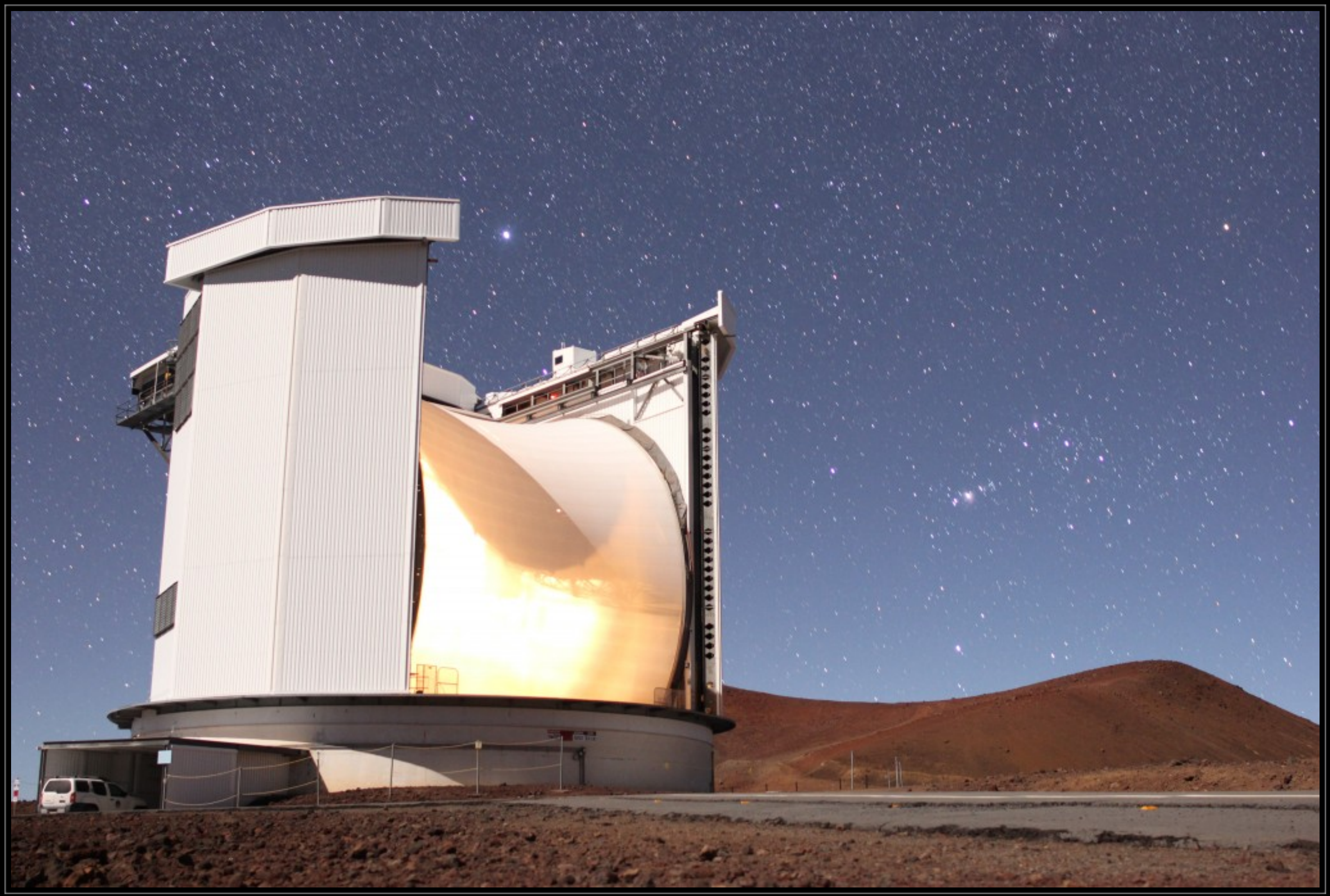
The JCMTOT

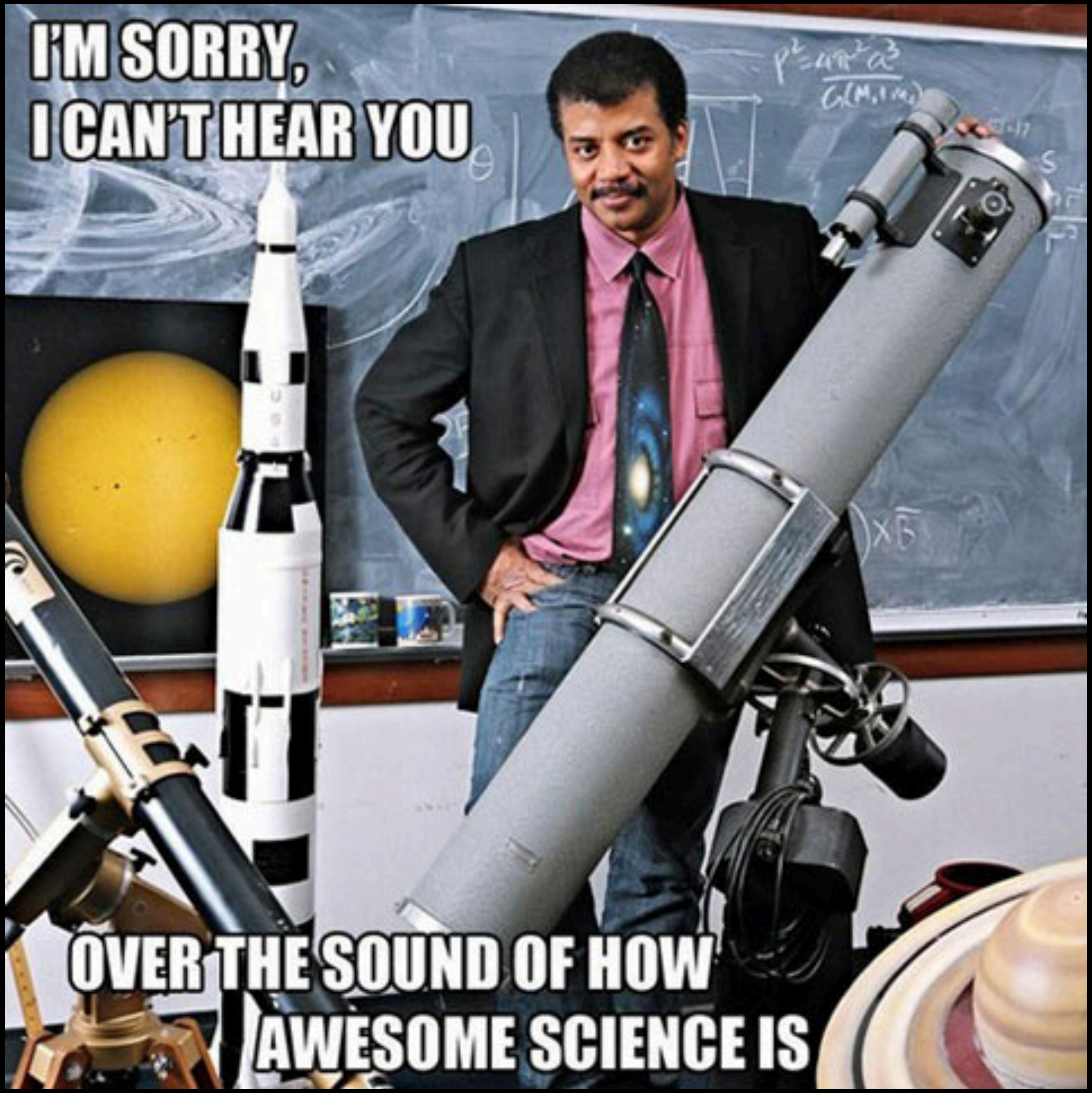
Building a Project from Scratch



Dr. Steve Mairs (ASTR351L Spring 2019)

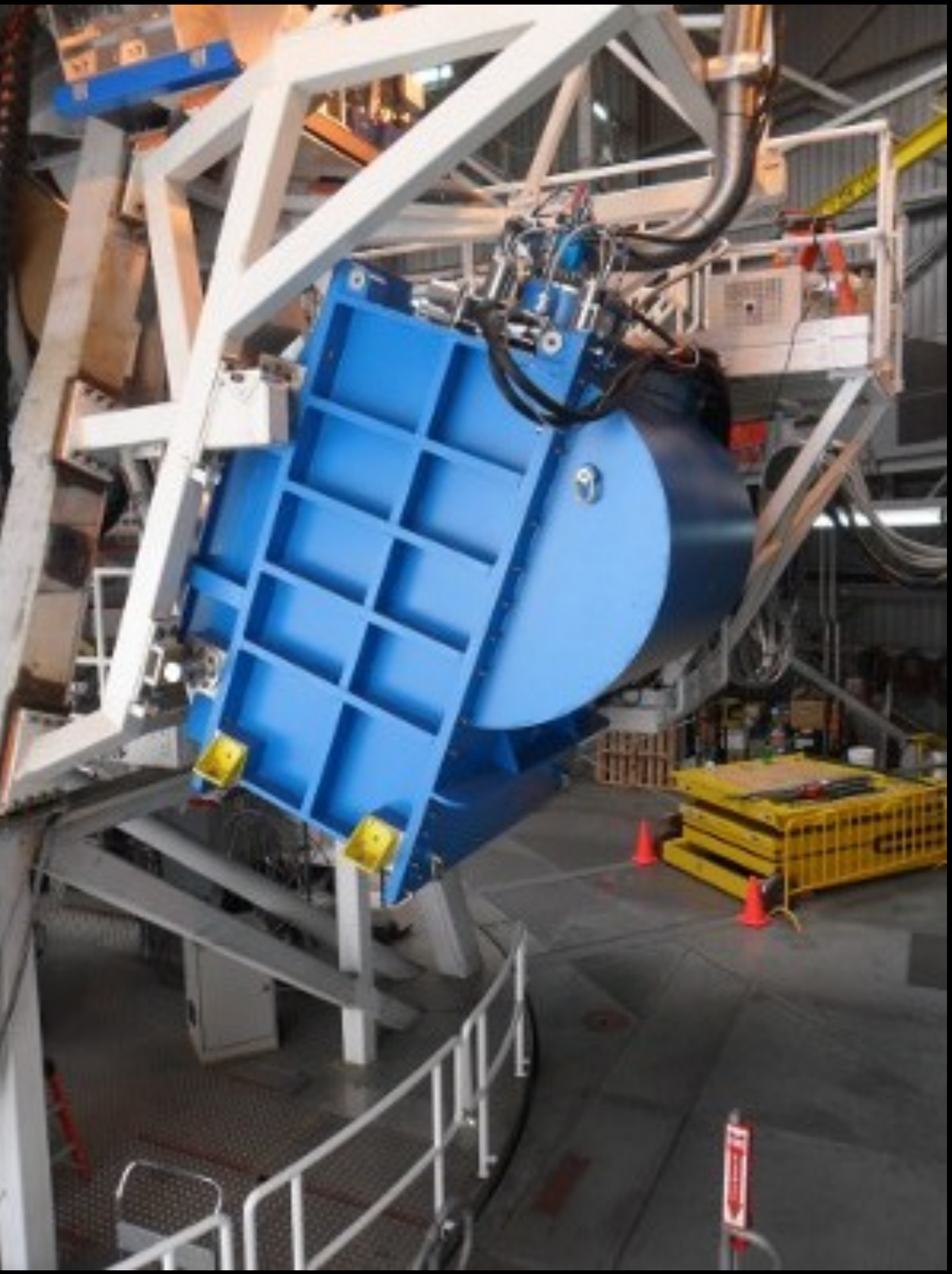
Overview

1. Review of the Instruments
2. ACSIS and a few observing strategies
3. The JCMT Observing Tool
4. Science Ideas
5. Proposal Writing/Resources



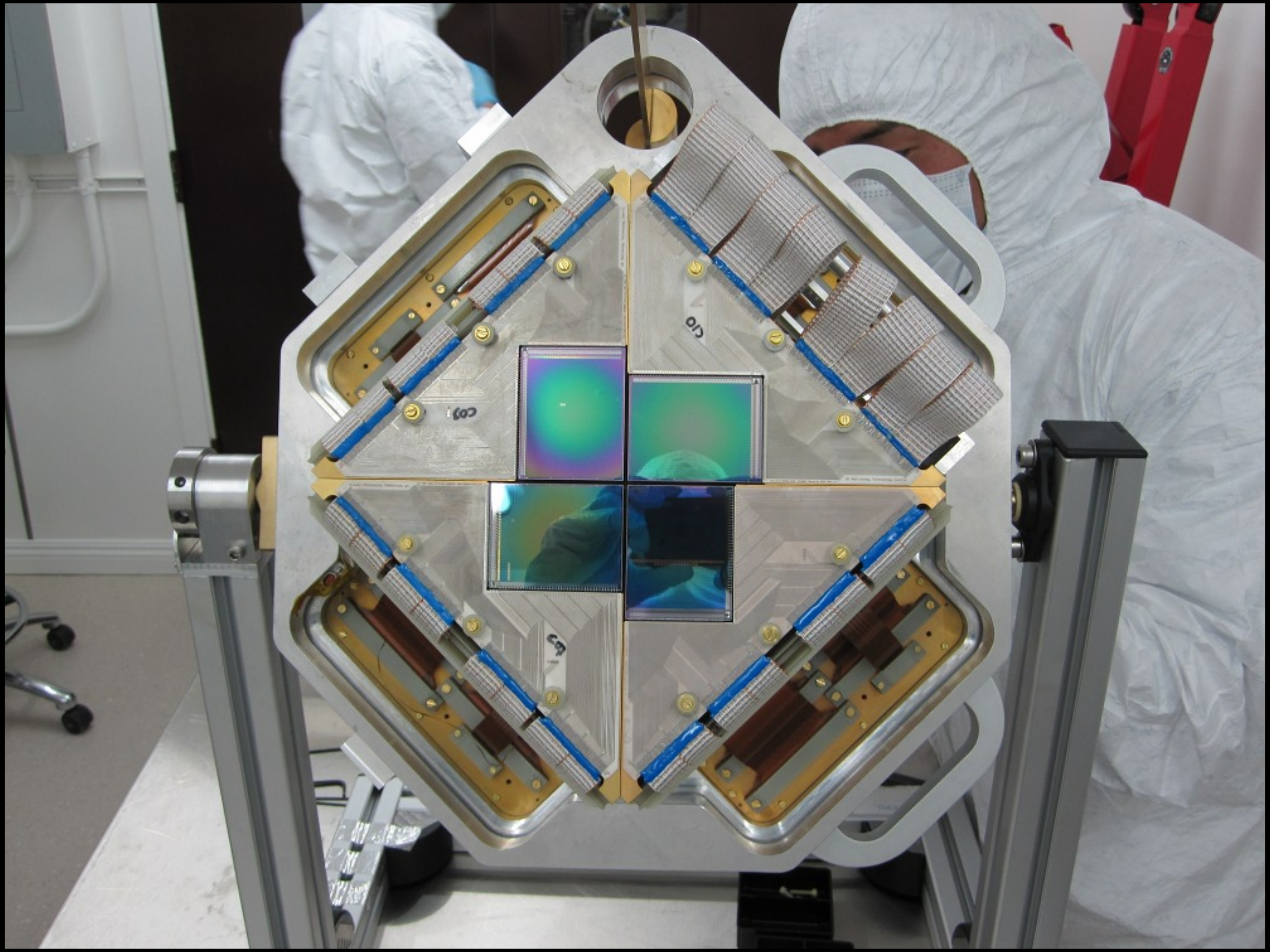
The Instruments: SCUBA-2

SCUBA-2: Instrument Overview



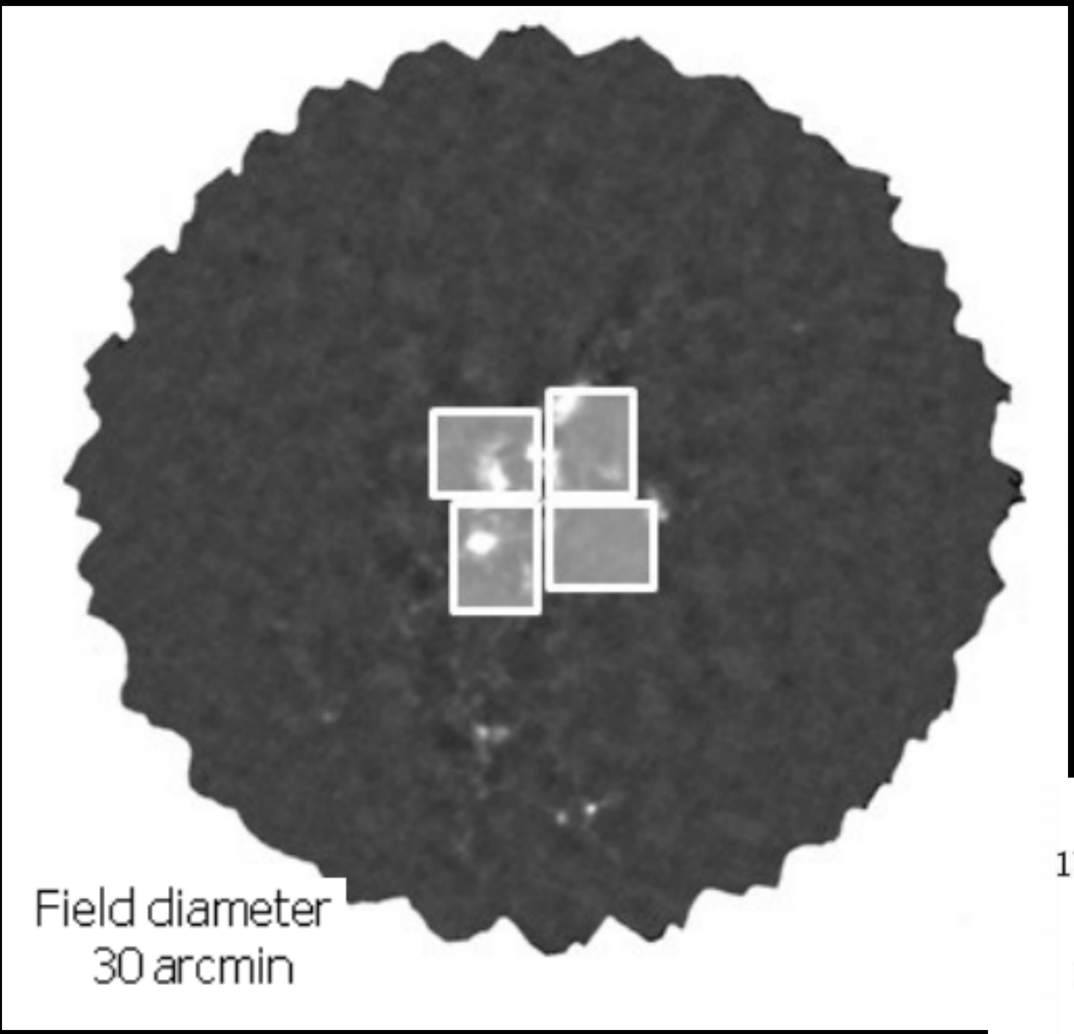
Continuum Imager:
850 μm and 450 μm Simultaneously

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



Beam @ 450um = 9.8”
Beam @ 850um = 14.6”

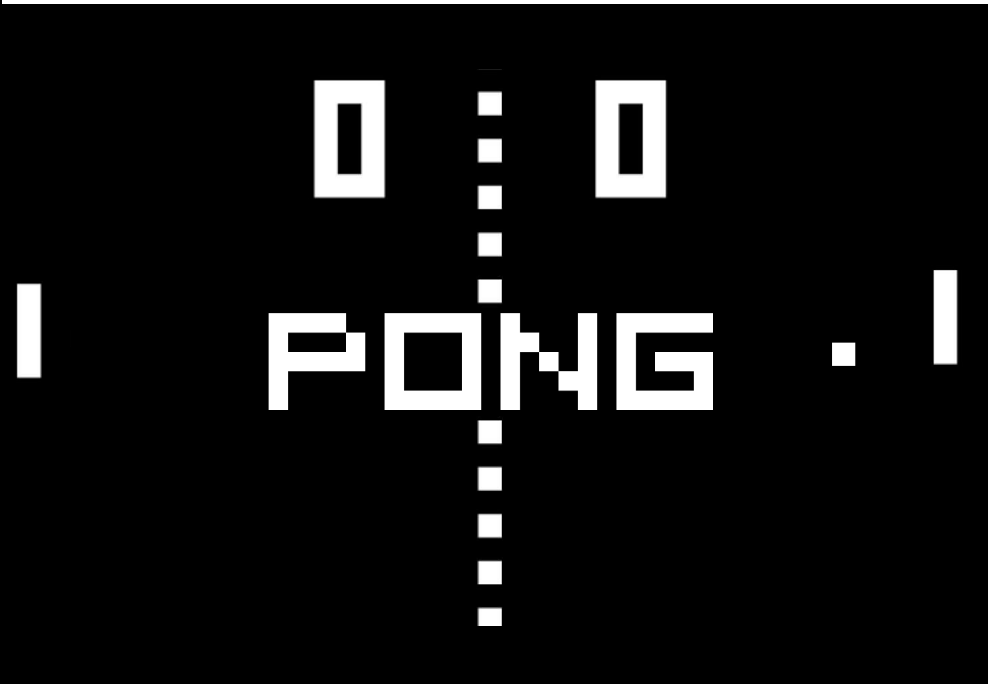
SCUBA-2: PONG Observing Mode

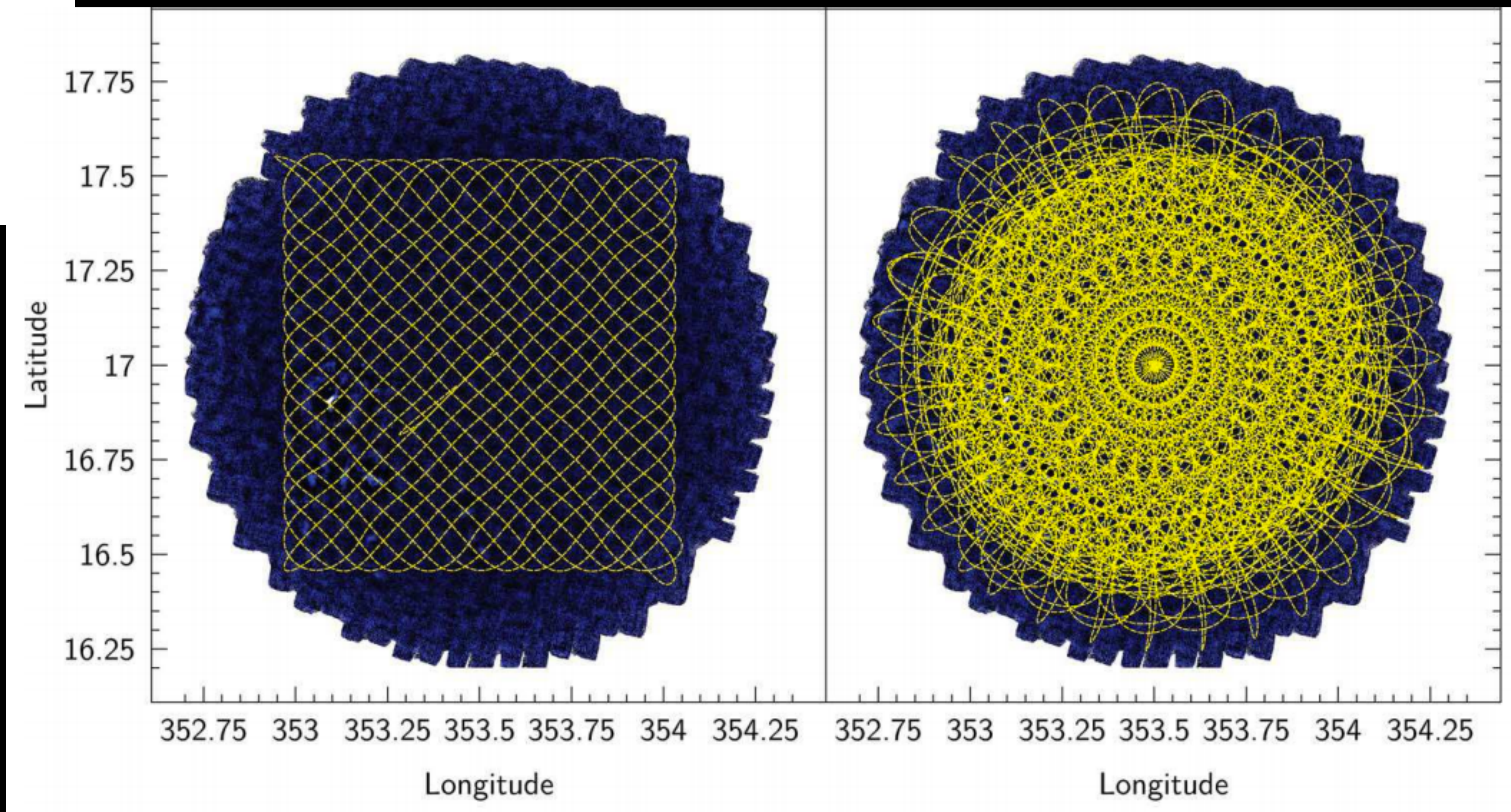


The telescope scans across the sky and across the same region at many different position angles

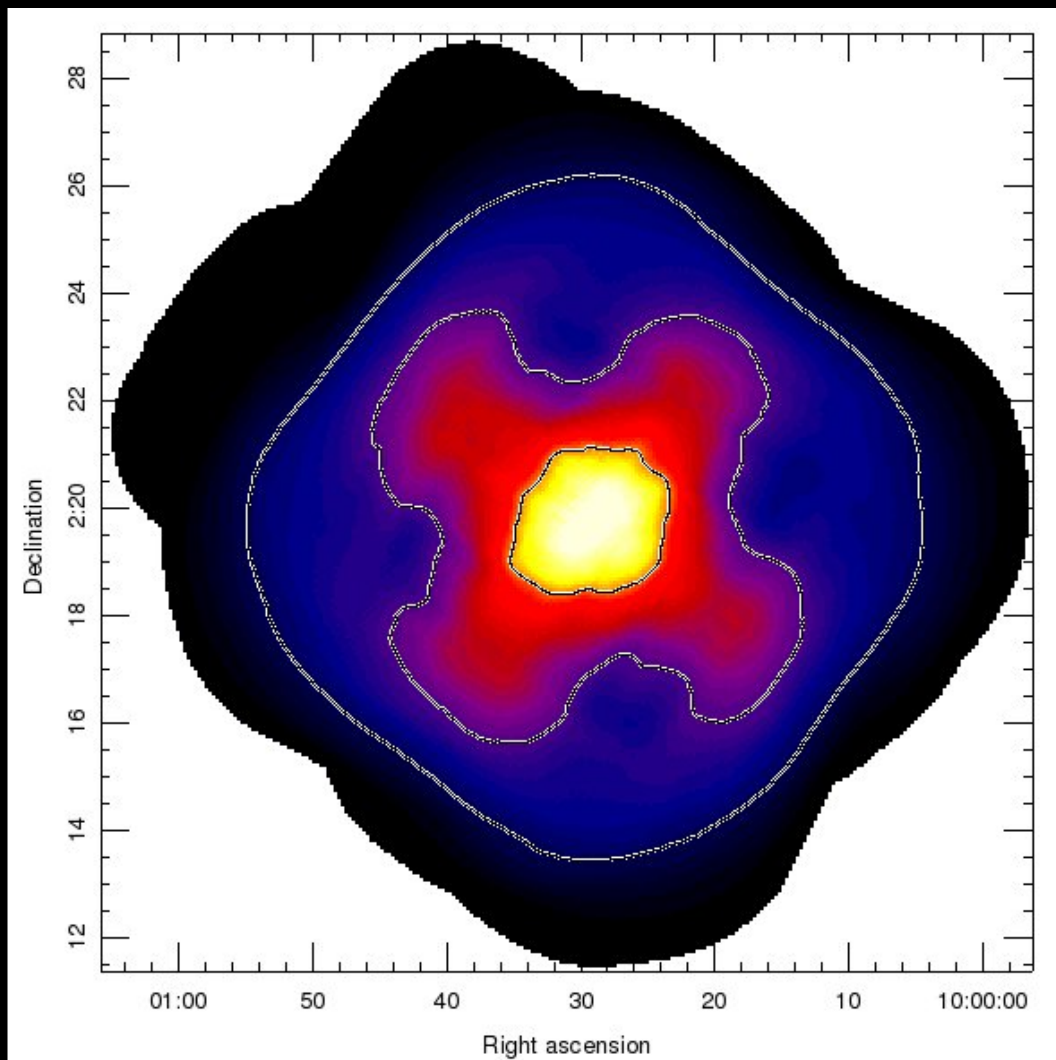
PONG options of: 15’, 30’, 90’, 1°, and 2°

Figures From: Holland et al. 2013



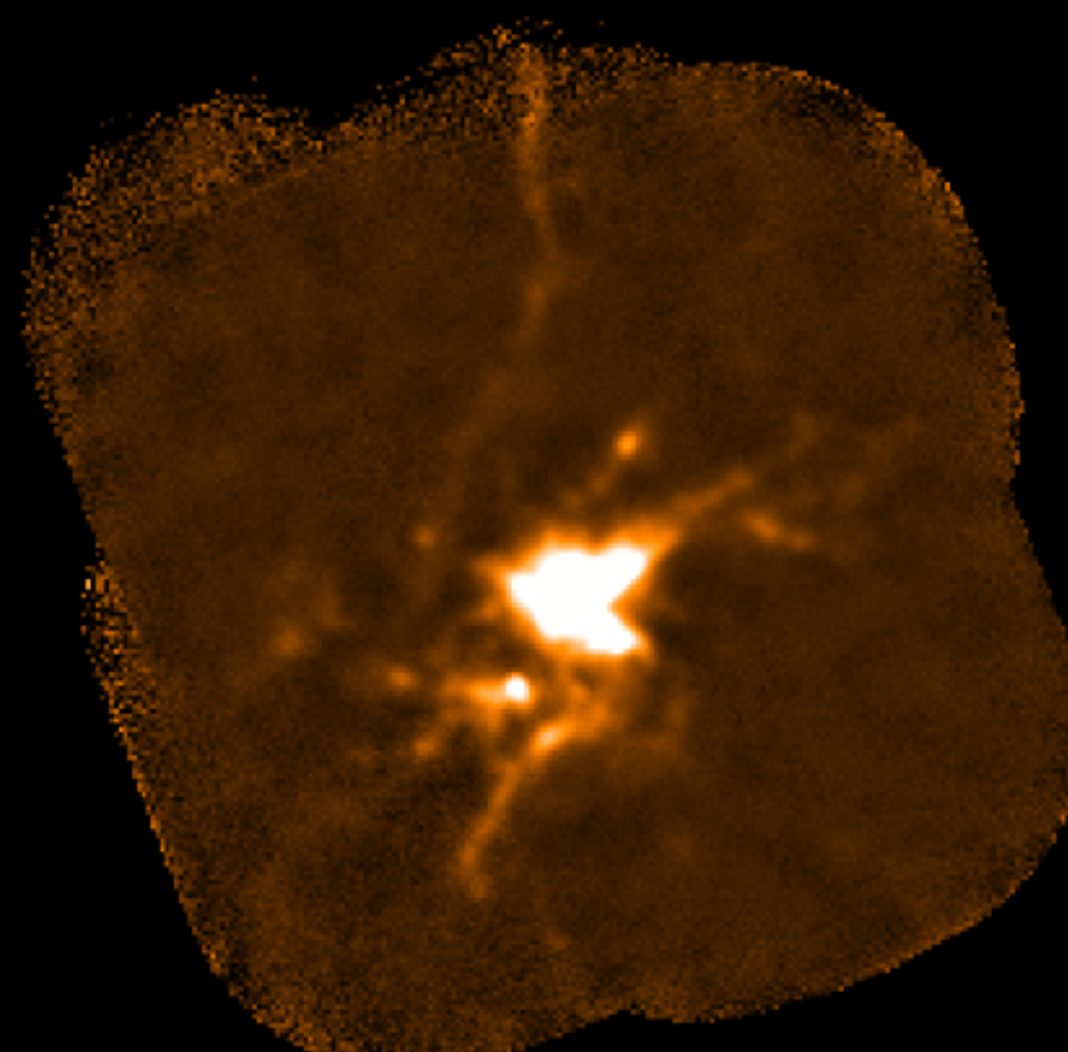


SCUBA-2: DAISY Observing Mode

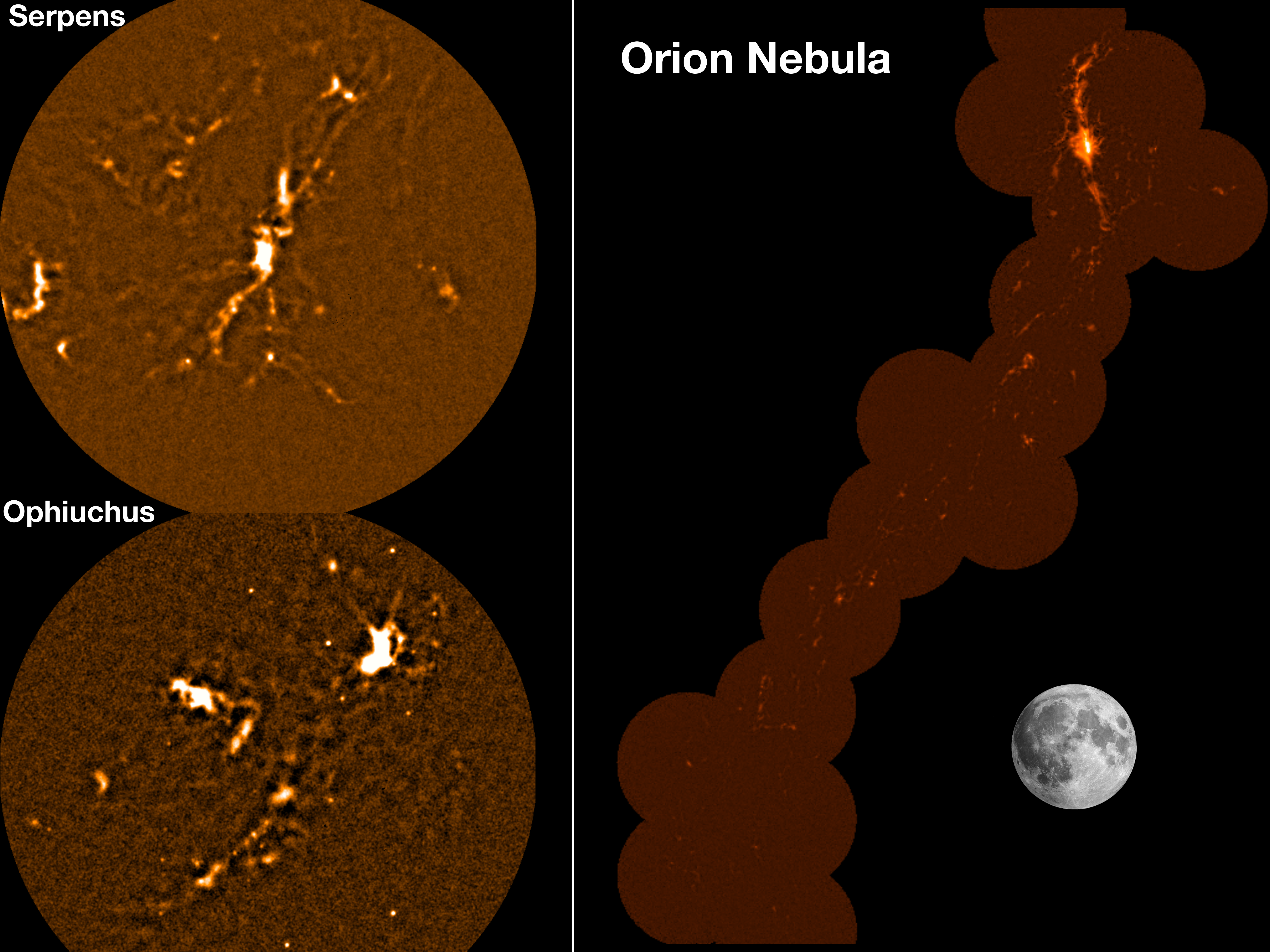


The telescope scans across the sky and across the same region at many different position angles

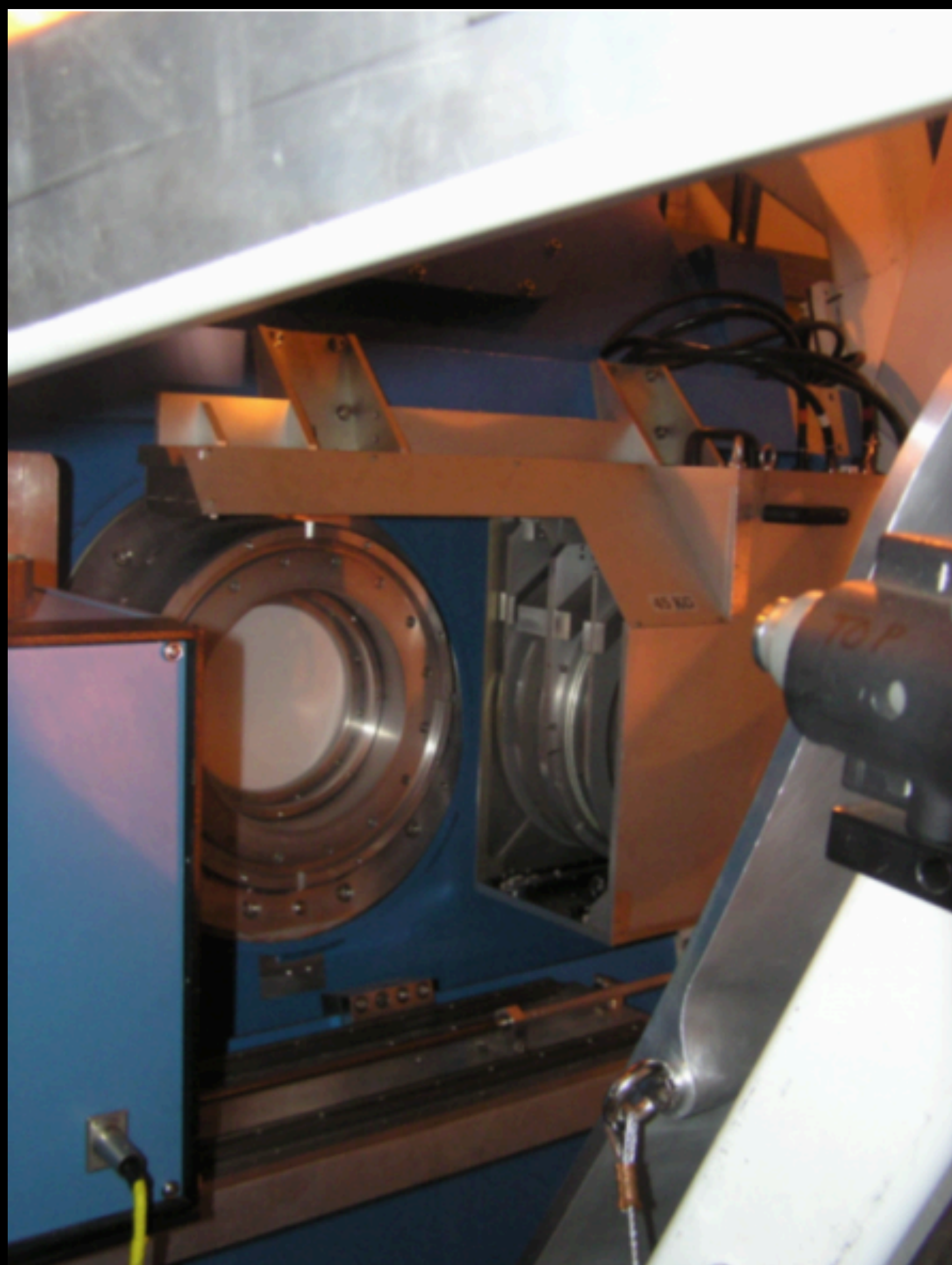
For smaller scale maps: 3 - 12 arcminutes

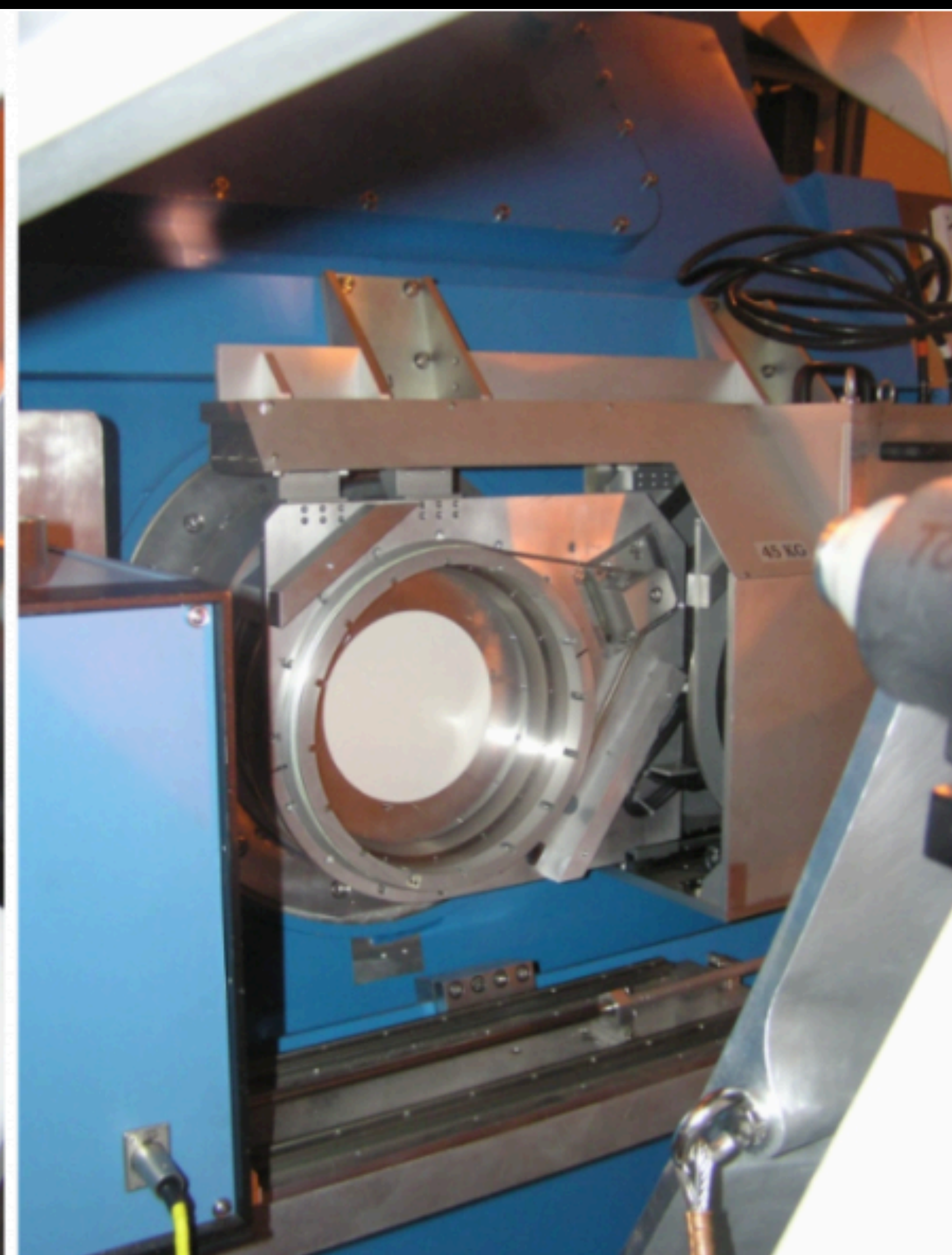


Also used for calibrations
On planets and planetary nebulae!

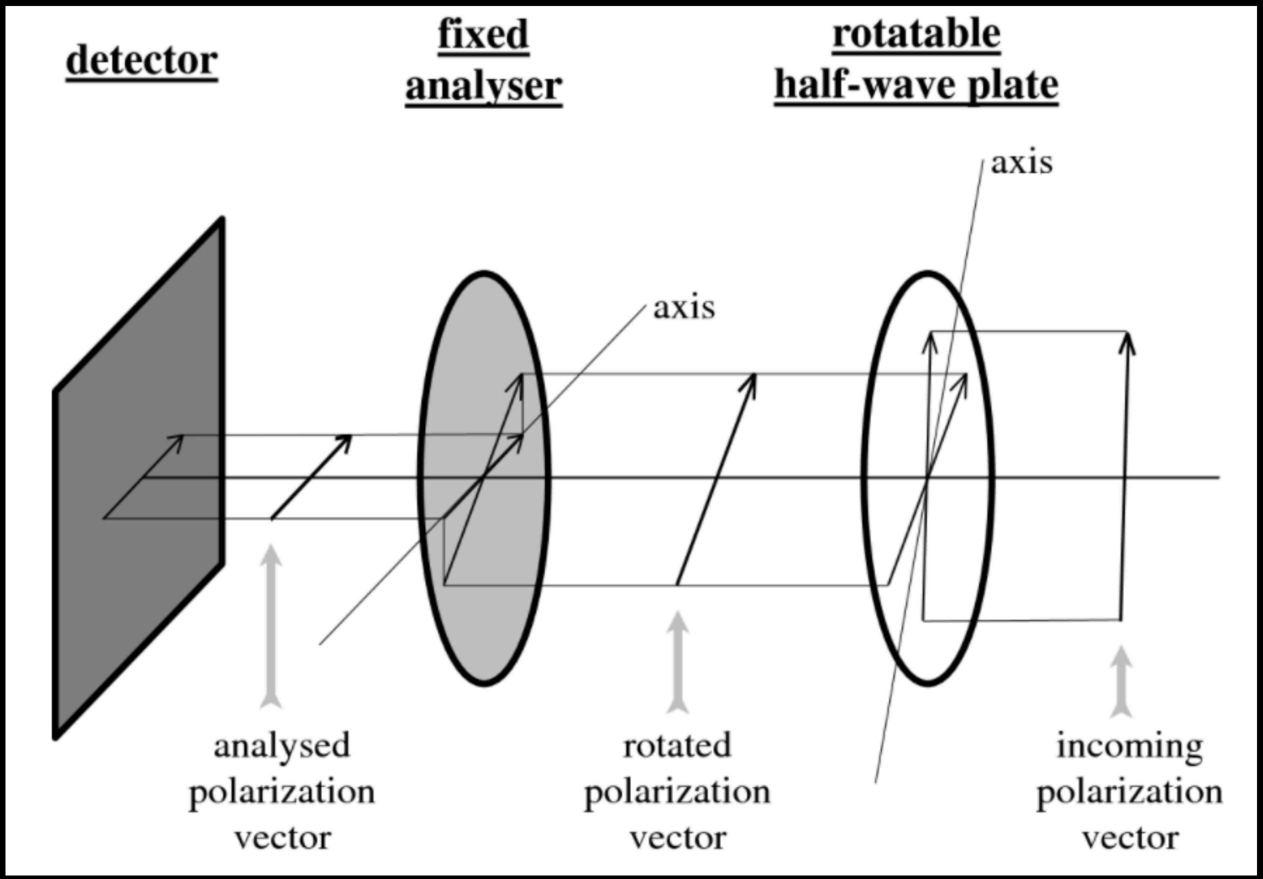

Serpens
Ophiuchus
Orion Nebula

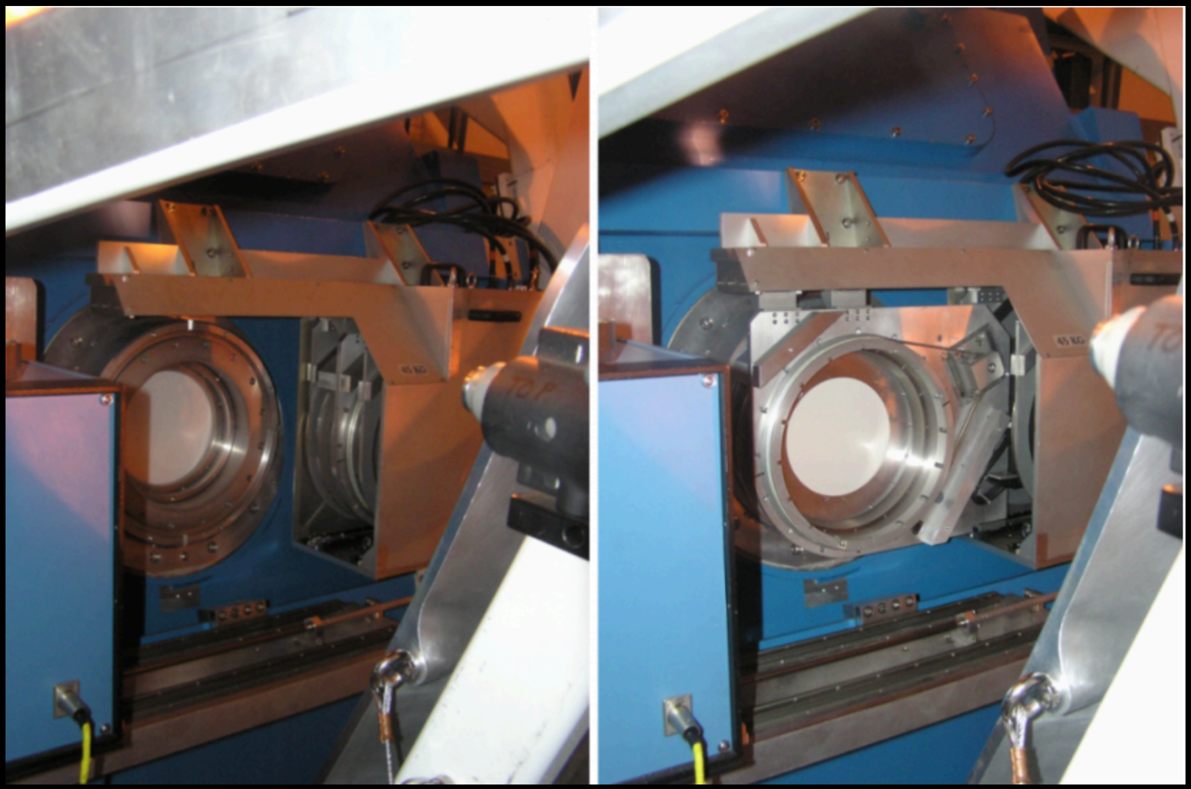
The Instruments: POL-2





POL-2: Polarimeter

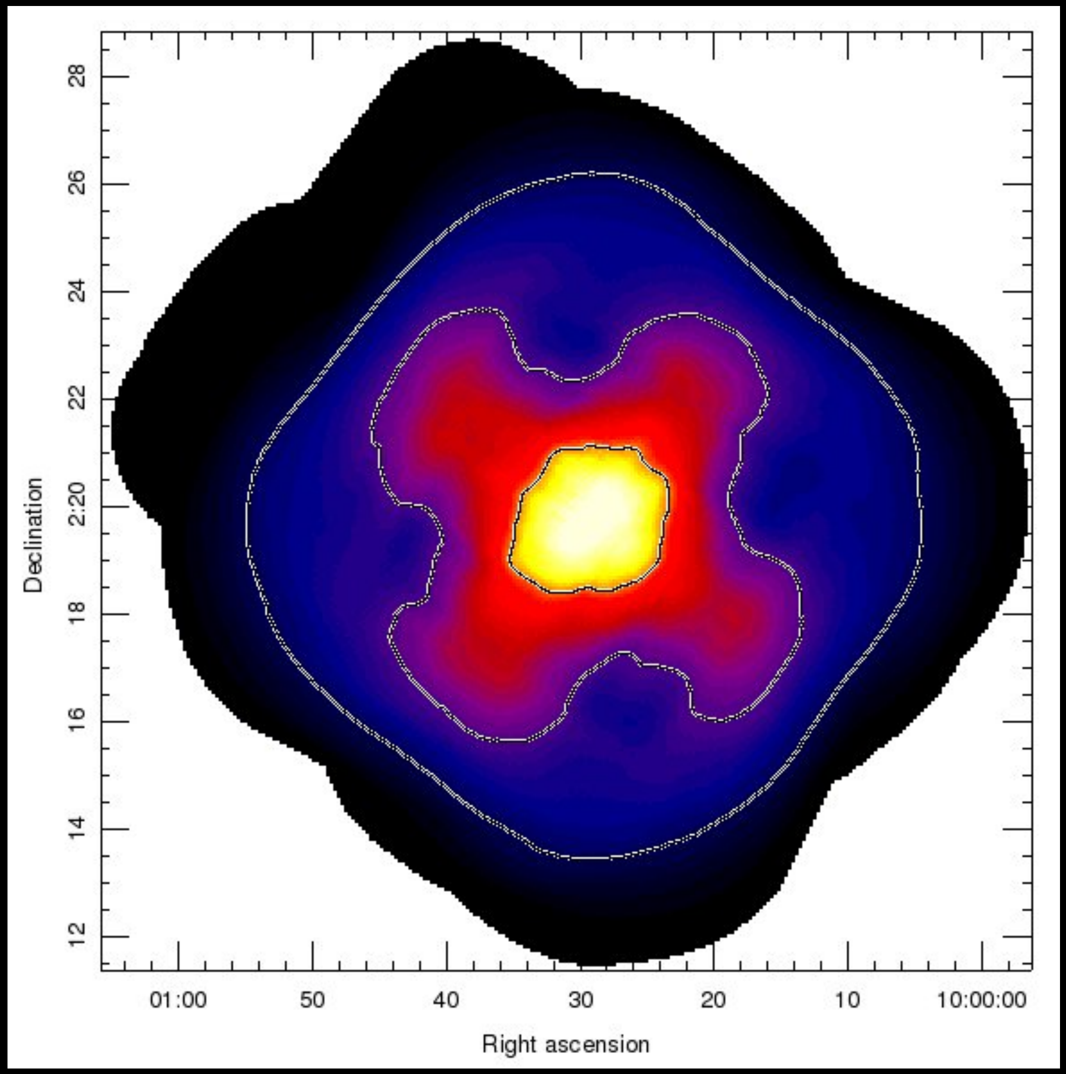




The long axis of dust grains tend towards an alignment perpendicular to B-field lines

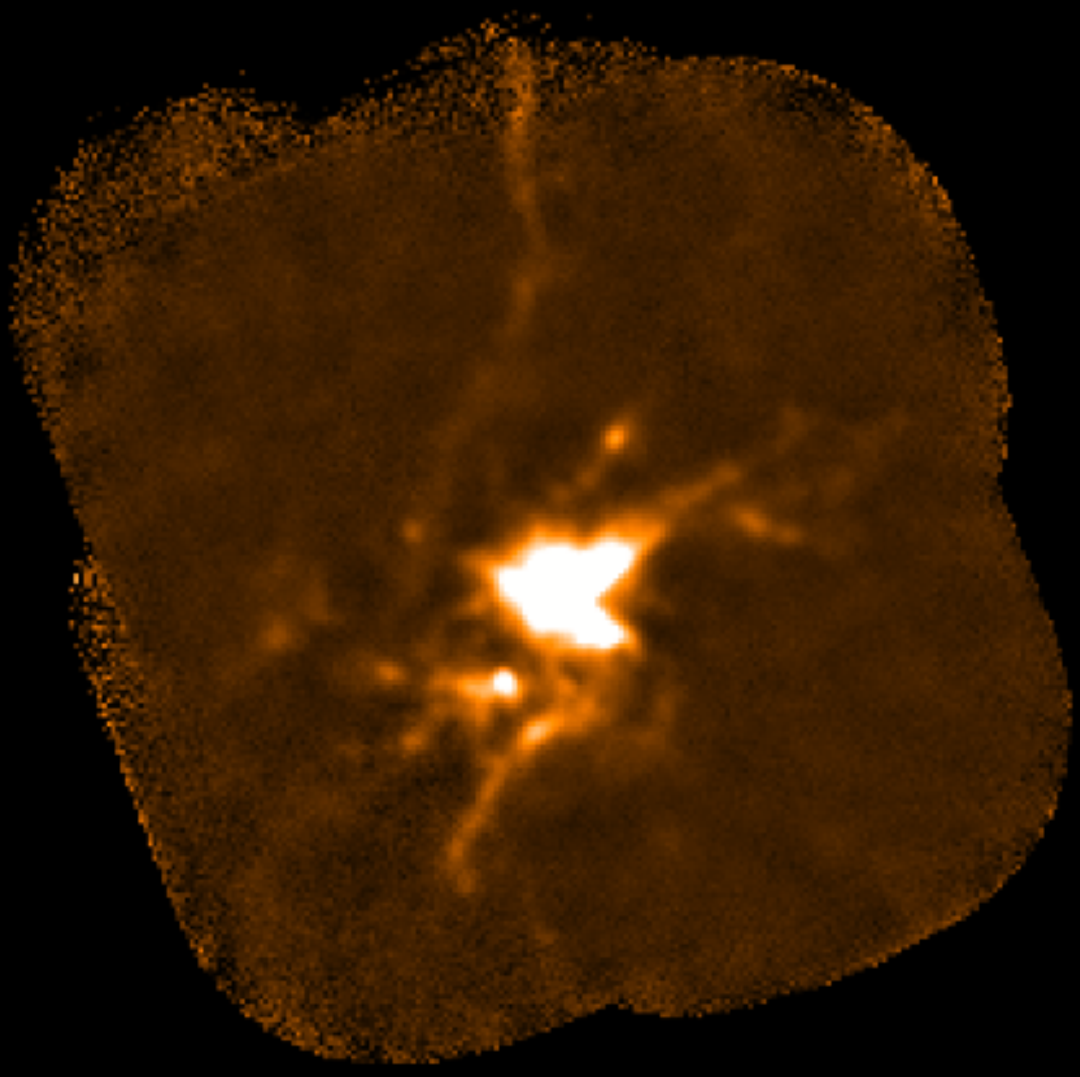
POL-2 works
in conjunction with SCUBA-2

POL-2: Only DAISY Observing Mode



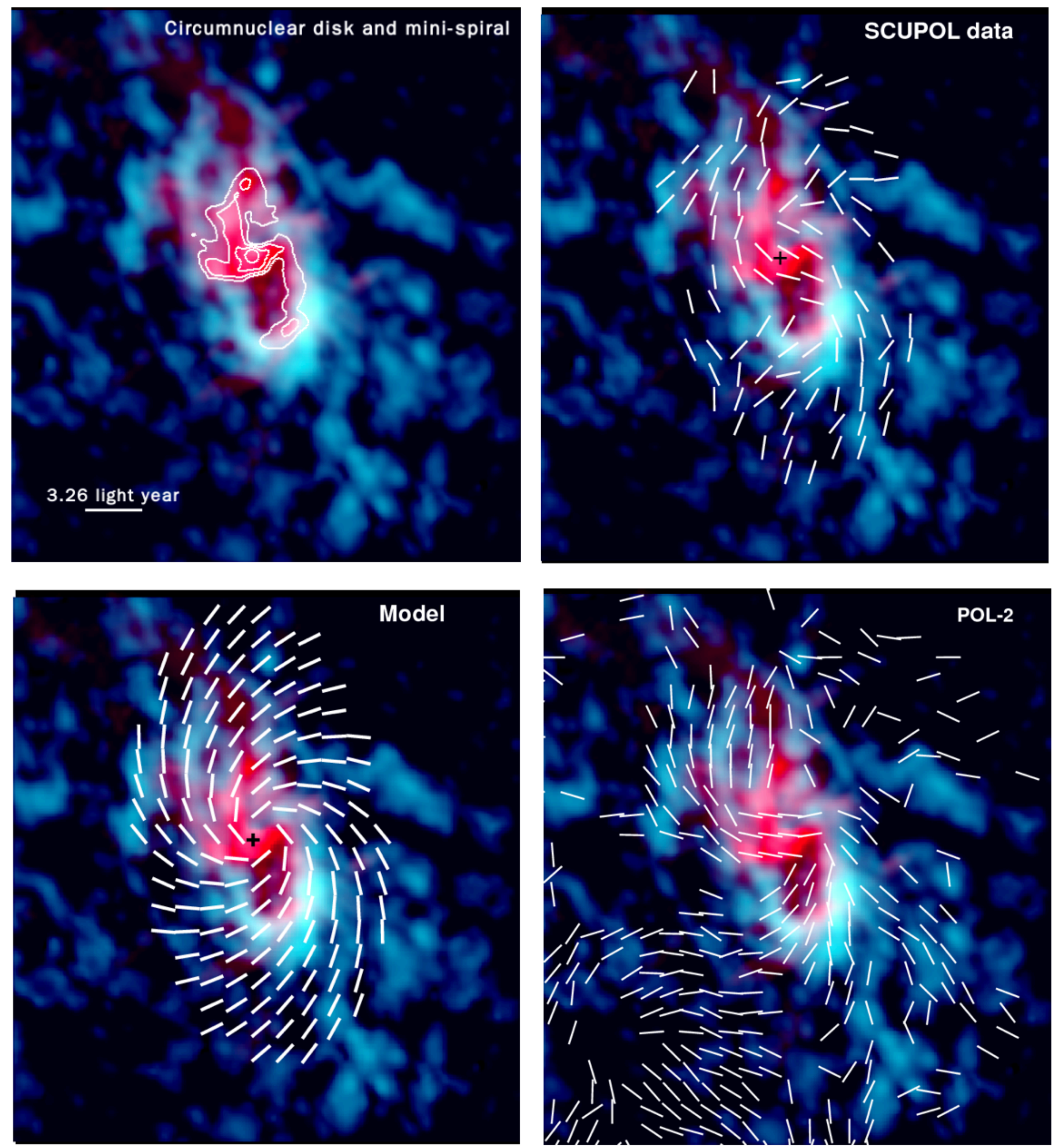
The telescope scans across the sky and across the same region at many different position angles

For smaller scale maps: 3 - 12 arcminutes

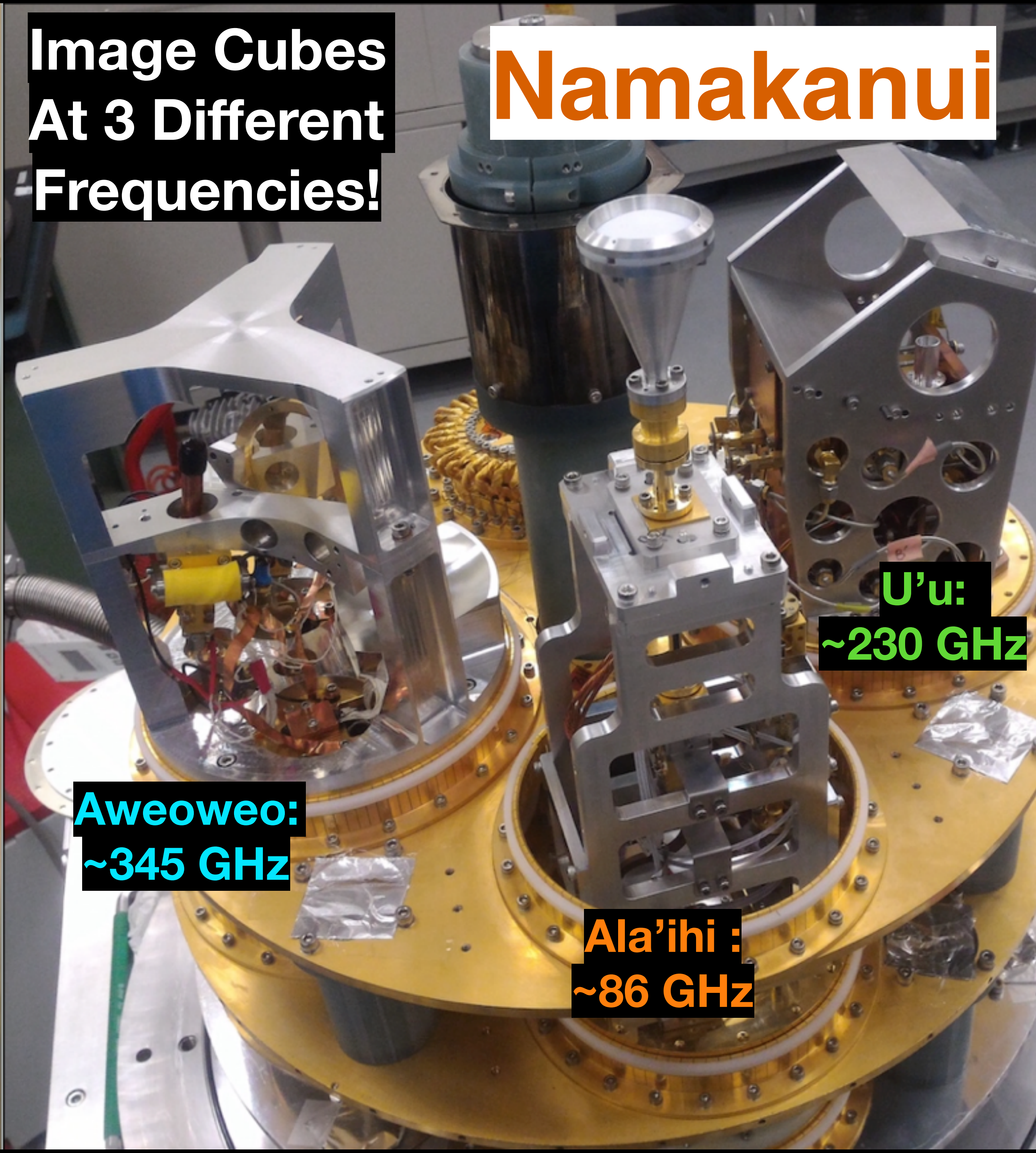


Also used for calibrations
On planets and planetary nebulae!

Tracing Magnetic Fields in Space!

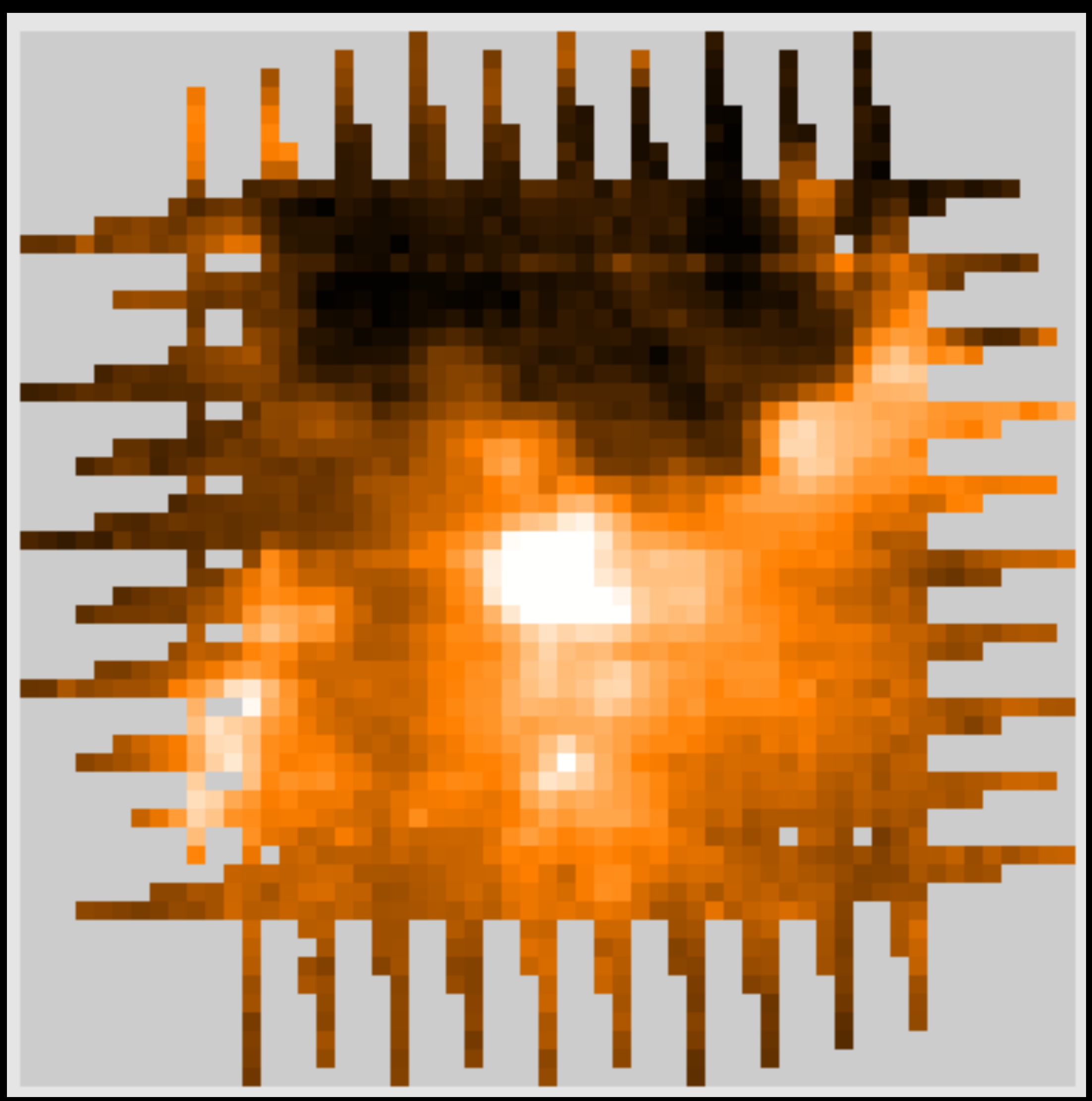


The Instruments:

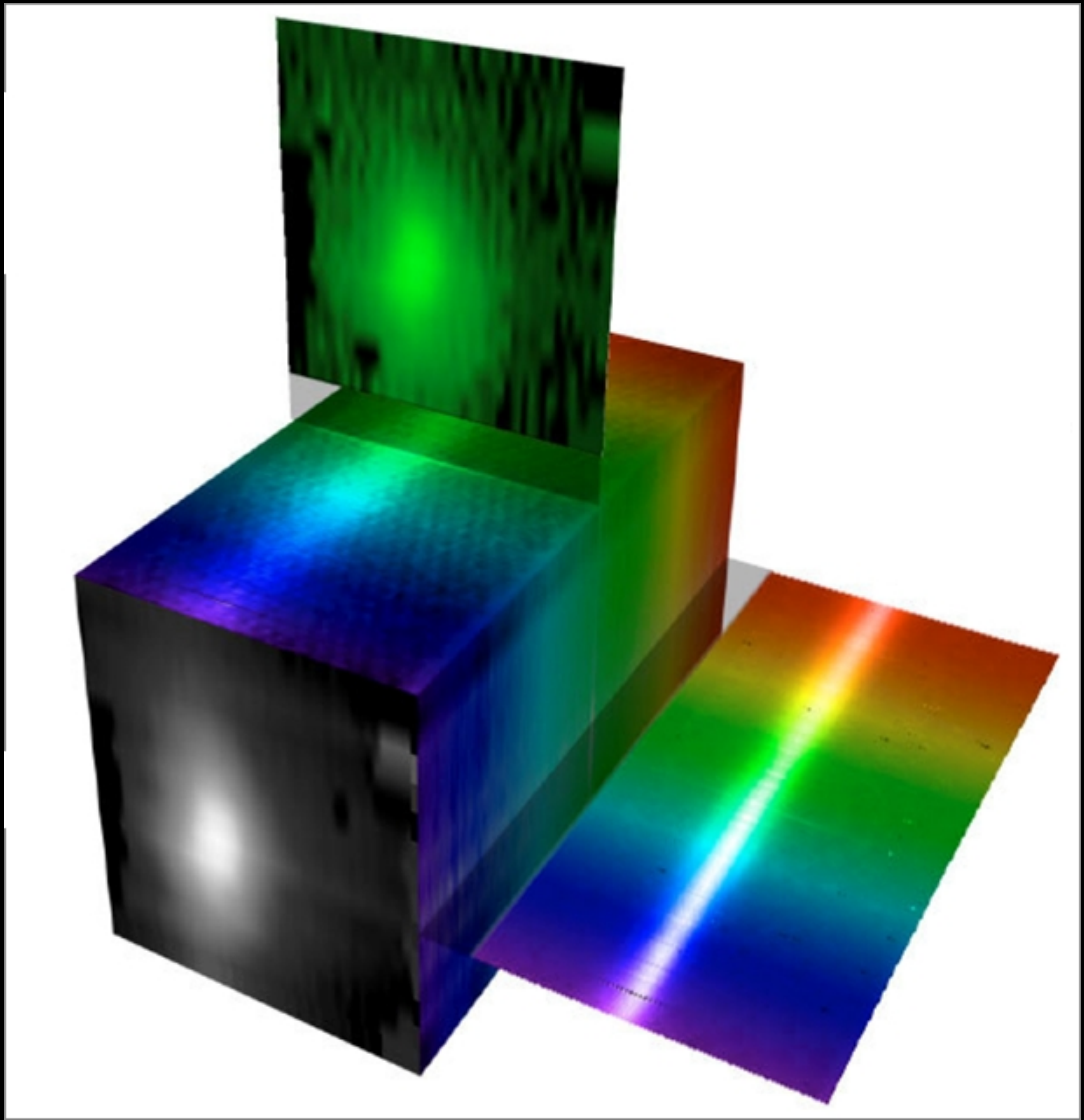


HARP/Namakanui

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

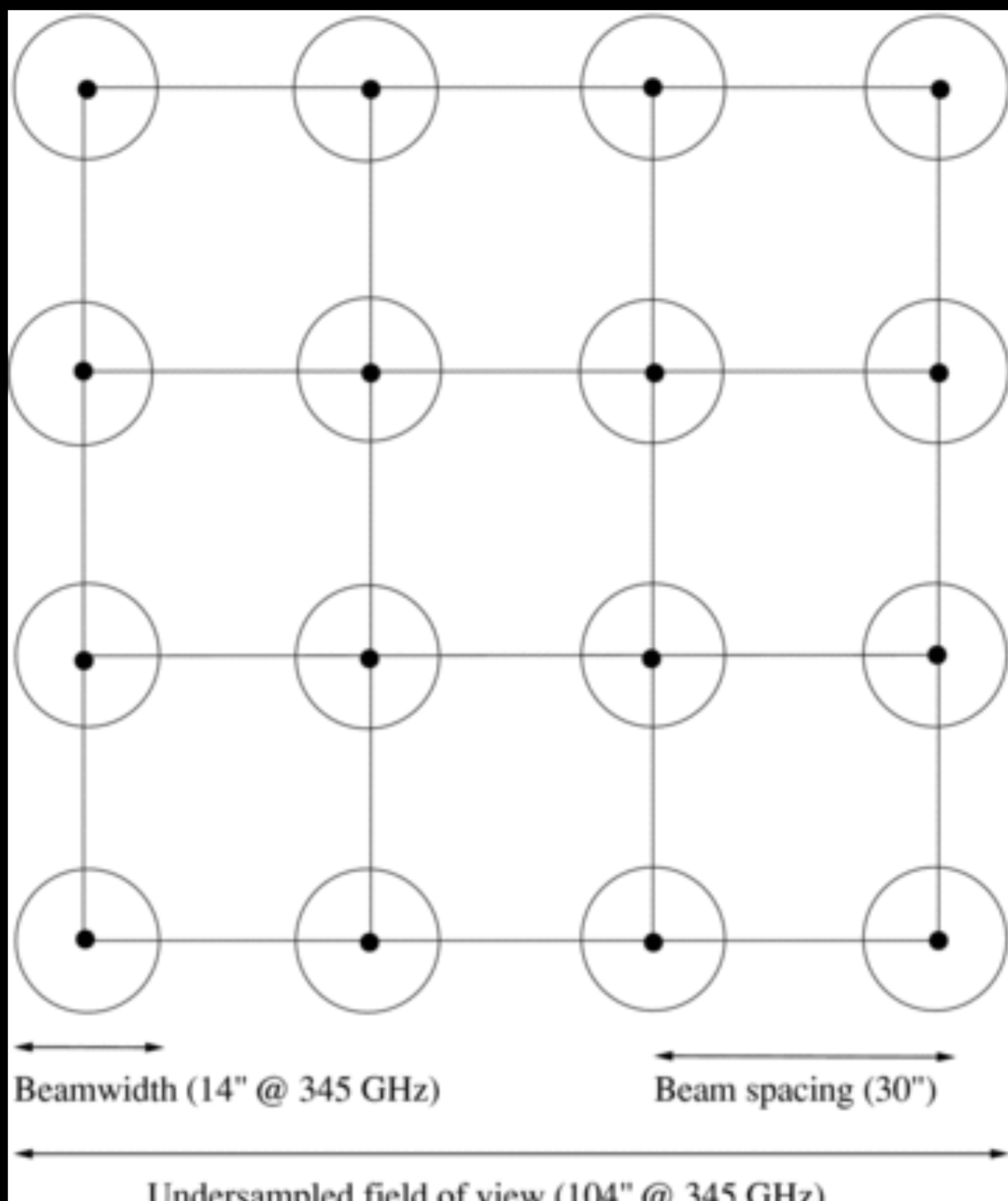


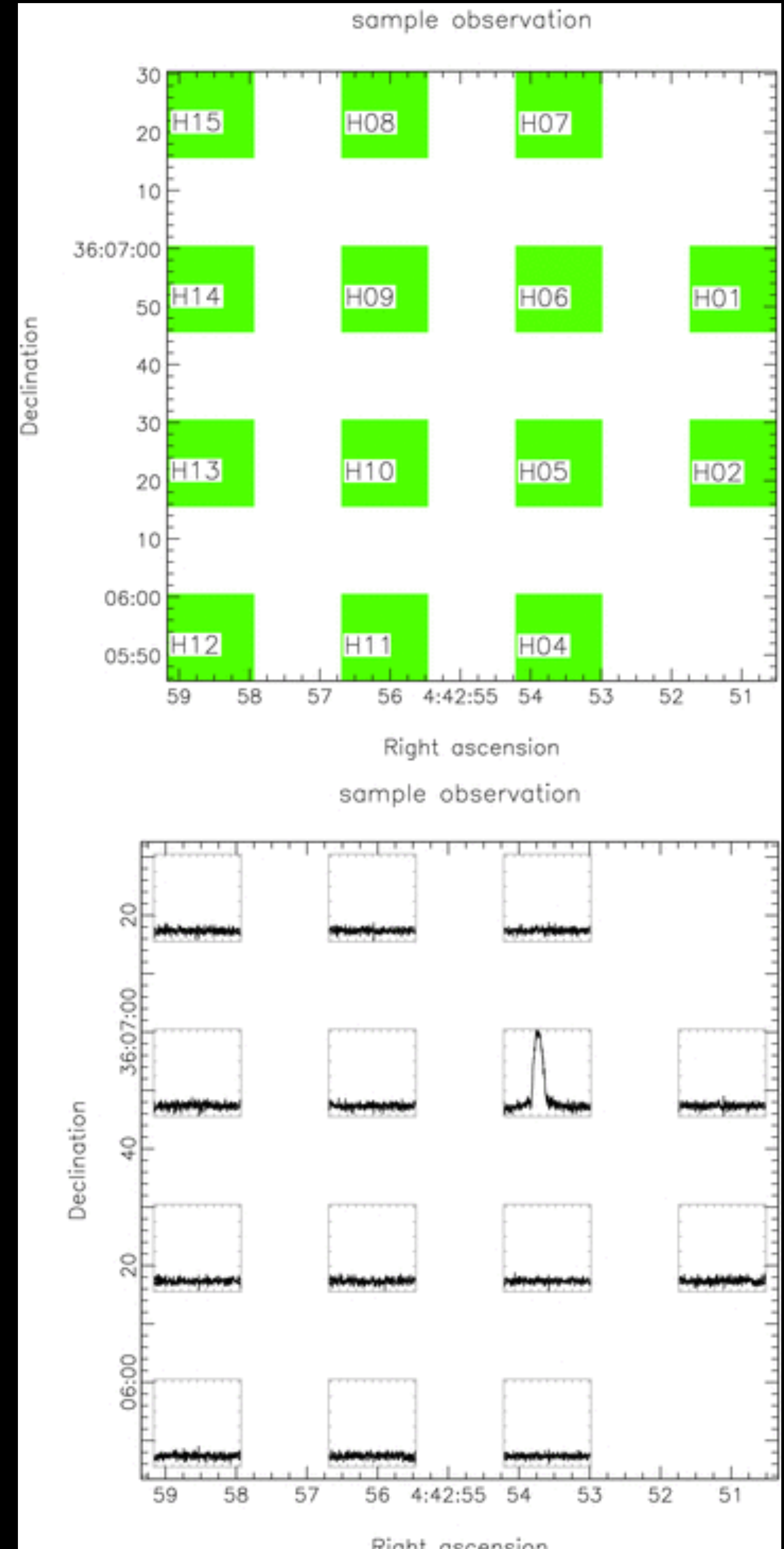
Instruments observe a range of frequencies
Each "channel" corresponds to a different frequency/wavelength/doppler velocity



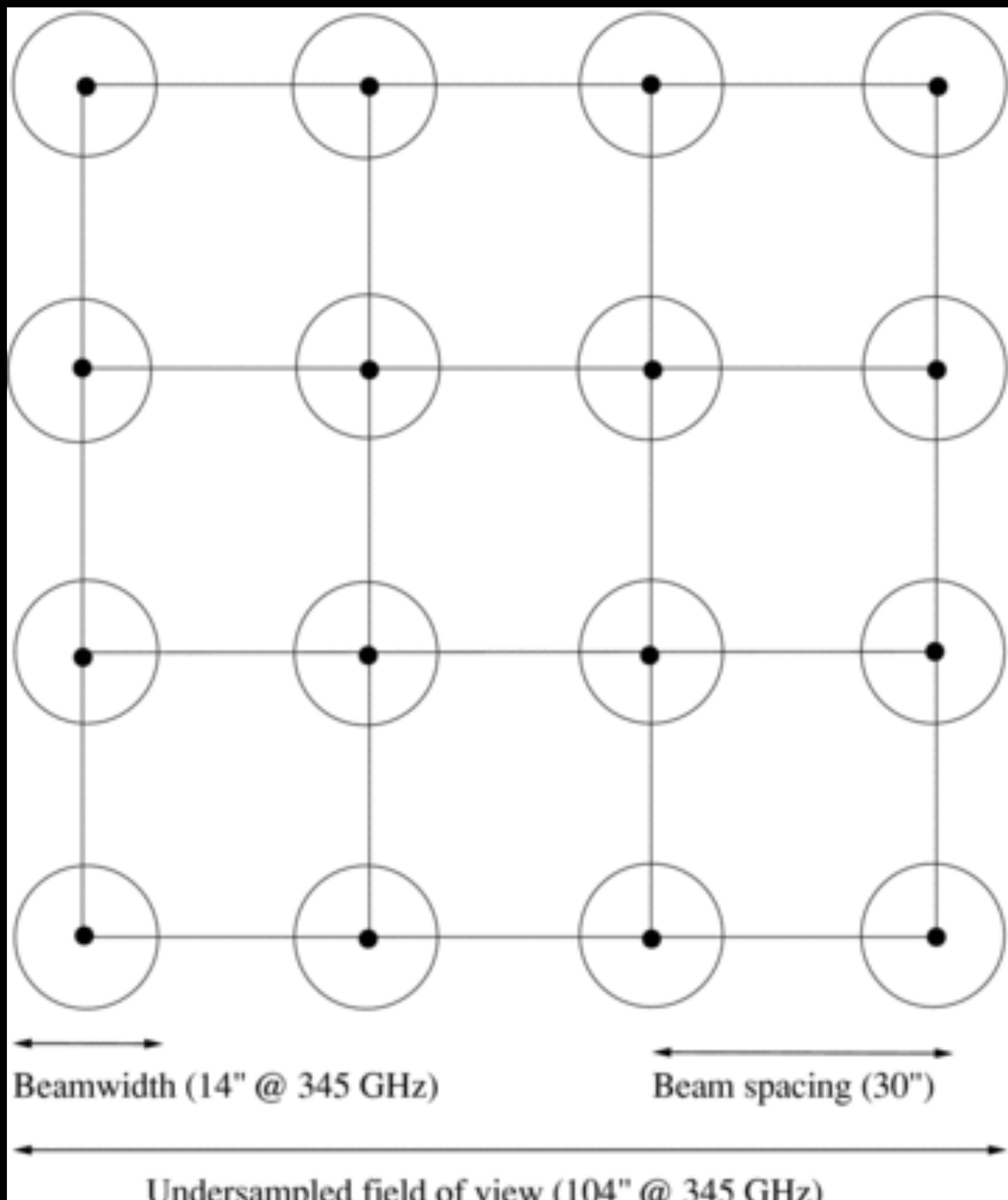
HARP/Namakanui
Stare Mode (Point Sources)

HARP has 16 Receptors that each produce a spectrum! Namakanui is a single pixel (3 cartridge) system

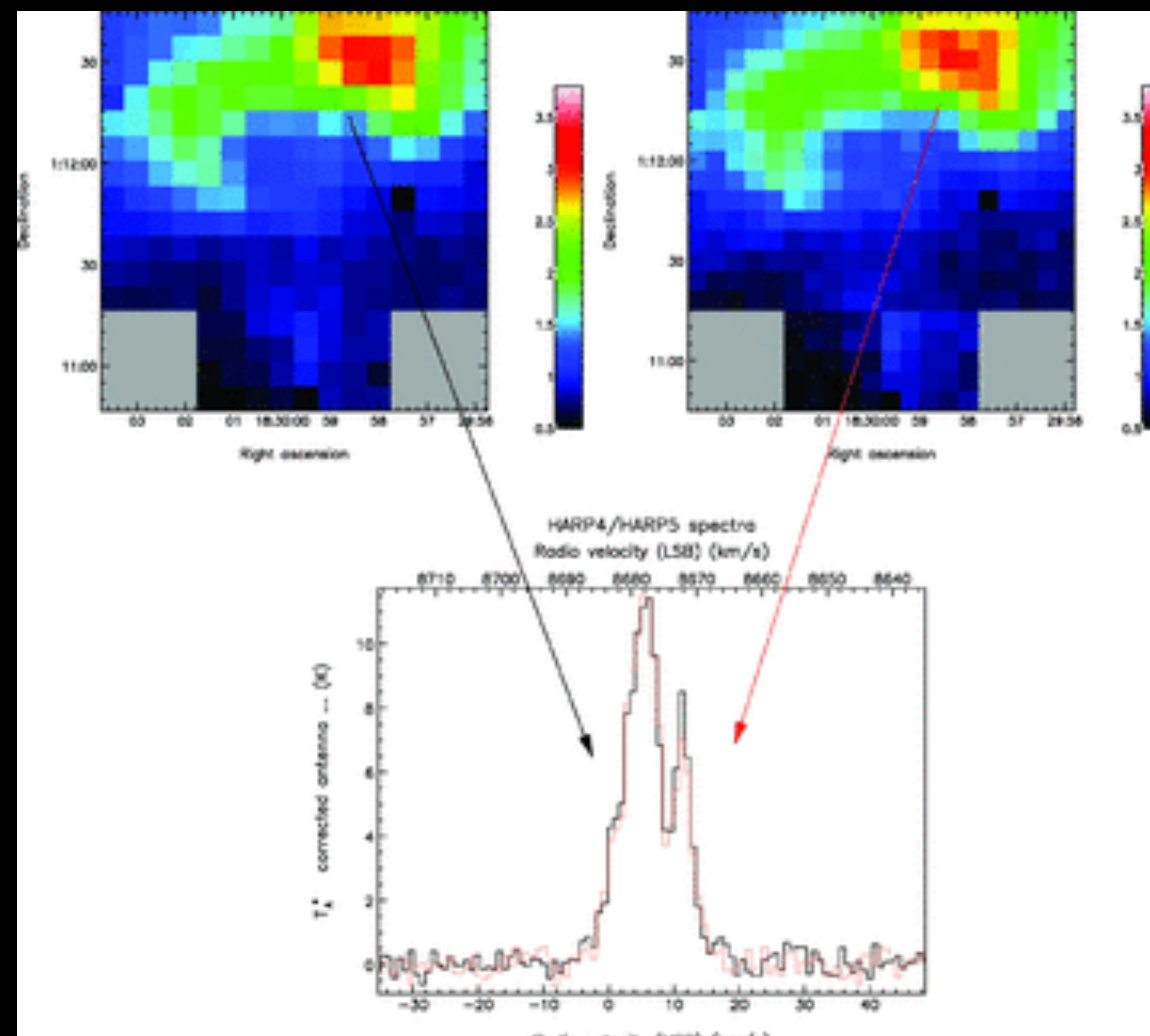




HARP/Namakanui — Jiggle Mode (<2')

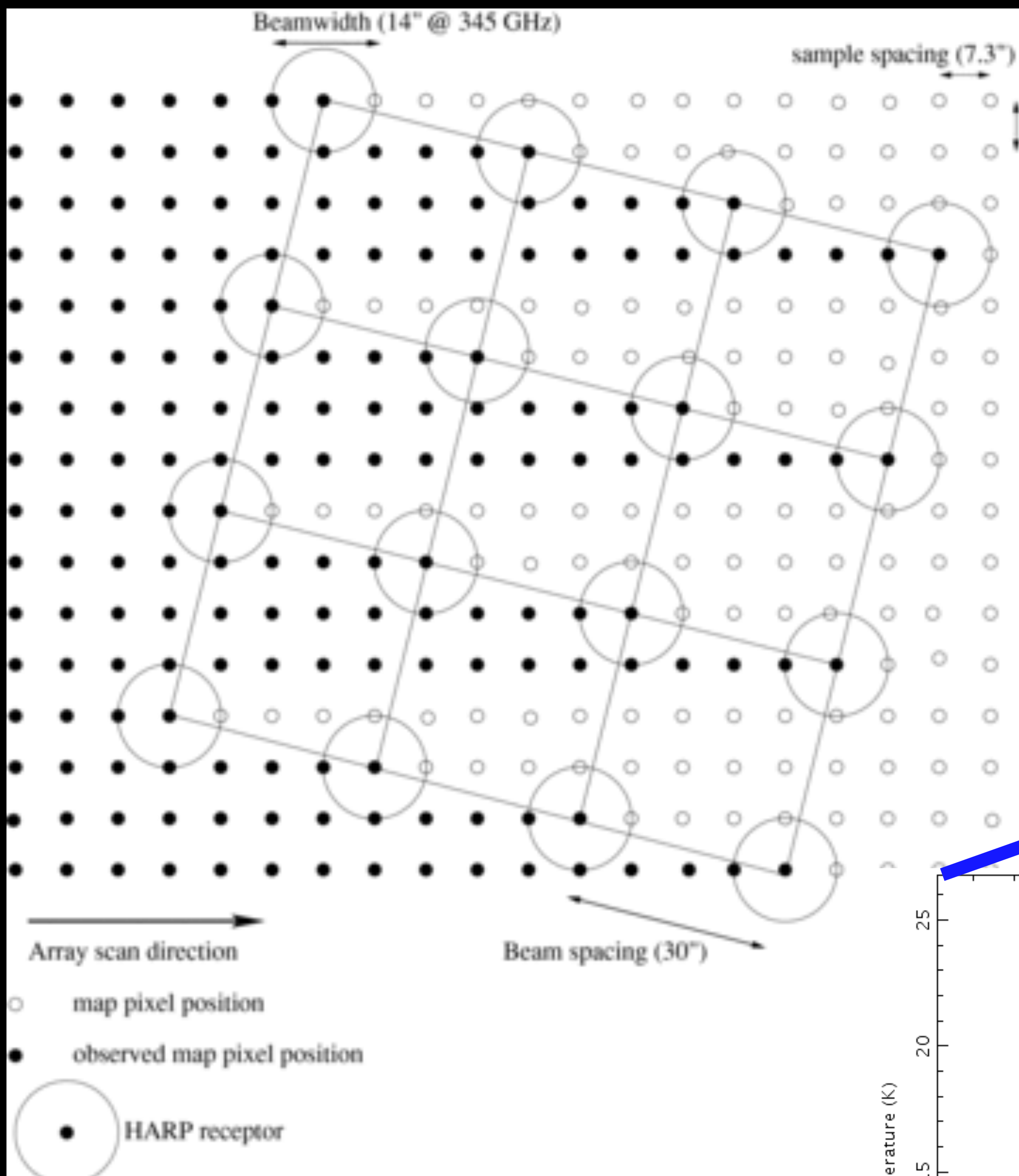


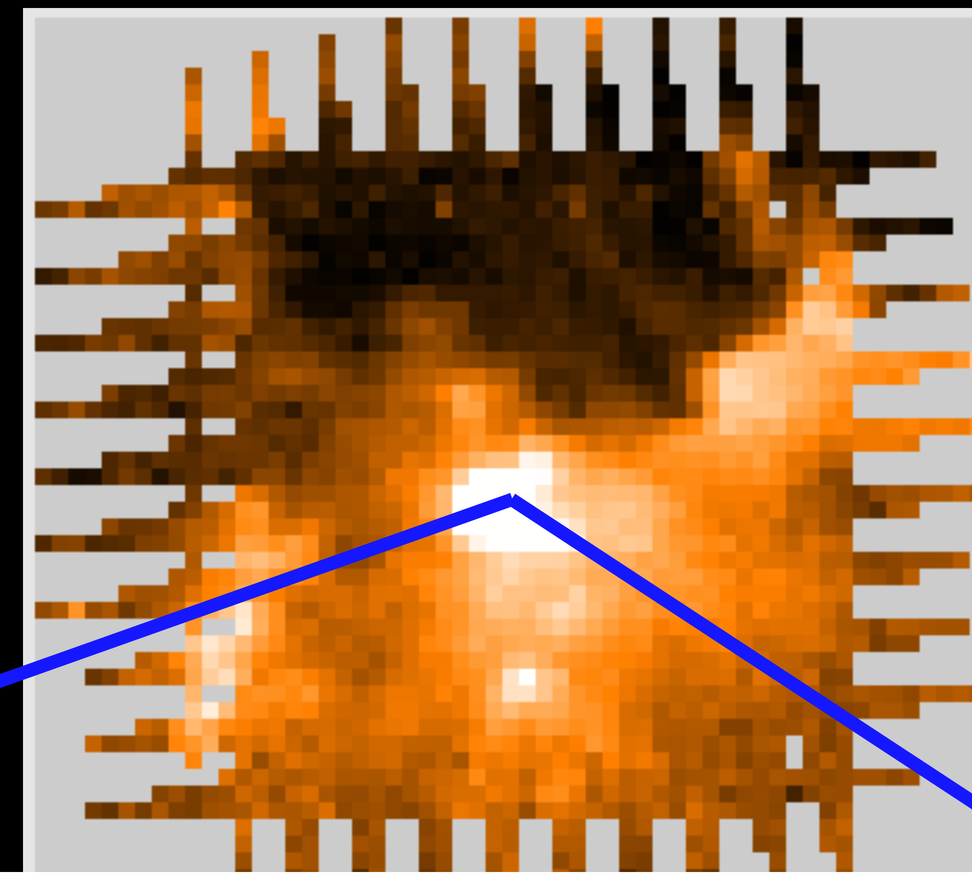
Jiggle thoseReceptors that each produce a spectrum around the sky in a grid to get a map!

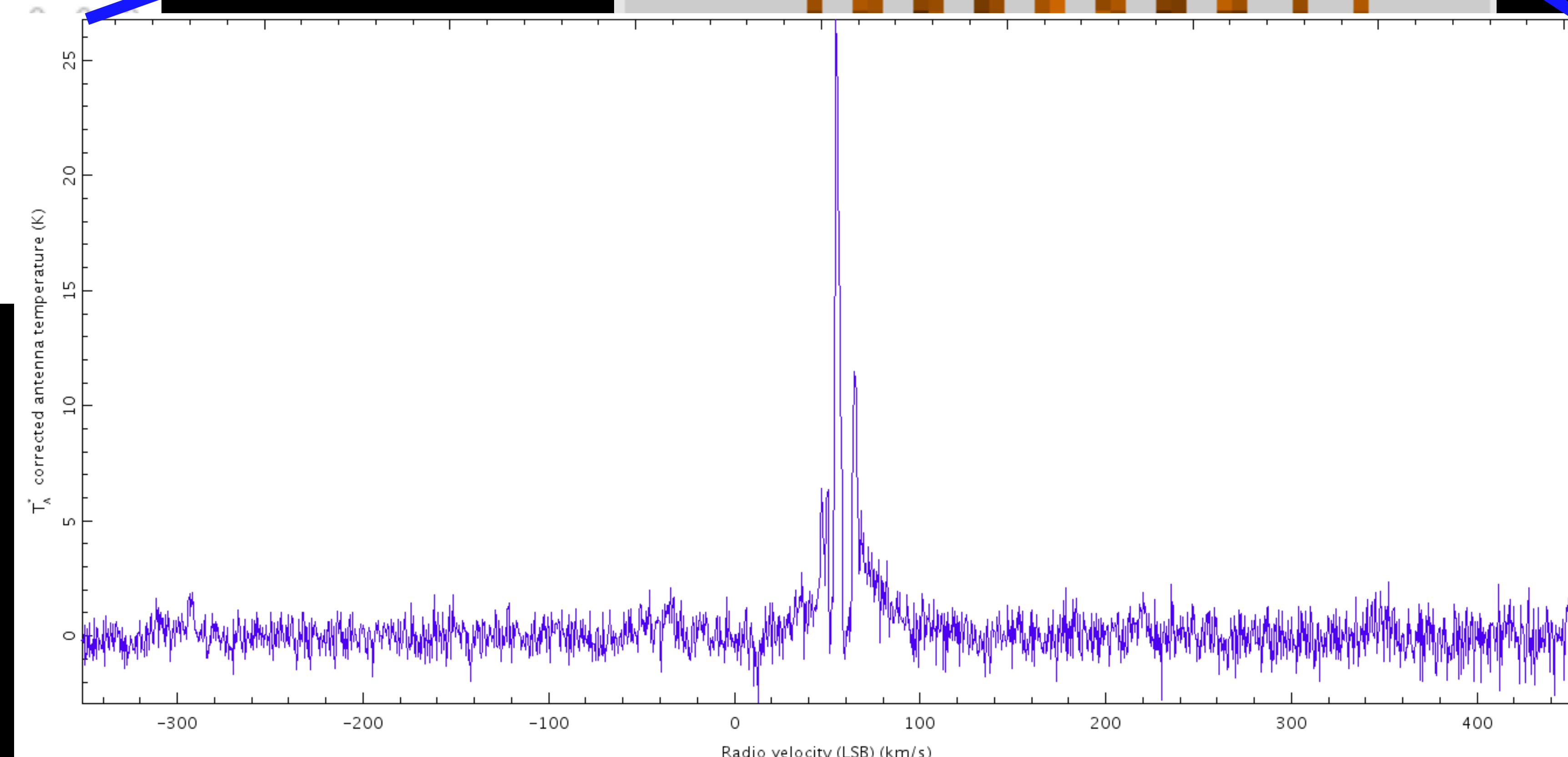


***Jiggles are efficient for small maps**

HARP/Namakanui: Raster Mode (>2’)







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

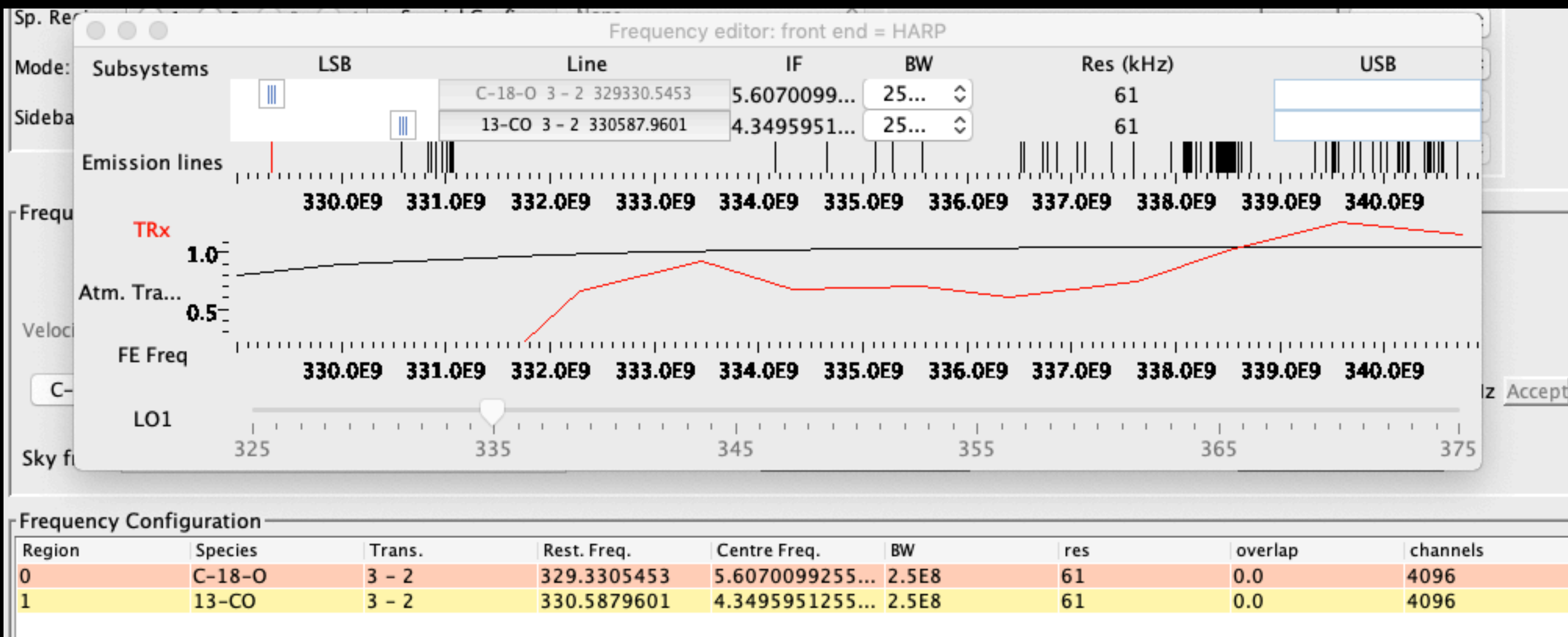
Available spectral windows: 250, 440, 1000, or 1860 MHz. The spectral resolution of ACSIS varies from 30 kHz to ~1 MHz

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”

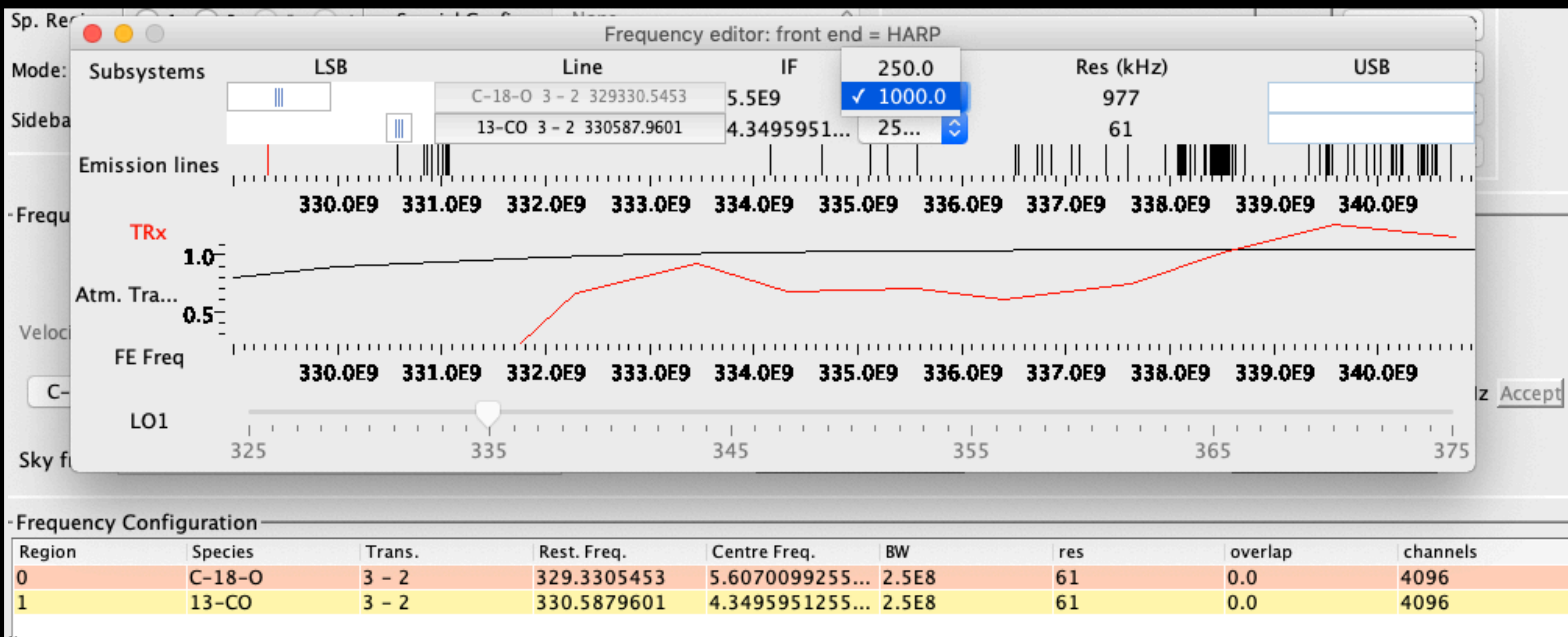


This is an example of 2 windows in the Lower Sideband to observe two different molecular lines simultaneously!

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”

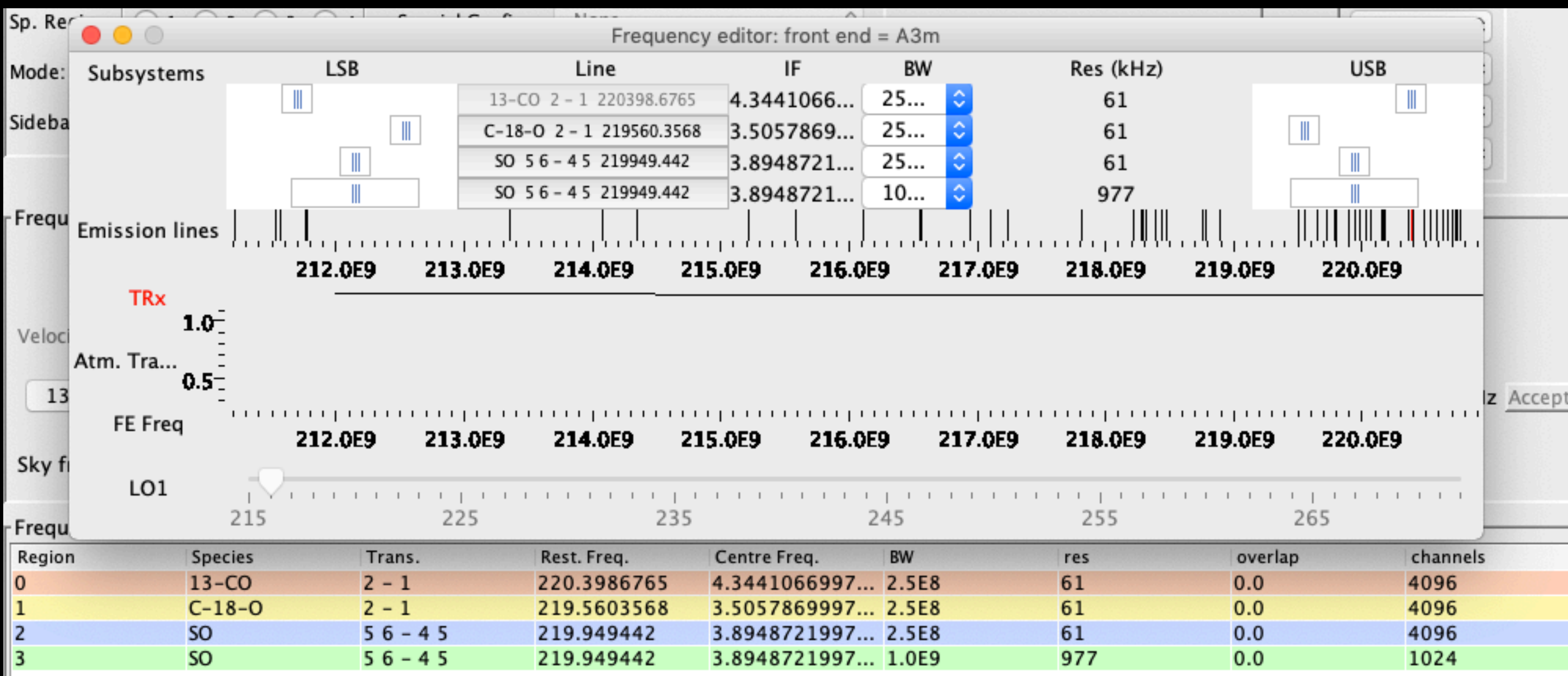


Look what happens when we change the bandwidth to 1 Ghz instead of 250 MHz (Note the Resolution!)

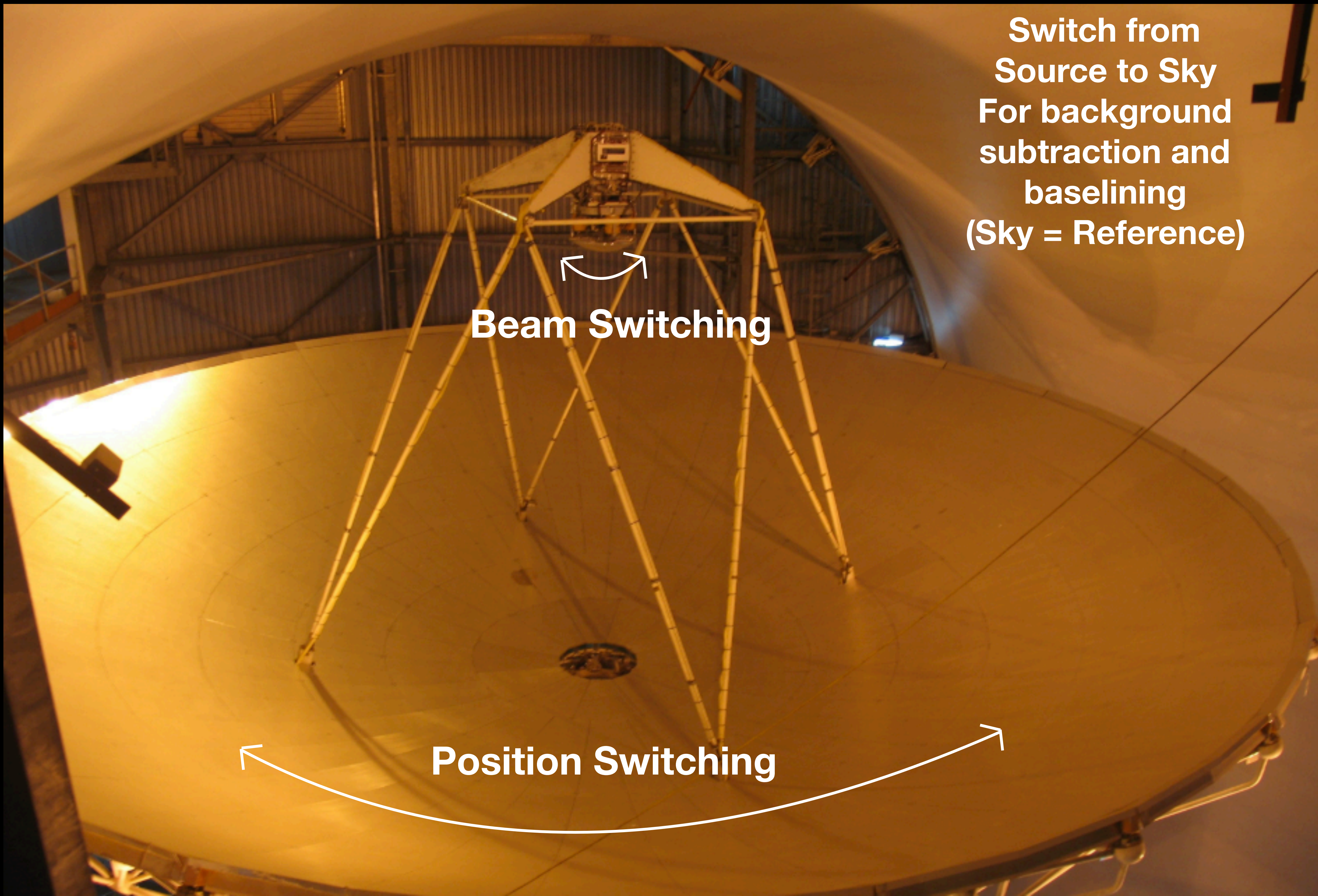
HARP and Namakanui Use: **ACSIS**

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



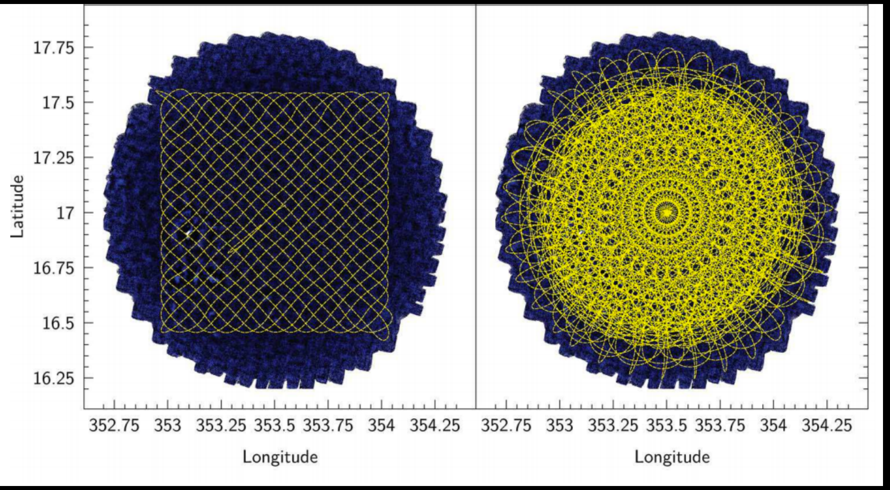
HARP/Namakanui Observing Modes

Map Size	
Compact source	Use a stare
Moderate extent (less than 2 arcmins)	Use a jiggle
Large extent (greater than 2 arcmins)	Use a scan
Little to no emission close (<180″) to target	Use a beam-switched (BMSW) chop to the reference position
Contaminating emission near source, or uncertain of region	Use a position-switched (PSSW) observation to a reference further from the source (up to 3 degrees) or frequency switching

SCUBA-2 Observing Modes

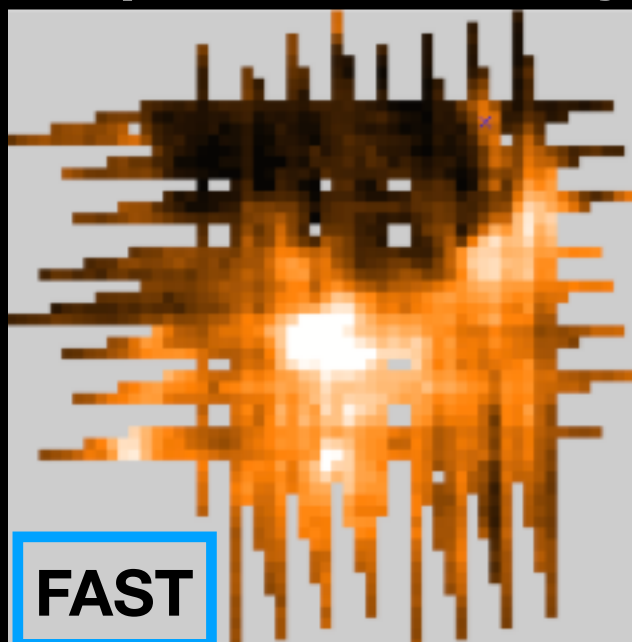
PONG options of: 15’, 30’, 90’, 1°, and 2°

DAISY mode for smaller scale maps:
3 - 12 arcminutes (Only option for POL-2)

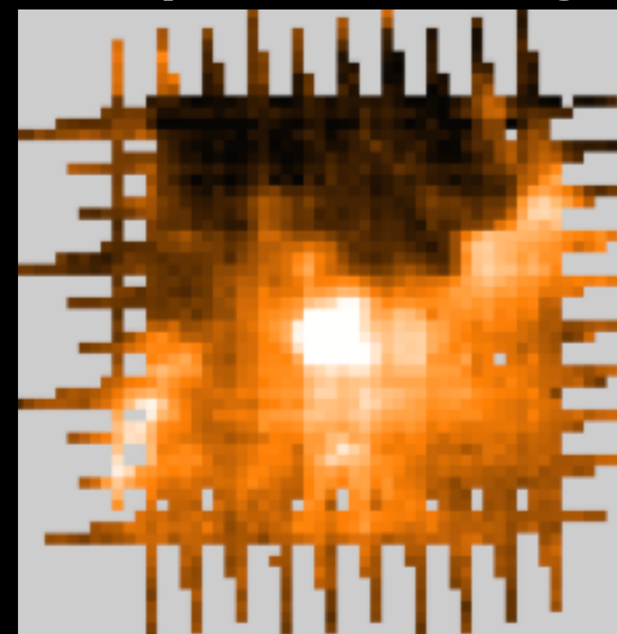


ACSIS: Array Spacings/Basket Weave

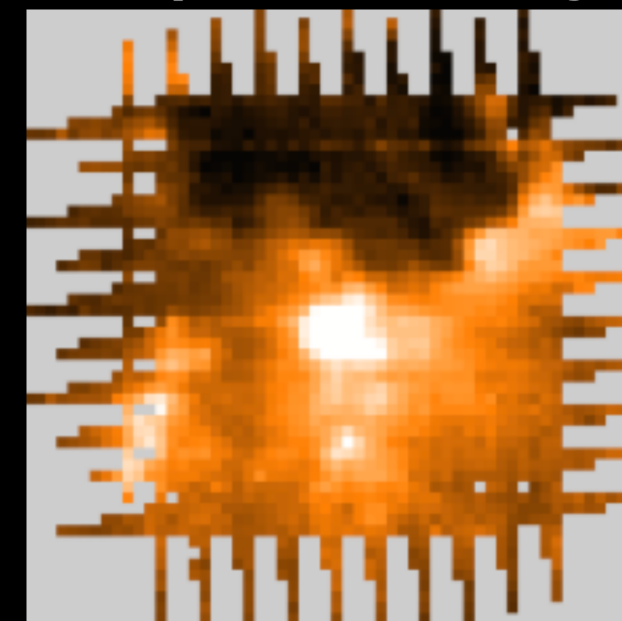
Step: Width of Array



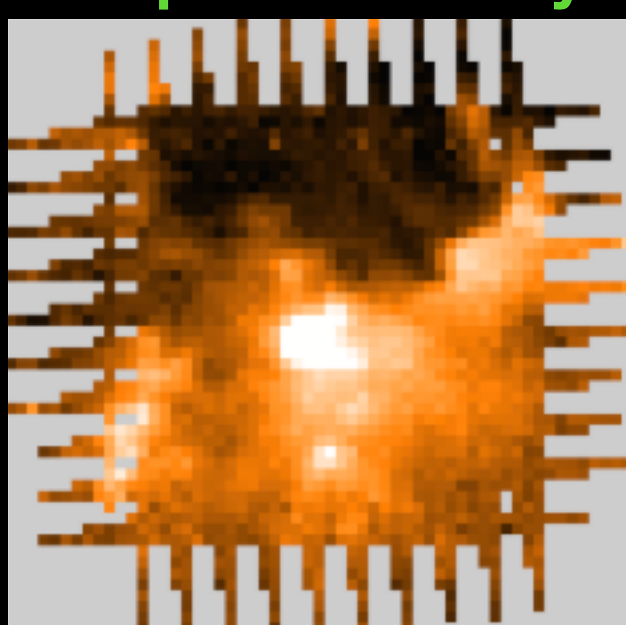
Step: 3/4 of Array



Step: 1/2 of Array

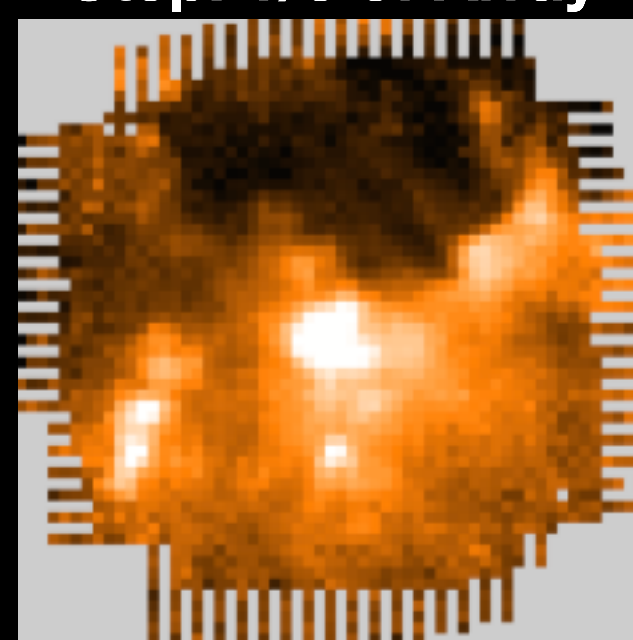


Step: 1/4 of Array

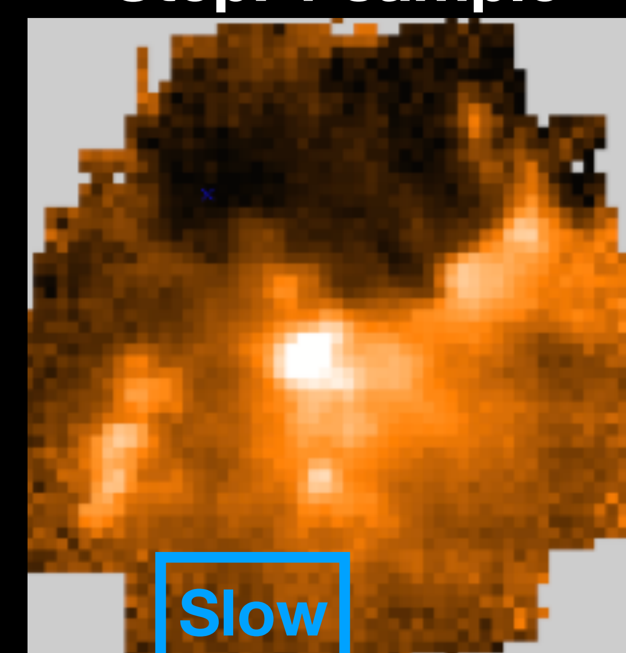


Usually the ideal compromise

Step: 1/8 of Array



Step: 1 sample



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

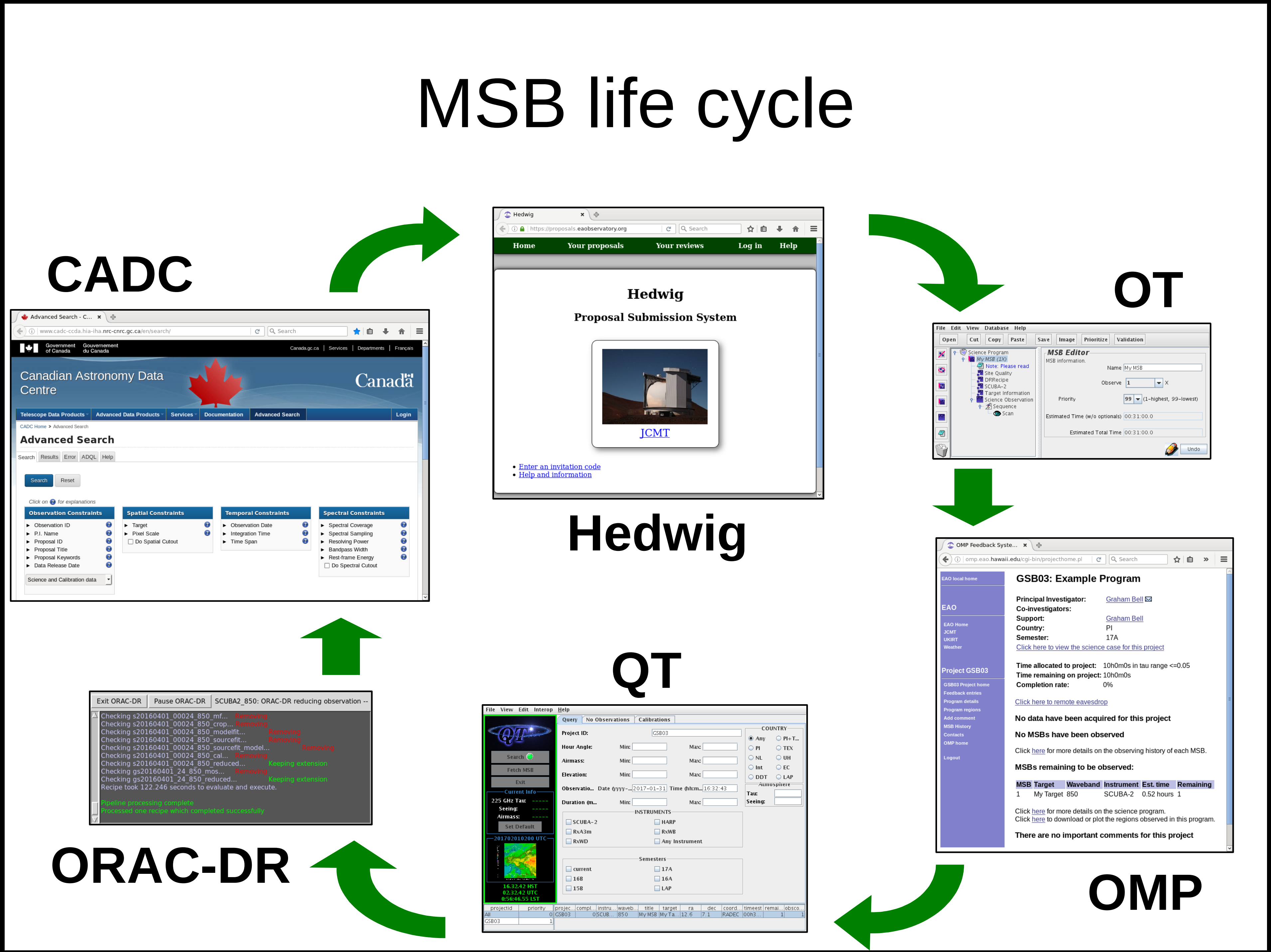
We will be using this tool to construct SCUBA-2/POL-2, HARP, or Namakanui projects

The JCMT Observing Tool (JCMTOT)

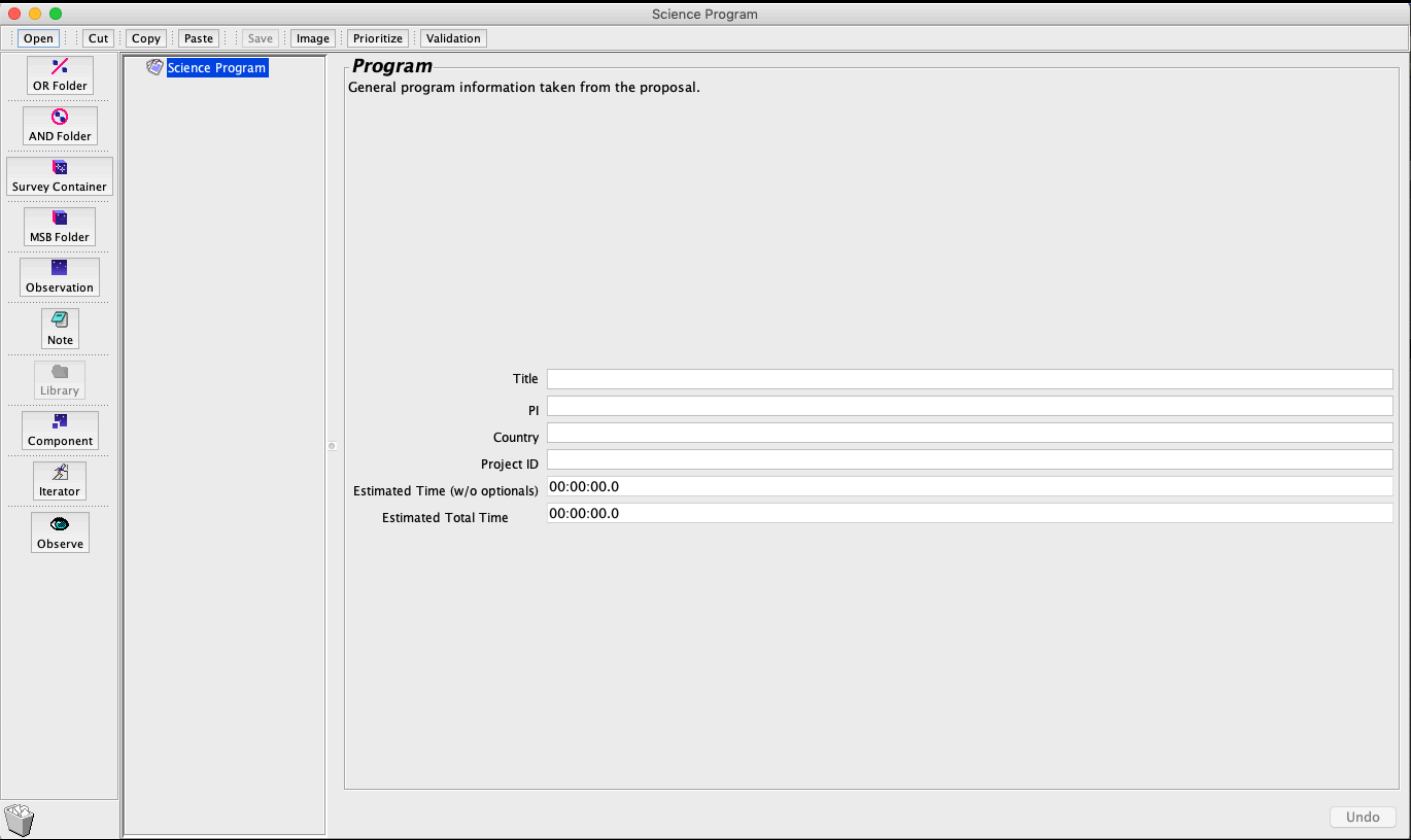
A science program is made up of

MSBs = Minimum Schedulable Blocks

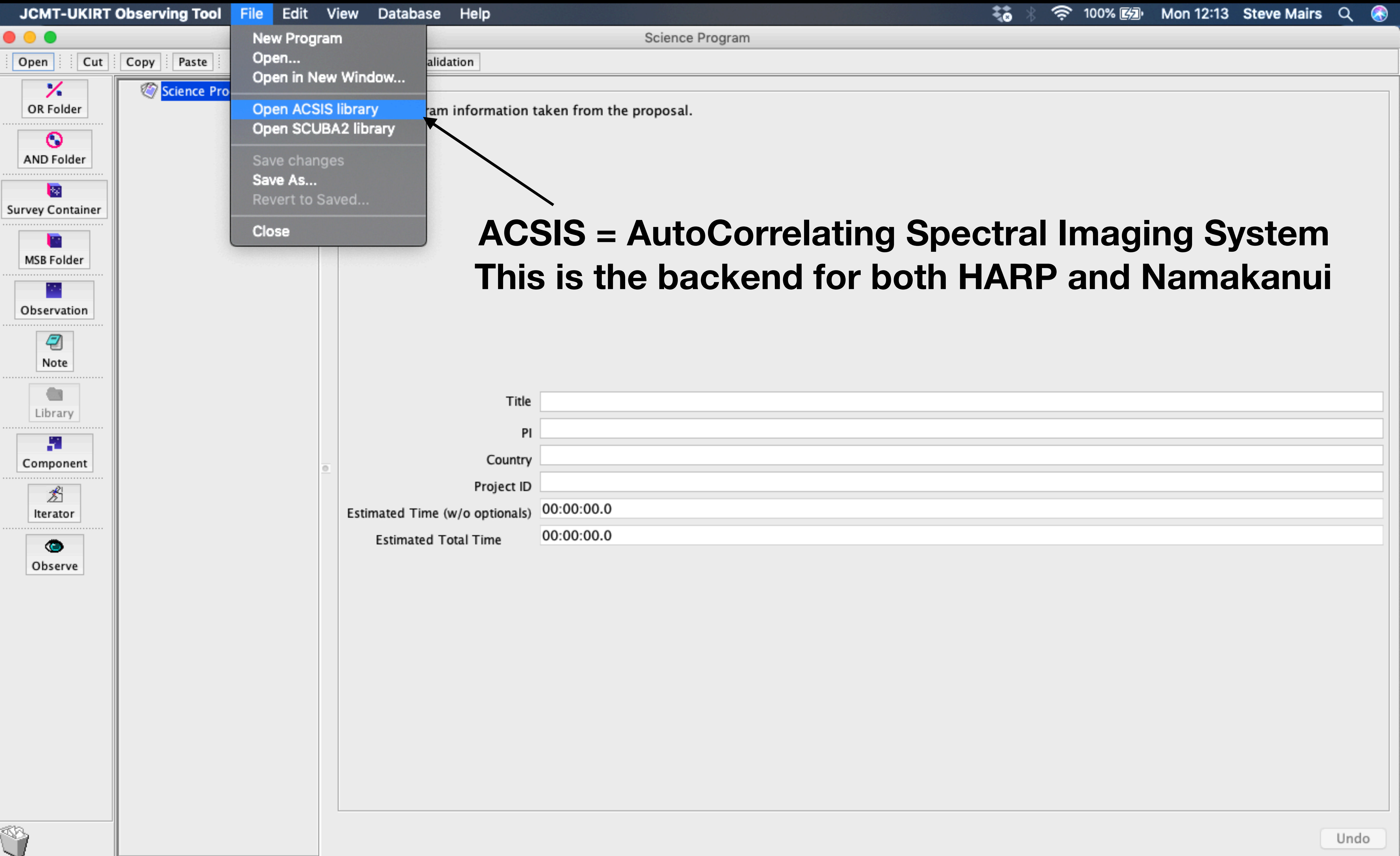
I.e. A short (30-70 minute) observation that is usable for science



The JCMT Observing Tool (JCMTOT)

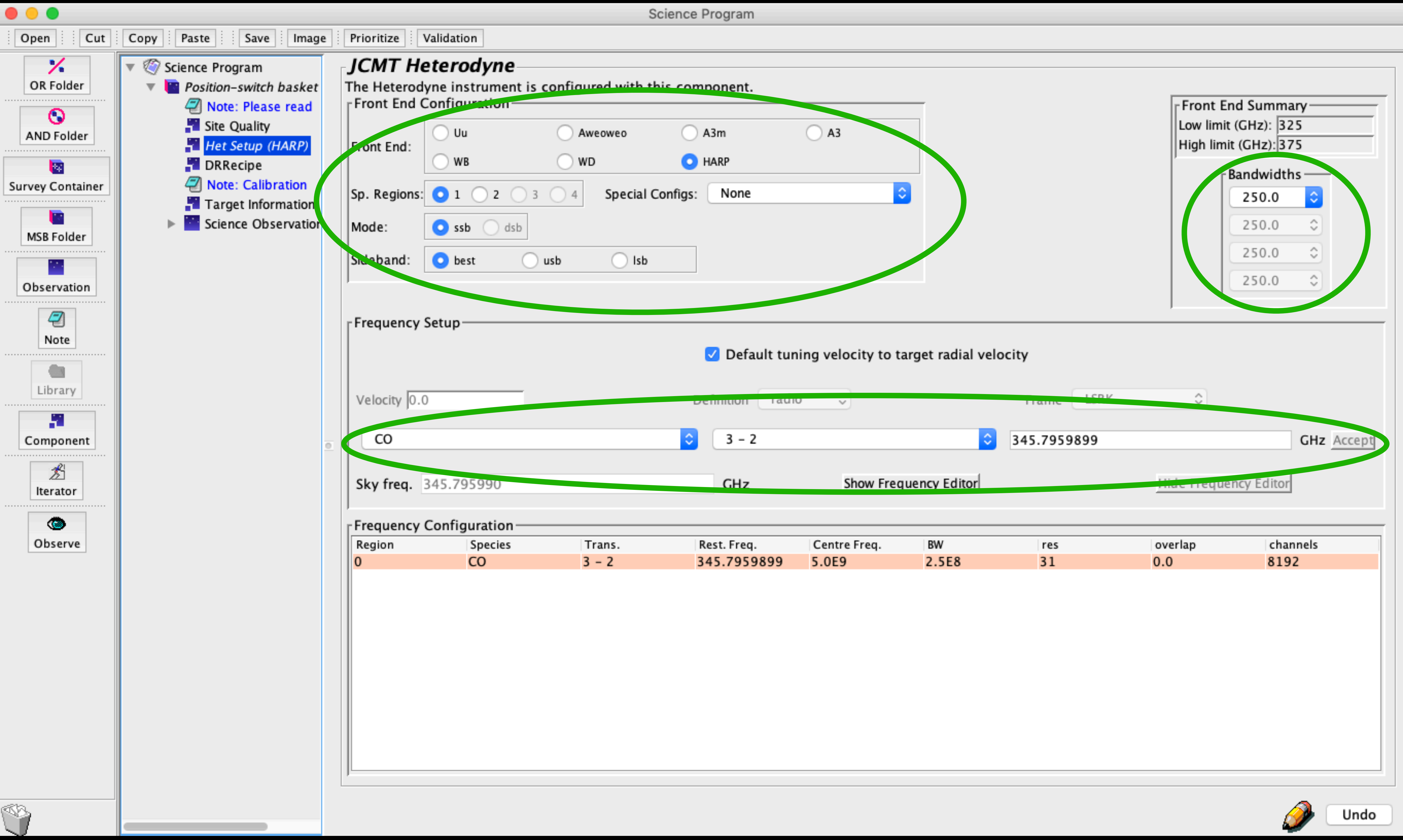


The JCMT Observing Tool (JCMTOT)

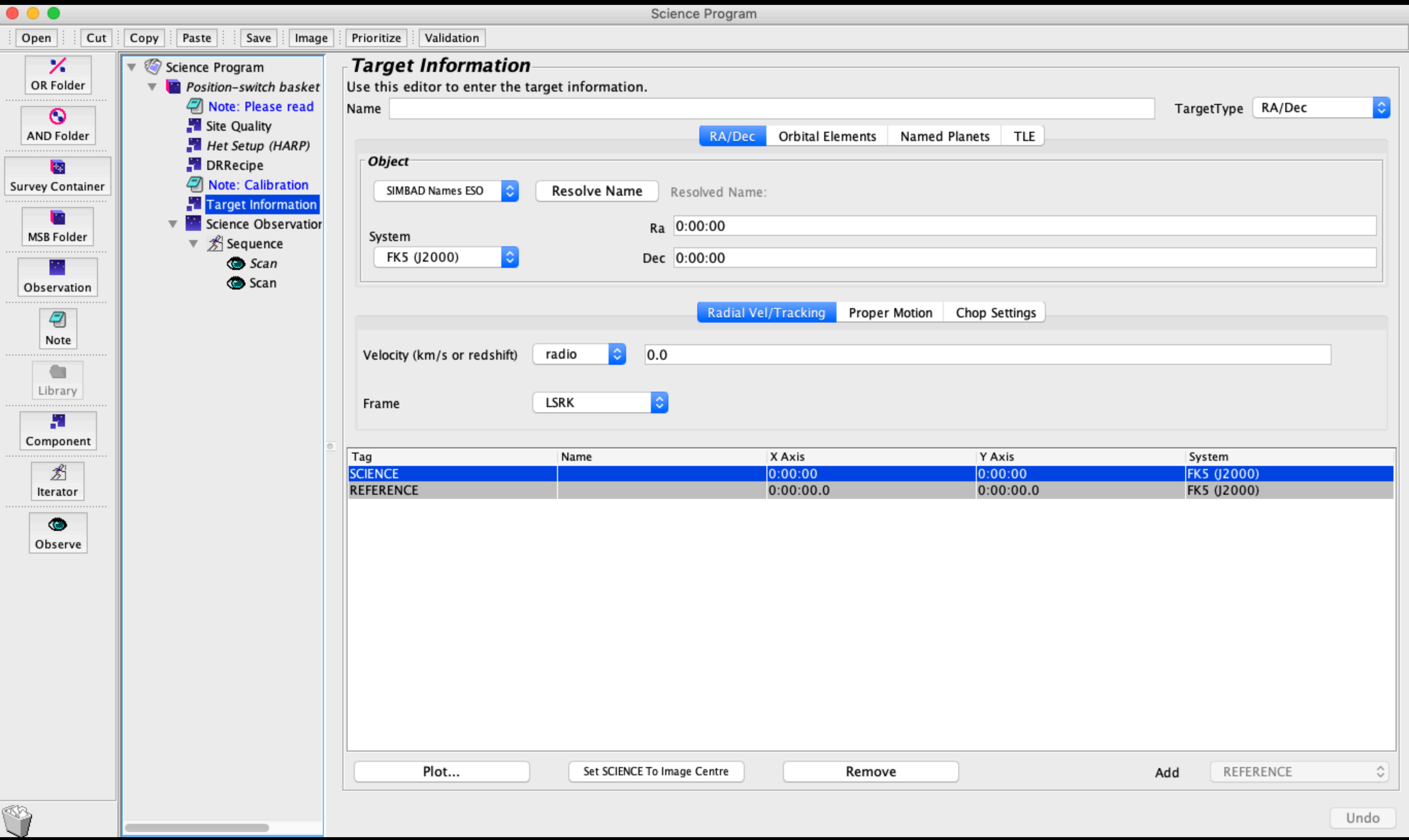


ACSIS = AutoCorrelating Spectral Imaging System
This is the backend for both HARP and Namakanui

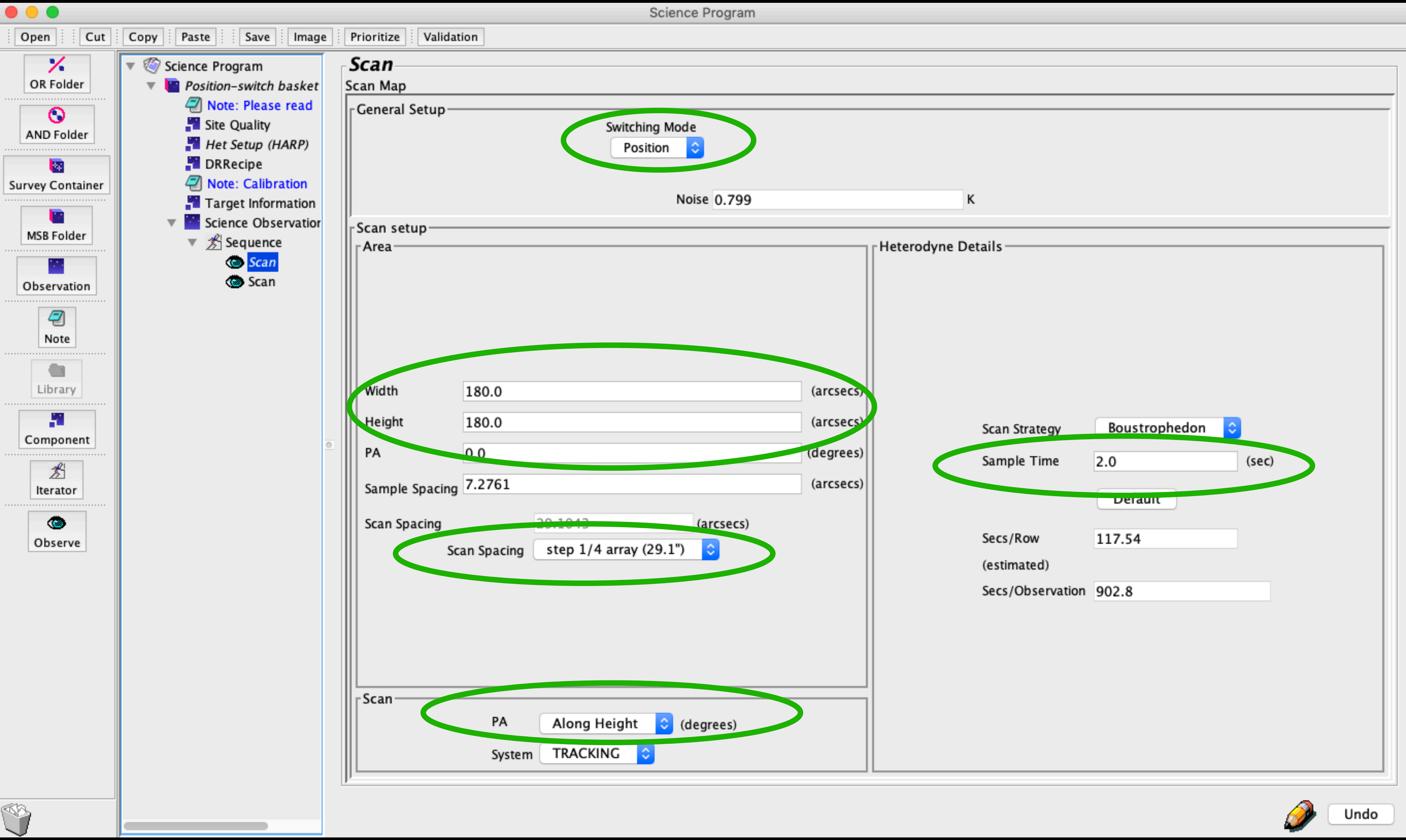
The JCMT Observing Tool (JCMTOT)



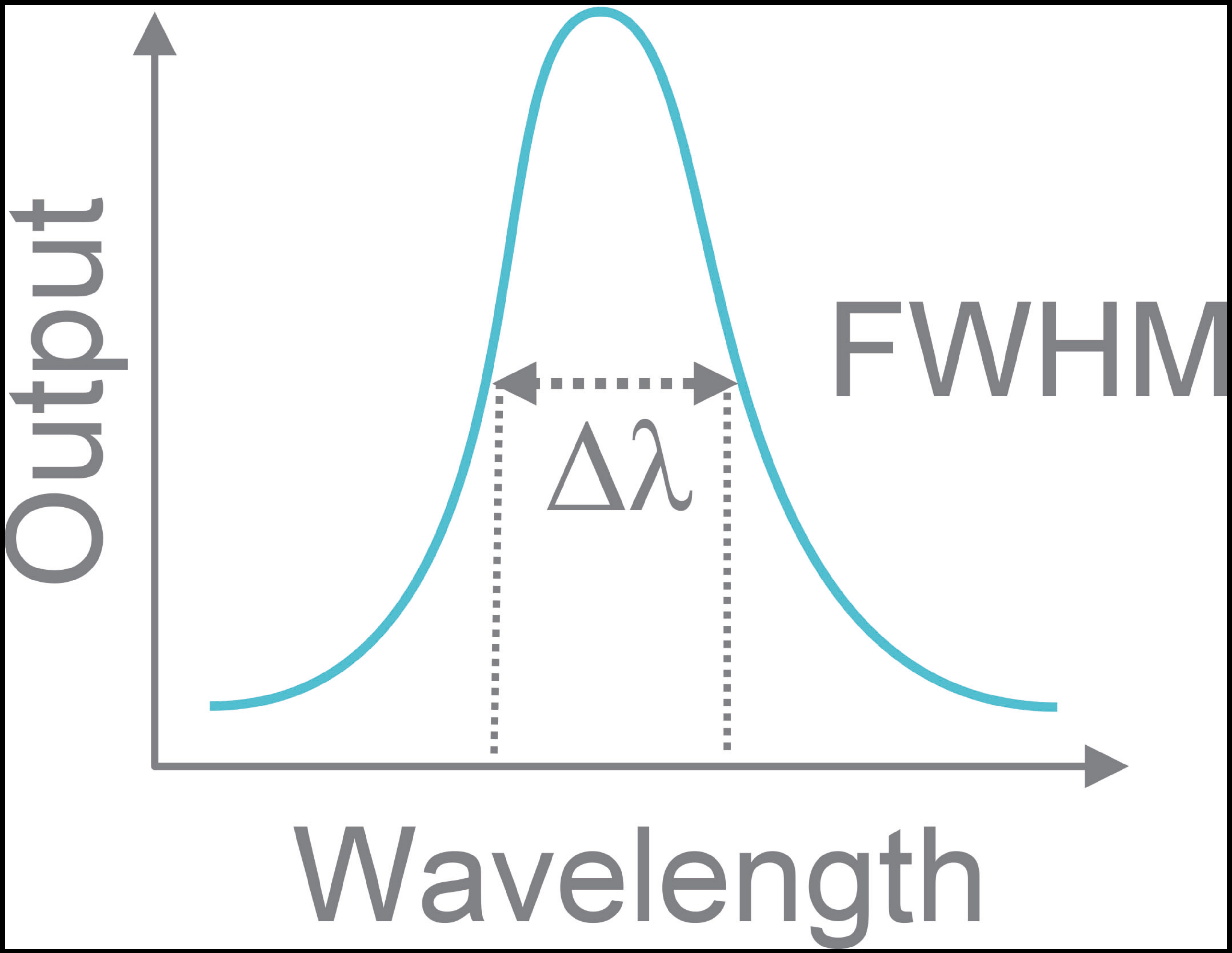
The JCMT Observing Tool (JCMTOT)



The JCMT Observing Tool (JCMTOT)

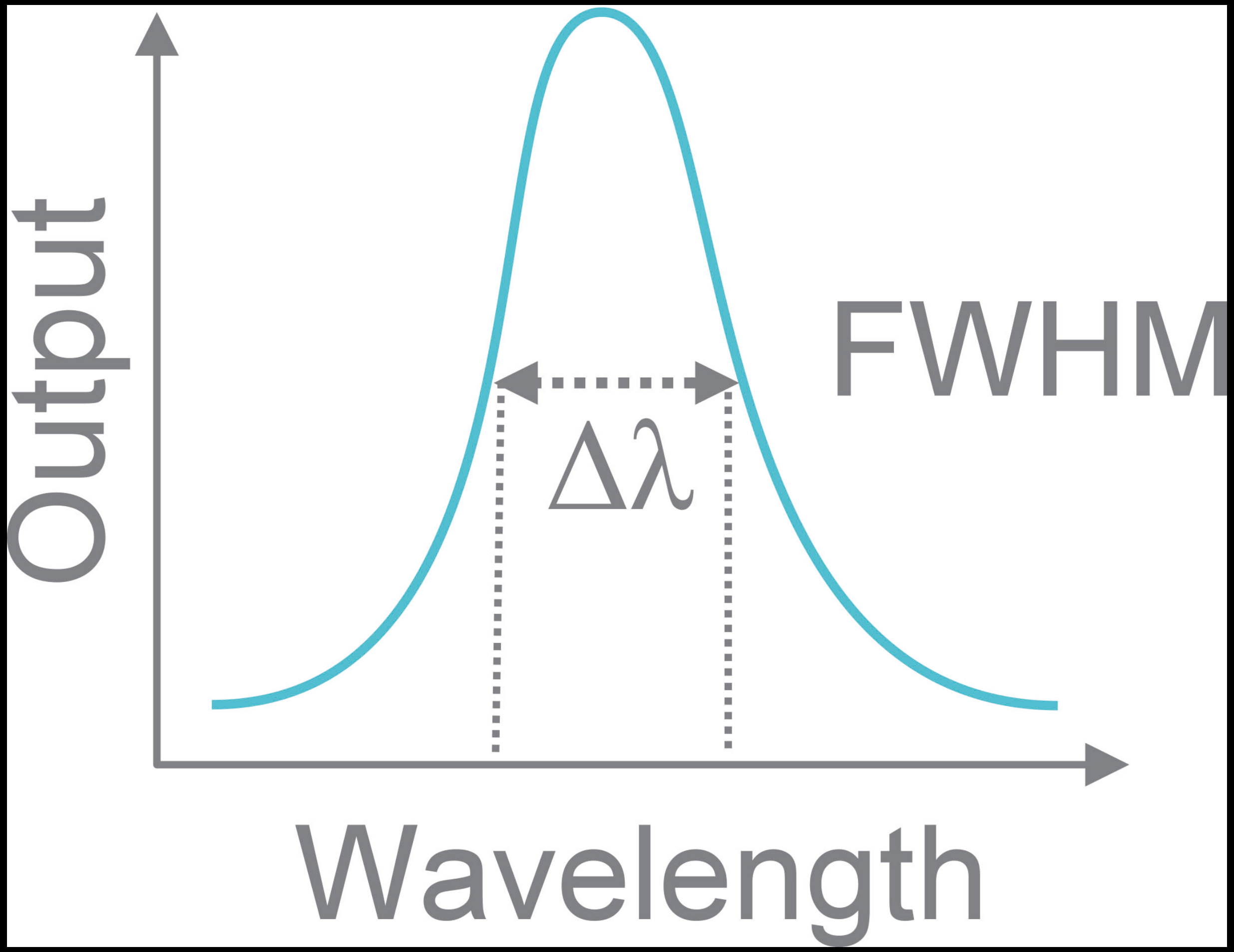


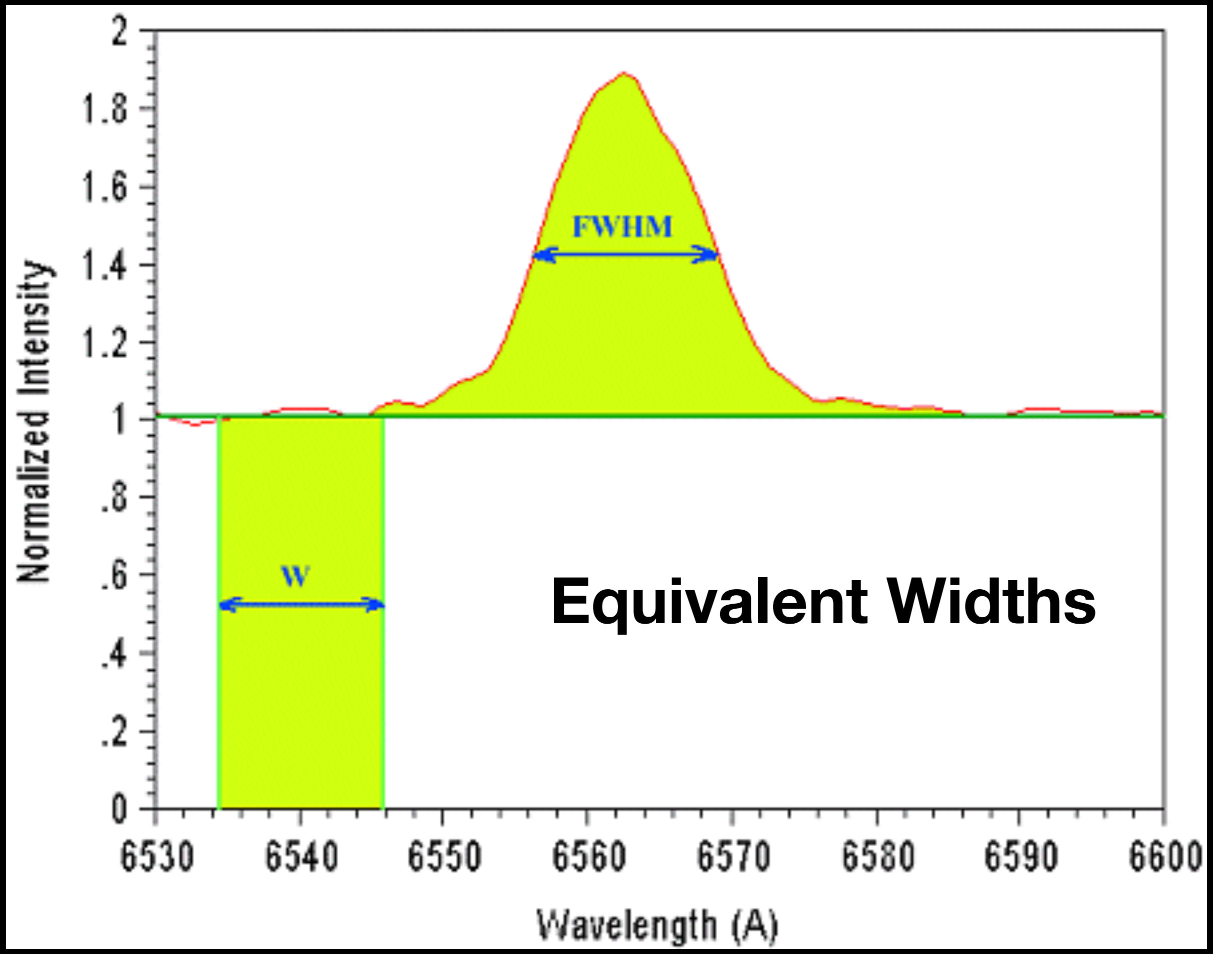
Heterodyne Science



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

Turbulence

Relative Energy States

Organised Bulk Motion

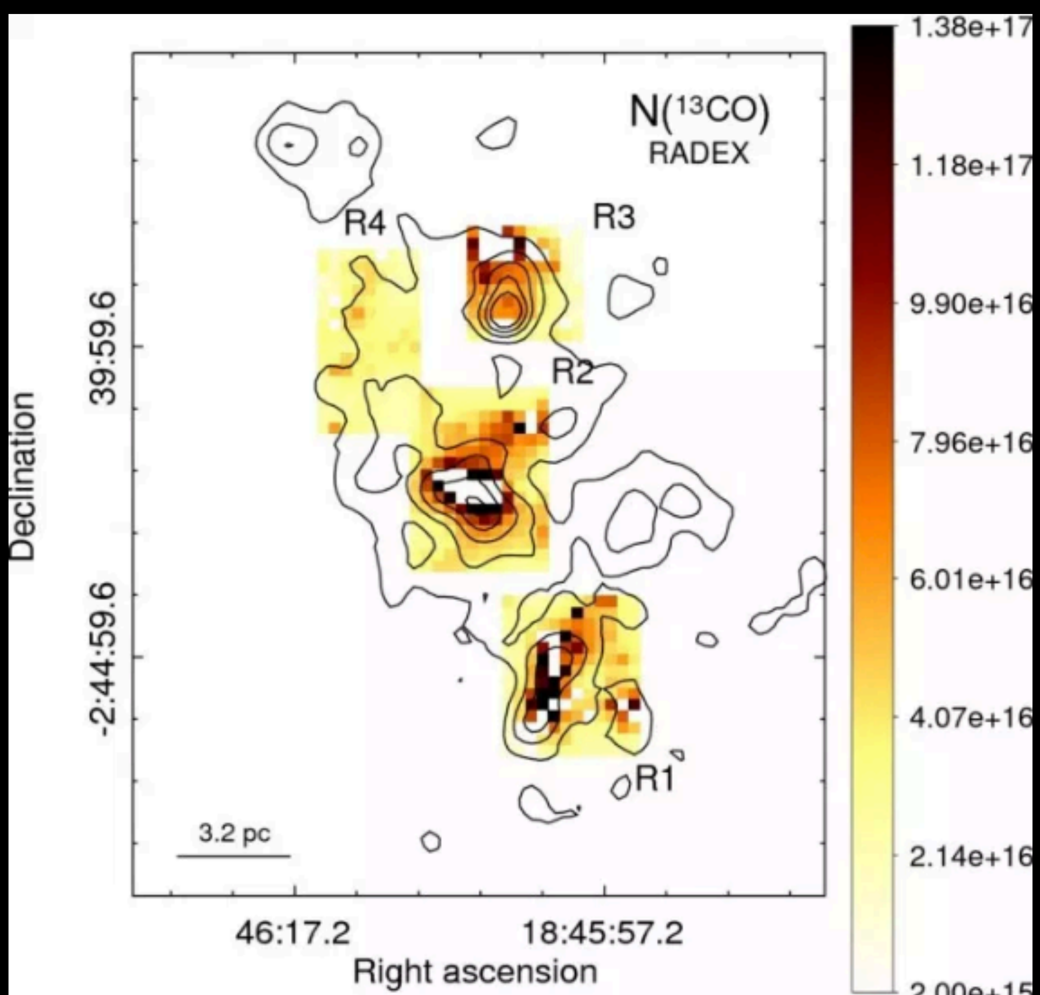
Interesting Chemistry

Physical Temperatures

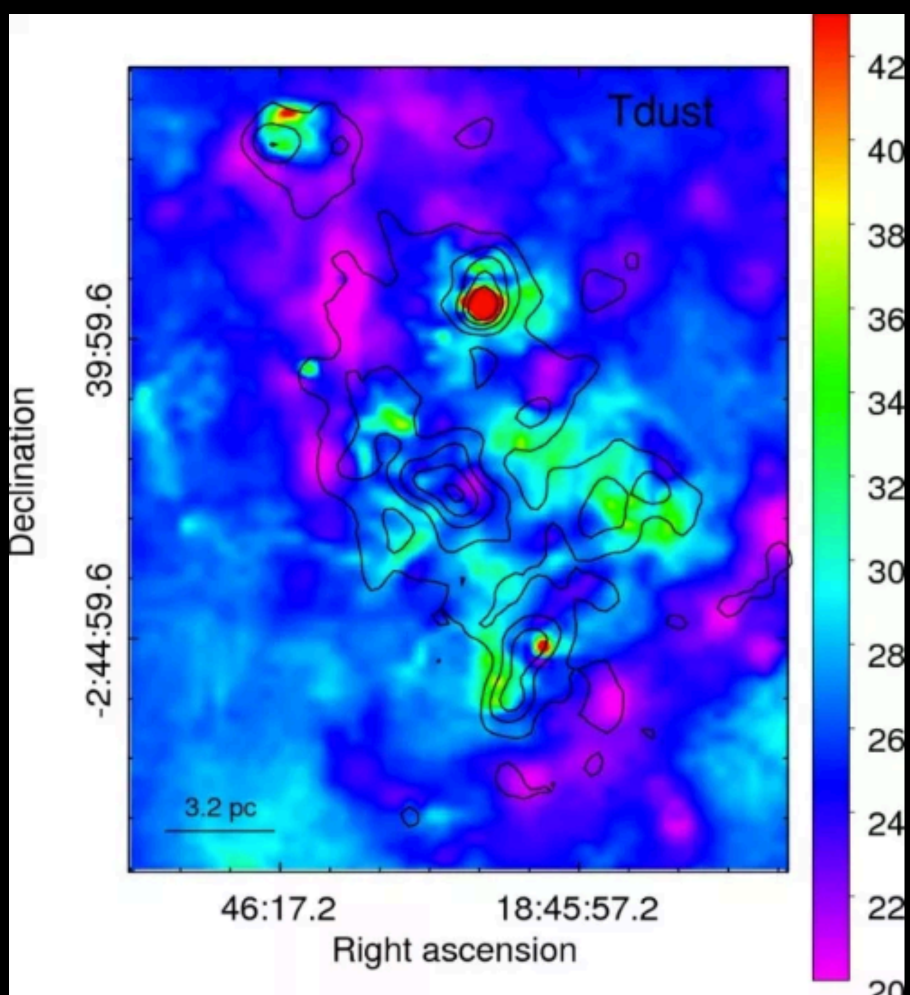
Heterodyne Science Ideas: Chemistry

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

13CO/C18O Abundance Ratio



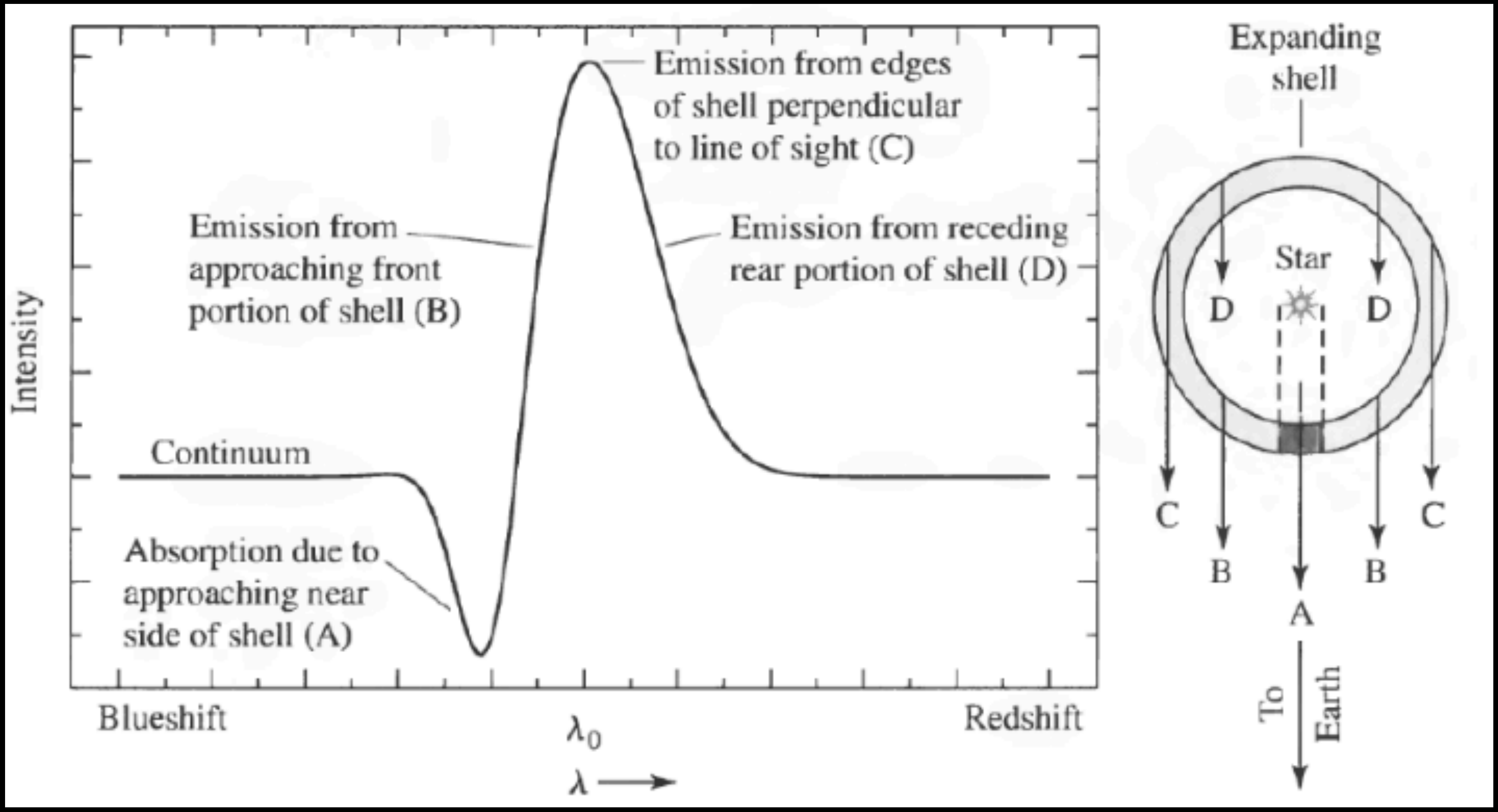
Temperature of the Dust



From Paron et al.: https://arxiv.org/abs/1807.03741

Line shapes: P Cygni Profile as an Example

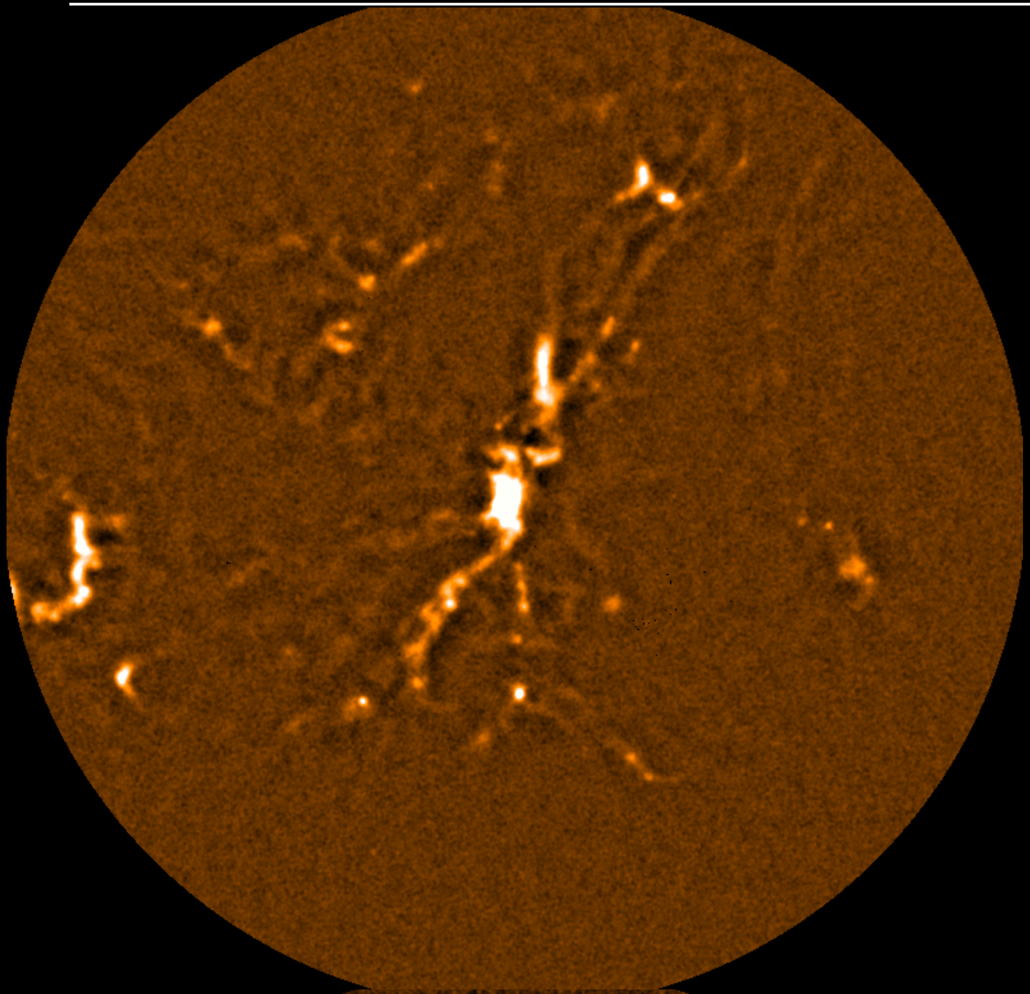
The shapes of molecular profiles can also tell us a lot!

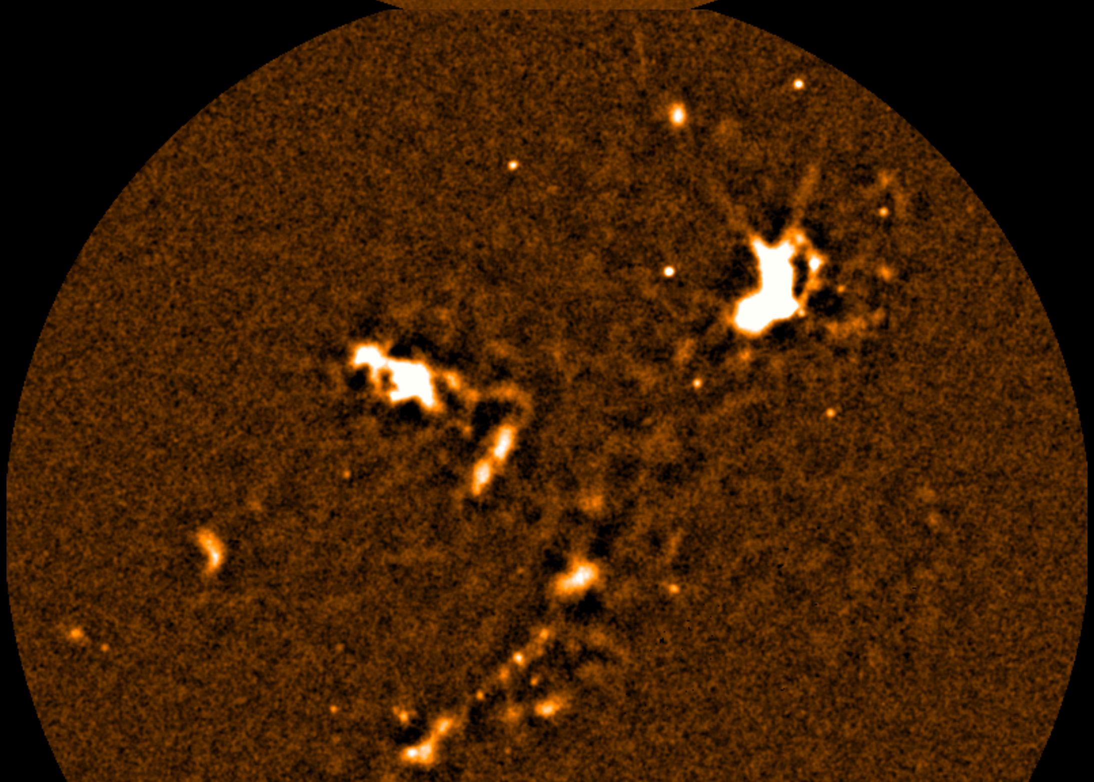


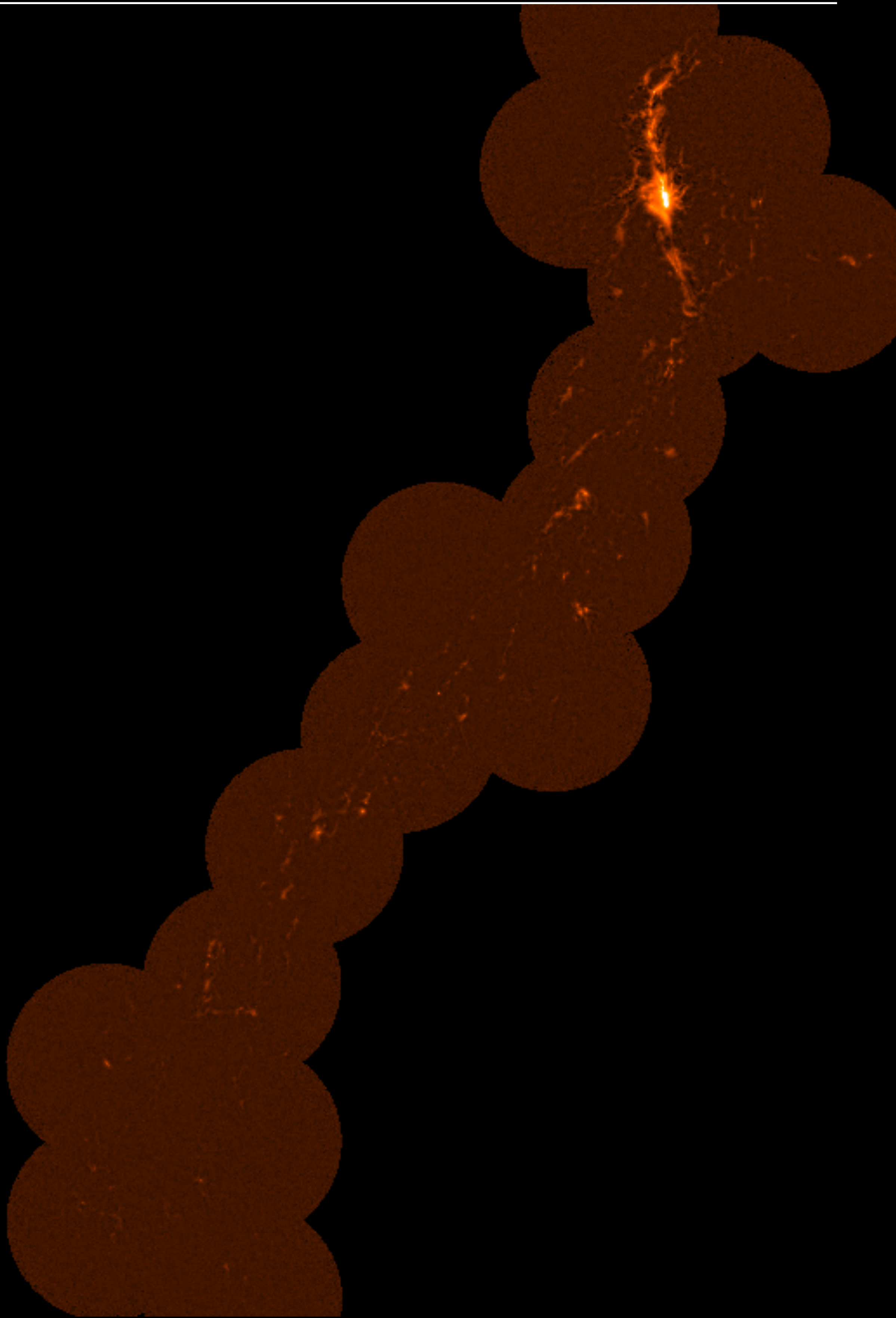
From: Carroll, B. W. & Ostlie, D. A. 2006, An introduction to modern astrophysics, Second edn.

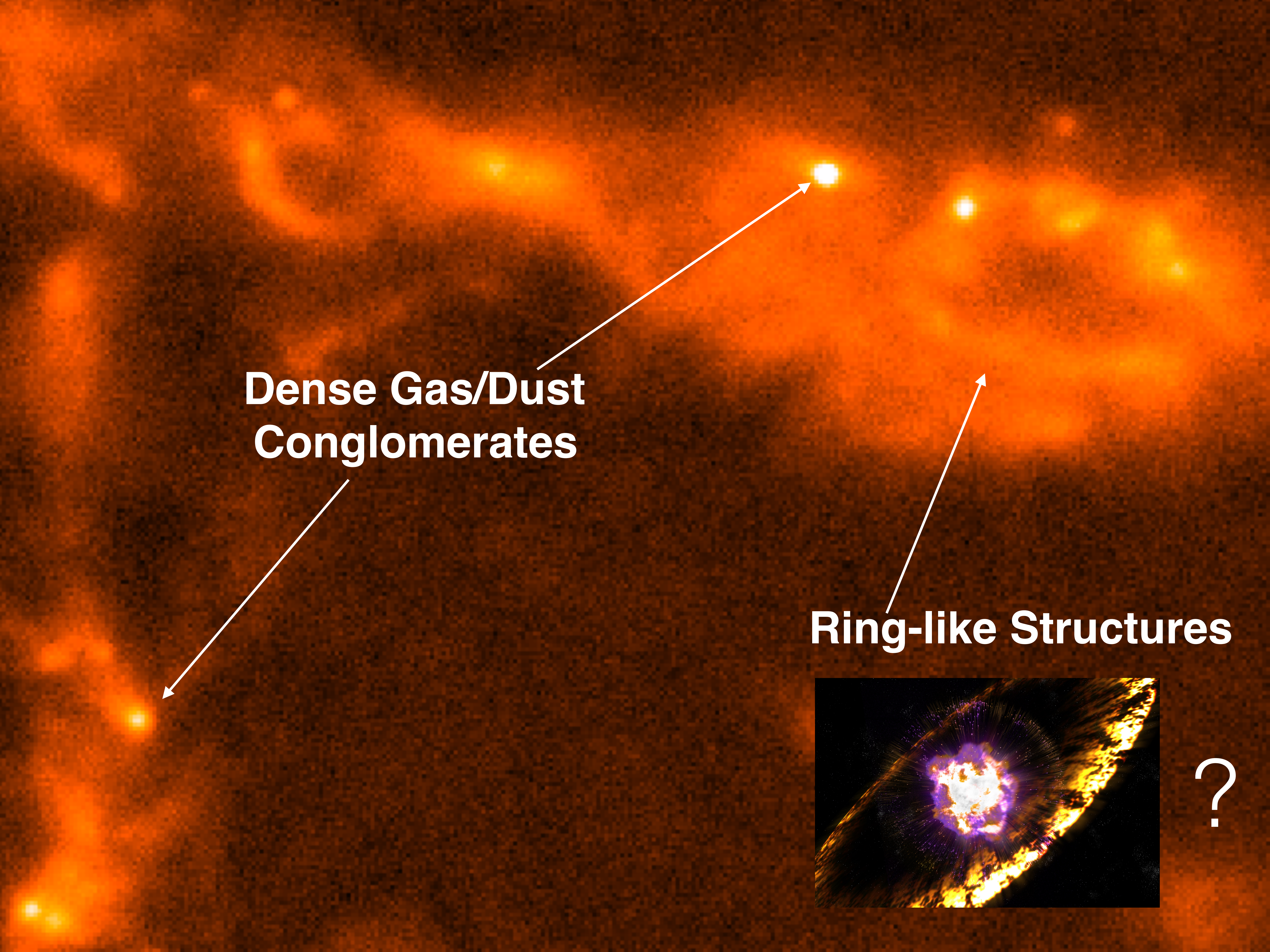
HARP alone can tune to the frequencies of transitions associated with ~70 different molecules including CO, HCN, Formaldehyde…

SCUBA-2 Science








Dense Gas/Dust
Conglomerates
Ring-like Structures
?

Stronger Pressure

More Heat

=

Expansion

=

No star formation

Stronger Gravity

More Stuff

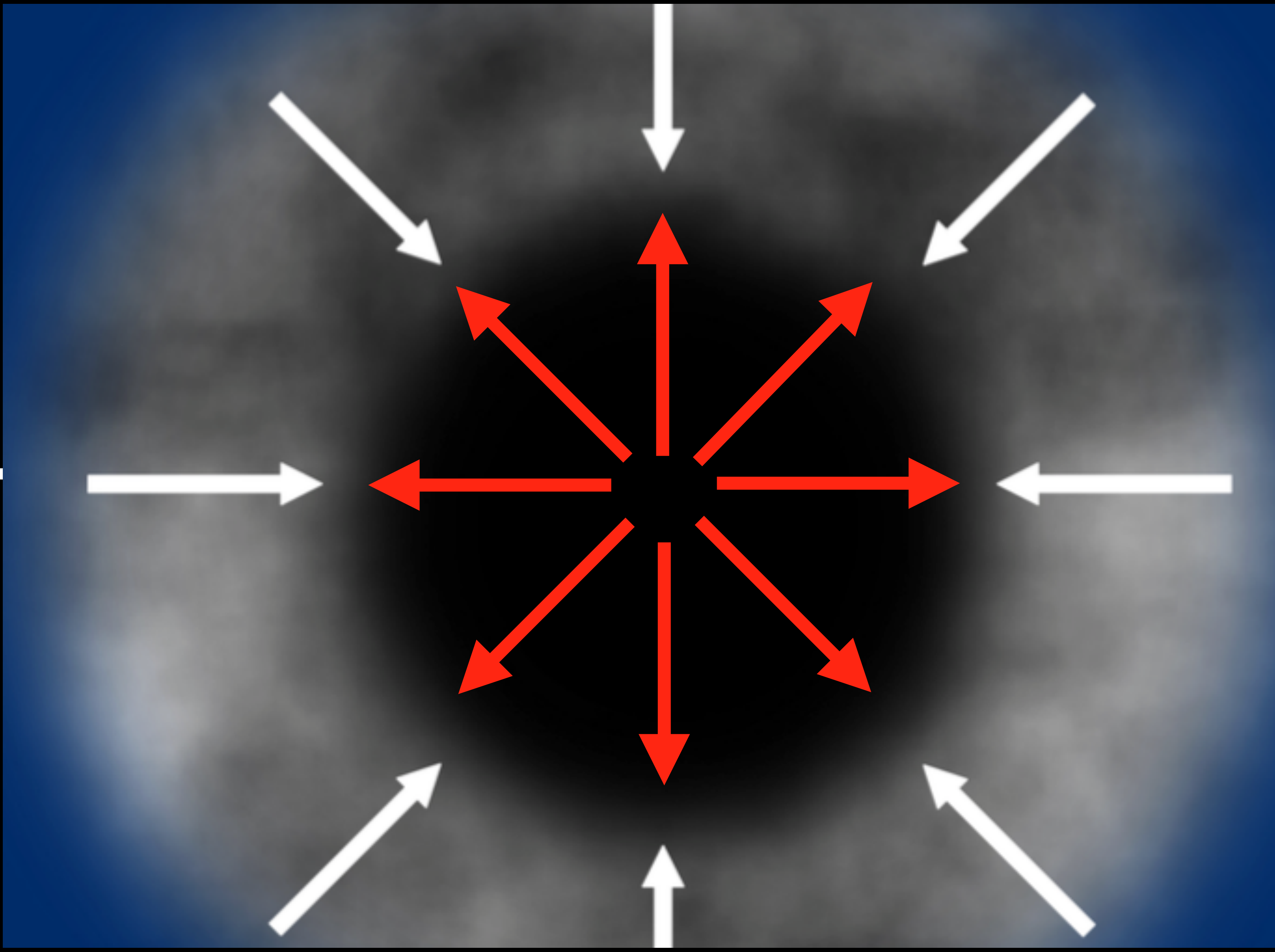
=

Collapse

=

Star Formation

Gravity

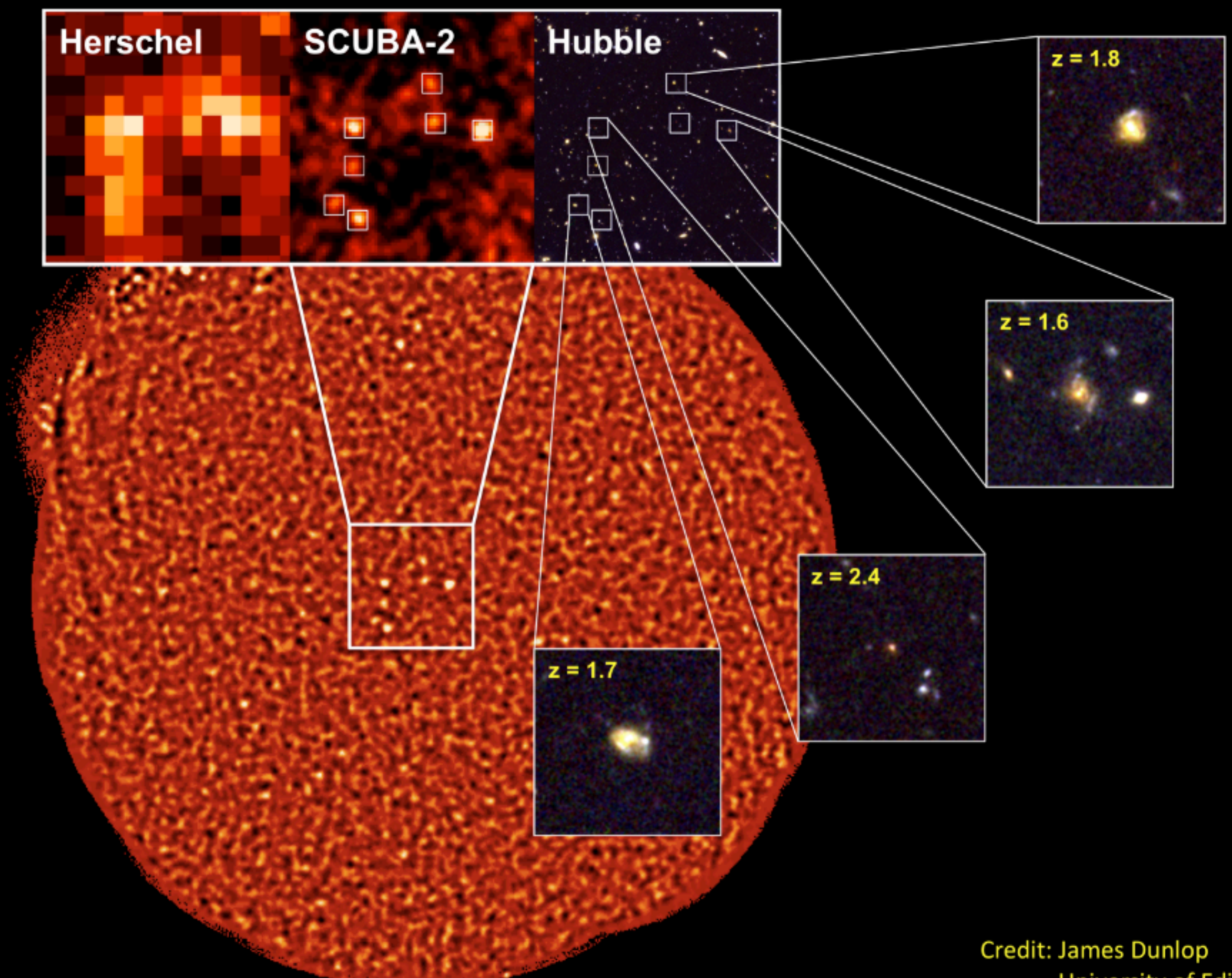


Thermal Pressure

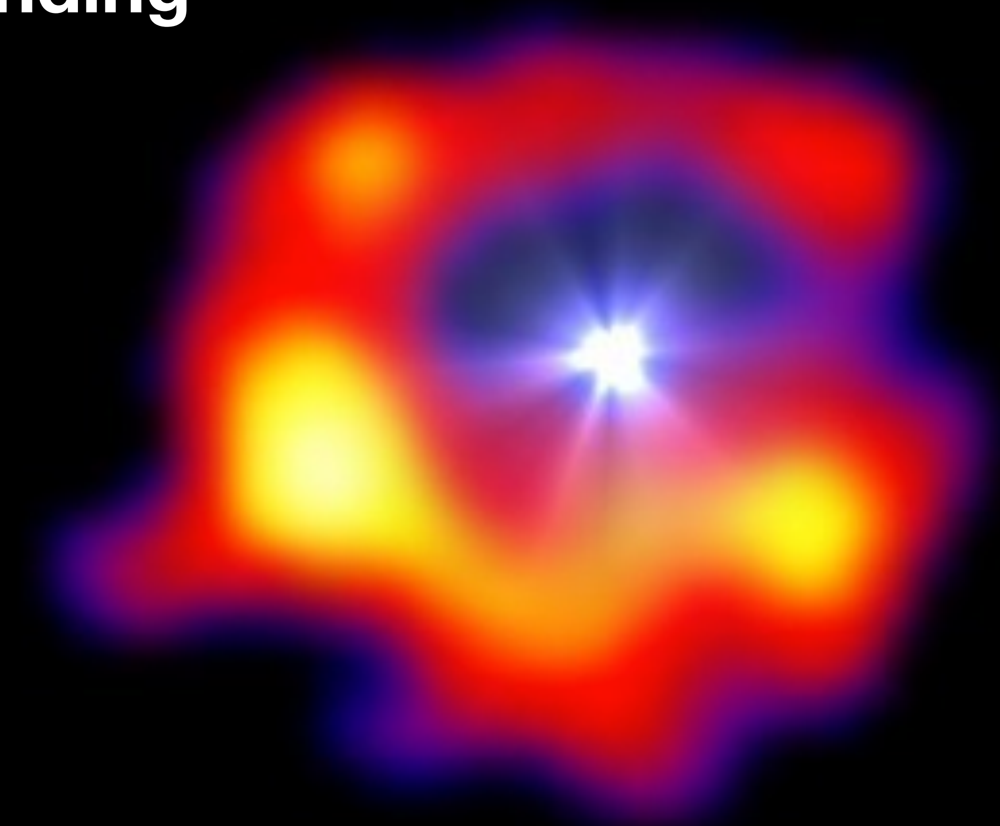
A constant struggle!

Is Archival Data Available (Other Telescopes)?

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

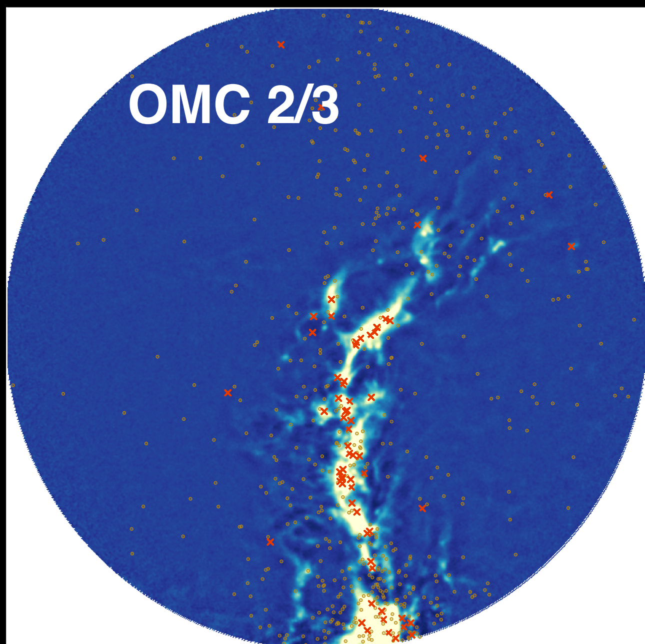


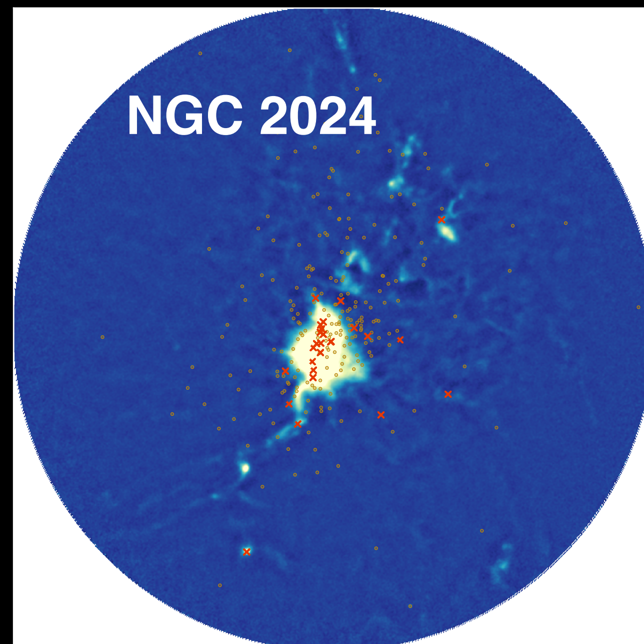
Credit: James Dunlop
University of Edinburgh

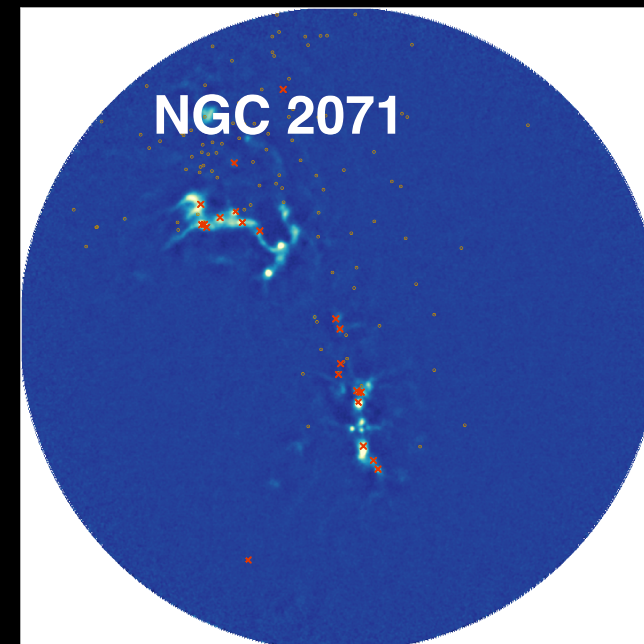


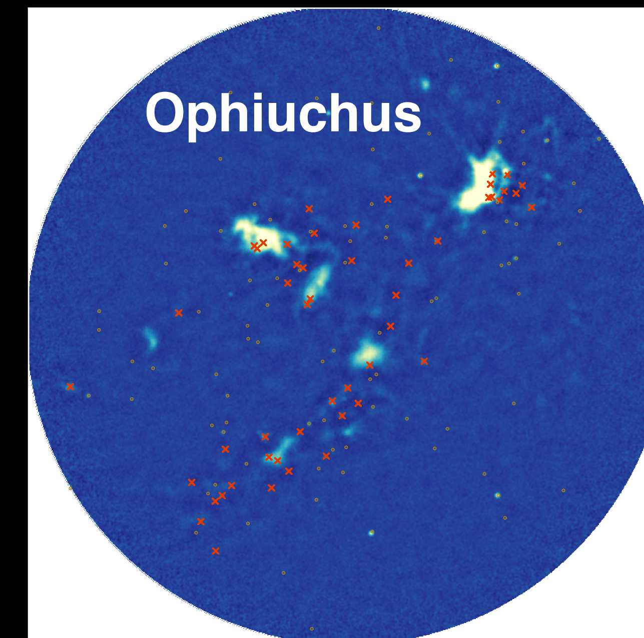
Remember, SCUBA uncovered a class of galaxies never seen before!

Survey Work! Spectral or Continuum! Example: The JCMT Transient Survey









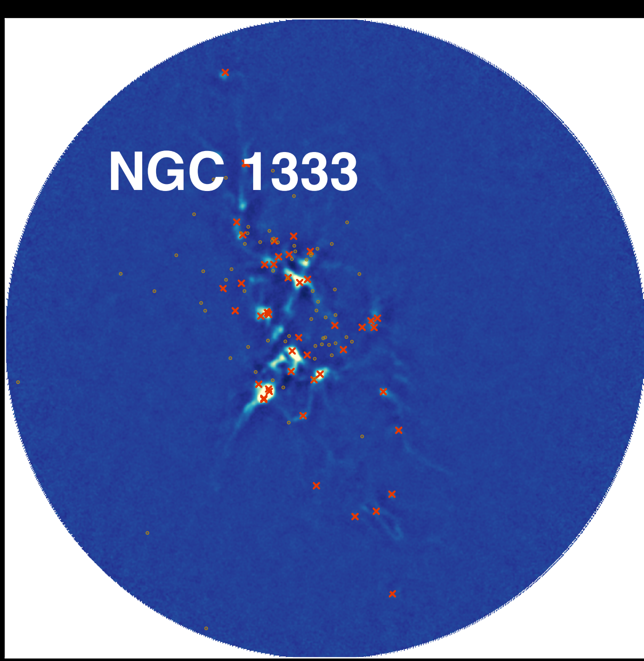
8 regions, < 500 pc (GBS)

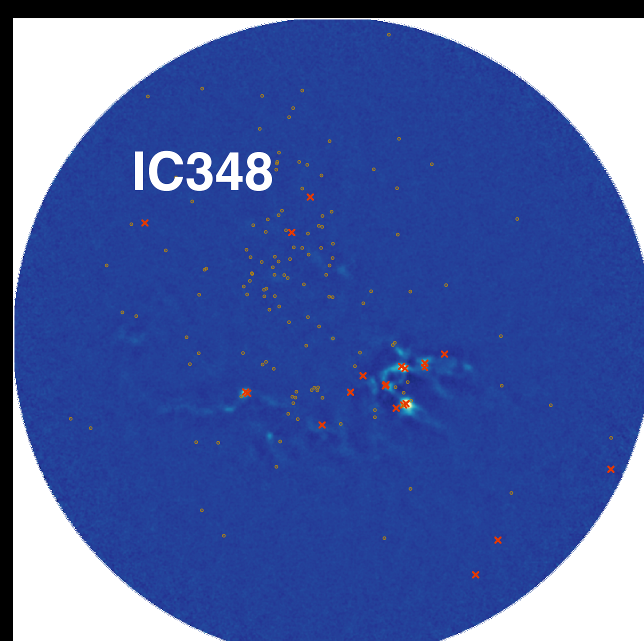
450μm and 850μm!

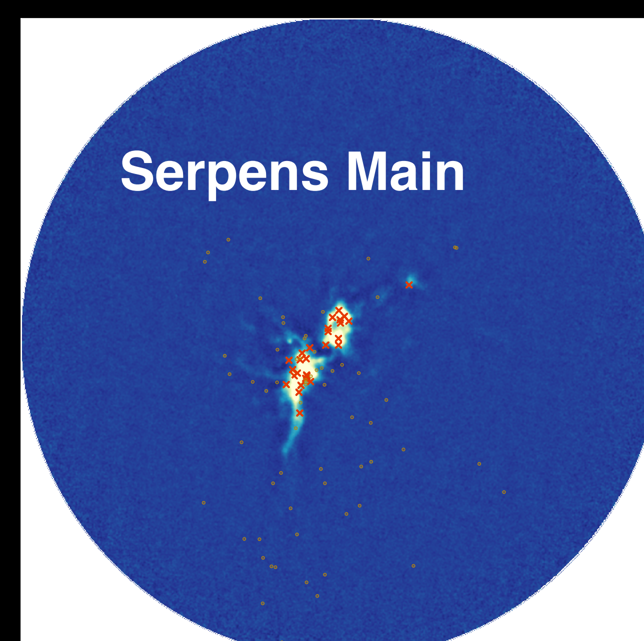
3 Years, Began: 12/2015

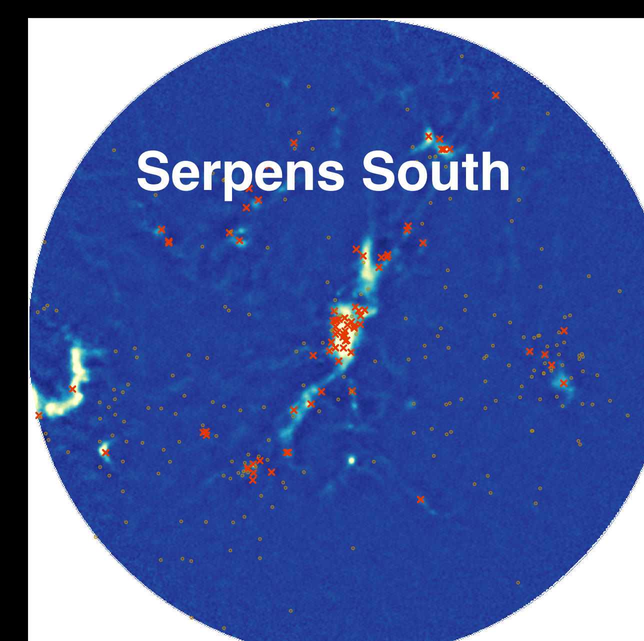
250 Protostars, 1400 Disk Sources

One Month Cadence









Combine Multiple Instruments!

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

$$B_{\rm pos} = Q' \sqrt{4\pi\rho}\,\frac{\sigma_v}{\sigma_\theta} \approx 9.3\,\sqrt{n({\rm H_2})}\,\frac{\Delta v}{\langle\sigma_\theta\rangle}\ \mu{\rm G}$$

SCUBA-2

HARP

POL-2

Crutcher et al. 2004, ApJ 600:279

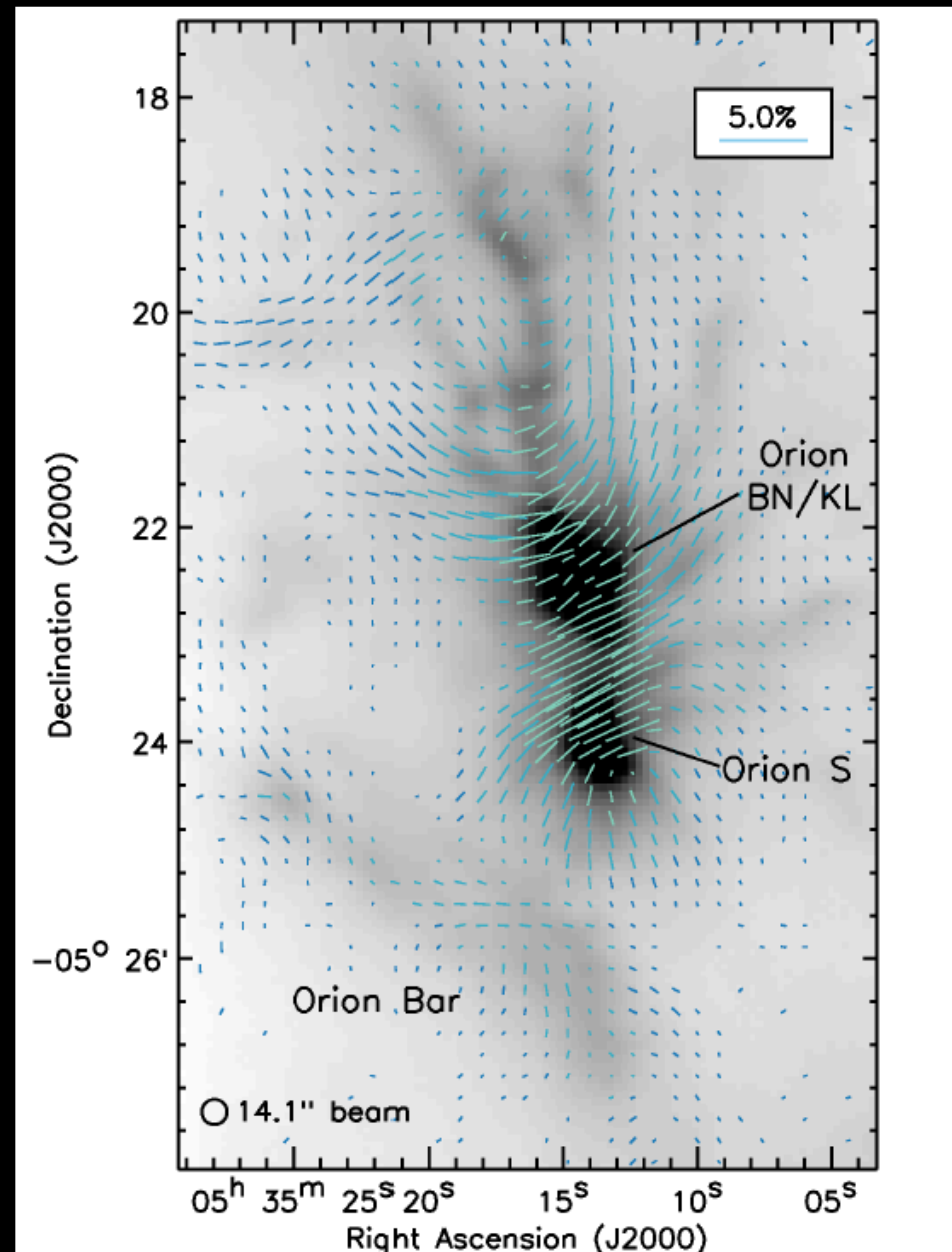


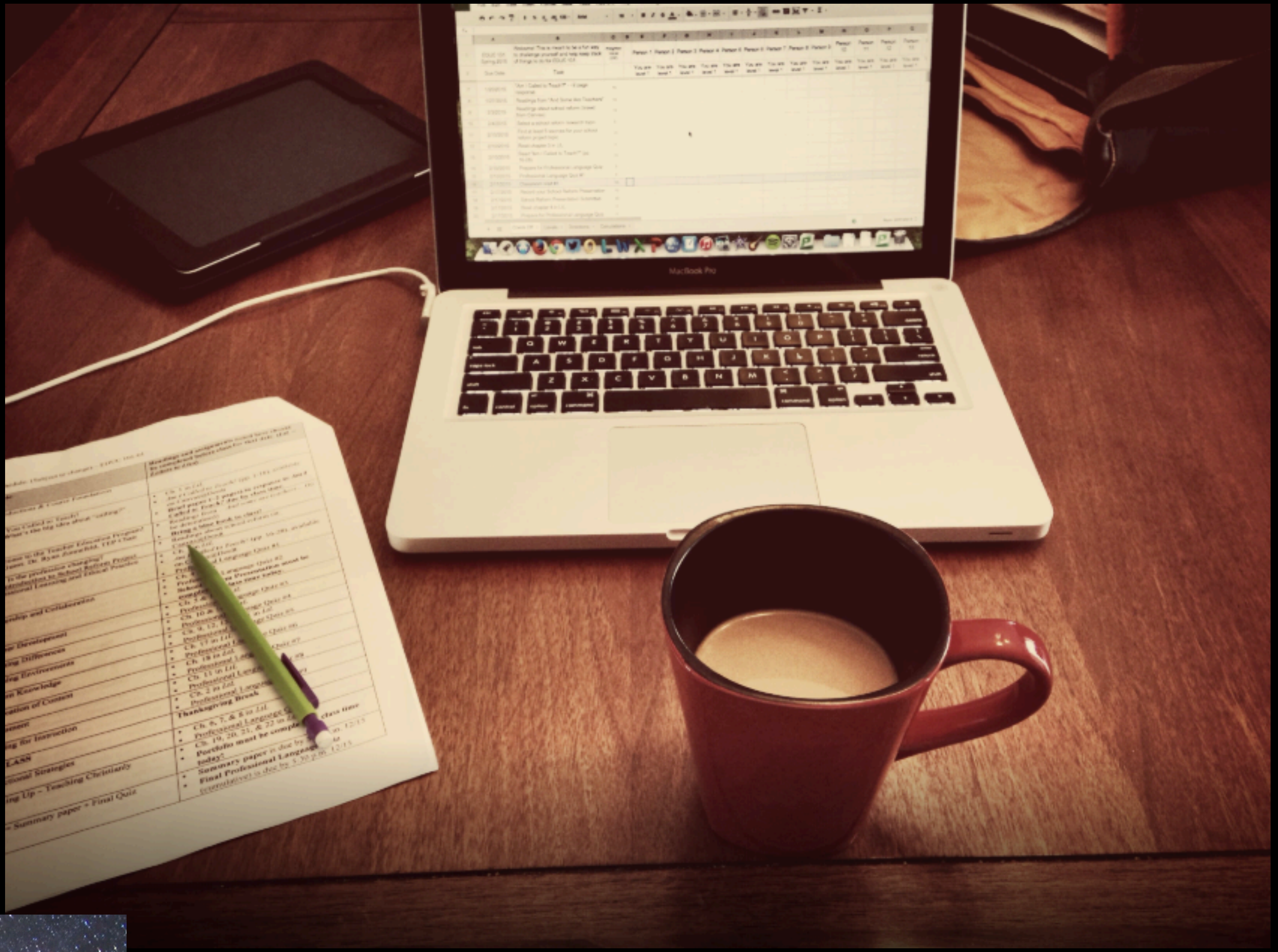
Figure: Pattle et al. 2017, ApJ 846:122

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!

Things to Keep in Mind

Requests for time are **limited to a maximum of 200 hours**
But usually proposals that require ~<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 ~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:

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

Start here for a PDF presentation of tips and Tricks

https://www.eaobservatory.org//JCMT/observing-tool-tutorials/jcmt_ot_tips.pdf

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/

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

What You Will Need To Submit for Grading

1. A complete proposal do 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.