= Gliese 581 g =

Gliese 581 g / ??li?z? / , (also known as Gl 581 g or GJ 581 g) , unofficially known as Zarmina , is an unconfirmed (and disputed) exoplanet claimed to orbit the red dwarf Gliese 581 , about 20 light @-@ years from Earth in the constellation of Libra . It is the sixth planet purportedly discovered orbiting the star . The discovery was announced by the Lick @-@ Carnegie Exoplanet Survey in late September 2010 , after a decade of observation . However , the ESO / HARPS survey team was not able to confirm that the planet exists .

Gliese 581 g has attracted attention because it would be near the middle of the habitable zone of its parent star . That means it could sustain liquid water on its surface and could potentially host life similar to that on Earth (the planet is predicted to have temperatures around ? 37 to ? 11 ° C) . If it is a rocky planet , favorable atmospheric conditions could permit the presence of liquid water , a necessity for all known life , on its surface . With an estimated mass of 2 @.@ 2 times Earth 's , Gliese 581 g would be considered a Super @-@ Earth and would be the planet closest in mass to Earth known in a habitable zone . This would make it one of the most Earth @-@ like Goldilocks planets found outside the Solar System and one of the exoplanets with the greatest recognized potential for harboring life .

The supposed detection of Gliese 581 g after such a short period of searching and at such close proximity has led some astronomers to hypothesize that the proportion of stars with habitable planets may be greater than ten percent .

= = History = =

= = = Discovery = = =

The planet was claimed to be detected by astronomers in the Lick @-@ Carnegie Exoplanet Survey , led by principal investigator Steven S. Vogt , professor of astronomy and astrophysics at the University of California , Santa Cruz and co @-@ investigator R. Paul Butler of the Carnegie Institution of Washington . The discovery was made using radial velocity measurements , combining 122 observations obtained over 11 years from the High Resolution Echelle Spectrometer (HIRES) instrument of the Keck 1 telescope with 119 measurements obtained over 4 @.@ 3 years from the High Accuracy Radial Velocity Planet Searcher (HARPS) instrument of the European Southern Observatory 's 3 @.@ 6 m telescope at La Silla Observatory .

After subtracting the signals of the previously known Gliese 581 planets , b , c , d and e , the signals of two additional planets were apparent : a 445 @-@ day signal from a newly recognized outermost planet designated f , and the 37 @-@ day signal from Gliese 581 g . The probability that the detection of the latter was spurious was estimated at only 2 @.@ 7 in a million . The authors stated that while the 37 @-@ day signal is " clearly visible in the HIRES data set alone " , " the HARPS data set alone is not able to reliably sense this planet " and concluded , " It is really necessary to combine both data sets to sense all these planets reliably . " The Lick ? Carnegie team explained the results of their research in a paper published in the Astrophysical Journal . Although not sanctioned by the IAU 's naming conventions , Vogt 's team informally refers to the planet as " Zarmina 's World " after his wife , and some cases simply as Zarmina .

= = = Nondetection in new HARPS data analysis = = =

Two weeks after the announcement of the discovery of Gliese 581 g , astronomer Francesco Pepe of the Geneva Observatory reported that in a new analysis of 179 measurements taken by the HARPS spectrograph over 6 @.@ 5 years , neither planet g nor planet f was detectable . Vogt responded to the latest concerns by saying , " I am not overly surprised by this as these are very weak signals , and adding 60 points onto 119 does not necessarily translate to big gains in sensitivity . " More recently , Vogt added , " I feel confident that we have accurately and honestly

reported our uncertainties and done a thorough and responsible job extracting what information this data set has to offer . I feel confident that anyone independently analyzing this data set will come to the same conclusions . "

Differences in the two groups ' results may involve the planetary orbital characteristics assumed in calculations . According to MIT astronomer Sara Seager , Vogt postulated the planets around Gliese 581 had perfectly circular orbits whereas the Swiss group thought the orbits were more eccentric . This difference in approach may be the reason for the disagreement , according to Alan Boss . Butler remarked that with additional observations , " I would expect that on the time scale of a year or two this should be settled . " Other astronomers also supported a deliberate evaluation : Seager stated , " We will have consensus at some point ; I don 't think we need to vote right now . " and Ray Jayawardhana noted , " Given the extremely interesting implications of such a discovery , it 's important to have independent confirmation . " Gliese 581 g is listed as " unconfirmed " in the Extrasolar Planets Encyclopaedia .

In December 2010 , a claimed methodological error was reported in the data analysis that led to the discovery of Gliese 581 f and g . The team around Steven Vogt inferred the number of exoplanets by using a reduced chi @-@ square , although the orbital models are nonlinear in the model parameters . Therefore , reduced chi @-@ square is not a trustworthy diagnostic . In fact , an investigation of the fit residuals showed that the data used by Vogt 's team actually prefers a model with four planets , not six , in agreement with the results of Francesco Pepe 's team .

= = = Further analyses of HIRES / HARPS data = = =

Another re ? analysis found no clear evidence for a fifth planetary signal in the combined HIRES / HARPS data set . The claim was made that the HARPS data provided only some evidence for 5 planet signals , while incorporation of both data sets actually degraded the evidence for more than four planets (i.e. , none for 581 f or 581 g) . Mikko Tuomi of the University of Hertfordshire performed a Bayesian re @-@ analysis of the HARPS and HIRES data with the result that they " do not imply the conclusion that there are two additional companions orbiting GJ 581 " .

" I have studied [the paper] in detail and do not agree with his conclusions , " Steven Vogt said in reply , concerned that Gregory has considered the HIRES data as more uncertain . " The question of Gliese 581g 's existence won 't be settled definitively until researchers gather more high @-@ precision radial velocity data " , Vogt said . However Vogt expects further analysis to strengthen the case for the planet .

By performing a number of statistical tests , Guillen Anglada @-@ Escude of the Carnegie Institute of Washington concluded that the existence of Gl 581 g was well supported by the available data , despite the presence of a statistical degeneracy that derives from an alias of the first eccentric harmonic of another planet in the system . In a forthcoming paper , Anglada @-@ Escude and Rebekah Dawson claim " With the data we have , the most likely explanation is that this planet is still there . "

= = = 2012 Reanalysis of HARPS Data = = =

In July 2012 , Steven S. Vogt Reanalyzed the 2011 data proposed by Forveille et al. noting that there were 5 objects (GJ 581 b , e , c , g , d with no evidence for f) . Planet g was orbiting around 0 @.@ 13 AU with an orbital period of 32 days placing it inside the habitable zone . Vogt concluded that the object had a minimum mass of 2 @.@ 2 M and has a false positive probability of less than 4 % .

= = = Further studies = = =

A study in 2014 by Paul Robertson , Suvrath Mahadevan , Michael End , and Arpita Roy concluded that Gliese 581 d is " an artifact of stellar activity which , when incompletely corrected , causes the false detection of planet g . " An additional study concluded that Gliese 581 g 's existence depends

on Gliese 581 d 's eccentricity .
In 2015 , a team of researchers reanalysed the data and suggested planet Gliese 581 d really could exist , despite stellar variability , and that last year 's claim of the existence of Gliese 581 d and g was triggered by poor and inadequate analysis of the data . Now that Gliese 581 d is widely accepted it is likely that Gliese 581 g 's existence is dependent on the eccentricity of the further out exoplanet Gliese 581 d as suggested by Paul Robertson .

= = Tidal locking and habitability = =

Because of Gliese 581 g 's proximity to its parent star , it is predicted to be tidally locked to Gliese 581 . Just as Earth 's Moon always presents the same face to the Earth , the length of Gliese 581 g 's sidereal day would then precisely match the length of its year , meaning it would be permanently light on one half and permanently dark on the other half of its surface . Tidal locking also means the planet would have no axial tilt and therefore no seasonality in a conventional sense .
With one side of the planet always facing the star , temperatures could range from blazing hot in the bright side to freezing cold in the dark side if atmospheric heat transport is limited . The atmosphere 's inventory of volatile compounds such as water and carbon dioxide could then permanently freeze on the dark side . However , an atmosphere of the expected density would be likely to moderate these extremes .

= = = Atmospheric effects = = =

An atmosphere that is dense will circulate heat , potentially allowing a wide area on the surface to be habitable . For example , Venus has a solar rotation rate approximately 117 times slower than Earth 's , producing prolonged days and nights . Despite the uneven distribution of sunlight over time intervals shorter than several months , unilluminated areas of Venus are kept almost as hot as the day side by globally circulating winds . Simulations have shown that an atmosphere containing appropriate levels of CO2 and H2O need only be a tenth the pressure of Earth 's atmosphere (100 mbar) to effectively distribute heat to the night side . Current technology cannot determine the atmospheric or surface composition of the planet due to the overpowering light of its parent star .
Whether or not a tide @-@ locked planet with the orbital characteristics of Gliese 581g is actually habitable depends on the composition of the atmosphere and the nature of the planetary surface . A comprehensive modeling study including atmospheric dynamics , realistic radiative transfer and the physics of formation of sea ice (if the planet has an ocean) indicates that the planet can become as hot as Venus if it is dry and allows carbon dioxide to accumulate in its atmosphere . The same study identified two habitable states for a water @-@ rich planet . If the planet has a very thin atmosphere , a thick ice crust forms over most of the surface , but the substellar point remains hot enough to yield a region of thin ice or even episodically open water . If the planet has an atmosphere with Earthlike pressures , containing approximately 20 % (molar) carbon dioxide , then the greenhouse effect is sufficiently strong to maintain a pool of open water under the substellar point with temperatures comparable to the Earth 's tropics . This state has been dubbed " Eyeball Earth " by the author .
Modeling of the effect of tidal locking on Gliese 581 g 's possible atmosphere , using a general circulation model employing an atmosphere with Earthlike surface pressure but a highly idealized representation of radiative processes , indicates that for a solid @-@ surface planet the locations of maximum warmth would be distributed in a sideways chevron @-@ shaped pattern centered near the substellar point .

= = = Temperatures = = =

It is estimated that the average global equilibrium temperature (the temperature in the absence of atmospheric effects) of Gliese 581 g would range from 209 to 228 K (? 64 to ? 45 ° C , or ? 84 to ? 49 ° F) for Bond albedos (reflectivities) from 0 @.@ 5 to 0 @.@ 3 (with the latter being more

characteristic of the inner Solar System) . Adding an Earth @-@ like greenhouse effect would yield an average surface temperature in the range of 236 to 261 K (? 37 to ? 12 ° C , or ? 35 to 10 ° F) . Gliese 581g would be in an orbit where a silicate weathering thermostat could operate , and this could lead to accumulation of sufficient carbon dioxide in the atmosphere to permit liquid water to exist at the surface , provided the planet 's composition and tectonic behavior could support sustained outgassing .

By comparison , Earth 's present global equilibrium temperature is 255 K (? 18 ° C) , which is raised to 288 K (15 ° C) by greenhouse effects . However , when life evolved early in Earth 's history , the Sun 's energy output is thought to have been only about 75 % of its current value , which would have correspondingly lowered Earth 's equilibrium temperature under the same albedo conditions . Yet Earth maintained equable temperatures in that era , perhaps with a more intense greenhouse effect , or a lower albedo , than at present .

Current Martian surface temperatures vary from lows of about ? 87 ° C (? 125 ° F) during polar winter to highs of up to ? 5 ° C (23 ° F) in summer . The wide range is due to the rarefied atmosphere , which cannot store much solar heat , and the low thermal inertia of the soil . Early in its history , a denser atmosphere may have permitted the formation of an ocean on Mars .

Two previously discovered planets in the same system , Gliese 581 c and d (inward and outward from planet g , respectively) , were also regarded as potentially habitable following their discovery . Both were later evaluated as being outside the conservatively defined habitable zone , leading Vogt et al. to remark that " The GJ 581 system has a somewhat checkered history of habitable planet claims " . However , a subsequent downward revision of the period of planet d from 83 to 67 days has bolstered its habitability prospects , although a large greenhouse effect would be needed .

= = = Potential for life = = =

In an interview with Lisa @-@ Joy Zgorski of the National Science Foundation , Steven Vogt was asked what he thought about the chances of life existing on Gliese 581 g . Vogt was optimistic : " I 'm not a biologist , nor do I want to play one on TV . Personally , given the ubiquity and propensity of life to flourish wherever it can , I would say that ... the chances of life on this planet are 100 % . I have almost no doubt about it . " In the same article Dr. Seager is quoted as saying " Everyone is so primed to say here 's the next place we 're going to find life , but this isn 't a good planet for follow @-@ up . " According to Vogt , the long lifetime of red dwarfs improves the chances of life being present . " It 's pretty hard to stop life once you give it the right conditions " , he said . " Life on other planets doesn 't mean E.T. Even a simple single @-@ cell bacteria or the equivalent of shower mold would shake perceptions about the uniqueness of life on Earth . "

= = Implications = =

Scientists have monitored only a relatively small number of stars in the search for exoplanets . The discovery of a potentially habitable planet like Gliese 581 g so early in the search might mean that habitable planets are more widely distributed than had been previously believed . According to Vogt , the discovery " implies an interesting lower limit on the fraction of stars that have at least one potentially habitable planet as there are only ~ 116 known solar @-@ type or later stars out to the 6 @.@ 3 parsec distance of Gliese 581 " . This finding foreshadows what Vogt calls a new , second Age of Discovery in exoplanetology :

Confirmation by other teams through additional high @-@ precision RVs would be most welcome . But if GJ 581g is confirmed by further RV scrutiny , the mere fact that a habitable planet has been detected this soon , around such a nearby star , suggests that ? ? could well be on the order of a few tens of percent , and thus that either we have just been incredibly lucky in this early detection , or we are truly on the threshold of a second Age of Discovery .

If the fraction of stars with potentially habitable planets (? ? , " eta @-@ Earth ") is on the order of a few tens of percent as Vogt proposes , and the Sun 's stellar neighborhood is a typical sample of the galaxy , then the discovery of Gliese 581 g in the habitable zone of its star points to the potential

of billions of Earth @-@ like planets in our Milky Way galaxy alone .