two coupled resonators were operated near the lasing regime. When adding loss by the nanotip, the detuning in the imaginary part of the eigenvalues reduced the loss of the mode in the resonator without the nanotip up to the point where the lasing threshold was reached, and the coupled system experienced a loss-induced onset of lasing.

The observation and control of an EP for a laser opens the way toward many further studies such as on self-pulsation effects in the temporal dynamics of the laser (*11*). A way to explore the fascinating topological aspects of EPs is to encircle them in the two-dimensional parameter space, parameterized by the nanotip-induced loss and the coupling strength. In passive resonators, a curious mode exchange and the accumulation of a geometric phase have been observed for this situation (*12*). How these phenomena translate to the lasing regime, where nonlinear mode interactions also play a role, is still an open question that may occupy both theorists and experimentalists in the years ahead.

> ***"The observation and control of an exceptional point for a laser opens the way toward many further studies..."***

Even beyond lasing, non-Hermitian systems can be found in many other contexts. In optical sensing, EPs can enhance single-particle detection (*13*), and in optomechanical systems, they can enable applications such as a phonon laser (*14*). Similar non-Hermitian concepts have even been applied to finance, where non-Hermitian Hamiltonians are used to describe stochastic financial instruments with striking effects that just wait to be explored. ■

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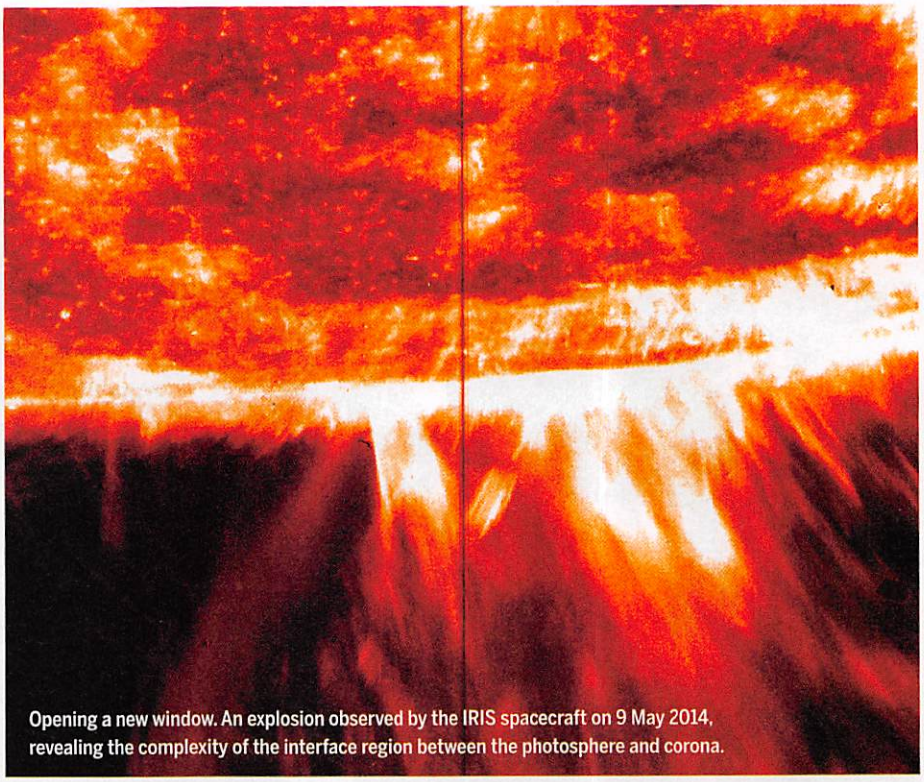

Opening a new window. An explosion observed by the IRIS spacecraft on 9 May 2014, revealing the complexity of the interface region between the photosphere and corona.

PHOTO: NASA/IRIS

ASTRONOMY

Looking closer at the Sun

The space-based IRIS telescope provides a new window to view the solar atmosphere

By **Louise K. Harra**

The Sun's atmosphere is a dramatic and dynamically changing one. The physical domains encountered as the atmosphere is explored from the Sun's surface to the outer corona differ widely. The region where the differences are more notable is the interface region, where the plasma characteristics change from optically thick to optically thin and the regime goes from gas-dominated to magnetic-dominated. NASA's Interface Region Imaging Spectrograph (IRIS) (*1–5*) is now observing this elusive region. The first results from the mission are showing a world of twisted magnetic fields throughout the region, "bombs" exploding at regular intervals, evidence of particle acceleration causing heating in coronal loops, and small jets and loops appearing at cool temperatures. These results are providing important input into how the solar atmosphere is created and maintained and how the solar wind is formed.

The Sun is the largest object in the solar system, providing the heat and light that allows us to survive. It is a middle-aged star that produces energy through nuclear fusion of hydrogen to helium at its core. The enormous energies propagate through the interior of the Sun by radiation and convection. In the convection zone, the churning hot plasma creates magnetic fields. Our first view of the energy escaping the Sun is at the surface (the photosphere). Here, evidence of the convection that occurs in the interior is seen—the magnetic fields that appear help to form the heliosphere within which the planets are shrouded. The heliosphere drives the solar wind that flows past our planet, and is the source of large explosions that can affect our delicate Earth environment.

The magnetic fields are the source of the "coronal heating problem": As you move away from the Sun's surface (and farther from the heat source in the core), the tem-

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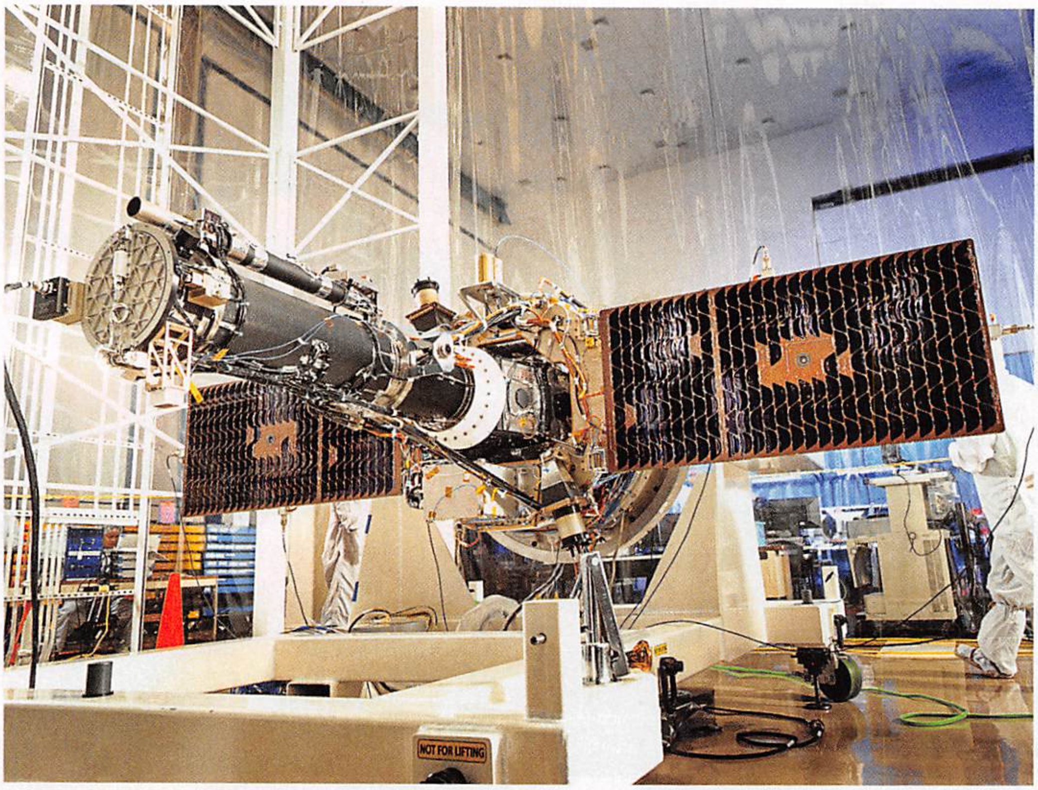

Preparing for launch. Interface Region Imaging Spectograph (IRIS) with solar wings deployed in the clean room.

PHOTO: JIM DOWDALL/LOCKHEED MARTIN

perature increases. The goal for solar physicists is to determine how the Sun produces winds with speeds that can be 50 times those of the most powerful hurricanes on Earth, and can create energetic flares that release tens of millions of times the energy of a hydrogen bomb. Although the magnetic field is known to be key to this understanding, the actual details of the energy transfer through the solar atmosphere have so far remained unclear.

IRIS, launched in June 2013, is the latest in a line of solar observatories that are exploring the Sun's interface region. It is a 20-cm telescope that observes near- and far-ultraviolet light from the Sun, which is normally blocked by Earth's atmosphere. It was designed to explore spectroscopically the elusive interface region of the Sun's atmosphere between the surface of the Sun (photosphere) and the outer hot atmosphere (the corona). This region has been difficult to observe because it goes from being optically thick to optically thin, from partially to fully ionized, and from gas to magnetic domination. In recent years, advances in computation have permitted the development of 3D radiative magnetohydrodynamic models that can provide insight into the observations made by IRIS.

IRIS has exceptional spatial resolution. With its spectroscopic capability focused on the interface region, it can probe the hot plasma to determine parameters such as temperature, speed, turbulence, and density. The example image of a large explosion at the solar limb reveals the incredible complexity of the Sun's atmosphere (see the first figure). The first results from IRIS address some of the key unsolved questions in solar physics.

The high-resolution IRIS observations have revealed red- and blue-shifted plasmas that exist parallel and adjacent to each other (*2*). The evidence for twist or torsional motions is seen in every magnetic domain on the Sun, from the quietest region to the larger active region, and even in coronal holes where the magnetic field is dominantly open. Evidence of the magnetic fields being so twisted provides insight into how energy is created and how rapid heating is associated with these regions of strong twist. Another phenomenon that has been revealed for the first time is that of very short, low-lying magnetic loops in the quiet Sun (*1*), settling a debate about their existence that had been raging for many years. The measurements show that this emission cannot be accounted for just by thermal conduction back from the hot corona. These loops are short and dense and can lose their energy effectively through radiation. They are also found to occur naturally in advanced 3D magnetic models that have recently become available. IRIS observations in coronal holes have also uncovered frequent high-speed small jets (*5*) that are located in the network structures that highlight the convective cells. These fast jets may contribute plasma to the solar wind.

IRIS has also explored the larger regions of strong magnetic field, called active regions. In a newly created active region, Peter *et al.* (*3*) found small regions of plasma within the active region that reach temperatures of 100,000 K and are embedded in a region of much lower temperature. They are found in small regions where magnetic flux of opposite polarity converges, and evidence of a bidirectional jet is seen, where the magnetic field lines that are being pushed together squeeze the plasma in both directions. These "bombs" that are firing off have much greater energies than previously expected.

In active regions, the dominant features in the atmosphere are the long magnetic loops stretching from one polarity region to another. Testa *et al.* (*4*) found rapid variability at the footpoints of these loops, and investigated what could create these. They found them to be heated by accelerated beams of nonthermal particles, which are generated in very small-scale flares called nanoflares. Through comparison with advanced numerical models, they have developed diagnostics that can probe the nonthermal characteristics of the smallest-scale particle acceleration ever observed. This provides much-needed constraints on models of how these particles are accelerated to such high energies—a process that is expected to occur throughout the universe in other, more distant, astrophysical phenomena.

The early results reported by the IRIS mission show the power of spectroscopy in terms of understanding energy sources on the Sun. All the phenomena described so far are low-energy or small-scale phenomena. With the Sun close to reaching a maximum in activity, IRIS observations will continue to be important to our understanding of the solar wind that emanates from the active latitudes, solar flares, and coronal mass ejections. ■

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