36,000 × 12,000 light-years for M 31 and 22,000 × 16,500 light-years for M 33, which are of the order of a "universe."

In the discussion *Mr. Goodacre, Dr. Steavenson, the Rev. T. E. R. Phillips, Capt. Ainslie, Mr. Scattergood, Dr. Crommelin*, and *Mr. Waterfield* joined.

Mr. Doig read a second paper on "An Estimate of the Distances of Fourteen Open Clusters." The diameters of the clusters were found to be of the order of 10 to 60 light-years. *Dr. Crommelin* and *Major Hepburn* joined in the discussion.

Mr. J. W. Wilson read a note on the Meteoric Origin of the Lunar Craters. If these formations are due to direct hits by meteors on the Moon's surface, the energy required to change the configuration of the surface by impact is drawn from the kinetic energy or energy of motion of the meteor, and some of it (according to the impact theory) must have been utilised in raising up the material of the Moon's surface from its original level to that which it occupies when forming a crater of the observed size and shape. To produce Copernicus the meteor would have to be at least 220 yards in diameter if moving at 20 miles per second, or 80 yards at 100 miles per second, and no known meteor is as large as this. But the impact of the meteor may have acted merely as a trigger for the release of internal lunar volcanic energy. In the case of a small crater of about 4 miles diameter it is possible that such might be formed by a meteor without assistance from internal volcanic energy. A meteor of about 4 feet in diameter, and moving at 50 miles per second, would be capable of producing a crater of about a mile in diameter. If such were produced to-day it would probably escape notice except in the case of a very well charted region.

Mr. Goodacre described an observation of colour presented by the well-known bright ray or streak, which runs S.E. from Proclus, on one day after Full Moon during the previous lunation. The streak showed a distinct purple tint along its western side, which gradually merged into a light brown at the opposite edge.

Cepheids in Spiral Nebulæ *.

MESSIER 31 † and 33, the only spirals that can be seen with the naked eye, have recently been made the subject of detailed investigations with the 100-inch and 60-inch reflectors of the Mount Wilson Observatory. Novæ are a common phenomenon in M 31, and Duncan has reported three variables within the area covered by M 33 ‡. With these exceptions there seems to have been no

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* Abstract of paper read at the Thirty-Third Meeting of the American Astronomical Society. From *Popular Astronomy*, vol. xxxiii. No. 4, April 1925.

† Messier 31 is the Andromeda Nebula.

‡ *Publications of the Astronomical Society of the Pacific*, xxxv. p. 290 (1922).

definite evidence of actual stars involved in spirals. Under good observing conditions, however, the outer regions of both spirals are resolved into dense swarms of images in no way differing from those of ordinary stars. A survey of the plates made with the blink-comparator has revealed many variables among the stars, a large proportion of which show the characteristic light-curve of the Cepheids.

Up to the present time some 47 variables, including Duncan's three, and one true nova have been found in M 33. For M 31, the numbers are 36 variables and 46 novæ, including the 22 novæ previously discovered by Mount Wilson observers. Periods and photographic magnitudes have been determined for 22 Cepheids in M 33 and 12 in M 31. Others of the variables are probably Cepheids, judging from their sharp rise and slow decline, but some are definitely not of this type. One in particular, Duncan's No. 2 in M 33, has been brightening fairly steadily with only minor fluctuations since about 1906. It has now reached the 15th magnitude and has a spectrum of the bright line B type.

For the determinations of periods and normal curves of the Cepheids, 65 plates are available for M 33 and 130 for M 31. The latter object is too large for the area of good definition on one plate, so attention has been concentrated on three regions: around BD+41°151, BD+40°145, and a region some 45′ along the major axis south preceding the nucleus.

Photographic magnitudes have been determined from twelve comparisons with selected areas No. 21 and 45, made with the 100-inch using exposures from 30 to 40 minutes. This procedure seemed preferable to the much longer exposures required for direct polar comparisons with the 60-inch. It involves, however, a considerable extrapolation based on scales determined from the faintest magnitudes available for the selected areas.

Tables I. and II. give the data for the Cepheids in M 33 and M 31 respectively. No magnitudes fainter than 19·5 are recorded, because of the uncertainty involved in their precise determinations. The now familiar period-luminosity relation is conspicuously present.

For more detailed investigation of the relation, the magnitudes at maxima have been plotted against the logarithm of the period in days. This procedure is necessary, not only because of the uncertainties in the fainter magnitudes, but also because most of the fainter variables at minimum are below the limiting magnitude of the plates. It assumes that there is no relation between period and range, for otherwise a systematic error in the slope of the period-luminosity-curve is introduced. Among the brighter Cepheids of M 33 the assumption appears to be allowable, for the ranges show a very small dispersion about the mean value of 0·8 magnitude. The average range and the dispersion are somewhat larger in M 31, but the data are too limited for a complete investigation.

The curve for M 33 appears to be very definite. The average deviation is about 0·1 magnitude, although a considerable systematic error is allowable in the slope. For M 31 the slope is

TABLE I.

Cepheids in M 33.

Var. No.	Period in Days.	Log. P.	Photographic Magnitudes. Max.	Min.
30	46·0	1·66	18·33	19·25
3	41·6	1·62	18·45	19·4
36	38·2	1·58	18·45	19·1
31	37·3	1·57	18·30	19·2
29	37·2	1·57	18·55	19·15
20	35·95	1·56	18·50	19·2
18	35·5	1·55	18·45	19·15
35	31·5	1·50	18·55	19·35
42	31·1	1·49	18·65	19·35
44	30·2	1·48	18 70	
40	26·0	1·41	19·00	
17	23·6	1·37	18·80	
11	23·4	1·37	18·85	
22	21·75	1·34	19·00	
12	21·2	1·33	18·80	
27	21·05	1·32	18·85	
43	20·8	1·32	18·95	
33	20·8	1·32	18·75	
10	19·6	1·29	18·80	
41	19·15	1·28	18·75	
37	18·05	1·26	18·95	
15	17·65	1·25	19·05	

TABLE II.

Cepheids in M 31.

Var. No.	Period in Days.	Log. P.	Photographic Magnitude. Max.
5	50·17	1·70	18·4
7	45·04	1·65	18·15
16	41·14	1·61	18·6
9	38	1·58	18·3
1	31·41	1·50	18·2
12	22·03	1·34	19·0
13	22	1·34	19·0
10	21·5	1·33	18·75
2	20·10	1·30	18·5
17	18·77	1·28	18·55
18	18·54	1·27	18·9
14	18	1·26	19·1

very closely the same, but the dispersion is much greater, averaging about 0·2 magnitude. This is probably greater than the accidental errors of measurement.

Shapley's period-luminosity curve for Cepheids *, as given in

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* Mt. Wilson Contribution No. 151. *Astrophysical Journal*, xlviii, p. 89 (1918).

his study of globular clusters, is constructed on a basis of visual magnitudes. It can be reduced to photographic magnitudes by means of his relation between period and colour-index, given in the same paper, and the result represents his original data. The slope is of the order of that for spirals, but is not precisely the same. In comparing the two, greater weight must be given to the brighter portion of the curve for the spirals, because of the greater reliability of the magnitude determinations. When this is done, the resulting values of $M-m$ are $-21{\cdot}8$ and $-21{\cdot}9$ for M 31 and M 33 respectively. These must be corrected by half the average ranges of the Cepheids in the two spirals, and the final values are then on the order of $-22{\cdot}3$ for both nebulæ. The corresponding distance is about 285,000 parsecs *. The greatest uncertainty is probably in the zero-point of Shapley's curve.

The results rest on three major assumptions: (1) The variables are actually connected with the spirals; (2) There is no serious amount of absorption due to amorphous nebulosity in the spirals; (3) The nature of Cepheid variation is uniform throughout the observable portion of the universe. As for the first, besides the weighty arguments based on analogy and probability, it may be mentioned that no Cepheids have been found on the several plates of the neighbouring selected areas Nos. 21 and 45, on a special series of plates centred on BD+35°207, just midway between the two spirals, nor in ten other fields well distributed in galactic latitude, for which six or more long exposures are available. The second assumption is very strongly supported by the small dispersion in the period-luminosity curve for M 33. In M 31, in spite of the somewhat larger dispersion, there is no evidence of an absorption-effect to be measured in magnitudes.

These two spirals are not unique. Variables have also been found in M 81, M 101, and N.G.C. 2403, although as yet sufficient plates have not been accumulated to determine the nature of their variation.

EDWIN P. HUBBLE.

On the Units of Distance in Stellar Astronomy.

THE order of magnitude of stellar distances has made it indispensable for astronomers to secure a larger unit of distance than the planetary unit (mean distance of the Earth from the Sun). But, unfortunately, various such units are in use, and consequently various systems of absolute magnitudes, too, which cannot but produce confusion in astronomical literature. Therefore, it is a prevalent desideratum to conciliate the different investigators round a common unit. Which of the various units is to be definitively adopted is a question which must be carefully

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* Equal to 930,000 light-years.