Chapter 1: A Day with Two Dawns and Midnight at Noon

The Sun has been bitten; a bite is missing. I see this only because a tiny cloud has passed in front of the otherwise blinding disk. The cloud then passes but the sight can't be unseen. There is something wrong with the Sun. The Sun is being eclipsed.

The bite I saw is the unseen Moon beginning its glide across the Sun. The Moon has been invisible for the last day. Yesterday just the barest sliver was visible in the eastern sky rising just moments before the Sun. Today that distance is shrinking to nothing before my eyes. Another cloud passes by in the late morning sky and, for a brief moment, I see the bite is getting bigger. The worlds are aligning.

Ancient Chinese records contain the characters for "ugly" and "abnormal" in conjunction with eclipses. The Greek origin of the word *eclipse* is *ekleipsis* meaning "an omission" or abandonment." For the Aztec, the eclipsed Sun "faltered" and became "restless" and "troubled."[1] It is no coincidence that cultures from all over the Earth witnessed this sight with some degree of dismay. The Sun is the giver of heat and life. It warms my upturned face; it dispels the cold of winter and night. The food that I eat either feeds on sunlight itself or feeds on those plants that do. We are all fed by the Sun. When the Sun goes away, it leaves behind the creeping fear that it might not come back.

Without the low clouds skittering across the sky, momentarily dimming the Sun to a pale disk (now with a slightly larger divot), this silent dance would be utterly unnoticeable right now. The fiery disk, the photosphere (the sphere of light), is so intensely bright that a tiny nick goes without notice. To look at the Sun for more than a moment reveals nothing, and prolonged searching of its surface without special eye protection invites permanent damage to my retinas. Fortunately a dollar buys me a simple pair of specially designed solar eclipse glasses and the clear orange disk of the Sun hangs before me in a jet-black sky, the growing cookie-bite in its limb is unmistakably bigger now.

I'm not the only one to associate the Moon's black mask as a bite from the Sun. For the Pomo, a Native American tribe in Northern California, eclipses are explained by a bear that walks the great starry band of the Milky Way. When he comes upon the Sun, the Sun refuses to step out of the way. For his impertinence, the two wrestle and the great bear bites the Sun; "Sun got bit bear" is the meaning of the word the Pomo use to describe an eclipse.[2] After his mighty battle with the Sun, the bear continues on along the Milky Way until soon he comes upon the Sun's sister: Moon. She too, refuses to step aside and again there is a great fight in the sky. This explanation reflects what we actually see since, whenever a solar eclipse occurs; a lunar eclipse is almost always visible two weeks before or afterwards.

In Viking lore, two great wolves stalk these celestial lights. Loki, the trickster god, set them hunting as an act of revenge against the other Nordic gods. In the *Grimnismal*, one of the poems of the *Eldar Edda*, they are named:

> Skoll the wolf who shall scare the Moon
> Till he flies to the Wood-of-Woe:
> Hati the wolf. Hridvitnir's kin,
> Who shall pursue the Sun.

Skoll is Icelandic for Repulsion, while Hati means Hatred. In Bolivian tradition, ravenous dogs bite the Moon, bloodying her face and dimming her light. This is precisely what is seen during a lunar eclipse as the Moon passes into the Earth's shadow and turns anywhere from a rosy red to a deep dark umber, resembling the color of clotted blood. In Armenia and ancient China it is a dragon that chases the Sun and Moon.

My favorite eclipse myth is one told in various forms across central and southeast Asia. In the intricate and elaborate Indian Hindu tradition the Devas are benign celestial beings, gods of elements like fire, air, and rain. They are half-brothers to the Asuras, power-mad demons with whom they battle for control of the Universe. This enmity has its beginning when the high God, Lord Vishnu instructed the Deva to work with the Asura to churn the Ocean of Milk (the Milky Way in the sky above) into ambrosia, the nectar of immortality. Unbeknownst to the Asura, Vishnu promised the Deva that they alone would get to share in the immortal ambrosia.

To churn the Ocean, the Deva and Asuras took the sacred Mount Meru as their turning rod. Around it they wrapped Vasuki, the serpent king, whom both Deva and Asura gripped to pull first this way and that. As the demons and deities alternated pulling, the great mountain spun amid a swirling vortex in the sea. When the ambrosia finally appeared out of the maelstrom, Laksmi, the wife of Vishnu, gave it only to the Deva to drink. The Asura, realizing they'd been tricked, went to war.

In the midst of the confusion, Rahu, an Asura demon, disguised himself as a god and snuck a drink. But the Moon and Sun deva recognized Rahu and appealed to Lord Vishnu to stop this theft, whereupon Vishnu flung his mighty discus at Rahu and cut off his head, which went flying into the sky. Because of Vishnu's quickness, none of the immortality liquid reached his body, but the ambrosia's effects on his throat rendered his head immortal. Rahu's head, therefore, chases the Moon and Sun through the sky to this day, angry for betraying him. When he swallows them we experience eclipses. But thankfully, they soon slip out his throat and reappear again.[3]

The tale of Rahu spread as people and their stories circulated across Asia. Northward, into Mongolia, Rahu is Arakho who is still betrayed by the Moon and cut in two by God. Amongst the Buryat people living along the shores of the great Siberian Lake Baikal, Rahu and Arahko became Alkha, who is chopped in two for his transgressions, the upper half still periodically munching on the Sun and Moon. Southeastward from India, among the Hindus of Indonesia, Rahu became Kala Rau who, nothing but head, eats the Sun, burns his tongue, and spits him back out again.[4]

While nearly all eclipse explanations seem rooted in calamity of one form or another, there are a few exceptions. The aboriginal Australians of Bremer Bay in Western Australia, tell the story that one day the Sun and Moon fell out of the sky. The Earth was split in half and all the lazy people wound up on the other side of the Sun. Every once in a while they want to see what the rest of us are up to, so they gather together and tip the Sun over so they can have a peek. Once everyone has his turn, they put the Sun back and that is why eclipses never last very long. For the Wirangu people of South Australia, a spirit man covers the Earth during an eclipse so that Sun woman and Moon man can have some privacy when, shall we say, they are "husband and wife together."[5]

Looking back at the sky now, an hour after that first contact, it's obvious to even those without special eclipse-glasses that changes are occurring. Though it's now almost noon the temperature has cooled and something strange is happening to the light. It's difficult to say at

first exactly what has changed about the way things look. It's growing darker, but it's not like any sunset I've ever seen. During summer evenings the Sun takes on a warm hue - the "golden hour" of photographers - where sunlight and shadow combine to give you a feeling of childhood on a long lazy evening. This is most certainly not that. The light is … green. Well, maybe not green exactly, but cold and wrong, sapped of color and saturation.

Shadows cast by the only leafy tree around reveal myriad little crescents on the ground beside me. Each crescent of light is an image of the eclipsed Sun where the tiny gaps between overlapping leaves act as little pinhole cameras projecting the sky's events onto the ground below. Had I not known what was happening before, this most certainly would have revealed what was happening above.

Even without glasses, a quick glance at the Sun out of the corner of my eye reveals the arc across the disk dividing the blinding from the merely brilliant. The life-giving nature of the Sun is no longer an abstract concept as it is clear that the Sun is going away. The sky is darker now, too, like the inside of a steel bowl inverted on the horizon.

Fifteen minutes later and the conditions are changing fast. The world has turned to twilight, lit by a single narrow spotlight as the sky has grown dark and all illumination comes from a narrow crescent; shadows are sharp in contrast to their typical appearance when formed by a bright extended Sun.

The crescent shrinks fast. The crowd gets to its feet. Conversations hush and I can hear that all birdsong has ceased; birds have returned to their nests to sleep in the unexpected night. The eclipse is now a multisensory experience of sight, sound and touch as an unseasonably cool wind gently blows across my arms. So little of the limb is left that surely totality should begin any second, but I can't tear my eyes away to look at my watch. Even the passage of time seems affected now, as a minute seems an hour, seconds like minutes.

And then, in utter silence, the blinding spot of light collapses upon itself as if falling down a deep well. Bright specks called Bailey's Beads suddenly dance and shimmer along the edge of the Moon, as the Sun's last rays stream through mountain valleys along the lunar limb. Quickly they wink out until, at last, there is a single glistening star set in a band of white fire encircling the Moon: the glorious diamond ring.

And then it's gone. Totality.

Where before there was light and heat, now there is only a cold, black hole in the sky surrounded by a ghostly crown. The corona, a ring of pearly tendrils envelopes the darkness and stretches off into the sky in all directions. Unimaginably beautiful, it is only during eclipses that the corona is ever visible and, all around it, I see the stars and brighter planets, which were also invisible until now. It is a day that has become night at noon with Sun, Moon, planets, and stars.

There is a tingle along my spine. As a professional astronomer I have spent my whole life studying the sky, photographing and poring over images of distant nebulae of gas and vast galaxies full of stars. I have seen the Milky Way encircle my horizon and rise over a hundred and eighty degrees of view. I have seen sunlight glint off the dust floating between the planets and witnessed a comet hang silently in the sky for weeks. But in all my life I have never seen anything as awe inspiring, as *awesome* in the original definition of the word, as a total eclipse of the Sun.

While I know the mechanics of this celestial alignment, in this moment I understand the difference between knowledge and feeling. The hair is raised on the back of my neck and my mind screams at the wrongness of what I am seeing. I now know why people throughout time did what they did to scare the demons, chase away the jaguars, and slay the monsters they imagined

in the sky. According to the French astronomer and historian Jean-Pierre Verdet, this fear-fueled call to action was universal. “Evidence of it has been found in the great civilizations of China and India, in the tribal societies of Africa, throughout the Americas from Canada to Peru, and in Babylon, too, where cauldron concerts join the lamentations of women: It seemed that everywhere the eclipses of the Moon and the Sun caused pandemonium.” [6]

There was purpose in this pandemonium. To scare the Sun-eating demons we needed to raise a ruckus, howl in hullabaloo and cause a kerfuffle. In Paraguay and Argentina, the people’s yelling and dogs’ barking frightened the celestial jaguar at lunch upon the Sun, while Norsemen would yell to frighten the demon dogs, and the Buryats of Siberia hollered and threw stones to scare away the bodiless Arahko. In India, if the sound of banging pots and pans was loud enough, then Rahu would be startled and, dropping the Sun from his jaws, the eclipse would be only partial. In North America, the Ojibway of Minnesota and Ontario sought to help the beleaguered Sun who had grown cold and faint by firing flaming arrows to help him regain his light. For the Aztec, matters were more serious:

> Then there were a tumult and disorder. All were disquieted, unnerved, frightened. There was a weeping. The common folk raised a cry, lifting their voices, making a great din, calling out, shrieking. There was a shouting everywhere. People of light complexion were slain [as sacrifices]; captives were killed. All offered their blood; they drew straws through the lobes of their ears, which had been pierced. And in all the temples there was the singing of fitting chants; there was an uproar; there were war cries.[7]

Eclipses were a sign of the end of the world for the Aztec, and for any unlucky, pale-skinned visitors, it was more than just a sign.

For an event that has touched almost every place on Earth at some point, remarkably few people have ever seen one. The path of totality is narrow: as much as 6,000 miles long and as little as 100 miles wide in some cases. For any one spot on Earth, an average of 300 years can pass between sight of two solar eclipses, so imagine what three in one lifetime must have meant (especially for those for whom they were a sign of end-times). In the American Southwest, astronomers and anthropologists have examined those places where just such a thing would have occurred. For the Hopi who have lived there for thousands of years, and who as part of the greater Chacoan culture (whom we used to call the Anasazi and who had distant connections with the civilizations of ancient Mexico) three separate clusters of eclipses crossed their region during the height of the Chacoan civilization a thousand years ago. During each cluster, some major change manifesting itself in the surviving architecture or ceremonial culture seems to have taken place.

The most recent cluster took place in the 14th century in a small region along the Little Colorado River in Arizona known as “fourmile ruin.” Here, the midline of three separate total solar eclipses crossed within an 80-year period and from this spot at about this time, the modern Hopi “Katsina” culture emerged. We know that for the Hopi, who are intensely private about their religious life, the Katsina ceremonies of masked dancers center around propitiating the gods and returning harmony to the world. According to Dr. Bruce Masse, environmental archaeologist at Los Alamos National Laboratory near Santa Fe, New Mexico, “Because of the importance of daily and annual cycles of the Sun, the appearance of solar eclipses was almost certainly interpreted as demonstrating that things were not right and that something should be done to

make them right."[8] Are the Katsinas, whose likenesses are found carved on little statues available in gift-shops all across the American Southwest, a response to that disorder?

For any who have ever seen a total solar eclipse, the great power it has to instill terror, delight, foreboding, and awe lies in the gulf of experience between inside and outside totality's path. It is literally the difference between night and day: seeing the corona and stars, or seeing nothing at all but a dimming Sun. Ninety-nine percent totality is definitely not ninety-nine percent of the spectacle.

The fear created in this unnatural day with two dawns is not confined to the past; it still has the power to rob people of this rare and beautiful phenomenon. On the morning of June 11, 1983, a total solar eclipse swept across Indonesia (giving Kala Rau one more meal). Ward Keeler, an American anthropologist working there at the time, beautifully recorded his experience of the day:

> [T]he air became very still and Java's lush vegetation glowed in the eerie light characteristic of sunset in the tropics. As at sunset, too, the horizon turned red, but it did so not only in the west but in all directions, and in the half-light distant volcanoes usually obscured by the glare of the Sun became visible. For the four minutes of total eclipse, the Sun, almost directly overhead, looked like a black ball surrounded by a brilliant white light. Most eerily of all, in one of the most densely populated rural areas in the world, there was no traffic on the roads, no movement in towns or villages, and no one watching the eclipse.[9]

For weeks prior to the event, newspapers, radios, and TVs had gone to great length to warn people about the event for fear that people would damage their eyes. Posters were prominently displayed in villages across the country bearing the message that watching the eclipse would cause you to go blind.

> In Central Java, this campaign was so effective that virtually no one dared even to look outside, let alone look at the sky, for a period of about three hours before and after as well as during the eclipse. People stayed inside their houses, some watching the eclipse on television, others lying in bed, all thoroughly intimidated by what had come to be known as the Sun's "sharp rays."[10]

I know that fear first hand. The last total solar eclipse to touch the continental United States did so in Portland, Oregon on February 26, 1979. I was a boy, only nine years old then. In my fourth grade class we made clay medallions of the upcoming eclipse; I still remember the black, yellow and white glazes we used. While others made black circles with yellow crescents in representation of the partial eclipse, I had found library books showing the corona and so carefully painted the white ring around the central black hole. Yet on the morning of the eclipse, rather than go out and see the sight for myself I hid indoors with the curtains drawn.

Just as in Java, the preceding weeks had been flooded with messages on the local news warning of the dangers inherent in what was to happen. As a boy, I had glanced at the Sun many times and never gone blind so I thought for sure this meant some strange rays must be present during an eclipse. Perhaps some strange influence of the Moon? Whatever they were, they must

instantly turn your eyes to ash if all the adults were so afraid. I'd better make sure to hide where I couldn't be tempted to glance for even a moment lest I burn my eyes out. Sharp rays, indeed.

To this day I remember watching the eclipse unfold on our RCA color TV. My first attempts to photograph an eclipse were easily accomplished by taking pictures of the glowing TV tube with my plastic drug-store camera. My only direct memory of the event itself was of how dark the house became while I snapped photo after photo of totality on the TV. As ancient Chinese records said: *tian-da-yi*, "the sky darkened greatly." I spent the next 20 years wishing I'd turned around, gone to the window, and simply looked up.

While I have seen eclipses since, I will never see that one. No two coronas are ever the same. Each is different and unknown until the moment of totality. Strangely, very few mythological accounts of solar eclipses ever mention the beautiful corona. Wondering if perhaps the corona is some relatively new feature of the Sun, the atmospheric scientists Pao Wang and George Siscoe, searched the vast history of Chinese astrological records from previous millennia. They found that for these astrologers, an eclipse's significance, the event for which it was a portent, depended entirely upon the appearance of the corona and eruptions of bright ionized gas (called prominences) that are occasionally visible. Here is what they found (including their interpretations in parentheses, of what these ancient astrologers thought they were seeing):

> (1) (If the king) does not share his fortune with his subjects, the condition is called unstable. Then there will be a total eclipse with Sun being black and its light shooting outward. (Jin-Fan-1-Chuan, also see Han Shu.)
>
> (This brings to mind coronal streamers rather than prominences, partly because the corona looks more like a continuation of sunlight while prominences look more like protrusions.)
>
> (2) If there is flame-like gas in the Sun, it means that high ranking officials will rebel (Huan-Tu-Chan, quoted in Kai-Yuan-Chan-Chin).
>
> (3) Jin Fan said, "Watch the Sun when it becomes dim. If one sees red gas as big as a squash jumping in the Sun, then the king will die".
>
> (It seemed very logical to watch the Sun when it was dim. Again we are not sure about what the red gas may have been. We also doubt that one can really see much detailed structure in the Sun with the unaided eye. However, Jin Fan also mentioned a way of aiding the eye to observe the 'dragons' beside the Sun: put a pot of water in the yard and watch the Sun (in the water) from dawn to dusk! The same method was also described by Cheng Ta-Chan (1123-1195 A.D.) in his book Yen-Fan-Lu except water was replaced by oil. Chu (1933) claimed that he used the same method in 1919, putting light ink water in the pot to watch the Sun and observed two circular spots in the Sun. If so, then Jin Fan probably saw the 'red gas' by a similar way. We wonder if diligent solar observers might have witnessed an occasional flare this way, and this was the gas referred to.)
>
> (4) In Jin-Fan-1-Chuan, "If the Sun is dark in the center with red and yellow color (surrounding the Sun), it signifies that the king has no power"…
>
> (5) In Jin-Fan-Yao-Chan (the original book, however, was lost), we find "If there are two ear-rings beside the Sun during eclipse while in the east, west, south, and north corners there are white clouds shooting outward, then the whole country will be in war". The book then lists other possibilities in which there can

also be green (or green-blue), red, yellow, or black clouds shooting outward. The word 'cloud' here should be interpreted to mean cloud-like gas.

(The five colors mentioned here are exactly the colour corresponding to Wu-Shin, five properties, i.e. metal, wood, water, fire, and earth, which were considered as essential elements of the Universe. It is conceivable that Jin-Fan listed all five just to make the list complete. Some of the colors therefore, may not really have been seen….

(6) In Lo Shou we find, "During the eclipse if there is comet-like gas under the Sun, then princes will lose their land".

(7) Kan Te said, "During the eclipse if there are rainbow-like things on top of the Sun, it says that high rank officials are trying to murder the king".

(8) Jin Fan said, "During the eclipse if the Sunlight becomes colorful, and a white rainbow of low brightness is beside the Sun, then the crown prince will lose to other princes".

(9) Jin Fan said, "During the eclipse if there is a cloud like a man sitting on top of the Sun, all the king and his subjects will be together peacefully".[11]

There is a written record of 916 solar eclipses in China between 2137 B.C. and 1785 A.D. But not every eclipse that could have been seen was recorded. One reason is that a cloudy day would obscure all but the darkest of partial eclipses. Another reason is that, because eclipses were regarded as a commentary on the king and court, if the ruler was a generous one, there was an incentive for his court astrologers to disregard all but the most obvious of partial eclipses. On the other hand, if the king was very bad, then there was an incentive for the court astronomer to note every possible eclipse, no matter how faint, including even some that couldn't possibly have occurred.

The search for this hidden meaning in special celestial events is the purview of astrology. For astrology to work, natural events needed supernatural meanings. A comet appears in the sky? War is imminent. A supernova (a new star) appears in Leo? A king will be born. The Sun is eclipsed? The king is wicked. When even I, a steely-eyed science-type, am moved to awe by a phenomenon, it is perfectly sensible to want to associate it with something of great importance.

So if eclipses record momentous events, then a momentous event must have had an eclipse (or, better yet, if I want my event to be seen as momentous, I'd better find an eclipse to fit it). In 1133, a nearly total solar eclipse was visible across England. Two years later King Henry I of England died and nearly 20 years of civil war broke out as Henry left no male heir. The Peterborough Chronicle, written around the time of Henry's death, attributed the eclipse of two years earlier to the correct day, August 2, but changed the year to 1135, saying, "men were greatly amazed and frightened and said that a great event would come after this." Sure enough, four months later Henry was dead: "a clear case of being wise after the event."[12]

These, "retroactive omens" reveal the importance in which these events were held by contemporary chroniclers. At Ragnarok, the end of the world described in Norse mythology, a possible solar eclipse occurs as "black become the sun's beams."[13] The Christian Rapture also has the Sun turning black on that day, surely an apocalyptic bookend to the darkness (presumed by some also to be an eclipse) that descended at noon as Jesus was nailed to the cross, as described in the Christian gospels.

The Aztecs were, therefore, not alone in seeing eclipses as harbingers of end-times and the displeasure of the gods. To be able to call on this power was a sign of one's own power. Just

such a story accompanies the first account of an eclipse by Europeans in the Americas. By 1504, Christopher Columbus had made four voyages to the New World. On the last voyage, Columbus lost two ships due to rot and was forced to beach his remaining two ships on the north shore of what is now known as Jamaica. The local inhabitants were initially helpful to the castaways, regularly bringing them food and providing shelter. As the days turned to weeks, however, Columbus's crew grew tired and mutinied, attacking and murdering their local benefactors, who themselves had begun to grow weary of the voracious new-comers on their shores. Enough was enough, the Jamaicans decided they were no longer going to feed the Europeans. Columbus was desperate, caught between mutiny and revolt. Fortunately, like all good navigators of the day, Columbus had his almanac of astronomical positions. From it he was able to calculate that a total lunar eclipse would take place three days later, on the evening of February 29, 1504.

Calling the local chieftains to him, he told them that his God had grown angry with them for their treatment of his men and, as a sign of their displeasure, would cause the Moon to be "inflamed with wrath." When the Moon rose after sunset, it was clear that something was wrong as a dark shadow slowly spread across its face. When the eclipse was complete and the disk was as red as blood, the Jamaicans pleaded with Columbus to make it stop. Columbus bade them wait while he retired to his cabin to pray and consider their request. In actuality, he went there to keep a watch on the hour-glass until the nearly 48 minutes of totality was almost over. At that time, he addressed the native delegation, announcing that if they brought the food once more, then they were forgiven and he'd bring the back the Moon. Of course they agreed and, at that moment, totality ended and its light was visible once more. Had Columbus been as poor at his calculations as he was a captain and territorial governor, the entire history of the Western world might have been altered that night.

Over three hundred years later, in a long-overdue case of "fool me once, shame on you, fool me twice, shame on me," a group of Sioux Indians proved to be less susceptible to this same trick. In 1869, Captain D.C. Poole of the U.S. 22nd Infantry spent 18 months as an agent to the Sioux in the Dakota Territory of the western United States. In his book describing his experiences, which, true to the times, was often far from complimentary to the people amongst whom he was living, he tells of a doctor in the region, who, with knowledge of a coming total solar eclipse decided to "impress" the Indians with his magic and healing arts:

> The doctor announced to some of the principal chiefs and warriors the coming event, telling them the precise time (taken from an almanac) when the Sun would be obscured and darkness follow, until he saw fit to have it pass away. When the day and the hour arrived, the doctor had his audience in readiness, duly armed with smoked glass. Being within the line of totality, and having a cloudless sky and the clear, delightful atmosphere of the plains, the phenomenon was observed under the most favorable circumstances. There was no mistake as to time; the Moon gradually crossed the disc of the Sun, a black, spherical mass, surely putting out its light.
>
> The Indians were impassive lookers on, until, as the eclipse reached its culmination, leaving only a narrow, bright rim around the outer edge of the Sun, the deepening steel-gray shadows attracted their attention, as well as that of beasts and birds. Then, concluding that the exhibition had gone far enough, and that they must drive away the evil spirits, they commenced discharging their rifles in the air. The light of the Sun gradually returning, they were thoroughly convinced that

it was the result of their efforts, and that the Indians' medicine was better than the white man's.

The doctor could predict the eclipse, but they could drive it away….[14]

Twenty years later in the novel, *A Connecticut Yankee in King Arthur's Court*, Mark Twain's Yankee hero used this same plot device to avoid execution at the hands of his Arthurian captors. Perhaps it is appropriate, then, that the next two total solar eclipses to touch the United States will both pass through Mark Twain National Forest just outside St. Louis, Missouri in 2017 and 2024. The paths cross just a few miles away near Carbondale, Illinois. How lucky for the residents there that they should get to see two eclipses in seven years by doing nothing more than standing at their front doors. When darkness falls across the U.S. on August 21, 2017, roughly half the people alive in the U.S. will not even have been alive in 1979, and only a minuscule fraction will have ever traveled outside the U.S. to see one.

Yet the power of astronomy for me, and science in general, is that I can predict the exact path of totality for both eclipses (and for as many eclipses as you would like in the future or the past) down to mile and to the second, and the proof of whether I am right or I am wrong will be waiting for you when you get there: either you see the corona or you don't. That is the predictive power of science.

Ask any scientist and she will tell you that science is what separates us from the animals. Science begat civilization, we say, and the oldest science is surely astronomy. Intuitively, at least for me as an astronomer, this makes sense. Our notions of time and direction all come from the sky and stars. And while we do know of some animals that use the Sun, Moon, stars and even the Milky Way to navigate, the knowledge necessary to track a herd or plant a crop to feed a community absolutely requires knowledge of the changing seasons. Today we can consult all manner of calendars to find the date and know when the first day of summer begins. And since the very idea of a "day" and "year" are astronomical in origin (the rotation of our planet for the former and its revolution around the Sun for the latter) then any actions, traditions, or ceremonies dependent on them must require some knowledge of astronomy. But all good science requires evidence. What is the evidence for our ancestors' astronomical knowledge? When did astronomy begin?

Let's imagine a family tree of our distant ancestors. Four million years ago, a small hair-covered *Australopithecus* ancestor of ours first stood erect out on the African savanna. As the American astronomer Neil deGrasse Tyson has said, "Once we were standing upright, our eyes were no longer fixated on the ground." Out, away from the cover of trees, the night sky was more vivid than almost any sky current humans can see. I can't even imagine what that first sky must have looked like. Thanks to our urban lighting, fewer than half the children born this year will ever see the Milky Way. Yet it and a sky full of stars were, until the last one hundred years, a nightly spectacle, along with the Moon and the bright wandering planets.

We are not the only beings on this planet who have noticed the Milky Way. African dung beetles use the band of light overhead as a navigational aid to quickly roll their dung-balls in straight lines away from competing beetles. In addition, baby sea turtles hatching on land use the light of the sky to navigate away from the darkness of shore to reach the bright reflective waters of the sea, while birds apparently use starlight to migrate over intercontinental distances. If these species can pay attention to the sky, then so could our distance australopithecine relatives. But use alone isn't science.

By 2.5 million years ago, our *Homo habilis* ancestor was using stone tools to chop, scrape, and pound food. Even if our *habilis* relatives didn't use their tools to hunt, but only to clean meat from scavenged carcasses, they would have had to follow the herds in their annual migration to find food. Evidence exists that *Homo habilis* used seasonal camps when following the herds, but were these habitations set up ahead of time as our ancestors noted the changing seasons with the changing sky, or were they merely set up and taken down as the herds moved along? Lions follow herds, but they aren't scientists. Science is all about prediction. It's connecting different pieces of information to make predictions for when an action or result will happen again. Science seeks to take the guess-work out of survival.

A million years later our *Homo erectus* forebears learned to roast meat over a fire and, for the first time, extend the day's work into the evening, long after the Sun had set. Perhaps the world's first artificial light allowed our distant ancestor to stay out at night and look at the Moon and stars for the first time without fear of nocturnal predators. Perhaps the first constellations, long lost to prehistory were created during those nights. How sad then that 1.5 million years later, our primordial fear of the darkness has led us to use our lighting technology to render the stars utterly invisible to most people on Earth.

Over a million years later, only 60,000 - 100,000 years ago, our distant *Homo sapiens* grandparents fed on shell fish in the tide pools along the southern coast of Africa. The tides are tied to the Moon. The time of high and low tides shifts each day in conjunction with the rising of the Moon. The height of the tides changes as the Moon's illuminated phase changes throughout the month: extremely high (called astronomical) tides occurring when the Moon is new or full. If your community's diet depended upon the local pools that are only revealed at low tide, surely these patterns would quickly present themselves. Those that learned the pattern fed themselves and their families; those that didn't got washed out to sea. Undoubtedly, this would be a case of natural selection for pattern recognition. Sadly, we have no direct evidence that our forebears associated these cycles in the sea with the cycles in the sky.

But let us think for a moment about what is required to make these mental connections. The rising ocean tide is a direct physical effect; it gets you wet and sweeps out to sea anything in its path. Later, it goes back out and reveals tide pools full of delicious food (food you don't have to stalk and, in return, won't stalk you). The Moon, by contrast, is so far away you can't touch it, hear it or smell it. There is no reason these two things should be connected at all. In fact, what connection there is can only be revealed through observations over a long period of time, requiring memory, abstract pattern recognition, and a belief in an underlying order or connection.

The archaeologist, Steven Mithen refers to these skills as "cognitive fluidity." Like our physical form, which evolved over millions of years, evolutionary psychologists theorize that our mind (i.e., how we use our brains to perceive the world and draw conclusions from that perception) has also evolved. Mithen's hypothesis is that the cognitive fluidity that marks modern human beings is the result of a sudden breakthrough around 60,000 years ago that coupled together different types of intelligence that were present were previously separate. These different forms of intelligence include social intelligence (the ability to interact in a group and structured society), and natural historical intelligence - the intelligence to build fire, tools, and hunt.[15]

> Cognitive fluidity enabled technology to be developed which could solve problems and store information. Of perhaps even greater significance, it allowed

> the possibility for the use of powerful metaphors and analogy, without which science could not exist.[16]

Once our ancestors developed this cognitive fluidity, then according to Harvard University evolutionary biologist Louis Liebenburg, it was the need to track game that may have first stimulated the type of thinking necessary for the origins of science.

For the vast majority of our history we humans lived in small hunter-gatherer communities. Through simple trial-and-error, our early ancestors learned which plants were edible and which were not: a process that requires no extensive deduction, or complex hypotheses (for instance, there are almost no general laws for predicting what berries and mushrooms are poison and which aren't).

But tracking wild game is different. Today, the !Kung Bushmen of the northwestern Khalahari Desert (the ! marks a clicking sound not made in any European language) are hunter-gatherers whose way of life is thought to have changed little over the last ten thousand years. Liebenburg has lived with members of the !Kung and in 1990 took part in their hunt for the fleet-footed kudu, a species of antelope native to the Khalahari along the Namibia-Botswana border. After experiencing (and nearly dying during) a grueling "persistence hunt," where the !Kung relentlessly track the prey under the hot noon-time Sun until the animal collapses from heat exhaustion, Liebenburg observed that, "animal life is dynamic, involving a multitude of variables that are continuously changing in real time. Animals are not only highly mobile, living in complex communities, but also actively avoid hunters. Apart from involving knowledge based on direct observation of animal behavior, both simple and systematic tracking also involve knowledge founded on the recognition of signs and the association of particular signs with specific animals and their observed behavior…."[17]

Unlike animal predators that can follow prey by their acute sense of smell, we humans possess a comparatively poor sense of smell (while our superior eyesight is rendered useless in brush-covered and hilly terrain). We therefore need some other method of tracking that makes use of both our sense of sight and our developed mind:

> Apart from information based on direct observations and recognition of signs, speculative tracking also requires the interpretation of signs in terms of creative hypotheses. The speculative tracker creates imaginative reconstructions to explain what the animals were doing, and on this basis makes novel predictions in unique circumstances. Speculative tracking involves a continuous process of conjecture and refutation to deal with complex, dynamic, ever-changing variables. Speculative tracking requires creative hypothetico-deductive reasoning and may therefore explain how, through natural selection, humans evolved the ability to do creative science.[18]

In other words, if you couldn't put yourself in the mind of your prey and understand where it was going, or how close it was to exhaustion (both of which were based upon successfully interpreting the tracks it left on the brush and in the dry African sand) then you didn't bring as much meat home to your offspring as the other tribes who were competing for the same game as you. As the astronomer Carl Sagan stated in his book, *Demon-Haunted World: Science as a Candle in the Dark*, "For me, all of these formidable forensic tracking skills are science in action."

After we'd evolved this skill of deductive reasoning and hypothesis-testing, when was it that we first applied it to the sky? There are those who believe that 20,000 years ago, our ancestors in the Congo made marks on animal bones that recorded the changing lunar phases (in some cases including identification of the solstices). But marks on a few ancient bones are difficult to interpret. Not all archaeologists are even sure they weren't created by other animals.

No, one of the first, most unambiguous pieces of evidence of human astronomical knowledge is found in a vast graveyard in modern Sudan that dates from between 10,000 - 12,000 years ago. Less than a mile from the Nile in what once was ancient Nubia, there is a complex of graves in which 58 bodies were found (most showing signs of a violent death) all buried on their left-side, head to the East, facing the rising Sun.[19] The simple fact that they face the East, means someone knew how to identify one of the four cardinal directions. These directions are defined by the sky. The East is where the Sun rises on the spring and fall equinoxes, the West is where it sets. The line joining north to south is where the Sun is at its highest during the day and at night (at least in the northern hemisphere) the North is the direction around which all the stars turn. Here in the Nubian Desert is finally evidence of an astronomical knowledge and of its association with some abstract, intangible meaning.

When one first asks the question, "Why does the Sun rise in the East?" there are two paths by which one can find an answer. Along one path lies science, along the other lies religion. For most of human history these paths ran side by side and were often indistinguishable, as the answer, "Because the gods make it so," can cover a lot of phenomena and is a pretty difficult explanation to refute. This is what we see in the stories of eclipses. Demons and deities eat the Sun and Moon and do so because we've angered them.

This is a tricky path to follow because any phenomenon we don't understand can therefore be said to be due to the gods or God. Why does the Sun rise in the East and not fall from the sky? It's the work of the god Apollo and his gleaming chariot. Why do the Sun, Moon and stars all circle overhead? Because God has placed the Earth at the center of the Universe around which all things orbit. Even Sir Isaac Newton was not immune to this line of thinking. After discovering the laws of gravity that kept all the planets in orbit around the Sun, he still didn't know where they had gotten their initial velocities and why they all orbited in a common plane, "This most beautiful system of the Sun, planets and comets, could only proceed from the counsel and dominion of the intelligent and powerful Being."

This tendency to explain everything we can't currently explain as due to God or the gods is called the "God of the Gaps," a term first coined by Henry Drummond, a 19th-century Scottish evangelist. Over time, as we discover more about our world, the gaps in our knowledge grow smaller as does our need for miraculous intervention to explain what we see. This is neither fair to science nor religion. For the religious-minded individual who looks for physical proof that God is at work in the cosmos, the duties of His job grow less consequential with every year. God gets demoted from being the Prime Mover of the heavenly firmament to merely twiddling the knobs on the values of a few physical constants.

For science, the "God of the Gaps" is unfair because every time a god or miracle is invoked to explain what is unknown (in essence to say what is unknown is unknowable), all further investigation stops. Once someone plays the "Miracle Card" there is no reason to keep asking questions or testing your hypotheses.

So while the question "why" can be fraught with metaphysical traps and stray into religion, science also asks "how;" a question that has answers open to direct experimentation. How long is a day? How can I learn this from the changing position of the Sun in the sky? How

do the locations of the Sun and the stars at night define direction? How does the changing direction the Sun rises (and the changing stars in the sky at night) correspond to the passage of time and the change of the seasons?

Today, as it has been for the last 100,000 years, it is important to predict the coming rainy season, and the return to life of the plants and animals. In the Khalahari, the rainy season is when the first plants and flowers bloom and hunting communities break into groups with small bands setting out across the wide region to track game. For the Ju/wasi, one of the other tribes of this region, the rainy season is predicted by the annual return of the Pleiades star cluster overhead immediately before dawn. Together with two other bright stars, Canopus and Capella, they form a giant constellation called *tshxum*, the "green leaf horn," which spans nearly 90 degrees across the great open African sky. The anthropologist, Lorna Marshall wrote of her experience seeing this great constellation:

> In due time, The Pleiades were pointed out and identified as the *tshxum*. As a visual object in the sky, The Pleiades are unique; there is no fear of losing track of them…. The magnificent Canopus was also easily recognised and was firmly identified as one of the horns of the *tshxum*…. People would point to a place in the north-east sky about half way between the zenith and the horizon, and say the green leaf horn would appear there at the time the first flowers bloom….Old Gau had remembered that I wanted to see the green leaf horn and came the first morning after our arrival…to waken me before dawn, saying he could show me the star. I quickly climbed out of my tent, and saw a dark sky blazing with a myriad of stars. The Pleiades were in the zenith.[20]

In the eyes of careful observers, the sky becomes the calendar easily used to predict the changing seasons upon which individual and complex society's survival (and ultimately civilization) depend. This transition from a chaotic world of seemingly random changes to a predictable world of returning stars, rain and food, is perfectly embodied in the story of eclipses. Their awe-inspiring apparition was unmistakable, vaguely episodic, and thus possible to predict. Surely it must mean *something*. He who could understand the changing appearance of the stars, Sun and Moon and thus predict eclipses had the power to decide what these eclipses meant. It was they who could announce the coming of a new king, a victory over great enemies on the battlefield, or the loss to evil foes. In short: through them eclipses brought forth order out of chaos.

My attention returns to the black Sun overhead. Once more, the Bailey's Beads dance across its limb as the Moon finally begins to pass beyond the solar disk. A single bead grows to a needle of light in a second diamond ring even more beautiful that the first. Quickly, I turn my head to the East and catch sight of the Moon's shadow racing away across the clouds at over a hundred miles a second.

And then it is over and my first thought is, "When can I see another?" Thanks to our understanding of the Sun, Moon, and Earth, I know what that answer is - down to the second - for any eclipse in the future, wherever I wish to go. That is all the proof I need, that science now successfully describes the world around me. This is not to say that our ancestors were foolish to fear the sky. Thanks to science, while we no longer fear demons and believe in omens, we do understand that ancient terrors like comet impacts and nearby supernova explosions could

destroy most life on Earth (and in some instances already have). But, thankfully, we now know that eclipses are utterly without harm, and thus it is the one astronomical phenomena that have made the transition from omen, to scientific tool, to tourist attraction.

As with the rise of the Hopi Katsina culture, Columbus' lunar eclipse (and as we will see with Albert Einstein's eclipse of the 20th century) eclipses have already altered our history and shaped our world view from the days when our hunter-gather ancestors stood alone on the savanna to when I look up at the sky tonight and realize we are just one planet in an ever-growing family of planets throughout our galaxy. This is the story of science, the path down which a total eclipse of the Sun leads. This is that story.

---

[1] Krupp, E. C., 1991, Beyond the Blue Horizon, pp. 158-162.
[2] Ibid. pg 162.
[3] Berriedale Keith, A. and Carmoy, A. J., 1917, "The Mythology of All Races, Vol. VII, India, Iranian", L. H. Gray and G. F. Moore (eds.) Marshall Jones Co., Boston, pg 151.
[4] Littman, M., Espenak, F., and Wilcox, K, 2009, Totality: Eclipses of the Sun, Oxford University Press, Oxford, pg. 40
[5] Hamacher, D. W. and Norris, Ray P., 2011, "Eclipses in Australian Aboriginal Astronomy," Journal of Astronomical History and Heritage, 14(2), pg. 105
[6] Verdet, J-P, 1992, The Sky: Mystery, Magic, and Myth, (trans. Anthony Zielonka), Harry N. Abrams Inc., New York, pg. 73
[7] Krupp, E. C. 1991, pg. 162.
[8] Masse, W. B. and Soklow, R., 2005, "Black Suns and Dark Times: Cultural Responses to Solar Eclipses in the Ancient Puebloan Southwest", Current Studies in Archaeoastronomy: Conversations Across Space and Time, J. W. Fountain and R. M. Sinclair (eds), Carolina Academic Press, Durham, North Carolina, pg. 64.
[9] Keeler, W., 1988, "Sharp Rays: Javanese Responses to a Solar Eclipse", Indonesia, no 46, pg. 91.
[10] Ibid. pg 91.
[11] Wang, P. K. and Siscoe, G. L., 1980, "Ancient Chinese Observations of Physical Phenomena Attending Solar Eclipses", Solar Physics, Vol. 66, pp190-191.
[12] Henige, D., 1976, "Day was of Sudden Turned into Night": On the Use of Eclipses for Dating Oral History", Comparative Studies in Society and History, Vol. 18, No. 4, pg. 491.
[13] Dronke, U. (Trans.), 1997, "The Poetic Edda: Volume II: Mythological Poems." Oxford University Press
[14] Poole, D. C., 1881, "Among the Sioux of Dakota", D. Van Ostrand Pub., New York, pp. 76-77.
[15] Robbins, L. H., 2000, "Astronomy and Prehistory", Astronomy Across Cultures, the History of Non-Western Astronomy, H. Selin (ed.), Kluwer Academic Pub., Great Britain, pg. 37.
[16] Mithen, S. 1996, The Prehistory of the Mind. London: Thames and Hudson.
[17] Liebenburg, L., 2013, "The Origin of Science", Cybertracker.org, Cape Town, South Africa, pg. 140
[18] Ibid, pg. 141
[19] Robbins, 2000.
[20] Marshall, L., 1975, "Two Ju/Wa Constellations", Botswana Notes & Records, Vol. 7, pg. 155.