The Science Case for Band 1 (31-45 GHz)

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Based on `The Science Case for Building a Band 1 Receiver for ALMA'
Johnstone et al. - Astro-Ph

Band 1 Characteristics

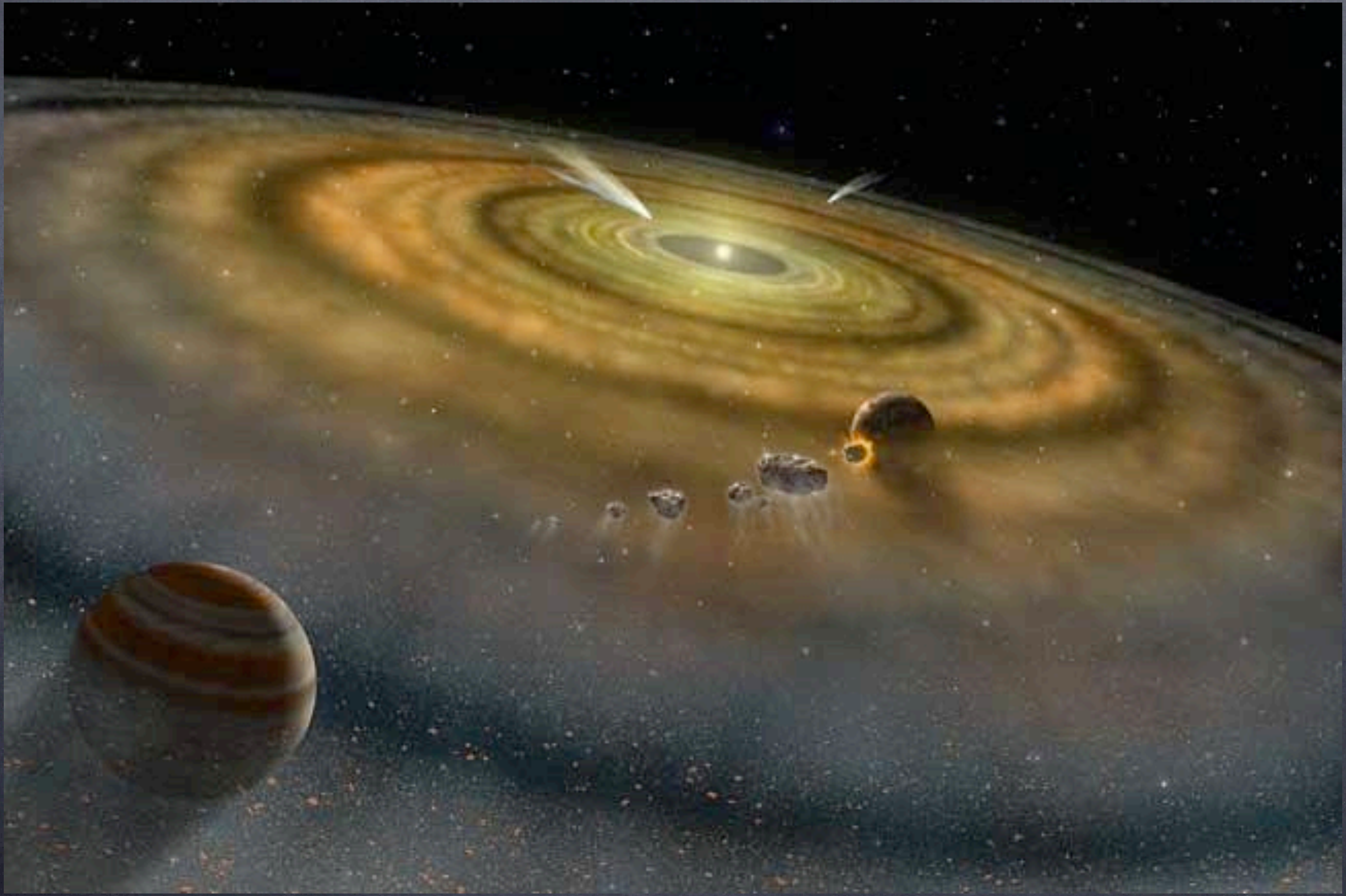
- frequency range -> 31-45 GHz
  - what drives these limits scientifically?
- 8 GHz instantaneous bandwidth
  - excellent for continuum studies
- angular resolution down to about 0.1″
- velocity resolution down to about 0.1 km/s

Equivalent to Level 1 Science Goals

- Evolution of grains in protoplanetary discs
  - as a complement to gas kinematics
- Detection of the CO 3-2 line in distant Galaxies
  - probing the era of re-ionization ($6.5 < z < 10$)

Level One Science:

Evolution of Grains in Discs



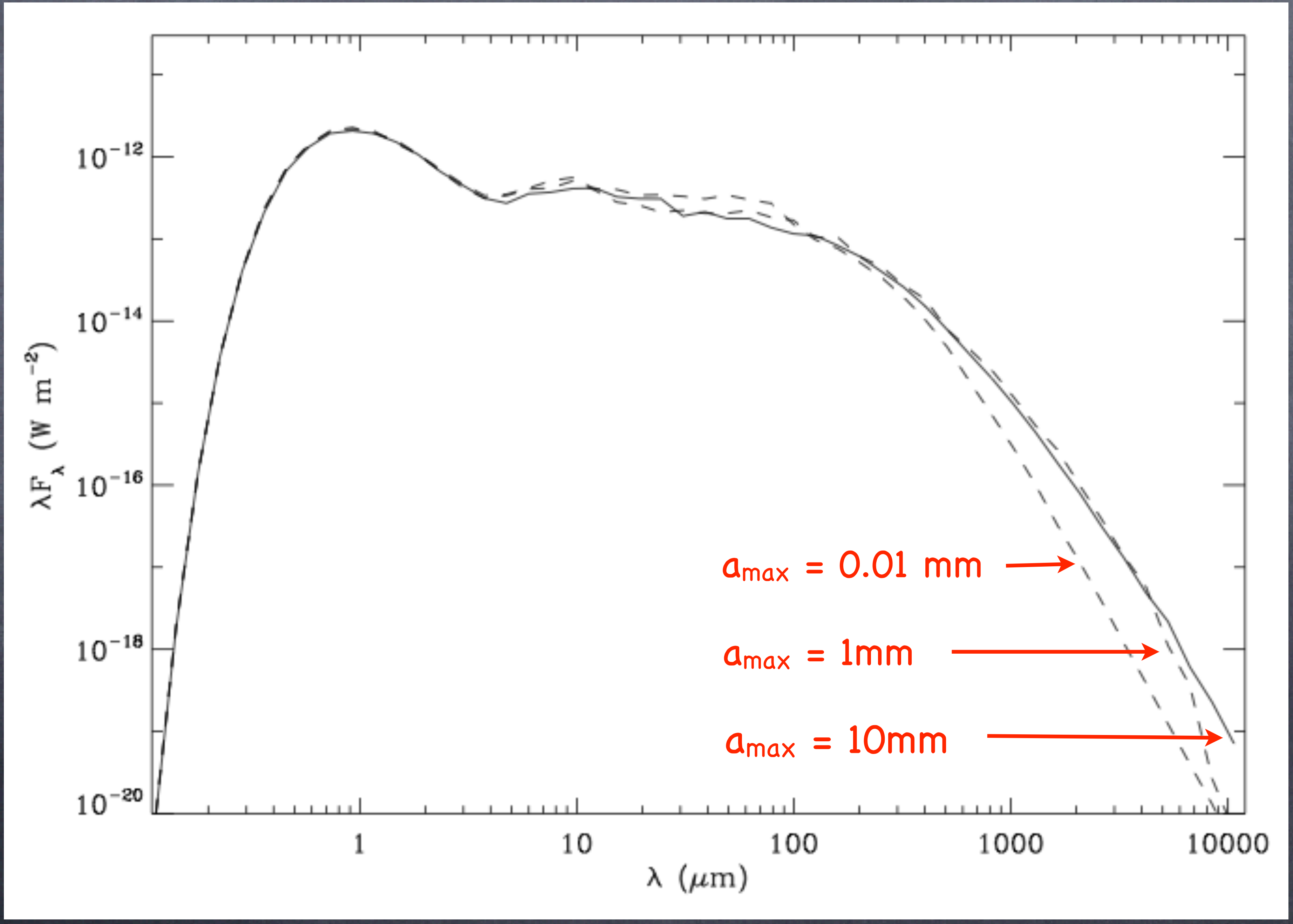
Level One Science:

Evolution of Grains in Discs

- Planet formation takes place in disks surrounding young stars
- To form terrestrial planets dust grains must agglomerate from ISM sizes to planetesimals
- Larger dust radiates more efficiently at longer wavelengths -> Band 1
- The timescale for this grain growth appears to be between 1-10 Myrs

SED for 3 Disc Models

changing only maximum grain size



Level One Science:

Evolution of Grains in Discs

- Band 1 follows grain growth through cm-sizes
  - with Band 3,4 etc yields dust emissivity index
- Band 1 can resolve nearby discs ~ 10's AU scale
- Band 1 observations will also help disentangle the contribution from free-free emission

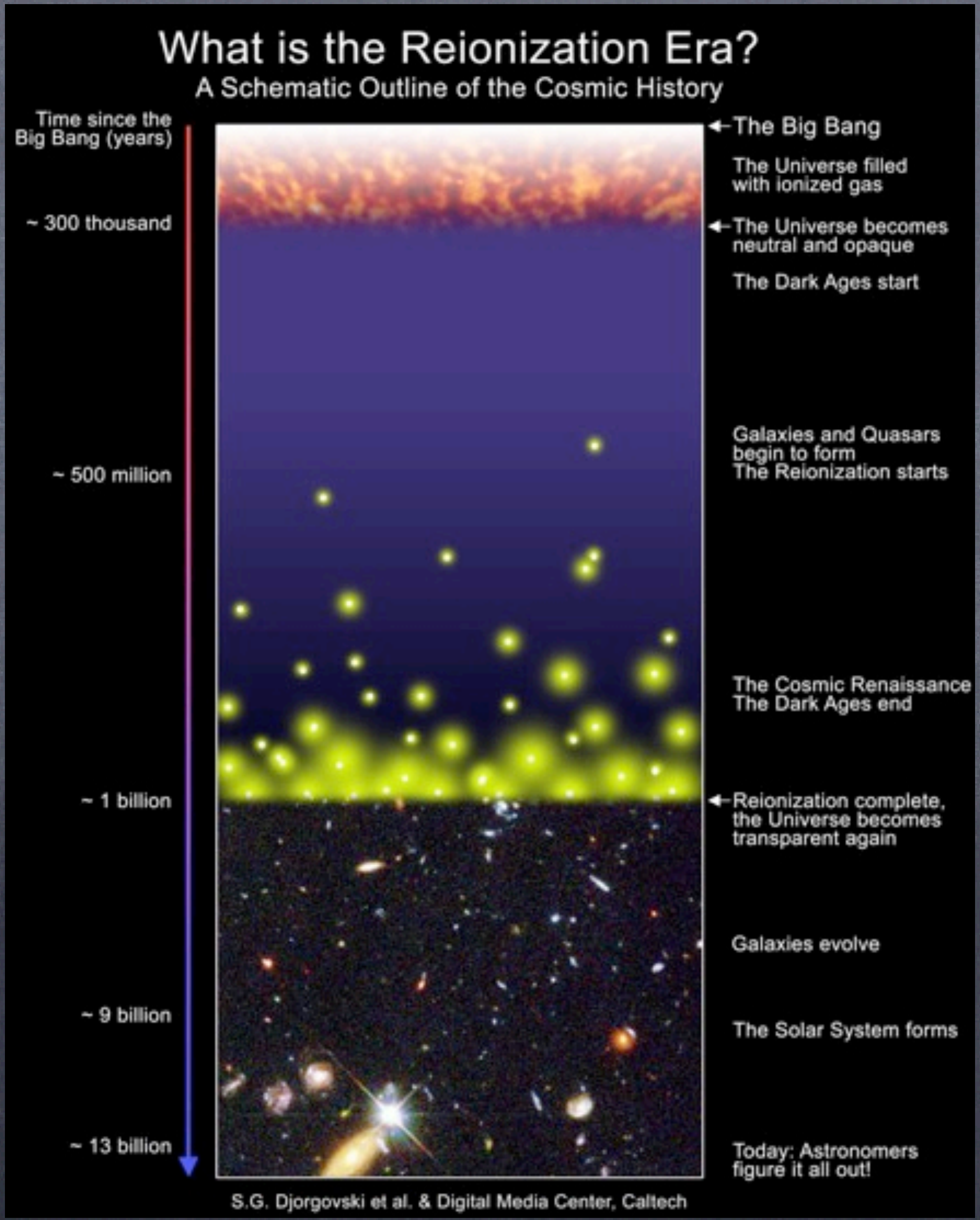
Level One Science:

Evolution of Grains in Discs

- For older Debris Discs the grains are being eroded to smaller sizes
- Larger grains have longer resonant lifetimes and thus are better probes of structure
- Many debris discs close to the Sun
    - therefore subtend large areas on the sky
    - large ALMA primary beam very helpful
        - also the ACA will be instrumental

Level One Science:

First Generation of Galaxies



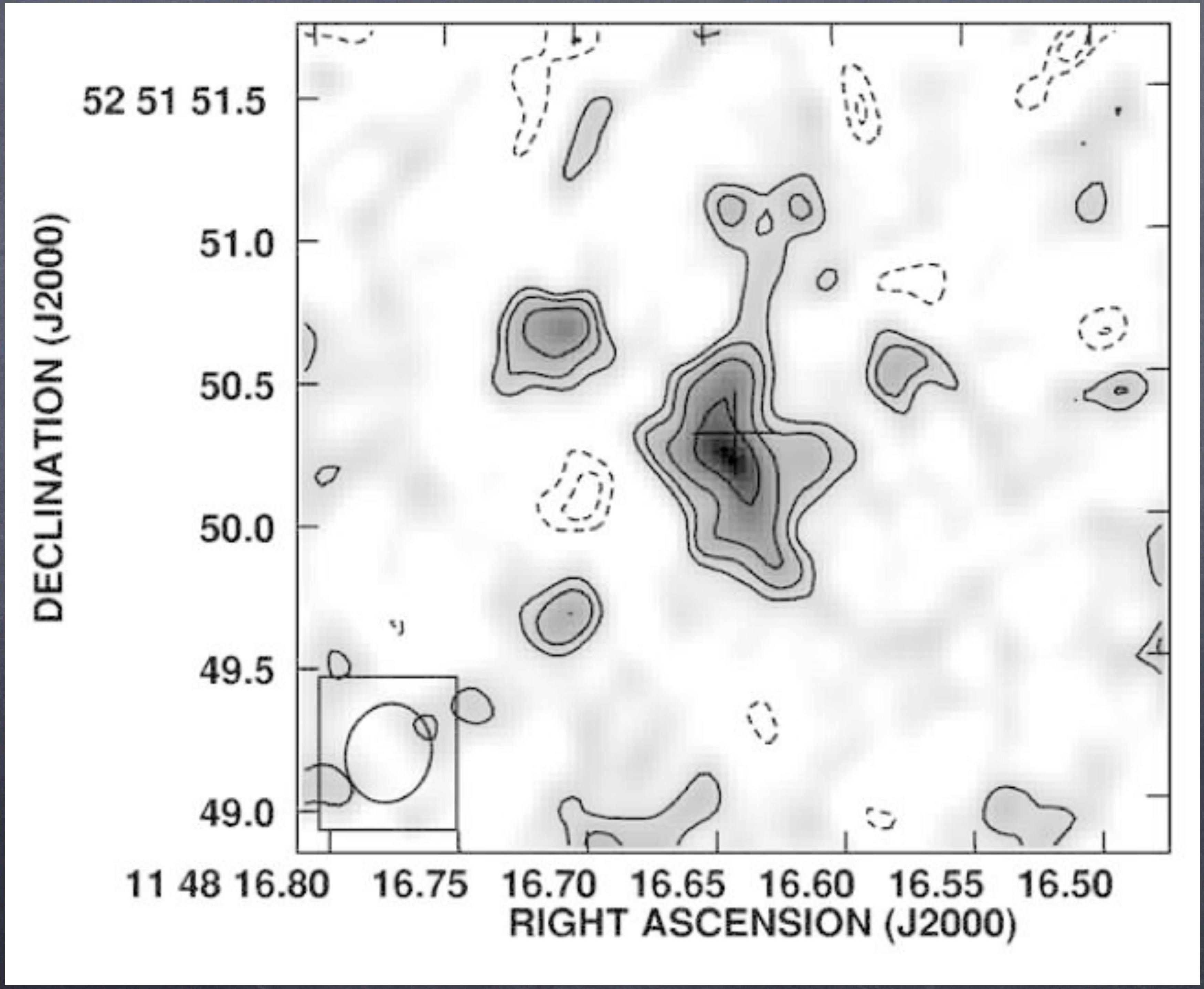
Level One Science:

First Generation of Galaxies

- the first generation of Galaxies began the re-ionization of the Universe
- it appears the Universe was re-ionized by about $z = 11 \pm 1.4$
- the 'near' edge of re-ionization has been inferred to be at $z > 6$
- thus, lots of interest in studying $6 < z < 11$
  - nominal Band 1 -> $6.5 < z < 10$

VLA Image of a Quasar

J1148+5251 CO 3-2 at z = 6.419



Walter et al. 2004

Level One Science:

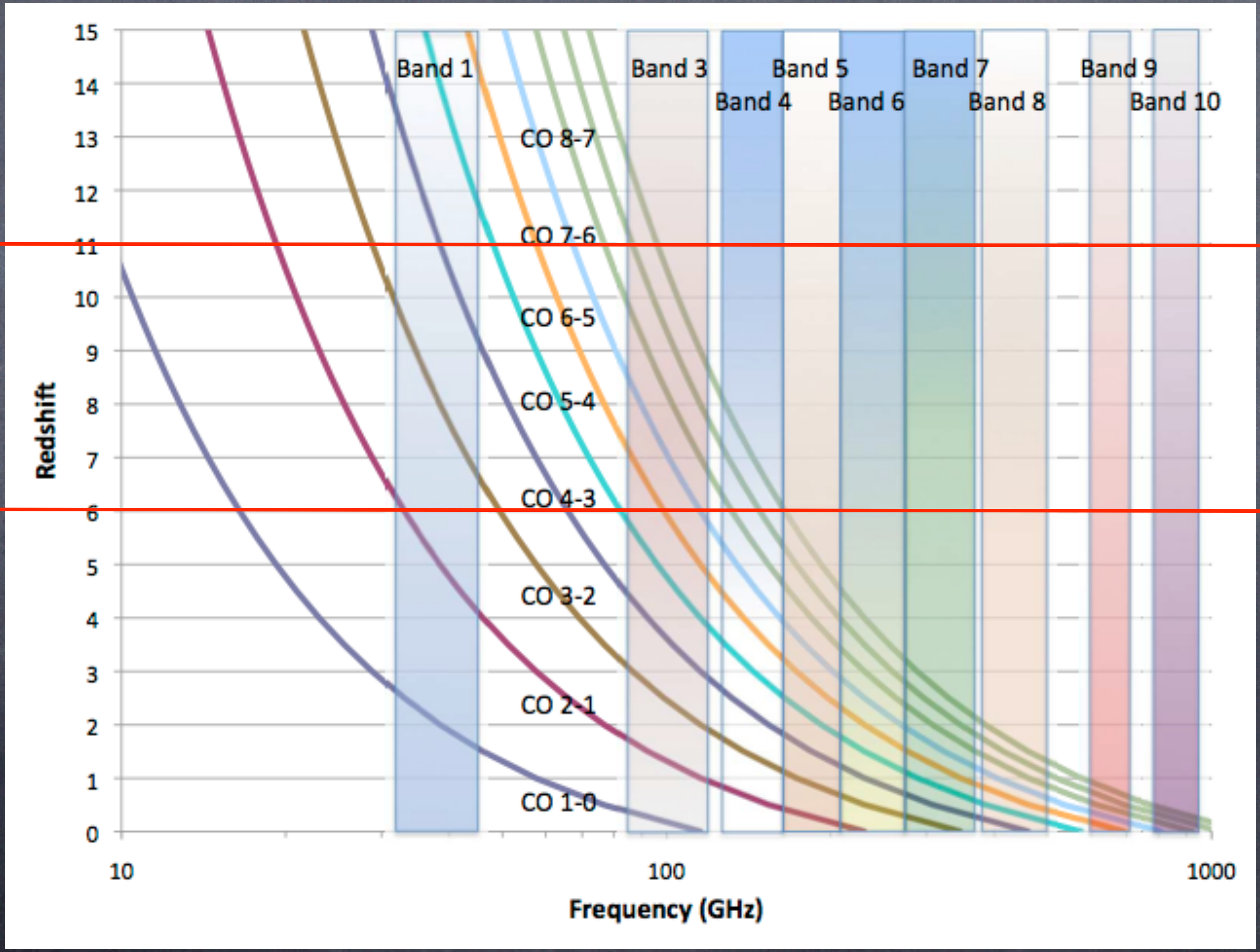
First Generation of Galaxies

- Band 1 is very well suited for CO 3-2 measurements over this redshift range
  - might want to push to even higher frequencies ~ 50 GHz (to get $z \approx 6$)

ALMA CO coverage vs z

observed frequency of ^{12}CO

Zone of Re-ionization



Zone of Re-ionization

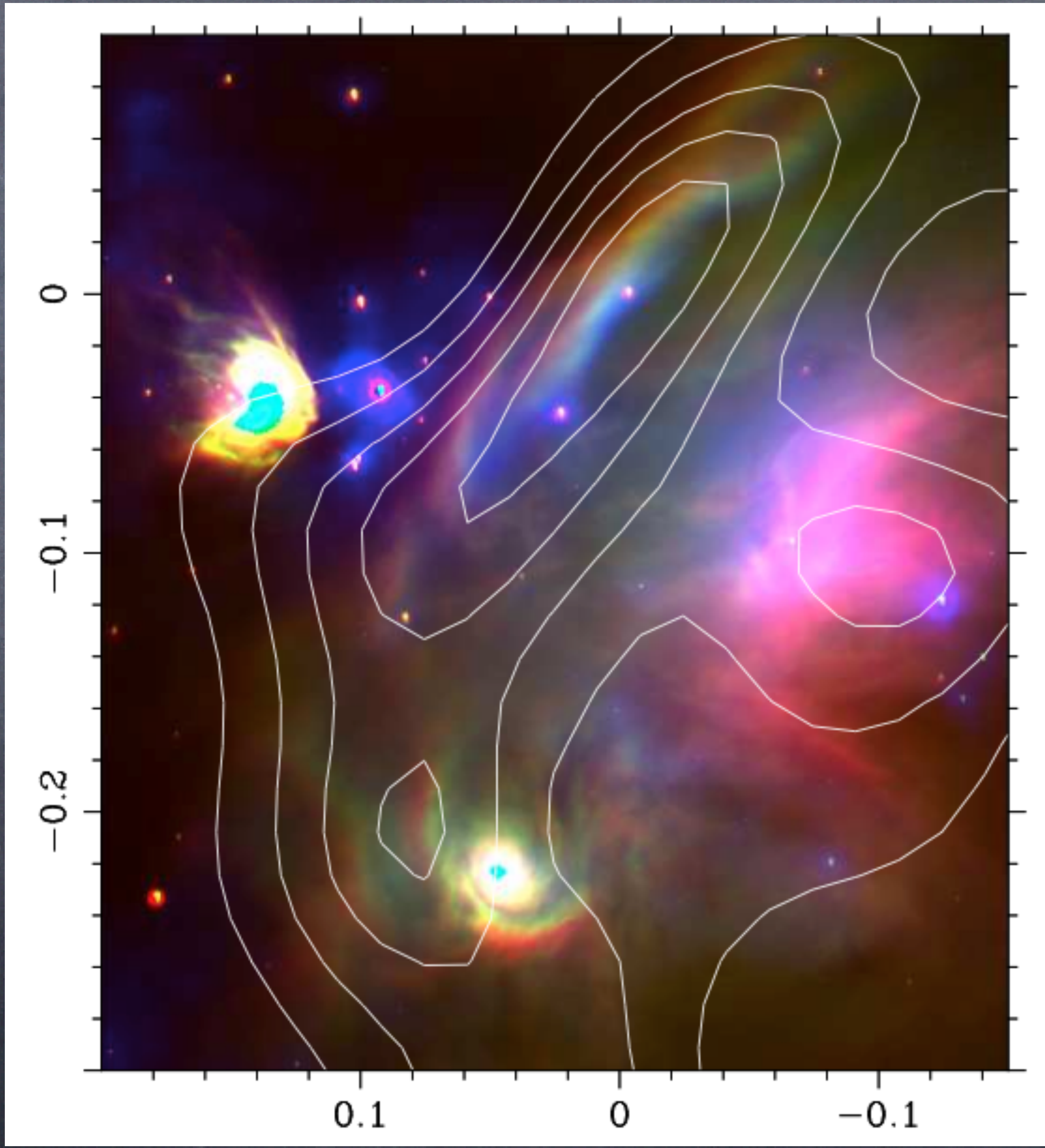
A Broad Range of Science

1) Continuum Observations

- very small grains (PAHs and other carbon sinks)
  - can be made to spin and therefore radiate
  - spectrum peaks between 30-40 GHz
  - excellent way to examine this dust component
- pulsar wind nebulae, supernovae, X-ray binaries
  - synchrotron emission from relativistic particles
- young stellar jets
  - free-free emission from dense ionized gas

Emission from Spinning Dust

Oph PDR (Red MIPs, Green IRAC, Blue 2mass, Contour 31GHz)



Casassus et al. 2008

A Broad Range of Science

2) Molecular Line Diagnostics

- chemical differentiation
  - ability to spatially resolve heavy molecule condensations in dark clouds
  - ability to spatially resolve molecular outflows from young stars
- maser diagnostics
  - need to probe range of conditions - large frequency range
  - two excellent maser candidates are SiO and CH_3OH
- magnetic fields through Zeeman measurements
  - CCS line at 33 GHz is considered optimal for this
- molecular gas content in AGN at high redshift
- star-forming galaxies at redshift $z \approx 2$

Sample Molecular Line List

Molecular Transitions between 34 and 49 GHz (ALMA Band 1: 31–45 GHz).

CH_3CCH	2–1	34.183414 GHz
HC_5N	13–12	34.614386 GHz
SO	2_3–2_2	36.202040 GHz
HC_3N	4–3	36.392332 GHz
HCS^+	1–0	42.674205 GHz
HC_5N	17–16	45.264721 GHz
CCS	4_3–3_2	45.379033 GHz
HC_3N	5–4	45.490316 GHz
CCCS	8–7	46.245621 GHz
C_3H_2	2_{11}–2_{02}	46.755621 GHz
$C^{34}S$	1–0	48.206956 GHz
CH_3OH	1_0–0_0	48.372467 GHz

A Broad Range of Science

3) Sunyaev-Zel'dovich

- clusters of Galaxies contain hot inter-cluster gas
  - CMB photons inverse Compton scatter off this gas
  - characteristic decrement of background emission at radio wavelengths
    - amplitude of depression related to electron pressure in cluster
  - Band 1 has sensitivity to detect SZ from halos around massive galaxies
- Band 1 provides resolution to map sub-structure
  - challenge the models of cluster evolution
  - better understand virialization and hydrostatic equilibrium

Band 1 Characteristics Redux

- frequency range: 31-45 GHz (what drives these limits scientifically?)
    - Galaxies at re-ionization might benefit from a higher ending frequency ~50 GHz
    - but CCS 3-2 at 33 GHz is important for Zeeman measurements and 'young' cores
    - also consider SiO 1-0 (45GHz), CCS 4-3 (45GHz), CS 1-0 (49GHz)

Fin