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Cosmos Unveiled: The Cosmic Dawn

The Era of the First Stars

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Conclusion

This free sample contains the Introduction and Chapter 1. The complete book contains the full contents above.

Introduction

The cosmic dawn is the moment the universe first lit up: the hundreds of millions of years during which the first stars and galaxies condensed out of the darkness and their light began to strip electrons from the hydrogen gas that filled all of space. It is the least photographed era in all of astronomy. No telescope has imaged the first star directly, and none may for decades; the period is reconstructed, one inference at a time, from the afterglow of the Big Bang itself, from the shadows that neutral hydrogen imprints on the light of the most distant quasars, and from the handful of galaxies that telescopes at the very edge of their powers have barely caught.

This book tells the story of that hidden epoch and of the half-century of detective work that has brought it into focus: the prediction that a dark age must have followed the Big Bang's initial blaze, the accidental discovery of that blaze's fading echo, the quasar surveys that found the fog lifting, the satellite maps that timed it, and the new infrared eyes in space that now push within a hundred million years of the first light. The chapters ahead cover the physics of reionization, the instruments and methods used to measure an event no one can see, the record-breaking galaxies and stars by which the era is now charted, the mysteries the data refuse to resolve, and the observatories being built right now to resolve them.

It is a story that keeps changing under its tellers' feet. Each generation of telescopes has found the dawn earlier, brighter, and stranger than the last generation's models predicted, and the follower of these pages should hold every number with the same provisional grip the astronomers do.

One habit of the literature is worth adopting from the start: the cosmic dawn is spoken of in the past tense but argued about in the present. Every sentence in this book about the first stars is built on something measured now, in this decade, by instruments that were unimaginable when the 1940s prediction was first written down. The dawn itself is fixed history; the study of it is one of the fastest-moving fields in all of physical science.

The follower of the account should also know what the book refuses to do. It will not present contested readings as settled ones. Where the field argues, the argument is shown. The flattened radio profile found by one experiment in 2018 remains unconfirmed; the surprisingly bright early galaxies remain under audit; the timing of the first starlight carries wide error bars. Honest uncertainty is not a weakness of the cosmic dawn literature. It is the literature's dominant feature, and this book keeps it in the frame throughout.

In the fields of Big Bang theory and cosmology, reionization is the process that

caused electrically neutral atoms in the primordial universe to reionize after the lapse of the "dark ages".

Chapter 01: The Discovery of The Cosmic Dawn

The discovery of the cosmic dawn did not happen in one night, and no single astronomer can claim it. It arrived in stages, each a decade apart, as instruments caught up with a prediction that had been sitting in the literature since the 1940s: that the early universe, after its first brilliant beginning, must have gone dark, and that the darkness must have ended only when the first stars turned on.

The first stage was the discovery of the afterglow itself. In 1965, Arno Penzias and Robert Wilson found the microwave hum of the Big Bang, the cosmic microwave background, confirming that the universe had indeed begun hot and dense. The glow told cosmologists the temperature at which the primordial gas cooled enough for atoms to form, and by implication, everything that happened afterward happened in a universe of neutral hydrogen, transparent to the eye but opaque to the ultraviolet light that the first stars would produce.

The second stage came from quasar surveys. In 2001, the Sloan Digital Sky Survey found that the spectra of the most distant quasars were eaten away at precisely the wavelengths where neutral hydrogen absorbs, evidence that a fog of atomic hydrogen still filled space at that time and had not yet been cleared. The third came from satellites: the WMAP mission's map of the microwave sky, released in 2003, carried in its polarization the faint signature of the moment the fog burned off. Between those measurements and the theory that connected them, the cosmic dawn stopped being a speculation and became a subject, with its own name, its own epoch, and eventually its own research institutes.

Among the institutes built to study it is DAWN, the Cosmic Dawn Center, a joint venture of the Niels Bohr Institute of the University of Copenhagen and the University of Australia's astronomy group, funded in partnership with Danish and Australian research foundations. Its very existence is a measure of how fast the field moved: a research center dedicated to a period no telescope had directly witnessed.

The main objective of the center is to investigate the period known as the Cosmic Dawn (the transition period following the Cosmic Dark Ages), i.e. Research conducted at the center is focused on the specific period in the history of the Universe known as the Cosmic Dawn.

This largely unexplored period, 300-600 million years after the Big Bang is when the first stars, black holes, and galaxies are believed to have formed. Many of the observations used by the center originate from the Atacama Large

Millimeter Array (ALMA), one of the more powerful telescopes in the world.

In the future, the center aims to mainly use the James Webb Space Telescope and the Euclid Telescope of the European Space Agency (ESA).

DAWN scientists were instrumental in the construction of three instruments (NIRSpec, MIRI and NIRISS) for the project, and will be involved in the analysis of the first data from the telescope. As of April 18, 2020, DAWN authors have published at least 187 refereed papers garnering 1602 citations, which, among others, can be found at the NASA/ADS library.

GN-z11 is a high-redshift galaxy discovered by NASA's Hubble Space Telescope in the constellation Ursa Major. It is among the farthest galaxies from Earth ever found.

The 2015 discovery was published in a 2016 paper headed by Pascal Oesch and Gabriel Brammer (Cosmic Dawn Center). Up until the discovery of JADES-GS-z13-0 in 2022 by the James Webb Space Telescope, GN-z11 was the oldest and most distant galaxy yet identified in the observable universe, having a spectroscopic redshift of z = 10.957, which corresponds to a proper distance of approximately 32 billion light-years (9.8 billion parsecs).

Data published in 2024 established that the galaxy contains the most distant, and therefore earliest, black hole known in the universe, estimated at around 1.6 million solar masses. The object's name is derived from its location in the GOODS-North field of galaxies and its high cosmological redshift number (GN + z11).

A second stage of discovery came from the quasars. Quasars are the brightest sustained beacons in the sky, visible from so far away that their light passes through material that existed before reionization finished. When astronomers stacked quasar spectra from the giant surveys of the 2000s and 2010s, they could watch the neutral hydrogen thin out with distance: nearby lines of sight showed almost none, while the most distant lines of sight showed the opaque absorption that only a neutral universe produces. The pattern gave reionization its ending near the universe's billionth birthday, and gave the cosmic dawn a measurable far edge.

The third stage is still arriving. It is the attempt to detect the dawn's own radio signal, the faint shift that primordial hydrogen left on the afterglow of the Big Bang as the first stars' ultraviolet bathed it. A 2018 announcement from a radio experiment in the Western Australian outback reported a dip in the radio sky at the frequency predicted for hydrogen at the dawn's height, deeper than the standard model could explain. The claim has not been confirmed by other instruments, and the field treats it as a stimulus rather than a result. But the

announcement changed the conversation: for the first time, someone claimed to have heard the dawn itself, and every radio array on Earth and on paper adjusted its plans accordingly.

The fourth stage opened with the infrared flagship telescope launched at the end of 2021. Within its first survey seasons it returned galaxies so early, and in several cases so bright, that they sat at the edge of what the formation models had allowed. Those observations did not close the file on the dawn. They reopened it, which is the discovery story of this chapter in miniature: each new instrument has not so much answered the old questions as sharpened them.

One more stage belongs in the discovery story because it arrives from outside astronomy entirely: the laboratory. The era's timing is anchored partly by the measured properties of the hydrogen atom, partly by the measured nuclear chemistry of the first minutes, and every improvement in either ripples into the dawn's calendar. The prediction of a dark interval once sat comfortably in theory; the confidence that it was brief and ended early now rests on numbers measured in accelerators and atomic clocks. The cosmic dawn is discovered in stages, and some of the stages happen on laboratory benches.

The stage names take a word here, because the vocabulary of the field was assembled piecewise and partly from other sciences. The plasma era ended when electrons and protons combined into atoms, an event cosmologists call recombination, roughly 380,000 years into the expansion. What followed was named by contrast: the dark ages, a period with no starlight at all, which gravitational clumping slowly transformed. The transition that ended the dark ages is the one this book tracks, and it goes by two names that mean nearly the same thing. The phrase cosmic dawn centers the star formation, the lighting of the first lamps; the phrase reionization centers the gas, the second stripping of electrons that followed the first one at the beginning of time. Astronomers use them interchangeably, and so, after this introduction, will this book.

End of free sample. The full book is available at putrabooks.github.io

ABOUT THE AUTHOR

Aira Astralis is a science writer specializing in astronomy and space exploration. Her work spans the full breadth of humanity's relationship with the cosmos -- from the earliest naked-eye observations to the engineering marvels of modern space missions.

Her books are built on a foundation of primary sources: peer-reviewed research, mission archives, and direct engagement with the scientific community. She writes for readers who want to understand not just what we know about the universe, but how we came to know it.

She believes that the most important frontier is not out there but in the gap between what scientists discover and what the public understands. Her books exist to close that gap.