We gratefully acknowledge Professors Leighton and Neugebauer for providing observing charts of the objects they have discovered.

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MOUNT WILSON AND PALOMAR OBSERVATORIES
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A VERY SMALL, CONDENSED GALAXY

In 1961 a long-range program to probe more deeply into the nature of galaxies was started by systematically photographing unusual galaxies with the 200-inch telescope. The resulting *Atlas of Peculiar and Interacting Galaxies* is now finished and in the process of being reproduced for publication. During the accumulation of data on objects in different classes, a number of galaxies with very small diameters for their apparent brightness—some barely distinguishable from stars—were noted. With the completion of the photographic catalogue phase, it is now possible to investigate spectroscopically some of these unusual objects.

The object reported in this paper was discovered toward the end of the atlas program. On a limiting exposure with the 200-inch telescope, in good seeing, what looked to be a faint, close double star turned out on close inspection to have fuzzy edges. Figure 1 shows an enlargement of the discovery plate (a 25-min 103a-J) and directly below it a short exposure of the same object (3-min IIa-O). A spectrum obtained in April, 1965, is shown directly below the two direct photographs. The position of the object is $11^h17^m35^s + 51^\circ41'10''$ (1965).

The identification of the major emission lines in the spectrum, from blue to red, and the measured redshift of each line is given below:

Emission Line	$\Delta\lambda/\lambda$
[O II] . .	+0 00434
Hγ	Blended with Hg I night-sky line
Hβ .	+0 00443
[O III]	+0 00458
[O III]	+0 00434
Mean	+0 00442±0 00005

This yields a recessional velocity of $v_R = 1326 \pm 15$ km/sec. The object is indicated to be extragalactic.

A short-exposure photographic transfer in the blue (IIa-O with no filter) shows that the apparent magnitude of each object is about $m_{pg} = 17.8$ and 17.9 mag. (± 0.3 mag.). The separation of the two components is $1\overset{''}{.}1$. The two components are slightly closer than tangent and have diameters of approximately the same apparent size ($1\overset{''}{.}1$). Using a Hubble constant of 100 km/sec/10^6 pc gives a distance to the object of $d = 13 \times 10^6$ pc. At this distance the luminosity of the components is only $M_{pg} = -12.7$ and -12.8 mag., and the diameter of each object is only $D = 70$ pc!

Peculiar velocities of extragalactic nebulae are, on the average, less than 500 km/sec

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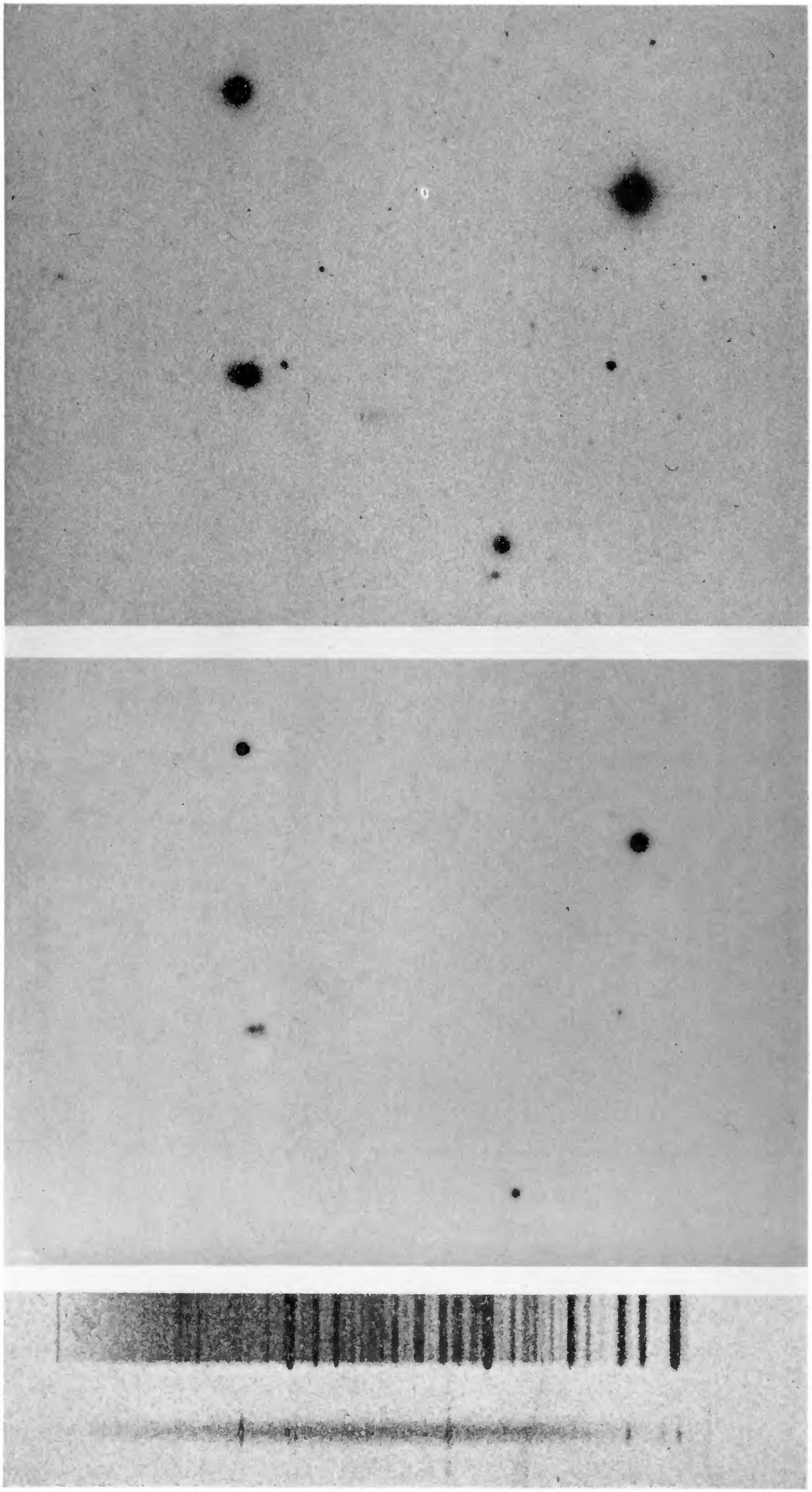

FIG. 1.—*Top:* Discovery plate with 200-inch telescope. The exposure is limiting (25 min) with 103*a*-J plate. *Middle:* 3-min exposure on II*a*-O emulsion. The lower of the two left-hand images is the small galaxy, which is double, and separated by about 1″.1. *Bottom:* Spectrum at about 400 Å/mm.

(Hubble 1936; Humason, Mayall, and Sandage 1956). But even if the peculiar velocity of this particular object were considerably greater, we would still be able to estimate its distance well enough to be certain of its very unusual nature (see Table 1). It is about ten times brighter than the brightest globular clusters known in either our own or nearby galaxies, but it is the same order of diameter as these largest star clusters. On the other hand, it is about ten times less luminous than what is normally called a dwarf galaxy, and almost a hundred times smaller.

The first problem is one of terminology. The object contains gas (presumably the continuum between the emission lines is starlight, although no absorption lines have been detected as yet). The object is at extragalactic distances (of the order of distance of

TABLE 1

LUMINOSITIES AND DIAMETERS OF SELECTED GALAXIES AND STAR CLUSTERS

Object	M_{pg}	Diam (kpc)	Source	Object	M_B	Diam. (pc)	Source
Galaxies:				Star clusters:			
M87	−20 7	34	Holmberg (1950,1958) photometry with modern distance moduli	NGC 1866 .	− 9 6	35	Gascoigne (1954)
M31	−20 3	39					
M81	−19 4	28		47 Tuc	− 9 5	50	Arp (1965)
M33.	−18 3	16		ω Cen	− 9 4	50	
LMC	−17 8	13		h Per	− 8 9	19	Arp (1964); Wildey (1962)
SMC	−16 2	9					
NGC 205	−15 7	5 2					
M32. .	−15 5	2 4		M5 . .	− 8 2	30	Arp (1965)
NGC 185	−14 4	2 8		NGC 4147	− 6 0	16	Arp (1965)
NGC 147	−14 1	3 6		M71	− 7 0	8	
CG 1/21+34	−20 3	2 2	Zwicky (1964)	Present object: CDG	−12 7	71	Each component
CG 1/01+30.	−19 3	2 9			−12 8	71	
CG 12/28+13	−15 7	0 64					
3C 273	−26	0 011	Greenstein and Schmidt (1964)*	Possible range	−13 8	110	If pec velocity is −750 km/sec
3C 48 .	−25	0 001			−11 0	31	If pec velocity is +750 km/sec

* Diameter of gaseous emission regions.

the Virgo cluster of galaxies) and yet is not near any large galaxies (the nearest large galaxy has an apparent diameter of only 5′ and is more than $1\frac{1}{2}°$ away in the sky). Therefore, because of its probable composition and spatial isolation, it must be considered as a galaxy. Because of its very small dimensions and very low luminosity, however, I have referred to it as a compact dwarf galaxy (CDG) in Figure 2.

The nature of the object is very much of a puzzle. Since the object is so small, it does not seem likely that the gas which gives rise to the emission lines can remain excited, either by collision or hot-star radiation, over very much of a cosmic time scale (10^{10} yr). On the other hand, could such a small density fluctuation in the early universe have delayed contracting until now? If so, could the system acquire its indicated energy in the contraction? Questions such as these as to its age, stability, and composition, of course, must await more observations, particularly spectrophotometry of continuum and lines and high-dispersion spectroscopy. Some comments on the implication of this object for our observational picture of galaxy content of space, however, can be made.

Figure 2 shows how, in a plot of luminosity against diameter, this object falls almost exactly between the objects commonly called galaxies and those commonly called star clusters. This is interesting in itself because it poses the question of what is the lower limit of the amount of matter that can form into an isolated galaxy. Another important question deals with the luminosity function of galaxies. It is known that the number of galaxies per unit volume increases rapidly as intrinsically fainter galaxies are considered. For example, the galaxies heretofore called "dwarf" (about $M_{pg} = -16$ mag.) constitute about 66 per cent by number of all the galaxies (Arp 1964). This suggests that there could be even greater numbers fainter than this that are unobserved. The answer to this last supposition hinges on their discoverability, which is related to the second important feature of the present discovery, namely, its very condensed structure.

The very condensed state of the galaxy under discussion is shown by its place in Figure 2. Normal galaxies lie more or less along a diagonal line in this log luminosity–log diameter plot. The new object falls far to the left of the line for normal galaxies. It falls, in fact, as far to the left as an object could fall and still be distinguishable from a star on a

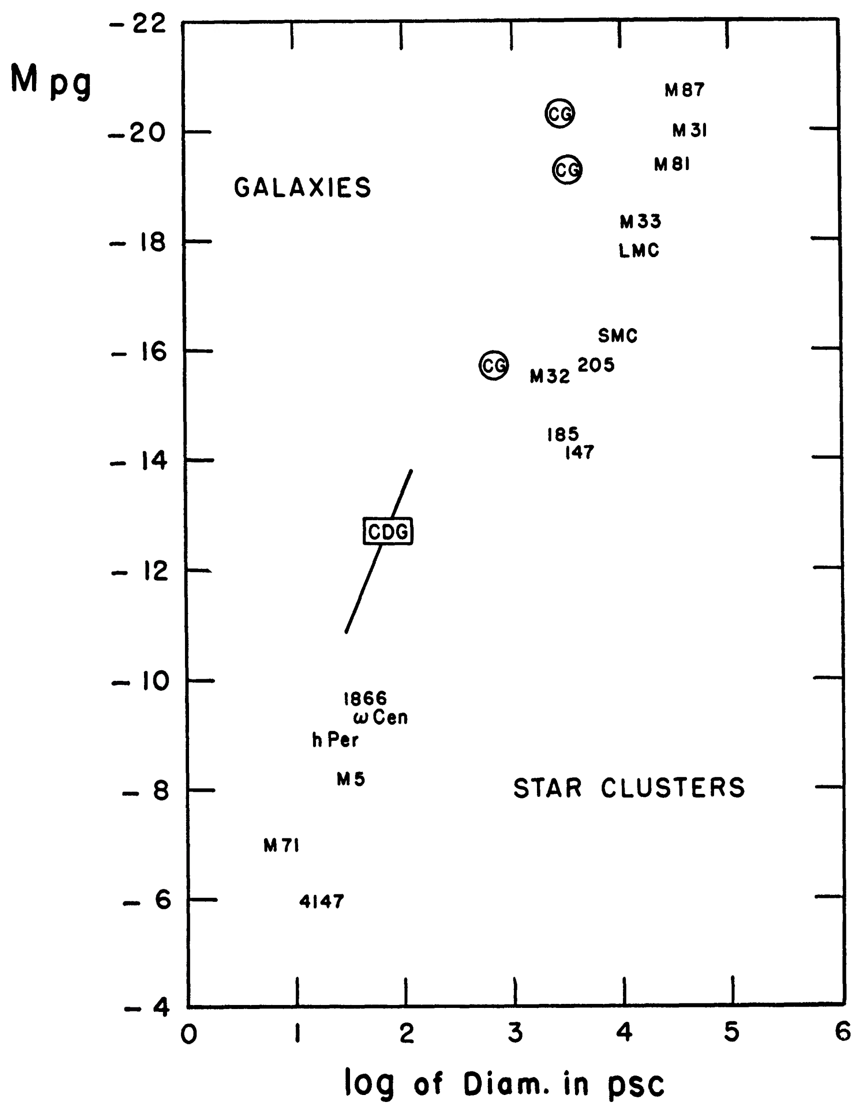

FIG. 2.—Luminosity-diameter diagram for selected galaxies and star clusters (see Table 1). The circled symbols *CG* represent Zwicky's (1964) compact galaxies. The box represents the compact dwarf galaxy (CDG) discussed in the present paper.

direct photograph. Both Zwicky's compact galaxy at $1^h21^m+34°$ and the present one are more than ten times smaller than normal galaxies of comparable luminosity. Objects more compact than this would not be discovered as galaxies unless some other feature (such as radio radiation) drew attention to them.

On the large-diameter side, of course, the surface brightness of a galaxy diminishes as the square of the increase of its linear dimensions for a given luminosity. Naturally the discoverability of a galaxy of a certain total luminosity decreases sharply as its dimensions increase past a certain point. This conclusion is observationally supported by data

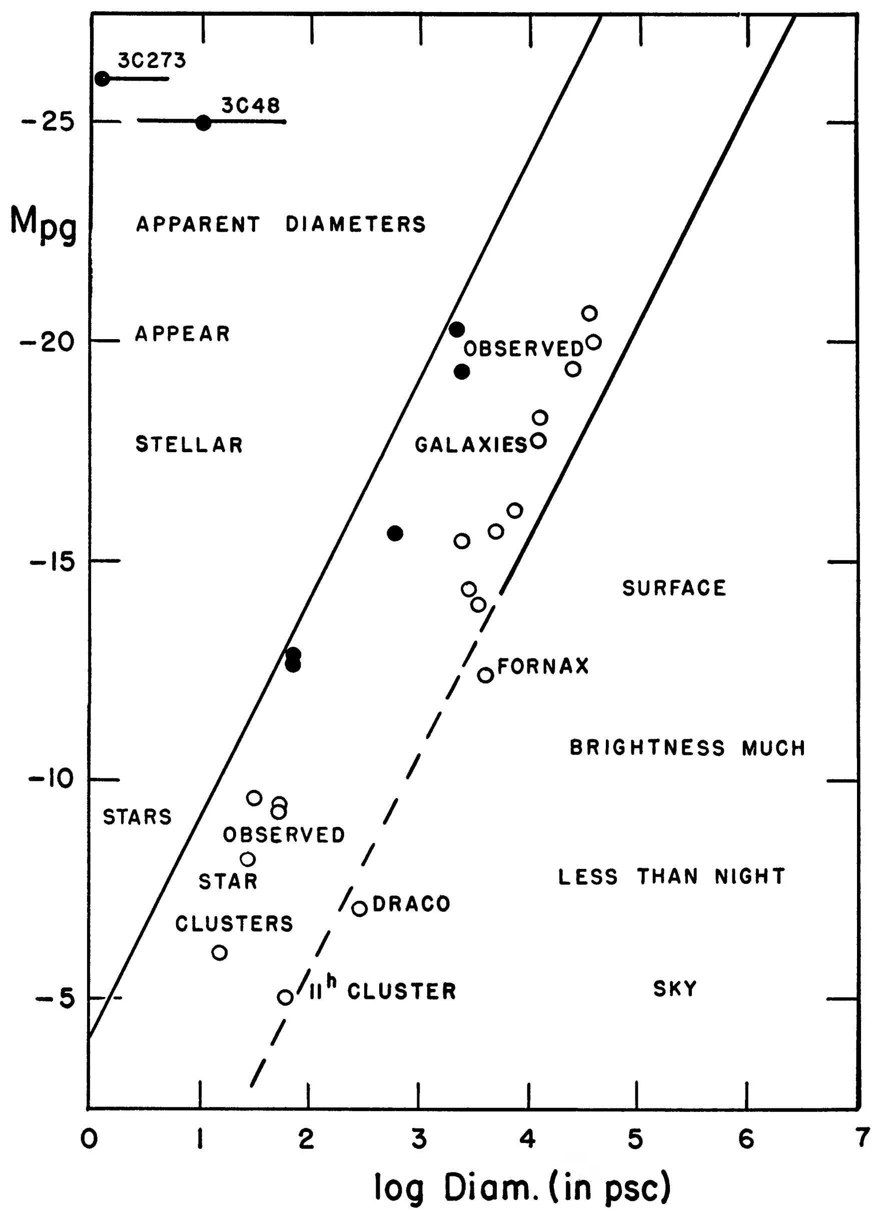

FIG 3.—Luminosity-diameter diagram showing the region to which discovery of galaxies on direct photographs is limited. Some galaxies discovered by radio emission (quasi-stellar objects) and some that are close enough to notice concentration of individual stars (Fornax and Draco) are shown falling outside this band of observational selection. Line on left is for objects with 1″ apparent diameter at apparent magnitude 18.0. Line on right represents a surface brightness of about m_{pg} = 25.5 mag/square second of arc.

on galaxies like NGC 147, which are harder to detect because of their low surface brightness than because of their faint apparent magnitude. Galaxies like Sculptor and Fornax (the latter has $M_{pg} \approx -12$ mag.) must be close enough to show individual stars to be detected.

As a result of these two observational considerations, we can draw a band through the luminosity-diameter diagram (Fig. 3), which contains the known galaxies and outside of which galaxies would not be recognized as such on direct photographs. Since the band is more or less filled, *galaxies could well exist outside this band that have simply not been discovered*. It is significant to note that quasi-stellar radio sources fall outside this band at high luminosity. Nearby in space we know galaxies less condensed than this band (Sculptor and Fornax) because we can detect their individual stars.

In order to make a more complete inventory of the contents of space it would seem extremely important to search out the different possible kinds of galaxies that may have until now been missed. Photographic surveys aimed at detecting small differences of surface brightness near the sky limit can be used to detect the large, spreadout systems. Objective-prism and broad-band photometric surveys could be used to detect very condensed extragalactic systems.

Note added in proof.—Using filters which isolate the spectral region of the O III lines, the 48-inch Schmidt disclosed another object, similar to the one discussed here, in the same general region of the sky ($11^h25^m32^s$, $+54°06'$). This second object is brighter in apparent magnitude and size, but spectra with the 200-inch telescope confirm the similarity to the original object and indicate a redshift about twice as great. A third object, $12^h11^m33^s$, $+13°45'$ (1965), was photographed in February, 1965, and shows a faint plume but appears stellar on 200-inch photographs. It has an emission-line spectrum showing a recessional velocity of about one-tenth the velocity of light and must fall somewhere in the upper-left region of Figure 3 with the stellar-appearing galaxies.

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May 3, 1965
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ACCURATE RADIO-SOURCE POSITION MEASUREMENTS WITH THE NRAO INTERFEROMETER

The two-element interferometer at the National Radio Astronomy Observatory began operation during the summer of 1964. The first few months in service were devoted to