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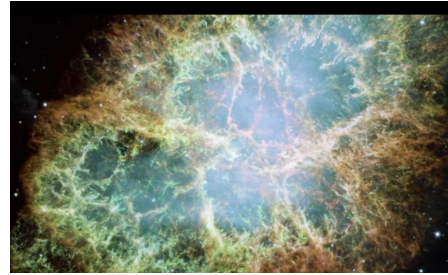
<b>Hubblecast Episode 74: Hubble and Heaven's Carousel</b>	<b>Visual notes</b>
<p><b>00:00</b> 1. Ambient Sound/artwork sound</p>	
<p><b>[Interview with Esa Pietilä (composer)]</b> 2. How all these elements are put together; I find it fascinating - very well done - it is touching - I was also laughing at some points - --</p>	
<p><b>00:00</b> <b>3. Intro</b></p>	

**00:00**

**[Narrator]**

4. Over its lifetime Hubble has inspired new thinking about the Universe and contributed to more fields within physics and astronomy than we could ever have imagined.

But Hubble has also become an icon of discovery, of human achievement, and of culture. And has been the inspiration for artistic work that goes beyond the science. Creations of art and sound. Creations like Tim Otto Roth's *Heaven's Carousel*, premiered in March 2014 at the fourth Hubble Space Telescope Conference at the Accademia dei Lincei in Rome.



**00:00**

**[Tim Otto Roth]**

5. What's the point? What you, well, you see it glowing but finally you will see or will hear that are sounds coming out.

So what I'm doing? I am translating light physics into acoustics.

So imagine, that's the simple experiment of Heaven's Carousel. You hear the stars, the galaxies up on there.



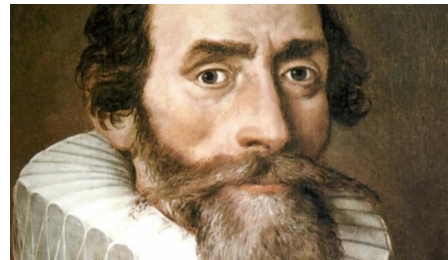
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**[Narrator]**

6. Tim Otto Roth has used sound to interpret the light that Hubble collects when it looks at the stars. This allows us to explore the physics of light with our ears and follows an ancient tradition of linking music to astronomy.

2500 years ago the Pythagoreans speculated about a connection between planetary motions and the small-numbered ratios that describe musical harmonies. These ratios form the foundation of western music and the mathematics of this harmony of the spheres was even used by the renowned astronomer Johannes Kepler.

More recently, in the 1800s, Christian Doppler wondered whether the effect that he observed in stars, and which would later bear his name, could be demonstrated with sound. And so it was, first using a brass band on an open railway wagon and then later, by the *Heaven's Carousel*.



**00:00**

**[Dr J]**

7. The Doppler effect causes a shift in the observed wavelength of radiation. If the source of the radiation and the observer are in motion relative to each other.

Now in this simulation, we have a light source moving into the right. So to Alice sitting on the right, the source appears bluer because the wavelengths are compressed. But Bob on the left, sees redder light because the wavelengths are stretched. The light is blue- or redshifted.

The same thing happens to sound. As the train with a brass band passed the audience, they would have heard the pitch changing from higher to lower.



00:00

**[Tim Otto Roth]**

8. Just because I could not afford a whole brass band sitting for days or weeks at a carousel turning around well I just took loudspeakers playing sine waves.



00:00

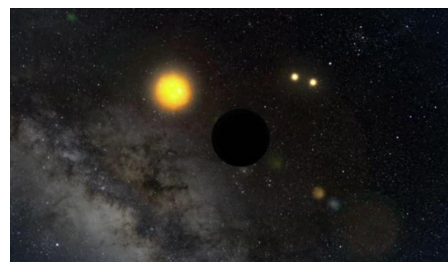
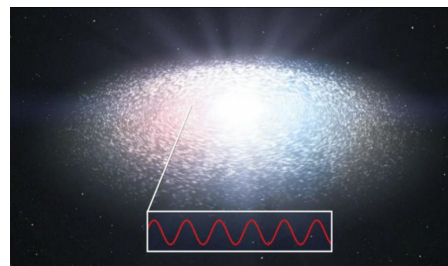
**[Narrator]**

9. At the centre of the *Heaven's Carousel* the pitch of the tones is constant, and no Doppler effect is heard. The 36 speakers circle overhead and neither approach nor recede from your ears.

As you move out from the centre the effect becomes steadily stronger. Each new position brings a new perspective and a different set of pitches can be heard, changing with the changes in direction of the speakers. Wavelengths are stretched as the speakers recede, and compressed as they approach.

The Doppler shift explains what we see in the local Universe when objects are moving away from or towards us. This is one way that astronomers have detected exoplanets orbiting nearby stars.

But this effect also has a cosmological cousin. A form of redshift that allowed Hubble's namesake, Edwin Hubble to discover in the 1920s that the Universe is expanding. A discovery that revolutionised our thinking about the cosmos.



**00:00**

**[Dr J]**

10. Space itself is stretched as the Universe expands and stretched with it are the wavelengths of light from distant galaxies. The more distant a galaxy, the more its light-waves are stretched as they travel across the Universe, and the redder its light appears. *This* is the cosmological redshift.

Now, clearly the cosmological redshift is somehow connected with distance, but the exact relation between the two depends on how the Universe expanded in the past.

Astronomers have studied this relationship using far-away exploding stars called supernovae. By comparing their redshifts with Hubble's observations of their actual distances, they discovered that the Universe began accelerating around about 6 billion years ago.

Now this came as quite a shock - because after all, the combined gravitational pull from all of the matter in the Universe should in fact slow down the expansion of the Universe. Why it is instead speeding up is one of the deepest mysteries in contemporary physics.



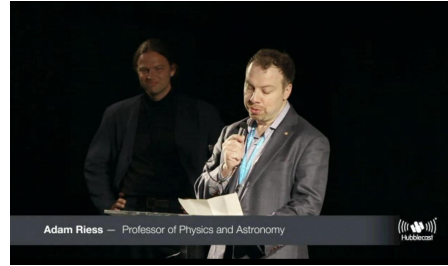
**00:00**

**[Adam Riess]**

11. To the cosmologist acceleration offers insights into the age and fate of the Universe and perhaps an echo of the prior growth spurt called inflation.

But it seems only natural that new knowledge evokes feelings. And feelings are better communicated by art than by science.

This incredible dynamic sculpture created by Tim Otto Roth channels some of those feelings about the accelerating Universe. Important themes related to the discovery are echoed in the piece. Blue shifts and redshift; isotropy and homogeneity; our inability to see the strings directing the action; the struggle to perceive depth in the Universe, are just a few. And I am sure you will have and will find many more.



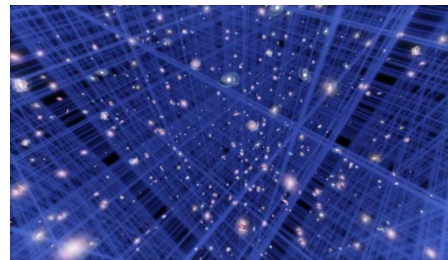
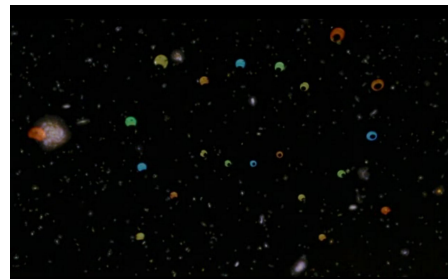
**[Narrator]**

12. Hubble has shown us the Universe and the Heaven's Carousel has transformed these red- and blueshifts into a moving fabric of speakers and sound. The expansion of the Universe played out in a concert of sound and light.

At times these sources of sound are telling us through their pitch that they are moving away from us. Leaving the same clues that planets around distant stars leave for today's astronomers.

And at other times, a high pitch and dazzling ice blue, transitions to a deep red and a pitch almost too low to hear. Making us feel like an observer of cosmic time, listening as the Universe expands and its contents accelerate away from us.

\*Ambient sound\*



**Ends xx:xx**

