Expectation from radio community

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The University of Tokyo
Now ALMA is a reality

Thanks to the strong support from Astronomical Society of Japan

• Producing more compelling, exciting outcomes is the first priority of our community

• How can we exploit the unprecedentedly high capabilities of ALMA?
  – ALMA is not very suited for wide-area surveys
  – Early science papers are often based on wide-area survey data using single dish telescopes

➤ survey telescopes are essential
Survey telescopes for ALMA operated by NAOJ

Band 1,2,3,(4)

North

Band 1,3

South

Band 6, 7, 8, [9], 10, “11”

Frequency
Survey telescopes for ALMA operated by NAOJ + EAO

North
- NRO 45m
- Band 1, 2, 3, (4)

South
- Mopra 22m
- Band 1, 3

Band 6, 7, 9

Band 6, 7, 8, [9], 10, “11”
SCUBA-2 Imaging Exploration of the Epoch of Reionization: “SIXER” project

• A wide, medium-deep 850μm extragalactic/cosmological survey
  – Area: 33 deg²
    • >> wider than existing confusion limited deep mm/submm surveys using AzTEC, LABOCA, SCUBA2 etc.
  – Depth: 3 mJy/beam (1σ)
    • 10× wider and 3× shallower than existing SCUBA2 Cosmology Legacy Survey (S2CLS)
  – will unveil ~300 bright submm sources
  – Synergies with HSC wide/deep surveys & SPIRE surveys (HerMES) ➔ unveiling z>4 dusty population

Yoichi Tamura et al.
SIXER occupies a unique parameter space especially for $z > 4$
SIXER occupies a unique parameter space especially for \( z > 4 \)
Proposed survey fields & synergies with HSC/Subaru, Herschel, Spitzer, & JVLA

<table>
<thead>
<tr>
<th>coordinate</th>
<th>Area (deg²)</th>
<th>ALMA</th>
<th>HSC-Deep</th>
<th>HerMES</th>
<th>SWIRE/SERVS</th>
</tr>
</thead>
<tbody>
<tr>
<td>XMM-LSS</td>
<td>02h22m -04°30’</td>
<td>10.0</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>ECDF-S</td>
<td>03h32m -28°20’</td>
<td>8.5</td>
<td>yes</td>
<td>--- †</td>
<td>yes</td>
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<tr>
<td>E-COSMOS</td>
<td>10h01m +02°15’</td>
<td>7.0</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
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<tr>
<td>ELAIS-N1</td>
<td>16h11m +55°00’</td>
<td>9.4</td>
<td>---</td>
<td>yes</td>
<td>yes</td>
</tr>
</tbody>
</table>

† ~3 deg² overlap with the HSC-Wide layer
FIR properties of quasar host galaxies: synergy with HSC-Deep layer

- Many quasars will be uncovered by HSC-Deep layer surveys ➔ stacking analysis will be very powerful!

<table>
<thead>
<tr>
<th>log ((L_{\text{Bol}}/L_{\odot}))</th>
<th>10</th>
<th>10.5</th>
<th>11</th>
<th>11.5</th>
<th>12</th>
<th>12.5</th>
<th>13</th>
<th>13.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>log ((L_{\text{FIR}}/L_{\odot}))</td>
<td>11.1</td>
<td>11.2</td>
<td>11.3</td>
<td>11.4</td>
<td>11.6</td>
<td>11.7</td>
<td>11.9</td>
<td>12.0</td>
</tr>
<tr>
<td>(S_{850\mu m}) (mJy)</td>
<td>0.21</td>
<td>0.26</td>
<td>0.33</td>
<td>0.42</td>
<td>0.66</td>
<td>0.84</td>
<td>1.3</td>
<td>1.7</td>
</tr>
<tr>
<td>Number of QSOs</td>
<td>18480</td>
<td>16170</td>
<td>9240</td>
<td>6930</td>
<td>4620</td>
<td>2310</td>
<td>693</td>
<td>69</td>
</tr>
<tr>
<td>Stacked 1σ noise (mJy)</td>
<td>0.022</td>
<td>0.024</td>
<td>0.031</td>
<td>0.036</td>
<td>0.044</td>
<td>0.062</td>
<td>0.11</td>
<td>0.36</td>
</tr>
<tr>
<td>Expected S/N ratio</td>
<td>9.5</td>
<td>11</td>
<td>11</td>
<td>12</td>
<td>15</td>
<td>14</td>
<td>12</td>
<td>4.7</td>
</tr>
</tbody>
</table>

Table: expected number of quasars as a function of bolometric luminosity and resultant 850μm detectability
SIXER is an open collaboration among Japan, Taiwan, UK, etc.

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(sub)mm VLBI with EA telescopes?

- 1mm VLBI experiment using SPART 10m (@Nobeyama) - JCMT 15m (@Mauna Kea)
  - 6,000 km baseline → fringe spacing = 40 μ-arcsec
  - ~3 hours durations for Sgr A* → QPO from acc. disk?

Maezawa et al. (Osaka Pref. Univ.)
Beyond JCMT
Large scale future missions discussed in Japan Radio Astronomy Forum Symposium

Jan. 27-28, 2015 @NAOJ, Mitaka

- Long-term ALMA development
  - Discussion with Taiwan, Korea
- (LiteBIRD)
- SKA
- Antarctic THz telescope
- Next generation large mm/submm survey telescope

Deeper, wider

Ultra-deep, very high resolution

By Oguri & Takada

Deeper

shallow

wider

narrower
Frontiers for mm/submm surveys


@z=2, T_{dust}=35K

Different at z>4

confusion??

SPT
θ~1 arcmin

S/H-ATLAS
36 arcsec

1,700

Star formation rate [M_{\odot}/yr]

170

17

10^{11}

10^{13}

Luminosity [L_{\odot}]

Shallower

Deeper

Narrower

Wider

Survey area [deg^2]

ALMA

Kohno+

Dunlop+

Scott 850 μm

LABOCA 870 μm

BOLOCAM 1.1 mm

AzTEC 1.1 mm

MAMBO 1.2 mm

SPT 1.4 mm

SPIDER 500 μm

BLAST 500 μm

SCUBA 850 μm

※Different at z>4

※confusion??

FIR luminosity [L_{\odot}]

(1σ)

(1σ)

LARGE SUBMILLIMETER TELESCOPE

- LARGE APERTURE (D = 50 m)
- WIDE FIELD OF VIEW (Φ > 0.5 deg)
- SUBMM/MM FREQUENCY BAND
- SURVEY-ORIENTED

Mm/submm ultra wide band spectrograph
MOSAIC

Deshima
Deep Spectroscopic High-z Mapper
(Endo et al. 2011)

- 325 – 905 GHz
- 6 beams
Issues

• Intimate communication between EAO, NAOJ, and the community is essential for optimization/prioritization of resource
  – There exist a wide range of opinions
• How to realize “ESO-like organization”
  – Not to just maintain observatories
  – To build up EA-lead ambitious next generation facilities!
  – What is the next move then?