Using the SMA
Mark Gurwell
SMA Community Day
11 July 2011
Outline

• Submillimeter Array Background
• SMA Specifications
• Proposing for SMA Time
  ▪ Statistics
  ▪ Tools
  ▪ Process
  ▪ Help
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What is the SMA?

The SMA is a pathfinding instrument comprised of eight 6 meter antennas on Mauna Kea, HI, designed for high spatial and spectral resolution imaging in submillimeter atmospheric windows.

The SMA is now being used to study Solar System bodies, protoplanetary disks, star forming regions, evolved star envelopes, the Galactic Center, nearby galaxies, and ultraluminous galaxies at cosmological distances.

The SMA is a collaborative project of the Smithsonian Astrophysical Observatory, part of the Harvard-Smithsonian Center for Astrophysics, and the Academia Sinica Institute of Astronomy and Astrophysics (Taiwan)
Historical Perspective

- 1984: SAO Study
- 1994: OSDA U. Hawaii
- 1996: ASIAA expansion
  +2 antennas (to 28 baselines)
- 2004: first SMA science
- 2011: >336 refereed papers
  (rate > 1/week for 5 yrs)
Submillimeter Windows

Cold material is best seen in submillimeter “light”
Submillimeter Windows

SMA Low Frequency Bands

SMA High Frequency Bands

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Submillimeter Windows

SMA Low Frequency Bands

Transmission

\( \nu \) (GHz)

SMA High Frequency Bands

Transmission

\( \nu \) (GHz)
Single Aperture vs Interferometry

Resolution $\sim$ wavelength/size

- SMA, 8 x 6-m, (41" at 1mm)
- JCMT, 15-m (17" at 1mm)

200 meters for 1" at $\lambda = 1\text{mm}$
Spatial Frequencies

Short baselines – large spatial scales

Long baselines – small spatial scales

For high spatial dynamic range but small number of sampling points (antennas) need multiple configurations
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Antennas: 8 antennas of 6 m diameter, 12 µm rms surface cost + imaging speed + collecting area (~JCMT)

Configurations: 24 pads in four rings
baseline lengths 8 - 508 m,
subarcsecond resolution, best ~0.1”

Receivers: max 8 per antenna; 1 or 2 simultaneously, each single pol.
full frequency coverage of atmospheric windows
dual polarization, “high” & “low” combinations allowed
‘230’ 177-256 GHz (L)
‘345’ 256-360 GHz (L)
‘400’ 320-420 GHz (H)
‘600’ 600-720 GHz (H)

Correlator: Bandwidth: 2 SB x 4 GHz (1 receiver) / 2 GHz (2 receivers)
up to 25 kHz resolution!
Sensitivity and bandwidth to span/resolve extragalactic/galactic lines
Antenna Stations

4 Nested Rings (Keto 1997)

4 Configurations

<table>
<thead>
<tr>
<th></th>
<th>Subcompact</th>
<th>Compact</th>
<th>Extended</th>
<th>Very Extended</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diameter</td>
<td>9”</td>
<td>3.5”</td>
<td>1.3”</td>
<td>0.5”</td>
</tr>
<tr>
<td>Distance</td>
<td>6”</td>
<td>2.5”</td>
<td>0.8”</td>
<td>0.3”</td>
</tr>
</tbody>
</table>

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230 345
Field of View/Resolution

Jupiter HCN(3–2) Integrated Emission [SMA: 28 April, 2007]

Titan CH$_3$CN Integrated Emission [eSMA: 23 March, 2009]
Single or Dual Rx Operation

Two receiver operation:

Single receiver operation with twice the bandwidth
SMA IF System

Offset from LO (GHz)

Gunn LO

s01 Upper Sideband

s48 Lower Sideband

-8  -7  -6  -5  -4  -3  -2  -1

1 or 2 Rx, 2 GHz

1 Receiver, 4 GHz

Upper sideband sky frequency increases this way

Lower sideband sky frequency increases this way

4.016 GHz

32 MHz Coverage Gap

1 Receiver, 4 GHz Coverage

1 Receiver, 4 GHz Coverage

1 or 2 Receiver, 2 GHz Coverage

IF Frequency (GHz)
## SMA Correlator

<table>
<thead>
<tr>
<th>Bandwidth</th>
<th>230 GHz</th>
<th>345 GHz</th>
<th>690 GHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Continuum</td>
<td>5200</td>
<td>3500</td>
<td>1740</td>
</tr>
<tr>
<td>4 GHz / sideband</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Best Uniform Spectral Res.</td>
<td>1</td>
<td>0.7</td>
<td>0.35</td>
</tr>
<tr>
<td>812.5 kHz</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum* Spectral Res.</td>
<td>0.03</td>
<td>0.022</td>
<td>0.01</td>
</tr>
<tr>
<td>25 kHz</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
SMA Correlator

Submillimeter Array Background

Arp 220

$^{12}\text{CO}(2-1)$

$^{13}\text{CO}(2-1) \times 10$

$^{18}\text{O}(2-1) \times 10$

$^{12}\text{CO}(6-5)$

1000 km/s

1 km/s

TW Hydra

SMA CO(3-2)
SMA Correlator – 4 GHz IF Example

 Courtesy Nimesh Patel
Polarization

- Single receiver, cycling quarter-wave plates (time-sharing to obtain full Stokes coverage)

- Dual receiver, direct full Stokes (no time-sharing, more efficient)

G31.41+0.31 (Girart et al)
<table>
<thead>
<tr>
<th>Config</th>
<th>Beam</th>
<th>Point-Source Sensitivity (mJy)</th>
<th>Temp</th>
<th>Point-Source Sensitivity (mJy)</th>
<th>Temp</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUB</td>
<td>7.4”x7.1”</td>
<td>0.7</td>
<td>0.35 mK</td>
<td>70</td>
<td>31 mK</td>
</tr>
<tr>
<td>COM</td>
<td>3.3”x2.9”</td>
<td>0.5</td>
<td>1.2 mK</td>
<td>49</td>
<td>117 mK</td>
</tr>
<tr>
<td>EXT</td>
<td>1.3”x1.0”</td>
<td>0.5</td>
<td>9.1 mK</td>
<td>49</td>
<td>855 mK</td>
</tr>
<tr>
<td>VEX</td>
<td>0.5”x0.4”</td>
<td>0.5</td>
<td>54 mK</td>
<td>49</td>
<td>5.2 K</td>
</tr>
</tbody>
</table>
# Sensitivity (6 hr)

<table>
<thead>
<tr>
<th>Config</th>
<th>Beam</th>
<th>8 GHz (Full Continuum)</th>
<th>1 km/s</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Point-Source Sensitivity (mJy)</td>
<td>Temp</td>
</tr>
<tr>
<td>SUB</td>
<td>4.9”x4.7”</td>
<td>1.9</td>
<td>0.85 mK</td>
</tr>
<tr>
<td>COM</td>
<td>2.2”x1.9”</td>
<td>1.35</td>
<td>3.3 mK</td>
</tr>
<tr>
<td>EXT</td>
<td>0.8”x0.7”</td>
<td>1.35</td>
<td>24 mK</td>
</tr>
<tr>
<td>VEX</td>
<td>0.35”x0.3”</td>
<td>1.35</td>
<td>150 mK</td>
</tr>
</tbody>
</table>
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  ▪ Statistics
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Observing and Proposal Information

- CfA allocates 72% of SMA Time (UH/ASIAA split rest)
- ‘open skies’ policy…accept proposals from anywhere
- proposal deadlines on 6 month cycle (March/September)
  - next deadline: **Wednesday, September 14, 2011**
- dynamic queue scheduling according to weather
- RTDC archive, data in public domain after 15 months
- Calibration and Imaging:
  - MIR (OVRO)/Miriad or AIPS (soon CASA)
Proposals

• Proposals reviewed by TAC (9-13 members) consisting of scientists from SMA, CfA, and outside community (IAA + CfA hold joint TAC science review)

• Each proposal reviewed by minimum of 4-6 TAC members

• Proposals ranked, discussed and reevaluated at face-to-face

• configuration schedule to best accommodate highest ranked proposals

• Proposals are rated as
  A: highest rating, executed on a best effort basis
  B: middle rating, to be executed as time permits
  C: lowest rating, will not be executed
Proposal Statistics

Number unique PIs: 172
Allocated 1+ A tracks: 108
1+ successful obs: 169
Time Oversubscription

Majority of time requests come at 345 GHz
Submillimeter Windows

SMA Low Frequency Bands

Transmission

ν (GHz)

SMA High Frequency Bands

Transmission

ν (GHz)
Proposal Statistics (through 2010B)

**No. of Proposals**
- Star Formation: 500 (55%)
- Extragalac.: 279 (31%)
- Galactic Center: 34 (4%)
- Other: 13 (1%)
- Planetary: 18 (2%)

**Time request**
- Star Formation: 500 (55%)
- Extragalac.: 279 (41%)
- Galactic Center: 34 (7%)
- Other: 13 (1%)
- Planetary: 18 (2%)
RA Coverage vs Semester

Distribution of Requested Time (SMA Semesters 2005B–2008A)

Summer Semester (March Deadline)

Winter Semester (Sept. Deadline)
http://sma1.sma.hawaii.edu

Call for Proposals
Technical Info.
Tools
User Account
Proposal Creation
Project Tracking
SMA Observer Center: Tools - Mozilla Firefox

File Edit View History Bookmarks Tools Help

http://sma1.sma.hawaii.edu/tools.html

SMA Observer Center: Tools

Tools

Beam Calculator / Sensitivity Estimator
Planetary Visibility Function Calculator
Submillimeter Calibrator List
Passband Visualizer / Correlator Configuration Tool
System Temperature Calculator
SMA data archive search (at the CfA Radio Telescope Data Center)
Beam Calculator/Sensitivity Estimator I

\[ \nu = 345.8 \text{ GHz USB} \]
\[ \eta_{\text{AP}} = 0.740 \text{ (dish } \sigma_{\text{RMS}} = 20 \mu\text{m}) \]
\[ \eta_{\text{MISG}} = 0.680 \]
\[ T_{\text{RX (DSB)}} = 116.2 \text{ K} \]
\[ \text{Precip. Water Vapor: } 2.00 \text{ mm} \]
\[ \tau_{225 \text{ GHz}} = 0.110 \text{ (model: am v3.6)} \]
\[ \tau_{\text{main sb}} = 0.372 \text{ } \tau_{\text{image sb}} = 0.385 \]

\[ \text{Transit } T_{\text{SYS }}^{f (SSB)} = 828.6 \text{ K} \]
\[ \text{On source int. time} = 4.62 \text{ h} \]
\[ \text{Beam size} = 0.95'' \times 0.81'' \]

<table>
<thead>
<tr>
<th>BANDWIDTH</th>
<th>RMS NOISE/BEAM</th>
<th>( T(RJ) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 GHz</td>
<td>2.9 mJy</td>
<td>35.3 mK</td>
</tr>
<tr>
<td>2 GHz</td>
<td>3.9 mJy</td>
<td>51.1 mK</td>
</tr>
<tr>
<td>100 km/s</td>
<td>16.2 mJy</td>
<td>212.6 mK</td>
</tr>
<tr>
<td>1 km/s</td>
<td>161.5 mJy</td>
<td>2.13 K</td>
</tr>
</tbody>
</table>
Beam Calculator/Sensitivity Estimator II

345.8 GHz USB  Pads:  1  9  11  12  14  15  16  17

\[ \text{DEC} = -29.0^\circ, \quad \text{EL}_{\text{min}} = 20.0^\circ \]

Beam (Full SMA Primary Field)

- \( B_{\text{max}} = 0.95'' \)
- \( B_{\text{min}} = 0.81'' \)
- \( \text{PA} = -12.0^\circ \)

Beam (Center of Field)

10% Contours, Normalized Beam

Natural Weighting
Passband Visualization

Correlator Mode: 1 Receiver 4GHz mode

Specify a line: HCN4-3,354.5054759.ρ or enter your own frequency

Spectral band to locate line: 13

Sideband: Upper

Optional: V_LSR adjusts the frequency based on the input LSR radial velocity.

V_LSR: km/s

Zenith angle: 0 deg

Precipitable water vapor: 2.0 mm (tau225=0.105)

Atmospheric absorption will take several seconds

Draw Orion survey?

SMA tuning command: dopplerTrack -r 354.5054759 -s 13 -u

LO center Freq: 349.4644759

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Calibrator Database
Radio Telescope Data Center
Smithsonian Astrophysical Observatory

Submillimeter Array Archive Search

Source1 = whya
And/Or = And

Date Range (ymmd-d-ymmd) = 090101-110701

Use the icon to request the data you would like.

Notes:
1. Calibrated data. Click here for sample calibration script.
2. Num/Bsln = Maximum number of baselines; Prj/Bsln = Maximum projected baseline (kilo baselines); Time = time on source (before flagging).
3. Quality: (sat) satisfactory; (usat) unsatisfactory; (pol) polarimetry, not calibrated; (marg) marginal quality, not used

<table>
<thead>
<tr>
<th>Get Data</th>
<th>Source</th>
<th>RA (j2000)</th>
<th>Dec (j2000)</th>
<th>LO Fr (GHz)</th>
<th>Num Bsln</th>
<th>PrjBsln (kmb)</th>
<th>Time (min)</th>
<th>Data</th>
<th>Quality</th>
<th>PI</th>
</tr>
</thead>
<tbody>
<tr>
<td>twhya</td>
<td>11:01:51.92</td>
<td>-34:42:17.0</td>
<td>341:44:6</td>
<td>00:21</td>
<td>07:04:35</td>
<td>00:78</td>
<td>090125_10</td>
<td>pol</td>
<td>meredith hughes</td>
<td></td>
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<tr>
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<td>13:49:02.00</td>
<td>-28:22:03.5</td>
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<td>23:01:11</td>
<td>01:18</td>
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<td>sat</td>
<td>sebastian mueller</td>
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<td>-28:22:03.5</td>
<td>341:53:7</td>
<td>00:42</td>
<td>09:32:38</td>
<td>01:00</td>
<td>100129_08</td>
<td>sat</td>
<td>sebastian mueller</td>
<td></td>
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<tr>
<td>whya</td>
<td>13:49:02.00</td>
<td>-28:22:03.5</td>
<td>341:53:7</td>
<td>00:42</td>
<td>53:06:31</td>
<td>00:06</td>
<td>100129_17</td>
<td>sat</td>
<td>sebastian mueller</td>
<td></td>
</tr>
</tbody>
</table>
How to Propose

• Propose via the web forms at the SMA Observer Center; requires an initial one-time registration and account creation which takes just a few minutes.

• Proposal submission includes filling in detailed project time requests and a cover sheet, and uploading a science and technical justification (PDF; 2 pages text + 2 pages figures, tables, references).

• If you have any questions, or are interested in assistance and/or collaboration with an experienced SMA user please contact us at propose@sma.hawaii.edu.
Proposing Starts Here

To propose and execute SMA observations, an SMA project account is required (SMA Observer Center account holders can use their usual login information)

Create a new SMA project account

If you require an SMA Staff account, contact sma_oc [at] sma [dot] hawaii [dot] edu

Username: 
Password: 

Log in
If You Need Help…
or just have a Question

Questions regarding proposal feasibility and preparation, potential collaboration or technical help? Questions regarding the SMA Observer Center, problems with tools or proposal submission?

Contact us at propose@sma.hawaii.edu

We are available to provide advice and help
http://sma1.sma.hawaii.edu

Proposal Deadline: 14 Sep 2011
<end>
why night is better

Typical diurnal atmospheric phase noise variation over 4 days
The MIR Cookbook

Chunhua Qi
email: cqi at cfa.harvard.edu

March 4th, 2010

A pdf version of this document is available here

A pdf version of 2 pages cheatsheet is available here

The latest MIR package is located here

SMA Data Errors and MIR Fixes are summarized here