

A unique source in a unique location

Revealing the Heart of the Galaxy

The Milky Way and Its Black Hole

Robert H. Sanders
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Reviewed by Matthew Walker

The greatest astrophysical discoveries come in two flavors: those that fundamentally alter the human perspective and those that cannot be adequately explained by conventional physics. Discoveries of the first kind have displaced our planet, our sun, and our galaxy from presumed central locations and might eventually include the detection of extraterrestrial life. Dark matter, dark energy, and other discoveries from the second category point the way toward new physics. In his latest book, *Revealing the Heart of the Galaxy: The Milky Way and Its Black Hole*, veteran astrophysicist Robert Sanders tells the story of a discovery that combined both qualities during its long development over most of the past century and culminated with a consensus among astrophysicists that the center of the Milky Way is home to a giant black hole.

An expert in stellar and gas dynamics, Sanders narrates an often personal account of observational results and theoretical ideas (with several wrong turns along the way) behind the discovery of that “unique source in a unique location.” He traces the story’s origins to heroic efforts during the early 20th century to determine the size and structure of the sidereal system composed of point-like stars and fuzzy or spiral-shaped nebulae. Clever techniques for measuring distances to those objects soon yielded perspective-altering results: Many of the nebulae lie far beyond the stars, proving that our Milky Way is but one of many galaxies in a gigantic universe. Furthermore, like all galaxies, ours has a center, but one that is far from the Sun.

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Sanders links those results as the foundation for studying galactic nuclei, a topic he proceeds to cover with a detailed seriation of results spanning the 1963 discovery of quasars to the recent detection of huge gamma-ray bubbles rising from the Milky Way’s center. The driving question is: What mechanism can be responsible for the emission of extremely powerful radiation from relatively tiny regions at the centers of many galaxies (typically about 10^{40} W from within the innermost light-year)? In its most illuminating passages, *Revealing the Heart of the Galaxy* explains how some of the world’s most distinguished scientists systematically identified and ruled out various candidates. The review is pedagogical and introduces the reader to a rich variety of astronomical phenomena, both observed and hypothesized. It also develops the thesis that “astrophysics is, in a real sense, applied physics: the concepts of modern physics are applied to astronomical problems. Moreover, explanations of astronomical phenomena are sought in terms of *known* physics.”

So it is only after careful elimination of conventional explanations that the astrophysicist can justify resorting to the exotic. That principle becomes the source of dramatic tension when the frontier of physics evolves as rapidly as that of observational astronomy. Indeed, in the late 1960s, just months after general relativity’s curious spacetime singularities were first dubbed “black holes,” it was shown that the energy liberated during the accretion of gas onto a sufficiently large one—that is, a black hole with a mass hundreds of millions of times greater than the Sun’s—could plausibly power even the most luminous galactic nuclei. With that idea came the bold prediction that the Milky Way itself hosts a dormant (because gas is not accreting), and hence less conspicuous, supermassive black hole. In its climactic sections, *Revealing the Heart of the Galaxy* gives a blow-by-blow account of the race among teams of astronomers as they vie for time on the world’s largest telescopes to find unambiguous evidence for that black hole’s existence.

According to the preface, the book is “aimed at nonspecialist readers and students and historians of astronomy.” But the content eventually veers toward the technical. Early chapters focus on the contributions and even personalities of individuals, with particular emphasis on pioneering observers like Jacobus Kapteyn and Jan Oort. In later chapters, such character studies give way to detailed descriptions and interpretations of an ever-growing body of astronomical data. There the storytelling often seems to labor under the weight of more than 100 references to published work. Toward the end, the nonspecialist will find it challenging to navigate among so many interconnected results.

Yet it is refreshing to see an author err on the side of rigor instead of oversimplification. Moreover, Sanders restores balance by inserting helpful summaries after particularly dense sections. Those interludes contain charmingly personal reflections on both the practice and development of astronomy and help to ensure that interested readers of all backgrounds can share in the thrill of a wondrous discovery.

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Quantum Field Theory and the Standard Model

Matthew D. Schwartz
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Well before two research teams at CERN’s Large Hadron Collider announced the discovery of a Higgs-like boson, the standard model of particle physics had been validated by data collected across a broad range of energies. Theory—in particular, the formulation of the standard model as a relativistic quantum field theory (QFT)—played a significant role in that success. To be sure, a QFT is an abstract and highly mathematical construct, but it offers a calculational framework from which can be derived predictions that can be tested to high precision.

To this day, QFTs are the primary theoretical tools for advancing the frontiers of knowledge about the basic principles underlying the behavior of matter. For

