

Post-Starburst Properties of Post-Merger Galaxies

Li et al. 2023, arXiv:2305.07474, Accepted in MNRAS

ABSTRACT

Post-starburst galaxies (PSBs) are transition galaxies showing evidence of recent rapid star formation quenching. To understand the role of galaxy mergers in triggering quenching, we investigate the incidence of PSBs and resolved PSB properties in post-merger galaxies using both SDSS single-fiber spectra and MaNGA resolved IFU spectra. We find post-mergers have a PSB excess of 10 – 20 times that relative to their control galaxies using single-fiber PSB diagnostics. A similar excess of ~ 19 times is also found in the fraction of central (C)PSBs and ring-like (R)PSBs in post-mergers using the resolved PSB diagnostic. However, 60% of the CPSBs + RPSBs in both post-mergers and control galaxies are missed by the single-fiber data. By visually inspecting the resolved PSB distribution, we find that the fraction of outside-in quenching is 7 times higher than inside-out quenching in PSBs in post-mergers while PSBs in control galaxies do not show large differences in these quenching directions. In addition, we find a marginal deficit of HI gas in PSBs relative to non-PSBs in post-mergers using the MaNGA-HI data. The excesses of PSBs in post-mergers suggest that mergers play an important role in triggering quenching. Resolved IFU spectra are important to recover the PSBs missed by single-fiber spectra. The excess of outside-in quenching relative to inside-out quenching in post-mergers suggests that AGN are not the dominant quenching mechanism in these galaxies, but that processes from the disk (gas inflows/consumption and stellar feedback) play a more important role.

- Post-starburst(PSB)銀河は直近のquenchingを示すtransition銀河
→ Quenchingの理解に有用な天体
- 銀河相互作用がquenchingを引き起こす物理を明らかにしたい
(Gas consumption, AGN, stellar feedback)
- Post-merger銀河の中でのPSB銀河の割合や性質を調べる
(これまでの多くの研究はPSBの中でのmerger)
 - 銀河中心だけでなく、IFUによってoutskirtのPSB的性質も調査

観測データ

- SDSS DR14のSingle fiber分光
- MaNGA MPL-11のIFU分光
- MaNGA-HI

MergerとControl sampleの作り方

- MergerはNair&Abraham 2010に従ってvisual classification
- それぞれのmerger天体に $\Delta \log M_*/M_\odot = \pm 0.1$, $\Delta z = \pm 0.005$ のnon-interacting 10天体をSDSSから選び出す(controlと呼ぶ)

→ 1,051 post merger vs 10,510 control

PSBの同定の仕方

- Chen+2019の手法
 - $EW(H_{\delta A}) > 3 \text{ \AA}$
 - $EW(H_{\alpha}) > -10 \text{ \AA}$
 - $\log(EW(H_{\alpha})) < 0.23 \times EW(H_{\delta A}) - 0.46$
 - median spectral S/N > 10 per pixel
- さらに $EW(H_{\alpha})$ によってnon-PSBはSF, GV, Retiredを分類
- Goto 2007の手法は厳しすぎる
- Resolved PSBはspaxel中のPSB割合 $PSB f_{\text{spaxel}} > 5\%$

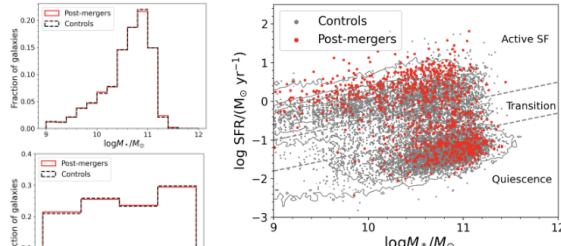


Figure 2. Star formation rates (SFRs) vs. stellar mass diagram of the DR14 post-merger and control sample. The contours represent the 90,234 galaxies from the DR14 parent sample with the outer most contour including 99% of the sample. The two division lines are drawn by eye based on the contours, which divide galaxies into active star-forming (SF), transition and quiescence.

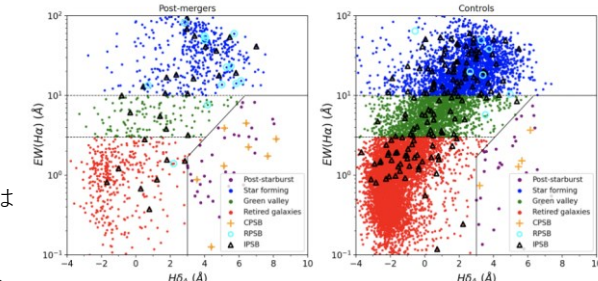


Figure 3. The equivalent width of H-alpha emission vs. H-delta absorption for the DR14 post-merger sample (left) and control sample (right) based on SDSS single-fiber spectra. PSB galaxies (purple) are identified to be located inside the lower right solid box region (Chen et al. 2019). Non-PSB galaxies are classified into star-forming (blue dots), green valley (green dots) and retired galaxies (red dots) based on their H-alpha equivalent width. The MaNGA resolved PSBs (Control PSBs, Ring-like PSBs and Irregular PSBs) are over-plotted in different symbols, which will be discussed in Section 4.2.

PSBの割合が高い

- Single fiberではpost-mergerでのPSB割合が10-20倍高い
- IFUによるResolved PSBでは(CSPBs+RPSBs)に限ると、post-mergerでのPSB割合が19倍高い
 - IPSBsはpost-mergerとcontrolで大きく変わらず、permanent quenchingではなく、sporadicなSF decayではないか？

→ Mergerがquenchingを起こすのに重要

- Resolved (C+R)PSBの60%はsingle-fiberだと見落し

→ IFUによるPSB探査が重要

Single-fiberによるPSB割合

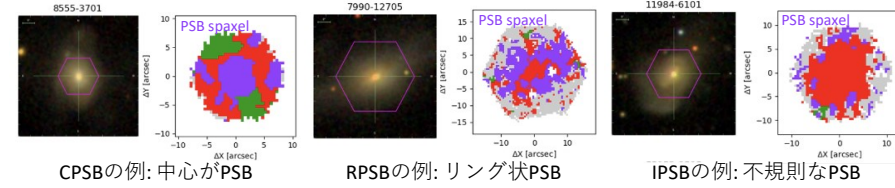
	Goto (2007)	Chen et al. (2019)
1,051 DR14 Post-mergers	4 (0.4% ± 0.2%)	41 (3.9% ± 0.6%)
10,510 DR14 Controls	3 (0.03% ± 0.02%)	31 (0.3% ± 0.1%)
Excess	13.1 ± 9.8	13.2 ± 3.1
136 MaNGA Post-mergers	1 (0.7% ± 0.7%)	8 (5.9% ± 2.0%)
1,360 MaNGA Controls	1 (0.07% ± 0.07%)	4 (0.3% ± 0.1%)
Excess	9.9 ± 14.0	20.0 ± 12.1

Table 1. The numbers and fractions of PSB galaxies classified by different methods with single-fiber spectra in the DR14 samples and the MaNGA observed samples. The Chen et al. (2019) method classifies more PSBs than the Goto (2007) method while their PSB excesses are consistent. The PSB fractions and excesses in the DR14 post-merger (control) sample are consistent with those in the MaNGA observed post-merger (control) sample.

MaNGA IFU分光によるPSB割合

	CPSBs	RPSBs	IPSBs	C+R PSBs	C+R+I PSBs
136 Post-mergers	8 (5.9% ± 2.0%)	13 (9.6% ± 2.5%)	28 (20.5% ± 3.5%)	21 (15.4% ± 3.1%)	49 (36.0% ± 4.1%)
1,360 Controls	4 (0.3% ± 0.1%)	7 (0.5% ± 0.2%)	145 (10.7% ± 0.8%)	11 (0.8% ± 0.2%)	156 (11.5% ± 0.9%)
Excess	20.0 ± 12.1	18.6 ± 8.5	1.9 ± 0.4	19.1 ± 6.9	3.1 ± 0.4

Table 2. The numbers and fractions of PSB galaxies classified by using the Chen et al. (2019) method and MaNGA resolved spectra. PSB galaxies are classified into central (C) PSBs, ring-like (R) PSBs and irregular (I) PSBs. The last two columns show the C+R PSBs only and the total (C+R+I) resolved PSBs, respectively.



CPSBの例: 中心がPSB

RPSBの例: リング状PSB

IPSBの例: 不規則なPSB

Outside-in quenchingを示すものが多い

- Post-mergerではoutside-inがinside-outより7倍多い
(outside-in: 中心SF/Green valleyで外側PSB/retired, 中心PSBで外側retired)
- Mergerによるquenchingはdiskから効くものが支配的(gas inflow/consumption, stellar feedback)

	AGN	Outside-in	Inside-out	Globally quenching	Quenched overall	No clear trend
PM	22.4% ± 6.0%	44.9% ± 7.1%	6.1% ± 3.4%	6.1% ± 3.4%	8.2% ± 3.9%	12.2% ± 4.7%
Control	17.9% ± 3.1%	19.2% ± 3.2%	25.6% ± 3.5%	0.6% ± 0.6%	3.2% ± 1.4%	33.3% ± 3.8%
Excess	1.3 ± 0.4	2.9 ± 0.6	0.2 ± 0.1	10.2 ± 11.6	2.6 ± 1.7	0.4 ± 0.1

Table 3. The fractions and excesses of different quenching situation in 49 PSBs in post-mergers and 156 PSBs in controls. Outside-in quenching is more common in post-mergers while inside-out quenching and quenching with no clear trend are more common in non-merging controls. Fractions of galaxies which are globally quenching, being quenched overall, or being AGN contaminated are similar in post-mergers and control galaxies considering errors.

Post-merger PSBはわずかにfgas(HI)が小さい

- MaNGA-HI観測
- ControlではPSB vs non-PSBで差はない

→ Gas consumption/expulsionがpost-merger PSBの要因か？
(注) 分子ガスではない

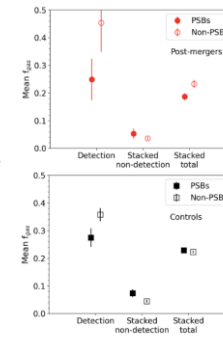


Figure 11. Upper panel: The mean HI gas fraction in PSBs (filled circles) and non-PSBs (empty circles) in post-mergers. There are 15 PSBs and 22 non-PSBs with HI detections while 13 PSBs and 29 non-PSBs have HI non-detections. There is no detection in the stack of the 29 non-detections. Hence, the upper limit is shown. PSBs tend to have less HI than non-PSBs in post-mergers. Lower panel: The mean HI gas fraction in PSBs (filled squares) and non-PSBs (empty squares) in control galaxies. There are 15 PSBs and 275 non-PSBs with HI detections while 50 PSBs and 513 non-PSBs have HI non-detections. There is no difference in the HI gas fraction of PSBs compared to non-PSBs in controls.

MS図上でもoutside-in

- RPSBsはMS付近に分布
- CPSBsはTransition領域に分布
- PSBが領域が外側から内側に進むにつれて、銀河全体もquiescentに

