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Calibration of MeerKAT autocorrelation data for HI Intensity Mapping

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The MeerKLASS collaboration is using the MeerKAT telescope in single dish (autocorrelation) mode to constrain cosmology through observations of the redshifted 1.42 GHz neutral hydrogen (HI) emission line out to redshift 1.4. This measurement uses the technique of "intensity mapping", which uses HI emission to trace the formation of structure through mapping the density fluctuations on the largest scales, rather than trying to detect individual galaxies. Conducting this experiment in single dish mode allows us to measure the linear scales of structure formation, which are resolved out by even the shortest MeerKAT interferometric baselines, though interferometry can be used to study the non-linear scales.

Single dish observations introduce additional complications to the calibration of the data beyond those necessary for interferometry. To ensure that ground spill and atmospheric emission does not vary across the observation we adopt a constant elevation scanning strategy. We scan for approximately 10 degrees in azimuth before reversing direction, driving the telescope at 5 arcminutes per second so that we return to the same sky potion multiple times; this allows us to mitigate the effects of 1/f noise, which we also remove through the use of a very stable noise diode.

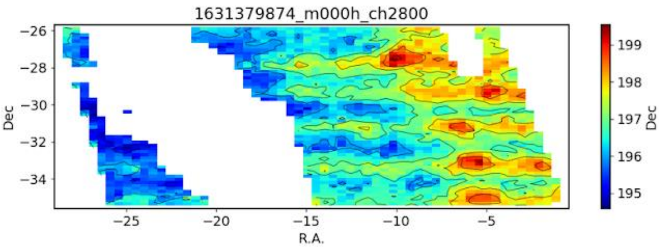

Figure 1 The phenomenon of stripes across the MeerKLASS sky maps at approximately constant Declination. Data excised due to the passage of a satellite through the field is also visible.

An unexpected phenomenon that we discovered in some of our data was stripes across the sky maps. These stripes appeared at approximately constant Declination and affected all frequency channels. We have concluded that these stripes are the result of non-linearity in the MeerKAT receivers and the presence of a bright GSM tower at Vanwyksvlei, 54 km from the telescope. As the telescope drives in azimuth, the GSM tower moves into and out of the far sidelobes of antenna beam, introducing a varying increase in the system temperature of around 1K (compared with the total system temperature of approximately 16K). Although the RFI from the GSM tower is well localised in frequency and can successfully flagged from the data, when the GSM emission is detected strongly in the antenna sidelobes, the receiver gain increases and, due to the total power nature of the measurements, the broadband signal level increases, even in channels which are RFI-free. We have been able to implement a mitigation for this effect by correlating the power level detected in the GSM band against the power in the RFI-free channels, hence giving us a correction function.

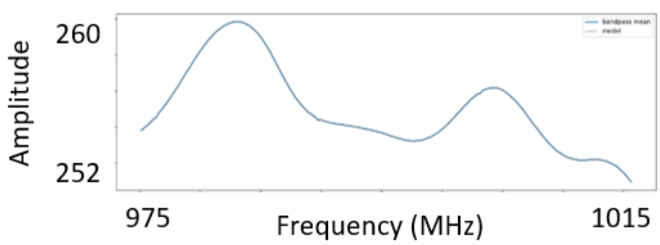

Figure 2 MeerKAT bandpass in an RFI free window used for cosmology.

A second effect in our data is that of standing waves on the receiver bandpass. We have found individual antennas have very different bandpasses, characterised by a ripple with approximately 20 MHz period. We have tied this ripple to standing waves in the antenna optics resulting from the panel layout in the MeerKAT antennas, allowing us to fit a physically motivated model for the bandpass and hence calibrate out the effects of these standing waves.