Testing the fundamentals of helium theory

The agreement of two independent measurements of a single parameter to within 8 parts in 10 billion would normally qualify as a great triumph of experimental physics. However, the precision of both experimental and theoretical determinations of energy levels in the helium atom has so greatly improved over the last two years that even this minute discrepancy looms large.

"The agreement is really quite remarkable," says theorist Gordon W.F. Drake of the University of Windsor in Ontario, who pioneered several techniques for calculating helium energy levels. "Tests [of such precision] have never been done before in systems more complicated than hydrogen. These results provide a profound test of our understanding of systems containing more than one electron."

At the same time, the tiny but significant difference between the two experimental results suggests a need for further evaluation of the experimental work to uncover possible errors. Craig J. Sansonetti and his colleagues at the National Institute of Standards and Technology (NIST) in Gaithersburg, Md., performed one of the experiments; William L. Lichten and his colleagues at Yale University in New Haven, Conn., did the other.

"I don't know what the cause of the difference is," Sansonetti says. "I have no quarrel with the Yale experiment, nor do I know of any error that could enter in our experiment that would make a difference." Sansonetti presented his viewpoint this week at an American Physical Society meeting in Washington, D.C.

With only two electrons moving under the influence of its nucleus, a helium atom has a deceptively simple configuration. In reality, various subtle effects, including the repulsive force between electrons, introduce complexities that vastly increase the difficulty of doing high-precision experiments and performing extremely accurate theoretical calculations involving helium.

Because each of a helium atom's electrons can have only certain, well-defined energies, one can picture a helium atom's energy levels as the rungs of a ladder. Theorists can calculate, in effect, the positions of these rungs, but experimenters can determine only the sizes of the gaps between rungs.

To find the actual value of a particular low-lying energy level in helium, the Yale group used a laser to excite helium atoms already in this state to a much higher energy level. By precisely determining the energy involved in the transition and by taking the difference between this measured value and the accurately computed energy of the upper level, the researchers deduced the energy level of the original, low-lying state.

Their measurement, like an earlier, less precise result obtained by the NIST team, differed significantly from the theoretically derived energy for this particular state. That disagreement between theory and measurement prompted John D. Morgan III of the University of Delaware in Newark and his collaborators to refine their theoretical calculations, bringing theory into closer agreement with experiment.

Meanwhile, using a different experimental approach that relies less on computed energy-level values, Sansonetti and his colleagues increased the precision of their energy-level determination to match the Yale effort. Taking experimental uncertainties into account, however, the NIST and Yale results failed to overlap.

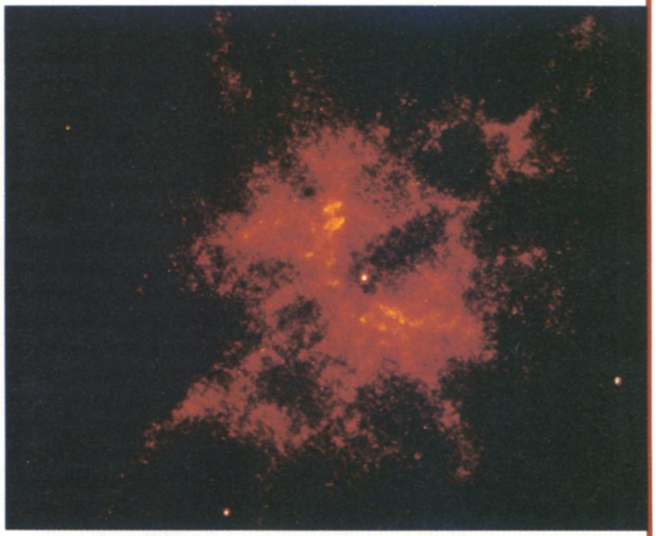
Researchers in both camps have since expended considerable effort to learn why their results differ as much as they do, but they have had little success finding an explanation. "If this disagreement persists, one of us is going to have to either redo the experiment or think of another experiment to clarify the situation," says Yale's David C. Shiner.

Further refinements in the theoretical calculations — to take into account effects that had previously been ignored as too small to matter at this level — may help pin down which team will have to return to the laboratory.

Despite this nagging discrepancy, theoretical and experimental techniques have now advanced sufficiently to allow the helium atom to join hydrogen as a prime setting for testing fundamental physics, specifically as a sensitive probe of quantum electrodynamics — the basic theory of how light interacts with matter — in a many-electron atom. *— I. Peterson*

Hubble camera captures hottest star ever

For years, astronomers have searched for the hot star that they knew must lie at the center of a Milky Way cloud of dust and gas called NGC 2440. This cloud, or nebula, fluoresces as a result of energetic, ionizing radiation that could only come from a high-temperature star embedded within it. But Earth's turbulent atmosphere acts to smear light from the star with that of the surrounding nebula, preventing ground-based telescopes from viewing the star.



Heap/NASA

False-color image shows the nebula NGC 2440, with its bright, central point of light: a white dwarf with the hottest temperature of any star ever recorded. White represents the highest-intensity emissions. White dots that form a right angle at upper right are an artifact of the imaging camera.

Orbiting above Earth's blurring atmosphere, the Hubble Space Telescope has now captured the first image of that star. Moreover, calculations indicate it has the hottest temperature of any star ever recorded by any telescope, says Sally R. Heap of NASA's Goddard Space Flight Center in Greenbelt, Md.

Sporting a temperature of 200,000 kelvins, the star belongs to a group of hot, dense objects known as white dwarfs, says Heap. White dwarfs represent the final evolutionary stage — just before complete burnout — of stars born with a mass no more than a few times that of the sun. Since these dwarfs last for a mere 10,000 years, imaging this star seems a particular feat. "It's as if we've captured this object during its 15 minutes of glory," says Heap, who announced the findings this week at a press conference in Washington, D.C.

She and her colleagues estimated the dwarf's torrid temperature by measuring the surrounding nebula's luminosity — which comes from ultraviolet radiation emitted by the star — as well as the visible-light brightness of the star itself.

The nebula formed millions of years ago during a time when the hot star was larger and had more mass. At that epoch, says Heap, the star had evolved into a puffed-up object called a red giant, which eventually blew off its outer envelope of gas and dust, creating the nebula. *— R. Cowen*