A Black Hole's Journey

An Audio Universe Production

By Chris Harrison and Rose Shepherd

Scene 1 - Introduction

Visuals: *Start lobby area of the spaceship.*
Audio: *Music stars*

Captain Lambert: Hello passengers. Welcome onboard the Sonic Explorer spacecraft for our Audio Universe tour!

I'm Captain Lambert. I'll be guiding you from the command deck.

We are already travelling through interstellar space. So…please use the elevator to reach the observation deck.

Visuals: *Enter elevator and go upwards towards the viewing deck. Arriving at the viewing deck. Outside can see spacecraft moving slowly through space.*
Audio: *Elevator sounds and beep to show arrived at top of elevator*

Captain Lambert: Welcome to the observation deck!

Let's explore our special equipment.

As most of the Universe is invisible to our eyes, the Sonic Explorer is fitted with special cameras and sensors. For example, we can turn invisible X-rays and gravitational waves into images we can see.

Visuals: *Visual holographic screens to show examples images*

Captain Lambert: Our revolutionary sonification machine can also turn signals and information into *sounds*.

But remember, sound does not travel through the vacuum of space, but we can use sound to represent light and other information.

This means that you can enjoy our tour with your eyes open or closed…but don't go falling asleep!

Visuals: *Visual projectors have been 'turned off'.*

Captain Lambert:
Let's test out our sonification machine.

When the machine is re-tuning you will hear this sound…

Audio: *Sonification Machine Tuning sound*

I've tuned ready for light from glowing balls that we use for testing our machine.

These balls will orbit around the observation deck and our machine will turn their light into sound.

Let's listen to the first one now. Starting at the front…

Audio: *Orbit sound for less dense object sonification test*

To the left…

Behind…

To the right…

And back at the front.

Now let's use the second ball. This has the same mass as the first ball - the same number of kilograms. However, it is smaller in size. That makes it a more dense object.

We will represent the light from this more compact and denser object with a lower pitched sound.

Here we go…

Audio: *Orbit sound for more dense object sonification test*

Test complete!

Okay passengers, today our journey will be exploring the stars. From Earth stars look like pin-pricks of light in the night sky, but today we'll get up close to these giant balls of gas!

Let's start the tour!

Visuals: *Flight travelling a bit quicker than before, spending some moments in a pleasant flight sequence. During this flight sequence approaches the outside of star cluster which will be the focus of Scene 3 (containing several different types of stars).*

Audio: *flight music, after acceleration of engine*

Scene 2 - Black Hole Capture

Visuals: *Feel of some shuddering, some alarms going off. Black Hole approaching in the distance.*
Audio: *Some relatively subtle alarm: robotic voice: "Warning: Black hole, warning: black hole". Dramatic feeling music.*

Captain Lambert: Oh no…we've stumbled upon a black hole!! - this is not good, we're getting pulled in!

Visuals: *Spaceship gets caught into orbit around black hole, over the next bit of dialogue gradually the ship becomes a stable orbit around the black hole.*

Captain Lambert: Hang on…We're picking up signals…maybe somebody is trying to help us! I will translate these…

Audio: *A mixture of chirps (like gravitational wave sounds) and noise which morphs into the following dialogue from the Black Hole.*

Black Hole: Hey! …. Hey! … Hey!

Captain: Hello? This is Captain Lambert on board the Sonic Explorer. Who is there?

Audio: *A mixture of chirps (like our GW sounds) and noise which morphs into the following dialogue from the Black Hole (a bit like tuning an analogue radio).*
Visuals*: Black hole shimmers as it speaks*

Black Hole: Same old story…there's a black hole…they must be destructive…blah blah blah…

Captain Lambert: I-I-Is that the black hole communicating with us?

Audio: *Alarms have faded away, music has faded away*

Black Hole: **Tuts** Yes I am a black hole.

Listen! You are fine in that orbit. Your ship is going around me because of my gravity. Just like your Earth orbits your Sun.

Captain Lambert: We do seem to be in a stable orbit. Passengers, everything is under control!

Visuals: *Black Hole alarms completely off. Gradually into a gentle orbit around black hole*
Audio*: Everything calming down.*

Black Hole: But…if you really want to get away so much…you can fly away with enough speed….

You're only in trouble if you get *too* close and then you can't travel fast enough to escape my gravitational pull.

You know…I used to be a star shining brightly. Everyone said I was beautiful….

Now everyone's scared of me, all I hear is: "*you're a black hole, sucking everything up and destroying everything*".

Captain Lambert: Err..Yes that *is* what I'd heard about black holes, that's why we have the alarms!

Black Hole: But it's not true! I don't suck. I'm very gravitationally attractive!

Captain Lambert: Anyway…if you'll excuse us, we are on our way to look at some stars.

Black Hole: Wait a minute!

I want to get the facts straight. Would you go on my guided tour? I can show you my Black Hole Journey.

Captain Lambert: Well… it seems we do have a lot to learn…

Let's do it!

…but…you promise we won't get sucked into a black hole?

Black Hole: I told you, black holes don't suck!

I've been waiting for people to try out my tour! There aren't many tourists here…

I'll transmit the route's co-ordinates and my messages to your spaceship as you visit the five different locations!

Captain Lambert: Passengers…time to sit back and enjoy A Black Hole's Journey!

Visuals: *Some sort of title screen appears with the name of the show, a short bit of flight time.*
Audio: *Brief music after acceleration of spacecraft*

Scene 3 – Stars Forming

Visuals: *After a few seconds ship slows down to have good view of star cluster*

Captain Lambert: Oh..we are already at the first stop!

Black Hole: That's right! You'd planned to explore stars - well - you're in luck. That's how my journey starts!

Captain Lambert: Oh, the stars are beautiful!

Black Hole: Yeah yeah…everybody loves stars…

Captain Lambert: Oh…sorry….

Black Hole: Anyway, once upon a time there was just a giant cloud here, called a nebula. Mostly made of hydrogen gas.

Visuals: *Screen comes up ready to play gas cloud animation. Playing the video only (no sonification) whilst this explanation is happening.*

Black Hole: About 100 Million years ago this started collapsing inwards because of gravity.

Lots of dense lumps were made inside it. These became giant balls of gas.

They got so hot and dense the hydrogen particles could start joining together and they produced loads of heat and light.

That's nuclear fusion!

and so the stars were born!

Captain Lambert: o0o, let's tune our sonification machine to represent this!

We'll represent the collapsing nebula cloud with a noisy sound. Then, every time a star is formed, we will hear one pluck of a harp. These will get higher in pitch and come more quickly when the stars are being created faster.

Audio: *Sonification Machine Tuning*

Black Hole: Let's do the first few million years, when the 100 stars with the most mass were made in this cloud.

Your Sun does have a lot of mass…300,000 times more than your Earth.

But stars, like *I* used to be, have *much* more impressive masses, with tens or hundreds of times more mass than the Sun!

Captain Lambert: Okay. Let's play it!

Audio+Visuals: *Play star-forming sonification video*

Black Hole: Your sonification machine is great! Your passengers can explore space, even if they have limited or no vision.

Captain Lambert: That's right! Plus, everybody can learn something new by listening to information, even if they can see perfectly well.

Visuals: *Fade sonification video away*

Black Hole: So…me and these other stars ran out of fuel a long time ago…

Let me show you what happened.

Captain Lambert: The transmitted co-ordinates show…I should steer the ship towards…another black hole!

Scene 3b - Black Hole Formation

Visuals: *Very short flight sequence to supernovae remnant*
Audio: *Ship's acceleration*

Captain Lambert: There's a glowing ring of gas, it is gigantic!

And wait…

…if we zoom in with our camera to its centre....we can observe the black hole!

How exciting!

Visuals: *Use screen to "zoom-in" onto another black hole (a non-talking, standard black hole!).*

Black Hole: Stars which have much more mass than your Sun can turn into black holes. They also blow away their outer layers of gas to make a supernova. Like that gas you see!

This is what happened to me!

Captain: Can you tell us *why* this happened?

Black Hole: Yes…Let me show you an example.

This star used to contain 80 times more mass than your Sun!

Visuals: *Bring up another screen ready for the animations. Show a hot blue burning star. Show animation schematic, looking at core, with animated arrows outwards for pressure and inward arrows for gravity during this part. This will be the same animation as we will later use including the sound.*

Black Hole: Inside a young star's centre, called the core, super-hot hydrogen gas is going through nuclear reactions, and making an *outward* pressure force.

But gravity is pulling *inwards* trying to make the star shrink and collapse.

When the push from pressure and pull from gravity are balanced, the star is stable and won't collapse or explode.

Captain: Passengers…it is like a tug of war of the forces!

Black Hole: Erm…I guess so.

Captain Lambert: Let's represent the burning star when in force balance with this sound!

Audio: *Sonification Machine Tuning and then play short except of low density star*

Visuals: *Show animation during this speech to show the outward pressure disappearing and the core collapses (gravity is still strong with large arrows), then when Helium ignites, the whole thing is smaller but outward arrows and inward arrows back in balance.*

Black Hole: These forces were balanced nicely until the hydrogen fuel ran out, then the outward pressure went away and gravity started winning! The star's core shrunk inwards.

..until it fired up again, now burning Helium gas, but with a denser core!

Captain Lambert: Oh right! We can represent the light from this denser core with this lower pitched sound…

Audio: *Play short except of denser star*

Black Hole:
For a while, the forces were balanced again.

But not for long, only a few hundred thousand years. When the Helium ran out, everything sped up…until… no more fuel. No more outward pressure, gravity won!

In just seconds, the core collapsed inwards and inwards with nothing to stop it!

A black hole was made!

Visuals: *Remove screen*

Captain Lambert: Fascinating. But what caused this ring of gas around the black hole?

Black Hole: Remember…it's called a supernova.

When the star collapsed it sent out a powerful shockwave and the outer layers of the star were blown away in a big explosion!

Captain Lambert: We can use a wind sound for the supernova explosion.

Audio: *Sonification Machine Tuning*
Visuals: *Bring up screen again. We will see the animation again but this time with sound.*

Passengers let's experience the whole process of that star becoming a black hole. Here we go…

Black Hole:

Hydrogen burning.

Hydrogen running out…

Helium burning.

Helium running out…

Supernova coming…

Black Hole: Black holes are the densest objects in the Universe!

A lot of mass in a very very small space is why my gravity is so strong!

And the gas from supernovae explosions can go on to form new stars! The circle of star life.

Captain Lambert: This has been really interesting! But will all the stars become black holes?

Black Hole: Not all stars are lucky enough to become black holes like me!

Most don't have enough mass. They will turn into neutron stars, or white dwarf stars. These have outward pressure forces stopping them from collapsing into black holes.

But these are still very dense. A neutron star contains several Suns worth of mass squashed into just a few kilometers in size.

Captain Lambert: A star squashed into the size of a small city! That is very dense!

…How much would a teaspoon of neutron star weigh?

Black Hole: Err what? I guess about 3 billion tons…

Captain Lambert: Ooo…You would need a very heavy-duty teaspoon!

Black Hole: Hmmm....Let's move on to the third part of our tour…

Captain Lambert: Setting the ship's path. Here we go!

Scene 4 - Gravitational Waves

Audio: *Ship's acceleration followed by music*

Visuals: *Flight sequence, ending with two black holes slowly orbiting each other*

Captain Lambert: Woah! Two black holes and they are going around each other!

One looks like it has more mass than the other.

Black Hole: Yes! As these black holes orbit around each other, their super strong gravity pulls on space itself.

As they spiral around and around, they make invisible ripples in space that travel through the Universe…squeezing and stretching anything they pass through.

We call these ripples gravitational waves!

Let me show you what will happen in the future to these black holes…

Visuals: *Bring up orbiting black hole visualisation+sonification on screens.*

Captain Lambert: Okay! I'll set this up to use a whoosh sound each time one of the black holes passes in front of us. The gravitational wave will be a hum sound.

Audio: *Sonification machine*

Captain Lambert: We can also add something visual to show the gravitational wave moving outwards.

Black Hole: The hum will get higher in pitch as the black holes spiral in faster and faster because the ripples from the gravitational waves are getting faster and faster.

Visuals+Audio: *Play sonification animation*

Captain Lambert: Cool! They merged together into one black hole.

Captain Lambert: Oo, Oo, I know why two black holes got closer and closer! They find each other *very* attractive!

Black Hole: *Sigh* Gravitational attraction brings the black holes together.

Captain Lambert: It was meant to be a joke...they find each other *attractive*....never mind...

Captain Lambert: Can we detect these gravitational waves on Earth?

Black Hole: Yes! But it's very difficult. You can't use normal telescopes.

You need super accurate lasers and mirrors to measure ripples in space that are much smaller than the width of an atom!

We get these signals from pairs of black holes or neutron stars merging together all over the Universe!

Let's experience some of the many gravitational wave signals that were detected on Earth, sped up so several months of detections are played in just 30 seconds!

Each will sound different because of the different masses merging together.

Captain Lambert: Okay, and we will also use pulses of light to represent where the signals are coming from.

Sounds coming.

Audio-Visual: All sky GW sequence (April-September events) [30 seconds]

Black Hole: These mergers happened so far away from us it took millions to billions of years for the signals to reach us!

But time to move on to the fourth station of our tour!

Captain Lambert: Receiving the location…

Let's go!

Scene 5 - Accretion

Flight sequence approaching an accreting black hole gradually get closer [~15 seconds].

Captain Lambert: Oh my! That star is being sucked into a black hole!

Visuals: Black Hole on screen looking directly at the audience (to tell Captain Lambert off!)

Black Hole:
Captain Lambert!
tut, tut, tut
what did I tell you?

Captain Lambert: Oops... Black holes don't suck…

So, what *is* happening here?

Visuals: *Ship settles at a "safe distance", could gently move around the system but accretion disk should be the main focal point throughout. Should not be able to see the X-ray light (yet)*

Black Hole: The strong force of gravity is pulling on the star's gas, making it spill into orbit around the black hole. This gas ends up spiralling inwards.

Captain Lambert: The gas looks like a very bright disc shape.

Black Hole: We call it an accretion disc.

Captain Lambert: and there appears to be narrow beams of light above and below the disk.

Black Hole: We call those jets.

Black Hole: Telescopes can find black holes because of the bright flickering light caused by this gas.

Captain Lambert: I'm going to tune our sonification machine to this visible light.

Black Hole: Wait! Make sure to tune into the X-ray light too!

Captain Lambert: Will do! We can also overlay our special X-ray camera.

Visuals: *Overlay a screen in the main field to include the flickering X-ray light.*
Audio: *Sonification Machine Tuning*

Captain: I've tuned the visible light to a musical chord, and the X-rays to be represented by a wind sound. These sounds will now get more intense as the light gets brighter, and less intense when it is fainter.

Audio+Visuals: *Full Sonification*
Visuals: *Turn off X-ray camera at end*

Captain Lambert: So powerful!

So what eventually happens to this gas?

Visuals: *Bring up on screens the animation of test particle*

Black Hole: Well…Let's imagine one lump of gas that's got very close to a black hole. If it loses energy, it spirals in and in, until it has no chance of escaping.

It eventually falls onto the black hole, adding mass to it.

That's how black holes grow!

Captain Lambert: Okay. We can represent a lump of gas with a sound which gets lower in pitch as it gets closer to the black hole. I'll add a click sound for when it becomes part of the black hole.

Audio: *Sonification Machine Tuning*

Captain Lambert: Here it is!

Visuals+Audio: Spiralling sonification and animation of one particle falling in.

Black Hole: Hey! Why don't you play that again but with seven lumps of gas?

Captain Lambert: Good idea! Passengers, see if you can hear all 7 clicks when each of the lumps becomes part of the black hole.

Visuals and Audio: Spiraling sonification and animation of lots of particles falling in

Captain Lambert: Hmm…it seems a bit like water spiraling down a kitchen sink's drain hole….

Black Hole: You *do* like comparing objects in space with your Earthly objects, don't you?

I'm not sure you understand the *gravity* of this situation!

Captain Lambert: *That's a good joke*…!

Black Hole: Nothing escapes you…

But remember. Black holes aren't really *holes* but a star's core, which has collapsed into a very very small space!

Captain Lambert: Passengers…we've learnt how things fall onto a black hole!

Black Hole: *Exactly.* Not a sucking force like your *Earthly vacuum cleaners*, just gravity. But if you get too close, you would be in a *whole* lot of trouble…

There's a distance close to the black hole, called the event horizon, where it doesn't matter how fast something travels, the force of gravity is too strong.

Even light - the fastest thing in the Universe - can not escape!

Visuals: Re-show gravitational wave videos and flickering X-rays accretion video on screens

Captain Lambert: Hence being black! But as we've experienced, the material *spiralling in* can be very bright, *and* gravitational waves can be released - so we know that black holes are there!

Black Hole: Great summary Captain Lambert. I'm glad you've been paying attention!

But…You don't need to worry. The nearest known black hole to your Earth is over 1500 light years away! That's 15 thousand million million kilometers.

Anyway…it's now time to move on to the last part of the tour!

Captain Lambert: According to these co-ordinates**…**off to the centre of our galaxy we go!

Scene 6 - Supermassive Black Holes

Visuals: *Flight sequence to centre of galaxy*
Audio: *Acceleration followed by music*

Captain Lambert: Woah! Those stars appear to be moving around something…but what?!

Black Hole: No prizes for guessing…

Captain Lambert: Of course, a black hole!

Black Hole: By measuring the orbits of these stars over time, you can work out the mass of the black hole.

Captain Lambert:…and the answer is?

Black Hole: 4 million Suns worth of mass!

Captain Lambert: Mind blowing!

Black Hole: Well..it is a *supermassive* black hole.

All large galaxies contain one at their centres, some of these black holes contain the same mass as *billions* of Suns.

Captain Lambert: How did they get there?

Black Hole: Well…we don't know yet how the supermassive black holes first got there. But we do know how they grow.

Big galaxies contain 100s of billions of stars. These were made from gas, like we experienced before! The supermassive black holes grow at the very centre of the galaxies, also from gas falling onto them.

Captain Lambert: Can we observe how a galaxy, like our Milky Way, might be formed?

Black Hole: Let's do it!

Like before, you should represent the black hole growing with a click sound,

the number of stars being created with harp sounds,

and the powerful energy from supernovae explosions or the material falling onto the supermassive black hole with a wind sound.

Captain Lambert: Setting this up…

Audio: *Sonification Machine Tuning*

Black Hole: As you listen you might notice some big changes in these sounds. This is often after a large cloud of gas or even another smaller galaxy passes nearby or falls into the main galaxy.

Let's play it!

Audio-Visuals: *Galaxy formation sonification on screen*

Captain Lambert: Passengers…we've just witnessed billions of years of a galaxy's formation!

Black Hole: And remember….our Milky Way is just one of billions and billions of galaxies in the Universe!

Captain Lambert: Incredible!

Scene 7 - Ending

Visuals: *Fade screen away. Black Hole appears on the front centre screen for final good bye*

Black Hole: Okay! That's the end of my black hole journey!

You've learnt how black holes are made, how they grow, how you detect them, how some black holes....

Captain Lambert:...that black holes don't suck, they are very attractive because of their very strong gravity.

Black Hole: Err…bit rude interrupting me…but at least you've finally got it!

Black Holes Don't Suck!

That's my job done!

Goodbye!

Audio+Visuals: *Black Hole disappears quickly like a TV screen turning off, with corresponding sound effect*

Captain Lambert: oh…..hello? …Hello? oh... it looks like they've gone.

Well passengers…that's it then!

Visuals: *Start visual sequence making way back to the elevator plus relevant sound effects. Should feel like the very start sequence (in reverse).*

Captain Lambert: Time to make your way back down the elevator of our Sonic Explorer Spacecraft.

On behalf of Audio Universe Tours, I hope you enjoyed the experience!

Goodbye!

Visuals: *Back down the elevator, when get to the bottom fade to credits,*
Audio: Sound of elevator, along with music, and elevator ding indicates the end of the main show and into credits

Credits (Spoken)

A Black Hole's Journey was brought to you by

Rachel Lambert as the voice of the Captain and

Penny Donaldson as the voice of the Black Hole.

Rachel is a Qualified Teacher of Children and Young People with Vision Impairment and Penny is a school pupil with limited vision.

The show was written and directed by
Chris Harrison and Rose Shepherd

The visualisation and production is by
Tommy Howell

Sonifications by
George Caselton,
Chris Harrison,
Rose Shepherd
and James Trayford

and the Music by
Leigh Harrison

There were other significant contributions from
Fergus Baker
Jan Henneco
Adam Ingram
Laura Scott
Nic Bonne
Dominic Bowman
Daniel Hayton
Patrick O'Neill
Matt Williamson and
Newcastle City Council Children's Vision Team and their pupils.