Astronomy
Detecting Galactic Jets

Narration
Stellar jets like this can only be seen within the Milky Way. But well beyond our Galaxy we often see truly enormous jets emerging from the compact centres of other galaxies.
These galactic scale jets are also millions of time further away, so how can radio astronomers see them at all, never mind achieve such high resolution – a hundred times better than the best ground-based optical telescopes? Radio waves have wavelengths thousands of times longer than optical wavelengths. That means that even the largest radio dishes cannot match - by themselves - the optical resolution of the human eye. However, radio signals from many dishes can be brought together and compared electronically, giving much better resolution.

Peter Wilkinson
Because we want to analyse these signals in the computer, the first thing we do is disguise them. We do that in this rack of electronics here – you'll see one board for each of the telescopes, seven in all. And then what we want to do is compare the signals from each of the pairs of telescopes spread out across England and we do that in a special purpose computer we call a correlator, down here. And you'll see twenty-one boards in all down here, one for each of the pairs of telescopes, or baselines, in the array. But what do these comparisons look like?

Narration
As the Earth turns and the radio source is tracked across the sky, the waves arriving at any pair of dishes progressively move in and out of step with each other, producing an interference pattern – the blue lines. It is these periodic variations which carry information about the detailed structure of the source. In this case, it's actually a double radio source. Here the image is synthesised from fringe patterns like this idealised one, simulating a single pair of nearby radio dishes. During the day the pattern subtly changes but when they're combined together we see the first clue of a double structure. A longer baseline gives more fringes and hence details on a finer scale are revealed – a pair of hot spots near the middle row. With more than two dishes – with an array of dishes – we have many baselines at different orientations simultaneously. As the Earth turns and the different views are added together, the structure of the central double source slowly becomes more evident. Longer recordings give better pictures. Finally, after further computer processing and image enhancement, even the fine jets can be resolved. It is these jets that are responsible for the commonly observed double structure – giant radio lobes extending on opposite sides of an unseen active centre.

Barrie Jones
The dish behind me is one of an array of seven spread round Britain called the MERLIN array. It's only when radio telescopes work together in that sort of way that we get such high resolutions. Now, there are many arrays of radio telescopes around the world – another important one is called the VLA, or Very Large Array, in New Mexico.

Rick Perley
The Very Large Array comprises twenty-seven antennas, arranged in each of three arms: one arm to the North, one arm to the South-West, one arm to the South-East. Along these arms we can move these antennas on transporters up to 21 kilometres away. There are a number of fixed pads along these arms on which the antennas are placed. By putting antennas on these positions we collect information from each antenna, multiply the signals from each antenna from all other antennas and collect 351 pairs of information, which are used to make images of the radio sky.

Antennas spread way down the arms give us high resolution for fine details and when the antennas are close together we are looking at a very broad scale structure, for low resolution and studies of angular areas.

Barrie Jones
So we can only get the highest resolutions if the telescopes in the array are really far apart. The telescopes in MERLIN array are much further apart than those in the VLA. The nearest telescope to this one in Cambridge is actually about a hundred miles away in Worcestershire. But the really clever thing is when we couple one array with another one that's a huge distance away. In that way we get truly incredible resolutions.

Narration
Here, for example, is MERLIN image of 3C273, the first jet discovered. But linked up to VLA across an 8,000 kilometre baseline, we can see even finer detail closer to the nucleus itself.

Narration
The technical breakthrough that made this possible was the development of extremely accurate clocks, atomic clocks, based on hydrogen masers. Now it became possible to bring the signals together simply by mail. The digital tapes are recorded at widely separated locations, but at a precisely known time. This means the VLA can extend its baseline from remote antenna in Hawaii in the Pacific to others across the Atlantic in Europe. And MERLIN antennas in England can be combined with others in global arrays, enabling distant radio sources to be mapped with incredible resolution. This technique, called Very Long Baseline Interferometry, has given radio-astronomy the edge in high resolution imaging. For example, in these images of 3C273, taken only two years apart, they could just detect movement of the matter down the jets which must, therefore, be moving very fast, close to the speed of light.

Meg Urry
The high velocity of the jets has a funny consequence – that the light is beamed in the forward direction and so a jet pointing at us is not only blue-shifted, but appears much, much brighter than the receding red-shifted jet - so at any angle other than the plane of the sky, the oncoming jet will be much, much brighter than the receding jet and we may only, in fact, see one-sided jets.

Narration
Astronomers have now observed hundreds of jets emerging from galaxies at all possible orientations. Most of them, indeed, appear one-sided. Is the receding jet really dimmed so much we just can't see it? What we can see is the longer jets that twist and turn and bend in bright, writhing arcs, as if blown by some galactic wind. Others may even collide and interact with each other. They may look different but they all seem to originate in the same way. A dusty torus fuelling a very bright disc of material spiralling or, as astronomers say, accreting onto a compact core at the nucleus of the galaxy. Often long, narrow jets stretching thousands of light years beyond the parent galaxy.