**Video may be found at youtube by searching for “The Cloud Mystery –Svensmark, Shaviv & Veizer” and choosing the first item returned (length 52:53).**

The video outlines the key contributions of the three scientists in their developing a theory of Earth's climate which is independent of the activities of humans. What follows is largely a transcription of the video rather than a synopsis of the presentation.

After a tedious intro at 1:32 we are finally told by the narrator that "the galaxy drives our climate system in ways that we are only beginning to fully understand" and then at 1:50 we see a pensive Henrik Svensmark overlooking some clouds and we are told that his work will alter our understanding of climate change. Svensmark opens up with talk of "exploding stars" and "dramatic changes in solar activity" (which are the twin drivers of the mechanism to be explained to us). The narrator goes on to say that "over the years we have followed Svensmark in his struggle to be heard in a Climate Community resistant to the idea that present day climate change might have natural causes". And then there's mention of CO2 and clouds followed by rising theme music and the title "THE CLOUD MYSTERY" is posted at 3:15.

"Understanding clouds is a very very crucial point" Svensmark tells us as we see him trucking down a corridor and entering a room and sitting before a flat screen display with a colleague. In his Danish accented English he goes on to say: "The mere idea that processes in space and not just processes on earth is important for climate I think is deeply fascinating".

3:46 Svensmark: "In 2005 we actually found experimental evidence that the sun and the galaxy is determining climate here on earth but for some reason no scientific journal wanted to publish this. It was a big disappointment for me and my team."

4:12 We hear Eugene Parker (Professor Emeritus, Physics Astronomy and Astrophysics, University of Chicago): "There is a problem that has always been with us. New ideas are rarely welcome in science where particularly some young person not known in the field proposes some radical new idea he may experience great difficulty in getting it published."

4:30 Svensmark: "The bottom line seems to be that instead of thinking of clouds as something being, erm, a result of the climate it actually sort of upside down ... it is that the climate is a result of changes in the clouds."

4:54 Svensmark: "The first time I got an idea of how important clouds could be on the earth's climate was when my boss Eigil Friis-Christensen made a discovery where they found a beautiful correlation or agreement between solar activity and the earth's temperatures. The agreement was so good that it could not be accidental and this was really a big inspiration for trying to understand and trying to use clouds as part of that explanation."

5:55 Friis-Christensen: "When we published this in 1991 it was at a time where everybody believed that the warming that had taken place during the century was mainly due to carbon dioxide increase and man made greenhouse gases. So when this community saw this perfect, nearly perfect, correlation between solar magnetic activity changes and temperature they were very surprised. What we could see was that when the magnetic activity of the sun was larger then the temperature on the earth was higher. Nobody had an answer to what kind of mechanism could be a cause of that.

6:49 Svensmark: "We knew that somehow the magnetic activity on the sun had to have an influence on the earth's climate, direct or indirect, but how this would come about was a real scientific mystery. But one day someone stepped into my office and mentioned cosmic rays."

7:12 Svensmark: "When I heard this word cosmic rays it made me immediately think of an experiment I did in High School where we had what is called a cloud chamber. Inside the cloud chamber you have supersaturated air and when a particle, for instance a cosmic rays, go through it make a string of small droplets like a small cloud. With this image in my head I thought what if cosmic rays are responsible for forming clouds and what if the sun with its magnetic field is capable of changing the clouds on earth. Then we would have a perfect explanation on how the sun would be responsible for climate through our everyday clouds that we see on the sky."

8:09 Svensmark: "You cannot see or feel the cosmic rays but they're let loose whenever stars die in supernova explosions."

8:45 Svensmark: "... the sun fights the cosmic rays and controls just how many hits the air."

8:57 Svensmark: "In order to find out if cosmic rays affect the clouds I began to look for data. I collected satellite data of the variation of clouds in the atmosphere and compared them with variations in the cosmic ray intensity. There was a beautiful clear ... correlation that surprised me more than I ever dreamed of."

9:48 Svensmark: "The magnetic field that comes out of the sun has more than doubled over the last hundred years. As a result fewer cosmic rays have sprayed the atmosphere and fewer clouds has formed. The consequence has been a warmer earth. When a strong magnetic field comes out of the sun fewer cosmic rays spray the earth; that means fewer clouds to keep us cool, while a lazy sun with a weak magnetic field lets in more cosmic rays from the stars and in the air they make more clouds. That's how the stars and the sun controls the earth's cloudiness."

Views from Parker and Paal Brekke (Solar Physicist) and various conversations emphasising the importance of Svensmark's work...

13:00 Subsequent to footage of Henrik and Eigil boarding a plane, Svensmark: "When we presented our results in Birmingham in 1996 we were of course very excited to present the results but much to our surprise it was received very very negative. And the only thing we had done was to present a scientific result which showed that the sun through the clouds might be very very important er for climate."

13:37 Friis-Christensen: "There was of course a reaction also from the International Panel on Climate Change, the UN panel. [unintelligible] ... scientific chair at the time, he thought it was irresponsible of us to to say that something else than the CO2 could be the main driver for climate."

14:00 Svensmark: "The whole climate community really hated the idea that the sun should have a major impact on climate. That was seen as a disaster. I was actually shocked about the responses that we got."

14:29 Svensmark: "During the last twenty-five years CO2 has been the dominating theory trying to explain all climate variation. However, if you look at historical climate there is absolutely no doubt that the sun has been extremely important, and you cannot ignore it."

14:50 Location moves from Denmark to Israel with Nir Shaviv at the Dead Sea. Shaviv shows sediment layers and speaks about the climate variations which can be seen in it. Mentions carbon-14 and points out that it is actually cosmic rays which generate that "cosmogenic" isotope.

17:24 Shaviv: "This link between solar activity and climate on earth, it's not hypothetical, you just see it's in the records; when the sun was more active you indeed see that it was more warm on earth, and vice versa."

17:40 Shaviv: "Three hundred years ago, for example, the sun was not very active and we were in height of the little ice age when it was cold in many places on earth. A thousand years ago it was er, the sun was active, it was as active as it is today, and it was warm everywhere --the vikings could map all of Greenland because the northern shores of Greenland were not frozen."

18:08 Shaviv: "Most of the people today think that most of the climate change is because of CO2, but this is wrong: most of the warming over the twentieth century is because of the sun."

18:47 Svensmark: "If we look at earth from space we will see that about sixty to seventy percent is covered by clouds. If more cosmic rays comes down we will have slightly more clouds and you can imagine the opposite --fewer cosmic rays we have a little fewer clouds."

19:10 Svensmark: "Instead of thinking of clouds as a result of climate it's actually showing that the climate is a result of the clouds because the clouds take their orders from the stars."

19:51 Svensmark: "After we found the link between cosmic rays and clouds we only knew that it was a total cloud cover but I had to find out what type of clouds. And at some point it became possible with a new dataset to investigate exactly this. And at that time I got help from Nigel Marsh -- he helped analysing these data and much to our surprise we found that the link is anchored [?] to the low clouds so it seems as if cosmic rays are changing low clouds and that is very very good news for the whole idea."

21:44 Svensmark: "The reason low clouds are so important is that they actually reflect a lot of the sunlight back into space."

21:59 Svensmark: "And you can imagine if you change the amount of low clouds you change the amount of energy that the surface gets. That means that low clouds have a strong cooling effect on the earth's climate. So if we have more low clouds climate will become colder and if we have fewer cosmic rays, we have fewer low clouds and the earth becomes warmer."

22:33 Richard Turco, Director, UCLA Institute of the Environment: "I first heard about Henrik Svensmark's work when we became interested in looking at how aerosols, or very small particles, are produced in the earth's atmosphere in the first place. And this is important because all clouds are formed upon aerosol particles that are in the atmosphere."

22:58 Turco: "In terms of the work that we've done what we've found is that the galactic cosmic rays are capable of modulating the aerosols or particles, small particles, in the lowest part of the atmosphere. In fact we can show that the aerosols produced by galactic cosmic rays are significantly modulated in the lower layer which contains these clouds that produce a cooling effect on the earth. What we don't understand at this point is exactly how and why they, they're formed."

23:48 Turco: "Every cloud droplet that's formed is formed on a particle initially, in the air, and so it's absolutely crucial to understand how these particles come about and what their properties are otherwise we can't ever hope to understand clouds and, and their behaviour."

24:06 Svensmark: "And that's where cosmic rays actually might come in, because what do cosmic rays do when they enter the earth's atmosphere? They produce small ions. ... It is the belief that these small charges help forming these small specks or aerosols in the earth's atmosphere."

24:36 Turco: "Whereas most people would think that since there's water in the atmosphere that naturally there'll be clouds but that isn't true. The only way that clouds can form in the atmosphere, in our atmosphere, under normal conditions is to condense onto an aerosol existing particle in the air. Every cloud droplet that's formed is formed on a particle initially in the air. All clouds are formed upon these aerosols. And so it's absolutely crucial to understand how these particles come about and what their properties are otherwise we can't ever hope to understand clouds and their behaviour."

25:34 Svensmark: "In science it's not enough just to have a good theory, you also need some experiments to support the ideas. I was very determined to get an experiment that could show that we have this connection between cosmic rays, aerosol formation and clouds."

27:00 There is an interlude where Sir John Mason (Former Director-General, The UK Meteorological Office) stands up in a lecture and upbraids Svensmark on the grounds that his proposed experiment is "completely misconceived and will tell you nothing about what happens in the atmosphere". Ultimately they agree to disagree. We're left wondering if Mason is au fait with all the current work on atmospheric aerosols.

28:40 Svensmark has devised an experiment in Copehagen to show whether his idea "was right or wrong. Unfortunately it turned out to be much more difficult than I thought it would be."

29:08 Svensmark: "Building the laboratory, building the experiment, getting the funds it actually took almost four years."

29:17 Svensmark: "The idea in this experiment is to investigate what is the role of cosmic rays and the idea is that we in the end will be able to mimic the

processes that are going on in the real atmosphere so this whole chamber is built in such a way that we can control ions inside it and we'll be able to reveal for the first time how important ions are in the production of forming new aerosols and in the end new clouds."

30:29 Shaviv: "Originally I got interested in the topic when a colleague of mine in Germany asked me what are the effects of supernovae on life on earth. I decided to give him a serious answer. I ... looked at the literature and eventually stumbled upon Henrik Svensmark results about cosmic rays and cloud cover."

30:55 Shaviv: "So I realized that if this hypothesis is correct, that cosmic rays affect cloud cover and climate, what it would mean is that also a variations which don't originate from the sun would also variations from the whole milky way they too will affect climate on earth."

31:14 Shaviv: "Ever since I was a kid I was interested in astronomy, that's why I became an astronomer. I never realized as a kid, I mean I always appreciated this Milky Way the fact that you can go out in a dark night and see this beautiful galaxy that we're inside of; it's something that we actually live in, it's part of us, and its affecting us, it's affecting climate here on earth and you must take it into account, into consideration if you want to understand past variations in the climate."

32:39 Shaviv (at blackboard doing chalk diagram): "If we look at the Milky Way from the top what we'll see are four spiral arms and that's because the Milky Way is a Spiral Arm Galaxy. So we have four spiral arms. We are located here on some small armlet. We are rotating around the sun once every year but the whole solar system rotates around the Milky Way once every about two hundred and fifty million years, that's one galactic year. What this means is that every a hundred and fifty million years when you pass through a spiral arm of the galaxy it's colder by something about five degrees or ten degrees; when we're outside those spiral arms it's hot."

33:30 Shaviv: "When we enter a spiral arm of the galaxy we're going to witness more cosmic rays reaching the earth, more atmospheric ionization, more cloud condensation nuclei, and therefore more low altitude clouds, or to be more precise, whiter low altitude clouds which better reflect the sunlight and cool the earth. So the bottom line is that when we enter a spiral arm of the galaxy we should expect lower temperatures."

34:40 Shaviv: "About seventy million years ago we started approaching and entering the Sagittarius spiral arm and earth became exposed to a higher flux of cosmic rays because of all the stars around us. This larger flux of cosmic rays was responsible for the formation of more clouds and colder conditions here on earth. The ice sheets that later formed they actually pushed all those cliffs out of the water like bulldozers and they rippled the landscape so what we see here in these cliffs is a good example for hot conditions on one hand when those cliffs were formed and cold icehouse conditions, which we have today, which are responsible for the uplifting and current conditions of these cliffs. It may sound strange to most people that we're talking about icehouse conditions today. But if you look on the long timescale you find that during most of earth's history we didn't have any ice caps whatsoever. Today we have. Four hundred and fifty million years ago we had very cold conditions here on earth, however we had more than ten times as much C02 in the atmosphere; so clearly, CO2 is not a major climate driver, at least it wasn't a major climate driver then."

37:56 Jan Veizer (Professor Emeritus, Earth Sciences, The University of Ottawa): "I have been working almost all my, all my life on issues related to environment. I suppose one of the biggest and biggest problems and issues was, what was the climate and how the temperature was the water change. We working on the fossils like this, called brachiopods. These shells record the temperature of the past oceans. When they form they reflect the temperature of the ocean water because they build in the atom of oxygen then you could measure this proportion of oxygen and you could get a measure of the temperature of the past oceans and that means of the temperature of the earth and climate. So when we can measure this we will get a record of ocean temperature for five hundred million years. When I look at the data I realized that actually there were some oscillations in the general trend of temperature and that those oscillations fitted quite well with what we knew from geology what kind of a climate was at that time. Working with a, with a colleagues we did a variation and statistical study of that and we saw that there was some kind of a periodicity roughly of

about a hundred and forty million years switching back and forth between hothouse and icehouse. I suspected that the reason for this rough periodicity was something to do with the sky, but I was searching for it and couldn't find anything. So, essentially I gave up, I didn't have an explanation."

39:56 Shaviv: "Jan Veizer, he reconstructed the temperature using geochemical records. And the difference between that reconstruction and what I was using is that Jan Veizer actually reconstructed the actual temperature through, he knew exactly how warm it was and how cold it was. So I emailed him."

40:19 Veizer: "One evening I was sitting in my office working suddenly an email popped up and this was Nir Shaviv and he says well I may have an explanation for you. He was telling me that he was working on cosmic rays variability over the, more or less the same time intervals, and that the variability in the amount of cosmic rays hitting the earth over this time interval was more or less similar to the variation on, in those oxygen atoms or in the climate which we observed."

40:55 Shaviv: "After I teamed up with Jan Veizer we had an actual temperature reconstruction. And what we could learn was that it was colder here on earth by something like five to ten degrees when we were inside the spiral arms of the galaxy. Nobody found anything like that before and we were simply amazed from it. But more interestingly what it means is that cosmic rays are the main climate driver on earth, at least on geological time scales. And the only explanation you have for it is Svensmark's theory about the cloud cover."

41:28 Shaviv (pointing at projector presentation): "When you compare the geological record to the astronomical record that's what you get, you see that the two bar codes give you the same product. The black line is the geological reconstruction of the temperature on earth using the geochemical records that er, of Jan Veizer and what you see in the red is the cosmic ray flux variations. When both things are added together they correlate very well. Statistically it's very significant. Ah, but you don't have to believe the statistics you can just look at it and realize that er, it's very meaningful."

42:06 Svensmark (subsequently in front of a projector presentation showing forty years of ocean temperatures with a red curve rising prior to temperature descent and descending prior to temperature rise): "It's been said so many times that the sun has not been responsible for the heating we are seeing over the last maybe twenty, forty years, however if you look at the data for instance, the ocean data, you will actually see that there's a very good agreement between temperatures and solar activity. And what you see is the temperature of the ocean down to about fifty metres. If you compare the overall agreement with how the red curve is varying, it's very good, and the red curve that is the cosmic rays, that is how the cosmic rays have been varying over this period. So we actually see, even today, that the sun is dominating the temperatures, or how temperatures evolve. It has done so in the past, it's doing this now, and will also do it in the future."

43:01 Shaviv: "An experiment like the one taking place here in Copenhagen is crucial because it, if successful, it will shed a lot of light on the physical origin of the link between cosmic rays and climate. And this will be the last piece in the puzzle which would, would make the picture complete."

43:41 Shaviv: "The results of this experiment... hopefully we will know exactly how the sun affects climate, how it modulates the cosmic rays reaching the earth, how cosmic rays control the amount of ionization and how ionization controls climate er through er most probably er formation of cloud cover."

44:22 Svensmark: "It's very interesting after nearly eight years of work that we finally got to this stage of trying to understand the er, the, these experiments."

45:44 Svensmark: "What we find when we mimic a higher flux of cosmic rays is that we actually produce more aerosols in the chamber. This actually means that cosmic rays are producing aerosols and these are the aerosols which are responsible for forming clouds in the real atmosphere.

46:11 Svensmark: "Through our experiments we have found a new form for atmospheric chemistry which we think is responsible for the formation of new aerosols and therefore also for clouds in the earth's atmosphere. And it shows that events in the universe are driving climate here on earth to an extent that has never been understood before."

47:58 Svensmark: "We thought we had a really scientific breakthrough in the understanding of how cosmic rays affect the earth's cloud cover, therefore also the earth's climate. But for very strange reasons we could not get the paper published. I think we submitted it four times to different journals and we still could not get these results published."

48:25 Shaviv: "Henrik Svensmark and his group has very nice results and I would have expected them to be published immediately, a few months after they found it, instead it took them sixteen months to publish it and, er, the reason I think is because of reluctance of the climate community as a whole, in particular those who are supporting the anthropogenic greenhouse gas theory, to accept the idea that this new theory which is already shown to be supported by a lot of empirical evidence is also supported by experimental evidence."

49:01 Svensmark: "The most frustrating part about the rejections was that there was no real critique that we had done anything wrong, it was things like "it's not interesting", "it's too long". There was no real critique of the ideas so therefore this type of rejection was even more frustrating."

49:22 Parker: "Editors are sometimes remarkably naive about these things but I think they really should really look into these things and when a negative report is conspicuously without substance they should ask their referee to clarify it. This is as a new dimension now that Global Warming is a political issue things become politically incorrect and in the United States at least we have cases of good solid research on global warming being refused for publication because somebody has made up his mind that that isn't the way it is and you can't publish. I think this is not only unfortunate for the author it's unfortunate for the country and the world as a whole because this is a problem we had better get straight so we know what to do."

50:18 Svensmark: "Finally I think after more than a years of waiting we got the paper published in the Royal Society."

50:39 Svensmark: "At the end of this journey I can now say with great confidence, yes we have found a very beautiful solution to the cloud mystery and what remains a mystery is when the rest of the climate community will understand that far greater powers are controlling the climate from the outside."

51:03 Shaviv: "The sun affects climate here on earth, the Milky Way affects climate here on earth, and if you want to understand what's going on we have to take these factors into account. It's beautiful because instead of us living here in this isolated planet we're part of this galactic ecosystem..."