observed so far "certainly doesn't do much in restricting what exactly the [form of the] quintessence is." The most that can be said, he explains, is that one form of quintessence seems to be ruled out: defects in the fabric of space, called light nonabelian strings, that might have been left over from the big bang. The Perlmutter group is now analyzing 40 supernovae, which could give a clearer picture of the mysterious energy.

But whatever form the acceleration energy takes, there appears to be just enough of it to combine with matter and give the critical density of mass and energy that is predicted by leading theories of the big bang. To gauge the total, Garnavich, with CfA's Saurabh Jha and others, added the supernovae data to observations of the cosmic microwave background radiation, often referred to as the big bang's afterglow. Slight ripples in the background reflect conditions in the early universe and yield clues to basic cosmic parameters. The result is just the right density to make the universe geometrically "flat"—the kind of universe predicted by the simplest versions of inflation, the theory of how a sort of spark in the primordial nothingness could have set off the big bang.

Everything that researchers have concluded so far from these distant beacons rests on a crucial assumption: that the redshifts actually are caused by universal expansion. Most cosmologists don't question this assumption, but a few mavericks have proposed alternative explanations for the reddening of distant objects—for example, a sapping of the photons' energies as they traverse great distances.

Type Ia's offer a way to distinguish among these possibilities, because the physics of the explosions force them to brighten and dim on a predictable schedule. That "light curve" should appear to be stretched out for supernovae rushing away from Earth, because the light carrying news of later and later events would have to travel longer and longer distances.

By examining the light curves of about 40 supernovae, Berkeley's Gerson Goldhaber and others in the Perlmutter group found spectacular confirmation that they really are speeding away from Earth: Events that actually take a month on Earth were stretched to almost 7 weeks for the most distant of the supernovae. Although no one was surprised by the result, says Goldhaber, it's one more example of the light a standard candle can shed on the cosmos.

–James Glanz

ATOMIC PHYSICS

On the Trail of Supercharged Hydrogen

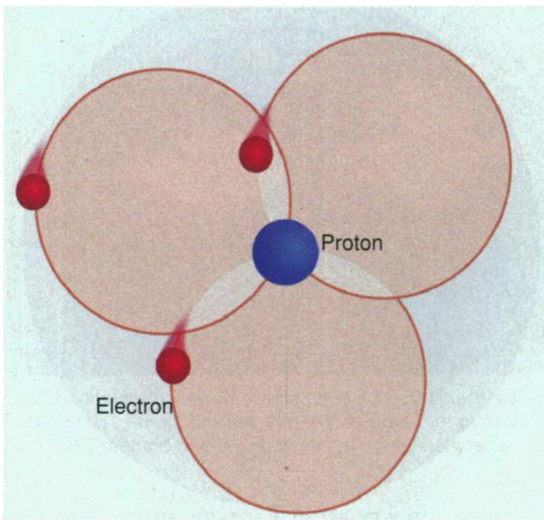
Hunters of exotic atoms usually make their forays to the furthest reaches of the periodic table, where they hope to bag big game by creating heavier and heavier elements. But a trophy may await physicists at the other end of the table, near ordinary hydrogen. New calculations suggest that with a laser's light touch, physicists may be able to create a hydrogen atom carrying two or more extra negative charges. If the feat can be done, it would open up new research avenues for using light to manipulate atoms.

As any chemistry student could tell you, hydrogen, the simplest atom, consists of an electron orbiting a one-proton nucleus. Researchers can vary hydrogen's charge by stripping the lone electron to leave a positively charged nucleus or by adding an electron to give the atom a negative charge. A hydrogen atom with two electrons repels additional electrons; that's why one would not expect to stumble across a hydrogen ion sporting any more than two. "Such ions don't exist in nature," says Harm Geert Muller of the Institute of Atomic and Molecular Physics in Amsterdam. Indeed, in a recent experiment, Lars Andersen at Aarhus University in Denmark shot free electrons at hydrogen ions with two electrons (H^-) but was unable to forge a beast bearing three. "We simply couldn't create such an ion," says Andersen.

Muller and colleague Ernst van Duijn, however, may have found a new way to foist two or even three extra electrons onto a hydrogen atom, to create H^{2-} or H^{3-}. The trick is to use intense laser beams, which contain powerful electric fields, to steer the extra electrons into wide orbits, essentially spreading out their charge. The electrons then "are able to take turns in occupying positions near the nucleus," says Muller.

It took some fancy computational footwork to arrive at that conclusion. In calculations compiled in Van Duijn's Ph.D. thesis, published by the institute last month, the Dutch duo developed a new way to calculate the diffuse shape of a hypothetical multielectron hydrogen ion. "We developed a computation method that specifically could deal with the shapes such an ion would take," says Muller. Their formulas showed that polarized laser light, whose photons vibrate in a preferred plane, could push the electrons into wider orbits. Such orbits would minimize the repulsive forces between electrons, allowing more than two to orbit the same proton. Some experts, however, are skeptical that this electron swarm would stick around a proton long enough for researchers to detect exotic hydrogen as an integral ion. "It could turn out to be an unrealizable phenomenon," says Chris Greene of the University of Colorado, Boulder.

SOURCE: E. VAN DUIJN / IAMP



Three's a crowd. Calculations suggest that a laser can force three electrons to orbit a single proton.

Muller and Van Duijn are plotting a strategy to prove their calculations right. The required lasers are available, says Van Duijn, but the challenge "is to get electrons and protons together in a laser beam." Lasers powerful enough to forge the ion only deliver ultrashort pulses, lasting up to 10^{-12} seconds. The brief illumination rules out the possibility of shooting free electrons at negative hydrogen ions. "Because of the short laser pulses, you have a very low probability for collisions," says Muller.

A way to skirt this problem may be to start out with a larger molecule, such as methane, and use a laser like a sniper to remove its electrons. This would trigger a "Coulomb explosion" in which repulsive forces rip apart the stripped-down, positively charged methane. "The trick will be to choose a laser of such an intensity that it allows three electrons to end up around one of the ejected protons," says Muller. One might then look for H^{2-} or H^{3-} with a photoelectron spectroscope, which could shoot photons into the ions and measure specific energies of electrons ejected by multielectron hydrogen. "This experiment is definitely on our Christmas list," says Muller. If they succeed, he adds, exotic hydrogen ions may be useful for, among other things, generating soft x-rays for probing molecular structure.

–Alexander Hellemans

Alexander Hellemans is a science writer in Naples.