

6. Earendel – The Most Distant Star in The Universe

NASA's James Webb Space Telescope (JWST) has confirmed and expanded upon the Hubble Space Telescope's discovery of "Earendel", the most distant star ever observed — shining just one billion years after the Big Bang.

Earendel – The 'Morning Star' of the Early Universe

Meaning and Naming – The name Earendel originates from Old English, meaning "morning star" or "rising light", symbolizing a new beginning in the cosmic timeline. The naming reflects its significance as one of the earliest observable individual stars in the universe.

Nature and Characteristics

Star Type – Massive B-type star, known for its high temperature and brightness.

Temperature – More than twice as hot as the Sun.

Luminosity – Nearly one million times more luminous than the Sun, making it exceptionally bright despite its vast distance.

Uniqueness – Unlike most stars in the early universe that are part of distant galaxies and appear blended, Earendel's light is individually resolvable due to gravitational lensing.

Location – Sunrise Arc Galaxy

Earendel resides in the Sunrise Arc galaxy, a galaxy observed during the universe's first billion years. The Sunrise Arc is a gravitationally lensed galaxy, which makes it appear highly magnified from Earth.

This galaxy serves as a natural laboratory for studying –

1. Earliest star clusters and stellar nurseries.
2. Formation and evolution of galaxies in the early universe.
3. Properties of primordial stars and early cosmic chemical composition.

Gravitational Lensing – The Key to Discovery

Concept – Gravitational lensing occurs when light from a distant object is bent and magnified by the gravitational field of an intervening massive object, such as a galaxy cluster. Einstein's General Theory of Relativity explains that mass curves spacetime, and light follows this curved path, akin to light bending through a glass lens.

Discovery Mechanism

Alignment – Earendel lies directly behind a massive galaxy cluster called WHL0137-08, located between the star and Earth.

Lens Effect – The cluster's immense gravity bends and magnifies light from the distant star and its host galaxy.

Amplification – Gravitational lensing boosted Earendel's brightness by over 4,000 times, allowing instruments like the James Webb Space Telescope (JWST) to observe it as a distinct point of light.

Scientific Importance of Earendel

Age and Cosmic Context

Earendel shone approximately 1 billion years after the Big Bang, making it the farthest individual star ever observed. Comparative Milestones –

1. Earendel – 1 billion years post-Big Bang
2. Quyllur (Red Giant detected by JWST) – 3 billion years post-Big Bang
3. Hubble's earliest individual star record – 4 billion years post-Big Bang

Key Insights for Astrophysics

Stellar Evolution – Provides direct evidence of how massive stars formed and evolved in the early universe.

Cosmic Dark Ages – Helps understand the transition from dark ages to the formation of the first galaxies.

Chemical Composition – Offers clues about early metallicity and chemical enrichment processes in

primordial stars.

Galaxy Formation – Observing Earendel and its host galaxy aids in reconstructing early galactic structures and star formation rates.

Broader Implications

Testing Cosmology Models – Observing such early stars allows scientists to test models of early universe expansion, star formation, and galaxy evolution.

Understanding Massive Star Formation – Earendel's extreme brightness and mass challenge theories of how the first massive stars could form in low-metallicity environments.

Gravitational Lensing as a Tool – Demonstrates the power of natural cosmic lenses in exploring the distant universe, which would otherwise remain unobservable even by JWST or Hubble.

Hubble Space Telescope (HST)

Launch – Launched in 1990 by NASA and ESA; placed in low Earth orbit (~547 km).

Observation Range – Works in visible, ultraviolet, and near-infrared wavelengths.

Major Discoveries – Captured the Hubble Deep Field, estimated the Universe's age (~13.8 billion years), and provided evidence for dark energy.

James Webb Space Telescope (JWST)

Launch – Launched on December 25, 2021, by NASA, ESA, and CSA (Canadian Space Agency).

Orbit & Position – Operates at the Sun–Earth L2 point (~1.5 million km from Earth).

Observation Range – Specializes in infrared wavelengths, allowing it to see through cosmic dust.

Mirror Design – Features a 6.5-meter gold-coated mirror, much larger and more sensitive than Hubble's 2.4-meter mirror.

Scientific Achievements – Captured images of SMACS 0723 (Galaxy Cluster), Pillars of Creation.

Objective – Studies early galaxy formation, exoplanet atmospheres, and the origins of stars and elements.

