"CHARMing" – building a receiver for the LMT

E.M. Gallagher
e.m.gallagher@icloud.com
STFC RAL Space, Harwell Campus, Didcot, Oxfordshire, OX11 0QX

Science and Technology Facilities Council

RAL Space

CHARM is the Collaborative Heterodyne Astronomical Receiver for Mexico

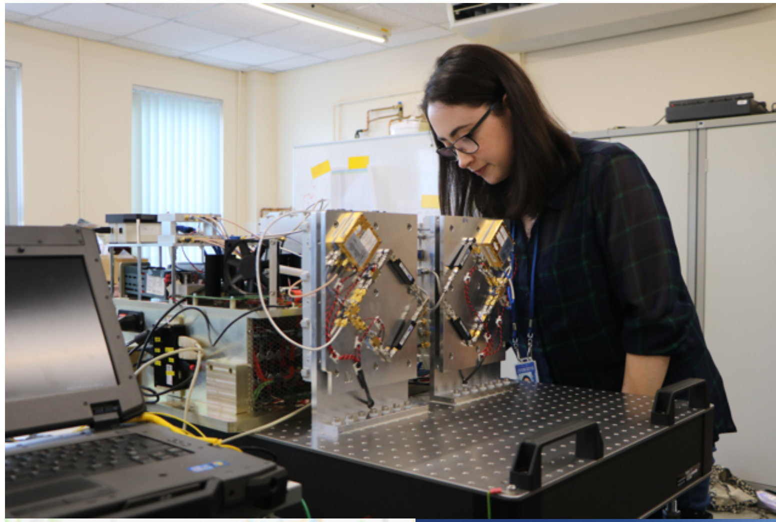
The Large Millimetre Telescope (LMT) is a huge Cassegrain radio telescope system designed to operate at wavelengths from 4mm to 0.85mm. CHARM operates at 0.86mm and is the highest frequency instrument at the LMT.

Located at an elevation of 4,600m on the Sierra Negra mountain within the Pico de Orizaba National Park, the LMT 50m diameter primary dish is yet to be characterised for wavelengths shorter than 1mm. CHARM will aid in this characterisation task and determine the efficiency of the telescope dish at 0.86mm, this will allow future use of the telescope at these wavelengths.

CHARM is part of the Astronomical Systems, Technology and Engineering Collaboration also known as ASTEC which is a knowledge transfer program between the UK and Mexico.

The aim of this collaboration is to train Mexican Scientists and engineers in the design, construction and operation of astronomical heterodyne receivers that employ new technologies. It also encourages links between UK and Mexican astronomers and researchers.

The project is supported through a Global Challenges Research Fund award in collaboration with the University of Manchester, Instituto Nacional de Astrofísica, Óptica y Electrónica (INAOE) and The University of Mexico.



Heterodyne receiver technology

Heterodyne receivers are based on a key component called a mixer – this takes the incoming signal and mixes it with a frequency generated by a local oscillator in the instrument (see fig 1.) This creates what we call the intermediate frequency that can be more easily processed using off the shelf components than the original signal.

CHARM uses 4 wide band spectrometers, centred at 345GHz in order to pick up a the carbon monoxide rotational transition line (CO J=3-2) at ~ 345.8GHz which is commonly found in the Interstellar Medium.

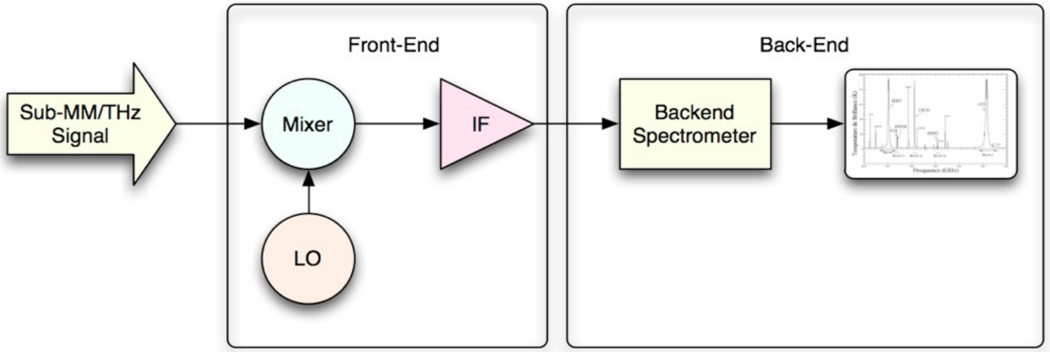
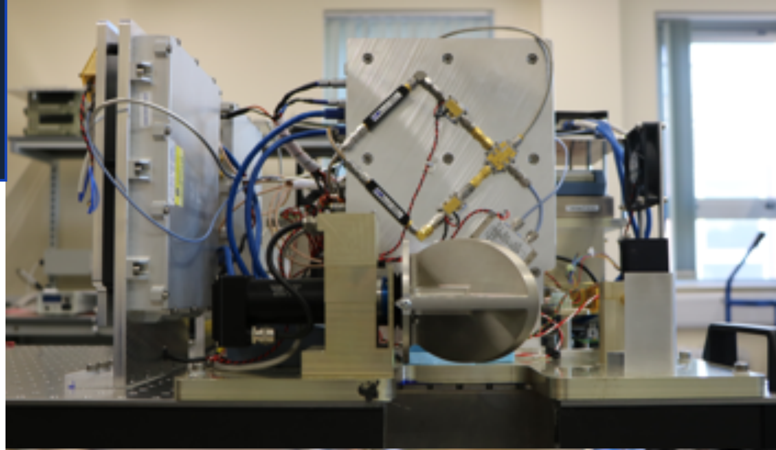
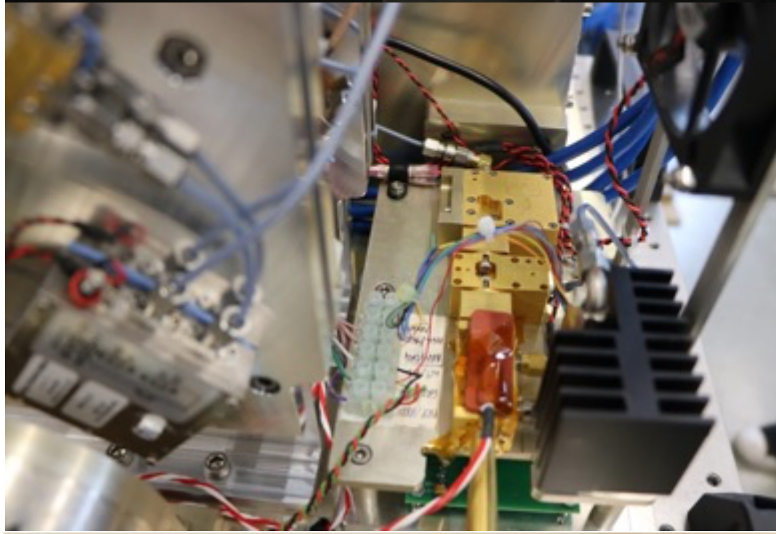
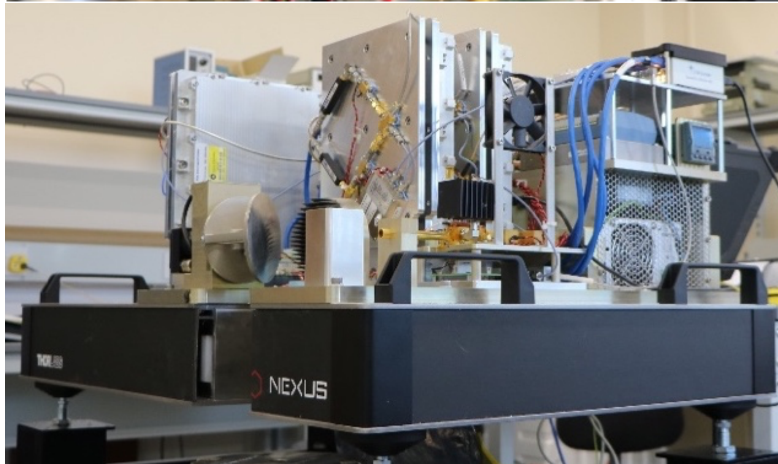


Figure 1: showing operation and components of a basic heterodyne receiver. Credit: Prof. B.Ellison

A previous RAL instrument, SHIRM (the Sub-Harmonic Image Rejection Receiver,) was taken as the basis for the development of CHARM. SHIRM was a compact receiver, observing spectral lines in the atmosphere, and had a sideband separation and switching system architecture that achieved excellent results in support of atmospheric studies and demonstrated technical advancements in signal down-conversion and data processing[1].







Science and Technology Facilities Council RAL Space

[1] Rea, S., Oldfield, M., Gerber, D. (2014) 'Field test of a total-power radiometer comprising a 340 GHz sub-harmonic image rejection mixer (SHIRM) receiver for atmospheric remote sensing', *International Foundation HFSJG,* Activity Report 2014, pp. 81-84 [Online]. Available at: *https://www.hfsjg.ch/wordpress/reports/2014/123_RAL_Gerber_cf.pdf* (Accessed: 26th May 2019)

Development and testing

Some core components from SHIRM were reused. However, the critical mixer component was found to be unsuitable for astronomical observation due to its reduced sensitivity and was replaced by a newly developed and improved sub-harmonic mixer, tested at a range of frequencies and bias levels to obtain the lowest noise temperature

CHARM uses a double sideband system (see fig.2 for detail.) Although this can complicate spectral identification, it provides an overall improvement in the system sensitivity and allows increased tuning and wider spectral coverage. The intermediate frequency output from the mixer undergoes a further down conversion before being signal processed, a step that was also enhanced along with the important introduction of new signal processing electronics in the form of four high-speed wideband digital spectrometer units. These improvements have increased the instantaneous bandwidth of CHARM to 8GHz per sideband.

The ability of the system to perform sensitive observations was tested using the Allan Deviation method (fig. 3). This implied that a system integration time of ~10 seconds was achievable (which is more stable than the fluctuation of the atmosphere,) and was likely to improve in the more controlled environment of the LMT receiver cabin.

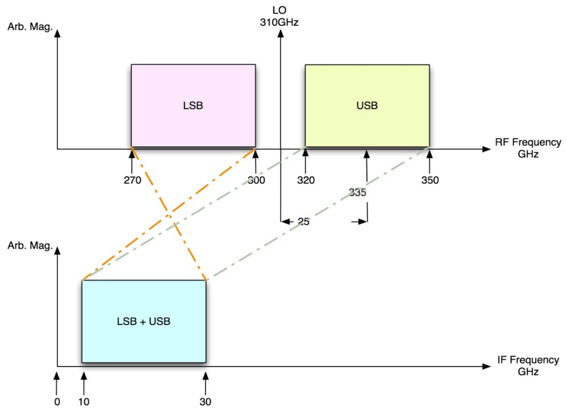


Figure 2: showing how a double sideband system overlaps, which can lead to spectral confusion but increased sensitivity. Credit: Prof. B.Ellison

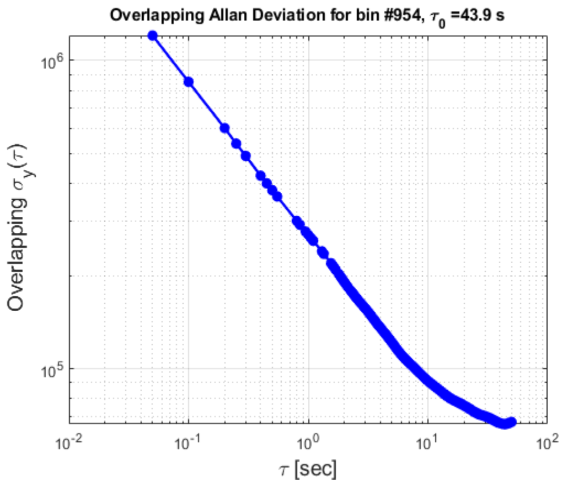
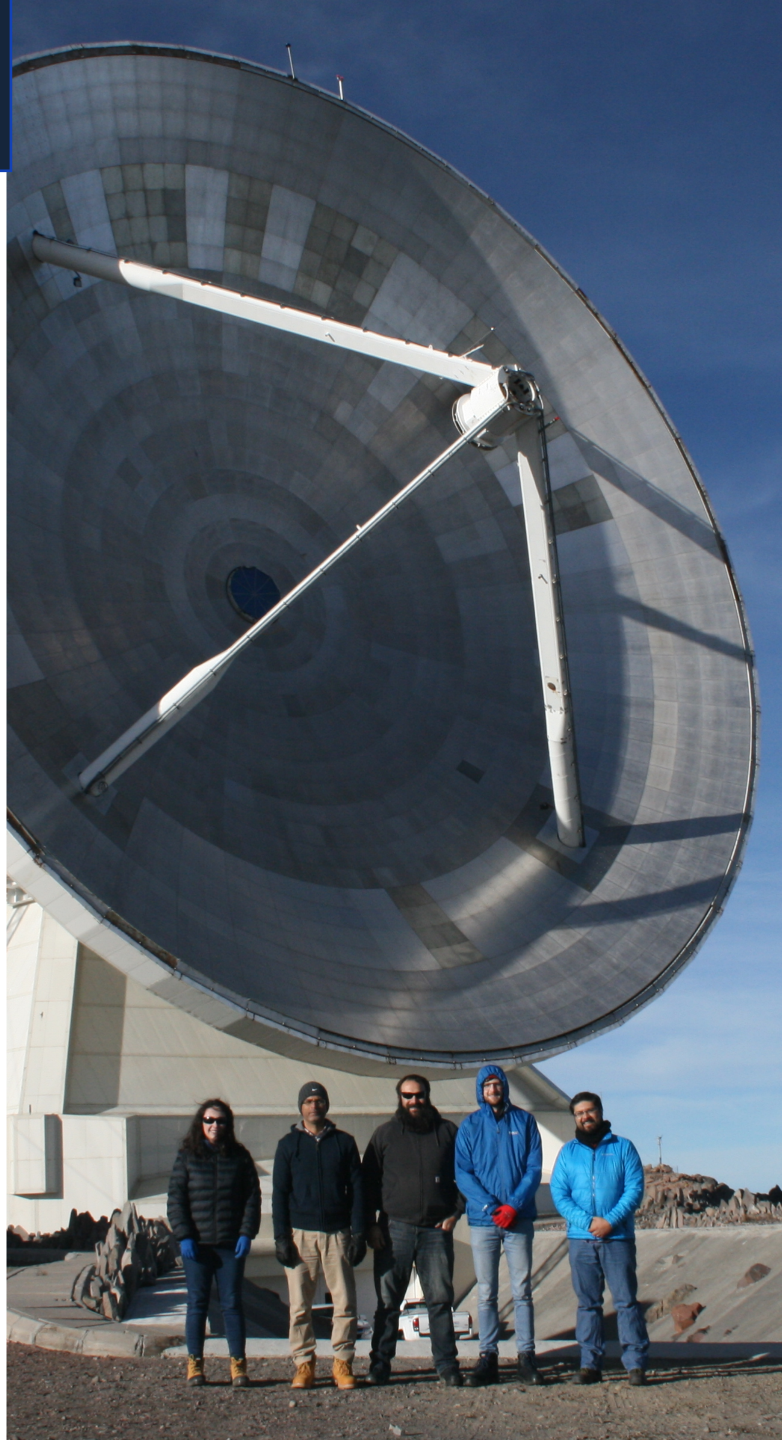


Figure 3: Allan Deviation plot for selected best spectral bin - the square root of Allan variance against observation time (τ) for the best bin number in a given spectra



Science and Technology Facilities Council RAL Space

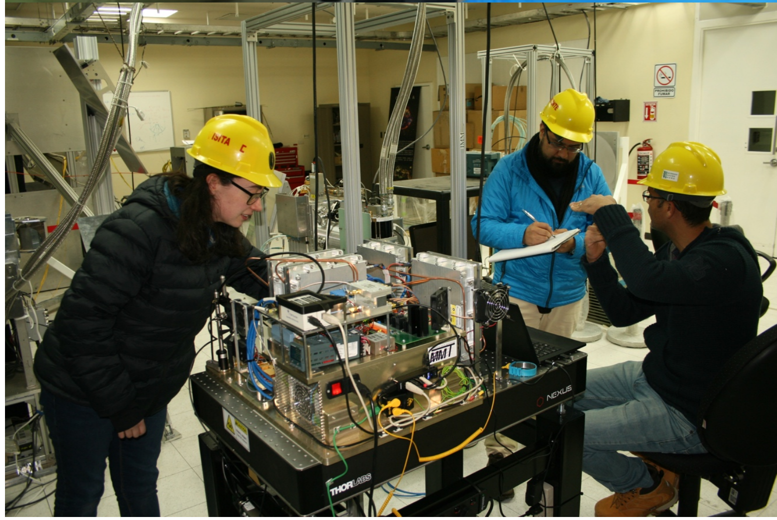
Observing with CHARM

Following successful installation in Sept 2019, CHARM first light observations showed the first demonstration of LMT capability at 0.85mm/345GHz. This could result in increase to LMT VLBI capabilities by demonstrating performance at this wavelength. Observations will continue into 2021.

CHARM will be used to observe astronomical spectral lines originating from young star forming regions of the interstellar medium (ISM) . These observations are associated with cold dark regions that are invisible at shorter wavelengths and they can tell us more about star formation and stellar evolution

CHARM has two settings for astronomical observing - On the Fly (OTF) and Position switching (PSW). OTF is commonly used for mapping large extended sources and PSW is used for smaller sources with on and off source integrations.

Results are to be presented at the SPIE Astronomical telescopes + instrumentation conference later this year by Edgar Colin-Beltran of INAOE on behalf of the group.



Acknowledgements

N.S Daghestani, F. Cahill, A. Obeed, E. Colin-Beltran, G.Fuller, B.N. Ellison

Thanks to the GCRF for funding and the RAS for the awarding of the Patricia Tomkins undergraduate prize 2019.

UKRI Science and Technology Facilities Council RAL Space