Celestial Mechanics
Stars, Planets, Satellites, and Relativity

Lecture by A. R. Hochstrim
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1 hour, 06 minutes, 31 seconds

Speaker: A. R. Hochstrim

Transcribed by: Sherry Yin

Time	Transcription
00:00	Marian Longstreth: It is a pleasure to welcome so many students at the second lecture on the series, The Physics of Space, sponsored by the Theatre and Arts Foundation of San Diego County, the Scripps Institution of Oceanography, General Atomic, and Convair San Diego. Today we shall have the opportunity of hearing the senior research engineer at Convair, whose special field is the study of missile reentry phenomena and the application of relativity in the determination of the trajectories of space vehicles. He is a native of Poland but studied physics, mathematics, and chemistry at Goethe University in Frankfurt, Germany. In 1949, he came to the United States of America and received his Master Degree of Science at Florida State University. He has had many papers published, among them are three on the gas properties behind shock at hypersonic velocities. He will speak to us now on celestial mechanics, stars, planets, satellites, and relativity. I take great pleasure in presenting to you, Adolf R. Hochstim.
01:20	[Audience Clapping]
01:28	Mr. Hochstim: Thank you. I want to apologize for my English there. I'll proceed with this lecture and I'll outline a little two large fields for one hour of discussion. I'm going to talk about planets, satellites, and galaxies, and I'm not going to describe the particular motions of all those celestial bodies but I will concern mainly on the basic physical principles, which were discovered and are very well-established, how they move, and why they move. And I, you get this impression actually that I will not go to any detail in this lecture and I wish you only to remember this may be what I had one time a famous professor in Germany told me, I mean told the class which I was attending that the lectures usually are only outlines for the material to be presented and to be studied at home and not all the information about the subject.
02:50	Mr. Hochstim: So this, I hope I will succeed with this lecture if I only will create some type of curiosity in you so you will go to the books for all the details which would you like to know. At the end of the lecture, I will demonstrate to you, if you would like to closely, some of the experiments which I designed especially for this lecture. I had a little tough luck with this and I don't, couldn't get too strong lights for that demonstration so I don't know if you could all see this. So I will show it anyway and if you wouldn't be able to see, at the end of the lecture you can come and see it from close up. I think that is a spectacular illustration of conic sections. It really belongs to the mathematics. Those conic sections were discovered long ago by ancient Greek's mathematicians but peculiarly there is no nice models for that demonstration and it's very hard to conceive all those ellipses, hyperbolas, parabolas, and circles which you can obtain by cutting a cone with a plane.
04:05	Mr. Hochstim: I hope this will clear up in your mind. To tell you the truth, I knew about how it should look but I've never seen it myself until about an hour ago when I played with this cone. Now, I would like to have the first slide and show you

something about the distances of planets. I was warned I'd get a shock. Could you focus this, please? No, it's upside down. [Audience laughing]. This is the solar system and when I was asked and I asked a girl to - an artist at Convair - to plot this to the scale, we got a little difficulty. The scale is so large that if I would need to put the Sun here and the first planet Mercury here, I would need to put the last Pluto and I think about half a mile away. So what we did here, I didn't even realize myself the dimensions, we plotted something called semi-logarithmic scale. This means that each let's say inch here if you go by 1 inch and then you go to the second inch, the second inch then identify 10 times longer distance; the third inch will identify a hundred times larger distance, and so on. Now I, to get the idea of how far the planets are really away from the Sun and from each other, I want to tell you, that you probably know, the velocity of light travels with extremely fast speed. The velocity of light is something like 300,000 kilometers per second or approximately 886,000 miles or so and in the conversion. And velocity of light is so fast that in one second it goes something like eight times around the world.

06:13 Mr. Hochstim: Now, can you imagine the speed of this light that if it leaves the Sun, it will arrive in Mercury after three minutes? Can you imagine the dimensions, the tremendous dimensions here if it takes three minutes for light to reach Mercury, takes six minutes to reach Venus, eight minutes to reach Earth? And what it means? It means that if suddenly the Sun, hypothetically let's say, will disappear or stops shining its light, we will not notice it until eight minutes after. Now, eight minutes of this tremendous distance, this is millions million miles, some kilometers, something like 150 million kilometers is Earth away from the Sun. Now, farther away is Mars and the light will reach from the Sun in 30 minutes, then Jupiter 43 minutes, and so on to the last planet in our solar system; the light will travel five hours I think, and 30 minutes and this is just hard to conceive this distance. Now even if we can never travel according to relativity, we can never travel faster than velocity of light and probably never as fast as velocity of light. So we can travel, let's say, something with one-tenth of velocity of light. Not now, maybe in thousands years progress of science. Then finally sometimes we can reach the outside planet, the fastest would be something like 50 hours.

07:48 Mr. Hochstim: At the present time, it would take many years to reach, a couple hundreds years probably to reach Pluto, to the last planet. All of those planets move in elliptical orbits. and I'll illustrate it later what we mean by the word ellipse. but some of them move by very elongated ellipses. And these are called, they are planets also but recently discovered and they are called asteroids. The asteroids here have very elliptical orbits and most of them, thousands of small objects, the small planets, few miles in diameter to few feet in diameter and they are mainly located between Saturn and Jupiter. These little points here indicate satellites, natural satellites, I think. With Jupiter here, these mini-satellites: Uranus, Saturn, and so on. Earth has one satellite, natural, it's the Moon. Now in this lecture, we will be given some of the planet Neptune. They will indicate that Earth has maybe three or four satellites if they see it. Now as you see, also the objects which can move in so-called hyperbolic orbits, which you will see this hyperbolas in a few minutes. Now, those are called comets and they move in hyperbolic or parabolic orbits. And if I may have the next slide, you see a spectacular photograph of a comet. The comet goes around the Sun also and we don't know exactly what it is composed of but mainly of dust and very low-density gasses of solid particles. They are very spectacular and if you see the next slide, please. May I have the next slide, please?

09:50 Mr. Hochstim: This doesn’t matter which way. So, this is a comet and it has one particular features. It goes very fast over the sky, in a couple of days or so it will disappear. This is a comet which was seen first in 1908 and this is a thousand miles long tail it has. And an interesting feature of the comet is, has the comet tail is always away from the Sun. This means the Sun is now here and as it, as the comet travels around the Sun, the tail will always be in such a way that is away from the Sun. The explanation of this which is not yet the most satisfactory is that the light exerts a pressure on the little dust particles and this is why those little light particles of dust move away from the center of this comet. Now, you know probably there are many meteorites and meteors and I would not discuss them because you probably already know them, you had the so-called falling stars in many of the books and so on. I would like to explain, this is all for the slide, thank you. Could you, may I have the lights also, please? Now, I would like to explain. This is, this is all. Thank you for right now.

11:29 [Audience Laughing]

11:35 Mr. Hochstim: Just turn it off. No, turn it off, please. Thank you.

11:45 [Audience Clapping]

11:51 Mr. Hochstim: I, I would like to tell you something about the conic sections and I hope this equipment will illustrate what I mean by those ellipses, parabolas, hyperbolas. Here you see a little cone, inverted cone, they are doubles, this is a doubled cone actually. And if you cut the cone under any angle, you would get certain curves on the surface of the cone. If you cut the cone under such an angle here, you would get a curved ellipse. In this equipment, I painted this cone with fluorescent material. And if I shine an ultraviolet light, it will glow at the point where the light hits the surface and you will see this ellipse. Now, if I move this light source or the plane of light, I have a beam of light, very plane light, parallel to the axis, you will see a hyperbola, a curve this way which is open. And on top of the other cone, and you'll see another part of the hyperbola. Hyperbola has two parts.

13:10 Mr. Hochstim: When we say that comet travels on a hyperbola, we really mean it travels on one part. And if you hear that the comet travels on hyperbola, this means it never returns back to the Earth. This means if the 1908 comet traveled on hyperbola, this means it approached the Sun here, see the Sun, it approached the

Sun, and went away in space forever. But if for example, it travels on an ellipse, this means it will turn back. The same thing is for parabola, parabola is a curve which you obtain with a light shining parallel to one of the sides. And obviously, if I had a light traveling parallel, it will never cut the other cone. So parabola has only one part, looks exactly like this too, but it has only one part of this curve. Now, there are - maybe I better explain - maybe I can proceed to this experiment. And I don't know if everybody will see. So please, actually you could come a little closer maybe. Would this be all right? I guess there would be too much noise in that recorder. So we better proceed with the experiment and those who wouldn't be able to see could see it later after the lecture.

14:34 Mr. Hochstim: Now if I could have a complete darkness. Or, I have a double cone here. You see it later after we turn on the lights. Could I have the light just for a second? I want to show you the cone first before I. May I have the lights just for a minute second to show the cone, please? [Audience Laughing] Ok, as you can see, I have this cone here and ok lights off I guess. I guess everybody is seeing this double cone. Now look here, can you see this glow? I wonder how far can you see it. This is the piece. Turn off this lights. [Audience Laughing]. Ok, do you see, do you see this blue image on the cone? Can you see it clearly? Now, this is a circle because the line cuts the cone perpendicular to the axis or parallel to the base. Now, this will be at any point if I make it parallel, the circle, and then of course on the other part of the cone again. Now, if I tilt it a little, this cone, then I'll get an ellipse. I hope it works. Yeah, all right. Now you see a very nice ellipse, there are many ellipses. There are infinite amount of ellipses you can get here and all of them, as long as I keep them a little under the angle to the axis.

16:28 Mr. Hochstim: I'm afraid I wouldn't be able to show you the hyperbola very sharp because I need those two slits and if I remove them the light will be not as intense. It's sharp but nevertheless, I will show you but you could almost imagine if I have a small little cone, you could see it. But you see now those ellipses and these are exact curves and they were known to the Greeks. The ancient Greeks, what they did, they cut from a piece of wood, something like an ellipse, and then cut it on a certain corner. This model is nice because you can get almost any ellipse without cutting the cone. And now, I want to show you the parabola and hyperbola. You could see probably. Oh, I can demonstrate parabola on this little cone. You see now is a circle and now as I tilt there is an ellipse, ellipse, ellipse and suddenly the ends go away, and at one point. They don't meet any more and this is the parabola you see. They are many parabolas as long as they are parallel to the axis. See if a comet or planet will move on the parabola, they will never come back. They go one way and since the ends don't meet never, it will never come back.

17:45 Mr. Hochstim: Now, hyperbola would be a curve, which is something like this and goes on the other side. I think you could see it slightly like that. Let me get, you could, can you see one part on this cone and one little part on the other cone? I, it's not too good. Maybe I can remove one slit, maybe we can get it. I didn't have the time to try that, if it works, just last minute. Now you can see on both sides. Can you see? Now, let me see, maybe, now this is hyperbola. It has, there are actually two curves and you can see for example, now one part glowing and one hyperbola, and the distance between these two parts of hyperbola is large. Now, it's smaller and smaller. Now if I, in this position, you have a very nice ellipse. Now, this is parabola. It doesn't, the ends don't meet together. Can you see that and can you see the both ends? Now for example an ellipse. And now again, we go again and get a circle. Now we can have another ellipse here this way and this is again parabola, very nice parabola I guess for those. You can come over later and play with it if you want to. May I have the lights, please?

19:45 Mr. Hochstim: [Johannes] Kepler was the first, around the 16th or 17th century, who discovered that planets do move ellipses, on exact ellipses. And to tell you about ellipses, I couldn't do this on a model. Ellipse has two points. This is one called focus and this is another focus and Sun is in one of those points, locus. The Sun is located at one of those points. So all the planets move around on ellipses. But Kepler didn't know that, but lately, we know. And this is from, Newton originated idea, that any object can move on the ellipses, also on parabolas, and also on hyperbolas. And when you start, for example, sending a satellite around the Earth, if this is the Earth and we send a satellite, one possible orbit, it would be a circle as you saw. Because all bodies will move on a conic sections. Now, another possible orbit would be if we give more energy to the satellite it will go a little faster with greater velocity and the satellite will go in ellipse, and Earth, center of the Earth, is in one of these points called, I mean this is the focus of this ellipse.

21:25 Mr. Hochstim: It will give a little more energy at certain particular energy, or those ellipses will get more ellipses like this and so on. And then finally, at one particular energy, we would get a parabola. And as you know parabola, the ends don't meet and a satellite going inside this parabola will just disappear and go away. And who knows, maybe it will be attracted later by the Moon or other planets if it meets it on the way. But theoretically, it could go in parabola. There is one parabola in such a case. But now what happens if you give them more energy? If you give them more energy, it will go on hyperbola. And that, there are many now hyperbolas possible and also escapes from the Earth. Now, as, this is what is called the first law of Kepler, that the bodies, celestial bodies move on one of the conic sections. This means ellipses, circle, parabola, hyperbola. But this is only true when you have one body, a heavy body like Earth, and one light satellite or if you have a heavy Sun and one or few planets. If you have let's say systems like Earth and Moon in the vicinity of the Moon, those orbits, what is this called, the trajectory of those planets, those orbits are not more conic sections and they are very complicated curves. And the second slide will illustrate the Moon phases and I don't think, I'll just show you for a second but I will proceed to the third slide almost immediately. Just showing you for a few minutes, a few seconds, that second slide, and then we will go to the third one.

23:24 Mr. Hochstim: Now, this year by the phases of the Moon and I just thought it would be of interest, would be of interest to show how, why do we see those various parts of the Moon not always full in light. But when the sun is here, then obviously this part, this part here, it's all in. Just see what happens. The colors are such, this is a negative of the picture. So this side is light supposed to be, this is supposed to be dark. That's not, is it? It's not very - So as you see the Sun, this is the lighted part, this is the dark part. But this is always light, this is dark. This is light dark because they are away from the Sun and light from the sun is parallel. Now, it would appear to us as the full Moon here, and I guess this is hard to see because this is on the negative. I apologize for that slide. But I will show you this in a spectacular demonstration with the ultraviolet light. I have a globe here and let's for a moment assume that this is the globe of, I mean represent the Moon, not the Earth. Just ignore the political map on it. And I will illustrate you why you see those little parts, not the entire sphere. I, this is all for the slide, thank you.

25:08 Mr. Hochstim: Now, I have here this strong ultraviolet light and I painted this globe with that - this is very dangerous light and I don't want you to look at it - and I painted this globe with ultraviolet so it glows. And assume this moment this is Moon, this is much lighter than black, and white light, and regular light because it has no dispersion. This means that there's a definite edge between light and dark where regular light is dispersed and you don't have this sharp division between light and dark. And as you see as the Moon moves, if this is the Sun and you are located where is the Earth, then you will see this in various phases. In this phase, the moon appears to be all in light. Of course, then Moon travels in certain position where you don't see it all and suddenly, I don't know if you can see it, it will appear to you as a small crescent. Can you see this? And now more, I didn't see it from your side never. Ao I don't know if you can at all see it but. So you see that the idea of a crescent is here, that you are located with respect to the Moon and Sun in such position that you see this light only on a part of the hemisphere. May I have the third slide, please? The next slide.

26:45 Mr. Hochstim: Now, I plotted those curves from a newspaper. I couldn't find any information but I guess this is all right. And here we have orbits of Earth satellites and the Earth rotates around this axis here. This is the North Pole and this is the South Pole. And the nice things about it, if you're interested, for certain time if this is the axis, the Earth will rotate in this direction from east to west, from west to east and the plane of the satellite remains fixed to certain degree of approximation. This means for a while you can imagine that this is, the satellite goes on space in the same way and only the Earth moves underneath. And this is not very true because of certain small effects due to the Earth is not exactly spherical and due to this effect, this plane of orbit will slightly move. In about a year, it will move about three times around the Earth or so, depending on the particular orbit. But you saw a very complicated pattern of one satellite on the Earth. They are just very simple, you can do this. You simply, you yourself can make a little wire around the globe and move the satellite on it and rotate the Earth underneath and then you see which point on the Earth this satellite will be. This will hold for about 100 or so rotations. Then the orbit must be a little tilted. Now, you have heard so much about this on the newspaper and TV that I'm not going to discuss this in more detail except I want to tell you that this is you see a satellite, this is the orbit of a satellite and this particular orbit of a satellite is very easy to see is ellipse and those small almost ellipses, almost approaching a circle. Now, may I see the next slide, please?

28:56 Mr. Hochstim: This will be hard. I want only to show that you want without it, with only knowledge of little algebra can compute the time of any given satellite you would get from a newspaper. And I pick up just from *San Diego Union* or from any other paper I could as well. Pick up the data of the maximum altitude at which the satellite is seen and the minimum altitude and from this information, I compute the orbit of a satellite. Now, this slide I guess it will be available to high school so you could try to get it and I got almost exactly the prediction of the time which agrees which was reported. This is just rough calculation and you can see, you can get it almost very closely without, without much detail of electronic computers because the basic principle of physics is behind it. And this is called the third law of Kepler, skipping the second. And the third law of Kepler, which says that if this is an ellipse, if this is an ellipse and this distance is A from the center to here and we call this the cubes of this distances, A cube - this distance cubed - divided by the time it travels around to make a complete cycle, divided by the time squared is constant. This means for the Moon the distance A, this distance cubed, divided by the time it goes around is equal to the distance on any satellite from the Earth divided by the time it travels.

30:43 Mr. Hochstim: So if you knew, you know all the data about the Moon and now you know the data about the particular satellite if it's given to you, then you can compute the time. Now, this distance, this is the Earth and this is the maximum distance at which the satellite is seen, this is the minimum, and the 2R is the diameter of the Earth. So obviously the maximum plus minimum plus two R gives you a distance of 2A. And knowing the ranges of the Earth, you can get the A forever any satellite for which you know the range maximum, range minimum. This is what I did. I took all this various satellites and arranged them in order such that this elliptical distance A, that 2A, this big axis of ellipse is largest here and smaller this way. Now I take A and cubed it, take square root of the A cubed, and compute the time by the simple relation, you can get the T here. I'm not going to go into too much detail about this calculation. Anybody who took algebra from you could do this very simply. And then you get a little equation, the T for satellite is equal to some constant and multiply by this factor. So you multiply this by some constant you get, 96.8 minutes, 104.3 minutes, and so on.

32:08 Mr. Hochstim: And the data, the newspaper gives a very close data on the satellite when they check with the satellite people. They gave even better data and they check even better, within about one or two minutes. And this one and two minutes require an electronic computer to get these little details. But for high school purposes and college purposes, I think it's sufficient if you get the time from simple calculations like that. Now, this is his famous third law of Newton and we're base, we're basing it, the Moon is also a satellite and we know all the data about the Moon. Now, I would like to on a blackboard, to do a very simple problem to compute how far away from us we should shoot, sometimes in the future a satellite such which will have 24-hour rotation around the Earth. If it has 24 hours, the time of the orbit will be 24 hours and the Earth's rotation is in 24 hours, then it would be always, let's say this is an equatorial plane above the equator. So if you from the equator at the top, you always will see on the top of you this satellite and will always go with the Earth. So with respect to Earth, we will be stationary; I mean from the Earth you couldn't tell if this traveled. This is a very interesting satellite and let's see how far away is it possible that we can do it right now and send such a satellite, which will have the same period as Earth. No how can we do very simply that? May I have the light, please?

33:52 Mr. Hochstim: I am, I'm going to talk later about some stars and galaxies without mathematics. This is the last one little equation, and for those who took algebra, this will be very simple. Now, what happens this here - I'm getting shocked from it. Now, the distance A of the ellipse, the A from Moon, from satellite, this particular satellite we would like to, cubed over A over T time for the satellite, which we want, squared must be equal to A for the Moon cubed divided by period of satellite, area of the moon squared. Now let's put some numbers to it. We would like to have, we would like to know what is the distance for A cubed satellite, so we take A cubed of satellite equals T squared satellite which brings this on that side of the equation and here we will have A of Moon cubed divided of T square Moon.

35:29 Mr. Hochstim: Now, if we take the cube root out of it, you would get A satellite equals T squared satellite, over T squared Moon, and cube root out of this. So this is, this over that, and still, we would have A cubed. The cube root is A Moon. Now, we can take, now let's see. Let's put T for satellite, we would like to have one day. So this is the square root of one over and T squared for the Moon, this is the cube root and T squared for the Moon is equal, you know maybe 27 roughly days the Moon goes around the Earth. So let's take 27 squared, or 27 times 27. You know how much is this. The cube root of 27 itself is three because three times three times three is 27. So what is this? The A satellite is equal, the cube root of this is one-third. And the cube root of this is one-third. So it's one-ninth A Moon. This means if we send a satellite such that the distance A satellite is one-ninth of the distance to the Moon, the period of the satellite would be one day. It would be stationary, or the satellite with respect to the Earth on equator. Now, as you see this, Kepler's Law gives you know, which is very complicated calculation effects of the Sun and so on and the effects of the Moon. We can get some little fraction on it but closely within maybe a thousand miles on a scale of satellites and moons. This is good. Now, if I may have the next slide.

37:30 Mr. Hochstim: I will show you something which probably you heard about it. This is a Pioneer, Pioneer vehicle and this is the vehicle to the Moon and since on November 11th is the next day, November 10 or 11, the next day when the satellite will be fired or may be fired. By the way, how do I know if this is the next possible date? The Moon travels around the Earth in an ellipse. And the point which is closest to the Earth is called perigee. The point away is called apogee. By the way, I have a little hint how you remember the apogee is far away from the Earth because apogee starts with a letter away so this A, apogee, away is a good hint to remember. So if that Moon will be in perigee, just means closest to the Earth, this is also during the time when we don't see the Moon. The Moon is called, I mean the full moon, and in the new moon I'm sorry, the new Moon and this is the time. The next time is November 11th and then sometime in December. So since you probably will hear about it and very, so I can show you a little detail. The numbers here are not for Pioneer or for any other possibility and for Pioneer or for the next vehicle, the data will be very close but not exactly, this is just a little rough calculation. But I show you how you are supposed to, how one should do it, and how we already did with the Pioneer. On the Earth, which is running this way, we sent a vehicle 4,300 miles away from the center of the Earth, and then at this point, the last stage fires.

39:32 Mr. Hochstim: And at a certain angle of 14 degrees 20, this math is very critical, we fire a rocket. You see this math, this angle is the first, the first few stages go and then the last stage must put this in this orbit which is precisely 35,000 hundred feet per second for this particular trajectory, could be a little variation. What happens to Pioneer? Pioneer got a little off in the angle here and it went like this, like this, and then before it just straight all around and went back to the Earth because it went little off the trajectory. Now, even if we are lucky with the trajectory, we send this in such a way. Now the Moon in the meantime, at the moment we fired here, the Moon is here. The Moon travels around the Earth, so at one-tenth of a day, it's about two or so hours later that the vehicle we sent should be already here. By that time, the Moon moved a little. At the end of one day, the vehicle should be here somewhere. At 1.5, somewhere here and the Moon comes closer. So you see we have already predicted this part such that the vehicle comes close to the Moon. Now even if this vehicle comes, if the Moon is at 2.2 days, I think for Pioneer it was something like 2.6. Anyways, two and a fraction of a day, the times later, after it was fired, the vehicle has 7,700 feet per second and if nothing is done to it, it will escape straight away from the Earth and Moon system, somewhere unknown. In order to stay in orbit around the Moon, velocity must be reduced to 4,300 feet per second, so almost a factor of two.

41:33 Mr. Hochstim: So you fire a retroactive rocket which you heard so much about in the news-news. You should, well, we should fire a rocket here to slow it down, then few possibilities remain. If it slow down a lot, then even it will go in as you know already on parabola, hyperbola, ellipse, or circle. If it goes on hyperbola here, it will escape. If it goes on parabola, it would escape too. But if it goes on an elongated orbit, this means if we slow down sufficiently, it will be in an ellipse like that. Now of course, the Moon travels so this, at the time this makes an ellipse the Moon is already somewhere here but this will travel around the Moon in ellipses around and send us information all the time about the Moon. If we send two strong ellipses, this is this part of the ellipse, even at this point the velocity was reduced to such amount that there is a little too strong of a velocity in this direction, it may go this way and go back here and then suddenly start to feel the Earth and become either satellite of the Earth or fell to the Earth. The other possibility too is to the slow down, slow so much that it collides with the Moon. In fact, there will have no velocity sufficient to be a satellite and fall to the Moon.

42:53 Mr. Hochstim: I thought that this would be of interest too since this is just probably November, on November 11 maybe, we will hear something more about it. Now, may I have the next slide? As you remember, we are in the universe and we start to feel that we are approaching the stars, how to say. Now, this is a very enthusiastic feeling, a very wonderful feeling that we go out in space. This is a little, maybe disappointing which I'm going to show you. The distance is so large, that in a million, million years, it would travel a million years and will never reach that. So I guess for the mankind we can never get there. But we studied the only signal which we can obtain from there is a radio signals or we can obtain light. First, when we look in the sky we see the Milky Way, and Milky Way here is the first people who saw, saw thought that this is some kind of cloud but with a powerful telescope various stars can be resolved. Every particular star is just like our Sun and maybe each little dot here, each little Sun, star contains planets and the rest is just too, we can never, we really can never know. But all these multitudes of possible stars, everyone having a Sun, this distance is somewhere along 70,000 light-years.

44:30 Mr. Hochstim: It takes about 70,000 light-years to go to this particular picture, I mean particular here, stars. And this is part of our system our galaxy, the Milky, Milky Way galaxy. There's a tremendous cluster of stars of which our Sun is just one of those little stars. Now if we go to the, with a more powerful telescope and look a little farther, what we see is - may I have the next slide, please? We see galaxies somewhere far away, far away from our system. How, I don't know, by this picture, I think it's about 500,000, 500,000 light-years. This means what you see right now, let's say assuming that this picture was taken this year, the light from those stars was started 500,000 light-years away. This means the light traveled 500,000 light-years or 500,000 years ago, this picture was taken, in a way. And this is not from every star at the same time of course. So maybe now they do not exist but when we will know if something now happened in this system, we will know only

500,000 years later because this is the fastest signal we can achieve. So now, we can postulate any theory about it.

46:10 Mr. Hochstim: Now, the lights traveling from this galaxy have a nice spiral structure. A galaxy, a Milky Way is the same way but we cannot, of course, see it from the outside. Where would the Sun be? Would the sun, our Sun is in our Milky Way somewhere here? No. It is rather disappointing to find out that our Sun is rather a third or four grade star and somewhere, located somewhere in this neighborhood in our galaxy. So you see those, this is an entire cast of another, in another world, other galaxies away from similar spiral clusters by tremendous distance separated and this cluster here is called Milky Way, where we are in and our little Sun and the planet called Earth. Now, if we go to the next picture, I show you how you can look at it if you see from the side, with respect to us, can be seen from the edge. See the previous one you saw from that side, this galaxy we can see from the edge and the spiral arms also indicated. On our Milky Way similar, this is the Sun, our Sun is somewhere here. I don’t know. Now, this distance is something like 70,000 light-years. This means between one point in here something like 70,000 light-years. Now, this galaxy is also thousands of light-years away from us. This means that the light travels thousand years, many thousand years before it arrives to the Earth. May I have the next slide, please? Or this just as indicates we may just skip this slide, it’s not particularly important right now. May I have the next slide, please?

48:03 Mr. Hochstim: This shows you the period of the satellite varies with the time because due to the friction of the Earth in the air, the period is shorter and shorter. It’s slowing down until it burns completely. May I have the next slide, please? Now, here’s another cluster. It’s rather different, far away, a thousand years light-years away from us but it has no spiral structure. A cluster like this and the nebula like that with gas, now what is inside? We don't really know, maybe we can on the result with the power because the stars are so close or maybe there are some clouds or vapors, which we don't know, many mysteries about it. Now, the astronomers are interested in the motions of the galaxies, how they rotate, how they move around the galaxies, one galaxy with respect to another. The astrophysicists and physicists are interested in how hot are the temperatures inside of the stars. What kind of processes? Why do they burn? Why do they suddenly explode? Suddenly around 1052 BC, a star on the sky like this almost which couldn't be seen at all became the most brilliant star in all the sky. The Chinese and the Japanese reported about it. And when we pointed the telescope to it, we saw tremendous, something like the that clouds and explosions in millions of miles away from the point. From a thousand years from now, they exploded in tremendous amounts. Why did they explode? What was the force which exploded the entire star? It’s completely unknown and there are many mysteries about it which you could study at the laboratory and with the high-temperature gasses. The hydrogen bomb inside involves temperatures of the order, of those one or any of those stars. May I have the next slide, please?

49:57 Mr. Hochstim: This is a very beautiful photograph taken a few years ago and I think it's Mt. Willson Observatory where they found the clouds, gaseous clouds far away from us and this are some kinds of clouds which probably radiated in the following way. The light from a star hits the clouds and it reflects to us or it makes it glow and you can see this trail here and those little clouds. I mean this dimension is gigantic. I mean it's thousands and thousands light-years, light might travel from one end to another. May I have the next slide, please? This is a famous galaxy of Orion and you can see also this galaxy is not completely clear. You have lights here, clouds and stars mixed together. Next slide, please. Again, this is almost the end. This is a beautiful spiral galaxy too and an entire world by itself away from us has the spiral arms and in the center has a nucleus, which may be burning or maybe it's full of gas would reflect from the neighboring stars. And is this the last one? Yeah, may I have the next one, please? May I have the next one, please? Well, this is a very beautiful galaxy, also spiral arms in the center clouds and the next one, please. This is the galaxy from which about one million light-years. This means this picture, the light came from, from it one million years ago and this galaxy, the famous galaxy of Andromeda and the various dimensions which are, we're not very sure, one million or one and a half million years ago and the dimensions here are very large too. This was a composite photograph and here are some little galaxies about 35,000 years light-years away from the main one. And I guess, I end this talk with this, with one million light-years from here. Thank you.

52:32 [Audience Clapping]

52:54 Marian Longstreth: I'm so glad you could hear [unclear] because you know Dr. Hochstim stayed up until 3:30 AM last night to preparing this material you saw today. Thank you so much.

53:05 [Audience Clapping]

53:17 Marian Longstreth: I'm not sure if you have time to stay, but I am sure Mr. Hochstim would be willing to answer a few questions by those who came today.

53:28 Mr. Hochstim: I remember last time it was not very well the acoustic, maybe somebody who would like to ask a question can come over here to the microphone. Would this be all right?

53:37 Marian Longstreth: If you ask a question, repeat it in the microphone so other people would be able to hear it as well. Any questions?

53:49 Speaker 1: You said that nothing can exceed the speed of light. What is your basis for this statement?

53:55 Marian Longstreth: Now, repeat the question.

53:57 Mr. Hochstim: The question was that I said that nobody can go faster than the velocity of lights, is this right? And what was the basis of it? The theory, the special theory of relativity, which was developed by Professor Albert Einstein around 1905, verified that no velocity, no velocity, no material velocity is possible faster than velocity of light. So at the present stage of our knowledge, this is many times verified by many experiments this special theory of relativity and there's no doubt present time, you know many times we had some ideas which later were completely disproved. But in the present time, it looks like very good statement. No material object can move with faster than velocity of light.

54:56 Marian Longstreth: Okay, will you stand up, please?

54:59 Student 1: Sir, why is it, no matter how fast you chase light that you cannot reduce the speed [unclear]?

55:06 Mr. Hochstim: Could you repeat it, please? I didn't hear what -

55:08 Student 1: Why is it that no matter how fast you chase light that you cannot reduce the speed at which you are chasing them? It will always escape you at 180 miles per second.

55:17 Mr. Hochstim: How fast you change what? I don't understand.

55:19 Marian Longstreth: Chase it.

55:20 Mr. Hochstim: Oh, chase it. Well, this all is explained in how, why, [Laughing]. Why, I don't know. I wasn't prepared for chasing the light and I didn't expect it. [Laughing]. The question was why if I chase the light, if I am at all, why could I never overpass it or something like that? Now in the, first, I don't think I will be able to, but even if we could reach it, almost the velocity of light, we could never add those velocities together. This means, and one very nice example which could illustrate is that, if for example, you go on one missile. Let's say it was velocity of light. This is out the question is but let's say. And when another missile approaches with velocity of light, is the relative velocity of light of approach, twice the velocity of light? You know you go with that 10 miles power for one way and 10 miles for another way. The two cars approach with relative velocity of 20 miles per hour. But with the velocity of light, it doesn't hold that way. Our own intuition from a regular motion fails. It must be corrected if you approach velocity of light.

56:35 Mr. Hochstim: For example, like masses, mass, a body has a certain mass. But if we move with velocity of light, the mass changes. We have never seen something like that on the earth and if a car moves with 50 miles per hour, you never see an increase in mass, though there is a tremendously small increase in it. But finally, when you move with velocity of light, or approach to it, the mass is changing. There are many beautiful phenomena but let's leave it to that special theory of relativity. There's also general theory of relativity where you have this famous problem that if you, if two twins - you have probably heard about this problem - two twins on the Earth. One twin leaves the Earth and goes flying to space, moving with velocity almost approaching the velocity of light. When he returns back, and many people say according to certain parts of special theory of relativity, the man, the twin who comes back will be all young, still young. But his twin is already 90, very old who was on the Earth. This is one way of getting young, staying young, going out with the velocity of light.

57:45 Mr. Hochstim: Now, the general theory of relativity to our displeasure disapproves this and verifies, the general theory says that even if you come back to the Earth, you can, you will be still with the same age. Because what the general theory of relativity says that when you move away from the Earth, you are staying very young. But when you suddenly want to return, you must de-exelecerate and this produces aging. I mean the time goes much faster. The person traveling on it will never notice anything. Now, those things are not very cleared, up to now. Up till recently, in journals like *Physical Review* and physical reviews and many other foreign journals still, the debate is going on what will happen to a man if he goes almost with the velocity of light and comes back. Would he be still the same age? I mean would he still, would his age be comparable to let's say his twin on the Earth or would he be younger or older? …[unclear] leave it up to now. Very probably he will come with the same age. I can't see it.

59:01 Speaker 2: If an object of mass the object travels with the speed of light, will it be converted into energy or will it crash?

59:14 Mr. Hochstim: There was a very nice book written by Professor. Oh, I am sorry. [Laughter] I was eager to answer that. If the object obtains velocity of light, what will happen to it, or will it turn to energy or something? The problem was very nicely illustrated and one time when I was worrying about a problem of this type, I got the answer from a little book by Professor Gamow, George Gamow and the reason I advise all of you to read it is because it's very popular, very, tremendous amount of humor in this book too. This book is called *Mr. Tompkins Explores the Universe* and the second volume I think is *Mr. Tompkins Explores the Atom*. In this book when *Mr. Tompkins Explores the Universe*, Mr. Tompkins is sitting in the lecture and falls asleep. So he heard half of his lecture about velocity of light and so on, then he dreams that he's in the world with a velocity of light as 10 miles per hour. Then he wonders what will happen if he goes with the velocity of light 10 miles per hour and he sees somebody on a bicycle going about nine miles per hour. Of course, he can never reach 11 miles per hour, 10 miles is the limit because this is the velocity of light. So he sees this man all shrinked, all of the bicycle is very thin and he tells, he tells the inhabitants of this world that I will never go on a bicycle, I will shrink! So this inhabitant from the other world says, oh, don't worry, just go on the bicycle and see what happens. So Mr. Tompkins goes on this bicycle and reaches four miles, five miles, eight, nine, nine point nine. He cannot get more than 10 miles. And nothing happens to him but suddenly he sees all these houses, everything around him shrunked. So you see this maybe answer the question. It's just relative. If you move with the velocity of light, nothing happens to you or close to the velocity of light, only the person who looks at you, who will have a lot of funny ideas about you. [Audience Laughing]

1:01:26 Marian Longstreth: There's a question here, could you stand up, please?

1:01:29 Speaker 3: How do you measure the distance of the galaxies?

101:34 Marian Longstreth: Could you repeat the question, please?

1:01:36 Mr. Hochstim: How do astronomers measure the distance between galaxies? This is a very nice question and to tell you the truth, how well they measure those galaxies? A few years ago, they said that all measurements should be multiplied by a factor of two. So this may be answered in the, the accuracy. This is, if you study trigonometry, you will know that if you know a base, the distance of a base, and two angles, and the way you can see some object, then you can determine the distance. Now, we have very good data about the distance from the Earth to the Sun or on the ellipse. This means from perihelion to aphelion, which is nomenclature like perigee, apogee. From one point of ellipse to another point of ellipse, we know the distance. Now, this we use as one distance. Then look at the galaxy at a certain angle, look at the galaxy with the other angle, and get some approximate distances. Those distances we see within a factor of two are good. There are other little methods of measuring this velocity of light, velocity of, the distance between galaxies but this is one of the ways.

1:02:56 Marian Longstreth: One more question and that's about it, you'll have to go home. Would you stand up, please?

1:03:02 Speaker 4: When the Pioneer was shot off -

1:03:05 Mr. Hochstim: I can't hear you, I'm sorry.

1:03:07 Speaker 4: When the Pioneer was in the last days [unclear] why did it just shoot off into outer space and then coming back travel around the moon?

1:03:19 Mr. Hochstim: Very good question. I would like to, why if, if I understood you, why is the vehicle shot from the Earth. Why was it going this way and turned around to the Moon and didn't go straight? This is right? Now, if you remember the slide, the, it was pointed in a certain direction here but it already reached velocity such that it felt the gravitation of the Moon. The, I was building a little model for you but you could do it maybe yourself at home. I didn't have time. You could get a little tool from plaster or something you can make a little type of a cup. One cup representing the energy well of the Earth, another of the Moon. If you drop a little ball bearing, you will see that if you drop with not a big velocity it will turn around the Earth. But if you drop with another velocity, it will turn around the Moon. In one particular point - oh thank you, this was that one. You see actually what happened, this went in this direction and you're correct it would go this way. Now it feels the gravitation of, this is complicated because the two gravitational fields are working simultaneously. This as it was here, it started to feel the attraction of the Earth. So it wanted probably to go like that. To tell you the truth, it did. [Audience Laughing].

1:05:13 Mr. Hochstim: But it was anticipated, if the astronomers are correct, that at this point, it started to feel the attraction of the Moon. It should, it should feel the Moon's attraction and go around to the Moon. And so, there's two fields counterbalancing each other. You can do yourself a little experiment. You can take a little magnet, two south poles, and another south pole or north pole, north pole, and take a little ball bearing, or paper clip if you want on a string, and swing it around the Earth. And sometimes you get a swing like this, it goes around in a letter almost like that eight. I tried it, tried to do it for here but I didn't have enough time. Some high school teachers could demonstrate this in private lectures. Now, this again is all for questions. I will be very happy to spend here about half an hour or so with you and answer some questions and also to demonstrate to you the equipment in more detail to all those who are interested to see them up close.

1:06:25 [Audience Clapping]