical classification of E's is now warranted. A lovely montage and catalogue of dust-lane ellipticals is provided by Bertola [3].

Sandage and Brucato [48] pointed out that the original classes called Irr I and Irr II in the Hubble Atlas are not satisfactory because they combine widely differing objects into the same bin, namely "Irr". To distinguish galaxies which are not E, S0, or S but which have an amorphous appearance to the unresolved light, sometimes with imbedded resolved stars, they proposed the term "amorphous" galaxies. Sandage and Brucato emphasize that these objects are similar to, but not precisely like, the Irr II's in the Hubble Atlas, and that some similar objects classified as I0 by de Vaucouleurs may be peculiar spirals or S0's. One of the hallmarks of the amorphous class is a well-developed early-type absorption spectrum spread throughout the disk.

In the case of spirals, many aspects of the "grand design" and "flocculent" spiral morphologies have now been quantified [31]. These are aspects of spiral structure morphology that are not directly built into Hubble classifications. Flocculent galaxies lack bimodal symmetry and have a spiral-like structure composed only of small pieces of arms. Grand design galaxies generally have a two-armed structure and the arms are longer and more continuous than in flocculent galaxies. To account for these differences and for combinations of the two pattern types in many galaxies, Elmegreen and Elmegreen [30] proposed a system of 10-12 "arm classes" or AC's to highlight a systematic orderliness of spiral arms. The AC's are not exactly the same as van den Bergh luminosity classes because they emphasize symmetry and arm length, rather than arm contrast.

The identification of the locations of specific dynamical orbital resonances in spiral galaxies has seen much progress in recent years. Research has focussed on two classes of objects: grand design spirals by the Elmegreens, and ringed galaxies by myself. The paper by Elmegreen and Elmegreen [29] summarizes how to recognize the primary orbit resonances in a relatively typical grand design spiral, NGC 1566. For this purpose, purely *morphological methods* guided by expectations from spiral structure theory are used. The features considered are spiral arm kinks, gaps, spurs, bifurcations, endpoints to star formation ridges, dust-lane crossover points, interarm star formation, and the ends of a weak bar. If consistency can be found between the positions of these features and those inferred for specific resonances from a rotation curve, then the pattern speed of the wave can be derived with reasonable confidence. However, even in an extreme grand design case like NGC 1566, the resonance features are very weak. It takes a great deal of tenacity, for example, for the reader to study and identify clearly all of the features summarized in Table 1 of Elmegreen and Elmegreen [29].

Ringed galaxies refer to normal galaxies classified in the de Vaucouleurs revised Hubble system with the symbols (R)SB(r), (R')SB(rs), (R')SAB(s), (R)SAB(r,nr) etc., that is, objects which have inner, outer, or nuclear rings or pseudorings. These rings are believed to define the locations of specific orbital resonances with a bar or oval, and if correct they are much more obvious optical features with a direct link to resonances than some of the features seen in the best grand design spirals. Thus, they provide a promising way of indirectly estimating pattern speeds of bars and ovals, of which very little is known. At the moment, there is a great deal of evidence that the outer rings and pseudorings of SB and SAB galaxies trace the location of the outer Lindblad resonance, or OLR. This follows from statistics of their shapes and orientations with respect to bars [10], from their relative sizes with respect to inner rings [2] and most of all from their morphology [15]. The *Catalogue of Southern Ringed Galaxies* [12] is designed specifically to understand the link between rings and resonances, and has been the basis for the studies of Buta [10] and Buta and Crocker [15].

A number of interesting findings have been made concerning cluster galaxies. A photometric study of brightest cluster members, or "BCM's", including gE, D, and cD types (Schombert [51, 52, 53]) has led to a refined and quantitative classification of these galaxies based on luminosity profile shapes. Schombert has noted that the characteristic extended envelopes of cD galaxies are generally fainter than 10% of the night sky brightness and are not readily seen on PSS prints. Thus, the rather shallow luminosity profiles of cD's is what led to their recognition, in addition to their central location in clusters. It is the existence of a true extended envelope that distinguishes the cD from the D class.

As emphasized by Sandage and Binggeli [47] (=SB), the Virgo Cluster contains galaxies of virtually every known morphological type. Of particular interest has been the identification in Virgo of dwarf S0, or dS0 galaxies, which morphologically are like S0's but which are of considerably lower luminosity and surface brightness than normal S0's (see also Binggeli and Cameron [4]). Most of the galaxies in Virgo fainter than $B \approx 14$ appear to be dwarf E, or dE, systems. SB emphasize that the "great void" in luminosity below Sa, Sb, and Sc types is real - there are no convincing cases of dSa, for example. This confirms that the Hubble sequence is largely defined by giant galaxies. However, although no examples of dSa or dSb were found in Virgo, a promising example was found by van den Bergh [63] in the compact, apparent elliptical galaxy NGC 3928, a member of the Ursa Major Cloud of galaxies.

The luminosity class system of van den Bergh has been extended to classes V-VI and VI by Corwin (see introduction to RC3) to allow for a greater range of apparent surface brightnesses seen among dwarf and late-type galaxies on the SRC-J sky survey. The RSA luminosity class system was also refined by SB to allow for a greater apparent range of surface brightnesses seen among Im galaxies in the Virgo Cluster. Among the galaxies classified as Im V by SB are "huge" Im types having significant diameters (up to 10 kpc) and peak central surface brightnesses less than 10% of night sky in blue light. These are accompanied by similar huge dE systems. The data from a variety of sources of luminosity classes have been compared and combined in RC3 [24].

Van den Bergh, Pierce, and Tully [65] (=BPT) have discussed the classification of 231 Virgo Cluster galaxies from CCD images. They propose a revision to the classification system of van den Bergh [62] to include Sd and Sm types, and demonstrate that the accuracy of luminosity classification is improved on digital images ($\sigma(M_T^B) \approx 0.7$ mag) compared to classifications based on photographic plates published in the RSA ($\sigma(M_T^B) \approx 1$ mag). Of particular interest in this work was the identification of a possible new class of galaxies, called "Virgo types." These galaxies have fuzzy outer regions and active star formation in their bulges or inner disk regions, and constitute 43% of 88 Virgo cluster spirals. In contrast, BPT find that the Ursa Major cluster includes only 2 "Virgo types" out of 35 spirals, suggesting real differences. BPT suggest that the early "Virgo types" represent a mild form of the Butcher-Oemler effect that persists at zero redshift.

In a study of the HI and optical properties of cluster galaxies, Bothun, Schommer, and Sullivan [6] identified a class of *red*, HI-rich, low surface brightness spirals. A sample of these objects is compiled by Schommer and Bothun [54], and two extreme examples of the class, NGC 3883 and UGC 542, were studied by van der Hulst et al [66]. The types of these galaxies range from Sa to Sc in Schommer and Bothun [54], and NGC 3883 is quite distinctive for its size and appearance in Abell 1367. Van der Hulst et al [66] interpret these galaxies in terms of a threshold HI surface density for star formation and possible interrupted star formation activity or an altered IMF.

An important serendipitous finding from a study of a field of the Virgo Cluster was an object dubbed "Malin 1" [7]. This galaxy appears small enough on PSS prints that it did not make inclusion into the UGC [42]. However, on amplified deep IIIa-J plates, Malin 1 shows an extended, low surface brightness disk surrounding a small bright core. The object is not a member of the Virgo Cluster (it is $\approx$ 20 times as distant) and is now recognized as a new class of giant, HI rich, low surface brightness disk galaxies the likes of which had not been appreciated before. The properties of Malin 1 are further summarized and described by Impey and Bothun [36], and a second example of the class was reported by Bothun et al [8]. These objects are now interpreted as disk galaxies whose HI surface density is so low that they evolve only slowly.

The study of interacting galaxies has led to the recognition of several new morphologies. Polar ring galaxies [69] are believed to be cases where a small satellite has been disrupted into a polar orbit around an S0. Hoag-type ringed galaxies [55] may be related cases where the central object is an EO system. X-galaxies are edge-on S0's displaying a distinct X-shape across the center that may also be related to polar ring galaxies [68]. "Ocular" galaxies are interacting galaxies displaying an "oval-apex" structure resembling an eye [32]. The latter objects are particularly interesting, because they represent a type of bar not distinguished within the Hubble system. A key feature is a double arm on one side, as illustrated in Figure 1 of Elmegreen et al [32].

Of particular interest to students of spiral structure is the discovery of a leading spiral arm in the interacting galaxy NGC 4622 [16]. The arm was first noticed by Byrd on a well-known commercially available photograph published in Shu [56]. The galaxy is of type SA(r)ab and shows two major outer arms that wind clockwise, but inside the inner ring a single arm winding in the opposite sense is present. Since the "discovery" photograph was taken in blue light, Buta, Crocker, and Byrd [15] (=BCB) re-observed the galaxy in the Cousins I-band to test whether the arm is stellar or an artifact of dust. The leading arm was found to be a clear feature in the galaxy's old disk population. The fact that only a single leading arm is observed in this case, rather than two, is strong evidence that the arm was generated by a tidal interaction, as discussed in detail by BCB.

The widespread use of high quality CCD's, especially the large format TEK CCD's at KPNO and CTIO, has greatly increased the number of large-scale images available for classifying galaxies. What is particularly important is that a typical modern CCD can provide in a short amount of time images that are deeper in limiting surface brightness than the SRC-J sky survey, and yet still provide detailed information on the central regions of galaxies. Thus, they bypass the main problems of direct prime focus or Schmidt plates and have the potential of adding greatly to our knowledge of morphology. It is also clear that recent advances in infrared detectors make the development of a classification system in the 1-3 μ wavelength range a real possibility. The advantages of using near infrared images to type galaxies are their increased sensitivity to the dominant old stellar populations, which tends to enhance the visibility of features such as bars and bulges. The young component of galaxies which dominates blue light images for many spirals as well as dust will be less prominent and therefore not important for typing purposes. The number of "cells" required to classify galaxies should therefore decrease somewhat. However, going to the infrared will not change the pitch angle of spiral arms or the relative sense of the Hubble sequence. What is clear is that the number of "non-barred" galaxies will probably decrease, as can be gathered just the ESO-B and ESO=R sky survey charts.

Finally, in the future some catalogues of galaxies will probably include automatic classification [1, 58]. This is an approach still under development, owing to the difficulty of defining some aspects of morphology, but once a satisfactory methodology is achieved, it has the potential of providing more consistent classifications than might be achieved visually.

6. CONCLUSIONS

One of the sobering realizations of recent years has been the discovery that a large fraction of the matter in galaxies is unseen. As discussed by Freeman (this conference), the evidence for this dark matter is overwhelming, and we are forced to conclude that most of what we see in galaxy morphology may only be like icing on a cake. However, this icing makes galaxies more interesting than they might otherwise be and it offers a lot for understanding galaxy structure and evolution. It seems clear that external influences can drive morphology in a variety of different ways, from gas stripping, accretion, and mergers, to tidally generated bars and spiral structure. Natural formation of bars and spiral patterns can probably also occur, and the influence of the orbital resonances of these non-axisymmetric disturbances can add further complexity to what we see. Morphological classification has many limitations and can only be used as a guide to understanding the underlying dynamics. However, even though it can be misleading, classification is still alive and well in the 1990's, as evidenced by the publication of the RC3. Now, for the rest of a conference like this, we have to weigh the evidence for nature vs. nurture in influencing galaxy structure and evolution.

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