

= Gliese 876 =

Gliese 876 is a red dwarf approximately 15 light @-@ years away from Earth in the constellation of Aquarius .

It is the second closest known star to the Sun confirmed to possess a planetary system ( after Gliese 674 ) and the closest such system known to consist of multiple planets . As of 2011 , four extrasolar planets have been found to orbit the star .

The planetary system is also notable for the orbital properties of its planets . It is the only known system of orbital companions to exhibit a triple conjunction in the rare phenomenon of Laplace resonance ( a type of resonance first noted in Jupiter 's inner three Galilean moons ) . It is also the first extrasolar system around a normal star with measured coplanarity .

Two of the middle planets are located in the system 's habitable zone , however they are giant planets believed to be analogous to Jupiter .

= Distance and visibility =

Gliese 876 is located fairly close to the Solar System . According to astrometric measurements made by the Hipparcos satellite , the star shows a parallax of 213 @. 28 milliarcseconds , which corresponds to a distance of 4 @. 69 parsecs ( 15 @. 3 ly ) , currently making it the third closest known star with orbiting planets , after Epsilon Eridani and Gliese 674 . Despite being located so close to Earth , the star is so faint that it is invisible to the naked eye and can only be seen using a telescope .

= Stellar characteristics =

As a red dwarf , Gliese 876 is much less massive than the Sun : estimates suggest it has only 32 % of the mass of the Sun . The surface temperature of Gliese 876 is cooler than the Sun and the star has a smaller radius . These factors combine to make the star only 1 @. 24 % as luminous as the Sun , and most of this is at infrared wavelengths .

Estimating the age and metallicity of cool stars is difficult due to the formation of diatomic molecules in their atmospheres , which makes the spectrum extremely complex . By fitting the observed spectrum to model spectra , it is estimated that Gliese 876 has a slightly lower abundance of heavy elements compared to the Sun ( around 75 % the solar abundance of iron ) . Based on chromospheric activity the star is likely to be around 6 @. 5 to 9 @. 9 billion years old , depending on the theoretical model used . However , the low rotational period of the star as well as its membership among the young disk population suggest that the star is between 0 @. 1 ? 5 billion years old .

Like many low @-@ mass stars , Gliese 876 is a variable star . Its variable star designation is IL Aquarii and it is classified as a BY Draconis variable . Its brightness fluctuates by around 0 @. 04 magnitudes . This type of variability is thought to be caused by large starspots moving in and out of view as the star rotates . Gliese 876 emits X @-@ rays .

= Planetary system =

= Observation history =

On June 23 , 1998 , an extrasolar planet was announced in orbit around Gliese 876 by two independent teams led by Geoffrey Marcy and Xavier Delfosse . The planet was designated Gliese 876 b and was detected by Doppler spectroscopy .

Based on luminosity measurement , the circumstellar habitable zone ( CHZ ) is believed to be located between 0 @. 116 and 0 @. 227 AU .

On April 4 , 2001 , a second planet designated Gliese 876 c was detected , inside the orbit of the

previously discovered planet . The relationship between the orbital periods initially disguised the planet 's radial velocity signature as an increased orbital eccentricity of the outer planet . Eugenio Rivera and J. Lissauer found that the two planets undergo strong gravitational interactions as they orbit the star , causing the orbital elements to change rapidly .

On June 13 , 2005 , further observations by a team led by Rivera revealed a third planet , designated Gliese 876 d inside the orbits of the two Jupiter size planets .

In January 2009 , the mutual inclination between planets b and c was determined using a combination of radial velocity and astrometric measurements . The planets were found to be almost coplanar , with an angle of only  $5.0 \pm 3.9^\circ$

$2.3^\circ$  between their orbital planes .

On June 23 , 2010 , astronomers announced a fourth planet , designated Gliese 876 e . This discovery better constrained the mass and orbital properties of the other three planets , including the high eccentricity of the innermost planet . This also filled out the system inside e 's orbit ; additional planets there would be unstable at this system 's age .

In 2014 , evidence of the presence of newly Gliese 876 f and Gliese 876 g was discovered . These planets have been having almost the same mass as Gliese 876d .

If this system has a comet disc , it is undetectable " brighter than the fractional dust luminosity  $10^{-5}$  " of a recent Herschel study .

None of these planets transit the star from the perspective of Earth , making it difficult to study their properties .

== Orbital arrangement ==

Gliese 876 has a notable orbital arrangement . It is the first planetary system around a normal star to have mutual inclination between planets measured without transits ( previously the mutual inclination of the planets orbiting the pulsar PSR B1257 + 12 had been determined by measuring their gravitational interactions ) . Later measurements reduced the value of the mutual inclination , and in the latest four planet models the incorporation mutual inclinations does not result in significant improvements relative to coplanar solutions .

The system has the second known example of a Laplace resonance with a 1 : 2 : 4 resonance of its planets . The first known example was Jupiter 's closest Galilean moons - Ganymede , Europa and Io . Numerical integration indicates that the coplanar , four planet system is stable for at least another billion years . This planetary system comes close to a triple conjunction between the three outer planets once per orbit of the outermost planet .

== Planets ==

The outermost three of the known planets likely formed further away from the star , and migrated inward .

Gliese 876 d

Gliese 876d , discovered in 2005 , is the innermost known planet . With an estimated minimum mass only  $5.88$  times that of the Earth , it is possible that it is a dense terrestrial planet .

Gliese 876 c

Gliese 876 c , discovered in 2001 , is a giant planet at  $0.62$  Jupiter mass planet . It is in a 1 : 2 orbital resonance with the outermost known planet , taking  $30.340$  days to orbit the star . The planet orbits within the habitable zone . Its mass makes it more likely to be a Class II planet in the Sudarsky extrasolar planet classification . The presence of surface liquid water is possible on sufficiently massive satellites should they exist .

Gliese 876 b

Gliese 876 b , discovered in 1998 is around twice the mass of Jupiter and revolves around its star in an orbit taking approximately 61 days to complete , at a distance of only  $0.208$  AU , less than the distance from the Sun to Mercury . Its mass makes it more likely to be a Class II or Class III planet in the Sudarsky model . The presence of surface liquid water is possible on sufficiently

massive satellites should they exist .

Gliese 876 e

Gliese 876 e , discovered in 2010 , has a mass similar to that of the planet Uranus and its orbit takes 124 days to complete .