# Worlds Beyond Earth

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Final VO

The Moon was the perfect choice for our first voyage to another world, as it's our closest neighbor, and the journey takes just a few days.

The twelve Apollo astronauts who walked across the lunar surface collected rock samples that helped us discover that the Moon formed from Earth itself, during a collision with an object the size of Mars, four-and-a-half billion years ago.

Looking at the Moon on a clear night, you can see darker patches that are ancient lava flows, telling us the Moon was once volcanically active, just like Earth.

But those days are long gone!

The craters littered across the lunar surface are the scars of impacts made by comets and asteroids over billions of years. They show us it's been a long time since the Moon was a dynamic world.

I’m Lupita Nyong’o and today we’re on a mission to explore worlds beyond Earth to find out if Earth is unique in the solar system or if there are other active, thriving…even habitable worlds out there.

While humans haven’t physically travelled farther than the Moon, for decades we’ve been launching spacecraft to investigate the giant disk of objects orbiting the Sun.

These robotic explorers are programmed to gather and send data back to Earth, allowing us to experience the wonder of these distant places from the safety of our home.

The planets closest to the Sun were forged of rock and metal. Mercury, Venus, Earth and Mars.

The asteroid belt contains millions of rocky remnants from the formation of the planets. Despite their number, if you squeezed all the asteroids into one object, it would have a mass less than our Moon. These asteroids mark the boundary between the inner and outer solar system.

Our largest worlds sit on the cold side of the asteroid belt. They have no solid surfaces. Jupiter, Saturn, Uranus and Neptune.

Past the orbits of the planets we enter the Kuiper Belt, home to millions of icy relics from the early solar system. Some will be knocked out of their orbits and become comets as they dive close to the Sun. But the largest among them are frozen worlds, including the dwarf planet Pluto.

The outermost region of the solar system is the mysterious Oort cloud, with trillions of icy objects that are barely held by the gravity of the distant sun.

Gravity, which holds our solar system together, also ignited its birth.

Four and a half billion years ago, gravity caused a giant interstellar cloud of gas, ice and dust to collapse in on itself.  A star – our Sun -- was forged in the center, surrounded by a swirling disk of debris. Within this disk, a diverse set of objects formed – the planets, moons, comets and asteroids that populate our solar system.

This computer simulation shows how young planets form by gathering up material and carving out their orbits...

This theory of how our solar system came to be, is supported by observations of a similar process happening today in the rings that form a disk around Saturn.

Saturn is the second largest planet in our solar system.  It's surrounded by a large family of moons, with even more on the way!

The Cassini spacecraft spent 13 years diving in and out of the Saturn system, capturing close-up images of its dynamic rings.

This computer simulation based on Cassini's data, shows moonlets – baby moons the size of houses – acting just like planets forming around a star. Most of these moons will break apart before maturing, but others could develop into unique worlds for future explorers to discover. Like Titan…

Titan is Saturn's largest moon, bigger than the planet Mercury.

On its grand tour of the outer solar system, the Voyager 1 spacecraft flew by Titan to discover a much thicker atmosphere than expected; a clue to the existence of an active world below.

We were eager to see what lay beneath, so decades later we equipped the Cassini spacecraft with radar vision and the Huygens lander.

Titan's surface was a shocking contrast to our own Moon's cratered terrain! Huygens beamed home images that virtually transported us to an almost Earth-like world, 1.4 billion kilometers away.

Huygens found an active surface carved by wind and rain. But Titan is far too cold for liquid water, so rain here is made of methane; natural gas condensed to liquid, which evaporates from the surface to form clouds – just like water does on Earth.l

We were surprised to discover a moon so unlike our own. But nearly every mission we've launched into space has uncovered something unexpected -- including secrets buried deep inside these alien worlds.

Take Saturn's neighbor, Jupiter: a planet with a mass greater than all the others combined, with its own large family of moons.

Scientists discovered that as these moons orbit Jupiter, they perform a rhythmic gravitational dance, pulling and tugging at one another. The interior of colorful Io is squashed and stretched by these forces, just as the tug of Earth's Moon causes our ocean tides.

The result is explosive! Heat from friction melts rocks inside Io, causing eruptions of lava plumes from the frosty surface. Io is the most volcanically active object in the solar system—an amazing world of fire and ice!

The effects of an active interior can extend well beyond a world's surface. The Galileo spacecraft mapped a giant, invisible magnetic field around Jupiter.

This magnetic field is generated by Jupiter's hot insides, where liquid, metallic hydrogen churns around the planet's core.

Galileo also detected how the moon Europa distorts this magnetic field, revealing another Jupiter-family secret: a salty, liquid ocean beneath Europa's icy crust. This alien sea contains more liquid water than in all the oceans on Earth!

We've found many more Earth-like features out here on the cold side of the asteroid belt than most scientists predicted. Now let's take a look closer to home.

To get there, we'll have to fly to the warm side of the asteroid belt. Just like comets do when they get diverted out of their distant orbits.

The Rosetta spacecraft took 10 years to chase down its target, Comet 67P, a frozen object just a few kilometers in size.

As Rosetta closed in, its instruments went to work analyzing the comet, finding not only frozen water and rock dust, but organic matter, including amino acids – the basic building blocks of life!

Months later, as the comet got closer to the Sun, Rosetta saw how 67P's ice was heated and

transformed into gas that streamed off into space, carrying organic matter and dust grains with it.

We've seen the craters that comets like this one made on the surface of the Moon. Comets have also collided with Earth, and all the other planets, delivering potentially life-giving ingredients to these worlds.

But for these ingredients to nurture life, they need to be held in the right conditions; somewhere not too hot and not too cold, where liquid water is abundant. We find this environment in the Goldilocks Zone, nestled between Mercury, which is too hot, and the asteroid belt, where temperatures drop too low. It includes Venus, Earth and Mars.

Our closest planetary neighbor, Venus, is a similar size to Earth and made of the same materials…we could almost call it Earth's twin. Yet, in many ways, it couldn't be more different.

Venus' slow rotation and the structure of its interior prevents the planet from generating a magnetic field. Without one, Venus is blasted by solar wind, which over billions of years has stripped the planet of its

water, allowing carbon dioxide to build up in its atmosphere.

Equipped with radar vision, the Magellan spacecraft peered through Venus' thick haze. It found a world strewn with volcanoes capable of feeding the atmosphere with water vapor and other gases. But all the carbon dioxide built up in its atmosphere trapped heat from the Sun, turning Venus into a greenhouse world with a surface hot enough to melt lead.

Going to Venus deepened our understanding of global warming. It showed us that pumping carbon dioxide into our own atmosphere leads to rising temperatures and threatens life on Earth.

Unlike Venus, our other close neighbor is freezing cold. We know a lot about Mars because we've sent dozens of orbiters, landers and rovers, to explore its atmosphere and surface.

Mars has the largest volcanoes in the solar system. Long ago, volcanic eruptions generated a thick atmosphere.

Mars also has the deepest and longest canyons. Layers of sediments within them show us a record of dramatic climate change.

Our missions have also shown us that Mars once held underground aquifers of liquid water. Catastrophic flooding occurred when these aquifers collapsed, carving the spectacular landscape we see today.

This computer simulation takes us back in time to show us how the once active planet supported seasonal lakes and was able to weather and erode the impact craters left behind by comets and asteroids bombarding it from space.

Mars' water supply and active volcanoes created the conditions for life, but they didn't last long.

Mars is about half the size of Earth, so its insides cooled faster.  Its volcanoes became inactive and the magnetic field decayed away.  Mars lost most of its atmosphere leaving behind a dry, frozen desert – a failed Earth.

It was around the same time that Mars was giving up, approximately 3.5 billion years ago, that life on Earth was just getting started.

I think it's about time to head home now, to check out our own planet, with our new perspective.

Unlike Venus and Mars, Earth *is* surrounded by a magnetic field. It forms a shield that deflects the solar wind, enabling life to flourish.

It protects our Technosphere, the array of human-made satellites that support our civilization, and continually feed us information about our planet.

Earth's magnetic field is generated by our hot, dynamic insides, where liquid iron churns within our outer core.

Our planet pumps out heat, feeding volcanoes at the surface, helping to sustain an atmosphere containing the perfect blend of molecules for life.

Earth has it all! It is just the right size, located in just the right place, bringing together all the right ingredients – which, over the course of billions of years, led to the evolution of complex life.

Our neighbors have shown us that even if we start out the same, we can grow up to be very different.

Earth truly is “a grand oasis in the vastness of space.”  Now, it’s up to us to sustain it.