Search for high-z radio galaxies by Subaru HSC and FIRST catalogs

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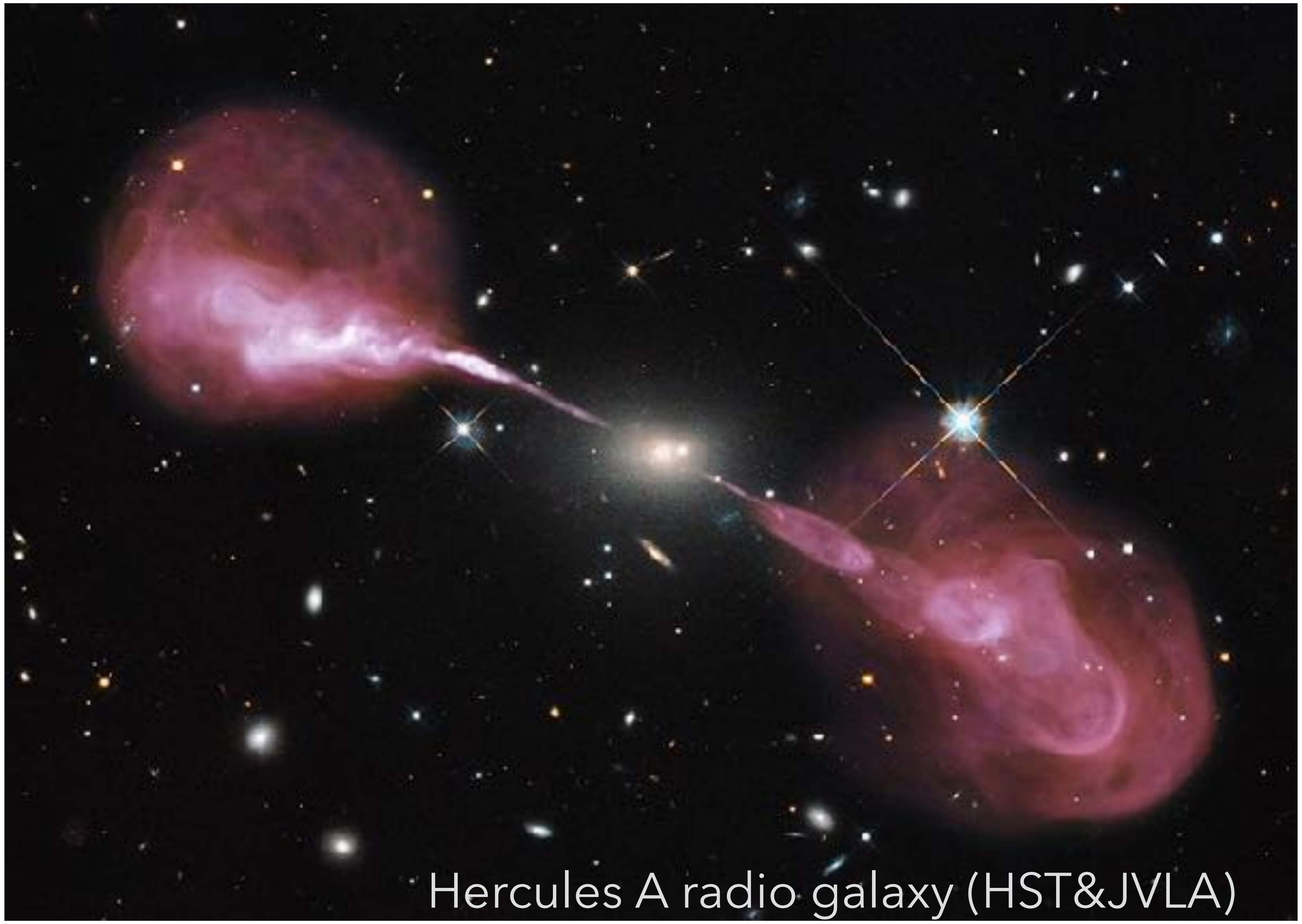
Radio Galaxies

Important population in evolution/formation of AGNs/galaxies

- Powerful radio jets – AGN feedback, formation of massive galaxies
- Massive host galaxies – Formation of massive galaxies
- Overdense environment (high-z) – AGN, formation of massive galaxies and cluster



Hercules A radio galaxy (HST&JVLA)

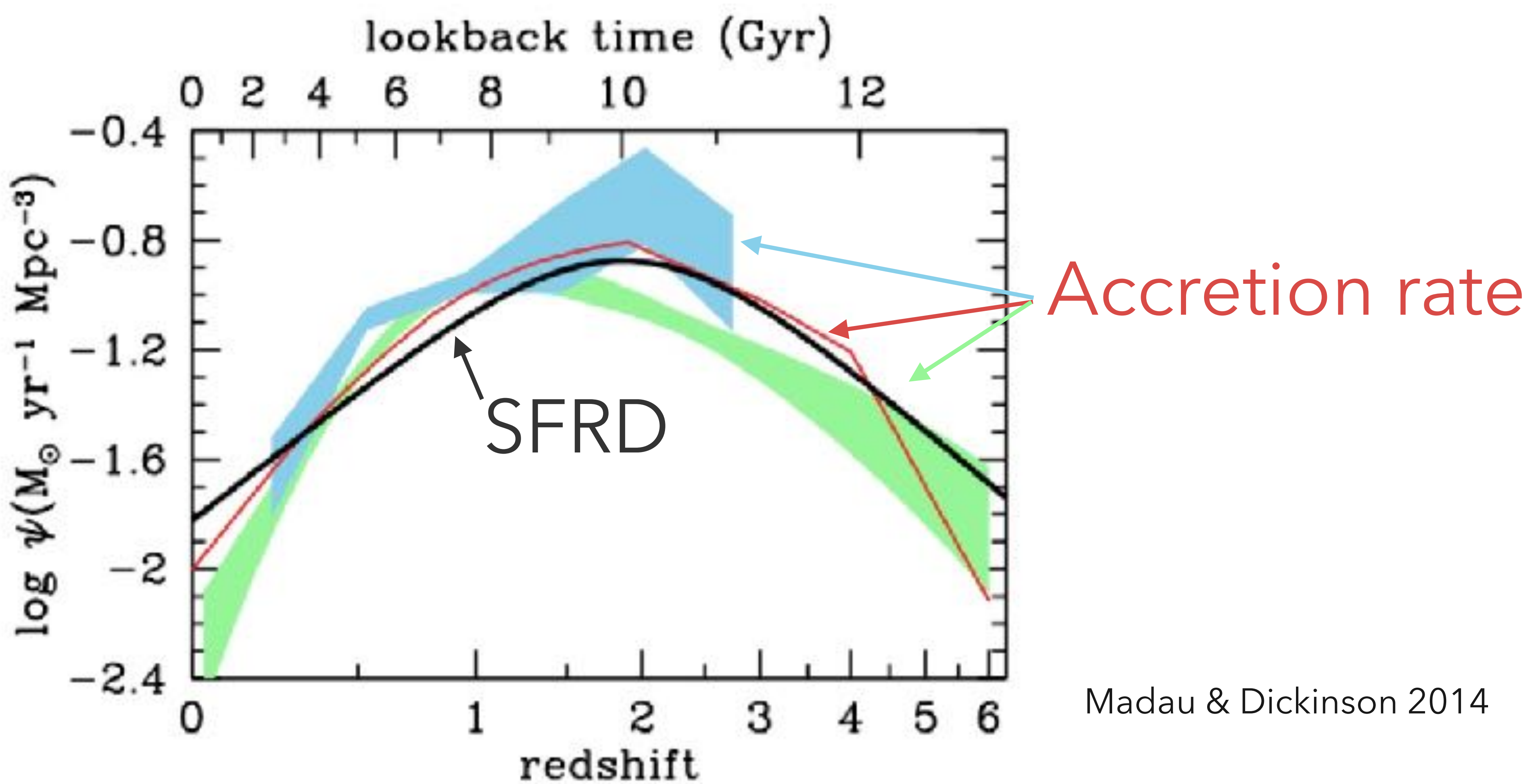
Definition

- L(5GHz)/L(B) > 10 [Kellermann et al. 1989]
- L(1.4GHz) > 10^24 W/Hz [Tadhunter 2016]

Very Bright in radio → valuable probe to high-z galaxies

Radio Galaxies at z > 1

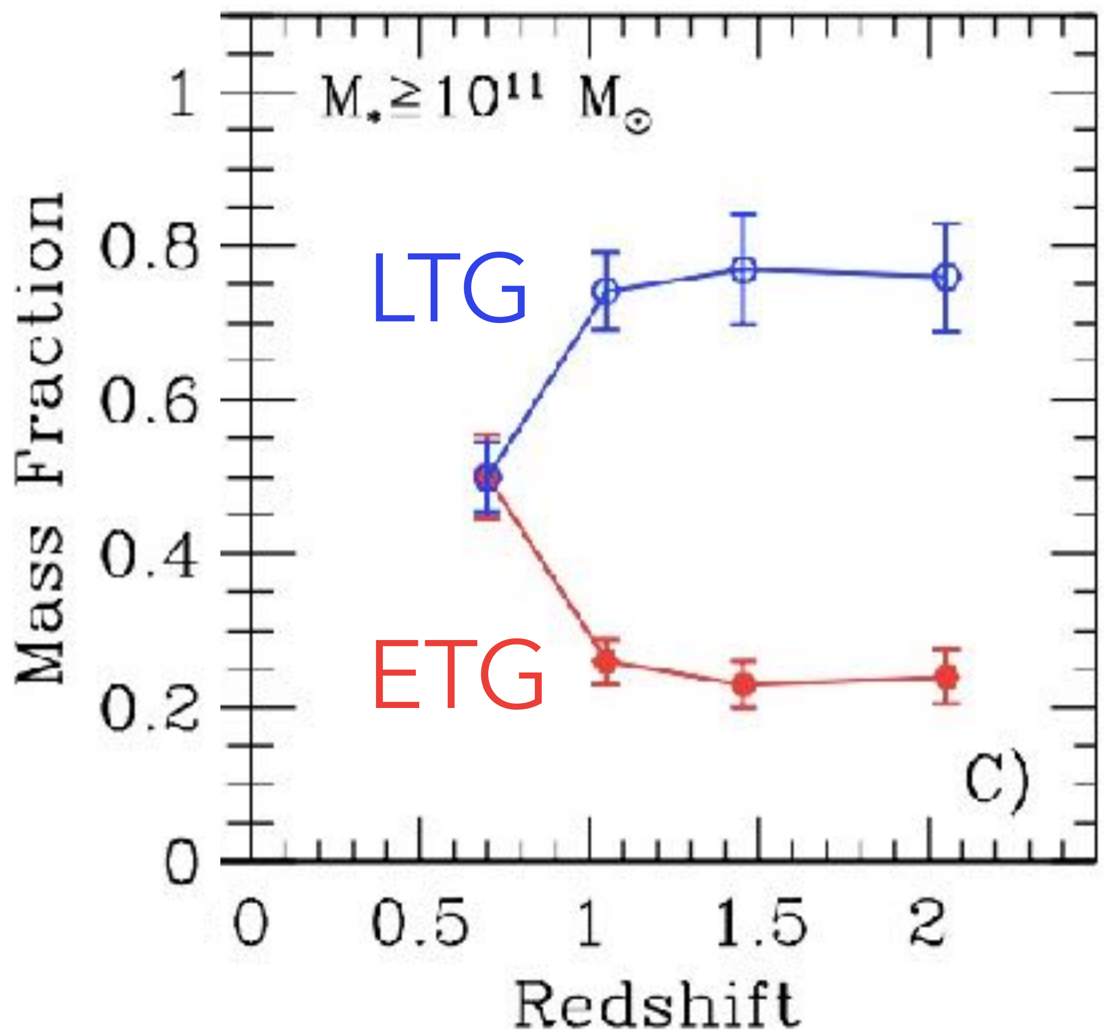
- Redshift evolution of Radio Galaxies
- z>~1 universe is particularly important epoch
  - a growth period of BH and Star formation
  - a build-up of stellar mass in massive elliptical galaxies



Madau & Dickinson 2014

Radio Galaxies along redshift

- Evolution of Radio Galaxies themselves is standing question
- z>~1 universe is particularly important epoch
  - a growth period of BH and Star formation
  - a build-up of stellar mass in massive elliptical galaxies



Tamburri et al. 2014

Radio Galaxies along redshift

- Evolution of Radio Galaxies themselves is standing question
- z>~1 universe is particularly important epoch
  - a growth period of BH and Star formation
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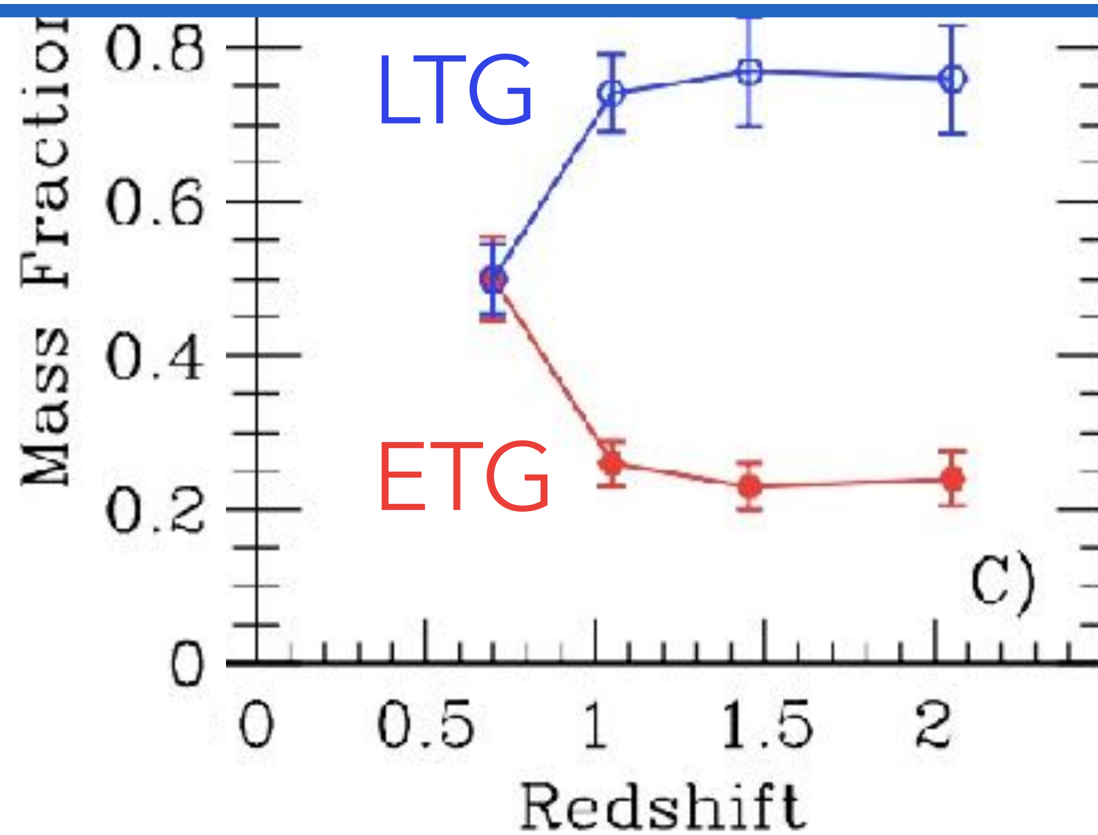
How did Radio Galaxies behave at z > 1 ?

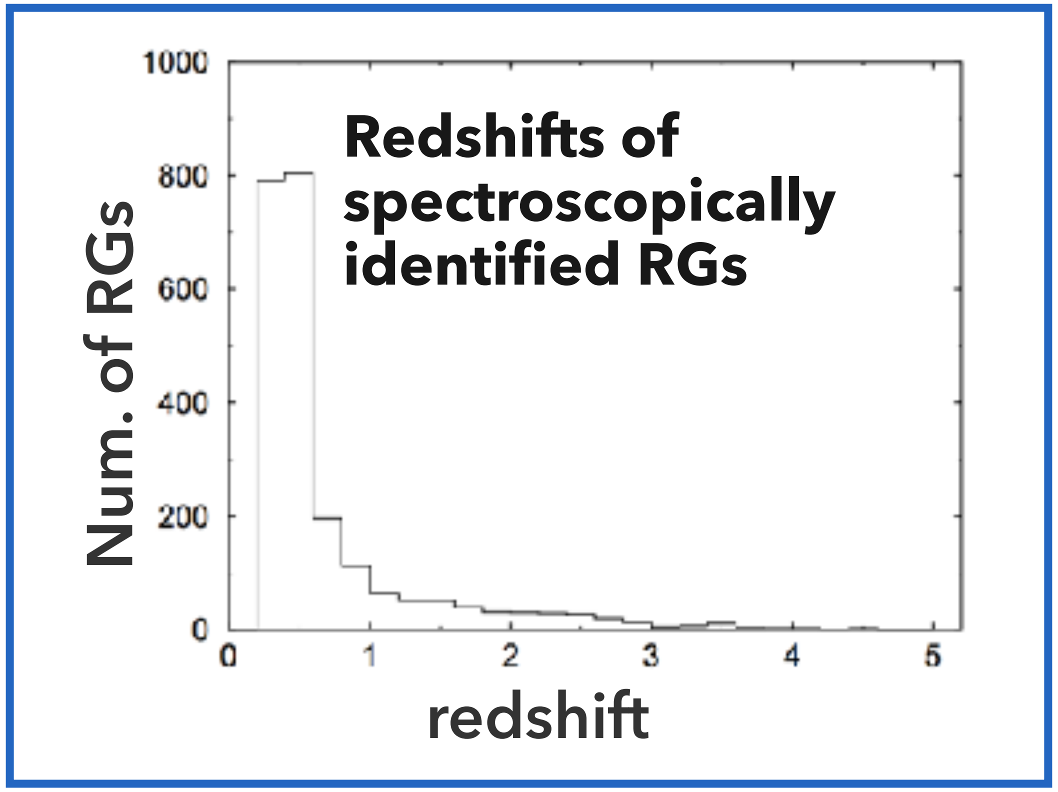


Tamburri et al. 2014

Previous Statistic Studies: Low-z RGs

! Few identified high-z radio galaxies

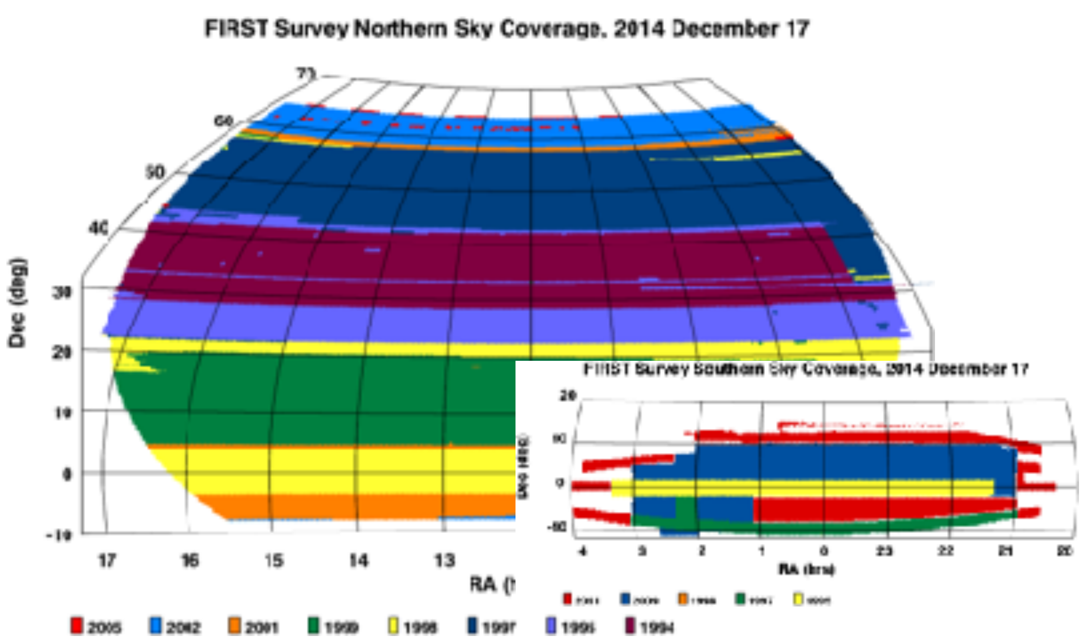
! Almost all the identified RGs are at z <1



Khabibullina & Verkhodanov 09

- **SDSS - FIRST sample**
  - z < 1
  - Matching rate ~ 30 % (Ivezic et al. 2002, Helfand 2015, Ching et al. 2017), even if complex radio morphologies are included.

➡ Optically faint host galaxies
Low space density (a few/deg^2/mag)



FIRST 1.4GHz VLA Survey

cf. Henfand+15

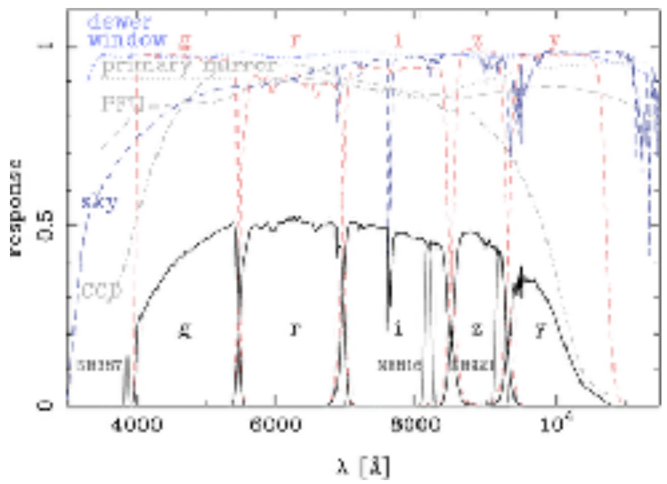
Search for radio galaxies with HSC & FIRST

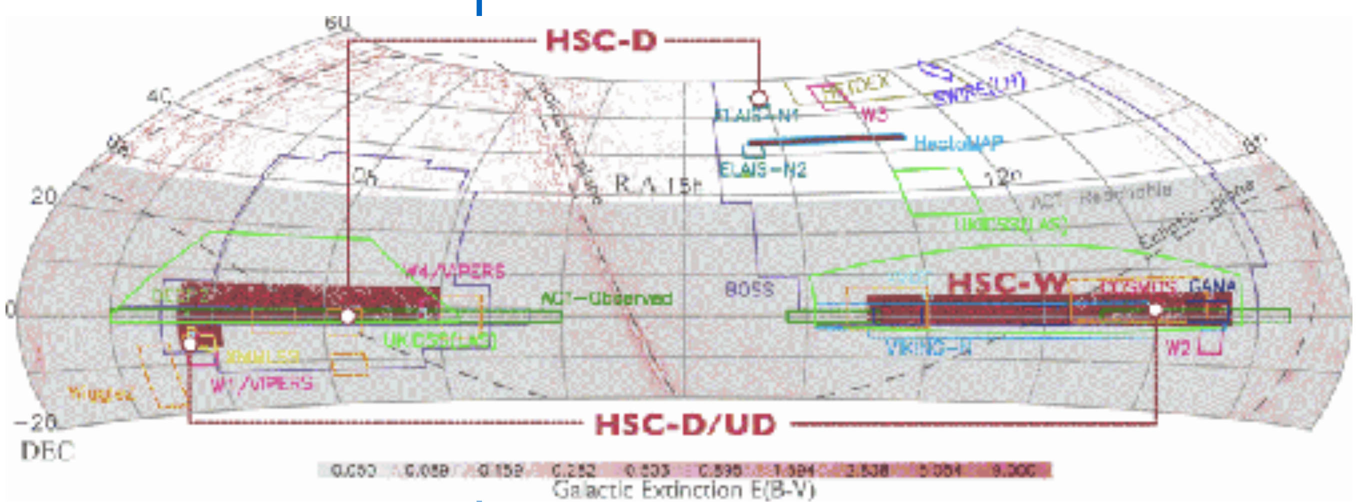
Subaru HSC-SSP

- Wide-field imaging survey with g,r,i,z,y multi-band filters
- Wider and deeper (Aihara et al. 2017)

	Wide	Ultra-Deep
Limiting mag i [mag]	26.4	27.0
Area [deg^2]	178	4

- HSC-SSP enables us to detect RGs with a higher redshift and/or a higher radio-loudness





FIRST 1.4GHz survey

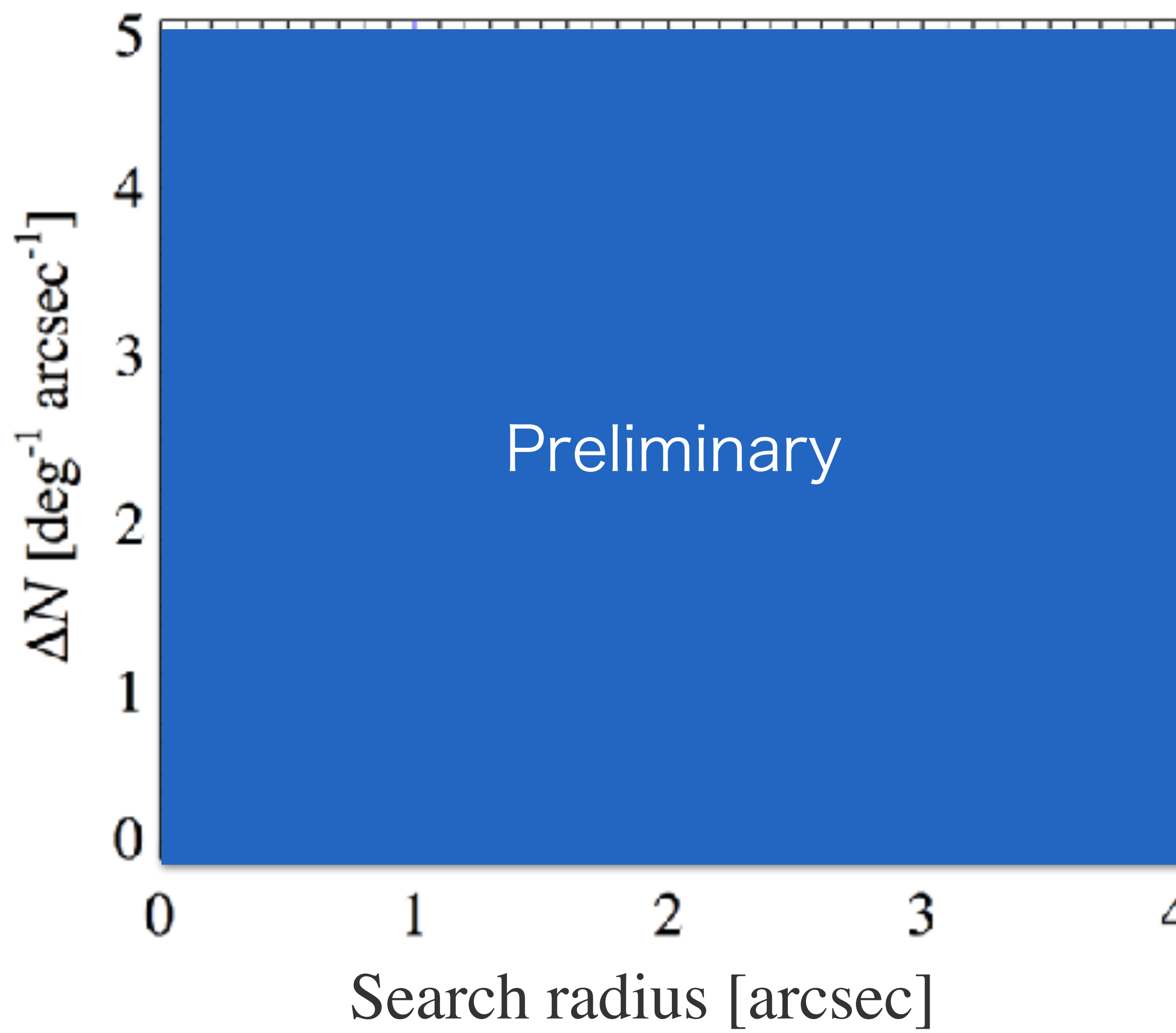
- 1.4 GHz (20 cm) continuum
- Area = 10,575 deg^2; ~ the SDSS region
- Detection limit = 1 mJy
  - Relatively shallow sensitivity → Detections of radio-AGNs ($L_{(1.4GHz)}$ > 10^{24} W/Hz) rather than star-forming galaxies at z > 0.5
- Angular resolution = 5″
- Astrometry < 0.5″

Subaru HSC - FIRST cross match

	FIRST	HSC	Matches	Matches/ FIRST	Chance coincidec	Completeness
Wide	8,282	23,795,523				
UD-COSMOS	118	643,932				

Preliminary

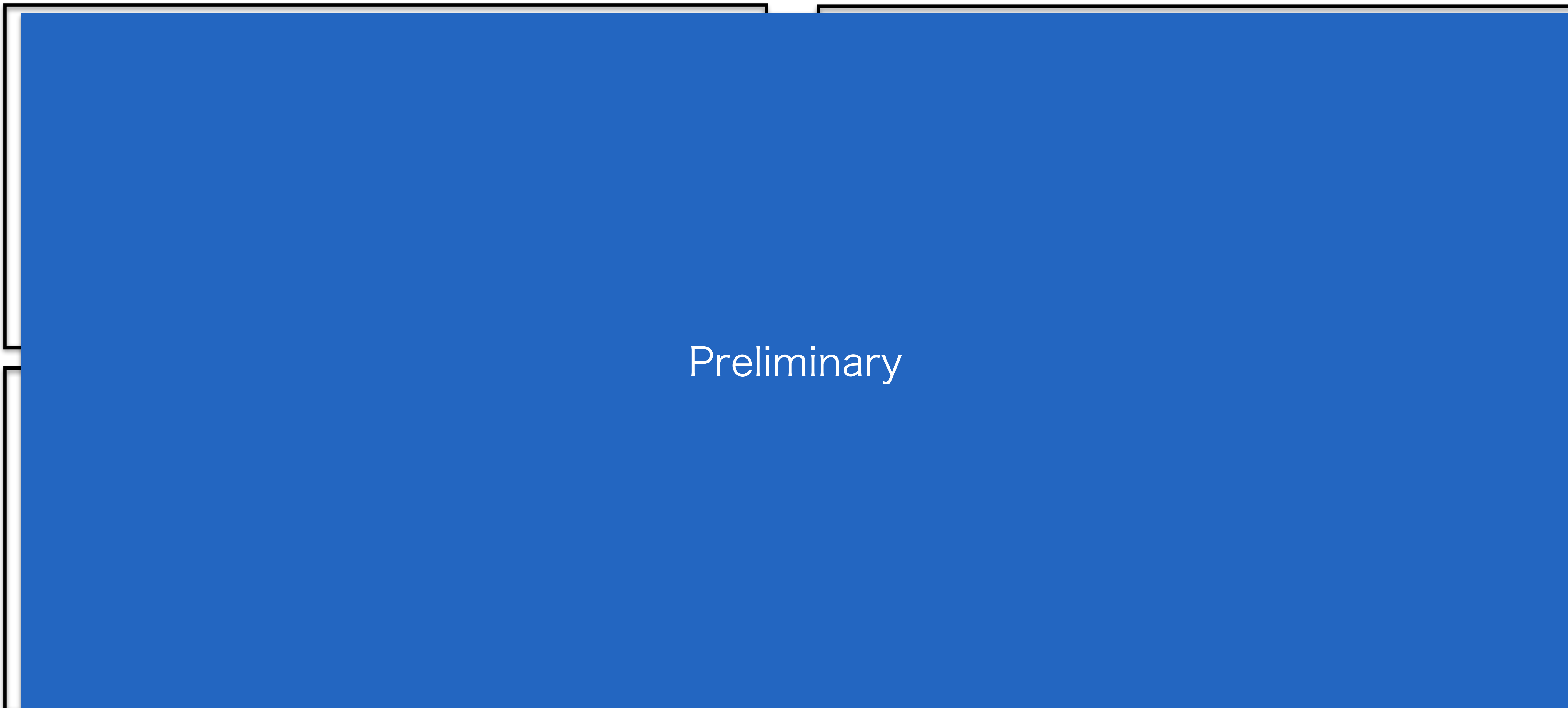
- **Positional matching** between FIRST and Wide / UD-COSMOS with a search radius = 1″
- **Radio-core:** we focus on matching to radio-core; complex morphology radio sources is minor (10%)



HSC & FIRST Images

HSC i
10″x10″

FIRST
2′x2′



Radio loudness (observed frame)

- Radio loudness,

  R = F(radio) / F(optical)

  = F(1.4GHz) / F(i-band)

- **Optically faint radio sources** have high observed-frame R
- Such rare objects are found in the Wide survey (●, ▲) rather than the Ultra-Deep (●, ▲).

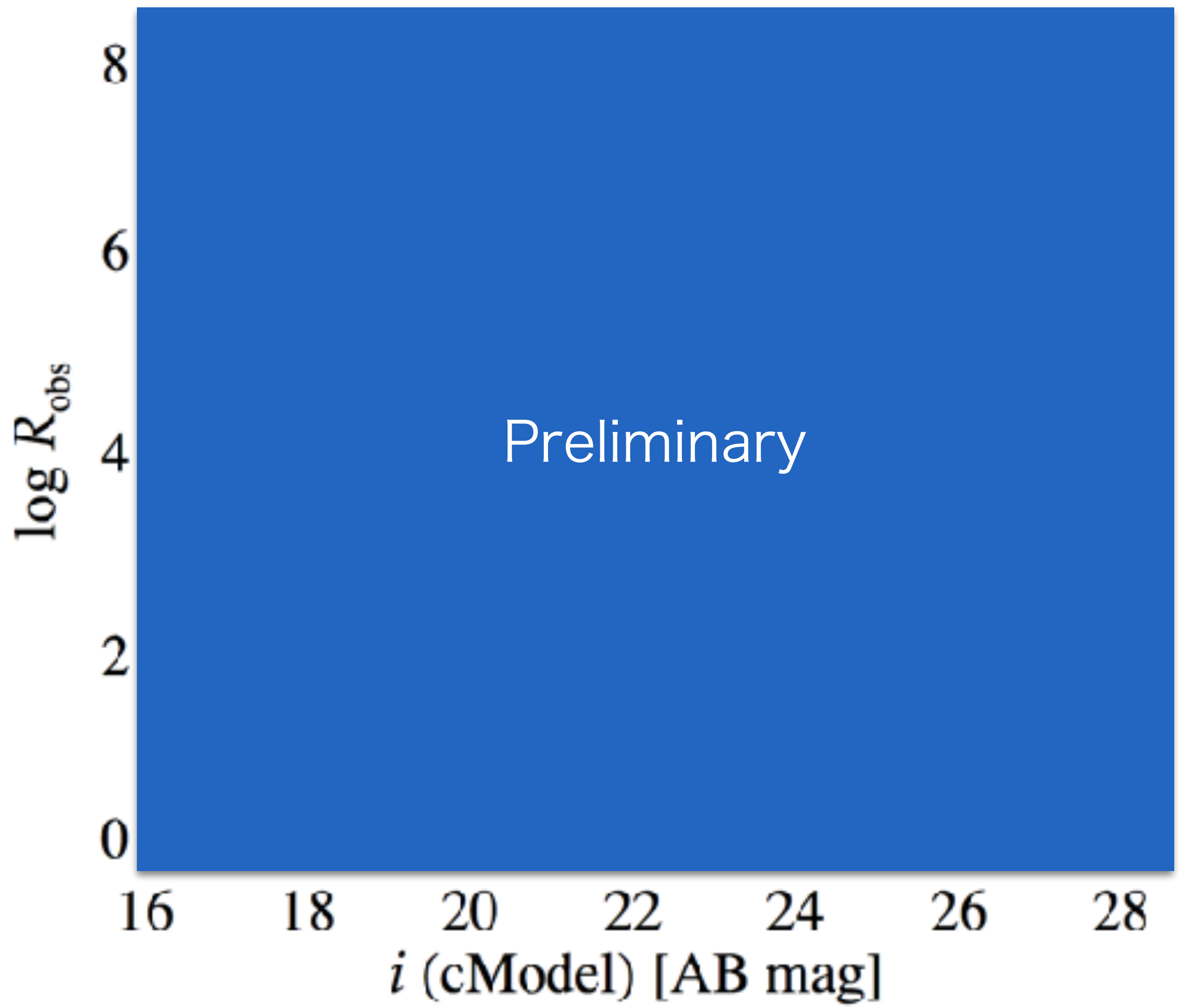
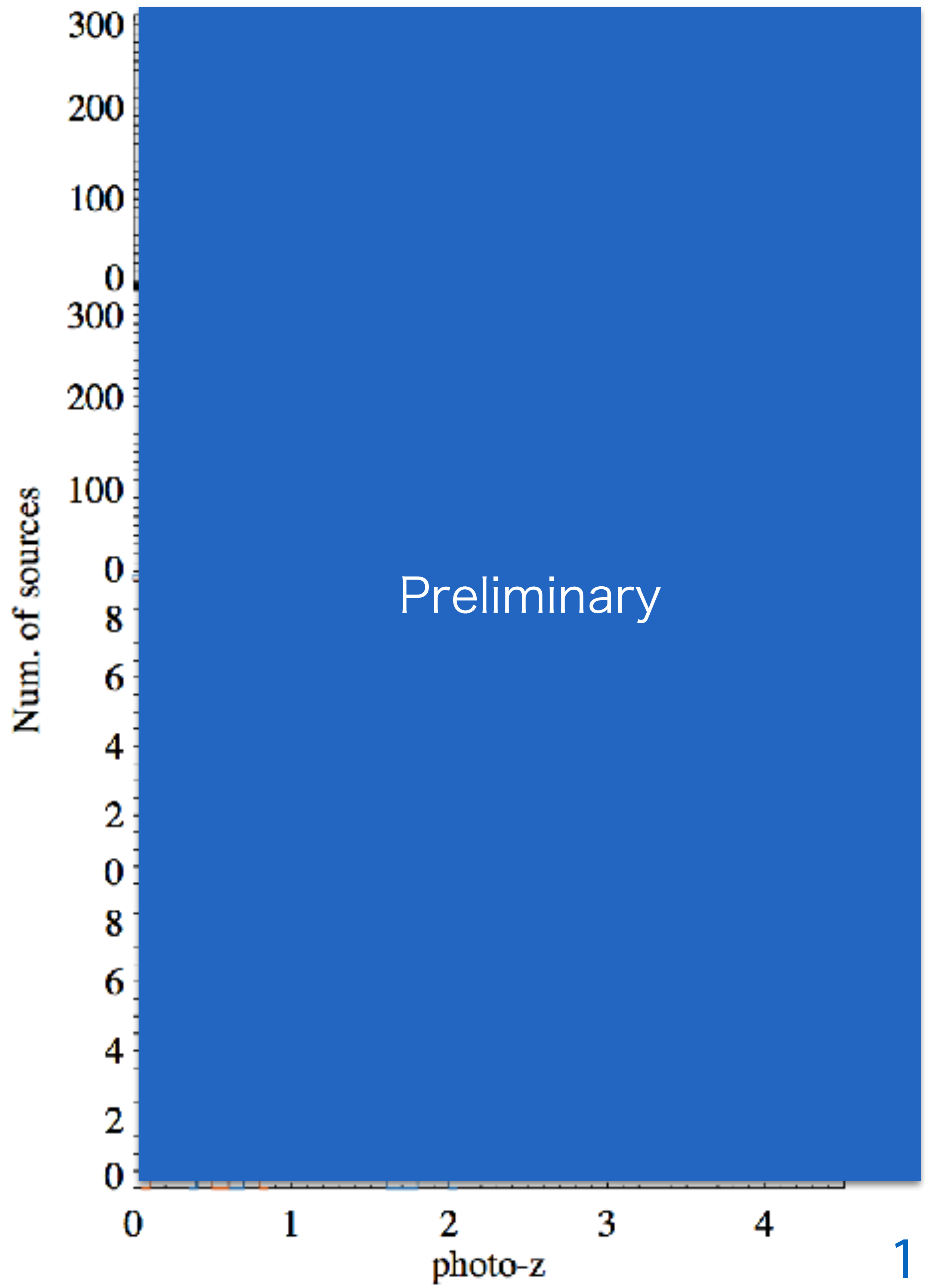


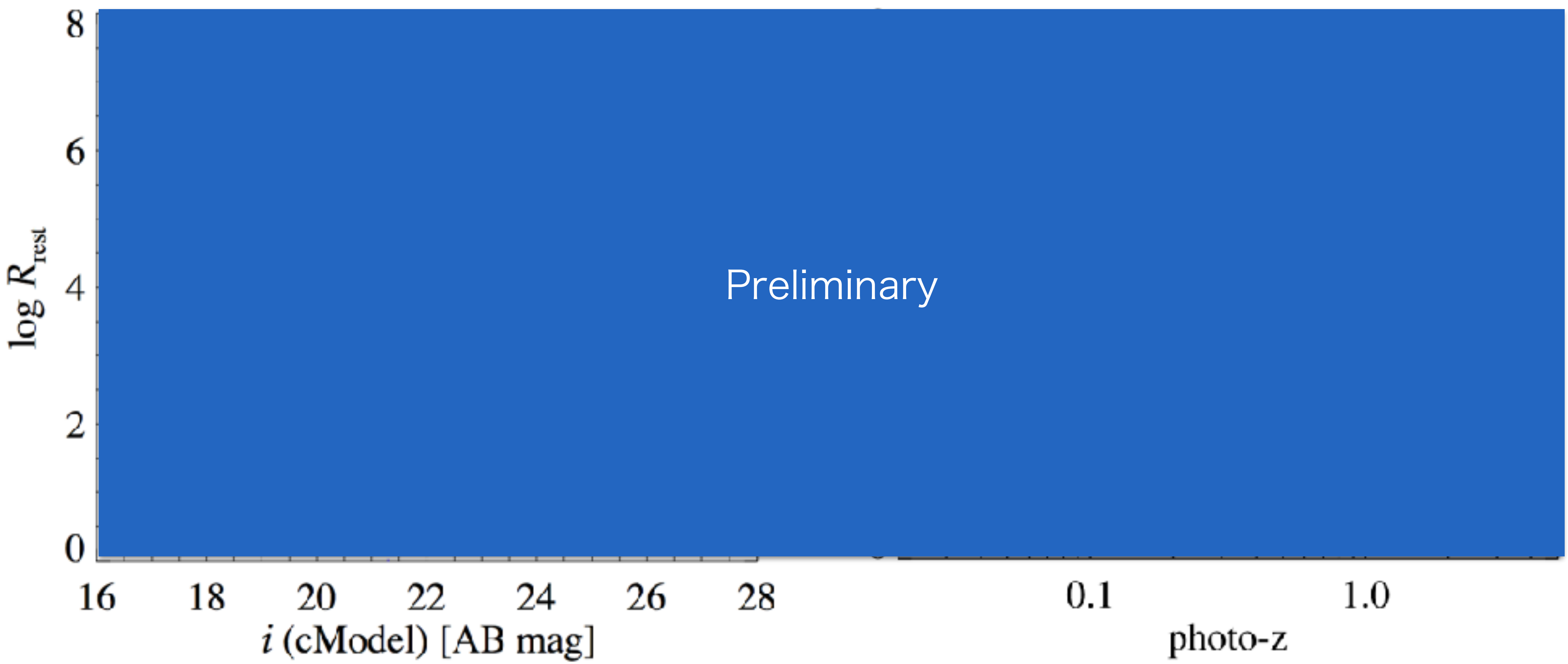
Photo-z of the HSC-FIRST samples

- `Mizuki` SED template fitting (Tanaka 2015)
- xxxx (xx) HSC-FIRST Wide (UD) RGs have secure photo-z
- Almost all the samples have photo-z of 0.2 - 1.5
- **Optically faint (HSC-level) RGs** are located at z >~ 1



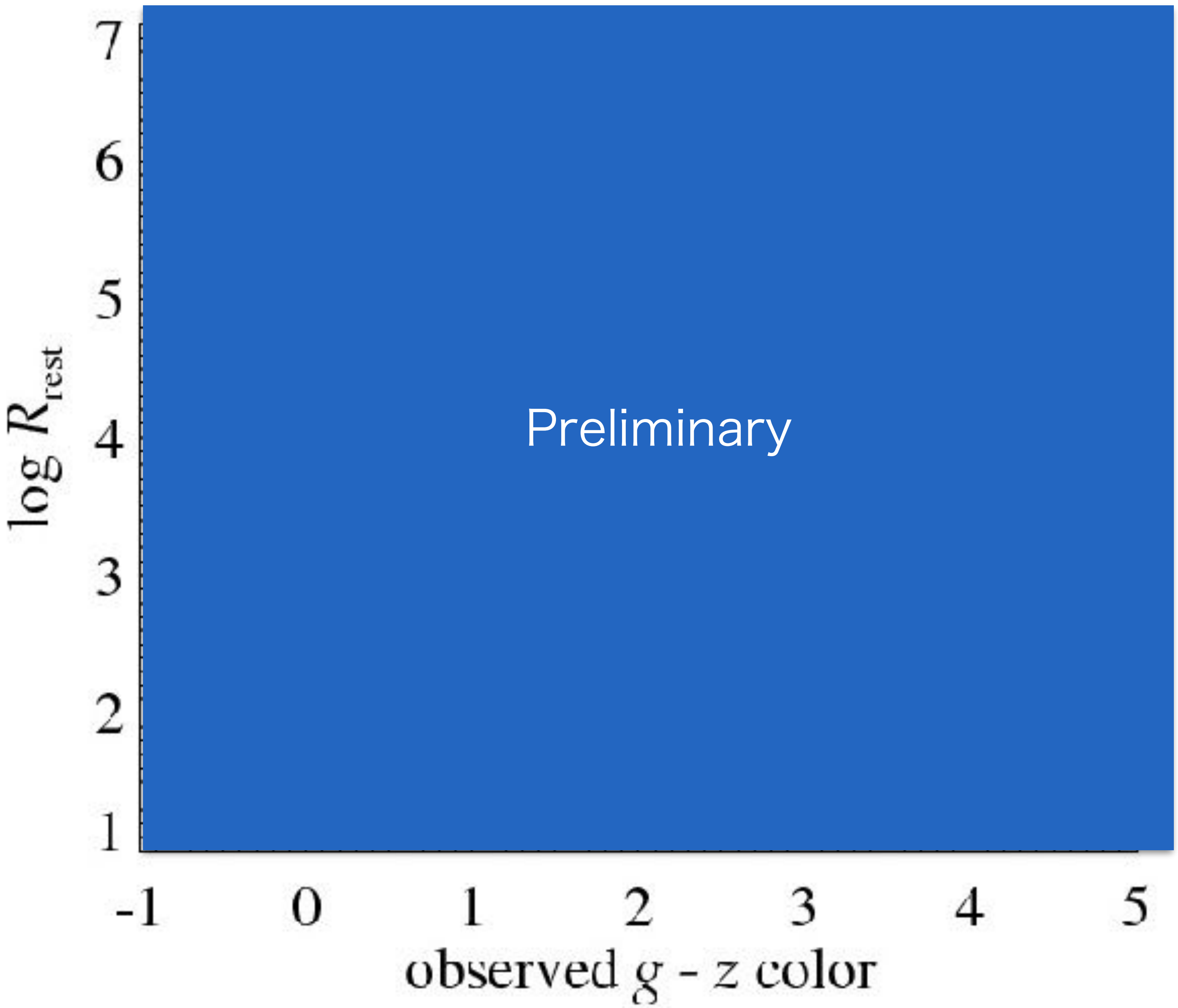
Radio loudness at the rest-frame

- Rest-frame R = rest 5GHz flux / rest g-band flux
  - rest 5GHz flux = *k*-corrected obs-1.4GHz with radio-index α = -0.7 and z_{photo}
  - rest g-band flux = a production from `Mizuki` SED template fitting
- Even when R is k-corrected, optically faint (z~1) RGs show high R.

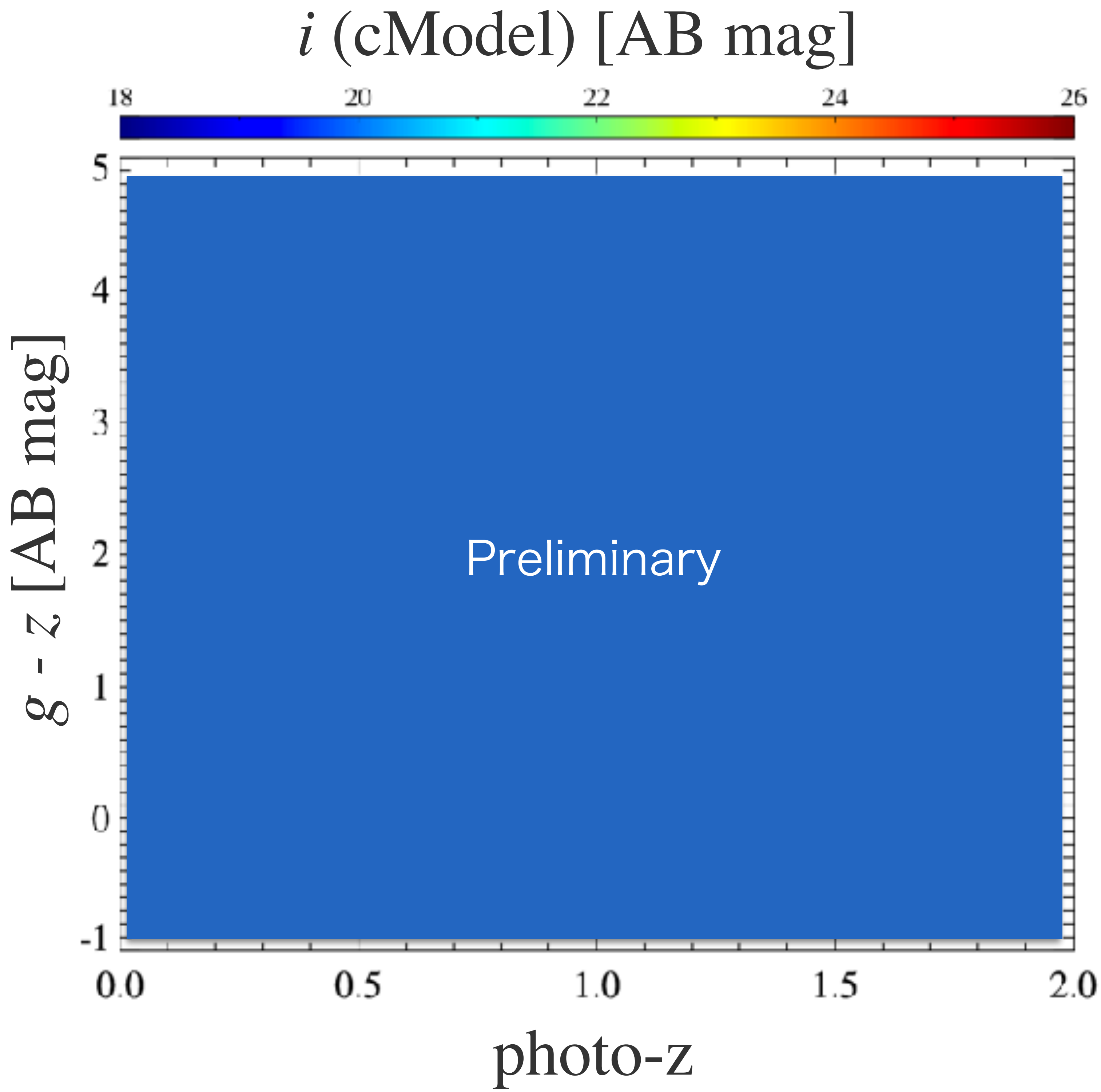


Optical color

- HSC-level RGs have a large dispersion of color
- We have high R and blue color sources



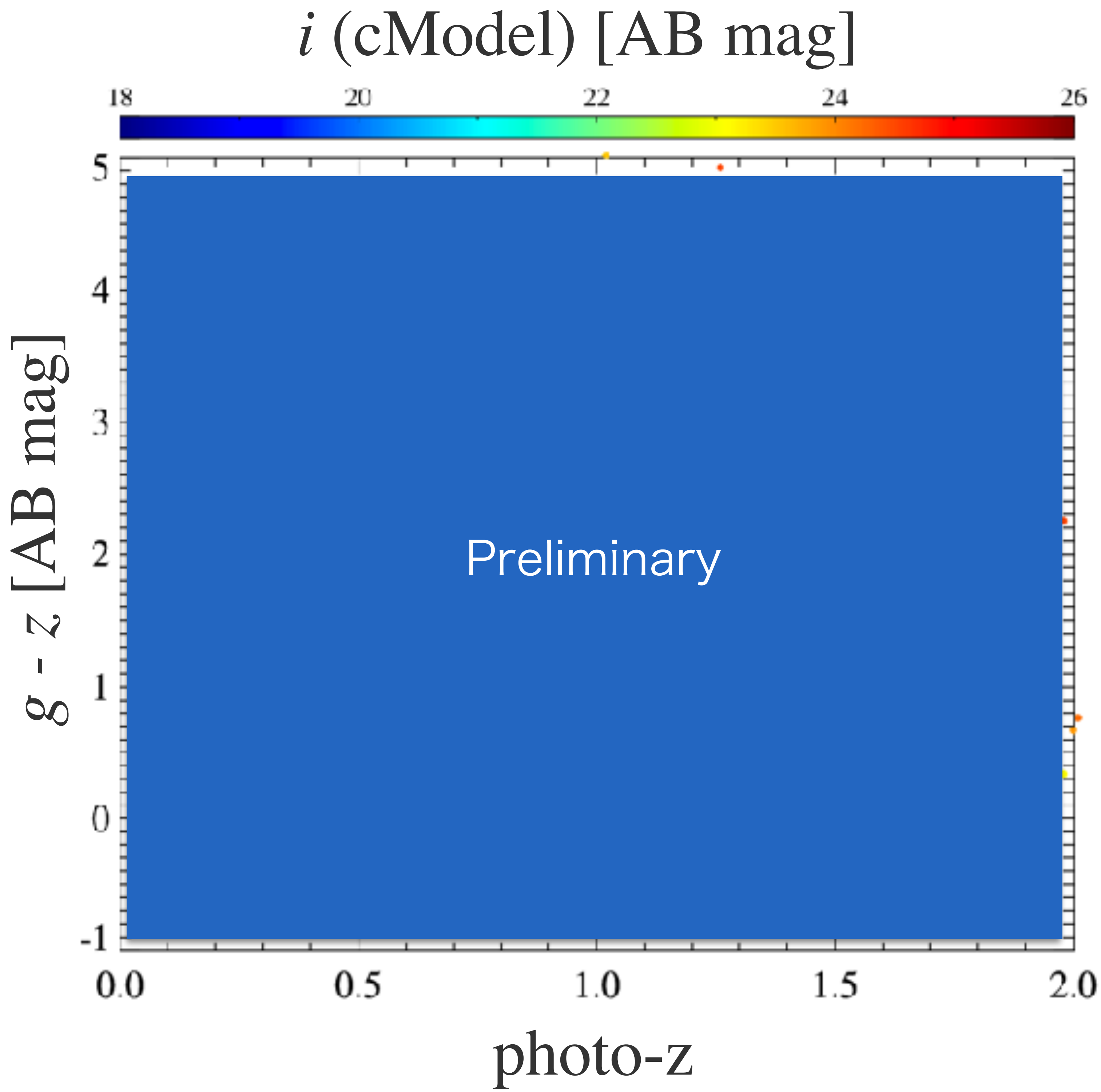
Blue Radio Galaxies



SDSS-level (i<21.3 mag)

- local z<1
- red g-z:
  elliptical host galaxies

Blue Radio Galaxies



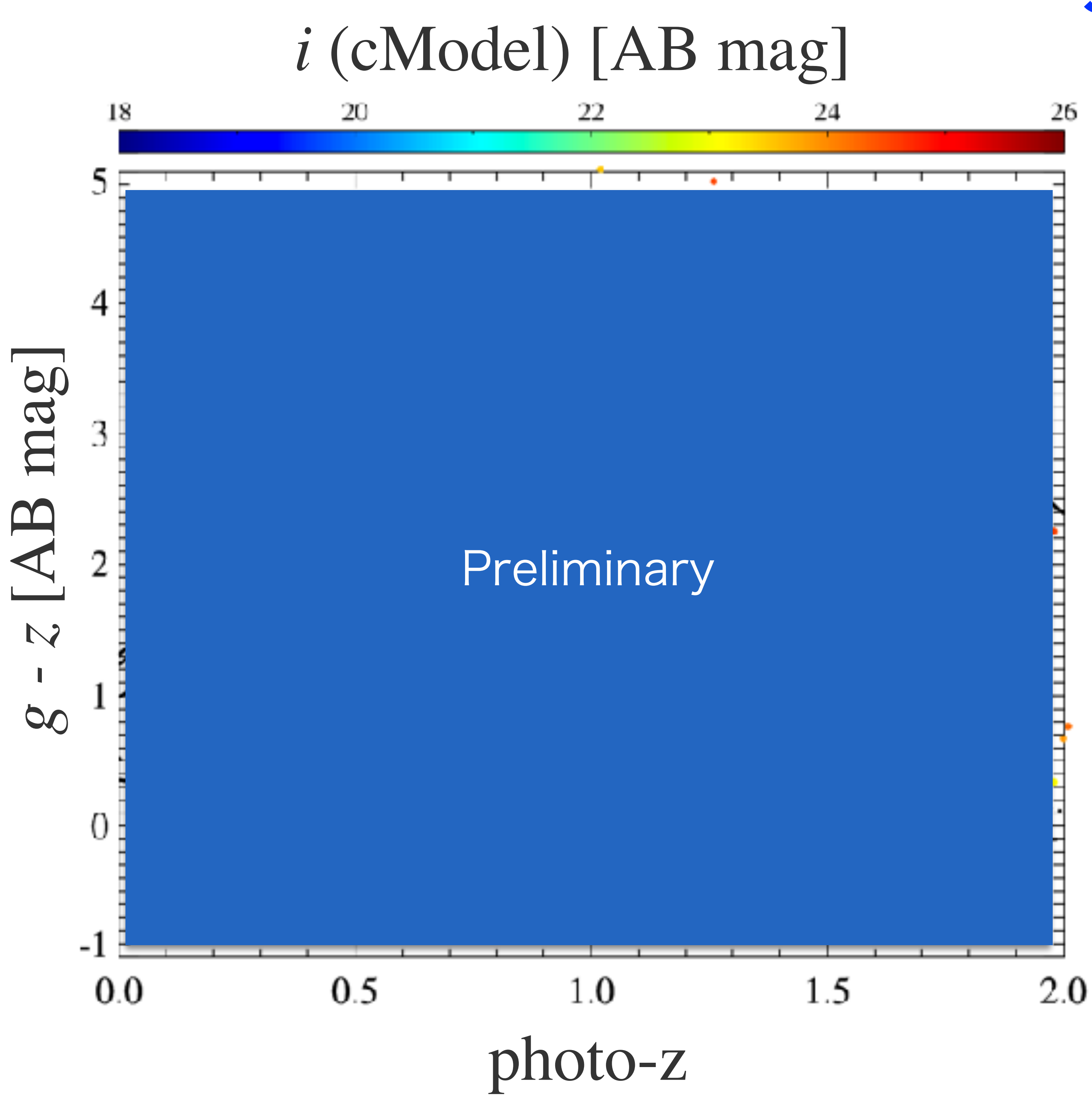
SDSS-level (i<21.3 mag)

- local z<1
- red g-z: elliptical host galaxies

HSC-level (i>21.3 mag)

- redshifted, z>1
- large dispersion in g-z (= rest UV @z~1)

Blue Radio Galaxies



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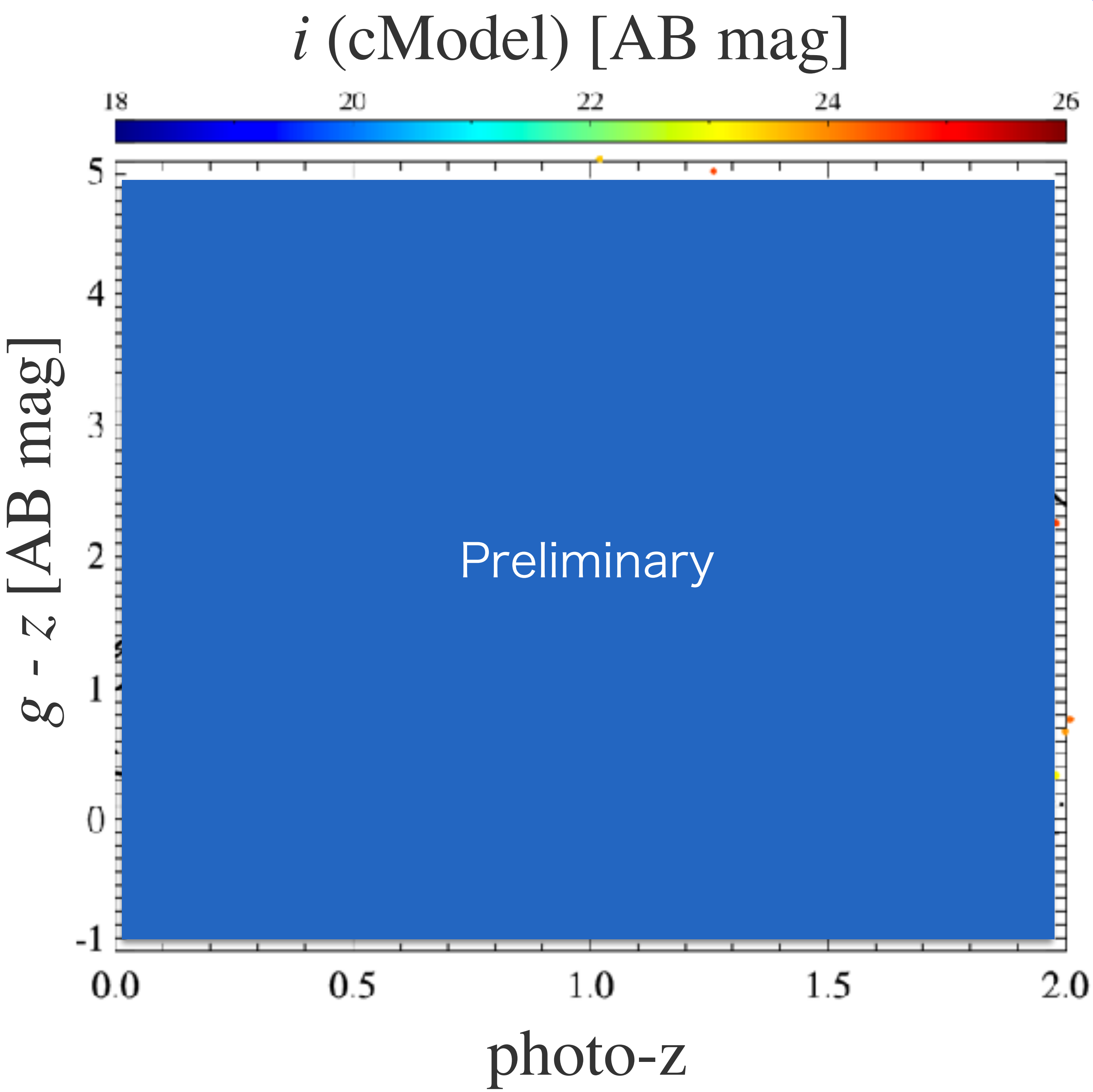
  (= rest UV @z~1)

Blue Radio Galaxies



SDSS-level (i<21.3 mag)

- local z<1
- red g-z:
  elliptical host galaxies

HSC-level (i>21.3 mag)

- redshifted, z>1
- large dispersion in g-z
  (= rest UV @z~1)
- Blue g-z
  - relatively young elliptical galaxies (post-starburst) ?
  - AGN light

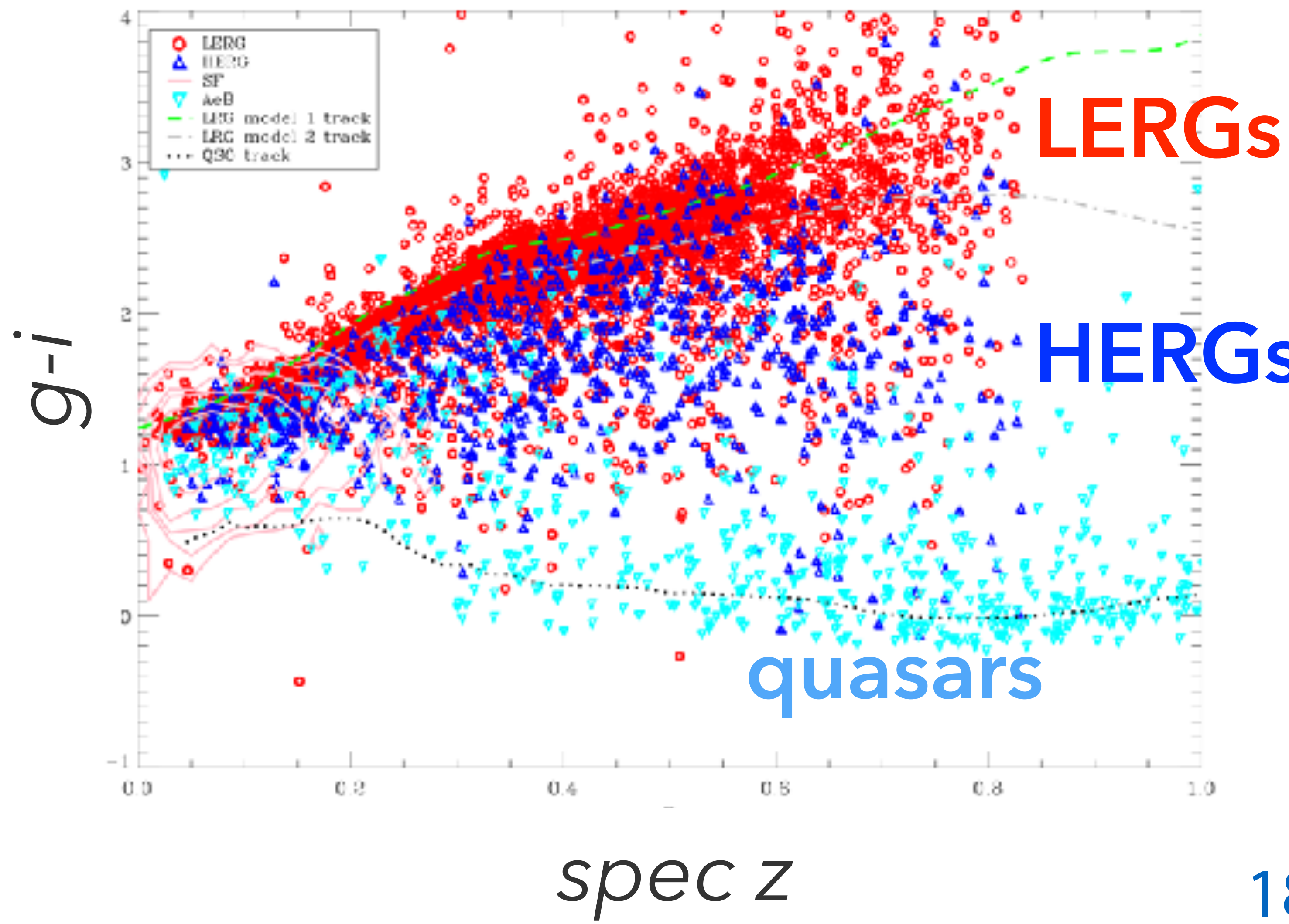
High Excitation Radio Galaxies

- Blue color RGs are similar to HERGs (high-excitation RGs)
- HERGs have young stellar population & low stellar mass, suggesting jets via **cold-gas accretion triggered by galaxy-merger** (Best & Heckman 2012).

SDSS-FIRST RGs (Ching+17)

- HERGs show no Broad emission lines (Ching+17)
  - ➡ Blue color may comes from star formation

Need spectroscopy



Summary

- To create high-z (z>~1) RG sample, we started the search for HSC-FIRST RGs
- We successfully identified > xxxxx radio sources in ~xxx deg^2 field.
    - Subaru HSC-SSP provides good opportunities to probe high-z RGs.
    - Optically faint RGs are located at z~1, and have higher radio-loudness and bluer color than bright RGs.
    - They show similar characteristics to HERGs.

- Future work
    - Spectroscopy z>1 RGs
    - Optical morphology and clustering will be investigated.