

Synergy between galaxy formation and cosmology using submillimeter-wave line intensity mapping

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Image credit: Aaron M. Geller, Northwestern, CIERA + IT-RCDS

The Observable Universe

Explore the Universe with Line Intensity Mapping (LIM)

CMB Recombination Dark Ages Cosmic Dawn/ First Stars Reionization Growth of Structure

Inflation

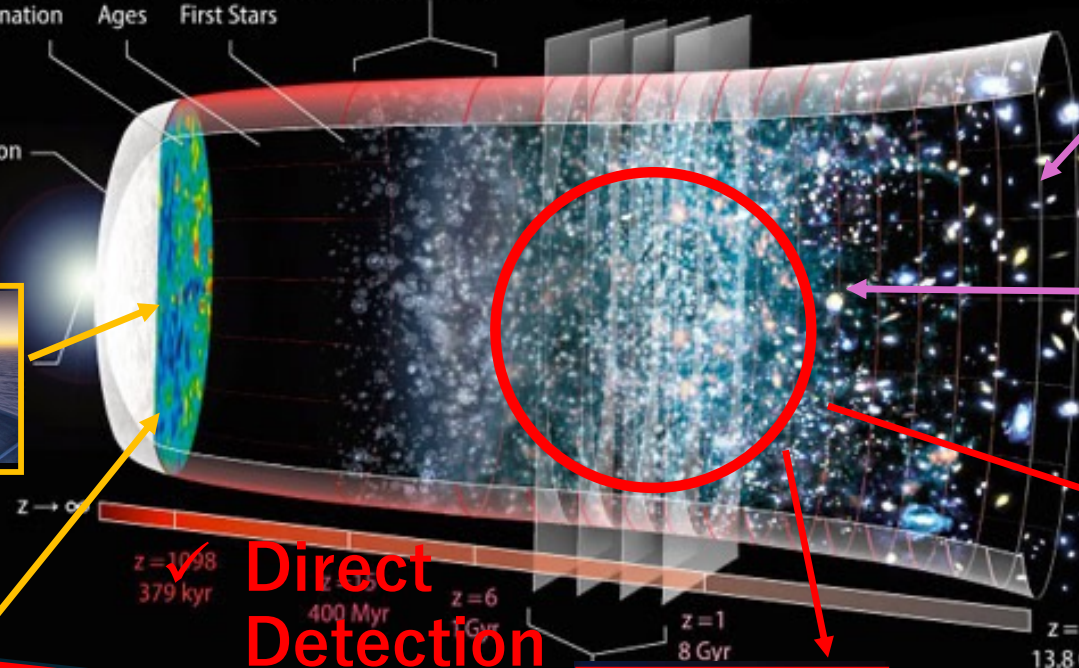
Big Ban



SPT + BICEP



LiteBird



z = 1098
379 kyr

z = 6
400 Myr

z = 1
8 Gyr

z = 0
13.8 Gyr

Direct Detection

Line-Int

Now

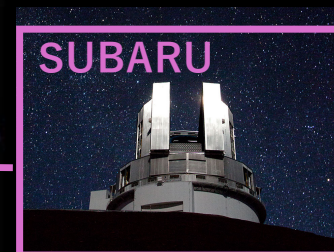
Time

Cosmic ray



CTA

Dark energy/Galaxy survey



SUBARU

✓ Line Intensity mapping



ASTE + TIFUUN

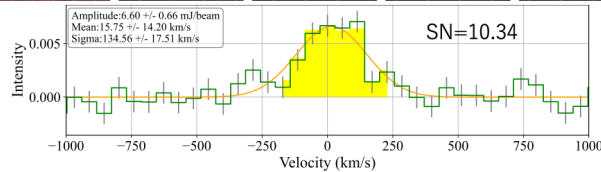
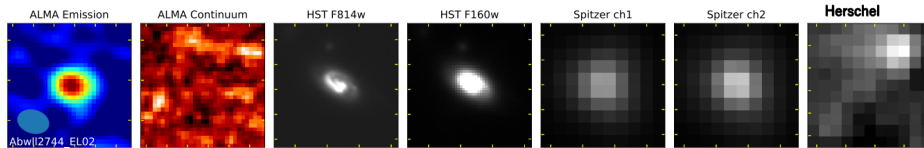
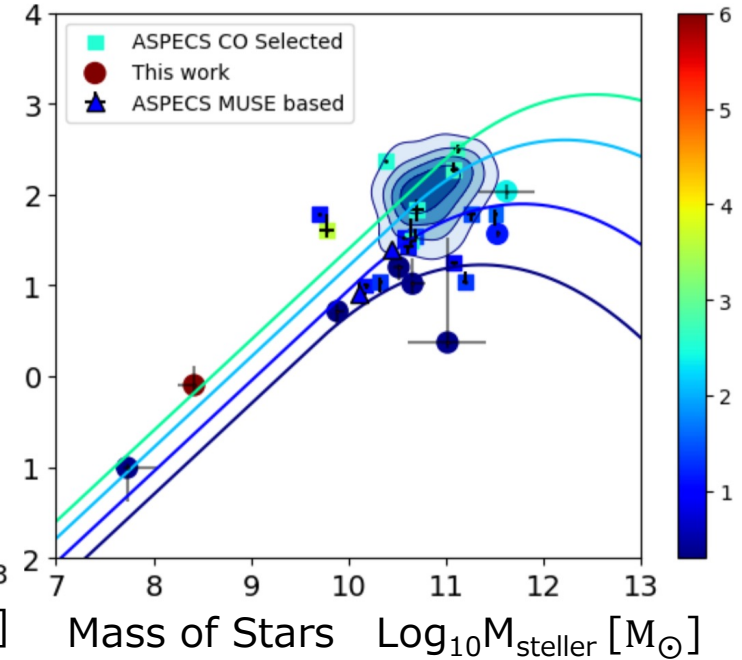
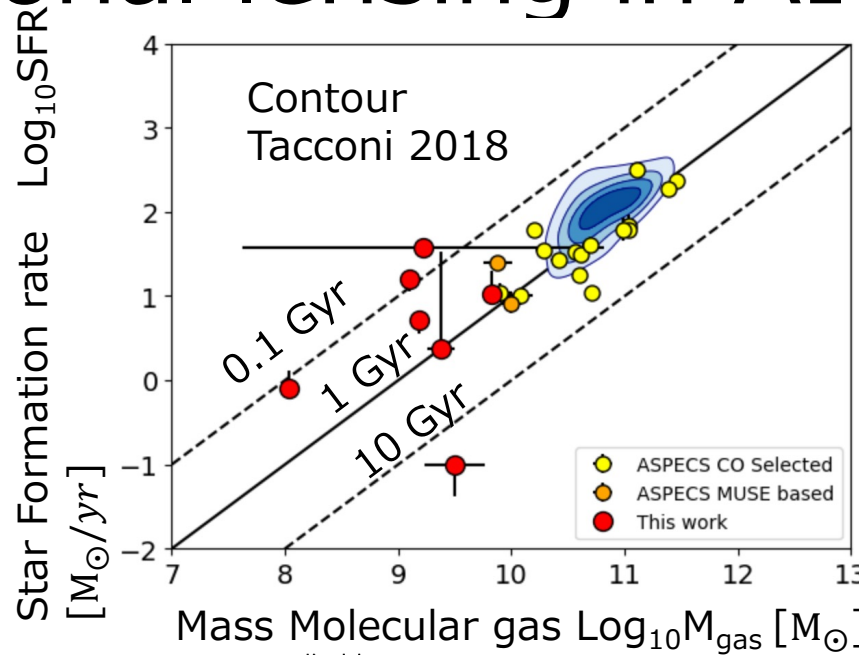
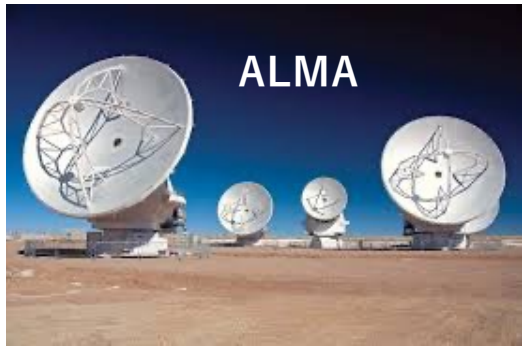


ALMA

Image Credit: NASA / LAMBDA Archive Team 2

Direct detection of galaxies using gravitational lensing in ALMA

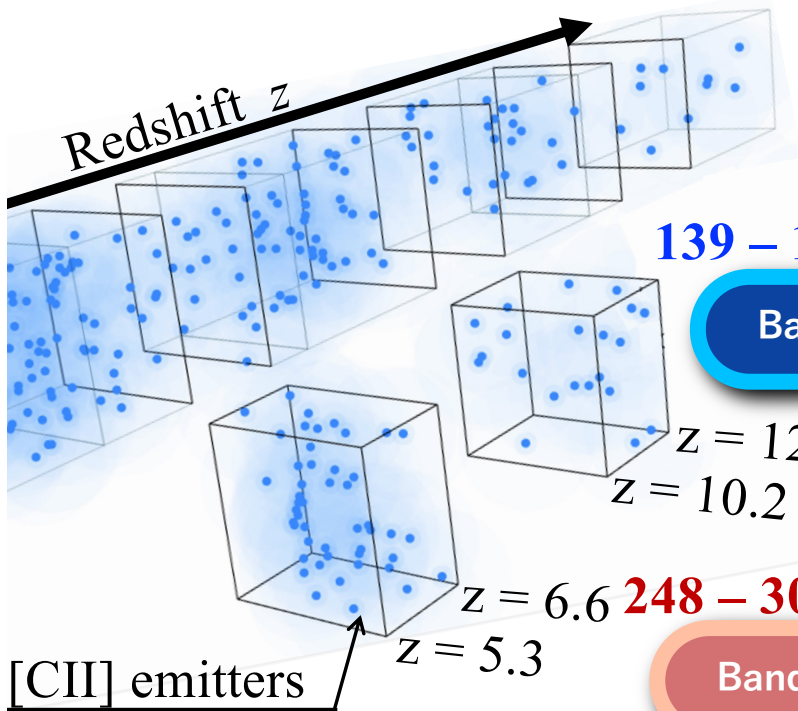
Narita, K., et al., in preparation



The integral intensity map is created by yellow part of the spectrum.

Estimating physical properties of galaxies from multi-wavelength data

Dual-band line intensity mapping using TIFUUN TIFON

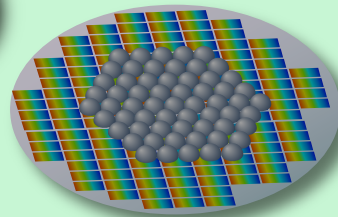


- 100 spaxels x 100 colors (R~500) x 2 bands = 20,000 voxels in total
- Simultaneous observations of line pairs at the same redshift range
 → cross-correlation to mitigate contaminations & systematics

139 – 170 GHz

Band-1

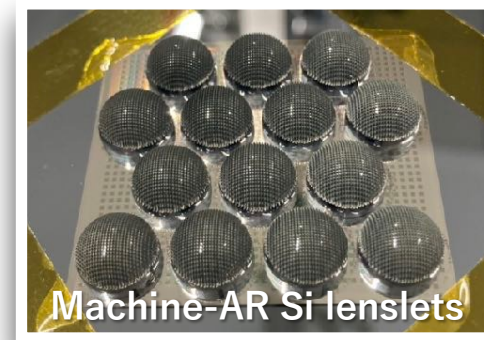
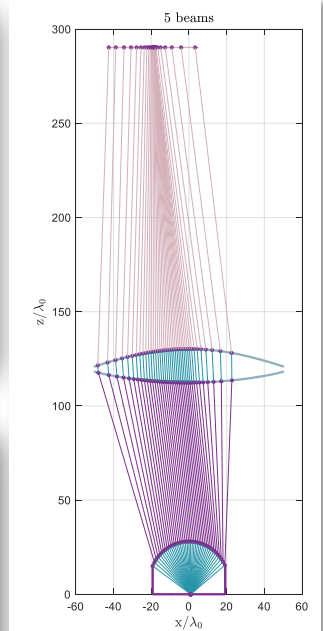
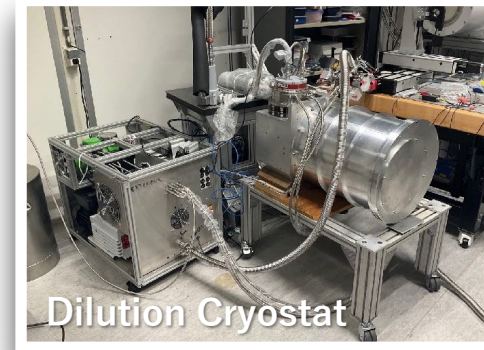
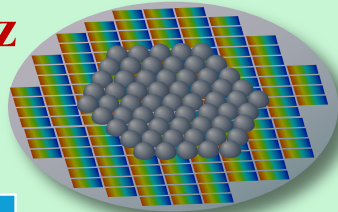
Integral Field Units



$z = 12.6$
 $z = 10.2$

248 – 301 GHz

Band-2



Wideband & Wide FoV optics

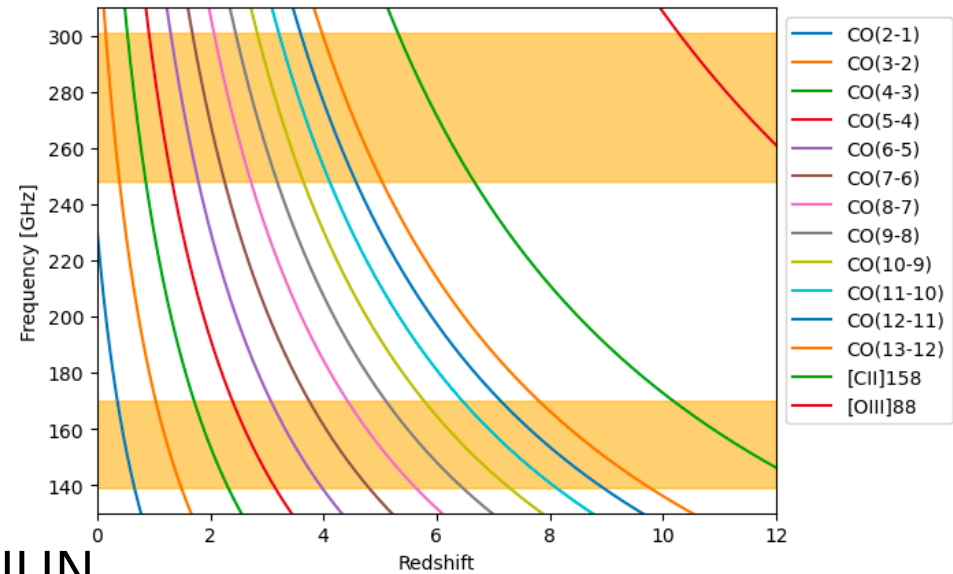
Redshift range	Band-1	Band-2
$z = 10.2 - 12.6$	[CII] 158 μm	[OIII] 88 μm
$z = 1.9 - 2.2$	CO(4-3), [CI](1-0)	CO(7-6), [CI](2-1)

Field of view (@ASTE)
 ~8 arcmin (Band-1)
 ~5 arcmin (Band-2)

Development of analytical methods for intensity mapping observations

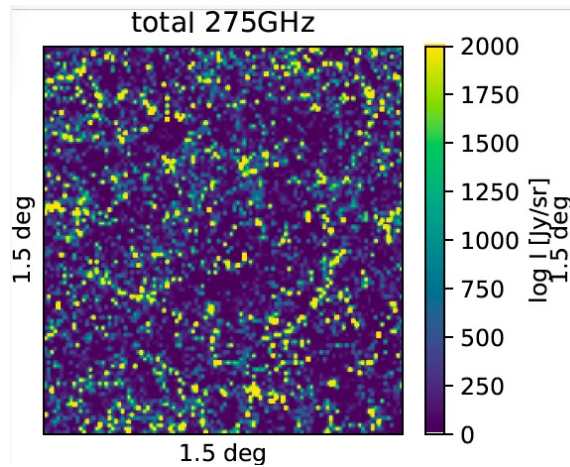
- ✓ Removal of emission lines from foreground galaxies

Dual band detection of foreground line emitters!

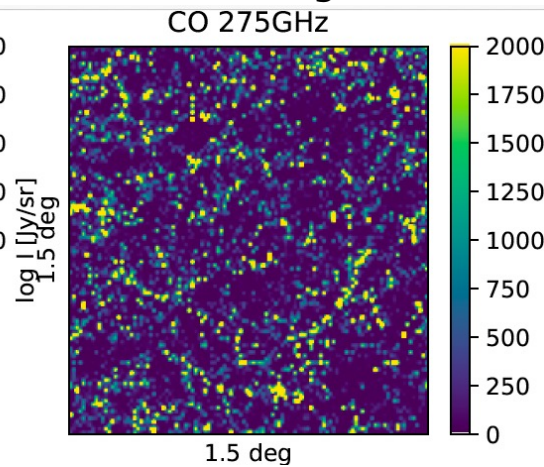


Mock observation in TIFUUN

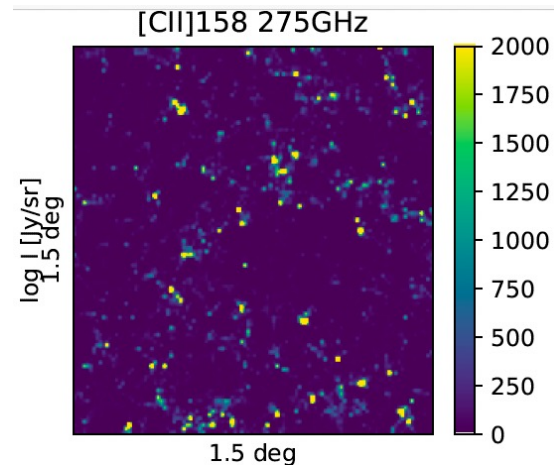
Total Emission lines



Foreground Emission lines from CO galaxies



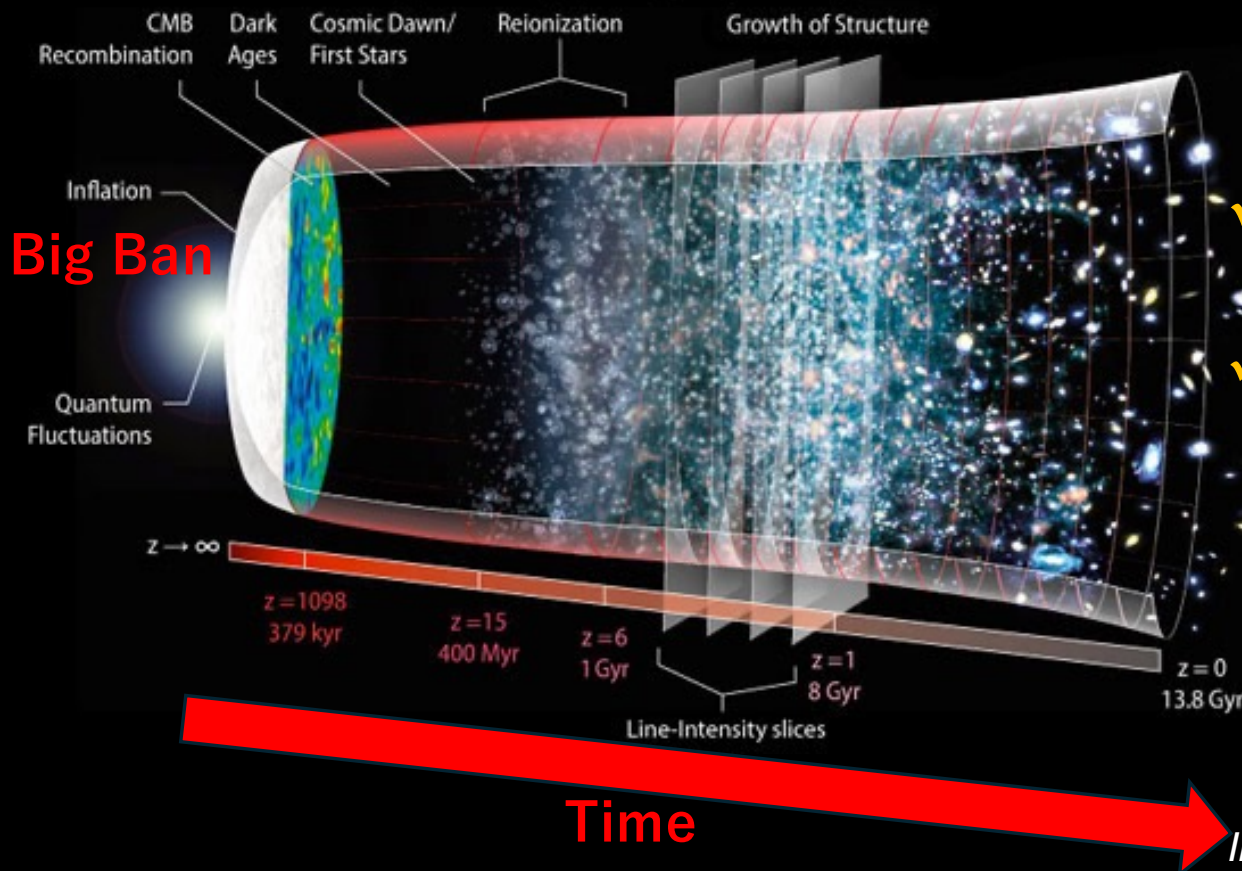
Emission lines from C II galaxies from 12.8 Gyr ago



Back up slides

Universe Mysteries

Explore the Universe with Line Intensity Mapping (LIM)



- ✓ What mechanism drove inflation?
- ✓ What is dark matter?
- ✓ How did the first galaxies and stars form and evolve across cosmic time?

Image Credit: NASA / LAMBDA Archive Team 7