Growing-up at high redshift: from proto-clusters to galaxy clusters

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Submillimeter Galaxies in the SSA22 Protocluster at z=3.1

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Outlines

§ Introduction

- SMGs and Proto-cluster
- SSA22 Field

§ Observations and Data Analysis

- Multi-wavelength Data set
- Counterpart Identification

§ Results and Discussions

- photometric redshifts
- SMGs within the z=3.1 Large Scale Structure
- Submm bright AGNs at the core of the Protocluster

§ Summary and Future works

Introduction

Submillimeter Galaxies (SMGs)

§ Physical properties (e.g., Chapman ea 2005, Smolcic ea 2012)

- Thermal dust emission is dominant

  $L_{FIR} \sim 10^{13} L_{Sun}$, SFR ~ 1000 M_{Sun}/yr

- High-redshift

  $z \sim 1\text{-}5$, $z_{median} \sim 2.2\text{-}3.1$

- Massive

  $M_{gas} \sim 10^{10\text{-}11} M_{Sun}$, $M_{stellar} \sim 10^{10\text{-}11} M_{Sun}$

§ Overlap with AGNs (e.g., Alexander ea 2005, 2008)

- A part of SMGs horbour X-ray luminous AGNs.
- FIR Luminosity should be still dominated by Star-formation.

=> Why Protocluster ?

SMGs and a Protocluster

§ Predictions in the CDM framework

- SMGs should reside in massive DH and clustering
- would be Progenitors of massive elliptical galaxies.

§ Observational Evidence

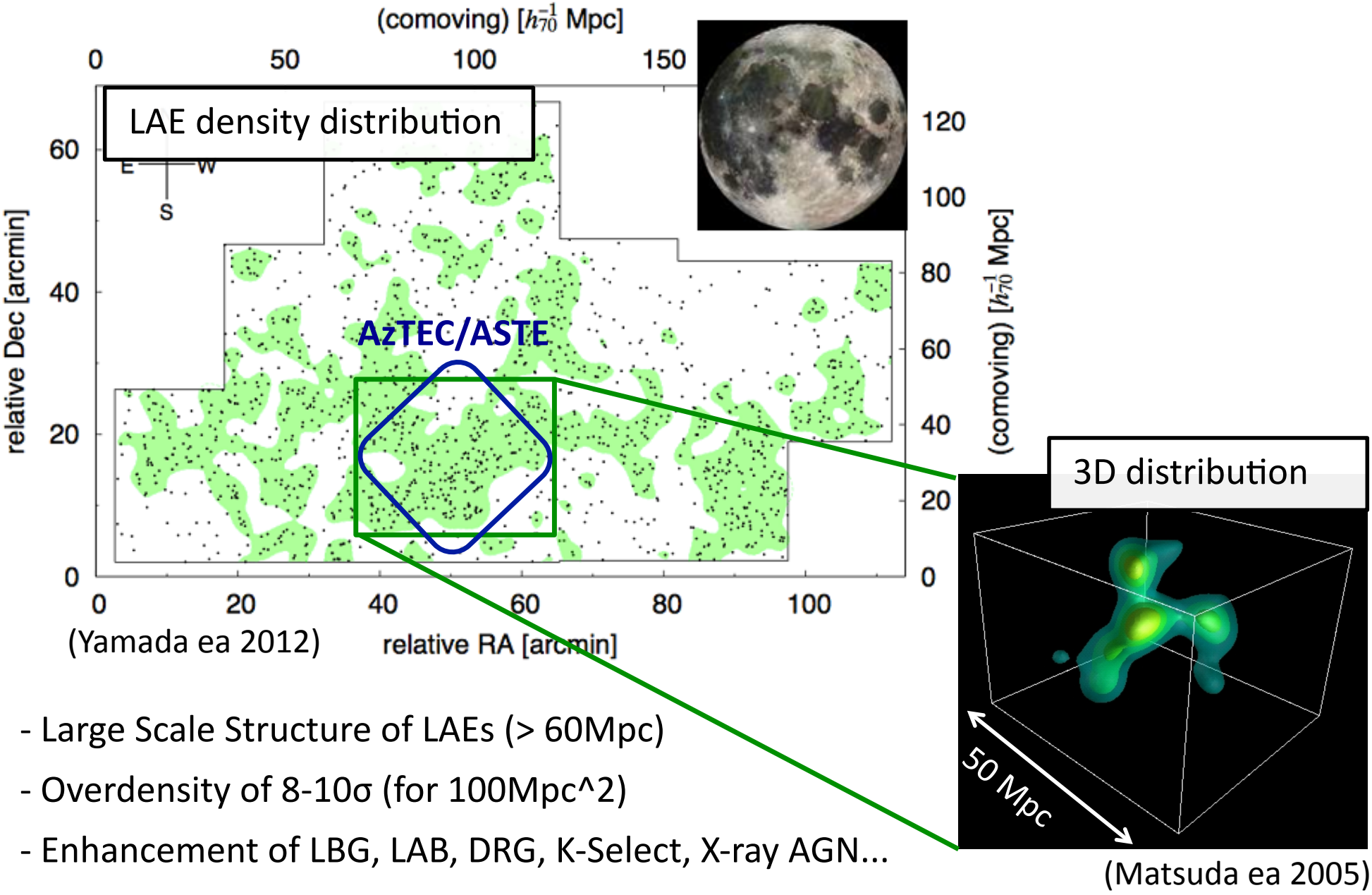
- high amplitude of clustering (e.g. Hickox ea 2012)
- SMGs in overdense regions

  (e.g., Capak ea 2012, Daddi ea 2009, Chapman ea 2009)

=> the relation between SMGs and each protocluster is still unclear...

-> SSA22 Protocluster at z=3.1!

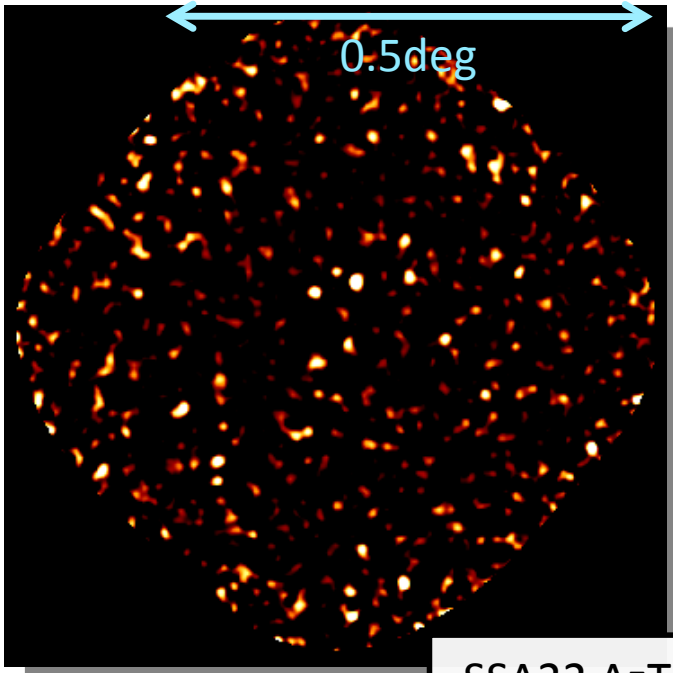
SSA22 protocluster at z=3.09



- Large Scale Structure of LAEs (> 60Mpc)
- Overdensity of 8-10σ (for 100Mpc^2)
- Enhancement of LBG, LAB, DRG, K-Select, X-ray AGN...

Observations and Data Analysis

AzTEC/ASTE SMG Survey in SSA22

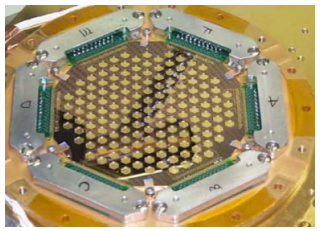


SSA22 AzTEC 1.1mm Map

Wavelength	1.1mm
Survey area	992 arcmin^2 (50% cov.)
Noise level (1σ)	0.6 – 1.2mJy/beam
N. of sources	112 (S/N>3.5)

(Tamura ea 2009, Tamura ea in prep)

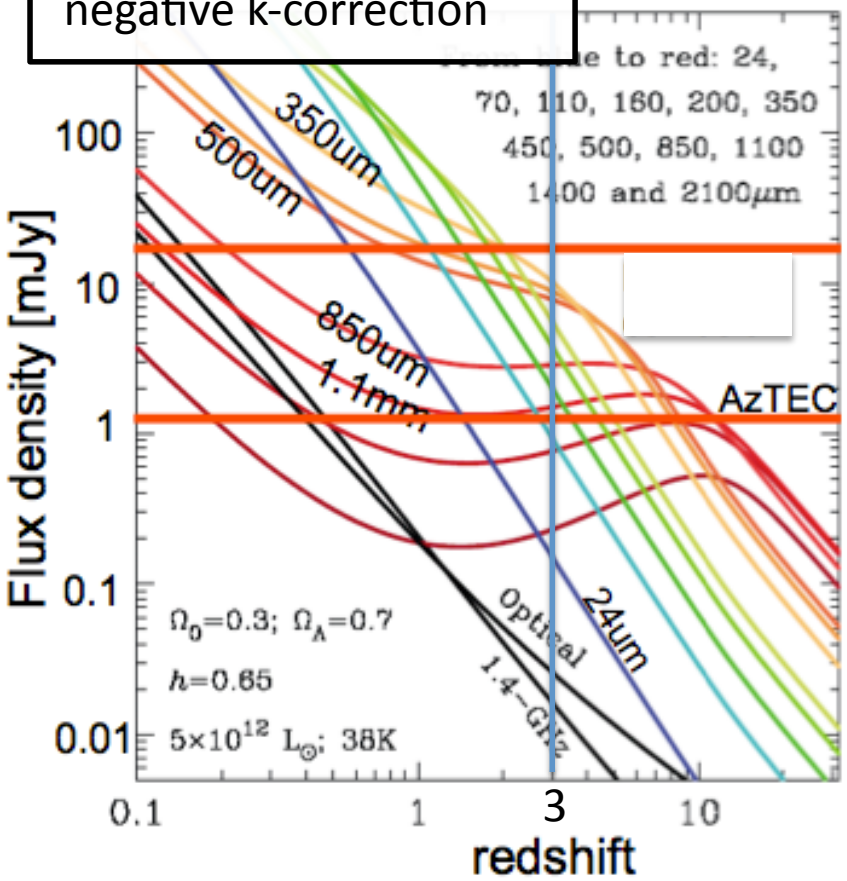
10m dish, ASTE (Ezawa ea 2008)



AzTEC Camera

(Wilson ea 2008)

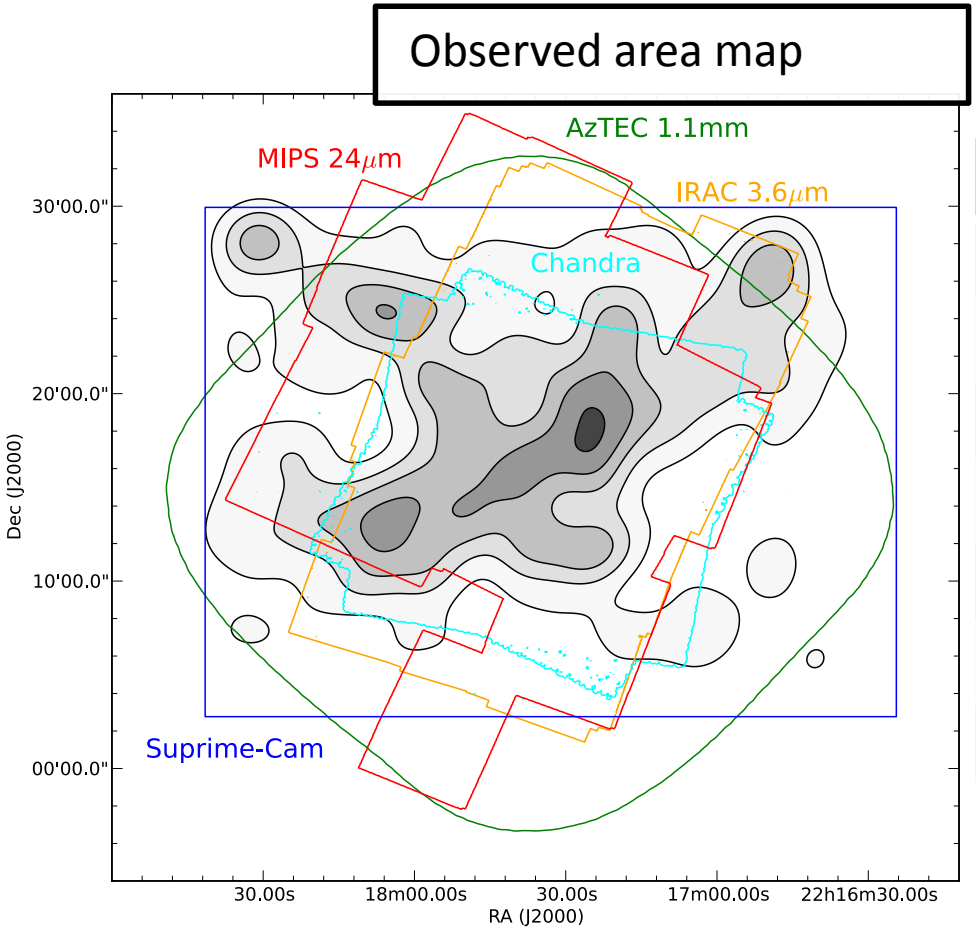
negative k-correction



(Blain ea 2002)

Multi-wavelength Identification

§ Observations



Inst.	Band / λ	Ref.
VLA	1.4 GHz	PI: R. Ivison
MIPS (not full)	24 um	Archive
IRAC (not full)	ch1 – ch4	Archive
MOIRCS (not full)	J, H, Ks	Uchimoto+11
UKIRT	J, K	Archive
S-Cam / WFCAM	U, B, V, R, i', z'	Hayashino+04
Chandra (not full)	U	Archive

(Umehata ea in prep)

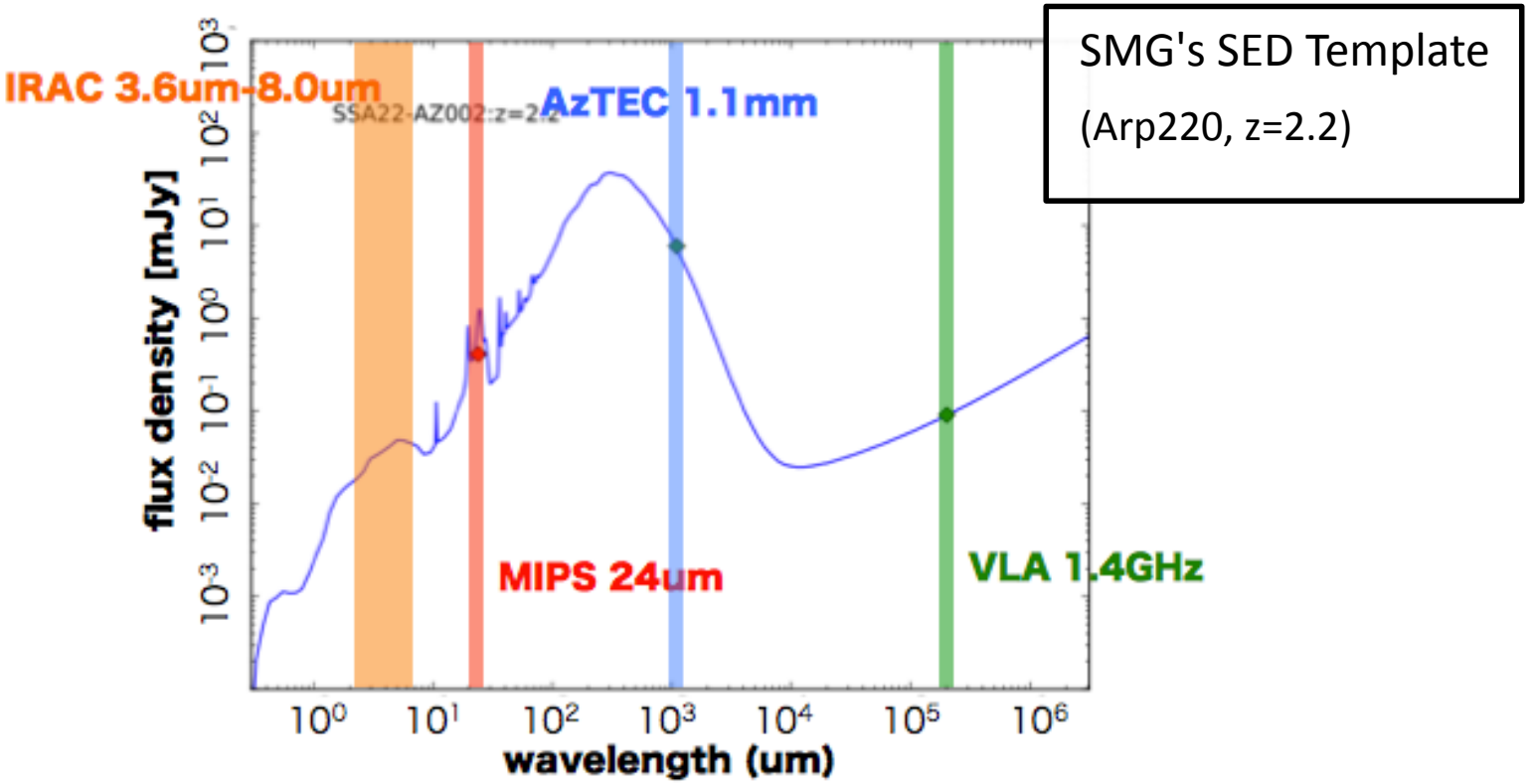
Multi-wavelength Identification

§ Counterpart Identification

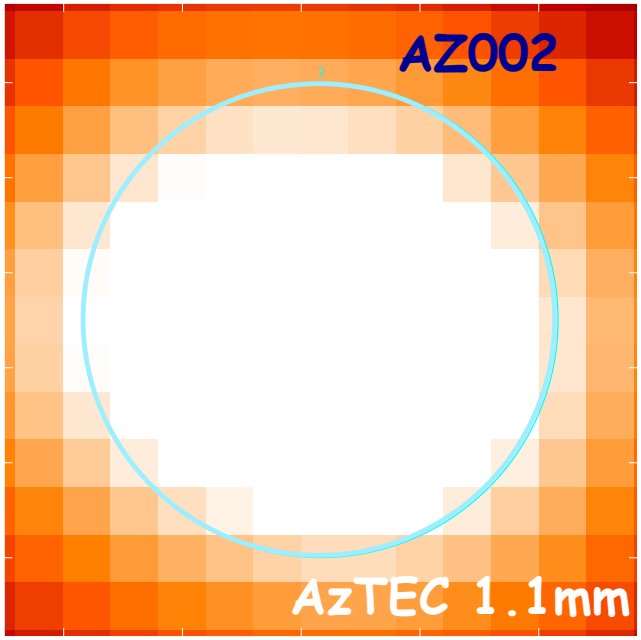
(e.g., Ivison ea 07, Biggs ea 2010,, Yun ea 11)

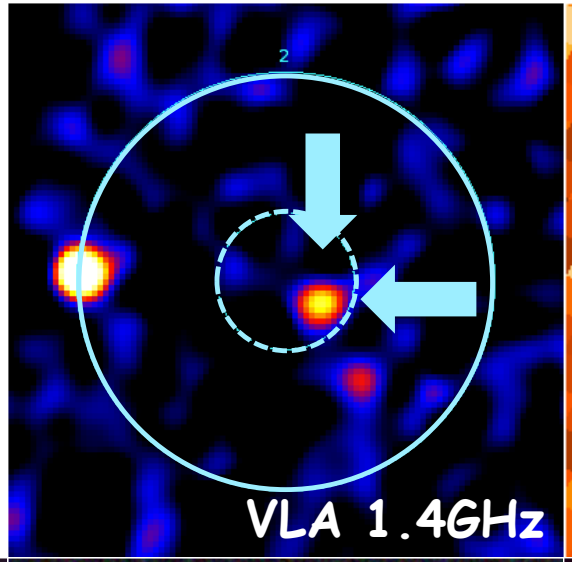
- Reference Data set

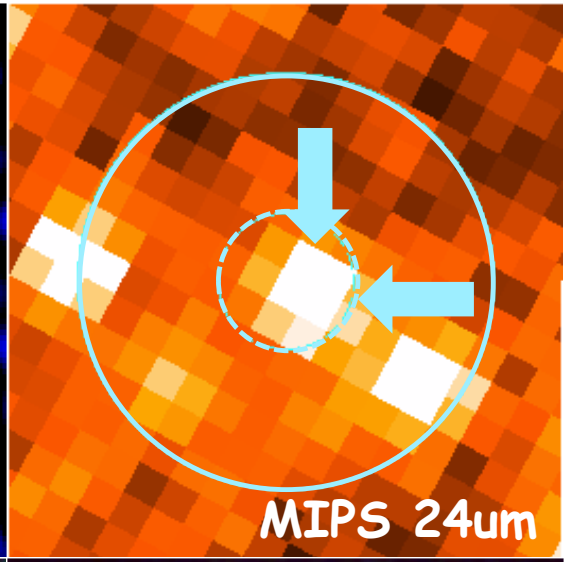
(1) VLA 1.4GHz, (2) MIPS 24um, (3) IRAC Color of 3.6, 4.5,5.8,8.0 um

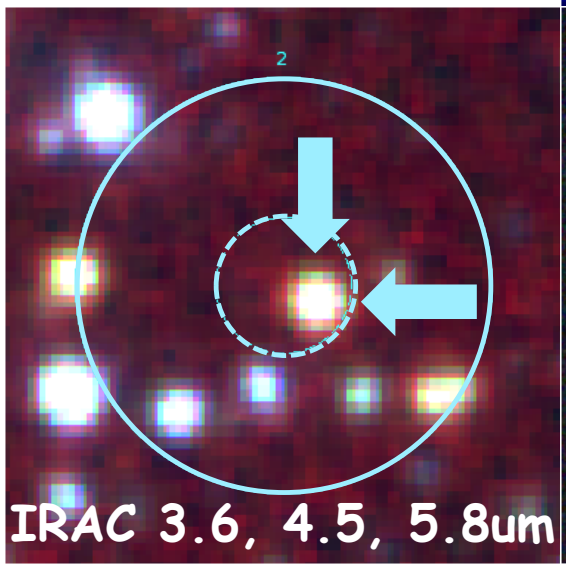


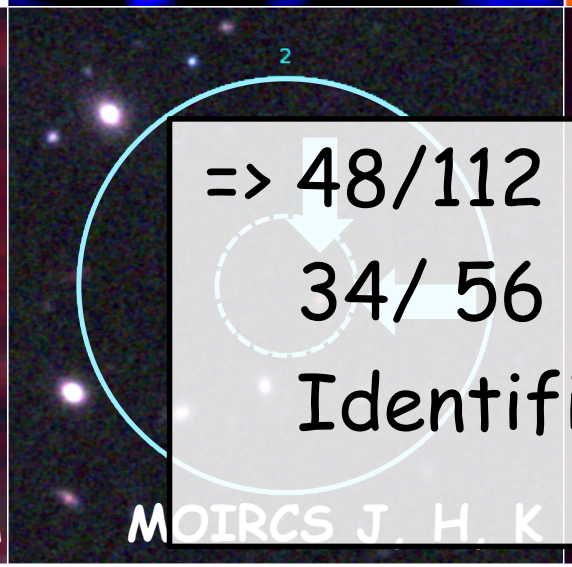
Counterparts Identification

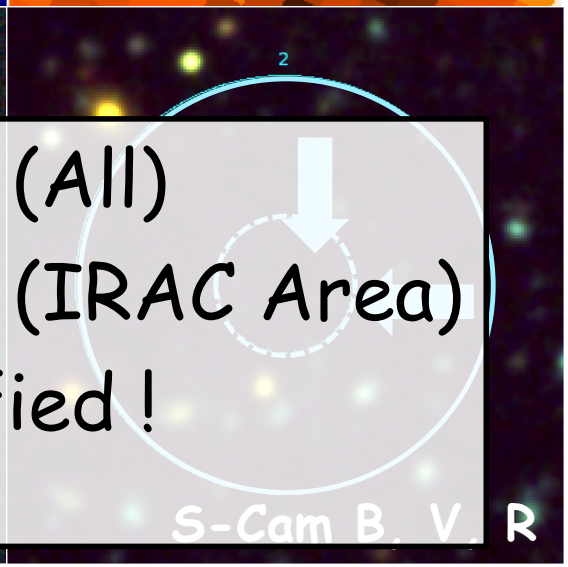












40"

40"

=> 48/112 (All)

34/ 56 (IRAC Area)

Identified !

Results: Photometric Redshift

Photo-z estimation

§ HYPERZ

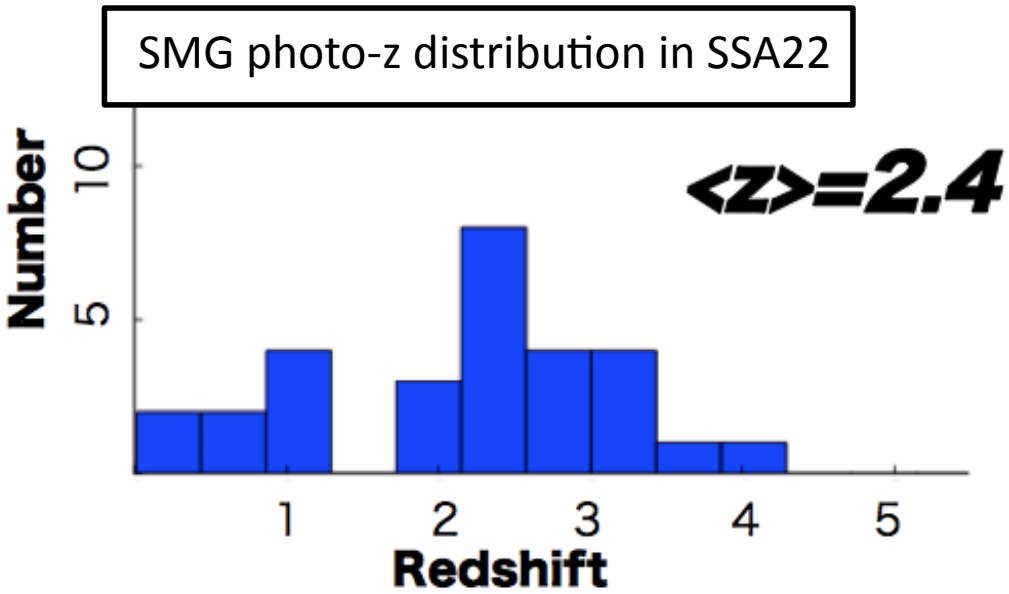
- Photometry Data

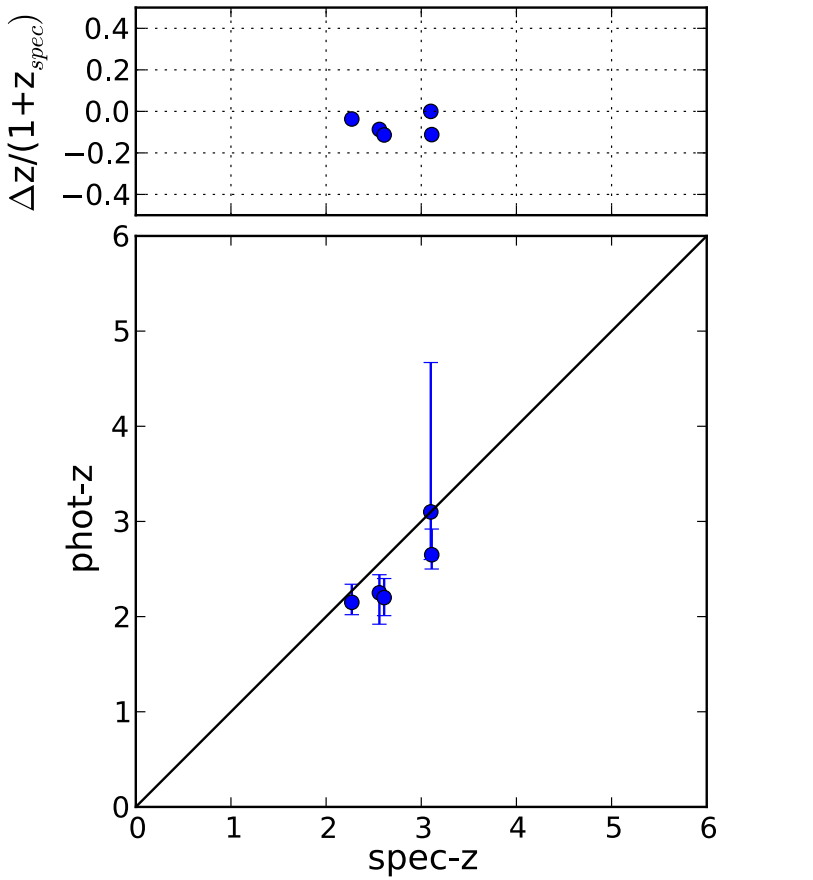
  U, B, V, R, i', z', J, (H), K, (Ks), 3.6, 4.5, 5.8, 8.0um

- SED Template : Bruzual & Charlot, 2003

- redshift range : 0.0-6.0

- Av range : 0.0-5.0 mag

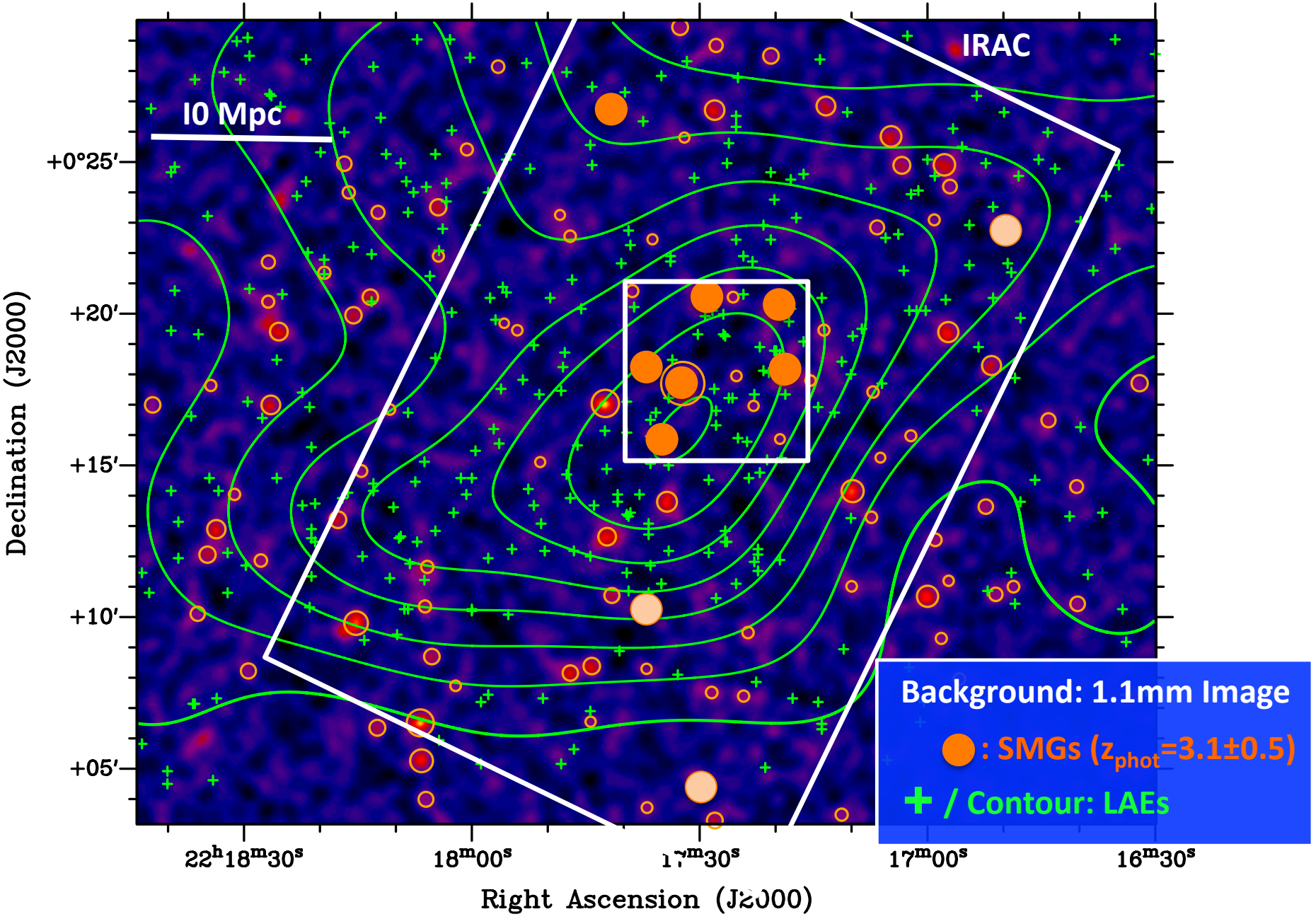




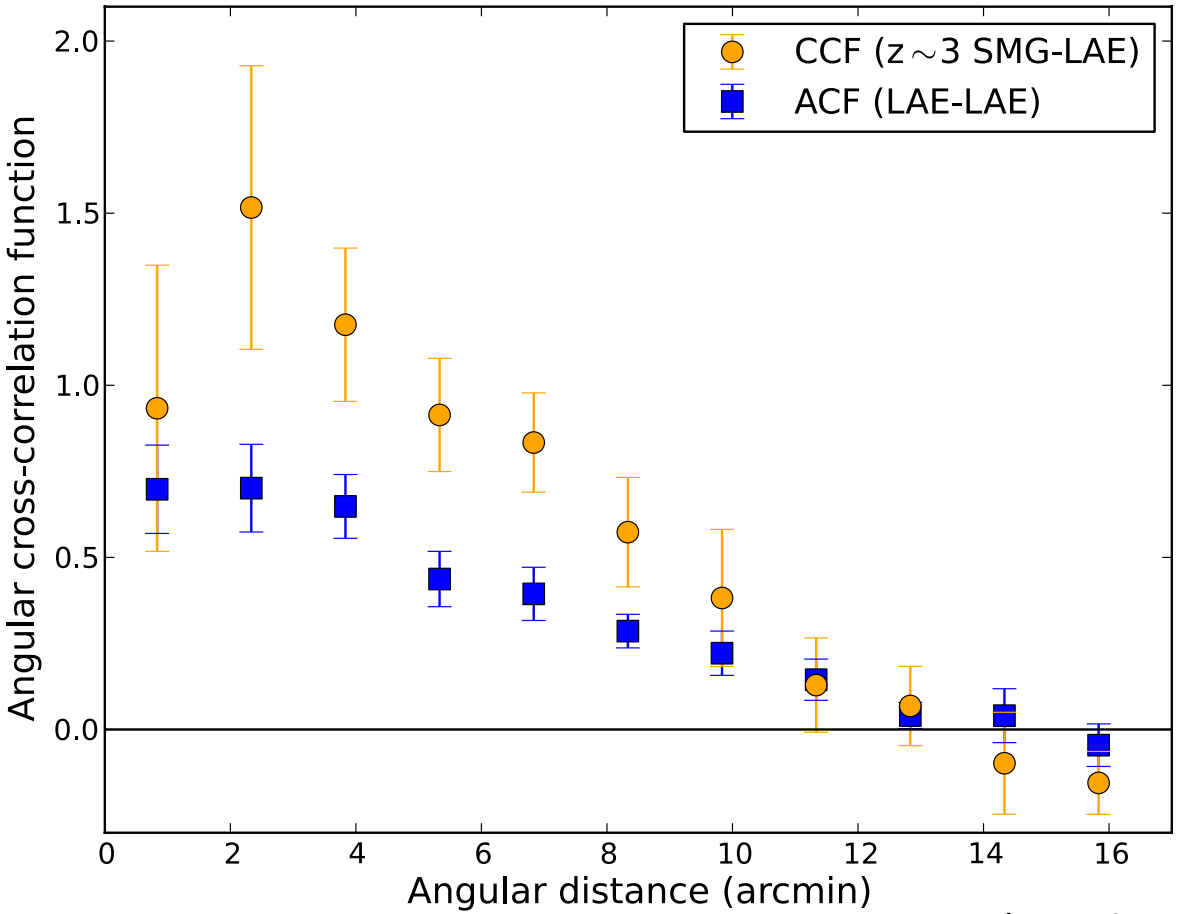
(Umehata ea in prep)

Discussion: SMGs at z=3 protocluster

SMGs and the LSS at z=3



Angular correlation Function

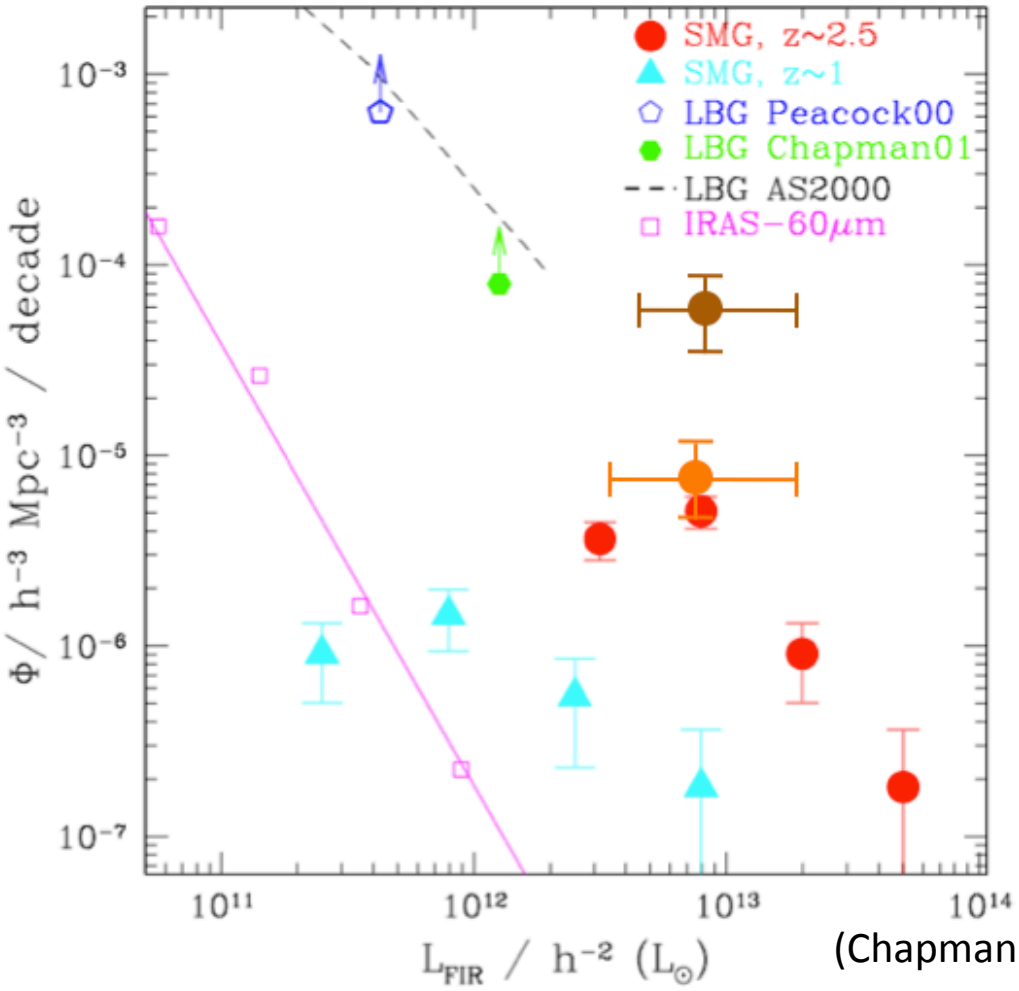


(Umehata ea in prep)

=> SMGs should reside in the LSS traced by LAEs at z=3.1 universe.

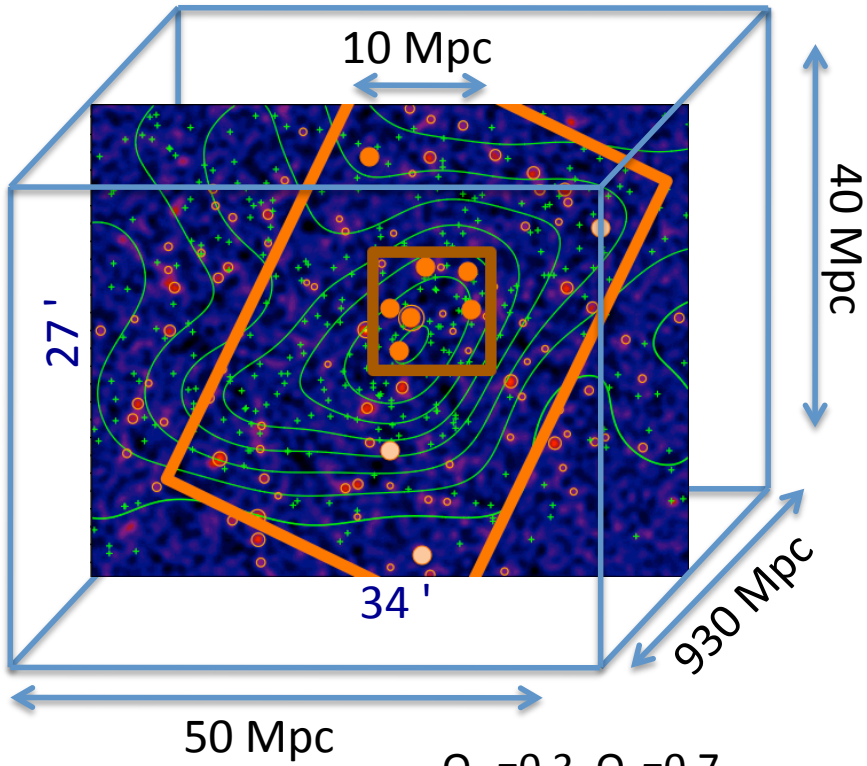
=> Biased SMG formation in the mass assembled regions.

Space density at z~3



(Chapman ea 2005)

(comoving scale)



Ω_M=0.3, Ω_Λ=0.7

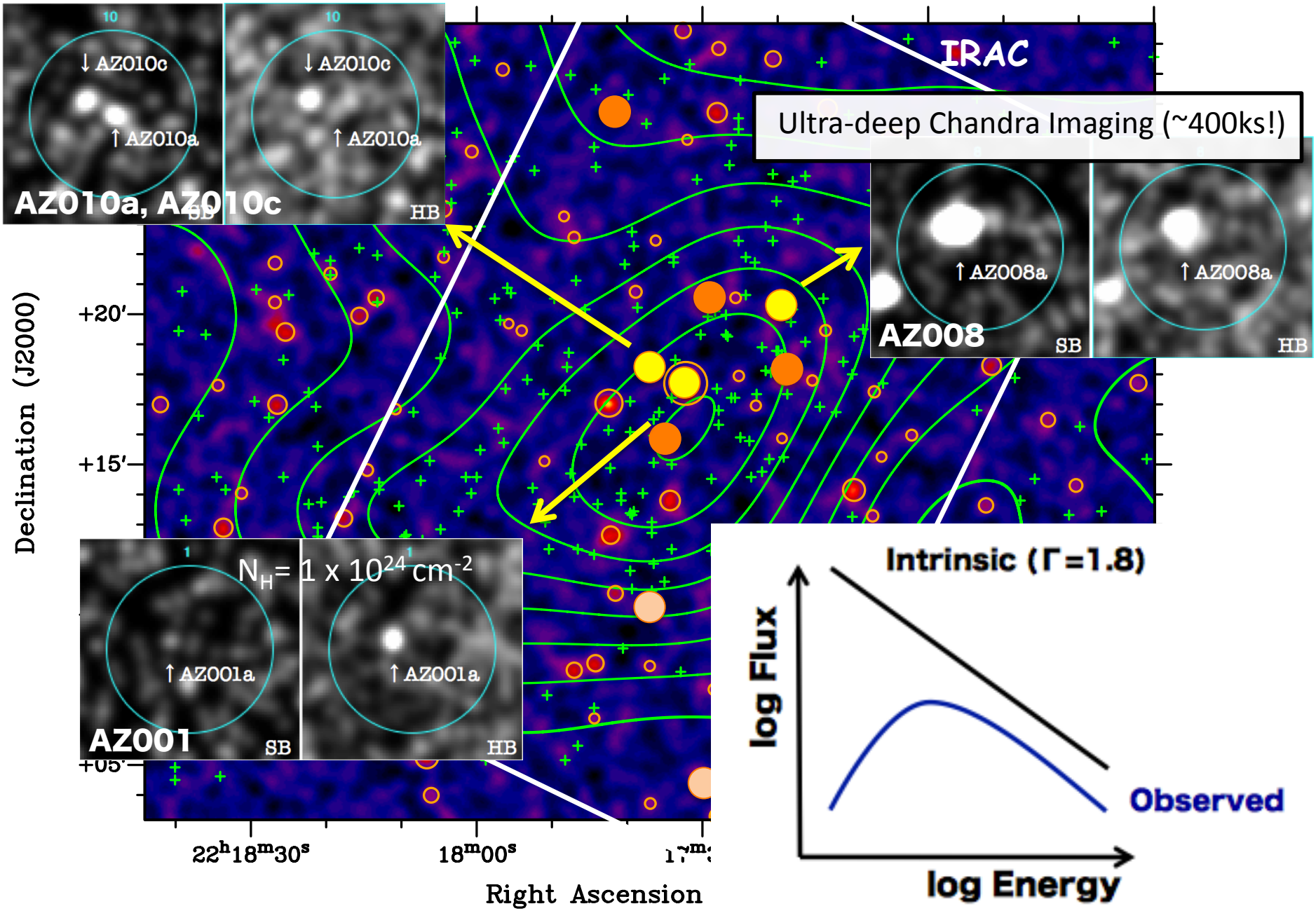
H_0=70km/s/Mpc

z=2.6-3.6

=> At a proto-cluster core, Space density is greater by an magnitude of magnitude ?

Discussion: Submm bright AGNs

Submm Bright AGNs at z~3



Stellar mass vs BH mass

- Bolometric Luminosity

$$f_{\rm bol} = L^{\rm bol}/L_X$$

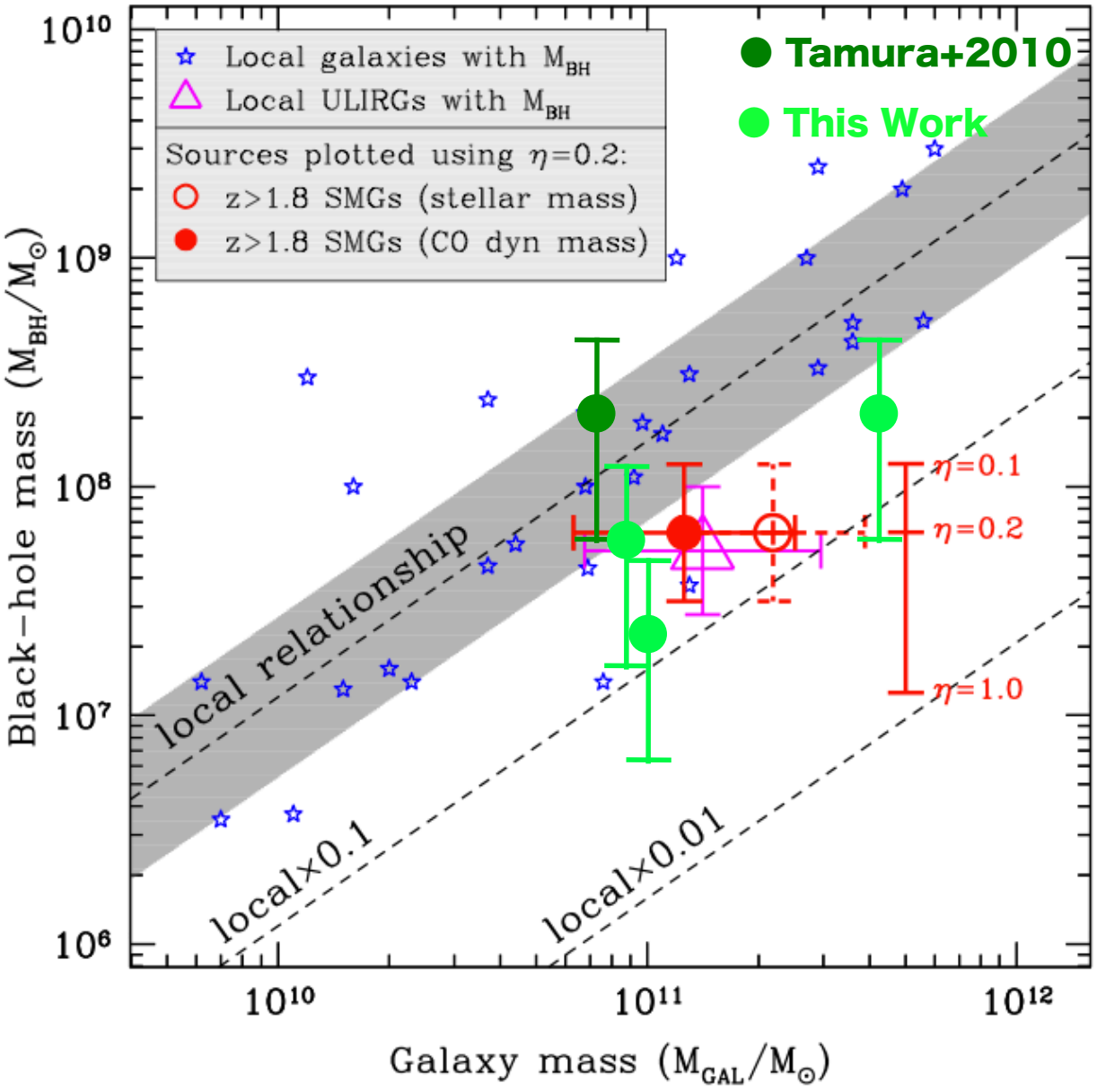
f_{bol} : bolometric correction

- Eddington Luminosity

$$L \leq \frac{4\pi c G m_p}{\sigma_T} M$$

- Eddington ratio

η = L_{bol} / L_{edd}



(Alexander ea 2008)

Summary and Future Plan

§ We have investigated the nature of 1.1mm SMGs in the SSA22 Field.

§ SMGs in the protocluster at z=3.1

- Counterpart ID and photo-z search show 7 SMGs are candidates.
- High concentration and density at the core indicate biased SMG formation at the overdense environment.
- CCF also argued SMGs should reside in z=3.1 Protocluster.

§ Submm bright AGNs in the protocluster at z=3.1

- 3 Submm bright AGNs at z~3 are found at the core.
- These would be at their terminal epoch of Starburst.

§ Future Plans

- Spectroscopy follow up are strongly required