STEM *Talks*

Presenter: Dr Jasmina Lazendic-Galloway - *2016*

Title: Supernova explosions: Destroyers and creators of habitable worlds - (16:23)

Time	***Dialogue***
00:10 00:32	When I was an undergraduate student I had an opportunity to work with an astronomer. Her work was to measure the positions of asteroids. Asteroids are moving very fast through the sky. Sometimes you just see them for one night. She measured the position of these particular asteroids that wouldn't be returning for years and then she learned that she ended up being the only astronomer observing that asteroids at that time. Everywhere else in the world all the other observatories couldn't observe it. They had cloudy weather. At that moment I knew that I wanted to become an astronomer. I knew I wanted to become a scientist because it meant that your work builds on a larger body of knowledge and can be quite unique. So that's how I became an astronomer and my expertise became exploding stars.
0:54 01:17	We have many stars out there in the sky and some of them are smaller than our sun. Some of them are like our sun and some of them are much bigger than our sun. Those ones that are more than 10 sizes of our sun, they explode and we call them Supernova remnants. They create spectacular images because there is a lot of energy released in these explosions and it's a bit of a detective story for astronomers to actually figure out what happened because no matter how much we can estimate what kind of star it is, we don't know how old it is. We don't know if it will explode tomorrow or if it will explode in a million years. So by observing these remnants of explosions that we call supernova remnants we then work backwards to figure out what was the star? What was the mass of the star that created this remnant and then we go and find that star in our current images.
01:44 02:11	So detective work is part of being a scientist as well. This is very exciting for us. This is part of the work I like and having these spectacular images to look at all day is super fun. So having to look and find the remainder of the star that exploded is the hardest part in this field because often they can be so small and their emission can be over whelmed by the brighter emission of the super nova remnant. Here you see with a circle where that tiny star that is the remains of the exploding star is and you can see how small; it is only about 20km in size and the remnants that travel further on extends to a much larger area and is much brighter. This is Cassiopeia A one of the youngest supernova remnants in the galaxy. It is only about 600 years old and even for this remanent it was very hard to find that remainder of the star.
02:38 03:03	But my recent research actually brings me much closer to home. So we all live on earth and we think it is very special but astronomers know that it is quite special. We are the only planet in the solar system that is habitable, which means it can support life. Mercury is too close to the sun so we know that it would never have been able to support life, but Venus and Mars are not too far off and they should have been able to support life, but somehow Earth ended up being the only planet in the system that had life. So then we start our detective story trying to figure out why earth is the only planet that has life. What is the property we have that the other planets don't? So to do that we obviously have to compare our planet with all the other planets, so we look at the eight major planents in our solar system and we divide them into two groups

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03:33 03:56	Ones we will call terrestrial, which are rocky planets like our earth and the others we will call gases, like Jupiter and Saturn because they are mostly made of gas. So rocky planets reside closer to the star [our sun] so we have four planets residing close to our sun because rocky material can survive closer to the hotter regions, but lighter material like hydrogen and helium can't survive so close to the star. They get evaporated or pushed away. So gaseous planets, gas will be formed further away. So in terms of supporting life we know that gaseous planets cannot support life. There is a small chance that they could but we are going with the highest possibility so we stick with the terrestrial planets. So then we zoom into our four terrestrial planets, Mercury, Venus, Earth and Mars and we try to figure out again what it is that the earth has that the others don't.
04:42 04:47	So we try and look at a cross section. Obviously we can't really do this. We can't slice a planet but we can measure in a different way, an indirect way we can estimate what the interiors and exteriors are. So we know planets have cores and crusts. The crust is made from lighter material like silicon and the core is made from heavier elements like iron. So when we estimate what is in the core of the planet we find that the earth is the only planet that has a partially molten core. All the other planets are already cooled down and their cores are solidified but the earth appears to be the only one with a partially molten core. What that means is basically the core behaves like a magnet and it gives us a magnetic field which is what we are the only planet to have.
05:12 05:33	So then we have to continue our detective story and figure out why is it that we are the only ones that have iron. So we have to think where do all these elements come – where do iron and silicon come from? So they all come from stars. Stars are the only places where heavier elements, those above helium are created. All the stars are formed in a molecular cloud. Those are basically a condensation of gas and dust spread out through our galaxy and then those clouds collapse and they form stars but depending on how much gas has collided in that region it will either form stars like our sun or you will form stars that are much more massive, much bigger than our sun. And like everything else those stars live and then they die and the way they die differ these two types of stars.
06:00 06:26	So if you have a normal type of star which is like our sun we say we say they die relatively gentle death. They just release their outer layers and the core of the star remains to shine for millions of years but with a massive star they live much much faster, only about a million years and they explode. They are so powerful, they are so massive that their gravity when they collapse blow the whole outer layers of the star and they are ejected as a super nova shell. So the event of the explosion is called a supernova and sometimes it can be so powerful it can outshine the whole galaxy in which these stars have died. The supernova event marks the event in which the outer layers of the shell have ejected and they form supernova remnants. In this process is where the elements are ejected. So elements are created in different layers of the star. They all start in the core obviously.
06:57 07:19	The star starts burning hydrogen to helium and then helium into carbon and then carbon into oxygen and so on. Oxygen to silicon and then silicon to iron and then when the star burns things up to iron it can't sustain this process anymore because iron is a very stable element. So when we are burning the fusion of iron we don't get as much energy released as the energy needed to burn iron. So in this moment the thermonuclear reaction is fusing these elements and provide a push outwards and those reactions stop and gravity of the star prevails and all the outer layers collapse into the star and then the core of the star collapses to become what we call a neutron star, or if it is really really massive it becomes a black hole, but the outer layers are spread out and they are ejected as supernova remnants. So this is the process by which these stars then release those elements, heavier than helium into the interstellar medium.

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07:53 08:15	And we know this by observing many supernova remnants. They roughly happen once per centaury in our galaxy and we have about 300 of them that we can observe at the moment. So we observe them in many details and then we try to model what has happened. So this is a projection of Cassiopeia A because we detected a different ejector from different elements and we tried to put them in a model and then manipulate them and recreate that model to understand how this process works. So you can see different elements. You can see iron in green and so on. We basically understand how this process works and we know that is how elements get dispersed throughout the interstellar medium. But then we continue our detective story. How do elements get to build planets?
08:39 08:58	So when we look at star forming regions in which we know stars are still being formed and with stars we know that there should also be planets still being formed around them. We can look at here the Orion nebula which is one of the youngest star forming regions in the galaxy, and you can see those brighter regions of the image. This is where massive star are heating the region around them and making it very bright. And then as you see further away you can see individual stars and you still see a lot of gas and dust that will go into building stars. When those massive stars explode they will disseminate their elements throughout this star forming region. If we try and zoom in we will see a little region where we see proto planetary discs.
09:23 09:53	So we know that as the star is being formed at a certain point a star lights up and there will be debris discs around from which planets will be forming and then as the massive stars release their elements, those elements basically get embedded into these proto planetary discs. So if we are able to zoom in further we would see something like this. A proto planetary disc is basically made of gas and dust and that dust starts colliding and creating little rocks and those rocks collide to create bigger rocks and those bigger rocks eventually collide to create planets while the star is still shining in the centre. So if we were able to zoom further more we would see those rocks building bigger planets.
10:06 10:42	And the collision basically releases heat and then melts those rocks and that's how planets slowly cool off eventually and solidify. So this is what we think happened to Mars and Venus but it didn't happen to earth. So there has to be some source that somehow that the proto planetary material that building earth had to then create an extra energy source to keep our core molten and what we think that extra element is, is Aluminium 26. It's a radioactive element that decays over about 1 million years and releases something like 4 million electronvolts (eV) of energy. That's a lot of energy that can then be used to keep our iron core still molten. So the question then becomes - why only earth and why is that existence of the molten core important?
11:04 11:35	As I mentioned before it's because we have the molten core behaving basically like a magnet so it gives us a magnetic. That magnetic field protects us from the solar wind. All the stars big and small produce solar wind. They are basically highly charged particles that are released from time to time from the surface of these suns. And our sun has moderately strong or moderately weak solar wind so regardless of their strength they have power to disassociate water. When they come to disassociate water hydrogen and oxygen are broken down, hydrogen being very light would leave our atmosphere and water would slowly evaporate. This is what we think happened to Mars. Because Mars doesn't have a strong magnetic field this is how we think Mars lost its water. When it was older it had oceans similar to earth. So this is one reason that this magnetic field allows earth to be habitable, to be supportive of life because we think the easiest way to make life is having water, liquid water on the surface of a planet.

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12:07 12:23	But another reason is that because you create life you have to protect it from cosmic rays. Cosmic rays are again created in these supernova explosions and they travel throughout the galaxy. They are the highest energy particles there are and if they are able to come to the surface of a planet they will irradiate a living organism. What that means is they will go through our body and disassociate water inside our bodies and we know we are mostly made of water which means is it would create genetic mutations and [the] life would not be able to progress as fast as is possible.
12:42 13:01	So our magnetic field protects us by preserving our water and protecting us from these cosmic ray particles which have to go around, [they have to follow] the magnetic field lines and go around our Earth. Of course some of these particles from [the] solar wind do come in through some regions of the magnetic field but they give us those beautiful Auroras that we see. So when we then look why is Earth the only place that maybe captures this Aluminium 26? Why [didn't] Mars and Venus have Aluminium 26? We have to then look back and figure out what is the distribution of this element.
13:21 13:56	Because Aluminium 26 decays over a million years the supernova events that we think have created our solar system would have long gone by now that humans came on the scene, so we can't observe Aluminium 26 anymore directly but we can observe Magnesium 26 which is an element into which Aluminium 26 decays. And this line of magnesium is emitted in gamma ray wavelengths which are some of the highest energies we can observe, so we need a satellite to launch them [the detectors] above our atmosphere to observe this line. So what we can do now is basically try and see if we map (and you see here a rough map of the galaxy in the magnesium line) but we can now zoom [in] on individual stellar forming regions to understand if this emission is uniformly distributed and therefore all terrestrial planets in that solar system should be habitable or maybe somehow for some unknown mechanism to us at the moment this Aluminium 26 is clumped up and only certain planets get to embed it into their larger body.
14:30 14:48	So this is the way that we untangle the story. We find something unique and then try to find the reason why that exists. So to me that is part of the science. Of understanding that process, behaving like a detective and trying to find the answer. So this way we know that supernova remnants can create habitable worlds. They can create worlds that can support life but we also know that they are highly destructive. [They would] ... If there are any planets around these stars they would be destroyed by these explosions. [They are] Basically one of the most massive events in the universe and they would be just engulfed and any life would be obliterated if there is time to develop life. But they don't just pose [a] threat for the planets around them they also pose [a] threat for us as a nearby object because they release so much energy.
15:21 15:42	They release so much gamma [radiation] rays that basically they could come and do [the] damage even with or without [the] magnetic field we would not be protected if we had a relatively nearby supernova remanent. So if we get irradiated we would all turn into superheros like the Fantastic Four and that would be great. But in a worst case scenario only cockroaches would survive. Cockroaches [they] have bodies with the least amount of water so they would suffer the least amount of genetic mutation and they will be able to go on and continue for us. Luckily we know there is no massive star within 75 light years which is roughly the distance it would take us to reach some of these emissions. So we can all rest in peace that we are not going to be irradiated and cockroaches are not going to take over our world. Thank-you.