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Video Podcast **Hubblecast 23 Special Edition -** **Eyes on the Skies Chapter 5: Seeing the Invisible** **FOR IMMEDIATE RELEASE 14:00 (CET)/8:00 AM EST 25 November, 2008**		
00:30 **[Dr. J]** When you listen to your favourite piece of music, your ears pick up on a very wide range of frequencies, from the deepest rumblings of the bass to the very highest pitched vibrations. Now imagine your ears were only sensitive to a very limited range of frequencies. You'd miss out on most of the good stuff! **00:55** But that's essentially the situations that astronomers are in. Our eyes are only sensitive to a very narrow range of light frequencies: visible light. But we are completely blind to all other forms of electromagnetic radiation.		Dr. J. in a concert hall
01:00 However, there are many objects in the Universe that do emit radiation at other parts of the electromagnetic spectrum.		Full screen Graphics of the Hidden Universe – from across the electromagnetic spectrum.
01:08 For example, in the 1930s it was discovered by accident that there are radio waves coming from the depths of space. Some of these waves have the same frequency as your favourite radio station, but they are much weaker and of course there's nothing to listen to.		Dr. J. in a concert hall With old images of the first radio telescopes behind him.
01:25 In order to "tune in" to the radio Universe, you need some sort of receiver: a radio telescope. Now for all but the longest wavelengths, a radio telescope is just a dish. Much like the main mirror of an optical telescope. But because radio waves are so much longer than visible lightwaves, the surface of a dish doesn't have to be nearly as smooth as the surface of a mirror. And that's the reason why it's so much easier to build a large radio telescope than it is to build a large optical telescope. **01:55**		Dr. J. in Virtual Studio with TV screens behind

Also, at radio wavelengths, it is much easier to do interferometry. That is, to increase the level of detail that can be seen by combining the light from two separate telescopes, as if they were part of a single, giant dish.		Footage of Very Large Array (full screen, Dr. J. not in view anymore).
The Very Large Array in New Mexico, for example, consists of 27 separate antennas, each measuring 25 metres across. Now each antenna can be moved around individually, and in its most extended configuration, the virtual dish mimicked by the array measures 36 kilometres across.		Videos behind Dr. J.
02:29 So what does the Universe look like in the radio? Well, for a start our Sun shines very brightly at radio wavelengths. So does the centre of our Milky Way Galaxy. But there's more.		
02:41 Pulsars are very dense stellar corpses that emit radio waves only into a very narrow beam. In addition, they rotate at speeds of up to several hundred revolutions per second. So in effect, a pulsar looks like a rotating radio lighthouse. And what we see from them is a very regular and fast sequence of very short radio pulses. Hence the name.		
03:05 The radio source known as Cassiopeia A is in fact the remnant of a supernova that exploded in the 17th century.		 Radio image of Cas A
03:12 Centaurus A, Cygnus A and Virgo A are all giant galaxies that pour out huge amounts of radio waves. Each galaxy is powered by a massive black hole at its centre.		
03:24 Some of these radio galaxies and quasars are so powerful that their signals can still be detected from a distance of 10 billion light-years.		
And then there's the faint, relatively short-wavelength radio hiss that fills the entire Universe. This is known as the cosmic microwave background, and it is the echo of the Big Bang. The very afterglow of the hot beginnings of the Universe.		Dr. J. in Virtual Studio

03:50 **[Narrator]** Each and every part of the spectrum has its own story to tell. At millimetre and submillimetre wavelengths, astronomers study the formation of galaxies in the early Universe, and the origin of stars and planets in our own Milky Way. But most of this radiation is blocked by water vapour in our atmosphere. To observe it, you need to go high and dry		Animation of electromagnetic spectrum (from Hidden Universe). Show how certain wavelengths are blocked by the atmosphere.
04:12 To Llano de Chajnantor, for example. At five kilometres above sea level, this surrealistic plateau in northern Chile is the construction site of ALMA: the Atacama Large Millimeter Array. When completed in 2014, ALMA will be the largest astronomical observatory ever built. 64 antennas each weighing 100 tonnes, will work in unison. Giant trucks will spread them out over an area as large as London to increase the detail of the image, or bring them close together to provide a wider view. Each move will be made with millimetre precision.		Footage of Chajnantor.
04:52 **[Dr. J]** Many objects in the Universe also glow in the infrared. Discovered by William Herschel, infrared radiation is often also called "heat radiation" because it is emitted by all relatively warm objects, including humans.		Dr. J. in virtual studio with infrared images of the universe in the background
You may be more familiar with infrared radiation than you think. Because on Earth, this kind of radiation is used by night vision goggles and cameras.		Dr. J. shown in infrared
05:19 But to detect the faint infrared glow from distant objects, astronomers need very sensitive detectors, cooled down to just a few degrees above absolute zero, in order to suppress their own heat radiation.		Cryogenically cooled detector.
05:34 Today, most big optical telescopes are also equipped with infrared cameras. They allow you to see right through a cosmic dust cloud, revealing the newborn stars inside, something that just cannot be seen in the optical.		Dr. J. in virtual studio
For example, take this optical image of the famous stellar nursery in Orion. But look how different it is when seen through the eyes of an infrared camera!		M42 image; crossfade to infrared image
05:59 Being able to see in the infrared is also very helpful when studying the most distant galaxies. The newborn stars in a young galaxy shine very brightly in the ultraviolet. But then this ultraviolet light has to travel for billions of years across the expanding Universe. The expansion stretches the lightwaves so that when they are received by us, they've been shifted all the way into the near-infrared.		Pan across infrared deep field image. 

06:25
[Narrator]
This stylish instrument is the MAGIC telescope on La Palma. It searches the sky for cosmic gamma rays, the most energetic form of radiation in Nature.

Footage of MAGIC telescope on La Palma

Lucky for us, the lethal gamma rays are blocked by the Earth's atmosphere. But they do leave behind footprints for astronomers to study. After hitting the atmosphere, they produce cascades of energetic particles. These, in turn, cause a faint glow that MAGIC can see.

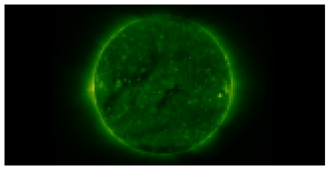
06:55
And here's the Pierre Auger Observatory in Argentina. It doesn't even look like a telescope. Pierre Auger consists of 1600 detectors, spread over 3000 square kilometres. They catch the particle fallout of cosmic rays from distant supernovas and black holes.

Images of the Pierre Auger Observatory

07:16
And what about neutrino detectors, built in deep mines or beneath the surface of the ocean, or in the Antarctic ice. Could you call those telescopes?

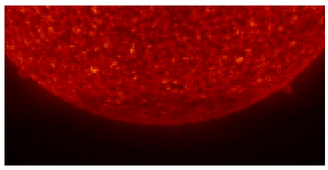
Well, why not? After all, they do observe the Universe, even if they don't capture data from the electromagnetic spectrum.

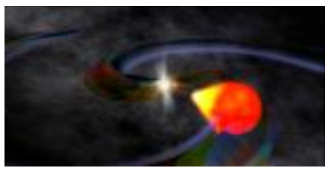
07:35
Neutrinos are elusive particles that are produced in the Sun and supernova explosions. They were even produced in the Big Bang itself.



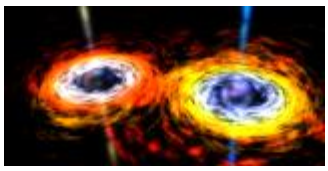
Unlike other elementary particles, neutrinos can pass through regular matter, travel near the speed of light and have no electric charge.

Although these particles may be difficult to study, they are plentiful. Each second more than 50 trillion electron neutrinos from the Sun pass through you.





08:05
Finally, astronomers and physicists have joined forces to build gravitational wave detectors. These "telescopes" do not observe radiation or catch particles. Instead, they measure tiny ripples in the very structure of space-time – a concept predicted by Albert Einstein's theory of relativity.



08:25 With a stunning variety of instruments, astronomers have opened up the full spectrum of electromagnetic radiation, and have even ventured beyond.		  
08:36 But some observations simply can't be done from the ground. The answer? Space telescopes.		Cross to deep space image (slowly panning). Out of the distance Hubble comes into view. 
09:12 END		