Dissecting environmental effects on AGN triggering of late-type SDSS galaxies

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Abstract

We explore the role of various environments in triggering star formation (SF) and narrow-line active galactic nucleus (AGN) in SDSS spiral galaxies and the SF-AGN connection, using a volume-limited sample with $M_r < -19.5$ and $0.025 < z < 0.055$ selected from the SDSS Data Release 7. To avoid the dependency of AGN activity on bulge mass, the central velocity dispersion of the sample galaxies is limited to have a narrow range of $130 < \sigma < 200$. We note that in gas sufficient galaxies, AGN feeding lags behind starburst, whereas as the gas exhausts, the SF slows down and AGN seems to even prevent the SF, and thus divide the high- σ sample into two subsamples according to their cold gas content at central region traced by fiber star formation rate, SFR_{fib}. We find that a high density (cluster) environment causes a significant increase in AGN activity despite gas depletion in host galaxies. However, the finding is only noticeable in the high-σ and low SFR_{fib} sample. It seems that a galaxy interaction with the nearest neighbor directly affects the SF of the central region. However, it is unclear whether it directly affects AGN activity.

Data sample

► The volume-limited **late-type (spiral / irregualr)** galaxies sample from SDSS DR7
- The range of r-band absolute magnitude : $M_r < -19.5$
- The range of redshifts : $0.02 < z < 0.055$ (**determined for fiber aperture to enclose the bulge at a center**)
- Morphology classification : Park & Choi (2005), Choi et al. (2010, KIAS-VAGC)

► Fixing the mass of the supermassive black hole (M_{BH})
- The range of stellar velocity dispersion : $130 < \sigma < 200$ ($7.4 < \log(M_{BH}/M_{\odot}) < 8.1$)
($M_{BH} - \sigma$ relation; Tremaine et al. 2002)

► AGN definition : **Composite galaxies** & **pure AGNs** (based on BPT diagram)
- $S/N \geq 6$ for flux of narrow emission lines
- **LINER-like emission objects are excluded.** ($W_{H\alpha} < 3$ Å, Cid Fernandes et al. 2011)
- SFR_{fib} : For SFGs, emission lines were used (Brinchmann et al. 2004) while for others models were fit to the fibre photometry.

Definition of Environment

► **Large-scale environment**

• **The galaxy background density ($\rho_{20}/\bar{\rho}$) :** Defined by twenty nearest neighboring galaxies over a few Mpc scale of a target galaxy in the sample and normalized by the mean density of the universe $\bar{\rho}$. (Park & Choi 2009)

$$\rho_{20}(x)/\bar{\rho} = \sum_{i=1}^{20} \gamma_i L_i W_i(|x_i - x|)/\bar{\rho}$$

► **Small-scale environment**

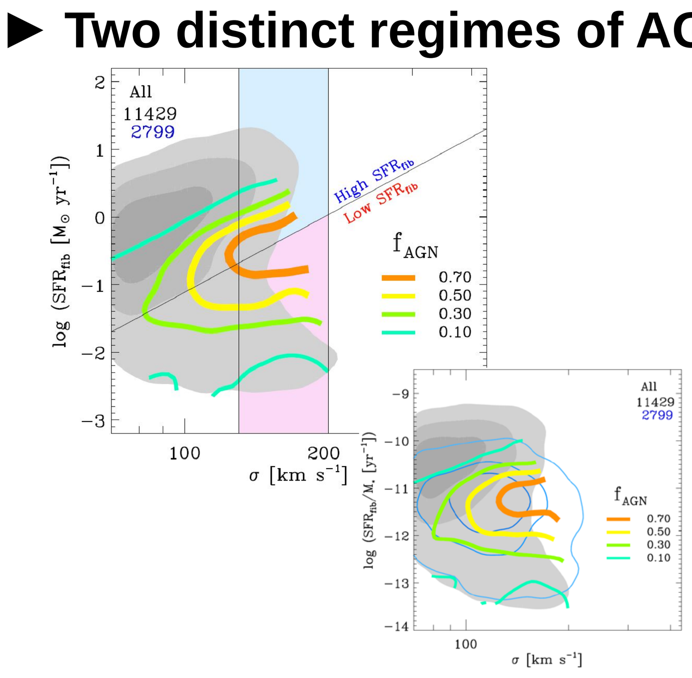
• **The projected separation ($r_p/r_{vir,nei}$) :** Defined by the projected separation between the host target galaxy and the nearest neighbor galaxy normalized by the virial radius of the nearest neighbor galaxy. The virial radius of the nearest neighbor galaxy r_{vir} is defined as the projected radius r_p where the mean mass density within the sphere with radius of r_p is equal to 740 times the mean density of the universe $\bar{\rho}$.

$$r_{vir} = (3\gamma L/4\pi\bar{\rho}/740)^{1/3}$$

- **The nearest neighbor galaxy** : Defined as located closest to the galaxy on the sky and satisfies magnitude and radial velocity condition. $\Delta M_r = 0.5$ & $\Delta v = 400\ km\ s^{-1}$

Results 1

► **Two distinct regimes of AGN feeding**



• **Selection of only massive galaxy sample**

130 < **σ** < 200

- A little dependency of f_{AGN} on BH mass
- A strong dependency of f_{AGN} on central SF

• **Two subsamples divided by the peak of f_{AGN}**
(Opposite behaviors of the dependence of f_{AGN} on central SF)

- **The galaxies with sufficient central gas (highSFR_{fib})**
SFR_{fib} ⇩ ⟶ f_{AGN} ⇧

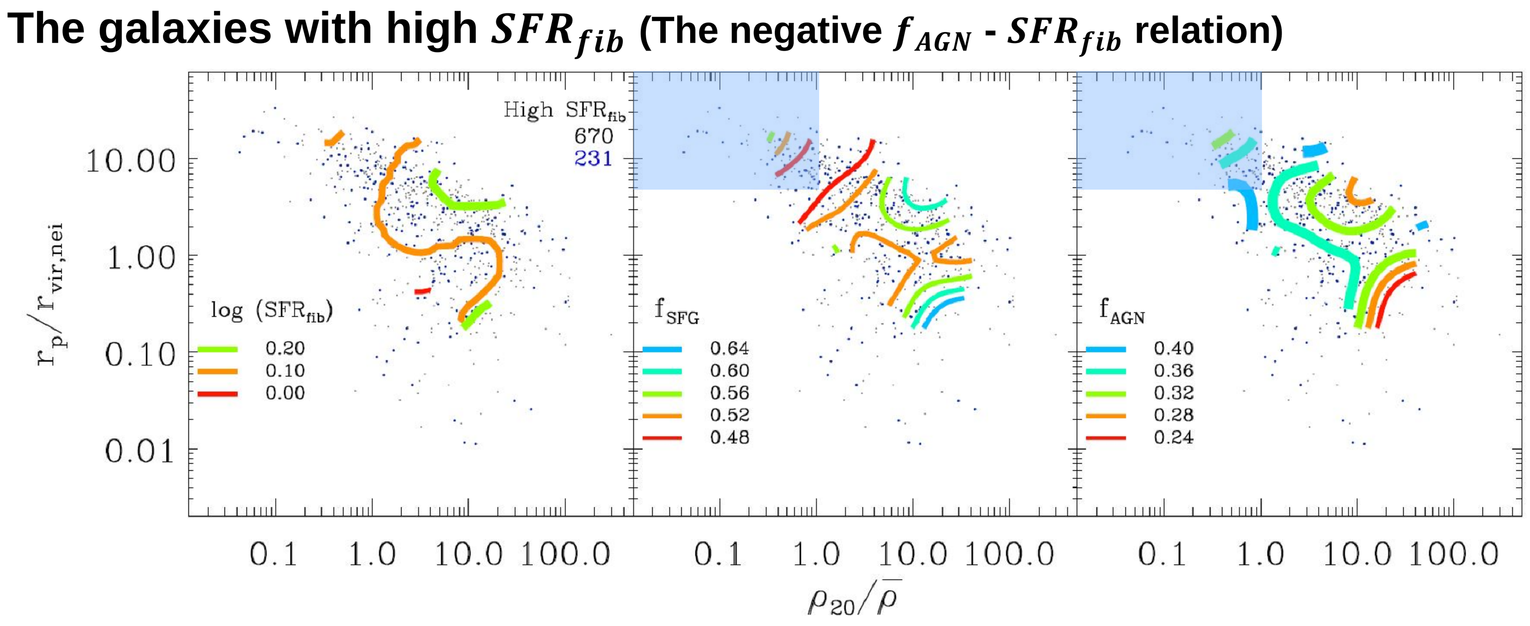
- **The galaxies with lack of central gas (low SFR_{fib})**
SFR_{fib} ⇩ ⟶ f_{AGN} ⇩

• If the supply of cold gas in a galaxy bulge is plentiful, AGN feeding seems to lag behind starburst and is regulated by BH mass. Once the gas runs out, the AGN feeding seems regulated by the rate at that depends on central gas supply.

► **The effect of environment on AGN feeding**

☻ Note that since we calculate the median values of galaxy parameters, the variation over various environments is not large.

◆ **The galaxies with high SFR_{fib} (The negative f_{AGN} - SFR_{fib} relation)**

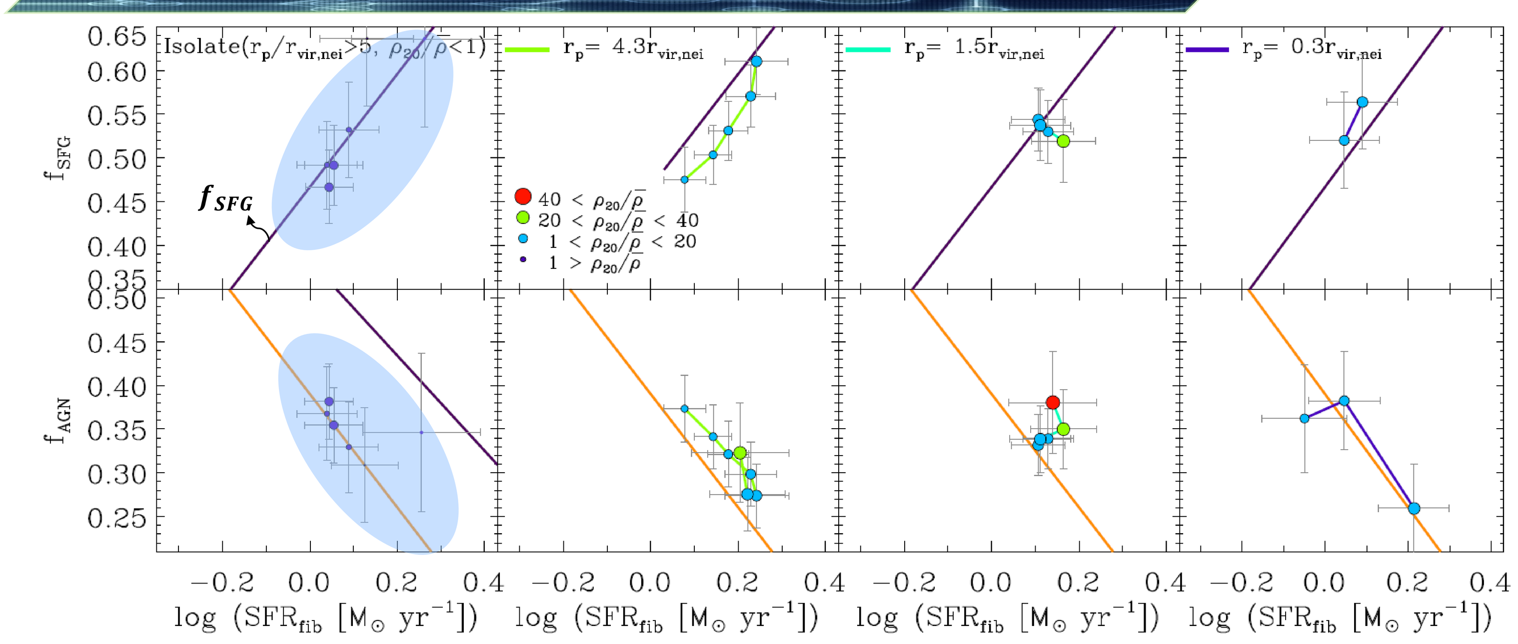


• The median relation of $1 - f_{SFG}$ vs. SFR_{fib} ⟺ f_{AGN} vs. SFR_{fib}
(Very similar slopes between of them)

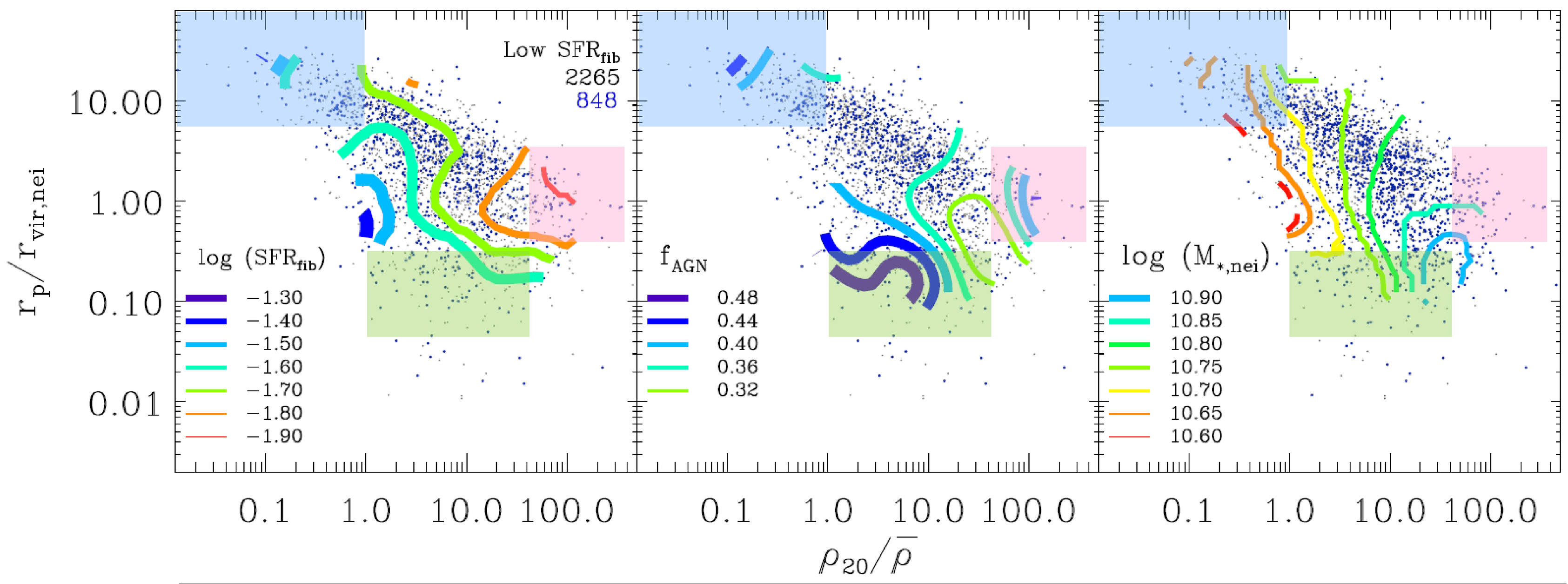
• The relation between AGN feeding and the central SF in **the isolated region** still persists in other environments.

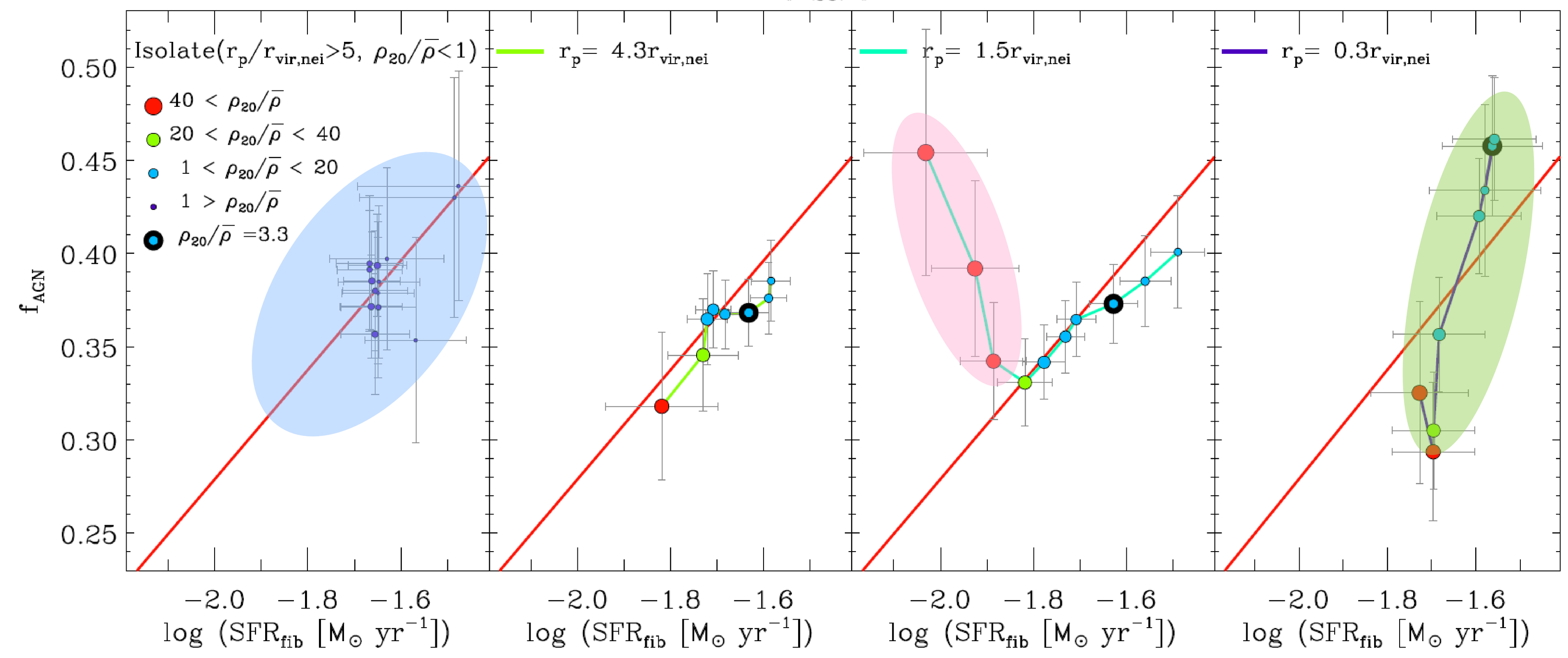
➧ Assuming that for galaxies with a plentiful central cold gas, AGN feeding lags behind starburst, no environment is likely to reduce the time delay until the AGN is triggered.

Results 2



◆ **The galaxies with low SFR_{fib} (The positive f_{AGN} - SFR_{fib} relation)**





• Even in the very high density regions (ρ_{20} > 40 $\bar{\rho}$), where a galaxy is just entering the virial radius of its influential neighbor (e.g. outer part of a cluster), the f_{AGN} (mostly weak AGNs) increases despite the lack of central gas fuel.

- Notice that this work cannot resolve the very high density regions, where a galaxy approaches more closely its neighbor.

• A stronger dependence of the f_{AGN} - SFR_{fib} relation found in the galaxy interaction region ($r_p < 0.3\ r_{vir,nei}$).

- The interaction of neighboring galaxies appears to have a small but significant effect on AGN feeding (compare blue dots with bold border).
- As $\rho_{20}/\bar{\rho}$ increases, f_{AGN} sharply decreases. Notice that the stellar mass of neighbours in the region increases significantly.
- The f_{AGN} in the very high density regions appears to increase silightly, but it's not clear.

Conclusion

• For galaxies with a plentiful supply of cold gas in a bulge, the median relation between AGN fraction and central SF is hardly changed depending on the environment. Various environments only affect the central gas supply, which as a result affects AGN feeding. No environment is likely to reduce the time delay until the AGN is triggered.

• For galaxies with lack of the cold gas in a bulge, the median relation between AGN fraction and central SF is significantly changed when entering the cluster region and when having neighbors with hotter and denser halo gases within their virial radius.

• In conclusion, the environmental effect of AGN activity is only noticeable in galaxies with a massive bulge and deficient central gas fuel. These results can be observed only after dissecting the effects of morphological type, bulge mass, and central gas supply.

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