Revealing mass and environment quenching since z~1

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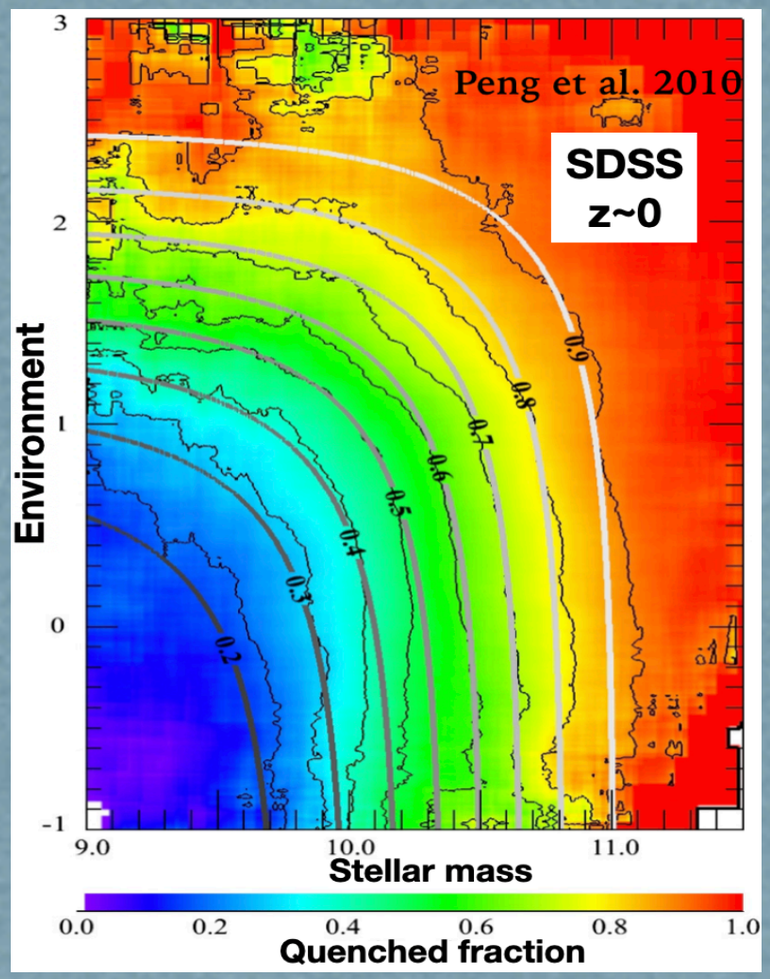
Subaru Users Meeting FY2021

2022.01.12

Galaxy quenching

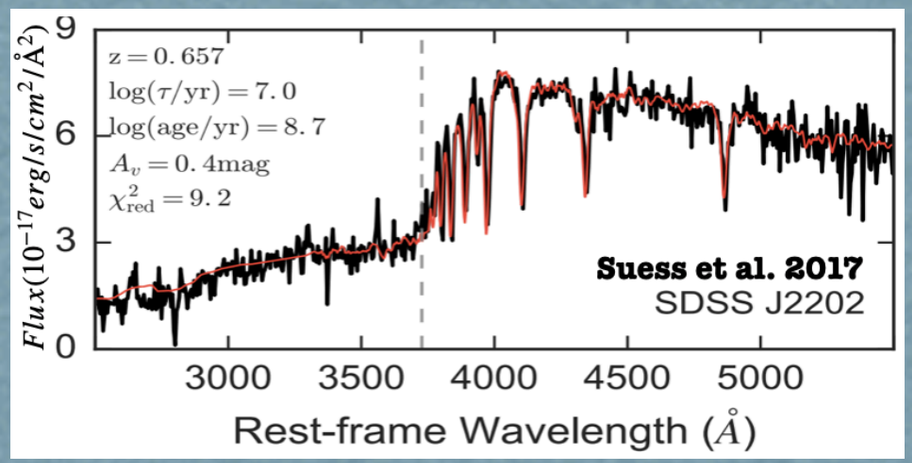
- Galaxy quenching: the process galaxies suppress their star formation activities

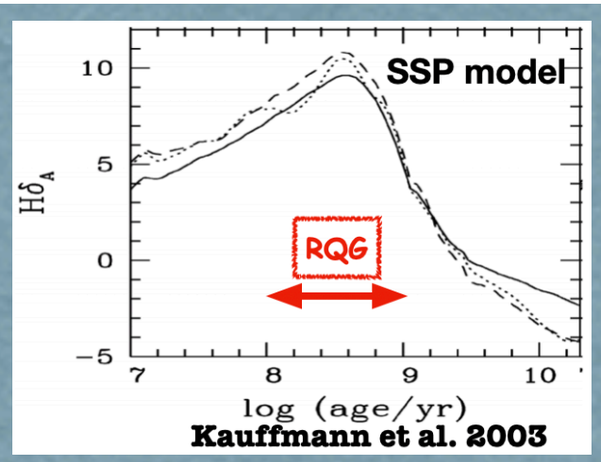


- Mainly affected by stellar mass and environment
  - Internal effect (mass quenching)
    - AGN feedback; morphology quenching…
  - External effect (environment quenching)
    - Tidal effect; ram pressure stripping…
- Timescales are different
- Stellar mass, environment, quenching timescale are important for understanding quenching scenario

Recently-quenched galaxy

- Recently quenched galaxies: still in or shortly after quenching process ➤ directly deliver information





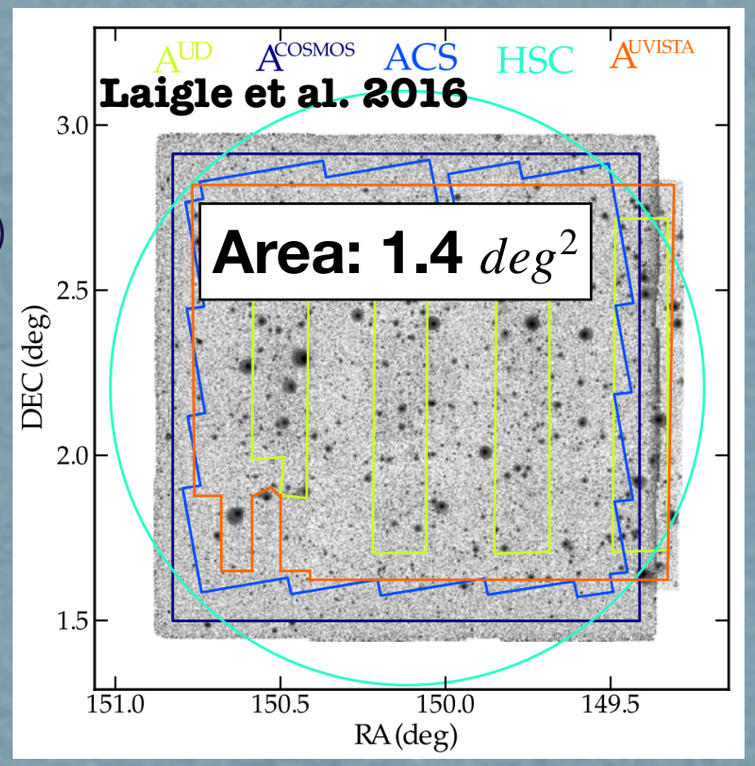
- Spectral features of RQGs: passive spectra + strong Balmer absorption lines
  - Due to large fraction of A type stars
- Evolution of Balmer absorption line strength
- The strength peaks between 0.1-1 Gyr ➤ recently-quenched phase

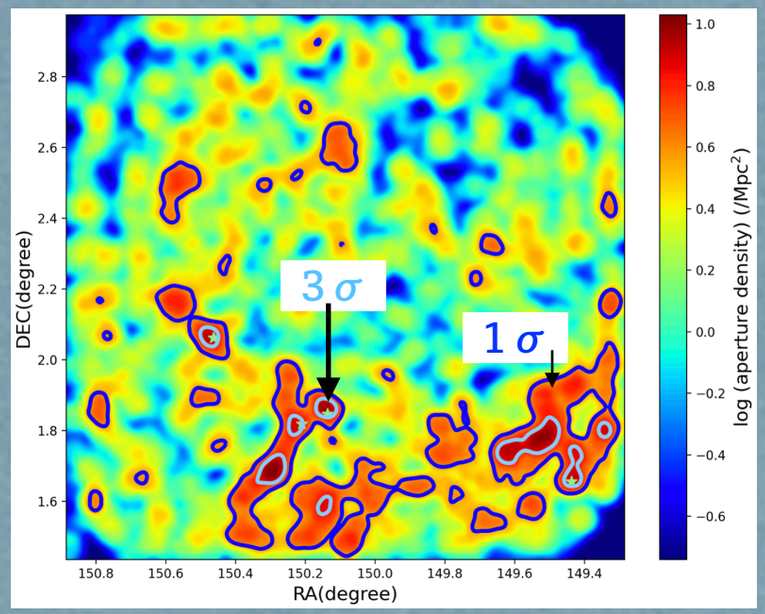
- Quenching timescale is short ➤ RQGs are rare ➤

spectroscopic data are expensive to get

Sample selection

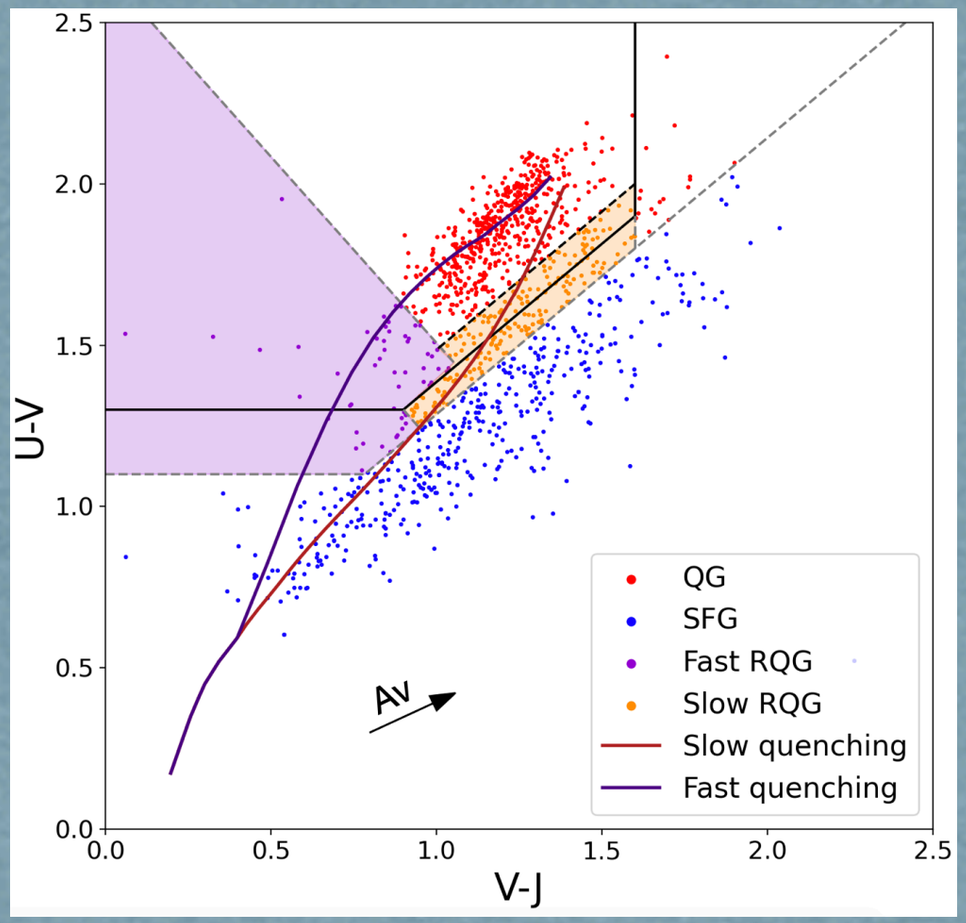
- COSMOS2015 catalog
  - Type flag == 0 (galaxy type)
  - Photometric redshift (LEPHARE; 26 bands) 0.5<z<1.0
  - Stellar mass (LEPHARE) $M_* > 10^{9.8} M_\odot$
  - At least 2 optical bands and 2 NIR bands
- Use local density ($\Sigma 5$) as proxy of environment
  - 3 σ contours select overdensity (cluster); 1 σ contours select field
  - Select 17 clusters in total
- Determine the final sample: all galaxies within 2.8×2.8 Mpc^2 square aperture, in redshift ±0.05 range



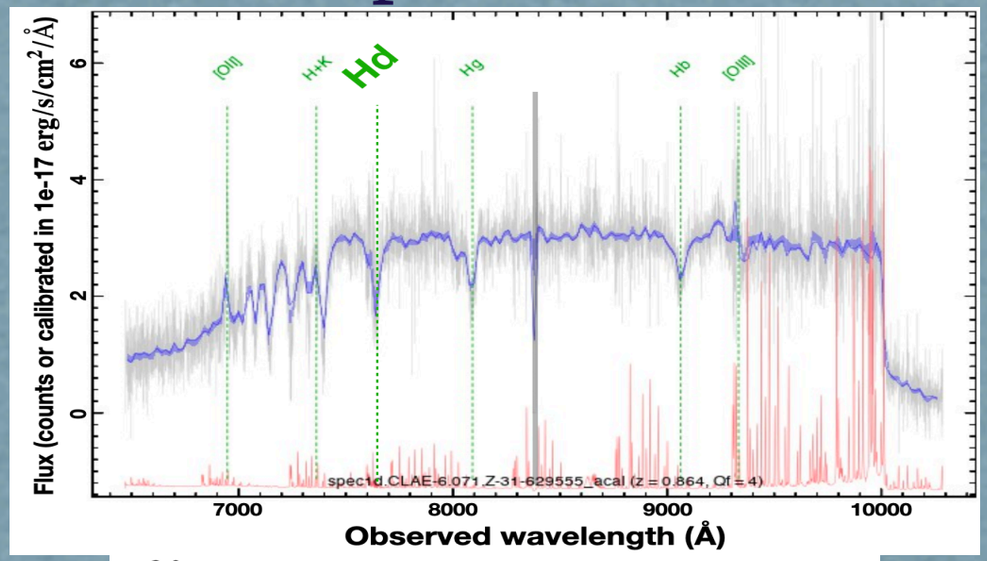


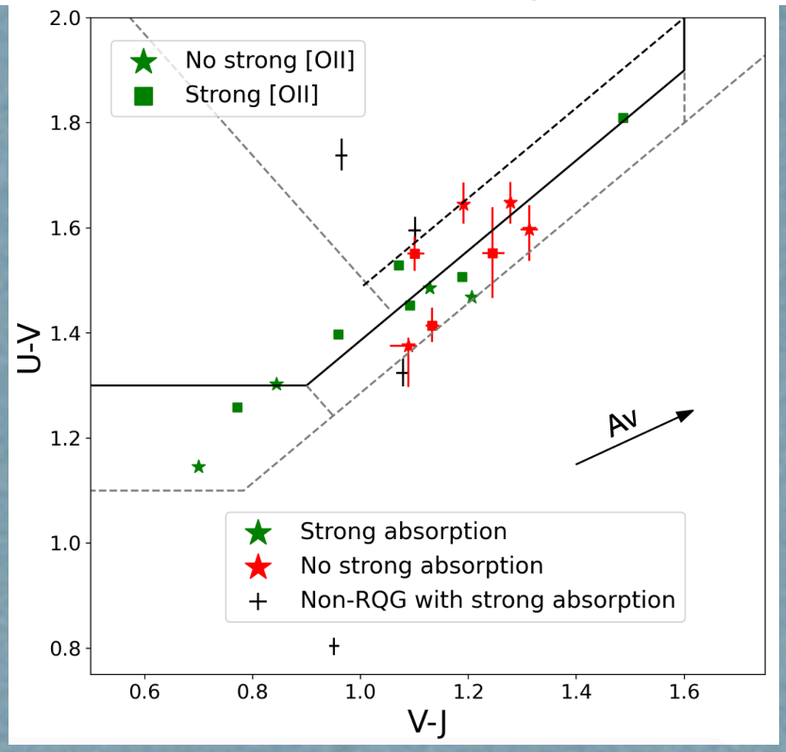
UVJ selection

- Classify SFG, QG, RQG based on rest-frame color information
- Use model evolution paths with 0.1 and 1 Gyr timescale to separate fast and slow quenching RQGs



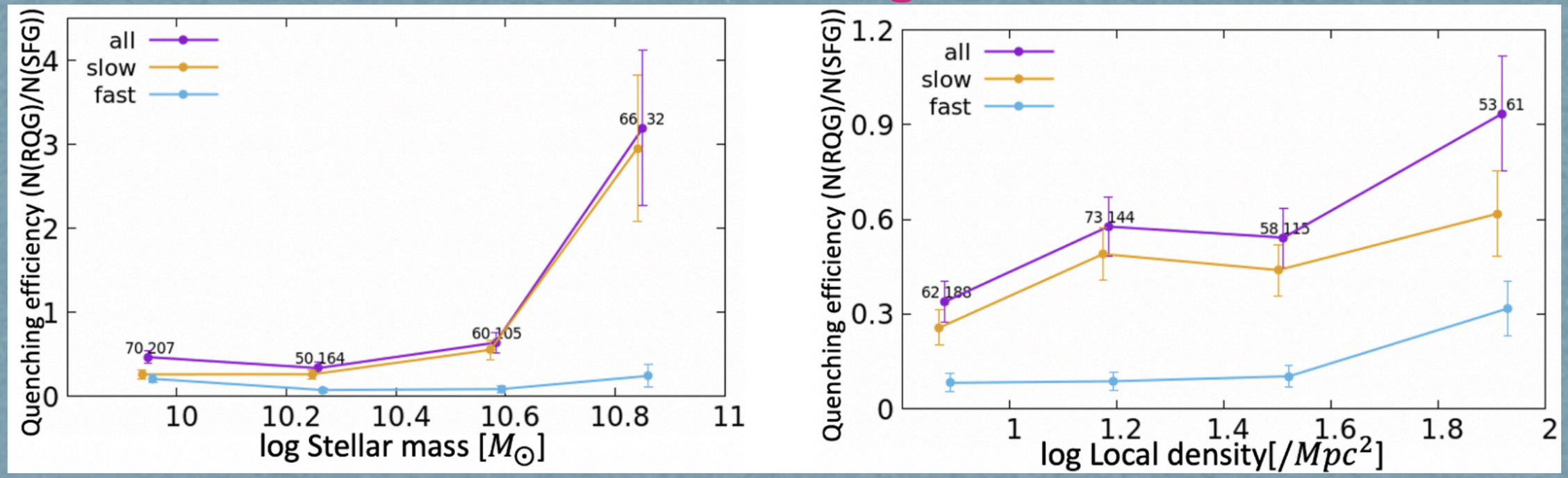
- Spectral confirmation using DEIMOS spectra





Quenching efficiency

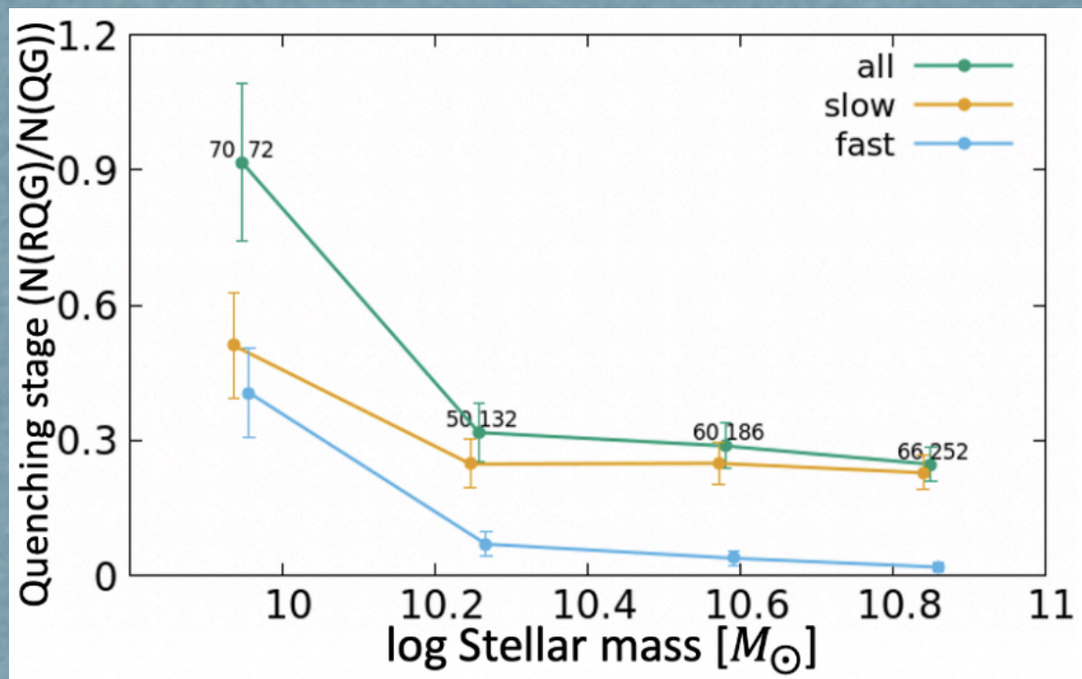
- Defined as N(RQG)/N(SFG); larger value== more efficient

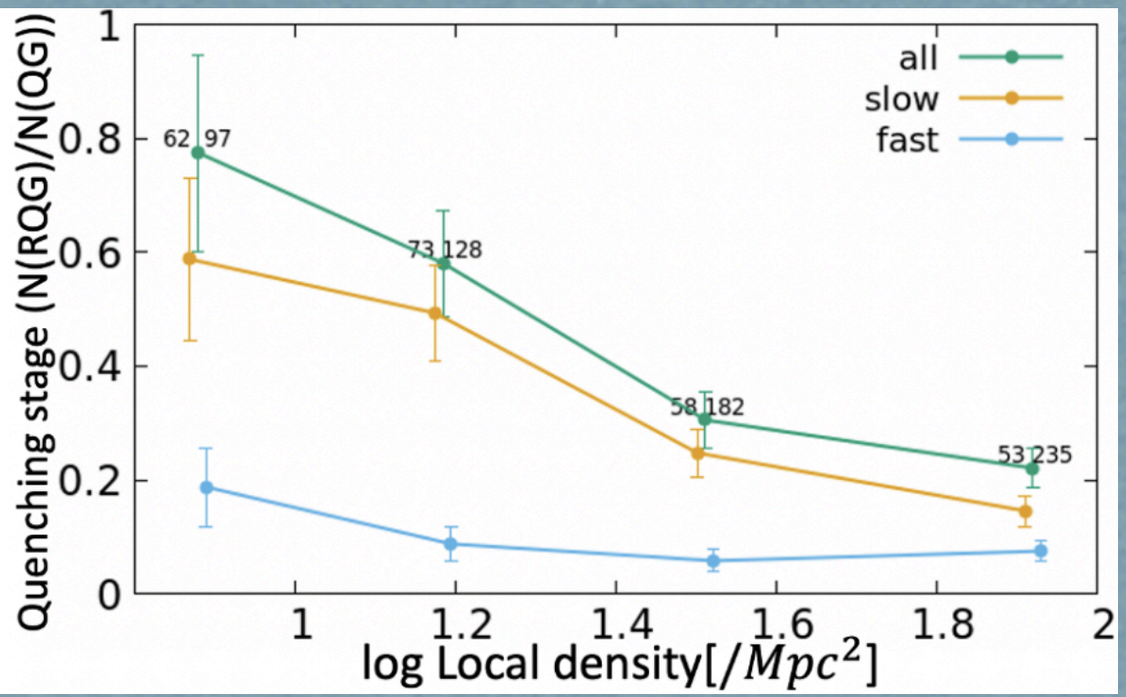


- Quenching efficiency has both mass and environment dependence
- Visibility time（time a galaxy stay in RQG region）may affect the dependences
  - The mass dependence of N(RQG)/N(SFG) may partly due to mass dependence of visibility time

Quenching stage

- Defined as N(RQG)/N(QG); large value==earlier stage

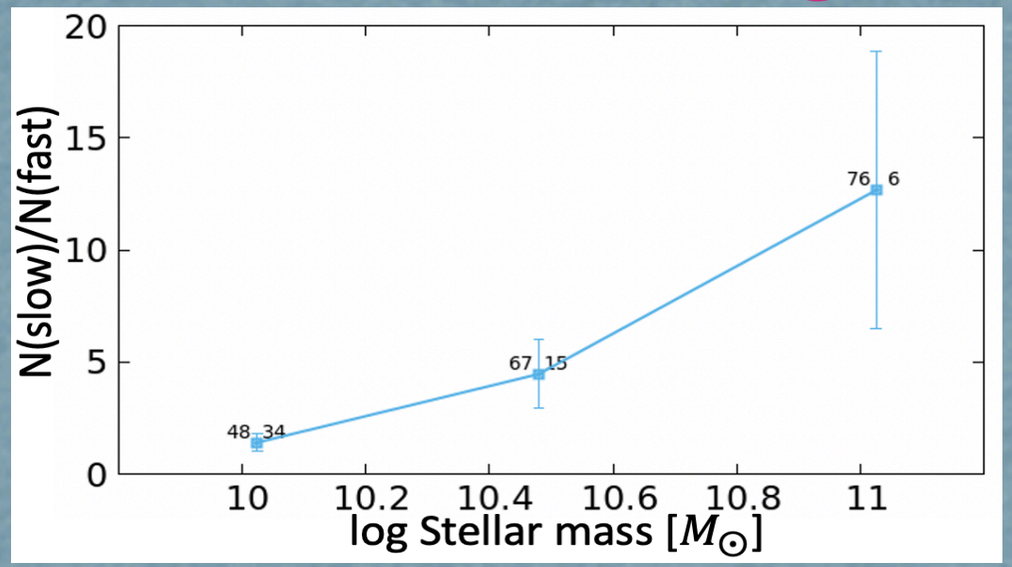


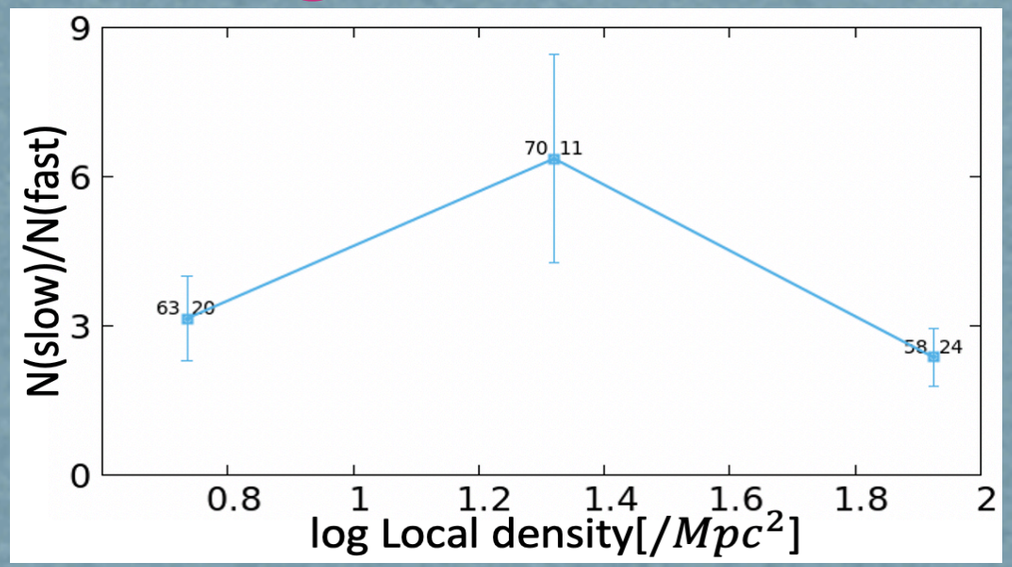


- Massive galaxies started quenching earlier
- Galaxies in denser environment started quenching earlier
- Visibility time does not show strong impact on this result

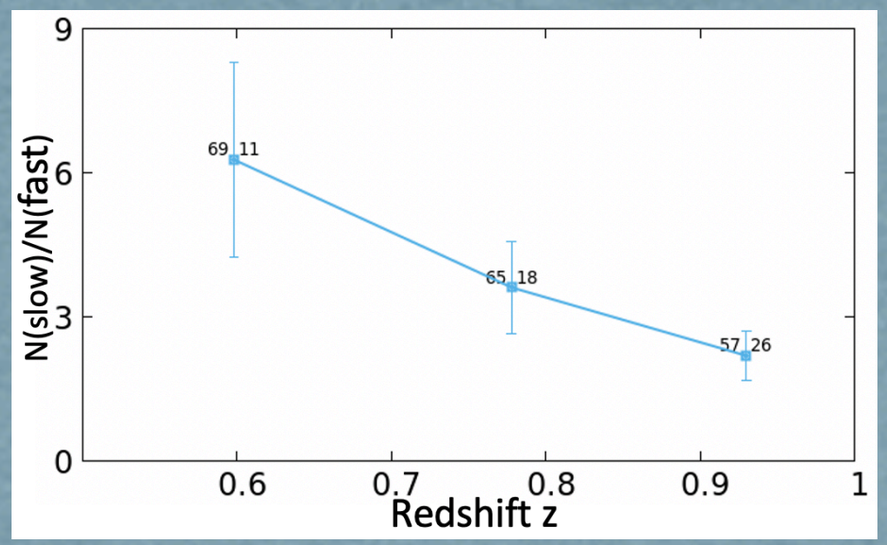
Quenching timescale

- N(slow)/N(fast); larger value == longer timescale





- Massive galaxies tend to have longer quenching timescale
- Environment does not show clear impact on quenching timescale
- The importance of slow quenching increases along cosmic time



Interpretation of results

	Stellar mass	Local density	Redshift
Q.E.	↗	↗	/
Q.S.	↘	↘	/
Timescale	↗	No clear dependence	↘

- Denser environment and larger stellar mass enhance quenching
- Mass dependence of Q.E. may be affected by visibility time
- Massive galaxies quench earlier ➤ downsizing scenario
- Denser environments are in later stage of quenching ➤ inside-out quenching of clusters
- Mass and redshift dependences of timescale ➤ quenching mechanisms for different mass/redshift should be different

Description	N(slow)/N(fast)
①high mass + low local density	6.500±2.264
②low mass + high local density	1.308±0.343

Case ①: Slow quenching in massive galaxies, does not depend on environment; consistent with long timescale AGN feedback

Case ②: Fast quenching in dense environment, especially effective on low mass galaxies; consistent with ram pressure stripping

Future prospects

- Expand analysis area and redshift range
  - COSMOS ➜ all HSC DEEP fields
  - Redshift 0.5-1.0 ➜ redshift 0.5-2.0（since the cosmic noon）in IRAC covered fields
- Spectroscopic confirmation of RQGs
  - Pilot projects: FOCAS, MOIRCS, MOSFIRE
  - RQG spectroscopic survey: PFS
- Derive physical properties from RQG spectra
  - Quenching timescale
  - Starburst strength
  - Visibility time

Summary

- UVJ diagram can effectively select RQG and roughly separate different quenching timescales
- Efficiency of quenching depends on both mass and environment, but the mass dependence might be affected by visibility time
- Our results support downsizing scenario and inside-out quenching scenario in clusters
- Quenching timescale depends on both stellar mass and redshift
- Systematic spectroscopic survey of RQG is essential for further study of galaxy quenching

Thank you very much for your attention!