Exploring the Helium Reionization Era

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In Big Bang cosmology, the universe began as a hot, dense, gas fireball. Due to its extreme initial temperature, charged particles (ions) within the gas were not bound together into neutral atoms, but freely streamed outward with other subatomic particles as the universe expanded and cooled. Among these particles were abundant free electrons, which easily scattered light’s photons, making this early epoch look like an opaque fog. After about 400,000 years, the universe cooled to the point where the electrons could combine with protons to form atoms of hydrogen and other light elements. Following this transition, called Recombination, photons were not as scattered and the universe became transparent.

Ironically, the period immediately after Recombination is referred to as the Dark Ages. Although the universe was transparent to light, this period was dark because no discrete sources of light yet existed. Insufficient time had elapsed to form stars and galaxies. A visitor to this period would only observe an eerie, diffuse, blue-violet glow streaming from the earlier ionized epoch.

Astronomers think star formation began around 100 million years after the Big Bang based on data from NASA’s Wilkinson Microwave Anisotropy Probe satellite. They believe these first stars were perhaps 100 to 200 times more massive, and much hotter than our Sun. These giant stars produced immense quantities of ultraviolet radiation that reionized atoms of hydrogen gas in the regions surrounding the stars.

The ensuing period is known as the Reionization Era, which lasted from about 400 million years to approximately 1 billion years after the Big Bang. (This era is explained in more detail in “The Search for the Earliest Galaxies” on page number 119.) During this time, most of the atoms of neutral hydrogen in intergalactic space apparently reionized back into plasma, though scientists do not yet fully understand how. The number of stars and galaxies seen appears insufficient to account for the amount of ionization observed.

The bright quasar MC2 1635+119 dominates the center of its host galaxy, which is known by the same name. This quasar is relatively nearby, about 2 billion light-years away, and found in the constellation Hercules. Studying such nearby quasars should clarify their role in ionizing the helium in the universe some 11.5 billion years ago.
Researchers also believe primordial helium experienced a similar, but later, transition from a neutral state to an ionized one. Because more energy is required to strip two electrons from a helium atom to form ions than to strip a single electron from an atom of hydrogen, even more time passed before the stars and galaxies built up the energy capacity to do this. It now appears that it took about 2 billion years.

Astronomers used Hubble’s Cosmic Origins Spectrograph (COS) to discover it took this amount of time before the universe produced sources of ultraviolet radiation with sufficient energy to reionize the helium produced in the Big Bang. This radiation did not come from super-massive stars, though, but rather from quasars—the brilliant cores of active galaxies.

Quasars are a class of extragalactic objects discovered in the 1960s that emit an immense amount of energy from a compact source. The first ones found looked like stars emitting unusually high amounts of radio waves and were named quasi-stellar radio sources (quasars). Scientists now recognize most quasars do not emit copious radio waves, so instead call them quasi-stellar objects (QSOs).

QSOs are extremely old and distant, and their energy production is thought to arise from supermassive black holes located at the centers of galaxies. As surrounding material is gravitationally pulled into a black hole, it forms an accretion disk—a flattened ring of debris and gas encircling the black hole. Extremely energetic jets shoot out perpendicularly to the disk in both directions. Like looking into a narrow searchlight beam, an observer aligned on the line-of-sight to one of these jets would see an intensely bright, compact source. It would look like a brilliant, distant star but with a distinctly different spectrum from normal stars. This is in fact how QSOs appear.

**The Quasar Epoch**

The epoch when helium was being reionized corresponds to a transitory time in the history of the universe when quasars were most abundant. Researchers led by Colorado astronomer Michael Shull dated the era of strong ionizing radiation and an associated phase of universal heating from 11.7 billion to 11.3 billion years ago, when the universe was between 2 billion and 2.4 billion years old. During this early time, galaxies collided more frequently. These impacts provided the material to engorge supermassive black holes in the cores of these galaxies with infalling gas, thus producing quasars.
Quasars (alternately QSOs) are compact sources of immense energy. Their energy is believed to arise from a supermassive black hole located at the center of an accreting disk of material. Stellar material feeds the accretion disk around the black hole. A narrow, powerful beam of radiation blasts from the black hole along its spin axis.
In the inner regions around these black holes, the gravitational energy of the accreting matter was converted into powerful ultraviolet radiation that blazed out of the active galaxies. This radiation heated the intergalactic helium from 18,000°F (9,982°C) to nearly 40,000°F (22,204°C) and reionized the helium atoms.

The scorching conditions may have additionally hindered the growth of smaller dwarf galaxies during this 400-million-year interval. Energy from the reionized helium would have heated the intergalactic gas and inhibited it from gravitationally collapsing to form new generations of stars in smaller galaxies. The lowest-mass galaxies would have been unable to hold onto their gas, which would have escaped back into intergalactic space without forming stars.

Astronomers constructed this view of galactic history by using a quasar’s light beam like a cosmic core sample. Superimposed on the quasar’s spectrum is evidence from earlier epochs of the otherwise-invisible ionized gas clouds interspersed between galaxies. *Hubbles COS* was specifically designed to distinguish the faint ultraviolet signature from these gases.
So far, Shull and his team have taken observations along only one sightline to detect and characterize the helium transition era. They and other researchers plan to analyze additional *Hubble* data to determine if helium reionization took place uniformly across the universe.

**Further Reading**


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Dr. Michael Shull is a professor of astrophysics at the University of Colorado at Boulder. He was raised in Fargo, North Dakota and St. Louis, Missouri. Dr. Shull received his BS in physics from the California Institute of Technology and his PhD in physics from Princeton University. His theoretical and astronomy interests include studies of gas between the stars and galaxies, galaxy formation, the first stars, supernovas, and quasars. Dr. Shull is a science co-investigator on the *Hubble* Cosmic Origins Spectrograph Investigation Definition Team.