LEO GOLDBERG (1913 - 1987): SATELLITES TO SUPERGIANTS

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Abstract

A review is given of some highlights of the scientific and administrative career of the noted American astronomer, Leo Goldberg, and his use of AAVSO data for a recent study of Betelguese (alpha Orionis).

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For Leo Goldberg, the dream of observing the sun from an artificial satellite began in 1937 when he was a graduate student at Harvard. At that time Meghnad Saha visited Cambridge and related the news that physicists in Germany were launching balloons to observe the sun's ultraviolet spectrum (Saha 1937). Saha's enthusiasm for the results of Erich and Victor Regener planted a seed in Goldberg's mind. However, it took two decades for that seed to come to fruition (Goldberg 1974; 1986). Before he could launch a solar satellite, Goldberg had to finish his Ph.D. thesis, secure a position in astronomy, contribute his services to World War II, and await the development of rockets and the right political environment.

Having studied theoretical astrophysics with Donald Menzel, Goldberg completed his thesis in 1938 on "The Intensities of Helium Lines." For it he received from Harvard not only a Ph.D. but also the Bowdoin Essay Prize. He subsequently received an appointment as a special research fellow at the observatory. Harlow Shapley, the director then, wanted Goldberg to develop some marketable skills in observational astronomy. Accordingly, Goldberg began photographing Cepheid variables and visually estimating their magnitudes. For the estimates he used a "flyspanker," a device with a calibrated series of images of different densities. Goldberg later recalled his feelings about that assignment: "Happily, I was rescued from this fruitless exercise by an appointment to the McMath-Hulbert Observatory, where I began my career as a solar astronomer in July 1941, on the eve of our entry into World War II" (Goldberg 1986). During the war years, the armed services needed maps of sunspots to help predict disturbances in the ionosphere that could affect vital radio communciations. So Goldberg sent solar observations taken at the Michigan facility to Washington. As it turned out the success of the solar program in those years secured government support of solar physics in peacetime.

After the war Goldberg came to a turning point in his career: "In 1946, I seriously considered joining Lyman Spitzer at Yale University in a project to instrument high-altitude rockets for spectroscopy, but an offer to become director of the University of Michigan Observatory seemed to offer more challenge." (Goldberg 1986) From 1946 to 1960 Goldberg was not only the director of the observatory but also the chairman of the Department of Astronomy at the University of Michigan. In the 1950's he established a new radioastronomy observatory there and a new vacuum spectrograph at the McMath-Hulbert Observatory. He also played a major role in the events that led to the creation of the Association of Universities for Research in Astronomy (AURA) and Kitt Peak National Observatory (KPNO) in Tucson, Arizona.

While Goldberg was developing ground-based facilities in this period, other astronomers, notably Richard Tousey and his colleagues at the Naval Research Laboratory, were pioneering in photographing the solar ultraviolet spectrum during flights of V-2 rockets. The results were so spectacular that astronomers soon dreamed of transforming the short-lived rockets into long-term satellites that would have an unobstructed view of the whole starry realm. In 1955 both the United States and Russia announced their plans to launch such satellites during the International Geophysical Year (IGY). And with the launch of Sputnik 1 in October 1957, it was Russia that actually opened the door for space astronomy. A year later, when the National Air and Space Administration (NASA) began to operate, Goldberg was ready for the space age with a proposal for astronomical experiments on satellites.

Although he had begun at the University of Michigan to develop instruments for a solar satellite, Goldberg decided to move to Cambridge where he accepted a joint appointment at the Smithsonian Astrophysical Observatory and at Harvard University as the Higgins Professor of Astronomy: "I decided in January 1960 to accept an offer of a professorship in Harvard University and to transfer the solar satellite endeavor to Cambridge. One year earlier, I had declined an invitation from Harvard to become director of its observatory and chairman of the Department of Astronomy because I did not feel I could do justice to the job without incurring strong opposition and even hostility from friends who were also my former professors. Now, one year later, I decided that after 14 years, I had had enough of observatory administration for a while ..." (1986)

During the next decade he was the Principal Investigator for experiments on three of the eight Orbiting Solar Observatories and on the Apollo Telescope Mount of the Skylab mission. The astronomical results from OSO-4, OSO-6, and the ATM/SKYLAB were highly successful. However, organizing solar space experiments in Cambridge was not without trials and tribulations. When he delivered the George Ellery Hale Prize Lecture to the American Astronomical Society (AAS) in 1985 he recalled some of them: "The first years of satellite astronomy were great for character building but barren for science. Three of the early OSO's suffered disasters; one accidentally tried to launch itself from inside the hanger [sic], another suffered severe damage from high-voltage arcing in orbit, and a third fell into the Atlantic. But eventually all the pieces fell into place, in a figurative sense, and the program was a great success. More than seven years after we began work, images radiated by a series of ions with successively higher ionization potential displayed the structure of the sun's atmosphere at different heights in the chromosphere and corona. It was on images like these that we first called attention to the coronal holes now known to be the sources of enhanced solar wind." (Goldberg 1985a)

In addition to all his space science administration in the 1960's, Goldberg also assumed the directorship of Harvard College Observatory and the chairmanship of the Department of Astronomy at Harvard from 1966 to 1971. Then, in 1971 he headed west to become the director of KPNO, a post he held until 1977. There, he turned from looking at space data of solar spectra to studying ground-based data of supergiants. In particular, he began working on high-resolution profiles of spectral lines in Betelguese (Goldberg et al. 1975).

Soon after he became the director of KPNO, Goldberg garnered several honors: the Distinguished Public Service Medal presented by NASA in 1973; selection as President of the IAU for the term 1973-1976; and an invitation from the AAS to give the Henry Norris Russell Lecture at its December 1973 meeting in Tucson. The topic of his talk was "Research with Solar Satellites" and in it he recalled: "The sight of a new spectrum would be sure to evoke excited and enthusiastic comment, particularly if it were in a previously inaccessible spectral region. Thus, no one expressed more eloquently than Russell the sense of excitement and anticipation with which astronomers reacted to the first ultraviolet spectra of the Sun obtained with a V-2 rocket by Tousey in October of 1946. In May 1947, Russell wrote me that 'these rocket spectra are certainly fascinating. My first look at one gives me a sense that I was seeing something that no astronomer could expect to see unless he was good and went to heaven!'"

In September 1977 Goldberg was chairman of a U.S. delegation of nine astronomers and one historian of Chinese science who spent 25 days in China visiting observatories and other scientific institutions (Goldberg 1978). The purpose of the visit, jointly arranged by the U.S. and China, was to further relationships with Chinese astronomers and survey the state of science there. Although China's tradition in astronomy dates back to the fifth century B.C., it had declined steadily since the fourteenth century A.D. The situation began to change in the twentieth century when the Purple Mountain Observatory was built on the outskirts of Nanking. However, three years after it was completed in 1934, Japan occupied Shanghai and the astronomers moved south to Yunnan Province. There they set up an observing station near Kunming. This station has now expanded to became the Yunnan Observatory, the principal center for astronomical research in the south of China. Most of the other observatories active today were built after the establishment of the People's Republic of China in 1949.

There are some programs in variable star research at Yunnan Observatory. And both the Purple Mountain Observatory and the Hsing-lung station of Peking Observatory have been searching for flare stars and variables in interstellar dark clouds. Purple Mountain Observatory has also been engaged in the photometry of Cepheid variables with ultra-short periods of less than 0.1 day (Goldberg 1978).

Meanwhile, back at KPNO the development of high-resolution spectroscopy on the 4-meter telescope made it possible for Goldberg and others to look for pulsations, convection, and other solar phenomena in bright stars such as Betelguese. It had been observed that the angular diameter of the supergiant increased with decreasing wavelength, suggesting limb darkening and possibly scattering by dust. The latter phenomenon implied mass-loss. Therefore Goldberg made some of the first measurements of the periodic motions in the atmosphere of Betelguese (Goldberg et al. 1979) to study its mass-loss (Goldberg 1985b). He also investigated how changes in its radial velocities related to its variability (Goldberg 1984a).

Another new technique used at KPNO to observe Betelguese was that of speckle interferometry. Developed in the late 1960's by Antoine Labeyrie in France, it was applied to the supergiant by C. Roger Lynds and his co-workers (1976). When they analyzed Betelguese with this technique, they produced the first picture of a stellar surface ever seen (McAlister 1988). Subsequently, Goldberg and his colleagues used the technique to determine the diameter and limb darkening for the supergiant (Cheng et al. 1985 and 1986).

In May 1979 Goldberg delivered the George Darwin Lecture to the Royal Astronomical Society. First he discussed the problems of determining the mechanisms and rates of mass loss in bright giant and supergiant stars. Then he presented his analysis of various radial velocities obtained with new high-resolution spectroscopic techniques. His results indicated that the model for the atmosphere of Betelguese be revised to include mass loss (Goldberg 1979). In January 1980 he and his colleagues reported to the AAS that while the radial velocities of the shell absorption lines remained constant from 1974 to 1979, those of the photosphere decreased by 8 km/sec, signifying motion toward the observer (Goldberg et al. 1979). And in a subsequent analysis of data taken in 1984-1986, his assistants determined a 420-

day period for the variations in radial velocity of five metallic absorption lines in the photosphere (Patten, Smith, Goldberg 1987). They reported it at the AAS meeting in January, 1988.

Of interest to the AAVSO is that when Goldberg needed an ongoing set of visual observations for Betelguese to correlate with the radial velocity data from the photosphere, he used the extensive and complete set of AAVSO observations from 1917 onwards. In a review paper on "The Variability of Alpha Orionis," Goldberg remarked: "For nearly 50 years after Stebbins' pioneering work [published in 1931] only occasional photoelectric measurements of [alpha] Ori have been published ...In the absence of extensive photometric data, we have been led to examine the records of the AAVSO, which are quite complete for the last 60 years or more ...The AAVSO data must be viewed with great caution. The standard deviation of a single estimate may be as high as 0.2-0.4 mag, but the number of estimates entering into each 25-day mean may be as high as 50. Some observers tend to be systematically high in their estimates and others systematically low; differences as large as 0.5 mag. have been noted for the same night. Nevertheless, the sheer volume of the data and their extensive temporal coverage make them worthy of attention. Moreover, the data show several systematic trends, some over long time periods, which are difficult to attribute to observational error." (Goldberg 1984a)

In this paper Goldberg pointed out that the large, rapid decreases in the radial velocity that had frequently been observed in alpha Orionis might be connected with the star's pulsation. He also suggested that instabilities in the atmosphere could be related to mass ejection and the formation of dust grains (Karovska 1986).

During the 1980's, while he continued working on scientific problems such as mass-loss in red supergiants, Goldberg received in 1985-1986 the first appointment to the Martin Marietta Chair of Space History at the National Air and Space Museum of the Smithsonian Institution in Washington. There, he enjoyed outlining and writing papers on some of the highlights of his life in science: from the early days of studying quantum mechanics at Harvard, through the days of sending up solar experiments on OSO satellites, to heading up a delegation to go to China. Always a pioneer, Leo Goldberg has left a large legacy, both scientifically and personally.

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Photograph 1. Leo Goldberg.