A 'bucket full of photons' may yield clues about the Sun's magnetic fields

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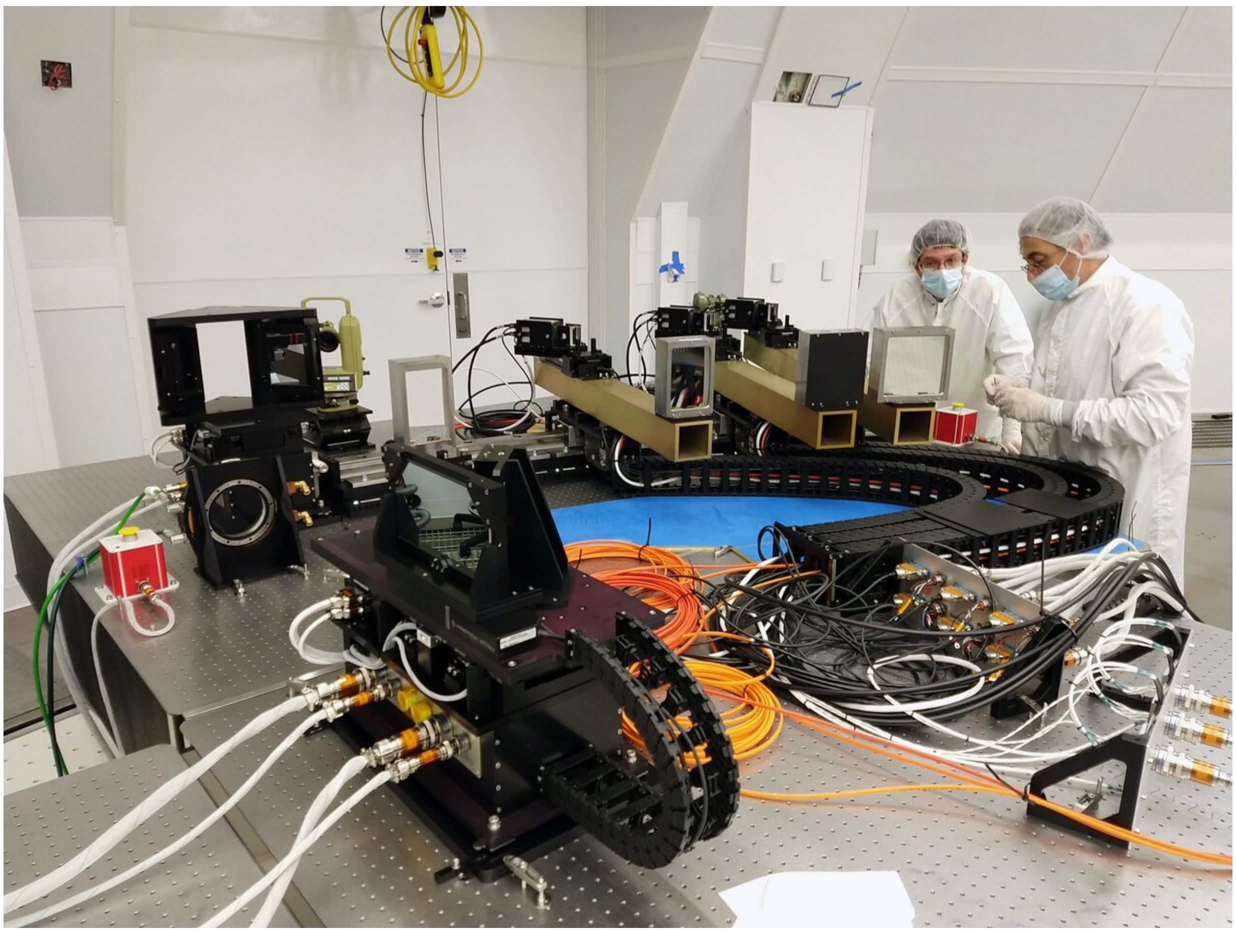

Predrag Sekulic of the National Solar Observatory (left) and Roberto Casini of NCAR's High Altitude Observatory (right) work on the three tunable spectral channels of the Visible Spectro-Polarimeter in the Inouye Solar Telescope's instrument room. Credit: Andrew Carlile, HAO

The first images from the National Science Foundation's 4-meter Inouye Solar Telescope, released in late January, revealed the Sun in jaw-dropping detail. The telescope's size—it is the largest solar telescope in the world—allowed researchers to zoom in on the solar surface at a higher resolution than ever before.

But the new telescope's size has another advantage beyond the ability to capture the Sun at an unprecedented resolution. It will also allow scientists to capture an unprecedented amount of light.

"You can use a big telescope, like the Inouye Solar Telescope, two ways," said Roberto Casini, a scientist at the National Center for Atmospheric Research (NCAR). "You can look at the Sun in the finest detail the telescope aperture allows, or you can sacrifice some of that detail to use the telescope like a photon bucket. The Inouye Solar Telescope gives us a very big bucket."

Scientists at NCAR's High Altitude Observatory (HAO) hope that using the telescope as a photon bucket will give them the opportunity to discover new signatures of polarization across the spectrum of visible light radiating from the Sun, which may have been too faint to find with previous smaller telescopes. Such signatures, which give scientists critical clues about the workings of the Sun's intricate magnetic fields, are easier to pick out when more sunlight can be captured.

To search for these signals, Casini and his HAO colleagues designed and built one of the Inouye Solar Telescope's five instruments: the Visible Spectro-Polarimeter (ViSP). This extremely versatile instrument can observe any wavelength across the visible spectrum of the Sun's radiation, allowing scientists a huge degree of flexibility to explore. It will also be coupled with a facility software package that will quickly turn the data collected by ViSP into a science-ready product. Casini hopes that ViSP's engineered flexibility and its data-processing capability will spark a renewed focus on what mysteries the Sun's polarized light can reveal.

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From the few to the many: making spectro-polarimetery accessible

For more than a century, scientists have known that magnetic fields affect the light emitted or scattered by the ions in the solar atmosphere, producing polarization. By modeling and interpreting the polarization signature of these fields, scientists can trace the large-scale shape and structure of the Sun's magnetic fields. Ultimately, this will help researchers better understand solar eruptions and how to predict them. These violent events produce space weather that has the potential to disrupt radio communications, power grids, and GPS signals, as well as endanger astronauts and damage satellites.

But detecting and interpreting the polarized light from the Sun has always been a challenge. Part of the reason is because the signal is typically very weak, and scientists need to collect a lot of photons to distinguish that signal from the Sun's unpolarized background. The instruments used to detect polarization also contribute to this difficulty because they can introduce polarization themselves. For example, the mirrors used in telescopes to direct the path of the incoming light to the detector also polarize that light. The skill that has been needed to disentangle the polarized signal coming from the Sun and interpret that signal is quite specialized.

"Solar spectro-polarimetry up to this day has been an art mastered by only a few," Casini said.

HAO has a long history in the science of spectro-polarimetry and has built other instruments to study the Sun, including a spectro-polarimeter that is still operating at the Dunn Solar Telescope on Sacramento Peak in New Mexico. But the amount of observations taken by that instrument and others has far outstripped the amount of science-ready data made available to the community. This is because the observations are bottlenecked waiting for one of the few experts in the field to do the complex analysis needed to turn the raw data into something usable by a broad range of solar scientists.

Casini—who still keeps a cardboard box of tapes from Sacramento Peak sitting on his office floor until he has time to analyze them—says ViSP and the Inouye Solar Telescope are designed to break this bottleneck. The instrument, which can be set up and run with a minimum of human intervention, will feed data directly into facility software that can digest the information and transform it into a usable product for science.

"We want to overcome the inaccessibility of the science of polarimetry and create science-ready data for everybody," Casini said.

The possibility of discovering something new

The hands-off, automated design of ViSP has another distinct advantage as well. Unlike its predecessors, which have to be manually reconfigured to study different wavelengths of light, ViSP set up can be easily modified from a computer console to observe any wavelength in the Sun's visible spectrum.

With older, labor-intensive spectro-polarimeters, scientists have tended to stick with well-tested wavelengths of light that are already known to be sensitive to the Sun's magnetism. Scientists will be able to use ViSP to study these same wavelengths, and exploit the resolution of the Inouye Solar Telescope to look at this polarization in unprecedented detail.

But ViSP will also give scientists a license to explore the full spectrum of visible light, where they may stumble on new polarized signals that have never been discovered before and which could enrich their understanding of the Sun's magnetic fields. Finding these previously undiscovered signals is perhaps more likely with ViSP because, in addition to the instrument's automated flexibility, it is mounted beneath an enormous telescope capable of letting in so much light. New polarized signals may be fainter than those that are already known, and their detection will require an even larger pool of photons in order to isolate the signal from the noise.

"Because this is the largest solar telescope, it really provides an opportunity to look for new stuff—things that may have been neglected in the past because we didn't have enough light-collecting power," Casini said. "Now we have enough light."

ViSP is still in the final process of site acceptance and science verification, during which Casini and his colleagues are set to show that the instrument is meeting all the promised requirements and it is therefore scientifically viable. Once this process is complete the instrument will begin science operations. Ultimately, all the telescope's instruments, including ViSP, will be available for researchers across the world to use. Casini, for one, is excited for what solar researchers may learn.

"We have really produced an instrument that lets you explore the visible spectrum of the Sun however you want, and we may be surprised by what we find," he said. "There is a lot we still may learn from serendipitous discovery."

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