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New Simulation Poised to Chart the Staggered, Scattered Cosmic Dawn

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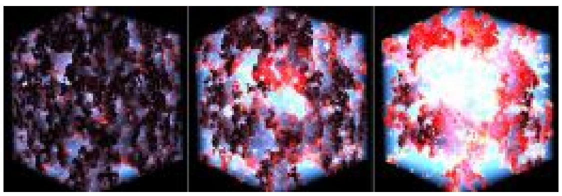

A portion of space 1 billion light years across, depicted in three moments of a reionization simulation comparable to the one pending in Alvarez and Ho''s calculations. Dark colors indicate cold neutral gas, while red to blue to white indicates increasingly hot ionized gas. The bubbles form small but expand and merge. (Image courtesy of Marcelo Alvarez, Ralf Kaehler and Tom Abel. Click for larger image.)

(PhysOrg.com) -- A new simulation method recently developed by Stanford astrophysicist Marcelo Alvarez and Science Undergraduate Laboratory Internship student Patrick Ho spurns complexity to make headway in understanding the early universe's structure formation. Collapsing a complicated trajectory into a single relationship, their calculations cut simulation time from weeks to hours.

Short of trace amounts of helium, in early times there was only neutral (non-ionized) hydrogen. Simplicity, monotony—it matters little what one attributes to such a state: the smooth swathe that existed soon after the universe cooled from the Big Bang’s hot mess of free electrons and energetic radiation is termed by astrophysicists the cosmological "dark ages." The preponderance of neutral hydrogen absorbed enough light to make this era all but opaque.

Not until poorly-understood gravitational, thermal and chemical interactions produced the first stars would the universe forever leave an era of homogeneity and produce the complex structures and phenomena of today. This transition, known as the reionization epoch, lasted approximately 500 million years. It is named for the phase change in the intergalactic medium. Billions of light years in the past, it marks the edge of the observable universe. Even its brightest objects—quasars that radiate the energy of a trillion suns—are barely visible in the Earth's most powerful telescopes.

The reionization epoch's inaccessibility means that scientists know little about how the process of ionization actually occurred. It's believed to have started from slight density perturbations in the original hydrogen gas and accompanying dark matter. Collecting into denser clumps over time, these areas finally collapsed to form stars, which emitted radiation that grew abundant enough to ionize the surrounding hydrogen. Ionized regions expanded in bubbles reaching 30 million light years across, merging and eventually growing into one bubble the size of the entire universe.

Unlike other simulations, which model each step of this process—including calculations for the stellar formation and radiation-gas feedback mechanisms—Alvarez and Ho rig the final state of ionization directly to the initial density wrinkles. The result is blazing speed. While other simulations "could last weeks on supercomputers with hundreds of computers running in parallel, we can do similar resolution and volumes in hours on a desktop computer," says Alvarez. Though rougher, the method produces no blows to exactitude because prior simulations produced results excessively precise for the simulations' level of accuracy, the scientists say.

The speed will enable the new simulation to give cosmological theory a good workout. The faster simulation will aggressively pursue more parameters in more tests, closing in on ratios that describe the universe's stellar production and ionization efficiency.

The calculations also accommodate larger chunks of space, surpassing the volume simulated using the previous state-of-the-art approach by 1000 times. This capacity produces an enormous leap in the simulation's ability to study uncommon but disproportionately meaningful events like quasars. Though extremely rare in both reality and simulations, quasars are the most observable objects in the reionization epoch. Their empirical importance makes their inclusion critical as a consistency check in theoretical studies such as this simulation.

The impetus behind larger-scale simulations stemmed from recent appreciation for the irregular distribution of matter across scales that were previously considered to be close to homogeneous. Far from a uniform foam, the intergalactic medium was "more like a web," says Alvarez. "There were places with more stuff and places with less stuff, forming a complex network of filaments and sheets surrounded by large voids." The staggered pace of this evolution means that the dark ages, formerly understood as a discrete time period, ended at different times in different places. "It's like the Renaissance," muses Ho. "Did it end when the first person in Europe started thinking something, or when 25 percent did?"

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