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Plasma is rare on Earth, but it fills the sky. From stars and nebulas to auroras at the poles and solar wind, plasma is the most common visible state of matter – the more familiar ones being liquid, gas and solid.

To more deeply understand this state of matter that makes up 99% of the visible universe, NASA has selected the HelioSwarm mission, an array – or "swarm" – of nine spacecraft, which is tentatively scheduled to launch in 2028 and collect data for at least one year. Kristopher Klein, University of Arizona assistant professor of planetary sciences in the Lunar and Planetary Laboratory, will serve as the mission's deputy principal investigator.

Plasma is matter so incredibly hot that atoms are stripped of their electrons to create what's called ionized gas.

"This mission is leveraging the fact that we have a powerful source of plasma nearby – the sun – that we can use like a natural laboratory to understand this universal process," Klein said.

The sun's plasma is so superheated and energetic that it escapes the sun's gravity and rushes outward as solar wind.

The mission will provide scientists with data to study turbulence in the solar wind. As the solar wind expands to fill the heliosphere – the outermost atmosphere of the sun, which encompasses much of the solar system – it interacts with the magnetic fields of Earth and the
sun, so the mission will study the interaction between these fields as well.

"Studying the interaction between the solar wind and Earth's magnetic field is important from a basic physics perspective, and it's also important to understand how energy moves through the system and evolves," Klein said. "And during periods of heightened solar activity, these processes also affect things like global positioning and communications satellites, other spacecraft and astronauts."

"As a species, we're launching more spacecrafts and are becoming more reliant on having more satellites for everyday activities, so understanding how to live with our star is important," he said.

Most of Klein's research is theoretical. He studies how energy moves through different kinds of plasma. With that background, Klein's role as mission deputy principal investigator is to ensure that the science questions can be answered with the instruments onboard the HelioSwarm spacecraft.

Klein has been involved in two other NASA missions to study the sun: the Wind Spacecraft and the Parker Solar Probe. Many other UArizona Lunar and Planetary Lab faculty will also provide support as the HelioSwarm mission progresses.

HelioSwarm is so named because rather than measuring the solar wind at a single point in space at a given time, the mission will consist of one hub spacecraft and eight co-orbiting small satellites, which will swing in large 14-day-long flower-petal-shaped orbits around Earth to allow for multiple measurements in many different configurations. At its farthest point in orbit, a satellite will reach 60 times the distance between Earth and the moon. The hub spacecraft will maintain radio contact with the other satellites, and radio contact between the swarm and Earth will be conducted through the hub spacecraft and the NASA Deep Space Network of spacecraft communication antennas.

The spacecrafts' ever-changing orbital patterns were intentionally designed to provide a more holistic picture of the solar wind as it evolves.

"Think about the solar wind like a waterfall," Klein said. "If you want to understand a waterfall, you have to measure at multiple points throughout its flow. There have been previous missions that have had a few spacecrafts providing multipoint measurement, but the dream is to have a set of spacecrafts that will be separated in such a way that some of them will be relatively close and others far. By doing that, we can measure both large- and small-scale physics at the same time and get a better understanding of how energy flows and evolves as it moves through the solar system."

The HelioSwarm mission's principal investigator is Harlan Spence from the University of New Hampshire. NASA's Alan Zide is the program executive. NASA's Ames Research Center in Silicon Valley, California, will provide project management. Funding and management
oversight for the mission is provided by the Heliophysics Explorers Program, managed by the Explorers Program Office at NASA's Goddard Space Flight Center in Greenbelt, Maryland.

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