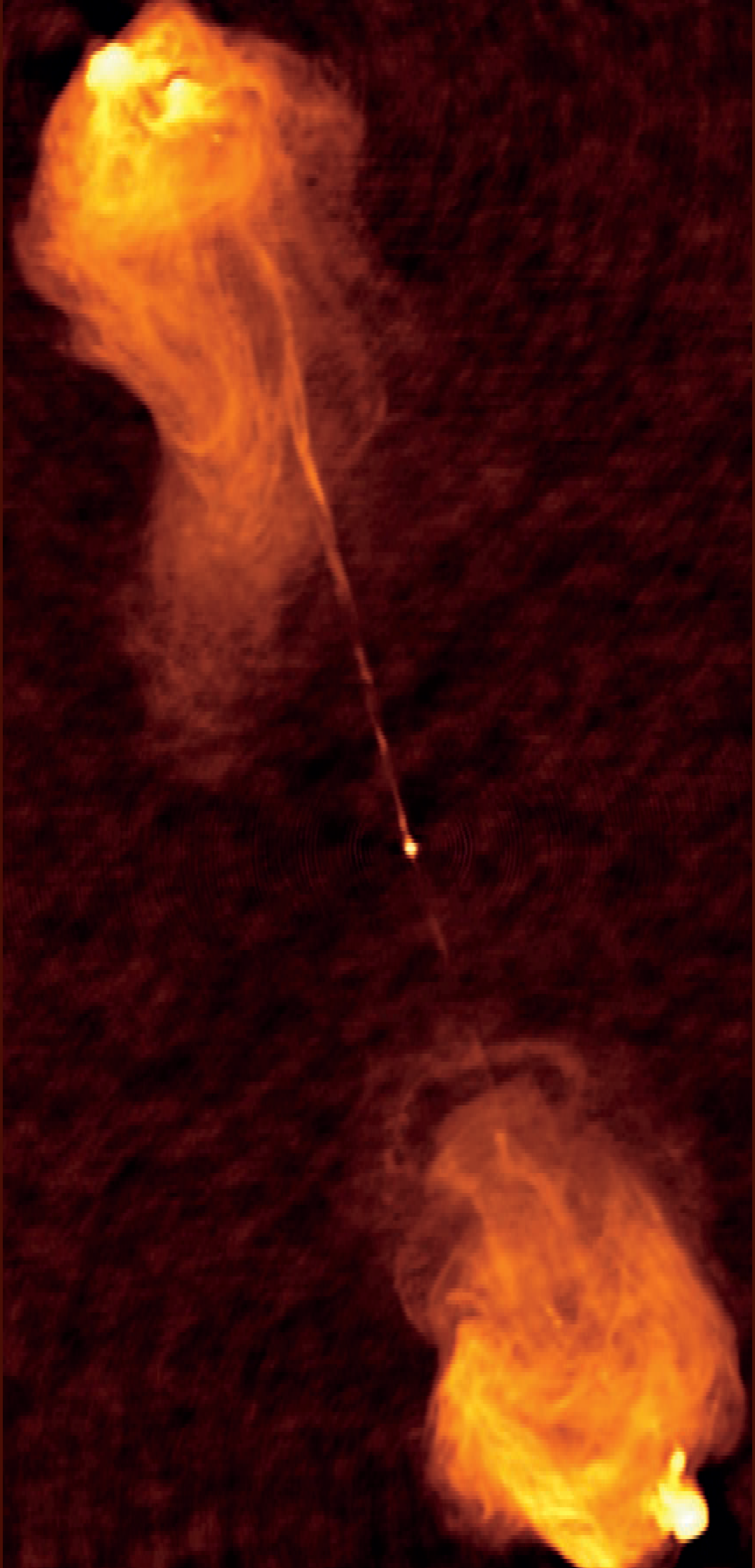

7 THE RADIO AND MICROWAVE UNIVERSE

FIGURE 51: RADIO IMAGE OF CYGNUS A

Cygnus A was one of the first sources of cosmic radio radiation to be identified with a visible-light object in the sky. Seen in visible light it is a nondescript elliptical galaxy, a faint smudge like multitudes of others that provides no hint that it is by far the most powerful radio source in our reasonably local neighbourhood (if you can call a distance of 800 million light-years local). This radio image was made with the Very Large Array (see Chapter 2) in New Mexico and it shows the double-lobed structure that is so characteristic of the powerful radio sources associated with some galaxies and quasars. The energy that supplies the radiation from these lobes is channelled from the nucleus of the associated galaxy along narrow jets that are clearly seen in this image. The source of all this energy is the collapse of material onto a rapidly spinning supermassive black hole in the core of the galaxy. With a mass of around a billion times the mass of the Sun (or 300 times more massive than the black hole at the centre of our own Milky Way galaxy), this Active Galactic Nucleus (AGN, see Box: Black holes, quasars and Active Galactic Nuclei below) will appear as a quasar when seen from some directions.

Seen with radio telescopes, the sky is unrecognisable to a visible-light astronomer. In place of the stars in the Milky Way there are objects sprinkled throughout the entire Universe. Radio sources are rare but often intrinsically very powerful, making them detectable at very large distances. The emissions from these radio galaxies, quasars and titanic stellar explosions are the result of immensely energetic sub-atomic particles speeding through regions of twisted magnetic fields. This process is quite different from that producing the heat radiation from the surfaces of stars and it leads us to the sites of some of the most violently energetic action in the Universe.

“The first radio observations led to the realisation that the Universe could look very different to us when seen through new ‘eyes’ tuned to a different radiation”

Beyond the far limits of infrared light, we move into the radio **spectrum**. At the shortest **wavelengths** (on the order of a millimetre or so) we have the band dubbed microwaves, which are commonly used in wireless phones. At longer wavelengths the radio spectrum spans centimetres, metres and upwards. The radio spectrum is open and unbounded in the sense that there is no “longest” radio wavelength. However, in practical terms, low energies and extreme wavelengths beyond a kilometre or so become very difficult to generate or detect.

Initially astronomers were not very optimistic about the possibility of even seeing the objects they already knew at radio wavelengths. They could calculate the amount of radio radiation expected from stars — and it was puny. Even so, starting in 1932 and subsequently stimulated by the development of radar for military use during the Second World War, radio astronomy was mankind’s first major excursion into the hidden Universe. The first radio observations led to the realisation that the Universe could look very different to us when seen through new “eyes” tuned to a different radiation.

Radio regimes

Extremely Low Frequency (ELF) radio waves with wavelengths of tens of thousands of kilometres are of little interest to earthbound radio astronomers since they are completely absorbed by the ionosphere — the screen of charged particles that envelops our planet. Submariners, however, rely on them to communicate with home base. By the time we reach a few tens of kilometres (VLF or Very Low Frequency), however, the sky becomes clear and remains so until the wavelength has dropped below a centimetre (SHF, Super High Frequency or microwave). The millimetre and submillimetre regimes are plagued by absorption from water in the atmosphere, but are of great interest to astronomers since they can be used to detect and measure the huge amounts of cold material between stars and throughout the Universe.

“The first interferometers enabled the identification of sources that were mysteriously inconspicuous to visible-light telescopes”

Although the Sun, because it is so close, was soon identified as a discrete source of radio waves, it was found that the few other bright radio sources in the sky were seen in regions lacking very prominent stars.

The race was on to match these sources of radio radiation to objects that were already familiar to astronomers in visible light. The problem here was that early radio telescopes, despite their significant size, could not precisely locate the positions of the radio sources in the sky (see Box: Resolution of a telescope).

Since it would be hard — and costly — to build a single radio telescope that would be large enough to achieve the needed resolution, telescope builders had to do some lateral thinking and figure out how to connect widely spaced antennas in a way that would allow them to act as a single, larger telescope. The resulting technique of interferometry (see Box: Interferometry) is now widely used, especially at radio wavelengths, to enable high resolution imaging using arrays of many telescopes. By mounting some telescopes on satellites, telescopes in these arrays can even be separated by distances greater than the diameter of the Earth.

The first interferometers enabled the identification of sources that were mysteriously inconspicuous to visible-light telescopes — peculiar-looking galaxies and the apparent remnants of stellar explosions called supernovae. Why do these emit such copious amounts of radio radiation and so little visible light?

Resolution of a telescope

The ability of a telescope to distinguish fine details, known as its spatial resolving power, depends in a relatively simple way on both the telescope size and the wavelength of the radiation it is imaging: the greater the number of wavelengths of light that fit across a telescope mirror or lens, the higher the resolution of the telescope. Since radio waves are typically 100 000 times longer than visible waves, a radio telescope would have to be about 240 km in diameter to achieve the same resolving power as Hubble, which has a mirror that is only 2.4 metres across.