INTRODUCTION

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A new permanent exhibition titled *Explore the Universe* opened quietly at the National Air and Space Museum on September 21, 2001, in the wake of the events of the 11th. More than ten years in planning, overlapping with six years in definition and development and hardly one year in full-scale production, it carries the simple but powerful message that as we have created new tools and techniques to explore the universe, our understanding of the universe has changed in dramatic ways. And our understanding is likely to continue changing as we acquire new tools of perception. This book of illustrated essays is meant to complement the exhibition as a personal accounting of the challenge and spirit of living in this universe, of recognizing that there is indeed a realm fit for study "Beyond Earth," and having the privilege to be able to explore it.

The exhibition itself concentrates on Western thought and human accomplishment. This book goes beyond the walls of the museum to explore how people of diverse backgrounds, cultures, and eras have discovered and described the cosmological state they have found themselves in, as they either study other cultures, practice science in their own culture, or go about their daily lives aware that they are part of a larger world, a world beyond the senses and beyond certainty. The authors have been asked to explore how their work, or the work of their subjects, has influenced their lives, their colleagues' views, and even the rest of the culture in which their science emerged. The result, I hope, is a suite of varied personal explorations of cosmology, some of which link scientific imagery to culture in the broadest sense and others that look at how culture has been somehow shaped by an awareness of the universe. Here we look at cosmology through the eyes of different cultures and at culture seen through the eyes of historians and cosmologists.

These essays are in large part personal visions by scholars who in their work have shown an interest in searching out visual metaphor in astronomical maps, world models, social structures, and computer data derived from a wide range of sensory devices. Underlying this effort is an interest in linking modes of visual representation to knowledge in science, but the thrust of the essays will be largely synthetic, speculative, and either broad ranging or anecdotal, but not heavily analytical nor encyclopedic. They will be, above all, personal statements, personal explorations.

The essays in this first section are historical, ethnographical, and anthropological, describing worldviews—or cosmologies—as they emerged in different cultures and at different times. Some comment on the interplay of cosmological worldview and the culture that created it. But they all are, moreover, products of personal and professional intellectual journeys—those taken by the writers as they explored questions they raised about the world around them. In this way we have provided a collective portrait of our own personal, intellectual pursuits and how we, as individual scholars, grew or changed as a result.

Authors have been chosen who have taken an intellectual journey and who can write engagingly about it in ways that, we hope, will reach a wide audience. These essays are narrative journeys taken by interesting people who are doing interesting things. They are not biographical profiles, but vignettes, stories about what it feels like to discover something new about the universe and about cultures that have pondered the universe in different ways. Some of the essays will let us take a peek at our craft, as scientist or historian, and how we acquired questions and sought out answers. Most of us have been fortunate enough to experience the thrill, either directly or indirectly, of encountering new universes. Our job here is to communicate the excitement and wonder of the encounter. This is payback time in a culture that permits and even applauds the efforts of those who choose intellectual journeys of discovery.

The book divides easily into three sections. The first grouping of essays explores our growing awareness of the universe as both a physical and a spiritual place. Our focus is on Western culture, and on how our sense of place has changed over time as we sought ways to predict the behaviors of things seen in the heavens. In reviewing our own history, we must be keenly aware of how our ever increasing ability to observe and to model the physical universe as a mechanism, or now as a set of rules, has actually removed us from the root questions that set us on this long journey of discovery. To remind us of these all-important roots to humanity, we have added several essays that explore both contemporary and historical cultures that retain a deep attachment to the spirit of the universe. If nothing else we hope this will remind all of us that the universe is not, as astrophysicist Sandra Faber likes to say, "out there. It is right here." We hold a portion of it in our very being.

This book was in large part stimulated by the presence of an exhibit and derives much of its flavor from it. Most of the authors were in one way or another involved as advisors to the exhibition team, and many elements of the exhibitry have found their way into these pages. Eric Long's wonderful photography, David Romanowski's lyric scripting, Beatrice Mowry's elegant designs all have informed and illuminated the book. Many of the graphics, including the dust jacket cover art, are works commissioned for the exhibition. The suite of illustrations collected by Joan Mathys for the exhibition provided the basis for the visual materials presented here.

Transforming the exhibition into a book has been managed with consummate skill and creativity by the editorial and photographic book staff of the National Geographic Society. Kevin Mulroy's enthusiasm for the project made it possible, Melissa Ryan's visual acuity made it live, Lyle Rosbotham made it fit together with delightful elegance, Marlis McCollum made it read right, and Lisa Thomas made it happen. It has been a privilege working with all of them.

CELESTIAL CALCULATORS

Astrolabes are sophisticated, handheld instruments that were used for centuries as mechanical maps of the universe, as calculating and teaching devices, and as traveler's navigational aids. The concept of the astrolabe dates from classical Greece, where philosophers such as Hipparchus (180 B.C.) explored ways to project maps of the sky onto flat surfaces. The most well-known early discussion of an actual instrument using this form of sky projection is found in Claudius Ptolemy's Planisphaerium (ca A.D. 150). By the tenth century the Islamic world had adopted and refined the astrolabe.

Usually made of brass, astrolabes were used for centuries to teach people about the sky and to take observations of sky phenomena for astronomical, civil, and religious purposes. Holding the astrolabe by a small ring with one hand, the astronomer sighted along the movable pointer, called an "alidade," lining up the sun, the moon, a planet, or a bright star, and then carefully recording what the angular altitude of that object was above the horizon. This simple observation linked the astronomer's position on Earth, the time of day or night, and the date of the year with the place of that object in the sky. All the complex circles and charts on the astrolabe were mechanisms to calculate how these quantities were related and allowed the astronomer to use the sky as a great clock. Most often it was used as a powerful tool and as an authoritative symbol for the casting of horoscopes.

Astrolabes came in many sizes and styles, but their basic function did not change between the 10th and the 17th centuries, either in the East or in the West, which demonstrates the relative stability of the science of astronomy during this period. One of the oldest astrolabes in the collection of the Smithsonian's National Museum of American History was constructed in Muslim Spain ca 1090 and is among the most ancient in existence. This four-inch radius astrolabe has several interchangeable plates, each engraved with the local coordinates for a different latitude. The pointers on the top plate indicate the positions of 22 bright stars. The top plate can rotate to show where those stars will appear at different times or dates, much like a modern paper or plastic star finder. The instrument could be used to predict when the sun or certain bright stars would rise or set on any date, but most often was probably used to tell the time of prayer. Eventually this astrolabe passed from Arabic hands into the West. As it did, many of its original Arabic inscriptions were probably erased to allow for Hebrew inscriptions. Both Arab Kufic and Hebrew inscriptions are still to be found on various parts of this extraordinary device. Another example, from 16th-century France, is a bit larger in diameter, but otherwise functions the same as the 11th-century example. Known as the "Galois 1548," it was constructed for use at a latitude of 48 degrees north.

The astrolabe was slowly introduced into Western culture through Muslim Spain. By the 13th century, Latin texts were available describing them, though the device gained its broadest popularity starting in the late 14th century, after Geoffrey Chaucer recommended it as an important astrological forecasting device. It became a central instrument in the education of the elite. Although European instrument makers discarded the Islamic prayers inscribed on earlier astrolabes, they retained the Arabic names of the stars. Some 1,600 astrolabes of all types survive today, though only a few hundred have been thoroughly studied.

Some astrolabes combined the features of a quadrant and an astrolabe. Only seven of these devices are known to exist today. This one, located in the center of the grouping above, dates from 1325. The circular face of this brass astrolabe has essentially been "folded over" twice to fit on a quarter-circle. It could serve as a measuring tool and perform many of an astrolabe's calculation functions. It was used as a sighting device for astronomical and terrestrial observations. Quadrants were generally easier to use than astrolabes and ranged in size from small handheld versions to large mural quadrants many feet across. After the invention of the telescope, large quadrants were often combined with telescopic sights for improved positional measurements. Today, the ancient technology of the astrolabe and the quadrant form the foundation for the planispheres and moving star charts that adorn telescope shops, planetarium bookstores, and public star parties, helping us maintain the connection between the Earth and sky that has existed for centuries.

—David DeVorkin

The French astrolabe (left) dates from the 1500s; the Islamic astrolabe (right) was crafted in 1090. The medieval instrument between them—only a few still exist—combines features of an astrolabe and a quadrant, a tool for measuring altitude.