ALMA Science Highlights

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KASI

Goal of Full ALMA Operations

▶ Detect a redshifted [CII] 1.9THz line emission from MW-like galaxies at z=3 within 24h

▶ Image gas kinematics in 1Msun protostellar/protoplanetary disk at 150pc, thus studying physical, chemical, B-field structure of disk and detecting tidal gap by planet formation

→ *Ji-hyun's talk*

▶ Provide "precise" images at 0.1" resolution for all sources with elevation > 20deg
(high image fidelity, inc. zero spacing, DR=1000)

Do Always Gas-rich Major Mergers Lead to Ellipticals?

Cold Molecular Gas in Merger Remnants
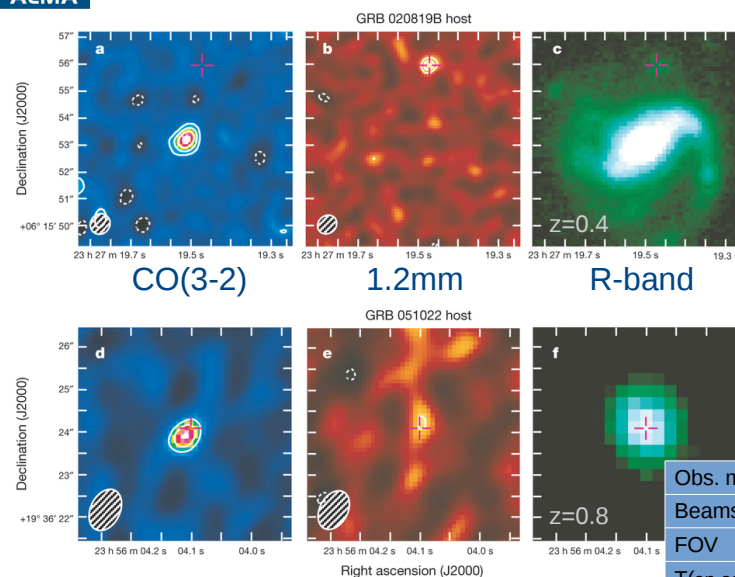(Ueda et al. 2014)
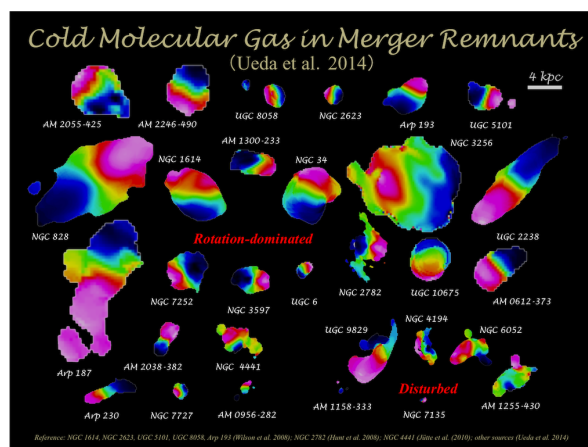
1st moment (velocity) maps

- Sub-kpc scale CO(1-0) survey for optically-selected merger remnants
- 21(39) mergers with ALMA (+CARMA & SMA)
- 80% show rotating molecular gas disk (compact or extended)
- Gas disk formation is very common after gas-rich mergers

Obs. mode	Band3 (115GHz) FDM
Beamsize	1" – 4" (<1 kpc)
FOV	~50"
T(on-source)	7 – 27min
Depth	2-5mJy per 20km/s

Ueda et al. (2014)

GRB Host galaxies

GRB 020819B host

CO(3-2)   1.2mm   R-band

z=0.4

GRB 051022 host
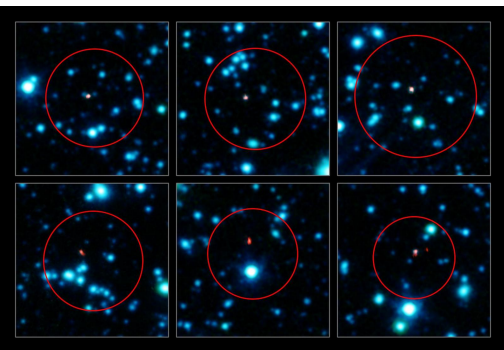
z=0.8

Right ascension (J2000)

- First detection of CO *emission* from GRB hosts
- Gas-to-Dust Ratio:
  G/D > 51-60 (host)
  G/D < 9-14 (site)

Hatsukade et al. (2014)

Obs. mode	Band6 (250GHz) FDM
Beamsize	0.8" – 1"
FOV	~25"
T(on-source)	47 – 71min
Depth	0.04mJy per 7.5GHz

Pinpoint Fuzzy Submm Blobs

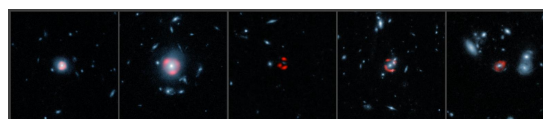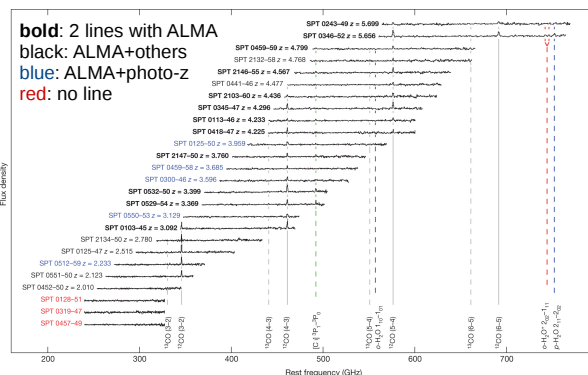red circle: APEX 19" beam
blue: IRAC 3.6um
red: ALMA (1.5")

- Follow-up LESS sources in 870um
- LESS (LABOCA ECDFS Submm): 126 sources from 310h on APEX12m
- Brightest SMGs are splitted into multiple sources
- Serendipitous [CII] detection

Obs. mode	Band7 (344GHz) TDM
Beamsize	~1.5" (LESS: 19")
FOV	17.3"
T(on-source)	2min per source
Depth	0.4mJy (LESS: 1.2mJy)

Hodge et al. (2013), Karim et al. (2013), Swinbank et al. (2013)

Blind Redshift Survey for Strongly Lensed Submm Galaxies

bold: 2 lines with ALMA
black: ALMA+others
blue: ALMA+photo-z
red: no line

- Blind 3mm spectral scan for 26 sources from South Pole Telescope survey
- Determine z distribution
- Multiple lines in 12 sources (23 detected in single)
- More z>4 galaxies (N>10) than previous studies

ALMA 3mm continuum on HST image
Vieira et al. (2013), Weiss et al. (2013)

Obs. mode	Band3 spectral scan 5 tunings: 84-115GHz
Beamsize	(3"x5") – (5"x7")
FOV	45" – 61"
T(on-source)	2min x 5 tunings per source
Depth	1.4mJy per (50 – 65km/s)

Line Detection of Typical galaxies in Proto-clusters at z=5.2
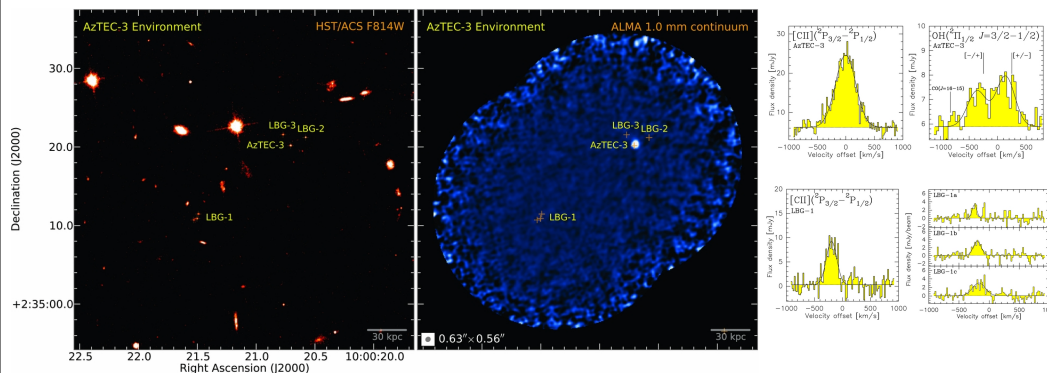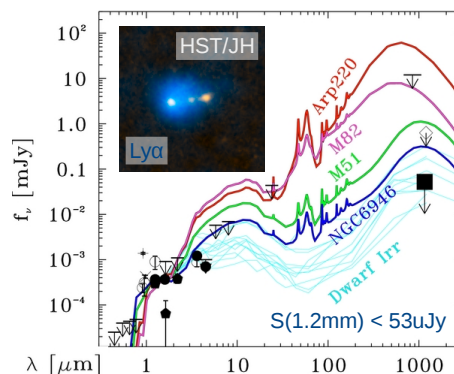

- [CII], OH line observations for a protocluster around SMG AzTEC-3 in COSMOS field
- [CII] detection for AzTEC-3 (starburst) and LBG-1 ("typical" galaxies)

Obs. mode	Band7 (300 GHz) FDM
Beamsize	~0.6"x0.6"
FOV	20" (mosaicking)
T(on-source)	125min
Depth	50uJy per 7.5GHz

Riechers et al. (2014)

Primordial ISM in an infant galaxy

S(1.2mm) < 53uJy

L(CII) < 5.4 10⁷Lsun

- Dust & [CII] observations for a triple merger system, Himiko at z=6.595
- Not detected despite SFR = 100Msun/yr
- Very low dust content or primordial ISM near the end of re-ionization epoch
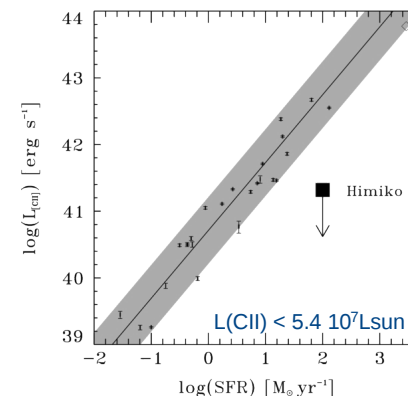
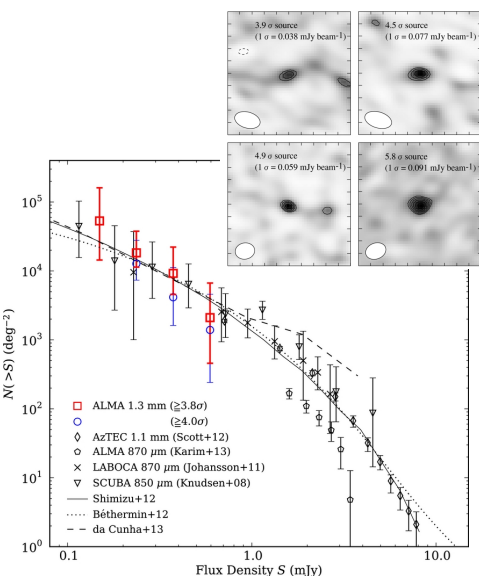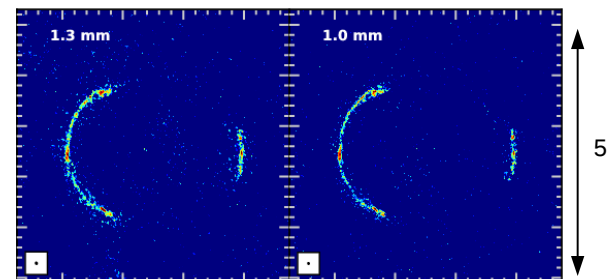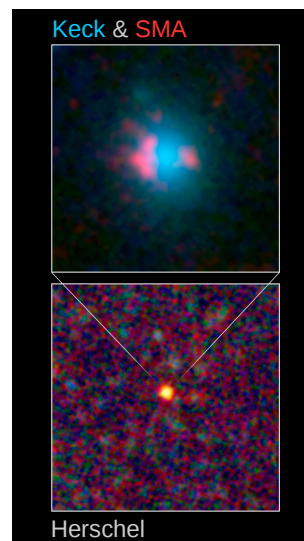| Obs. mode	Band6 (250GHz) FDM
Beamsize	0.6" x 0.8"
FOV	25"
T(on-source)	3.2h
Depth	17uJy per 19.4GHz 83uJy per 200km/s

Ouchi et al. (2013)

Resolve mm cosmic background

- ALMA 1.3mm number counts
- CO(5-4) line survey for 20 z=1.4 galaxies in SXDF
- Serendipitous detection of 15 sub-mJy sources with >0.15mJy
- ~80% of backgrounds are resolved into individual galaxies
- Good ALMA archival projects?

Obs. mode	Band6 (238GHz) FDM
Beamsize	0.6" – 1.3"
FOV	26"
T(on-source)	8 – 15min
Depth	0.04 - 0.10 mJy

Hatsukade et al. (2013), Ono et al. (2014)

Probing ISM in 180pc resolution at z=3

- ALMA Long Baseline Campaign 2014
- Lensed SMG SDP.81 at z=3.04 from H-ATLAS

Obs. mode	Band4/6/7 (151/236/290GHz) FDM
Beamsize	**0.023" – 0.060" (baseline ~15km)**
T(on-source)	5.9h/4.4h/5.6h (for good uv-cov.)
Depth	8/10/10 uJy

ALMA Science Verification Data, Vlahakis et al. (2015), Rybak et al. (2015)

In Cycle 3, ALMA can ...

▶ Resolve molecular clouds in a nearby, star-forming galaxy:
HCN mosaic of the full (4kpc) M83 bar with 30pc resolution **(3hr)**

▶ Study black holes and their environments:
Measure BH mass of NGC4526 using CO(2-1) kinematics **(1h)**

▶ Detect the ISM in high redshift galaxies:
Dust emission from ULIRGs (10^{12} Lsun) out to z=10 **(7min)**

▶ Trace the formation of galaxy clusters, cosmic structure:
Survey clustering in a sample of 23 Lyα blobs at z=3.1 **(1h)**

Summary: Extragalactic Science

- $\times 10$ sensitivity,
  $\times 4$ bandwidth &
  sub-arcsec resolution are revolutionizing astronomy

- New to ALMA & interferometry?

  – Start with "A Primer for *Early Science (Cycle 3)"*
  – "Science-ready" products to be delivered
  – Ask help at EA-ARC Korean node in KASI