

LAB 2

QUENCHED GALAXY SIZE EVOLUTION IN THE EARLY UNIVERSE

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WHAT ARE QUENCHED GALAXIES?

A quenched galaxy is a galaxy that is no longer forming stars, within this project we focused on quenched galaxies in the early universe with a redshift between 3 and 6.

Due to their lack of star formation they are usually faint and hard to see but JWST allows for deep-field and near infrared surveys to identify them, allowing images to be taken.

Usually a galaxy takes billions of years to form stars, and further billions of years to become quenched, but exist in the early universe, questioning our current model of the universe

The following images shows quenched galaxies



NGC 4150
a quiescent elliptical
galaxy

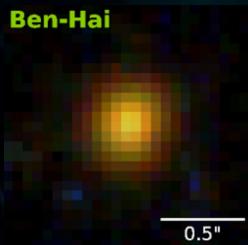
Source:

[https://en.wikipedia.org/wiki/Quenching_\(astronomy\)](https://en.wikipedia.org/wiki/Quenching_(astronomy))

NGC 4388, a spiral
galaxy with reduced star
formation rate

PROJECT OVERVIEW

- This project is about the size evolution of three quiescent galaxies: Bến Hải, Hương Giang and Thu Bồn.



- Investigated the neighbouring galaxies.
- 3 steps;
 - 1) Locate Neighbours
 - 2) Visualise neighbours and host
 - 3) Determine the gas mass and explore what happens when they merge.





PROJECT PROCEDURES

STEP 1: LOCATING NEIGHBORS

Use my catalog of neighbors around massive quenched galaxies. Focus on three spectroscopically confirmed high-redshift quenched galaxies: Ben-Hai, Huong-Giang, and Thu-Bon.



STEP 2: VISUALIZING IMAGES

Read photometric fluxes from COSMOS-Web tile files and create RGB images to visualize how neighbors are spatially related to their quenched hosts.



STEP 3: AN EXTREME SCENARIO

Based on stellar mass, estimate the gas mass of each neighbor. Then consider a scenario where all neighbors fall into the quenched host at once. Would the added gas be enough to restart star formation?



STEP 1: IDENTIFY NEIGHBORS

INPUT: NEIGHBORS_INFO

A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	id	ra	dec	tile	bayes.un	bayes.un	bayes.sté	bayes.sté	bayes_ssfr				
2	1013	387778	149.945	2.50338	B1	2.76985	1.35128	8.4E+07	7.8E+07	-7.93356			
3	1014	388044	149.947	2.50443	B1	3.12935	2.53552	4E+08	4.1E+08	-8.13381			
4	1015	388161	149.945	2.50605	B1	3.29405	1.44515	3E+08	2.3E+08	-8.39989			
5	1016	388487	149.944	2.50837	B1	3.03406	1.01052	9.3E+08	4.6E+08	-8.58855			
6	1017	388505	149.949	2.50856	B1	2.76421	2.22062	1.4E+08	2E+08	-8.14537			
7	1018	413886	149.945	2.50359	B1	3.1519	2.08316	2E+08	4.4E+08	-8.19694			
8	1019	413905	149.944	2.50446	B1	3.05626	2.0702	2E+08	4E+08	-8.20397			
9	1020	413940	149.944	2.50511	B1	2.76771	2.49402	1.8E+08	2.3E+08	-8.05579			
10	1021	413969	149.946	2.50535	B1	2.91856	2.05012	2E+08	3.6E+08	-8.21596			
11	1022	413974	149.948	2.50452	B1	2.98056	2.06082	2E+08	3.8E+08	-8.21037			
12	1023	413978	149.948	2.50464	B1	3.28772	2.10265	2.2E+08	6.3E+08	-8.17839			
13	1024	413980	149.944	2.50615	B1	3.3265	2.10589	2.2E+08	6.7E+08	-8.17349			
14	1025	413987	149.948	2.50473	B1	3.02003	2.06503	2E+08	3.9E+08	-8.2069			
15	1026	413991	149.947	2.50532	B1	3.29757	2.10559	2.3E+08	6.5E+08	-8.17606			
16	1027	414027	149.949	2.50544	B1	3.01813	2.06554	2E+08	3.9E+08	-8.20706			
17	1028	414090	149.95	2.50636	B1	3.08392	1.93482	3E+08	3.1E+08	-8.29117			
18	1029	414092	149.947	2.50761	B1	2.97809	1.91135	3.2E+08	3.3E+08	-8.30861			
19	1030	414118	149.945	2.50897	B1	3.23428	2.09545	2.1E+08	5.4E+08	-8.18768			
20	1031	414176	149.944	2.51015	B1	3.15952	2.09028	2.1E+08	4.9E+08	-8.1919			
21	1032	394686	149.949	2.54895	B1	3.35029	2.14661	1.7E+08	1.6E+08	-8.01492			
22	1033	416492	149.946	2.54931	B1	3.07277	2.32281	7.8E+08	2.8E+08	-8.06568			
23	1034	416532	149.95	2.549	B1	3.27106	2.03833	1.2E+08	2.4E+08	-8.19759			
24	1035	416573	149.949	2.55015	B1	3.45478	2.41903	1.5E+08	2.1E+08	-8.0728			
25	1036	416577	149.948	2.55069	B1	3.42164	1.99866	1.9E+08	2.2E+08	-8.22417			
26	1037	416581	149.948	2.55082	B1	3.07667	2.079	2.2E+08	4.6E+08	-8.19983			
27	1038	416646	149.949	2.55171	B1	3.22856	2.04107	1.3E+08	2.5E+08	-8.19821			
28	1039	416665	149.945	2.55361	B1	3.13478	2.01729	1.1E+08	1.7E+08	-8.21025			
29	1040	416678	149.945	2.55369	B1	3.38342	2.11266	2.4E+08	8.1E+08	-8.15983			
30	1041	416693	149.946	2.55382	B1	3.17757	2.00653	1.1E+08	1.5E+08	-8.21637			
31	1042	416704	149.949	2.55286	B1	3.2667	2.04523	1.2E+08	2.7E+08	-8.1933			
32	1043	416782	149.951	2.55449	B1	3.39155	2.11439	2.4E+08	8.3E+08	-8.15892			
33	1044	399652	149.954	2.58563	B1	3.25972	1.98311	2E+08	2.2E+08	-8.24826			
34	1045	417847	149.951	2.57839	B1	3.82676	2.56245	1.2E+08	1.4E+08	-7.97096			
35	1046	417886	149.952	2.57856	B1	3.24688	2.44146	1.1E+08	1.6E+08	-8.05922			
36	1047	417942	149.951	2.58043	B1	3.73244	2.46343	2.1E+08	2E+08	-8.03233			
37	1048	418025	149.953	2.58317	B1	3.64737	2.1622	0	0				
38	1049	418108	149.953	2.58326	B1	3.27463	2.10059	2.2E+08	6E+08	-8.18134			

neighbors_info



OUTPUT: REAL_NEIGHBORS_INFO

A	B	C	D	E	F	G	H	I	J
1375	524681	150.4336	2.465776	B4	4.142785	2.565501	5.43E+08	4.71E+08	-8.15433
1376	524701	150.44	2.463628	B4	3.609926	2.277166	1.26E+08	1.36E+08	-8.10801
1377	524745	150.4382	2.464506	B4	3.916943	2.665735	9.89E+08	9.19E+08	-8.3007
1378	524871	150.4395	2.464822	B4	3.759666	2.564961	2.98E+08	2.68E+08	-8.04914
1379	525009	150.441	2.464961	B4	3.584868	2.419363	4.13E+08	3.85E+08	-8.18655
1380	540093	150.4407	2.464017	B4	3.647368	2.162204	0	0	
1381	540191	150.4399	2.465576	B4	3.647368	2.162204	0	0	
1401	539953	150.4534	2.457522	B4	3.647368	2.162204	0	0	
1402	539982	150.4553	2.457324	B4	3.647382	2.162202	5976710	15352543	-8.17776
1403	561599	150.4576	2.453729	B5	3.588714	1.417745	3.88E+08	2.82E+08	-8.41095
1404	561618	150.4575	2.453886	B5	3.610805	1.437069	3.24E+08	2.52E+08	-8.35564
1405	561961	150.4542	2.457766	B5	3.621133	1.713091	1.02E+09	7.85E+08	-8.49064
1406	561977	150.4519	2.458774	B5	3.876846	2.398573	2.46E+08	2.29E+08	-8.09131
1407	573262	150.4533	2.453932	B5	3.573644	2.04011	2.36E+08	4.52E+08	-8.19192
1408	573345	150.4552	2.454843	B5	3.647368	2.162204	0	0	
1409	573348	150.4548	2.455002	B5	3.775696	2.471172	1.08E+08	1.27E+08	-7.98782
1410	573353	150.4538	2.455462	B5	3.647368	2.162204	188647	625184.5	-8.17317
1411	573447	150.4534	2.457615	B5	3.647368	2.162204	0	0	
1412	573458	150.4548	2.457439	B5	3.64737	2.162203	2320884	5824706	-8.17759
1413	573497	150.4533	2.458659	B5	3.647368	2.162204	0	0	
1645	646333	150.0837	2.396752	B7	3.261909	1.477952	2.68E+08	1.99E+08	-8.44229
1646	646429	150.0878	2.395917	B7	3.311066	2.21227	4.38E+08	4.05E+08	-8.31279
1647	646466	150.0895	2.395475	B7	3.063335	1.29202	1.03E+09	6.34E+08	-8.65244
1648	646726	150.088	2.398002	B7	3.083529	1.65731	4.28E+08	3.31E+08	-8.4078
1649	646842	150.0897	2.398387	B7	3.066082	1.807705	4.98E+08	5.03E+08	-8.2954

real_neighbor_info



STEP 1: IDENTIFY NEIGHBORS

PROCESS: CODE

```
[1]: # this sets up basic packages
import numpy as np
import pandas as pd
import astropy.units as u
import astropy.cosmology.units as cu

from astropy.coordinates import SkyCoord
#from regions import Regions, CircleSkyRegion

[2]: # This reads in the QG coordinates
qg_info = pd.read_csv(r'C:\Users\nguye\Downloads\three_QGs_basic.txt',
                      delimiter=' ',
                      names=['name', 'RA', 'Dec', 'M_star', 'spec_z'],
                      skiprows=2)
qg_cat = SkyCoord(ra=qg_info['RA'].values*u.degree, dec=qg_info['Dec'].values*u.degree)

# This reads in the tentative neighbor coordinates
neighbor_info = pd.read_csv('C:/Users/nguye/Downloads/neighbors_info.csv')
# replace with your path
neighbor_cat = SkyCoord(ra=neighbor_info['ra'].values*u.degree, dec=neighbor_info['dec'].values*u.degree)
```

Loads information about three quenched galaxies and their surrounding candidates.
-> Converts both sets of positions into a standardized astronomical format (SkyCoord).
-> Sets up everything for the next step => distances or matches between QGs and neighbors will likely be computed.

STEP 1: IDENTIFY NEIGHBORS

CODE

```
markers = []

# Now, loop over the three rows, read the coordinates of each QG and find neighbors around them from my catalog.
for idx in range(3):

    # This locates the coordinates of the QG
    QG_coords = qg_cat[idx]

    ##### Now, search for neighbors
    separation = QG_coords.separation(neighbor_cat)
    # write the code separation (1 line) in question mark

    # Next, set a criteria (catalog mask) such that we only take separations under 15"
    # Type your code down here.
    annulus = 15*u.arcsec
    catalog_mask = separation < annulus

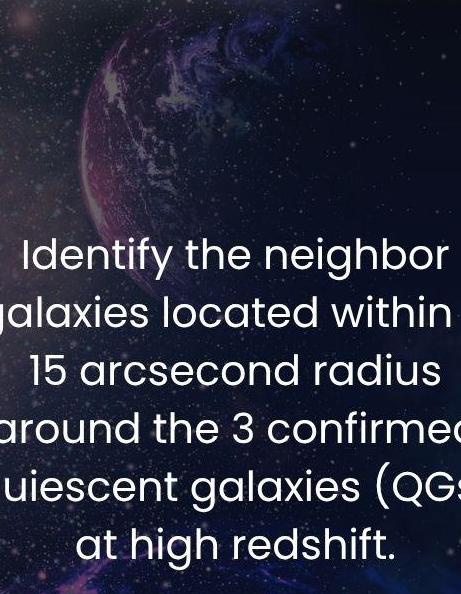
    # Finally, let's select from neighbor_info only the sources that pass our criteria.
```

```
markers = [item for sublist in markers for item in sublist]
```

```
markers
```

Now, having identified the neighbors, let's use the 'markers' list to retrieve full info about those neighbors from my catalog. And then save this into a CSV file

```
real_neighbor_info = neighbor_info.loc[neighbor_info['id'].isin(markers)]
real_neighbor_info.to_csv('real_neighbor_info.csv', index=False)
```



Identify the neighbor galaxies located within a 15 arcsecond radius around the 3 confirmed quiescent galaxies (QGs) at high redshift.

RESULTS - OUR REAL NEIGHBORS CATALOG

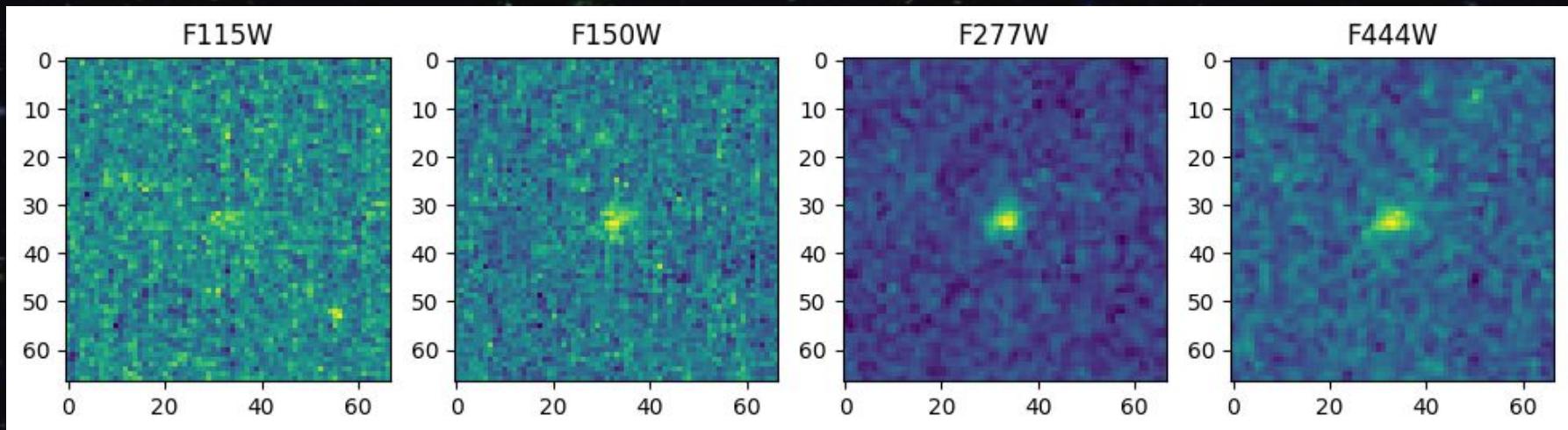
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524701	150.4399654944308	2.4636275911502348	B4	3.6099527568907644	2.277165947412199	125612971.8588607	135732748.56384507	-8.108013689371344
524745	150.43815950516284	2.464506228743016	B4	3.9169429956515858	2.665735306511617	989190771.6844692	918682424.3726482	-8.300697732888674
524871	150.4394799416388	2.464822276620937	B4	3.759666292756537	2.5649608305071827	297695327.30861855	267801980.97288588	-8.049135519720613
525009	150.4410219113748	2.4649607197745187	B4	3.584868092488266	2.4193633526515983	413391260.28406936	385137708.1152301	-8.186554425545102
540093	150.4406889453416	2.4640170618923807	B4	3.647368421052597	2.1622036568601932	0.0	0.0	
540191	150.4387914063155	2.4655763332004685	B4	3.647368421052597	2.1622036568601932	0.0	0.0	
539953	150.45342911781265	2.4575217672950904	B4	3.647368421052597	2.1622036568601932	0.0	0.0	
539982	150.4553054586313	2.4573238884702966	B4	3.6473818586299713	2.1622022913003054	5976710.480291346	15352543.167146487	-8.17776454541482
561599	150.45759904877826	2.453729371072041	B5	3.5887142405134447	1.417745418056183	388424020.548375	282202876.7349175	-8.410950821735327
561618	150.45747559823042	2.45388636853438	B5	3.6108049200681296	1.4370692396661682	324013616.4086968	251862663.7478616	-8.355640627468247
561961	150.45422941396112	2.4577657982479617	B5	3.6211328327858743	1.7130906512024513	1021314237.2515996	785124823.8741832	-8.490635241386686
561977	150.45187945056767	2.458774153431859	B5	3.876845547834963	2.398572635466976	246347018.79330173	228616744.5449255	-8.091314177921609
573262	150.45326402887156	2.4539315898984344	B5	3.5736441336266145	2.040110151028046	235848590.51038465	451508697.375501	-8.191915869152817
573345	150.45516621837982	2.4548426620324975	B5	3.647368421052597	2.1622036568601932	0.0	0.0	
573348	150.4548148526806	2.455001955749816	B5	3.7756956480047497	2.4711723701083588	107896860.70356476	127219823.42790322	-7.987819470453752
573353	150.45384486836346	2.455462048977187	B5	3.647368443116942	2.1622036570683036	188646.9628891604	625184.4793496105	-8.173172034880789
573447	150.4534476113607	2.457614818516059	B5	3.647368421052597	2.1622036568601932	0.0	0.0	
573458	150.454846654763	2.457439141647056	B5	3.6473701844847057	2.162203488099474	2320883.5323717683	5824706.124375985	-8.177587008363004
573497	150.45333791720176	2.4586591974202827	B5	3.647368421052597	2.1622036568601932	0.0	0.0	
646333	150.08368291615793	2.3967521501215434	B7	3.261908654816766	1.477952155675023	267552611.0502559	198867420.28750017	-8.442285664247992
646429	150.0878453662985	2.395917099804501	B7	3.311066233238201	2.12269503204704	437656380.82895786	404850501.5336344	-8.312786633673891
646466	150.089530532641	2.395475185811596	B7	3.0633346014002134	1.2920199006653157	1028787293.4507807	634360330.2650397	-8.652441570521072
646726	150.08804385312536	2.3980022288909444	B7	3.08352877635187	1.6573104480402232	428023645.0252032	330618084.5905949	-8.407799684431797
646842	150.08971373161884	2.3983874224640207	B7	3.0660821673873353	1.807705386680028	498147104.8115418	503160093.4262012	-8.295403155857763

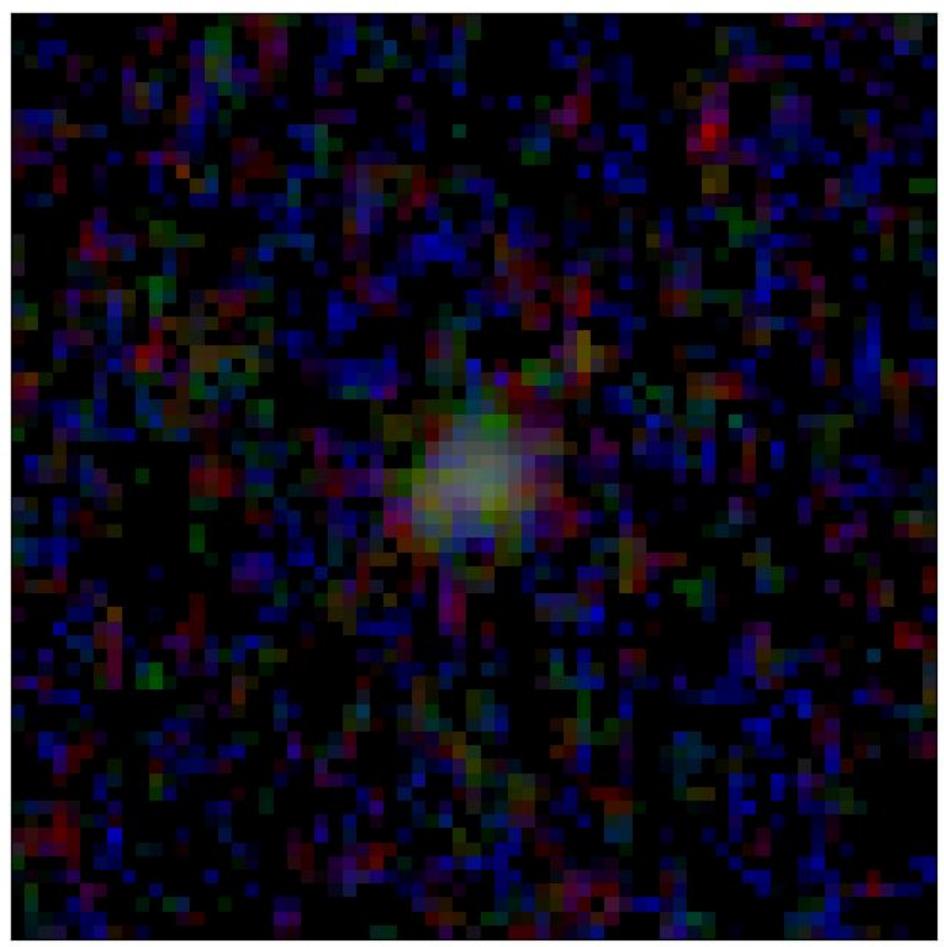


Criteria:
separation < 15 arcsec
Result:
a total of 25 neighbors

STEP 2: MAKING FALSE COLOR RGB IMAGES

Making 2D cutouts for the 4 bands for each neighbor



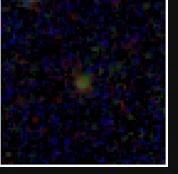
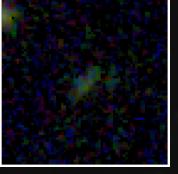
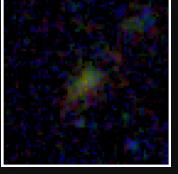
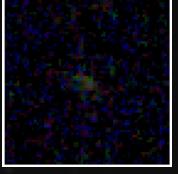
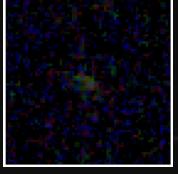
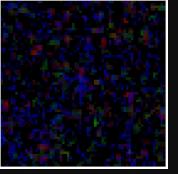
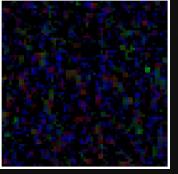
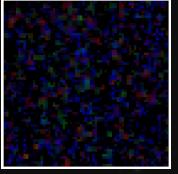
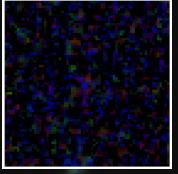
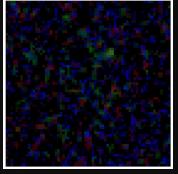
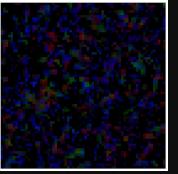
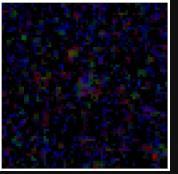
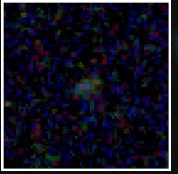
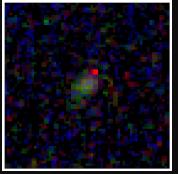
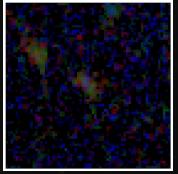
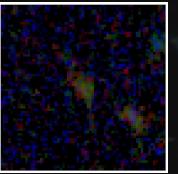
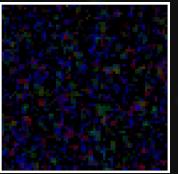
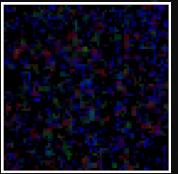
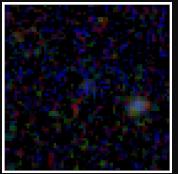
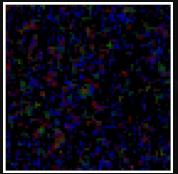
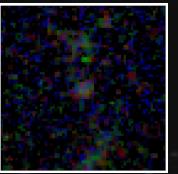
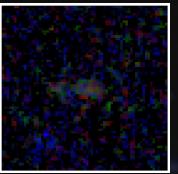
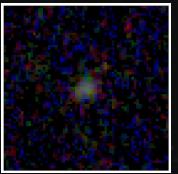
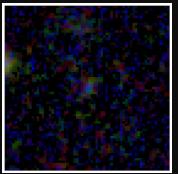
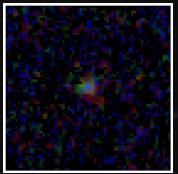


Our false color RGB image
of a neighbor galaxy

R band: F444W

G band: F277W

B band: F150W



Our RGB images of 25 neighbors

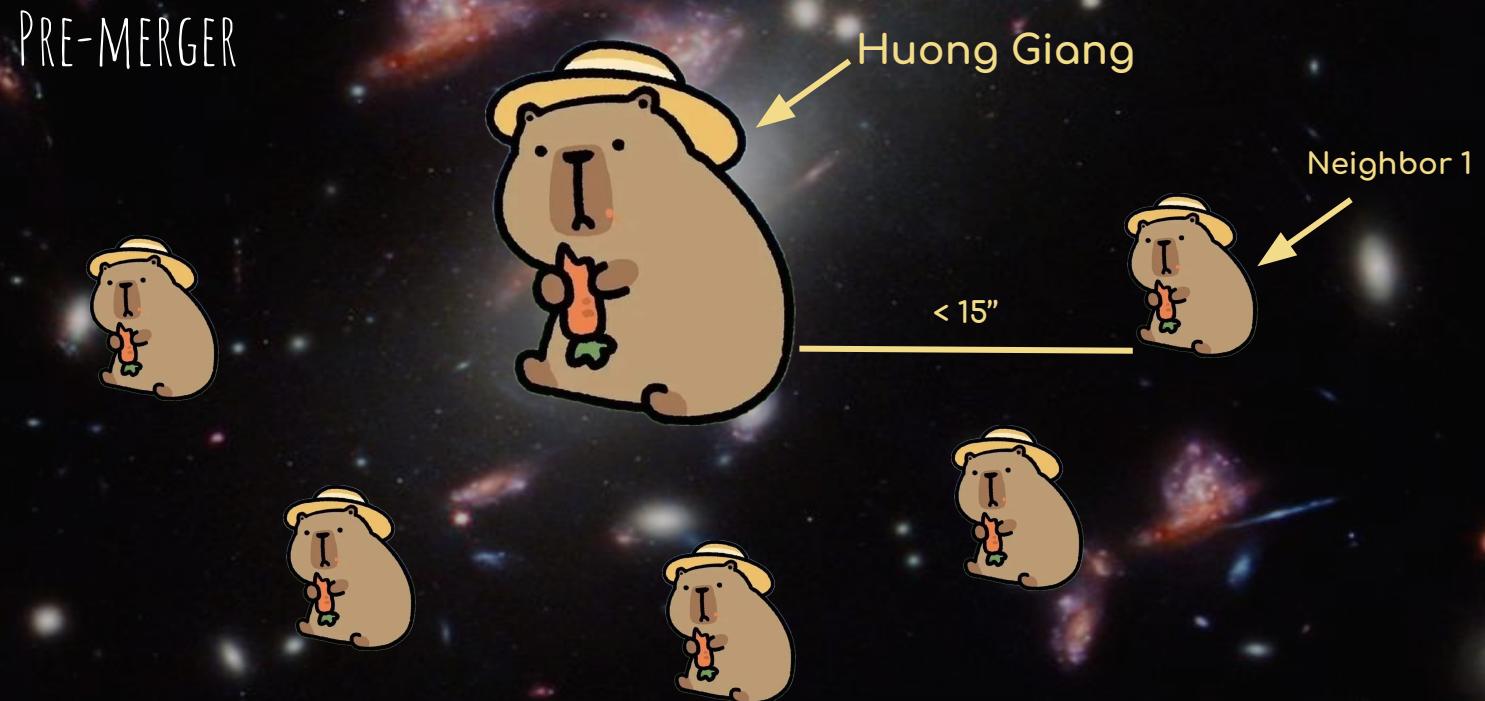
STEP 3 : COULD OUR QUENCHED GALAXIES REIGNITE STAR FORMATION?



Case opened: We consider an extreme scenario where all neighbors fall into their quenched hosts at once!!!

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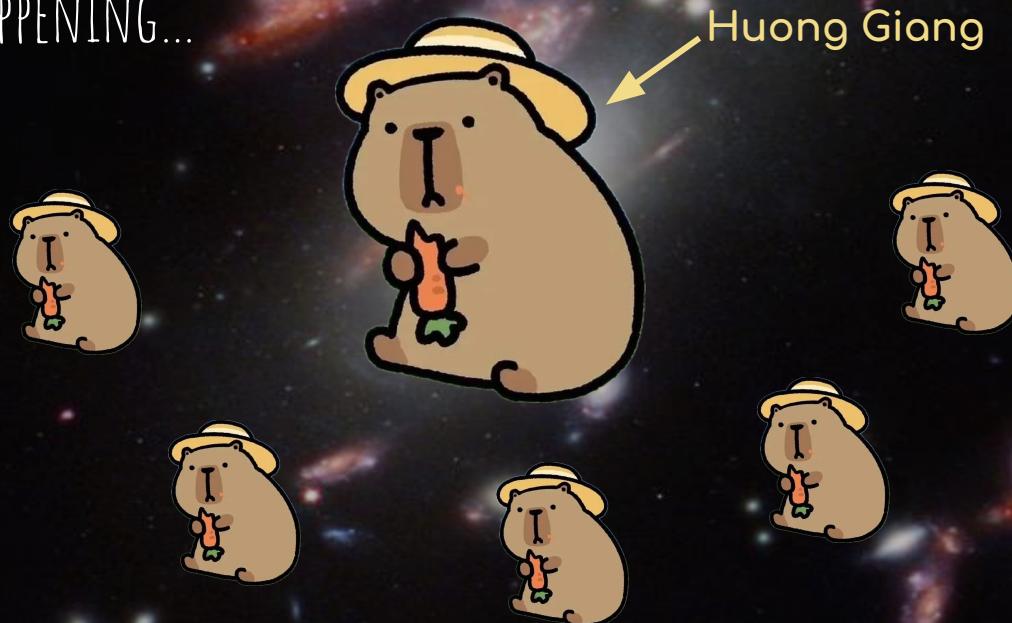
STEP 3



Case opened: We consider an extreme scenario where all neighbors fall into their quenched hosts at once!!!

STEP 3

MERGING HAPPENING...



Huong Giang

Case opened: We consider an extreme scenario where all neighbors fall into their quenched hosts at once!!!

STEP 3

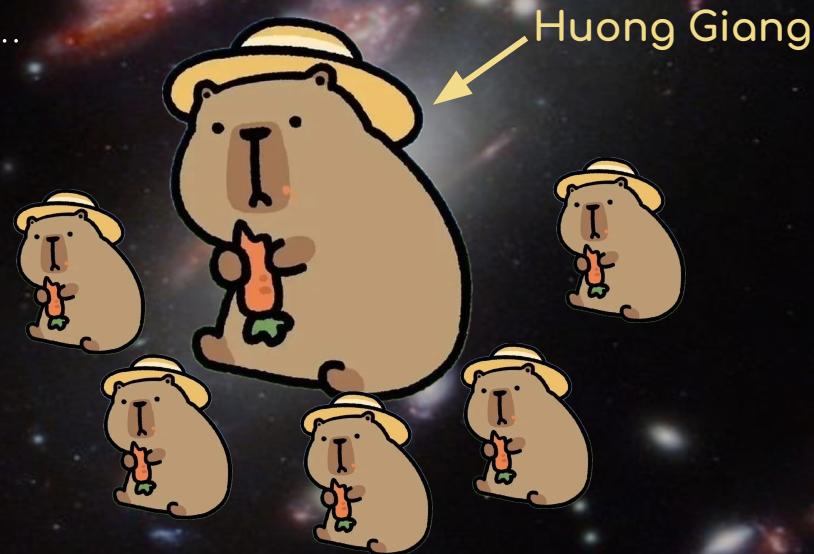
MERGING HAPPENING...



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STEP 3

MERGING HAPPENING...



Case opened: We consider an extreme scenario where all neighbors fall into their quenched hosts at once!!!

STEP 3

MERGING HAPPENING...



Huong Giang

Case opened: We consider an extreme scenario where all neighbors fall into their quenched hosts at once!!!

STEP 3

POST MERGER

Huong Giang & her
neighbors

Case opened: We consider an extreme scenario where all neighbors fall into their quenched hosts at once!!!

STEP 3

POST MERGER

HOW MUCH GAS HAS BEEN
ADDED?

IS IT ENOUGH TO REIGNITE
STAR FORMATION?

Case opened: We consider an extreme scenario where all neighbors fall into their quenched hosts at once!!!

TASK 3

GAS FRACTION FORMULA

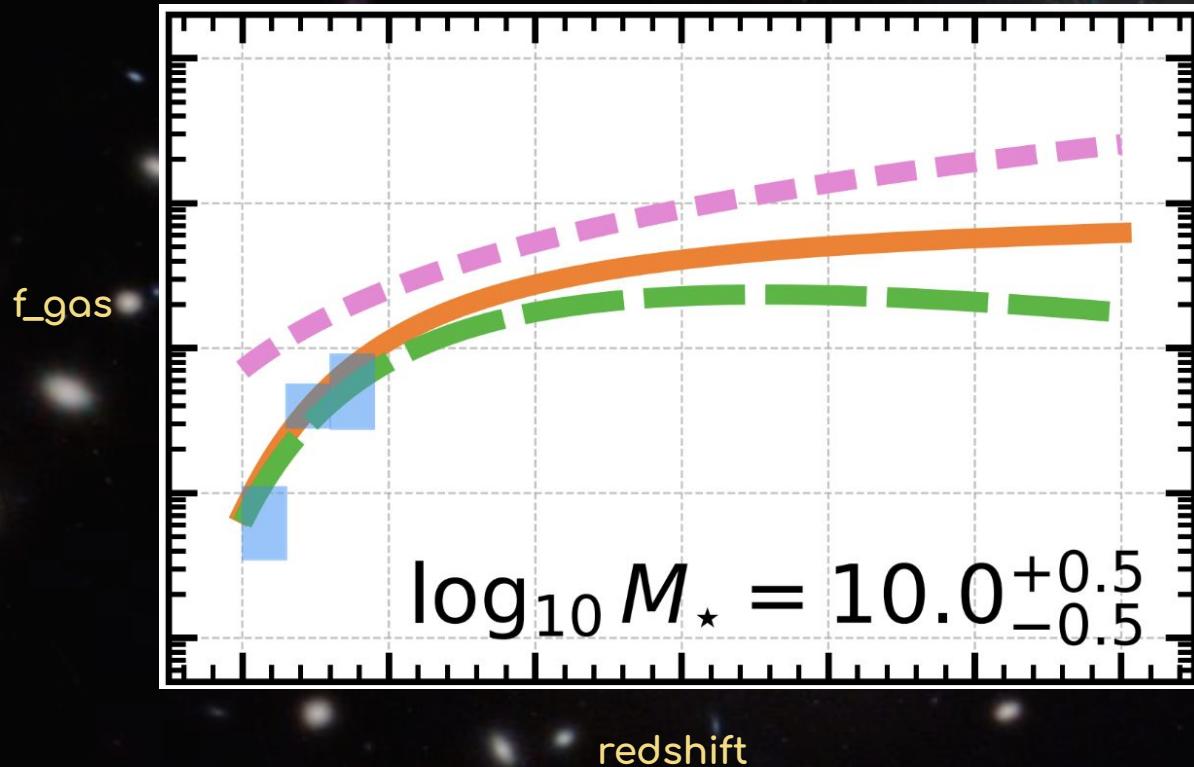
$$f_{gas} = \frac{M_{gas}}{M_{star}}$$

GAS FRACTION FORMULA FOR OUR EXTREME CASE

$$f_{gas} \times Total\ mass = f_{gas, QG\ pre-merger} \times QG\ stellar\ mass + f_{gas, neighbors} \times Neighbor\ mass$$

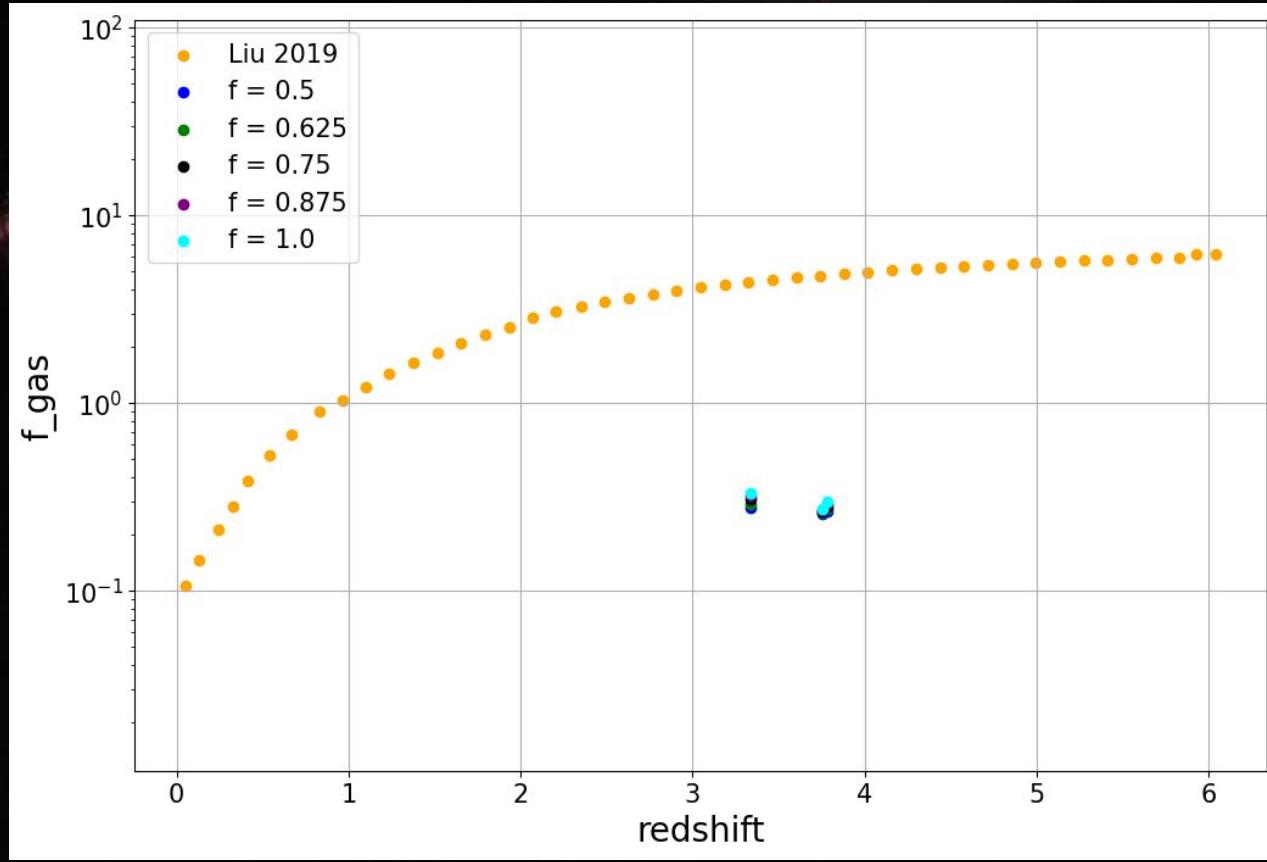
Case opened: We consider an extreme scenario where all neighbors fall into their quenched hosts at once!!!

TASK 3

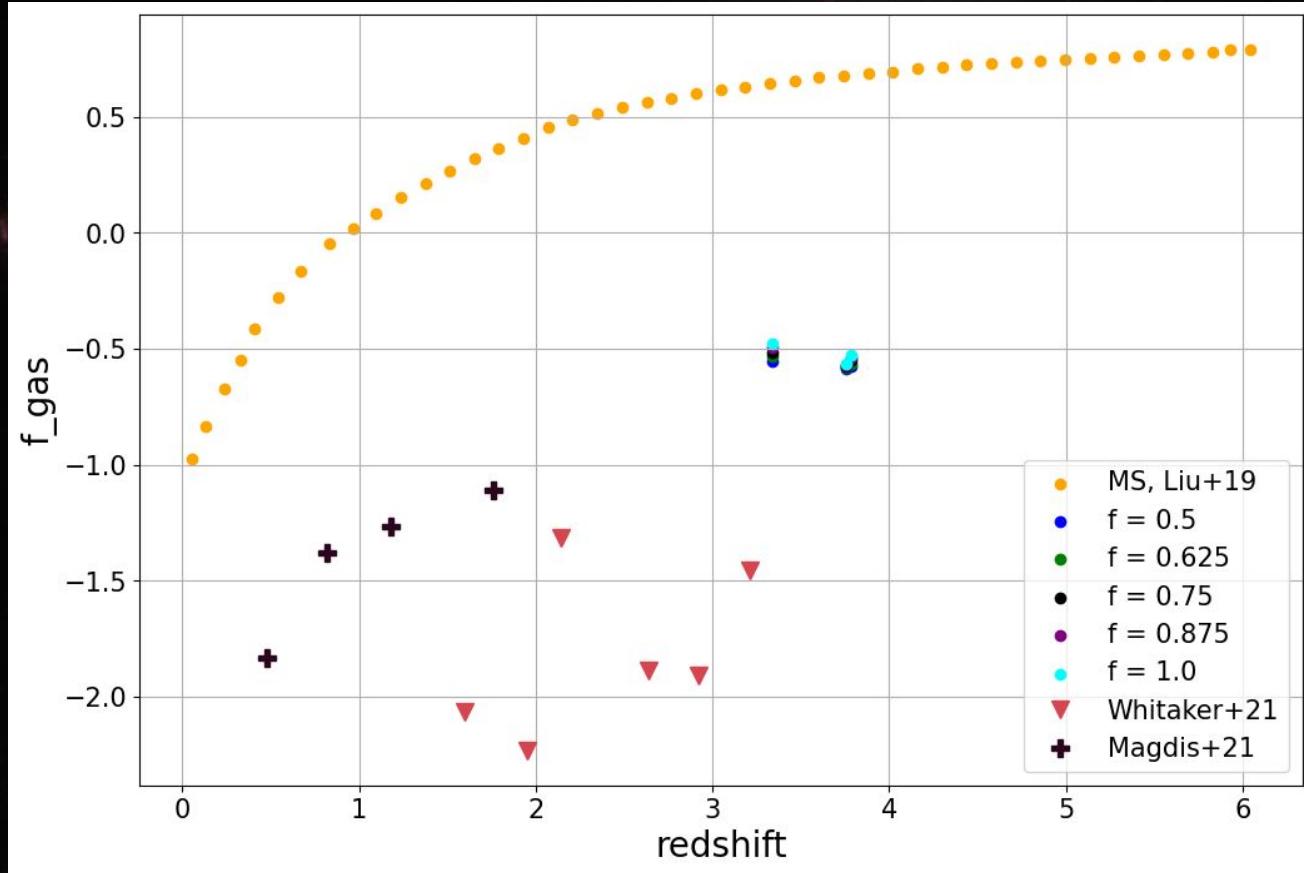


Our threshold
for restarting
star formation:
the orange line
from Liu et al
2019

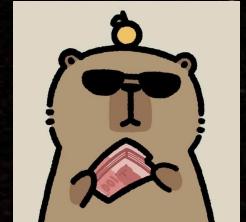
RESULTS - PLOT OF LOG_10(F_GAS) WITH RESPECT TO REDSHIFT



RESULTS - PLOT OF LOG_10(F_GAS) WITH RESPECT TO REDSHIFT



CONCLUSION



- From 3 steps above, we conclude that 25 neighboring galaxies have been identified.
- In the extreme merging case, the three quenched galaxies we are studying - Thu Bồn, Hương Giang, and Bến Hải cannot form a single star.
- Learned many valuable skills: practice using Python, WebPlotDigitizer, the COSMOS-Web catalog.
- Presentation skills, teamwork, and research abilities.



Thank you for your listening!
Any Questions?

