Imprints of the super-Eddington accretion on the quasar clustering

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ABSTRACT
Super-Eddington mass accretion has been suggested as an efficient mechanism to grow supermassive black holes (SMBHs). We investigate the imprint left by the radiative efficiency of the super-Eddington accretion process on the clustering of quasars using a new semi-analytic model of galaxy and quasar formation based on large-volume cosmological N-body simulations. Our model includes a simple model for the radiative efficiency of a quasar, which imitates the effect of photon trapping for a high mass accretion rate. We find that the model of radiative efficiency affects the relation between the quasar luminosity and the quasar host halo mass. The quasar host halo mass has only weak dependence on quasar luminosity when there is no upper limit for quasar luminosity. On the other hand, it has significant dependence on quasar luminosity when the quasar luminosity is limited by its Eddington luminosity. In the latter case, the quasar bias also depends on the quasar luminosity, and the quasar bias of bright quasars is in agreement with observations. Our results suggest that the quasar clustering studies can provide a constraint on the accretion disc model.

Key words: cosmology: theory – dark matter – galaxies: haloes – galaxies: formation – quasars: general – large-scale structure of Universe

1 INTRODUCTION
Some observations (Mortlock et al. 2011; Wu et al. 2015) have found optically bright quasars even at high redshift, z ∼ 7. These quasars are powered by mass accretion on to supermassive black holes (SMBHs). The observations suggest that SMBHs with mass M_{BH} ∼ 10^9M⊙ already exist at such high redshift. While some physical processes through which these SMBHs form have been proposed (see Volonteri 2010 and references therein), how the SMBHs form during less than 1 Gyr after the Big Bang is still debated. Super-Eddington mass accretion, for which the mass accretion rate exceeds the Eddington rate

\[ \dot{M}_{\text{Edd}} \equiv L_{\text{Edd}}/c^2, \]

has been suggested as an efficient mechanism to grow SMBHs (e.g. Volonteri & Rees 2005; Madau, Haardt & Dotti 2014; Alexander & Natarajan 2014; Volonteri, Silk & Dubus 2015), where L_{\text{Edd}} is the Eddington luminosity L_{\text{Edd}} ≡ 4\pi G M_{\text{BH}} m_p c/\sigma_T, m_p is the proton mass, and \sigma_T is the Thomson scattering cross-section. During the super-Eddington accretion, the photons produced in the accretion flow are advected inwards by the optically thick flow and cannot be radiated away (e.g. Begelman 1978). This type of the accretion flow is described by a well known solution called slim disc (e.g. Abramowicz et al. 1988; Watarai et al. 2000; Mineshige et al. 2000). The structure of the slim disc becomes geometrically thick. Pacucci, Volonteri & Ferrara (2015a) show analytically and numerically that in this condition the outflow by radiative feedback has a negligible role, and the BH can accrete 80–100 per cent of

\[ \dot{M}_{\text{Edd}} \equiv L_{\text{Edd}}/c^2, \]
the gas mass of the host halo. Although there are some observations suggesting that some active galactic nuclei (AGNs) are accreting at super-Eddington rates (e.g. Netzer & Trakhtenbrot 2014; Jin, Done & Ward 2017), it is still uncertain whether the super-Eddington accretion actually occurs or not.

The luminosity of a quasar with the super-Eddington accretion phase would be limited to several times of the Eddington luminosity $L_{\text{Edd}}$ due to the ‘photon trapping’ (e.g. Ohsuga et al. 2005). This means that the radiative efficiency is low at a high accretion rate. This limitation could affect the clustering of quasars, in particular, at higher redshifts, because accretion rates for quasars tend to be higher at such higher redshifts (Bonoli et al. 2009; Enoki et al. 2014). If this is true, future wide field surveys may clarify how mass accretion occurs. In this paper, we focus on the slim disc solution, although alternative radiatively inefficient models exist, e.g. ZEro-BeRnoulli Accretion (ZEBRA; Coughlin & Begelman 2014) and the ADiabatic Inflow-Outflow Solution (ADIOS; Blandford & Begelman 1999).

In the previous study with our semi-analytic model (Oogi et al. 2016; hereafter O16), we have shown that the model quasars with a given host halo mass have various Eddington ratios, $L/L_{\text{Edd}} = \eta M_{\text{BH}} / M_{\text{Edd}}$, and various luminosities due to a variety of elapsed times from the beginning of the quasar activity. As a consequence of this, the median mass of quasar host haloes depends only weakly on the quasar luminosity. In O16, we did not take into account the fact that the radiative efficiency depends on the accretion rate when considering the super-Eddington accretion (e.g. Pacucci et al. 2015a). This effect changes the Eddington ratios and luminosities of model quasars with a given host halo mass. This suggests that the behavior of the luminosity for the accretion rate in the slim disc affects the estimated host halo mass and the spatial clustering of quasars.

In this Letter, we investigate the imprint left by the radiative efficiency of the super-Eddington accretion process on the clustering of quasars. For this purpose, we use a new semi-analytic model of galaxy and quasar formation based on high-resolution $N$-body simulations.

The remainder of this Letter is organized as follows. In Section 2, we outline our semi-analytic model and the models of radiative efficiency of SMBHs. Section 3 gives the mass distribution of the quasar host haloes and the quasar bias for our models. In Section 4, we discuss the BH growth at high redshift via the super-Eddington accretion, and summarize our results.

**2 MODEL**

We use a semi-analytic model, $\nu^2$GC (Makiya et al. 2016), which is an extension of the Numerical Galaxy Catalog ($\nu$GC) (Nagashima et al. 2005; Enoki et al. 2014; Shirakata et al. 2015). In this model, we adopt merger trees of dark matter (DM) haloes using state-of-the-art cosmological $N$-body simulations (Ishiyama et al. 2015) with the Planck cosmology (Planck Collaboration et al. 2014). The simulation used in this Letter contains $4096^3$ dark matter particles within a comoving box of $500$ $h^{-1}$ Mpc, and the minimum halo mass is $8.79 \times 10^9$ $h^{-1}$ $M_\odot$ (see Ishiyama et al. 2015 for details). This simulation enables us to investigate quasar host haloes with statistical significance. The model includes all the main physical processes involved in galaxy formation: formation and evolution of DM haloes; radiative gas cooling and disc formation in DM haloes; star formation, supernova feedback and chemical enrichment; galaxy mergers. Free parameters related to galaxy formation processes are set to the values adopted in Makiya et al. (2016).

Our model also includes SMBH growth and quasar formation. We assume that major mergers of galaxies trigger starbursts in the nuclear regions and cold gas accretion on to SMBHs. We define a major merger as that with the mass ratio $M_2/M_1 \geq 0.1$, where $M_1$ and $M_2$ are the baryonic masses of the more and less massive galaxies, respectively. During major mergers, we assume that a fraction of the cold gas is accreted on the SMBH. The accreted mass $\Delta M_{\text{BH}}$ is modeled as follows:

$$\Delta M_{\text{BH}} = f_{\text{BH}} \Delta M_{\text{star,burst}},$$

where $\Delta M_{\text{star,burst}}$ is the total stellar mass formed during the starburst. We set $f_{\text{BH}} = 0.005$ to match the observed correlation between masses of host bulges and SMBHs at $z = 0$. Our model also reproduces the observationally estimated SMBH mass function. We assume that the time evolution of the accretion rate is as follows:

$$M_{\text{BH}}(t) = \frac{\Delta M_{\text{BH}}}{t_{\text{life}}} \exp(-t/t_{\text{life}}),$$

where $t_{\text{life}}$ is the quasar lifetime, and that $t_{\text{life}} \propto t_{\text{dye}}$.. We note that we allow for super-Eddington accretion in this model. The cold gas accretion leads to quasar activity. We assume that a fraction of the rest mass energy of the accreted gas is radiated. The radiative efficiency is determined by the models we describe below. Further details of our model of galaxy and quasar formation are given in Enoki et al. (2014) and Makiya et al. (2016).

We also consider the radio-mode gas accretion and the feedback process. In this mode the accreted gas powers radio jet that puts energy into the hot halo gas and prevents the hot gas from cooling and resultant star formation. The radio-mode feedback occurs when (i) the timescale of gas cooling is sufficiently long compared with the dynamical timescale of the halo, and (ii) the cooling luminosity of
the gas, which is assumed to balance the heating luminosity by the AGN, is sufficiently low compared with the Eddington luminosity. Although this gas accretion grows the mass of SMBHs, this is not significant contribution for the entire mass growth of SMBHs. This is because the mass growth of SMBHs is dominated by the gas accretion during major mergers (Makiya et al. 2016). Further details of the implementation of the radio-mode feedback are given in Makiya et al. (2016).

To examine the effect of the photon trapping in the accretion flow on the quasar host halo mass and the clustering, we adopt a simple model for the radiative efficiency \( \eta \equiv L/Mc^2 \) of a quasar, which imitates the effect of photon trapping for a high mass accretion rate,

\[
\eta = \left( \frac{1}{\epsilon_{\text{agn}}} + \frac{\dot{m}}{f_{\text{Edd}}} \right)^{-1},
\]

where \( \dot{m} \) is the normalised mass accretion rate \( \dot{m} \equiv \dot{M}_{\text{BH}}/\dot{M}_{\text{Edd}} \) and \( \epsilon_{\text{agn}} \) is a free parameter. The form of the model is the same as Sakurai, Inayoshi & Haiman (2016). In this model, the radiative efficiency decreases with increasing accretion rate, while it is constant for low accretion rates \( (\dot{m} \lesssim 10) \). The parameter, \( \epsilon_{\text{agn}} \), provides a constant radiative efficiency at such low accretion rates. \( f_{\text{Edd}} \) corresponds to the maximum Eddington ratio for high mass accretion rates. In our previous work, O16, \( f_{\text{Edd}} \) corresponded to \( \infty \), which leads to \( \epsilon_{\text{agn}} = \eta \). We set the parameter \( f_{\text{Edd}} = 1, 2, \) and 10 to examine the effects of the maximum Eddington ratio on the quasar clustering. We call the models with these parameters \( \eta_1, \eta_2, \) and \( \eta_{10} \) model, respectively. For comparison, we also adopt \( f_{\text{Edd}} = \infty \) as a model in which we allow for any super-Eddington luminosity (\( \eta_{\infty} \) model). We set \( t_{\text{life}}(z = 0) \) and \( \epsilon_{\text{agn}} \) to match the luminosity function of quasars with the observation at \( z = 2 \) in \( \eta_{\infty} \) model. We obtain \( t_{\text{life}}(z = 0) = 2 \times 10^7 \) yr and \( \epsilon_{\text{agn}} = 0.03 \). In O16, we employ this model. To examine the photon trapping effect, we fix all parameters except for \( f_{\text{Edd}} \) and examine the effect of the change of \( f_{\text{Edd}} \) on the results. We show the Eddington ratio in the models used here as a function of the accretion rate in Fig. 1. To obtain the quasar B-band luminosity, we use the bolometric correction from Marconi et al. (2004).

3 RESULTS

3.1 Accretion rate distribution

To show the importance of the model of the radiative efficiency during super-Eddington accretion, in particular, at high redshift, we first show the redshift evolution of the normalised accretion rate for our model quasars in Fig. 2. This figure shows that the normalised accretion rate increases with redshift. The super-Eddington accretion is expected to occur, in particular, at high redshift. We expect that the slim accretion disc model affects the quasar clustering more strongly at higher redshift.

3.2 Quasar host halo mass

Here, we investigate the impact of the model of radiative efficiency on the quasar host halo mass. Fig. 3 shows the mass distributions of the quasar host haloes for three quasar-magnitude bins and their median halo masses (dashed lines) at \( z = 2.5 \) when the number density of quasars has a noticeable peak. We define bright, intermediate, and faint quasars as those with B-band magnitudes \( M_B - 5 \log h < -24.5 \), \( -24.5 < M_B - 5 \log h < -23.0 \) and \( -23.0 < M_B - 5 \log h < -21.0 \), respectively. We show different models of radiative efficiency in different panels.

Fig. 3 clearly shows that the radiative efficiency, in other words, the maximum value of the quasar luminosity affects the quasar host halo mass distribution. We see that decreasing the upper limit of the quasar luminosity, the median host halo mass increases. For \( \eta_{\infty} \) model, there is only a weak dependence of median host mass on quasar magnitude. On the other hand, for \( \eta_1 \) model, there is a strong dependence of the median halo mass on quasar magnitude. While, for \( \eta_{10} \) model, the difference between the median halo masses of bright and faint quasars is \( \sim 0.5 \) dex, for \( \eta_1 \) model, the difference reaches \( \sim 1.2 \) dex. This trend can be understood as follows. Because of the fact that more massive haloes have more massive BHs in our model, when two quasars in haloes with different masses have same luminosity, the quasar in the less massive halo needs to have a high Eddington ratio. As a result, decreasing the upper limit of the quasar luminosity, the median host halo mass increases. This trend appears in the quasar bias described in Sec. 3.3.

In all magnitude range, the median host halo mass increases with the decreasing upper limit of quasar luminosity, although the upper limit affects the median stronger for bright quasars than that of faint quasars. The median host halo mass of bright quasars increases more than that of faint quasars by adopting the upper limit of quasar luminosity. This is because more luminous quasars within less massive haloes have higher Eddington ratios. Therefore, in this case, the median host halo mass depends on the quasar luminosity.

3.3 Quasar bias

We estimate the quasar bias using the median host halo mass and the following equation derived by Sheth, Mo & Tormen (2001). This is because the bias of quasars is primarily de-
Figure 3. Mass distributions of DM haloes hosting bright (red, thick solid), intermediate (green, dashed) and faint (blue, thin solid) quasars at $z = 2.5$. Each panel corresponds to a different model of radiative efficiency, as indicated by the legend. The vertical dashed lines are the median masses of the distributions.

Figure 4. Redshift evolution of the bias of bright (red, thick solid), intermediate (green, dashed) and faint (blue, thin solid) quasars. Each panel corresponds to a different model of radiative efficiency, as indicated by the legend. Observational results by the large-scale surveys of SDSS and 2QZ (Porciani et al. 2004; Croom et al. 2005; Padmanabhan et al. 2009; Ross et al. 2009; Shen et al. 2009) are also plotted (small filled circles and error bars), whose magnitudes are converted to $M_B$. The color coding represents the luminosity of quasars in the same way as for the models.

determined by the median host halo mass. Sheth et al. (2001) relates the halo bias and its mass:

$$b(M, z) = 1 + \frac{1}{\sqrt{ab + c}} \left( \sqrt{a(M_h^2)} + \sqrt{a(M_h^2)}^{1-c} \right)$$

$$= \frac{(a(M_h^2)^c}{(a(M_h^2)^c + b(1-c)(1-c/2)}.$$  

(5)
where $a = 0.707$, $b = 0.5$, $c = 0.6$, $\delta_c = 1.686$ is the critical overdensity required for collapse and $\nu = \frac{L}{\sigma(M)}$. $D(z)$ is the linear growth factor and $\sigma(M)$ is the variance of mass fluctuations. We have confirmed that this method works well in O16. The redshift evolution of the bias is shown in Fig. 4, where we show different models of radiative efficiency in different panels. Decreasing the upper limit of the quasar luminosity, the quasar bias increases. The upper limit of the quasar luminosity affects the bias for brighter quasars and at higher redshift more strongly. At $z \gtrsim 2$, the bias of bright quasars increases significantly for $\eta_1$ and $\eta_2$ models. This is because of the following two reasons. First, in these cases only massive BHs become bright quasars due to the upper limit $L_{\text{max}}$, which is proportional to $M_{\text{BH}}$, i.e. $L_{\text{max}} \sim L_{\text{Edd}} \propto M_{\text{BH}}$. Second, in our model more massive BHs reside in more massive haloes, which is in agreement with the observations (e.g. Ferrarese 2002; Fine et al. 2006, but see also Sabra et al. 2015). Therefore, luminous quasars having massive BHs show the strong clustering in these cases. On the other hand, the quasar bias hardly changes for all magnitude bins at low redshift ($z \sim 1$) even for $\eta_1$ and $\eta_2$ models. This is because most quasars have luminosities below the Eddington luminosity in this epoch. These quasars are not influenced by the upper limit.

We compare our results with observations. We compile observational results by the large-scale surveys of SDSS and 2QZ (Porciani, Magliocchetti & Norberg 2004; Croom et al. 2005; Padmanabhan et al. 2009; Ross et al. 2009; Shen et al. 2009). For $\eta_1$ model, the bias of bright quasars is in agreement with the general increasing trend of the bias shown in observational data. In addition, for $\eta_2$ model, the bias is in agreement with the observation at $1.5 \lesssim z \lesssim 2$. Future surveys of quasars will allow us to make more accurate comparison to the model.

4 SUMMARY AND DISCUSSION

In this Letter, we have investigated the large-scale clustering of quasars, including the models of radiative efficiency during super-Eddington accretion using our semi-analytic model, $\nu^2$GC. We have shown that the model of radiative efficiency strongly affects the quasar clustering. While the quasar bias has no significant dependence on quasar luminosity for the no-limit model, it has significant dependence on quasar luminosity for the model in which quasar luminosity is limited by its Eddington luminosity. This is because only massive BHs become high luminosity quasars due to the limit, and, in general, such massive SMBHs reside in massive haloes.

The luminosity dependence of the quasar bias is a reflection of the super-Eddington accretion model. This indicates that quasar clustering studies provide a constraint on the accretion disc model. The existence of the super-Eddington accretion discs are observationally suggested. Netzer & Trakhtenbrot (2014) have estimated the fraction of super-Eddington accretion discs in AGNs with different BH masses and accretion rates and have suggested that the super-Eddington accretion discs are very common among AGNs at various BH masses and redshift ranges. Super-Eddington accretion may also leave an imprint on the spectra of the radiation from the accreted gas on to SMBHs. Pacucci et al. (2015b) have simulated the spectra by using radiation-hydrodynamic and spectral synthesis codes, and have shown the characteristics of the spectra for Eddington-limited accretion and super-Eddington accretion flows. Studying the spectra from high-$z$ AGNs would help in understanding the importance of super-Eddington accretion on to high-$z$ SMBHs. The quasar clustering at high-$z$ we have investigated in this Letter may give a complementary method to investigate the AGNs with the super-Eddington accretion discs.

Our results show that models should take into account the photon trapping effect when considering the super-Eddington accretion. There are many studies investigating the quasar clustering using semi-analytic models (e.g. Kauffmann & Haehnelt 2002; Enoki, Nagashima & Gouda 2003; Bonoli et al. 2009; Pandakis et al. 2013; Gatti et al. 2016) or cosmological hydrodynamical simulations (e.g. Degraf, Di Matteo & Springel 2011; DeGraf & Sijacki 2017), however, most of these studies do not allow for the super-Eddington mass accretion. Recent theoretical (Pacucci et al. 2015a) and observational (Netzer & Trakhtenbrot 2014) studies suggest that models including the super-Eddington accretion and the resultant photon trapping effect could help us understand further physical mechanisms which cause the observed quasar clustering.

We have shown that for $\eta_1$ model, the bias of bright quasars is in agreement with the observation at $z \gtrsim 2$. Previous studies (e.g. O16; Allevato et al. 2016) claim that it is difficult to explain the strong quasar clustering at high redshift ($z > 2$) (Shen et al. 2007, 2009; Allevato et al. 2016). Our results support a picture in which BHs grow super-Eddington accretion, and could solve the problem of the strong clustering. Future observations of high-redshift quasar clustering will allow us to make more accurate comparisons to the model we introduced here and to estimate the role of super-Eddington accretion process during BH growth. For X-ray selected AGNs, Cappelluti et al. (2010) have shown the weak X-ray luminosity dependence of AGN clustering. Future theoretical studies are needed to explain the luminosity dependent clustering of these relatively low luminosity AGNs.

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REFERENCES

Abramowicz M. A., Czerny B., Lasota J. P., Szuszkiewicz E., 1988, ApJ, 332, 646
Alexander T., Natarajan P., 2014, Science, 345, 1330
Allevato V., et al., 2016, ApJ, 832, 70
Begelman M. C., 1978, MNRAS, 184, 53
Blandford R. D., Begelman M. C., 1999, MNRAS, 303, L1
Bonoli S., Marulli F., Springel V., White S. D. M., Branchini E., Moscardini L., 2009, MNRAS, 396, 423
Cappelluti N., Ajello M., Burlon D., Krumpe M., Miyaji T., Bonoli S., Greiner J., 2010, ApJ, 716, L209
Coughlin E. R., Begelman M. C., 2014, ApJ, 781, 82
Croom S. M., et al., 2005, MNRAS, 356, 415
DeGraf C., Sijacki D., 2017, MNRAS, 466, 3331
Degraf C., Di Matteo T., Springel V., 2011, MNRAS, 413, 1383
Enoki M., Nagashima M., Gouda N., 2003, PASJ, 55, 133
Enoki M., Ishiyama T., Kobayashi M. A. R., Nagashima M., 2014, ApJ, 794, 69
Fanidakis N., Macciò A. V., Baugh C. M., Lacey C. G., Frenk C. S., 2013, MNRAS, 436, 315
Ferrarese L., 2002, ApJ, 578, 90
Fine S., et al., 2006, MNRAS, 373, 613
Gatti M., Shankar F., Bouillot V., Menci N., Lamastra A., Hirschmann M., Fiore F., 2016, MNRAS, 456, 1073
Ishiyama T., Enoki M., Kobayashi M. A. R., Makiya R., Nagashima M., Oogi T., 2015, PASJ, 67, 61
Jin C., Done C., Ward M., 2017, MNRAS, 468, 3663
Kauffmann G., Haehnelt M. G., 2002, MNRAS, 332, 529
Madau P., Haardt F., Dotti M., 2014, ApJ, 784, L38
Makiya R., et al., 2016, PASJ, 68, 25
Marconi A., Risaliti G., Gilli R., Hunt L. K., Maiolino R., Salvati M., 2004, MNRAS, 351, 169
Mineshige S., Kawaguchi T., Takeuchi M., Hayashida K., 2000, PASJ, 52, 499
Mortlock D. J., et al., 2011, Nature, 474, 616
Nagashima M., Yahagi H., Enoki M., Yoshii Y., Gouda N., 2005, ApJ, 634, 26
Netzer H., Trakhtenbrot B., 2014, MNRAS, 438, 672
Ohsuga K., Mori M., Nakamoto T., Mineshige S., 2005, ApJ, 628, 368
Oogi T., Enoki M., Ishiyama T., Kobayashi M. A. R., Makiya R., Nagashima M., 2016, MNRAS, 456, L30
Pacucci F., Volonteri M., Ferrara A., 2015a, MNRAS, 452, 1922
Pacucci F., Ferrara A., Volonteri M., Dubus G., 2015b, MNRAS, 454, 3771
Padmanabhan N., White M., Norberg P., Porciani C., 2009, MNRAS, 397, 1862
Planck Collaboration XVI, 2014, A&A, 571, A16
Porciani C., Magliocchetti M., Norberg P., 2004, MNRAS, 355, 1010
Ross N. P., et al., 2009, ApJ, 697, 1634
Sabra B. M., Saliba C., Abi Akl M., Chahine G., 2015, ApJ, 803, 5
Sakurai Y., Inayoshi K., Haiman Z., 2016, MNRAS, 461, 4496
Shen Y., et al., 2007, AJ, 133, 2222
Shen J., et al., 2009, ApJ, 697, 1656
Sheth R. K., Mo H. J., Tormen G., 2001, MNRAS, 323, 1
Shirakata H., Okamoto T., Enoki M., Nagashima M., Kobayashi M. A. R., Ishiyama T., Makiya R., 2015, MNRAS, 450, L6
Volonteri M., 2010, A&ARv, 18, 279
Volonteri M., Rees M. J., 2005, ApJ, 633, 624
Volonteri M., Silk J., Dubus G., 2015, ApJ, 804, 148
Watarai K.-y., Fukue J., Takeuchi M., Mineshige S., 2000, PASJ, 52, 133
Wu X.-B., et al., 2015, Nature, 518, 512