Paleolithic era

- During the Paleolithic era, from about the time of *Homo erectus* 2 million years ago, to the end of the Ice Age, about 12,000 years ago, our ancestors were hunter-gatherers.
- Even during this early time people were observing the heavens and finding patterns in the motions of the Sun, Moon, planets, and stars.
- There are apparently thousands of fragments of bone with records of observations of the Moon, some as early as 40,000 years ago.
Neolithic era
• Dates from ca. 10,000 BCE.
• Rapid appearance of:
  ✦ houses
  ✦ growing crops
  ✦ domesticated animals
  ✦ technologies of textiles, pottery, copper tools
  ✦ villages with populations of 100-1000 (e.g. Jericho)
• By about 5000 BCE civilization established both in Egypt and in Mesopotamia, with many small villages.
• Astronomy was important: witness neolithic stone monuments such as Stonehenge.

1.2 A potted history of Mesopotamia

The Ancient Near East

Sumerians
• There was continual fighting for supremacy among various tribes in the region over the centuries.
• However there was remarkable continuity of civilization, with conquerors largely adopting and preserving the existing culture.
• The Sumerians (from the south) were the first to settle the area, ca. 4000 BCE.
• They established irrigation, grew crops, domesticated animals, made pottery and bronze tools & weapons.
• By about 3300 BCE they developed a system of writing, cuneiform, by making wedge-shaped marks in soft clay which was then baked in the Sun.
• First use of wheeled carts about this time.

Cuneiform tablets

Akkadians & Amorites
• About 2300 BCE a northern tribe established a unified kingdom in Mesopotamia.
• Sargon I conquered all the Sumerian city-states and built a new capital city called Akkad.
• The Akkadian empire spread Sumerian culture throughout the Middle East.
• About 1900 BCE the Amorites, a tribe from the west, conquered Akkad.
• Their capital was Babylon, built straddling the Euphrates River.
• The sixth Amorite king, Hammurabi, began his reign in 1792 BCE.
• Under Hammurabi Babylon became the most splendid and important city of the ancient Near East.
Hammurabi

- Hammurabi introduced the famous code of laws (“an eye for an eye, a tooth for a tooth”).
- He created many civic improvements and monuments.
- He set up the first common calendar for the empire (which of course required astronomical observations to maintain).
- Several epic poems, including the creation myth, the *Enuma Elish*, are thought to have originated in this period.

The Assyrians

- Yet another kingdom, the Assyrians, developed in the north, and by ca. 1800 BCE they had established independence from the Amorites.
- They were warlike, fierce, and ruthless, and introduced horses & chariots and iron weapons into their military arsenal.
- From ca. 880 BCE they set about systematically conquering, and by 720 BCE under Sargon II they had become the great power of the ancient Near East.
- Sennacherib, the son of Sargon II, re-conquered Babylon and completely destroyed the city, and set up his capital at Nineveh.
- Assyrian kings made a collection or copies of all extant cuneiform tablets, Sumerian, Babylonian, Assyrian, for their library.
- This cache was discovered ca. 1850, and provides our best source of our knowledge of Mesopotamian culture.

Chaldeans

- Assyrians spent so much effort on warfare they weren’t able to produce sufficient food.
- Chaldean nomads overthrew the Assyrians ca. 600 BCE.
- Second Chaldean king was Nebuchadnezzar, who re-established and re-built Babylon as his capital.
- Here art, architecture, literature, and astronomy flourished.
- Temple scribes (astronomers) were required to observe and record astronomical events as well as weather and other events.
- These data were a prime source of astronomical information for the Greeks centuries later.

Babylon: Ishtar Gate

The city of Babylon was famous throughout the ancient world. This is one of 8 gates leading into the city of Babylon, and the most magnificent. This gate stood next to the palace of Nebuchadnezzar. Just south of the palace was a ziggurat (pyramidal temple) 300 ft high, probably the Tower of Babel mentioned in the Bible.

Persians

- In 539 BCE the Persian king Cyrus successfully attacked Babylon and established Persian rule over the empire.
- In this period astronomy continued to mature:
  - fixed cycle of 7 months intercalated over a 19-year cycle to keep the lunar calendar in step with the seasons.
  - standardization of the zodiacal system of constellations.
  - sophisticated arithmetic methods for more precise celestial forecasting.
- Persian empire conquered by Alexander in 331 BCE.
- Alexander died in 323 BCE and his empire was divided among his generals.
- In Mesopotamia the Seleucid dynasty began with Selukos I, and Babylonian astronomy reached its peak during this period.

1.3 Babylonian astronomy
Cuneiform tablets

- Discovery and deciphering of cuneiform tablets, mostly over the past century, is our primary source of information about Babylonian astronomy.
- Tablets list planetary observations, star catalogs, and tables for calculating lunar eclipses, along with weather and other general information.
- Dates go back to 2000 BCE, but there are continuous dated records from ca. 750 BCE.
- The following description of Babylonian astronomy is based on tablets from this latter period.

Babylonian math exercises

1.3.1 The calendar

- Common calendar based on the lunar cycle of phases.
- New months began when the first crescent was visible after new moon.
- Thus a new month begins at sunset (and also for the Jewish and Islamic calendars).
- Synodic month = 29.5 days, so 12 lunar months total to 11 days less than a year.
- They added an extra month, at first irregularly, by the edict of the king.
- During the Persian dynasty they realized that 235 synodic months was almost exactly 19 years (the Metonic cycle) and they introduced a fixed cycle of 7 months intercalated over 19 years.

1.3.2 Constellations & the Zodiac

- The sky was divided into three belts, one along the celestial equator, and the other two above and below respectively.
- One of the texts, “MUL.APIN,” lists about sixty stars or constellations in sequential order as they rise just before the Sun does (a heliacal rising) throughout the year, and the corresponding constellation just setting in the west.
- Names and areas of most of the Greek zodiacal constellations which we use today were adopted from the Babylonians.

Circular star-list

1.4 Babylonian celestial forecasting
1.4.1 The problem

- The Babylonians had a large, land-based empire to administer from a central location, Babylon.
- A common calendar was essential for activities like planting, harvesting, paying taxes, etc.
  (N.B. the valley was so fertile they could plant three cycles of crops in a year, if irrigated properly.)
- We now know the various regularities and irregularities of celestial phenomena; the Babylonian problem was to predict all these, and in particular:
  - when the new moon was first visible on the western horizon,
  - when solar and lunar eclipses would occur,
  - reappearance of planets and constellations.

1.4.2 Arithmetical methods

- Methods of the Babylonian astronomers were based on:
  - Long, continuous records.
  - A social structure to produce and store these records.
  - Searching for cycles or patterns in the records.
  - Finding patterns or cycles in deviations from the regularities, and fit these with linear zig-zag and step functions.
  - They then used the results to extrapolate to the future.

Example 1. Period relations

- N events of one sort correspond to M events of a different sort.
  235 synodic months = 19 years
  1 year = 235/19 months = 12.3684 synodic months
  Subtract off the even 12 months: remainder 0.3684 months.
  19x0.3684 months = 7 months,
  so 7 intercalated months are required every 19 years.

Example 2. Zig-zag functions

- Here we have an average period relation, but one quantity increases by a constant increment to some maximum and then decreases by that decrement to some minimum, then repeats the cycle.
  - Consider the amount of time the Moon is visible over the course of a month: zero at new moon, 12 hr at full moon about 15 days later.
  - The Babylonian astronomer would use a constant increment of 12/15 hr per night = 48 min per night for the waxing half of the cycle, and then a decrement of 48 min per night for the waning half the lunar cycle.
  - A similar technique was used to calculate the times of each new moon, and ephemerides of the planets.

1.4.3 Results

- Excellent celestial forecasting.
  - They could predict the seasons and the time of new moon very reliably.
  - Estimates of the synodic month and length of a year were accurate to a couple of minutes.
  - Very accurate calendar based on the knowledge that 235 lunar months very nearly equals 19 solar years.
  - They could predict lunar eclipses reliably.
  - They knew about the 223-month Saros cycle after which eclipses repeat themselves.
  - (They could not predict solar eclipses reliably, of course.)
- We can date events from 7th C BCE to 1st C to a precision of better than a day using Babylonian calendar records.
Solar & lunar eclipses

Ideas of space & time
- The Babylonians had no concept of abstract space.
- They only considered concrete places.
- Similarly, they had no concept of abstract time which flows independently of anything else.
- Time for them was found in the periodicities and rhythms of Nature and life.
- Their concept of time, like many other ancient civilizations, was a recurring cycle.

No cosmological theorizing
- What the Babylonians apparently did not do: they did not theorize about what made the heavenly bodies behave the way they did.
- They were apparently content to be able to forecast celestial events, and did not worry about an underlying picture or model of what was happening.
- In the following section we attempt to understand why this was so.

1.5 Astronomy in the context of Babylonian culture

Mesopotamian culture
- Society in Mesopotamia seems to have rather suddenly taken characteristic shape in the 4th millennium BCE.
- Villages developed into cities.
- Governing authority became centralized and a kind of democracy emerged:
  - a general assembly (of men)
  - a council of elders
  - in times of crisis a king was appointed temporarily

Mesopotamian cosmology
- This sort of democracy seems to have been applied to the Mesopotamia idea of the Universe.
- Among the influences affecting the view of the world was that Nature was unpredictable: rivers could suddenly rise and destroy crops, there could be torrential rains that washed everything away, or strong winds, or scorching heat.
- All these were seen as gods with wills and personalities of their own.
- To bring order to the cosmos required the command of some more powerful god.
- Bringing order to the cosmos also required the gods all to be participants in a sort of cosmic state.
Cosmos as a State

- The leader was the god of heaven, Anu.
- The “seven gods who determine destinies” were a sort of council of elders.
- Anu’s son, Enlil, the god of the storm, was a sort of executive assistant who carried out the decisions of the elders.
- Human society on earth was not a parallel, but an extension of the cosmic state.
- Kings on earth were appointed by Anu, and their commands were understood to be commands from Anu: kings ruled by divine right.
- Anu therefore not only controlled Nature, but also required obedience to the laws and customs of society.

The Enuma Elish

- This is the great cosmological epic poem from Mesopotamia.
- It dates from the time of Hammurabi, ca. 1800 BCE.
- It has two sections, one dealing with the origin of the Universe, and the other showing how the order on earth was established.
- In the earliest versions the hero was Enlil, but he was replaced by Marduk, the god of Babylon, in the earliest known version extant.
- (Later the Assyrians replaced Marduk with their god, Assur.)
- Each year in Babylon the victory of Marduk over the forces of chaos was re-enacted at the New Year festival.

1.6 The relation between cosmology and culture: the Enuma Elish

Subject of the myth

- The Enuma Elish has two major sections.
- The first deals with how the structure of the Universe came to be.
- The second shows how the present world order was established.
- However, note the ways in which these two subjects are woven throughout the story.

Cast of characters

- Apsu--represents the sweet waters & male fertility.
- Tiamat--represents the sea or salt water & chaos.
- Mummu--probably represents cloud banks & mist.
- Lahmu & Lahamu--silt, born of the union of Apsu & Tiamat.
- Anshar & Kishar--the horizon, born of the union of Lahmu and Lahamu.
- Anu--god of the sky & born of the union of Anshar & Kishar.
- Nudimmud, also Ea or Enki--here represents the Earth.
- Marduk, the god of Babylon.

Summary of the Enuma Elish

- Salt and sweet water comingle to produce silt, which in turn forms the horizon.
- The sons of the gods make so much commotion that Apsu decides to kill them.
- Ea learns of the plot and kills Apsu.
- Tiamat becomes enraged that her husband has been killed and vowed revenge.
- Marduk says he is willing to fight Tiamat.
- The gods give Marduk authority and test him, and he goes out and kills Tiamat.
- He divides her corpse in half to create the earth and sky.
- Marduk then establishes dwelling places for the gods.
The Enuma Elish

- Then Marduk decides to create Man, using the blood from the slain body of Tiamat’s husband, Kingu.
- The duty of these Men is to perform menial tasks for the gods.
- The gods construct a house for Marduk in Babylon to honor him.
- There is a great feast in praise of Marduk to celebrate his victory over Tiamat.
- Instructions are given to the people to remember and recite Marduk’s deeds.

Summary of the cosmology of the Enuma Elish

- Marduk created Man.
- Objects in the heavens are gods, placed there by Marduk.
- They behave the way they do because they are obedient to the command of Marduk.
- Making astronomical measurements, for calendric and astrological purposes, was a religious duty.
- The predictable behavior of celestial objects was evidence of absolute obedience to divine commands.
- Men on earth were created to serve the gods, and expected to show the same sort of obedience to the king, who was the gods’ representative on earth, and whose commands emanated from the gods.

Implications

- The emphasis on obedience makes Babylonian society a very conservative society.
- Note how this myth effectively removes the possibility of naturalistic explanations for celestial events: there is nothing to explain.
- This helps us to understand why the Babylonians did not theorize about the heavens.
- They made regular observations of the heavens and achieved excellent celestial forecasting by inventing brilliant arithmetical methods.
- As far as we are aware, they were content to make celestial predictions and did not develop any theories to explain why the celestial objects behaved as they did.

Stars over Ancient Babylon

There is a very nice 45-min film called “Stars over Ancient Babylon” that was developed by the History of Science Department at the University of Oklahoma. It can be viewed in a variety of formats (streaming video, download QuickTime video or pdf). The website is:
http://bsci.cas.ou.edu/exhibits/exhibit.php?exbid=47&exbpg=1