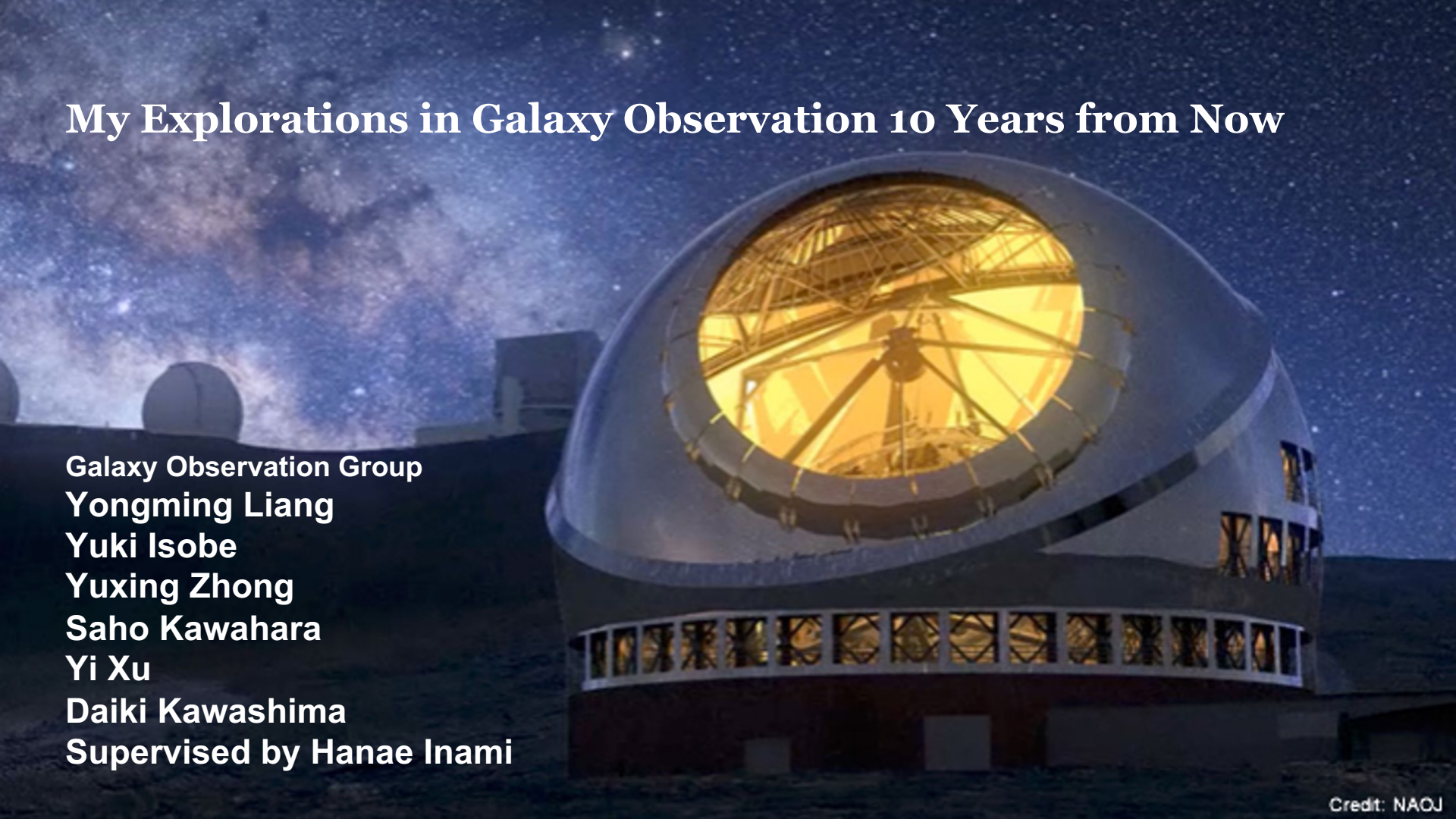
My Explorations in Galaxy Observation 10 Years from Now



Galaxy Observation Group
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Credit: NAOJ

Tasks of our group

銀河観測 (稲見華恵)

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Subject: "My Explorations in Galaxy Observations 10 years from now"

After learning a lot about galaxies and the ISM at this workshop, you may have noticed that there are still many unexplored areas. What would be the most exciting project for you to investigate your favorite type of galaxies in the future? You can think of this as an extension of existing or planned observatories/instruments, but feel free to use your imagination of new technologies that you think may be available in 10-20 years from now. No need to think about the community, but think what *you* (or your group) as an astronomer will want and enjoy doing!

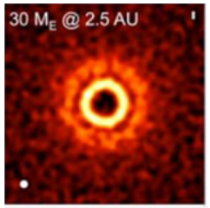
課題：「10 数年後に狙う独自の銀河観測」

このワークショップで銀河と ISM についてたくさん学んだと思いますが、その中でも未踏の研究があることに気がついたかも知れません。将来、自分が最も興味ある銀河を研究するとしたら、どのようなプロジェクトが最もエキサイティングだと思いますか？既に存在する観測装置や将来計画の延長となるような内容でも良いですし、10-20 年後に実現しそうな技術を想像してそれを使った内容でも構いません。今はコミュニティ全体のことは一旦忘れて、あなた自身またはあなたのグループが、楽しそう！やってみたい！と思うような内容を考えてみてください。

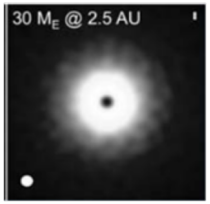
Introduction

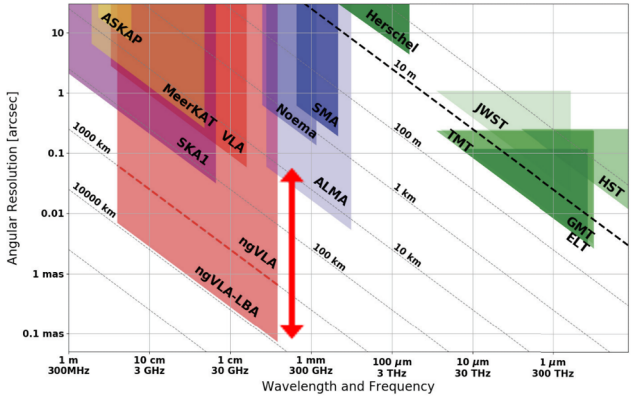
- **ngVLA (Project 1)**
  → angular resolution : 0.2 mas at 30 GHz
  (~3 dex larger than ALMA)

ngVLA



ALMA



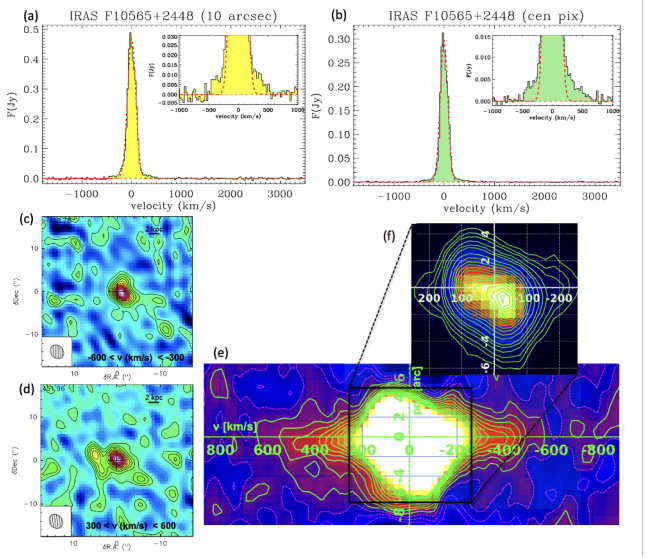


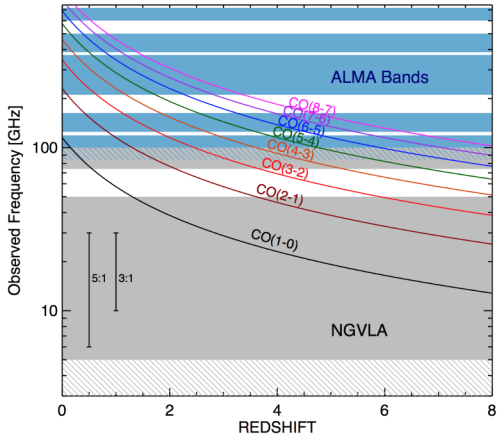
ngVLA(left) and ALMA(right) simulated observations of protoplantary disk continuum emission (Ricci+18)

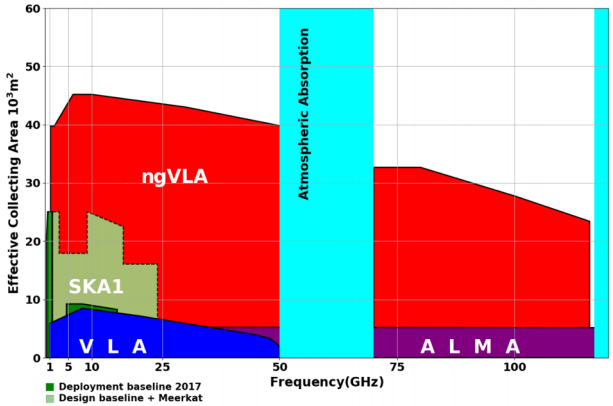
- **LSST (Project 2)**
  → Survey volume ~2 dex larger than SDSS

- **TMT (Project 3)**
  → ~3 mag deeper for point sources compared to Subaru

Project 1. Cold Gas Observation with Next Generation Very Large Array (ngVLA)





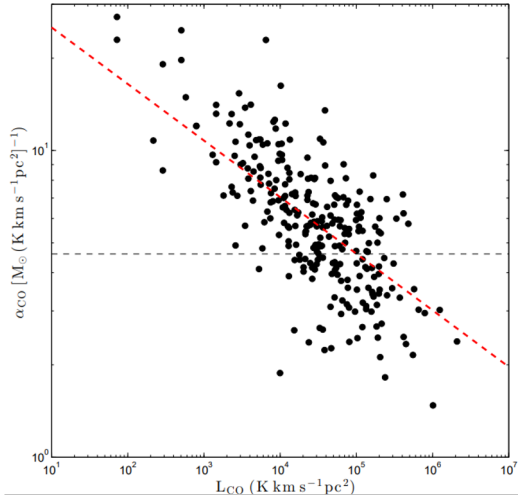


Current observations of ALMA:

- Both gas distribution and kinematics can be obtained
- Evidence of galactic winds at low redshift galaxies

With next generation telescopes:

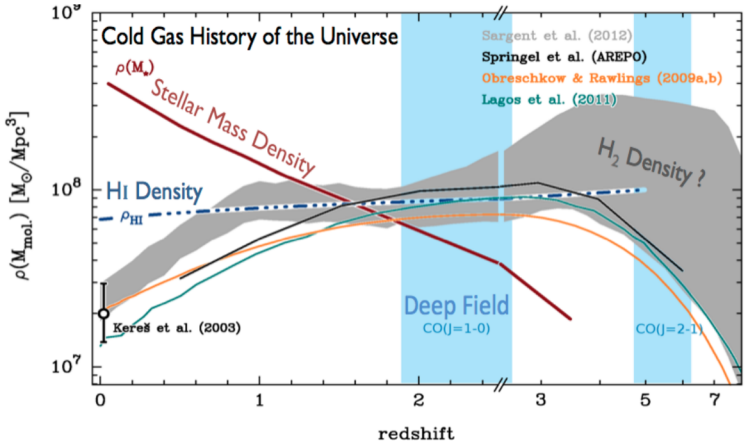
- covering lower frequency
- higher sensitivity for high-z objects

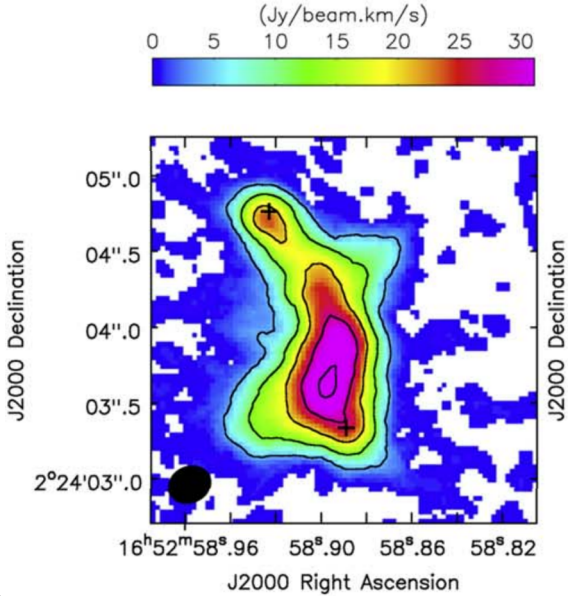


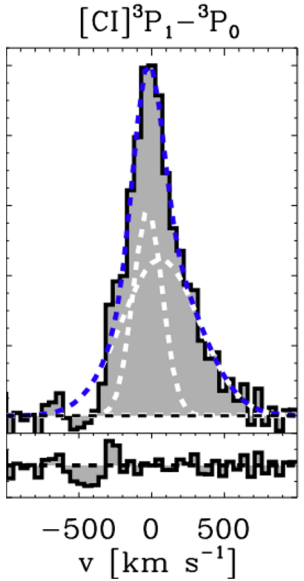
upper left: CO-to-H2 conversion factor against CO luminosity for GMCs in Milky Way (Solomon+1987; Bolatto+13)
lower left: cold gas history (R. Pavesi PhD Thesis)
ngVLA can fill the blanks

lower: [CI](1-0) intensity-weighted moment map of a nearby merging galaxy NGC 6240 (Cicone+18)
molecular outflow peaks between the double cores

- a common scenario?



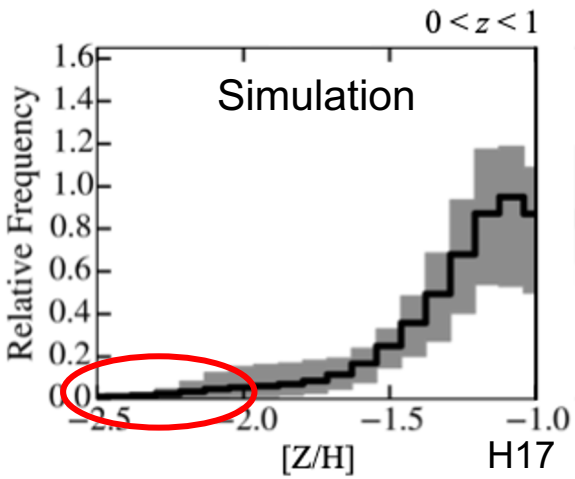




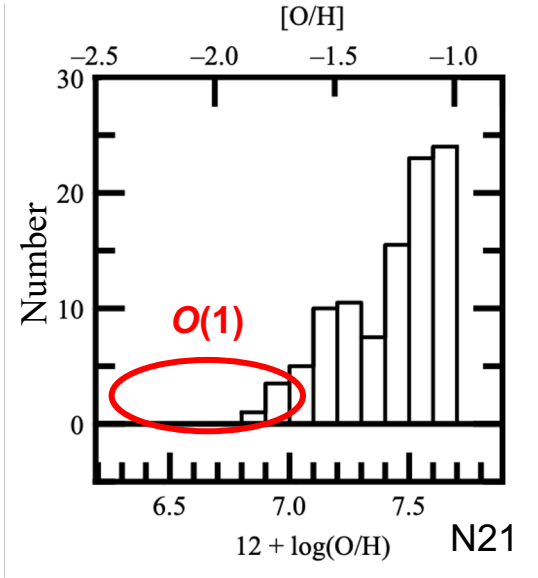
Project 2: Exploring galaxies w/ < 1% Z_sun

IGM partly < 1% Z_sun (Hafen+17)

Q. Do local galaxies w/ **< 1% Z_sun** exist?

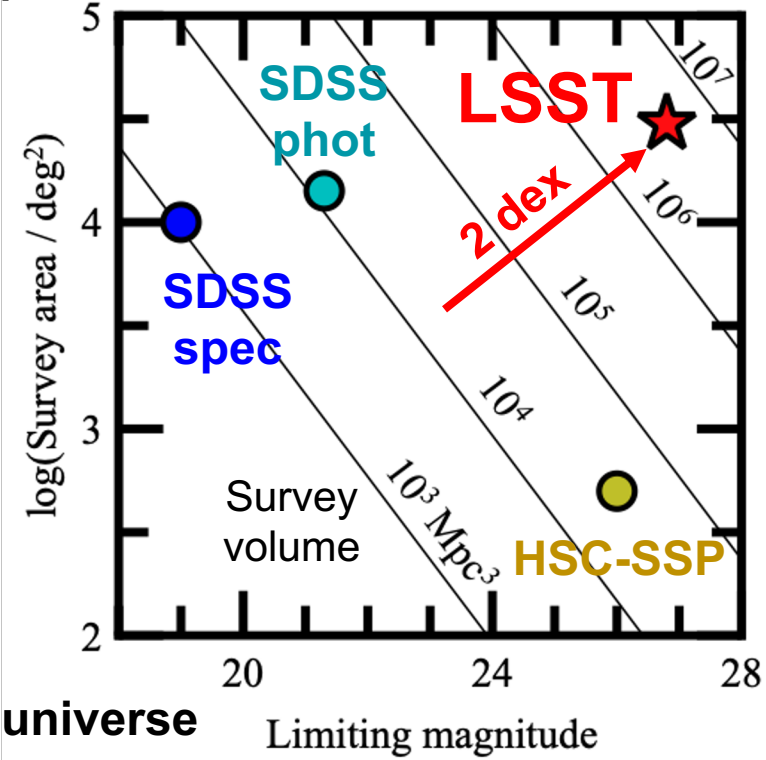


Metal-poor galaxy surveys w/ SDSS and HSC-SSP:
Down to 1.6% Z_sun (Kojima+20)
***O*(1)** galaxies at the low-Z end (Nakajima+21 in prep.)
→ We need **larger survey volume**



Exploring metal-poor galaxies w/ LSST

Data: Large Synoptic Survey Telescope (**LSST**)
i_lim ~ **26.8 mag**, **30,000 deg^2** (in 10 years)
→ Survey volume **~ 2 dex larger** than SDSS phot or HSC-SSP
→ ***O*(100)** new galaxies at the low-Z end

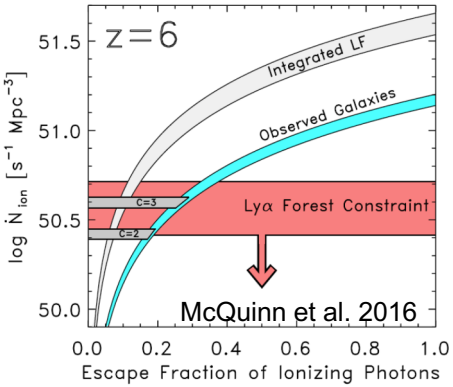


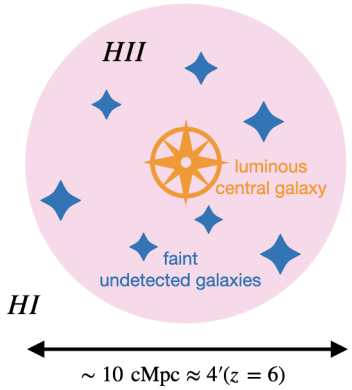
Galaxies w/ < 1% Z_sun
- Exist: Identifying extremely primordial galaxies comparable to **first galaxies** (Wise+12)
→ Hint of star formation in **the very early universe**

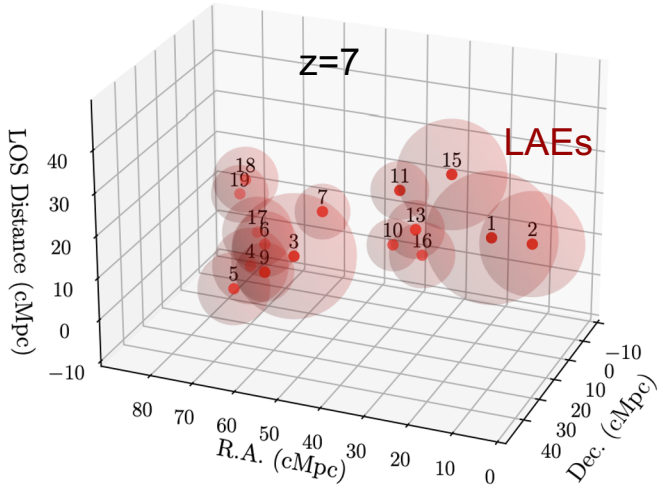
- Not found: Identifying '**metallicity floor**'
Hint of chemical enrichment **in local void regions**

Project 3: Undetected UV-faint galaxies at EoR:

The dominant powering sources of cosmic reionization?





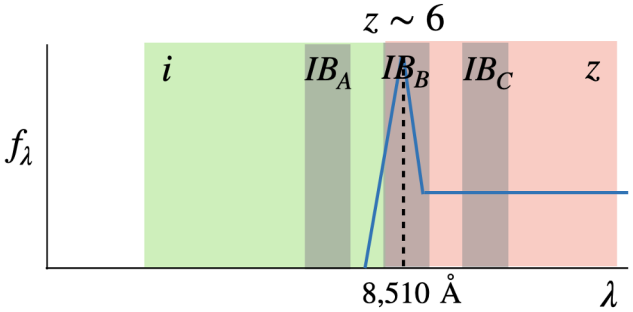


Hu et al. 2021

Science motivation: They are unknown!!

- <u>Powering sources of the cosmic reionization</u>
  Only luminous galaxies & AGNs cannot provide enough ionizing photons measured by IGM transmission. (Bright gal. vs. Faint gal.)
- <u>Inhomogeneous reionization and environmental dependence</u>
  A proto-cluster at z=7 (Hu+2021) has offered a direct picture of how reionization gets enhanced in an overdense region, but how about general regions? (Proto-cluster vs. General regions)
- <u>Escape fraction of ionizing photons in faint populations.</u>

Project 3: Undetected UV-faint galaxies at EoR:
The dominant powering sources of cosmic reionization?



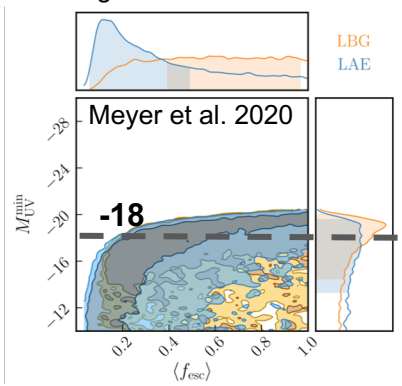
Observation:
Targeting z~6 detected LBGs/LAEs with IGM info (e.g., Kakiichi+18, Meyer+20)

(1) Photometric: IBs/NBs around targeted redshifts
Possibility with TMT & LUVOIR

(2) IFS: Coverage around 8,500 Å with ~ 1'x1'
No existing planned instrument yet.

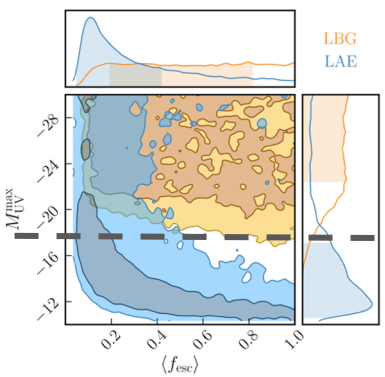
Models

Bright Galaxies Dominate



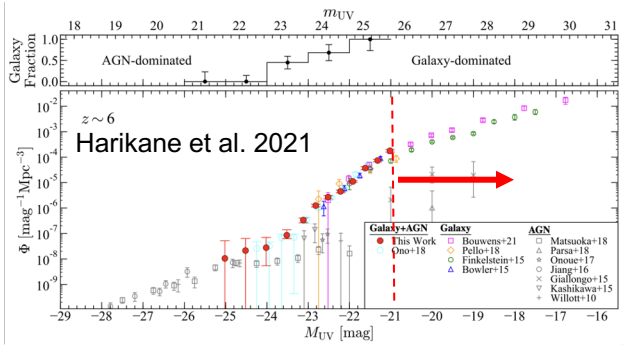
$M_{\rm UV,min} \sim -18(-16)$

Faint Galaxies Dominate



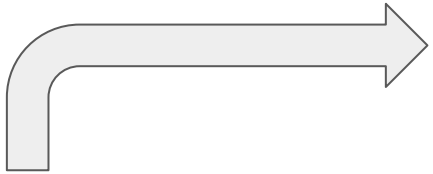
$-17 \lesssim M_{\rm UV,max,LAE} \lesssim -10$
$M_{\rm UV,max,LBG} < -18.4$

Ref Obs



TMT-like telescope should be feasible to recover part of faint gal. compared to Subaru
→ deeper by 3 mag, i.e., Muv ~ -18

Future perspectives



◯new technology will bring us.....?
(=we want .....)

〈realize〉
・**quick, deep, wide survey**
・narrow band observation
〈improve〉
・large telescope
・low temperature
・reduce zodiacal light
・reduce atmospheric extinction
・fast transfer speed

..etc

◯What is the new technology?

"steady?" development
・cooling technology
・communication technology
・miniaturization
・transmittance & reflectance

"innovative"development

・set telescope on the moon -天文月報2017年 9月号
→huge mirror

・set telescope in the Antarctic -ATT10
→high atomospheric transmisson on the ground

・unknown new material
→weight saving and good reflectance

・**control separated mirrors & detectors in spece**
→we will be able to observe in various situation

Conclusions

We can investigate

- Molecular gas of z > 3 galaxies
- Presence of galaxies w/ 1% Z_sun
- Undetected UV-faint galaxies at EoR

using near-future instruments

But we can improve more!