

SEARCH FOR NEW PLANETS

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I have introduced a system for students, especially school children and college students, who come to my talks and afterwards ask for my autograph. I tell them "I will not easily give you my autograph. You will have to work for it and I have to work for it also". I tell them to write me a post card with any question on science and I will try to answer it in my own hand-writing with my signature under it. When I state this rule perhaps 10% or 5% take up the offer; but even then I am overwhelmed with letters asking questions. I confess in some cases I cannot answer the question, in some cases I go and find the answer while in some cases I know the answer. I reply in any case.

The questions that are fired at me vary in content and level. But one of the questions which comes now and then (mostly from the students of Maharashtra) is the question related to the existence of a 10th planet and its details. Perhaps in their text book it is stated that there is a 10th planet in our solar system. Some name has also been given to that planet. So I have to first disillusion them and say that we still know of only 9 planets. No 10th planet, if at all it exists, has been confirmed. Discovery of a 10th planet is not going to be easy, because one has to be very certain before one may identify what one is seeing as a planet. When I was doing my homework for answering this question I happened to read up about planets a little more and I found many interesting facts about the discovery of planets. However, please bear in mind that I am not an expert on this subject. I am telling you some of the interesting details which I have also picked up reading the recent literature in astronomy. Let me begin with a historical episode.

In our solar system, we have the Sun in the centre and then there are the inner planets—Mercury and Venus, followed by the Earth and the red planet Mars. Then comes the asteroidal belt, before Jupiter and of course the planet with rings, Saturn. These planets were known for a long time.

Subsequently Uranus was discovered in 1781 by John Herschel, the senior of the famous father and son astronomer-duo and my story begins in the 1840's. The newly found planet was naturally observed carefully by astronomers over several decades. By then it was already known that the planets follow elliptical orbits as outlined by Kepler and one of the great achievements of Isaac Newton had been to show that with his laws of mechanics and his inverse square law of gravitation these orbits can be worked out mathematically. Thus by then, that is about 200 years ago, scientists had acquired confidence in the validity of Newton's law of gravitation and all the resulting planetary dynamics.

Nevertheless, through continuous observing astronomers began to discover discrepancies in the orbit of Uranus and the question was : Why is Uranus behaving like this ? Why was it not following the exact elliptical orbit predicted by the Newton-Kepler formalism? Now many times it happens in science that new findings do not match the predictions of a well established theory. Under this situation there are three options available. One is that the observations leading to the result are wrong and generally theoreticians like to follow this option ! Observers of course are delighted whenever their observations disprove certain theories that are well established. So they get back and say to the theorists : We have checked everything and it is time you took a critical look at the theory. Thus, sometimes observations turn out to be erroneous and have to be corrected while on other occasions theories turn out to be wrong or at least incomplete. In the case of Uranus both these options failed. For, while the observations, taken over decades, could not be faulted, the Newtonian theory also looked blameless.

Against this background two young astronomers—, John

Adams in Cambridge and U.J.J. Leverrier in Paris—independently thought of the third option. They did a calculation on the assumption that in the neighbourhood of Uranus there is a new planet (not discovered till then), whose gravitational effect on Uranus would disturb its orbit. With this assumption each went on to work out where this planet should be. Adams came up with the answer first, with the prediction as to where the planet should be seen in the sky. He sent his prediction to two leading astronomers, Challis, the Director of the Cambridge Observatory in his own city and also to the Astronomer Royal Airy at the Royal Greenwich observatory. Both these senior astronomers, however, ignored this suggestion to look for a new planet. Perhaps they thought that coming from such a young person it was not important. Perhaps they thought that whatever they were doing was more important than looking for something which may or may not be in the sky. Whatever the reason, they ignored it. Now Leverrier, who also reached similar conclusions fared no better in France. He asked the leading French astronomers to look for the planet. They also did not take him seriously. So finally he sent his enquiry to Berlin Observatory. There was a young astronomer named Galle, who actually took the suggestion seriously. He trained his telescope in the direction suggested by Leverrier and found the new planet. That is how the new planet Neptune was discovered.

There is a further story attached to this episode. First of all, all the French and British astronomers felt bad that had they taken the ideas of their young colleagues seriously, they would not have missed the opportunity of finding a new planet. The second point is that when Leverrier's letter reached the Berlin observatory, the Director of the observatory was not there. He was at home celebrating his birthday. Instead young Galle happened to be around who opened the letter. So one may speculate that had the Director been around, he might have thrown the letter in the waste paper basket.

For us the moral of this story is that we should respect suggestions coming from younger people, because they might turn out to be important.

The discovery of Neptune was essentially possible because Uranus happened to be disturbed by it. In general, unless you see its gravitational effect, you cannot readily see a new planet. If you want to find a new 10th planet beyond Pluto, it will be poorly lit by the Sun and will not be easy to find. But if its gravitational effect can be seen on other surrounding planets or satellites, then it may be possible to detect it.

Let me, however, move on to another planetary puzzle of the last century. By 1865 people looking at the motion of planet Mercury (the innermost planet) saw that its orbit too was not following the Newtonian law! The point nearest to the Sun in Mercury's orbit, the perihelion, which should have remained fixed, was slowly changing its direction: so the orbit itself was rotating very slowly. Why? Leverrier, who by now had become a senior and respected astronomer in France, thought that the reason for this was perhaps an intra-Mercurial planet, i.e., a planet closer to the Sun than Mercury, that was disturbing the orbit of Mercury. He followed his earlier method that had worked so well for Uranus in 1845 and concluded that such a planet was plausible. He named the planet Vulcan and asked the observers to look for it. The planet was looked for but could not be found. In fact there is no such planet! So why was Mercury's orbit showing an anomaly? Ultimately it was found out that this puzzle cannot be solved within the Newtonian framework. The Newtonian theory turned out to be incomplete and the problem was solved only in this century by Einstein's general theory of relativity.

Let me come now to the 9th planet Pluto. In Maharashtra there was an observer of comets who had maintained extensive records—his name was Venkatesh Bapuji Ketkar. In a note in the French journal *Société astronomique de France* in May 1911, he conjectured that there is a possible 9th planet beyond Neptune. In fact, Ketkar predicted 2 extra planets, the 9th and the 10th beyond Neptune. One of them he named *Brahma* and the other *Vishnu*. A western name for *Brahma* was given as

Janus. Ketkar predicted that the period of the ninth planet would be about 242 years. This differs from the actual period of Pluto by about 6 years which is not much! However, such a quantitative statement was made by Ketkar but without giving a reason as to how he arrived at this number.

In the meantime at the turn of the century, two astronomers from the West, Percival Lowell and William Pickering, argued somewhat similarly as Adams and Leverrier stating that they had noticed some further discrepancy in the motion of Uranus and this could be ascribed to a new (9th) planet. People began to look for this planet around 1929-30.

How do you look for a new planet in the sky? In Figure 1 you see two separate photographs taken 24 hours apart. You see here one object which has moved in relation to the stellar background. And if you observe such a shift then you suspect that the object is not a star. It could be a comet or a planet which is moving relative to its neighbourhood and so it could be part of the solar system. Arguing in this way C.W. Tombaugh discovered the 9th planet on 15 February 1913. It was given the name "Pluto".

Now Pluto's orbit is not entirely outside Neptune's orbit. For part of its period Pluto is closer to the Sun than Neptune as seen in Figure 2. For example this has happened from 28 November 1978 (till about 1999). So, with this possibility for a few years we may have a different answer to the question : Which is the farthest planet? On an average, compared to the Earth, Pluto is nearly 40 times farther away from the Sun. Its year is equal to 248 Earth years. But look at Pluto's day—it is 6 earth days and 9 hours. Pluto's days are thus long ones and it has retrograde motion. We can also ask whether Pluto has a satellite of its own like the Moon is to the Earth. In fact Pluto does have a satellite which is called Charon. Because of Charon's gravitational pull Pluto wobbles around its position. From the wobbling of Pluto we can work out where its satellite is. This is a very important piece of information. Whenever

you look at an astronomical object, be it a star or a planet, if it is wobbling then you have a strong reason to suspect that there is another object in its neighbourhood which is disturbing it by its gravity. The discovery of any new planet either in our solar system or in another may come about because of this particular property. This is the best way of discovering new planets in general.

Next, let me go back in time to ask how was our solar system born. Because that may help us understand the problem of looking for other solar systems. Can other stars have planets around them ? We are naturally interested not only in an extra planet in our solar system but in knowing whether some other stars have planets or not. One of the reasons for this interest is the very widespread belief that if intelligent life exists somewhere in the universe, it can exist on a planet going round a star. Why is it so? Because life requires energy to sustain it and that energy comes from the star. Life cannot grow on a star itself because it is very hot. What you need is a platform, safe distance away from the star where life can develop. A planet provides one. So if we are able to locate planets round other stars, we have a strong hope of looking for life there.

How do you look for life ? If we have radio-telescopes we can look for radio-signals from technologically developed super-intelligent beings from some other planets. So we need to know where those planets are.

Let us look at Figure 3 which describes our present understanding of the origin of the solar system. It starts with an enormous primordial gas cloud, which contains beside hydrogen some molecules and various other elements. Because of its own gravity the cloud shrinks and, if it has some rotation around an axis, it will shrink more like a disk than a sphere. This happens because rotation makes things fly outwards from the axis of rotation. After a few million years of slow contraction, therefore, the cloud takes the shape of a disk with a central bulge which contracts more like a sphere and becomes very hot. This bulge ultimately becomes the sun or the central star of the

planetary system. Meanwhile the disk keeps spinning round the bulge, and while doing so it develops instability. It cannot retain its shape and breaks up into linear structures which ultimately get into conglomerations of dust and gas. These are the planetary bodies, where you have bits and pieces combined together to form balls that keep going round the central star.

We have in this way a scenario for the formation of the solar system. We can ask further questions. For example, how long did it take for this whole system to form? Based on the geological and palaeontological evidence the present age of the solar system is about 4.6 billion years. So it is quite old compared to the time taken by the planets to form. The formation of planets itself may take a few hundred million years; it being hard to put a precise time span on it. But subsequent life of the solar system or the planetary system is pretty well governed like a clock work. Newton himself had given this analogy—that all the planets go round like a precisely regulated clock.

The next question one can ask is—are all these planets made up of the same material? We obviously find, specially after planetary explorations, that inner planets are more dense. They contain more metals while outer planets contain more solidified gaseous material. How did this happen? As we go farther away from the Sun the ambient temperature drops it being hottest on the surface of the Sun. If we are trying to condense matter into solids near the Sun, we can do so with matter, which can condense at high temperatures. So we get predominantly metals forming the inner planets, whereas if we go a farther out towards low temperatures, we arrive at outer planets made of lighter solidified gases that condense at low temperature. The actual composition of the planets confirms this particular pattern and this gives us confidence that this disk-bulge picture is essentially correct.

Taking all this into account we can ask: How does it help our search for new planets lying elsewhere beyond our solar system? Attempts to look for new planetary

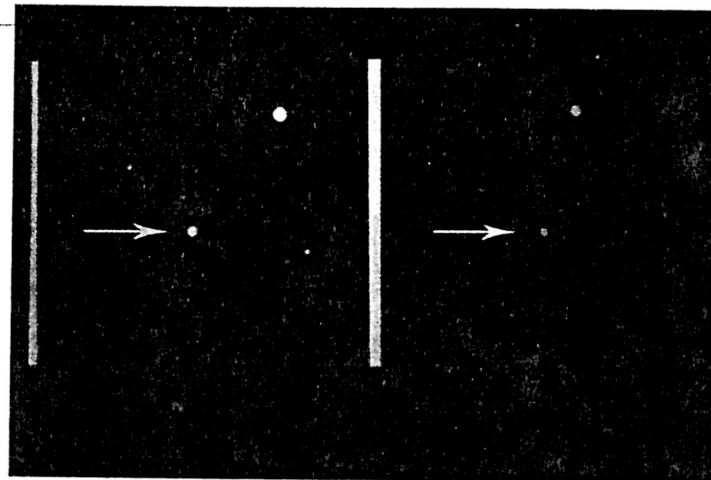


Figure 1

The two photographs of the same part of the sky taken at 24 hours gap in time show one bright spot displaced relative to the background. Such a displacement is indicative of the spot being a planet.

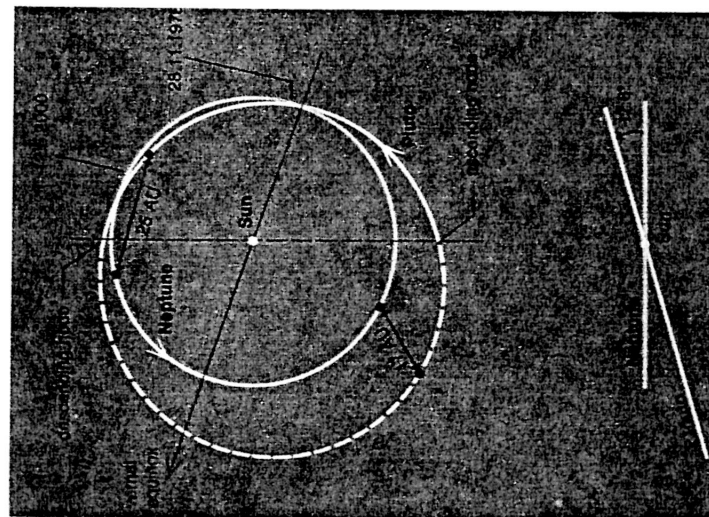


Figure 2

The orbits of Pluto and Neptune intersect and this happened in 1978 when Pluto came closer to the Sun than Neptune.

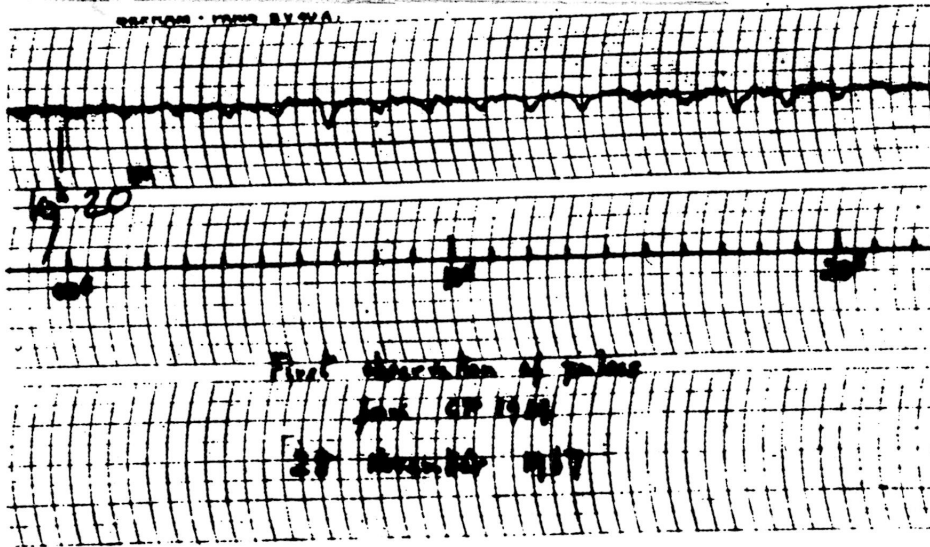


Figure 5
Signals from the first pulsar discovered in 1967.

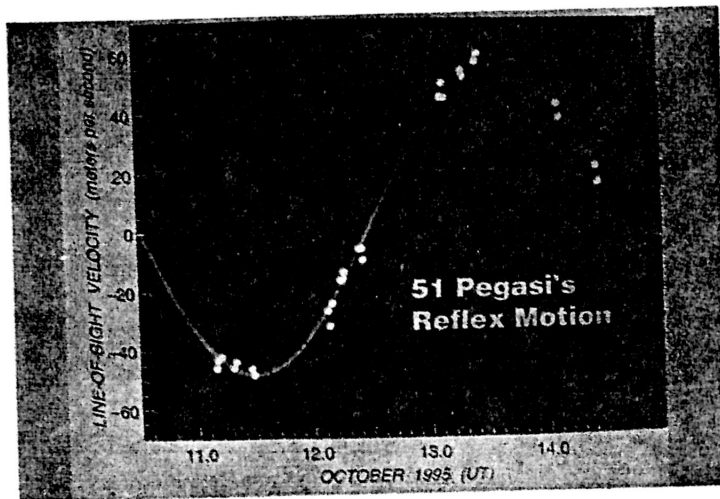


Figure 6
The variation of line of sight velocity of the star 51 Pegasi indicates the existence of a planet around the star.

systems was made by the IRAS (the Infra-Red Astronomy Satellite) which was launched in 1983 and had a lifetime of 10 months. But in that brief period the IRAS made so many different discoveries that people are still analysing and discussing their implications.

One class of IRAS discoveries was of proto-planetary disks. In Figure 4 you have a star called Beta Pictoris—it is a star not too far from us. Its image is formed in infra-red. When you heat up something at a low temperature it radiates infra-red radiation. So, although we say planets do not radiate anything they do radiate a modest amount of infra-red radiation. Now as I mentioned the stage before planets formed had a disc spinning around the star. Figure 4 shows such a disc around the Beta-Pictoris star and there is a strong suggestion that the star is going through the process of forming planets. This and other such examples found by IRAS provides grounds for believing that the process of star-formation also produces planets around stars. So, planets must be very common.

This conclusion of course encourages the lobby of scientists looking for extra-terrestrials because there is a greater chance of finding them on planets around Sun-like stars. In 1991, however, radio astronomers from Jodrell Bank reported the discovery of a planet around a completely different kind of star. Unlike a star Beta Pictoris, which is reasonably young, what the Jodrell Bank people found was a "Pulsar" harbouring a planet.

A pulsar is an evolved star, almost towards the end of its life. Let us first see what pulsars are like. When a star like our Sun, goes through its entire lifetime of producing light, ultimately it will exhaust all its nuclear fuel. It will then settle down as a very compact white dwarf star. But if the star is more massive than the Sun, let us say 20 times more massive than the Sun, it evolves very fast and rapidly burns out its nuclear fuel. But towards the conclusion of this stage it becomes unstable and explodes. While doing so, it leaves behind a core which can be seen as a pulsar. Such an exploding star was seen in 1054 A.D. by the

Chinese and their findings are recorded in their astrological manuscripts. They note that a "guest star" appeared in the sky. Now, why did they use the word "guest"? Just after explosion the star shines enormously brightly but prior to it, the star might be faint and may not have been seen. So, they saw the star suddenly coming in the sky and a few days after the explosion it faded out. To the Chinese viewers the star was therefore a guest visitor to the sky! Did anybody in India record this event which must have been spectacular? We might argue that July falls during the monsoon season, but even then there is clear sky in some parts of the country. Hence this event should have been noticed and recorded. So, we should examine manuscripts which purport to that period—to see some oblique reference, even a poetic one to the event.

Today we see in the place a shining cloud-like debris that is known as the Crab Nebula. Such an exploding star is called a supernova. After such an explosion all its outer envelope is thrown out in bits and pieces. Only the innermost portion survives. And that pulsates very regularly.

The discovery of the first pulsar was made in Cambridge in 1967. When Jocelyn Bell, a research student in the Cavendish Laboratory, was looking for inter-planetary scintillations, she found some very regular signals coming which you see recorded in Figure 5. Of course when very regular signals come you first look for man made sources—somebody might be setting up a factory or running a machine! A very sensitive telescope will pick up those signals. The Cambridge astronomers analysed and confirmed that these signals were not of terrestrial origin. There was also the more esoteric possibility that these were the long awaited signals from the extra-terrestrials! This could be likely as the pulse period was short, of the order of $4/3$ second. Till then astronomical objects were not normally known to have such short and regular periods. Hence the signals might well have been sent by some advanced extra-terrestrials. But this exciting possibility was also ruled out when it was found that there was no

modulation in these signals. If they were coming from extra-terrestrials residing on a planet going round a star, the well-known Doppler effect would operate. As the planet would sometimes be moving towards us and sometimes away, the Doppler effect should alternately increase and decrease the frequency of radiation. No such effect was seen.

After considerable analysis of the data, Jocelyn Bell's mentor, Tony Hewish, concluded that this was a hitherto unknown source and called it "pulsar". Later systematic searches for pulsars revealed hundreds of them in our galaxy. They have been associated with the rapidly spinning very dense cores left behind by supernovae.

But in 1991 when the Jodrell Bank group announced that a particular pulsar seemed to have a planet around it this came as a complete surprise. No one expected to see a planet around a star that was the remnant of a gigantic supernova explosion. How would a planet form in such circumstances?

How did the astronomers make this discovery? The pulsar signals seemed to show a small wobble and that could only be explained if the pulsar had a planet around it, gravitationally disturbing it. So, we are back to the same gravitational effect that I was talking about in the context of Uranus, Neptune and Pluto. The announcement of the discovery was an immediate sensation. A special conference was later arranged to discuss this but as it turned out the discovery was a false alarm. Suspicion as to its validity in fact arose when it was discovered that the predicted planet was having a period of 6 months or 1 year: exactly matching the Earth's period! Ultimately it turned out that because we are observing it from the moving Earth, our motion also affects the data and produces the periodic pattern. So, this was no real effect: it was simply the result of observing a pulsar from a moving object. Ironically while this discovery was being retracted by Andrew Lyne from Jodrell Bank, Aleksander Wolszczan, an astronomer working at the radio telescope at Arecibo in Puerto Rico reported that he had found another pulsar with two planets.

Now, remember if you have a false alarm people are less inclined to believe a similar case. They will obviously ask for check and double-check of the records. But Wolszczan had already taken sufficient care to see that the effect of Earth's motion or any other kind of spurious effect is removed. Thus he was confident of the reality of the effect which was also checked by others.

So, at least two planets have been known to move around a particular pulsar and one of these two planets has a mass of 2.8 times the mass of the Earth, the other 3.4 times the mass of the Earth. Their respective periods of going round the pulsar are 66.6 days and 98.2 days. So they are moving relatively fast like Venus or Mercury. Their distances from their parent star are 70 million kilometres and 54 million kilometres. So they are relatively close by. Just for comparison the Earth is orbiting the Sun at a distance of 150 million kilometres. Now observers have claimed that there is a third planet also in that system. But, we still do not know how those planets got there. That is however for the theoreticians to worry about !

Now let me come to another example of the discovery of a planet announced a few months ago. This planet is not around a pulsar but around a star that is more like the Sun. It is more comforting to the theoretician that at least a Sun-like star has a planet. This has been discovered by the method which I mentioned earlier viz., that if the star has a planet around it the star's position will oscillate. Figure 6 shows the line of sight velocity of the star (called 51 *Pegasi*) measured by using the Doppler effect. This motion is oscillatory and tells us very definitely that such a star has a planet of about $1/2$ the mass of Jupiter and its period is about 3.22 years. So, the planet's year is longer than the Earth-year, and it is at a distance of 7 million kilometres, very close to the central star. These conclusions are arrived at by the analysis of this particular curve.

If you now take stock of the situation, we have three known planetary systems. Our Sun which has got nine

planets. Then we have the pulsar with 2 (may be 3) planets and the third example is of 51 *Pegasi* with one close massive planet.

The technique of interferometry has been used by radio-astronomers very effectively for several years, may be two or three decades. But now optical astronomers who use visual light can also use this method for detecting new planets. Here you have two dishes: two optical telescopes combining their light signals together so that they can interfere and from such signals you can improve the clarity of your image very much. People have recently found that with optical interferometry they can see objects much more clearly; for example what had appeared as a single star known as *Cappella* was recently resolved into a double system. So instead of one blob for one star they would see two and these two are going round each other.

This technique can be used with suitable bigger telescopes to look for planets going around the stars also—which would normally be invisible. If this happens and I am sure it is bound to happen—more and more optical interferometers will be built. For example the twin Keck telescopes, each with a mirror of 10 metre diameter, will form a big interferometer. For such a powerful combination of telescopes finding new planets will be a routine. So, may be within another decade we will have found a large number of planetary systems. The SETI (Search for Extra-Terrestrial Intelligence) programme can then be revived again to make more sustained observations of some of these selected planets to see whether life exists in outer space. So I end in an optimistic vein that we may find that we are not alone in the Universe, that the Universe contains more intelligent people than us. We should not therefore delude ourselves into thinking that we are the cleverest creation of this Universe.