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HOST GALAXY OF TIDAL DISRUPTION OBJECT, SWIFT J1644+57

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ABSTRACT

We analyze the host galaxy of the tidal disruption object, Swift J1644+57, based on long-term optical to NIR data obtained with CQUEAN and UKIRT WFCAM observations. We decompose the bulge component using high resolution HST WFC3 images. We conclude that the host galaxy is bulge dominant. We investigate optical to NIR light curves and estimate the multi-band fluxes of the host galaxy. We fit spectral energy distribution (SED) models in order to determine the stellar mass. Finally, we estimate the mass of the black hole in the center of the host galaxy based on several scale relations.

Key words: transient, galaxy: morphology, black hole: scale relation

1. INTRODUCTION

A remarkable tidal disruption event, Swift J1644+57 was detected by the Swift Burst Alert Telescope (BAT) on 28 March 2011 (Levan et al., 2011). This event was well known for the tidal disruption of a star. A star passing by the super massive black hole (SMBH) in the center of the galaxy was captured by the gravitational potential. Afterward, it was disrupted by the tidal force exerted by the SMBH. This event released powerful energy over the whole electromagnetic spectrum. The X-ray emission extended over a long period, showing a light curve proportional to $t^{-5/3}$. This curve corresponds to a power law light curve for the tidal disruption of a star (Rees, 1988).

This event occurred near the SMBH in the center of the galaxy. There have been several efforts to constrain the mass of the SMBH responsible for the tidal disruption. Burrows et al. (2011) estimated the SMBH mass to be $\sim 2 \times 10^7 M_\odot$ using the M-L relation and X-ray variability. The result of Miller & Gültekin (2011) is $\sim 10^{5.5} M_\odot$ based on the relation between black hole mass, radio luminosity, and the X-ray luminosity. Levan et al. (2011) showed that the black hole mass is in the range of 2×10^6 - $10^7 M_\odot$, which is derived through the scaling relation between SMBHs and host galaxy properties. Abramowicz & Liu (2012) estimated $\sim 10^5 M_\odot$ by the quasi periodic oscillation resonance hypothesis. Krolik & Piran (2011) argued that the mass of the SMBH should be less than $10^5 M_\odot$. In this study, we investigated the properties of the host galaxy, such as morphology and stellar mass. By doing so, we estimated the mass of the SMBH more accurately based on several scale relations between black hole mass and the the properties of host galaxies.

2. MORPHOLOGY OF THE HOST GALAXY

The morphology of the host galaxy of Swift J1644 was determined with GALFIT software (Peng et al., 2010). We used *HST* WFC3 multi-drizzled images for this analysis. We found that the host galaxy of Swift J1644+57 is bulge dominant. The Sérsic index of a well fitted model galaxy is 2.93. We tried to add a disk component. When a disk component is added, the bulge to total host galaxy flux ratio (B/T) is 0.73, indicating a bulge dominant galaxy. We could not find any evidence of a pseudobulge, although we examined this possibility. The point spread function (PSF) model is always simultaneously fitted with the center of the galaxy in order to account for the transient component near the SMBH. An example of the 2-dimensional fitting result is shown in Figure 1.

3. LIGHT CURVES

We estimated multi-band fluxes of the host galaxy of Swift J1644+57 based on long-term optical to NIR light curves. The NIR flux from the transient component was quenched ∼ 500 days after the BAT trigger following the X-ray flux. On the other hand, we found that there are no notable changes at optical bands, possibly caused by significant dust extinction. We concluded that the fluxes from the pure host galaxy of Swift J1644+57 were revealed ∼ 500 days after the BAT trigger.

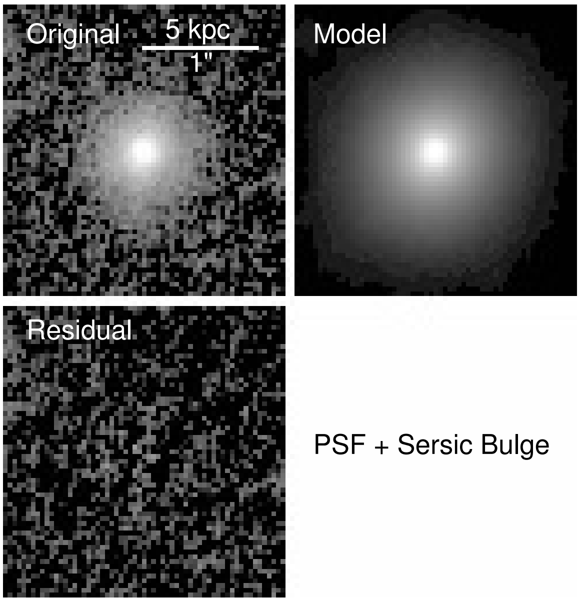

Figure 1. An example of the 2-dimensional fitting result for the single Sérsic bulge + PSF model.

4. SED FITTING

We fitted an SED to the host galaxy of Swift J1644+57 to extract various properties, particularly the stellar mass. For this purpose, we used the SED fitting code, CIGALE (Code Investigating GALaxy Emission) (Noll et al., 2009). We selected a Maraston stellar population model (Maraston, 2005) and Kroupa IMF (Kroupa, 2001). The code uses a model for SED attenuation by dust from Calzetti et al. (2000). For emission by dust, the code uses the semi-empirical models of Dale & Helou (2002). The estimated stellar mass of the host galaxy is $\sim 10^{9.1} M_\odot$.

5. BLACK HOLE MASS

Tight scale relations between the masses of SMBHs and physical properties of the host galaxies are known through many studies. We estimated the black hole mass based on such scale relations. We used the scale relation between the black hole mass and the stellar mass of the bulge from Sani et al. (2011). We had already concluded that the host galaxy is bulge dominant, so we can expect that the stellar mass estimated in this study belongs to the bulge. The relation is

$$\log(M_{\rm BH}/M_\odot) = \alpha + \beta \times [\log(M_{{\rm bul},\star}/M_\odot) - 11],$$

where $\alpha = 8.16 \pm 0.06$, $\beta = 0.79 \pm 0.08$, and the intrinsic scatter is 0.38 ± 0.05. The estimated mass of the SMBH is $\sim 10^{6.6} M_\odot$

We estimated the black hole mass bythe $M_{\rm BH}$-$L_{\rm bul,K}$ relation in Kormendy & Ho (2013). The relation is

$$\log(M_{\rm BH}/10^9 M_\odot) = -\alpha - \beta \times (M_{K,{\rm bul}} + 24.21),$$

where the α is 0.265 ± 0.050, β is 0.488 ± 0.033, and the intrinsic scatter is 0.30. The estimated black hole mass is $\sim 10^{7.3} M_\odot$.

We determined the unknown bulge fraction of the galaxy and multi-band fluxes from the host galaxy by 2-dimensional decomposition and light curve analysis. Our black hole mass estimations are improved compared to previous ones, as we identified information that is very essential when applying the scale relations.

Details of this work will appear in Yoon et al. (in preparation).

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