Episode- 13
Orbital Variations & Climate change

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Rabi	Father (50 years, a teacher in college)
Renu	Mother (45 years, science communicator)
Mita	daughter (18 years, college student)
Sunil	Son (10 years, student)
Sasank	Rabi's brother, physics lecturer
Gopal	Tourist guide (40 years)

(Summer vacation is coming, a family planning to go to somewhere)

Mita: Papa, our college going to have summer vacation, shall we go somewhere?

Rabi: All of you discuss and decide where to go.

Sunil: We will go to Mumbai, I want to meet Sahrukh Khan.

Mita: Are buddhu, Sahrukh doesnot walk on Mumbai Street that you just go and meet him.

Sunil: Then we will go to chandipur.

Renu: No your Sasank uncle is coming, he wants to go to konark, and he is doing some research on sun.

Mita: Good, I will also go with him. I want to know more about sun and its energy.

(A car stopped, doorbell rang)

Sunil: Perhaps sasank uncle came.

Renu: Mita, go and see who has come.

(Sasank enters)

Sasank: Namaste bhaiya, namaste bhabi.

Mita/Sunil: Namaste chacha. Where is chachi.

Sasank: She has some work in her office, so could not come. She will join us later.

Rabi: Sasank, I have booked guesthouse at Konark, tomorrow we will start very early.

Sasank: Ok Bhaiya, we all will go, Mita, you may be interested for our work on sun and its energy.

Mita: but chacha, why you want to go to Konark.

Sasank: because it is the sun temple. ok tomorrow while we will go, I will tell you many things about Sun and its impact on global warming.

Music

Scene - 2

(They reached at Konark, people are talking, vendors noise, vehicle sound)

Gopal: Sir, do u required guide, I can explain Konark temple very well.

Sunil: No we don't need a guide. Our chacha is doing research on sun and its impact on earth. So he knows many things. He will explain to us.

Gopal: Then I will also go with you. I want to know about Konark. But let me explain a little bit.

Sasank: Ok Let him say what he wants to speak.

Gopal: This temple is dedicated to the God Sun.

Mita: But Sun is not a God.

Sasank: Yes Mita, you are right. Sun is not a God. But it influences us in everything. It's energy which controls everything.

Rabi: That is why it is we say Sun is the source of All.

Sasank: Since it is the Sun's energy that drives the weather system, scientists naturally wondered whether they might connect climate changes with solar variations.

Mita: But it seems that Sun is stable over the timescale of human civilization.

Rabi: Sun greatly dominates the sky.

Gopal: That is the reason we worship him as God.

Sasank: (laughs) In a way you are correct Gopal. But it is an heavenly body which dominates our life.

Renu: The Sun is the source of most of the energy that drives the biological and physical processes in the world around us—in oceans and on land it fuels plant

growth that forms the base of the food chain, and in the atmosphere it warms air which drives our weather.

Sasank: The rate of energy coming from the Sun changes slightly day to day. Over many millennia the Earth-Sun orbital relationship can change the geographical distribution of the sun's energy over the Earth's surface.

Mita: Does it affect our climate in any way?

Rabi: It has been suggested that changes in solar output might affect our climate—both directly, by changing the rate of solar heating of the Earth and atmosphere, and indirectly, by changing cloud forming processes.

Gopal: I did not know that Sun is so influential in our life. I find it very interesting to listen your discussion.

Sunil: I am feeling thirsty, why can't we go to that shop and sit there for some time and have something to drink.

Mita: Good idea.

Sunil: Didi, I always give good idea, but you never listen.
(They are going to a nearby shop and asking for some tender coconut water, discussion continues)

Rabi: That is why the first scientific speculations about different climate asks how sunlight falls on the earth in different places.

Sunil: What is exactly the meaning of climate?

Sasank: The very word climate, from Greek klimat, inclination or latitude, originally stood for a simple band of latitude. When scientists began to ponder the possibility of climate change, their thoughts naturally turned to the Sun

Rabi: Early modern scientists found it plausible that the Sun could not burn forever, and speculated about a slow deterioration of the Earth's climate as the fuel ran out.

Renu: Yes, in 1801 the great astronomer William Herschel introduced the idea of more transient climate connections. It was a well-known fact that some stars varied in brightness.

Sunil: Is our Sun a star?

Mita: Yes. It is a star of medium size.

Sunil: What do you mean by medium star?

Rabi: It was a well-known fact that some stars varied in brightness. Since our Sun is itself a star, it was natural to ask whether the Sun's brightness might vary, bringing cooler or warmer periods on Earth?

Sasank: As evidence of a connection between Sun and weather, Herschel pointed to periods in the 17th century, ranging from two decades to a few years, when hardly any sunspots had been observed. During those periods, he remarked, the price of wheat had been high, presumably reflecting spells of drought.

Sunil: What is sun spot?

Renu: Sunspots are darker, cooler areas on the surface of the sun in a region called the photosphere.

Sunil: That means Sun is cooler also.

Sasank: No, no, the photosphere has a temperature of 5,800 degrees Kelvin. Sunspots have temperatures of about 3,800 degrees K. They look dark only in comparison with the brighter and hotter regions of the photosphere around them.

Rabi: Sunspots can be very large, up to 50,000 kilometres in diameter. They are caused by interactions with the Sun's magnetic field which are not fully understood.

Sunil: So big!

Rabi: A sunspot is simply a region on the surface of the sun—called the photosphere—that is temporarily cool and dark compared to surrounding regions. Solar measurements reveal that the average surface temperature of the sun is 6000° Celsius and that sunspots are about 1500° Celsius cooler than the area surrounding them (still very hot), and can last anywhere from a few hours to a few months.

Sasank: Sunspots are magnetic regions on the sun with magnetic field strengths thousands of times stronger than the Earth's magnetic field, and often appear in pairs that are aligned in an east-west direction. One set will have a positive or north magnetic field while the other set will have a negative or south magnetic field.

Mita: Does the two magnetic fields are equally strong at every place?

Renu: No, sunspots have a magnetic field that is about 1000 times stronger than the surrounding photosphere.

Sunil: How many sun spots can we see at a time?

Sasank: Sometimes the sun contains a large number of sunspots, while at other times, few or none are seen. In 1843, the German chemist and amateur astronomer Heinrich Schwabe discovered that there was a fairly regular cycle of change in the number of sunspots and that this cycle lasts about 11 years.

Rabi: The part of the solar cycle with low sunspot activity is referred to as "solar minimum" while the portion of the cycle with high activity is known as "solar maximum" or "solar max" - every 11 years or so.

Sunil: But how do they count the number of sun spot?

Sasank: okay, the "sunspot number" is calculated by first counting the number of sunspot groups and then the number of individual sunspots. The sunspot number is then given by the sum of the number of individual sunspots, then they calculate from this.

Rabi: Most sunspot groups have, on average, about ten spots, this formula for counting sunspots gives reliable numbers even when the observing conditions are less than ideal and small spots are hard to see.

Renu: Sunspots are storms on the sun's surface that are marked by intense magnetic activity and play host to solar flares and hot gassy ejections from the sun's corona.

Mita: I have read somewhere that sun is more bright than earlier. Is it true?

Sasank: Some studies indicate that sunspot activity overall has doubled in the last century. The apparent result down here on Earth is that the sun glows brighter by about 0.1 percent now than it did 100 years ago.

Rabi: Solar wind, according to NASA's Marshall Space Flight Centre, consists of magnetized plasma flares and in some cases is linked to sunspots. It emanates from the sun and influences galactic rays that may in turn affect atmospheric phenomena on Earth, such as cloud cover.

Renu: This is not sure. Scientists are the first to admit that they have a lot to learn about phenomena like sunspots and solar wind, some of which is visible to humans on Earth in the form of Aurora Borealis and other far flung interplanetary light shows.

Mita: Does it have any relation with climate change?

Sasank: Few people say sun spot and solar wind is responsible for global warming. They say it's no coincidence that an increase in sunspot activity and a run-up of global temperatures on Earth are happening concurrently. Variation in solar energy has far more effect on earth's climate than the activities on earth.

Renu: Many climate scientists agree that sunspots and solar wind could be playing a role in climate change, but the vast majority view it as very minimal and attribute Earth's warming primarily to emissions from industrial activity—and they have thousands of peer-reviewed studies available to back up that claim.

Rabi: Peter Foukal of the America who has tracked sunspot intensities from different spots around the globe dating back four centuries, also concludes that such solar disturbances have little or no impact on global warming.

Sasank: Scientists have considered the sun-climate hypothesis to explain Earth's rapid warming. The evidence collected show that the sun noticeably affects our climate over millions of years, but it is not the cause of recent warming.

Mita: How it is chacha?

Sasank: The rate at which energy from the Sun reaches the top of Earth's atmosphere is called "total solar irradiance" (or TSI). TSI fluctuates slightly from day to day and week to week. In addition to these rapid, short-term fluctuations, there is an 11-year cycle in TSI measurements related to sunspots.

Mita: Is there any research or theory related to this? There will be a science seminar in our college. I can prepare a talk on this.

Sunil: Chacha will tell you and you will copy that. Copycat.

Mita: Papa, lease tells sunil, I am not copying chacha, but gathering data from him and I will prepare my own project.

Rabi: Don't fight, Sunil, try to understand what chacha is telling.

Sasank: Two different hypotheses have been proposed to test whether solar radiation can explain climate change.

Mita: What are they?

Sasank: he first hypothesis relies on the fact that in both the 11 year cycle and, in the longer term, the changes in solar energy are highest at ultraviolet or short wavelengths. The short wavelength radiation is particularly effective in modifying ozone concentrations in the level of the atmosphere above where typical weather occurs.

Mita: Could you please explain?

Sasank: According to this hypothesis, modifications in the ozone layer could in turn filter down to that level of the atmosphere where our weather is formed, potentially modifying clouds and temperatures there.

Renu: What is the second hypothesis?

Sasank: The second hypothesis relies on the fact that changes in solar activity also change the flow of small, charged, highly energetic particles (known as cosmic rays) that travel through the atmosphere toward Earth.

Mita: How does this particle affects the atmosphere?

Sasank: These particles in turn create more ions (charged atoms or molecules) from air molecules in the atmosphere, and it has been suggested that these ions might modify cloud formation, causing large changes in weather and temperatures

below. However, the effect of cosmic rays on cloud formation is too weak to effect the Earth' climate in a significant way.

Mita: Are these hypothesis are established facts?

Sasank: So far, there is no convincing evidence that either of these hypotheses adequately demonstrate a causal link between small changes in solar irradiance and the increase in Earth's surface temperature that has been measured for more than a century.

Rabi: The 11 year solar radiation cycle, as well as small increase in TSI since 1750, appear in some studies to be correlated with variations in cloud patterns. But, these changes in solar energy absorbed by the Earth appear to be far too small to explain the major changes in our climate.

Renu: Are other particles affecting global climate?

Sasank: The rate at which solar energy reaches the Earth's surface in any location depends on the season, time of day, cloudiness and the concentration of small aerosol particles in the atmosphere. During the last two decades, aerosol emissions increased in some countries and decreased in others. Research shows that the impact of these particles on global average surface temperature over this time period is small.

Mita: What is causing increases in the Earth's average temperature, and how do we know this?

Rabi: We do know with a good degree of certainty that between 1750-2011, or since the beginning of the industrial period until today, the average increase in energy hitting a given area of the atmosphere due to heat-trapping gases is 56 times greater than the increase in radioactive forcing from the small shift in the sun's energy.

Sasank: There are other factors also which affects the earth's climate.

Mita: What are they?

Sasank: Perhaps one of the most apparent factors contributing to Earth climate change is the angle at which the earth is tilted. This is the angle at which Earth's axis of rotation is from the vertical, also known as Earth's obliquity.

Sunil: Yes I know, Earth's current tilt angle is approximately 23.5 degrees.

Sasank: The axial tilt angle affects climate largely by determining which parts of the earth get more sunlight during different stages of the year. This is the primary cause for the different seasons Earth experiences throughout the year, as well as the intensity of the seasons for higher latitudes

Renu: Please explain it Sasank.

Sasank: yes bhabi, For example, in the Northern Hemisphere, if there were no axial tilt, i.e. Earth's obliquity would be zero degrees, then there would be no

change in the seasons from year to year. This would be because there would be no difference in the amount of solar irradiation received, year-round, anywhere on Earth.

Mita: But if the tilt would have been more…

Sasank: if Earth's axial tilt angle was great (45+ degrees), the seasonality of each hemisphere, individually, would be highly exaggerated. Summers would be extremely hot, with substantially more hours of daylight than night each day. Winters would be extremely cold, with substantially more hours of night than daylight each day.

Rabi: Earth's eccentricity can also play a large role in Earth climate change. The role is perhaps not as large of an impact as Earth's Obliquity, but still large nonetheless.

Sunil: What is eccentricity?

Rabi: Eccentricity is defined as the difference in shape between an ellipse and a perfect circle. In the case of climate, eccentricity is applied to the shape of Earth's orbit. In a similar fashion to Earth's obliquity, the more uniform Earth's orbit is (more like a perfect circle), the less difference there is in climate change throughout the year.

Mita How does eccentricity affect climate?

Rabi: Unlike obliquity, eccentricity affects the entire planet approximately the same, instead of primarily changing polar climate. The base idea with eccentricity is this: “How far away is the earth as a whole from the sun?” If there is no eccentricity to Earth's orbit, then Earth will remain at the same distance from the sun throughout the year, therefore producing no climate change.

Renu: Any other possible factor?

Sasank: The precession of solstices and equinoxes is the third factor that plays a role in Earth climate change that deals directly with the earth itself. The basis of the precession of solstices and equinoxes is that it causes the seasons to occur at different times in Earth's revolution around the sun throughout a cycle recurring about every 23,000 years.

Sunil: Then our case is closed, It: is greenhouse gases, and not solar activity, that are the main cause of climate changes this past century?

Sasank: Well, We cannot say so fast. Because when sunspot numbers rise and fall, there’s more going on than simply changes in solar brightness.

Mita: Then what else is happening?

Sasank: Periods of reduced sunspot activity correspond to periods of reduced magnetic activity on the sun, and reduced outflows of charges particles from the sun, the so-called solar wind. The solar wind whizzes past the Earth and deflects cosmic rays from deep space from hitting our atmosphere.

Sunil: Then what happens?

Sasank: A recent proposal from Danish scientists suggest that when cosmic rays strike our atmosphere, they create tiny aerosol particles that lead to increased cloud formation and less sunlight hitting the Earth. So it's a double whammy… fewer sunspots mean a dimmer sun, which also means more cosmic rays into the atmosphere and more cloud cover which further cools the Earth. And vice-versa when there is more solar activity.

Rabi: Another recent theory suggests increased UV light from the sun drives energy flow from the upper to lower atmosphere by disrupting a layer of ozone high in the atmosphere. How this affects climate is unclear.

Renu: As it turns out (as far as we know), computer models of the climate do not take these indirect effects of solar activity into account when calculating the change in global climate.

Sasank: And while human activity counts for only 5% of carbon dioxide emitted into the atmosphere each year, the sun accounts for ALL the energy striking the Earth and driving its dynamic and enormously complex ocean currents and atmosphere.

Rabi: So you see, despite what you hear in the media, there is still much uncertainty about how the Earth's climate really operates and changes over time, and how changes in solar activity drive climate change. Healthy and open skepticism, as always, is appropriate.

Sasank: And remember… the Earth is so complex that even the best computer model in the world can't tell you with any certainty whatsoever whether you'll need an umbrella when you head out the door to go the office a week from today.

Mita: Thank you chacha, I got so much data for my project.

Sunil: Yes chacha, I was thinking sun is so far away from us, how it could affect our life? But now I understand everything is happening for sun only.

Mita: Whether it is a sunny day or rainy day, depends on Sun.

Gopal: Now you all are agree with me that Sun is the God.

Sasank: No Gopal, Sun is not the God, but it affects our life in almost every aspect.

Gopal: I was telling people sun is the God, from today I can tell people sun is not the God. but it controls our life.

Sunil: Then sun must be providing us food, I'm hungry, let us go and eat our lunch.

(everybody laughs)…