How do you nail down gravity?

Physicists have been attempting to figure out the strength of gravity for two hundred years, with only limited success. The problem is that gravity is incredibly feeble, compared to electromagnetic, weak and nuclear forces. The force of gravity between two 1-kilogram objects four inches apart is equivalent to a hefty billionth of a pound — about the weight of a single E. coli bacterium. See page 3 →
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Greetings,

It’s an exciting time to be an undergraduate in the UW’s Physics Department. More and more of these young students (59 this year) are doing practical research. This is a major jump from three years ago, when 38 undergrads were doing research; and 1994, when there were only 16.

I have been encouraging undergraduate research in the physics department for a long time, and I am very happy at its explosive growth. I must credit, in part, the scholarships from the Mary Gates Endowment. This year, eight physics undergraduates have received this award, and I expect this trend to continue.

There is more good news for undergraduates. Their instructional laboratories have been on a shoestring budget for as long as anybody can remember. Now, thanks to a new lab fee authorized by the UW, we will receive $175,000 per year dedicated to laboratory improvement and maintenance. Besides updating the freshman labs, we can carefully plan ways to correlate the experiments more closely with the lower-division curriculum. The lab improvement committee is headed by John Cramer, who is planning three types of labs: one for qualitative measurements, another for basic principles, and one for topics that are developed entirely in the laboratory.

In my last message, I talked about my desire to expand our visiting committee to help us raise money for graduate fellowships and develop internships in industry. I am happy to report that we have five new members: David Heckerman, Fred Mottler, David Hadley, Charles Wiborg, and Charles Schmitt. Mottler and Schmitt received their post-graduate degrees here at the UW, and Wiborg received his under-graduate degree here. We spent our first meeting discussing possible industry internships for undergraduates. I am looking forward to future talks, and invite more of you to get involved.

Because of an enormous effort by our recruiters, we have an entering graduate school class of 31 this year — our largest in twelve years. It is becoming more and more competitive to get excellent graduate school candidates, who often receive competing offers from several schools. Because of generous gifts from donors, we were able to offer eight fellowships this year, including three in memory of Kenneth Young. An esteemed member of our faculty who died last year, Young was deeply concerned with the recruitment of graduate students. Among our 31 new students are people from France, Australia, Japan, China and all over the U.S.

As you may already know, the university has come to an important milestone in reaching an agreement with Sound Transit, which is proposing a light-rail system from 45th Street to just beyond Sea-Tac Airport. After years of negotiation, Sound Transit has agreed to isolate the railroad tracks that lie close to the UW in order to protect the research environment in physics, as well as other laboratories. The agency will put a floating slab under half a mile of tracks that run in front of the physics building, the new oceanography building and the projected life sciences building. With this agreement in place, I am hopeful that construction of the light-rail system will not unduly impact us. We should know next month if Congress approves the $500 million funding request for light rail in Puget Sound. If all goes as planned, the system will begin running in the fall of 2006.

Lastly, with this issue of Physics we begin publishing twice a year. I hope you enjoy reading about the ‘weightiest’ discovery in gravity for two hundred years (see next page). Jens Gundlach and the Eot-Wash group deserve our congratulations for their work. We also have a new Physics News section (page 7) written by Vladimir Chaloupka. This section, which you can also find online, includes links to various sites of topical interest in physics.

Sincerely,

David G. Boulware
STALKING GRAVITY

Continued from front page

What’s more, gravity cannot be shielded. You can’t insulate it like electricity. So when you’re measuring the gravitational attraction between two objects, you’re done for the minute the cat comes into the lab, or an airplane flies overhead. Moreover, gravity travels over infinite distances, unlike the strong force acting between quarks.

Recent attempts in the 1990s to zero in on the intrinsic strength of gravity (G) have produced widely disparate results, making the answer even less clear. “It’s an embarrassment to modern physics,” says UW scientist Jens Gundlach.

Gundlach began puzzling over the gravity question about the time he joined the UW physics faculty in 1993. The German-born physicist had been working on tests of the equivalence principle, another important test of gravity, as a post-doctoral student with the Eot-Wash group at the UW. “People would always ask me, ‘How well do you know the gravitational constant?’” says Gundlach. Not very well, he’d have to admit.

In the year 1686, Isaac Newton discovered that any two objects in the universe will attract each other with a force proportional to their mass, and inversely proportional to the squared distance between them. One hundred and twelve years later, Henry Cavendish, an eccentric English nobleman with a scientific bent, measured gravity for the first time. He suspended a weighted dumbbell from a thin fiber and measured the twist in the fiber when two lead balls were put close to it. With his torsion balance experiment, Cavendish measured the strength of gravity with an uncertainty of about seven percent, or 7 parts in 100.

Since then, physicists have conducted hundreds of experiments — most of them variations on Cavendish — to get a more precise value for G. Today, the official value for the strength of gravity, which is set by the Committee on Data for Science and Technology, is uncertain to only 0.15%, or 1500 parts per million. Definitely more accurate than Cavendish, but not close enough for physicists. The strength of electromagnetism, by comparison, is known millions of times more precisely.

In the classic torsion balance experiment, the strength of gravity was measured by the twist of the dumbbell, which is caused by its attraction to the heavy metal balls. Without knowing the dumbbell’s dimensions and its density
 distribution very precisely—a difficult assignment—it was impossible to take an accurate measurement. Gundlach began obsessing about this puzzle.

"I had a Eureka moment," says Gundlach. "I realized that if I made the pendulum a flat plate rather than a dumbbell, I could eliminate the biggest uncertainty of all." In 1997, Gundlach began building his own instrument in the UW's Nuclear Physics Laboratory. He was later joined by postdoc Stephen Merkowitz. Funding for the experiment came from a precision measurement grant from the National Institute of Standards and Technology, as well as from the National Science Foundation.

While Gundlach's experiment, like many before it, was a modification of Cavendish's classic torsion balance experiment, a few simple changes made Gundlach's measurements much cleaner. Replacing the dumbbell with the flat plate was only one of his so-called "tricks." He also put the entire pendulum on a revolving turntable to counteract another nagging problem—the fiber which held the dumbbell was twisting, causing skewed measurements. "Now, the turntable is controlled by a feedback loop that speeds it up or slows it down so that the suspension fiber never has to twist," Gundlach explains.

The gravity-shielding problem (cats and airplanes) was circumvented by placing the two large attractor masses on a different turntable which revolves in the opposite direction from the pendulum, at a much faster speed. "This makes our signal easily distinguishable from gravitational forces from other objects in the lab," explains Gundlach. (The forces he is looking for are happening at a much faster and well-defined frequency.) His instrument is so noise-sensitive, in fact, that it picked up the Kingdome implosion (see graph on this page).

With the gravitational constant known so precisely, it becomes possible to figure out the weight of Earth. Gundlach used satellite data to compute this value. While his research has yet to undergo peer review, his preliminary calculations put the mass of the earth at 5,97225 sextillion metric tons. "We are already confident that we know the mass of our home planet Earth more precisely than it has ever been known to mankind," says Gundlach.
PHYSICS ON THE WEB: A RESOURCE GUIDE

Have you ever looked for physics information on the web? Here are some sites which are critically evaluated and annotated, yet should be easy to use.

The UW Physics Department home page (http://www.phys.washington.edu/physics/news) provides many links both to local information, as well as to general physics resources. Click on that address, and you will find all the other links on this page.

The Los Alamos preprint server is a spectacular display of the revolution in scientific publishing. It is sheer pleasure to explore its workings. Any article submitted by the authors is linked to the papers cited, and also to subsequent papers which cite this article (which enables you to see what people thought of it.) For any article, you can view the title, an abstract, and the full text, figures and all. Categories on the archive include everything from astrophysics to quantum physics. Mathematics, computer science and non-linear science are also represented. This is the future, and it works!

PhysicsWeb is an impressive electronic journal from the Institute of Physics. For full access there is a (modest) fee, but many news articles, book reviews etc. are free, and quite excellent.

The American Institute of Physics provides comprehensive, free information on physics, at many levels. The link to Physics News Update is particularly useful and interesting; it is possible to subscribe (again: no charge) to regularly receive updates by email.

The sometimes witty, sometimes acerbic comments on "What's Now" by Bob Parks are also available by free subscription. Dr. Parks enjoys debunking nonsensical claims and waste and ends each of his weekly missives with "Opinions are the author's and are not necessarily shared by the American Physical Society, but they should be."

A SHORT WORLD TOUR OF PHYSICS NEWS

The speed of light has attained a new record: Lene Vestergaard Hau and her Harvard colleagues succeeded in slowing down light traveling in Bose Einstein Condensate to a mere 1 mph. Further slowing of the speed to some 1 cm/sec could have important practical applications.

Another record has been broken at UW: the Eot-Wash Group has extended the measurement of the force of gravity down to a distance of 0.2 mm. This provides an important test of current theories with "extra dimensions" of space-time. It is also the first time gravity has ever been detected at a distance much less than a centimeter.

For the first time in the history of the American theater, the Tony award for best new drama was awarded to a play about - you guessed it - physics. Copenhagen deals with the role of Werner Heisenberg in the unsuccessful German effort to develop an atomic bomb. Fittingly, the play explores "the extension of quantum uncertainty to the realm of human motivations," according to Physics News Update.

Another new play, Now Then Again, has opened at the Bailiwick Repertory Theater in Chicago. It is a romantic comedy set at FermiLab. Its principal characters are physicists and its plot line is based on the transactional interpretation of quantum mechanics of our own Professor John Cramer, who acted as a consultant during the play's rewrites and rehearsals.

Last but not least, the field of physics has the privilege of being the subject of the first movie made exclusively for Internet distribution. The Quantum Project stars John Cleese. According to PhysicsWeb, it is about "quantum physics, the World Wide Web, and spiritual mystery." However, some technical difficulties remain. Not only did the film crash PhysicsWeb's browser, it crashed the PC of this writer (vladi@u.washington.edu). So, there you have it.
The frontiers of physics and biology are not the only new worlds being explored by the UW’s Physics Department. By this fall, it may have embarked on an entirely new adventure — a remodelling of the Nuclear Physics Laboratory that could have long-ranging consequences for atomic physics and astronomy as well as for nuclear physics.

“This field has changed quite a bit in the last ten years,” explains Hamish Robertson, the scientific director of the UW’s Nuclear Physics Lab. “We’re no longer so focused on the properties of nuclei,” he says, “but have become much more outwardly directed. There’s more emphasis on the role of nuclear physics on finding out the origin of the universe and of dark matter.” Robertson also says that nuclear physics has a role to play in discovering the properties of neutrinos. “They are still very poorly understood particles,” he says, “but neutrinos play a tremendous role in the formation of the universe.”

Robertson and his colleagues at the Nuclear Physics Laboratory (NPL) hope to create a new center for experimental nuclear physics and astrophysics at the University of Washington, based at NPL. The center would encourage collaborations between nuclear physicists, astrophysicists, cosmologists and particle physicists. Robertson envisions, for example, a collaboration with Chris Stubbs, a professor of physics and astronomy whose present work lies in the hunt for dark matter. “We might work with him to measure the position of the moon to an accuracy of a millimeter,” says Robertson. “It would be an extremely sensitive test of long-range non-Newtonian gravitational effects.”

In our next issue, we will update you on the progress of both new Physics Department initiatives.
THE SKY'S THE LIMIT

It all started with two bored undergraduates.

Last summer, Dawn Erb and Jeremiah Murphy were out at the Manastash Ridge Observatory near Ellensburg, where the UW has a large optical telescope. Erb and Murphy, both physics/astronomy majors at the UW, were trying to track the variable star HS0551+7241.

Problem was, it was too cloudy to see anything.

Looking for something to do, the two UW juniors found an old shortwave radio and fixed its antenna. "Then I had a wild, harebrained idea," says Murphy, an enthusiastic young man from Kentucky. "This thing is a primitive radiotelescope! Maybe we could get radio signals from it!"

No signals, no noise, no nothing. Far from discouraged, Erb and Murphy returned home and started researching radiotelescopes. "They're perfect for Seattle, because they can see through cloud cover," explains Erb, a Seattle native. Pulling classmate Sean Doyle into the loop, she and Murphy discovered it was possible to build a radiotelescope from scratch. If they got the satellite dishes donated, a nice one would only cost about $200,000 or so. Now where were those students going to get that kind of money?

Enter the Student Technology Fee (STF), a granting organization controlled by UW students. Funded by quarterly tuition fees of $40 paid by all undergrads, the STF was a radiotelescope waiting to happen. "One million dollars of the STF grant went unspent last year," says Doyle, a UW senior from Everett. "We thought we could probably take it off their hands." Enlisting twelve other students, Erb, Murphy and Doyle formed the Undergraduate Astronomical Institute (UAI). With the help of post-doc Stacy Paalen, the three scientist-entrepreneurs wrote a $193,000 grant proposal to the STF.

To their amazement, the proposal was accepted in its entirety by the student granting committee. "They told us it had a high coolness factor," says Doyle.

Literally. The best way to see the clouds of cool hydrogen gas in the spiral "arms" of our galaxy is by radiotelescope. As a matter of fact, most of what we know about our galaxy's structure comes from radio observations.

Today, a 10-foot radiotelescope sits atop the UW's atmospheric sciences building - the first small-scale project at the UW originated completely by undergraduates. By this fall, Doyle, Erb and Murphy hope to get radio signals from the sun. After that, they want to look at ionization storms on Jupiter and radio waves from the center of the galaxy. They are designing a web page to control the instrument (the address is http://www.phys.washington.edu/~sps/UAI/RADIO/home.html). They will be able to control the telescope from inside the UW's Physics building.

After Jupiter and the sun, the sky's the limit. "There will be a lot of radio projects we haven't even thought of yet," says Doyle. Their biggest dream is to build a series of telescopes, which would greatly increase their radio reception. Most likely, however, they will have to leave that to younger students. The original threesome are all graduating soon.