CURRENT SCIENCE — 50 YEARS AGO

RESEARCHES ON GALAXIES AT THE HARVARD OBSERVATORY*

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AMONG the many attempts of mankind to survey the universe, astronomy is almost unique in its combination of sweeping fields and sharp limitations. It reaches further into space than any other science; and it finds the demands of space and time more binding. Vast distances and dimensions are involved; processes are exceedingly slow, in terms familiar to man. The result is a constant challenge to man's ingenuity to devise techniques and to interpret observations.

Some of the problems that confront us when we examine our own galaxy, the Milky Way, also need solving when we study the distant universes that make up the rest of the Cosmos. Questions of size and structure, of dynamical conditions, are the same. There is the same analysis of the population of our own and other galaxies near enough to be examined in detail—stars and star clusters, gaseous nebulæ, stars that vary in light. (It may be pointed out that the terms "galaxy" and "nebula" are frequently used interchangeably to mean a great organization of stars. But since the word "nebula" is also used for the bright or dark clouds of gas or dust particles which are characteristic elements in many galaxies, we shall use the term "galaxy" mainly in the following account.)

Because we are involved in the midst of the Milky Way system, and at a great distance from all the others, there are many problems that arise only when we look beyond the Home Galaxy. The most essential problems deal with the general structure of the Metagalaxy, as the system of all such organisations of stars is called. What is the nature of the Cosmos? How many, and of what kinds, are the elements it comprises, and how are they disposed throughout space and time?

Again, we can study some of the distant galaxies to greater advantage than we can examine our own system. It is extremely difficult to obtain information about the Milky Way as a whole. We are not sure whether it is a single spiral or a group of the smaller galaxies or an irregular system. The presence of absorption, the crowding of stars, the difficulties of obtaining perspective, throw us into confusion and uncertainty. But the other galaxies are observable from the outside. In some of the nearer ones, such as the Andromeda Nebula and the Magellanic Clouds, we can even study individual stars and clusters and gaseous nebulæ. Thus we are much more likely to learn what a typical galaxy is like by leaving the Milky Way, and exploring the neighbouring systems.

(1) One of the most fruitful sources of information about the structure and contents of an individual galaxy is the pair of systems lying close to the Milky Way, and probably functioning as its satellites. The Large and the Small Magellanic Clouds are much closer to us than any other external system—they are not a hundred thousand light years distant. Even a small telescope reveals something of their nature. Larger instruments show plainly many thousands of their stars, and other conspicuous features. At the Harvard Observatory a number of studies have been directed to the analysis of the Clouds as typical galaxies. Some of them are here briefly mentioned:

(*a*) The Clouds have been the source of considerable material on variable stars, which furnish the yardstick for measuring great distances. Over three thousand of these fluctuating stars are now known in the two Magellanic Clouds.

(*b*) A number of globular clusters found on the borders of each of the Clouds in the past two years have increased their recognised diameters considerably. The Large Cloud is now known to be about eighteen thousand light years across, and the Small Cloud about twelve thousand.

(*c*) Spectrographs of the brightest stars in the two

* Published in *Curr. Sci.*, Vol. 5, December 1936, p. 287.

Clouds are being taken with the 60-inch telescope. They will yield definite values of the radial velocities, and possibly information on the rotations of the Clouds—valuable material for the study of the dynamics of a galaxy.

(2) A recently developed type of analysis which is being extensively used at the Harvard Observatory on the brighter galaxies is the method of densitometer measures. Photo-tracings across the images of nebulæ are made which indicate the distribution of intensity of light. Thus two phenomena can be examined with considerable accuracy—the diameter of the object and the changes in density of luminous matter across its surface. Diameters have been measured on many photographs, and the results show that the galaxies are very much larger than they had been believed to be. The outer extensions are much fainter than the central regions, and therefore not visible to the eye in examining photographic plates. The results are of inestimable importance in dealing with many problems of galactic structure—primarily, for example, the heretofore unexplained disparity between the two principal types of galaxies, spiral and spheroidal objects. The latter, an almost featureless type of galaxy, had been estimated as much smaller than the spiral form; but the densitometer measures indicate that the diameters of the spheroidals are increased by the faint extension more than are those of the spirals. Thus an apparent discrepancy in the workings of nature has been to a large extent removed by our increased knowledge of the phenomena.

(3) The distribution of the galaxies on the celestial sphere and their distribution through volumes of space are of primary importance in a study of the Metagalaxy. In order to get complete knowledge of such distribution, large regions of the sky should be examined, so that the accidents attendant on small samplings will be obviated. For this purpose the Harvard Observatory is using at both the Northern and the Southern Stations telescopes which combine a fairly large field with space-penetrating power. On a single photograph there is covered an area of thirty-five square degrees of the sky; and nebulæ to the eighteenth magnitude—which means, roughly, to a distance of seventy five million light years—can be recorded in an exposure of three hours. Thus, with a reasonably small number of photographs taken on adjoining regions, several hundreds of square degrees are examined as a unit.

The Harvard survey of galaxies to the eighteenth magnitude has so far revealed on photographic plates some hundred thousand previously unknown galaxies, in both the southern and the northern skies. One significant fact that appears is the unevenness of their distribution. Although in many regions they appear with average frequency, in others they are surprisingly scarce; and in still others, more surprising, there are very great concentrations. In the south, for instance, in the neighbourhood of the constellation Horologium, is a very extensive area of extraordinary richness. Here the galaxies seem to form a great stream, or cloud, many times more dense than the average. Within this Metagalactic Cloud of universes are several small spots of extreme density—spots in which the frequency is a hundred times the normal. Such clusters of galaxies are found scattered over the sky. They cover, to be sure, only a small portion of the entire sphere; but no description of the Universe, or theory about it, can be complete that does not take into consideration these irregularities in the cosmic scheme.

(4) Clusters of galaxies are of interest not only for the rôle they play in the structure of the Metagalaxy. They also provide an opportunity for the study of relative sizes and brightness of individual members. All objects within a cluster may be considered as being at the same distance from us. Thus the variations in diameter and brightness can be taken as absolute differences. A study of twenty-five groups of galaxies, ranging in population from less than a dozen to several hundred, has been publishd by Dr. Shapley. About a score of clusters of galaxies discovered on Harvard plates are as yet unpublished. A programme is now being carried on at the Southern Station for the analysis of some of these groups with the 60-inch reflector which will yield large-scale photographs for detailed study of their members. It will also bring more complete knowledge about the numbers and magnitudes of individuals in the clusters.

The studies listed above represent some of the explorations that are designed to give a consistent and detailed picture of the Metagalaxy. Limitations of space have made it necessary to omit discussion of other allied programs now being carried on at Harvard. There is, for instance, a study supplementing the earlier work on the galaxies brighter than the thirteenth magnitude over the entire sky. The new work goes to the fifteenth magnitude, and thus augments knowledge of the "inner Metagalaxy". There is also the investigation of variable stars in our own system in high latitudes, which outlines the Milky Way in its minor diameter. Such problems necessarily entail a great deal of laborious routine, and can bring final results only after some years of continued research.

The past decade or two have seen the opening of many doors into the outer world. The present time and the coming decades will bring observational material by which we can fill out the picture of what lies beyond the Milky Way.

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NEWS

MEASURES TO PREVENT UNFAVOURABLE ZERO-GRAVITY EFFECTS

Soviet biologists have proved that zero gravity affects such a fundamental biological process as mitosis—division of cells. It may cause, in particular, restructuring of cells. For the first time, such changes were found in the spiderwort tissues exposed for a long time to spaceflight conditions. Three per cent of the cells under study developed structural changes. In conditions of the earth such phenomena were not observed even after exposure to radiation, vibrations and temperature gaps. The results of research have been corroborated by numerous experiments staged on other objects. This work has been registered as a discovery by the USSR State Committee for Inventions and Discoveries.

Weightlessness has proved to affect negatively not only mitosis, but cosmonauts also experience unpleasant blood flushes in the head and, in long-duration flights, develop changes in the cardiovascular system and in metabolism. Soviet scientists have developed measures to prevent the unfavourable zero-gravity on living organisms, which extends the time of man's stay in orbit. (*Soviet features*, Vol. 25, No. 137, September 8, 1986; Information Department, USSR Embassy in India, P. B. 241, 25 Barakhamba Road. New Delhi 110 001).

NEW MYSTERIES OF VENUS DISCOVERED

Studying the images of Venus on the radar, transmitted by Soviet interplanetary stations *Venera*-15 and *Venera*-16, Soviet scientists unexpectedly discovered a mass of gigantic collision craters having the diameter ranging form 8 to 140 kilometres on the surface of the planet. Many of these formations are 1,000 million years old.

Scientists have established that despite their ancient origin, the condition of all the these craters is perfect. They are raised and are seen very well on the photographs. Meanwhile, not a single crater of the kind has remained on the earth as they simply distintegrated as time passed.

It means that in the last 1,000 million years nothing has practically taken place on Venus. Otherwise, the volcanic and tectonic activity would have left traces. Most probably at the earliest stages of its existence, Venus was more active than the Earth. Possibly, because of the closeness of the sun, all geological processes on it took place more intensively and, as a result, they stopped 1,000 million years ago.

As to the mass of the matter it contains, the densest atmosphere of Venus is equivalent to the layer of rock 300 metres thick. Therefore, traces on its surface could be left only by very big meteorites. For example, to form a crater with a diameter of 140 kilometres the cosmic body should be about 14 kilometres across. (*Soviet features*, Vol. 25, No. 137, September 8, 1986; Information Department, USSR Embassy in India, P. B. 241, Barakhamba Road, New Delhi 110 001).