Part 1

The Fantasy

IN A MAYAN KINGDOM LONG AGO, there lived a princess gifted with an intellect like no other. Her name was Da'Lau, which means "one who seeks." The subjects of the empire whispered with awe the princess's name because she was smart, possessing a bright mind full of insatiable curiosity.

She was born under the spell of the Pleiades, the brightest star cluster in the northern hemisphere, also known by her people as Tz'ab. Swinging in her cradle, the infant princess would gaze at the night sky, awestruck by the glorious beauty of the luminous stars arranged in alluring constellations. In the stillness of night, the babe spent hours enthralled by the splendor of the million points of light shinning against the obscurity of the celestial vault. Ever since, the princess developed a peculiar affinity with the heavens.

One summer night when she was six, Da'Lau caught sight of tiny fireballs crossing the sky, yet fleeting, lasting an instant shorter than a single breath. She asked her teachers about the little stars falling all around, but no one knew. So the little princess imagined they were the sparks cast out by the burning of the cosmic fires.

Mystified, she also observed the Earth's Moon moving over the sky and noted how it changed every night, from a full illuminated disk to a thin silver crescent. The young girl wondered why some nights the Moon would disappear completely from view only to reappear nights later, grow from slender to full and start the cycle once again.

Why does the Moon look bigger when it hangs low near the horizon—Da'Lau asked when she was ten—than when it's overhead at night? No one knew. So, she intended to one day explain the reason behind the lunar cycle, its size, and she promised herself to solve the mystery of the Moon's dark blemishes, visible even by day.

K'uk', an enchanted bird with vivid plumage and a long brilliant tail, patiently listened to Da'Lau's questions. This magical quetzal had befriended the princess as a child, carrying her into the air, past the puffy clouds, so she could see all there was to see of our beautiful home planet. Soaring high on the wings of the quetzal, Da'Lau discovered the Earth as it really is, a wonderland with turquoise blue oceans and green dense jungles, tall mountains and gentle rolling hills. From above she beheld rain forests and unbroken plains that stretched into the distance like a green carpet woven with grass. In the midst of all that, she spotted villages and great cities swarming with people that looked so small like the teeny ants in her garden.

In those exhilarating childhood excursions with her bird friend, Da'Lau discovered towering pyramids peaking through sweltering jungles, and farther away she distinguished peculiar structures in the middle of arid deserts. K'uk' lifted the girl over majestic volcanoes crowned with white snow and lulled her over singing waterfalls hidden in the middle of rain forests; the quetzal flew her over smooth green pastures and lovely fields sprinkled with colorful flowers. Since then the princess learned to cherish the Earth, as a child loves her mother.

Da'Lau was profoundly aware of the wondrous beauty of the earthly landscapes, remembering the awesome scenery she had seen as a child. "That *is* Kab', my home!" she exclaimed before soaring higher through the dark sky with her wings shimmering under the moonlight.

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At a far distance away all was quiet, and the princess felt a pang of loneliness. All about her was darkness so intense she could almost reach out and touch it. After a few moments, she overcame her apprehension and kept on her journey, thinking that even the endless sky must end, though she could not imagine it.

In her trajectory, Da'Lau first went by the Earth's Moon and discovered it was another world, a spinning rocky sphere but somehow not like ours. Astonished, she scanned the airless desolate *luna* and hovered over it, surveying its dusty valleys and gigantic craters. She beheld the bright highlands and the dark smooth Maria. At last she knew what the curious dark spots on the Moon were and smiled for discovering the secret.

Da'Lau then searched for Venus, the Great Star planet much revered by the Maya. As she flew over it, she plunged her gaze toward the cloudy orb about the size of Earth, probing the peculiar incandescent clouds, striving to penetrate the hidden surface below. Venus—she discovered—was a scorching world, enclosed with acid vapors and a choking atmosphere. She wondered why the morning star planet so beautiful seen from the Earth was so deceptively hostile.

The princess flew onward toward our own star but she stopped first over the closest planet to the Sun, the one that looked so old with its heavily cratered surface. Floating over Mercury, Da'Lau caught her first sight of the splendid Sun. From afar she watched the luminous ball of plasma, immense compared with the planets, rotating with violent explosions on its atmosphere that flared with mighty whirlpools of fire. Incandescent solar flares forcefully extended to reach far into space.

Changing course, the princess continued her flight across the vast space. "I will travel just a little farther," Da'Lau thought. First she went by a rocky red planet with the largest mountains she had ever seen; its crimson surface was covered with crates, plains, and colossal canyons. The princess concluded it was the reddish point of light in the sky her teacher had taught her to track as it became visible in the morning after its period of invisibility. The tutor also trained her to measure the times when the planet's motion reversed its direction relative to the stars. The girl smiled with pleasure remembering her scholarly lessons.

Leaving the Red Planet, she crossed paths with glittering comets as they traveled their periodic voyages, with their spectacular icy heads and long sinuous tails shining against the light of the Sun. Da'Lau went through gas giant planets surrounded with many moons and gleaming colored rings of rocky dust. The princess shivered when she reached the frigid outer edges of our solar system. Her heart fluttered like a butterfly when she turned her head around and saw how infinitely small the Earth is, how vulnerable that azure-hued dot with white specks is, almost imperceptible amidst the blackness of space. And with that as her last glance, Da'Lau bid adieu to her beloved planet.

Questions to Ponder

1. If the princess Da'Lau were a beam of light, how long would it take her to cross the Solar System?
2. As a beam of light, how many light years would it take her to cross the Milky Way Galaxy?
3. What happens to a body when it approaches the speed of light?
4. What do you think happened to the princess when she fell into the black hole? Did she find the door to another universe, the heavens she longed for?
5. How far from us are the stars? How far is Proxima Centauri—the nearest star beyond the Sun—from the Earth?
6. Could Da'Lau cross the universe at speeds higher than the speed of light? If so, how?
7. Do you think that humans will be able to travel (some day) to other stars within our own galaxy?
8. If astronomers discovered a planet like Earth orbiting a star located 10 light years away, would humans be able to visit it? How long would it take for a spaceship to make the trip moving at half the speed of light?
9. The total size of the Milky Way galaxy is about 100,000 light-years across; can you determine this distance in km (or miles)?
10. How long would it take for a spaceship to cross the Milky Way galaxy? Assume the spaceship can travel at 10 percent of the speed of light.
11. What is "time"?
12. Is time eternal?
13. In the fantasy, as Da'Lau became one with the stars, *past and future were interchanged*. What does this statement mean?
14. What is spacetime?
15. How big is our Universe? How did it begin? How old is it?
16. How many stars are in the visible Universe? How many galaxies?
17. Does the Universe have a center? Does it have an outer edge?
18. How big is the Solar System compared with the size of the known or visible Universe?
19. What makes the stars and planets move?
20. How do stars form?
21. Why do stars die?
22. Will our Sun die, too? If so, how? When? What would happen to our Earth?
23. How many stars are in the Milky Way galaxy, our home galaxy?
24. Do you believe there are planets—similar to Earth—circling other stars in the Universe?
25. Do you believe we are alone in the Universe?
26. Is life like ours possible in extrasolar planets? If not, how about another form of life? How do you image it?

Part 2

The Reality of the Fantasy

THE TALE OF THE MAYA PRINCESS that traveled across the Universe is, of course, a fantasy. However, her idealized intergalactic voyage in spacetime helps us to frame a vision of the cosmos in all its magnificence. It also helps us to ponder and ask questions related to what we cannot see and the exploration of space we have yet to accomplish.

Over the past years, I've become increasingly interested in the physics of the Universe, as seen from my aerospace engineer perspective. Specializing in space propulsion was a choice I made to get closer to my childhood dream of finding a way to voyage to the stars. But how could I conceive a rocketship without knowing the space environment where it would travel? Not only does a rocket engineer need to know and appreciate the enormous distances to be traveled, but she also must understand the physical challenges of a vehicle moving in outer space.

Kuxan Suum is a metaphor for human spaceflight. My intention in writing such allegory was to bring to the forefront several scientific challenges faced by engineers and scientists involved in the space program. In writing a fantasy, telling a story of a human-being traveling through space, I also wished to convey the sense of awe for the human feats that characterize the exploration of the Universe. The thread that stitches Kuxan Suum is its surreal invocation of travel through the cosmos—the sublime, the practical, and the science.

Before we can talk about spaceflight, we need a virtual tour of the Universe, to image and become aware of its complexity and size in order to conceive such a voyage. First we have to establish the enormous distances that separate us humans from other bodies in the sky. In addition to its size, the space environment is quite complex. Therefore, we must characterize and gauge the cosmic atmosphere where our spaceships would navigate.

If we could observe at once—as Da'Lau did—everything in the Universe, we would notice that everything is in motion:

- The Earth rotates on its axis and revolves around the Sun (our own star).
- The Earth has its own natural satellite we call Moon, which rotates and circles around us.
- There are other seven planets that circle the Sun in distinct orbital paths, along with their own moons. In our Solar System we'd also encounter dwarf planets, asteroids, and millions of small bodies circling and gravitationally bound to the Sun.
- The Sun (and everything gravitationally bound to it) revolves around the center of the Milky Way (our own Galaxy).
- Millions of other stars also circle our galaxy.
- The Milky Way galaxy is one of billions of clusters of stars that exist in the Universe.
- The galaxies are running away—the Universe is expanding!

That's the space environment in a nut shell. Now let's ask two fundamental questions:

a gas giant, about 15 percent bigger than Jupiter but 30 times closer to its star than Earth is to the Sun. HD 189733b is located 63 light-years away in the constellation Vulpecula.

Finding water on one extrasolar planet implies that other planets in the Universe could also have water or some other liquid. This also raises the question of whether some extrasolar planets might support extraterrestrial life. Simply based on the size of our universe and the laws of probability, the odds are excellent that our Solar System is not unique in the Universe.

Some researchers have expanded their work to include search for habitable planets, those planets having a temperature of about 300 K to allow for the possibility of liquid water. Other researchers examine the atmospheres of exoplanets for signs of life, particularly for the presence of certain life-related chemicals such as oxygen and carbon dioxide. The major technical challenge lies in distinguishing the light from the extrasolar planet, as the radiation emitted by its parent star nearby is overwhelming.

Should we also consider that life in other parts of the Universe may be possible in forms different from those on Earth? Certainly! In 2007, a panel of scientists recommended expanding the search for extraterrestrial life to include what they call "weird life," organisms that lack DNA or other molecules found in life on Earth.

Scientists have looked to life on Earth to guide their search for life on other worlds, and as such they have focused on detecting water. But there could be other kinds of chemistry that support life, in a form that would differ from life as we know it. For example, DNA uses phosphorus in its backbone. Is it possible to build a backbone out of arsenic instead? Instead of water, can life exist in other liquids such as ammonia or methane? Maybe. These ideas and others as yet formulated should not be excluded, as they could be within the realm of possibility.

Black Holes: Monsters of the Universe?

Black holes may be worse monsters than we thought! Not only do they relentlessly devour matter around them, but they may also be able to steadily splutter out deadly energy.

By definition, a black hole is a cosmic object with a gravitational field so powerfully intense that it cuts off a region of space from the rest of the Universe—no matter or radiation (including visible light) that enters that region can ever escape. The object is surrounded by a spherical border, called the event horizon, through which light can enter but it cannot exit, and for that is called black.

Note from the Author

Do you want to know how the story of the Maya princess ends?

There is much more in *Kuxan Suum: Path to the Center of the Universe*. Starting with an overview of the birth of the Universe, an introduction to the concept of time, discussion of the unsolved mysteries of the Universe (dark matter and dark energy), and some views about traveling faster than the speed of light, these are some of the topics highlighted in the book to put in perspective the galactic travel of the princess Da'Lau. The book includes some of the most gorgeous images of space taken from the Hubble Space Telescope to illustrate the story.

I invite you to read *Kuxan Suum* to learn where the Mayan princess ends her voyage among the stars, and to discover how truly magnificent is the cosmos.