Scientists Measure Sun's Smallest Visible Magnetic Fields

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Solar physicists from Lockheed Martin , and The Institute of Theoretical Astrophysics of the University of Oslo have analyzed the highest resolution images ever taken near the solar disk center and found surprising new small-scale magnetic field structures. Their results, which were reported yesterday at the American Astronomical Society's meeting in Denver, address long-standing issues on the formation and decay of sunspots and the forecasting of magnetic activity such as solar flares and coronal mass ejections. Such activity influences the upper atmosphere and magnetosphere of Earth and can damage satellites in orbit.

"These new images and magnetic field measurements show that the Sun can still surprise us when we look at things 100 km (62 mile) in size," said Dr. Tom Berger, principal investigator on the study, and solar physicist at the Lockheed Martin Solar and Astrophysics Lab (LMSAL) at the company's Advanced Technology Center in Palo Alto, Calif. "Using the Swedish one-meter Solar Telescope (SST) on the island of La Palma, Spain, we have discovered new ways in which the smallest 'elements' of the Sun's magnetic field arrange themselves in the turbulent flowfields of the Sun's surface."

The Sun undergoes an 11-year cycle in which its magnetic flux, as seen most prominently in the form of dark sunspots, peaks and wanes. Sunspots demarcate highly magnetic "active regions" in the solar atmosphere that unleash flares and coronal mass ejections. When coronal mass ejections are directed toward Earth they can damage satellites in orbit, expose high flying airplanes to radiation, and even adversely effect power stations on the ground. Scientists still do not understand how active regions are formed, why they vary with a roughly 11-year period, or how and when flares and mass ejections occur.

In addition to the large and obvious sunspots, active regions contain a myriad of smaller magnetic structures surrounding the sunspots. These smaller structures are much more dynamic than sunspots, constantly emerging, moving, and rearranging due to their interactions with the convective flowfield. This constant motion in the small-scale "plage" fields around sunspots builds up magnetic "tension" in the larger scale magnetic fields, like a spring winding tighter and tighter. The magnetic "spring" eventually snaps causing "magnetic reconnection" and subsequent flares and/or mass ejections.

Scientists are uncertain of the origin of the small-scale magnetic structures on the Sun. Some of the structure clearly originates from sunspots as they decay away over their lifetime. But small-scale structure is found all over the Sun, often far from sunspots in regions of "quiet Sun." Sunspots are believed to be formed by a "global-scale dynamo" system located about 30% of the way down to the Sun's center, at the bottom of the "convection zone." However recent observational and theoretical evidence suggests that most of the small-scale magnetic flux in the quiet Sun may be generated by a "local dynamo" mechanism seated in the upper convection zone and photosphere. Determining where and how magnetic fields are generated on the Sun, and by inference on other stars as well, is a key goal of astrophysics.

The images used in this study (that can be accessed at the URL below) reveal small-scale magnetic fields in the area of a decaying active region. By studying the structure and motion of these small-scale fields, scientists hope to be able to differentiate between magnetic structures generated from sunspot decay and those perhaps generated by a local dynamo process.

When these images were first seen, Dr. Berger and the team were surprised to find a variety of magnetic formations that had not previously been seen on the Sun. Earlier studies, based on images from smaller telescopes, had led scientists to believe that small-scale magnetic structure always took the form of small discrete "flux tubes," or individual blobs of magnetic field. However the new images show surprising "ribbon" and "flower" structures that indicate much more complex interactions of the small-scale magnetic field with the granule flowfield.

In addition to the images, the new data includes the highest resolution magnetogram, or direct measurement of the density of magnetic fields on the Sun, ever taken. By combining the images and the magnetogram, Dr. Berger and the team are measuring the magnetic content of these new structures for the first time. Further studies of magnetic flux in quiet Sun regions will be used to compare with the images shown here in an effort to understand the origin and fate of small-scale magnetic flux on the Sun.

Preliminary analyses of the data are in a paper submitted for peer-review to the journal Astronomy & Astrophysics .The authors are Dr. Tom Berger and Dr. Alan Title of Lockheed Martin Solar and Astrophysics Lab; Dr. Luc Rouppe van der Voort, Dr. Mats Carlsson, Dr. Viggo Hansteen, Astrid Fossum, and Elin Marthinussen of The Institute for Theoretical Astrophysics, University of Oslo; and Dr. Goran Scharmer and Dr. Mats Lofdahl of The Institute for Solar Physics of the Royal Swedish Academy of Sciences, Stockholm. Future studies will examine movies of these small-scale structures to determine their dynamical interactions with granules.

Headquartered in Bethesda, Md., Lockheed Martin is a global enterprise principally engaged in the research, design, development, manufacture, and integration of advanced-technology systems, products, and services. The Corporation's core businesses are systems integration, space, aeronautics, and technology services. Employing about 125,000 people worldwide, Lockheed Martin had 2002 sales surpassing $26.6 billion.

NOTE TO EDITORS: Low- and high-resolution JPEG image files of the discovery are available at the following URL: http://www.lmsal.com/Press/SPD2004/

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