

Pottery, lunar eclipses, and state-of-the-art analytical techniques solve a 3,500-year-old mystery.

By Vahe G. Gurzadyan

An aerial photograph of an ancient city, likely Babylon, showing a complex grid of streets and buildings. The scene is illuminated from above, creating a dramatic play of light and shadow. The city is set against a dark, hazy background, possibly a river or a plain. The overall tone is mysterious and historical.

# Astronomy and the

**I**t's not often when sophisticated techniques developed for astronomy can answer an Earthly mystery that has persisted for thousands of years. Yet there is a direct link joining the Cosmic Background Explorer (COBE) spacecraft and lunar laser-ranging to the precise dating of a celebrated historical event — the fall of Babylon

to the Hittites in the second millennium B.C.

One of the most famous cities in the ancient world, Babylon was strategically located on the Euphrates River. There it wielded political

power and controlled trade throughout a large region of Mesopotamia (modern-day Iraq). Yet we remember it today as a fount for our scientific heritage. Babylonian astronomy is directly echoed in

the *Almagest* of Claudius Ptolemy (about A.D. 140), which epitomized this science until the time of Copernicus 14 centuries later. Even nowadays our culture is bound to such inventions as the sexages-

A nightjar on the wing the evening of June 27, 1954 B.C., would have seen the rising, eclipsed Moon bathing the Mesopotamian city of Ur in its light. Records of this total lunar eclipse were crucial for dating the fall of the celebrated city of Babylon 250 kilometers to the northwest. Ur is featured because this eclipse "foretold" the death of its greatest king, Šulgi. Jupiter gleams near the Moon.





# Fall of Babylon

imal system and the zodiac. My involvement with Babylonian astronomy started in 1995, when I met Hermann Gasche, a leading European archaeologist, coordinator of excavations in various areas of Mesopotamia, and author and editor of many books on the archaeology of the region. Our association seemed pre-ordained. Several years earlier,

One key for establishing dates in the ancient world is the changing shapes of pottery. These vessels are typical for the years just before Babylon's fall to the Hittites. The tall ones are probably mugs for beer, a favorite Babylonian beverage.



JARS: JAMES A. ARMSTRONG, CITY OF LIR; S&P / STEVEN SIMPSON, TECHNICAL CONSULTANTS JAMES A. ARMSTRONG AND ROGER W. SINNOTT



Copying cuneiform texts isn't always easy! In 1926 Ashkharbek Kalantar, the author's grandfather (in helmet), supervised the work involving an Urartian rock inscription at Armenia's Lake Sevan. Today the water level is 20 meters lower.

while visiting Armenia, Gasche became aware of unpublished works prepared in the 1920s and '30s by the archaeologist Ashkharbek Kalantar, my grandfather, and arranged for their publication.

As we sat in his Paris studio full of pictures of pottery, Gasche excitedly told me about a problem he had been working on with two American researchers, archaeologist James Armstrong and Assyriologist Steven Cole. The vessel shapes he had studied at various archaeological sites couldn't be accommodated within the time frame of the so-called Middle Chronology (see box below) of Mesopotamia, which was the most commonly accepted scheme but also the most criticized. (Archaeologists fre-

Ancient sites mentioned in the text are included on this map, which also shows modern Baghdad and Kuwait city.

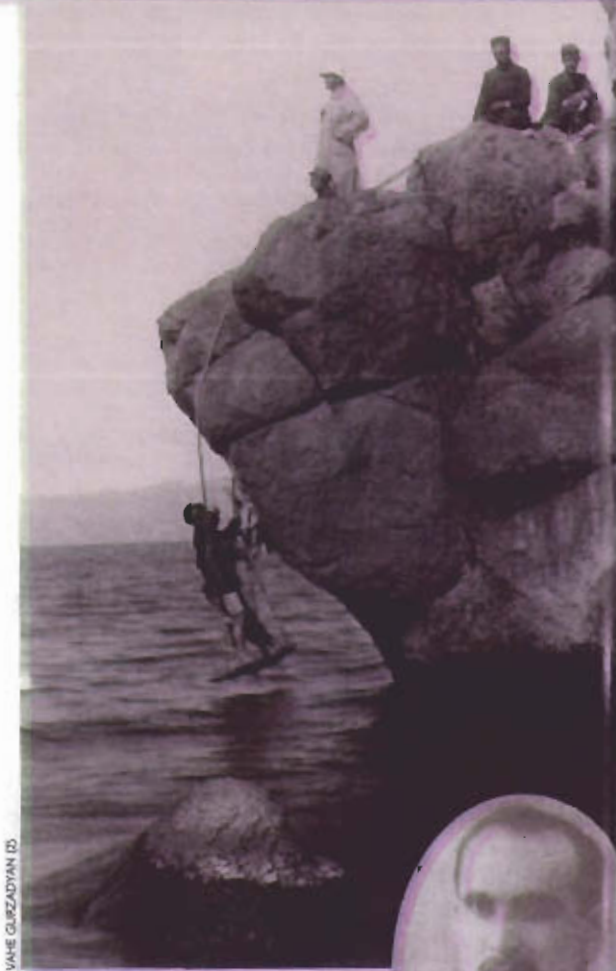


quently use pottery evidence to help date ancient cultures.) To reconcile what Gasche and his colleagues had found required shortening the Middle Chronology by about a century.

Part of the reason behind Gasche's excitement was a group of tablets recently unearthed at a site in a Baghdad suburb called Tell Muhammad. Among these tablets were two bearing references to a lunar eclipse that occurred 38 years after Babylon was resettled. He wanted to see whether I could use that eclipse and other astronomical sources to establish an *absolute chronology* for around the time Babylon fell and perhaps simultaneously resolve the pottery enigma. Such a chronology can be established only through astronomical records like those on the eclipse tablet. Indeed, the standard Near Eastern chronology from about 1400 to 700 B.C. — based on the so-called Assyrian Kinglist — is anchored by records of the solar eclipse of June 15, 763 B.C.

My first step was to carefully examine the existing literature and the methodology of ancient Babylonian astronomers and mathematicians. It soon became ev-

ident that chronologies for eras earlier than 1400 B.C. — based on the so-called Venus Tablet from the reign of King Ammīsaduqa of Babylon — were flawed. The reason is trivial: although the tablet contains sightings of the planet that could conceivably be dated, its 20 identified fragments are actually cor-



VAHE GURZADYAN (2)



## Babylonian Chronologies

Using ancient records, historians have been able to work out the internal chronology of the 500-year period that ended with Babylon's defeat by the Hittites. However, providing *absolute dates* has proved to be very difficult, particularly because this period is separated from the earliest reliable Mesopotamian dates, which cluster around 1400 B.C., by an intervening period of unknown length.

Since simply "counting back" from 1400 B.C. is not possible, researchers have turned to the Venus Tablet for help (see text above). They identified observational cycles of 56 and 64 years that seemed to

underlie the data recorded on the tablet and, as a result, were able to propose a series of alternative chronologies. The three most frequently cited, commonly referred to as "High," "Middle," and "Low," place the fall of Babylon in 1651, 1595, and 1531 B.C., respectively. Even though

the reliability of the Venus data has been seriously questioned, Mesopotamian scholars have generally utilized one or another of these chronologies.

Vahe Gurzadyan has now shown that the 56- and 64-year cycles, which had the practical effect of limiting the number of viable chronologies, cannot be extrapolated from the Venus Tablet data. Instead

By James A. Armstrong



PHOTO BY JAMES ARMSTRONG



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rupted copies made about a thousand years after the events took place.

The Venus Tablet is one (Number 63) of a series of some 70 tablets collectively known as *Enūma Anu Enlil*. Two others (Numbers 20 and 21) record a pair of lunar eclipses connected with the Third Dynasty of Ur, which dominated Babylonia around 4,000 years ago.

### Unscrambling the Evidence

I started with a reexamination of the Venus Tablet. This remarkable text, identified in the 1920s by the Jesuit Franz Kugler, contains data on first and last visibilities of Venus during a 21-year period that is believed to involve the reign of King Ammisaduqa, who governed a little over a century after the famous Babylonian king Hammurabi.

Following an orbit inside Earth's, Venus becomes temporarily invisible when it aligns itself either between the Earth and Sun (inferior conjunction) or beyond the Sun (superior conjunction). These passages mark when Venus switches from being a "Morning Star" to an "Evening Star" or vice versa. Very important to the Babylonian astronomers, as documented in the Venus Tablet, is that these morning/evening visibility cycles repeat almost precisely in the sky every 8 years. (Five of Venus's conjunction-to-conjunction periods of 584 days equal 8 years within a couple of days.)

Almost from the time of its discovery

it became evident that the Venus Tablet contains errors made by the original scribe as well as later copyists. Also, parts of it are obscured and unreadable. So it's not surprising that scholars have disagreed on its usefulness for dating events in the ancient Babylonian world. Erica Reiner and David Pingree, for example, claimed it was impossible to extract reliable chronological information from the tablet. Nevertheless, researchers have continued to rely on the Venus Tablet to generate chronologies for the centuries preceding the fall of Babylon.

In modern jargon, we can say the tablet has "noisy" data, and that's where my experience with COBE proved useful. In 1996 I worked with COBE team member Sergio Torres on ways to pluck real signals from COBE's complete data set. This was no easy task because of pervasive contamination by noise from the cosmos, the Earth's atmosphere, and the detectors themselves. We were analyzing the distortion of "hot" and "cold" spots in sky maps of the cosmic microwave background, and we finally detected a tiny signal that matched a theoretical prediction to suggest the universe might have negative curvature and expand forever. (We published the result in *Astronomy and Astrophysics*, Vol. 321



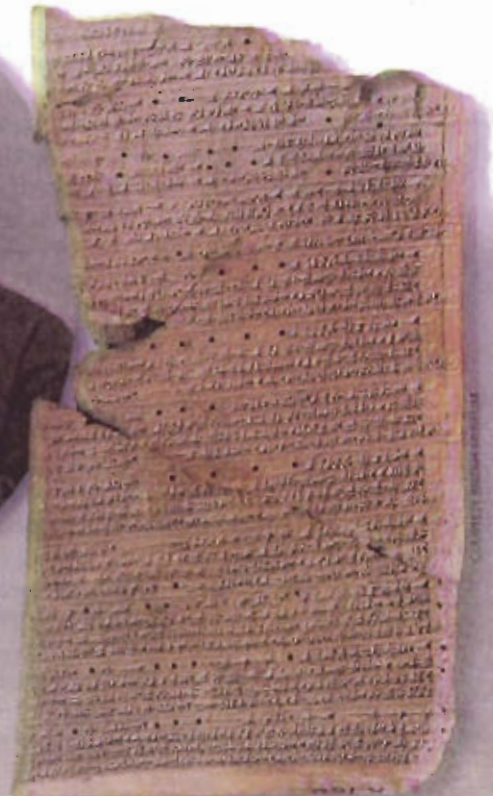
Hammurabi, who ruled in the 17th century B.C., is the most recognizable name pertaining to ancient Babylon. The bas-relief at the top of this stele depicts the king (left) receiving his famous code of laws from the Sun-god Shamash. This stele, a copy of one in the Louvre, is at Harvard University's Semitic Museum.

[1997], page 19.)

When I applied the same kind of sifting to the Venus Tablet, I came up empty-handed. The Monte Carlo technique of random sampling, as well as other statistical schemes, revealed noise but no significant signal except for that

there is only an 8-year cycle, which, theoretically at least, permits many alternative chronologies for the five centuries leading up to Babylon's fall. However, because Gurzadyan has also been able to identify and date a pair of lunar eclipses from the early part of this half-millennium span, the fall of Babylon can be confidently pegged at 1499 B.C.

With its cuneiform text, this tablet is believed to record 16th-century B.C. visibilities of the planet Venus and was long regarded as providing a key to dating events in ancient Babylon. However, the author has shown that data contained on the tablet are corrupted and unusable for that goal. The so-called Venus Tablet, pictured at right, which has confounded many Babylonian scholars, was first recognized by the Jesuit priest Franz Xaver Kugler in the 1920s as containing chronological information.

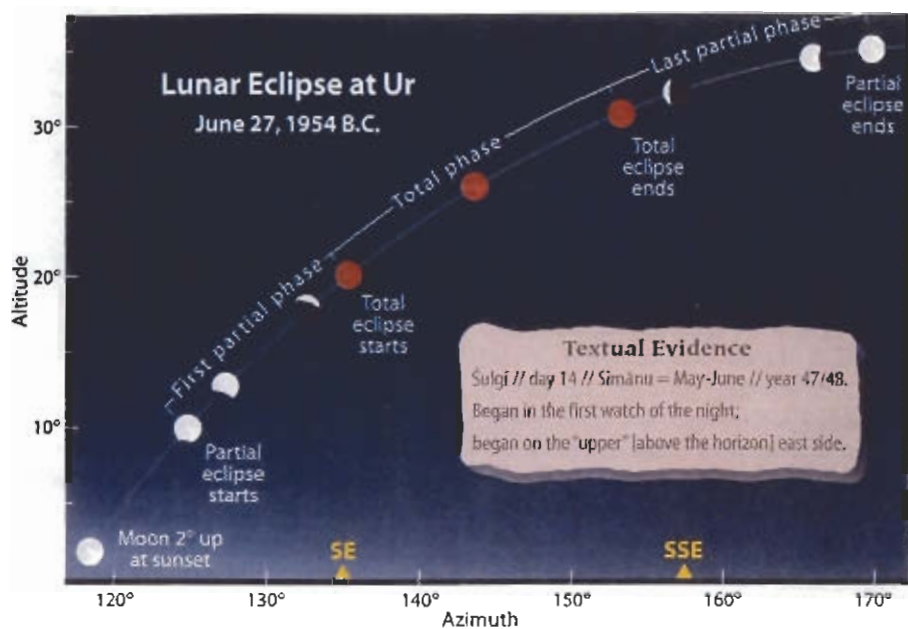


SETI-COAG MICHAEL UTTER

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**The ancient scribes preserved important descriptive information about these eclipses that is crucial for dating them correctly: the time of day that each began and where the Moon was in the sky.**



**Totally at the lunar eclipse of June 27, 1954 B.C., lasted for 1<sup>h</sup> 28<sup>m</sup> according to the 1979 *Canon of Lunar Eclipses* (Jean Meeus and Hermann Mucke). The exact placement of its phases along the Moon's path in the sky over Ur that night cannot be known precisely, due to the cumulative effect of the slowdown in the Earth's rotation rate during the last 40 centuries. The scenario depicted here is a reasonable fit to the vague and ambiguous ancient text (*Inset*).**

of the 8-year Venus cycle.

Another lesson from COBE is that the nature of the noise itself can be studied — in other words, some corruptions might be identified because they have a systematic character. The opportunity to apply such modern analytical techniques to archaeology is new and might lead to important insights about ancient texts.

Then I turned to dating the two lunar eclipses recorded during the Third Dynasty of Ur, which occurred more than 400 years before Babylon's fall. The problem was to accurately match up modern predictions of what should have been seen with what was actually observed. At first glance this seems to be a simple task. Indeed, there is plenty of software for home computers that can do the calculations, and there are lists that tell where eclipses occurred thousands of years ago and give such circumstances as their beginning and ending times to an accuracy of minutes.

However, before utilizing such resources one has to clearly understand the

approximations inherent in both the input data and in the algorithms for the calculation. A program can work well over short time spans but not over long ones, because planetary motions are essentially nonlinear and initial errors propagate exponentially. Therefore, for an orbit to be precisely defined over a given span of time, the input data have to be sufficiently accurate and all planetary perturbations have to be properly taken into account. The perturbations, particularly, are responsible for many unforeseen effects, including chaos and other unpredictables.

Archaeologists are basically interested in two consequences of such calculations. One is the determination of the moment the Moon arrives at a point in its orbit opposite the Sun, when it can pass through the Earth's shadow and be

**At the left of this Babylonian sales contract are sealings that serve as signatures of witnesses. Seals found at the ancient Syrian city of Terqa can be made self-consistent in time only through the chronology described here.**

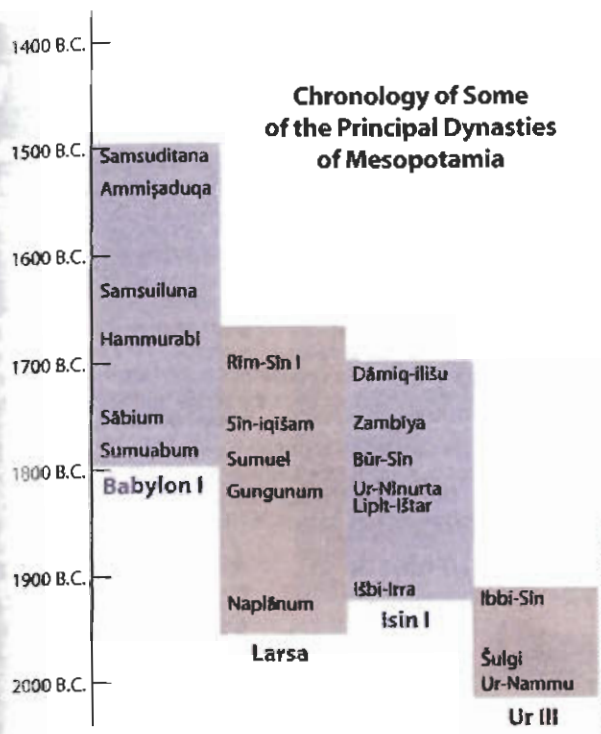
eclipsed. The second is to find the local time an observer's clock would show for the event. The physical interrelated effects that contribute to uncertainty include tidally and nontidally induced variations in the Earth's rotation rate and the gradually increasing distance of the Moon from Earth. With events that happened 4,000 years ago, like the Ur eclipses, these effects can result in prediction errors of up to two hours, not merely minutes, despite using the most accurate data available.\*

My search was constrained by the textual evidence in Tablets 20 and 21 of the *Enūma Anu Enlil*. The two eclipses described there had been linked by ancient astrologers with decisive events in Babylonian history; the death of Šulgi, the greatest of the kings of Ur, and the destruction of Ur at the hands of the Elamites. The ancient scribes preserved

*\*Historically, lunar occultations of stars provided information about the Moon's position. But a dramatic improvement in the accuracy of the data occurred after Apollo astronauts placed laser reflectors on the Moon. Kenneth Nordvedt, the initiator of the project, told me how he once deliberately took the same plane as physicist Robert Dicke, then chairman of NASA's Physical Science Committee, so he could persuade Dicke to include the laser-ranging reflectors on forthcoming Apollo missions. As a result, we now have much better knowledge of the parameters that define the Moon's orbit, its principal perturbations by the Sun, Venus, and Jupiter, and other factors.*







Key Dates Surrounding Babylon's Fall, Second Millennium B.C.	
2018	Year 1 of King Ur-Nammu, founder of Third Dynasty of Ur
1954	June 27th eclipse (Tablets 20 & 21 of <i>Enūma Anu Enlil</i> )
1953	Death of King Šulgi
1912	March 16th eclipse (Tablets 20 & 21 of <i>Enūma Anu Enlil</i> )
1911	Fall of Ur; end of reign of King Ibbi-Sīn
1798	Year 1 of King Sumuabum, founder of the First Dynasty of Babylon
1696	Year 1 of King Hammurabi
1651	Fall of Babylon ("High Chronology")
1595	Fall of Babylon ("Middle Chronology")
1550	Year 1 of King Ammīšaduqa
1531	Fall of Babylon ("Low Chronology")
1499	Fall of Babylon (this article); end of reign of King Samsuditana
1496	Resettlement of Babylon
1459	May 16th eclipse (Tell Muḥammad Tablets)

important descriptive information about these eclipses that is crucial for dating them correctly: the time of day that each began and where the Moon was in the sky. We also know that the eclipses had to occur 41 to 44 years apart because we know the relative dates of the two historical events to which they were connected.

My colleagues and I agreed that I should attempt to identify the two eclipses by scanning a 300-year interval centered on the date of the fall of Ur (2005 or 2004 B.C., according to the Middle Chronology). As it turned out, across these three centuries only the eclipses of June 27, 1954 B.C. and March 16, 1912 B.C. fit the ancient descriptions of the eclipses within possible inaccuracies of interpretation.

### Assembling the Case

Now we could fix a date for the fall of Babylon. We had the date of the fall of Ur, and the ancient records were detailed enough for us to establish, within only a few years, the length of time that separated Ur's collapse from events that took place in Babylon several centuries later. Next, the Venus Tablet allowed us to link the reign of Ammīšaduqa and the 8-year cycle of Venus. Only simple arithmetic was needed to identify the possible Venus-derived dates for the fall of Babylon. When those were compared with the information from the lunar eclipses, the date of Babylon's fall could be fixed as 1499 B.C. This date, some 96 years more recent than the

Middle Chronology date of 1595 B.C., fits well with the pottery evidence that led Gasche to ask me to look at the ancient astronomical records in the first place.

Having established this date, I could now look at the information about the eclipse as recorded on the tablets from Tell Muḥammad and determine when Babylon was resettled. However, in contrast with the *Enūma Anu Enlil* record, I was not dealing with eclipse descriptions. The Tell Muḥammad tablets simply mention the eclipse in a so-called year-name\* that can be translated as "The year that the Moon was eclipsed." The two tablets also bear a second date formula as well: "Year 38 that Babylon was resettled."

This redundancy allows us to date the resettlement of Babylon after its fall to the Hittites. Based on the available evidence, the Tell Muḥammad eclipse most likely occurred on May 16, 1459 B.C., so Babylon was resettled in 1496 B.C., only three years after its collapse.

### Epilogue

Our absolute chronology follows work by generations of scholars. This quest has been important because any change in the Babylonian chronology affects dates of events in other ancient kingdoms of the Near East. Elamite dynas-

\*At this time in Babylonia, each year was named for something noteworthy that occurred, such as a military victory. However, this name was applied to the year following the memorable event. Thus, the year called "The year that the Moon was eclipsed," referring to the May 16, 1459 B.C., eclipse, is 1458 B.C.

ties, the Old Hittite Kingdom, the Levant in the Middle Bronze Age, and the Second Intermediate Period in Egypt must now be fitted into this new scheme.

Subsequent to our study, my colleagues and I learned of independent investigations that strongly support our new chronology. In particular, Guido Gualandi, who has studied the seals from the ancient city of Terqa in eastern Syria, reports that only by using a "low" chronology like ours can he make sense of the similarities among seals of the city's different kings. Furthermore, studies of records in Egyptian papyri from around 1800 and 1500 B.C. by Rolf Krauss also support our results rather than the Middle Chronology, which Krauss says nobody ever really believed! This prominent scholar confessed to me that he had been almost certain that the absolute chronology of the Near East would not be determined during his lifetime.

Best of all, the morning after we had established the date of the fall of Babylon, I visited the British Museum with my daughter, Diana. The Babylonian kings there were smiling at us!

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