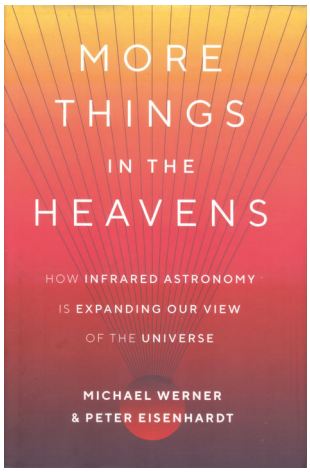


More Things in the Heavens: How Infrared Astronomy is Expanding our View of the Universe. Michael Werner and Peter Eisenhardt. Princeton University Press, 41 William Street, Princeton, New Jersey 08540, USA. 2019. xiv + 289 pages. Price: US$ 35.00/£30.00.

What would the Universe look like if we had infrared eyes? What if the eye had a pupil size of 85 cm, and we are somehow transported to an Earth-trailing orbit around the Sun? Well, we would have then seen the Universe exactly the way NASA's Spitzer Space Telescope had seen. We would have also learned that there are more things in the heavens than we have known. '*More Things in the Heavens*' is the title that Michael Werner and Peter Eisenhardt chose for their book, written for a general audience, that delightfully recounts the story of the Spitzer telescope and the pathbreaking discoveries it has made. As the subtitle makes it amply clear, the book is also an invitation to a journey that reveals to us how infrared astronomy is expanding our view of the Universe. It turns out that the infrared view of the Universe is dramatically different from what is seen at other wavelengths. This book describes how the Spitzer telescope has contributed to shaping our infrared view of the Universe.

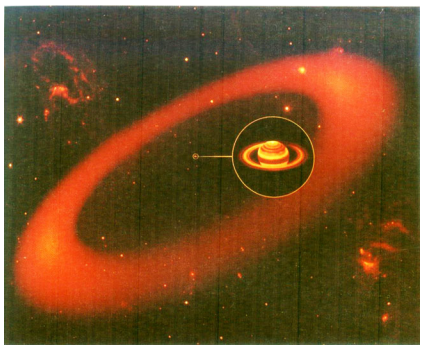
The Spitzer space telescope (hereafter Spitzer) is the last of NASA's Great (space) Observatories, launched to observe the Universe across the entire electromagnetic spectrum. The previous three, the Compton Gamma Ray Observatory, the Chandra X-ray Observatory and the Hubble Space Telescope, operated at gamma-ray, X-ray, and UV and visual wavelengths respectively. Spitzer, launched in 2003, observed the skies at the infrared wavelengths, ranging from 3 to 40 μm. After being in orbit for more than 16 years and producing over 8000 research papers, the Spitzer mission officially ended in January 2020. Compared to the previous infrared space missions, Spitzer has been a remarkable success and the results it has produced have profoundly impacted our understanding of the infrared Universe. This was primarily because of the significantly higher sensitivity of the Spitzer telescope plus instruments and the mission's longevity. As pointed out by the authors in the book, the long operational lifetime of Spitzer provided the 'thinking time' required 'for (the) exploitation of the capabilities of a powerful new facility'.

The authors have been closely associated with Spitzer for decades, starting from its early days: Werner has been the project scientist of the Spitzer mission since 1983. Eisenhardt has worked on various aspects of the mission since 1987 and has served as the instrument scientist for all three of Spitzer's instruments at one time or another. Writing from this vantage point, the authors showcase Spitzer's contributions in addressing the fundamental questions about the Universe and humanity's place in it: (i) Where did we come from? (ii) How did the Universe evolve? (iii) Are we alone?

The book is well structured. The first two chapters set the tone nicely. The first chapter elucidates some of the concepts and principles underlying infrared studies that are extensively used in the later chapters, such as the connection between blackbody radiation and temperature, wavelength-dependent attenuation of radiation by dust grains and the redshift caused by the expansion of the Universe. It also provides a brief history of the space infrared missions before Spitzer and mentions a few future ones to place the Spitzer mission in context. The second chapter gives a whirlwind tour of the infrared view of the Universe as seen by Spitzer, starting from the solar system, then moving to birth and death of stars, and exoplanets in the Galaxy, finally going beyond the Milky Way to survey external galaxies to the distant reaches of the Universe. It provides a clear and concise overview of the major Spitzer discoveries discussed in detail in the subsequent chapters.

A lively account of a selection of scientific highlights from Spitzer in wide-ranging areas of astronomy makes up the rest of the book. Each chapter begins with an introduction to the research field/area followed by a description of the field's current status, all in a language accessible to non-experts. The Spitzer discoveries and results are presented next, and the implications of these results are discussed, thereby highlighting the advances made by the mission. Throughout, the narrative foregrounds the organized and creative ways in which astronomers have used Spitzer to study the Universe in the infrared.

A review of a book on Spitzer cannot be complete without highlighting some of its fundamental contributions. In the area of star and planet formation, exoplanets and solar system (discussed in chapters 3–7), Spitzer studies have shown that in terms of the basic architecture and composition, planetary systems around other stars are not different from the solar system. For example, exoplanetary systems show two dust belts similar to the Zodiacal dust/asteroid belt and Kuiper belt seen in the solar-system. Spitzer's infrared spectra have further demonstrated that the material (dust and gas) found in solar-system comets is almost indistinguishable from that found in young and old exoplanetary systems around other stars. Another significant contribution of Spitzer in this area has been the discovery of the 'V-ring' around Saturn, that orbits far outside of the previously known rings and that glows brightly in the infrared. In the area of the Milky Way Galaxy and its neighbours (covered in chapters 8–10), Spitzer observations helped refine the distance



The newly discovered giant ring of Saturn found by Spitzer is shown on a scale that shrinks the planet and its previously knowing rings (shown enlarged in the circular inset) to a point. Note that the tilt of the plane of the giant ring differs from that of the previously known rings (Courtesy A. Verbiscer).

measurements to the Large Magellanic Cloud, which significantly improved the estimate of the Hubble constant by bringing down the measurement uncertainties by more than a factor of three. Hubble constant is a fundamental parameter related to the expansion of the Universe, and constraining its value has important implications for various cosmological models. Finally, Spitzer observations of the infrared radiation from the faraway galaxies (discussed in chapters 11–15) have helped establish the star formation history of the Universe. The cosmic star formation peaked about 3 billion years after the Big Bang and has been dropping steadily since then. It is about a factor of ten below the peak value in the current Universe.

The final chapter revisits the fundamental questions raised at the beginning of the book to assess the advances made by Spitzer towards answering these questions. This effort not only places Spitzer's contributions in a broader perspective, but also provides a succinct summary of the breakthroughs achieved. The book also has two appendices: the first provides a short history of the Spitzer telescope, whereas the second gives technical details about how Spitzer works and how it is used. A general reader would find these discussions quite useful to learn more about the Spitzer mission. I found the notes provided at the end of the book for each chapter quite helpful and instructive. In addition to supplementing the material in the chapters, it also contains historical vignettes and anecdotal accounts.

This book belongs to a rare genre of 'popular science' books about big science missions. Very few such books explain mega-science projects that carry out cutting-edge research at a level easily accessible to the layperson. This book therefore, is a timely and welcome addition to this genre. The authors have done a commendable job explaining several conceptual and technical ideas deploying analogies and similes in a familiar and engaging language.

Yet, it contains a substantial amount of scientific and technical information. Being an astrophysicist and having used Spitzer extensively for my research, I have thoroughly enjoyed reading the book. I have also learned a few new things, particularly on the galaxy evolution and cosmology, aided by the lucid explanation provided. But I suspect the book may not be easy reading for a layperson without some technical background. Nevertheless, I strongly recommend reading it. It would, undoubtedly, be a worthy addition to the physics and astronomy collection of college and university libraries.

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