# editorial

## Opportunities in astrophysics

The articles appearing in this special issue on astrophysics show vividly why this field has become one of the most exciting areas of work in modern physics and astronomy. My own conviction will be evident since, after some years in optics and microwave physics, I have lately been working in astrophysics. The trend toward astrophysics could become even more pronounced with physicists from a wide variety of fields attracted to astronomy and making significant contributions. As a ready example, one can foresee many interesting problems for optical physicists in the area of astrophysics that engages our group at Berkeley—the development and exploitation for astrophysics of techniques for electromagnetic waves ranging from a few centimeters to a few microns. Recently at a symposium of the Optical Society of America on the future of science and technology I had the opportunity to point out that this broad region of the spectrum represents one of the more neglected areas of physics, and one that has been particularly underdeveloped for astrophysical uses. One should not underestimate the importance of x-ray astronomy, ultraviolet astronomy, or even further developments in the more extensively exploited visible region. But between 1-cm and 1-micron wavelengths there are four decades of the spectrum that are promising for astronomy and where fascinating discoveries have recently been made, but which are as yet remarkably undeveloped.

Consider sensitivity, for example. In the optical and in the microwave region, techniques are available that can detect a signal borne on only a few photons. In much of the infrared region, $10^4$ to $10^5$ photons are presently needed, so that one can hope to gain several orders of magnitude in sensitivity. Why does the infrared region appear so poor in sensitivity? In part, it is because infrared heat radiation is so pervasive that it interferes with infrared signal detection. On the other hand, with modern cryogenics, as well as the possibility of working in space beyond the atmosphere, there is no reason why instruments cannot be in a very cool environment and thus realize several orders of magnitude gain in sensitivity even in the regions of most abundant heat radiation.

There are also orders of magnitude to be gained in spectral resolution. It has only been during the last couple of years that the first spectral line from outside the solar system was clearly detected in the ten-micron region. This region is one of the more transparent atmospheric windows and is rich in molecular and atomic resonances, but even here techniques for astronomy are quite undeveloped. Of course, many parts of the infrared region are almost completely unused because one can't get through the opacity of the atmosphere. There are others where favorable conditions, such as low water-vapor pressure and high altitude, allow partial transparency. But with high-flying airplanes, high-altitude balloons, satellites—and perhaps in one, two or three decades astronomy on the lunar surface—the entire four decades of the spectrum between 1 cm and 1 micron could be made available for fruitful astronomical work.

In the realm of spatial resolution, there is also an enormous improvement possible. In the visible region, we have had Michelson's stellar interferometer and then the Hanbury-Brown–Twiss interferometer. In the microwave region there has been the spectacular development of long-baseline interferometry, with baselines stretched from continent to continent. Work reported recently by Michael Johnson on a 10-micron stellar interferometer that uses the coherence of laser beams and heterodyne detection is, I believe, the first attempt at very high angular resolution in the middle of the infrared region. It seems likely that such interferometry can be extended to large baselines, and consequently to exceedingly high angular resolution, on many bright and interesting infrared objects. Such resolution may also give striking new precision in measurements of proper motions and for crucial experiments in cosmological and gravitational physics.

Very large collecting surfaces may eventually be used in the infrared, with the possibility of compensating for atmospheric disturbances by use of coherent test signals, or of eliminating the atmosphere entirely by working in space or on the lunar surface.

Astronomy has in the recent past dealt primarily with the hottest objects found in the heavens, and yet we now know that a very large fraction of the mass in space and many important evolutionary processes involve cooler objects that emit weakly or almost not at all in the optical region. Thus, wavelengths longer than those of visible light allow us to study such objects as dust clouds and protostars, and to see through the obscuration that has so plagued visible astronomy into new and interesting regions such as the center of our own galaxy.

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