Statistical study of recently quenched galaxies in preparation for PFS survey

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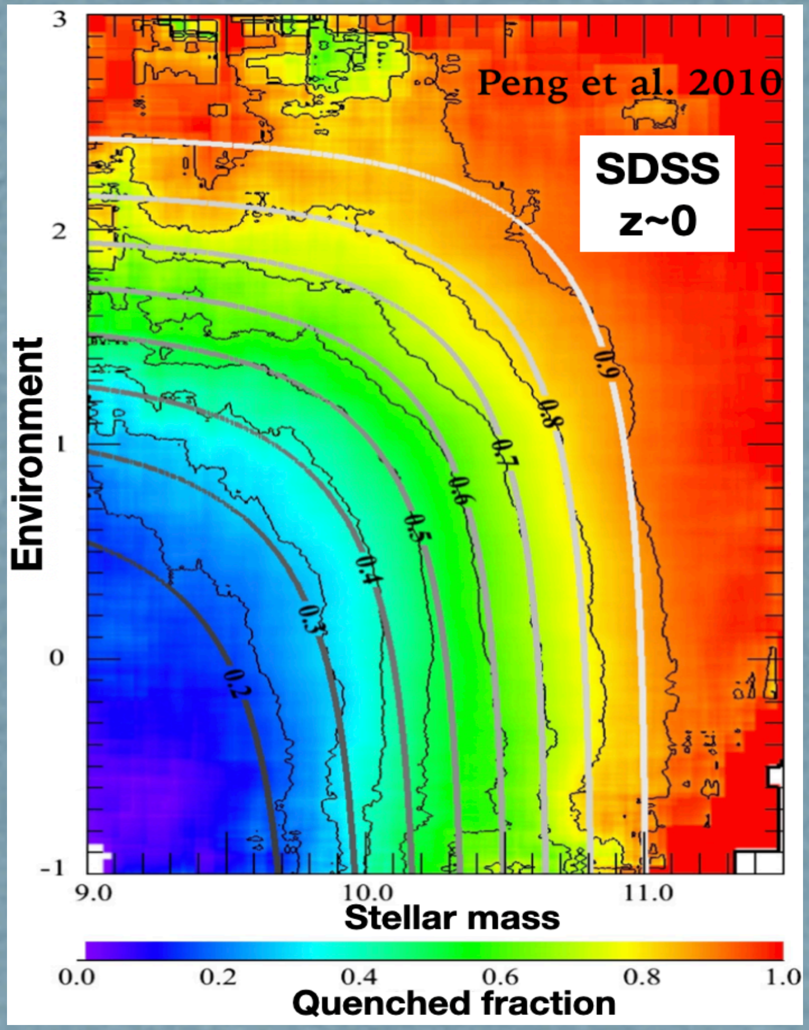
Galaxy quenching

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

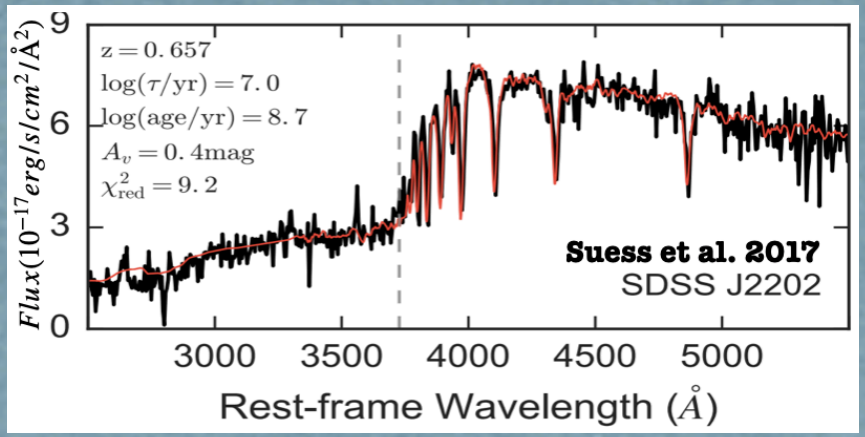


- Mainly affected by stellar mass and environment
  - Internal effect (mass quenching)
    - AGN feedback; morphology quenching…
  - External effect (environment quenching)
    - Tidal effect; ram pressure stripping…
- Timescales are different

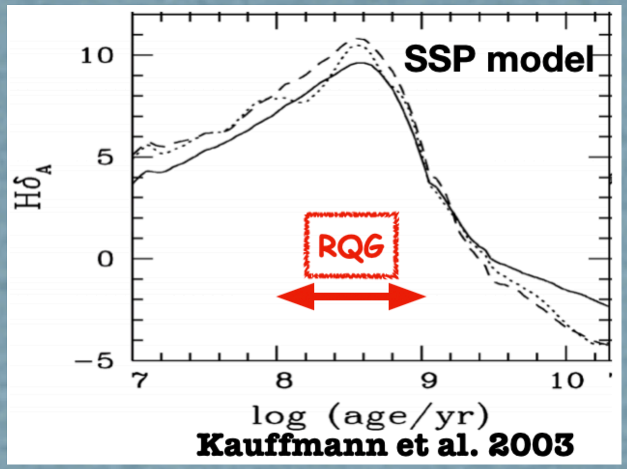
- Stellar mass, environment, quenching timescale are important for understanding quenching scenario

Recently-quenched galaxy

- Recently quenched galaxies: still in or shortly after quenching process ➤ directly deliver information
- How to identify a RQG precisely? Use galaxy spectrum



- Spectral features of RQGs: passive spectra + strong Balmer absorption lines
  - Due to large fraction of A type stars



- H δ absorption line strength

Recently-quenched galaxy

- What kind of spectroscopic sample do we need to study mass and environment dependence of quenching?
  - Wide range of stellar mass
  - Various environments

A statistical sample of RQG spectra is necessary

- Quenching timescale is short ➤ RQGs are rare ➤ large parent sample + efficient selection method

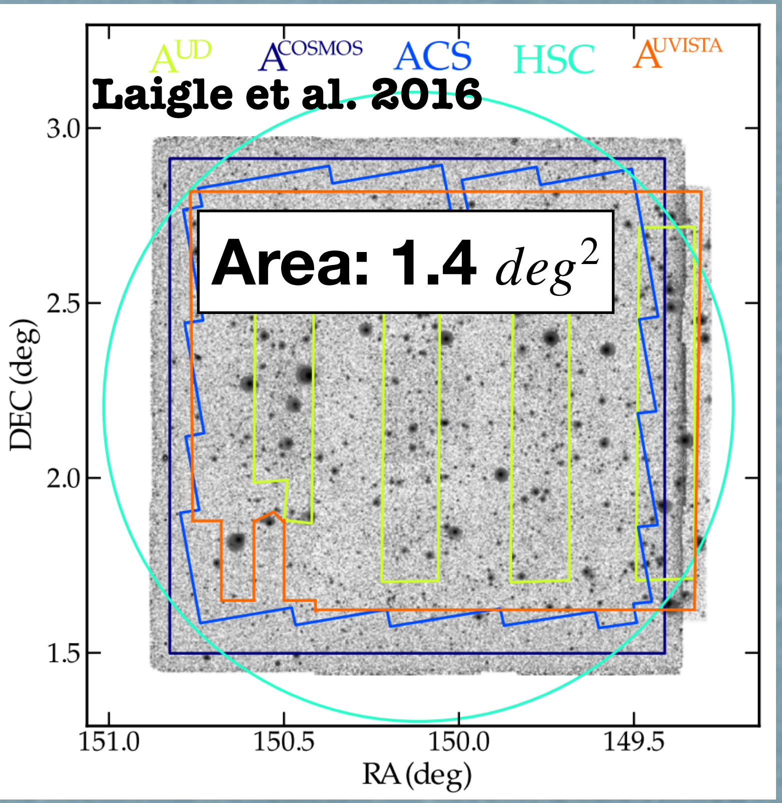
- Parent sample: HSC-SSP Deep (Wide area+deep data)

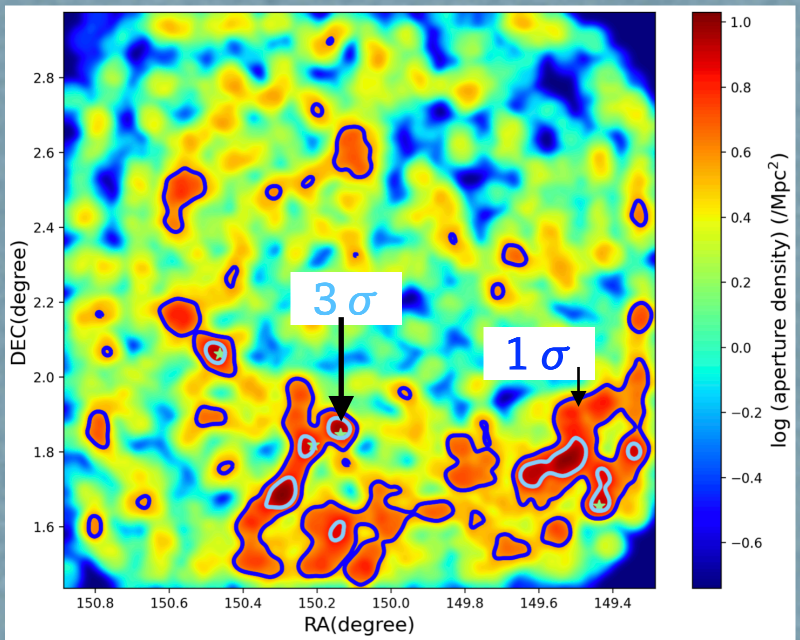
★ Selection method (This work)

- Future spectroscopic observation: PFS (multi-object capability + large FOV)

Sample selection

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





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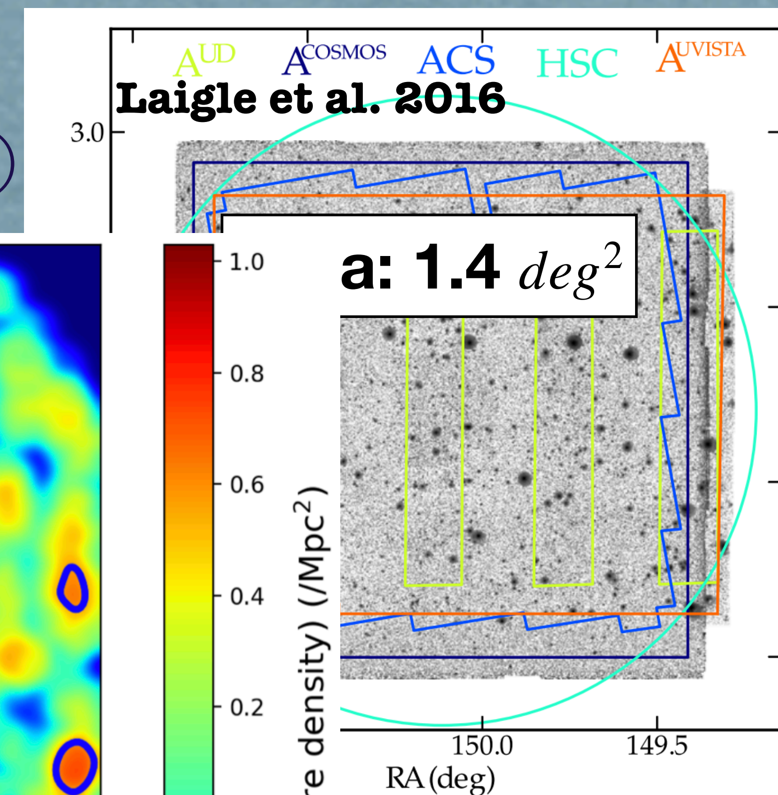

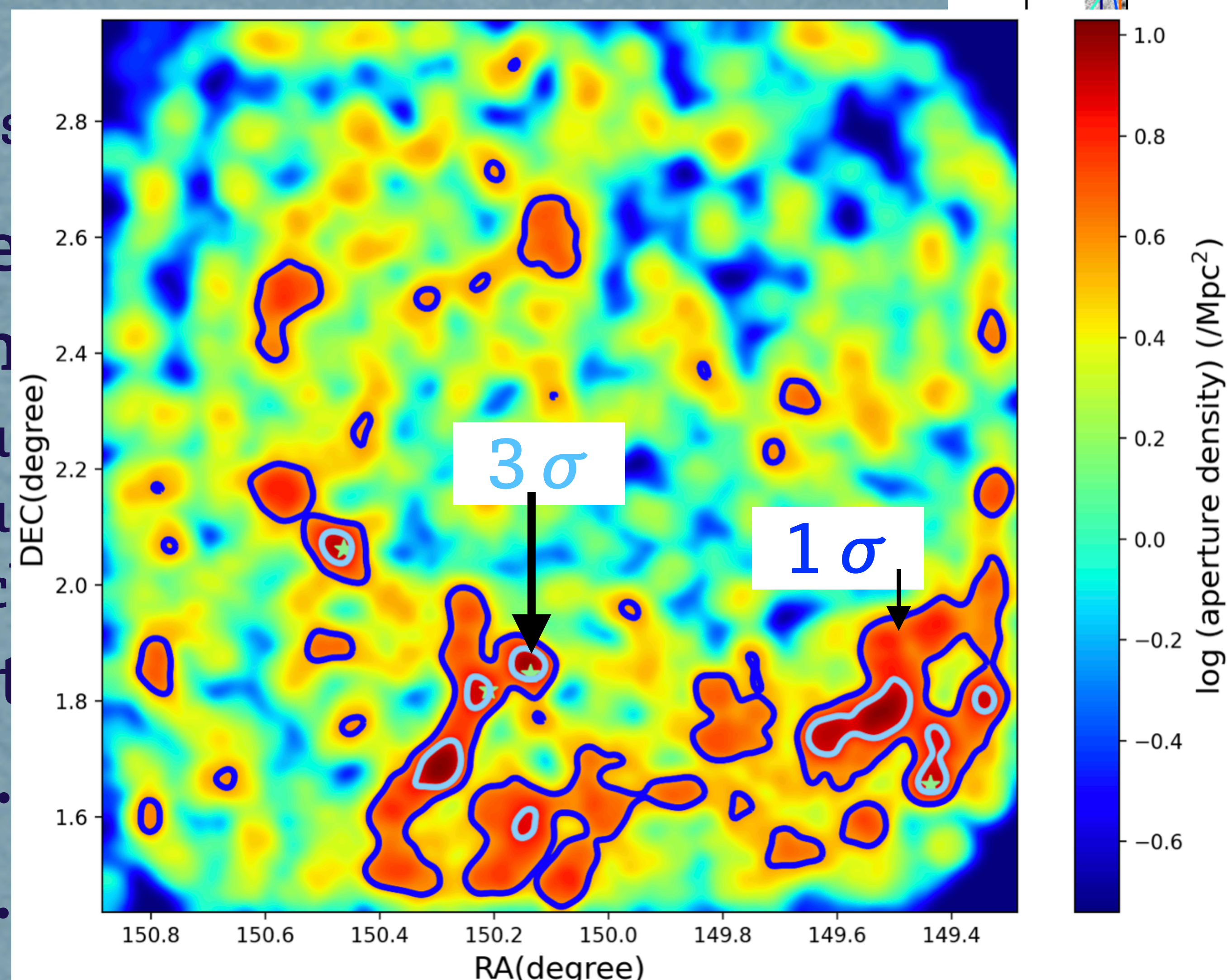

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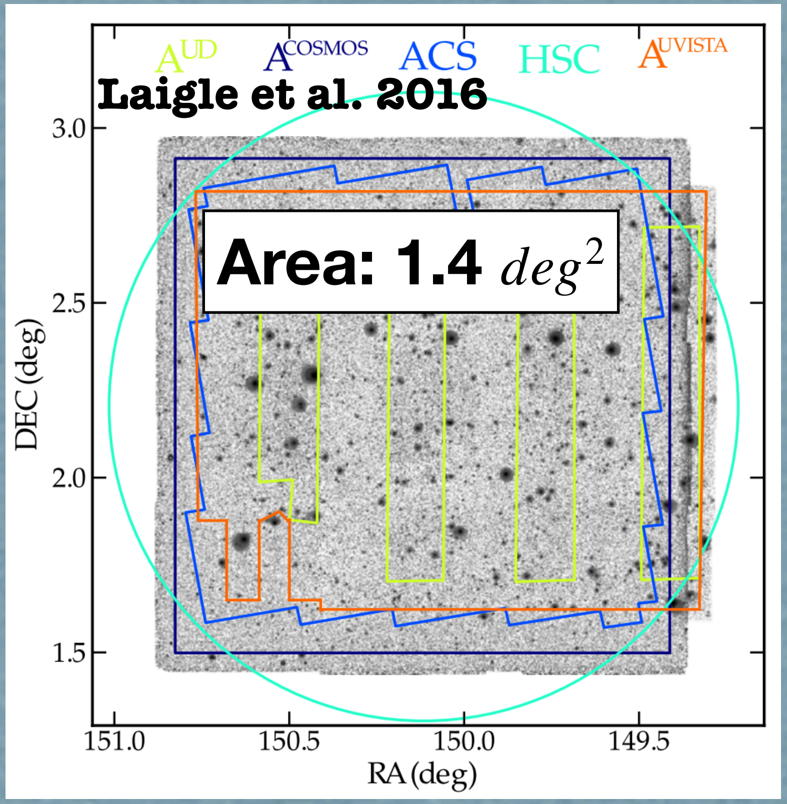
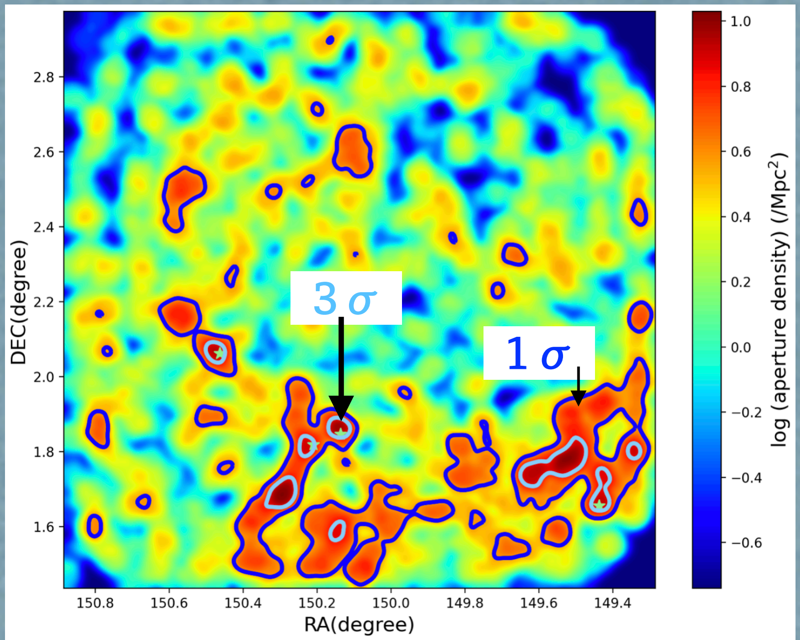
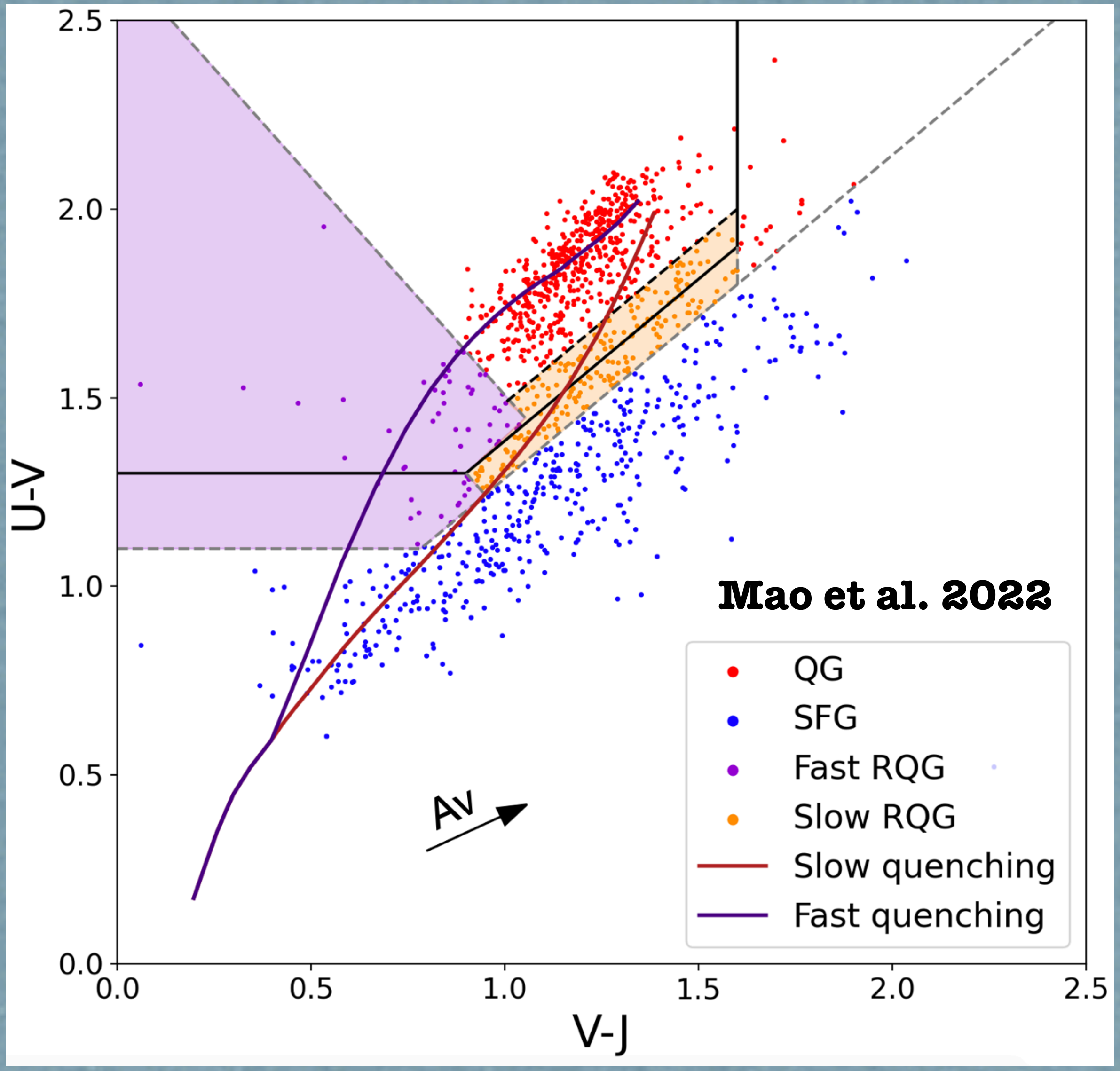




UVJ selection

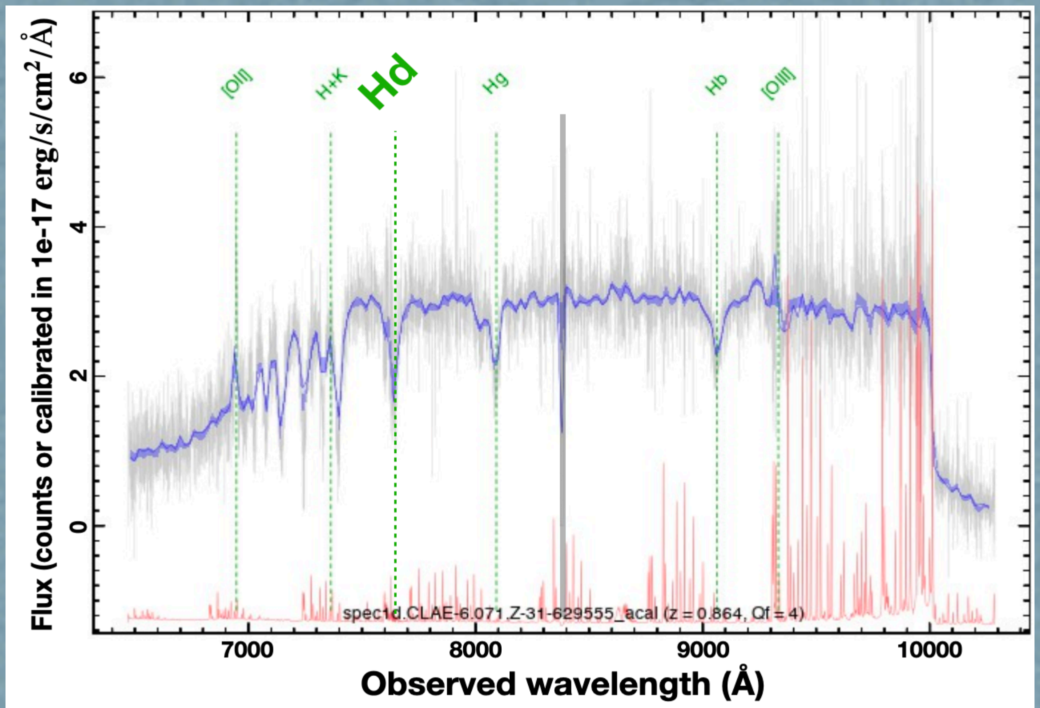
- Classify SFG, QG, RQG based on rest-frame color information
  - RQGs lie between star-forming (SFG) and quiescent (QG) galaxies

- Rest-frame color evolution path of two model galaxies
- Use models with 0.1 and 1 Gyr quenching timescale to separate fast and slow quenching RQGs

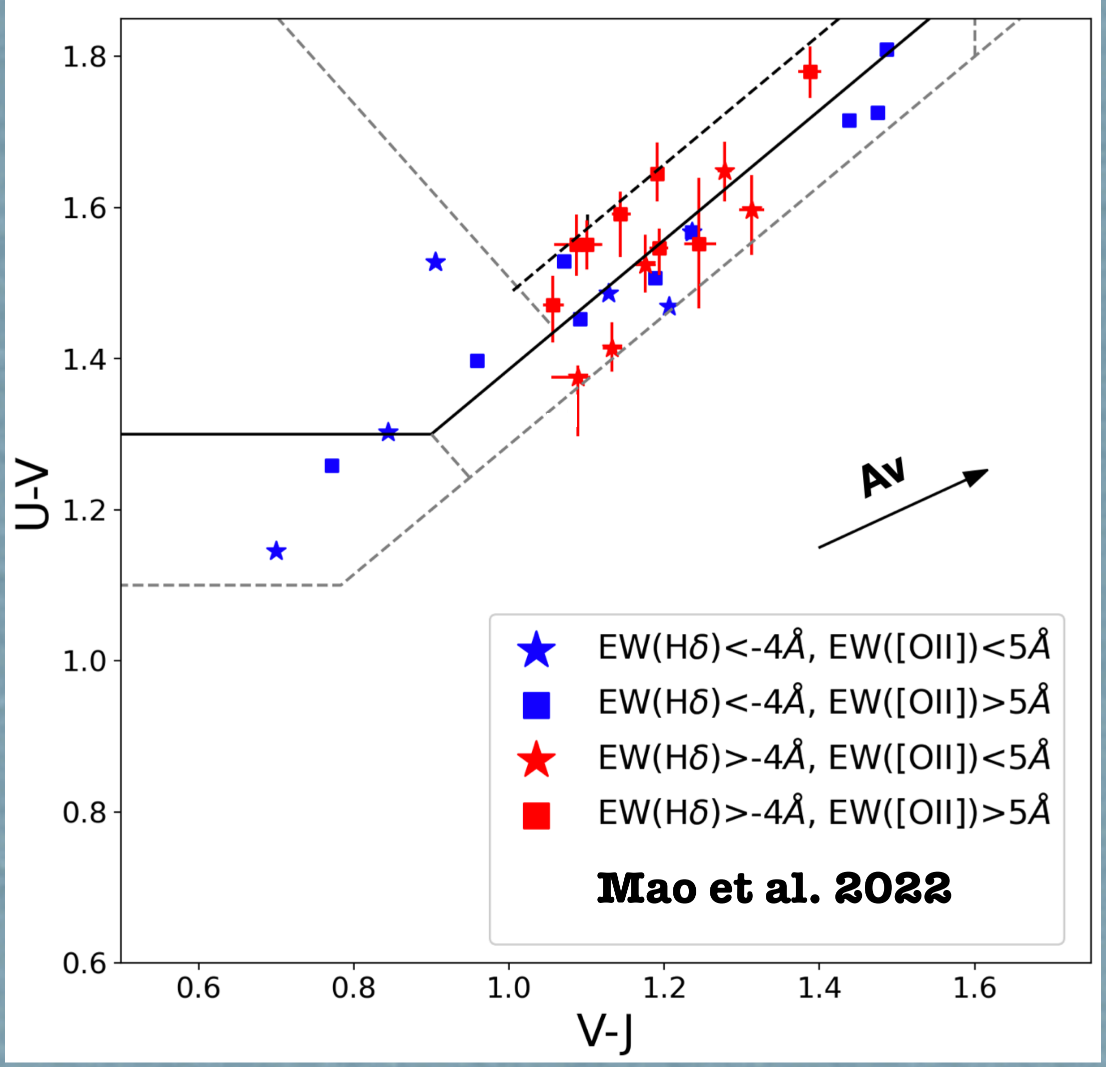


Spectral confirmation

- Spectral confirmation using DEIMOS 10K spectroscopic catalog & LEGA-C
    - Lick index EW(Hδ_abs)

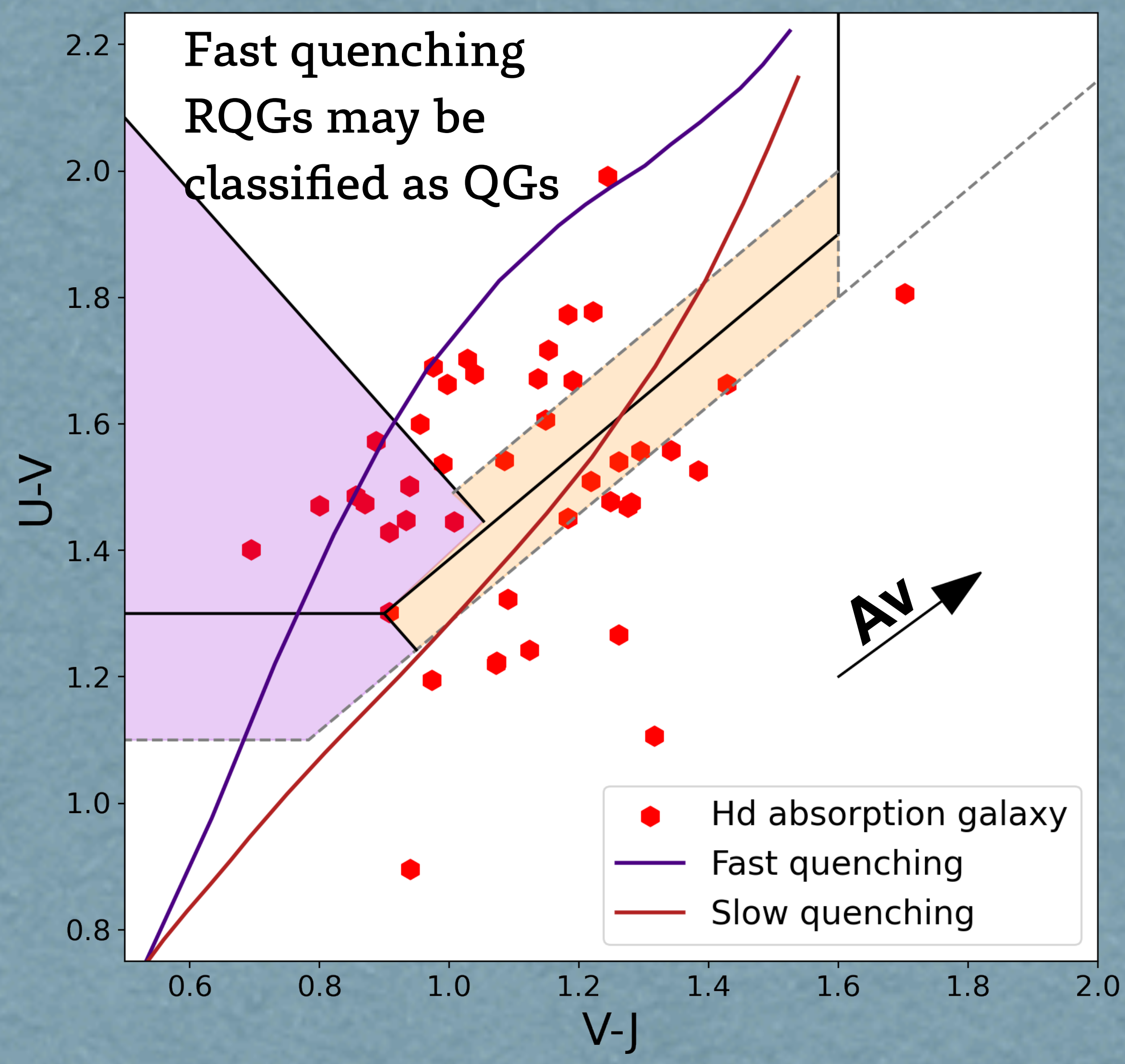


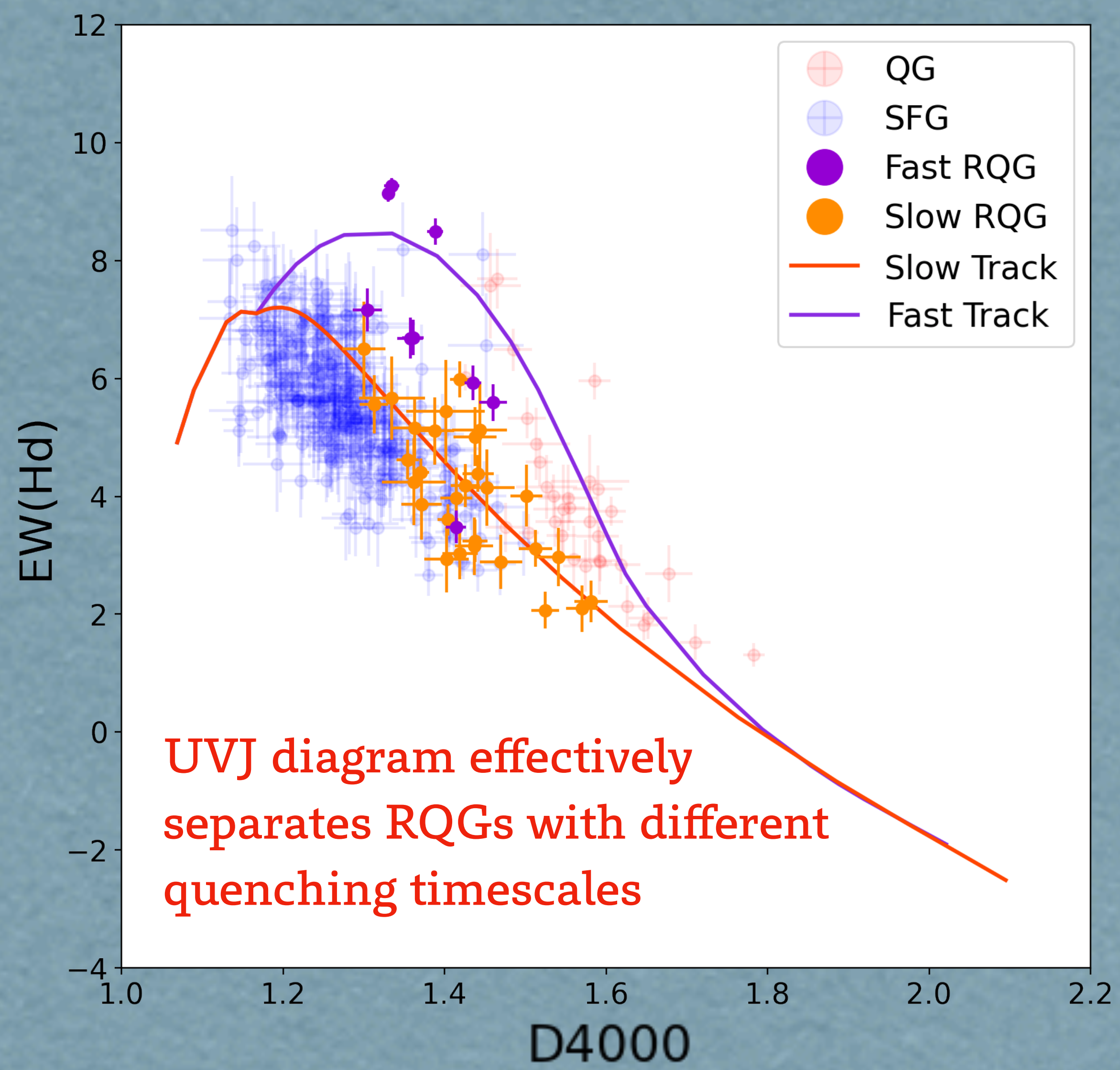
Contamination rate is not high



Spectral confirmation

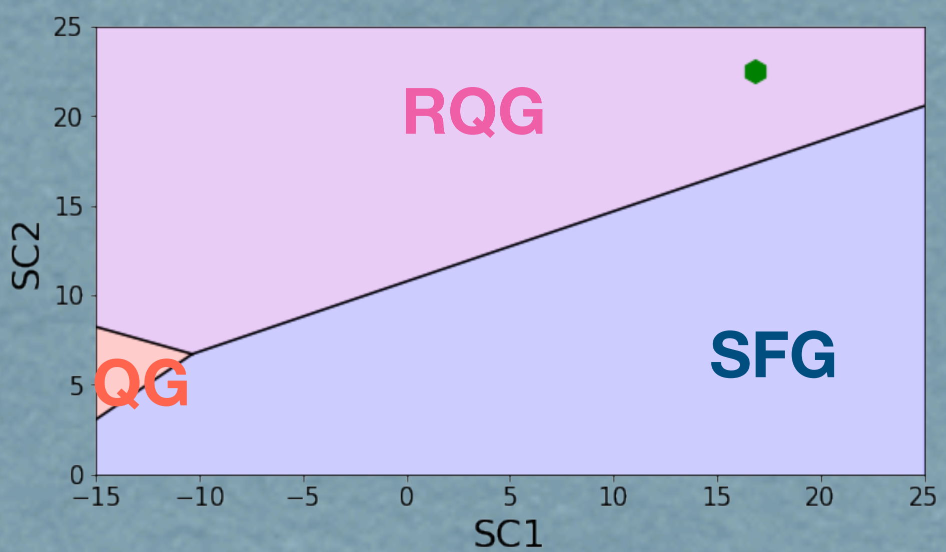
- Select strong H δ absorption galaxy in all LEGA-C sample
- LEGA-C galaxies with both H δ and D4000 measurements

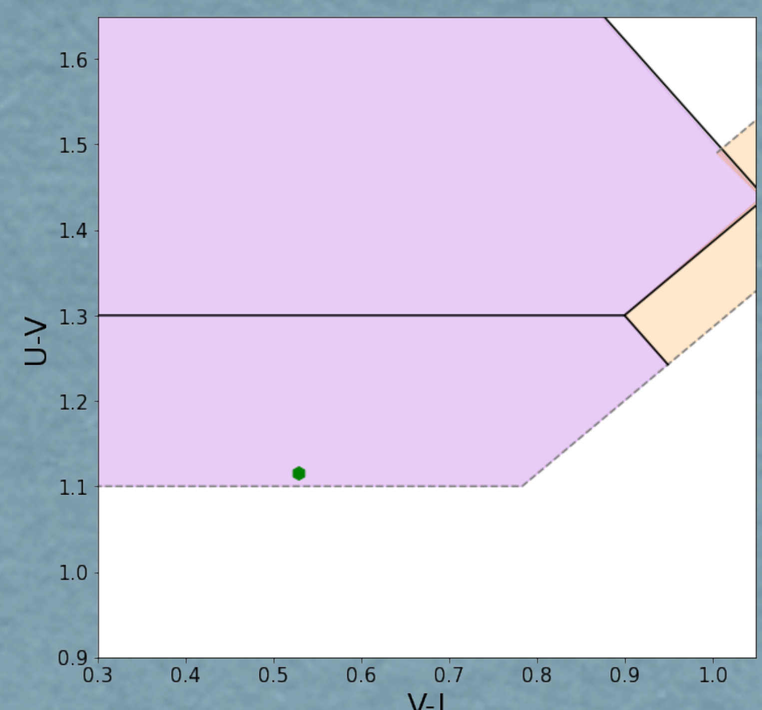


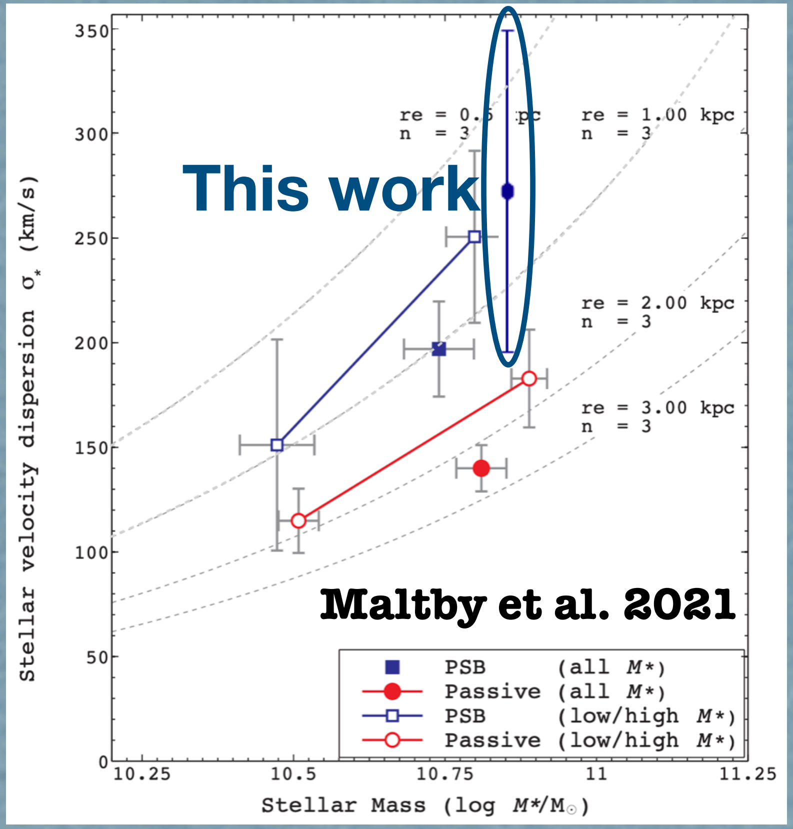


Spectral confirmation

- Confirmation of a high-z PCA-selected (Wild et al. 2014) RQG (S20B, Subaru/MOIRCS, PI: T. Kodama)
  - Spectroscopic redshift z~1.99
  - Clear H δ absorption and 4000A break
  - In fast quenching RQG region => confirm UVJ selection
  - RQGs(PSBs) have higher dynamical mass than passive galaxies

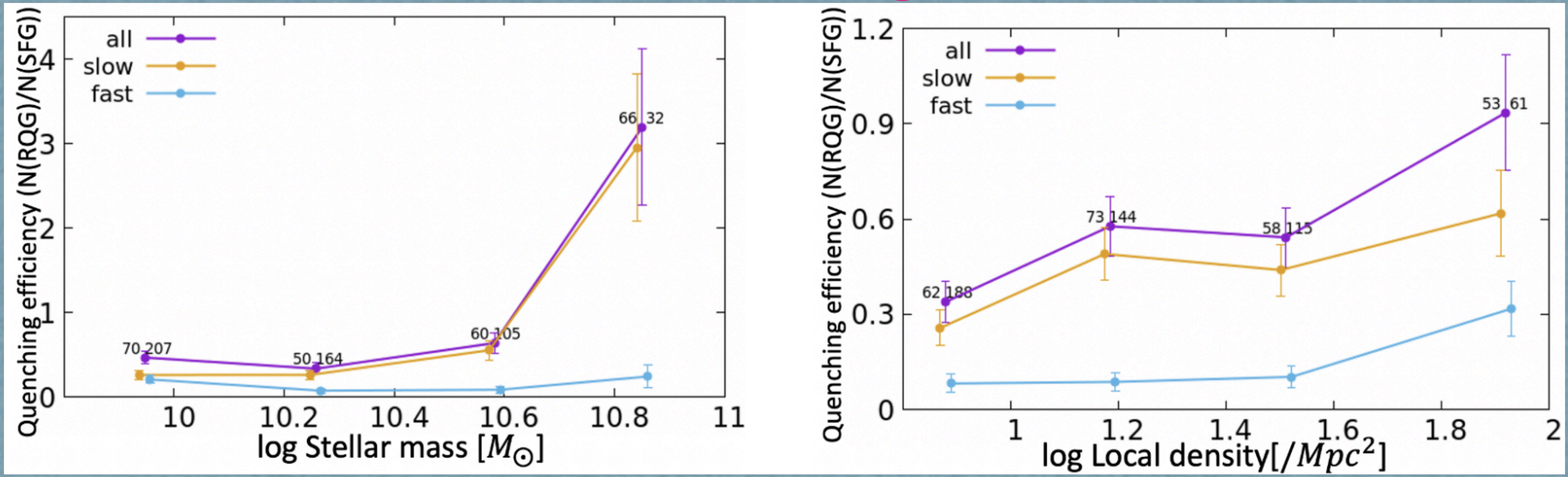






Quenching efficiency

- 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

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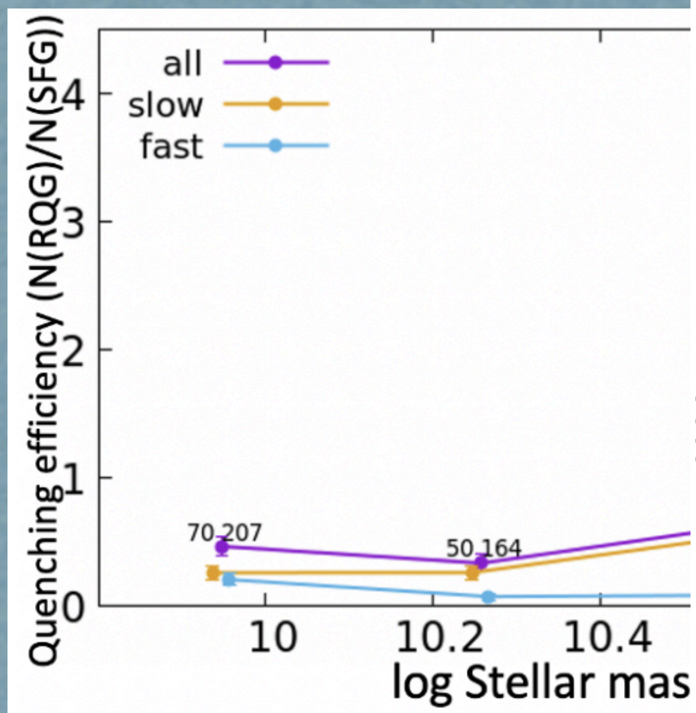

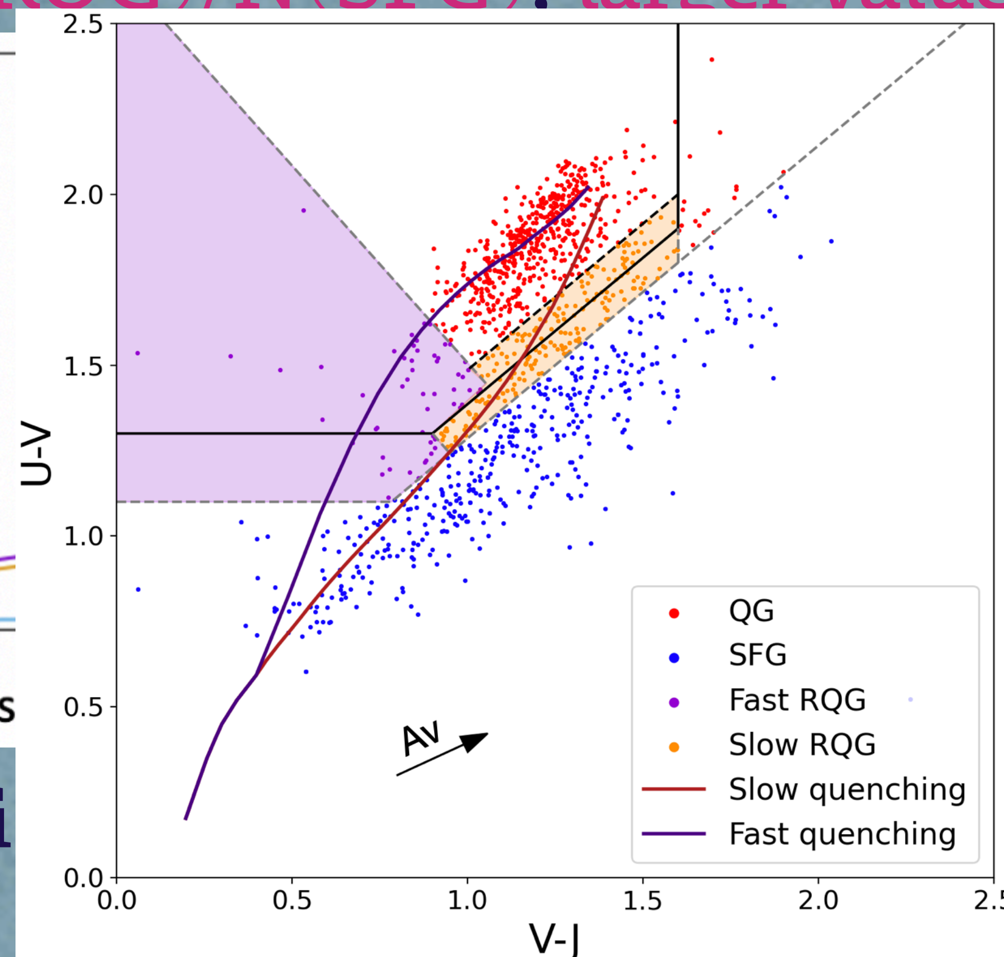

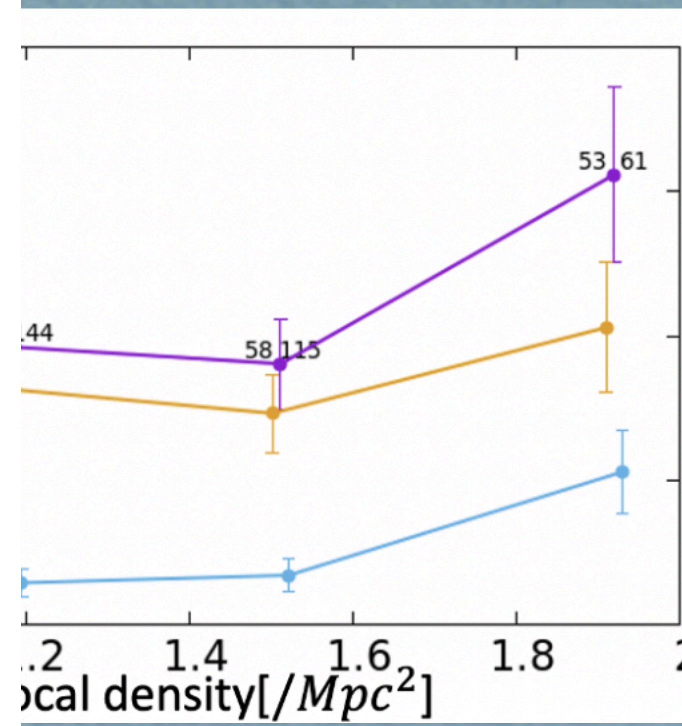

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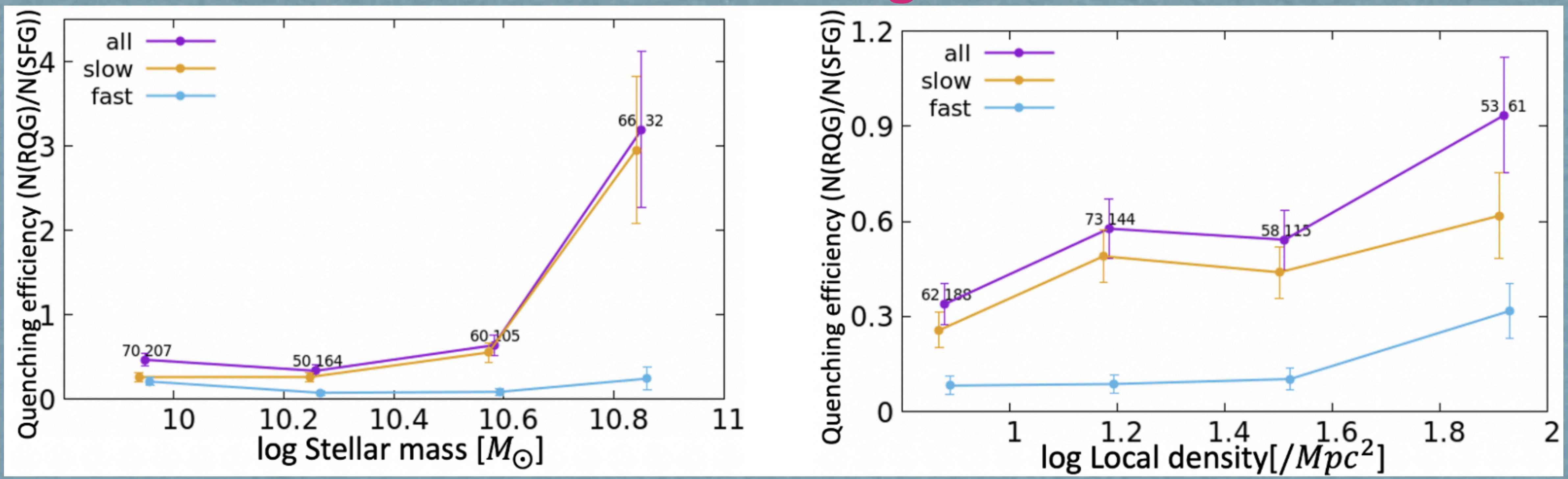

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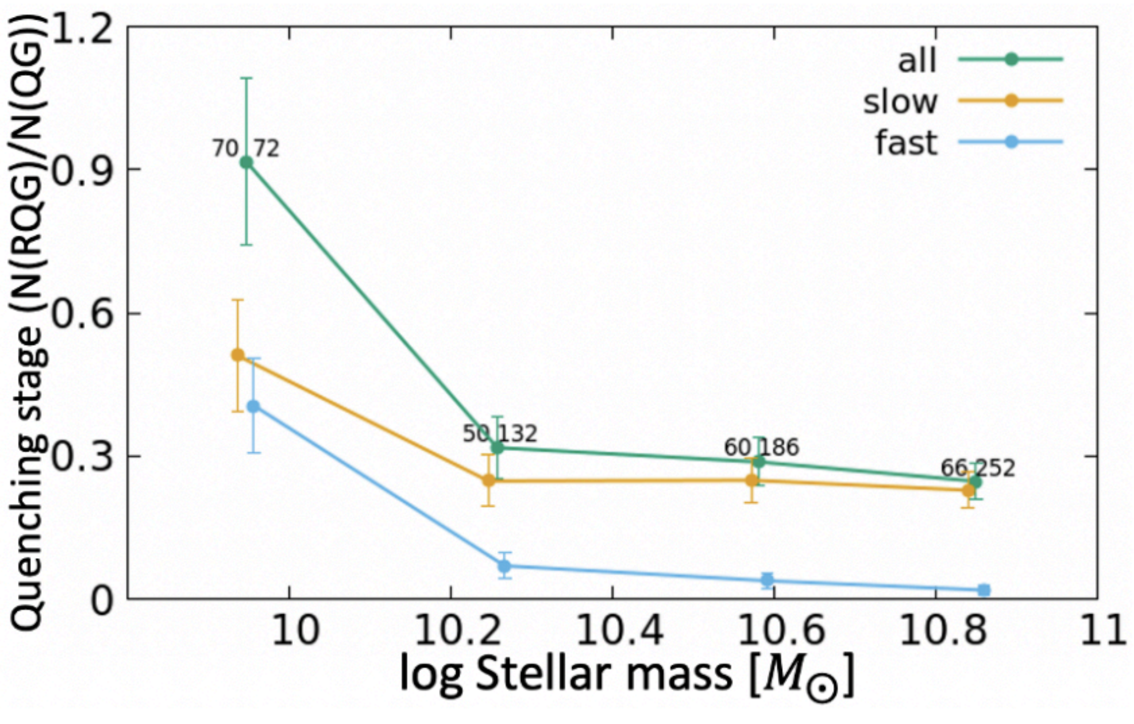
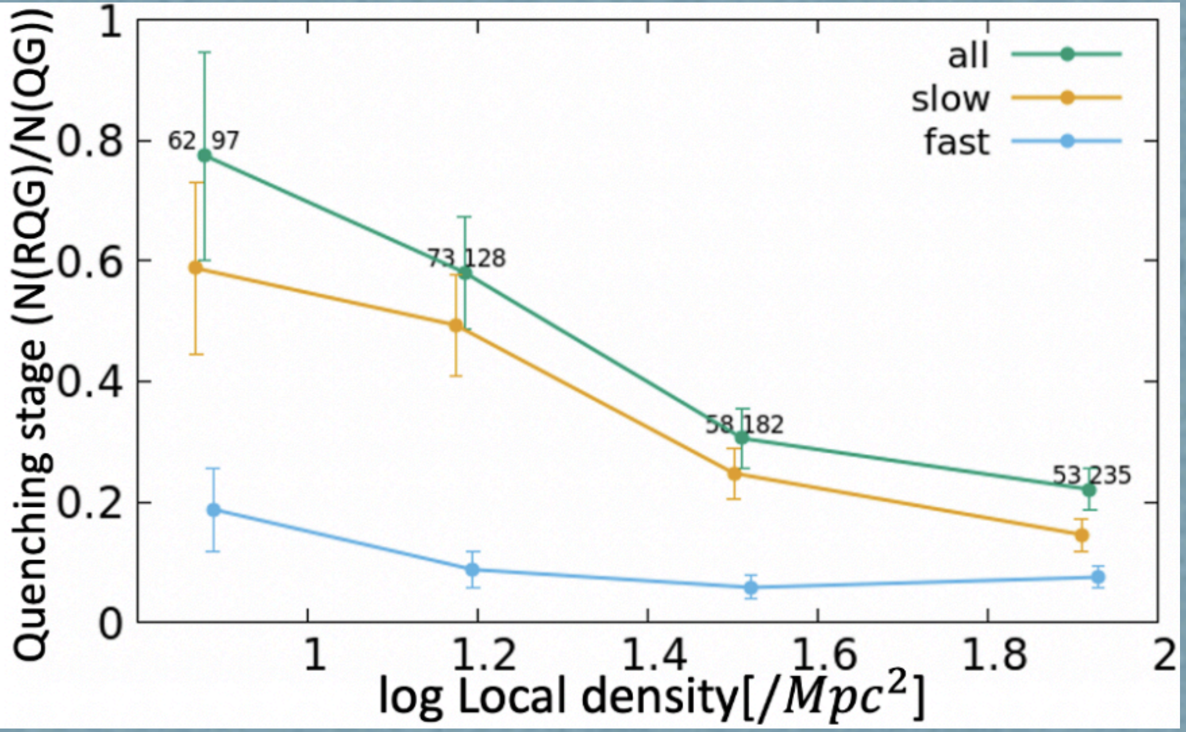
Quenching stage

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

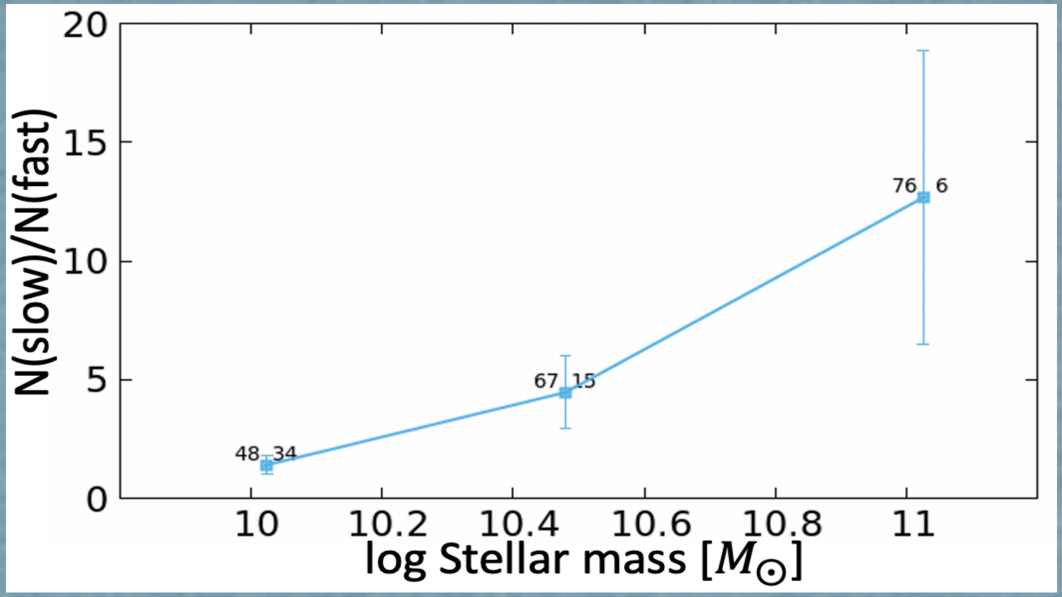


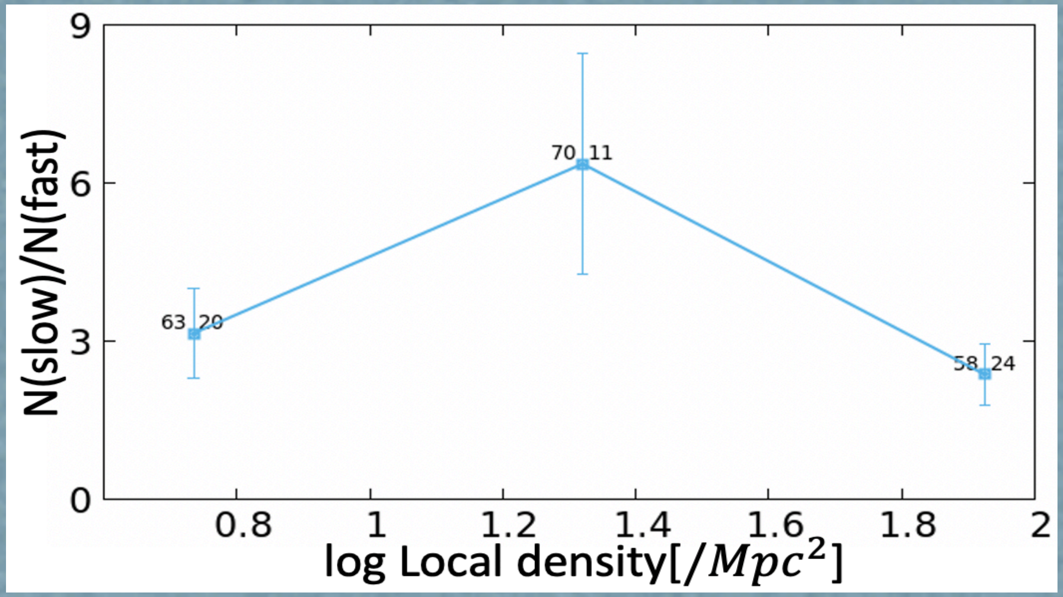


- Massive galaxies started quenching earlier➤ downsizing scenario
- Galaxies in denser environment started quenching earlier➤ inside-out scenario in cluster
- Visibility time does not show strong impact on this result

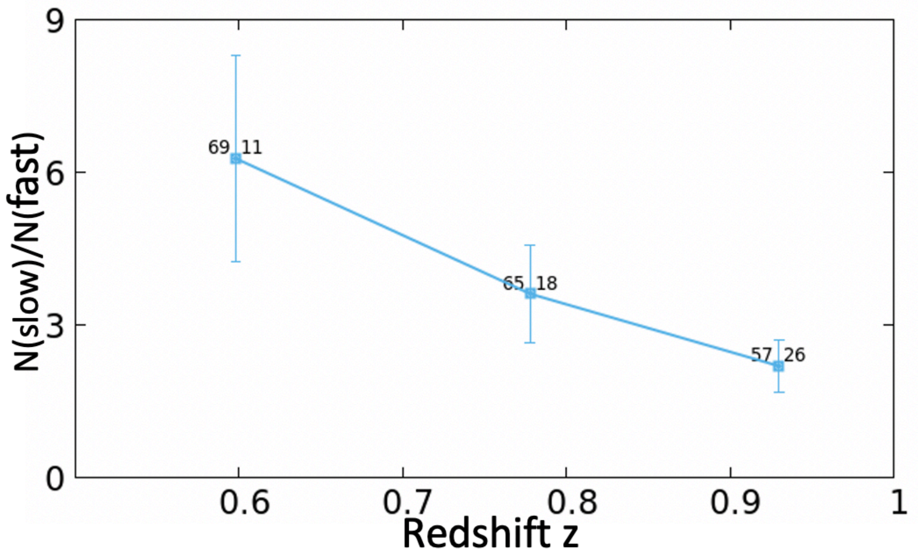
Quenching timescale

- 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



Summary 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 scenario in cluster
- Quenching timescale has mass and redshift dependence ➤ quenching mechanisms for different mass/redshift should be different

Future prospects

◉ Target selection from photometric data and preliminary analysis

- 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

Future prospects

◉ Spectroscopic follow-up

- Spectroscopic confirmation of RQGs
  - Pilot projects: MOIRCS(S20B, PI: T. Kodama), FOCAS(S23A, PI: Z. Mao)
  - 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
- Our results support downsizing scenario and inside-out quenching scenario in clusters
- Quenching timescale depends on both stellar mass and redshift
- There is degeneracy between quenching properties and visibility time of RQG, which can only be disentangled by spectra

✦ UVJ selection can prepare us for RQG spectroscopic survey
✦ Systematic spectroscopic survey of RQG by PFS will make our understanding of quenching scenario a large step forward

Thank you very much for your attention!