THE EXPANDING UNIVERSE

The 200-inch telescope reveals that the universe is expanding at the rate of 38,000 miles a second

EARLY THIS SUMMER Dr. Milton L. Humason reported the first significant results of extragalactic research with the 200-inch telescope since it went into operation at Palomar Observatory almost two years ago.

Specifically, the 200-inch telescope has extended the law of the "red-shift" 50 per cent farther out into space—to a distance of 360 million light years (one light year being equal to 6,000,000,000,000 miles). In so doing it has furnished the best evidence yet that the universe is expanding at a phenomenal rate of speed.

The law of the red-shift was formulated about 22 years ago by Dr. Edwin P. Hubble as a direct result of his discovery of ways of estimating distances of nebulæ.

The few spectra of nebulæ then available went out to distances of only seven or eight million light years.

The spectrum of a nebula shows a number of bright and dark lines, each indicating the presence of light of a particular wave length. In the spectra of the more distant objects, however, these lines are shifted from their normal positions toward the red, or longer wave-length, end of the spectrum. Dr. Hubble discovered that the red-shifts increase in direct proportion to the distances of the nebulæ observed—an indication that the nebulæ (i.e., stellar systems) are rushing away from us, and that the universe is expanding.

Soon after these discoveries were made, Dr. Humason went to work to extend Hubble's relation with the 100-inch telescope at Mount Wilson. By 1942 he had pushed the law of the red-shifts out to about 250 million light years—the spectrographic limit of the Hooker telescope. His data, gathered over a period of twenty years, not only confirmed Dr. Hubble's discovery but permitted the law of red-shifts to be formulated on a more reliable basis. Red-shifts, it was found, increased directly with distance at the rate of about 100 miles per second for each million light years.

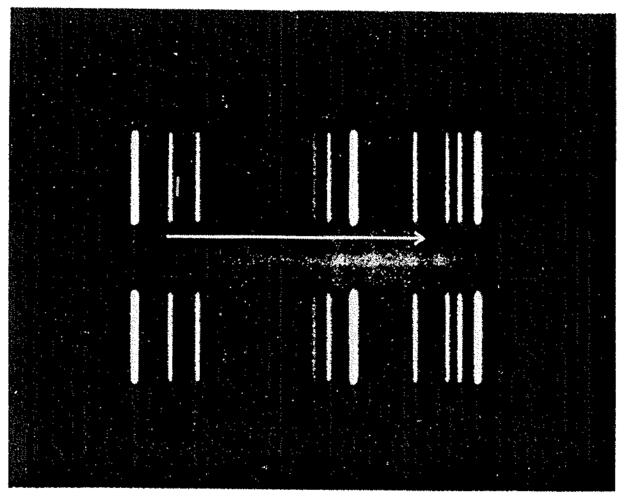
Now, with the 200-inch telescope, Dr. Humason has again extended the observed range of the law—to 360 million light years. As soon as suitable nebulæ can be found, he believes the range can be pushed out to 500 million light years.

This project may take several years. Clusters at great distances, suitable for observation, must be found on photographs taken with the 48-inch Schmidt, the 100-inch and the 200-inch telescopes.

Most of the 48-inch Schmidt plates examined for the purpose are being gathered in the course of the National Geographic-Palomar Observatory Sky Survey, a four-year project of mapping the entire sky visible from Palomar Mountain. Until the telescope went into operation, only about 20 clusters of nebulæ were known. But within the last two years several hundred more clusters and groups have been discovered, all the way out to the limit of the Schmidt.

So many have been discovered, in fact, that it is no longer practicable to identify one as "the" Virgo cluster, or even as the Virgo-A or Virgo-B cluster. Each is now identified by its precise location in the sky.

Discovery of clusters beyond the reach of the 48-inch must depend on chance finds by the 100- and 200-inch telescopes. Although they reach deeper into space, their fields of view are much smaller than the Schmidt's. The



This un-retouched spectrum photograph represents an observation near the limit of the 200-inch. The horizontal band of light in the center is the spectrum of two nebulae. Vertical lines are comparison spectra of helium. Arrow shows how far the H and K lines of calcium are shifted from their normal position toward the red.

The red-shift illustrated on page 15 was measured from spectra of the two brightest nebulae in the Hydra Cluster, indicated by arrow here. The distance of the cluster is estimated at 360 million light years.

Schmidt can photograph an area as large as the Big Dipper, while the 200-inch is limited to an area equivalent to one-quarter of the moon.

Such unpredictable finds may accumulate slowly, but they are necessary preliminaries to recording the red-shifts at the top spectrographic range of the Hale telescope, Dr. Humason said.

Red-shifts are measured on spectrograms obtained with difficulty in a slow and painstaking observing program. To get them Dr. Humason worked in the prime focus cage suspended in the tube of the huge telescope seven stories above the Observatory floor.

He exposed half-inch square spectrographic plates to the feeble light from the far-off nebulæ for four to six hours each. Similar spectrograms of dim objects, though at a lesser distance, would have taken about 25 hours each with the Mount Wilson 100-inch, the world's second largest astronomical instrument. Photographic work Dr. Humason was able to do in three winter nights of reasonably "good seeing" at Palomar—where the 200-inch mirror gathers as much light as a million eyes—might have taken three years on Mount Wilson.

The light observed from the most distant cluster studied to date left its source some 360 million years ago. At that time, on the velocity-shift interpretation, the cluster was roaring away at 38,000 miles a second. Since then it may have migrated 70 million light years deeper into space. The message that tells what is happening to it today will reach earth several hundred millions of years from now.

A most important astronomical milestone will have been reached, if at some point in his continuing study, Dr. Humason should find that more distant clusters show red-shifts corresponding to velocity increases of less, or more, than 100 miles a second for each million light years distance.

Should the red-shift be less than expected in that distant past, the interpretation would be that the rate of expansion of the universe has been speeding up since then. This would mean that the expansion began earlier than now indicated and that the "age of the universe" is more than the two billion years which present data indicate.

Should the red-shifts be greater than expected, the reverse would be true.

Whether this evidence may be found is, of course, impossible to predict. Its interpretation depends, too, on an accurate knowledge of the distances involved and an answer to the question of whether red-shifts actually are velocity-shifts. A possibility exists that the light from far-off objects may have lost energy during its long, lonely journey through space, causing its wave lengths to increase. In this case, some principle of nature as yet unknown would account for the red-shifts.

However, whether or not they represent speeds of recession, Dr. Humason said, the red-shifts promise to give astronomers a convenient yardstick to establish the distances of new-found objects in space. Once the red-shift is measured, the distance will automatically be known. This will be possible when the range of the law, now regarded as a first approximation, is pushed still further into the cosmos and after uncertainties in distances assigned to outlying nebulæ are removed.

The latter is the province of Drs. Hubble, Walter Baade and their colleagues. They report that construction of a thoroughly reliable scale of cosmic distance is now under way, using all the resources on Mount Wilson and Palomar.

The over-all program involves not only photography but also extremely sensitive photoelectric cells developed during World War II. They are being used to measure the brightness of stars and nebulæ several million times fainter than the faintest stars the eye can see.

Step by step, as outlined by Dr. Hubble, the distance scale will be set up as follows:

Globular clusters, or compact masses of thousands of stars, relatively near the earth, will be used to establish the distance of the great spiral nebula, Messier 31. This will fix the brightness of its Cepheids, or regularly varying giant stars, and its novæ, or exploding stars.

Cepheids and novæ then will be used to measure the distance of other nebulæ as far out as the Ursa Major Cloud and the first cluster found in Virgo. These are roughly six and eight million light years away.

This done, the astronomers will have a collection of about a thousand nebulæ of all types. The nebulæ themselves can then be calibrated as distance indicators. Their average brightness, variations from the average and the brightest nebulæ in clusters will provide a yardstick to measure the distance of more remote clusters.

"When the new scale is available," Dr. Hubble says, "the law of red-shifts can be formulated precisely. It can then be discussed with confidence as a clue to the nature of the universe."