ESSAYS ON SCIENCE AND SOCIETY

Of Comets and Meteors

As an Iowa farm boy, I contracted a case of polio and it prevented me from becoming a professional tennis player. When I entered the University of California at Los Angeles, it was still my main ambition to excel at tennis. A mathematics major enabled me to bring home good grades without having to spend much time on studies. But I never made the tennis team.

In my junior year, I shifted from mathematics to astronomy because the course Frederick C. Leonard gave had intrigued me, and this determined my career. Subsequently, he obtained a teaching fellowship in astronomy at the University of California at Berkeley for me. After earning my Ph.D., I accepted Harlow Shapley's offer to head Harvard College Observatory's observing program. My interests, besides computing comet orbits and looking for new comets on the photographic plates—I found six—included galaxies, but the institute's director made it clear by subtle means that this area of research was not for me.

A brilliant Estonian, Ernst Opik, had demonstrated that the sun's gravitational field could hold meteors in huge orbits around the sun. He also concluded that many meteors were on hyperbolic orbits about the sun. In 1933, I calculated the radiants of meteors that might belong to the gravitational field of a nearby star, Sirius, through which we were passing. But none of the observed radiants of meteors suggested a hyperbolic origin.

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In 1936, Fletcher Watson and I used newly available small synchronous motors as timing shutters over the small patrol cameras at the two Massachusetts stations of Harvard Observatory, separated by 26 miles. I began to measure the density of the atmosphere above 60 km altitude by calculating the atmospheric drag on meteoroids.

World War II interrupted this program. During the war, I worked in radar countermeasures at the Harvard Radio Research Laboratory. I coinvented the chaff-cutter that transformed 3 ounces of aluminum foil into 3000 half-wave dipoles, which, when dropped by B-17 or B-24 aircraft, produced echoes that confused German radars. Also for the military, I later invented a "meteor bumper," a thin outer skin for a spacecraft that could explode a meteoroid (at a speed of many miles per second), such that only gas would strike the real skin of the spacecraft without puncturing it. This "Whipple shield" has been improved and is used on most space vehicles today.

After the war, I returned to my photographic meteor studies in New Mexico, assisted by two co-workers. We utilized super-Schmidt meteor cameras, which were ideal for photographing meteors, producing precise velocities and orbits along with upper-atmospheric densities over the range of roughly 60 to 90 km. Almost all the meteor orbits came out to be elliptical about the sun, leaving perhaps 1% or so uncertain enough that they might be hyperbolic. This conclusion still seems to hold today.

In the 1940s, many astronomers believed that comets were interplanetary gravel banks, not discrete bodies. I was convinced that they must be discrete bodies of ice and dust, but had no proof. On each return, the comet with the shortest period (3.3 years), Encke's Comet, returned half an hour to an hour earlier than predicted. This led to the idea that it might be encountering some mysterious resisting medium in space. Halley's famous comet also returned three days late in 1910. I finally realized how the orbit of such a body might change slightly through the gas vaporization from the ices.

The vaporizing ice leaves the comet with relatively high speed, producing a reactionary force. This results in a slight change in the comet's orbital motion. The idea that comets consist of ice and dust (called "dirty snowballs" by the press) is now generally accepted. When Halley's comet returned in 1986, it showed a discrete nucleus about the size of Manhattan, finally confirming the concept.

When an artificial satellite was proposed for the International Geophysical Year (IGY) in the middle 1950s, I became involved. At that time, international geodesy was still primitive, with uncertainties of 100 meters or more for points on land and up to a kilometer for island positions. An artificial satellite would be a marker that could be used for geodesy by photographic observations with Earth-based cameras. Newly designed cameras for tracking the proposed artificial satellite from 12 stations around the world would reduce the worldwide geodetic uncertainty to 10 meters. The National Science Foundation provided the funds.

I also proposed and helped organize an amateur international *Moonwatch* program for tracking satellites. By 1959 there were more than 200 teams active in many countries. When the Russians won the IGY satellite contest by launching Sputnik in October 1957, the U.S. military refused to release information about it. The amateur teams were the only American source of information about Sputnik, easily visible to the naked eye as it circled the world.

My scientific staff fulfilled my promise of geodetic accuracy. Today, the progress in electronics and radar, along with artificial satellites, has produced the global positioning system (GPS), which makes such geodetic positioning accuracy available to anyone at negligible cost.

Today, the incredible potential of space exploration is beginning to be realized. Not much longer will we be confined to Earth. There is reason to hope that Earth-crossing bodies that might devastate large areas of our planet can be found and diverted.

Fred L. Whipple

was born in Iowa in 1906. During his career as an astronomer, he discovered six comets and advanced the study of comets and meteors. He has encouraged amateur astronomers and advised many U.S. governmental and scientific agencies.

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