Calibration strategies at JCMT

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Mission statement

- Providing accurate calibration is the responsibility of the observatory (although at ground based observatories the observer is expected to ensure that his/her data are calibratable)
- However
  - Many observers feel that time spent on calibration is a waste of time
  - Time allocation committees do not want to allocate time for calibration

How do we do it?

- Use engineering time
  - Include calibration plan and calibration verification as part of commissioning
  - Pursue calibration programs using engineering nights (never worked at JCMT, although some of the data came and do come from engineering time)
- Tax science time
  - Most of JCMT calibrators came from my own science projects and science time, but it is also
    - Easy and straight forward to add in calibration work for service and queue observations
    - Some additional data can be obtained from visiting astronomers (use data archive)

Calibration difficult !!

- The sub-mm sky is ‘never’ photometric and the transparency poor (even at very good sub-mm sites)
- The atmosphere adds sky noise and anomalous refraction
- Telescopes have relatively poor efficiency, may vary (varies) as a function of elevation, temperature (day/night or even winter/summer)
- Instruments noisy (often only single pixel) and occasionally unstable
- Very few celestial sources suitable as calibrators

Photometric calibration (SCUBA)

- Having an imager is essential
  - One can essentially eliminate sky-noise
  - Use extended (but still compact) objects as calibrators
  - Monitor the psf (beam size) all the time

Recommended observing strategy

- Early evening (point, focus, map a calibrator)
- Repeat every one to two hours until 8 or 9 pm, after that every two to three hours
- Observe at least three calibrators during a night; one primary, two secondaries, if two not available, boot strap using a bright blazar or science target
  - At 850 micron I expect to do better than 5% (relative to primary calibrator), at 450 better than 15 (or 20%)
  - About 20 to 30% spent on calibration and pointing

Calibration (reduction)

- Crucial to know the atmospheric opacity
  - Use tipping monitor at CSO 1.3mm
  - Use wvm on telescope (measures los wv content)
  - SCUBA sky dips (only if nothing else available)
- Always use at least two calibrators (one for control), which means at least three if one calibrates a whole night (I additionally even use pointing sources to check the calibration)
- The current SCUBA calibrator list was created by mostly using Dutch time over a 6 month time period

Heterodyne observations

- All JCMT receivers use three load calibration (hot, cold,sky)
- Occasional sky dips (gives spillover efficiency)
- Need to regularly monitor aperture and beam efficiency using planets (requires knowledge of beam size)
  - Pointing, focus check (second pointing)
  - Photometry
  - Beam map
- Monitor line calibration (using a set of UC HII regions, two protoplanetaries and IRC+10216), additionally calibration checks from a pointing list of AGB stars (~70)
  - This is really underutilized. I created the first list of line calibrators. Lorne Avery created a web interface, which give representative spectra for important lines. With more work we could do much better. Nothing has been done after Lorne left (to my knowledge)

Calibration Errors

- Sideband imbalance or sideband rejection (if SSB) - often due to poor tuning
- Unequal T_A(sig) & T_A(im) - near the edges of atmospheric windows
- Errors in T_{hot} and T_{cold}
- Pointing and focus errors (& antenna efficiencies
- Poor phaselock