NATIONAL GEOGRAPHIC

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SOLAR SYSTEM IN ACTION

In 1543 the astronomer Nicolaus Copernicus theorized that Earth orbited the sun, and scientists have been expanding our knowledge of the solar system ever since. Digital technology has provided a significant boost in recent decades, helping us identify previously unknown, heliocentric, and highly dynamic objects that shed new light on how our solar system evolved—and how it can be orderly and chaotic at the same time.

PLANET SIZE, SPACING, AND ALIGNMENT ARE NOTIONAL.

Sun

Mercury

Venus

Earth
1 AU

One astronomical unit (AU) equals the distance between the Earth and the sun.

Mars

Rocky ring

MAIN ASTEROID BELT

More than a million bits of space rubble—and counting—orbit the sun in the area between Mars and Jupiter known as the main asteroid belt. Reaching up to 584 miles wide, these mostly rocky and metal leftovers hold clues to the formation of the planets some 4.6 billion years ago.

FROST LINE

The frost line marks the approximate distance from the sun beyond which water can condense into ice in space. Objects that formed within it are mostly rocky and metallic.

Minding the gap

Astronomers once thought a planet might be found here. It's home to a ring of minor planets, called asteroids.

Jupiter's gravity creates spaces in the belt known as Kirkwood gaps.

MAIN ASTEROID BELT

HILDA ASTEROIDS

Jupiter
5.2 AU

Saturn
9.5 AU

Uranus
19.8 AU

Neptune
30.1 AU

The biggest of all

Jupiter, a massive ball of hydrogen and helium, exists almost like a mini solar system. It has four inner planet-size moons and swarms of outer moons.

The two great influencers

Jupiter's and Neptune's gravities govern small objects. Many move in synchronicity, or resonance, with their larger planet. Unstable bodies such as icy comets and Centaurs (with traits of both comets and asteroids) cross their orbits.

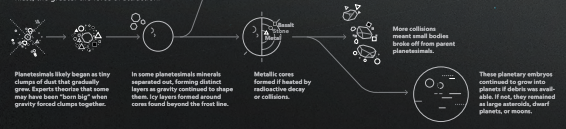
ORBITAL DIRECTION

One revolution is called an orbital period.

CENTAURS

PLANET FORMATION

Swirling material collides, creating the beginnings of planets, called planetesimals. Gravity draws these objects together; the greater the mass, the greater the force of attraction.



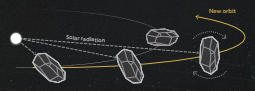
Planetesimals likely began as tiny clumps of dust that gradually grew. Experts theorize that some may have been "born big" when gravity forced clumps together.

In some planetesimals minerals separated out, forming distinct layers as gravity continued to shape them. Icy layers formed around cores found beyond the frost line.

Metallic cores formed if heated by radioactive decay or collisions.

LURKING DANGER

Objects crossing Earth's orbit are potentially hazardous. Experts are studying how to use spacecraft to divert them before they might impact Earth.



LIGHT NUDGE

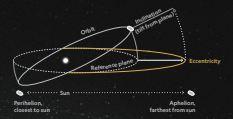
As an asteroid rotates, the side facing the sun is warmed by light particles. When the warmed side rotates away, it can release enough radiation into space to alter its orbit.

BANDING TOGETHER

Clusters of asteroids with similar orbital properties, known as asteroid families, are evidence of ancient collisions. They orbit in bands with others of the same composition.

TUG-OF-WAR

Trojans are asteroids balanced between the gravitational pulls of the sun and a planet. Jupiter's Trojans alone are thought to number in the millions.



ECCENTRIC ORBITS

Objects orbit in an ellipse; the amount of deviation from a circle is called eccentricity. They slow down when far from the sun and speed up as they draw closer.

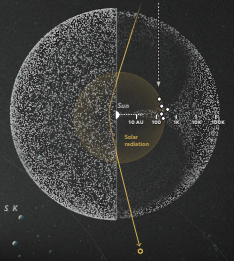
PERIODIC VISIONS

Ice and debris on comets vaporize when near the sun, emitting ion and dust tails. Tail particles burn as meteor showers if Earth passes through them.

EDGE OF INFLUENCE

The Oort cloud is a sphere of ancient, icy bodies that exist so far from the sun's gravitational hold that they can be shifted by passing stars. They can have highly eccentric orbits thousands of years long.

Five uncrewed spacecraft have traveled through the Kuiper belt.



Neptune can force objects in the scattered disk (part of the Kuiper belt) into highly inclined and elliptical orbits or even out of the belt altogether.

SCATTERED DISK

OTHERWORLDLY VISITORS

Scientists detected interstellar objects traversing the solar system in 2017 and 2019. Future telescopes are expected to find many more.

Icy, slow orbiters

KUIPER BELT

Beyond Neptune's orbit lies an even larger set of debris from our planets' early years. Here, bodies such as the dwarf planet Pluto, its moon Charon, and countless hunks of frozen water, methane, and ammonia make their way around the sun. Scientists estimate hundreds of thousands of these remnants could be over 60 miles wide each.

Objects in the classical Kuiper belt likely formed closer to our planets' orbital plane and have stable, nearly circular orbits around the sun.

CLASSICAL BELT

Stunted growth

Dwarf planets have enough gravity to become round and often have their own atmospheres and moons. But they haven't gained enough mass to clear the debris around their orbits as the eight planets have.

Pluto

Charon

Haumea

Makemake

Arrokoth

PLUTINOS

40 AU

KUIPER BELT

50 AU

PRIMORDIAL BUILDING BLOCKS

A contact binary such as Arrokoth is created when two building blocks slowly merge. In addition, the Kuiper belt also has many binary pairs that orbit around a shared point in a gravitational lock with one another.

The hinterland

Out here, 50 to 5,000 astronomical units (AU) away, is an area so distant and with so little gravity the outer giants hold no power over it. Some scientists wonder if something else is influencing objects here—is there another planet yet to be discovered?

COLLISION AND CREATION

Our star, the sun, was formed by the collapse of an interstellar cloud. In the wake of its creation, a volatile and rotating disk of dust and gas was left behind—the beginnings of our solar system.

FORMATION: 4.6 BILLION YEARS AGO

Rocky material

Possible fifth gas giant

Neptune may have formed closer to the sun than Uranus.

Neptune

Uranus

Icy material

Once the planets took shape, the chaos was not over. Interactions with shifting planetesimals pushed Jupiter and Saturn around. A possible fifth gas giant may have been ejected.

MIGRATION: 4.1 TO 3.7 BILLION YEARS AGO

Scatter

Planet migration

Ejected

Gravitational interaction with planetesimals

Uranus

Neptune

Scatter

Icy comets and rocky asteroids crashed like billiard balls as the giants migrated outward. Scientists are still investigating the dynamics of planetary migration.

PRESENT: 3.7 BILLION YEARS AGO TO TODAY

SUN

M V E R M

1 AU

Asteroid belt

5 AU

15 AU

20 AU

25 AU

30 AU

Trans-Neptunian objects (TNOs) are celestial bodies found beyond Neptune.

This dramatic shuffling redistributed the bodies in our solar system, eventually settling them into their present orbits and trapping these ancient relics in place.

TERRESTRIAL PLANETS

Craters, canyons, and volcanoes mark these rocky, windswept planets. Earth's water may have come from asteroid collisions.

JUPITER

Twice as massive as all the other planets combined, it has dark rings that come from meteoroids striking its moons.

SATURN

Its magnetic field is 1,000 times stronger than Earth's. Its gravity prevents debris in its rings from forming moons.

URANUS

Tipped on its side from a suspected collision, Uranus rotates from east to west (as does Venus).

NEPTUNE

Like Jupiter, it has massive storms with 700-mile-an-hour winds. Its moon Triton has geysers that spew nitrogen.

INNER PLANETS
ROCKY CRUSTS, SOLID CORES, NO RINGS

OUTER PLANETS
ICE AND GAS WITH SOLID CORES, MANY MOONS AND RINGS

KUIPER BELT AND BEYOND
ICY BODIES PAST NEPTUNE'S ORBIT

DIAGRAMS ARE TO SCALE.

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