N77-33068

THE AERONOMY STORY: A MEMOIR+

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In the 20th century, recognition of the importance of the physics and chemistry of the Earth's upper atmosphere gave ionospheric research an increasingly strong theoretical base. Eventually, it paved the way for a broad spectrum of scientific activities that are now referred to as space research, or space science. No history of research in space can be complete, I submit, without an account of the part that aeronomy played in the origin of space science, and the role that it has continued to play in international space developments. In this brief memoir, I hope to look very briefly both at the past and the future of scientific research in space from the vantage of my personal experiences.

No attempt will be made here to present a complete picture of the way in which ionospheric research and aeronomy eventually led to research in space; rather, my account will be essentially autobiographical. Such an approach seems warranted because relatively few scientists early recognized the importance of the physics and chemistry of the Earth's upper atmosphere. Fewer still were responsible for the truly remarkable impact that upper atmospheric research had upon international cooperation in science in the 1950s. The creation of that remarkable enterprise, the International Geophysical Year (IGY), and the unprecedented continuation of space research thereafter, stems from the same taproot as aeronomy.

In a remarkable tribute published on the occasion of Sydney Chapman's eightieth birthday,[1] there are four short articles, each with the title "Ionospheric Physics and Aeronomy." The authors are J.A. Ratcliffe, David R. Bates, M. Nicolet and W.B. Hanson.[2] These four distinguished investigators call attention to the contributions that this great scientist made to two of the most exciting parts of what I now like to refer to as "Astrogeophysics." I refer, of course, to two important disciplines, ionospheric physics and aeronomy, experimental and theoretical methods for studying the Earth and its

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+Presented at the Fourth History Symposium of the International Academy of Astronautics, Constance, German Federal Republic, October 1970.

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relations to the Sun. With this in mind, I could properly call this short memoir, "The Astrogeophysics Story," because more than any other single influence, the development of aeronomy under the inspiration of Sydney Chapman and a relatively small group of younger scientists has been responsible for the remarkable achievements and even more remarkable promise of science in space.

Chapman's interest in what is now called aeronomy began in the early 1920s, grew considerably in the 1930s, and continued unabated in the period following World War II. It was Chapman, with the help of a few of us who became increasingly active in aeronomy after the end of the war, who supported adoption of the new name, the International Association of Geomagnetism and Aeronomy (IAGA), for what was previously the International Association of Terrestrial Magnetism and Electricity. This change was announced at the 1954 General Assembly of the International Union of Geodesy and Geophysics (IUGG) in Rome, where Chapman was the presiding officer.

With this change in the name of one of the seven associations that made up the IUGG, aeronomy finally found an international home that it has occupied with increasing activity and distinction. I had the privilege of being president of the IAGA from 1957 to 1960, and of the IUGG from 1963-1967. I also had the pleasure of organizing a symposium on the upper atmosphere at the IUGG General Assembly held in Oslo, Norway, in 1958. It was there that aeronomy began to come of age. Subsequently, a regular series of upper atmosphere symposia have been held on the occasion of each successive IUGG General Assembly, and aeronomy has become an increasingly visible and important part of the IUGG and has begun to play a significant role in the activities of the International Union of Radio Science (URSI).

The story of aeronomy, as the reader may have guessed, is largely the story of Sydney Chapman's leadership of an ever-growing group of scientists. In addition to his outstanding scientific example, he brought these men together in the IAGA, helped them develop very important parts of astrogeophysics, and inspired them in many areas of international scientific cooperation that exist today in the International Council of Scientific Unions (ICSU). I say this because aeronomy was principally responsible for the interest in and eventual great success of the International Geophysical Year and its remarkable offspring, science in space.[3] Thus, it was no accident that Sydney Chapman served as the International President of the IGY. It was my honor to be Chairman of the U.S. National Committee for the IGY in the National Academy of Sciences. The story of the IGY and its continuing impact on international cooperation in many areas of science since 1957 is a dramatic example of the unforeseen effects of imaginative scientific efforts.

To provide future historians with otherwise inaccessible material and guidance on the unwritten story, I believe that scientists should write more autobiographical notes than have normally been customary. In this memoir, I should mention briefly my own scientific experiences that have played some part in the development of astrogeophysics. These will be almost entirely restricted to my role in the steadily increasing emphasis on laboratory studies of atmospheric and space physics, and to my related activities in the ICSU.

My interest in atmospheric physics really began in 1927 at Princeton University, with my discovery that the green line of atomic oxygen, a prominent feature to both the aurora and the airglow, could be observed in the spectrum of the Lewis-Rayleigh afterglow of nitrogen. This discovery came shortly after McLennan, also in 1927, had produced an oxygen green line in electrical discharges and identified it with the airglow line measured by Babcock and with the auroral green line. After reading J. C. McLennan's paper I realized that the line I had observed in the nitrogen afterglow was due to traces of oxygen that had been present. This accidental discovery led me to further studies deliberately directed at an understanding of the spectra of aurora and airglow.[4]

At the time of this first observation of the green auroral line of chemiluminescence, I knew practically nothing about either the aurora or the light of the night sky, as the airglow was then known. My principal interest involved the production and properties of atomic gases, based on my thesis on atomic hydrogen, written shortly after R. W. Wood had produced atomic hydrogen in electrical discharges. At Princeton I studied other atomic gases produced by electrical discharges, examining them outside the discharge. I started with further experiments on atomic hydrogen, but soon turned to nitrogen in an attempt to explain the long-lived afterglow of nitrogen, now known as the Lewis-Rayleigh afterglow.

The fact that the Lewis-Rayleigh afterglow was a property of nitrogen, combined with my accidental observation of the green line in the afterglow, led me to believe strongly that continued studies of the afterglow would help explain the then incompletely understood spectra of the aurora and the night airglow. My move in 1928 to the University of California, Los Angeles, brought me into close contact with Babcock and other Mt. Wilson astronomers, and their interest in the night airglow encouraged me to continue my studies of active nitrogen and its possible relationship to upper atmospheric spectra. Here, I should mention the 1928 Cario-Kaplan hypothesis which used both metastable atoms and molecules of nitrogen in an attempt to explain the long life of the afterglow of active nitrogen. None of the metastable atoms or the metastable molecule of nitrogen which were used by Cario and myself to explain the afterglow had ever been directly observed in the laboratory; the green line of oxygen was a "forbidden line" that originated on a low-lying metastable state of atomic oxygen. The idea of introducing metastable states into the nitrogen afterglow problem really came from the discovery of the green line excitation referred to earlier.

During the 1930s I continued studies of active nitrogen that led to the discoveries of other nitrogen afterglows, and to the direct identification of metastable nitrogen molecules and atoms in both afterglows and discharges. These studies also led me to the identification of forbidden nitrogen atomic and molecular radiations in auroral spectra. My relatively simple laboratory studies helped considerably to clarify our understanding of the Earth's upper atmosphere and at the same time added to our knowledge of the atoms and molecules of nitrogen and oxygen. In my own mind at least, I am certain these experiments helped me to realize the importance of the upper atmosphere as a great and complex laboratory in which the chemistry and physics of oxygen, nitrogen and hydrogen could be studied.

The introduction of rockets for scientific purposes in the 1940s led to exciting and rapid developments in aeronomy.[5] Nearly all that we had learned before instrumented rockets became available was subject to changes that this new tool made possible. We could now look at the Sun without the interference of the Earth's atmosphere, and we could study the high atmosphere directly.

My role in these post-war developments, in the second half of the forties and the early fifties, helped stimulate interest in the upper atmosphere. However, I also trained a number of outstanding students, some of whom have distinguished themselves in atmospheric and space research. In addition, I found myself in a strong position to develop support for the then relatively expensive rocket experiments, and in this way to move into the great period of rocket and space studies that occurred during the IGY.[6] I have no doubts regarding the quality and quantity of exciting scientific results that will come to mankind as a result of the initiation of the space program during the IGY.

Part of the citation for the Hodgkins Medal and Prize of the Smithsonian Institution, which I shared in 1965 with S. Chapman and M. Nicolet, stated that the award was given for continuing effort in making and inspiring laboratory experiments directed at understanding the observed radiations from the upper atmosphere, anticipating the significance of space research, major contributions to the International Geophysical Year, and enthusiastic support of international geophysical research. I mention this only because it is very unlikely that the award would have come to me had I not accidentally produced the green auroral line in chemiluminescence many years before.

I submit strongly that as important as the scientific parts of the aeronomy story may be, the social, political and economic aspects of aeronomy, ionospheric physics, solar-terrestrial relationships, and science in space may be far more significant historically. Scientists must learn to tell the story their discoveries hold for society if support for making accidental discoveries in fundamental experimentation is to continue. My part in the aeronomy story is but one of many examples of the significance of such unforeseen discoveries.

REFERENCES

1. Sydney Chapman, Eighty: From His Friends, edited by S. Akosofu, B. Fagle, and B. Haurwitz, (published jointly by the University of Colorado and the University of Alaska, 1968), 230 pp.

2. See Chapman, pp. 27-41.

3. A valuable history of the U.S. IGY Satellite is Vanguard: A History, by Constance McL. Green and Milton Lomask (Washington, D.C.: NASA Historical Series, SP-4102), 1971.

4. Cf., S. K. Mitra, "Lights from the Night Sky," Chapter X, The Upper Atmosphere, Calcutta: Asiatic Society, 1952, pp. 512-15.

5. See H. E. Newell, Jr., High Altitude Rocket Research (New York: Academic Press, 1953).

6. It was my honor to be made chairman of the U.S. National Committee for the IGY in May 1954. See Lloyd V. Berkner and Hugh Odishaw (eds.), Science in Space (New York: McGraw Hill, 1961), a useful summary of the IGY projected for continued effort. Also see Sydney Chapman, IGY: Year of Discovery (Ann Arbor, University of Michigan Press, 1959); Walter Sullivan, Assault on the Unknown (New York: McGraw Hill, 1961); and William Corliss, NASA Sounding Rockets, 1958-1968, (Washington, D.C.: NASA SP-4401, 1971).