Morphological Evidence for a Past Minor Merger in the Seyfert Galaxy NGC 1068

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NGC 1068 is one of the archetypical Type-2 Seyfert galaxies in the local Universe. Thanks to its close proximity (~15 Mpc) and nearly face-on configuration, many observational studies have been done about the galaxy.

There are two major hypotheses on how the Seyfert-type Active Galactic Nuclei (AGNs) are triggered. One mechanism attributes to the internal secular process, where the galactic disk generates the non-axisymmetric structure (e.g., bars) which efficiently removes the angular momentum of the circulating gas to dump it to the center. NGC 1068 indeed has the bar structure in the center. However, it is also known that the axis of the dust torus around the central Supermassive Blackhole (SMBH) is nearly perpendicular to the rotation axis of the galactic disk. Such misalignment between the central dust torus and the disk of host galaxy is often observed among Seyfert galaxies. Explaining the mis-alignment is not so easy for the triggering scenario by secular evolution.

The other hypothesis is the external trigger such as mergers. On this standpoint, Taniguchi (1999) proposed the AGN unification model by mergers. They discussed that all Seyfert AGN activities were triggered by the minor merger of the *nucleated* (= with the SMBH at its center) satellite galaxy [1]. When a satellite is merged to the main galaxy, most of its body will be destroyed by the tidal field of the main galaxy. However, if it is nucleated, its core with a SMBH can survive and go into the center of the main galaxy to merge with the host SMBH. During the sinking process, the gravitational interaction can violently disturb the gas near the center of the main galaxy, which will lead to the AGN activity. As the angle of the dust torus and the narrow line region around the SMBH is basically determined by the orbit of the sinking satellite, its correlation with the rotation axis of the main disk would be weak as observed. However, no previous studies ever detected the morphological sign of the minor merger around NGC 1068.

We thought that the sign of minor merger might still remain at the very outer part of the host galaxy, due to its longer dynamical timescale. We observed NGC 1068 by Subaru in late 2016. Using the deep optical data by Hyper Suprime-Cam (HSC) and Suprime-Cam, we have discovered the very faint signatures of the past tidal interaction for the first time [2]. This is shown in the top panel of the Figure 1. There are two very faint (>27 mag arcsec^{-2}: r band AB) spurs near the north and the south of the main disk. Their morphology suggests that they are a part of the loop (see the insets at right of the Fig. 1[top]). Such stream structure can be made by the minor merger occurred several Gyrs ago. And also, there are the intriguing structures on the faint outer disk. The bottom panel of fig.1 is the contrast-enhanced image of the outer disk structure. The one-arm structure ("Banana") as well as the "ripple" on the other side are clearly visible. Such structures are also shown to be made by the past minor merger event several Gyr ago by the simulations (see discussions in Tanaka et al. 2017 for more).

Our findings are consistent with the proposed idea by Taniguchi (1999). We recently started the new imaging survey for faint tidal signature on Seyferts by HSC. We will expand the sample size to see how minor merger is important to trigger the Seyfert activity.

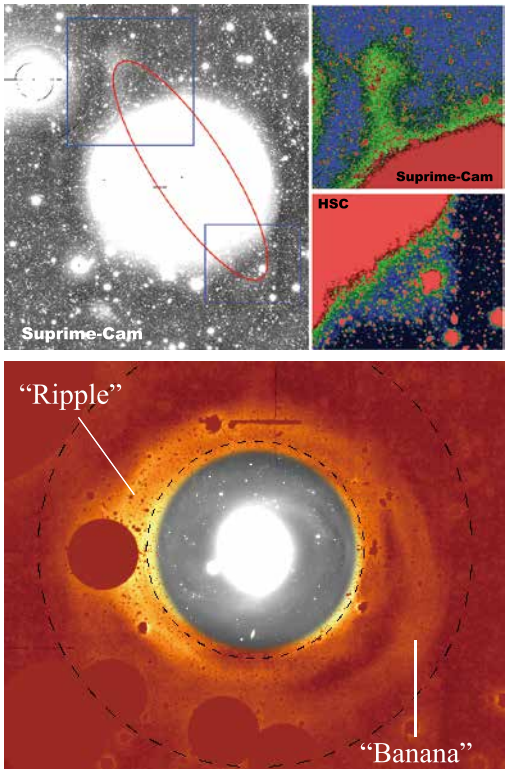

Figure 1: [Top] The discovered diffuse signatures around NGC 1068 by Subaru. Their morphology apparently resembles a part of a loop which could be the tidal stream (see the right two panels). The image size is 19′ × 21′. [Bottom] The contrast-enhanced view of the faint outer disk of NGC 1068. The single-arm structure ("Banana") and the ripple-like feature ("Ripple") are seen. See the ref. [2] for more detail.

References

[1] Taniguchi, Y.: 1999, *ApJ*, **524**, 65.
[2] Tanaka, I., Yagi, M., Taniguchi, Y.: 2017, *PASJ*, **69**, 90.