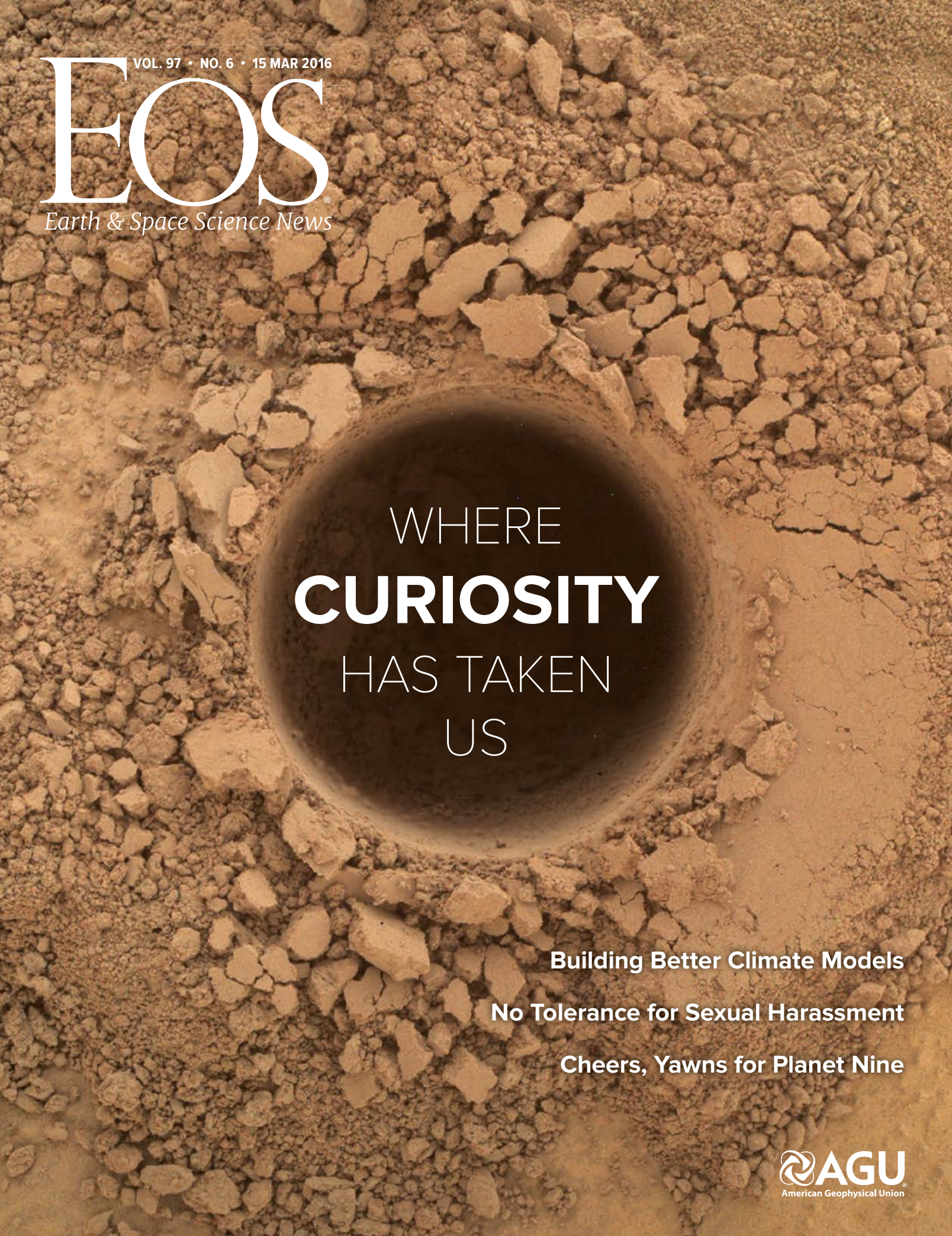
VOL. 97 • NO. 6 • 15 MAR 2016

EOS

Earth & Space Science News



WHERE
CURIOSITY
HAS TAKEN
US

Building Better Climate Models

No Tolerance for Sexual Harassment

Cheers, Yawns for Planet Nine

AGU
American Geophysical Union

Proposed Planet Nine Elicits Cheers, Yawns, Hunt for Proof

For more than a century, astronomers have speculated—in vain—that a giant, unseen planet, or even a lurking sister star to the Sun, roams the fringes of the solar system.

Astronomer Percival Lowell, back in 1906, invoked a "Planet X" to explain the then unaccounted for motions of Uranus and Neptune. In 1984, researchers postulated that a dwarf star, dubbed Nemesis, periodically dipped into a relatively dense region of comets in the far reaches of the solar system, sending comets hurtling toward the inner solar system and causing an apparent 26-million-year cycle of mass extinctions on Earth. Those are just a couple of the ghost bodies that never did turn up.

Enter "Planet Nine." In the *Astronomical Journal* (see http://bit.ly/P9paper), researchers recently reported new evidence of another such orb. Although the observations cited by study coauthors Konstantin Batygin and Mike Brown of the California Institute of Technology in Pasadena are indirect and based on a new analysis of previously known data (see http://bit.ly/Sedna-like), the report made a sensation, lighting up the journal's website with nearly a quarter million downloads in the first 5 days after the paper was posted on 20 January.

"Planet X is proposed every time someone sees some sort of anomaly in the outer solar system," said Brown, an astronomer widely known for his role in helping to demote Pluto to a dwarf planet a decade ago. "Usually those [anomalies] end up being bad data. We think that this is the first time the data actually support the hypothesis," he told *Eos*.

Kuiper Belt Objects Aligned

The data show an unexplained orbital alignment and common motion of six disparate objects in the Kuiper Belt, the doughnut-shaped reservoir of icy bodies, including Pluto, that lies beyond the orbit of Neptune. Those data have convinced some planetary scientists—but by no means all—that gravitational shepherding of the Kuiper Belt objects by a massive, distant planet best explains the mysteriously matching features.

In a blog entry posted the week after the paper was published (see http://bit.ly/Search-4-P9), Brown wrote, "From some very simple calculations, we can show that the probability of these alignments happening due to chance is only about 0.007%. You could also say that there is a 99.993% chance that the alignments we are seeing in the outer solar system are real, and that we are not simply being fooled into seeing a pattern where none exists."

"This is the strongest evidence presented so far" for Planet X, said David Nesvorny of the Southwest Research Institute in Boulder, Colo., who analyzes the dynamics of solar system objects but wasn't involved in the new study.

In 2011, Nesvorny suggested that the present-day architecture of the solar system was best explained if the Sun originally had a fifth giant planet, in addition to Jupiter, Saturn, Uranus, and Neptune. The additional planet would ultimately have been gravitationally kicked out of the solar system—unless a close encounter with a nearby star at just the right time stabilized the orbit, keeping Planet Nine at the solar system's edge, Nesvorny told *Eos*.

Caltech/R. Hurt (IPAC)

The recently proposed "Planet Nine" orbits far from our Sun, which shines dimly in the background of this artist's representation of the purported planet. The astronomers who hypothesized Planet Nine suspect that it would be a gaseous planet similar to Uranus and Neptune. Crackles of lightning illuminate patches of the would-be planet's night side.

Seeing Is Believing

Batygin and Brown's hypothetical planet would lie 7 times farther away than Neptune does, or at 200 astronomical units (AU), when closest to the Sun, on an elliptical orbit that might take it as far out as 1200 AU, the team reported. One astronomical unit is the average distance between the Earth and the Sun.

NASA's Wide-Field Infrared Survey Explorer (WISE) spacecraft, which observes at infrared wavelengths, has ruled out a distant solar system planet the size of Saturn out to 10,000 AU and an object the size of Jupiter out to 26,000 AU (see http://bit.ly/No-Planet-X). But the much smaller Planet Nine would glow, dimly, in visible light, not infrared, Brown explained. Batygin and Brown have begun hunting for the object with the National Astronomical Observatory of Japan's Subaru Telescope on Hawaii's Mauna Kea.

Some researchers have reacted coolly to the Planet Nine hypothesis. "The paper presents some interesting arguments, [but] I think the claims are being made more strongly than the evidence merits," said astronomer Brett Gladman of the University of British Columbia in Vancouver, Canada, who was also not part of the study.

"The arguments that Konstantin and Mike have presented are clever and carefully worked out, but it's not a slam dunk," said exoplanet hunter David Latham of the Harvard-Smithsonian Center for Astrophysics (CFA) in Cambridge, Mass., likewise unassociated with the new Batygin-Brown work. "It's still early in the community reaction to the announcement, and other clever people may come up with counterarguments."

Alignment sans Planet

Astronomers Ann-Marie Madigan of the University of California, Berkeley, and Michael McCourt of the CFA have already presented a different argument. In an article published in the *Monthly Notices Letters of the Royal Astronomical Society* (http://bit.ly/RAS-paper) on the same day that Batygin and Brown published their finding, Madigan and McCourt suggest that gravitational interactions among the myriad small icy objects in the outer solar system can suffice on their own to cause the orbital alignment of the six telltale objects in the Kuiper Belt that inspired the Planet Nine hypothesis.

The researchers' simulations show that gravitational tugs among objects located from about 100 to 10,000 AU from the Sun would drive some of them to form a cone-shaped distribution, inclined to the Kuiper Belt, which in turn could cause the alignments Batygin and Brown studied. "This spontaneous behavior is just something that the disk does on its own—we don't need to invoke an external reason [such as a ninth planet] for it," said Madigan, who described her simulations during a 26 January lecture

at the SETI Institute in Mountain View, Calif (see http://bit.ly/SETI-talk).

Madigan noted that observations can test the validity of her team's hypothesis. In the past, she said, sky surveys generally weren't looking for faint, distant solar system objects in orbits tilted out of the main Kuiper Belt disk because researchers didn't think many such bodies existed. But two ongoing ground-based sky surveys, the Panoramic Survey Telescope and Rapid Response System (Pan-STARRS) and the Dark Energy Camera Legacy Survey (DECam Legacy Survey), can hunt for the cone-shaped distribution of objects that would tilt out of the plane in which the planets orbit the Sun. One object, dubbed 2013 RF98, which has the right coordinates to potentially be part of that distribution, has already been detected by DECam, she said.

Testable Predictions and Other Scenarios

"The good news is that both theories make testable predictions, and we will find out the right answer soon," Madigan said.

In addition to aligning the modestly tilted orbits of some Kuiper Belt objects, Planet Nine should have more radically reoriented the orbits of other Kuiper Belt objects, simulations by Batygin and Brown predict. The unseen planet's gravity would have driven those additional objects into orbits completely perpendicular to the plane in which the solar system's eight known planets orbit the Sun. Over the past 3 years, four such objects have been found. Finding more Kuiper Belt objects with this perpendicular orientation would strengthen the case for Planet Nine, Brown told *Eos*.

Planet Nine and the competing conical distribution of outer solar system objects don't offer the only ways of explaining the alignments of the six Kuiper Belt objects that caught the attention of Batygin and Brown, according to Latham. For instance, a gravitational encounter with a star that passed near the solar system sometime in the past few hundred million years might also do the job, he said.

"How long would the pattern last without a Planet Nine to herd the objects?" Latham mused. "These are not necessarily new ideas, but now there is renewed motivation to look at them. It will be interesting to see if there is a flurry of papers exploring related ideas."

By **Ron Cowen,** Freelance Science Journalist; email: roncowen@msn.com

Report Stresses Need for Real Research in Undergraduate Classes

No one likes an 8 a.m. chemistry lab featuring the same old experiments every year. Now a high-level committee of scientists and educators is offering insights into the challenges, rewards, and prospects of replacing "cookbook" lab work in undergraduate education with course-based research.

In 2012, the President's Council of Advisors on Science and Technology declared that discovery-oriented research courses should replace standard undergraduate lab work (see http://bit.ly/PCAST_STEM). Then a convocation took place in May 2015 under the auspices of the National Academies of Science, Engineering, and Medicine for a fact-finding mission. The group met to learn how educators are incorporating research into their undergraduate courses and whether those models can be applied across 2-year and 4-year institutions, at freshman to senior levels.

> Strategies for integrating course-based undergraduate research must be flexible.

"Bringing research experiences into the academic year course structure will provide opportunities to reach many more students," the committee stated in its report from the convocation, titled *Integrating Discovery-Based Research into the Undergraduate Curriculum* (see http://bit.ly/convoc-report).

Hands-on Science

Niccole Cerveny, a geography professor at Mesa Community College in Mesa, Ariz., developed one of the models of undergraduate research highlighted in the December 2015 report. She believes that undergraduate research should be heavily emphasized in course work.

Several years ago, Cerveny's students spent time at the Deer Valley Petroglyph Preserve in Glendale, Ariz., where they studied natural weathering on Native American rock art. The students created a "weathering index" to help park managers strategize on preservation efforts. Because the research was tied so closely with the local community and culture, the students were much more enthusiastic about the hard work that comes along with scientific discovery.

"Even if it wasn't their own culture, there was meaning in engaging in the science," Cerveny said. "They got positive results of being involved in science."

As an undergrad, Cerveny herself experienced a research-based course and values it to this day. "With my own experience in undergrad research, I just really feel strongly that it's the best way to reach students," she said.

Challenges and Looking Ahead

The biggest challenge to integrating course-based research into undergraduate classes is "not adopting but adapting models" that already exist, such as Cerveny's in Arizona, said Laura Guertin, an Earth science professor at Penn State Brandywine in Media, Pa., who was on the committee that wrote the report. Not every institution or instructor has the same financial or administrative opportunities, so strategies for integrating course-based undergraduate research must be flexible.

Instructors must also adapt, Guertin said. With set lab exercises, instructors know step by step how an experiment will go and how the students will get there. But if you present students with an unknown research question, "that means you as an instructor have to give up some control," Guertin said.

Guertin also pointed out other challenges, such as procuring financial aid for students; providing instructors with sufficient administrative support; and providing support to nontraditional students, such as single parents, those with disabilities, or those in the military.

After meeting to develop a strategy to incorporate more undergraduate course-based research, the committee intends to release a new report in the coming year.

By **JoAnna Wendel,** Staff Writer

Editor's Note: For a personal account about the 3-day convocation that resulted in the report, visit http://bit.ly/Convoc-On-GeoEdTrek to read Guertin's three-part blog post on the AGU Blogosphere.