



Looking for the Origin of the Stars

A Low Noise Detector for Millimetre Wave Radio Astronomy

In December 1998 Dr Stéphane Claude and Dr Charles Cunningham of the National Research Council, Canada, completed an important upgrade of one of the Superconducting-Insulator-Superconducting (SIS) heterodyne receivers at the James Clark Maxwell radio telescope on the Mauna Kea mountain in Hawaii. The receiver is cooled by an Oxford Instruments hybrid helium cryostat.



New stars are born within the large clouds of interstellar dust and gas in our galaxy. We can learn about their formation by studying the sites of young stars, such as the Orion nebulae. These clouds often contain a wide variety of chemical species such as carbon monoxide, hydrogen cyanide and methyl alcohol. Such molecules have many rotational transitions at millimetre and submillimetre wavelengths and the strength and shape of their spectral lines are good probes of the chemistry and kinematics of the star formation region.

Detecting these faint, high frequency signals has required the development of dedicated instruments using superconducting technology. Detection uses heterodyne mixing, which combines the observed signal with that generated by a local oscillator. The difference in frequency is the output intermediate frequency (IF). The new receiver consists of a superconducting SIS mixer, cooled by an Oxford Instruments hybrid helium cryostat, a liquid nitrogen

calibration load, and various instrument controls. It is stable and exhibits low noise across its frequency range of 211-276 GHz and is fix-tuned across this entire band. These features greatly improve observing efficiency by enhancing signal levels and permitting quick frequency changes to detect a number of spectral lines in each source. The receiver has a particularly wide, 1.8 GHz, IF bandwidth which is important for observation of extragalactic objects that have a large velocity range.

The Oxford Instruments cryostat ensures the very stable bath temperature of 3.7 K (at an altitude of 4000 m) required for low-noise mixing operation of the Niobium SIS junctions ($T_c = 9.26$ K). Importantly, at such a remote site, it only needs a weekly refill despite being tilted during observations, an action which reduces the helium hold time. The cryostat also provides the rigid internal supports required so that the focus of the beam in the mixer is not altered by the movements of the telescope. The new mixer uses a full height waveguide and a coplanar SIS chip which includes four Nb/AlOx/Nb

junctions mounted in series [1]. The mixer operates in a double side band mode with no side band rejection. For optimum mixer stability, a magnetic field is applied to the SIS junctions to suppress unwanted Josephson oscillations. Stable operation is paramount for completely automatic operation. The receiver is very sensitive, exhibiting an equivalent noise temperature of 60-80 K across the frequency band.

The development of low noise computer controlled receivers is particularly important for future interferometers such as the ALMA project (Atacama Large Millimetre Array).

Reference
[1] A R Kerr, S -K Pan, A W Lichtenberger and H H Huang, "A Tunerless SIS mixer for 200-280 GHz with low output capacitance and inductance", *Proceedings of the Ninth International Symposium on Space Terahertz Technology*, pp.195-203, 17-19 March 1998.

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