DISCOVERING NEW WORLDS

How We Find Exoplanets and Notable Discoveries

INTRODUCTION

For thousands of years, humanity wondered if other solar systems existed among the stars. Do planets orbit other suns? Could these distant worlds harbor life? Until recently, these questions remained firmly in the realm of speculation and science fiction. Astronomers had every reason to believe other planets existed beyond our solar system, but no way to detect them.

That all changed in the 1990s. The first confirmed exoplanet orbiting a Sun-like star was discovered in 1995, and since then, our understanding of planetary systems has undergone a revolution. Today, we've confirmed over 5,500 exoplanets and identified thousands more candidates awaiting verification. These discoveries reveal that planets are commonplace in our galaxy, with most stars hosting at least one planetary companion.

Even more exciting are the incredible varieties of worlds we've found—from scorching "hot Jupiters" orbiting close to their stars, to rocky "super-Earths," to planets orbiting in the habitable zones where liquid water might exist on their surfaces. The diversity of these exoplanets far exceeds what we see in our own solar system, challenging and expanding our understanding of how planetary systems form and evolve.

In this guide, we'll explore the ingenious methods astronomers use to detect these distant worlds, examine some of the most remarkable exoplanets discovered so far, and look at what these discoveries tell us about our place in the cosmos.

THE CHALLENGE OF FINDING EXOPLANETS

Why Exoplanets Are Hard to See

Finding planets around other stars presents enormous challenges:

- **Extreme Distance**: The nearest stars are trillions of kilometers away
- **Extreme Brightness Contrast**: Stars outshine their planets by factors of millions to billions
- **Tiny Angular Separation**: Even large planets appear extremely close to their stars from our perspective

To understand the difficulty, imagine trying to spot a firefly hovering next to a searchlight from hundreds of miles away. This is why direct imaging of exoplanets is so challenging, and why astronomers have developed indirect detection methods.

The First Discoveries

The path to finding exoplanets was long and filled with false starts:

- **1992**: First confirmed exoplanets discovered orbiting a pulsar (not a main-sequence star)
- **1995**: 51 Pegasi b—first confirmed exoplanet orbiting a Sun-like star
- **1999-2000**: First transiting exoplanet detected (HD 209458 b)

Historical Note: The 2019 Nobel Prize in Physics was awarded partly to Michel Mayor and Didier Queloz for their 1995 discovery of 51 Pegasi b, recognizing the significance of this breakthrough in astronomy.

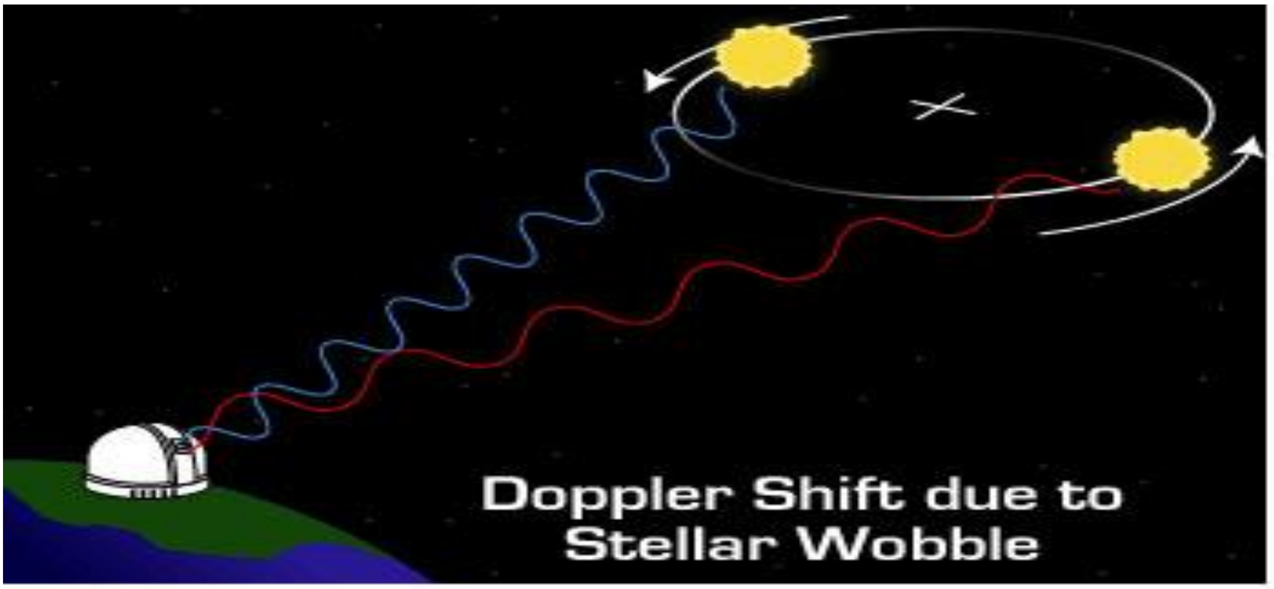
DETECTION METHODS: HOW WE FIND EXOPLANETS

Radial Velocity (Doppler Spectroscopy)

The first successful method for finding exoplanets around Sun-like stars:

How It Works:

1. A planet and its star orbit their common center of mass
2. As the star moves slightly toward and away from Earth, its light waves are compressed or stretched
3. This creates a measurable "wobble" in the star's spectral lines
4. The pattern of this wobble reveals the planet's mass (minimum) and orbital period



![Diagram showing how a star "wobbles" due to a planet's gravitational pull, changing the wavelength of light we observe]

Strengths:

- Can detect planets that don't transit their star
- Provides information about planetary mass
- Works well for large planets in close orbits

Limitations:

- Favors massive planets close to their stars
- Only gives minimum mass (unless inclination is known)

- Requires long observation periods for planets with long orbital periods
- Star's own activity can mask or mimic planetary signals

Notable Discoveries:

- 51 Pegasi b: First exoplanet around a Sun-like star
- HD 189733 b: Well-studied hot Jupiter with detailed atmospheric characterization
- Proxima Centauri b: Closest known exoplanet to Earth (4.2 light-years)

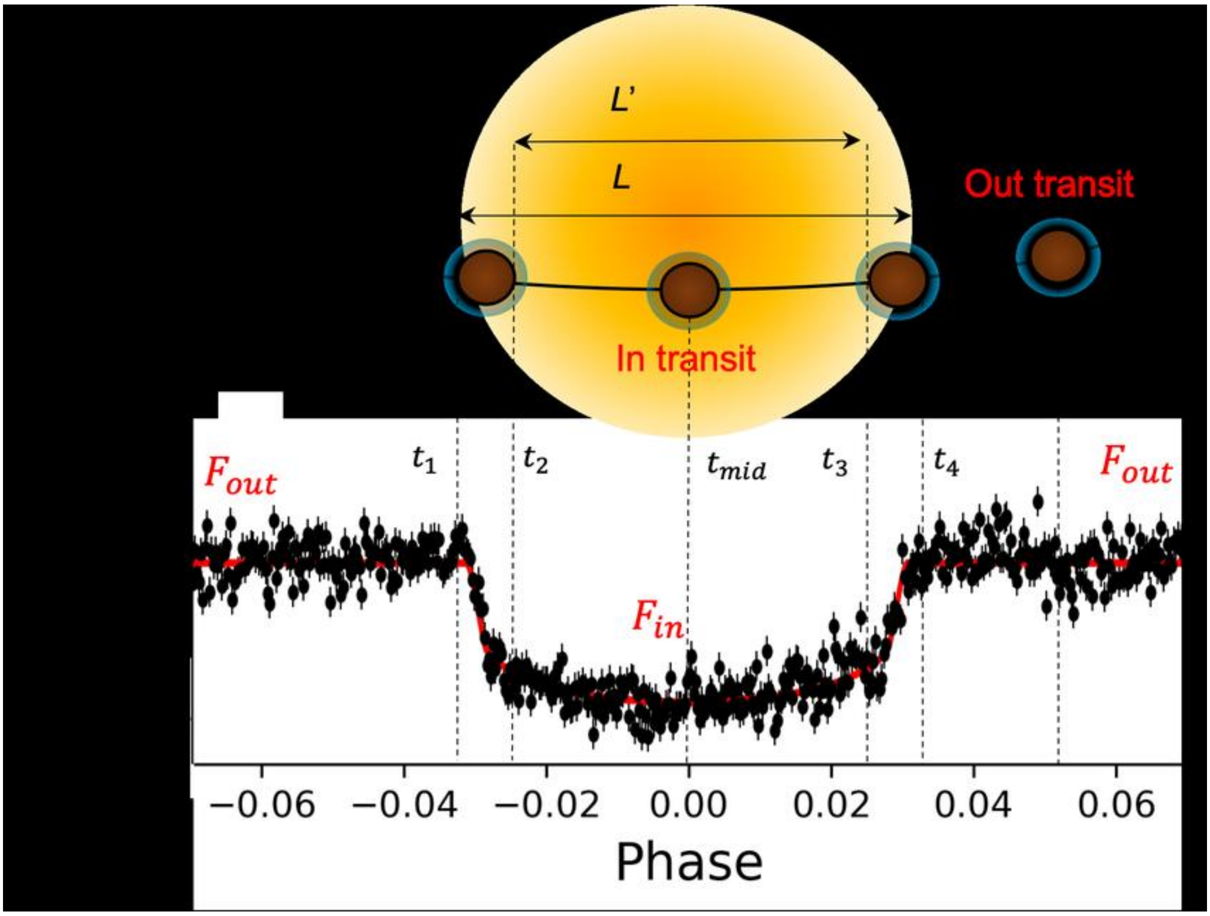
Did You Know? The "wobble" caused by Jupiter on our Sun is about 12 meters per second (about 27 mph). Earth causes a wobble of just 9 centimeters per second (0.2 mph). Modern instruments can detect wobbles as small as 10 centimeters per second!

Transit Method

The most productive technique for discovering exoplanets:

How It Works:

1. We observe a star's brightness over time
2. When a planet passes between the star and Earth, it blocks a tiny fraction of starlight
3. This creates a characteristic dip in the star's brightness
4. The depth, duration, and frequency of these dips reveal the planet's size, orbit, and other properties



![Diagram of a transiting exoplanet causing a measurable dip in a star's brightness over time]

Strengths:

- Can survey many stars simultaneously
- Provides planet radius information
- Enables atmospheric studies via transmission spectroscopy
- Can detect multiple planets in a system

Limitations:

- Requires precise alignment (planet's orbit must be edge-on from our perspective)
- Only about 1-10% of planets transit their stars from our viewpoint
- Requires multiple observed transits for confirmation
- Can be mimicked by star spots or binary stars

Notable Missions and Discoveries:

- **Kepler/K2 Mission**: Discovered over 2,600 confirmed exoplanets
- **TESS (Transiting Exoplanet Survey Satellite)**: Finding planets around the brightest nearby stars

- **TRAPPIST-1 System**: Seven Earth-sized planets orbiting a red dwarf star, several in the habitable zone

Amazing Fact: During a transit, a Jupiter-sized planet blocks only about 1% of a Sun-like star's light, while an Earth-sized planet blocks a mere 0.01%. Detecting such small changes requires extremely precise measurements!

Direct Imaging

The most intuitive but technically challenging method:

How It Works:

1. Use advanced techniques to block the star's light
2. Employ adaptive optics to overcome atmospheric distortion
3. Use infrared observations where young planets are relatively bright
4. Process images to reveal the faint light of planets near the star

Strengths:

- Provides actual images of exoplanets
- Can detect planets in wide orbits that other methods miss
- Allows direct study of planetary atmospheres
- Best for young, massive planets far from their stars

Limitations:

- Extremely difficult due to contrast and proximity issues
- Works best for young, hot planets (which glow in infrared) in wide orbits
- Not effective for detecting Earth-like planets yet
- Requires advanced technology and special observing conditions

Notable Discoveries:

- **HR 8799 system**: Four giant planets directly imaged
- **Beta Pictoris b and c**: Planets in a young, nearby system
- **PDS 70 system**: Planets observed during formation, still accreting material

![Direct image of a multi-planet system showing planets as bright spots around a masked central star]

Technical Marvel: To directly image exoplanets, astronomers use coronagraphs (instruments that block starlight) and advanced data processing techniques like Angular Differential Imaging. The upcoming James Webb Space Telescope and future extremely large ground-based telescopes will dramatically improve our direct imaging capabilities.

Gravitational Microlensing

A technique that uses gravity's effect on light:

How It Works:

1. When a star passes in front of a more distant star, its gravity bends and magnifies the background star's light
2. If the foreground star has a planet, the planet adds a brief, additional magnification
3. The resulting light curve reveals the planet's presence and approximate mass

Strengths:

- Can detect low-mass planets at large orbital distances
- Works for planets around distant stars
- Can find planets not detectable by other methods
- Not limited by the planet's luminosity or orbit orientation

Limitations:

- Events are random and non-repeatable
- Limited follow-up possibilities
- Provides less detailed information about the planets
- Requires constant monitoring of dense star fields

Notable Discoveries:

- **OGLE-2005-BLG-390Lb**: One of the first low-mass exoplanets discovered
- Evidence for free-floating planets not orbiting any star
- Planets around stars in the galactic bulge

Did You Know? Microlensing surveys suggest that "rogue planets" not orbiting any star may outnumber stars in our galaxy! These wandering worlds were likely ejected from their original solar systems through gravitational interactions.

Astrometry

Measuring the precise positions of stars:

How It Works:

1. A planet causes its star to wobble around their common center of mass
2. This wobble creates tiny changes in the star's position in the sky
3. By tracking these positional changes over time, we can infer the presence of planets

Strengths:

- Can detect planets in any orbital orientation
- Provides true mass measurements (not just minimum mass)

- Works well for planets with long orbital periods

Limitations:

- Requires extremely precise measurements
- Most sensitive to massive planets around nearby stars
- Needs observations over long time periods
- Has confirmed relatively few planets so far

Notable Missions:

- **Gaia spacecraft**: European mission precisely measuring the positions and motions of billions of stars
- Future mission concepts focus on microarcsecond astrometric precision for exoplanet detection

Precision Required: To detect an Earth-mass planet around a Sun-like star at 10 parsecs distance requires measuring stellar positions with precision better than 0.3 microarcseconds—equivalent to measuring the width of a human hair from 1,000 kilometers away!

Timing Variations

Looking for irregularities in regular astronomical events:

Transit Timing Variations (TTVs)

- Planets in the same system gravitationally influence each other
- This causes slight variations in the timing of transits
- These variations can reveal non-transiting planets

Pulsar Timing

- Pulsars emit radio signals with clock-like precision
- Planets orbiting a pulsar cause tiny variations in pulse arrival times
- This method discovered the first confirmed exoplanets in 1992

Did You Know? The first confirmed exoplanets were discovered around pulsar PSR B1257+12. This stunned astronomers, as pulsars are remnants of violent supernovae and were thought unlikely to host planets. Yet this system contains at least three planets, showing that planet formation is more robust than expected!

CHARACTERIZING EXOPLANETS: BEYOND DETECTION

Determining Planetary Properties

Once we've found an exoplanet, the next challenge is learning about its nature:

Physical Properties

- **Mass**: Primarily from radial velocity measurements
- **Radius**: From transit depth measurements
- **Density**: Combining mass and radius to infer composition (rocky, gaseous, etc.)
- **Temperature**: Estimated from distance to star and stellar properties

Orbital Characteristics

- **Orbital period**: Time between transits or radial velocity cycles
- **Semi-major axis**: Average distance from the star
- **Eccentricity**: How elongated or circular the orbit is
- **Inclination**: Angle of the orbital plane relative to our line of sight

Studying Exoplanet Atmospheres

The frontier of exoplanet characterization:

Transmission Spectroscopy

1. During transit, starlight passes through the planet's atmosphere
2. Atmospheric gases absorb specific wavelengths of light
3. By analyzing which wavelengths are absorbed, we can identify atmospheric components

Emission Spectroscopy

1. Measure the star+planet system before and during secondary eclipse (when planet passes behind star)
2. The difference reveals the planet's thermal emission spectrum
3. This provides information about temperature and composition

Phase Curves

1. Monitor system brightness through a planet's entire orbit
2. Reveals day/night temperature differences and weather patterns
3. Can indicate presence of clouds and atmospheric circulation

Current Capabilities:

- Detected water vapor, sodium, potassium, and carbon-bearing molecules in hot Jupiter atmospheres
- Identified clouds and hazes on several exoplanets
- Measured temperature maps of several close-in gas giants

Technical Challenge: Atmospheric characterization currently works best for large planets close to their stars. Studying Earth-like exoplanet atmospheres will require next-generation telescopes like the James Webb Space Telescope and future extremely large ground-based observatories.

REMARKABLE DISCOVERIES AND PLANETARY SYSTEMS

Diverse Planetary Types

Exoplanet discoveries have revealed planet categories not found in our solar system:

Hot Jupiters

- **Characteristics**: Gas giants orbiting extremely close to their stars
- **Examples**: 51 Pegasi b, HD 189733 b, WASP-121 b
- **Significance**: Challenge to planetary formation theories, as giant planets are expected to form far from their stars
- **Physical conditions**: Dayside temperatures of 1,000-3,000°C, possible atmospheric escape, extreme winds

Super-Earths and Mini-Neptunes

- **Characteristics**: Planets with masses between Earth and Neptune (2-10 Earth masses)
- **Examples**: GJ 1214 b, K2-18 b, 55 Cancri e
- **Significance**: Most common type of known exoplanet, yet absent from our solar system
- **Possible compositions**: Range from scaled-up rocky worlds to water worlds to small gas planets

Ultra-Short Period Planets

- **Characteristics**: Rocky planets orbiting their stars in less than 1 day
- **Examples**: Kepler-78 b, WASP-47 e, K2-141 b
- **Significance**: Extreme environments with surface temperatures hot enough to melt rock
- **Formation mystery**: How they survive so close to their stars remains puzzling

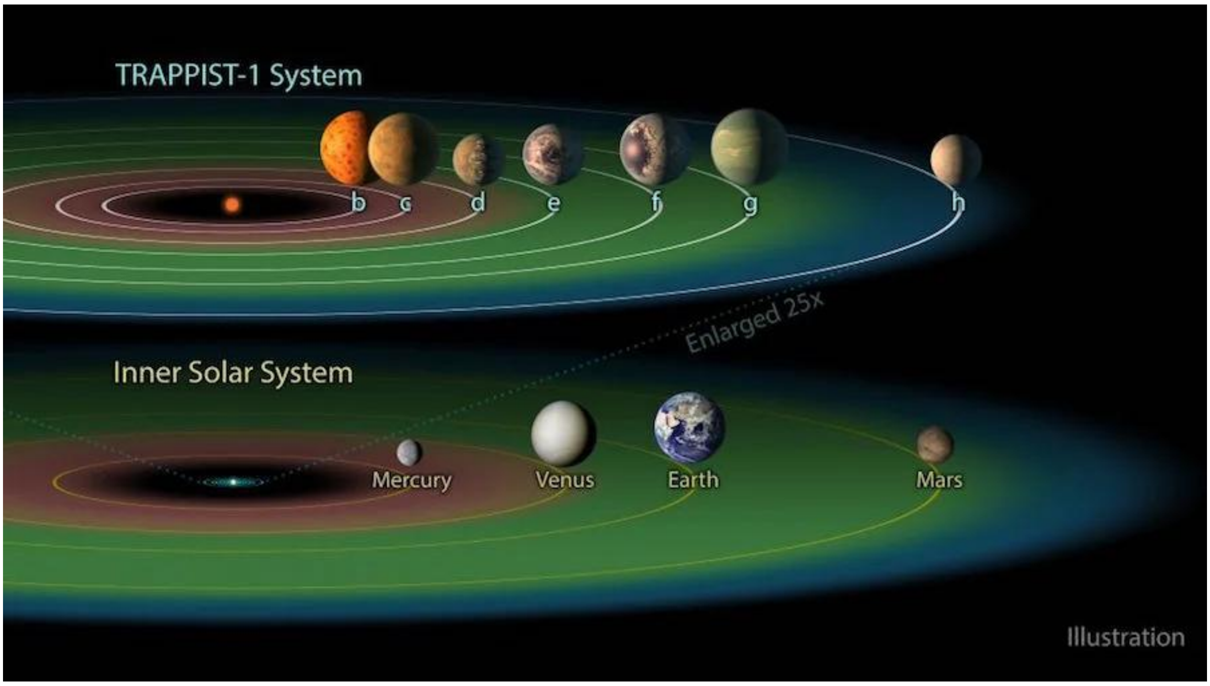
Amazing Fact: The hottest known exoplanet, KELT-9b, has a dayside temperature of over 4,300°C (7,800°F)—hotter than many stars! It's so hot that molecules break apart into their constituent atoms in its atmosphere.

Multi-Planet Systems

Some of the most fascinating exoplanetary architectures:

TRAPPIST-1 System

- **Configuration**: Seven Earth-sized planets orbiting a cool red dwarf star
- **Remarkable feature**: All seven planets transit their star from our perspective
- **Significance**: Three planets orbit in the habitable zone
- **Resonance**: The planets orbit in a resonant chain, with orbital periods forming near-integer ratios



![Diagram of the TRAPPIST-1 system showing the seven Earth-sized planets compared to the inner Solar System]

Kepler-90 System

- **Configuration**: Eight detected planets (tie with our solar system for most known planets)
- **Architecture**: Resembles a miniature version of our solar system with small planets close in and larger ones farther out
- **Discovery note**: The eighth planet was found using machine learning algorithms

HR 8799 System

- **Configuration**: Four directly imaged giant planets
- **Significance**: One of the first multi-planet systems to be directly imaged
- **Architecture**: Planets in wide orbits (14-68 AU) around a young star

Did You Know? Many exoplanetary systems are much more compact than our solar system. The seven TRAPPIST-1 planets all orbit closer to their star than Mercury orbits our Sun, yet the system is stable due to orbital resonances, where the planets' orbital periods form neat mathematical ratios.

Potentially Habitable Worlds

Exoplanets that capture our imagination for their life-hosting potential:

Proxima Centauri b

- **Distinction**: Closest exoplanet to Earth (4.2 light-years)
- **Properties**: At least 1.3 Earth masses, orbiting in habitable zone of the nearest star
- **Challenge**: Orbits a red dwarf star prone to powerful flares that may impact habitability

TOI-700 d and TESS Habitable Zone Planets

- **Significance**: Among the first Earth-sized habitable zone planets found by TESS mission
- **Properties**: Similar in size to Earth, receives comparable sunlight to Earth

Kepler-442 b

- **Characteristics**: One of the most "Earth-like" planets based on size and stellar radiation
- **Properties**: About 33% more massive than Earth, receives about 70% of the sunlight Earth receives

Habitable Zone Definition: The region around a star where temperatures might allow liquid water on a rocky planet's surface. The boundaries depend on the star's brightness, the planet's atmospheric composition, and other factors.

Important Note: "Potentially habitable" means only that a planet has the right distance from its star for liquid water. Many other factors affect true habitability, including atmospheric composition, magnetic field strength, geological activity, and the star's radiation environment.

Planets in Extreme Environments

Some exoplanets exist in conditions that stretch our understanding of planetary physics:

Circumbinary Planets

- **Configuration**: Planets orbiting binary star systems
- **Examples**: Kepler-16b (the first confirmed "Tatooine" planet), Kepler-47 system
- **Challenge**: Forming and maintaining stable orbits in the gravitational field of two stars

Exoplanets Around Dead Stars

- **White Dwarf Planets**: Debris and planetary material found around white dwarf stars
- **Pulsar Planets**: The first exoplanets discovered were around a pulsar
- **Significance**: Shows planets can survive (or reform after) the death of their host star

Rogue Planets

- **Characteristics**: Planetary-mass objects not orbiting any star
- **Detection**: Found primarily through gravitational microlensing
- **Origin theories**: Ejected from their birth systems through gravitational interactions
- **Population estimate**: May outnumber stars in the Milky Way

Amazing Fact: The rogue planet CFBDSIR 2149-0403 wanders through space alone, without a host star. With a temperature of about 400°C, it must have internal heat sources or formed very recently to still be so warm without stellar heating.

STATISTICAL INSIGHTS: WHAT THE EXOPLANET POPULATION TELLS US

How Common Are Planets?

The big-picture lessons from exoplanet surveys:

- **Occurrence Rates**:
  - About 20-50% of Sun-like stars have at least one planet
  - Red dwarf stars host an average of 2-3 planets per star
  - Nearly every star in our galaxy likely hosts at least one planet
- **Size Distribution**:
  - Most common sizes are super-Earths and mini-Neptunes (2-4 Earth radii)
  - A "radius gap" exists around 1.8 Earth radii, separating rocky planets from those with substantial atmospheres
  - Earth-sized and smaller planets are abundant but harder to detect
- **System Architecture**:
  - Compact multi-planet systems are common
  - Many systems have different architecture than our solar system
  - Planetary migration (changes in orbital distance over time) appears common

Statistical Revelation: Based on exoplanet statistics, astronomers estimate there are at least 100 billion planets in our galaxy alone, with at least 25 billion potentially habitable Earth-sized worlds orbiting in the habitable zones of their stars.

The Galactic Habitable Zone

Not all regions of the galaxy are equally conducive to life:

- **Concept**: Just as stars have habitable zones, galaxies may have regions more suitable for life
- **Factors**:
  - Star density (too high means frequent disruptive stellar encounters)
  - Supernova frequency (too high means frequent sterilizing radiation events)
  - Metallicity (availability of elements heavier than helium needed for rocky planets)
  - Age of stars (enough time for complex life to evolve)
- **Current Thinking**:
  - Our Sun's location in the galactic suburbs may be particularly favorable
  - The sweet spot balances having enough heavy elements for rocky planets while avoiding too many cosmic hazards

Did You Know? The concept of a Galactic Habitable Zone is still debated among astrobiologists. Some argue that life could adapt to conditions throughout much of the galaxy, while others suggest that truly life-friendly environments might be more limited.

EXOPLANET DETECTION MISSIONS AND INSTRUMENTS

Ground-Based Programs

Telescopes and instruments on Earth making major exoplanet discoveries:

Radial Velocity Surveys

- **HARPS** (High Accuracy Radial velocity Planet Searcher): European instrument that has discovered numerous exoplanets
- **ESPRESSO** (Echelle SPectrograph for Rocky Exoplanet and Stable Spectroscopic Observations): Next-generation spectrograph with precision of 10 cm/s
- **Keck/HIRES**: Prolific planet-hunting instrument at Keck Observatory

Transit Surveys

- **SuperWASP** (Wide Angle Search for Planets): Network of robotic telescopes that has found numerous hot Jupiters
- **MEarth**: Searching for planets around the smallest stars and brown dwarfs
- **SPECULOOS** (Search for Planets EClipsing ULtra-cOOl Stars): Discovered the TRAPPIST-1 system

Direct Imaging

- **VLT/SPHERE** (Spectro-Polarimetric High-contrast Exoplanet REsearch): Advanced imaging instrument at the Very Large Telescope
- **Gemini/GPI** (Gemini Planet Imager): Dedicated exoplanet imaging instrument
- **Subaru/SCExAO** (Subaru Coronagraphic Extreme Adaptive Optics): Cutting-edge imaging system

Space-Based Missions

Telescopes above Earth's atmosphere with exoplanet-finding capabilities:

Past Missions

- **Kepler/K2** (2009-2018): Revolutionary mission that discovered thousands of exoplanets using the transit method
- **CoRoT** (2006-2013): European mission that pioneered space-based transit detection
- **Spitzer Space Telescope** (2003-2020): Infrared observatory that characterized many exoplanet atmospheres

Current Missions

- **TESS** (Transiting Exoplanet Survey Satellite, launched 2018): Scanning the entire sky for transiting planets around the brightest stars
- **CHEOPS** (CHaracterising ExOPlanet Satellite, launched 2019): European mission focusing on detailed study of known exoplanets

- **Gaia** (launched 2013): Astrometry mission that will detect thousands of planets through stellar wobbles

Future Missions

- **James Webb Space Telescope** (launched 2021): Revolutionary infrared observatory that will characterize exoplanet atmospheres in unprecedented detail
- **Roman Space Telescope** (planned launch ~2027): Will use both transit and microlensing techniques to find thousands of exoplanets
- **PLATO** (PLAnetary Transits and Oscillations of stars, planned launch ~2026): European mission to find and characterize Earth-like planets

Mission Success Story: The Kepler Space Telescope was designed to determine how common Earth-like planets are in our galaxy. Despite technical failures cutting its primary mission short, Kepler's extended K2 mission continued making discoveries. Overall, Kepler revealed that planets are remarkably common, with most stars hosting at least one planetary companion.

FUTURE DIRECTIONS IN EXOPLANET SCIENCE

The Search for Biosignatures

The next frontier: looking for signs of life on exoplanets:

- **Atmospheric Biosignatures**:
  - Oxygen/ozone in combination with methane
  - Seasonal variations in atmospheric composition
  - Chemical disequilibrium that could indicate biological activity
- **Surface Biosignatures**:
  - Vegetation red edge (chlorophyll's reflectance signature)
  - Surface color variations due to biological pigments
  - Seasonal changes in surface features
- **Key Observational Needs**:
  - High-resolution spectroscopy of atmospheres
  - Direct imaging with sufficient contrast
  - Long-term monitoring of potentially habitable planets

Technical Challenge: Detecting biosignatures on Earth-like exoplanets requires technologies still in development, including space-based coronagraphs, starshades, and extremely large ground-based telescopes.

Theoretical Frontiers

Areas where exoplanet science is advancing theory:

- **Planet Formation Models**:
    - Explaining the diversity of observed systems
    - Understanding planetary migration during system formation
    - Accounting for observed correlations between stellar properties and planet types
- **Exoplanet Climates**:
    - Modeling atmospheric circulation on tidally locked planets
    - Understanding habitability around different stellar types
    - Predicting observable features of different climate states
- **Exotic Compositions**:
    - Investigating carbon planets, water worlds, and other compositions not seen in our solar system
    - Understanding interior structures of super-Earths and mini-Neptunes
    - Modeling exotic atmospheric chemistries

Theoretical Impact: Exoplanet discoveries have forced significant revisions to theories of planet formation and evolution that were based solely on our solar system.

Next-Generation Detection Technologies

Technologies being developed to advance exoplanet science:

- **Extremely Large Telescopes**:
    - Giant ground-based telescopes with primary mirrors 25-40 meters in diameter
    - Will provide unprecedented angular resolution and light-gathering power
    - Examples: European Extremely Large Telescope, Giant Magellan Telescope, Thirty Meter Telescope
- **Space-Based Starshades**:
    - Flower-shaped occulters flying thousands of kilometers from space telescopes
    - Block starlight before it enters telescope, enabling direct imaging of Earth-like planets
    - Prototypes in development for future missions
- **Laser-Based Calibration**:
    - Laser frequency combs providing ultra-precise wavelength references
    - Enable radial velocity measurements with 1 cm/s precision
    - Could detect Earth-mass planets in habitable zones of Sun-like stars

Future Vision: The combination of these technologies could eventually allow us to create crude maps of the surfaces of nearby rocky exoplanets, potentially revealing continents, oceans, and even large-scale vegetation patterns.

CONCLUSION: FROM SCIENCE FICTION TO SCIENCE

In just a few decades, we've journeyed from wondering if planets existed beyond our solar system to cataloging thousands and beginning to study their atmospheres. This rapid progress represents one of the most significant advances in astronomy's long history.

The discovery of exoplanets has profound implications for our understanding of our place in the universe. We now know that planetary systems are the rule, not the exception, with planets of all sizes orbiting stars of virtually every type. The incredible diversity of these systems—from hot Jupiters to compact systems of super-Earths to potentially habitable worlds—reveals that our own solar system is just one arrangement among countless possibilities.

Perhaps most significantly, we've learned that potentially habitable planets are abundant. Statistically, there are likely billions of Earth-sized worlds in the habitable zones of their stars in our galaxy alone. While we don't yet know if any harbor life, the sheer numbers suggest that if life can arise on suitable planets, the universe may be teeming with biology.

The field of exoplanet science continues to advance at a breathtaking pace. With upcoming telescopes and technologies, we stand at the threshold of being able to characterize the atmospheres of rocky planets, search for biosignatures, and perhaps obtain the first evidence that life exists beyond Earth.

What began as a speculative question—"Are there planets around other stars?"—has evolved into one of the most exciting frontiers in modern science. Each new discovery brings us closer to answering humanity's ancient questions about our cosmic context: How common are worlds like Earth? Are we alone in the universe? The answers await as we continue to explore these new worlds.

GLOSSARY OF EXOPLANET TERMS

Biosignature: A feature that indicates the presence of life, such as certain atmospheric gas combinations

Habitable Zone: Region around a star where temperatures might allow liquid water on a rocky planet's surface

Hot Jupiter: A gas giant planet orbiting very close to its star

Microlensing: Detection method using gravity's bending of light to discover planets

Radial Velocity: Planet detection method measuring a star's "wobble" due to a planet's gravity

Secondary Eclipse: When a planet passes behind its star from our perspective

Super-Earth: A planet with mass greater than Earth's but less than Neptune's (roughly 2-10 Earth masses)

Transit: When a planet passes in front of its star from our perspective

Transit Timing Variation (TTV): Changes in transit timing caused by gravitational interactions between planets

Transmission Spectroscopy: Technique to study a planet's atmosphere by analyzing starlight that passes through it

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This resource was created for Galactic University's "Cosmic Explorations" course. All information is current as of 2025.