tainable by stars is suggested by recent observational and theoretical work, and this limit is much fainter than -16 . The study of globular clusters, for example, has yielded sufficient knowledge of the luminosity of more than a million stars to show that not one is within ten magnitudes of this enormous brightness. The luminosity of about 2,000 stars of the solar environs is now known, and probably none is even a ten-thousandth as luminous as absolute magnitude -16 . Hence stellar luminosities of this order seem out of the question, and accordingly the close comparability of spirals containing such novae to our Galaxy appears inadmissible.

Let us abandon the comparison with the Galaxy and assume an average distance for the brighter spirals²³ that will give a reasonable maximum absolute magnitude for the novae. Then the measured internal motions also become reasonable and in good agreement with spectroscopically determined rotational velocities; likewise the distances become reconcilable with the data from proper motion.

The simple hypothesis²⁴ that the novae in spirals represent the running down of ordinary galactic stars by the rapidly moving nebulosity becomes a possibility on this basis of distance, for the brighter spirals are within the edges of the galactic system. Further, it is possible to explain the peculiar distribution of spirals and their systematic recession by supposing them repelled in some manner from the galactic system, which appears to move as a whole through a nebular field of indefinite extent.²⁵ But the possibility of these hypotheses is of course not proposed as competent evidence against the "island universe" theory.

CONCLUSIONS.

Observation and discussion of the radial velocities, internal motions, and distribution of spiral nebulae, of the real and apparent brightness of novae, of the maximum luminosity of galactic and cluster stars, and finally of the dimensions of our own galactic system, all seem definitely to oppose the "island universe" hypothesis of the spiral nebulae. Data relating to proper motion are also in better harmony with the hypothesis that spiral nebulae are not stellar systems. The evidence now supporting the "island universe" interpretation appears unconvincing, for many of the best arguments formerly proposed on that side of the question have been invalidated or much weakened by recent research. We have, however, no evidence that somewhere in space there are not other galaxies; we can only conclude that the most distant sidereal organizations now recognized—globular clusters, Magellanic clouds, spiral nebulae—cannot successfully maintain their claims to galactic structure and dimensions.

THE USE OF SELENIUM CELLS IN ASTRONOMY.

By LEWIS J. BOSS.

SELENIUM is a non-metallic element, occupying the intermediate space between Sulphur and Tellurium. It was discovered in 1817 by Berzelius while he was experimenting with the Falun pyrites, with a view towards producing sulphuric acid from them. Selenium is obtained in three different forms, namely, amorphous, vitreous, and colloidal selenium. There is also another modification of selenium, known as metallic selenium. Of these we need only be concerned with the vitreous and metallic forms.

The metallic form of selenium is produced from the vitreous

generally, and is the only modification of the element which is light sensitive. The vitreous selenium is gradually heated until the temperature approaches 100°C . and then begins to pass rapidly into the metallic state, the temperature rising at 217°C .

This metallic selenium conducts electricity and exposure to light increases its conductivity. This effect is most pronounced when selenium is used which has been exposed for a considerable time to a temperature of 210°C ., until it has attained a granular crystalline structure.

This final annealing is very essential to making the most sensitive and delicate cells. The selenium must be as pure as possible, as Marc has observed that impure selenium does not crystallize as well in a given time as does pure selenium. As a matter of interest it might be well to note here that in selenium crystals an X-ray analysis shows the selenium atoms to be placed at the corners of triangles in such a manner as to form hexagons. The distance between these atomic centers is 3.69×10^{-8} cm. when measured perpendicular to a regular surface running parallel to the principal axis. These hexagonal plates are fitted one against the other lengthwise, so as to build up an acicular hexagonal crystal. The distance between these as shown by the X-ray spectrum seems to be 3.7×10^{-8} cm., or .37 millionths of a centimeter.

After this crystalline state has been attained by the selenium cell it becomes very sensitive to even the most minute changes and variations in the amount of light allowed to fall upon it. Grubenbergh has produced cells which recorded changes of one-hundredth candle power at a distance of a mile. As Marc has calculated the thickness of the selenium layer which is affected by the light action to be about $1/1,500,000$ inch thick, it can be readily seen that small variations in light intensity will greatly affect the conductivity of the cell. This change also takes place almost instantly, at least the lapse of time is less than .01 second. There does not seem to be any appreciable difference in the action of the cell whether the light striping it is colored or not, although no one has studied this phase of the subject to any great extent. Personally I have thought that on some cells at least, certain wave-lengths of light, notably λ 680-660 (between the B and C lines of the spectrum) affected them to a greater extent than did other portions of the spectrum.

The field of variable star observations seems to open up a vast field for the use of these cells in that they will detect the smallest changes in light variations where the eye could see no change whatever. Many stars, such as α Orionis whose period has never been determined, offer a field of great interest to observers who may elect to make use of these cells. By means of a suitable indicating device a continuous curve of light variations may be traced throughout the night.

These cells may be used in determining the relative amount of light given off by an eclipsed body and, if calibrated beforehand, could be made to read in direct light units. During lunar total eclipses they might be used to measure the amount of earth-light received by the moon.

Another use to which they might well be put is the comparison of magnitudes and brilliancy of stars. For instance let the cell be arranged to receive the light from star A (let us say); then after noting on the indicating device (galvanometer, etc.) the deflection produced by the light of star A, swing the cell so that it receives the light from star B. If the deflection is the same, then star A and star B are of the same magnitude, but if the readings differ, then the proportion of difference in the readings is the proportion of difference in the magnitude. In this same way the cells might advantageously be used in recording brilliancy changes in Novae.

In view of the great delicacy and sensitivity of these cells it is to be hoped that they will become the subject of more research in the future than they have in the past, and that they may aid in the advancement of man's most sublime science—Astronomy.—Reprinted from *Popular Astronomy*, March, 1920.

²³Provisionally, let us say, of the order of 20,000 light-years. If novae in spirals attain apparent magnitude 16, certainly bright stars, if present, should be easily photographed, and the failure to resolve the brightest spirals indicates that they are not composed of typical stars. (Cf. a suggestion on the origin and constitution of spiral nebulae, *Mt. Wilson Contr.*, No. 161, p. 29, and also the mathematical theory by Jeans, *Monthly Notices* 77, 186, 1917). At a distance of 20,000 light-years, if there were ordinary stars of absolute magnitudes between 0 and +5, they would appear of magnitudes 14 to 19, and therefore conspicuous on ordinary photographs. Even if 200,000 light-years distant, the giant stars would be easily resolved on existing photographs.

²⁴*Pub. Ast. Soc. Pac.*, 30, 53, 1919.

²⁵*Mt. Wilson Contr.*, No. 161, Sections VII and VIII, 1918.