Star-forming S0 Galaxies in SDSS-MaNGA: fading spirals or rejuvenated S0s?

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ABSTRACT

We investigate the origin of rare star-formation in an otherwise red-and-dead population of S0 galaxies using spatially resolved spectroscopy. Our sample consists of 120 low redshift ($z < 0.1$) star-forming S0 (SF-S0) galaxies from the SDSS-IV MaNGA DR15. We have selected this sample after a visual inspection of deep images from the DESI Legacy Imaging Surveys DR9 and the Subaru/HSC-SSP survey PDR3, to remove contamination from spiral galaxies. We also construct two control samples of star-forming spirals (SF-Sps) and quenched S0s (Q-S0s) to explore their evolutionary link with the star-forming S0s. To study star-formation at resolved scales, we use dust-corrected H_α luminosity and stellar density ($\Sigma_\star$) maps to construct radial profiles of star-formation rate (SFR) surface density (Σ_{SFR}) and specific SFR (sSFR). Examining these radial profiles, we find that star-formation in SF-S0s is centrally dominated as opposed to disc dominated star-formation in spirals. We also compared various global (size-mass relation, bulge-to-total luminosity ratio) and local (central stellar velocity dispersion) properties of SF-S0s to those of the control sample galaxies. We find that SF-S0s are structurally similar to the quenched S0s and are different from star-forming spirals. We infer that SF-S0s are unlikely to be fading spirals. Inspecting stellar and gas velocity maps, we find that more than 50% of the SF-S0 sample shows signs of recent galaxy interactions such as kinematic misalignment, counter-rotation, and unsettled kinematics. Based on these results, we conclude that in our sample of SF-S0s, star-formation has been rejuvenated, with minor mergers likely to be a major driver.

星形成を示すS0銀河はSpなのか？S0なのか？

- Merger, AGN feedback, 高密度環境等により星形成が抑制されred-deadでearly-typeな形態を持つ銀河へと進化すると考えられる。
- 一方で、星形成を示すearly-type銀河 **blue early-type galaxies** も見つかっている。
  - 見た目はearly-typeだが星形成の兆候を示す銀河。
  - 低質量側に多い。gas fractionはSp並み。
    →normal E銀河にminor mergerによってfresh gasが供給され星形成が起きている？
- 本研究ではearly-typeの中でもS0に着目し、星形成しているS0の起源を探る。
  - MaNGAデータを用いて、global/resolvedの性質をS0とSpで比べる。
    - 形態：MaNGA DR15 (TType, P_Q0)
      - SDSS画像では見落としているかもしれない渦状腕をHSC, DESI, PanSTARRSで目視確認。
    - 星形成：SED fitから求めたsSFR。
  - 星形成しているS0 (SF-S0), していないS0 (Q-S0), 星形成しているSpiral (SF-Sp)を抽出。

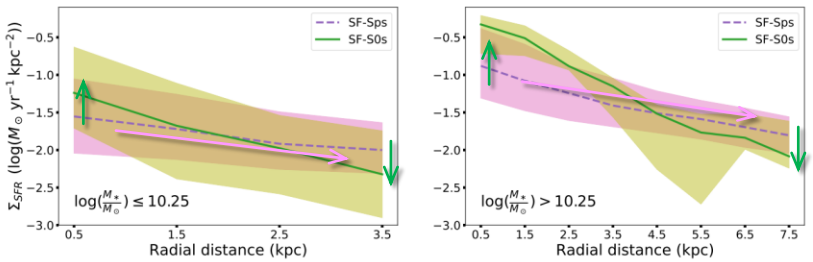


Figure 6. Σ_{SFR} radial profile for star-forming S0s (SF-S0s, green solid line) and star-forming spirals (SF-Sps, purple dashed line) for both low stellar mass (left panel) and high stellar mass (right panel) bins. 25 – 75 percentile bands depicting the scatter of a particular sample are also shown

. The typical measurement error on the radial profiles is very small (~ 0.001 dex). Σ_{SFR} radial profile for SF-S0s is centrally peaked, and declines relatively more rapidly than that of SF-Sps.

←Fig.6: ΣSFRの動径分布
SF-S0の星形成は中心が強い。
SF-Spはなだらか (diskに付随)。
→ SF-S0はSF-Spがquenchしつつある種族では無い。

Figure 2. The stellar mass ($\log \frac{M_\star}{M_\odot}$) histogram for the three samples. The control sample of star-forming spirals (SF-Sps) having 1468 objects is depicted by the purple dashed line, the sample of star-forming S0s (SF-S0s) having 120 objects is depicted by the green solid line, and the control sample of quenched S0s (Q-S0s) having 227 objects is depicted by the orange dash-dot line. The stellar mass range of SF-Sps and Q-S0s has been imposed to be the same as that of SF-S0s. On average, Q-S0s have a higher stellar mass as expected of quenched early type galaxies. Most of the SF-S0 galaxies have $\log \frac{M_\star}{M_\odot} < 10$, consistent with the findings of previous studies. Area under all histograms is normalised to unity.

Figure 10. The Star Formation Main Sequence (SFMS) plot for the three samples. The control sample of star-forming spirals (SF-Sps) having 1468 objects is depicted by light-purple circles, and the control sample of quenched S0s (Q-S0s) having 227 objects is depicted by orange triangles. We further categorise the main sample of SF-S0s based on stellar and H_α kinematic maps, as explained in the text (Section 5.2). At the very low stellar mass end, most of the SF-S0 galaxies are kinematically unsettled. Whereas, at the high stellar mass end, most of the SF-S0 galaxies are kinematically regular.

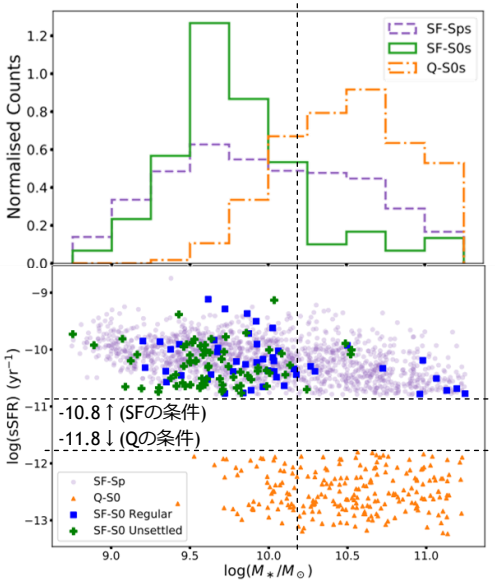
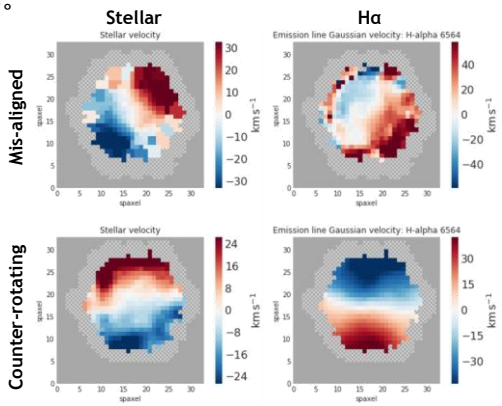


Fig.2/10: SF-S0, Q-S0, SF-Sp サンプルの分布→
Q-S0はmore massive (low-mass側が少ないのはselection effect [SED fit出来ない]もある)。
Log(Ms)=10.25付近でSF-S0 fractionが減少。

Fig.8: Ms-Re分布→
SF-S0はQ-S0と同様の分布。
→ SF-S0はSF-Spとは構造的に異なる。
B/Tの比較からも同様の結果。



↑ Fig.9: SF-S0銀河の速度分布
SF-S0をRegular (stellarとHαで分布が一致), disturbed (どちらかor両方がdisturbed), mis-aligned (回転軸が不揃い), counter-rotate (逆回転) の4種に細分。

➔
- Regularの割合は40%
- SF-S0の多くは最近interactionやminor mergerを受けて"unsettled"。
- Unsettledのほとんどはlow mass側で、high massのSF-S0はregular。(high-mass銀河の回転を乱すのは容易ではないため？)

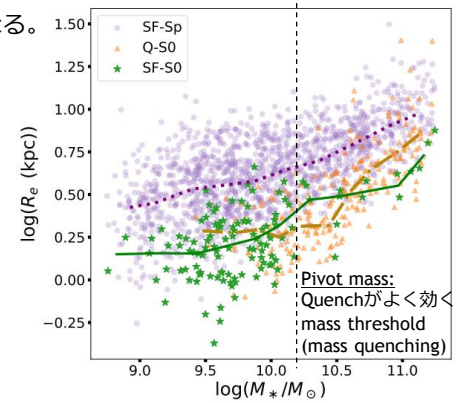


Figure 8. The size-mass relation for SF-Sps (purple circles), SF-S0s (green stars) and Q-S0s (orange triangles). Y-axis is the r-band half-light radius (R_e), and X-axis is the stellar mass. The solid lines represent the median trend for each sample

✓SF-S0は死にゆくSF-Spではなく、minor mergerで一時的に息を吹き返したQ-S0。
✓星形成によりmassiveになるとquenchが効いてmassive Q-S0へ。