The three-dimensional global magnetic field of the solar corona was mapped by computer graphics from a spherical harmonic solution of Laplace's equation, with the measured line-of-sight field through the photosphere of the sun. The derived coronal maps were compared with a photograph of a solar eclipse. [The SCI® indicates that this paper has been cited in over 160 publications.]

Martin D. Altschuler
Department of Radiation Therapy
School of Medicine
University of Pennsylvania
Philadelphia, PA 19104

January 28, 1987

At the end of the 1950s a photoelectric (spectral-differencing) device called the magnetograph was put into operation at the Mt. Wilson Solar Observatory. It could measure, with high spatial resolution, the weak line-of-sight component of the photospheric magnetic field across the visible solar disk. The first years of magnetograph operation revealed the existence of large-scale magnetic fields in the photosphere, with a net unipolar magnetic flux. The magnetograph opened the possibility, suggested 25 years earlier by S. Chapman, that the spherical harmonic method used to study the earth's magnetic field could also be used for the sun. With the assumption that the powerful electric currents that generate the solar magnetic field are confined to the photosphere and below, measurement of the line-of-sight magnetic field component over the entire solar surface can provide the boundary condition for the solution of Laplace's equation, and thus the magnetic field of the solar corona. Gordon Newkirk, Jr., and I acquired data from R. Howard of Mt. Wilson for an entire solar rotation (which included the eclipse of 1966) and solved for the current-free coronal magnetic field in terms of spherical harmonics. Enormous magnetic-field loops that extended high into the corona and connected distant photospheric points mapped by E. Parker and Chapman had been discovered, and the dynamics driving this wind draws the coronal magnetic field radially from the sun. The effect of the solar wind on the coronal magnetic field could be simulated with a zero-potential surface at about two solar radii (because several fields are perpendicular to constant potential surfaces). This surface was included in our calculations, and the resulting current-free coronal magnetic field was compared with the eclipse photographs, with encouraging results.

Our work was successful because it appeared at the dawn of the scientific space age, just as the sun was being mapped in new wavelengths. G. Dulk and J. Wild showed that there were large radio bursts stretched along our calculated loops of coronal magnetic field. The K i coronal line, D. Howard and I developed, revealed similar large-scale magnetic-field loops. To obtain the three-dimensional density distribution of the corona, R.M. Perry and I developed techniques analogous to medical computed tomography (CT). Combined, the calculations of coronal density and magnetic field revealed 'coronal holes' with a current-free magnetic field above unipolar photospheric regions. Also, the propagation of coronal magnetohydrodynamics (MHD) waves from flares was calculated by Y. Uchida, who found that wave intersections with the chromosphere explained flare disturbances known as Moreton-Athay waves. Later, much improved magnetic maps were developed. R. Levine showed that many of the terrestrial magnetospheric disturbances could be traced to coronal holes at high solar latitudes.

All these three-dimensional efforts led me away from solar physics and into the emerging technologies of medical CT-scanning, computer vision, and three-dimensional optimization for radiotherapy. My coauthor, Newkirk, became director of the High Altitude Observatory and remained at the forefront of solar research until his death this past year.