# The existence and origin of extrasolar planets

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**Experimental evidence for the existence of extra-solar planets is evaluated and planet origin theories are critiqued from a creation perspective. Three methods of experimental detection, the astrometric, spectroscopic (Doppler), and direct transit measurement, are explained. Several cases of possible extrasolar planets are examined, leading to the conclusion that these objects are indeed planets orbiting other stars. The existence of these objects is not seen as contrary to Biblical theology, but rather provides additional examples of the creativity and power of God. The existence of these planets does not confirm the belief that life could evolve in other solar systems.**

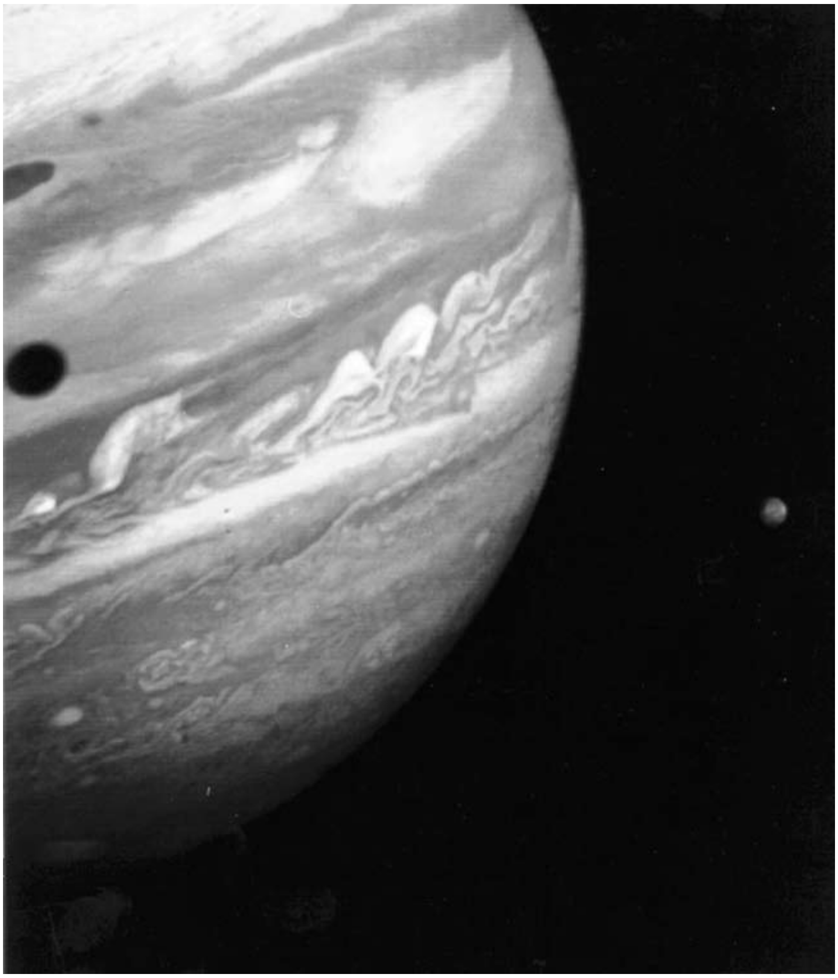
**Planet origin theories are reviewed to show that naturalistic theories for the origin of planets have fundamental weaknesses that would apply in any solar system. These difficulties include the properties and dissipation of protoplanetary discs. To explain how extrasolar planets can be extremely near their stars, it is becoming accepted today among scientists that the extrasolar planets formed several astronomical units from their star and then migrated closer to the star. The complexities and difficulties of this process make naturalistic origin theories implausible. However, in a young-age creation point of view, such planets could have been created at any distance from the star, making complex migration processes unnecessary.**

Modern astronomical research proceeds at a rapid pace due to the application of new technologies in astronomy and astrophysics. There is a need for many fundamental questions in astronomy to be addressed by young-age creationists in a manner that is up-to-date. One of these pressing questions creationists need to answer is whether extra-solar planets actually exist. This paper will suggest how creationists may deal honestly with the observational evidence regarding extrasolar planets, and not compromise on Biblical convictions. After some necessary background, the following will discuss certain theological concerns, the nature of the observational evidence for the existence of extrasolar planets, and problems with existing theories of their origin. It will be concluded that the existence of these objects, as an issue of experimental science, does not conflict with the young-age creation viewpoint. On the other hand, on the issue of their origin, planet formation theories of today are in conflict with a Biblical creationary worldview. Accepted naturalistic theories must be rejected by creationists in favor of them being supernaturally and recently created.

### Definitions and background

The term 'extrasolar planets' refers to planetary bodies that exist in orbit around other stars outside of our solar system. The classification of objects as either planets or brown dwarfs is considered by astronomers today to depend on their mass, the role of nuclear reactions in their energy production and their origin.[1,2] Objects ranging up to about 10 or 20 Jupiter masses ($M_J$) that would supposedly form from dust and gas accretion from a protosolar disc are considered to be planets.[3] Objects from about 10 or 20 $M_J$ to 80 $M_J$ are generally considered brown dwarfs, though some have argued that brown dwarfs can have masses down to 3 $M_J$.[2] Brown dwarfs are believed to form from the gravitational collapse of nebulae, since they are actually stars. Very little nuclear fusion takes place in brown dwarfs. Some fusion of normal hydrogen may occur in brown dwarfs, but they do not possess adequate mass for deuterium fusion reactions, as do normal stars. The gravitational collapse produces significant heat in brown dwarfs. The temperature of brown dwarfs is generally a few hundred degrees cooler than the effective temperature of a star. Both extrasolar planets and brown dwarfs give off most of their energy in the infrared region of the spectrum. The most abundant substances in both types of objects seem to be molecular hydrogen and water.[4] Since only very limited nuclear fusion occurs in brown dwarfs, they have a very low luminosity. It is believed that the energy given off by brown dwarfs dramatically decays over time. Planets, on the other hand, are believed to form by rocky planetesimals accreting into a core, then this core attracts gas and dust to form the outer gaseous layers of a gas giant planet.

The distinctions between large gaseous planets and brown dwarfs continue to be debated. Nineteen objects were recently discovered in the sigma Orionis star cluster that challenge current naturalistic origin theories and blur definitions of planets and brown dwarfs. These new objects appear to be in the mass range of 5 to 15 $M_J$ and they are not orbiting stars.[5] Assuming these masses are correct, this would put these objects in a size class usually considered too small to be brown dwarfs. So, the nature of these objects is being hotly debated among researchers. It is important to note that when they are not orbiting stars, this seriously limits the type of data that can be gathered. The usual methods for determining the masses of extrasolar planets and brown dwarfs cannot be used for these objects. None of the three methods described in this paper for detecting extrasolar planets can be used to study these 'rogue planets'.



*At 318 times the mass of the Earth and over 1500 times the volume, Jupiter is the largest non-stellar object within the solar system. Jupiter's satellite moon, Io, can been seen to the right of giant planet.*

This makes the mass estimates very uncertain, and thus the nature of these objects is also uncertain.

Astronomers have been interested in detecting extrasolar planets for many years, but doing so presented formidable problems. An extrasolar planet is millions or billions of times fainter in brightness than the star it is close to. One problem with detecting these objects is the way light from the star masks the light of the planet. Most attempts to detect brown dwarfs and planets involve measuring how the object affects the motion of the star. This is done by one of two methods. In the early 1900s astronomers began attempting to make precise measurements of the position of certain nearby stars, in hopes of finding evidence of planets from perturbations of the star's position. This is the astrometric method. This method works best if the star is of relatively low mass and the planet is very massive but farther from its star than Jupiter is from our Sun. This is because when the planet is closer to its star, the displacement of the star, seen as a periodic variation in its measured position (or 'wobble') is less pronounced and therefore harder to measure. If the planet is farther from the star on the other hand, the displacement of the star by the planet will be larger and easier to detect. The farther the planet is from the star, the longer is its orbital period. Of course, the distance from Earth to the star in question is critical as well, so planets would be harder to detect around more distant stars.

This displacement of the star by orbiting planets is certainly possible and is a consequence of well understood physics. It is known for example that our Sun undergoes this same 'wobble'. The center of mass of our solar system is not located exactly at the center of the Sun, due to the gravitational pulls of the various planets on the Sun. Though the path followed by the Sun around the solar system center of mass is somewhat complicated, it is roughly as if it were rotating about a point near the Sun's surface.[2] So, this means the center of the Sun is being displaced a distance of over 695,000 km (about 432,300 miles). In our solar system, Jupiter is responsible for most of this effect on the Sun. A hypothetical observer at a distance of 30 or 40 light-years from Earth, plotting the position of our star over a period of years, would see a periodic variation in the position of our star in relation to the background stars (called the proper motion). In recent years use of the astrometric method has been limited to researchers using some of the very largest telescopes. To date there have been no successful detections of extrasolar planets with the astrometric method. There have been a few reports of attempts to directly image a few planet objects themselves, but these measurements are generally considered very uncertain. In coming years, NASA plans to build large space-based telescopes that will use the astrometric method to search for extrasolar planets.

The other method used is the spectroscopic method, which involves study of the spectrum of the distant star. The spectroscopic method uses Doppler techniques to measure the velocity variations of the star as it moves toward or away from Earth. To give perspective, Jupiter causes a variation in the speed of the Sun of 13 m per second. Today's techniques in spectroscopy are quite accurate and can sometimes detect speed variations even less than this. The presence of an orbiting companion, whether it is a brown dwarf or a planet, will cause the emission or absorption lines from the star to shift up and down in frequency due to the Doppler effect. These red and blue shifts in the spectra will be very repeatable and consistent if it is indeed from a real companion object. Since there are other processes that can cause similar red and blue shifts of star light, care must be taken to rule out the possibility that the periodic variation is not caused by some process other than the motion of the star. Generally, the observations must be repeated several times, often over periods of years in order to determine if the red and blue shifts are repeatable and not a temporary phenomena. The spectroscopic approach is best suited for cases where the planet is found quite close to the star, since velocity variations will be more pronounced in that case than if the planet were farther away.

In Doppler measurements like this, it is only really the radial velocity in relation to Earth that is actually measured. This radial velocity is the component of the velocity of the star along a line connecting the Earth and the distant star. If the star does clearly show a periodic change in its Doppler shift, this can indicate the star is being pulled and moved slightly in its motion by the regular orbits of the companion object. From the period of the Doppler variations the orbital period of the companion object can be estimated, and the magnitude of the Doppler variations allows the radial velocity variations to be determined. The amount of velocity variation is used with known data on the star to calculate the minimum mass necessary in the planet to cause the velocity variations in the star. The actual mass of the companion cannot be determined, only a lower limit can be determined. This determination assumes the variation of the redshift is indeed a Doppler effect due to motion of the star. The lower limit on the mass of the companion assumes that the companion's orbit is aligned exactly in angle with the 'line of sight' connecting Earth and the star. If the orbit of the companion around the star is inclined in relation to the Earth line of sight, then its mass must be greater than the lower limit in order for its gravity to have the same observed effect on the velocity of the star. This is important to understand because if an object has been claimed to be found that is 6 $M_J$; its mass could actually be greater if the planet's orbit were inclined significantly.

There is one other technique for detecting extrasolar planets, but this approach has only been possible in one case to date.[6] It is a direct transit measurement. Direct transit measurements are done in our solar system, when Mercury or Venus passes between the Sun and Earth. When this occurs, Venus, for example, would be blocking a very minuscule portion of the Sun, and light from the Sun would be modified as it passes through Venus' atmosphere. (If this occurred for Venus, the composition of Venus' atmosphere could be measured.) For direct transit measurement to be possible for extrasolar planets, the orbit of the extrasolar planet must be aligned so that the planet will pass between Earth and the star. When the planet passes between the star and the Earth it causes a minute drop to be seen from Earth in the intensity of the light from the star. Transit measurements allow researchers to estimate the density of the planet and the inclination of its orbit in relation to the star. Measuring the density is quite important because this can distinguish a gaseous object from a solid one. The astrometric and spectroscopic methods have no way of determining if the companion object is gaseous or rocky in character, because what is actually measured is light from the star and not from the companion object itself.

In November 1999 researchers Marcy, Butler and Vogt, using the Keck Observatory in Hawaii, reported doing such a transit measurement of a planet around star HD 209458. This star is similar to our Sun and is 153 light-years from Earth. Doppler measurements indicated the planet was about 62% the mass of Jupiter and orbited the star once every 3.5 days. After measuring the drop in the brightness of the star, Marcy's team was able to predict times when other astronomers could measure the same drop in the following days. Astronomers at two observatories were able to confirm the observation exactly as predicted, at Fairborn Observatory in Arizona and at Harvard University. This may be the strongest evidence for the detection of extrasolar planets. The density determined by the Marcy and Butler team implies this planet is even less dense than Saturn. One of the measurements of the transit event involved a 1.58% drop in the brightness of the star.[6] This may seem like a very small change in brightness, but modern techniques are able to measure effects on this scale. Some statistical analysis of the observations were involved to obtain the parameters from theoretical models to fit observations to theory. This same transit technique is used routinely in other astronomical research, such as in observations of eclipsing binary stars.

## Theological concerns

The Bible does not provide enough information to answer the question of whether extrasolar planets exist. The Bible does state that God made the stars (Gen. 1:16). The Bible indicates that the stars were created with a purpose of giving light on the Earth (Gen. 1:17–18). Certainly God did create many, many more objects in space than could be seen by the people in the ancient world. It would not be surprising for God to create (in the beginning) more in space than what human beings can see and measure today. The vastness of the heavens is often mentioned in the Bible to help us see our own limitations in contrast to God's unlimited nature and power. It may also be appropriate to say that some of the great variety God created was made just for God's own pleasure. It is possible that some things God created were not intended to be seen by man. Thus, the existence of objects too faint to see directly does not pose a theological problem in my opinion. If these objects do exist, when did they form, during the creation week or after? I would take the view that they were created during the creation week. If these objects formed by natural processes alone with no divine intervention, the time necessary would not be compatible with the young-age position. Therefore rapid or instantaneous supernatural creation during the creation week seems likely. Allowing for their existence theologically, the experimental evidence for the existence of extrasolar planets can be evaluated.

## Evaluation of the evidence

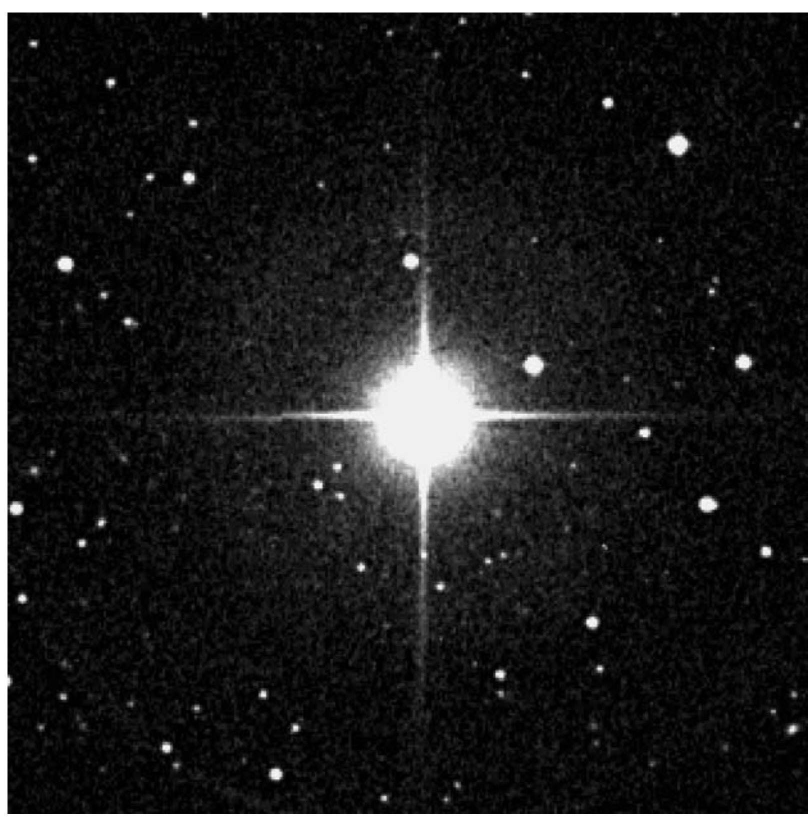
The first serious candidate for an extrasolar planet was reported in October 1995 by a Swiss team (Mayor and Queloz[7]). It was the star known as 51 Pegasi. A periodic Doppler shift in the spectrum was found that varied with a period of 4.23 days. The magnitude of the blue and red shifts were equal and it was repeatable.[2] The result was quickly confirmed by another team of astronomers.[3] The planet at 51 Pegasi was calculated to have a minimum mass of 0.5 $M_J$ and the velocity variation of the star about 56 m per second. The surprising point was that it was too close to the star, only 0.05 AU (astronomical units, 1 AU=150 million km, mean Earth-Sun distance). This was not easy to reconcile with accepted origin theories for the formation of planets.

There was some controversy and debate among astronomers over this finding. Another researcher from the University of Western Ontario, David F. Gray, challenged the 51 Pegasi planet, claiming to have found evidence that the variation observed in the spectra was actually due to intrinsic pulsations in the star and not due to a planet affecting the motion of the star.[8,9] Later measurements failed to confirm the pulsation hypothesis. In addition, there was no evidence of a brightness variation as would be expected from a variable star.[10,11] So, stellar pulsations seem to have been ruled out for the case of 51 Pegasi and today most astronomers would accept the existence of a planet around this star.

Tables 1 and 2 present data on a variety of representative examples of possible extrasolar planets. Table 1 lists information regarding the companion objects, while Table 2 lists information about their stars. Table 1 shows two sets of values in some cases. The figures without braces are the originally published values, whereas figures in braces have been updated since the original measurements. Where only one set of figures is listed, the updated figures are not significantly different. A number of general observations can be made from this list. Many of these objects are much closer to their stars than Jupiter is from our Sun. The spectroscopic method for detecting the objects tends to preferentially find objects with short orbital periods. All confirmed discoveries to date have used the spectroscopic method. The objects listed in Table 1 range in mass from 0.5 $M_J$ to 6.6 $M_J$. Most of these objects seem to have very circular orbits, with 70 Virginis and 16 Cygni being notable exceptions.[3,12] Some of these objects are in binary star systems and one interesting system, 16 Cygni, is trinary.[12] For most of these objects, the orbital periods appear to be significantly different than the rotation period of the star. This tends to rule out the possibility of the spectral shifts being due to large sunspots or other phenomena intrinsic to the star.

Properties of the example stars are given in Table 2 corresponding to Table 1. The evidence for the extrasolar planets cannot be explained by appealing to some unusual phenomena intrinsic to certain stars. The stars listed in Table 2 are all type G and F stars,[17] which are all quite similar to our Sun. There is a tendency for the stars found with planets to be similar to our Sun because they are relatively nearby and researchers tend to look for stars believed to be 'young' in the process of stellar evolution. Most stars in our region of the galaxy are not too different from our Sun. The stars found with extrasolar planets seem to all be within about 150 light-years of Earth. Note that there is still some controversy among astronomers on the question of what distinguishes a brown dwarf star from a large planet. There are also other types of low-mass stars that could produce effects similar to an orbiting planet. So, distinguishing between brown dwarfs and large gaseous planets is not foolproof. All these issues are considered by researchers hunting for extrasolar planets.

A few star systems appear to actually possess more than one planet. Upsilon Andromeda[6,18,19] is said to have three detectable planets. The innermost of the three is less than 1 $M_J$, but the other two are more massive than Jupiter and yet all three of them are located less than 3 A.U. from their star. This severely challenges naturalistic origins theories because the temperature at that distance would not allow



*51 Pegasi attracted enormous attention when it was claimed that an extrasolar planet was orbiting the star. Swiss astronomers (Mayor and Queloz) showed that the star exhibited periodic Doppler shifts, which could be an effect of a nearby planet.*

***Table 1.*** *Data on representative extrasolar planets. Values not in braces { } are those published in the original papers. Values in braces are updated figures from the exoplanets.org web site,[19] as of 28 October 2000. This site is maintained by the Marcy, Butler, Vogt research*

| Star Name for Companion | Min. Mass (M) | Orbital Semi-Major Axis of Planet (AU) | Orbital Period from Doppler Variations (d-days; y-years) | Velocity Amplitude Variation for the Star (meters/sec) | Estimated Eccentricity |
|---|---|---|---|---|---|
| 51 Pegasi,[8] HR 8279 | 0.5 {0.46} | 0.05 {0.052} | 4.23 d {4.231} | 59 ± 3 m/s {55.2} | 0.01 {0.01} |
| rho Cancri, [13] HR 3522 | 0.84 | 0.11 | 14.65 d | 77 ± 4 | 0.051 |
| tau Boötis,[13] HR 5185 | 3.87 | 0.046 | 3.31 d | 469 ± 4 | 0.018 |
| 47 Ursae Major[14] | 2.39 {2.60} | 2.1 {2.09} | 2.98 y {1084 d} | 45.5 ± 3 {50.9} | 0.03 {0.13} |

gases to condense and form such large planets. The innermost planet was discovered in 1996 by the Marcy and Butler team.[2] Three years later both they and another team of astronomers separately found evidence of the other two companions.[6] For planets more distant from the star, data must be collected and analyzed over a longer period of time. In coming years as more data is collected and analyzed, it is possible more systems could be found with more than one planet.

The above examples are not exhaustive and new reports of extrasolar planets continue to be published. Though these findings seem to indicate that planets do exist beyond our solar system, there are other considerations and new astronomical data that could call into question the planet status of some of these objects. First, is it really known how small a star can be? The lower limit for the mass of brown dwarfs is not clear, though the consensus seems to be to take it as 10 or 15 $M_J$. Assuming this to be valid, none of the examples listed here could be considered dwarf stars rather than planets, unless their masses were revised upward in the future. There have been some cases of objects reported to be planets or brown dwarfs but which were later reclassified as a star. This may continue to happen for some cases as more data becomes available. However, there simply are too many cases of confirmed observations to dismiss all the reports of extrasolar planets.

On 29 March, 2000 NASA's Ames Research Center issued a press release announcing that two extrasolar planets had been found which are smaller than Saturn.[20] Saturn is about one-third of Jupiter's mass. Two teams using the Keck telescope in Hawaii found an object of 0.25 $M_J$ around star HD 46375 in the constellation Monoceros and an object of 0.22 $M_J$ around star 79 Ceti in the constellation Cetus. Both of these objects orbit very close to their stars. The Monoceros planet has an orbital period of 3 days and the 79 Ceti object orbits its star every 75 days. If these objects are confirmed as planets, they seem to make it less likely that brown dwarfs can be an adequate explanation for all the various cases. Though new information could conceivably cause some objects now considered planets to be reclassified as brown dwarfs, it seems this is unlikely for all the cases of extrasolar planets known today. These objects are being discovered frequently; currently there are about 50 possible extrasolar planets.

## Planet origin theories

Until recently, our solar system provided the only examples of planets available for scientists developing theories on planetary origins. By 1995, most planetary scientists had become rather comfortable with the existing accepted theories for the origin of our solar system. It has been generally accepted that though there are unanswered questions about minor details, the main processes involved are believed to be understood. For the extrasolar planets (or exoplanets), it was found that some concepts from existing planetary origin theories just did not work well. In a helpful review of the subject, Marsha Freeman[6] makes the following comment.

> 'These striking differences between what we can see in Earth's neighborhood, and what we are finding in other planetary systems, has directly challenged the conventional theories of planet formation. Scientists had assumed that were they to find other solar systems, such systems would conform, at least in basic parameters, to our own.'

In examining naturalistic planetary origin theories, conflict with a young-age creationary viewpoint is evident.

The following comments will offer some suggestions on how young-age creationists may reinterpret the data on these interesting objects. After reviewing accepted theories on the origin of planets, general problems with the naturalistic origin of any planet will be considered, then special problems with the origins of extrasolar planets.

The modern Nebular Hypothesis for the formation of our solar system was reviewed and critiqued from a creationist viewpoint by Spencer[21] in 1994. A recommended evolutionary review of the subject is found in Lissauer.[22] The general process assumes that all objects gravitationally bound to our star have a common origin from a nebula or molecular cloud that existed in space before the formation of our Sun. Such nebulae and clouds are definitely observed in space. They often are made up of high-temperature plasmas and possess magnetic fields; they also rotate. As the cloud cools, it is believed that it would contract into a disc. The Sun would form in the center while the disc was still opaque, being made up of both volatile gases (hydrogen, helium, ammonia, for instance) and microscopic mineral grains (dust). The mineral grains would combine and aggregate into larger and larger particles. These dust particles would grow until they were eventually macroscopic objects. The macroscopic objects thus formed would continue to combine and accrete into larger objects (roughly 1 km in dimension and larger) known as planetesimals. Planet cores and terrestrial rocky planets would accrete from the planetesimals. For gaseous planets such as Jupiter or Saturn, it is believed that a solid core of at least approximately 10 Earth masses must form from the disc or it would not possess enough mass to cause sufficient quantities of gases to accrete onto the protoplanet. Thus for gaseous planets, the formation of the core and the formation of the gaseous envelope around the core are two different processes. This is important because it is believed the extrasolar planets found to date are likely to be large gaseous planets similar to Jupiter or Saturn.

Though a great deal of theoretical work has been done and much observational data is available on our solar system, weaknesses remain in planetary origins theories that exclude any supernatural creation. Certain difficulties encountered in such research for the planets in our solar system would also apply to any planet in any other solar system. Many mathematical models and computer simulations have been done that attempt to work out portions of the planet formation process, but the entire process cannot be modeled and many aspects of the theory cannot be tested experimentally. These difficulties include:

1. Our limited understanding of particle accretion and collision processes
2. Unrealistic assumptions about nebulae and their transition to a disc
3. Models tend to assume unrealistically high densities for the protoplanetary discs and
4. The discs may dissipate before the planets can form.

First, there is a limited understanding of accretion and collision processes for the wide range of particle sizes. The formation of planets, by accepted naturalistic theories, requires that particles of micron dimensions ($10^{-6}$ m) grow into large planets over 100,000 km in diameter. The protoplanetary disc consists at first of a mixture of gas and dust. Planet formation must be largely complete before the star enters the T Tauri phase[23] of its existence. During this stage, theory suggests that the star gives off a very intense solar wind that drives much of the excess gas and dust out of the system.

Theoretical studies of planet formation often start with considering particles of about a micron in size. Collisions and other behavior of such particles can be studied in experiments, but as you deal with larger and larger particles, experimental studies of collisions become impractical. One experimental study by Blum and Wurm[24] made the following comments about the limits of current research

***Table 2.*** *Star data for representative extrasolar planets.*

| Star Name for Companion | Spectral Type | Distance from Earth (LY) | Star's Rotation Period | System Type | Uniformitarian Age (Gigayears) |
|---|---|---|---|---|---|
| 51 Pegasi, HR 8279 | G5 IV or V | 50 | 37 d | Single | |
| rho Cancri, HR 3522 | G8 V | 54 | 42 – 44 d | Binary | 5 |
| tau Bootis, HR 5185 | F7 V | 50 | 3.5 – 4 d | Binary | 2 |

on dust accretion.

> 'However, though this general scenario is widely accepted, many details used in the models are still to be considered as *ad hoc* assumptions without experimental verification. In particular, the morphological structures of the evolving dust aggregates and, therefore, their dynamic coupling to the nebular gas motion and their further evolution have hardly been investigated empirically.'

Second, theoreticians have not been able to start with realistic observed conditions like in the interstellar medium or actual observed molecular clouds and show mathematically how the cloud could contract into a disc. Boss[25] commented that computer models simulating cloud collapse start with initial densities 'considerably higher than dense molecular cloud cores'. Also, an important paper by Lissauer[22] states that 'hydrodynamical calculations have not yet linked the observed states in the interstellar medium (ISM) to a star surrounded by a disc'.

The density and lifetime of the protoplanetary disc are crucial to today's theories of planet formation. A large planet similar to Jupiter must form its solid core in a period of about a million years or less. If the core does not form in this time, the planet will accrete less gas and in the end the planet's mass would be less. The core must have adequate mass that it will gravitationally attract gases to the protoplanet to make the gaseous outer layers. This accretion of the gaseous layers is often referred to as the 'runaway' stage in the planet's formation, since theory says it is much more rapid than the formation of the core. It appears common for researchers to increase the density of the disc or of the initial nebula in their model, in order to allow the core to form more quickly, before the disc dissipates.[26] Sometimes parameters such as the disc density are adjusted to make the theory work, but they are not adjusted for valid reasons. Planetary scientists estimate that these dust discs may have lifetimes that vary from about 100,000 to 10 Ma.[26] The disc could dissipate then before the core grew large enough. This is especially a problem in our solar system for Uranus and Neptune since their masses are less than the masses of Jupiter or Saturn. Jupiter and Saturn would form in less time than Uranus or Neptune, but Uranus and Neptune's planet cores would probably not have sufficient mass to reach their present size. At the greater distances from the Sun, the disc is less dense, and there is less gas to form the outer layers of a large gaseous planet. This has presented an ongoing problem for theories on the origin of the gaseous planets in our solar system. The same problem could apply to extrasolar planets as well.

## Extrasolar planets and orbit migration

Extrasolar planets, such as 51 Pegasi, severely challenge accepted naturalistic theories of planet formation because the orbits of these bodies are extremely close to their star. Many of these planets are comparable in mass with that of Jupiter but are closer to their star than Mercury and Venus are in our solar system! This puts them close enough to the star that gases, and even minerals in some cases, could not condense onto the protoplanet due to their high temperatures in that region. This has led scientists to conclude that the exoplanets found much nearer to their stars than Jupiter or Saturn must have moved or migrated after they formed.[2,27] Thus, elaborate theories have been developed involving tidal effects between a forming protoplanet and a disc, to explain the orbits of these objects.[28,29] Various density waves and dynamical resonances are believed to be capable of causing even a large planet to migrate or drift in its orbit either inward toward the star or outward away from the star. This migration process is caused by the disc, so if the disc dissipates sufficiently the migration will stop. Or, the planet could clear out a zone of dust on either side of its orbit and if this clear zone becomes wide enough it may stop the migration because the edge of the dust disc will be too far away to affect the planet significantly. Note that even if the dust disc does not dissipate before the planet can move as above, the process depends on the disc being able to sustain certain density waves and resonances for the entire time required for the planet to migrate the necessary distance. This distance could be up to several astronomical units.

The complexities and difficulties of such a process are most evident perhaps for the case of the upsilon Andromeda system (Table 1). This system seems to have three planets, placed at distances of 0.06, 0.83, and 2.5 A.U. from the star. The eccentricity of these planet orbits increase at the greater distances. The innermost of these planets is less massive than Jupiter, the middle planet is about double the mass of Jupiter, and the outer planet even larger. By the migration theory, the smaller planet would migrate farther and more rapidly since the mass of the disc is more significant relative to the planet. The middle planet on the other hand, is much more massive and yet it would have to migrate a distance of at least perhaps 3 or 4 A.U. It seems implausible that the disc could support the migration process long enough for this middle planet. Even the outer planet would had to have migrated a minimum of perhaps 2 to 3 A.U. These migration times would have to take place in a timeframe of a few million years at the most, if conditions in the disc permitted it.

However, such planets could be located at any distance from a star if they were supernaturally created, since in a creation view they do not have to naturally condense and then migrate to a different orbital configuration. Also, if these objects are young (less than 10,000 years), though there could be loss of gases from some of these planets due to their high temperatures near the star, the loss of matter is not so significant as it would be if these objects were billions of years in age. **Thus, viewing these objects as young and created in their present orbits is a much simpler alternative to the complex orbital migration theories currently in vogue.** This alternative is overlooked or deliberately avoided by scientists today, who operate solely from a naturalistic set of presuppositions.

## Conclusions

Though caution is in order in accepting claims of newly discovered extrasolar planets, I recommend that young-age creationists accept these objects as real planets. It is conceivable that some of the alleged exoplanets could be reclassified as brown dwarfs, but this is not likely to occur for many. The growing list of possible exoplanets is of sufficient variety in characteristics that it is difficult to account for them with any designation other than 'planet'. Observations have often been confirmed by two or even more teams of astronomers. Though I do not speak from personal experience with these types of measurements, I would accept that today's observational techniques do have adequate precision to detect the periodic motions of a star due to a companion planet. The transit measurement conducted for star HD 209458 late in 1999 probably constitutes the strongest evidence for detection of an extrasolar planet. In time, it is possible that more transit measurements may be achieved.

Planetary scientists considered naturalistic origin theories for our solar system to be quite successful before the discovery of extrasolar planets. Today, origin theories for our solar system are being modified in the light of research into the formation of the exoplanets. Some scientists are suggesting that theories on the formation of Uranus and Neptune be modified to incorporate planet orbit migration after formation. This serves to reveal that evolutionary origin theories for our solar system have never been without problems. The formation of the dust and gaseous protoplanetary disc and its nature and lifetime are important questions. Such discs could dissipate before large gaseous planets could form. The discs could also cause the protoplanet to fall into the star.[25] In addition to these difficulties which would plague the formation of any planet in any solar system, the formation of extrasolar planets has its own special difficulties due to the necessity of the planet's orbit changing after its formation. It is often true that when significant complexity is added to origin models, plausibility suffers. This is likely the case for the complex process of planet orbit migration. **It is much simpler to explain the existence of the extrasolar planets if they are viewed as less than 10,000 years in age and as being supernaturally created.**

There are interesting implications of the existence of the exoplanets, and other important related questions that need to be addressed by creationists. First, there is observational evidence of the existence of dust discs or sometimes spherical halos around some stars. The evolutionary ages estimated for these stars have been used to determine plausible lifetimes of dust discs. Creationists need to evaluate the evidence for these dust discs. In a creation view, these discs may or may not be related to the origin of the stars and exoplanets. In an evolutionary naturalistic view, the presence of these discs is taken to be substantial evidence for the validity of current origin theories. Is the evidence for these discs compelling? Could they have been created when the star and its planets were created? Are there other possibilities for the origin of these discs? These are important questions creationists should research in the future.

Scientists taking an evolutionary point of view are often motivated in the search for extrasolar planets by the desire to find evidence that life could evolve outside our solar system. Actually, there are serious technical difficulties with the evolution of life even on a planet with an ideal environment such as Earth.[30,31] Even if scientists found evidence of millions of extrasolar planets very much like Earth, life could not form on any of them apart from the hand of the Creator-God. The logical connection between the existence of these objects and naturalistic origin theories is tenuous. The evidence for the existence of exoplanets is a matter of experimental science, but theories of their origin is not within the scope of empirical science and is thus outside experimental verification. From an evolutionary point of view, the exoplanets discovered to date generally do not give much hope of being good candidates for life. This is because in the planet migration process, any earth-like planet which initially may have formed nearer to the star would very likely be destroyed by the migration of the larger gaseous planet inward toward the star. The larger planet would destabilize the orbit of a smaller, more terrestrial type planet like Earth. This problem has been mentioned by Boss.[2] Also, large gaseous planets are not plausible environments to support life due to magnetic and radiation effects (similar to known effects at Jupiter), as well as the question of temperature and the availability of water and oxygen, to name a few. The characteristics of extrasolar planets discovered to date do not lend support to the existence of life outside our solar system. Extrasolar planets should not be viewed as threats to the young-age creation viewpoint. Rather they should be seen as further examples of the power and creativity of God.

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