Preface

July 11, 1991—along with thousands of others, both of this book's authors had been drawn to the city of La Paz, near the southern tip of the Baja California peninsula. The magnet was what had been billed as the "eclipse of the century," an event that would blot out the Sun for over 6 min.

Anticipation rose as the Moon's first notch into the solar limb appeared. Then the lunar limb's dark outline encroached gradually upon the Sun over the space of an hour as the sky and the landscape dimmed and yellowed (Fig. 1). Finally the Moon's shadow swept in from the northwest like an avenging angel as the city's lights came on beneath our hillside location. The shadow enveloped us, ushering in the main event on schedule—we can predict solar eclipses to a fraction of a second and where they occur to a few tens of meters—and even the weather, where our predictive powers are less impressive, cooperated with cloud-free skies.

Although this was not our first total eclipse, we fell under a combination of surprise, awe, and a little fear—a perfect example of what is sometimes called *the sublime*. In physical terms we were now within a sunless cone of negativity that stretched from us to the silhouetted edge of the Moon. It might as well have been forever, for we can't truly grasp a distance of hundreds of thousands of kilometers, even though it is an infinitesimal step in astronomical terms. We did know we were no longer fully earthbound but for a few minutes part of the larger cosmos.

As always the event was beautiful and (even though almost record-breaking in length) over all too soon as the lunar shadow passed on across the Sea of Cortés to mainland Mexico.

And that's one drawback of total solar eclipses—their brevity. The other is their scarcity. There is only one or (rarely) two per year for the entire Earth, each total phase lasting at best a few minutes, and each zone of totality a narrow strip. For La Paz it was the first such event for centuries, and one wouldn't return for centuries more.

And yet—although many don't realize the fact—total solar eclipses are just one type of solar eclipse, albeit the most spectacular type. Thus, just 3 years later, an annular solar eclipse—where the Moon is too far from us to completely cover the Sun, leaving a fiery ring of light instead—would cross the Baja California peninsula. Furthermore, solar eclipses are just one form of eclipses in general—La Paz

Fig. 1 The excitement builds up among the Minnesota Astronomical Society group as totality approaches during the 1991 July 11 total eclipse of the Sun at the square of the Parroquia Inmaculado Corazón de María school in La Paz, Baja California Sur, Mexico. (Photograph by William Sheehan)

would witness a partial lunar eclipse just 5 months later, near 1991's December solstice. For that matter, 4 days before the long solar eclipse, on the evening of July 7th, still from La Paz, aided by a telescope, you could have watched Jupiter's moon Ganymede emerge from eclipse, as it left the shadow of the Giant Planet.

The list grows longer, because eclipses themselves are closely related to the phenomena known as occultations and transits. More than two centuries earlier, in 1769, a French-Spanish expedition traveled halfway around the world to the southern Baja California peninsula to witness a transit, when the planet Venus crossed the face of the Sun. The site they chose was the mission of San José del Cabo, now a thriving city where many in 1991 witnessed the solar eclipse.

Preparing the present book was an educational and humbling experience for its authors, as their eyes were opened to the great variety of eclipse events. Called *eclipses*, *transits* and *occultations*, these broad categories often overlap—the only encompassing term appears to be *eclipse events*. These phenomena occur throughout our Solar System, but also beyond as stars eclipse other stars and planets transit distant suns. Celestial shadows permeate the universe. One of our major objectives for this book is to convey the near-endless variety of eclipse events.

Celestial shadows also permeate the field of astronomy, both for amateurs and professionals. Observations of their effects help us measure the ozone in our own atmosphere, pinpoint the location of the Moon, inform us of the makeup of the atmospheres of the planets, measure the diameters of stars, discover the planets of other suns, and even help to measure the distances of other galaxies. It is hard to imagine any branch of astronomy that has not profited from these phenomena.

Judging by the number of scientific reports relying on the observation of eclipse events, this is a growing field. Yet their investigation has a history stretching back to ancient times, for example when Ptolemy of Alexandria fixed the location of the Moon and planets by watching them pass over stars. In more modern times, solar eclipses led to the discovery of the Sun's inner atmosphere—its *chromosphere*—and its outer atmosphere—the *corona*. In the eighteenth century, Venus's atmosphere was revealed by its transits across the Sun.

Sadly, though, many in the astronomical community are unaware of the full depth of the history of their field—this includes professional astronomers and planetary scientists as well as amateurs. A single book such as ours can make only a beginning here, but we have tried to weave throughout our subject matter the history of our growing awareness and utilization of these natural phenomena—the second of our major objectives.

This explains the long list of literature citations at the back of this book. We have repeatedly found that the best source for what astronomers have done and have discovered is to consult their original writings. And we have been surprised and gratified at the ever-increasing availability on the Internet of original sources, often in translation, even including rare books from the days of Tycho, Kepler, and Galileo.

Our third and final major objective is to entice amateurs into the observation of these events and supply some basic aids to help them get started. The sophistication of amateur astronomers, both in methods and equipment, has developed inspiringly in recent decades. Serious amateurs can often produce results comparable to those of major observatories and professional-amateur cooperation has, for example, helped discover exoplanets and measure the diameters of asteroids. Again, length limitations allow us only to introduce our readers to the sources describing the prediction, observation, and analysis of eclipse events. In order to encourage our readers to observe them, we describe the more interesting eclipse events coming up in the period 2014–2025. The science of eclipse phenomena is thriving, with the result that we must freely admit that much that we cover will soon become out of date—always the case with a healthy field.

Notes on Units of Measure

A near-universal application of the observation of eclipse events is measurement—the measurement of distance and physical size, angle and angular size, time, position, or mass for example. All these quantities have their own units, and often the same quantity can be expressed in more than one system of units.

The standard system in science for measuring distance and physical size is the *International System of Units* (SI), often called the "metric system." It is based on the meter, with prefixes denoting millimeters, kilometers, and so forth. The literature, both current and, particularly, older, often uses other units, such as what is variously called the Customary, Imperial, or English System, which uses inches, feet, and miles. When a dimension is given in the Customary System we have given the SI equivalent (and sometimes *vice versa*). As for angles and angular sizes, we use degrees (°), arc minutes (') and arc seconds ("). To give an idea of their sizes, the Sun's angular diameter is roughly 0.5 degrees, 30 arc min, or 1,800 arc sec. A person with good vision can resolve detail down to about 2–3 arc min; a typical amateur telescope to perhaps 0.5–1.0 arc sec.

Unless otherwise pointed out, we will express time and date in Universal Time (UT; formally Coordinated Universal Time or UTC), which for all intents and purposes is standard mean solar time at Greenwich Observatory, England. (To convert UT to your local time zone, or *vice versa*, refer to the world time zone map at http://aa.usno.navy.mil/faq/docs/world_tzones.php). We give dates in the Common Era (CE or BCE), with the Julian Calendar ("Old system" or "O.S.") before 1583 CE and the Gregorian Calendar ("New System" or "N.S.") thereafter. (When we use the astronomical system, which employs negative years, note that it *does* have a year 0, so that, for example, −43 is the same as 44 BCE). For astronomical events we give dates in year-month-day order, but mundane dates in the familiar month-day-year manner.

That said, we have to point out that astronomers often use their own, non-SI, units. They often express wavelength in angstrom units (Å), where 10,000 Å equals 1 μm (the latter is often still called "micron"). Distances within the Solar System, and sometimes in other stellar systems, are often given in astronomical units (au; 1 au = 149, 597, 870.700 km). For interstellar distances the parsec (30.86 trillion km) or light year (9.46 trillion km) is standard. (Note that this book uses "billion" and "trillion" in the American sense; i.e., 10^9 and 10^{12}, respectively). Astronomers use angles to measure north–south and east–west positions, but the east–west coordinate of right ascension is expressed in time units (where 1 h = 15°). Also, it is not unusual to find the mass of a planet or star expressed in solar masses (1 solar mass = 1.9884×10^{30} kg).

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