## ASTRONOMICAL STUDY OF THE UNIVERSE.

At the annual meeting for 1913 of the Royal Astronomical Society of Canada the president, Mr. L. B. Stewart, professor of Astronomy at the University of Toronto, in his presidential address, spoke on "The Structure of the Universe." That portion of his address which we believe will be of most interest to our general readers we abstract and publish as follows:—

It is proposed to sketch briefly the methods of investigation used in the study of the universe, the principal facts that have been learned up to the present, and some probable conclusions that may be drawn from those facts.

If it were possible to measure the distances of the stars with the ease and precision of determinations of direction, the investigation of the form of the stellar universe, and the distribution and motions of its individual members, would be a simple question of time and labor; but unfortunately astronomers are met at the outset by the impossibility of determining by direct methods, the distances of any but a few hundreds of the millions of stars that can be seen in our telescopes.

The only direct method of determining the distance of an individual star is by observing the difference in its direction as seen from the earth when at opposite points of its orbit. This is double the star's annual parallax. The relative method, by which these determinations are usually made, is admittedly unsatisfactory, especially in the case of small parallaxes, as it gives only the difference between the parallax of the star under investigation and the mean of those of the comparison stars, so that the result is always too small, and is frequently negative, showing that the parallax star is farther away than the mean distance of the comparison stars.

Another method—of limited application, as it can only be applied to binaries—has been recently used with success to determine the parallax of such systems. Micrometer measurements give the angular dimensions of the relative orbit of a pair of stars that are physically connected; but it was shown by Fox Talbot in 1871 that if in addition the radial velocities of the individual stars are found by means of the spectroscope, the absolute dimensions of the orbit of each star about the centre of gravity of the system, the masses of the individual stars, and finally their parallax, could be computed. In order that the method may be applicable it is necessary that the stars be separable in the field of the telescope. Burnham has separated stars closer to one another than 0".25, and it is considered possible to separate stars as close to one another as 0".1. In the cases of very distant binaries, if separable, they are situated at such wide distances apart that their relative motion is so slow that centuries must elapse before their orbits can be determined.

A method depending upon a study of the proper motions of the stars of a group, which may be used to obtain the mean parallax of the group, may be thus briefly described: The observed proper motion of a star is compounded of a real motion of the star in space projected upon the celestial sphere, and an apparent motion, termed the parallactic motion, resulting from that of thee solar system. This observed proper motion may be resolved into two others, one perpendicular to the direction of the sun's way, the other parallel to it. The former is termed the *r* component and is independent of the solar motion, and the latter the apical component. This latter is composed of the resolved part of the true proper motion of the star, and the parallactic motion.

Having outlined thus briefly the principal methods of investigation that are applied to the stellar universe, let us turn next to some of the results of the investigations that have been made, and the conclusions reached by their discussion.

Before doing so, however, it will be well to place before us some of the questions to which answers are sought, in prosecuting the study of our stellar system. The following are some of these questions:

Is the universe infinite in extent? If finite, are there other systems separated from ours by immeasurable distances; or do all the stars, nebulæ and clusters, that are visible in our telescopes, or on our photographic plates, form a single system; or are the nebulæ, or some of them, separate systems situated at such vast distances from us as to be irresolvable? Have our telescopes penetrated to the confines of the stellar universe, so that the stars that are brought to light by increased power, or longer exposure, are merely fainter stars and not more distant ones?

As before stated, a full answer to these questions cannot be given at present, and possibly a complete solution of the problem will never be reached, though probably the main conclusions arrived at by a discussion of the facts now in our possession will only be modified by future discoveries.

That the universe is finite in extent has long been considered as proved, from the fact that, if infinite, the heavens would shine everywhere with a brightness equal, at least, to that of our sun. This conclusion is only valid if there is no absorption of light in its passage through space; and experimental evidence seems to be accumulating which points to a possibility that there is such absorption, though the evidence cannot be considered entirely convincing.

Prof. Newcomb's conclusions regarding the extent of the universe may be thus summarized: The universe is limited in extent, and probably extends farther in the plane of the Milky Way than in the direction of its poles, but in every direction much farther than the limit within which the proper motions of stars have yet been determined. The boundary is probably somewhat irregular, and the stars gradually thin out as it is approached. It is quite possible that far outside our universe there may be collections of stars of which we know nothing. It is not possible to decide whether the star masses of the Milky Way lie on the boundaries of the universe or not; the number of lucid stars that seem to lie within the Milky Way favor the view that that body is contained within the stellar universe. The stars lying without the galactic region show no tendency to collect in clusters, but are distributed throughout space with some approach to uniformity.

Several estimates of the distance of the Milky Way have been made, based upon different principles and assumptions, and which therefore differ widely in their numerical amounts. Professor Very makes an estimate of its distance by means of the parallax of Nova Persei. Bergstrand had found that quantity to be 0".03, but from considerations based upon the rate of expansion of the nebulosity seen to surround the star after the outburst, Professor Very concluded that his value was too small, and placed it at 0".05. This makes the distance about 60 light years. He assumed the nova to be situated within the condensed part of the spiral structure of the galaxy; and it may be remarked here that nearly all the novæ recorded during the last 300 years are situated in or very near the galaxy, and so appear to be in some way connected with it.

He then proceeds to estimate the distance of the Andromeda nebula in a similar way. A nova appeared in the centre of the nebula in 1885, and attained the 7th magnitude. By assuming its intrinsic brightness to be equal to that of a galactic star of zero magnitude, its distance is found to be