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# This Week's Citation Classic®

**Altschuler M D & Newkirk G, Jr.** Magnetic fields and the structure of the solar corona. I: methods of calculating coronal fields. *Solar Phys.* 9:131-49, 1969.
[High Altitude Observatory, National Center for Atmospheric Research, Boulder, CO]

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 (visible solar surface) as a boundary condition. 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.]

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At the end of the 1950s a photoelectric (spectral-lineshape-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 relatively large areas of 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 appeared on our maps. However, less than a decade before, the solar wind predicted by E. Parker and Chapman had been discovered, and the dynamics driving this wind draws the coronal magnetic field radially out from the sun. The effect of the solar wind on the coronal magnetic field could be simulated with a zero-potential surface[1] at about two solar radii (because curl-free 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 made possible not only by the magnetograph but also by the existence at the National Center for Atmospheric Research of the large CDC mainframe computer and a new graphical display technique (now called vector computer graphics).

After the *Citation Classic* paper appeared, the application of our technique to solar studies was enhanced by the dedication of a remarkable woman who averaged and digitized by hand an entire atlas of magnetic-field maps. To see how the spherical harmonics and the coronal magnetic field changed with time, Dorothy Trotter averaged each map (one per month) of Howard's atlas of photospheric magnetic fields (1959-1966)[2] into 1,080 equal area boxes. (After 1967 the averaging was done by computer!)

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 large loops of coronal magnetic field. The X-ray corona from Skylab visually revealed similar large-scale magnetic-field loops. To obtain the three-dimensional density distribution of the corona, R.M. Perry and I developed techniques[3] analogous to medical computed tomography (CT). Combined, the calculations of coronal density and magnetic field revealed "coronal holes" with radial magnetic field above unipolar photospheric regions. Also, the propagation of coronal magnetohydrodynamics (MHD) waves from flares was calculated by Y. Uchida,[4] who found that wave intersections with the chromosphere explained flare disturbances known as Moreton-Athay waves. Later, much improved magnetic maps were developed.[5] R. Levine[6] 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.


1. **Schatten K H, Wilcox J M & Ness N F.** A model of interplanetary and coronal magnetic fields. *Solar Phys.* 6:442-55, 1969. (Cited 90 times.)
2. **Howard R, Bumba V & Smith S F.** *Atlas of solar magnetic fields 1959-1966.* Washington, DC: Carnegie Institution of Washington, 1967. Publ. No. 626.
3. **Perry R M & Altschuler M D.** Improved three-dimensional mapping of the electron density distribution of the solar corona. *Solar Phys.* 28:435-56, 1973.
4. **Uchida Y, Altschuler M D & Newkirk G, Jr.** Flare-produced coronal MHD-fast-mode wavefronts and Moreton's wave phenomenon. *Solar Phys.* 28:495-516, 1973.
5. **Altschuler M D, Levine R H, Stix M & Harvey J.** High resolution mapping of the magnetic field of the solar corona. *Solar Phys.* 51:345-75, 1977.
6. **Levine R H, Altschuler M D & Harvey J W.** Solar sources of the interplanetary magnetic field and solar wind. *J. Geophys. Res.* 82:1061-5, 1977.





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