1
Thirty Centuries of Eclipse Watching

A total eclipse of the Sun is a spectacular, awe-inspiring event. Throughout the past, human beings must have stopped in their daily struggle to survive in order to stare in disbelief at the gradual disappearance and reappearance of the Sun. We have no written records for most of this period. We can only guess at the reaction of neolithic peoples by extrapolating from the reaction of "primitive" peoples now. With few exceptions, they view a total eclipse of the Sun with fear, guilt, a desire to propitiate their gods, and afterwards, an enormous sense of relief.

Through most of recorded history, eclipses were viewed as a supernatural manifestation, usually an omen of some impending calamity. The idea that eclipses are linked to human events changed only slowly, and the idea was manipulated by the priestly class for the greater good of the state. Only the ancient Greeks were comfortable enough in their world to begin to view eclipses with detached interest.

A scientific study of eclipses did not begin until the 17th century, and barely got going until the middle of the 19th century. Thus, although men have been watching eclipses for 300 centuries, and have been recording them for 30 centuries, practically everything we know about them today has been learned in one century, and much of that in the last 40 years. This pattern of extraordinary acceleration in the pace of investigation is common throughout the recent history of science.

ANCIENT AND MEDIEVAL ECLIPSES

Throughout all of recorded history, learned men have written down their impressions of total solar eclipses. Scribes, astrologers, court annalists, official historians, and monks have all contributed to a vast pile of semiastronomical records. These records have modern value, not only for the history of science but for the history of ancient civilizations, because a clear record of an eclipse establishes a precise date in the past. A modern historian, trained in ancient languages, can supply an astronomer with the basic facts concerning an eclipse. The astronomer can then calculate the date and time of the eclipse with an uncertainty of only a few minutes if he is given its location and a date that is accurate to within a decade. Between them, the astronomer and the historian can relate the chronology of an ancient people to our modern calendar system.

This method has its pitfalls, however. In many cases, the original reference is extremely vague and more than one eclipse might qualify as a candidate. Moreover, some of the old historians (like Herodotus) embroidered the facts or even invented eclipses simply to stress the importance of a battle or the birth of a king. The modern scholar must decide whether a record is reliable as well as what it says.

R. R. Newton, who combines antiquarian and astronomer in one person, distinguishes three kinds of spurious eclipses:

1. *The Assimilated Eclipse.* A chronicler may shift the date of an eclipse by a year or more, consciously or unconsciously, to relate it to another event.

2. *The Literary Eclipse.* This type appears in a work of pure fiction, and is itself pure fiction, but is taken as real by some overeager reader. The eclipse of Plutarch (A.D. 71) is an example.

3. *The Magical Eclipse.* "Solar eclipses have a remarkable tendency to happen during battles, at the deaths of great personages or at the beginnings of great enterprises." Herodotus, for example, inserts a magical eclipse into history to punctuate the beginning of Xerxes' campaign against Greece.

This tendency of ancient historians to dramatize their work greatly complicates the work of modern scholars. But several investigators have risen to the challenge, examined reams of old documents and attempted to compile a reliable sequence of past eclipses. Table 1.1 compares the judgments of three experts, who have sifted the original evidence for reliable records of "large" (total, annular, or nearly total) eclipses.

What, then, is the oldest reliable record of a total eclipse? You

TABLE 1.1. Three Authors' Lists of Reliable Pretelescopic Eclipses

	DATE	PLACE	AUTHOR*
B.C.	2165? 1948?	China	Needham
	1375 May 3	Ugarit	SC, M
	1330 June 14	An-Yang	M
	1131 Sept 30	Gibeon	M
	763 June 15	Nineveh	M, N
	709 July 17	Chu-Fu	M, N, SC
	601 Sept 20	Ying	M, N, SC
	549 June 12	Chu-Fu	N, SC
	442 March 11	China	N
	431 Aug 3	Athens	N
	424 March 21	Athens	N
	392 Aug 14	Chaldonea	N
	382 July 3	China	N
	364 July 13	Thebes	N
	322 Sept 26	Babylon	M
	310 Aug 15	Sicily	N
	300 July 26	China	N
	198 Aug 7	Chang-An	M, SC
	188 July 17	China	N
	181 March 4	Chang-An	N, SC
	147 Nov 10	Chang-An	N
	136 April 15	Babylon	M, N, SC
	89 Sept 29	China	N
	80 Sept 20	China	N
	28 June 19	China	N
	2 Feb 5	China	N
A.D.	2 Nov 23	China	N
	59 April 30	Armenia	N
	65 Dec 6	Kuang Ling	M, N, SC
	120 Jan 18	Lo Yang	M, N, SC
	243 June 5	China	N
	360 Aug 28	China	N
	429 Dec 12	China	N
	484 Jan 14	Athens	M, N
	516 April 18	Nan-Ching	M, N
	522 Jan 10	Nan-Ching	M, SC
	590 Oct 4	Mediterranean	N
	840 May 5	Bergamo	N, SC
	912 June 17	Cordoba	SC
	916 June 17	Cordoba	M
	968 Dec 12	Constantinople	M, N, SC
	975 Aug 10	Kyoto	SC
	1033 June 29	Europe	N
	1079 July 1	Alcobaca	M

(*continued*)

TABLE 1.1 (*cont.*)

Date	Place	Author*
1093 Sept 23	Mideast	N
1124 Aug 11	Novgorod	M, SC
1133 Aug 2	Salzburg	M, N, SC
1140 March 20	Europe	N
1147 Oct 26	Europe	N
1176 April 11	Antioch	SC
1178 Sept 13	Vigeois	M, N, SC
1185 May 1	Europe	N
1187 Sept 4	Europe	N
1191 June 23	W. Asia	N
1207 Feb 28	Europe	N
1221 May 23	Kerulen R.	M, SC
1239 June 3	Mediterranean	M, N, SC
1241 Oct 6	Stade	M, N, SC
1263 Aug 5	Mideast	N
1267 May 25	Constantinople	M, SC
1310 Jan 31	Europe	N
1361 May 5	Mt. Sumelas	M
1406 June 16	Braunschweig	SC
1415 June 7	Prague	SC
1485 March 16	Melk	SC
1560 Aug 21	Coimbra	M, SC
1567 April 9	Rome	M, SC

*M = P. M. Muller
N = R. R. Newton
SC = F. Stephenson
J. Needham wrote *Science and Civilization in China*. (See the "Suggested Reading List" at the end of this chapter).

might imagine that the Egyptians would have been the first to note such an event, since their historical records date back to at least 4000 B.C., but for some reason the Egyptians are not even in the running. As Table 1.1 shows, all the candidates for the oldest eclipse record are Chinese or middle eastern.

The oldest of all dates to the time of the Hsia dynasty (2183 to 1751 B.C.). It appears in Shu-chin (literally, "The Book"), and is associated with the story of two astronomers, Hsi and Ho, who failed to predict a solar eclipse and were punished by decapitation. This story has come down to us through Gaubil's *Treatise on Chinese Astronomy,* which dates from A.D. 1732. To this very day, scholars argue whether the event of this date was an eclipse, and whether in fact the event occurred at all. The problem is that the Shu-chin was burned in a general repression of thought in 223 B.C., and was reconstructed in the 4th century, A.D.

However, P. K. Wang and G. I. Sisco quote a 5th century B.C. book that quotes yet another book written by Confucius, in which the Hsia dynasty event is mentioned unequivocally as a solar eclipse. J. Needham, in his monumental *Science and Civilization in China,* offers dates for this eclipse that run from 2165 to 1948 B.C.

R. R. Newton concludes that this eclipse was a myth because there are no words in the record that explicitly relate to a solar eclipse. Newton is extremely skeptical of ancient Chinese court annals in general. They contain over a thousand eclipses, but most of them cannot be verified by modern calculations. Were they due to clerical errors, faulty locations, or simple invention? We may never know.

The next most venerable record dates to 1375 B.C. "The Sun was put to shame and went down in daytime," says the historian, recording an event that was seen in Ugarit, an ancient city north of Latakia, in Syria. The date was not recorded, but given as "the day of the new moon in the month of Hiyar," which corresponds to April or May. A computer investigation by J. Sawyer and F. Stephenson yielded May 3, 1375 B.C. as the only acceptable date.

During the Shang dynasty in China, (1766 to 1123 B.C.), events of astrological importance were inscribed on oracle bones. According to Needham:

> Liu Chao-yang has suggested that oracle bones of the second millenium may contain the first recorded observations of the solar corona during an eclipse. The dates of bone fragments studied by Liu must be either 1353, 1307, 1302, or 1281 B.C.

The eclipse of June 15, 763 B.C. appears in the Assyrian Chronicles. The inscription reads "Insurrection in the city of Assur. In the month Sivan, the Sun was eclipsed." This eclipse plays a crucial role in establishing historical dates. Together with lists of kings and reigns, it establishes Assyrian chronology on our own modern calendar.

Perhaps the most famous of all antique eclipses was that of Thales, in 585 B.C. Herodotus in his *History* relates that the Lydians and the Medes were battling in the sixth year of their war when

> . . . day was on a sudden changed into night. This event had been foretold by Thales, the Milesian, who forewarned the Ionians of it, fixing for it the very year in which it actually took place.

Most of the controversy about this eclipse concerns not its date or its place (the neighborhood of the river Halys), but whether Thales knew enough astronomy to predict a total eclipse. Some scholars incline to the view that he was aware of the Babylonians' use of the saros cycle of 18 years in which eclipses repeat, and simply extrapolated from the eclipse of May 18, 603 B.C. However, other specialists believe that even the Babylonians of Thales' time were unable to predict solar eclipses, using the saros, although they might have predicted lunar eclipses.

The Chinese lagged the Greeks in their understanding of eclipses. Shih Shen, a Chinese astronomer of the 4th century B.C. realized that the Moon played some role in eclipses, but thought that its Yin influence overcame the Yang influence of the Sun. Liu Hsiang first proposed the modern explanation around 20 B.C.: "When the Sun is eclipsed, it is because the Moon hides him as she moves on her way."

Theon was an Alexandrian astronomer of the 4th century A.D. He was the first to record, not only the date of an eclipse (in A.D. 365) but also the times of its beginning, middle, and end. Theon must have used a clepsydra, a water clock, and measured time in fifths or sixths of an hour. High precision for those days! As we shall see in Chapter 3, Theon's careful record still counts in recent studies of the Moon's motion.

Hipparchus, perhaps the most eminent astronomer in Greek history, used two observations of the eclipse of 130 B.C. to estimate the Moon's distance from the Earth. The eclipse was total at the Hellespont but only 80% of total in Alexandria. Hipparchus already knew the difference in latitude between these places, from simultaneous observations of the same star. Thus, in effect, he knew their linear separation, in units of the Earth's radius. The eclipse observations now gave him the angular displacement of the Moon (its parallax, in astronomical parlance) as seen from the two locations. Trigonometry, which he was the first to apply to astronomy, then yielded the Moon's distance. He estimated it at 62 to 74 Earth radii. The current value is 60.27.

Evaluating the credentials of ancient eclipses is a harmless indoor sport, played by a small number of ardent specialists with, to be sure, the most serious of motives. It is fun to read how one expert refutes the arguments of another, using nothing more than his presumably better judgement of the cryptic historical records. For example, J. K. Fotheringham, in a key work on the Moon's motion, included in his 1920 analysis the eclipse of Archilochus, a Greek poet who wrote:

> Nothing there is beyond hope, nothing that can be sworn impossible, nothing wonderful, since Zeus, father of the Olympians, made night from mid-day, hiding the light of the shining Sun, and sore fear came upon men.

This presumed reference to an eclipse was identified by T. Oppolzer in 1882, using eclipse calculations and the fact that Archilochus divided his time between the islands of Paros and Thasos. However, that arch-skeptic, R. Newton, dismissed this passage as purely literary, after he found no fewer than *five* eclipses that could fit the facts.

For a thousand years following the eclipse of Theon in A.D. 365, astronomers continued to observe and record solar eclipses. The records become more numerous, and hopefully, more reliable. Newton has found seventeen eclipses between A.D. 840 and 1310 which were recorded by ten or more independent observers. These are listed in Table 1.1. During the 12th and 13th century, 32 eclipses were recorded somewhere in the world, with over 270 records derived from northern Europe alone. When we consider the disturbed state of society and the slow awakening of science during these two centuries, this interest in solar eclipses seems remarkable. However, astronomers did little more than note the location and time of an eclipse, and gave no descriptions of what they actually saw during the event.

Kepler seems to have been the first western astronomer to comment on the appearance of the solar corona, during the eclipse of 1605. The second reference appeared a full century later. Giovanni Cassini, director of the Paris observatory, described a "crown" of pale light surrounding the Sun during the eclipse of 1706. He attributed the light to some manifestation of the zodiacal light.[1]

Nine years later, Edmund Halley observed the eclipse of April 22, 1715, from the roof of the new quarters of the Royal Society of London. In the *Philosophical Transactions of the Royal Society* of that year, he described the shape of the corona and the appearance of the bright red prominences. He noted that they were different on the eastern and western limbs of the Sun, and suggested an explanation in terms of a thin atmosphere on the Moon. According to Halley:

> The eastern limb of the Moon had been exposed to the Sun's rays for a fortnight, and as a consequence it would be natural to expect that the heated lunar atmosphere might exert some absorbing effect on the solar rays, while on the contrary the western edge of the Moon, being in darkness and cold for two weeks, could exhibit no such absorbing action.

Although the idea of a lunar atmosphere was dispelled eventually, it took over 180 years to establish whether the phenomena observed during an eclipse were solar or terrestrial in origin.

DISCOVERY AND DEBATE IN THE NINETEENTH CENTURY

Most of us tend to forget how recently our present knowledge of physics and astronomy has developed. The date 1800, which coincides with the election of Thomas Jefferson as President of the United States, does not seem all that long ago. Yet, at that time, Sir William Herschel, one of the towering figures of eighteenth-century astronomy, seriously proposed the idea that the Sun was a cool, solid body, covered by a layer of luminous clouds, and not greatly different from the planets except for size and distance. It would be 40 years before the law of conservation of energy was proposed, and 70 years before physicists understood how the amount of energy radiated by a hot body varied with its temperature.

Herschel's ideas were rapidly dispelled by scientific investigation during a series of eclipses beginning in 1842. Until that time, scientists had shown little interest in the phenomena visible during an eclipse.

Francis Bailey, an English amateur astronomer, had witnessed the annular eclipse of 1836. He published a report describing a row of bright beads of sunlight that appeared along the Moon's limb at the maximum phase of the eclipse. "Bailey's Beads," as these are now called, are caused by sunlight shining between the mountains on the Moon. His description focused the attention of professional astronomers on the eclipse of 1842, which was visible across southern