Astronomy
Mapping the Milky Way

Narrator
In 1932 a radio engineer called Karl Jansky was working for the Bell Telephone Company investigating a mysterious radio static which beset short wave communication. Having exhausted all the most likely sources, Jansky looked further afield and, with some surprise, discovered that the radio interference came not from any man-made source, but from the Milky Way. This serendipitous discovery would seem to be important but it wasn't until 1944 that a breakthrough in understanding would open up the Milky Way when a distinguished Dutch astronomer called Jan Oort, pictured here with Adriaan Blaauw, turned his attention to the so-called radio static.

Adriaan Blaauw, New Leiden Observatory and the Kapteyn Institute
He started asking what kind of processes can emit this radio emission and he asked one special question – is there a process that produces a radio emission that you can compare to a single emission line in a spectrum?

Narrator
Oort posed the question to a young physics student called Hendrik van de Hulst, now widely regarded as the father of radio astronomy.

Hendrik van de Hulst, New Leiden Observatory
It was 1944 and Oort, with a fine nose for anything which might become important, asked me to review the theoretical interpretation, knowing of my interest in the interstellar gas, and so I did.

Adriaan Blaauw, New Leiden Observatory and the Kapteyn Institute
And van de Hulst came up with the reply, Yes, Professor Oort, I can tell you that it's wrong, it is the neutral hydrogen that is sort of floating in between the stars, we suppose it is there floating between the stars, but if it is there it will produce such an emission line.

Narrator
Just as stars give off light, hydrogen gas, believed to exist in clouds, mixed with interstellar dust, should also be radiating. Spontaneous atomic transitions would emit a long, invisible wavelength of 21 centimetres - not optical light, but radio waves that could travel across the entire galaxy unhindered.

Gerry Gilmore, Institute of Astronomy, Cambridge University
The fantastic thing about discovering an emission line like the 21 centimetre line, or any other line, optical …….. whatever wavelength, is that immediately you can measure a velocity. The reason you do this is the Doppler shift, very simple, but if I have something moving away from me like a little atom giving out a 21 centimetre photon, the sort of wave coming out the back gets stretched as it moves away, or if it's coming towards me the wave gets squeezed up. So when I then measure that way in my telescope and I measure exactly how much it's been stretched or how much it's been squeezed up, it'll come out at 20 centimetres, 22 centimetres, whatever, then I know how fast this thing was moving that emitted it.

Narrator
With this technique we can measure rotation of entire galaxies. The red shifted hydrogen on the left is moving away from us and the blue shifted hydrogen on the right towards us. The whole galaxy must be slightly inclined to our line of sight. We would detect no difference if it were face on to us. Radio astronomers have cracked the motion of hydrogen well beyond the stars. This striking animation based on a recent survey shows 21 centimetre radio emission from clouds of hydrogen right across the Milky Way. But rather than providing answers the

new data has reinforced an old problem. Ever since the 1950's when the first radio telescopes were being built, Doppler measurements have detected hydrogen moving far too quickly to be explained by the gravity of stars alone. So what is responsible? There has to be something else out there - an unseen mass that astronomers call 'dark matter'.

Gerry Gilmore, Institute of Astronomy, Cambridge University
Everything that I see is there, everything that I weigh must be there, gravity is correct, but they're just different, there's something else as well, some extra weight, and so the really interesting challenge is what on Earth is all this extra weight, this extra mass that is holding all the Milky Way together?

Jim Cohen, NRAL, University of Manchester
In this group of galaxies you'll see that the optical emission is confined to the small black bits, whereas the radio emission covers an enormous range many times the optical extent of the galaxies. What we find is really quite astonishing. If we measure the rotation velocities for galaxies, for all different types of galaxies, we find that instead of falling away these rotation velocities remain flat. They continue at essentially the same velocity to very large distances, and what this means is that the mass of the galaxy is continuing to increase to very great distances, even though there is apparently no visible matter there. In fact we know from these type of measurements that most of the mass of the galaxies must be some kind of dark matter. We simply don't know what this dark matter is.

Narrator
So if we think we know what our galaxy looks like from optical studies of our neighbours we should think again. The stars are only the tip of an iceberg. More than half the galaxy is in a form that remains to be discovered.

Butler Burton, Leiden Observatory
This record can serve as a scale model for our galaxy. The gaseous disc is represented by the record itself, the Sun is located about halfway in from the outskirts of the galaxy to the galactic centre, there's a bulge of stars in the galactic centre, the stellar disc extends out to about here, somewhere beyond the Sun. One of the most interesting things about our galaxy is at least interior to the Sun's location how thin it is, thin and flat, about as flat as this record is, except in the outer parts. In the outer parts the galaxy is warped very strongly and becomes much thicker. We've been trying to study this in much more detail. What has been necessary has been a new collection of data which samples the velocities, in other words the distances, in much more detail than has hitherto been possible.

Narrator
But high above the galactic plain there are clouds of neutral hydrogen moving quite independently.

Butler Burton, Leiden Observatory
If we look at the most extreme velocities we see the phenomena of high velocity clouds. These have been known from some time although we still don't know how far away they are. They're probably somewhere on the very outskirts of our galaxy. In the new data we can scan through these features and velocity to lower velocities and can establish connections with the lower velocity and material residing in our galactic disc itself. You also can measure from a map like this the thickness of the gas layer. The thickness is larger than what would be expected if the gas layer was confined by the stars. The stars, at least interior to the Sun's location in the galaxy, lie in a very thin disc and the gas layer confined by them lies likewise in a very thin disc. In these outer parts, where the stars are very scarce, it's the dark matter which is determining the thickness of the disc. The dark matter obviously resides in a much wider distribution because the gas layer shows a much wider distribution and latitude.