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.

--The Grimnismal, of the Eldar Edda

Chapter 0: A Day with Two Dawns and Midnight at Noon

I am an astronomer; I have spent my whole life watching the sky. I've been to observatories all over the world and used every kind of telescope to image distant star clusters, gaseous nebulae, and massive galaxies. For me, every clear night is an opportunity to see something beautiful and discover something amazing. I have seen a comet hanging silently in the sky for weeks, witnessed sunlight glint off the dust floating between the planets, and stood on a desert plain so dark that the brightest source of light was the rising Milky Way wrapped around the distant horizon. 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. It is the only astronomical wonder that requires no telescope or fancy equipment to see and looks more spectacular to the eye than through the lens of any camera.

For an event that has at some point touched almost every place on Earth, remarkably few people have ever seen a total solar eclipse. The fact that *anyone* on Earth is able to see one is due to the coincidence that our Moon is exactly the right size and distance from the Earth to completely cover the Sun. Roughly twice each year the Moon's shadow falls across the Earth, and where it does a solar eclipse occurs. In all but the very center of this shadow the Moon fails to fully cover the Sun, and the eclipse is only partial.

A *total* solar eclipse is different. Only at the very center of the shadow, where the alignment of Earth, Moon and Sun is absolutely perfect is a total eclipse possible. This spot of totality is small - maybe no more than a few dozen miles wide - yet the Moon's motion draws the shadow eastward across our planet in a path potentially thousands of miles long. For anyone on the ground, the experience can be either awe-inspiring or merely interesting, depending entirely on whether one is inside or outside that path. As those who have been to the shadow's center can attest: it is literally the difference between night and day. Ninety-nine percent totality is definitely not ninety-nine percent of the spectacle.

It's exactly 11:28 in the morning when a tiny nick in the side of the Sun first appears. Were it not for the shouts from the crowds around me on this August morning I never would have noticed it. The Sun is so bright during this initial, partial, phase of the eclipse that without the cardboard safety glasses protecting my eyes I never would have noticed it. But don't let these cheap glasses fool you, they're only necessary during the partial phase when the sun's rays are still as strong as on any normal day. But once totality occurs the spectacle will be perfectly visible to all and I can easily toss the pair aside.

Watching the notch turn into a bite, it is no coincidence that cultures from all over the Earth witnessed this sight with some degree of dismay. The Greek origin of the word *eclipse* is *ekleipsis* meaning "omission" or "abandonment." Ancient Chinese eclipse accounts contain the characters for "ugly" and "abnormal." For the Aztec, the eclipsed Sun "faltered" and became "restless" and "troubled."[1] The Sun is the giver of heat and life. When the Sun goes away, it leaves behind the creeping fear that it might not come back.

It takes forty minutes for the bite to grow so big that the Sun is now a crescent getting thinner by the minute. Beneath me that same crescent is visible by the thousands within the shadow of the tree under which I've taken refugee from the heat. Every tiny gap in the leaves overhead acts as a "pinhole camera" projecting a bright fingernail of light on the ground. Nearby children have spotted them too and begin to yell and giggle as they point and play amongst the tiny crescents. Had I not known what was happening before, this oddity would certainly have revealed the eclipse in progress above.

An hour has passed since this all began: only twenty minutes left until totality. Even without glasses, a quick glance out of the corner of my eye now reveals an arc across the Sun that divides the blinding from the merely brilliant. The life-giving nature of the Sun is no longer an abstract concept: the sky is growing darker and colors are strangely wrong. The landscape is sapped of saturation. The worlds are aligning.

With ten minutes left, the conditions are changing fast. The world has turned to twilight. The shadows of trees and me are sharp as if lit by a single spotlight. All illumination now comes, not from a yellow Sun set amid a bright blue sky, but from only a narrow white crescent in a sky no longer bright.

The crescent shrinks. The crowd rises. 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 Sun is left that surely totality should begin at 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 becomes an hour and seconds like minutes.

Suddenly, the thin sickle breaks apart into an array of brilliant specks that dance and shimmer along the jet-black rim. They are called Baily's Beads and they are the last rays of the vanishing Sun streaming through actual mountain valleys along the curved lunar rim. I finally remove my protective glasses to see them quickly wink away until there is only a single glistening star set in a band of white fire encircling the Moon: the glorious diamond ring.

And then the spot collapses upon itself and is 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. It is unimaginably beautiful, only ever visible during these few precious minutes of totality, and all around it are the brighter stars and planets invisible until now. It is a day that has become night at noon with Sun, Moon, planets, and stars overhead.

While I know the mechanics of this celestial alignment, it is in this moment of totality that 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. It is clear to me now why people throughout time did what they did to scare away the demons, chase away the jaguars, and slay the monsters they imagined devouring the Sun. 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."[2]

There has always been a purpose to this pandemonium. To scare the Sun-eating demons we needed to raise a ruckus, howl in hullabaloo and create a kerfuffle. In Paraguay and Argentina, the roar of the crowds and barking dogs frightened the celestial jaguar that ate the Sun. Norsemen yelled to frighten away Loki's demon dogs he'd sent to hunt and feed upon both the Sun and Moon. The Ojibwe of North America sought to help the beleaguered Sun by firing flaming arrows to help him regain his light. In India the people banged pots and pans to frighten Rahu, the immortal head who chased and ate both Sun and Moon.[3] If they were loud enough then Rahu would be startled, and dropping the Sun from his jaws, the eclipse would be only partial. For the Aztec, however, 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.[4]

Fortunately for any fair-skinned Aztecs, total solar eclipses from any one location are rare. Though eclipses happen roughly twice each year, each follows a different path across the

planet. Every 18 years these patterns repeat in shape, but one third way around the planet and a little farther north or south than the one before. As seen from a location high above the globe these paths slowly spiral around the planet from pole to pole until eventually any spot on Earth can expect to see totality every 300 years on average. Though three centuries is long in human terms, the different paths do cross, and a single person in a fixed location may periodically see two eclipses in as little as a dozen years or less. For cultures that looked to the sky for omens, where every new star, comet, or eclipse could be the sign of the end-times, imagine what seeing three total eclipses in one lifetime would have meant?

For the Hopi, distant cousins to the Aztec, just such an occurrence took place in the fourteenth-century among the canyons and mesas of the American Southwest. There, in the region along the Little Colorado River known as Fourmile Ruin, the paths of three total solar eclipses crossed within an 80-year period. It is from this spot that the modern Hopi "Katsina" culture is thought to have emerged soon thereafter.

Though the Hopi are intensely private about their religious life, it is known that the ceremonies involving masked Katsina dancers are meant to restore order and harmony to the world. According to 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."[5] Are Katsinas, whose likenesses can be found in gift-shops across the American Southwest, a response to the disorder ancient eclipses brought?

We are still plagued by fears of eclipses. On the morning of June 11, 1983, a total solar eclipse swept across Indonesia. 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.[6]

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."[7]

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. While others painted black circles with yellow crescents in representation of the partial eclipse, I had found library books showing the corona and so carefully painted the billowing 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 I had been flooded with messages warning of the dangers of going blind from what was about to happen. As a boy, I had glanced at the Sun many times, especially at sunset, and so I thought for sure this meant some strange rays must be present during an eclipse. Perhaps some strange influence of the Moon? Whatever the rays were, they must instantly turn your eyes to ash if all the adults were so afraid. I made sure to hide inside with the curtains drawn lest I accidentally catch sight of the dangerous event and burn out my eyes. Sharp rays, indeed.

Today I know that there are no special rays, sharp or otherwise. Only during the partial phase is the Sun so bright that staring at it for even a couple seconds can cause permanent damage to the retina (just as it will do on any other day). For this reason, it is only for curious onlookers during the partial phase that eclipse glasses are even necessary; when totality comes its light is as safe as it is awesome. Yet, in our zeal to be "safe" we flood the airwaves with our

fears, never with our hopes. That is why, to this day, my first eclipse memory is of watching the events unfold on my RCA color TV (snapping photos off the screen with my plastic drugstore camera). My only direct experience of the event itself was noticing how dark the house became as totality passed unseen overhead. It would be thirty-eight years before a total solar eclipse would touch this country again and I have spent every one of those years wishing I'd turned around, gone to the window, parted the curtains, and simply looked up.

My career as an astronomer has taken me around the world since then, partly in pursuit of exactly that which I so narrowly missed when I was nine. Yet though I have seen multiple solar eclipses since, I will never be able to see the one that I missed that day. Every eclipse is different. The corona that is such a startling phenomenon of totality is different every time depending upon the conditions on the Sun at just that moment, and its exact shape is unknown until the instant of totality.

Astrological records of ancient eclipses in China claimed that while solar eclipses were a reflection of the quality of the king, the corona's appearance revealed the political plots at work behind the throne:

> (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….
>
> 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.[8]

The search for meaning in celestial events is the purview of astrology and those who can predict an eclipse have the power to define what they mean. A comet appears in the sky? The king will be overthrown. A supernova (a new star) appears in Leo? A new 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 such a rare and beautiful phenomenon, it makes sense to want to associate it with something of great importance.

It therefore follows naturally that if eclipses record momentous events, then a momentous event must have had an eclipse. Perhaps it is only a coincidence that the Boston Red Sox won their first World Series baseball championship in 85 years during the final minutes of a total lunar eclipse in October 2004. Then again, perhaps the "Curse of the Bambino", incurred when Boston traded Babe Ruth to the New York Yankees in 1920, really did require the heavens to align and the Moon to enter the shadow of the Earth at the moment of victory before Boston's championship drought could end.

But not every such historic event has such a convenient eclipse. In that case it may be necessary to get a little creative and find an eclipse to fit. In 1133, a nearly total solar eclipse was visible across England. Two years later King Henry I of England died without a male heir and nearly 20 years of civil war ensued. The Peterborough Chronicle, written soon after 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."[9]

These, “retroactive omens” reveal the importance of these events to 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.”[10] The Christian Rapture also predicts the Sun will turn black, surely an apocalyptic bookend to the darkness that descended at noon as Jesus was nailed to the cross in the Christian gospels (assumed by some to be an eclipse).

If eclipses were harbingers of end-times, then to call on one was a sign of one’s power with the gods. Just such an event accompanies the first account of eclipses by Europeans in the Americas. By 1504, Christopher Columbus was in the midst of his fourth and final voyage to the New World when disaster struck in the form of shipwreck. He lost two ships due to rot and was forced to beach his remaining ships on what’s now Jamaica’s north shore. Even under the best of times, Columbus was a terrible administrator (he’d already been removed as Governor of the Indies on a previous voyage) so as the days turned to weeks Columbus’ crew grew tired and mutinied. The men turned on the locals who had initially brought them food, and began to pillage and plunder their homes. To be butchered for their generosity was too much for anyone to bear and the Jamaican chieftains revolted against the stranded Europeans.

Columbus was desperate. Caught between mutiny and rebellion, he consulted the astronomical almanacs he used for navigation. In them he found that three days later, on the evening of February 29, 1504 there would be a total lunar eclipse. During a total lunar eclipse, when the Moon is fully in the shadow of the Earth, the Moon takes on a reddish color from sunlight filtering through the Earth’s atmosphere. Unlike total solar eclipses that are visible only within a small band, total lunar eclipses are visible to everyone on the hemisphere where the Moon is above the horizon. So while Columbus’ almanacs only revealed that an eclipse would

be visible back in Europe, he had a 50% chance that it would be visible in Jamaica too. What was less certain was exactly when.

Columbus called the local chieftains together, and told them God was angry at their rebellion. God, Columbus said, would make His displeasure known by causing the Moon to be "inflamed with wrath." That evening, when the Moon rose after sunset, it was clear that something was wrong; a dark shadow was slowly spreading 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. Unlike a total solar eclipse that lasts only minutes or seconds it can take up to an hour for the Moon to move through the shadow of the Earth and Columbus' almanacs revealed that on that night totality would last for exactly 48 minutes.

As the time finally approached, Columbus stepped once more outside. Addressing the native delegation he announced that if they brought his men food once more, then they would be forgiven and he'd bring back the Moon. Of course they agreed and, at that moment, totality ended and light once more began to spread upon the face of the Moon. Had Columbus not been so lucky about the time and date of the eclipse, the entire history of the Western world might have been altered that night.

Over three hundred years later another European would try the same trick. Out on the plains of Dakota Territory in western North America, Captain D.C. Poole of the U.S. 22nd Infantry spent 18 months as an agent to the Sioux in 1869. There he met a local white doctor who had 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 [an early form of solar eclipse safety glasses]. 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….[11]

The power of astronomy, and science in general, is that we make predictions that can be tested. Wish to see a solar eclipse? Astronomers can calculate the location and time of any future eclipse down to the mile and the second. The proof will be waiting for you when you get there: either you see the corona or you don't. If you don't, then we learn we didn't understand the world as well as we thought and we look for what we got wrong so we don't make that mistake again. This process is at the heart of everything we know about the physical Universe in which we live.

Astrology also makes predictions. Based on the motions of the heavenly bodies it identifies all manner of auspicious dates and compatible mates. The one thing it does not do, however, is include the same self-testing, self-correcting mechanism that is the defining characteristic of science. Yet in a 2014 National Science Foundation survey, nearly half of all Americans (45%) responded that they believed there was some scientific basis to astrology.

The primal appeal of pseudo-sciences like astrology is understandable. Life is full of dangers and misfortune that plague us at random. Astrology gives us hope that there is a cosmic reason, a connection with the Sun, Moon, and stars, which gives order to the apparent chaos we encounter. Yet the science of astronomy reveals a far more direct way in which the heavens guide our lives on a daily basis.

The Sun gives us light and heat. What organisms don't feed directly on sunlight, feed on other organisms that do. Our everyday concepts of position, direction, and time intimately depend upon astronomy. What is a "day" but the rotation of our planet? A "year" measures its orbital motion about the Sun. Even the orbit of the Moon is marked in the period of time we call a "month." Imagine every task, chore, rite, or celebration that happens on an annual basis

and you will find a need for some astronomer in our past. Could civilization have arisen without astronomy? Might we all be the descendents of astronomers? Is there any evidence? Where 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 away from competing beetles. In Florida, baby sea turtles hatching on the sandy beach use the light of the sky to navigate away from the darkness of shore to reach the bright reflective waters of the sea. 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* ancestors were 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 they kept close to the animals upon which they depended? Lions follow herds, but they aren't scientists. Science is all about 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 darkness. Perhaps the world's first artificial light allowed our distant ancestor to stay out at night and look at the Moon and stars without fear of nocturnal predators. Perhaps the first constellations, long lost to prehistory were created during those nights.

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. When the tides were out they could scavenge a plentiful source of nutrition with little risk or work. 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. In addition, the height of the tides changes with the Moon: extremely high and low tides (called spring tides) occur when the Moon is new or full, extremely mild tides occur when only half the Moon appears lit . If your community's diet depended upon the local pools that are only revealed at low tides, 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.

But consider for a moment what is required to make these mental connections. The rising ocean tide is a direct physical effect; it gets you wet and the beaches disappear. Later, the tide goes out and reveals 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 that evolved over millions of years, evolutionary psychologists theorize that our mind (how we use our brains to perceive the world) has also evolved. Based on the appearance of painted artwork and ceremonial artifacts, Mithen hypothesizes that somewhere around 60,000 years ago our otherwise physically modern ancestors developed the ability to synthesize different forms of intelligence (the knowledge necessary to build fires, tools, and weapons, along with the ability to interact in a group and structured society) and to combine these in ways that incorporated abstract ideas, myths, and long term observations.[12] "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."[13]

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 only 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 all buried on their left-side, head to the East, facing the rising Sun.[14] 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; the answer, "Because the gods make it so," can cover a lot of phenomena and is a 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 always be blamed on 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 in the seventeenth-century 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 don't currently understand as due to God or the gods is called the "God of the Gaps," a term first coined by Henry Drummond, a nineteenth-

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 is seen. 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 parameters.

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 that the Sun rises (and the changing stars in the sky at night) correspond to the passage of time and the passage of the seasons?

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. It is, perhaps, no coincidence that the first signs of agriculture (tools and deposits of charred plant matter) are found at the roughly the same period in time as the Nubian burials.

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*. Like the ancient Chinese astrologers who courted palace intrigue, or even Christopher Columbus saving his own skin, whoever could understand the motion of the stars, Sun and Moon and thus predict eclipses had the power to decide what these eclipses meant and thus proclaim some semblance of order in a world of chaos. In a modern world where twice as many Americans believe there is some science to astrology than accept our understanding of evolution, we are still in thrall to the cycles and patterns of the heavens.

…

My attention returns to the black Sun overhead. Once more, the Baily'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 than 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. The light is returning, too quickly. Even the partially restored sun is now so bright that I'm forced to turn away. And then it is over and my first thought is, "When can I see another?"

That I chase eclipses where my ancestors feared them is not to say that they were foolish to fear the sky. Thanks to science, while we no longer blame demons and believe in omens, we do understand that ancient terrors like comet impacts and nearby supernova explosions could kill 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 phenomenon that has made the transition from terrifying omen, to scientific tool, to benign 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 twentieth-century, eclipses have already altered our history and shaped our world view. From the days when our hunter-gatherer ancestors stood alone on the savanna to when I look up at the sky tonight, the science of eclipses reveals we are just one planet in an ever-growing family of planets throughout this galaxy in an ever-expanding universe. This is the story of science, the path down which totality leads.

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