Research Methodology

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Lecture - 28
Proposing a Hypothesis Part 02

As an example of this process of formulating hypotheses and testing hypotheses; let me site the example of our quest to understand the origin of the solar system.

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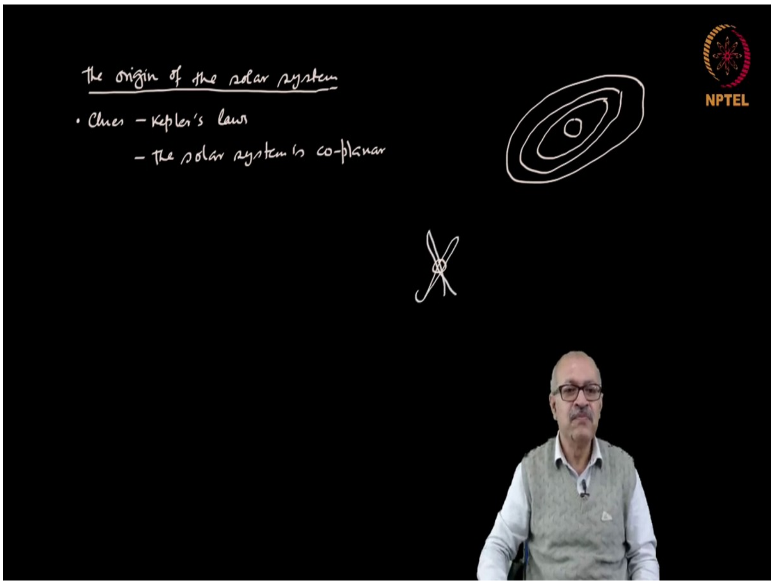

So, we are talking about the origin of the solar system. The origin of the solar system: this question itself did not occur to people, so long as people believed that the whole thing has been created by somebody, at some point of time. So, nobody really questioned that for a long time through the middle ages. Nobody asked what can be the origin of the solar system.

Only after Newton showed that the motion of planets can be predicted by humans, we can understand that using natural laws—only after that, only after the advent of mechanical materialism, people started worrying about the question of the origin of the solar system.

So, when this quest started, the first thing one does, is to find out what are the clues. Clues regarding the thing in question, in this case the solar system. What were the initial clues? Let us talk about the clues. The first clue was that in the solar system, all the planets move in elliptical orbits with the sun at a focus. That is the Kepler's law. So, the first one was the Kepler's law.

The second was that in a system where you have the sun at the center and the planets going in elliptical orbits, you can conceive various different planes of the orbits: one like this, another like that and third like this and so on and so forth. But that is not actually true. We find that all the planets move in the same plane. They are coplanar.

How do you know that? Simple. If you look at the sky on any evening and try to look at the planets, and if you do that night after night, you will find that all the planets are moving in a particular strip, a strip that is also shared by the motion of the sun and the moon. That means, everything is in a particular plane, and that strip is called the zodiacal strip.

Why does that happen? Because the solar system is coplanar. So, it is like, here is the sun, one is moving like this, another is moving like that, all of them in the same plane. It is not like sun is here, one is moving like this, another is moving like that. No, that is not true. So, that was a clue.

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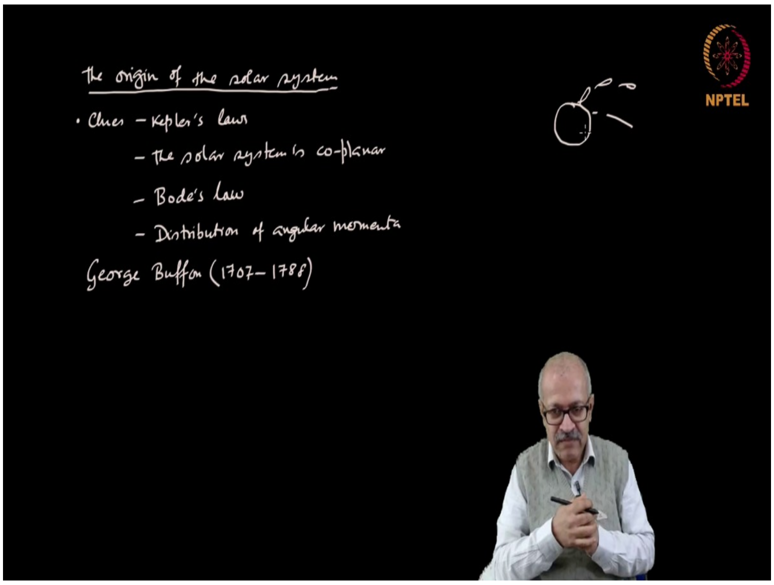

Then the distances to the planets also has an order, called the Bodes law. I will not get into the details of it. But the distance from the sun to the planets also follows some kind of a law, an empirically observed law. But nevertheless, the planets are not in just any position.

Thirdly, people had observed that the sun is actually rotating body and therefore, it has an angular momentum. The planets are also rotating around the sun, and therefore, they also have angular momentum. And when this angular momentum were measured, people found that the angular moment momentum of the sun, a huge body, is very low: about 0.5 percent of the total angular momentum of the solar system.

And the larger chunk of the angular momentum is carried by the four giant planets in the outer periphery: Jupiter, Saturn, Uranus, Neptune. So, the clue was regarding the distribution of angular momentum.

Such facts were known about the solar system when people started trying to guess how this solar system came into existence.

And the first shot came from a French naturalist, George Buffon. His timing was 1707 to 1788. He pictured that, at some point of time, the sun was an isolated body without any planetary system around it. And he guessed that some comet came and hit the sun. At that time, it was not known what comets are made of. They look big and therefore, he believed that it is a big object and it came and hit the sun.

So, there was a sun like this, and it is hit by something. So, a few droplets will spill out of this and these droplets ultimately condensed into the form of the planets. That was his hypothesis. Notice that, this hypothesis actually satisfies all the requirements that we have stated. The falsifiability requirement, I will come to that later.

After some time it was found that the comets are very small objects. They look big because that is diffused. They produce a long tail of very dispersed gaseous substance, but the mass of a planet is not substantial to do what Buffon actually pictured doing.

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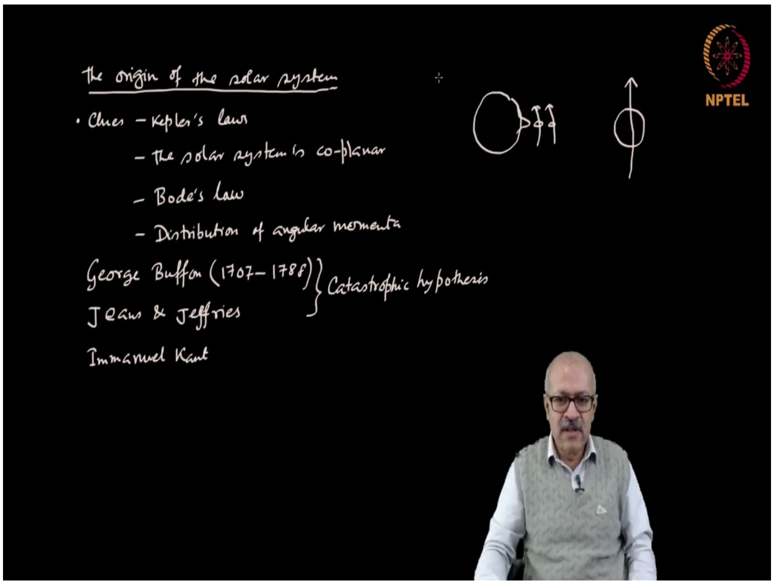

So, in that situation, two scientists James Jeans and Harold Jeffries, they proposed that, might be that the body which actually caused this was not a comet. But suppose the sun at some point of time was an isolated body without a planetary system, but another star passes nearby. What will happen?

Because of the tidal action, because of the attraction of that other body, there would be a bulge created and at some point of time, parts will be torn off from the body of the sun. And as this fellow moves away, these will keep on rotating around the sun and after some time, they will condense into the planets. This is also another hypothesis, which was consistent with the clues and satisfied all the requirements of being a scientific hypothesis.

These kind of hypotheses were called the 'catastrophic theories'. I would rather call them hypotheses. Catastrophic means the creation of the planetary system is caused by some event, something catastrophic happened, like the collision with something or a nearby star passing close by, so that it tears off a part of the sun. Something catastrophic.

The philosopher Immanuel Kant (we have met him earlier in the classes on causality and other things) is the person who pictured that everything in the material world are in a state of flux, in a state of change, evolution. Therefore, he also pictured the solar system as having been created through a process of evolution. How? He said that before even the sun was there, in that position there was a diffused nebula.

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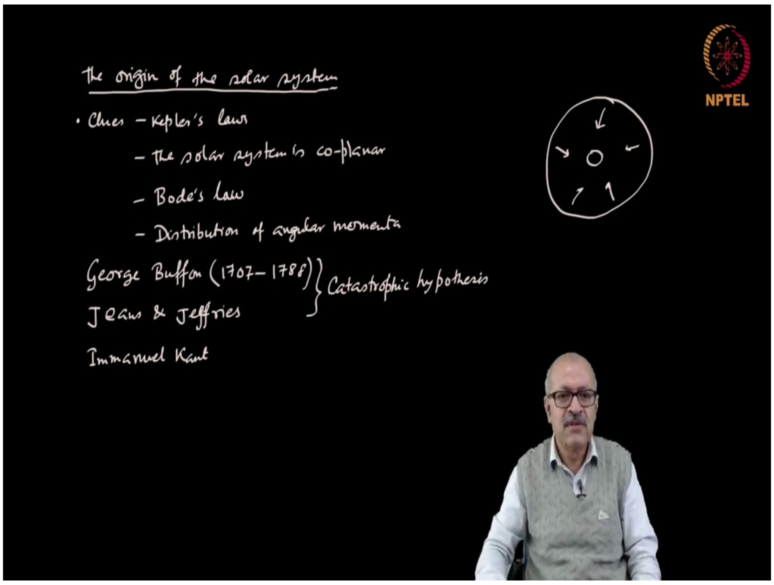

If I draw it here, there was a diffused nebula, say, over this range. There was a diffused nebula. Nebula means it is a dispersed cloud of gas and dust. This nebular cloud will have it’s own gravity and so, by the action of that gravity it started to condense. So, it would condense and collapse. It is called ‘gravitational collapse’.

And as it condensed and collapsed, the potential energy of the particles will be lost and that potential energy would be converted into kinetic energy of the particles and thereby the temperature of that gas will rise. At his time the fact of thermonuclear fusion was not known. So, he pictured that it will become hot and ultimately this collapsing process will produce this star at the center.

But while this was happening, if this initial mass of nebula has a slight bit of angular momentum, then, as it condenses, the angular momentum will be conserved. The conservation of angular momentum will make it spin faster. If it spins faster, it will become something like a disk. So, it will not be exactly like that. It will become a disk-like thing, something like this. I would picture it like this.

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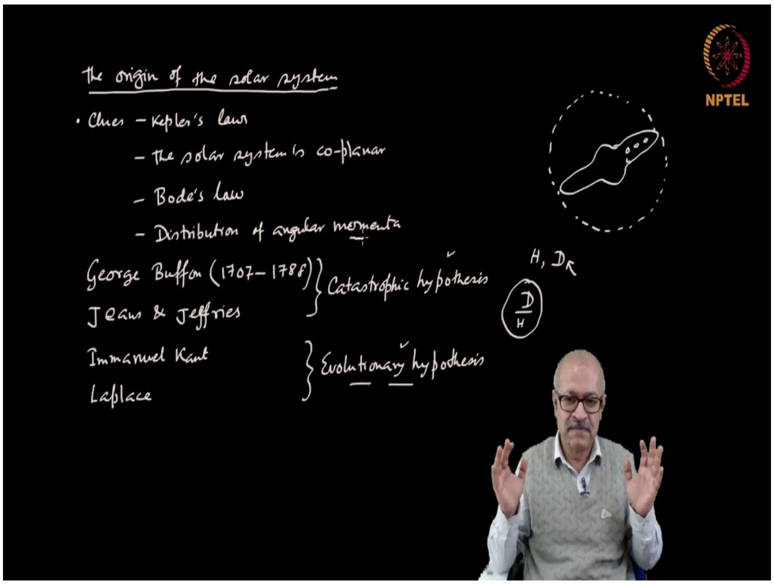

The central part, central bulge, that is what produced the sun and the disk-like part, this is an extended part of the disk, in that part the planets formed by condensation. That was Immanuel Kant's theory.

This theory was supported by many scientists including Laplace. So, when Laplace took up this particular idea (he was a great man in classical mechanics), he calculated and showed that this disk it will not remain a single disk. It will become composed of rings, rings of gas and dust. Each ring would condense into one planet and that is why the planets are there at different distances. So, it is not just a uniform mass on the disk, but it will look like rings, like the Saturn's rings, and the planets will form in these parts. It will go around, it will be rotating, and as the rotation happens, through collision between particles, planet formation will happen.

So, this was called 'evolutionary hypothesis'. Notice that both these hypotheses are scientific. Scientificity does not depend on whether ultimately it proves to be true or not. These both these hypotheses are scientific. They are based on material processes and phenomena. They satisfy the initial clues, so on and so forth.

But James Clerk Maxwell, the same Maxwell of Maxwell's distribution or Maxwells laws of electromagnetism, he argued that the sun and the planets, after all, formed from a mass of gas and dust that is distributed over a range something like this, that was initially distributed over a range something like this.

So, today whatever is the mass of the sun and the mass of the planets put together that must have been, at some point of time, distributed over this range. Suppose that is a sphere; so, how much will be the density of that sphere? When we calculated that density, he found that it is so low, that it would be insufficient to cause any gravitational collapse. So, the sun cannot form out of that kind of a process.

Because Max Maxwell showed that, for a great stretch of time the evolutionary hypothesis was actually abandoned, and the catastrophic hypothesis was actually supported by people. Then in the 1920s a German scientist Weizsacker hypothesized that the initial mass of the nebula was much larger than the mass of the solar system today, about 100 times larger. So, that would be sufficient to cause the collapse.

Then he said that when the sun starts burning, it emits what is known as the 'solar wind', and that is what ultimately pushed the large mass of gas from the periphery. That gas was lost into the neighboring areas, leaving only the planets bare. So, ultimately it will settle to a mass which is about one-hundredth of the initial mass of the nebula.

When that hypothesis was proposed, again the evolutionary hypothesis came into light; that means, both these became competing hypotheses.

Now notice, each hypothesis should have experimentally testable predictions. So, what can be the experimentally testable prediction? The people who proposed the hypothesis, at their time this methodology was not all that much developed. So, they themselves did not propose the experimentally testable prediction, but other people did. Other people started from that premise and by logical derivation they argued certain things.

For example, it was known that hydrogen and deuterium are two isotopes: hydrogen and deuterium, H and D. Deuterium is a very stable substance and it does not break up easily unless it is subjected to great heat, like at the center of the sun. When it takes part in thermonuclear reaction, then it can no longer remain deuterium.

So, when this was learnt, it had implication for the catastrophic and evolutionary hypotheses. Notice the question: 'were the sun and the planets co-genetic?' That means, were they born through the same process, or the sun was formed earlier and the planets later? Two possibilities.

Another question: 'were the material that form the planets today ever heated in the temperature of the sun?' Because, if they were a part of the sun, and they were torn off from the sun, then the that material was a part of the sun earlier.

Well, now this logic was that, if deuterium is a very stable substance unless subjected to the heat as in the body of the sun, then if the material that is now forming the planets was ever a part of the sun, then definitely the deuterium to hydrogen ratio would be different in the sun and in the planets. If the planets never were a part of the solar body, then the D to H ratio will be different, while if these bodies, the planets, were at some point of time a part of the sun, then the D to H ratio would be the same.

And then people went on to actually measure the D to H ratio in the sun and in the planets. For planets, we already have that. On the Earth, we could easily measure that. When people measured that, they found that these are different by two orders of magnitude, which means it immediately proved wrong those hypotheses that said that the planetary material was, at some point of time, a part of the sun.

Those theories are definitely wrong. Therefore, people homed on to, or they had a larger trust on, the evolutionary hypothesis, which is now accepted to be the correct explanation of the solar system.

In the meantime, other hypotheses were also proposed. For example, some people proposed that, it is a catastrophic theory, but the body that came close to the sun was not a full-fledged star. But it was a proto-star before the thermonuclear reaction started. Therefore, when the body actually passes, the tidal action will tear off drops. But these might not be from the sun, but from the other body. All those kind of theories were there. Notice that, people were, at the time, proposing many possible hypotheses that are consistent with the clues.

But ultimately the test came in the form of checking whether the material of the planets was, at some point of time, in the sun or not. And when that test came, people realized that the catastrophic hypothesis cannot stand any longer and we have to home on to the evolutionary hypothesis. And within the evolutionary hypothesis also, there were some variants, different hypotheses, and we are now working towards eliminating the wrong ones and homing on to the correct one.

For example, the reason for the distribution of angular momentum—that is still a point of argument and debate. What actually caused the specific distribution of angular momentum? People are trying to work on that. People are again proposing hypotheses and testing and the wrong ones are being eliminated to find out which one is correct. This is how science works.