http://www.exploratorium.edu/hubble/prologue/naked.html

How the Sky was Plumbed, Then and Now

by Phil and Phylis Morrison
from the print version of Exploratorium Magazine on space

The key facts of naked-eye astronomy had, we think, been realized long before writing arose. We cannot say much of what people knew before anyone could write it down, but that does not mean that they were ignorant of their own rich experience. Seasons were noted and found to recur with the motions of the luminaries. It seems to us that all the sky's visibly transient features -- the clouds, fog, mist, rain, thunder and lightning, rainbows and sun-dogs, even meteors and comets -- were studied many times by the old ones and eventually set well apart from the truly repetitive features -- the sun and moon, the night's starry points of light, and the soft glow of the Milky Way.

All this plays out by day and by night on the two-dimensional dome we call the sky. That it really has three dimensions is harder to realize; but some sort of eclipse every year or two will in the long run have persuaded people that the sky has depth like the lands. Sometimes the moon might pass in front of a star or planet, the earth cast a shadow to darken the full moon, or the new moon's dark disk briefly obscure the sun.

These were long generations of dance and These were long generations of dance and trance, no writing nor much ciphering yet, but plenty of tales by wise women and reflective hunters. Ages passed as small bands wandered the lands and watched the night sky until both became familiar.

Triangulating the Heavens

Without written texts it is hard to find much to cite from long-past astronomy, and the ubiquitous ancient legends that surround sky events remain pretty cryptic. But after writing had arisen in many places, once the sailors had regularly crossed blue water, once the travelers had made their way by land over thousands of miles, once the learned could calculate and measure shadows, angles, and hours, the rich Greek legacy of texts flowed vigorously on to Euclid and his celebrated successors. By then the round earth was a certainty for scholars, its size set at some five or ten thousand miles in diameter. What Babylon accomplished much earlier for meticulous arithmetic, Greece achieved after 500 b.c. for a powerful geometry. It is there and then that the physical magnitude of cosmic space finds its first known clear expression. The recognition of continuity between far-off landscape and the utterly trackless celestial domain was the key.

Anaxagoras, an articulate philosopher who taught in Athens about 450 b.c., wrote that "the sun, moon, and all the stars are flaming stones carried around by the revolution of the aether. . . . It is the sun that endows the moon with its brilliance, and that sun is larger than the Peloponnesus" (most of Greece southward of Athens). Such ideas connect with what we believe still. His theory drew his imprisonment under grave charges of atheism -

- in a city where the Sun was a god -- and he was set free only after personal intervention by Pericles himself, the leading Athenian statesman of the day. How could Anaxagoras have supported his points at that time? "Flaming rock" is not a bad beginning; for the heavenly lights are enduring, neither gods nor persons, animals nor plants, and surely not human-made.

Dating from pre-Columbian times, this Mayan manuscript known as the Dresden Codex contains a numerical record of the periods of the sun, moon, and Venus as they were seen to circle the earth.

How large is the moon? Well, we can see its disk, and, using geometry, we can conclude that its distance from us is about a hundred times its diameter. Each month the moon circles the sky. How far away is its circle? Certainly it never lies this side of the hills, and it always clears the mountains. So we know it is at least ten miles overhead. But were it as close as that, the full moon seen upon rising would be farther away eastward, and therefore it would appear smaller than when overhead.

We have also noticed for ourselves a wonderful though simple rule: things nearby seem to move past more quickly than distant ones. The rabbit hops across our field of view and is gone -- poof -- while the airplane or the rain cloud takes enough time for you to hum quite a snatch of song. Near motions seem fast, far ones slow.

The far-off moon walks along with you for a few hours, as no house or tree does: only the distant mountains can come with you that way. As the visible diameter is the same at moonrise, moon high, and moonset, the moon's orbit is understandable only if it is very large compared to our earth. Then it cannot come close or go far away as seen by any observer anywhere on earth. But if it is tens of thousands of miles away as we have shown, then it must be hundreds of miles across.

The sun never appears in front of the moon, though the moon can just block out the eclipsed sun. The sun is therefore farther than even the moon, so it is bigger than the moon, and hence bigger than the whole Peloponnesus! The sun is slower to circle the sky than the moon, taking a year, not a month, to move through the constellations of the zodiac, and so it is likely to be farther off -- a helpful check on the conclusion.

This bone engraving is over 30,000 years old. Alexander Mershack, the archaeologist who studied this piece of bone thinks it records the days that pass during the cycling of the moon.

Once each month the moon globe is half in shadow, half in light. Aristarchus, a century or two later than the time of Pericles, still well before Euclid, saw that the sun would need to be very much farther than the moon if that judgment of half shadow were precise. He set the angle between the sun and the half-moon at 87 degrees, and from the triangle he drew claimed that the sun was thirty times farther than the moon. The sun is actually four hundred times farther away; the sun-moon angle for the half-lit moon is 89.9

degrees. But that's hard to verify even today from the rough shadow on that mountainous surface.

It pleases us to see that the Greek invention of geometry was not an intellectual abstraction only, as it was taught when we went to school, but was a powerful tool for enlarging our most basic understanding of how the world is put together. Using geometry and their eyes, the Greeks had reason to believe that cosmic distances were much greater than earthly ones, cosmic space ampler by far than our own lands. That was a major new conception of the human place in nature; never mind the errors, even of magnitudes!