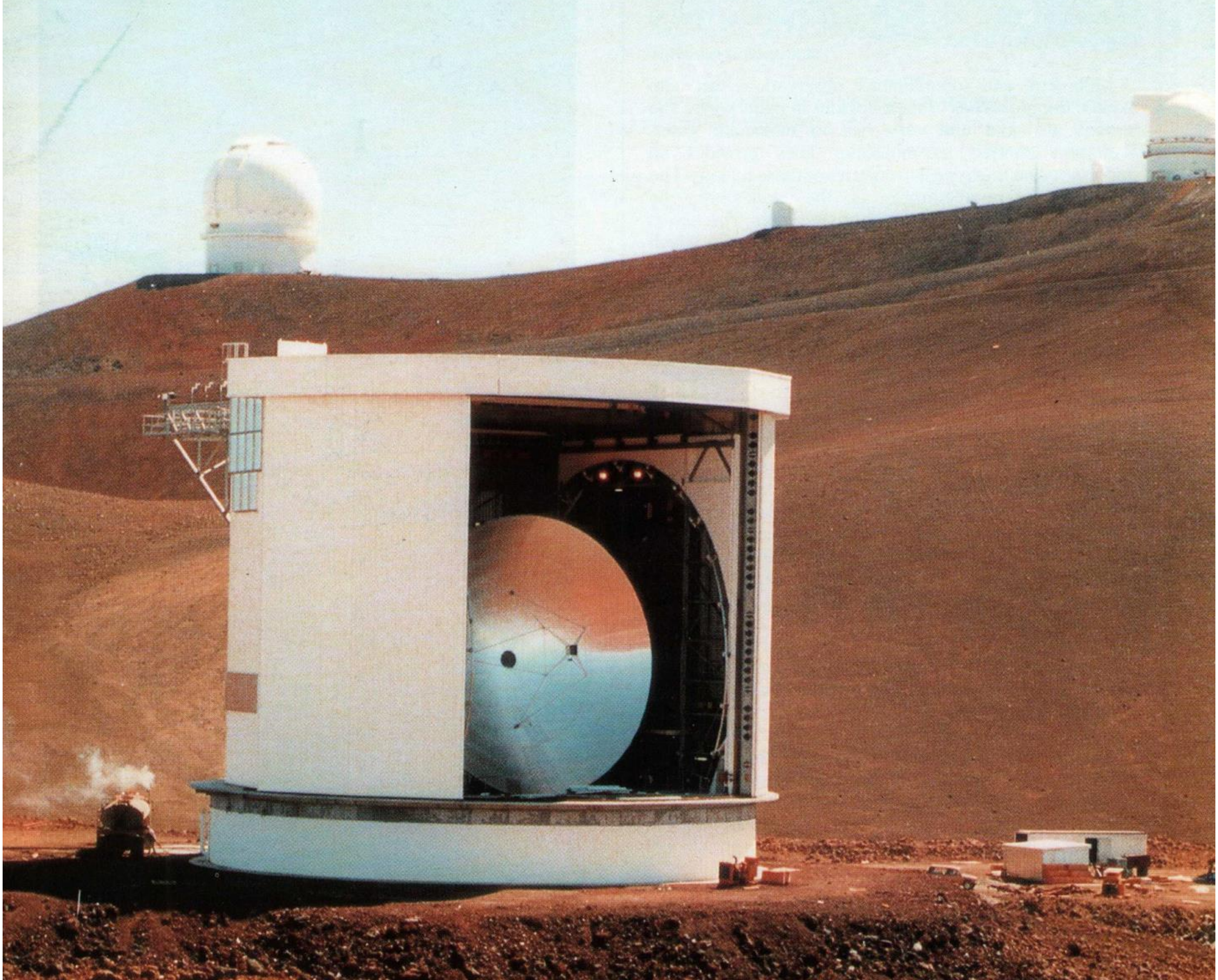
JAMES CLERK MAXWELL TELESCOPE



The James Clerk Maxwell Telescope is the largest of a new generation of radio telescopes designed to work in the sub-millimeter part of the electromagnetic spectrum.

Located at the Mauna Kea Observatory on the island of Hawaii, by an arrangement with the University of Hawaii, the telescope was designed and built jointly by the United Kingdom and the Netherlands.

Negotiations to place the telescope at the Mauna Kea Observatory began with the University of Hawaii in 1981. Preparations for the installation, first of the enclosure and then the telescope started in 1983. The construction was completed in the summer of 1986. Since then, extensive commissioning tests have been carried out. A highlight was the reception of the first radio signals on December 3 1986 since when spectral lines, mainly from the Orion Nebula have been observed.

This facility was opened by His Royal Highness,
The Prince Philip, Duke of Edinburgh on 27th April 1987.

SCIENCE

The dense regions of interstellar gas where stars form are opaque to optical radiation. However, at infrared and millimetre wavelengths these regions are transparent and the detailed processes going on inside them can be investigated. These wavelengths are the last to be opened to ground based telescopes.

Millimetre and submillimetre observations can help explain the properties of these regions in many ways. The regions are cool and very rich in molecular gases. Radiation emitted as molecular lines provides an important clue to physical properties of these regions. The densities and temperatures of the clouds can be determined as well as the motions in the gases. This allows us to gain a better understanding of the processes by which stars form - one of the key problems of modern astronomy.

Molecular line spectra from these regions allow us to map out in detail the distribution of chemical species within molecular clouds. This is one of the most interesting fields for the new discipline of interstellar chemistry. The densities found in interstellar clouds are much lower than those found in terrestrial laboratories and so many rare molecular species can survive in the interstellar gas.

Using molecular line radiation as a tracer of the abundances of different chemical species at different locations within galaxies is an ideal method of studying the chemical evolution of the material out of which the stars in galaxies are formed. It will be particularly helpful in understanding whether nucleosynthesis - the production of heavier elements from lighter ones, has occurred uniformly throughout galaxies, whether infall of matter from other galaxies or intergalactic space is important and how the regions around stars are enriched by the products of stellar nucleosynthesis.

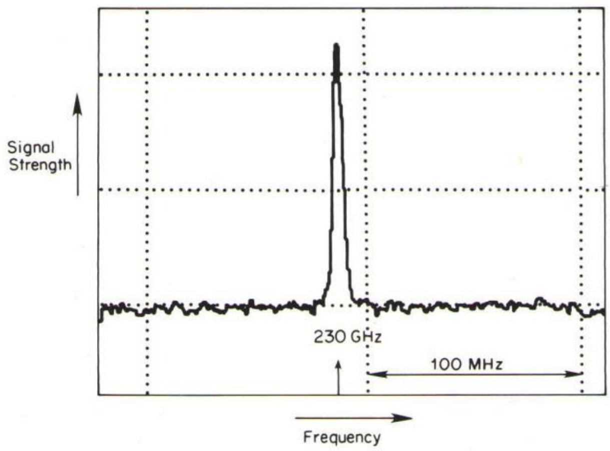
The continuum radiation emitted by the cool dust clouds in which stars form is detectable at submillimetre wavelengths. These regions need to be studied with high angular resolution to identify the regions where the youngest stars and their precursors, the protostars, are forming.

The nuclei of active galaxies like quasars are strong sources in the submillimetre waveband and the determination of their spectra and time variability is very important for understanding the total energy demand of the active nuclei and also the physical conditions in the most extreme conditions within such nuclei.

Many sensitive tests are possible involving fluctuations in the microwave background radiation. This radiation permeates all space and is the cool relic of the hot early phases of the Universe. There are many reasons why there should be small ripples in this radiation related to the origin and evolution of galaxies and some of these effects can be studied uniquely in the submillimetre waveband.

Above Right: The Orion nebula (Photograph by David Malin using the Anglo-Australian Telescope.)

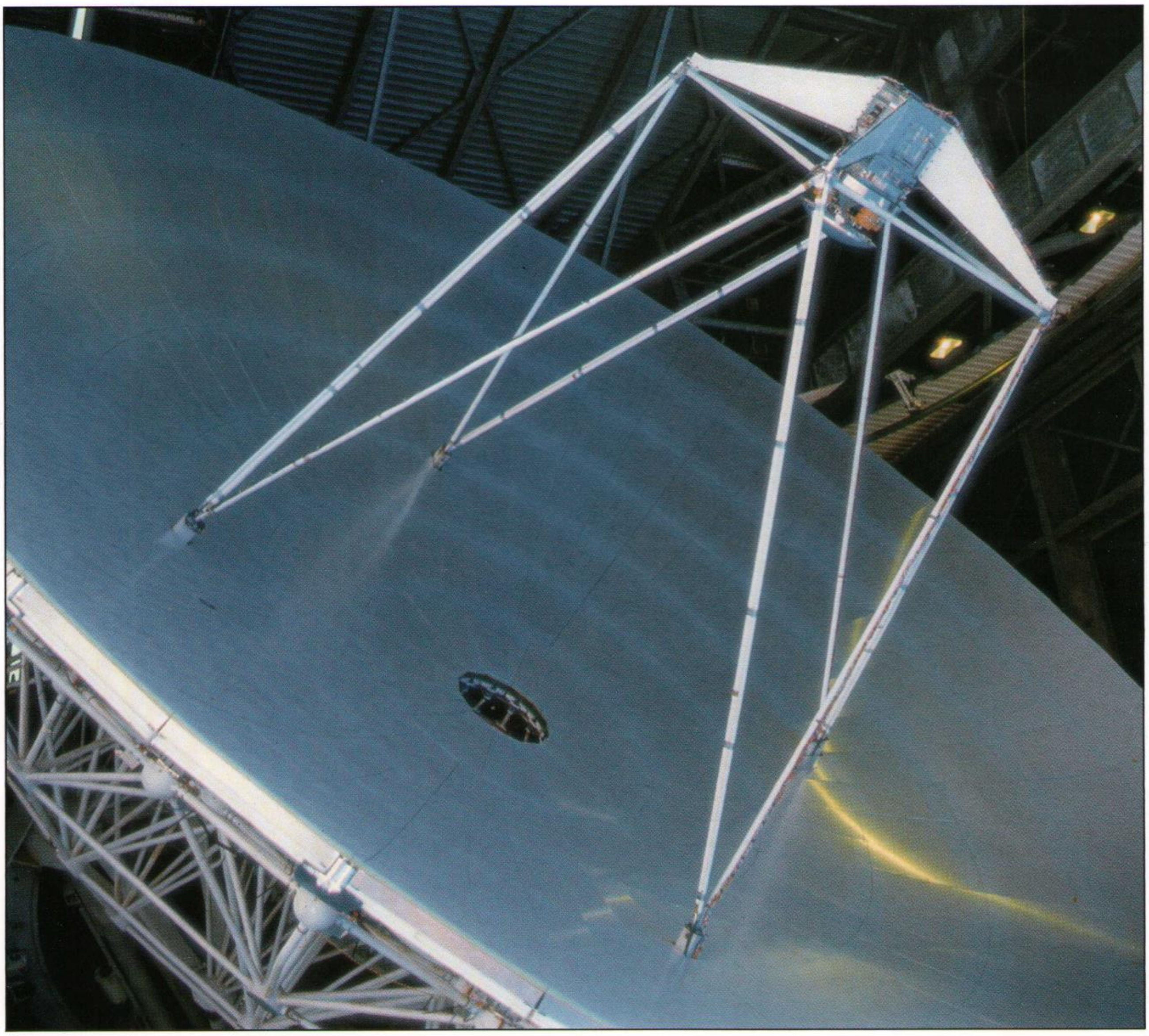
Right: First light results from the telescope



Spectral Line from Carbon Monoxide in the Orion Nebula.

(Observed on 11 December 1986)

TELESCOPE



Above: Close up of the secondary reflector and its support mechanism.

The telescope is a classical Cassegrain type with a 15 metre paraboloidal primary reflector and a 75 centimetre hyperboloidal secondary reflector. The primary surface is produced by supporting 276 lightweight aluminium panels on a mild steel space frame which deforms uniformly as the elevation angle changes to maintain a paraboloidal shape.

To operate efficiently at submillimetre wavelengths the telescope must retain its paraboloidal shape to a very high accuracy. The formal specification calls for a surface accuracy of 50 microns under all operating conditions, guaranteeing efficient operation down to 0.8mm wavelength. However, successful development of the surface panels, in particular, suggests that the accuracy will be close to 30 microns corresponding to efficient operation down to 0.5mm wavelength.

To match the high resolution (10 arcseconds at 0.8mm) associated with its diameter and accuracy, the pointing accuracy is specified to be 5 arcseconds absolutely and 2 arcseconds relatively.

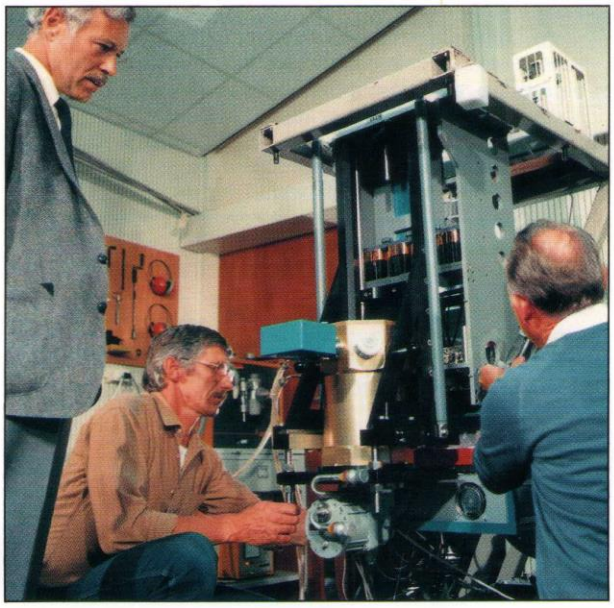
The reflector system is supported on an altazimuth mount. Movements in elevation and azimuth are made using direct current torque motors acting through frictional contact.

The secondary mirror is adjustable in three mutually perpendicular directions and can be vibrated in the plane perpendicular to the optical axis to allow background subtraction by on- and off-source measurements.

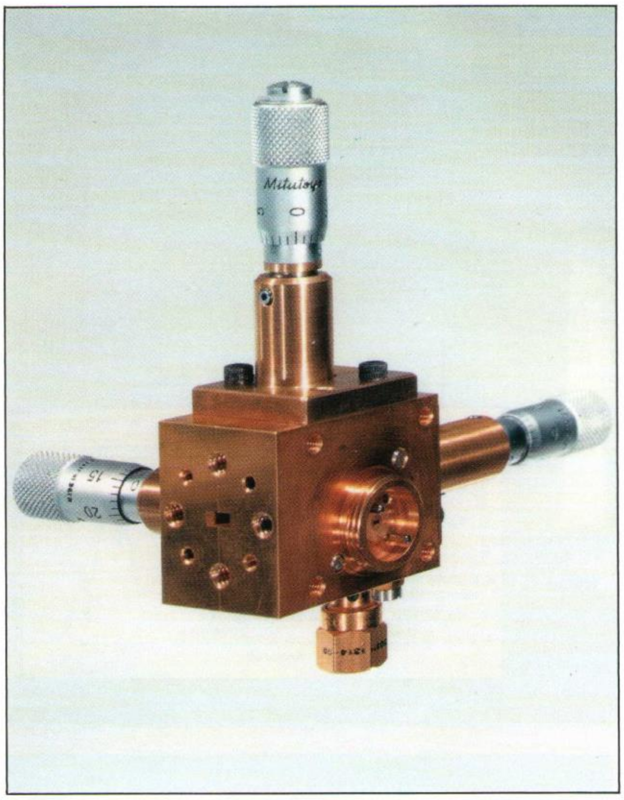
RECEIVERS

Sophisticated solid state detectors, often cooled to the temperature of boiling liquid helium (4.2K), form the basis of many submillimetre receiving systems. Using heterodyne techniques in accurately made mixers, signals of a few hundred gigahertz are reduced to frequencies which can be amplified, filtered and analysed to produce line spectra.

Other detectors, using bolometric techniques, receive energy over a continuous spectrum of frequencies covering the full range of the telescope. Separation into sub-divisions of the spectrum is achieved by filters on the input side of the system.



Above: The 345 GHz receiver made at Radiosterrenwacht Dwingeloo in the Netherlands.



The initial set of receivers will consist of:

- A continuum receiver with a set of filters, including filters for 150, 225, 345, 470 and 690 GHz.
- Two heterodyne line receivers based on cooled Schottky diode detectors to operate at 230/280 GHz and 345 GHz.
- A line receiver based on a cooled indium antimonide detector to operate at 490 GHz.

Above: High frequency doubler for 230 GHz receiver, made at Rutherford Appleton Laboratory

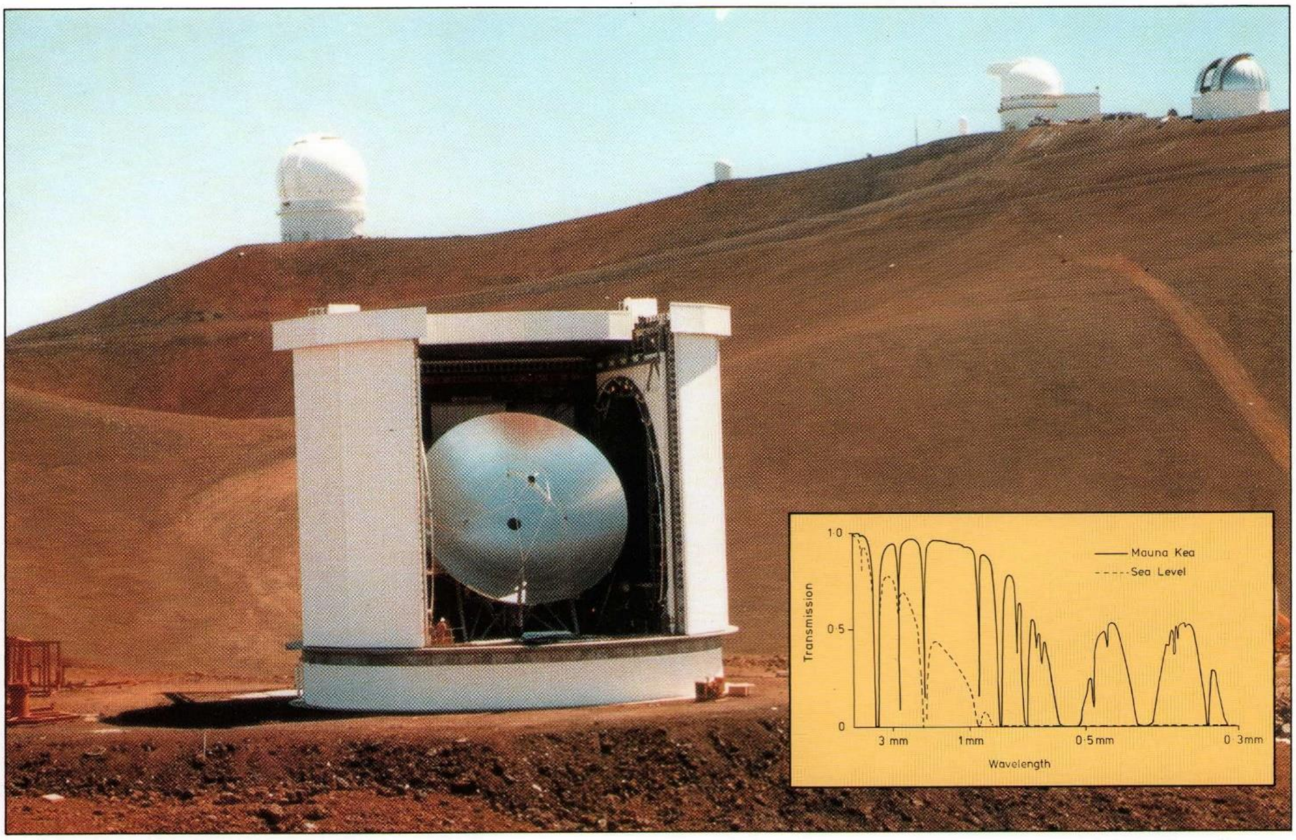
Right: Continuum receiver for frequency range 115 to 800 GHz, constructed at Royal Observatory, Edinburgh

SITE

At submillimetre wavelengths, atmospheric water vapour strongly attenuates radiation from astronomical objects. So, the telescope needs to be at a high site to be above as much of the water vapour as possible.

Isolated high mountains on islands make particularly good sites because the absence of large land masses reduces convection which would lift water vapour to higher altitudes. The volcanic mountain of Mauna Kea - altitude 4,200 metres, on the island of Hawaii, is the best site in the world where there is an established observatory. This observatory, which is operated by the University of Hawaii, already has six telescopes in operation. These include some of the finest optical and infrared telescopes in the world. The United Kingdom Infrared Telescope - UKIRT, which is operated by the Royal Observatory, Edinburgh, at 3.8 metres diameter is the world's largest infrared telescope.

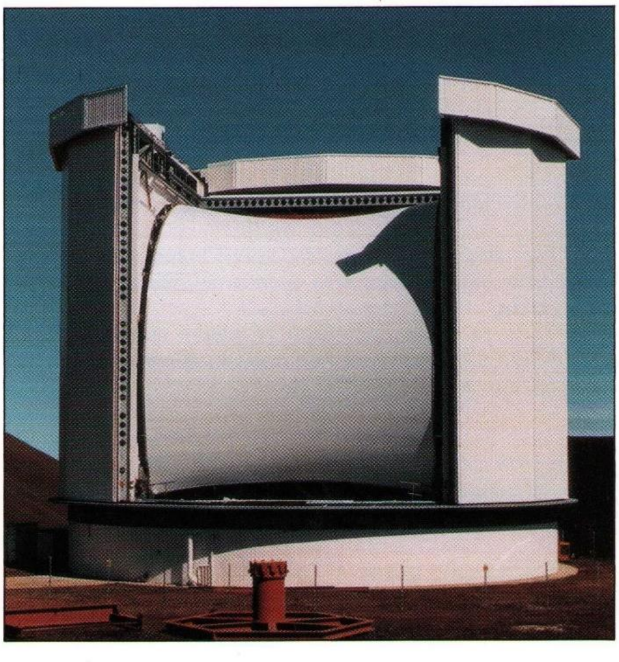
Inset: Atmospheric transmission at millimetre and submillimetre wavelengths



ENCLOSURE

Mauna Kea's environment can be harsh. Winds in excess of 150 km/h are experienced and the air temperature varies between +10 C and -5 C. Significant falls of snow can occur but the biggest problem is ice which can form horizontally to a thickness of more than 30 centimetres.

To protect the telescope and allow the surface accuracy to be maintained it is contained in an enclosure which rotates with it. The viewing aperture is, unusually, covered with a membrane of woven polytetrafluoroethylene which will operate up to 80 km/h wind speed. For higher wind speeds, the doors and roof shutters will be closed to provide protection up to 200 km/h. The membrane material not only has a transparency of greater than 90% over the operational waveband but also protects the surface of the telescope by transmitting no more than 20% of the incident solar radiation. The building, which weighs some 450 tonnes and is 22.3 metres high and 28 metres diameter, can be rotated in ten minutes.



The Organisation

RUTHERFORD APPLETON LABORATORY, OXFORDSHIRE

Overall responsibility for management of the project during the construction phase. Design of the enclosure and antenna including development and manufacture of the surface panels.

Development of high frequency mixers for the receiver systems.

ROYAL OBSERVATORY, EDINBURGH

Responsible for development and construction of the first continuum receiver with Queen Mary College. Responsible for operation of the facility after commissioning.

MRAO, UNIVERSITY OF CAMBRIDGE

Responsible for detailed guidance on the scientific aspects of the project. Partnership with Rutherford Appleton Laboratory in the design of the antenna. Development of the microprocessor system for control and monitoring, together with the software for data analysis. Construction of the first (230 GHz) heterodyne receiver.

NFRA, DWINGELOO THE NETHERLANDS

Responsible for receiver development and the construction of the 345 GHz line receiver with the University of Utrecht. Thermal analysis of complete facility.

QUEEN MARY COLLEGE, LONDON

Responsible for the electromagnetic analysis of the antenna and for receiver development including the detector for the 490 GHz receiver and filters for the continuum receiver.

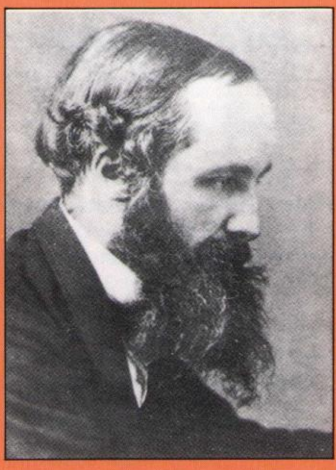
UNIVERSITY OF UTRECHT

Responsible for the design, development and construction of the secondary mirror system. Developed the acousto-optic spectrometer for the 345 GHz receiver.

OTHER PARTICIPANTS:

University of Kent—receiver correlator and detector development
Laboratory for Space Research Groningen—receiver development

James Clerk Maxwell



James Clerk Maxwell was born in Edinburgh in 1831 and was educated at that University. Later, he became the first Cavendish Professor of Physics at the University of Cambridge. His contribution to physics spanned the entire discipline, but his major achievements lay in the theory of electromagnetism and in the kinetic theory of gases. In the latter field he discovered the velocity distribution of atoms and molecules in gas, known as the Maxwell Velocity Distribution.

Of greater relevance to astronomy, he discovered the laws of electromagnetism through a brilliant piece of mathematical physics. In making these discoveries he showed that light is a form of electromagnetic radiation.

Science and Engineering Research Council

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