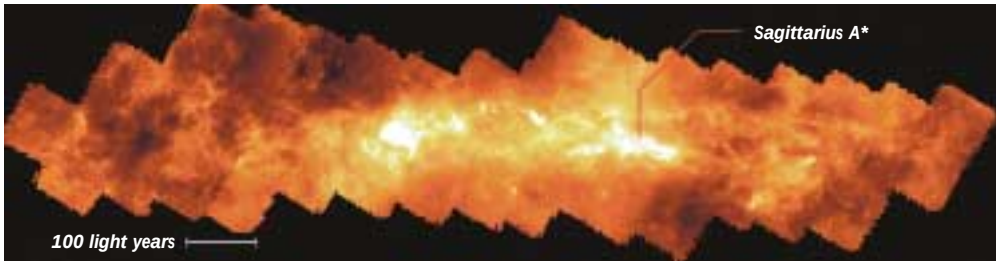
What lies in the heart of the Milky Way?



The centre of the Milky Way as mapped with SCUBA

UK scientists have been mapping the centre of our Galaxy in unprecedented detail

Douglas Pierce-Price

Our own star – the Sun – is just one of tens or hundreds of billions of others, which together form a vast collection of stars: a galaxy called the Milky Way. Our Galaxy has a flat spiral shape similar to external galaxies like NGC1232 shown opposite. Its stars are flattened into a disc with a radius of about 50,000 light years, with the stars becoming more concentrated towards the centre. Our Solar System is situated in the plane of this disc, about 26,000 light years from the Galactic centre. Since we are in the plane of the disc itself, when we look at the rest of the disc, its stars appear across the sky as a bright band. On a clear, dark night, without light pollution, you can clearly see the Milky Way with the naked eye. The Romans named it *Via Lactea*, and the word 'galaxy' also comes from the Greek for milk. It gets its name because there are so many stars, many too faint to be resolved with the naked eye, that they look like a diffuse milky-white band of light stretching across the entire sky.

However, even on such a clear night, there are 'imperfections' in the Milky Way – regions where the diffuse starlight suddenly becomes dark. In the 18th century, the famous astronomer, William Herschel, saw these 'holes in the sky', and wondered whether they really represented a lack of stars. In the early 20th century it was proven that these patches are caused by the absorption of starlight by interstellar material, rather than missing stars. Even looking towards the dense centre of the Milky Way, our view is obscured by these dark regions.

Molecular clouds

The interstellar medium (ISM) which exists between the stars is mainly hydrogen in cold clouds of gas, but about 1 per cent by mass is in the form of interstellar dust. In the coldest, densest regions the hydrogen forms a molecular gas which makes up about half of the ISM by mass. These 'molecular clouds' can reach sizes up to hundreds of light years, and can be several million times as massive as our Sun. They are the sites where new stars are born, and the most massive objects in the Galaxy. To understand where stars and, on a larger scale, galaxies come from, it is therefore important to understand these molecular clouds.

In its molecular form, hydrogen is rather difficult to detect. To find the gas clouds, astronomers must turn to other techniques. One way is to look instead for the interstellar dust that is intermingled with the gas. This dust is composed of fine particles of carbonaceous or silicaceous material, rather like soot or sand. Just as warm objects in everyday life emit invisible heat radiation which can be detected by infrared cameras, we can look for the 'heat glow' of interstellar dust. The dust grains are at temperatures of only about 20 degrees above absolute zero (-250 °C), and so they produce radiation with lower energy, and with wavelengths of about 1 millimetre.

The Galactic centre itself is a region of great astrophysical interest. It lies about 26,000 light years from Earth, in the constellation of Sagittarius. The physical conditions in the central nucleus are dramatically different from those nearer the Earth. The gas and dust clouds in what is known as the 'central molecular zone' are much denser and more turbulent. At the very centre is a mysterious object called Sagittarius A*, thought to be a supermassive black hole, which has a mass about 2.6 million times that of our Sun. Observations of the Galactic centre would be impossible using visible wavelengths of light, because of the obscuring dust. Using submillimetre

wavelengths (just under a millimetre), we can see right through to the clouds in the centre.

SCUBA's success

An international team of astronomers, led by research groups from Cambridge University in the UK and the Joint Astronomy Centre in Hawaii, has used this technique to peer into the heart of the Milky Way. We used a modern submillimetre-wave camera known as the Submillimetre Common-User Bolometer Array (SCUBA). It was built by the Astronomy Technology Centre in Edinburgh, and installed on the James Clerk Maxwell Telescope (JCMT) in Hawaii. The JCMT is near the 14,000-foot summit of Mauna Kea, where it is above most of the Earth's atmosphere, to achieve the best possible viewing conditions. With a diameter of 15 metres, the JCMT is the world's largest submillimetre-wave telescope. SCUBA has been in operation on the JCMT for about four years, and is currently the world's most powerful such instrument. Mauna Kea itself is one of the planet's best astronomical sites.

The breathtaking new survey is bigger and more sensitive than any previously made. The map shows no actual stars, despite the central concentration of stars that exists. This is because submillimetre wavelengths are instead ideally tuned to detect the clouds of interstellar gas and dust where new stars are born. This is the first detailed map to show essentially all the interstellar gas in the galactic centre.

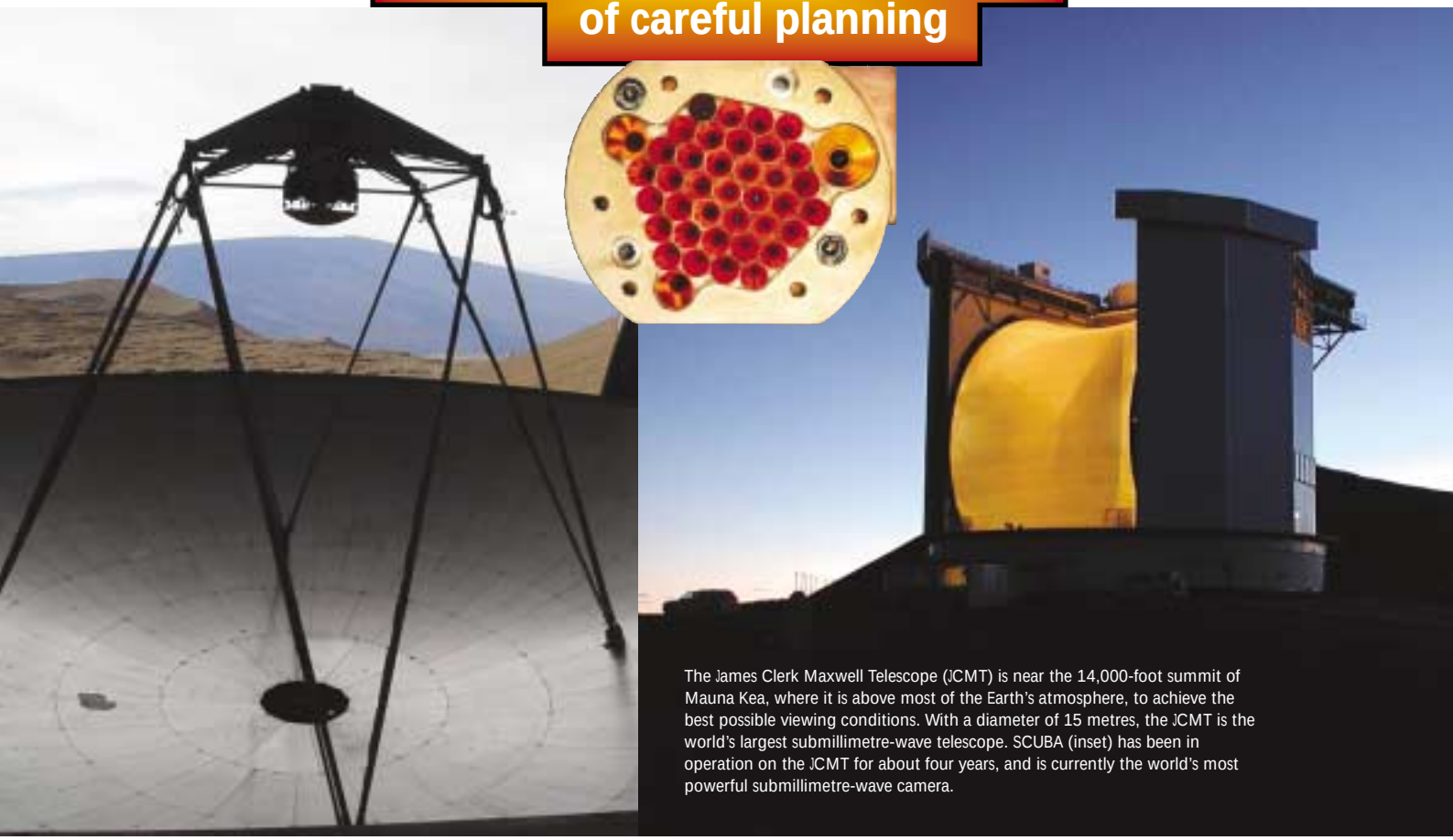
The unprecedented detail in the map reveals not only the expected dense clouds of gas, but also a wide network of wispy filaments linking them. The region is also peppered with gas bubbles and shells. Although the origin of these structures is not fully understood, astronomers believe they must have been shaped by intense winds from stars, twisted magnetic field lines, and the explosions of supernovae.

If the nucleus of our own galaxy is so complex, then what about others? The Milky Way is a relatively quiescent galaxy, but some 'starburst' galaxies such as M82 are undergoing intense star formation in their central regions. As other galaxies are much further away, they cannot yet be mapped with as much detail as this survey. However, the new ALMA telescope, to be built in the Atacama Desert, Chile, will enable astronomers to see at least 100 times more clearly. ALMA, of which construction begins in 2002, will let us see whether the nuclei of other galaxies have similarly intricate structures. ✦

Spiral galaxy NGC1232

Douglas Pierce-Price, University of Cambridge, E-mail: dpip100@mrao.cam.ac.uk

These observations were the result of many months of careful planning



The James Clerk Maxwell Telescope (JCMT) is near the 14,000-foot summit of Mauna Kea, where it is above most of the Earth's atmosphere, to achieve the best possible viewing conditions. With a diameter of 15 metres, the JCMT is the world's largest submillimetre-wave telescope. SCUBA (inset) has been in operation on the JCMT for about four years, and is currently the world's most powerful submillimetre-wave camera.