The JCMTOT
Building a Project from Scratch

Dr. Steve Mairs (ASTR351L Spring 2019)
Overview

1. Review of the Instruments

2. ACSIS and a few observing strategies

3. The JCMT Observing Tool

4. Science Ideas

5. Proposal Writing/Resources
The Instruments: SCUBA-2
SCUBA-2: Instrument Overview

Continuum Imager:

850 μm and 450 μm Simultaneously

4 subarrays each consisting of 40 x 32 = 5120 bolometers at each wavelength

Beam @ 450um = 9.8”
Beam @ 850um = 14.6”
SCUBA-2: PONG Observing Mode

The telescope scans across the sky and across the same region at many different position angles.

PONG options of: 15’, 30’, 90’, 1°, and 2°

Figures From: Holland et al. 2013
SCUBA-2: DAISY Observing Mode

The telescope scans across the sky and across the same region at many different position angles.

For smaller scale maps: 3 - 12 arcminutes.

Also used for calibrations on planets and planetary nebulae!
The Instruments: POL-2
The long axis of dust grains tend towards an alignment perpendicular to B-field lines.

POL-2 works in conjunction with SCUBA-2
POL-2: Only DAISY Observing Mode

The telescope scans across the sky and across the same region at many different position angles.

For smaller scale maps: 3 - 12 arcminutes

Also used for calibrations on planets and planetary nebulae!
Tracing Magnetic Fields in Space!
The Instruments:

**Ala’ihi**: ~86 GHz

**U’u**: ~230 GHz

**Aweoweo**: ~345 GHz

Image Cubes At 3 Different Frequencies!

Tuneable between 325-275 GHz!

**HARP**

**Namakanui**

U’u: ~230 GHz

Aweoweo: ~345 GHz

Ala’ihi: ~86 GHz
HARP/Namakanui

Generates Image Cubes With Velocity Information
For nearly 70 different molecules (CO, HCN, Formaldehyde…)

Instruments observe a range of frequencies
Each “channel” corresponds to a different frequency/wavelength/doppler velocity
HARP/Namakanui
Stare Mode (Point Sources)

HARP has 16 Receptors that each produce a spectrum! Namakanui is a single pixel (3 cartridge) system.
HARP/Namakanui — Jiggle Mode (<2’)

Jiggle those Receptors that each produce a spectrum around the sky in a grid to get a map!

*Jiggles are efficient for small maps*
In this way, we measure kinematic information over large areas.
HARP and Namakanui Use: **ACSIS**

**ACSIS** = Auto Correlation Spectral Imaging System

This is the system that takes the incoming raw signal and produces spectra.

Available spectral windows: 250, 440, 1000, or 1860 MHz. The spectral resolution of ACSIS varies from 30 kHz to ~1 MHz.

Built-in special configurations to observe several common molecules like CO and SiO.
HARP and Namakanui Use: ACSIS

Available spectral windows: 250, 440, 1000, or 1860 MHz. The spectral resolution of ACSIS varies from 30 kHz to ~1 MHz.

Bandwidth and Resolution can be split over multiple “windows”

This is an example of 2 windows in the Lower Sideband to observe two different molecular lines simultaneously!
Available spectral windows: 250, 440, 1000, or 1860 MHz. The spectral resolution of ACSIS varies from 30 kHz to ~1 MHz.

Bandwidth and Resolution can be split over multiple “windows”

Look what happens when we change the bandwidth to 1 Ghz instead of 250 MHz (Note the Resolution!)
HARP and Namakanui Use: **ACSIS**

Available spectral windows: 250, 440, 1000, or 1860 MHz. The spectral resolution of ACSIS varies from 30 kHz to ~1 MHz.

*Note that it is possible to get really fancy depending on your chosen receiver.*
ACSIS: Beam Switching vs Position Switching

Switch from Source to Sky
For background subtraction and baselining
(Sky = Reference)
### HARP/Namakanui Observing Modes

<table>
<thead>
<tr>
<th>Map Size</th>
<th>Use a</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Compact source</td>
<td>a stare</td>
<td></td>
</tr>
<tr>
<td>Moderate extent (less than 2 arcmins)</td>
<td>a jiggle</td>
<td></td>
</tr>
<tr>
<td>Large extent (greater than 2 arcmins)</td>
<td>a scan</td>
<td></td>
</tr>
<tr>
<td>Little to no emission close (&lt;180°) to target</td>
<td>beam-switched (BMSW) chop to the reference position</td>
<td></td>
</tr>
<tr>
<td>Contaminating emission near source, or uncertain of region</td>
<td>position-switched (PSSW) observation to a reference further from the source (up to 3 degrees) or frequency switching</td>
<td></td>
</tr>
</tbody>
</table>

### SCUBA-2 Observing Modes

- PONG options of: 15’, 30’, 90’, 1°, and 2°
- DAISY mode for smaller scale maps: 3 - 12 arcminutes (Only option for POL-2)
ACSIS: Array Spacings/Basket Weave

Step: Width of Array
Step: 3/4 of Array
Step: 1/2 of Array
Step: 1/4 of Array
Step: 1/8 of Array
Step: 1 sample

Usually the ideal compromise

FAST

Slow
The JCMT Observing Tool (JCMTOT)

This software helps you **design observing scripts** for the JCMT.

It has **example programs** that showcase single observations as well as surveys.

We will be using this tool to construct SCUBA-2/POL-2, HARP, or Namakanui projects.
A science program is made up of
MSBs = Minimum Schedulable Blocks
I.e. A short (30-70 minute) observation that is usable for science
The JCMT Observing Tool (JCMTOT)

Program
General program information taken from the proposal.

Title
PI
Country
Project ID
Estimated Time (w/o options) 00:00:00.0
Estimated Total Time 00:00:00.0
The JCMT Observing Tool (JCMTOT)

ACIS = AutoCorrelating Spectral Imaging System
This is the backend for both HARP and Namakanui
The JCMT Observing Tool (JCMTOT)
The JCMT Observing Tool (JCMTOT)
The JCMT Observing Tool (JCMTOT)
Heterodyne Science

![Graph showing output vs wavelength with FWHM and \( \Delta \lambda \)]
Heterodyne Science Ideas: Line Widths

Line widths can tell us a lot about the physical characteristics of systems.

Degree of broadening and relative strengths of lines gives us information about:

- Internal Thermal Pressure
- Organised Bulk Motion
- Turbulence
- Interesting Chemistry
- Relative Energy States
- Physical Temperatures

Equivalent Widths
What can the abundances of different molecules tell you about the physical environments of the source you are observing?

**13CO/C18O Abundance Ratio**

**Temperature of the Dust**

Line shapes: P Cygni Profile as an Example

The shapes of molecular profiles can also tell us a lot!

HARP alone can tune to the frequencies of transitions associated with ~70 different molecules including CO, HCN, Formaldehyde...
SCUBA-2 Science
Dense Gas/Dust Conglomerates

Ring-like Structures
More Heat $\Rightarrow$ Expansion $\Rightarrow$ No star formation

More Stuff $\Rightarrow$ Collapse $\Rightarrow$ Star Formation

Stronger Pressure $\Rightarrow$ Expansion $\Rightarrow$ No star formation

Stronger Gravity $\Rightarrow$ Collapse $\Rightarrow$ Star Formation

Gravity

Thermal Pressure

A constant struggle!
Is Archival Data Available (Other Telescopes)?

Consider combining data from other telescopes with JCMT data to fill in gaps of our understanding.

Remember, SCUBA uncovered a class of galaxies never seen before!
Survey Work! Spectral or Continuum! Example: The JCMT Transient Survey

8 regions, < 500 pc (GBS) 450μm and 850μm!

250 Protostars, 1400 Disk Sources

3 Years, Began: 12/2015

One Month Cadence
Chandrasekhar-Fermi (C-F) method combines POL-2, SCUBA-2, and HARP data to calculate the B-Field strength.

\[ B_{\text{pos}} = Q' \sqrt{4\pi \rho} \frac{\sigma_v}{\sigma_\theta} \approx 9.3 \sqrt{n(\text{H}_2)} \frac{\Delta v}{\langle \sigma_\theta \rangle} \mu\text{G} \]


This Assignment Is In 2 Parts

1. The Proposal
You will come up with a science program for which to propose JCMT observations (JCMT proposals are much the same in format as many other telescopes). Any instrument, any feasible science

2. Constructing the MSBs
You will then use the JCMTOT software to construct usable observing scripts for the telescope based on your program.
The Proposal

An example can be found here: https://www.eaobservatory.org/~s.mairs/ASTR351/assignments/Example_JCMT_Proposal_Mairs.pdf

Abstract

Scientific Justification:

1-3 pages describing the background on the science and why the Time Allocation Committee should select this work. It should clearly state exactly what instrument(s) you want to use and the total time request. Describe the specific scientific question(s) you would like to answer. Include well-labeled figures!

Include a Source List and Time Calculations

Technical Justification:

0.5 - 1 page justifying the required sensitivity you need to make a robust detection. This estimate can be derived using archival data from other telescopes, figures from papers you looked up as part of your research, or estimates from simulations that have been performed (Figures welcome!)

Include References
Getting Started: Questions to Ponder

What are some interesting astronomical questions that inspire you? Think Big!

Do a little research on the data that exists and think about how the JCMT could be used to follow up: Continuum? Spectral? Both?

Is (are) the source(s) visible from Hawai`i?

What time of year are your sources in the sky?

Is there a temporal component to your observations? (i.e. do you want to decide when to trigger observations? eg. flares, comets, gamma ray bursts...?)
Time Calculations

Don’t worry - we have online calculators!

**SCUBA-2**

https://proposals.eaobservatory.org/jcmt/calculator/scuba2/time

**Heterodyne**

https://proposals.eaobservatory.org/jcmt/calculator/heterodyne/time

You will need to justify the sensitivity you need to achieve your scientific goal

I.e.: What is the background noise necessary to make a robust detection? **Background noise is highly dependent on weather!**
Requests for time are **limited to a maximum of 200 hours**

But usually proposals that require $\sim<$50 hours are more successful

If your request is large - can you reduce the sample size? The required sensitivity? The size of the mapped area? The number of molecules?

Projects that can be performed in poor weather (Band 5) are likely to get time!

Generally, a Time Allocation Committee has $\sim$15 minutes to address your proposal, so make sure the thesis statement of your science stands out somehow - TAC members can’t perform detailed follow-up on references

Be creative, but not vague - I.e., a statement like “This data will shed light on our understanding of galaxy evolution” isn’t helpful, because every other proposal might contain the exact same sentence.
Part 2: The JCMTOT

Launching the JCMTOT from UH:

```bash
% javaws http://ftp.eao.hawaii.edu/ot/jac-ot.jnlp
```

Start here for a PDF presentation of tips and Tricks


There are also 2 tutorials (Basic and Advanced):

https://www.eaobservatory.org//JCMT/observing-tool-tutorials/jcmt_ot_basics.html

https://www.eaobservatory.org//JCMT/observing-tool-tutorials/jcmt_ot_tricks.html

Here is the full documentation with a convenient table of contents:

https://www.eaobservatory.org//JCMT/observing-tool/

More information on Heterodyne and SCUBA-2 Observing Modes:

https://www.eaobservatory.org/jcmt/instrumentation/heterodyne/observing-modes/

What You Will Need To Submit for Grading

1. A complete proposal to perform some observations.
   
   Ensure you have all the necessary components:
   
   Abstract
   Scientific Justification
   Target List
   Time Calculations
   Technical Justification
   References

2. A complete program that will run in the JCMTOT.

When you construct your program, ensure you use the “Validate” button on each of your MSBs and on the whole science program, itself. The system will let you know if there are any errors. When you save your work, a “.xml” file will be produced.

Submit the .xml file for grading.