Universe of Change

Narrator's Script

Modern life leaves little room for the night sky.

We rarely take time to look up. Instead, we fill our cities with light and sound and technological distractions. We crowd out the stars with unnatural illumination.

Imagine a time before electric lights flooded the view overhead. A time when the sky dominated half the world, from the horizon up. The world of our ancestors.

We can experience some measure of this reality when we travel away from the city—to witness a dark sky over the countryside or desert plains.

Here the night sky blossoms into it own: thousands of stars, pinpoints of light in the darkness, shed their faint glow on our eyes. The awe and mystery that surround this view have inspired countless generations. Our ancestors viewed this same sky and learned from it: they looked for patterns and learned rules of order.

As our culture has changed, so has our view of the universe that surrounds us. At the dawn of a new millennium, we see the universe as a place in constant transformation—a place we have only begun to discover.

A Universe of Change.

[CREDITS]

Constellations, Moon and Sun

Astronomy begins by watching the sky.

Although we usually think of astronomy in the dark, we observe the most basic astronomical pattern in the balance between day and night. This 24-hour cycle defines our lives and started our ancestors counting and tracking the passage of time.

The moon crosses the border between day and night, showing its face during both daylight and in the dark of night. And its face changes from day to day, from night to night... From thin sliver to full moon, the moon's phases mark time in the sky. This regular cycle did not escape the notice of our ancestors.

People have always searched for order in the night sky—in the motion of the sun and moon—even in the nearly random scattering of stars above. For at least thousands of years, we have connected stellar dots to form pictures—constellations—that tell stories in the sky.

In one part of the sky, the ancient Greeks imagined the character Orion in the midst of an elaborate hunting scene. [...] With these same stars, Egyptians drew their god Osiris on his journey along the Nile River. [...] The Bororo People of Central Brazil don't see a person at all—instead, they place a giant crocodile in this part of the sky. These patterns sprout from the human imagination, but people found other patterns as well.

Although the sun's brightness washes out the stars in the daytime sky, people discovered some time ago that the sun follows a particular path in the sky, along a line called the ecliptic. The constellations along this path have familiar names—Scorpius, Sagittarius, Capricorn, to name a few.

The moon follows this same path in the sky. It too travels along the ecliptic. If we watch the moon from day to day, night to night, we see it pass through its phases against these familiar background constellations.

And there are still other wanderers along this star-lit path.

Planets

Ancient observers paid close attention to star-like objects that appeared to move—to shift position relative to the unmoving constellations. The ancient Greeks called these objects “wanderers.” In English, the Greek name became “planets.”

We now think of the planets as places to visit. We have landed spacecraft on Mars and Venus; we have sent probes to photograph Jupiter, Saturn and the other planets. [...] But for our ancestors, these objects were simple wanderers. Itinerant members of the night sky.

They noticed that planets followed the same path as the sun and moon in the sky—along the ecliptic—and they learned how to predict the planets’ positions and appearances.

Planets move so predictably through our sky because they move predictably around our Sun. They follow orbits—paths around the Sun that we can calculate. Planets close to the Sun—such as Mercury, Venus, Earth, and Mars—orbit faster than planets farther away—Jupiter, Saturn, Uranus, and Neptune. Earth completes its trip around the Sun in just 365 days, or one year. Pluto, the most distant planet, takes nearly 250 years to make a single trip around the Sun.

With the fixed stars and the predictable planets, the sky presented a fascinating order to ancient people. They could use the sky as a reliable guide and as a basic clock and calendar to organize their time.

But sometimes, the sky could surprise them. They couldn’t predict everything that took place overhead, and some of the most disturbing and unpredictable objects were comets.

Observers in Asia and Europe viewed comets as bad omens. Because people could not easily predict when a comet would show up, they feared the appearance of these unexpected visitors to the night sky. For much of human history, comets disrupted the order of the heavens.

Most comets orbit the Sun, just like the Earth and other planets. They typically reside far away from the light and heat of the Sun—in the outer reaches of the solar system, beyond even Pluto. They are cold, icy bodies that may date back to the early history of the solar system.

We discover new comets every year. Wayward interplanetary travellers making trips toward the inner solar system. Most never get close enough to see without a telescope; many will not return for thousands of years. We can now think of comets' appearances as rare treats, difficult to predict, but wonderful to observe.

The Importance of Impacts

The Earth is an active place—wind, water, and the shifting of land masses over time obliterate much of the history of our planet's surface.

But on the Moon, without weather and geologic forces, we see history written on its surface. Circular, cup-shaped craters mark the spots where space debris has slammed into the Moon. Bright tracks spread out from some of the larger impact sites. Other impacts show dark centers where material has welled up from underneath the surface.

The scars that mar the Moon's face date back billions of years—to the early history of the solar system, when leftover dust and debris littered the spaces between the planets.

[May remove the following, which is written to visuals...]

Impacts affected not just the Moon, but all the planets, including the Earth. An object of planetary proportions—almost the size of Mars—may have once shared Earth's orbit, billions of years ago. If so, a collision could not have been avoided.

In a catastrophic event that nearly destroyed the young Earth, the two bodies would have slammed into each other with enough force to release huge quantities of matter. [...] The remnants of this disaster may have provided the raw material to create the Moon.

[...To here.]

Many of the spectacular features in our solar system may have originated during this chaotic time in the distant past... The rings that circle the giant planets... The enormous moon Triton that orbits Neptune backward... These, too, may owe their existence to cosmic impacts or near misses.

Today, most of the ancient debris has cleared away, and our solar system is a lonely, sparsely populated place. Even with enormous distances separating the planets, however, objects still manage to collide with one another on occasion.

In 1993, a comet named Shoemaker–Levy 9 was discovered in orbit—not around the Sun, like most comets—but around Jupiter, the largest planet in our solar system. Jupiter's gravity had captured the comet and broken it into numerous fragments.

Astronomers observed the comet for more than a year, and calculations showed that it would eventually collide with the giant planet. From July 14th through 16th, 1994, that is exactly what happened: one by one, the fragments of Shoemaker–Levy 9 collided with Jupiter, creating fireballs in the upper atmosphere of the giant planet.

Because astronomers had predicted the event, they managed to plan observations of the impacts. Comet fragments vaporized rapidly when they struck Jupiter's cloudtops,

and plumes of superheated material shot upward, creating brilliant flashes of light. Dark cometary material hovered in Jupiter's atmosphere for months afterward, leaving dark bruises that slowly dissipated, leaving little or no trace of the collision that created them.

Stars

Members of our solar system, planets and comets alike, constitute our family in space. Together, we huddle close to our parent star, the Sun. We depend on its light and heat, and its gravitational pull dominates our solar system.

Other stars lie at much greater distances. They appear as nothing but points of light, even when viewed by our largest telescopes—but we can study their light to determine more about their age, size, and structure.

Not even a century has passed since astronomers began to unravel the secrets of the stars, but one thing has become abundantly clear... Stars have lifetimes.

A human lifetime doesn't last long enough to see the stars change—either shift in position, sprout to life, or vanish in death. Even the shortest-lived stars have outlasted all of recorded history a thousand times over.

Instead, we observe a snapshot of stars at different points in their life cycles. When we examine the night sky, we see old stars, young stars, and stars in the middle of their lengthy lifetimes.

Short-lived stars are more massive than our Sun and appear bright and blue: they burn their fuel quickly, using it all up in a matter of millions of years. In their old age, they expand and become red. Other red stars are dwarfs—much smaller than our Sun, spending their fuel slowly and miserly, so they will last for tens of billions of years or more.

We also see regions giving birth to stars... The Orion Nebula shows up as a faint, hazy patch near the tip of Orion's sword in the constellation of the Hunter. In a small telescope, we can see filaments of glowing gas illuminated by bright, young stars. We can imagine a flight through this dense, gassy region, surrounded by the veil of stellar birth—glowing hydrogen and oxygen leftover from the newborn stars.

The Eagle Nebula became famous when the Hubble Space Telescope snapped its picture—its vast, dark columns of dust came to be known as the "Pillars of Creation."

Within these dense clouds of glowing gas, stars come to life. But this is simply the first part of a star's life story...

A star spends its existence in careful balance. The force of gravity pulls a star's mass inward, the substantial weight of its outer layers bearing down on its dense core. Inside the star's core, however, the creation of energy helps support the star's weight. The energy source that powers the star and causes it to shine also keeps its mass from falling inward.

This balance cannot last forever. Eventually, the star exhausts its energy reserves and dies. We see many examples of stars that have reached the ends of their lives... The outer layers of the star create elegant structures, nebulas nicknamed "Cat's Eye" and "Hourglass," among others.

Our Sun will meet a similar end. In another five billion years or so, the Sun will run out of the thermonuclear fuel that supplies its light and heat, and it too may end in a brilliant nebula.

Stars more massive than our Sun meet more violent ends. They burn through their energy reserves quickly, perhaps surviving only a few million years instead of a few billion. And when they run out of fuel, their collapse occurs quickly as well—in an event we call a supernova.

To understand what happens in a supernova, we need to observe a star from the inside. Layer upon layer within this star remain from its many stages of fuel burning. As we approach the star's core, we near the region where heavy atoms are crushed together.

The process of fusing atoms can no longer support the weight of the star. The core collapses.

As soon as the core collapses, mass begins falling inward. But the infalling mass bounces off the dense core—creating a shock wave. The shock wave rips through the star's outer layers.

The intricate structures created in a supernova take shape almost instantly on astronomical time scales, over merely hundreds or thousands of years.

Conclusion

People have actually witnessed a star die in a supernova... Nearly a thousand years ago, in the year 1066, people across the globe, from China to New Mexico observed a bright star make a sudden appearance in the constellation Taurus, near Orion—a star in its death throes, the remains of which we can observe with our telescopes.

We see a universe in the process of becoming. Although our brief lives afford only a fleeting glimpse of the activity in our universe, we have pieced together stories of transformation taking place unimaginably far away.

When we gaze at the night sky, we see the same stars our ancestors saw—the same night sky that inspired people thousands of years ago inspires us today. But our perspective has changed. With its tools and telescopes, modern astronomy has captured the sky and brought it closer to Earth.

Now, even as we lose the subtleties of the night sky to our city lights and after-hours distractions, we bring the stars inside... Onto a dome, into our minds, as we begin to comprehend our universe of constant change.

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