22 APRIL 2005 VOL 308 SCIENCE www.sciencemag.org

Solar Wind Origin in Coronal Funnels

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The origin of the solar wind in solar coronal holes has long been unclear. We establish that the solar wind starts flowing out of the corona at heights above the photosphere between 5 megameters and 20 megameters in magnetic funnels. This result is obtained by a correlation of the Doppler-velocity and radiance maps of spectral lines emitted by various ions with the force-free magnetic field as extrapolated from photospheric magnetograms to different altitudes. Specifically, we find that Ne^{7+} ions mostly radiate around 20 megameters, where they have outflow speeds of about 10 kilometers per second, whereas C^{3+} ions with no average flow speed mainly radiate around 5 megameters. Based on these results, a model for understanding the solar wind origin is suggested.

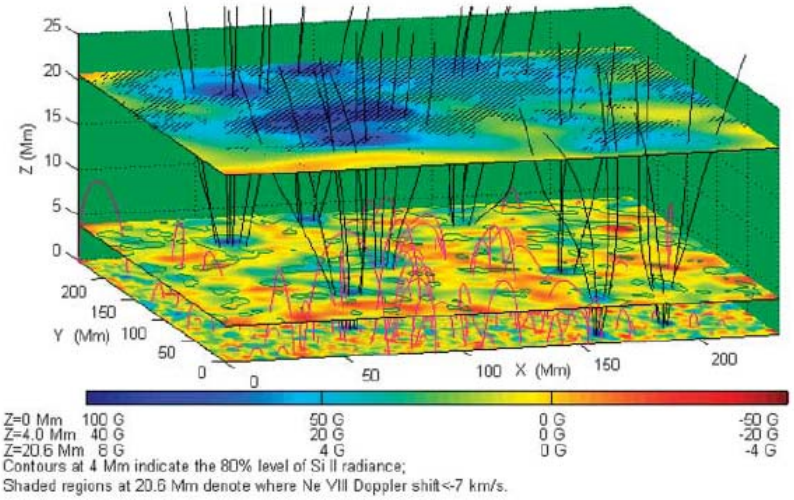

Fig. 4. Magnetic field structures in the 3-D solar atmosphere. The black solid curves illustrate open and the red curves closed field lines. Because the magnetic field strength decreases with increasing height (Z) in the corona, the scales on the color bars differ for different Z. In the plane inserted at 4 Mm, we compare the Si II radiance with the extrapolated B_z. The contours delineate the 80% level of the Si II radiance. In the plane inserted at 20.6 Mm, we compare the Ne VIII Doppler shifts smaller than −7 km/s with the extrapolated B_z. The shaded areas indicate where the Ne^{7+} outflow speed is larger than 7 km/s.

MDI and SUMER data from SOHO

PHOTOSPHERIC AND HELIOSPHERIC MAGNETIC FIELDS

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(Received 26 August 2002; accepted 24 September 2002)

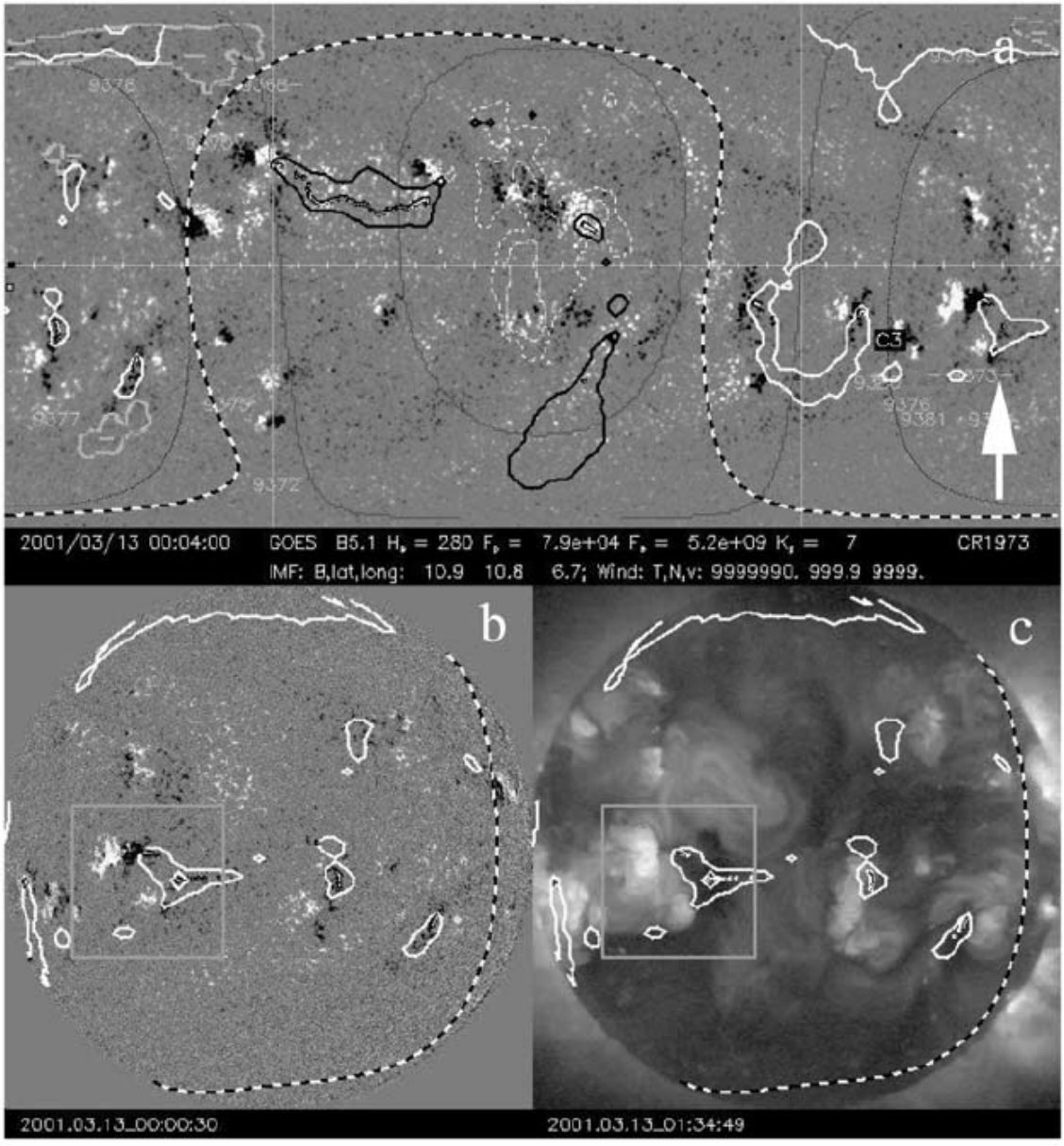

Figure 1 (a-c).

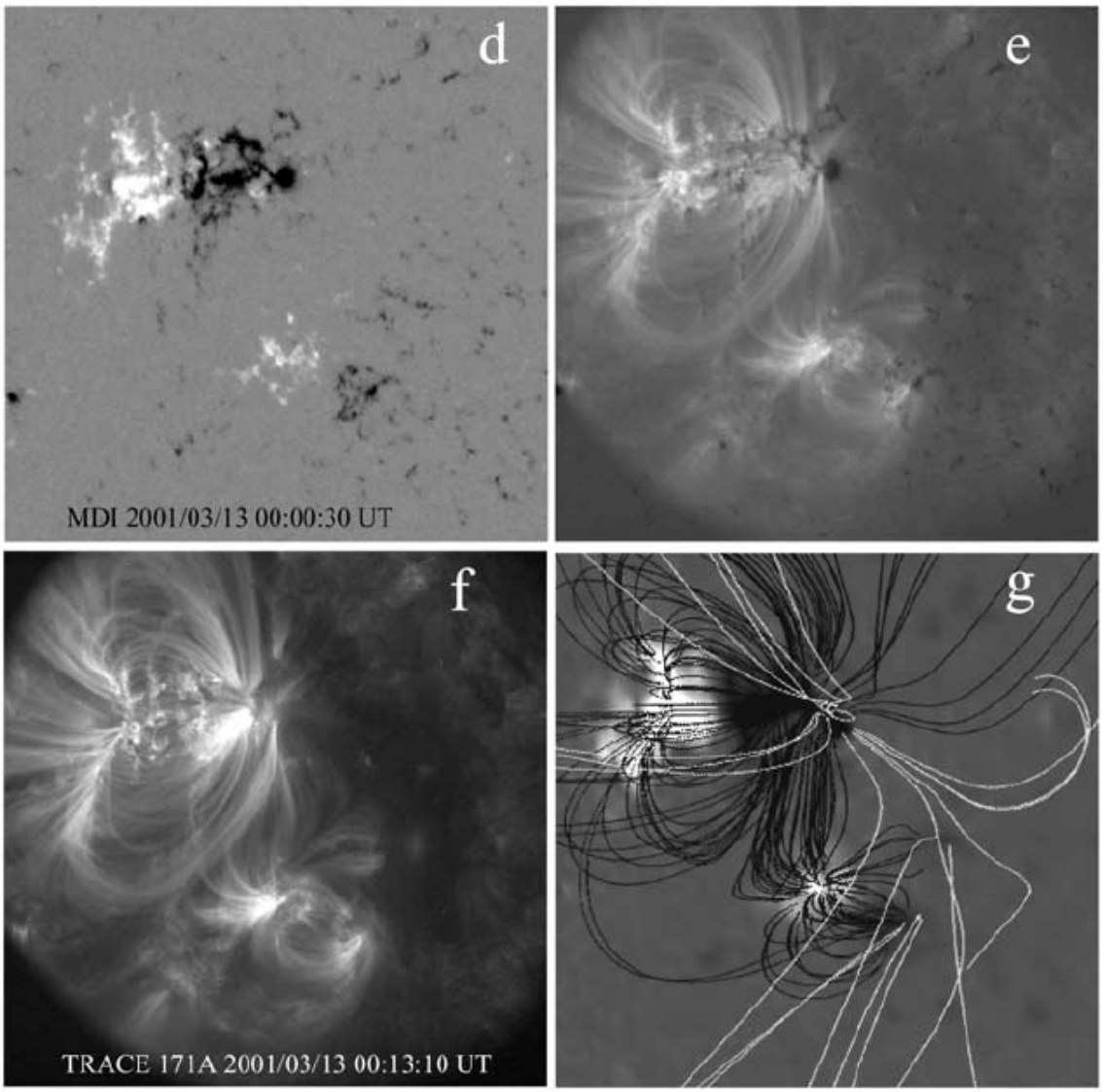

Figure 1 (d-g).

Figure 1. (a) Sample assimilation image (cf., Movies Ia and IIa on the CD-ROM): a $\sin(\theta) - \phi$ map of the photospheric magnetic field showing the 60° assimilation window (*large thin black oval*), front-back separators (*white vertical lines* 90° from 0° latitude at disk center), the far-side acoustic information (*thin dashed contours*), He 10830 Å coronal hole boundaries (*gray*), the projected current sheet (*black-white dashed*), the footprints of the open field (*black and white contours*) and of the equatorial IMF (*small dots*), and AR, flare, and filament-disappearance information. (b, c) SOHO/MDI magnetogram with contours of open field, and *Yohkoh*/SXT Al/Mg X-ray image with contours of open field (together shown in Movie III). See Appendix for further details. (d) MDI magnetogram detail (see gray square in panels (b) and (c)). (e) Blend of aligned TRACE 171 Å image and MDI magnetogram. (f) TRACE 171 Å image. (g) Detail of field extrapolation shown in Figure 13: open field lines are shown in *light gray*, closed field lines in *black*. The starting points of the field lines are determined by a random likelihood, proportional to the flux density in the magnetogram.

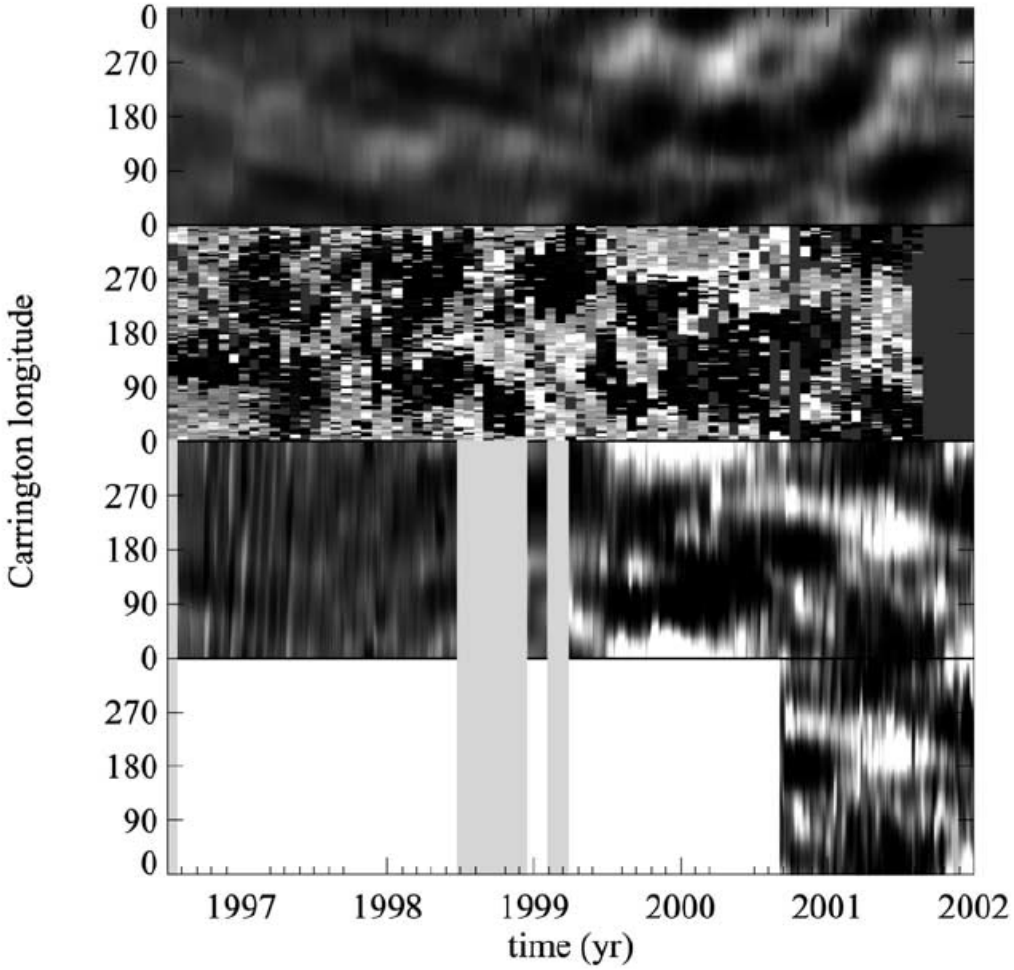

Figure 2. Gray-scale longitude–time diagram of the strength of the heliospheric field over the solar equator at the source surface at 2.5 $R_\odot$ (where it is a close approximation of the IMF). Each panel shows a vertical line for each 6-hr time step, that shows the field strength at the source surface. *Upper strip*: simulation model M of solar activity. *Second strip*: observed IMF at Earth (see text; neutral gray where no value is available – see right-hand edge). *Third strip*: model A based on assimilated MDI magnetograms. *Lower strip*: model A_f, which includes the assimilation of far-side acoustic images. Monopole corrections were applied as necessary.

Solar Physics **212:** 165–200, 2003.