Stellar age gradients and inside-out star formation quenching in galaxy bulges

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$<\delta\mu_{9G}> = \mu_{0Gyr}-\mu_{9Gyr}$
→ 青: $<\delta\mu_{9G}> \leq -2.5$ mag, 緑: $-2.5 \leq <\delta\mu_{9G}> \leq -0.5$,
赤: $-0.5 \leq <\delta\mu_{9G}>$

ABSTRACT

Radial age gradients hold the cumulative record of the multitude of physical processes driving the build-up of stellar populations and the ensuing star formation (SF) quenching process in galaxy bulges, therefore potentially sensitive discriminators between competing theoretical concepts on bulge formation and evolution. Based on spectral modeling of integral field spectroscopy (IFS) data from the CALIFA survey, we derive mass- and light-weighted stellar age gradients ($\nabla(t_{\star,B})_{\mathcal{L},\mathcal{M}}$) within the photometrically determined bulge radius (R_B) of a representative sample of local face-on late-type galaxies that span 2.6 dex in stellar mass ($8.9 \leq \log\mathcal{M}_{\star,T} \leq 11.5$). Our analysis documents a trend for decreasing $\nabla(t_{\star,B})_{\mathcal{L},\mathcal{M}}$ with increasing $\mathcal{M}_{\star,T}$, with high-mass bulges predominantly showing negative age gradients and vice versa. The inversion from positive to negative $\nabla(t_{\star,B})_{\mathcal{L},\mathcal{M}}$ occurs at $\log\mathcal{M}_{\star,T} \simeq 10$, which roughly coincides with the transition from lower-mass bulges whose gas excitation is powered by SF to bulges classified as Composite, LINER or Seyfert. We discuss two simple limiting cases for the origin of radial age gradients in massive LTG bulges. The first one assumes that the stellar age in the bulge is initially spatially uniform ($\nabla(t_{\star,B})_{\mathcal{L},\mathcal{M}} \approx 0$), thus the observed age gradients (~ -3 Gyr/R_B) arise from an inside-out SF quenching (**ioSFQ**) front that is radially expanding with a mean velocity v_q. In this case, the age gradients for massive bulges translate into a slow ($v_q \sim$1-2 km s^{-1}) **ioSFQ** that lasts until $z \sim 2$, suggesting mild negative feedback by SF or an AGN. If, on the other hand, negative age gradients in massive bulges are not due to **ioSFQ** but primarily due to their inside-out formation process, then the standard hypothesis of quasi-monolithic bulge formation has to be discarded in favor of a scenario that involves gradual buildup of stellar mass over 2-3 Gyr through, e.g., inside-out SF and inward migration of SF clumps from the disk. In this case, rapid ($\ll$ 1 Gyr) AGN-driven **ioSFQ** cannot be ruled out. While the $\mathcal{M}_{\star,T}$ vs. $\nabla(t_{\star,B})_{\mathcal{L},\mathcal{M}}$ relation suggests that the assembly history of bulges is primarily regulated by galaxy mass, its large scatter (~1.7 Gyr/R_B) reflects a considerable diversity that calls for an in-depth examination of the role of various processes (e.g., negative and positive AGN feedback, bar-driven gas inflows) with higher-quality IFS data in conjunction with advanced spectral modeling codes.

目的

- バルジ内でのage勾配からバルジの形成過程やquenching過程を探る
- 速いioSFQは元のage勾配をほぼ保存するが、遅いioSFQはnegativeな勾配を作る

先行研究memo
- 質量が重いほど早くバルジ形成 (Breda & Papaderos 2018)
- $M_{\star,B} \sim 3\times10^{10}\ M_\odot$, $\Sigma_{\star,B} \sim 10^9\ M_\odot$ kpc^{-2} くらいからバルジのSFQが始まり、支配的な励起メカニズムも変化

サンプル

- 135のnon-interacting, nearly face-on (<40deg), local (<130Mpc) LTG from CALIFA
- 8.9 < logM*,T < 11.5
- 8.3 < logM*,B <11.3

解析手順

各spaxelでのage
→radial profile
→$R_{PSF}<R<R_B$で線形フィット
→$\nabla(t_{\star,B})$

R_{PSF}=2.6″

R_B: Sersic profileフィットで表面輝度が24 mag/□″になる半径

Fig 1. age勾配の解析

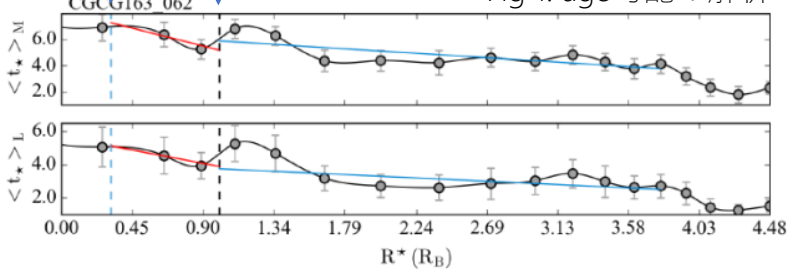


Fig 2.

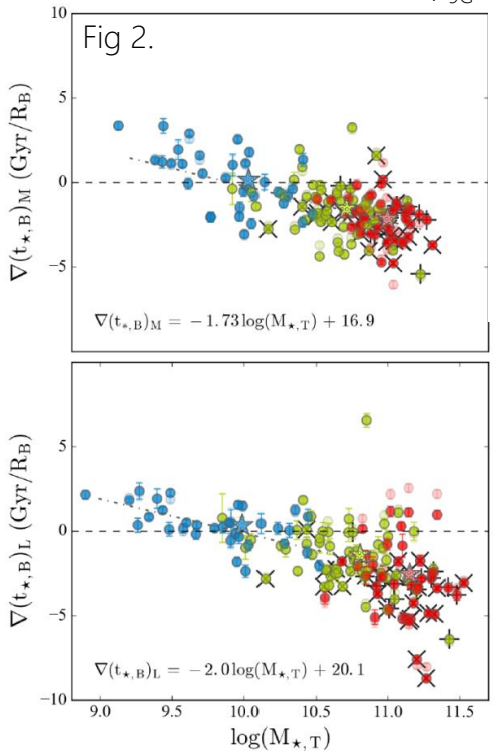
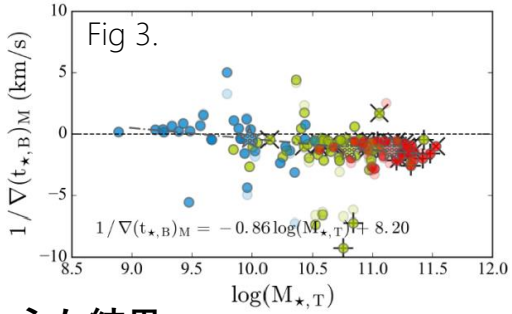


Fig 3.



主な結果

- age勾配が$M_{\star,T}$=10.5付近で正から負へと変化
- young low mass bulgeからold high mass bulgeへの変化
- ioSFQの速度は 1-2km/s

二つの単純なケースを考察

- 元々は一様なageだったのが、ioSFQで勾配を持った
- inside-outバルジ形成で元々勾配を持っていた

Fig 4. まとめの図