solar eclipse PA

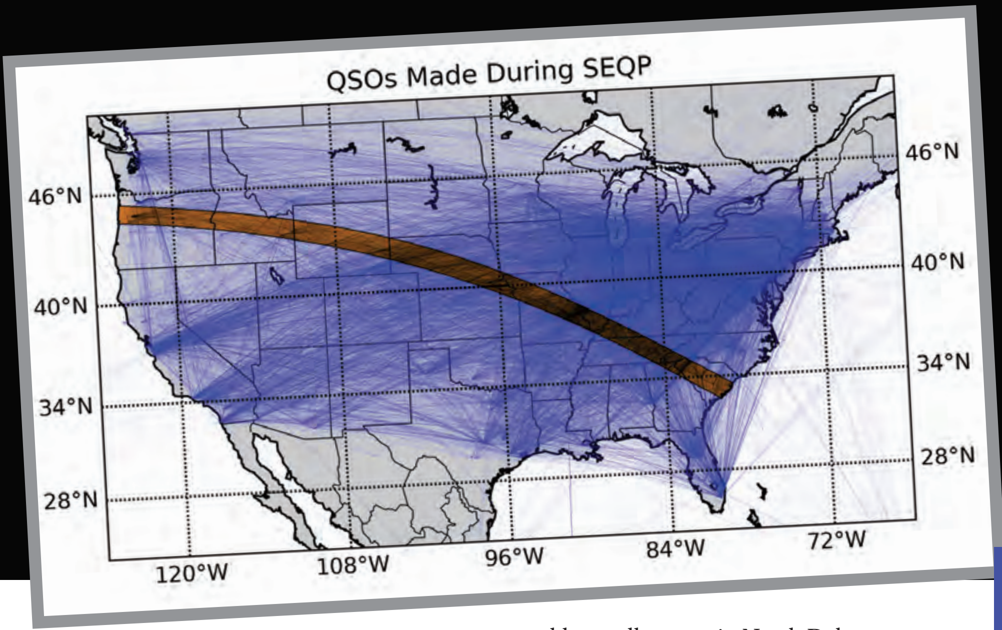
RTY

ON A BACK PORCH IN GILBERTSVILLE, KENTUCKY THIS PAST AUGUST, NEARLY 1,000 MILES WEST OF NEWARK, NATHANIEL FRISSELL MARVELED AT THE EERIE SPECTACLE UNFOLDING IN THE MIDDAY SKY AND THE CREEPING SHADOWS ENVELOPING THE TINY VILLAGE.

"It began with a small bite out of the Sun, and then the day got progressively darker and cooler, like the onset of a thunderstorm. By the time of the full eclipse, it had become almost twilight," he recounted. "We took off our glasses and stared at the Sun, which appeared as a black disk, ringed with bright, flame-shaped light. We were looking at the star's corona with the naked eye."

But Frissell, an assistant research professor of physics at NJIT's Center for Solar-Terrestrial Research, had not traveled to Kentucky merely to stargaze. Stationed directly along the eclipse's "path of totality" in a cabin he'd rented a year in advance and rigged that day with radio equipment, he'd chosen the site as ground zero for one of the largest ionospheric experiments in the history of space science.

He spent the day making contact via a 102-ft. wire antenna with a network of ham radio operators he'd assembled in every region of the world to test the strength and reach of their high-frequency signals as one measure of the eclipse's impact on Earth's upper atmosphere. "We planned to use our transmissions to identify how much of the ionosphere would be affected by the eclipse and how long those effects would last, among other phenomena," he said.



Since the eclipse, Nathaniel Frissell and his team of undergraduate researchers on campus have been compiling data submitted by more than 700 ham operators participating in their experiment that day, as well as from other networks. By recording radio signals, they can measure how different wavelengths behaved at various times following the path of totality. A chart to the left shows the paths of signals sent; graphs to the right show dips in signal propagation at higher frequencies and upticks at lower bands.

CITIZEN-SCIENTISTS UNITE!

More than 1,300 operators registered to take part in his Solar Eclipse QSO Party that day as "citizen-scientists" by recording the time, frequency and locations of their contacts with one another during the event.

Ham radio operators are able to communicate with each other across thousands of miles, despite the Earth's curvature, by using high-frequency radio waves that bounce off the ionosphere – the electrified region of Earth's upper atmosphere formed when ultraviolet light from the Sun dislodges electrons from neutral particles such as oxygen and helium – and are refracted back down on the other side of the globe. The composition of the ionosphere at different levels affects their ability to transmit.

By blocking the Sun's radiation, the shadow of the eclipse should have caused a decrease in ionospheric electron density, strongest in the region of totality, Frissell surmised. Within that zone, conditions would be most similar to night, thereby enhancing the strength and reach of lower band signals, while degrading the propagation of higher bands.

"Low-frequency ham radio signals (1.8-14 MHz) are more susceptible to absorption by the lower regions of the ionosphere than higher frequencies (14-30 MHz). These bands are therefore enhanced when solar radiation – and low-altitude electron production – is reduced. Higher frequencies, on the other hand, require a denser ionosphere for signals to be refracted back to Earth. At those higher bands, we expected the decrease in ionospheric density caused by the eclipse shadow to allow more signals to escape into space," he explained.

"A station in Texas may not normally be able to talk to one in North Dakota on a particular frequency at a certain time of day. We wondered if the eclipse would change the ionospheric state and possibly create communication paths that do not normally exist," he added. "If you suddenly alter the ionosphere as happens during an eclipse, by reducing the number of ions or changing the temperature, for example, does it create waves or instabilities? How far can these effects be detected?"

Since the eclipse, Frissell and his team of undergraduate ham radio researchers on campus have been compiling the data submitted by more than 700 hams participating that day. They're organizing it into six bands of radio frequency, from 1.8 to 28 MHz, and measuring how these different wavelengths behaved at various times following the path of totality. To augment their data set, they're including results from three other international ham radio observation networks as well.

THE ULTIMATE SUNSCREEN

"So far, we're seeing what we expected – a dip in signal propagation at the higher frequencies and an uptick at the lower bands," he says, adding, "For instance, the day started off with a lot of activity on the 14 MHz band, but there seemed to be a drop-off there as we got closer to the eclipse."

Frissell, a sophisticated practitioner of ham radio who is intent on elevating the technology's role in space science research, had been preparing for this rare event for more than two years. While a Ph.D. student at Virginia Tech, he founded the Ham Radio Science Citizen Investigation (HamSCI), an organization that connects professional researchers such as space physicists and astronomers with the amateur radio community. By merging their data, the different groups will be able to construct a comprehensive picture of atmospheric effects caused by space weather events ranging from the eclipse to more frequent phenomena, such as solar flares. In 2014, he first demonstrated the use of ham radio data by showing the effects of an X-class solar flare on high-frequency communications.

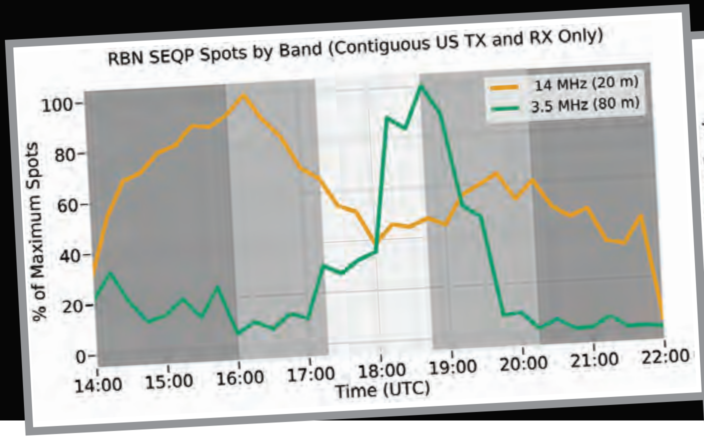
"What's exciting from a researcher's perspective is that people have access to tools such as digital radios and computers that are connected in ways they weren't in the past, allowing us to make observations

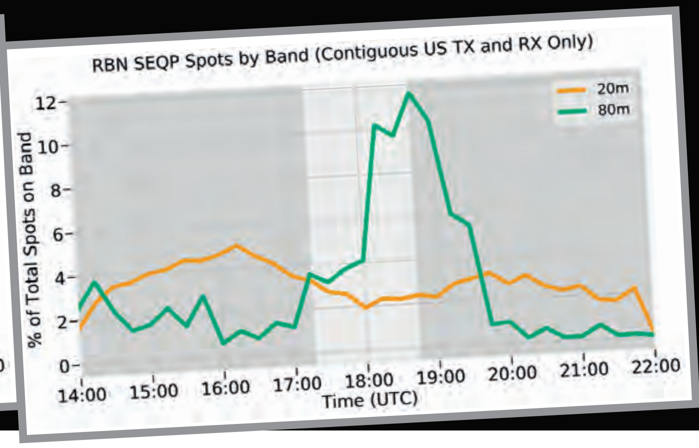
FOLLOWING IN THE MOON'S SLIPSTREAM

While much of the research around the eclipse focused on the effects of the Sun's brief, daytime disappearance on Earth and its atmosphere, a group of solar physicists leveraged the rare event to capture a better glimpse of the star itself.

NJIT physicists Dale Gary and Bin Chen and collaborators observed sunspots – the visible concentrations of magnetic fields on the Sun's surface – at microwave radio wavelengths from NJIT's Expanded Owens Valley Solar Array (EOVSA) near Big Pine, Calif. and from the Jansky Very Large Array (VLA) radio telescope near Socorro, N.M, which is operated by the National Radio Astronomy Observatory.

"Radio waves from the solar corona have long wavelengths, and as resolution is proportional to wavelength, our images ordinarily have rather low spatial resolution. But we can capture sharper images as we move in the direction of the Moon's motion as it blocks different parts of the Sun at different times," explains Gary, a distinguished professor of physics at NJIT's Center for Solar-Terrestrial Research (CSTR), adding, "Radio waves are sensitive to the otherwise invisible corona of the Sun, especially its magnetic field, so we're using the eclipse to make high-resolution images of the corona above active regions."





and then collect and share them," he notes. "For us, the eclipse presented an unusual opportunity to learn things we don't know about the ionosphere and one of the few times we've been able to conduct a controlled experiment around a space weather event. Normally, we have no advanced knowledge over when, where, and how they happen."

HamSCI GOES GLOBAL

His idea is taking off. Over the past year Frissell has been invited to speak at several scientific symposia around the country and in October will describe his research at the Space Weather Knowledge Exchange Workshop in Milton Keynes, England, sponsored by the U.K. Natural Environment Research Council, which seeks to promote ties between radio hobbyists and scientists. He will then share his data and analysis from the eclipse at the American Geophysical Union annual meeting in December.

"Nathaniel's citizen-science project during the eclipse provided unique data on the more global impacts on radio propagation across the wide range of frequencies used by amateur radio operators, who are often emergency communication first responders in their towns and cities around the world," noted Louis Lanzerotti, distinguished research professor of physics at NJIT. "The project also, importantly, stimulated enhanced scientific understanding in the amateur radio community."

STUDENT AMATEURS GO PRO

Frissell has assembled a formidable team of undergraduate researchers on campus who built a website and developed analytical tools to gather and interpret their eclipse data, recorded observations during the event and, on occasion, even lecture like pros.

Two days before the eclipse, Joshua Katz '19, a computer science major and member of the NJIT K2MFF Amateur Radio Club, and Shaheda Shaik, a graduate student researcher at NJIT's Center for Solar-Terrestrial Research, gave a night-time talk on the eclipse to a packed house at the United Astronomy Clubs of New Jersey (UACNJ) observatory at Jenny Jump State Forest. During the eclipse, Katz and Joshua Vega '19, a computer science major, returned to the observatory to run that node of the Solar Eclipse Party under the state's partial shadow cover.

Of the event, Katz enthused, "We'll be participating in an international data-collection effort, learning more about the space weather effects of the eclipse, exposing the general public to amateur radio and watching a beautiful once-in-a-lifetime solar event all on the same day. That's more excitement than programmers and data analysts like me are usually allowed to have in a single sitting!"

Spencer Gunning '20, a computer engineering major and the ham radio team's principal data cruncher and chart specialist, is immersed in hands-on research in the eclipse's aftermath. A principal thrill, he says, is rubbing elbows with so many different scientists. "Since I was seven or eight, I've thought about becoming an astronomer. Now, as a sophomore in college, I'm getting to work with them. Pretty amazing." ■

Tracey L. Regan is an NJIT Magazine *contributing writer.*

HAM RADIO DAYS When Ken Brown '71 was president of NJIT's amateur radio club in the early days of human space exploration, one of the technology's triumphs was the ability to listen in on the unfiltered conversations of Apollo Mission scientists en route to the moon.

This past August, Brown reunited with the club for a new adventure, in which his 21st-century counterparts played scientists themselves in one of the largest ionospheric experiments in space history. At the solar observatory at Jenny Jump State Forest for the eclipse, Brown looked on as Joshua Vega '19, a computer science major, attempted to contact hams around the country to assess the impact of the eclipse on the composition of Earth's upper atmosphere.

"Our roots are the same, but we've expanded into new technology, including digital and satellite communications," noted Peter Teklinski, the club's adviser since 1986. "What hasn't changed is that ham radio offers students the chance to learn – and even build – a new technology and then apply it, provide a service to the community and develop a lifelong hobby."

Formed in 1928, the club has a student-operated radio station with an FCC license, allowing its members to take part in notable events over nearly a century. Since 1988, for example, the club has assisted emergency responders at the New York City Marathon. After the 9/11 attacks, humanitarian aid workers in Edison used NJIT's 147.225 MHz repeater to communicate with mobile kitchens and showers in the old Brooklyn Navy Yard and near Ground Zero in Manhattan.

Looking for recreational outlets his freshman year and hoping to become a DJ, Spencer Gunning '20 stumbled on the radio club's table at open house and asked if he could play music over the equipment. "That's illegal!" was the reply. Intrigued, however, he decided to take a look at the radio room, "where I saw all the cool technology, learned I could have my own FCC license" and was hooked.

Last November, Gunning and Joshua Katz '19, were stationed in Central Park for the marathon, alerting medical technicians to runners in need of help. This fall, Gunning, Katz and Vega accompanied Nathaniel Frissell, assistant research professor of physics, to a digital communications conference in St. Louis to present their findings from the eclipse experiment Frissell orchestrated.

"I've put together statistical charts that look like flight maps, showing how many people participated, how they communicated and how many contacts were made," Gunning said, adding that what he did not predict when he signed up last year was "how many opportunities this has opened up for me." ■