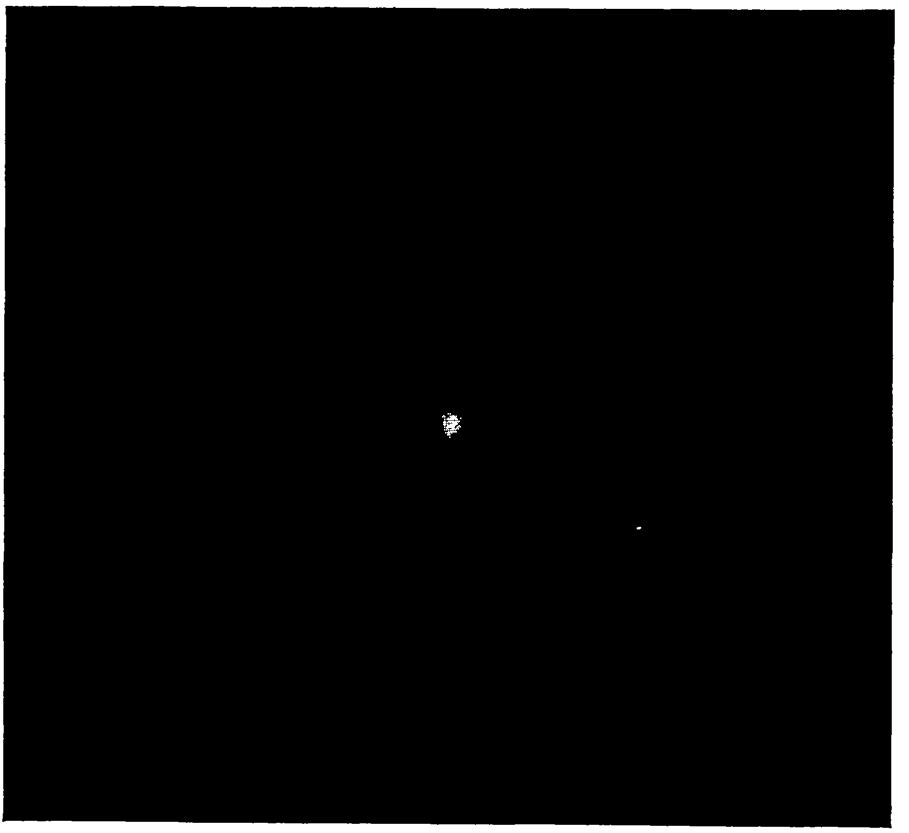
LEAFLET 23—July, 1929

A CLUE TO THE STRUCTURE OF THE UNIVERSE

(Excerpted from an article by Dr. Edwin P. Hubble of the Mount Wilson Observatory, by courtesy of the Carnegie Institution of Washington, D. C. and of the author.)



Nebula N. G. C. 7619, photographed in the 100-inch telescope at Mount Wilson. Believed to be some 25 million light-years distant from the Earth, and apparently receding from us at the rate of about 2400 miles per second. Some idea of its enormous distance may be had by comparing this photograph with that of Messier 51 (page 3), distant only 2,000,000 light-years from us and only one-fifth larger in actual size than is N. G. C. 7619.

A VELOCITY in the line of sight of 2400 miles per second has been measured for a faint nebula by Mr. Milton Humason of the Mount Wilson Observatory. The nebula, known as N. G. C. 7619, is in the direction of the constellation Pegasus, and is believed to be distant some 25 million light years. It is the most distant object whose

velocity has yet been measured, its speed being more than double that previously found for any astronomical body.

As in the case of all the other large velocities of nebulae, the new velocity is one of recession; the nebula is moving away from the Earth. It confirms a relation found by Doctor Hubble, between velocities and distances, according to which, the more distant an object is, the faster it *appears* to be moving from the observer.

This curious relation may be a clue to the structure of the Universe. The surface of the earth offers a simple analogy in two dimensions. Daily life in a small area, say in one's home town, is conducted as though the Earth were a flat body. For large areas, however, the case is entirely different. The Earth is clearly *not* flat, and the curvature intrudes itself on our daily lives; maps are distorted, and ships sail in great circles in order to cover the shortest distance between two given points. Accurate measures over a large area indicate the nature of the curvature. It is uniform, and the Earth's surface turns back upon itself to produce a definite finite area with no boundaries.

The structure of the Universe offers similar possibilities. Just as the spherical surface of the Earth is closed in two dimensions, so space itself may be closed and exhibit a definite finite volume with no boundaries.

Up to this point there is general agreement among the experts; but the next step, the form and structure of the Finite Universe, is still an open question. This problem is under investigation at the Mount Wilson Observatory, where the 100-inch reflector, the world's largest telescope, permits the examination of the greatest possible volume of space. The most distant objects that can be observed are the extra-galactic nebulae, stellar systems comparable with our own system of the Milky Way. They are scattered through space as far as the telescope can reach.

Four of the nearest, all less than a million light years from the Earth, appear larger than the Moon and can be seen faintly with the naked eye. With increasing distance, the nebulae appear smaller and fainter in constantly increasing numbers, until, at an average distance of two hundred million light years, they fade from view even in the greatest telescope. These nebulae thus offer the best opportunities for investigating the effect of distance upon velocities.

Velocities of approach or recession of a heavenly body are determined with the spectrograph, and the measures are relatively simple, once the spectra are obtained. When an

object is approaching us, the lines of the spectrum are shifted toward the left or violet end of the spectrum, i. e., to the left of the similar lines in the comparison spectrum; when receding from us, the lines are shifted in the opposite direction, i. e., to the right of the comparison lines or red end of the spectrum; and from the amount of such shift, the velocity of approach or recession may be computed. The difficulty lies in photographing the spectra. The nebulae are so faint that, even with large telescopes, exposures up to forty hours and often more are necessary. Night after night the observer must exercise the greatest care in continuously guiding the telescope, controlling the temperature of the spectrograph, the focus, and the comparison spectrum, and guarding against mishaps. Even when the plate is successfully developed and the shift of the lines has been measured, the skeptical mind of the scientist demands that the whole procedure be repeated, in order to obtain an independent check on the first result.

In spite of these difficulties, spectra of nearly fifty nebulae are now available. These are due very largely to the

Nebula Messier 51, photographed in the 100-inch telescope at Mount Wilson. Distant about 2 million light-years and apparently receding from us at the rate of about 175 miles per second. This is the famous "whirlpool" nebula, the first spiral ever discovered.

efforts of Slipher, at the Lowell Observatory, although the list of selected objects at Mount Wilson is already considerable. When the distances of these objects are compared with the radial velocities derived from the spectra, a direct relation between distance and velocity is clearly evident.

The more remote a nebula is, the faster it appears to be moving away from the observer. This relation was definitely established by Doctor Hubble out to a distance of about seven million light years, where the velocity of recession averages over six hundred miles per second. Beyond that, it is difficult to estimate the distances of individual nebulae; but several clusters of nebulae are known, and the distance of a cluster, that is, the average distance of many nebulae in a single cluster, can be rather well determined.

Mr. Humason took advantage of this situation and chose a cluster so remote that the spectrum of the brightest nebula could just be registered with the 100-inch reflector. This cluster is believed to be about 25 million light years away and the apparent velocity of the particular nebula was measured as about 2400 miles per second in recession from the Earth. The relation between velocity and distance was, within the probable errors, thus confirmed in accordance with the predictions of Doctor Hubble, through his studies of the nearer nebulae.

Here is a distance-velocity relation which probably holds out as far as the observations reach. It is difficult to believe that the velocities are real; that all matter is actually scattering away from our region of space. It is easier to suppose that the light-waves are lengthened and the lines of the spectra are shifted to the red, as though the objects were receding, by some property of space or by forces acting on the light during its long journey to the Earth.

The problem is now in the hands of the theorists, but the most significant feature of the present situation is the realization that science has reached a stage where theory and observation combined can investigate the actual structure of the Universe.

Editor's Note: Since the issuance of the Carnegie Institution Bulletin from which this leaflet has been prepared, Doctor Hubble reports that Mr. Humason has obtained velocities double that of "N. G. C. 7619," for nebulae in a cluster nearly twice as remote, thereby apparently more definitely establishing the distance-velocity relation.