Introduction to the Workshop: JCMT Instruments, Observing Modes, Data Reduction Basics

JCMT Users Meeting 2018, Seoul (서울)

Photo Credit: Will Montgomerie
Basic Data Reduction

1. Introduction:
   What are we doing today?

2. Brief Instrument Overview:
   - SCUBA-2
   - HARP
   - RxA

3. Data Reduction Basics
# Schedule

[Link to schedule](http://www.eaobservatory.org/jcmt/help/workshops/)

<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
</tr>
</thead>
<tbody>
<tr>
<td>09:30 - 10:30</td>
<td>Data Reduction I: Basic</td>
</tr>
<tr>
<td>10:30 - 10:45</td>
<td><strong>Coffee Break</strong></td>
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<tr>
<td>10:45 - 11:45</td>
<td>Data Analysis with Starlink</td>
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<tr>
<td>11:45 - 12:30</td>
<td>CANFAR as a Tool for Astronomers</td>
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<tr>
<td>12:30 - 13:30</td>
<td><strong>Lunch Break</strong></td>
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<tr>
<td>13:30 - 15:00</td>
<td>Data Reduction II: Advanced</td>
</tr>
<tr>
<td>15:00 - 15:30</td>
<td>The JCMT Observing Tool</td>
</tr>
<tr>
<td>15:30 - 16:00</td>
<td><strong>Coffee Break</strong></td>
</tr>
<tr>
<td>16:00 - 17:00</td>
<td>Scripting with Python (Jupyter)</td>
</tr>
<tr>
<td>17:00 - 17:30</td>
<td>The JCMT Archive</td>
</tr>
</tbody>
</table>
Continuum
&
Polarisation
SCUBA-2 - Instrument Overview

- 850 and 450 microns simultaneously
- 4 subarrays each consisting of 40 x 32 bolometers for each wavelength
- The continuous solid angle on the sky is \( \sim 43 \text{ arcmin}^2 \)

http://www.eaobservatory.org/jcmt/instrumentation/continuum/scuba-2/
PONG Observing Mode \( (15', 30', 90', 1^\circ, \text{ and } 2^\circ) \)

- The telescope scans across the sky and across the same region at many different position angles.
- This gives us a measurement of power received over time and allows us to disentangle spatial features from temporal features.

Figures From: Holland et al. 2013
Constant Velocity (CV) Daisy Observing Mode

- For compact sources, generally ~3’ or less
- Significant exposure time out to ~12’, though the best coverage is in the most central region

See:

www.eaobservatory.org/jcmt/instrumentation/continuum/scuba-2/observing-modes/

For more information
POL-2: Polarimeter

POL-2 works in conjunction with SCUBA-2: Carefully Commissioned at 850 μm

POL-2: Polarimeter

Three optical components:

1. A wire-grid polarizer used as calibrator
2. A rotating half wave plate
3. A wire-grid polarizer used as the analyzer

The detectors are the SCUBA-2 bolometers at both 450 and 850 microns
POL-2: Polarimeter Observing Mode

Observations are performed using an altered daisy pattern to allow the telescope to slew at slower speeds (to get sufficient Q & U)

There is currently no PONG option available for POL-2 observations

Standard CV Daisy

POLCV Daisy
Heterodyne Instruments
Heterodyne - Instrument Overview

www.eaobservatory.org/jcmt/science/reductionanalysis-tutorials/

- RxA : Single Pixel Receiver 230 GHz
- HARP : 16 pixel 345 GHz array receiver
- ACSIS : Multi-channel digital spectrometer (Backend)
RxA: 211-276 GHz, Dual Sideband

- Single receptor (pixel), 20” beam at 230 GHz
- Calibrated by an ambient load and liquid nitrogen
- Local Oscillator is 4GHz from center of observed band
- Uses ACSIS to produce Spectra in $T_A^*$
HARP: 325-375 GHz, Single Sideband

16 receptors (pixels), 14” beam at 350 GHz

14 receptors currently usable

www.eaobservatory.org/jcmt/instrumentation/heterodyne/harp/

http://cdsads.u-strasbg.fr/abs/2009MNRAS.399.1026b
ACSIS: The Heterodyne Backend

“Auto Correlation Spectral Imaging System” used by RxA and HARP

- Several options available:
  - 250 MHz Bandwidth; spectral resolution 0.0305 MHz
  - 1000 MHz Bandwidth; spectral resolution 0.488 MHz
  - 440 MHz (2x250)
  - 1860 MHz (2x1000) modes
  - 1-4 subbands (RxA)
  - 1-2 subbands (HARP)
Heterodyne: **Stare** Observing Mode

- HARP: 30” Spacing between receptors
  
  - RxA : Single Receptor

- Fixed location on the sky, for compact sources
Heterodyne: Jiggle Observing Mode (<2’)  

- Beam switching: Secondary mirror is “chopped” a maximum of 180’
- Position switching: Primary mirror is slewed to reference position
Heterodyne: **Raster** Observing Mode (>2’)

- For larger sources, a scan pattern that can be “basket weaved”
Example: G34.3 integrated intensity images

HARP Stare

HARP Jiggle-map

HARP Raster map

2 arcmin
30" pixels

2 arcmin
6" pixels

6 arcmin
7.25" pixels
Data Reduction Basics: SCUBA-2
The Signal in a Single Bolometer

\[ b(t) = f \times [e(t) \times a(t) + n(t)] \]

- \( b(t) \) = Signal Received by a Bolometer
- \( f \) = Scaling Factor (\( pW \) -> Jy beam\(^{-1} \))
- \( e(t) \) = Extinction Correction
- \( a(t) \) = Astronomical Signal
- \( n(t) \) = Sources of noise:
  - 1. \( n_w \) = Uncorrelated White noise
  - 2. \( g \times n_c \) = Common Mode noise + gain factor
  - 3. \( n_f \) = Excess noise (low freq.)
An example of Real Time Stream Data
From the SCUBA-2 Data Reduction Handbook

- **COM**: Signal common to all bolometers

- **FLT**: Low frequency noise (sky) missed by COM

- **AST**: Signal, spiking as the telescope scans across the source

- **RES**: Residual white noise (flat as expected)
SCUBA-2 Data Reduction Overview

- 5 main models applied to the data which separate sources of noise from astronomical signal

- More than 100 user defined parameters affect how each model is produced (see Mairs et al. 2015. MNRAS 454, 2557 for examples of DR tests)

- Currently testing 4 different methods based on the JCMT Gould Belt Survey and the JCMT Legacy Data Release

Chapin et al. 2013, MNRAS. 430, 2545–2573
Data Reduction Basics: Heterodyne
Heterodyne Data Reduction Overview

Included in your Raw Data:

Combination of several calibration measurements:

- Ambient load measurements,
- Sky measurements,
- A load of known temperature (heated for HARP, cooled for RxA3)

Corrected for:

- Atmospheric attenuation
- Scattering
- Rearward spillover (portion of beam not looking at sky)
Heterodyne Data Reduction Overview

- Construct a data cube
- Smooth the data cube
- Make integrated intensity moment maps
- Perform quality Assurance Checks

Data reduction process (briefly):

- Trim noisy edges
- Flag high/low frequency interference
- Mask bad detectors
- Remove noise spikes
- Mask emission/fit and subtract baseline
The Data Cube is Calibrated in $T_A^*$ (specific to the telescope)

For information on Heterodyne Calibration, see:
The JCMT Science Archive

~10 years of public HARP and RxA3 data with ACSIS and ~5 years of public SCUBA-2 data

★ Raw observations in instrumental time series format
★ Reduced individual observations (FITS)
★ Nightly products: Co-adds of obs. Taken by one project towards one source in one night
★ Detailed (searchable) metadata including position, wavelength, transition, weather
★ VO enabled - can search with TAP (e.g. through TOPCAT) on all metadata, not just those visible in advanced search

Thank-you very much!
정말 감사합니다