Calibration Techniques for the Thermal Background on ELTs

Observing in the thermal infrared is challenging due to the high thermal background. This background emission from the sky, telescope and instrument can be several orders of magnitude greater than the science signal. There are techniques to remove the background emission but for ELTs these techniques need to be adapted. Currently new methods are being developed to accurately remove the background for ELTs.
The results are of importance to the METIS instrument, the science cases are driven by deep observations, high spatial and spectral resolution and low magnitude observing which calls for great background calibration and subtraction methods.

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Sky structure and variability

- In the thermal infrared the sky background radiation is magnitudes greater than the science signals.
- The background is often assumed to be a blackbody radiating at ambient temperatures.
- The spatial variability is relatively large compared to the field of view of METIS, this leads to a flat behavior in the image plane.
- The variability of the sky is typical around one second, the science exposures need to be on timescales faster than the background fluctuations.

Telescope and instrument

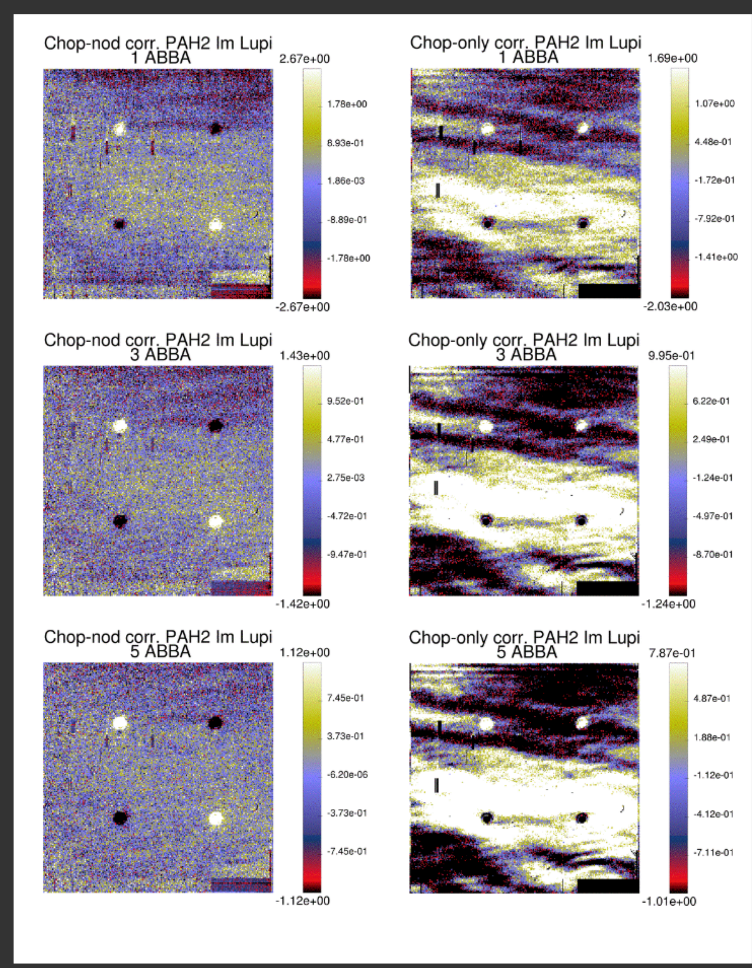
- The telescope acts as a grey body at ambient temperatures, all warm surfaces of the E-ELT radiate in the IR.
- The E-ELT total emissivity is assumed to be 15%.
- Sources of uncertainty in the emission profile of the telescope are the gaps between the mirror segments and variation in segment reflectivity.
- The background of the telescope varies with time but on slower timescales than the sky background.
- The spatial variability of the telescope is small because there are no structures or surfaces near the image plane.
- Thermal radiation from METIS can be controlled by lowering the internal temperature.

Detector

- The background signal and structure is time dependent.
- The background needs to be measured simultaneously with the signal or at a short time interval after the science measurement.
- Observing the sky simultaneously requires a perfect flat-field (gain stability) of the detector.
- Due to high background signals the detector linearity is important, non-linearities of the detector can complicate the background subtraction.
- Detector drifts need to be known and calibrated so that it minimally affects the residual noise.

Internal pupil chopping

- Traditional chopping: moving secondary mirror of the E-ELT is not available.
- Chopping mirror placed at intermediate pupil of the METIS instrument provides fast chopping (+-5") and residual tip-tilt beam stabilization.
- Telescope beam path changes during internal pupil chopping: this introduces residual sky noise.
- New chopping schemes need to be devised to minimize the background noise.



IM Lupi source observed with VISIR in the PAH2 filter(11.2 μm) in chop/nod mode (left column) and chop-only mode (right column). Three different integration times are shown: ~1 min, ~3 min, ~5 min. It is shown that chopping only without nodding the telescope results into a lot of residual noise. If one would only use an internal pupil chopper then the beam through the telescope changes and introduces even more noise. Hence we need to develop a chopping strategy that to counteract the introduced noise.

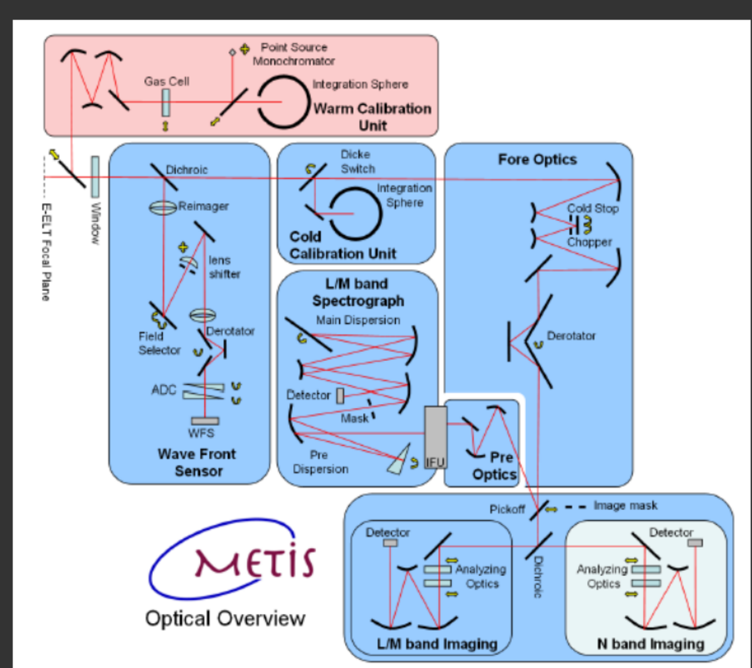
Image courtesy Eric Pantin

Drift scan mode

- Source signal drifts over the detector so that multiple pixels see the source at different times, non source pixels register the sky background emission.
- Telescope is not stationary during this mode because we want slow drifts of 0.1 FWHM per DIT but this is slow enough that the image on the detector is stable during one DIT.
- Only very compact sources can be observed in order not to degrade the spatial resolution.
- The source location in the field is not known so advanced strategies for the data reduction to accurately remove the background and detect the source.

Dicke switch

- The Dicke switch works by rapidly switching the telescope beam with an internal reference source.
- The intensity of the blackbody reference source is matched to the background surface brightness.
- Detector gain variations can be traced, the gain has an impact on the sensitivity as soon as it dominates the shot noise.
- Dicke switching allows to retain the spatial resolution given by the E-ELT that would be compromised when using a chopping scheme.



Schematic optical outline of the METIS instrument

Existing background subtraction techniques are being adapted to suit extremely large telescopes to accurately remove the background signal for ELTs.

References

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