= B ? V =

0 . In effect , the magnitude scale has been calibrated so that the magnitude of these stars is the same in the yellow , blue , and ultraviolet parts of the electromagnetic spectrum . Thus , Vega has a relatively flat electromagnetic spectrum in the visual region ? wavelength range 350 ? 850 nanometers , most of which can be seen with the human eye ? so the flux densities are roughly equal ; 2000 ? 4000 Jy . However , the flux density of Vega drops rapidly in the infrared , and is near 100 Jy at 5 micrometers .

Photometric measurements of Vega during the 1930s appeared to show that the star had a low @-@ magnitude variability on the order of ± 0 @.@ 03 magnitudes . This range of variability was near the limits of observational capability for that time , and so the subject of Vega 's variability has been controversial . The magnitude of Vega was measured again in 1981 at the David Dunlap Observatory and showed some slight variability . Thus it was suggested that Vega showed occasional low @-@ amplitude pulsations associated with a Delta Scuti variable . This is a category of stars that oscillate in a coherent manner , resulting in periodic pulsations in the star 's luminosity . Although Vega fits the physical profile for this type of variable , other observers have found no such variation . Thus the variability was thought to possibly be the result of systematic errors in measurement . However , a 2007 article surveyed these and other results , and concluded that " A conservative analysis of the foregoing results suggests that Vega is quite likely variable in the 1 @-@ 2 % range , with possible occasional excursions to as much as 4 % from the mean " . Also , a 2011 article affirms on its abstract that " The long @-@ term (year @-@ to @-@ year) variability of Vega was confirmed " .

Vega became the first solitary main @-@ sequence star beyond the Sun known to be an X @-@ ray emitter when in 1979 it was observed from an imaging X @-@ ray telescope launched on an Aerobee 350 from the White Sands Missile Range . In 1983 , Vega became the first star found to have a disk of dust . The Infrared Astronomical Satellite (IRAS) discovered an excess of infrared radiation coming from the star , and this was attributed to energy emitted by the orbiting dust as it was heated by the star .

= = Visibility = =

Vega can often be seen near the zenith in the mid @-@ northern latitudes during the evening in the Northern Hemisphere summer . From mid @-@ southern latitudes , it can be seen low above the northern horizon during the Southern Hemisphere winter . With a declination of + 38 @.@ 78 ° , Vega can only be viewed at latitudes north of 51 ° S. Therefore , it does not rise at all anywhere in Antarctica or in the southernmost part of South America , including Punta Arenas , Chile (53 ° S) . At latitudes to the north of + 51 ° N , Vega remains continually above the horizon as a circumpolar star . Around July 1 , Vega reaches midnight culmination when it crosses the meridian at that time .

This star lies at a vertex of a widely spaced asterism called the Summer Triangle , which consists of the zero @-@ magnitude stars Vega in the constellation Lyra and Altair in Aquila , plus the first magnitude star Deneb in Cygnus . This formation is the approximate shape of a right triangle , with Vega located at its right angle . The Summer Triangle is recognizable in the northern skies for there are few other bright stars in its vicinity . Vega can be identified easily because Altair and its two neighboring stars form a line which points at Vega .

= = Properties = =

Vega 's spectral class is A0V , making it a blue @-@ tinged white main sequence star that is fusing hydrogen to helium in its core . Since more massive stars use their fusion fuel more quickly than smaller ones , Vega 's main @-@ sequence lifetime is roughly one billion years , a tenth of our Sun 's . The current age of this star is about 455 million years , or up to about half its expected total main @-@ sequence lifespan . After leaving the main sequence , Vega will become a class @-@ M red giant and shed much of its mass , finally becoming a white dwarf . At present , Vega has more than twice the mass of the Sun and its full luminosity is about 40 times the Sun 's value . However ,

because of its high rate of rotation , the pole is considerably brighter than the equator . Since we see it nearly pole @-@ on , its apparent luminosity from Earth is notably higher , about 57 times the Sun 's value . If Vega is variable , then it may be a Delta Scuti type with a period of about 0 @.@ 107 days .

Most of the energy produced at Vega 's core is generated by the carbon ? nitrogen ? oxygen cycle (CNO cycle) , a nuclear fusion process that combines protons to form helium nuclei through intermediary nuclei of carbon , nitrogen , and oxygen . This process requires a temperature of about 15 million K , which is higher than the core temperature of the Sun , but is less efficient than the Sun 's proton @-@ proton chain reaction fusion reaction . The CNO cycle is highly temperature sensitive , which results in a convection zone about the core that evenly distributes the ' ash ' from the fusion reaction within the core region . The overlying atmosphere is in radiative equilibrium . This is in contrast to the Sun , which has a radiation zone centered on the core with an overlying convection zone .

The energy flux from Vega has been precisely measured against standard light sources . At 5480 Å , the flux is 3 @,@ 650 Jy with an error margin of 2 % . The visual spectrum of Vega is dominated by absorption lines of hydrogen ; specifically by the hydrogen Balmer series with the electron at the n = 2 principal quantum number . The lines of other elements are relatively weak , with the strongest being ionized magnesium , iron , and chromium . The X @-@ ray emission from Vega is very low , demonstrating that the corona for this star must be very weak or non @-@ existent . However , as the pole of Vega is facing us and a polar coronal hole may be present , confirmation of a corona as the likely source of the X @-@ rays detected from Vega (or the region very close to Vega) may be difficult as most of any coronal X @-@ rays would not be emitted along the line of sight .

Using spectropolarimetry , a magnetic field has been detected on the surface of Vega by a team of astronomers at the Observatoire du Pic du Midi . This is the first such detection of a magnetic field on a spectral class A star that is not an Ap chemically peculiar star . The average line of sight component of this field has a strength of ? 0 @.@ 6 ± 0 @.@ 3 G. This is comparable to the mean magnetic field on the Sun . Magnetic fields of roughly 30 gauss have been reported for Vega , compared to about 1 gauss for the Sun . In 2015 , star spots were detected on the star 's surface ? the first such detection for a normal A @-@ type star , and these features show evidence of rotational modulation with a period of 0 @.@ 68 days .

= = = Rotation = = =

When the radius of Vega was measured to high accuracy with an interferometer , it resulted in an unexpectedly large estimated value of 2 @.@ 73 ± 0 @.@ 01 times the radius of the Sun . This is 60 % larger than the radius of the star Sirius , while stellar models indicated it should only be about 12 % larger . However , this discrepancy can be explained if Vega is a rapidly rotating star that is being viewed from the direction of its pole of rotation . Observations by the CHARA array in 2005 ? 06 confirmed this deduction .

The pole of Vega ? its axis of rotation ? is inclined no more than five degrees from the line @-@ of @-@ sight to the Earth . At the high end of estimates for the rotation velocity for Vega is 236 @.@ 2 ± 3 @.@ 7 km / s along the equator , which is 87 @.@ 6 % of the speed that would cause the star to start breaking up from centrifugal effects . This rapid rotation of Vega produces a pronounced equatorial bulge , so the radius of the equator is 19 % larger than the polar radius . (The estimated polar radius of this star is 2 @.@ 362 ± 0 @.@ 012 solar radii , while the equatorial radius is 2 @.@ 818 ± 0 @.@ 013 solar radii .) From the Earth , this bulge is being viewed from the direction of its pole , producing the overly large radius estimate .

The local gravitational acceleration at the poles is greater than at the equator , so , by the Von Zeipel theorem , the local luminosity is also higher at the poles . This is seen as a variation in effective temperature over the star : the polar temperature is near 10 @,@ 000 K , while the equatorial temperature is 7 @,@ 600 K. As a result , if Vega were viewed along the plane of its equator , then the luminosity would be about half the apparent luminosity as viewed from the pole . This large temperature difference between the poles and the equator produces a strong ' gravity

darkening ' effect . As viewed from the poles , this results in a darker (lower intensity) limb than would normally be expected for a spherically symmetric star . The temperature gradient may also mean Vega has a convection zone around the equator , while the remainder of the atmosphere is likely to be in almost pure radiative equilibrium .

As Vega had long been used as a standard star for calibrating telescopes , the discovery that it is rapidly rotating may challenge some of the underlying assumptions that were based on it being spherically symmetric . With the viewing angle and rotation rate of Vega now better known , this will allow for improved instrument calibrations .

= = = Element abundance = = =

Astronomers term " metals " those elements with higher atomic numbers than helium . The metallicity of Vega 's photosphere is only about 32 % of the abundance of heavy elements in the Sun 's atmosphere . (Compare this , for example , to a three @-@ fold metallicity abundance in the similar star Sirius as compared to the Sun .) For comparison , the Sun has an abundance of elements heavier than helium of about ZSol = 0 @.@ 0172 ± 0 @.@ 002 . Thus , in terms of abundances , only about 0 @.@ 54 % of Vega consists of elements heavier than helium .

The unusually low metallicity of Vega makes it a weak Lambda Boötis @-@ type star . However , the reason for the existence of such chemically peculiar , spectral class A0 @-@ F0 stars remains unclear . One possibility is that the chemical peculiarity may be the result of diffusion or mass loss , although stellar models show that this would normally only occur near the end of a star 's hydrogen @-@ burning lifespan . Another possibility is that the star formed from an interstellar medium of gas and dust that was unusually metal @-@ poor .

The observed helium to hydrogen ratio in Vega is 0 @.@ 030 ± 0 @.@ 005 , which is about 40 % lower than the Sun . This may be caused by the disappearance of a helium convection zone near the surface . Energy transfer is instead performed by the radiative process , which may be causing an abundance anomaly through diffusion .

= = = Kinematics = = =

The radial velocity of Vega is the component of this star 's motion along the line @-@ of @-@ sight to the Earth . Movement away from the Earth will cause the light from Vega to shift to a lower frequency (toward the red) , or to a higher frequency (toward the blue) if the motion is toward the Earth . Thus the velocity can be measured from the amount of redshift (or blueshift) of the star 's spectrum . Precise measurements of this redshift give a value of ? 13 @.@ 9 ± 0 @.@ 9 km / s . The minus sign indicates a relative motion toward the Earth .

Motion transverse to the line of sight causes the position of Vega to shift with respect to the more distant background stars . Careful measurement of the star 's position allows this angular movement , known as proper motion , to be calculated . Vega 's proper motion is 202 @.@ 03 ± 0 @.@ 63 milli @-@ arcseconds (mas) per year in right ascension ? the celestial equivalent of longitude ? and 287 @.@ 47 ± 0 @.@ 54 mas / y in declination , which is equivalent to a change in latitude . The net proper motion of Vega is 327 @.@ 78 mas / y , which results in angular movement of a degree every 11 @,@ 000 years .

In the Galactic coordinate system , the space velocity components of Vega are (U , V , W) = (? 16 @.@ 1 ± 0 @.@ 3 , ? 6 @.@ 3 ± 0 @.@ 8 , ? 7 @.@ 7 ± 0 @.@ 3) km / s , for a net space velocity of 19 km / s . The radial component of this velocity ? in the direction of the Sun ? is ? 13 @.@ 9 km / s , while the transverse velocity is 9 @.@ 9 km / s . Although Vega is at present only the fifth @-@ brightest star in the sky , the star is slowly brightening as proper motion causes it to approach the Sun . Vega will make its closest approach in an estimated 264 @,@ 000 years at a perihelion distance of 13 @.@ 2 ly (4 @.@ 04 pc) .

Based on this star 's kinematic properties , it appears to belong to a stellar association called the Castor Moving Group . However , Vega may be much older than this group , so the membership remains uncertain . This group contains about 16 stars , including Alpha Librae , Alpha Cephei ,

Castor , Fomalhaut and Vega . All members of the group are moving in nearly the same direction with similar space velocities . Membership in a moving group implies a common origin for these stars in an open cluster that has since become gravitationally unbound . The estimated age of this moving group is 200 ± 100 million years , and they have an average space velocity of 16 @.@ 5 km / s .

= = Planetary system = =

= = = Infrared excess = = =

One of the early results from the Infrared Astronomy Satellite (IRAS) was the discovery of excess infrared flux coming from Vega , beyond what would be expected from the star alone . This excess was measured at wavelengths of 25 , 60 , and 100 ?m , and came from within an angular radius of 10 arcseconds (10 ?) centered on the star . At the measured distance of Vega , this corresponded to an actual radius of 80 astronomical units (AU) , where an AU is the average radius of the Earth 's orbit around the Sun . It was proposed that this radiation came from a field of orbiting particles with a dimension on the order of a millimeter , as anything smaller would eventually be removed from the system by radiation pressure or drawn into the star by means of Poynting ? Robertson drag . The latter is the result of radiation pressure creating an effective force that opposes the orbital motion of a dust particle , causing it to spiral inward . This effect is most pronounced for tiny particles that are closer to the star .

Subsequent measurements of Vega at 193 ?m showed a lower than expected flux for the hypothesized particles , suggesting that they must instead be on the order of 100 ?m or less . To maintain this amount of dust in orbit around Vega , a continual source of replenishment would be required . A proposed mechanism for maintaining the dust was a disk of coalesced bodies that were in the process of collapsing to form a planet . Models fitted to the dust distribution around Vega indicate that it is a 120 AU @-@ radius circular disk viewed from nearly pole @-@ on . In addition , there is a hole in the center of the disk with a radius of no less than 80 AU .

Following the discovery of an infrared excess around Vega , other stars have been found that display a similar anomaly that is attributable to dust emission . As of 2002 , about 400 of these stars have been found , and they have come to be termed " Vega @-@ like " or " Vega @-@ excess " stars . It is believed that these may provide clues to the origin of the Solar System .

= = = Debris disks = = =

By 2005 , the Spitzer Space Telescope had produced high @-@ resolution infrared images of the dust around Vega . It was shown to extend out to 43 ? (330 AU) at a wavelength of 24 ?m , 70 ? (543 AU) at 70 ?m and 105 ? (815 AU) at 160 ?m . These much wider disks were found to be circular and free of clumps , with dust particles ranging from 1 ? 50 ?m in size . The estimated total mass of this dust is 3 × 10 ? 3 times the mass of the Earth . Production of the dust would require collisions between asteroids in a population corresponding to the Kuiper Belt around the Sun . Thus the dust is more likely created by a debris disk around Vega , rather than from a protoplanetary disk as was earlier thought .

The inner boundary of the debris disk was estimated at 11 ? ± 2 ? , or 70 ? 100 AU . The disk of dust is produced as radiation pressure from Vega pushes debris from collisions of larger objects outward . However , continuous production of the amount of dust observed over the course of Vega 's lifetime would require an enormous starting mass ? estimated as hundreds of times the mass of Jupiter . Hence it is more likely to have been produced as the result of a relatively recent breakup of a moderate @-@ sized (or larger) comet or asteroid , which then further fragmented as the result of collisions between the smaller components and other bodies . This dusty disk would be relatively young on the time scale of the star 's age , and it will eventually be removed unless other collision events supply more dust .

Observations , first with the Palomar Testbed Interferometer by David Ciardi and Gerard van Belle in 2001 and then later confirmed with the CHARA array at Mt . Wilson in 2006 and the Infrared Optical Telescope Array at Mt . Hopkins in 2011 , revealed evidence for an inner dust band around Vega . Originating within 8 AU of the star , this exozodiacal dust may be evidence of dynamical perturbations within the system . This may be caused by an intense bombardment of comets or meteors , and may be evidence for the existence of a planetary system .

= = = Possible planets = = =

Observations from the James Clerk Maxwell Telescope in 1997 revealed an " elongated bright central region " that peaked at 9 ? (70 AU) to the northeast of Vega . This was hypothesized as either a perturbation of the dust disk by a planet or else an orbiting object that was surrounded by dust . However , images by the Keck telescope had ruled out a companion down to magnitude 16 , which would correspond to a body with more than 12 times the mass of Jupiter . Astronomers at the Joint Astronomy Centre in Hawaii and at UCLA suggested that the image may indicate a planetary system still undergoing formation .

Determining the nature of the planet has not been straightforward ; a 2002 paper hypothesizes that the clumps are caused by a roughly Jupiter @-@ mass planet on an eccentric orbit . Dust would collect in orbits that have mean @-@ motion resonances with this planet ? where their orbital periods form integer fractions with the period of the planet ? producing the resulting clumpiness .

In 2003 it was hypothesized that these clumps could be caused by a roughly Neptune @-@ mass planet having migrated from 40 to 65 AU over 56 million years , an orbit large enough to allow the formation of smaller rocky planets closer to Vega . The migration of this planet would likely require gravitational interaction with a second , higher @-@ mass planet in a smaller orbit .

Using a coronagraph on the Subaru telescope in Hawaii in 2005 , astronomers were able to further constrain the size of a planet orbiting Vega to no more than 5 ? 10 times the mass of Jupiter . The issue of possible clumps in the debris disc was revisited in 2007 using newer , more sensitive instrumentation on the Plateau de Bure Interferometer . The observations showed that the debris ring is smooth and symmetric . No evidence was found of the blobs reported earlier , casting doubts on the hypothesized giant planet . The smooth structure has been confirmed in follow @-@ up observations by Hughes et al . (2012) and the Herschel Space Telescope .

Although a planet has yet to be directly observed around Vega , the presence of a planetary system can not yet be precluded . Thus there could be smaller , terrestrial planets orbiting closer to the star . The inclination of planetary orbits around Vega is likely to be closely aligned to the equatorial plane of this star . From the perspective of an observer on a hypothetical planet around Vega , the Sun would appear as a faint 4 @.@ 3 magnitude star in the Columba constellation .

= = Etymology and cultural significance = =

The name Wega (later Vega) comes from a loose transliteration of the Arabic word w?qi ? meaning " falling " or " landing " , via the phrase an @-@ nasr al @-@ w?qi ? , " the falling eagle " . The term " Al Nesr al Waki " appeared in the Al Achsasi al Mouakket star catalogue and was translated into Latin as Vultur Cadens , " the falling eagle / vulture " . The constellation was represented as a vulture in ancient Egypt , and as an eagle or vulture in ancient India . The Arabic name then appeared in the western world in the Alfonsine Tables , which were drawn up between 1215 and 1270 by order of Alfonso X. Medieval astrolabes of England and Western Europe used the names Wega and Alvaca , and depicted it and Altair as birds .

Each night the positions of the stars appear to change as the Earth rotates . However , when a star is located along the Earth 's axis of rotation , it will remain in the same position and thus is called a pole star . The direction of the Earth 's axis of rotation gradually changes over time in a process known as the precession of the equinoxes . A complete precession cycle requires 25 @,@ 770 years , during which time the pole of the Earth 's rotation follows a circular path across the celestial sphere that passes near several prominent stars . At present the pole star is Polaris , but around 12

@,@ 000 BC the pole was pointed only five degrees away from Vega . Through precession , the pole will again pass near Vega around AD 14 @,@ 000 . It is the brightest of the successive northern pole stars .

Among the northern Polynesian people , Vega was known as whetu o te tau , the year star . For a period of history it marked the start of their new year when the ground would be prepared for planting . Eventually this function became denoted by the Pleiades .

The Assyrians named this pole star Dayan @-@ same , the " Judge of Heaven " , while in Akkadian it was Tir @-@ anna , " Life of Heaven " . In Babylonian astronomy , Vega may have been one of the stars named Dilgan , " the Messenger of Light " . To the ancient Greeks , the constellation Lyra was formed from the harp of Orpheus , with Vega as its handle . For the Roman Empire , the start of autumn was based upon the hour at which Vega set below the horizon .

In Chinese mythology , there is a love story of Qi Xi (??) in which Niu Lang (?? , Altair) and his two children (? and ? Aquilae) are separated from their mother Zhi Nü (?? , lit . " Weaving Girl " , Vega) who is on the far side of the river , the Milky Way . However , one day per year on the seventh day of the seventh month of the Chinese lunisolar calendar , magpies make a bridge so that Niu Lang and Zhi Nü can be together again for a brief encounter . The Japanese Tanabata festival , in which Vega is known as orihime (??) , is also based on this legend .

In Zoroastrianism , Vega was sometimes associated with Vanant , a minor divinity whose name means " conqueror " .

The indigenous Boorong people of northwestern Victoria named it as Neilloan , " the flying Loan " .

In Hindu mythology , Vega is called Abhijit . The author of Mahabharat , Maharshi Vyas , mentions in the chapter Vana Parva (Chap . 230 , Verses 8 ? 11) : " Contesting against Abhijit (Vega) , the constellation Krittika (Pleiades) went to " Vana " the summer solstice to heat the summer . Then the star Abhijit slipped down in the sky . " P. V. Vartak suggests in his book , The Scholarly Dating of Mahabharat , that the " slipping of Abhijit " and ascension of Krittika (Pleiades) might refer to the gradual drop of Vega as a pole star since 12 @,@ 000 BC . Vega is expected to become Earth 's pole star by the year 26 @,@ 000 by some estimates .

Medieval astrologers counted Vega as one of the Behenian stars and related it to chrysolite and winter savory . Cornelius Agrippa listed its kabbalistic sign under Vultur cadens , a literal Latin translation of the Arabic name . Medieval star charts also listed the alternate names Waghi , Vagieh and Veka for this star .

Vega became the first star to have a car named after it with the French Facel Vega line of cars from 1954 onwards , and later on , in America , Chevrolet launched the Vega in 1971 . Other vehicles named after Vega include the ESA 's Vega launch system and the Lockheed Vega aircraft .