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The First Galaxies in the Universe

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The First Galaxies in the Universe

Abraham Loeb and
Steven R. Furlanetto
Princeton U. Press, 2013. $130.00
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Anyone who loves galaxies will eventually wonder where they came from. And like archaeologists digging the earliest human hearths and temples out of the Neolithic dust, astronomers today are nearing the cosmic strata where the first galaxies are to be found.

Ninety years after Edwin Hubble discovered that many faint nebulae are in fact galaxies—"island universes" like our own Milky Way—his namesake telescope detected galaxies formed when the universe was only 2% of its present age. Yet the pale red dots seen by *Hubble* are only the most conspicuously luminous of galaxies at their epoch; most galaxies formed at that time are too faint to see with our current telescopes. But change is coming. Over the next decade, the *James Webb Space Telescope* (*JWST*), the Atacama Large Millimeter/Submillimeter Array, and 30-meter-class telescopes on the ground should see far enough back in time to observe the first building blocks of today's typical galaxies. Until then, thinking about the first galaxies is still a theory-heavy enterprise.

Enter Abraham Loeb and Steven Furlanetto, two of the most consistently active theorists on the subject. Their new textbook, *The First Galaxies in the Universe*, purports to be "a comprehensive, self-contained introduction" to its topic and aims to "bridge the gap between theory and observation." The book excels on the first of those ambitious goals and—but for a few significant omissions—succeeds on the second.

The First Galaxies in the Universe approaches its subject from a pedagogical distance. The first four chapters are devoted to the basics of structure formation out of the intergalactic medium (IGM). Though highly overlapping with many other introductory texts, the foundational material builds logically and at a suitable level of mathematical detail toward the specialized content in the last third of the book, even as it covers all the important basic concepts. While perusing those early sections, I particularly appreciated the obvious care taken by the authors and their publisher in selecting the supporting figures and in homogenizing their format and appearance in order to express the key points without needless distraction.

The book hits its stride in its final third with extended treatments of the reionization of the IGM, optical and IR surveys for high-redshift galaxies (such as by *Hubble* and eventually *JWST*), and two promising techniques for probing the first galaxies and the IGM gas that fuels their star formation. Those techniques are based on the Lyman-alpha electronic transition of hydrogen and the hyperfine spin flip between energy levels that produces the 21-cm line. The authors were among the early advocates and developers of the 21-cm-line method, and they are eminently qualified to produce a worthy source of pedagogical material on the theory of both techniques.

The 21-cm line promises to provide a nearly complete map of the normal matter in the universe over large swaths of sky prior to and during reionization, once new radio facilities such as LOFAR in the Netherlands and the Square Kilometre Array in Australia and South Africa are fully operational.

The Lyman-alpha line arises from reforming hydrogen that had been ionized by radiation from the first galaxies, and so it probes the interaction between stars and their surrounding gas.

However, the complexity of interpreting the Lyman-alpha and 21-cm signals belies their humble origins in simple transitions of nature's most abundant element. The many radiative-transfer effects that alter the shape and strength of the lines as the photons pass from the galaxies, through the IGM, and into our telescopes are covered in enough detail to equip readers with a good working understanding of how the lines are produced and interpreted. That material is a valuable resource for students entering the field and looking ahead to the day, sometime later in this decade, when new facilities will apply those techniques on a massive scale.

True to its aim, the book introduces the relevant observations throughout. Particularly in its discussion of the Lyman-alpha and 21-cm techniques, the promised bridge to observations is soundly built and, for a fast-moving field, impressively up to date. By contrast, other promising techniques for detecting and understanding the first galaxies receive only bullet-point treatment. Just the last seven pages of the text concern the rich "fossil record" of the first heavy elements and the early mass function of stars preserved within long-lived stars in the nearby universe. The "ultra-faint" dwarf galaxies on the outskirts of the Milky Way, believed by many astronomers to be preserved remnants of the first galaxies themselves, are mentioned only in passing. Coverage of constraints from microwave and IR radiation backgrounds is also cursory. That matters because all those approaches provide insight into physical processes that are critical to the formation of the first galaxies but invisible in the hydrogen emission that is so thoroughly described.

Students looking for an introduction to complementary avenues to the first galaxies will have to look elsewhere. But despite those omissions—the book's only real flaw—graduate students or senior undergraduates will find *The First Galaxies in the Universe* a thorough introduction to the topic. Interested professionals will find it a helpful entry point to the specialist literature on one of the most exciting frontiers in astrophysics.

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Letters to a Young Scientist

Edward O. Wilson
Liveright/W. W. Norton, 2013.
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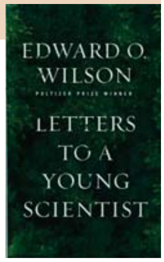

Ant expert Edward O. Wilson alternates between autobiography and wise counsel to the readers of his *Letters to a Young Scientist* in order to convince them that they made the right choice. The book's primary intended audience is undergraduates or graduating high school students who have chosen to pursue science but remain doubtful that they can make a career of it. Wilson's prose appears to be in deliberate contrast with scientific biographies that emphasize the uniqueness and sometimes the peculiarity of their subjects; that type of biography may discourage readers away from science. By instead presenting his life to engage the reader's empathy, Wilson aims to encourage young people to pursue science. (The need for more young scientists can hardly be overstated.) He's quite convincing, successively demolishing many legitimate fears through charming anecdotes from his career. He is also remarkably modest, given his own accomplishments as a distinguished professor at Harvard University and a two-time Pultizer Prize winner.

Letters to a Young Scientist is not merely a collection of platitudes. Perhaps the most persuasive sections are those in which the author challenges popular perceptions of what is needed to become a scientist. One example that might arouse some controversy in the physics community is the question of how much mathematics is needed for a scientist to be successful. Wilson argues—indeed, elevates to the level of a principle—that for any level of mathematical aptitude, an appropriate scientific discipline exists in which an aspiring scientist can succeed.

Conceding that physics and similar disciplines are inevitably quantitative, Wilson advocates that scientists in other, more qualitative disciplines collaborate with statisticians and mathematicians when they need to. However, I have found that even among physics majors, students' perceptions of their aptitude in math are often unduly negative. And judging from the reported problem of poor statistics in fields like medicine, there seems to be a need for better education in quantitative methods.

Wilson could actually have gone further and acknowledged that even within physics the level of mathematics required to succeed in particular subfields varies considerably. That variation is reason for theorists like me to work with others with different and equally valuable skills. But Wilson's advice might be unduly limiting in physics, given the successful efforts to improve pedagogy, notably through physics education research.

Perhaps the only really jarring section begins with the observation that "real scientists do not take vacations," which their significant others might be crestfallen to hear. Moreover, it's untrue. In some sense, I know what he means. For example, while cycling through the dunes of Cape Cod in Massachusetts last summer, I couldn't resist getting off my bike to inspect some moss that looked bioluminescent. It's hard for those of us who are passionate about science to switch off. But what concerned me was Wilson's immediate juxtaposition of that statement with his advice to seek jobs that minimize the required amount of teaching. That advice may resonate with some, but I dislike the implication—even if unintended, coming from a skilled lecturer—that real scientists don't like to teach.

Beyond the obvious audience, there is certainly value in the book to those further along in their careers. Many of us are tasked with teaching and advising students outside our field, so Wilson's ideas and stories could be a resource to help us do so effectively. Moreover, it's easy to find one's enthusiasm for science rekindled by the letters. I wrote this review in the middle of grant writing and during the October 2013 government shutdown; both experiences are likely to challenge the most committed person's perception of the glamor offered by the life scientific. Yet Wilson's fascinating descriptions of how careful experiments have uncovered the details of ant communication and social behavior proved a welcome antidote.

I hope that *Letters to a Young Scientist* will inspire other scientists to tell their own stories in a similar manner. The book, not surprisingly, focuses on biology, but much of the advice is transferable. Still, there certainly remains room for a book that specifically encourages students, particularly those from currently underrepresented groups, to pursue physics.

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