Astronomy
Radio Telescopes and Stellar Jets

Narration
Before radio telescopes, astronomers never even suspected the existence of these colossal outflows of matter – cosmic jets travelling at almost the speed of light from the centre of galaxies, right out into intergalactic space. But now astronomers have discovered jets at all scales, emerging from dense concentrations of matter - not only from galaxies, but also from stars.

Barrie Jones
In the 1940's a whole new form of astronomy began to flourish. Up until that time astronomers had been well used to looking at the sky at visible wavelengths, but the developments in radio technology for military purposes made it possible to look at the sky at radio wavelengths. Well, I'm here at the Mullard Radio Astronomy Observatory, part of the University of Cambridge and one of the leading centres for radio astronomy in the world today. Ever since the 1950's astronomers here have been using aerials and dishes to detect those very faint radio signals you get from the sky.

In this programme we're going to be exploring the strange phenomenon called jets. These were a great surprise when they were first discovered and even today they are largely unexplained.

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Here close to the summit of an extinct volcano in Hawaii, astronomers are using the James Clark Maxwell Telescope to pick up faint radio waves from gas and dust in clouds where stars are forming.

Ian Robson
The radio waves pass to the telescope through this membrane. The membrane protects the telescope surface from wind and dust and also direct sunlight during the daytime. The membrane of course is transparent to radio waves which pass through unhindered onto the mirror surface. The mirror surface is not made of glass; it is made of individual panels, each of which has an aluminium surface. The radio waves are reflected from the surface, upwards to the secondary mirror. They are then reflected downwards, and through the hole in the primary mirror. In operation the secondary mirror moves to and fro through a small angle, on and off source, to remove the sky background. We're now below the hole in the main mirror, where the radio waves pass from the hole, off this mirror, to a further mirror, and then inside the red cylinder. Deep inside the red cylinder is a very tiny diode, only one millimetre in size, the most sensitive detector in the world for millimetre radiation. It's cooled to a temperature of only four degrees above absolute zero. After detection, the electrical signal is further processed and then passed to the control computer which is in the control room. Can we have the spectrum up please, Richard? This is a really nice spectrum and the prominent spike in the middle is called a spectral line. In this case it's from the molecule carbon monoxide. This spectrum is just one of a set of spectra we've just taken at different points round a newly formed star. Here is a complete set of spectra we have just scanned across the jets from left to right and top to bottom. The spectral lines don't appear at precisely the same wavelength at different places on the map. The reason for this is that in some areas of the map, the molecules are moving towards us. This shifts the wavelength of the line to smaller values and at other places on the map, the molecules are moving away from us, moving the spectral line to larger wavelengths. Such regions are technically called bi-polar outflows because they have two jets emitted in opposite directions. We can process the data further to produce a more conventional map like this.

Here we see a series of slices taken through the object. Each picture or slice shows only a range of speeds of the carbon monoxide molecules in the bi-polar outflow. By combining the centre image with the extreme blue and red images we get a map of the region which clearly shows the bi-polar outflow. Arrows show the direction of each jet. The red one is moving away from us and the blue one is moving towards us.

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The puzzle is – what is driving these ejected jets from the cloud which we suppose is slowly contracting under gravity. Clearly there must be some other forces at work.

Barrie Jones
The problem is – what could these forces be? Now some energies show a disc, a rotating disc at right angles to the two jets and it's thought that a magnetic field that originates in this disc somehow launches the two jets, but the details are very uncertain. What we do know is that as well as jets from young stars there are also jets from old, dying stars.

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If we jump from star formation to the final stages of stellar evolution, we find outflows are still a major feature. Most dramatic of all are supernovae, cosmic explosions of massive stars, which leave behind a tiny dense body at the centre and a rapidly expanding shell of glowing gas. One relatively nearby shell called W50 has revealed something quite extraordinary. The radio contours map didn't at first reveal anything abnormal – a wispy outer shell with a bright source at the centre. But the strange shifting lines of the visible spectrum from the central bright source were without precedent. Doppler-shifted red and blue lines mixed together as if the star was receding and approaching at the same time. One amazing hypothesis to explain these spectra was of high speed jets wobbling. These jets are ejected at more than a quarter of the speed of light from a minute stellar remnant, a neutron star, or possibly a black hole – dragging material from a companion star that has somehow survived the supernova explosion. Ten years later radio astronomers made this remarkable sequence of high resolution maps, revealing the jets themselves as blobs of radio emission at the start of their high speed journey, tens of light years into space.

Barrie Jones
The radio telescopes that deliver the sorts of images that we're used to looking at today are a good deal more sophisticated than they were just a decade or so ago. They work at the very forefront of what modern technology can deliver. These dishes behind me are part of an array called the Ryle Telescope and the kind of images that we get from this sort of array show very well the jets that emanate from a neutron star, and from a black hole, that is from the remnants of dying stars. Now the stellar remnant is surrounded by a disc, an accretion disc, and it's made of gas and dust. Now this disc feeds material onto the compact object and in turn it is fed by a companion star. Now we're pretty certain that this disc is absolutely crucial in launching the two jets, but just as in the case of the young stars, the details are unknown.