27

From the ASTRONOMICAL JOURNAL
72, No. 1, 1967, February—No. 1346
Printed in U. S. A.

Faint Blue Objects in the Virgo Cluster Region

Vera C. Rubin and Sandra Moore*
Department of Terrestrial Magnetism, Carnegie Institution of Washington, Washington, D. C.
and
F. C. Bertiau, S.J.
Vatican Observatory, Vatican City State
(Received 25 October 1966)

Finding charts, coordinates, and color estimates are given for 233 faint blue objects located in the region of the Virgo cluster of galaxies. The objects have been found from a three-color plate taken with the Palomar 48-in. Schmidt telescope, following the method developed by Haro and Luyten.

THERE has been renewed interest recently in determining the nature of faint blue objects in intermediate and high galactic latitudes (Sandage 1965; Kinman 1965; Lynds and Villere 1965; Zwicky 1965; Greenstein 1966; van den Bergh 1966). Such studies contribute not only to the knowledge of the stellar luminosity function in the halo of our Galaxy, but also may reveal peculiar extragalactic objects such as compact dwarf galaxies and quasi-stellar objects. This paper presents the results of a search for faint blue objects in an area of 36 sq deg, centered on the Virgo cluster of galaxies.

The 48-in. Palomar Schmidt was used to obtain a three-color plate centered at $\alpha_{1950}=12^h27^m16^s$, $\delta_{1950}=13°06'08''$ ($l^{II}=283°$, $b^{II}=+75°$), using the method developed by Haro and Luyten (1962). A 103a-D plate was used; successive exposures of 40, 4, and 8 min were taken through an ultraviolet, a yellow, and a blue filter, with the telescope moved 12 sec of arc between exposures. Exposure times were chosen so that a faint A0–A5 star shows three equal images. A discussion of the details and the limitations of this procedure is contained in the *First Conference on Faint Blue Stars* (Luyten 1965). An unfiltered 103a-O plate was also obtained. From the three-color plate, 233 faint objects were found, each of which had ultraviolet and blue images brighter than the visual image.

Positions of all blue objects, presented in Table I, have been calculated on an IBM 1620, using a program developed by Bertiau and E. De Graeve. The program converts rectangular coordinates measured on a plate to equatorial coordinates, using the known coordinates of standard stars. In order to obtain the same precision all over the sphere, the coordinates of the standard stars are transformed so that the equator passes through the center of the plate. Because the projection of equatorial coordinates onto a plane is very nearly rectangular at the equator, a quadratic transformation is suitable. The 12 coefficients of two equations of transformation are derived by the method of least squares from the standards available; in the present case 23 standards were used. Finally, the computed coordinates of the program objects are transformed back to the original plate center. Since the positions are intended for purposes of identification, the precision of the measurements was 0.5 mm, which is equivalent to about $\frac{1}{2}$ min of arc on the Palomar Schmidt plates.

The magnitudes of the objects in Table I range from approximately 15th mag to the plate limit, about 19th mag. No individual magnitudes have been estimated, because of the complications of doing so on a three-exposure plate. Instead, an estimate of the relative intensities of the ultraviolet and visual images has been made, and is given in column 4: + = violet, ++ = very violet, +++ = extremely violet. This estimate, which is intended as a guide for future observations, is undoubtedly influenced by magnitude effects, particularly near the plate limit. The notes to the table record any peculiarities of the images detected during the search.

Identification charts for all objects in Table I are given in Plate V. The charts have been made from enlargements of the blue Palomar Sky Atlas prints. Figure 1 shows schematically the arrangement of the charts in Plate V. Five blue objects whose images are located in galaxies are not easily identifiable in Plate V, and are shown in Plate VI. These charts are enlargements from the three-color plate; the ultraviolet image

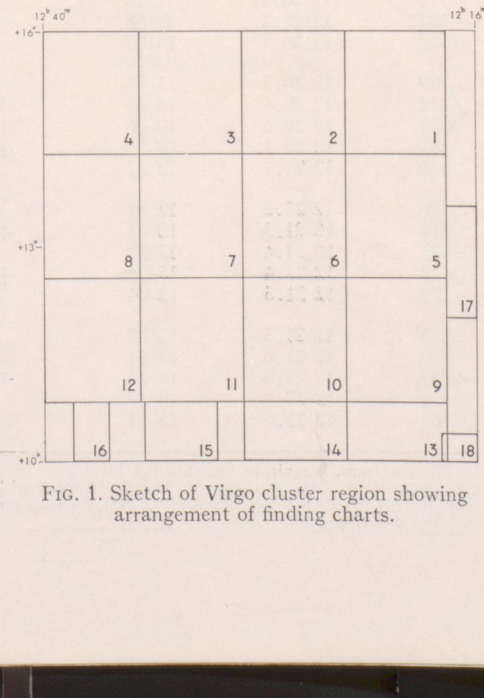


Fig. 1. Sketch of Virgo cluster region showing arrangement of finding charts.

* Present address: Harvard College Observatory.

THE ASTROPHYSICAL JOURNAL SUPPLEMENT SERIES, 46:267–286, 1981 August
© 1981. The American Astronomical Society. All rights reserved. Printed in U.S.A.

H I OBSERVATIONS IN THE VIRGO CLUSTER AREA

GEORGE HELOU
Center for Radiophysics and Space Research, Cornell University
C. GIOVANARDI
Osservatorio Astrofisico di Arcetri, Firenze, Italy
E. E. SALPETER
Center for Radiophysics and Space Research, Cornell University
AND
NATHAN KRUMM
University of Michigan, Ann Arbor
Received 1980 May 16; accepted 1981 January 26

ABSTRACT

We report 21 cm H I line data obtained at Arecibo for 35 galaxies in or near the Virgo cluster. For all galaxies but two, we show contour plots of the spectral profile as a function of position along the major axis, with an average of six profiles per galaxy. We tabulate detailed information on each spectral profile and discuss improved or new procedures for gain correction, sidelobe removal, and total flux estimations. For each galaxy, we tabulate systemic velocity, total line width, and H I extent and content. We report determinations of the kinematic major axis for five face-on galaxies, and for most galaxies, a complete determination of the spin vector is shown for the first time. Upper limits on the H I content of 29 undetected galaxies are also given.

Subject headings: galaxies: clusters of — radio sources: 21 cm radiation

I. INTRODUCTION

H I observations of galaxies with the 300 m dish at Arecibo[1] offer the advantage of single beam simplicity and efficiency over synthesis mapping, while still affording reasonably good spatial resolution, and frequency resolution no worse than any other instrument.

This paper presents H I data on 35 galaxies in the general direction of the Virgo cluster. This sample is not complete in a simple astronomical sense; the selection is explained in § II. The resolution is intermediate in that the H I extends typically over a few resolution widths per galaxy; details of data acquisition and reduction are given in § III. Results on hydrogen extent and content, kinematics, and spin vector positions are discussed in § IV. The reduced data are presented in tabular form and in rough "maps" of spectral distribution versus position along the major axis.

II. THE SAMPLE

This paper pools together the data from two independent observing programs, in view of the homogeneity of the data. In 1978 February, 12 of the galaxies (Group A) were observed in an experiment aimed at clearing the membership controversy (Sulentic 1977; Sandage and Tammann 1976) surrounding galaxies seen in the direction of Virgo, but at near zero redshifts, with suspiciously large angular diameters and high luminosities (Helou, Salpeter, and Krumm 1979).

In the first half of 1979, another 23 of the galaxies (Group B) were observed as part of a survey aimed at comparing H I properties of galaxies inside and outside the core of the Virgo cluster as a function of their location.

a) *Group A*

A list of galaxies within 6° of the Virgo cluster center ($12^h25^m, 13°06'$) taken from the Shapley-Ames catalog (Shapley and Ames 1932) is reasonably complete to $B_T \leq 12.76$ (Sandage, Tammann, and Yahil 1979). An unpublished list by Sandage (1977, private communication) includes optical velocities for most of those. Adjusting all velocities to the Local Group of galaxies according to the prescription of Yahil, Tammann, and Sandage (1977) and subtracting $V_{CM} = 1050$ km s^{-1} for the center of mass velocity of Virgo, one gets V_{VC}, a projected component of the velocity of each galaxy with respect to the Virgo center of mass. The first 18 entries in Table 1 are all the cases with $|V_{VC}| \geq 925$ km s^{-1}.

Two selection criteria were used on that list to form Group A: galaxies seen edge-on were favored to reduce

[1] The Arecibo Observatory is part of the National Astronomy and Ionosphere Center which is operated by Cornell University under contract with the National Science Foundation.

THE DISTRIBUTION OF DARK MATTER IN SPIRAL GALAXIES

George Lake and Laurie Feinswog

Department of Astronomy, University of Washington

Received:

Accepted:

Vera - You started it all!

GLOBAL STRUCTURE OF VIRGO CLUSTER GALAXIES

Sadanori Okamura
Kiso Observatory, Tokyo Astronomical Observatory
Mitake-mura, Kiso-gun, Nagano-ken, 397-01 Japan

Presented at ESO Workshop on
'The Virgo Cluster of Galaxies'
held at ESO, Garching, September 4 - 7, 1984

RESULTS FROM SURFACE PHOTOMETRY OF EXTENSIVE SAMPLES OF GALAXIES

Sadanori Okamura
Kiso Observatory, Tokyo Astronomical Observatory
Mitake-mura, Kiso-gun, Nagano-ken, 397-01 Japan

Presented at the Specialized Colloquium on
'New Aspects of Galaxy Photometry'
Eighth European Regional Meeting of the IAU
held at Toulouse, September 17 - 21, 1984

Astronomy Library

OBSERVATOIRE DE PARIS

Département d'Astrophysique Extragalactique
et de Cosmologie

A COMPACT GROUP IN VIRGO

G.A. MAMON

N° 89013

PRÉPUBLICATION

JUN 8 1989

ASTRONOMICAL INSTITUTE
UNIVERSITY OF BASEL

Preprint Series No. 26

21 cm-Line Width Distances of Cluster Galaxies and the Value of H_0.

R.C.Kraan-Korteweg, L.M.Cameron
and G.A.Tammann

September 1987

THE REMARKABLE TWISTED DISK OF NGC 4753 AND THE SHAPES OF GALACTIC HALOS

THOMAS Y. STEIMAN-CAMERON
Theoretical Studies Branch, NASA/Ames Research Center
and Lick Observatory, University of California Santa Cruz

JOHN KORMENDY[1]
Institute for Astronomy, University of Hawaii

and

RICHARD H. DURISEN
Department of Astronomy, Indiana University

Submitted to *The Astronomical Journal*

Hi Vera,

If you are interested, Francois will have a copy of the video described in this paper within the next few weeks.

Cheers
Tom

The compl ... with a disk that is stro ... re be explained as th ... erved dust distributio ... e and twisted such th ... adius. The model sho ... h the disk and the o ... s the observations wi ... ass is unseen, is nearl ... The ellipticity of the ... adial extent of the t ... ation mechanisms. If ... n the sense of the twist implies an oblate mass distribution. The flattening of the halo and the age of the accretion event cannot be determined independently, but physical arguments imply that the shape of the total mass distribution is between ~ E0.1 and E1.6.

[1] Visiting Astronomer, Canada–France–Hawaii Telescope, operated by the National Research Council of Canada, the Centre National de la Recherche Scientifique of France, and the University of Hawaii.

Observations of Surface Brightness Fluctuations in Virgo[1]

John L. Tonry[2,3]
Edward A. Ajhar[3]

Massachusetts Institute of Technology

Gerard A. Luppino[3]
Institute for Astronomy, University of Hawaii

ABSTRACT

We present observations of the surface brightness fluctuations of M32, NGC 3379, and thirteen Virgo cluster galaxies in the V, R, and I photometric bands. The scatter in $\overline{m}_I$ that we observe among the Virgo galaxies is consistent with the depth of the cluster, which implies the fluctuation luminosity in the I band is quite insensitive to stellar population differences, and that we are resolving the Virgo cluster front to back. We find that NGC 4365 is behind Virgo in the W cloud and NGC 4468 and NGC 4489 are in the foreground. We estimate that our relative distances may be as good as 3% for an individual galaxy, and we compare our distances with those obtained with planetary nebulae luminosity functions and with D_n-σ.

Computation of $\overline{M}$ for a large grid of Yale isochrones shows that $\overline{M}_I$ is expected to be insensitive to metallicity and age, and that other wavelengths yield information about stellar population parameters. However, if we assume a distance to M32 of 0.7 Mpc, we encounter a discrepancy in that $\overline{M}_I$ from the isochrones is 45% brighter than $\overline{m}_I$ measured for M32. We prefer the empirical calibration of shifting $\overline{M}_I$ from the isochrones to relieve this disagreement. Using this empirical calibration, we obtain an average distance to the Virgo cluster of 17 ± 1 Mpc, which implies a Hubble constant of 78 ± 6 km/s/Mpc. If we use the isochrone calibration directly, we obtain 21 Mpc and H_0 = 64 ± 5 km/s/Mpc.

We compare our "fluctuation colors" $(\overline{V}-\overline{R})$ and $(\overline{R}-\overline{I})$ with the isochrones and conclude that no single isochrone can match the stellar population in these galaxies, and that there must be a spread in metallicity. A comparison of $(\overline{V}-\overline{I})$ with the Mg_2 index suggests the possibility of detecting recent star formation.

[1]Observations in part from the Michigan-Dartmouth-MIT (MDM) Observatory.
[2]Alfred P. Sloan Fellow and Presidential Young Investigator
[3]Guest observers at Kitt Peak National Observatory, operated by AURA, Inc., under contract to the National Science Foundation.

I. Introduction

Determining extragalactic distances has never been simple. We estimate distances to nearby objects and then use these estimates to find distances to more distant objects which are too rare to be found nearby. This is the basis of the extragalactic distance ladder which employs a variety of techniques, many of which are based on purely empirical relations; the cumulative uncertainty in this hierarchy has made extragalactic distances a matter of controversy for most of this century. Only recently have methods been proposed which claim to achieve uncertainties smaller than ~ 20% per galaxy (*e.g.*, Tonry *et al.* 1989, Jacoby *et al.* 1990, Freedman 1990). Two issues are at stake: *reliability* which limits our determination of the overall size of the universe, and *accuracy* which affects our ability to determine peculiar velocities (which are typically less than 20% of the expansion velocity over distances typical of large scale flows).

Were it possible to observe large numbers of individual stars in external galaxies, the information about the stellar makeup of the galaxy would tell us an enormous amount about the galaxy's formation, evolution, and distance. Although it is not at all difficult to collect enough photons to permit this, it is impossible to resolve the stars individually unless they are exceedingly bright. Even the Hubble Space Telescope will have hundreds of giant stars in each resolution element at the modest distance of the Virgo cluster.

It is possible, however, to get an average flux per star even when we cannot resolve individual stars. The method we use here involves measuring the fluctuations in the surface brightness of early-type galaxies (Tonry and Schneider 1988). When more photons have been collected in a resolution element than the number of stars projected within that area, the resulting Poisson fluctuations become proportional to the square root of the number of stars present. In this regime, the rms fluctuation from pixel to pixel is $N^{1/2}\overline{f}$, and the flux per pixel is just $N\overline{f}$, where N is the number of stars projected in a pixel and $\overline{f}$ is the average flux per star. The ratio of the fluctuation variance to the average flux per pixel is then just $\overline{f}$, the average flux per star. This average flux is the luminosity-weighted average flux of the stellar population and corresponds roughly to the flux of a typical giant star. Hence, if we measure an average apparent magnitude $\overline{m}$ and know the average absolute magnitude $\overline{M}$, we determine a distance. Alternatively, knowing the distance gives $\overline{M}$, which provides information about a galaxy's stellar population.

In this paper we present high signal-to-noise observations of NGC 221 (M32), NGC 3379, and 13 Virgo galaxies. We discuss these observations and the data reduction in section II. We use a more thorough procedure than was used in Tonry *et al.* (1989), and we report on some of

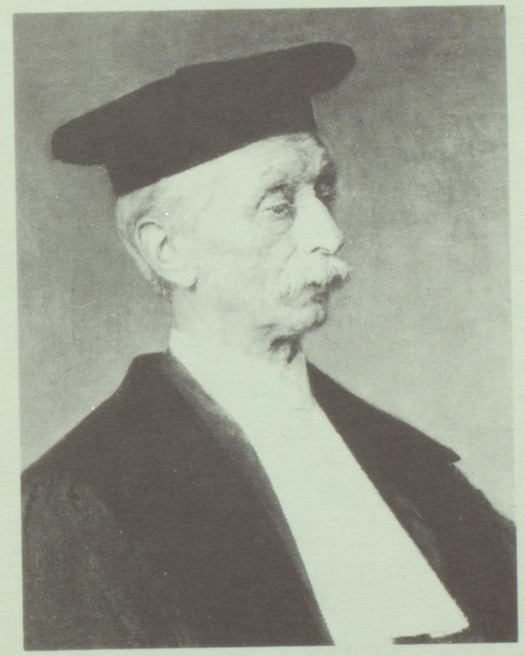
Astronomy Library

KAPTEYN INSTITUTE PREPRINT

Preprint no. 017

DISTRIBUTION AND MOTIONS OF ATOMIC HYDROGEN IN LENTICULAR GALAXIES. IX. NGC 3941 AND NGC 4694

Wim van Driel[1,2,3], Hugo van Woerden[1]



RuG

UNIVERSITY OF GRONINGEN

OCT 10 1989

KAPTEYN ASTRONOMICAL INSTITUTE AND SPACE RESEARCH LABORATORY

Draft - Not for circulation

Vera - I observed about 10 galaxies at CTIO (mainly DC2048) this summer and have another run at KPNO, both for Hα rotation curves. Not measured yet.
Brad

THE EFFECT OF THE CLUSTER ENVIRONMENT ON GALAXIES

Bradley C. Whitmore
Space Telescope Science Institute

1. INTRODUCTION

Perhaps the three most basic questions an extragalactic astronomer might be asked are:

1. Why are some galaxies flattened into disks while others are elliptical in shape ?
2. How big are galaxies ?
3. How massive are galaxies ?

Although we can fill journals with details about galaxies, an astronomer cannot really answer these three basic questions with any confidence. The first question raises the "nature *vs.* nurture" problem. Is the morphological type of a galaxy determined at birth by its initial conditions, or does the environment of the galaxy control its destiny? While the standard picture that different initial conditions cause the difference in morphology still seems plausible (e.g., Sandage, Freeman, and Stokes 1970, Gott and Thuan 1976), recent interest has centered on Toomre's (1977) suggestion that all galaxies begin as disks and then merge to form elliptical galaxies. The problem with the second question is that a galaxy does not really have an "edge", so the definition of size is somewhat arbitrary. What makes things worse is that rotation curves in spiral galaxies stay flat as far out as we can observe them, so the mass is still increasing linearly with radius with no sign of the edge of the dark matter in sight. The third question is also impossible to answer very precisely since we don't know what or where the dark matter is in a galaxy. The fact that only about 10 % of a galaxy is luminous means that we are studying only the tip of the iceberg, and shows just how little we really know about galaxies.

One of the principle reasons many of us are interested in the study of clusters is that these three basic properties of a galaxy, the morphological type, the size, and the distribution of mass, all appear to be affected by the cluster environment. As early as 1931 (Hubble and Humason 1931) it was known that elliptical galaxies were preferentially found in clusters, providing evidence that the morphological types were closely linked with the environment. The cluster environment also appears to be able to modify the size of a galaxy. cD galaxies can grow to prodigious size, possibly at the expense of the nearby galaxies which become shrunken via tidal stripping. Recent measurements of emission-line rotation curves also suggest that the massive halos of line b : Luminosity class according to the determination in the Corwin list or as newly determined by us.

Column 7 : Remarks

The nomenclature and abbreviations follow the Second Ref. Catalogue (de Vaucouleurs *et al.*, 1976) and the Lauberts Catalogue (1982).

References

CORWIN, H. G., DE VAUCOULEURS, A., DE VAUCOULEURS, G. : 1977 (I), *Astron. J.* **82,** 557 ; 1978 (II), *Astron. J.* **83,** 1566 ; 1980 (III), *Astron. J.* **85,** 1027 ; 1982 (IV), *Astron. J.* **87,** 47.

DE VAUCOULEURS, G., DE VAUCOULEURS, A., CORWIN, H. G. : 1976, *Second Reference Catalogue of Bright Galaxies* (University of Texas Press, Austin).

DE VAUCOULEURS, G., DE VAUCOULEURS, A., BUTA, R. : 1983, *Astron. J.* **88,** 764.

FEITZINGER, J. V., STÜWE, J. A. : 1984, *Astron. Astrophys. Suppl. Ser.* **58,** 365.

HOLMBERG, E. B. : 1937, *Lunds Annaler* **6,** 10.

LAUBERTS, A. : 1982, *The ESO/Uppsala Survey of the ESO(B) Atlas* (European Southern Observatory, Munich).

NILSON, P. : 1973, *Uppsala Astronomiska Observatoriums Annaler,* Vol. **6** (Uppsala General Catalogue of Galaxies).

VAN DEN BERGH, S. : 1959, *Publ. David Dunlap Obs.* Vol. **II,** No. 5.

VAN DEN BERGH, S. : 1966, *Astron. J.* **71,** 922.

TABLE I.

1	00 00 13 -80 37.5	12 F	-2.6 -27.4	2.9 1.6:	sp V	bar, knotty, sev. ** superp.
2	00 00 13 -53 02.8	149 P	1.9 102.6	1.5 0.6:	el IV-V	knotty
3	00 02 23 -65 02.7	78 F	13.6 12.4	1.1 0.6	el: V	knotty
4	00 04 19 -47 07.0	293 F	42.5 -110.6	0.8 0.4	sp:: V-VI	N, sev. knots
5	00 04 43 -52 53.9	149 P	38.0 110.3	1.7:: 1.3::	sp: V-VI	N, F, diff.
6	00 04 58 -37 44.5	293 F	51.7 122.5	0.7 0.3	el V-VI	N, 1' comp.(G38,S...,1.1:)
7	00 05 41 -34 51.4	349 F	63.0 13.5	2.2 1.3	el V-VI	LRLWW, knotty
8	00 07 45 -18 32.6	538 F	92.9 84.6	1.9: 1.8:	ir: IV-V	MCG-3-1-21, knotty, sev. ** superp.
9	00 11 49 -62 00.7	111 F	75.6 109.3	1.1: 0.9:	sp V	N, 1 * superp.
10	00 11 58 -47 50.8	193 P	106.1 112.9	1.2: 0.5:	el V	diff.
11	00 13 00 -32 27.6	410 F	-109.9 -128.7	1.3 0.9	el V	knotty, sev. ** superp.
12	00 17 49 -77 22.1	28 F	53.1 -127.3	1.7 1.2	sp V	bar, knotty, sev. ** superp.
13	00 22 27 -27 34.2	410 F	-3.3 133.1	0.9 0.8	sp V	N, sev. knots
14	00 24 06 -42 07.8	294 F	-18.2 -109.9	1.2 0.7::	el V	knotty, 1 * superp.
15	00 28 53 -23 02.6	473 F	85.5 112.0	1.3: 0.7:	el V	sev. knots, 3: ** superp.
16	00 29 28 -33 32.5	350 F	64.5 89.3	1.4: 1.3:	el: V-VI	diff., 19' comp.(G23,Sc,10.0:)
17	00 29 43 -40 32.5	294 F	38.1 -25.3	1.9 1.6	sp IV-V	N, knotty, m ** superp.
18	00 34 37 -81 13.1	12 F	67.4 -63.8	1.2 0.7	sp V	N
19	00 37 48 -20 58.0	540 P	-49.5 -51.6	0.9 0.8	sp V	N
20	00 40 35 -22 31.2	474 P	-43.3 139.2	1.9 0.7	el V	I 1574 = DDO-226, sev. knots
21	00 44 39 -22 52.0	474 P	7.0 120.9	1.2 1.1	sp V	MCG-4-3-6, N
22	00 46 52 -18 20.9	540 P	64.6 87.8	0.9: 0.7:	el:: V-VI	2 ** superp., v F, v diff.
23	00 47 21 -21 17.3	540 P	69.3 -69.1	2.3 1.1:	el V	MCG-4-3-1 = DDO-6
24	00 47 56 -20 10.7	540 P	77.2 -9.9	1.7:: 1.4::	el:: V-VI	v F, v diff.
25	00 53 18 -30 48.7	411 F	82.3 -37.6	0.9 0.8	sp V:	1 knot
26	00 54 25 -38 25.5	295 F	27.2 88.1	1.1 0.9	sp V	N, sev. knots, 35' comp. (G20,Sd,30.0:)
27	00 54 55 -24 38.6	475 P	-135.2 26.5	0.9: 0.7:	sp: V-VI	N, F, diff.
28	00 57 47 -33 58.7	351 P	109.1 63.0	65.0: 55.0:	el	A 0057-33, "Sculptor", in ** res.
29	01 08 33 -42 38.4	243 F	124.0 132.3	0.8 0.3	el V	knotty
30	01 09 21 -29 33.8	412 F	1.2 30.7	0.7 0.5	sp V	N
31	01 12 03 -25 38.9	475 P	71.8 -26.1	1.0 0.7	sp V	MCG-4-4-1, dwarf?, N
32	01 21 33 -34 33.8	352 P	106.7 23.6	1.0: 0.9:	el:: VI	2 knots, v F, v diff.
33	01 30 10 -76 14.8	29 F	75.9 -65.0	0.9: 0.7:	el V-VI	N, 2 ** superp.
34	01 35 17 -20 30.5	543 P	-122.1 -26.3	1.0: 0.9:	ir: V-VI	sev. knots
35	01 35 56 -23 27.6	476 P	97.3 80.7	1.0: 0.5:	ir V-VI	
36	01 37 57 -75 20.5	29 F	107.0 -20.2	1.1 0.8	sp: V-VI	N, sev. ** superp., 5' comp. (G53,Sa?,1.8)
37	01 42 58 -43 50.9	245 F	-87.9 68.8	4.7 3.4:	ir V	A 143, knotty, sev. ** superp.
38	01 43 39 -78 12.6	13 F	35.8 96.9	1.2: 0.9	sp V	N, 3 ** superp.
39	01 49 03 -44 41.5	245 F	-28.9 24.9	3.8 3.7	el V	SW, knotty, m ** superp.
40	01 51 26 -23 21.5	477 F	16.5 88.6	0.9 0.7:	ir: V-VI	2 ** superp., B * part. superp.
41	01 55 42 -69 14.4	52 P	54.3 43.7	0.9 0.8:	el: IV-V	sev. knots
42	01 58 32 -69 18.4	52 P	67.4 39.3	1.3: 0.7::	el:: V	sev. knots, diff.
43	01 59 27 -85 46.7	3 F	-26.5 -35.9	1.0: 0.8:	ir V	sev. knots, 3 ** superp.
44	02 05 07 -61 12.4	114 F	69.9 -64.3	1.1 1.0:	sp V	N, sev. knots
45	02 11 47 -55 09.7	153 F	-0.3 -4.5	0.9: 0.6:	el V	N
46	02 16 34 -36 45.6	355 F	-81.9 -101.6	1.3: 0.9::	sp: V-VI	N, diff.
47	02 16 54 -19 09.7	545 P	-124.9 48.2	2.5 0.9	sp IV-V	MCG-3-6-24, N, sev. knots, 15' comp.(G11,Sc,8.0:)
48	02 19 26 -39 01.9	298 F	98.6 49.1	1.2: 0.6:	ir: V-VI	3: ** superp., diff.
49	02 19 48 -21 21.5	545 P	-87.2 -68.4	1.2 1.0:	el: V	MCG-4-6-32, bar?, sev. knots
50	02 20 17 -29 05.0	415 P	28.1 49.7	1.1: 0.8	sp V	N, 1 * superp.
51	02 21 00 -40 24.4	298 F	112.5 -24.7	1.2:: 1.2::	el:: V-VI	N, v F, v diff.
52	02 23 38 -19 55.0	545 P	-40.0 8.7	1.0: 0.8:	el: V-VI:	1 * superp.
53	02 36 59 -58 27.3	115 F	36.1 78.0	1.0: 1.0:	sp: V	N, v diff.
54	02 37 36 -23 28.3	479 F	42.8 82.0	0.5: 0.3:	el VI	
55	02 37 55 -34 39.8	356 P	-109. 17.	70.0: 60.0:	el	A 0237-34, "Fornax"
56	02 39 31 -21 00.7	546 P	-104.6 -48.3	1.2:: 0.6:	sp V	MCG-4-7-20,
57	02 45 27 -42 20.8	299 F	91.1 -127.8	0.8 0.4	el V-VI	in cl.?
58	02 45 27 -20 49.2	546 P	-30.8 -37.5	1.0 0.7	sp V	MCG-4-7-42
59	02 51 03 -26 43.4	480 F	-61.7 -90.4	0.9: 0.7:	sp: V-VI	bar, 3 ** superp.
60	02 55 32 -35 08.3	356 P	83.7 -7.4	0.8: 0.3:	ir:: V-VI	knotty, F, diff.
61	02 56 19 -18 53.9	546 P	105.9 64.5	1.1 0.3:	el V	MCG-3-8-53, knotty
62	02 57 06 -32 16.4	417 F	-72.6 -114.6	0.9 0.7	sp V	sev. knots, 5' comp. (G08,Sa,3.8:)
63	03 01 17 -18 33.8	547 P	-94.4 75.4	1.1 0.7:	el V	MCG-3-8-66, knotty
64	03 01 39 -25 28.0	480 F	65.6 -23.9	1.9: 1.6:	sp IV-V	MCG-4-8-21 = DDO-227, N, sev. ** superp.
65	03 02 52 -36 28.1	357 P	-99.3 -81.2	1.7:: 1.3::	sp: V-VI	v F, v diff.
66	03 03 38 -73 47.3	31 F	-53.4 61.4	0.7: 0.5:	el V	N
67	03 03 42 -19 35.1	547 P	-63.5 21.1	2.8:: 1.0:	el:: V-VI	2 knots, 1 * superp., v F, v diff.
68	03 06 08 -53 38.6	155 P	-93.3 75.9	1.1 0.6	el: V	N, 18' comp.(G06,SBc,7.0)
69	03 10 34 -53 37.9	155 P	-58.4 77.7	1.0: 1.0:	sp V	N, diff.
70	03 12 13 -38 10.6	300 F	107.3 98.3	0.6: 0.5:	el VI	
71	03 13 42 -33 43.6	357 P	17.8 65.9	1.1:: 0.5::	el: V	N, F, diff.
72	03 13 58 -24 23.0	481 F	-46.8 39.4	1.9 1.7	sp: V	knotty, sev. ** superp.
73	03 16 32 -23 57.8	481 F	-15.8 62.0	2.2: 1.8:	ir V	knotty, sev. ** superp.
74	03 19 37 -42 10.4	301 F	-82.9 -122.8	1.0 1.0:	sp: V-VI	sev. knots
75	03 21 16 -18 50.6	548 P	-111.9 71.2	1.0: 0.9:	sp:: V-VI	v F, v diff.
76	03 22 42 -21 57.6	548 P	-92.0 -94.8	1.1: 0.9:	el: V	MCG-4-9-7, N, 16' comp. (G07,Sd,7.0:)
77	03 23 28 -20 31.0	548 P	-83.2 -17.7	0.5 0.3	el V	dwarf?
78	03 24 57 -35 41.6	358 F	-118.7 -50.8	0.9: 0.9:	el: V-VI	N, diff.
79	03 25 17 -33 39.6	358 F	-118.2 57.7	1.6 1.2	sp IV-V	Ka-9, knotty,sev. ** superp.
80	03 31 02 -35 54.3	358 F	-57.2 -60.8	0.6 0.3:	el V-VI	Ka-13, N, 3' comp.(G16,S..., 1.5:), 25' comp.(G17,Sc,14.:)

TABLE I *(continued)*.

81	03 31 10 -34 58.5	358 F	-51.9 -11.2	1.5 1.1	sp IV-V:	dwarf?, N
82	03 33 24 -61 15.	117 F*	-95. -78.	1.4: 1.0:	sp:: V	bar?, sev. ** superp., diff.
83	03 33 35 -51 37.3	200 P	29.2 -84.1	1.2: 1.1:	el:: V-VI	v F, v diff.
84	03 35 09 -73 38.8	31 F	64.4 67.4	1.2 0.9	ir V	sev. knots
85	03 36 48 -23 30.0	482 F	-37.7 82.7	1.4:: 1.1::	sp:: V-VI	dwarf?, N, e diff.
86	03 38 15 -35 46.9	358 F	25.2 -53.9	2.9 1.7	el: IV-V	N 1427A, knotty, sev. ** superp.
87	03 38 28 -31 50.8	419 F	-127.4 -101.2	1.0: 0.6:	el V	N
88	03 38 53 -37 34.2	301 F	115.2 121.8	0.6 0.5	sp: V-VI	N
89	03 40 08 -22 54.8	482 F	3.2 114.1	1.9: 1.7:	sp V	MCG-4-9-53, N, 1 B knot sev. ** superp.
90	03 40 56 -21 29.4	549 F	-122.5 -70.9	1.2: 0.9:	sp V	N?, 3 ** superp.
91	03 41 49 -25 04.8	482 F	23.4 -1.5	1.1 0.7:	el V-VI	
92	03 43 18 -35 43.5	358 F	79.9 -51.5	2.0 0.3:	el: V	knotty, 1 * superp.
93	03 45 18 -32 27.3	419 F	-49.7 132.3	0.9 0.6	sp: V	N, 1 * superp.
94	03 46 42 -39 34.6	302 F	-73.1 26.4	1.2:: 0.8:	sp:: V	N, sev. ** superp.
95	03 47 13 -48 34.3	201 P	-111.5 77.7	1.1: 1.1:	sp:: V-VI	v F, v diff.
96	03 47 39 -44 22.7	249 F	36.1 25.6	1.1 1.1	sp:: V	sev. knots, 3 ** superp.
97	03 49 52 -38 36.0	302 F	-41.2 79.0	2.4 1.8	sp V	Ka-21, knotty, sev. ** superp.
98	03 51 58 -39 19.5	302 F	-19.0 40.5	0.9 0.6:	el V	2 ** superp.
99	03 52 07 -49 08.1	201 P	-67.5 49.0	1.8: 1.3:	sp:: IV-V	I 2009, N, sev. knots, 1 * superp., v diff.
100	03 52 11 -36 12.6	359 P	-76.1 -63.5	1.0: 0.7:	ir:: V-VI	Ka-22, F, diff., 7' comp. (G07,E-S0,1.9:)
101	03 53 31 -51 55.7	201 P	-52.5 -99.6	0.6: 0.6:	sp:: V	N?, v F, e diff.
102	03 55 49 -46 30.8	249 F	109.6 -90.2	1.3 0.8	el V:	3 ** superp., 9' comp. (G33,Sc,5.0:)
103	03 57 41 -46 00.7	249 F	127.9 -64.2	1.9: 1.9:	ir V	knotty, sev. ** superp.
104	03 59 00 -18 12.9	549 F	104.1 103.7	1.4 1.0	el V	N, sev. knots
105	04 01 41 -70 10.4	55 F	-84.4 -12.2	0.5: 0.4:	sp:: V	N
106	04 02 08 -18 06.5	550 F	-126.1 96.1	1.0 0.3::	el: V	N, diff., 4' comp. (G02,Sb,2.0)
107	04 03 53 -22 45.9	483 F	25.5 118.2	1.2: 0.6::	sp: IV-V	N, 1 * superp.
108	04 08 04 -31 23.3	420 F	-52.7 -71.0	1.5: 0.8:	sp: V	N, knotty
109	04 08 38 -46 55.6	250 F	-29.4 -114.6	1.6 0.7::	sp V:	N
110	04 09 25 -47 55.0	201 P	85.6 113.2	0.9: 0.3:	el: V	F, diff.
111	04 09 53 -35 04.0	359 P	116.0 -3.8	0.7 0.3:	el V	
112	04 10 56 -33 07.7	359 P	130.5 99.1	1.7: 0.9:	sp: IV-V	N, diff., 12' comp. (G27,Sc,22.0:)
113	04 14 37 -43 27.9	250 F	27.0 69.7	1.0: 0.8:	el V-VI	bar?, F, diff.
114	04 15 30 -21 18.8	550 F	42.2 -74.3	1.1 0.8	sp: V	N
115	04 15 45 -31 24.8	420 F	34.6 -72.1	1.1 0.8	sp V	N
116	04 18 20 -36 48.3	360 F	-63.2 -87.0	1.2: 0.6:	el V	sev. knots, 2 ** superp.
117	04 19 52 -33 57.8	360 F	-48.5 64.7	0.7 0.3:	el V	
118	04 19 53 -62 59.3	84 P	-36. -106.	2.0: 0.7::	el: V	sev. knots, F, diff.
119	04 21 41 -63 43.6	84 P	-24.8 67.2	2.0 0.6:	el: IV-V	dwarf?, sev. knots, 1 * superp.
120	04 24 32 -56 58.2	157 F	3.0 -104.5	1.3 0.6:	el V	Se 37/3, knotty
121	04 25 31 -33 37.9	360 F	14.3 82.6	1.2 0.6:	el V	sev. knots
122	04 27 12 -46 25.8	251 P	-119.5 -74.1	1.2 0.7	sp:: V	N, sev. knots
123	04 27 30 -61 24.7	118 P	9.1 -73.0	0.8: 0.3:	el V	
124	04 28 37 -48 46.7	202 P	-9.1 62.1	1.1 0.4	el V	knotty
125	04 29 29 -44 20.2	251 P	-101.7 38.1	1.0: 0.9:	sp: V-VI	Ka-23, N, v F, v diff.
126	04 31 56 -40 34.8	303 P	118.9 -33.2	0.9: 0.6:	sp: V-VI	N, v diff.
127	04 33 54 -65 48.	84 P*	41. -44	1.0: 0.6:	ir V	sev. knots
128	04 36 17 -56 01.3	157 F	90.6 -56.2	1.1 0.6	el IV-V	knotty
129	04 38 55 -48 16.9	202 P	82.4 87.1	1.5: 1.4:	sp: V	sev. knots, F, v diff.
130	04 41 32 -47 43.0	202 P	106.8 116.4	1.3: 1.3:	el: V-VI	N?, v F, v diff.
131	04 44 41 -59 09.8	118 P	127.4 42.0	1.0: 1.0:	sp:: V	N, 1 * superp., v diff., 10' comp. (G43,SBc,9.0:)
132	04 45 11 -36 00.3	361 F	-32.3 -48.7	1.7 1.0:	sp V	bar?, knotty, sev. ** superp.
133	04 45 53 -54 39.0	158 P	-85.9 19.4	1.1: 1.0::	sp:: V	N, v F, v diff.
134	04 46 25 -35 11.0	361 F	-19.0 -4.9	1.1: 1.1:	sp:: V	N?, diff.
135	04 47 22 -59 30.2	119 P	-113.6 25.0	0.7: 0.3:	el: V-VI	F, diff., 2' comp. (G04,Sa?,0.8)
136	04 50 28 -48 22.0	203 F	-81.5 86.3	0.9 0.5	el: V	sev. knots, 1 B * superp.
137	04 50 53 -57 13.7	158 P	-44.7 -117.0	0.9 0.3:	el IV-V	
138	04 53 49 -37 15.8	361 F	59.6 -116.3	0.8: 0.5:	ir: V-VI	Ka-24, 1 knot, diff.
139	04 54 12 -61 38.	119 P*	-62. -86.	0.9:: 0.8::	sp:: V-VI	v F, e diff.
140	04 54 43 -56 18.8	158 P	-17.2 -67.8	1.3: 0.6:	el V	knotty, diff.
141	04 56 07 -26 17.4	485 P	121.0 -63.0	0.8: 0.5:	ir:: VI	1 knot, v F, v diff.
142	04 56 30 -59 11.8	119 P	-52.2 43.9	1.7: 1.0::	el:: VI	v F, e diff.
143	04 59 42 -39 40.5	305 P	-125.9 8.1	1.1: 0.8:	sp:: V	N, v diff.
144	05 00 58 -25 32.3	486 P	-86.1 -18.8	1.1 0.7:	sp V-VI	N, 5' comp. (G14,Sa,1.6:), 5' comp. (G21,Sb,1.4)
145	05 04 29 -58 17.3	119 P	2.5 92.9	1.3 0.4:	el: V:	N
146	05 07 16 -51 25.3	203 F	62.6 -76.5	0.9 0.6:	sp V	dwarf?, N, sev. knots
147	05 07 18 -63 03.2	85 F	-4.2 105.2	2.1 1.3	ir V	dwarf?, bar?, knotty, v m ** superp.
148	05 07 26 -81 22.1	15 F	74.0 -80.0	0.8: 0.4:	ir: V	F, diff., 1 * superp. 5' comp. (G18,S0,1.6:)
149	05 08 37 -33 04.8	362 P	-35.3 102.5	1.1: 1.0:	sp:: V-VI	N?, v F, v diff.
150	05 10 08 -33 01.9	362 P	-18.3 105.1	4.0 3.2	sp V	Ka-26 = DDO-231, knotty, sev. ** superp.
151	05 16 54 -21 35.7	553 P	30.3 -78.1	1.7 1.2	ir V	MCG-4-13-9 = DDO-37, knotty, sev. ** superp.
152	05 17 35 -37 09.3	362 P	61.0 -115.5	1.1: 1.1:	sp:: V-VI	1 * superp., F, diff., 4' comp. (G14,S0,1.3)
153	05 19 20 -37 00.3	362 P	79.9 -107.9	2.1 0.7	sp IV-V	Lu YC 0519-37, sev. knots, sev. ** superp.
154	05 23 10 -87 05.1	4 F	20.8 -111.8	1.5 0.8	el V	sev. knots
155	05 26 32 -24 41.0	487 F	-43.4 16.8	1.5: 1.1:	sp V	bar
156	05 26 47 -63 16.9	85 F	113. 88.	1.6: 0.8:	el:: V	v m ** superp., diff.
157	05 28 09 -87 37.5	1 F	-40.4 -126.0	1.3: 0.9::	ir V-VI	sev. knots, diff.
158	05 28 26 -24 54.8	487 F	-20.4 4.5	2.0: 1.5:	el: V-VI	3 ** superp., diff.
159	05 32 36 -39 12.1	306 F	-55.7 40.0	1.2 o.9:	sp V	bar
160	05 32 51 -34 12.7	363 F	-41.2 51.0	1.6 1.2:	el V	sev. knots

Canada

THE LUMINOSITY DISTRIBUTION OF GLOBULAR CLUSTERS IN THREE GIANT VIRGO ELLIPTICALS

by

William E. Harris, J.W.B. Allwright
Department of Physics, McMaster University

Christopher J. Pritchet
Department of Physics and Astronomy, University of Victoria

and

S. van den Bergh
Dominion Astrophysical Observatory, Herzberg Institute of Astrophysics
National Research Council of Canada

Submitted to Ap.J.

MAI 1990	MAY 1990
UN PRETIRAGE PREPARE PAR	A PREPRINT PREPARED BY
OBSERVATOIRE FEDERAL D'ASTROPHYSIQUE	DOMINION ASTROPHYSICAL OBSERVATORY
INSTITUT HERZBERG D'ASTROPHYSIQUE	HERZBERG INSTITUTE OF ASTROPHYSICS
CONSEIL NATIONAL DE RECHERCHES	NATIONAL RESEARCH COUNCIL

5071 WEST SAANICH ROAD,
VICTORIA, B.C., V8X 4M6, CANADA

Center for Astrophysical Sciences

POPULATION STUDIES IN GROUPS AND CLUSTERS OF GALAXIES IV. COMPARISON OF THE LUMINOSITY FUNCTIONS AND MORPHOLOGICAL TYPE DISTRIBUTIONS IN SEVEN NEARBY GROUPS

Henry C. Ferguson[1]
and
Allan Sandage[1,2,3]

Nomveber 1990

Preprint Number 75

Preprint Series

The Johns Hopkins University
Bloomberg Center for Physics & Astronomy
Baltimore, Maryland 21218

CORNELL UNIVERSITY
Center for Radiophysics and Space Research

ITHACA, N. Y.

CRSR 786

Dynamical Models and Our Virgocentric Deviation
From Hubble Flow

G.L. Hoffman and E.E. Salpeter

ABELL 154 AND VIRGO: PILOT STUDY FOR H I OBSERVATIONS OF DISTANT CLUSTERS OF GALAXIES

G. Lyle Hoffman and Hayes L. Williams[1]
Department of Physics, Lafayette College, Easton, Pennsylvania 18042-1782

Received 30 July 1990; revised 8 October 1990

ABSTRACT

As a test of procedures required to study the H I contents of spiral galaxies in distant clusters of galaxies, we have observed the cluster Abell 154 from Arecibo.[2] Fourteen candidate detections were found in two regions of the cluster comprising about 10% of the cluster area. We compare these results in detail with those we would expect to obtain for the exhaustively studied Virgo cluster displaced to the distance of A154. Most of our candidate detections are likely to be the combined profiles of two or more spiral galaxies, many of them too faint to appear on the list of morphological types classified by Dressler (1980). Any attempt to identify these H I signals with known bright spirals is problematic at best. The A154 profiles are systematically broader than we would expect for Virgo, but a crude application of the Tully–Fisher correlation indicates that they are still consistent with available photometric data. While the H I deficiency in Virgo would still be apparent at the A154 distance, we find no significant evidence for H I deficiency in A154.

1. INTRODUCTION

Nearby clusters of galaxies have taught us a great deal about the effects of environment on disk galaxies (Haynes *et al.* 1984; Giovanelli & Haynes 1985; Whitmore *et al.* 1988; Whitmore 1990). The H I deficiency of cluster spirals in particular has been studied in detail in Virgo (Haynes & Giovanelli 1986; Warmels 1988a, 1988b, 1988c; Huchtmeier & Richter 1989) and other nearby clusters (Gavazzi 1987, 1989; Magri *et al.* 1988), and it is by now well established that there is a strong correlation between H I deficiency and the local density of hot gas detected by x-ray emission, that earlier type spirals are more severely deficient than later types, and that the gas is depleted primarily in the outskirts of the galaxies. While this strongly suggests that the responsible agent is ram-pressure stripping of the diffuse H I gas in the outer disk by the hot intracluster medium, dwarf irregulars do not appear to be more severely deficient than spirals (Hoffman *et al.* 1988) as would be expected if ram-pressure stripping is responsible, and it cannot yet be ruled out that the deficiency is implicit in the cluster formation process, if galaxies of different morphological type form preferentially in different parts of the cluster (Dressler 1986; Magri *et al.* 1988).

H I depletion by an ongoing ram-pressure process would be expected to have different consequences for spiral star-formation rates and colors than would H I deficiency *ab initio* (Guiderdoni & Rocca-Volmerange 1985; Guiderdoni 1987). Molecular gas deficiencies (Kenney & Young 1989) and dust deficiencies (Bicay & Giovanelli 1987; Doyon & Joseph 1989) have been studied, with the main result that molecular gas and dust also appear to be depleted primarily in the outer parts of the disks, not from the higher density inner portions. There is evidently a secondary effect on either the total luminosity or isophotal diameter, so that the luminosity–diameter relationship varies in a complicated way from cluster to cluster (Giuricin *et al.* 1988).

To resolve some of these questions, it would be of interest to study how gas depletion and star-formation rates vary with time, i.e., to compare clusters in which ongoing ram-pressure stripping has been operative for significantly different times, or in which the spirals have had significantly different periods to evolve since the depletion was established. In any case it is important to greatly expand the sample of clusters so that we are not misled by small number statistics. This makes imperative H I observations of clusters at significantly greater redshift than those studied previously. At the extreme, the distance will be so great that the entire cluster will fall within the radio-telescope beam, and we will be able to compare only the *global* H I contents with Virgo (Hoffman *et al.* 1989b, hereafter referred to as HLHSW) and other clusters. Work along these lines is already in progress (Bothun 1989; Chengalur & Terzian 1990). The purpose of this paper is to examine procedures for observing clusters in the intermediate distance regime: distant enough that several H I sources at overlapping velocities will fall within each telescope beam, yet close enough that we can partially resolve the cluster and perhaps say something about H I depletion as a function of radius within the cluster. Synthesis telescopes such as the Very Large Array are well suited to study the most H I-rich members of clusters at the distance of Hercules ($\sim 11\,000$ km $^{-1}$) (Salpeter & Dickey 1985), but very long integrations are required and the velocity resolution falls far short of what can be achieved at Arecibo.

The cluster chosen for study is Abell 154. This is the most distant of the clusters for which Dressler (1980) gives detailed morphological types. With $cz = 19\,552$ km s^{-1} and a velocity dispersion of 833 km s^{-1} (Faber & Dressler 1977—hereafter referred to as FD; Zabludoff *et al* 1990—hereafter referred to as ZHG), it falls comfortably within the redshift limits of the Arecibo 22 cm feed, and its declination is also well suited to observation from Arecibo. It is slightly richer than Virgo (66 galaxies brighter than $m_3 + 2$ where m_3 is the magnitude of the third brightest galaxy; Virgo has 50 such galaxies), has a slightly smaller spiral fraction [S:E is 22:58 for Abell 154 (Dressler 1980), 56:70 for a Virgo sample extending to slightly fainter intrinsic luminosity (Binggeli *et al.* 1985—hereafter referred to as BST], and comparable x-ray luminosity (Jones & Forman 1984).

[1] Present address: Department of Physics and Astronomy, University of Delaware, Newark, DE 19716.

[2] The Arecibo Observatory is part of the National Astronomy and Ionosphere Center, which is operated by Cornell University under a management agreement with the National Science Foundation.

 © 1991 Am. Astron. Soc.

069

CORNELL UNIVERSITY

Center for Radiophysics and Space Research

ITHACA, N. Y.

CRSR 744

DYNAMICAL MODELS AND THE MASS OF THE VIRGO CLUSTER

G. L. Hoffman, D. W. Olson and E. E. Salpeter

EUROPEAN SOUTHERN OBSERVATORY
SCIENTIFIC PREPRINT no. 617

THE DISTANCE OF THE VIRGO CLUSTER - A REVIEW

G. A. Tammann

November 1988

Center for Astrophysical Sciences

POPULATION STUDIES IN GROUPS AND CLUSTERS OF GALAXIES III. A CATALOG OF GALAXIES IN FIVE NEARBY GROUPS

Henry C. Ferguson[1],

and

Allan Sandage[1,2,3]

April 1990

Preprint Number 66

Preprint Series

The Johns Hopkins University
Rowland Hall
Baltimore, Maryland 21218

High Chemical Abundances in Virgo Spiral Galaxies?[1]

Gregory A. Shields

Astronomy Department, University of Texas

Evan D. Skillman

Astronomy Department, University of Minnesota

Robert C. Kennicutt, Jr.

Steward Observatory, University of Arizona

Submitted to *The Astrophysical Journal*

Received: Aug. 27, 1990

Scheduled for publication

1991 April 10

---

[1] Observations reported here were obtained, in part, with the Multiple Mirror Telescope, a facility operated jointly by the University of Arizona and the Smithsonian Institute.

Canada

THE DUSTINESS, LUMINOSITY AND METALLICITY OF GALAXIES

by

S. van den Bergh and Michael J. Pierce

Dominion Astrophysical Observatory, Herzberg Institute of Astrophysics
National Research Council of Canada

To be published in Ap.J. Nov. 20 1990.

MAI 1990
UN PRETIRAGE PREPARE PAR
OBSERVATOIRE FEDERAL D'ASTROPHYSIQUE
INSTITUT HERZBERG D'ASTROPHYSIQUE
CONSEIL NATIONAL DE RECHERCHES

MAY 1990
A PREPRINT PREPARED BY
DOMINION ASTROPHYSICAL OBSERVATORY
HERZBERG INSTITUTE OF ASTROPHYSICS
NATIONAL RESEARCH COUNCIL

5071 WEST SAANICH ROAD,
VICTORIA, B.C., V8X 4M6, CANADA

Lafayette College

Astronomy and Astrophysics Preprint Series

BCD Galaxies in the Virgo Cluster: HI and IRAS Data, and Upper Limits on Proto-dwarf Galaxies

G. Lyle Hoffman, George Helou,
E. E. Salpeter and B. M. Lewis

Lafayette College

Department of Physics

Easton, PA 18042

THE ASTRONOMICAL JOURNAL VOLUME 89, NUMBER 9 SEPTEMBER 1984

H-ALPHA OBSERVATIONS OF SPIRAL GALAXIES IN CANCER, A1367, AND COMA

ROBERT C. KENNICUTT, JR.[a)]

Department of Astronomy, University of Minnesota, 116 Church Street, S.E., Minneapolis, Minnesota 55455

GREGORY D. BOTHUN[a)]

Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, Massachusetts 02138 and Division of Physics and Astronomy,[b)] California Institute of Technology, Pasadena, California 91125

ROBERT A. SCHOMMER[a),c)]

Department of Physics and Astronomy, Rutgers University, Piscataway, New Jersey 08854

Received 26 January 1984; revised 30 April 1984

anemia | loc. env.
gal morp | loc. env.
em. l. strength

ABSTRACT

We have used large aperture Hα photometry of 65 spiral galaxies in the Cancer, Coma, and Abell 1367 clusters to compare the ionized-gas contents and star-formation rates in cluster and field spirals. Overall, we do not observe any significant deficiency of Hα emission in the cluster members. Emission strength correlates strongly with integrated galaxy colors, but only weakly with H I content. All three clusters contain several galaxies with unusually strong Hα emission, including several H I-poor objects in Coma and A1367. Thus, spirals which appear "anemic" in their morphology or exhibit weak Hα emission are not necessarily H I poor; conversely, H I poor spirals can show strong Hα emission, indicating relatively high current star-formation rates. Gas depletion time scales for some objects in the core of Coma are significantly shorter than the field, indicating rapid stellar and gaseous evolution.

I. INTRODUCTION

An elusive problem in extragalactic astronomy continues to be the origin and evolution of disk galaxies. The dependence of galaxy morphology upon (local) environment appears to offer some hope for understanding the diversity of spiral morphologies that is presently observed. For instance, the discovery of extended x-ray emission from clusters of galaxies has led to suggestions of disk modification caused by the removal of cool disk gas by the hot intracluster medium (e.g., Gunn and Gott 1972; van den Bergh 1976). Since the discovery of cluster x-ray emission, a large number of possible environmental influences have been proposed and narrowed down to two (admittedly simplified) alternatives: (1) an intrinsic formation scenario that relegates the environmental effects to the varieties of initial conditions for galaxy formation (e.g., Dressler 1980); or (2) an interacting model, in which recent, vigorous processes are responsible (e.g., Gisler 1978; Lea and DeYoung 1976; Giovanelli and Haynes 1983).

The statistics of galaxian emission-line strengths may be used as a probe into the possible effects of environment on the internal evolution of galaxies. Gisler (1978) first demonstrated that elliptical galaxies situated in dense clusters possess systematically low nuclear emission, and he attributed this difference to the effects of gas ablation. van den Bergh (1976) has suggested that gas removal may have substantially altered the evolution of disk galaxies as well. To accentuate this, van den Bergh has offered an evolutionary classification system which introduced a new class of anemic spirals that preferentially inhabit clusters. Indeed, initial support for an outbreak of anemia in the cluster environment is offered by Hα emission and color surveys of spiral galaxies in A1367 by Kent (1980) and Stauffer (1981) and in the Virgo cluster by Kennicutt (1983a). These surveys reveal that the disk emission, and presumably the star-formation rate, is systematically lower in cluster members as compared to field galaxies. However, the statistics are poor, the samples are plagued by selection effects, and the explanation for the observed difference is unclear.

In this paper, we present results from a survey of Hα emission among the spiral galaxies in three rich clusters: Cancer, Coma, and A1367. These clusters possess a broad range of galaxy populations and intragalactic environments. We have combined the new Hα measurements with the extensive H I and *UBVR* data from Bothun (1981) to test whether the cluster spirals are indeed anemic in terms of their gaseous and stellar contents, or whether the different populations merely reflect a different distribution of (original) galaxy types in the clusters.

II. OBSERVATIONS

a) Emission-Line Photometry

In order to examine the statistics of gaseous emission in cluster spirals, Hα + [N II] photometry was obtained for 20 galaxies in Coma, 25 in A1367, and 20 in Cancer. Galaxies were selected on the basis of morphological type (spiral or irregular) as determined by Bothun (1982), and as cluster members on the basis of position (less than 2° from the cluster center) and velocity ($v_{\rm mean} \pm 1500$ km s^{-12}). The morphological types are not easy to determine unambiguously. The classifications in Bothun (1982) are heavily weighted toward bulge/disk ratio. We selected galaxies from the large sample studied in H I and *UBVR* by Sullivan, Bothun, Schommer, and co-workers (Bothun *et al.* 1984). The latter is a magnitude-limited (Zwicky catalog) sample. We obtained Hα photometry for all spirals in this sample down to $V = 14$, corresponding to $M_v \sim -20$ at A1367 and Coma, or -19 at Cancer, for $H_0 = 75$ km s^{-1} Mpc^{-1}. Below $V = 14.5$, the

---

[a)] Visiting Astronomer, Kitt Peak National Observatory, National Optical Astronomy Observatories, operated by the Association of Universities for Research in Astronomy, Inc., under contract with the National Science Foundation..

[b)] Present address.

[c)] Guest Investigator, Palomar Observatory, which is operated by the California Institute of Technology.

 0004-6256/84/091279-09$00.90 © 1984 Am. Astron. Soc.

THE ASTROPHYSICAL JOURNAL SUPPLEMENT SERIES, 63:247–264, 1987 February
© 1987. The American Astronomical Society. All rights reserved. Printed in U.S.A.

H I DETECTION SURVEY OF A COMPLETE MAGNITUDE-LIMITED SAMPLE OF DWARF IRREGULAR GALAXIES IN THE VIRGO CLUSTER AREA

G. LYLE HOFFMAN
Department of Physics, Lafayette College

GEORGE HELOU
Infrared Processing and Analysis Center, California Institute of Technology

E. E. SALPETER
Center for Radiophysics and Space Research, Cornell University

JOHN GLOSSON
Department of Physics, Lafayette College

AND

A. SANDAGE
Mount Wilson and Las Campanas Observatories
Received 1986 April 7; accepted 1986 July 23

ABSTRACT

We present new single-beam Arecibo H I observations[1] of 298 late-type galaxies in the Virgo Cluster drawn mostly from the new catalog of Binggeli, Sandage, and Tammann (1985). Two hundred seventeen of these constitute a magnitude-limited "complete sample" of such galaxies, types Sdm through Im and BCD. Sixty-one percent of this "complete sample" was detected, greatly enhancing our store of redshifts and H I masses for such galaxies in the Virgo Cluster. For detected galaxies, we present heliocentric velocities, 50% profile widths, and single-beam fluxes. For those that escaped detection, we have computed upper limits to the flux appropriate to the redshift range (-600 to $+3000$ km s^{-1}). Detailed analysis of these data will be presented in a companion paper.

Subject headings: galaxies: clustering — galaxies: redshifts — radio sources: 21 cm radiation

I. INTRODUCTION

Binggeli, Sandage, and Tammann (1985, hereafter BST), working from photographic plates obtained with the du Pont 2.5 m reflector at Las Campanas, have compiled an extensive catalog of galaxies in the Virgo Cluster area, including morphological types on a detailed scheme and an assessment from the optical morphology of whether each galaxy is likely to be a Virgo Cluster member or in the background. We have been involved in a program of mapping the brighter spirals (Sa–Sd) in the H I spectral line for some time (Helou, Hoffman, and Salpeter 1984, hereafter HHS) and the next installment (to $B_T \leq 14.0$) will be presented shortly (Hoffman *et al.* 1986*b*). Here we extend our H I detection survey to the late-type dwarf (Sdm–Im) members of the cluster. There is no clear demarcation between what constitutes a "giant" galaxy and what constitutes a "dwarf" (Hunter and Gallagher 1985); we prefer to distinguish on the basis of morphological type alone, and hereafter refer to *all* galaxies of types Sa–Sd as "spirals" and *all* galaxies of types Sdm, Im, and BCD as "dwarfs." (For photographic illustrations of these morphological types see Sandage and Binggeli 1984.) These observations have the advantages over previous compilations (Fisher and Tully 1975; Tully *et al.* 1978; Thuan and Seitzer 1979; Huchtmeier, Seiradakis and Materne 1981; Hunter, Gallagher, and Rautenkranz 1982; Davies and Kinman 1984) of (1) large numbers, (2) comparable distances for all, and (3) detailed morphological classifications on a coherent scheme. The optical diameters of the dwarfs are less than 2′, so most remain unresolved by the 3′.2 Arecibo beam; we report here only central-beam observations and anticipate that corrections of the fluxes for beam coverage will be small (Hoffman *et al.* 1986*a*, hereafter Paper II). Not *all* of the dwarfs are unresolved at Arecibo, however; mapping of a number of them will be reported at a later date (Helou, Hoffman, and Salpeter 1986).

A preliminary report of these investigations was made in Hoffman *et al.* (1985). Detailed analysis of these data and a study of their implications for various models of the structure, formation, and evolution of such galaxies, and environmental effects upon them, will follow in Paper II.

II. OBSERVATIONS

The BST catalog includes 293 galaxies of morphological types Sdm–Sm, Im, BCD, Amorphous, or the mixed type "dE or Im" (similar to IC 3475). We define our "complete sample" to be all of these having $B_T \leq 17.0$, plus all known fainter ImV's (since relatively few of these are brighter than $B_T = 17.0$). Thus defined, our complete sample numbers 217 gal-

[1] The Arecibo Observatory is part of the National Astronomy and Ionosphere Center, which is operated by Cornell University under contract with the National Science Foundation.

SPACE
TELESCOPE
SCIENCE
INSTITUTE

PREPRINT SERIES

No. 410

THE EFFECT OF THE CLUSTER ENVIRONMENT ON GALAXIES

Bradley C. Whitmore

February 1990

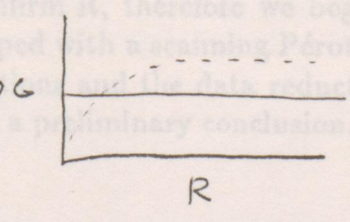
Operated by the Association of Universities for Research in Astronomy, Inc., for the National Aeronautics and Space Administration

Vera,

Hi, here is a copy of a talk given here during the NATO workshop on Baryonic Dark Matter (you may have it already). Look forward to seeing you here this summer.

Duncan

Vera - This group is getting some different
results than we got. They have done
6 galaxies in common with us. 4
agree quite well, 2 are quite different
and
reduce outer
gradie , V 4386
has .
They are
doing Note
that th
Rclust will
be or
U at t
they actually do get a slight correlation
in the same sence as we do.
The increase in # of galaxies with
$R_{cluster} > 3$ Mpc also flattens the
correlation. The real ~~ea~~ effect is almost
certainly not linear.



Their 7 lowest
OG's are all
< 1 Mpc, which is actually a pretty good
sign.

Brad

P.S. - My tenure just got approved!

UNIVERSITY OF CAMBRIDGE
INSTITUTE OF ASTRONOMY
The Observatories, Madingley Road, Cambridge CB3 0HA, England
Telephone: 0223-3375__ Telex: 817297 ASTRON G
Enquiries: 0223-337548 Telegrams: Observer Cambridge UK.

With compliments

DO ROTATION CURVES OF SPIRAL GALAXIES IN CLUSTERS DECLINE ? *

P.Amram[1], ... Sullivan[3]

1 Observatoire de ...
2 Observatoire de ...
3 Department of A...

ABSTRACT

Twenty one ro... been obtained from 2D Hα obse... with PALILA, a scanning Pérot-Fa... the gradient of the rotation curve... ...ed.

1. INTRODUCTION

One of the major astrophysical problem is the existence of flat rotation curves for which the existence of a dark halo should be invoked.If decreasing rotation curves exist in clusters they should be the proof that dark halos have been stripped or have never existed according to Rubin et al.(1988) and Whitmore et al.(1988). From a sample of 21 rotation curves in 4 different clusters they have shown that the gradient of the rotation curves is correlated with the distance of the galaxies to the clusters centers,the decreasing curves being in the center of the clusters.

If this effect is real, it is very important to confirm it, therefore we began an observing program at the Canada France Hawaii telescope equiped with a scanning Pérot-Fabry PALILA.

In section 2 we present our sample, the observations and the data reduction, in section 3 the results, in section 4 a discussion and in section 5 a preliminary conclusion.

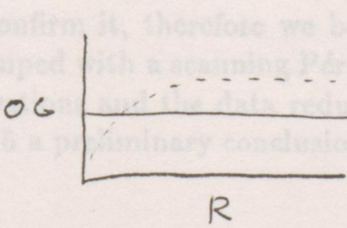
2. OBSERVATIONS AND DATA REDUCTION

The present sample consists of 21 galaxies belonging to 5 clusters: 5 galaxies in Pegasus, 6 in Cancer, [illegible] in Coma, 2 in Abell 539 and [illegible] in Hercules. The galaxies of this sample have been selected in order to be at different distances to the center of the clusters. Most of them are late type galaxies in order to present an important Hα emission,therefore,because of the lack of late spirals in the very center of the clusters we observed rather few galaxies in this region. The diameters of the observed galaxies are in the range 30 to 150 arcsec and the total magnitudes

* Based on observations obtained at the Canada France Hawaii telescope

Vera - This group is getting some different results than we got. They have done 6 galaxies in common with us. 4 agree quite well, 2 are quite different and both go in the sence to reduce the slope (NGC 6045 has outer gradient OG = 20% instead of our -11%, U 4386 has OG = 18% instead of our 37%).

They now have ≃ 30 galaxies, and are doing more southern ones soon. Note that they only have 1 galaxy with $R_{cluster} < 0.25$. The real test will be when they do the other 3 or 4 at $R_{cluster} \simeq 0.15$. Also note that they actually do get a slight correlation in the same sence as we do. The increase in # of galaxies with $R_{cluster} > 3$ Mpc also flattens the correlation. The real effect is almost certainly not linear.



Their 7 lowest OG's are all < 1 Mpc, which is actually a pretty good sign.

Brad

P.S. - My tenure just got approved!

DO ROTATION CURVES OF SPIRAL GALAXIES IN CLUSTERS DECLINE ? *

P.Amram[1], C.Balkowski[2], V.Cayatte[2], E.Le Coarer[1], M.Marcelin[1], W.T.Sullivan[3]

1 Observatoire de Marseille,2 Place Le Verrier, 13248 Marseille Cedex, France
2 Observatoire de Meudon, DAEC, 92195 Meudon Principal Cedex, France
3 Department of Astronomy, University of Washington, Seattle, WA 98195, USA

ABSTRACT

Twenty one rotation curves of galaxies belonging to 5 different clusters have been obtained from 2D Hα observations at the Canada France Hawaii telescope equiped with PALILA, a scanning Pérot-Fabry. The correlation found by Whitmore et al.(1988),between the gradient of the rotation curves and the localisation of the galaxies in the clusters is not confirmed.

1. INTRODUCTION

One of the major astrophysical problem is the existence of flat rotation curves for which the existence of a dark halo should be invoked.If decreasing rotation curves exist in cluters they should be the proof that dark halos have been stripped or have never existed according to Rubin et al.(1988) and Whitmore et al.(1988). From a sample of 21 rotation curves in 4 different clusters they have shown that the gradient of the rotation curves is correlated with the distance of the galaxies to the clusters centers,the decreasing curves being in the center of the clusters.

If this effect is real, it is very important to confirm it, therefore we began an observing program at the Canada France Hawaii telescope equiped with a scanning Pérot-Fabry PALILA. In section 2 we present our sample, the observations and the data reduction, in section 3 the results, in section 4 a discussion and in section 5 a preliminary conclusion.

2. OBSERVATIONS AND DATA REDUCTION

The present sample consists of 21 galaxies belonging to 5 clusters: 5 galaxies in Pegasus, 6 in Cancer, 6 in Coma, 2 in Abell 539 and 2 in Hercules. The galaxies of this sample have been selected in order to be at different distances to the center of the clusters. Most of them are late type galaxies in order to present an important Hα emission,therefore,because of the lack of late spirals in the very center of the clusters we observed rather few galaxies in this region. The diameters of the observed galaxies are in the range 30 to 150 arcsec and the total magnitudes

---

* *Based on observations obtained at the Canada France Hawaii telescope*

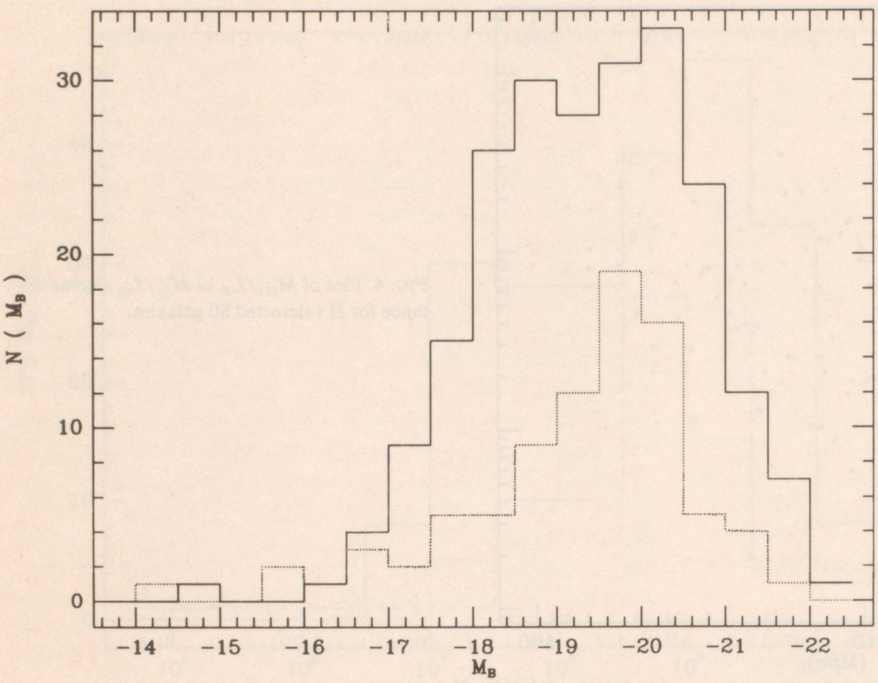


FIG. 2. Distribution of absolute blue magnitude M_B for the S0 galaxy sample. The solid line corresponds to the nondetections and the dashed line to the detections.

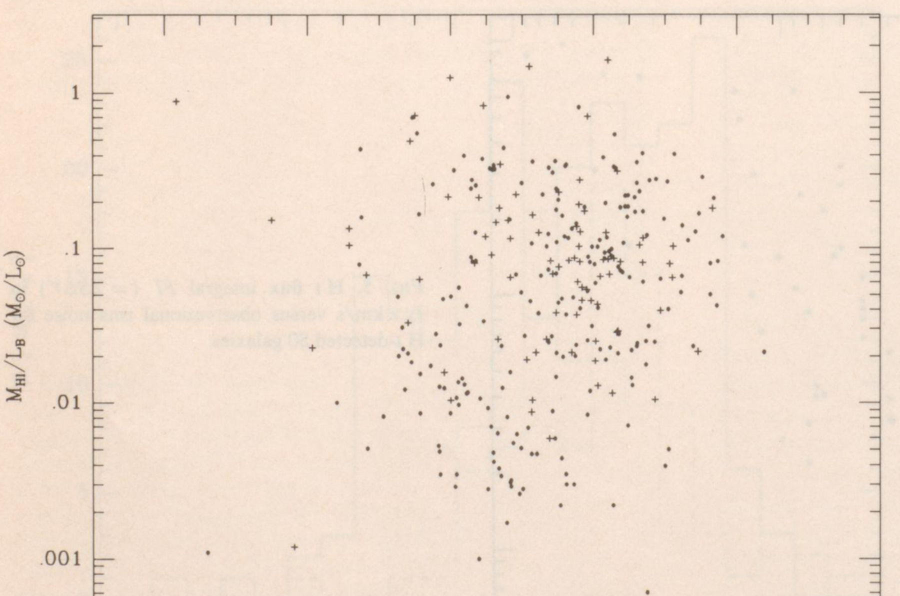


FIG. 3. Plot of $M_{\rm H\,I}/L_B$ in $M_\odot/L_\odot$, or its upper limit, versus absolute blue magnitude M_B for the S0 galaxy sample. The detections are plotted as crosses and the upper limits as circles.

THE ASTRONOMICAL JOURNAL VOLUME 104, NUMBER 3 SEPTEMBER 1992

CORRELATIONS BETWEEN *UBV* COLORS AND FINE STRUCTURE IN E AND S0 GALAXIES: A FIRST ATTEMPT AT DATING ANCIENT MERGER EVENTS

FRANÇOIS SCHWEIZER[1]
Department of Terrestrial Magnetism, Carnegie Institution of Washington, 5241 Broad Branch Road, N.W., Washington, DC 20015-1305

PATRICK SEITZER[1]
Department of Astronomy, University of Michigan, 830 Dennison Building, Ann Arbor, Michigan 48109-1090

Received 5 March 1992; revised 19 May 1992

ABSTRACT

A study of 69 E and S0 galaxies located mostly in the field and in groups reveals that the *UBV* colors become systematically bluer at any given luminosity as the amount of merger-induced fine structure increases. To quantify such fine structure, we define an index Σ that measures ripples, jets of luminous matter, *X* structures, and boxy isophotes; it ranges between 0 and 7.6 for the above galaxies. The correlations between *UBV* colors and this index Σ closely resemble the correlations found earlier between CN, Mg_2, and Hβ line strengths and the same Σ in 36 ellipticals [Schweizer *et al.* ApJ, 364, L33 (1990)]. Because Σ is a rough measure of dynamical youth or rejuvenation, both sets of correlations are most likely due to systematic variations in the mean age of the stellar populations, rather than to variations in their mean metallicity. The new color correlations emphasize that these suggested age variations are not limited to the nuclei, but occur globally in the stellar populations of E and S0 galaxies. These correlations also yield a rough ranking of E and S0 galaxies by the date of their last major merger event. To calibrate this chronology, we develop a simple two-burst model of evolving stellar populations in mergers and apply it to derive heuristic merger ages (HMA) from *UBV* colors for each galaxy. These HMAs vary mainly as a function of two parameters: the Hubble type of the premerger components and the gas-to-star conversion efficiency. For representative ranges of these parameters, the HMAs of our 69 E and S0 galaxies spread over at least 5 Gyr and up to 10 Gyr. Hence the scatter in color–magnitude relations—though relatively small—is fully compatible with the hypothesis that in the field such galaxies formed, or were seriously modified, by major mergers during at least 1/3 to 2/3 the age of the Universe. A mean HMA of ~8 Gyr is suggested for E's with no fine structure and 4.6 Gyr for those with the most fine structure. Good candidates for dynamically young ellipticals having formed through mergers of disk galaxies during the last 7 Gyr are NGC 3610, 1700, 4125, 4915, and 5322; significant rejuvenation seems to have occurred also in NGC 596, 3640, and 5018.

1. INTRODUCTION

Until the mid-1970s, E and S0 galaxies were thought to be simple in structure and uniformly old. Their geriatric stage seemed to be indicated by the general lack of gas, the smooth structures, and red colors indicative of old stellar populations. Yet, for the past decade new evidence has shattered these long-held beliefs. Gas has been found in E+S0 galaxies in all its known forms, ranging from the cold molecular state to x-ray temperatures. A multitude of fine structures (ripples, plumes, boxy isophotes, etc.) and kinematic anomalies (skewed kinematic axes, counterrotating cores) suggest increasingly that at least some early type galaxies were either formed (Toomre & Toomre 1972; Toomre 1977; Schweizer 1983, 1990; Barnes 1988; Barnes & Hernquist 1992) or structurally modified (Quinn 1984; Dupraz & Combes 1987; Hernquist & Quinn 1988, 1989) by mergers in relatively recent times. And population syntheses based on high-quality spectra suggest that E+S0 galaxies contain various admixtures of intermediate-age stars (O'Connell 1976, 1986; Faber 1977; Bica & Alloin 1987; Gregg 1989; Faber *et al.* 1992a). It seems now increasingly likely that even for the morphological types E and S0, galaxy building is a protracted process (Larson 1990; Larson & Tinsley 1978) and stellar populations evolve along a multitude of paths in star-formation-rate, metallicity, and age space (Hodge 1989).

The present paper is the third in a series of four, all resulting from a survey of fine structure in 74 E and S0 galaxies conducted with the KPNO 0.9 m telescope during 1985–1987. Shortly after obtaining the ~10^3 CCD frames, we discovered the presence of ripples in some S0 and Sa galaxies. These structures, similar to ripples ("shells") observed in ellipticals, suggest that some early type disk galaxies, too, may have experienced recent mergers (Schweizer & Seitzer 1988, hereafter referred to as Paper I). From the processed images, we then assembled a cata-

[1]Visiting Astronomer, Kitt Peak National Observatory, NOAO, which is operated by AURA, Inc., under contract with the National Science Foun-

Lafayette College

Astronomy and Astrophysics Preprint Series

Comparative Properties of Virgo Cluster
Dwarf Irregulars and Spirals

G. Lyle Hoffman, George Helou and
E. E. Salpeter

Lafayette College
Department of Physics
Easton, PA 18042

THE ASTROPHYSICAL JOURNAL, 339:812–835, 1989 April 15
© 1989. The American Astronomical Society. All rights reserved. Printed in U.S.A.

BLUE COMPACT DWARF GALAXIES IN THE VIRGO CLUSTER: H I AND *IRAS* DATA AND UPPER LIMITS ON PROTO–DWARF GALAXIES

G. LYLE HOFFMAN
Lafayette College
GEORGE HELOU
Infrared Processing and Analysis Center, California Institute of Technology
E. E. SALPETER
Center for Radiophysics and Space Research, Cornell University
AND
B. MURRAY LEWIS
Arecibo Observatory
Received 1988 April 6; accepted 1988 September 14

ABSTRACT

Blue compact dwarf (BCD) galaxies in the Virgo Cluster Catalog (VCC) are studied, using existing optical data, our H I observations (both previously published and new), and co-added *IRAS* data. In addition, we establish upper limits on the number of optically invisible H I clouds within the VCC survey area. We find that our BCDs lie mainly in two clumps: a low heliocentric velocity clump within the central core, which is most likely the same physical association as that formed by the low-velocity spirals that are thought to be falling through the cluster core from behind, and a diffuse cloud centered on the W group, behind and to the south of the cluster core. Our BCDs tend to have rather large H I profile widths; at constant width, the BCDs are comparable to other dwarf irregular galaxies in blue luminosity and H I flux, but the BCDs are significantly smaller (by a factor of 2 or 3) in optical diameter. We suggest that luminosity in a BCD is redistributed rather than increased from that of an Im galaxy of similar size or mass.

About one-third of the BCDs were detected at 60 or 100 μm by *IRAS* after co-addition, mostly at intensities just above the threshold sensitivity. This is a larger detection rate than for other dwarf galaxies at a comparable distance. The correlations of far-infrared (FIR) luminosity against optical and H I properties suggest that the FIR luminosity of BCDs is dominated by emission from the star formation regions, and that their interstellar medium is deficient in dust only by a modest factor of 2 or 3 compared with normal spiral galaxies. We do not find any significant number of H I clouds in the VCC area without accompanying optical emission. This absence of proto–dwarf galaxies, coupled with the presence of significant dust in observed BCDs, argues that most, if not all, of the Virgo BCDs must have experienced star formation prior to the current burst.

Subject headings: galaxies: interstellar matter — infrared: sources — radio sources: 21 cm radiation — stars: formation

I. INTRODUCTION

Dwarf irregular galaxies (morphological types Sm and Im) have long been considered to be laboratories of the star formation process (see reviews by Gallagher and Hunter 1984; Hunter and Gallagher 1986; and references therein). Evidence cited for high star formation rates in irregular galaxies includes their blue color, proportionately large H I content, chaotic appearance due to large H II regions, and lack of a dominant Population II component. While some of the largest of these galaxies show rotation curves not unlike those of spiral galaxies (Hoffman, Salpeter, and Helou 1986; Tully *et al.* 1978; Huchtmeier, Seiradakis, and Materne 1980; Krumm and Burstein 1984; Comte, Lequeux, and Viallefond 1985; Skillman, Terlevich, and van Woerden 1985; Briggs 1986; Skillman and Bothun 1986; Bottema, Shostak, and van der Kruit 1986; Hummel, Dettmar, and Wielebinski 1986; Skillman *et al.* 1987), at the extreme low-mass end of their distribution the irregulars show little rotation, and their dynamics are dominated by turbulent motions (Sargent, Sancisi, and Lo 1983; Sargent and Lo 1985; Brinks and Klein 1985; Morras and Bajaja 1986). A plausible theory of the structure and evolution of dwarf irregular galaxies is the stochastic self-propagating star formation (SSPSF) scenario of Gerola and Seiden (1978). This model (and earlier work by Searle, Sargent, and Bagnuolo 1973) suggests that dwarf irregulars should evolve in a bursting mode, with short-lived episodes of intense star formation activity alternating with quiescent periods of longer duration for smaller galaxy size (Gerola, Seiden, and Schulman 1980; Comins 1984).

The existence of the blue compact dwarf (BCD) morphological class finds a natural explanation in the SSPSF scenario. BCDs, as defined on a purely morphological basis by Sandage and Binggeli (1984, hereafter SB), are modeled after the "isolated H II regions" of Zwicky (1966), Markarian (1967), Sargent (1970), Sargent and Searle (1970), and Huchra (1977*a*, *b*). Thuan and Martin (1981) defined "blue compact dwarf galaxies" to be galaxies that appear almost stellar on the Palomar Sky Survey, comprising single H II regions with an enveloping galaxy of exceedingly low surface brightness (or none at all). SB have extended this definition to include objects comprising several such H II knots in a common low surface brightness envelope. In the SSPSF scenario, these would be the

---

LAFAYETTE COLLEGE

Department of Physics

Preprint

HI Detection Survey of a Complete Magnitude-limited Sample of Dwarf Irregular Galaxies in the Virgo Cluster Area

G. Lyle Hoffman, George Helou, E.E. Salpeter, John Glosson and Allan Sandage

THE ASTROPHYSICAL JOURNAL SUPPLEMENT SERIES, 46:267–286, 1981 August
© 1981. The American Astronomical Society. All rights reserved. Printed in U.S.A.

H I OBSERVATIONS IN THE VIRGO CLUSTER AREA

GEORGE HELOU
Center for Radiophysics and Space Research, Cornell University
C. GIOVANARDI
Osservatorio Astrofisico di Arcetri, Firenze, Italy
E. E. SALPETER
Center for Radiophysics and Space Research, Cornell University
AND
NATHAN KRUMM
University of Michigan, Ann Arbor
Received 1980 May 16; accepted 1981 January 26

ABSTRACT

We report 21 cm H I line data obtained at Arecibo for 35 galaxies in or near the Virgo cluster. For all galaxies but two, we show contour plots of the spectral profile as a function of position along the major axis, with an average of six profiles per galaxy. We tabulate detailed information on each spectral profile and discuss improved or new procedures for gain correction, sidelobe removal, and total flux estimations. For each galaxy, we tabulate systemic velocity, total line width, and H I extent and content. We report determinations of the kinematic major axis for five face-on galaxies, and for most galaxies, a complete determination of the spin vector is shown for the first time. Upper limits on the H I content of 29 undetected galaxies are also given.

Subject headings: galaxies: clusters of — radio sources: 21 cm radiation

I. INTRODUCTION

H I observations of galaxies with the 300 m dish at Arecibo[1] offer the advantage of single beam simplicity and efficiency over synthesis mapping, while still affording reasonably good spatial resolution, and frequency resolution no worse than any other instrument.

This paper presents H I data on 35 galaxies in the general direction of the Virgo cluster. This sample is not complete in a simple astronomical sense; the selection is explained in § II. The resolution is intermediate in that the H I extends typically over a few resolution widths per galaxy; details of data acquisition and reduction are given in § III. Results on hydrogen extent and content, kinematics, and spin vector positions are discussed in § IV. The reduced data are presented in tabular form and in rough "maps" of spectral distribution versus position along the major axis.

II. THE SAMPLE

This paper pools together the data from two independent observing programs, in view of the homogeneity of the data. In 1978 February, 12 of the galaxies (Group A) were observed in an experiment aimed at clearing the membership controversy (Sulentic 1977; Sandage and Tammann 1976) surrounding galaxies seen in the direction of Virgo, but at near zero redshifts, with suspiciously large angular diameters and high luminosities (Helou, Salpeter, and Krumm 1979).

In the first half of 1979, another 23 of the galaxies (Group B) were observed as part of a survey aimed at comparing H I properties of galaxies inside and outside the core of the Virgo cluster as a function of their location.

a) *Group A*

A list of galaxies within 6° of the Virgo cluster center ($12^h25^m, 13°06'$) taken from the Shapley-Ames catalog (Shapley and Ames 1932) is reasonably complete to $B_T \leq 12.76$ (Sandage, Tammann, and Yahil 1979). An unpublished list by Sandage (1977, private communication) includes optical velocities for most of those. Adjusting all velocities to the Local Group of galaxies according to the prescription of Yahil, Tammann, and Sandage (1977) and subtracting $V_{CM} = 1050$ km s^{-1} for the center of mass velocity of Virgo, one gets V_{VC}, a projected component of the velocity of each galaxy with respect to the Virgo center of mass. The first 18 entries in Table 1 are all the cases with $|V_{VC}| \geq 925$ km s^{-1}.

Two selection criteria were used on that list to form Group A: galaxies seen edge-on were favored to reduce

[1]The Arecibo Observatory is part of the National Astronomy and Ionosphere Center which is operated by Cornell University under contract with the National Science Foundation.