= Tau Ceti =

Tau Ceti ( ? Cet , ? Ceti ) is a star in the constellation Cetus that is spectrally similar to the Sun , although it has only about 78 % of the Sun 's mass . At a distance of just under 12 light @-@ years from the Solar System , it is a relatively nearby star , and is the closest solitary G @-@ class star . The star appears stable , with little stellar variation , and is metal @-@ deficient .

Observations have detected more than ten times as much dust surrounding Tau Ceti as is present in the Solar System . Since December 2012 , there has been evidence of possibly five planets orbiting Tau Ceti , with two of these being potentially in the habitable zone . Because of its debris disk , any planet orbiting Tau Ceti would face far more impact events than Earth . Despite this hurdle to habitability , its solar analog ( Sun @-@ like ) characteristics have led to widespread interest in the star . Given its stability , similarity and relative proximity to the Sun , Tau Ceti is consistently listed as a target for the Search for Extra @-@ Terrestrial Intelligence ( SETI ) , and it appears in some science fiction literature .

It can be seen with the unaided eye as a third @-@ magnitude star . As seen from Tau Ceti , the Sun would be a third @-@ magnitude star in the northern hemisphere constellation Boötes .

= = Name = =

Tau Ceti does not have a widely @-@ recognized traditional name , and is usually simply referred to as Tau Ceti .

The name " Tau Ceti " is the Bayer designation for this star , established in 1603 as part of German celestial cartographer Johann Bayer 's Uranometria star catalogue : it is " number T " in Bayer 's sequence of constellation Cetus . It has the proper name Durre Menthor . In the catalogue of stars in the Calendarium of Al Achsasi al Mouakket , written at Cairo about 1650 , this star was designated Th?lith al Na??m?t ( ???? ??????? - taalit al na??m?t ) , which was translated into Latin as Tertia Struthionum , meaning the third of the ostriches . This star , along with ? Cet ( Deneb Algenubi ) , ? Cet ( Thanih Al Naamat ) , ? Cet ( Baten Kaitos ) , and ? Cet , were Al Na??m?t ( ??????? ) , the Hen Ostriches .

In Chinese , the " Square Celestial Granary " ( Chinese : ?? ; pinyin : Ti?n C?ng ) refers to an asterism consisting of ? Ceti , ? Ceti , ? Ceti , ? Ceti , ? Ceti and 57 Ceti . Consequently , ? Ceti itself is known as the " Fifth Star of Square Celestial Granary " ( Chinese : ??? ; pinyin : Ti?n C?ng w? ) .

= = Motion = =

The proper motion of a star is its amount of movement across the celestial sphere , determined by comparing its position relative to more distant background objects . Tau Ceti is considered to be a high @-@ proper @-@ motion star , although it only has an annual traverse of just under two arc seconds . It will require about two thousand years before the location of this star shifts by more than a degree . A high proper motion is an indicator of closeness to the Sun . Nearby stars can traverse an angle of arc across the sky more rapidly than the distant background stars and are good candidates for parallax studies . In the case of Tau Ceti , the parallax measurements indicate a distance of 11 @.@ 9 ly . This makes it one of the closest star systems to the Sun , and the next @-@ closest spectral class @-@ G star after Alpha Centauri A.

The radial velocity of a star is its motion toward or away from the Sun . Unlike proper motion , a star 's radial velocity cannot be directly observed , but must be determined through measurement of the spectrum . Due to the Doppler shift , the absorption lines in the spectrum of a star will be shifted slightly toward the red ( or longer wavelengths ) if the star is moving away from the observer , or toward blue ( or shorter wavelengths ) when it moves toward the observer . In the case of Tau Ceti , the radial velocity is about ? 17 km / s , with the negative value indicating that it is moving toward the Sun .

The distance to Tau Ceti , along with its proper motion and radial velocity , allow the motion of the star through space to be calculated . The space velocity relative to the Sun is about 37 km / s . This

result can then be used to compute an orbital path of Tau Ceti through the Milky Way . It has a mean galacto @-@ centric distance of 9 @.@ 7 kiloparsec ( 32000 ly ) and an orbital eccentricity of 0 @.@ 22 .

= = Physical properties = =

The Tau Ceti system is believed to have only one stellar component . A dim optical companion has also been observed with magnitude 13 @.@ 1 . As of 2000 , it was 137 arcseconds distant from the primary . It may be gravitationally bound , but it is considered more likely to be a line @-@ of @-@ sight coincidence .

Most of what is known about the physical properties of Tau Ceti and its system has been determined through spectroscopic measurements . By comparing the spectrum to computed models of stellar evolution , the age , mass , radius and luminosity of Tau Ceti can be estimated . However , using an astronomical interferometer , measurements of the radius of the star can be made directly to an accuracy of 0 @.@ 5 % . Through such means , the radius of Tau Ceti has been measured to be 79 @.@ 3 ± 0 @.@ 4 % of the solar radius . This is about the size that is expected for a star with somewhat lower mass than the Sun .

= = = Rotation = = =

The rotation period for Tau Ceti was measured by periodic variations in the classic H and K absorption lines of singly ionized calcium , or Ca II . These lines are closely associated with surface magnetic activity , so the period of variation measures the time required for the activity sites to complete a full rotation about the star . By this means the rotation period for Tau Ceti is estimated to be 34 d . Due to the Doppler effect , the rotation rate of a star affects the width of the absorption lines in the spectrum . ( Light from the side of the star moving away from the observer will be shifted to a longer wavelength ; light from the side moving towards the observer will be shifted toward a shorter wavelength . ) By analyzing the width of these lines , the rotational velocity of a star can be estimated . The projected rotation velocity for Tau Ceti is :

veq · sin i ? 1 km / s

where veq is the velocity at the equator and i is the inclination angle of the rotation axis to the line of sight . For a typical G8 star , the rotation velocity is about 2 @.@ 5 km / s . The relatively low rotational velocity measurements may indicate that Tau Ceti is being viewed from nearly the direction of its pole .

= = = Metallicity = = =

The chemical composition of a star provides important clues to its evolutionary history , including the age at which it formed . The interstellar medium of dust and gas from which stars form is primarily composed of hydrogen and helium with trace amounts of heavier elements . As nearby stars continually evolve and die , they seed the interstellar medium with an increasing portion of heavier elements . Thus younger stars will tend to have a higher portion of heavy elements in their atmospheres than do the older stars . These heavy elements are termed metals by astronomers and the portion of heavy elements is the metallicity . The amount of metallicity in a star is given in terms of the ratio of iron ( Fe ) , an easily observed heavy element , to hydrogen . A logarithm of the relative iron abundance is compared to the Sun . In the case of Tau Ceti , the atmospheric metallicity is roughly :

equivalent to about a third the solar abundance . Past measurements have varied from ? 0 @.@ 13 to ? 0 @.@ 60 .

This lower abundance of iron indicates that Tau Ceti is almost certainly older than the Sun . Its age had previously been estimated to be about 10 Ga but is now thought to be around half that at 5 @.@ 8 Ga . This compares with 4 @.@ 57 Ga for the Sun . However , computed age estimates for Tau Ceti can range from 4 @.@ 4 ? 12 Ga , depending on the model adopted .

Besides rotation , another factor that can widen the absorption features in the spectrum of a star is pressure broadening . The presence of nearby particles will affect the radiation emitted by an individual particle . So the line width is dependent on the surface pressure of the star , which in turn is determined by the temperature and surface gravity . This technique was used to determine the surface gravity of Tau Ceti . The log g , or logarithm of the star 's surface gravity , is about 4 @.@ 4 ? very close to the log g = 4 @.@ 44 for the Sun .

= = = Luminosity and variability = = =

The luminosity of Tau Ceti is equal to only 55 % of the Sun 's luminosity . A terrestrial planet would need to orbit this star at a distance of about 0 @.@ 7 AU in order to match the solar @-@ insolation level of Earth . This is approximately the same as the average distance between Venus and the Sun .

The chromosphere of Tau Ceti ? the portion of a star 's atmosphere just above the light @-@ emitting photosphere ? currently displays little or no magnetic activity , indicating a stable star . One nine @-@ year study of temperature , granulation , and the chromosphere showed no systematic variations ; Ca II emissions around the H and K infrared bands show a possible 11 @-@ year cycle , but this is weak relative to the Sun . Alternatively it has been suggested that the star could be in a low @-@ activity state analogous to a Maunder minimum ? a historical period , associated with the Little Ice Age in Europe , when sunspots became exceedingly rare on the Sun 's surface . Spectral line profiles of Tau Ceti are extremely narrow , indicating low turbulence and observed rotation . The amplitude of the star 's oscillations are about half those of the Sun , and have a lower mode lifetime .

= = Life and planet searches = =

Principal factors driving research interest in Tau Ceti are its proximity , Sun @-@ like characteristics and their implications for possible planets and life . For categorization purposes , Hall and Lockwood report that " the terms ' solarlike star ' , ' solar analog ' , and ' solar twin ' [ are ] progressively restrictive descriptions " . Tau Ceti fits the second category , given its similar mass and low variability , but relative lack of metals . The similarities have inspired popular culture references for decades , as well as scientific examination .

Tau Ceti has been a target of a radial velocity planetary searches . As of 1988 , observations ruled out any periodical variations attributable to massive planets around Tau Ceti inside of Jupiter @-@ like distances . Ever @-@ more precise measurements continue to rule out such planets , at least until December 2012 . The velocity precision reached is about 11 m / s measured over a five @-@ year time span . This result excludes the presence of hot Jupiters , and probably excludes any planets with minimum mass greater than or equal to Jupiter 's mass and with orbital periods less than 15 years . In addition , a survey of nearby stars by the Hubble Space Telescope 's Wide Field and Planetary Camera was completed in 1999 , including a search for faint companions to Tau Ceti ; none were discovered to limits of the telescope 's resolving power .

These searches only excluded larger brown dwarf bodies and giant planets , so smaller , Earth @-@ like planets in orbit around the star were not precluded . If " hot Jupiters " did exist in close orbit they would likely disrupt the star 's habitable zone ; their exclusion was thus considered positive for the possibility of Earth @-@ like planets . General research has shown a positive correlation between the presence of planets and a relatively high @-@ metallicity parent star , suggesting that stars with lower metallicity such as Tau Ceti have a lower chance of having planets . Primitive life on Tau Ceti 's planets might reveal itself through an atmospheric composition unlikely to be abiotic , just as oxygen on Earth is indicative of life .

= = = SETI and HabCat = = =

The most optimistic search project to date was Project Ozma , which was intended to " search for

extraterrestrial intelligence " ( SETI ) by examining selected stars for indications of artificial radio signals . It was run by the astronomer Frank Drake , who selected Tau Ceti and Epsilon Eridani as the initial targets . Both are located near the Solar System and are physically similar to the Sun . No artificial signals were found despite 200 hours of observations . Subsequent radio searches of this star system have also turned up negative .

This lack of results has not dampened interest in observing the Tau Ceti system for biosignatures . In 2002 , astronomers Margaret Turnbull and Jill Tarter developed the Catalog of Nearby Habitable Systems ( HabCat ) under the auspices of Project Phoenix , another SETI endeavour . The list contained more than 17 @,@ 000 theoretically habitable systems , approximately 10 % of the original sample . The next year , Turnbull would further refine the list to the 30 most promising systems out of 5000 within one hundred light @-@ years of the Sun , including Tau Ceti ; this will form part of the basis of radio searches with the Allen Telescope Array . She also chose Tau Ceti for a final shortlist of just five stars suitable for searches by the ( indefinitely postponed ) Terrestrial Planet Finder telescope system , commenting that " these are places I 'd want to live if God were to put our planet around another star " .

= = Planetary system = =

On December 19 , 2012 , evidence was presented that suggest a system of five planets orbiting Tau Ceti . The planets ' estimated minimum masses are between two and six times the mass of Earth and their orbital periods range from 14 to 640 days . One of them , tentatively named Tau Ceti e , appears to orbit about half as far from Tau Ceti as Earth does from the Sun . With Tau Ceti 's luminosity of 52 % that of the Sun and a distance from the star of 0 @.@ 552 AU , the planet would receive 1 @.@ 71 times as much stellar radiation as Earth does , slightly less than Venus with 1 @.@ 91 times Earth 's . Nevertheless , some research places it within the star 's habitable zone . The Planetary Habitability Laboratory has estimated that Tau Ceti f , which would receive 28 @.@ 5 % as much starlight as Earth , would be narrowly within the habitable zone of the star as well .

The habitable zone for this star , defined as the locations where liquid water could be present on an Earth @-@ size planet , is at a radius of 0 @.@ 55 ? 1 @.@ 16 AU , where 1 AU is the average distance from the Earth to the Sun .

= = = Tau Ceti e = = =

Tau Ceti e is an unconfirmed , fourth @-@ known planet orbiting Tau Ceti that was detected by statistical analyses of the data of the star 's variations in radial velocity that were obtained using HIRES , AAPS , and HARPS . Few properties of the planet are known other than its orbit and mass . It orbits at a distance of 0 @.@ 552 AU ( between the orbits of Venus and Mercury in the Solar System ) with an orbital period of 168 days and has a minimum mass of 4 @.@ 3 Earth masses . Because the minimum mass of a super @-@ Earth is 5 Earth masses , Tau Ceti e may be Earth sized . If it possesses an Earth @-@ like atmosphere , the surface temperature would be around 68 ° C ( 154 ° F ) .

= = = Tau Ceti f = = =

Tau Ceti f is an unconfirmed fifth planet orbiting Tau Ceti that was discovered in 2012 by statistical analyses of the star 's variations in radial velocity , based on data obtained using HIRES , AAPS , and HARPS . It is of interest due to its predicted habitability and Earth @-@ like properties , with an Earth Similarity Index of 0 @.@ 71 and an orbit that places it in Tau Ceti 's extended habitable zone .

Few properties of the planet are known other than its orbit and mass . It orbits Tau Ceti at a distance of 1 @.@ 35 AU ( near Mars 's orbit in the Solar System ) with an orbital period of 642 days and has a minimum mass of 6 @.@ 6 Earth masses , which means it may be a super @-@ Earth . Assuming an Earth @-@ like atmosphere , the surface temperature would be approximately ? 40 °

C ( 233 K ) . With a denser atmosphere able to produce a stronger greenhouse effect it could have a much higher temperature , between 0 ° C and 50 ° C ; warm enough for liquid water to exist on the surface .

= = = Debris disk = = =

In 2004 , a team of UK astronomers led by Jane Greaves discovered that Tau Ceti has more than ten times the amount of cometary and asteroidal material orbiting it than does the Sun . This was determined by measuring the disk of cold dust orbiting the star produced by collisions between such small bodies . This result puts a damper on the possibility of complex life in the system , because any planets would suffer from large impact events roughly ten times more frequently than Earth . Greaves noted at the time of her research that " it is likely that [ any planets ] will experience constant bombardment from asteroids of the kind believed to have wiped out the dinosaurs " . Such bombardments would inhibit the development of biodiversity between impacts . However , it is possible that a large Jupiter @-@ sized gas giant could deflect comets and asteroids .

The debris disk was discovered by measuring the amount of radiation emitted by the system in the far infrared portion of the spectrum . The disk forms a symmetric feature that is centered on the star , and the outer radius averages 55 AU . The lack of infrared radiation from the warmer parts of the disk near Tau Ceti imply an inner cut @-@ off at a radius of 10 AU . By comparison , the Solar System 's Kuiper belt extends from 30 ? 50 AU . To be maintained over a long period of time , this ring of dust must be constantly replenished through collisions by larger bodies . The bulk of the disk appears to be orbiting Tau Ceti at a distance of 35 ? 50 AU , well outside the orbit of the habitable zone . At this distance , the dust belt may be analogous to the Kuiper belt that lies outside the orbit of Neptune in the Solar System .

Tau Ceti shows that stars need not lose large disks as they age and such a thick belt may not be uncommon among Sun @-@ like stars . Tau Ceti 's belt is only 1 ? 20th as dense as the belt around its young neighbor , Epsilon Eridani . The relative lack of debris around the Sun may be the unusual case : one research team member suggests the Sun may have passed close to another star early in its history and had most of its comets and asteroids stripped away . Stars with large debris disks have altered astronomical thinking about planet formation ; debris disk stars , where dust is continually generated by collisions , appear to form planets readily .