Researchers prepare for quantum sensing in outer space

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The Perito Moreno Glacier in Argentina as seen from the International Space Station on Feb 21, 2012. Credit: NASA

As part of a new NASA Quantum Pathways Institute consisting of a multi-university research team, UC Santa Barbara professor of electrical and computer engineering Daniel Blumenthal will help to build technology and tools to improve measurement of important climate factors by observing atoms in outer space.

"We are peering into a universe that we've never peered into before," he said.

Led by colleagues at the University of Texas (UT) at Austin, Blumenthal and the other researchers will focus on quantum sensing, which involves observing how atoms react to small changes in their environment, using it to infer the time-variations in the gravity field of Earth. This will enable scientists to improve accuracy in measurements of several important climate processes, such as sea level rise, rate of ice melt, changes in land water resources and ocean heat storage changes.

"There have been tremendous advances in quantum methods recently, mostly in the context of computing," said Srinivas Bettadpur, leader of the new project and director of the Center for Space Research at UT Austin. "We want to use quantum sensing technology in space—where you can watch the entirety of the planet—to solve next-generation problems by observing, interpreting and understanding climate processes."

The new Quantum Pathways Institute also includes researchers from University of Colorado Boulder, California Institute of Technology and the U.S. National Institute for Standards and Technology (NIST).

This will be the first effort to establish what is known as "Quantum 2.0"—that is, advancing beyond the quantum principles known in physics and actually translating them into usable device concepts.

The researchers will look specifically at changes in gravitational forces and what they mean for climate. As climate shifts—with ice caps melting and sea levels and temperatures changing—so, too, do gravitational forces around Earth and in outer space. Atoms orbiting

Earth react to those gravitational changes. By measuring those reactions, the researchers can give better readings of changes in climate processes.

The challenge for the team is two-fold. Parts of these sensing technologies exist today, but a lot of what they are building is new.

"In order to do this, we have to take the lasers and photonics and modulators and control electronics that make up 90% of the atom experiments here on Earth, and work really hard to get all that precision onto small, low-power chips that can be deployed in space," said Blumenthal, a self-described "laser person" whose research expertise lies in visible light and atomic and quantum photonic integration as well as optical and communications technologies.

One of the technologies he's working on helping move to the chip scale is the Institute's shaken lattice interferometer structure developed at the University of Colorado. This type of atomic interferometer sensor uses many lasers and optics to cool and trap the atoms to measure gravity gradients with extremely high sensitivity.

Add to that the challenge of sending these instruments into orbit.

"You can't have manual maintenance in space—once you send something out, it's out of reach; you cannot see it," Bettadpur said. "You have to put in a great deal of work to make sure the instrument will fly and the technology will function for several years, at least, to enable the discoveries."

To build this technology from the ground up and make it space-ready requires a large and diverse team of researchers. Bettadpur is an expert in orbital mechanics, gravity fields and space mission design. Blumenthal will be working with electrical and computer engineering colleagues Seth Bank and Dan Wasserman at UT Austin to develop the photonic (lightbased) integrated circuits for compact chips to measure small variations in Earth's gravity from space. Ufuk Topcu, an associate professor at UT Austin's Department of Aerospace Engineering and Engineering Mechanics, will apply his expertise in modeling complex systems to develop models for quantum sensing systems that can be used to improve their reliability and autonomous operation—both of which are key for space applications where device maintenance is not an option.

Other team members include Dana Anderson, an expert in experimental quantum physics and instrumentation; Penina Axelrad, an expert in quantum navigation and timing; Murray Holland, theoretical physics and quantum machine learning; and Marco Nicotra, quantum optical control, from University of Colorado, Boulder. From Caltech, systems, spaceflight and gravity science expert Michael Watkins is also part of the group. Michelle Stephens, a physicist and expert in precision measurement for space and quantum applications, joins from NIST.

Beyond gravity sensing to address Earth's climate issues, Blumenthal sees that this exquisitely sensitive space-based gravitational measurement technology could eventually be deployed for other, Earth-based applications as well as for purposes of future space exploration.

"It could be on the Space Station, or geostationary satellites," he said. "Or they could be sent to Jupiter or Venus or Mars to map out the gravity of those planets."

Provided by University of California - Santa Barbara

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