Spatially resolved star-formation histories of local post-starburst galaxies: Starburst and quenching spatial patterns consistent with recent mergers

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ABSTRACT

Post-starburst (PSB) galaxies, having recently experienced a starburst followed by rapid quenching, are excellent laboratories to probe physical mechanisms that drive starbursts and shutting down of star formation. Integral-field spectroscopy reveals the galaxies' spatially-resolved properties, where observed directional patterns can be linked to the galaxies' past evolution. We measure the resolved star-formation histories (SFHs), stellar metallicity evolution and dust properties of three local PSBs from the MaNGA survey, down to 0.5″ resolution (~ 0.3 kpc) using a hierarchical Bayesian model. Local parameters were constrained simultaneously with parameters describing spatial trends. We found that all three galaxies first experienced an outer, weaker and slower quenching starburst, followed by a central, stronger and faster quenching starburst that peaked ~ 1 Gyr after the first. The central starbursts induced a significantly stronger rise in stellar metallicity compared to the outer starbursts. These results are consistent with the effects of a recent gas-rich (wet) merger, where the first pericentre passage triggered starbursts in the outer regions, while the later coalescence triggers a stronger centralised starburst. We find non-axisymmetric features in the maps of burst mass fraction and dust attenuation in all galaxies, which could be caused by tidal effects during the recent merger. Comparisons with literature binary merger simulations suggests that the galaxies' rapid quenching was driven by gas consumption and the stabilisation against gas gravitational collapse by a growing spheroid, while AGN feedback was not necessarily a primary cause.

- **Post Starburst galaxies (PSBs)**
  - Experienced a starburst within the past 1.5 Gyr, followed by rapid quenching within a few 100 Myr.
  - Ideal population to understand quenching mechanism.
    - Possible drivers: Simple gas exhaustion, stellar/AGN feedback, morphology (bulge, stellar bar), and environment.
- Sample
  - Three face-on local PSBs selected from MaNGA survey without no visually obvious asymmetric/disturbed features.
- Spatially-resolved analysis
  - BAGPIPES with **Bayesian Hierarchical Modelling (BHM)**
  - Unlike traditional (non-hierarchical) IFS SED fitting, BHM takes into account global trend across the galaxy (radial profile or gradient) to obtain robust result even in low S/N outskirt regions.
- Highlights of this paper:
  - Technical aspect: Introduction of BHM approach for accurate SFH estimation.
  - Scientific aspect: Finding of outside-in quenching consistent with wet merger.

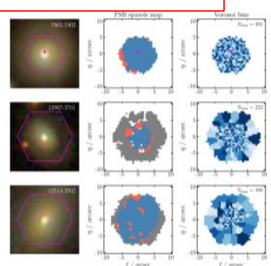

Figure 1. SDSS 3-colour images (**left**), the PSB spaxel selection (**middle**) and the Voronoi bin distribution (**right**) of our sample of three PSBs. Each galaxy's Plate-IFU is marked on the top right corner of the SDSS images. The MaNGA field of view is marked as the pink hexagon. In the middle column, we divide the spaxels into regions with no/faulty observations (not coloured), median spectral SNR < 8 too low to be classified (grey), classified as PSB (blue), and classified as non-PSB (red). Voronoi binning is performed with a threshold[2] SNR_g = 10 and accounting for spatial covariance. The colours in the right column are used to differentiate between spaxels in a given Voronoi bin. The magenta crosses in the top panels mark the location of the spaxel discussed in detail in Fig. 9 and Section 6.1.

↑ PSB spaxel classified by strong Hδ absorption and weak Hα emission.

Brief summary of the technical procedures:
MaNGA optical IFS spectra → BAGPIPES fitting
→ derive probability distributions → adopt radial trends
→ refine the distributions via BHM.

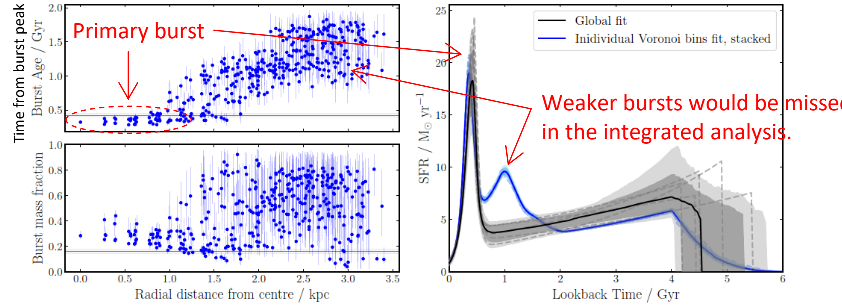

Figure 3. Fitting results of 7965-1902 from the non-hierarchical *stage 0* and *stage 1* models. The **left** panels plot the posterior burst age (top left) and burst mass fraction (bottom left) against radial distance from the galaxy centre for individual Voronoi bins in blue and the global fit as a gray horizontal line and shaded band. The **right** panel compares the SFH obtained from stacking the fitted SFH of all Voronoi bins (blue) to the fitted SFH from the global fit (black). The shaded regions denote 1 and 2σ uncertainty regions. The SFHs of 10 randomly drawn posterior samples are also shown as dashed curves. We observed the galaxy underwent two distinct starbursts, with the earlier one occurred predominantly in the outer regions, while the later, stronger one occurred predominantly in the centre. This is not captured by the global fit.

↑ Fig.3: Advantages of (traditional) resolved fitting over (traditional) integrated fitting.

- The resolved fitting found additional weak starburst at *t* ~ 1 Gyr which is hidden in the integrated fitting since the light from the central burst (*t* ~ 0.4 Gyr, *R* < 1 kpc) is dominant.

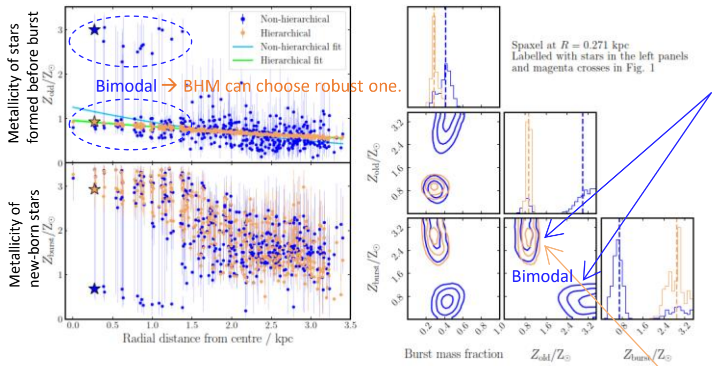

Figure 9. Comparing results from fitting all Voronoi bins of 7965-1902 independently (non-hierarchical, blue) and jointly under the hierarchical model (orange). **Left**: Radial gradients in pre-burst metallicity (top) and post-burst metallicity (bottom). The light blue curve shows a least squares fit to the posterior median values of the independent pre-burst metallicity estimates. The lime curve marks the hierarchical model's fit (posterior median). The large stars mark the locations of the Voroni bin shown in the right. **Right**: 2D posterior density distributions of a spaxel at $R = 0.271$ kpc (127[th] Voronoi bin, location marked with magenta crosses in Fig. 1) for burst mass fraction, pre-burst metallicity and post-burst metallicity. In the diagonal panels, the histograms show the 1D marginalised posterior distributions, and the vertical dashed lines mark the distributions' medians. In the off-diagonal panels, the contour lines correspond to (1,2,3)σ regions (enclosing the top 39.3, 86.4, and 98.9 per cent of marginalised posterior probability).

← Fig.9: Advantages of BHM approach over (traditional) resolved fitting.

- Traditional (non-hierarchical) fitting produces the bimodal probabilities for $Z_{\rm old}$ and $Z_{\rm burst}$ at *R* < 1 kpc.

BHM approach

Radial trends are assumed to further refine the probability distribution for each Voronoi bin.

- Sersic profile for M_s
- Modified logistic function for $t_{\rm burst}$
- Linear gradient for $Z_{\rm old}$, A_V and $\sigma_{\rm disp}$

Even if the initial probability is low, if it is consistent with the trend, the final probability can become relatively high.

- As a result, BHM can break this degeneracy by assuming the radial metallicity gradient, favoring ★ rather than ★.

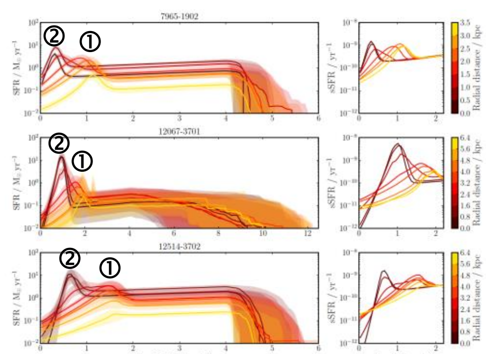

Figure 8. The SFHs of the post-starburst galaxies stacked in bins of increasing radial annuli from the galaxy centre. The **left** column shows SFR against lookback time. The **right** column shows sSFR against lookback time, in the most recent ~ 2 Gyr. Bins at larger radii are represented with lighter colours. In all panels and radial bins, the posterior median SFH is marked as a solid line, while the 1σ uncertainty region is marked as a shaded region of the same colour (uncertainty not shown in the right for simplicity). All three galaxies exhibit a two-phase outside-in sequence of starburst and quenching, where the outer regions first undergo starburst that quenches slowly, followed by a stronger central starburst after ~ 1 Gyr that quenches more rapidly than the outskirts.

← Fig.8: SFH of the PSBs.

- All three PSBs experienced a starburst in the outskirts, followed by another burst in the central regions about 1 Gyr later.
- This is consistent with **gas-rich merger** scenario:
  - ① **First pericenter** triggers mild starburst at the outskirt.
    - Slow (>300 Myr) decline due to gas infall toward the center.
  - ② **Final coalescence** triggers strong nuclear starburst.
    - Rapid (~100 Myr) decline due to gas consumption and bulge formation (morphological quenching).
- This "**outside-in quenching**" indicates that AGN feedback (inside-out quenching) seems not to be a primary driver.
- There are similarities with local LIRGs in starbursting, gas richness, and merging/interaction.→ PSB = descendants of LIRG?