THE NEW STELLAR SYSTEMS IN SCULPTOR AND FORNAX

By W. Baade and Edwin Hubble

Two remarkable stellar systems have recently been reported by Shapley,[1] one in Sculptor and the other in Fornax. The co-ordinates are as follows:

	Sculptor	Fornax
Right Ascension (1938)	$0^h\,57^m$	$2^h\,37^m$
Declination (1938)	$-34°\,2'$	$-34°\,47'$
Galactic longitude	241°	203°
Galactic latitude	−83°	−64°

The objects have been examined with the 100-inch reflector on Mount Wilson although, because of the low altitudes of culmination, observations are limited to a couple of hours per night under rather unsatisfactory conditions. Standard sequences, with IPg magnitudes, have been established by comparisons with SA 68, but possible variations in the sky introduce uncertainties of perhaps 0.2 mag. in the zero-points of the scales. Since the accumulation of complete and precise photometric data will evidently require much time, the following report is restricted to certain provisional results which establish the nature of the systems and the general orders of their distances and dimensions.

The Sculptor Sytem

On the Mount Wilson photographs, the image of the Sculptor system is slightly elongated in the E–W direction, the two diameters being about 45′ and 40′, respectively. The density in the central region (about $25' \times 20'$) is appreciably greater than that in the outer regions but otherwise the distribution of stars over the image is remarkably uniform. There are no indications of a nucleus, of clusters, or of diffuse nebulosity, either luminous or dark. The brightest stars in the system are about $m = 17.8$, and stars in large numbers appear rather abruptly within the next

[1] The Sculptor system is described in *Harv. Bull.*, No. 908, 1938. The two systems are discussed in "Two Stellar Systems of a New Kind," *Nature*, **142**, 715, 1938.

magnitude. In these respects the photographs fully confirm the general descriptions published by Shapley.[2]

Some 40 variables have been identified, although no periods have been definitely determined. Two of the variables are exceptionally bright with maxima near $m = 17.8$ and amplitudes of the order of one magnitude. The observations suggest Cepheid characteristics, and are consistent with periods of the order of one week. However, the possibility of periods close to one day has not been eliminated.

The remaining variables form a homogeneous group in which the mean maximum is $m = 19.12$ with a dispersion of about 0.12 mag.[3] The amplitudes are estimated to be of the order of one magnitude. In several cases, the sequence, bright-faint-bright, on successive nights, definitely establishes short periods. The latter observations, together with the small dispersion around the mean maximum of the group, permit the tentative identification of the stars as cluster-type variables. Since the semiamplitude of such stars is about 0.5 mag., and the median absolute magnitude is about $M = 0$, the observed apparent maximum, $m = 19.12$, indicates a modulus of the order of

$$\begin{aligned} m - M &= 19.62 \\ \text{Distance} &= 84{,}000 \text{ parsecs} \\ &= 274{,}000 \text{ light-years} \end{aligned}$$

The uncertainty in the distance may be as large as 15 per cent.

At such a distance, the median magnitudes of the two bright variables are of the general order of $M = -1.4$, corresponding to Cepheids with periods of the order of five or six days. The very brightest stars in the system are comparable with the two variables at maximum, and their absolute magnitudes are of the

[2] The Mount Wilson photographs, however, give no indications of faint extensions which, according to Shapley, furnish an over-all diameter of 80′.

[3] The frequency distribution of the estimated maxima is as follows:

Max.	*No.*	*Max.*	*No.*
18.9	3	19.2	9
19.0	6	19.3	3
19.1	15	19.4	2

order of $M = -1.8$. These results indicate that the system lacks supergiant stars. The stars which suddenly appear in large numbers are ordinary giants. Photographs through yellow filters, although not yet fully calibrated, confirm the absence of both blue and extremely red colors among the brighter stars of the system and, to this extent, are consistent with the foregoing interpretation.

Shapley's estimate of the total apparent magnitude is $m = 9.0$:. The corresponding absolute magnitude is $M = -10.6$. The linear dimensions are 1100×1000 parsecs. Thus the Sculptor system is a dwarf system, closely comparable with another member of the local group, namely IC 1613.[4]

The Fornax System

The image of the Fornax system is elliptical (elongated in the NE–SW direction) with diameters of the order of 50′ and 35′. The brighter stars appear systematically fainter than those in the Sculptor system by about 1.5 mag. The two systems are similar in containing no nuclei and no diffuse nebulosity, and in exhibiting a very uniform distribution of stars. However, the Fornax system differs from that in Sculptor in containing at least two globular clusters.

The apparent magnitudes of the clusters are of the order of $m = 14.2$ and 15.0 respectively, and the brighter is listed in Dreyer (NGC 1049; pB, S, R, stellar). Both clusters are partially resolved in the outer regions, and, in the brighter, the resolution is sufficient to permit the study of individual stars. A comparison of the brightest stars in NGC 1049 with those of the system shows that the upper limits are closely comparable, and thus affords convincing evidence that supergiants are also absent in the larger system. The apparent magnitude of the sixth brightest star in NGC 1049, $m = 19.67$, combined with Shapley's value[5] of the mean absolute magnitude of such stars

[4] Baade's (unpublished) investigations of IC 1613 indicate a total absolute magnitude of the order of -10.5 and a diameter of the order of 1000 parsecs. These values represent a revision of the preliminary results listed in Hubble, *The Realm of the Nebulae,* p. 145, 1936.

[5] Shapley, *Star Clusters,* p. 160, 1930.

for globular clusters in the galactic system, about $M = -1.7$, furnishes a modulus for the Fornax system,

$$m - M = 21.37$$
$$\text{Distance} = 188{,}000 \text{ parsecs}$$
$$= 610{,}000 \text{ light-years}$$

The uncertainty in the distance is probably of the order of 15 or 20 per cent.

On the basis of this modulus, the absolute magnitudes of the two globular clusters are -7.2 and -6.4, respectively, comparable with those of the brightest clusters in M 31 and the Magellanic Clouds, although somewhat fainter than the brightest in the galactic system. The brightest stars in the Fornax system are of the general order of $M = -2.2$, and are comparable with those in the Sculptor system. Both systems are lacking in supergiants.

Shapley's estimate of the apparent magnitude of the Fornax system, $m = 9.5$:, corresponds to the absolute magnitude, $M = -11.9$. The angular dimensions, $50' \times 35'$, represent linear dimensions of about 2750×1900 parsecs. The total luminosity and the dimensions are each within the range found among neighboring extragalactic nebulae, but the combination of the two, represented by the mean surface brightness, falls somewhat beyond the previously observed range.

The two systems are evidently dwarf, extragalactic nebulae. None of the individual features are entirely new, although the particular combinations are peculiar. Of special interest is the fact that we are now observing extragalactic systems which lack supergiants and are yet close enough to be resolved. The lack of supergiants, it may be emphasized, is by no means unique. For instance, the feature is fully established in the companions of M 31 (as well as in the central region of the great spiral itself).[6] The subject invites further investigation but discussion

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[6] The existence of this characteristic has been recognized for some time. The lack of supergiants in M 32 and NGC 205 is established by the fact that these nebulae are not resolved with the 100-inch reflector although stars brighter than $M = -1.5$ would be readily detected. The same argument (with brighter limits) may be applied to several irregu-

of the data now available would be largely speculative, and hence of little permanent value.

Finally, the addition of two new dwarfs to the three previously known in the local group, making a total of five dwarfs among eleven recognized members, raises an important question concerning the fainter branch of the luminosity function of extragalactic nebulae. Hitherto, it has been assumed that the two branches are symmetrical, although the brighter branch alone has been reliably determined. Although the information now available suggests that the local group is not a fair sample of nebulae in general, the new data emphasize the importance of a thorough re-examination of the luminosity function.

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MOUNT WILSON OBSERVATORY
December 1938

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lar nebulae. For instance, NGC 3077 and M 82 are unresolved, although, on the evidence of red shifts, they are presumably companions of the well-resolved spiral M 81. Another case is NGC 5253, which is unresolved, although a relatively small distance is indicated both by the red shift and by the supernova Z Centauri (1895). A considerable body of other data points less definitely in the same direction. As a working hypothesis, it has been assumed that, in a statistical sense, supergiants are lacking in the nebulae usually described as "elliptical," in the central regions of "early"-type spirals, and in irregular nebulae of types represented by M 82 and NGC 3077.