

# Preface

This book is aimed at those who might have visited a radio observatory, a planetarium, a museum, or whose curiosity was otherwise stimulated by something they read in the papers or heard about on radio or saw on TV. It is also aimed at amateur astronomer as well as students of introductory courses in astronomy who wish to assuage their curiosity by reading more about the remarkable science of radio astronomy. In fact, if you are just curious, or wish to buy a book because your niece has expressed a youthful interest in science, this is for you.

## The Exploration of the Radio Astronomical Unknown

Radio astronomy is one of the great adventures of the human spirit. Exploratory behavior, the primal urge that drives us into the unknown, is rooted in curiosity and expressed in a deep human hunger for venturing into new worlds, a hunger that has been dramatically expressed in thousands of years of slow, systematic, and sometimes frightening journeys of exploration and discovery. Such journeys, overland and across the seas and oceans, have carried people from their birthplaces to the most distant corners of the planet and farther. Like pollen on the wind, our species has moved from the caves of earth to the craters of the moon. Our instinct drives us on, not just to the planets, but further, into the universe beyond our senses where profound mysteries have been uncovered, mysteries that challenge our imagination and our capacity for comprehension.

Radio waves from space carry information about some of the most intriguing natural phenomena yet discovered by human beings. This is the bailiwick of radio astronomy. However, the cosmic radio whispers reaching the earth compete with the electrical din produced by TV, radio, FM, radar, satellite, and cell phone signals. Thus the faint radio signals from space that memorialize the death of stars, or tell of awesome explosions triggered by black holes in galaxies well beyond sight, are nearly lost against the background of human-made static. Yet such radio waves contain the secrets of interstellar gas clouds, quasars and pulsars, and carry messages from the remnants of the Big Bang that propelled our universe into existence.

In order to gather the faint cosmic signals and avoid the unwanted stuff, astronomers use powerful radio telescopes located far from cities. Those telescopes are huge metal reflectors that focus the electromagnetic messages from space, which are then amplified in sensitive receivers and fed to computers where they are converted into a visual form to be displayed, analyzed, interpreted, and hopefully understood.

The story of radio astronomy is a tale of the constant quest to express in clearer visual forms the information carried by the radio waves. For this reason radio astronomers are always inventing new techniques to allow them to 'see' the radio sources more clearly. The better we 'see' the sources of those radio waves, the more likely we may be to understand their inner secrets.

Ever since Galileo first turned a telescope toward the heavens in 1609 AD, centuries of technological innovation have afforded an increasingly clear view of astronomical objects in the far reaches of space. Larger and more sophisticated telescopes are always being designed and constructed. Today, modern technological marvels such as the Hubble Space Telescope, the mightiest optical telescope ever built to date, allow astronomers to perceive the visible universe with fabulous clarity. Not to be outdone, giant radio telescopes, arrays consisting of dozens of individual dishes, now reveal the radio universe in even greater detail, and they have opened our imagination to a cosmos beyond our senses in ways previously undreamed of.

## Seeking New Knowledge

Like any science that seeks answers beyond the borders of the unknown, radio astronomy requires a great deal of thought and effort and, especially recently, significant amounts of money. In asking governments for funds to construct radio telescopes, the modern explorers of space are following a time-honored tradition. Voyages of discovery have always been costly affairs, usually sponsored by empires, monarchs, or business interests. Even Columbus needed a 'research grant' from Queen Isabella to carry him across the ocean. Today, tax dollars are used to fund expensive scientific instruments, which are the modern vessels of discovery, and the scientist/explorer's challenges have become far subtler than they once were.

In ancient times the sponsor of an explorer's journey had an expectation that the ship would return with a cargo of sugar, tobacco, spices, gold, or silver—something that could be used in barter. It is no longer so. The new explorer searches for knowledge—subtle, ethereal knowledge. This may be returned in the form of a radio image of a distant galaxy or of the invisible center of an interstellar gas cloud. It is impossible to attach financial worth to such images, just as it is impossible to attach value to any bits of that elusive substance called knowledge. What is clear, however, is that many of the pictures of radio sources in this book are beautiful in their own right even as they reveal the existence of previously unknown phenomena, knowledge of which broadens our perspectives about the universe into which we are born.

## This Third Edition

When the first version of this book was published in 1973 it was possible to summarize all of radio astronomical discoveries in a single monograph without overwhelming the reader. That was because the science of professional radio astronomy was barely 20 years old. Since then enormous advances in electronics and receiver technology has spurred a rapid growth in our ability to map the heavens in the radio band. A subsequent variation of

this book, published in 1987, entitled *The Invisible Universe Revealed*, reflected the rapid growth of by including dramatic radio images, or radiographs, of distant sources of radio waves.

At the start of the twenty-first century our ability to produce stunning images of radio galaxies, for example, thanks to the impressive growth of computer technology, meant that the process of handling and displaying the data with color added for effect took another huge leap. (I do not subscribe to using the label 'quantum' to describe such a leap because a quantum is really a very, very tiny entity.) The official 2nd edition of *The Invisible Universe* published in 2007 included many of the most up-to-date colorized radiographs. In the nearly a decade since then the sheer volume of information that has been accumulated by a new generation of very large radio telescopes working over an increased wavelength range is staggering.

This 3rd edition of *The Invisible Universe* is timely because during the past decade radio astronomy has blossomed in dramatic ways. Previously I included a brief discussion of some planned radio telescopes, each a very large project, which have now come into being. The Atacama Large Millimeter Array (ALMA) is alive and well in Chile and significant segments of the Square Kilometer Array (SKA) operate in South Africa and Australia. What is fascinating about many of the new projects is their incredible isolation in scenically beautiful but stark locations. At the same time, China is coming into its own in the field of radio astronomy. It is within this context of progress that chapters have been updated, rewritten or added, and errors have been corrected.

The Invisible Universe

The Story of Radio Astronomy

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