Putting students closer to explosive solar events

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Assistant Professor of Physics Bin Chen at the monument to Karl Jansky, considered to be one of the founders of radio astronomy, in Holmdel, New Jersey. Jansky, a physicist and radio engineer, first discovered radio waves emanating from the Milky Way in the 1930s while researching interference with telephone communications for Bell Laboratories in Holmdel. In his honor, the unit that radio astronomers use to designate the strength of radio sources is the jansky, and the radio telescope operated by the National Radio Astronomy Observatory in Magdalena, New Mexico, bears his name — the Karl G. Jansky

Very Large Array. Credit: New Jersey Institute of Technology

NJIT has a long-established reputation as a leader in researching phenomena originating on the star closest to Earth—the Sun. NJIT's optical telescope at Big Bear Solar Observatory and radio telescope array at Owens Valley, both in California, have greatly expanded our understanding of solar events that periodically impact our home planet, events such as solar flares and coronal mass ejections (CMEs) that can disrupt terrestrial communications and power infrastructure in addition to other effects.

Under the auspices of the university's Center for Solar-Terrestrial Research (CSTR), NJIT investigators are collaborating with colleagues in the U.S. and other countries to gain even more critical knowledge of solar physics. It's knowledge essential not only for better basic understanding of the Sun but also to improve prediction of the solar explosions that threaten our technologies and to devise better countermeasures.

What's more, NJIT researchers are committed to fully engaging students in the search for this knowledge—researchers like Assistant Professor of Physics Bin Chen, who joined the NJIT faculty in 2016. Chen was recently awarded a five-year CAREER grant totaling more than $700,000 by the National Science Foundation (NSF). The NSF's Faculty Early Career Development (CAREER) program offers the foundation's most prestigious awards in support of younger faculty who, in building their academic careers, have demonstrated outstanding potential as both educators and researchers.

Chen completed his Ph.D. at the University of Virginia in 2013 with a focus on solar radio astronomy. His Ph.D. advisor introduced him to fellow solar astronomer, and now NJIT colleague, Distinguished Professor of Physics Dale Gary. Through his acquaintance with Gary, and the opportunity to collaborate on a research project using observational data from NJIT's Owens Valley Solar Array, Chen learned about the university's leading-edge efforts in solar radio physics. But before he joined NJIT after receiving his doctorate, Chen added to his research experience through a postdoctoral fellowship under NASA's Living With a Star program and as an astrophysicist at the Harvard Smithsonian Center for Astrophysics, where he worked on space missions dedicated primarily to solar science.

Shocking Insights

Although not yet fellow faculty members at NJIT, Chen and Gary did collaborate with researchers from the National Radio Astronomy Observatory, the University of California, the University of Applied Sciences and Arts Northwestern Switzerland and the University of Minnesota on an article for the journal Science published in 2015, "Particle Acceleration by a Solar Flare Termination Shock." The article presented radio imaging data that provides new insights into how a phenomenon known as termination shock associated with solar flares, the most powerful explosions in the solar system, helps to accelerate energetic electrons in the flares to relativistic speeds—propelling these particles into space at nearly the speed of light.

Chen is now continuing this investigation at NJIT. "There is a lot we don't know about the 'inside' of these solar explosions and how they release so much energy so quickly and so catastrophically," he says. "For example, how is the energy stored and suddenly released, often in a matter of seconds?

"The relativistic particle acceleration that we are also studying as part of this research is a process taking place across the universe and is a phenomenon associated with, for example, the massive star explosions known as supernovae. The Sun is a good place to research this phenomenon because its nearness in astronomical terms allows us to acquire a volume of high-resolution data impossible to obtain from observing vastly more distant stars."

For his research, Chen is drawing on streams of radio data from a number of sources. In addition to NJIT's radio observatory at Owens Valley, these include the Karl G. Jansky Very Large Array in New Mexico operated by the National Radio Astronomy Observatory and the Atacama Large Millimeter/Submillimeter Array in Chile. Recent upgrades at Owens Valley put it at the forefront of this research as a "new-generation" radio telescope. Another very important advantage afforded by Owens Valley, as Chen emphasizes, is that it is a facility dedicated full-time to solar research.

Chen is one of the few researchers seeking new knowledge of the Sun by taking advantage of an observing technique called dynamic spectroscopy imaging. This technique allows capturing an image of the Sun every 50 milliseconds at more than a thousand frequencies, and at two different polarizations. This adds up to 40,000 images per second and terabytes of raw data in a day that can be converted into 3D images with resolution far greater than previously obtainable. "This gives us the potential to learn so much more about what is going on in the heart of solar explosions," Chen says.

Beyond greater understanding of the fundamental physics involved, Chen adds that his research is very much supportive of the goals of the U.S. National Space Weather Strategy and Action Plan, which reflects critical awareness of how space weather generated by solar phenomena impacts many aspects of terrestrial life and infrastructure. He says, "Solar flares and CMEs are the main drivers of space weather. Better understanding of these drivers is essential for better prediction of such events and the implementation of protective measures."

Bringing the Sun to Campus

In Chen's estimation, NJIT is uniquely experienced in building, operating and maintaining facilities dedicated to radio observation of the Sun. Potentially, for students, this presents exceptional opportunities to learn at the frontier of the many disciplines relevant to investigating the Sun in the radio spectrum—including hands-on familiarity with the equipment involved. While a limited number of students do have a chance to work at Owens Valley, as well as at Big Bear, distance and lack of appropriate accommodations prevent many more from participating in solar research on site. That's why Chen also plans to apply a portion of his CAREER funding to creating a Solar Radio Laboratory on campus in Newark.

"The idea behind the Solar Radio Laboratory is to have a facility on campus with the same state-of-the-art technology found at Owens Valley, just without the antennas," Chen explains. "We'll have all the electronics, the radio technology, the data-science capability for processing data streaming from California. This will give students the same hands-on opportunities for working and experimenting with the instrumentation that NJIT has at Owens Valley, instrumentation that is really unique in the United States. Another goal is to use this as a test bed for future improvements at Owens Valley, and to engage students in developing those improvements."

For Chen, a complementary educational goal is to also advance the Hale COLLAborative Graduate Education (COLLAGE) program in solar physics, which commemorates the name of the pioneering American solar astronomer George Ellery Hale. There are very few graduate programs in this field in the U.S. and the necessary faculty and physical resources are widely distributed across educational institutions as well as geography. To address this situation, Philip Goode, NJIT distinguished research professor of physics and former CSTR director, proposed that NJIT join with the University of Colorado-Boulder and several other institutions that had solar physics programs in what is now known as the COLLAGE program.

"COLLAGE gives more students in different parts of the country access to the instruction and resources that allow them to complete master's and Ph.D. degrees in solar physics," Chen says. "I am already working with some 20 students, and that's actually quite a large number for our field. But not only are we increasing opportunities to study solar physics at the graduate level, we're learning more about coordinating resources among schools and teaching effectively online, which will benefit students who want to study many different complex subjects."

Provided by New Jersey Institute of Technology

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