SAMPLE

Worlds Beyond Earth: Super-Earths

Between Earth and Neptune

Aira Astralis

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Conclusion

This free sample contains the Introduction and Chapter 1. The complete book contains the full contents above.

Introduction

A super-Earth is a type of exoplanet with a mass higher than Earth's, but substantially below those of the Solar System's ice giants, Uranus and Neptune, which are 14.5 and 17.1 times Earth's mass respectively. The term "super-Earth" refers only to the mass of the planet, and so does not imply anything about the surface conditions or habitability.

The alternative term "gas dwarfs" may be more accurate for those at the higher end of the mass scale, although "mini-Neptunes" is a more common term.

In general, super-Earths are defined by their masses. The term does not imply temperatures, compositions, orbital properties, habitability, or environments. While sources generally agree on an upper bound of 10 Earth masses (~69% of the mass of Uranus, which is the Solar System's giant planet with the least mass), the lower bound varies from 1 or 1.9 to 5, with various other definitions appearing in the popular media.

The term "super-Earth" is also used by astronomers to refer to planets bigger than Earth-like planets (from 0.8 to 1.2 Earth-radius), but smaller than mini-Neptunes (from 2 to 4 Earth-radii). This definition was made by the Kepler space telescope personnel.

Some authors further suggest that the term super-Earth might be limited to rocky planets without a significant atmosphere, or planets that have not just atmospheres but also solid surfaces or oceans with a sharp boundary between liquid and atmosphere, which the four giant planets in the Solar System do not have. Planets above 10 Earth masses are termed massive solid planets, mega-Earths, or gas giant planets, depending on whether they are mostly made of rock and ice or mostly gas.

Whether any of them hosts life is the question that keeps the category interesting, and the chapters that follow trace that hunt from first discovery to current frontier.

Chapter 01: The Discovery of Super-Earths

The category earned its first famous resident in June 2005, when radial-velocity monitoring of the nearby red dwarf Gliese 876 turned up a third planet, Gliese 876 d. The newcomer carried roughly 7.5 Earth masses and whirled around the star once every two days, so close that its dayside was pegged at 430 to 650 kelvin, far past the boiling point of water.

In April 2007, a team headed by Stephane Udry based in Switzerland announced the discovery of two new super-Earths within the Gliese 581 planetary system, both on the edge of the habitable zone around the star where liquid water may be possible on the surface.

With Gliese 581c having a mass of at least 5 Earth masses and a distance from Gliese 581 of 0.073 astronomical units (6.8 million mi, 11 million km), it is on the "warm" edge of the habitable zone around Gliese 581 with an estimated mean temperature (without considering effects from an atmosphere) of -3 degrees Celsius with an albedo comparable to Venus and 40 degrees Celsius with an albedo comparable to Earth.

Subsequent research suggested Gliese 581c had likely suffered a runaway greenhouse effect like Venus. Two further possible super-Earths were discovered in 2006: OGLE-2005-BLG-390Lb with a mass of 5.5 Earth masses, which was found by gravitational microlensing, and HD 69830 b with a mass of 10 Earth masses. The smallest super-Earth found as of 2008 was MOA-2007-BLG-192Lb. The planet was announced by astrophysicist David P. Bennett for the international MOA collaboration on June 2, 2008.

This planet has approximately 3.3 Earth masses and orbits a brown dwarf. It was detected by gravitational microlensing. In June 2008, European researchers announced the discovery of three super-Earths around the star HD 40307, a star that is only slightly less massive than the Sun. Planets have at least the following minimum masses: 4.2, 6.7, and 9.4 times Earth's. The planets were detected by the radial velocity method by the HARPS (High Accuracy Radial Velocity Planet Searcher) in Chile.

In addition, the same European research team announced a planet 7.5 times the mass of Earth orbiting the star HD 181433. This star also has a Jupiter-like planet that orbits it every three years. Planet COROT-7b, with a mass estimated at 4.8 Earth masses and an orbital period of only 0.853 days, was announced on 3 February 2009.

The density estimate obtained for COROT-7b points to a composition including rocky silicate minerals similar to that of the Solar System's four inner planets,

a new and significant discovery. COROT-7b, discovered right after

HD 7924 b, is the first super-Earth discovered that orbits a main sequence star that is G class or larger. The discovery of Gliese 581e with a minimum mass of 1.9 Earth masses was announced on 21 April 2009.

It was at the time the smallest extrasolar planet discovered around a normal star and the closest in mass to Earth. Being at an orbital distance of just 0.03 AU and orbiting its star in just 3.15 days, it is not in the habitable zone, and may have 100 times more tidal heating than Jupiter's volcanic satellite Io.

A planet found in December 2009, GJ 1214 b, is 2.7 times as large as Earth and orbits a star much smaller and less luminous than the Sun. However, interior models of this planet suggest that under most conditions it does not have liquid water.

By November 2009, a total of 30 super-Earths had been discovered, 24 of which were first observed by HARPS. Discovered on 5 January 2010, a planet HD 156668 b with a minimum mass of 4.15 Earth masses, is the least massive planet detected by the radial velocity method. The only confirmed radial velocity planet smaller than this planet is Gliese 581e at 1.9 Earth masses (see above).

On 24 August, astronomers using ESO's HARPS instrument announced the discovery of a planetary system with up to seven planets orbiting a Sun-like star, HD 10180, one of which, although not yet confirmed, has an estimated minimum mass of 1.35 +/- 0.23 times that of Earth, which would be the lowest mass of any exoplanet found to date orbiting a main-sequence star. Although unconfirmed, there is a 98.6% probability that this planet does exist.

The National Science Foundation announced on 29 September the discovery of a fourth super-Earth (Gliese 581g) orbiting within the Gliese 581 planetary system. The planet has a minimum mass 3.1 times that of Earth and a nearly circular orbit at 0.146 AU with a period of 36.6 days, placing it in the middle of the habitable zone where liquid water could exist and midway between the planets c and d.

Two definitions anchor the chapters ahead. A sub-Neptune, also called a mini-Neptune, is a planet smaller in radius than Neptune but larger than the small-planet radius gap; and the habitable zone, familiar as the Goldilocks band, is the range of orbits around a star within which a planetary surface could potentially support liquid water.

End of free sample. The full book is available at putrabooks.github.io

ABOUT THE AUTHOR

Aira Astralis is a science writer specializing in astronomy and space exploration. Her work spans the full breadth of humanity's relationship with the cosmos -- from the earliest naked-eye observations to the engineering marvels of modern space missions.

Her books are built on a foundation of primary sources: peer-reviewed research, mission archives, and direct engagement with the scientific community. She writes for readers who want to understand not just what we know about the universe, but how we came to know it.

She believes that the most important frontier is not out there but in the gap between what scientists discover and what the public understands. Her books exist to close that gap.