Preface

Why is the sky dark at night? If the Universe is infinite and uniformly populated with luminous galaxies which have existed forever, then the night sky should be ablaze with light. Obviously it is not—but why? Thinkers through the ages have come up with at least a dozen different answers to this question, which was dubbed "Olbers' paradox" in 1952. It was not really paradoxical then; nearly all of those who noticed the puzzle (including Olbers himself in 1823) were perfectly content with their answers, whether right or wrong. And it is neither paradoxical nor puzzling today: the reasons for the darkness of the night sky are now well understood. Yet the problem runs so deep, and touches upon so many fundamental aspects of cosmology and metaphysics, that it continues to hold a perennial fascination for astronomers and the public alike. Perhaps most profoundly of all, the darkness of the Universe at optical wavelengths is a clue to the *finiteness in time* of those sources of light that we call home: the stars and galaxies. They could not have existed forever, or the cosmos would have filled up with light. The fact that it has not tells us approximately how long they have been shining. In fact, by measuring the intensity of the night sky and applying some simple physics, we can estimate the elapsed time since the big bang with a fair degree of accuracy. Alternatively, we can calculate exactly *how* dark the sky should be at night, using what astronomers have learned about stars and galaxies together with the dynamics of the Universe according to Einstein's theory of general relativity. The results agree closely with what we see.

Such is the precision of modern observational cosmology, however, that we can go further than this and use the exact level of intensity of the extragalactic background light at all wavelengths (not just the optical) to look for hints as to *what else* may or may not be shining in the Universe. Cos-

mologists are now convinced that the Universe is dynamically dominated by two mysterious and apparently independent substances, known as dark matter and dark energy, whose energy density dwarfs that of conventional matter and radiation, and whose properties are inconsistent with anything in the existing standard model of particle physics. Very little is known about these new forms of matter-energy. However, most of the candidates that have been proposed so far are not *completely* dark. Rather, they decay into or otherwise interact with photons in characteristic ways that can be accurately modelled and compared with observational data. Experimental limits on the intensity of cosmic background radiation in the microwave, infrared, optical, ultraviolet, x-ray and gamma-ray bands rule out certain kinds of decaying dark energy, as well as dark matter in the form of light axions, neutrinos, unstable weakly-interacting massive particles (WIMPs) and objects like black holes. Thus does Olbers' paradox gain new importance as a window on the Universe, both seen and unseen.

The topic of the dark night sky is one which we, as authors, have had the opportunity to study not only as a pastime but also as a profession. We are grateful for the input of numerous researchers, and for the hospitality of several universities, notably Berkeley and Stanford. However, as we emphasize in the following (mainly technical) account, *anybody* with a clear mind can make the connection between the fact that the night sky is still dark and the fact that the Universe is young. The naked eye confirms the birth of the Universe in something like a big bang. The poet and writer Edgar Allan Poe guessed as much when he made the connection between darkness and age long before there were astrophysicists as such. We therefore dedicate this book to the thinking reader, who has looked at the glory of the night sky and wondered *what does it mean?*

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