Cosmic Origins
from alcohol to life

1) Star formation in GMCs and Galaxies ...
2) Spectral Complexity versus Physical Reduction
3) The view from the high-z universe
4) Developing the Future of ALMA now
SFR Correlations

Heiderman's talk (and others)
• Copious line emission is possible once gas reaches 20 K!
  • When does line emission = a hot core?
  • Are there molecules that definitely require significant ice melting to exist in gas phase?

• Chemical differences are interesting
  - Templates?

• Don’t be scared by complexity!
  • Look for more than you expected = it’s interesting!
  • Support the labs, modelers, tool makers!

• Do you really get all this for free?
## Sample Correlator Modes for Early Science

<table>
<thead>
<tr>
<th>Mode</th>
<th>BW per sideband</th>
<th>Channels per sideband</th>
<th>Velocity Res. (km/s) 230 GHz</th>
<th>Min. Integration**</th>
</tr>
</thead>
<tbody>
<tr>
<td>7 (dual)</td>
<td>2 x 2 GHz</td>
<td>2 x 4096</td>
<td>0.64</td>
<td>5 sec</td>
</tr>
<tr>
<td>12 (dual)</td>
<td>2 x 62.5 MHz</td>
<td>2 x 4096</td>
<td>0.02</td>
<td>5 sec</td>
</tr>
<tr>
<td>13 (cross)</td>
<td>2 x 2 GHz</td>
<td>2 x 2048</td>
<td>1.28</td>
<td>5 sec</td>
</tr>
<tr>
<td>18 (cross)</td>
<td>2 x 62.5 MHz</td>
<td>2 x 2048</td>
<td>0.04</td>
<td>5 sec</td>
</tr>
<tr>
<td>70 (cross)</td>
<td>2 x 2 GHz</td>
<td>2 x 64</td>
<td>40.8</td>
<td>0.1 sec</td>
</tr>
</tbody>
</table>

*** Estimated minimum integration times for 50 antennas and maximum data rate of 64 MB/sec

Early Science might be a great time for line surveys!
Large Area Surveys - II

- Requires: Increasing the field of view or increasing the mapping speed (or both)
  - Increasing field of view = Focal Plane Arrays (FPAs):
    - Most radio telescopes only utilize a fraction of the available focal plane. The usable size depends on the exact optics of the telescope.
    - Number of pixels to fill focal plane increases as frequency
    - Number of correlations = data rate required scales as the number of pixels \( \times \frac{N(N-1)}{2} \) where \( N \) is the number of antennas

- Increasing mapping speed = on-the-fly (OTF) mapping. Requires short integration times = high impact on data rate and compute power

Examples:
- ALMA – OTF map of 1 square degree in CO(3-2) in 50 hours would require \(~2\times\) the current maximum data rate (64 MB/s). Raw data \(~20\) TB. Image would have 100 Mpixels per channel!
- GBT – 100 GHz FPA with 100 pixels, footprint=4 arcmin. To cover 1 square degree in \( N_2H^+ \) (93.1 GHz) takes \(~10\) hours. The data rate would be 0.26 GB/s (32x the current spectrometer) and the cube would be \(~10\) TB in size. \( \Rightarrow 1\) TB/hour!

• Biggest Challenges: Archiving, Data analysis, and Visualization
Spectral Line Surveys

• Spectral lines are critical tools for probing physical conditions, understanding astrochemistry, and discerning the chemical building blocks of life
  – Requires: wide bandwidths plus high spectral and angular resolution. Many diagnostic lines observed simultaneously, removing calibration uncertainties and increasing science throughput.
  – Data rates of ~1 GB/s are required

• ALMA – Wide bandwidth (8 GHz/pol), but baseline peak data rate (64 MB/s) utilizes ~6% of correlator capability (1 GB/s). Restricted by network hardware, ability to process and archive.
  ➢ Processing 1 GB/s will require ~1000 CPUs

• EVLA – Similar baseline data rate, but with capacity for 1 million channels (30x ALMA)
  ➢ 1 GB/s will require 1000s of CPUs to process. Capable of 32 GB/s!

• 2 GHz of bandwidth toward a massive star forming region (Brogan et al. in prep.)

• Biggest Challenges: Data rate, Processing, Analysis and Visualization
Pre-stellar Low Mass Cores

Bergin & Tafalla 2007 and references therein

Beuther et al. 2009
High-redshift CO studies

ALMA will be able to observe several CO J transitions for high-z sources but... will miss the CO(1-0) transition for all but $z<0.4$ galaxies!

Peak galaxy formation epoch: $1<z<3$

CO(1-0) gives you a measure of the total cold gas reservoir available to fuel star-formation

eVLA can get CO(1-0) for high-z galaxies (but only more northern sources) - is adding Bands 1 & 2 on ALMA a possibility? wanted? a priority?

Figures from Walter & Carilli 2007
ALMA Development

- ALMA partners invite Proposals for Studies relevant to the ALMA Development Plan with the aims of
  - Providing opportunities for groups within the regional partnership an opportunity to propose upgrades which may be implemented as part of the ALMA Development Plan
  - To support development of conceptual and detailed designs for upgrades
  - To encourage relevant long-term research and development
- Limited funding available to support groups for the studies, allocated competitively.
- NRAO will issue a Call for Studies soon with the expectation that funding will start this year.
- NRAO will engage the community strongly in ALMA Development, beginning with these Studies. Studies are solicited which
  - Directly enhance scientific capabilities of ALMA by enabling new science
    - Enhanced data throughput (e.g. increasing data rate or pipeline efficiency
    - New Receiver Bands (7mm, 4mm, superTHz, improving or expanding existing bands)
    - Improvement of the System (correlator enhancement, LO improvements, VLBI capability)
  - Indirectly enhance the scientific capabilities of ALMA
    - improving data analysis tools,
    - operations efficiency, or
    - calibration.
Early Science

Configurations for ES?
ALMA offers quasi-unique opportunity for
  • High frequency imaging of the southern sky
    • At 690 GHz primary beam is ~9”—extended sources different to image
    • Long tracks on short baselines result in shadowing.
  • Detection of water emission obscured from less transparent sites
Band 7 (275-373 GHz/1.1-.8mm)
Comparison with IRAM 30m