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RUTH NORTON.
SUPERVISOR OF PUBLIC RELATIONS

PHONE TRAFALGAR 3-1300
EXT. 444, 311 AND 481

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ASTRONOMY FROM THE SPACE STATION *

by

Fred L. Whipple, Ph.D.
Chairman, Department of Astronomy
Harvard College Observatory
Cambridge, Mass.

I am going to limit my discussion to the purely astronomical problems which will face the astronomer when he begins an observational program to be undertaken from an observatory located above the earth's atmosphere. I am going to omit intentionally the exceedingly important observations of the earth, particularly those meteorological and geophysical in character.

The astronomer must first design and locate an observatory that can be operated under the extremely unusual conditions in empty space. There are some very interesting problems concerning the simple matter of locating the observatory with respect to the satellite station. The only really practical location is in the precise orbit of the satellite vehicle, ahead or behind; otherwise an oscillation normal to the orbital plane will occur in each revolution as well as drift motions away from the satellite vehicle. In 24 hours the drift is nearly 40 times the distance towards or away from the earth with respect to the station orbit. The observatory could even be placed in such a fashion that it describes a circular orbit about the station, without being attached to it. This solution to the problem, however, is not a desirable one, since the station comes within the line of sight of the telescope too frequently. The astronomer would really wish to have the observatory at a greater distance from the earth than 1,075 miles, because of the large solid angle of the earth as seen from the orbit.

A number of technological problems with regard to the operation of the instrument must be considered and solved. Covering the surface of the mirror with a metallic reflecting coat, however, will be the easiest of all because of the complete vacuum in space. Furthermore, much electronic equipment will operate without the complication of vacuum seals, which constitute

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a considerable problem of electronic design and construction in a gaseous medium like our atmosphere. Various problems, such as orienting the instrument, holding its position accurately, etc., are of great interest in technological design. The question of shielding surfaces from rapid temperature changes produced by the sun and earth is also a very important one. The observer will not be able to touch the telescope nor be within it, because of the precise directional control required for most problems. Hence all guiding will be remote control, as well as opening shutters and other operations. The changing of films and plates can best be done by remote control, storage units being transferable to the telescope from the satellite station.

The spectroscopic techniques used in the satellite station will be adaptations of laboratory techniques now used in vacuum for the far ultra-violet, X-ray and gamma rays. Because of the universal vacuum surrounding the station, many of these electronic problems, photoelectric problems, etc., will be greatly simplified. Large regions in the radio spectrum will be opened up by the existence of the station above the ionosphere, and we may expect a large branch of radio astronomy from the satellite vehicle. Furthermore, there exists the possibility of constructing rather large antennas in space, so that the resolving power of radio astronomy may be greatly increased.

The useful electromagnetic spectrum ranges at least over a power of 10^{20} in wave length or frequency. The eye sees over scarcely a range of 2 in this 10^{20}, while the infra-red and ultra-violet transmission of the atmosphere permits a range of about a factor of 10. Recent innovations in radio astronomy open up a vast range of some 30,000 times from about one millimeter to 30 meters wave length. Extremely great progress is being made in this range of the spectrum, but the most interesting parts, which lie in the ultra-violet, X-ray and gamma ray regions, are completely invisible from the earth's surface. Modern rocket explorations have made great strides in solar studies over these far regions. The entire spectrum from less than one angstrom unit in wave length (10^{-8}cm.) up to radio-type waves comparable to the dimensions of the earth can all be observed from the satellite station.

The over-all astronomical fields of research to be covered will include (a) solar problems, (b) the planets and smaller bodies in the solar system, (c) the stars, (d) the galaxies and (e) the interstellar medium of gas and dust. It is staggering to think of the innumerable intriguing observations that one can hope to make from space.

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The solar problems will undoubtedly be handled by small, specialized equipment of several varieties, each designed to attack a special problem of solar structure and activity. The present rocket program in the United States will give us preliminary information on many solar phenomena occurring in the far ultra-violet and X-ray region. We will be particularly interested in the direct measurement of corpuscular radiation from the sun, the far ultra-violet and X-ray spectra and variations as correlated with solar activity such as prominences, flares, corona, etc. It is possible also that from space radar observations of passing corpuscular streams can be observed by reflection. Perhaps the question of cosmic ray sources in the sun will have been solved by the time the satellite observatory is ready, but certainly there are many studies of great interest bearing on this problem.

The planetary problems will make use of the high-resolving power of a large telescope, with say a 100- or 200-inch mirror. On Mars, for example, a resolving power of approximately 10 miles should be possible with a 100-inch telescope. Of equal interest will be a study of the complete chemical composition of all planetary atmospheres, since the far ultra-violet light will reveal the presence of molecules and atoms that do not absorb light in the photographic regions or, such as water vapor, are largely absorbed in our own atmosphere. Detailed observation of the composition of cometary atmospheres will be invaluable, not only with regard to the evolution of planets but concerning the possibility of life on them.

In stellar astronomy, a huge endeavor involving spectroscopy in the far ultra-violet and X-ray region, and even in the gamma-ray region will provide any large telescope, or even several of them, with problems for generations. Problems of stellar composition can be solved for all elements that are present even in exceedingly minute quantities, but I expect that the cream of these researches will have been skimmed by the great progress at present in the photographic spectrum. Nevertheless, the extent of the spectroscopic astrophysical field of endeavor is so great that innumerable new problems will arise and be solved in the early years of the satellite station. These problems particularly concern not only the nature, composition and evolution of stars, but the processes going on in the atmospheres, particularly loss of material, circulation of great clouds of material about double-star systems, and possibly in some cases the accretion of matter from the interstellar medium.

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If the nature of stellar evolution has not been thoroughly outlined before the satellite station is built, there is no question but that the space observatory will speed the rate of solution by a large factor. Furthermore, it will be possible to obtain clear insight as to the spectacular novae, super-novae, peculiar variable stars, huge giants, and extremely hot stars, as well as the white dwarfs of extremely high densities.

A very important problem that will probably not be solved before the space observatory will be that of the composition of the interstellar medium. Beyond the earth's atmosphere, it will be possible to determine the percentage of almost all trace elements in the interstellar medium: through the earth's atmosphere, even with radio astronomy techniques, only a very few of them can be isolated. The importance of this problem becomes apparent when we realize that many of the great gas and dust clouds of the Milky Way are stellar incubators in which new stars are, indeed, at the present time being born. We know that we observe many ancient stars, three billion years old or more, and at the same time a number of youngsters, perhaps only a hundred thousand years in age. There are already indications of fundamental differences in composition between these two groups of stars, young and old. Many questions of the greatest import in evolutionary problems concern the way in which the interstellar medium may have changed composition during the three or four billion years of universe history. Possibly these changes have occurred by selective accumulation of stars from lust, rather than the gases, perhaps by the addition of heavier elements to the stellar medium by explosions of stars and nuclear changes within them, or possibly matter is being created at the present time, as Hoyle has suggested.

The observatory in space may well reveal the secrets of the origin of the universe itself. The most important problems for the space astronomer may then become new ones, beyond the horizons of our science today.

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Fred Lawrence Whipple - Biography

A.B., University of California at Los Angeles, 1924-27
Ph.D., University of California, 1927-31
Honorary M.A., Harvard, 1945

Teaching Fellow, University of California, 1927-29

Lick Observatory Fellow, 1930-31

Instructor, Stanford University, summer 1929; University of California, summer 1931

Staff member, Harvard College Observatory, 1931- ; in charge of the Oak Ridge Station, 1932-37

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Fred Lawrence Whipple - Biography (cont.)

Instructor, Harvard University, 1932-38; lecturer, 1938-45; Associate Professor, 1945- ; Chairman Committee on Concentration in the Physical Sciences, 1947-49; Chairman Department of Astronomy, 1949-

Research Associate, Radio Research Laboratory, O.S.R.D., 1942-45, in charge of development of Confusion Reflectors, "Window," as a Radar Countermeasure; was sent twice on consulting missions to the United Kingdom and once to Mediterranean Theatre, 1944; "Window" was used extensively by the American Air Force and Naval Air Forces

Member V-2 Rocket Scientific Panel, U. S., 1946-

Member U. S. National Advisory Committee on Aeronautics, Sub-Committee, 1946-

Member U. S. Research and Development Board Panel, 1947-

Chairman of Commission 22, Shooting Stars, of International Astronomical Union 1946- ; and member of Commission 20, Positions and Motions of Asteroids, Comets and Satellites; and Commission 36, Spectrophotometry

Research Associate of the Institute of Meteoritics, University of New Mexico, 1947-

Member of Committee on Standardization in the Field of Photography, American Standards Association

Member U.S.A. National Committee of International Scientific Radio Union, 1949-

Active leader of Project on Upper-Atmospheric Research via Meteor Photography sponsored by the Bureau of Ordnance, U.S. Navy, 1946-

Vice President American Astronomical Society, 1948-50

Recipient of Donohue Medals for the independent discovery of six new comets

Recipient of Presidential Certificate of Merit for scientific work during World War II

Recipient of J. Lawrence Smith Medal of the National Academy of Sciences for research on meteors, 1949

Member Pi Mu Epsilon, Phi Beta Kappa, Sigma Xi, American Academy of Arts and Sciences, American Association for the Advancement of Science, American Astronomical Society, American Meteoritical Society, American Geophysical Union.