By Dr. M. H. Montgomery

'Thousands of Tiny Hammers' Drive the Sun's Beat

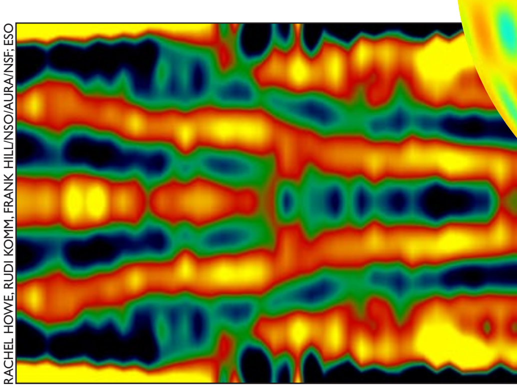
We like to think of the Sun as a steady and stable star, and for the most part it is. In fact, it is likely that this stability has been a key factor in the development of life on Earth. The Sun is not completely static, however, and like a small child (or indeed, many adults), it just can't quite sit still.

While the Sun is approximately 4.5 billion years old, it has several phenomena which occur on shorter, more human time scales. For instance, there is the "solar cycle," in which the number of sunspots peaks every 11 years. This cycle is also accompanied by the flipping of the Sun's global magnetic field from north to south or south to north. In addition, the sunspots themselves form and dissipate with a time scale of a few months. Finally, the Sun also has flares which erupt within a few minutes and dissipate in a few days.

But the Sun has another behavior which it does regularly with a time scale of 5 to 15 minutes: it jiggles, or, more precisely, it oscillates. In fact, the Sun doesn't just oscillate in one mode at a time; it oscillates in over one million modes simultaneously!

Each of these oscillation modes has a slightly different frequency and structure, so each one tells us something different about the Sun's interior. For instance, some of these modes propagate from the surface down to the center of the Sun, while others stay just near the surface.

By using the information contained in the different modes we are able to reconstruct the interior structure of the Sun. In fact, given the wealth of data available, we may know more about the center of the Sun than we do about the center of Earth! For instance, we know that the depth of the Sun's surface convection zone is 28.7 percent of its radius, and we know that it rotates like a solid body inside of this point.



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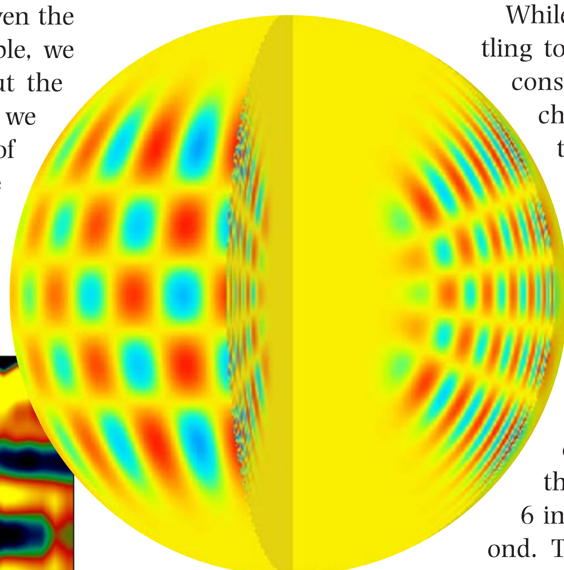

Above: The Sun rings like a gong with thousands of vibration modes, which are shown by different colors. At left, differences in how fast the Sun is rotating at different latitudes, from 1996 (left) to 1999.

In fact, we can make a close analogy with a terrestrial phenomenon. Every now and then, Earth has an earthquake, producing waves which travel through the planet's interior and reemerge elsewhere on its surface. Some of these waves are recorded by seismographs, and by combining the information from many seismographs, we learn about the structure and composition of Earth's interior. This is how we know, for instance, that Earth's outer core is liquid rather than solid. This field of research is called seismology.

Similarly, there are processes in the surface of the Sun which act as a source of waves.

The outer 29 percent of the Sun is convective, which means that hot fluid from below is continually bubbling up and cooler fluid from the surface is sinking downward. This makes the surface of the Sun a bubbling cauldron, and these bubbles shake the Sun and cause it to vibrate. Put another way, the Sun is like a gong which is constantly being hit with thousands of tiny hammers, causing it to vibrate with thousands of frequencies simultaneously.

Each of the thousands of rising and falling convective bubbles acts as the source of a "starquake," so we can think of the Sun as continuously having earthquakes. In analogy with Earth, this field of study is called helioseismology, and the study of the oscillations of other stars is called asteroseismology.

While it might be unsettling to think of the Sun as constantly bubbling and changing, these pulsations are reassuringly small.

The change in the Sun's brightness caused by a given oscillation mode is only about one part per million. The speed at which these changes move across the Sun's surface is just 6 inches (15 cm) per second. This smallness makes them completely negligible from an everyday standpoint, and is the reason that solar oscillations were not definitively detected until the early 1980s.

Solar-like oscillations have even been detected in a handful of other stars, and future space missions and ground-based telescopes will allow us to analyze the structure of these stars in the same way that we now study the Sun.

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