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Active galactic nuclei flicker: an observational estimate of the duration of black hole growth phases of $\sim 10^5$ yr

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ABSTRACT

We present an observational constraint for the typical active galactic nucleus (AGN) phase lifetime. The argument is based on the time lag between an AGN central engine switching on and becoming visible in X-rays, and the time the AGN then requires to photoionize a large fraction of the host galaxy. Based on the typical light travel time across massive galaxies, and the observed fraction of X-ray-selected AGN without AGN-photoionized narrow lines, we estimate that the AGN phase typically lasts $\sim 10^5$ yr. This lifetime is short compared to the total growth time of 10^7–10^9 yr estimated from e.g. the Soltan argument and implies that black holes grow via many such short bursts and that AGN therefore 'flicker' on and off. We discuss some consequences of this flickering behaviour for AGN feedback and the analogy of X-ray binaries and AGN lifecycles.

Key words: galaxies: active – quasars: general – galaxies: Seyfert.

1 INTRODUCTION

When the massive black holes in galaxy centres accrete, they become visible as quasars or active galactic nuclei (AGN). The energy liberated by accretion episodes is thought to be a critical regulatory mechanism in galaxy evolution (e.g. Sanders et al. 1988; Silk & Rees 1998). But how exactly does this connection operate? Amongst the most basic unknowns is the time-scale on which the AGN phase operates. Indirect measurements of the typical AGN phase are on the order of 10^7–10^9 yr (e.g. Martini & Weinberg 2001; Marconi et al. 2004). Taking the local relic black hole mass density and comparing it to the total light emitted by quasars and assuming a reasonable radiative efficiency yields such long (10^7–10^9 yr) *total* accretion time-scales (Soltan 1982; Yu & Tremaine 2002; Marconi et al. 2004). This does not constrain however whether the entire mass growth consists of a single accretion phase, or is broken up into shorter phases.

AGN variability has been observed on short time-scales all the way out to multiple decades (e.g. Ulrich, Maraschi & Urry 1997). The *natural time-scales* of the AGN central engine however are significantly longer than human time-scales. This leaves a major gap on the time-scale domain on which we can easily study AGN variability: we can see AGN vary on human time-scale, and we can constrain the total growth time using statistical arguments.

In this paper, we present an *observational argument* for why nearby AGN – and perhaps all AGN – switch on rapidly ($\sim 10^4$ yr) and 'stay on' for $\sim 10^5$ yr before switching off. In order to reconcile this result with previous measurements of AGN lifetimes, we argue that AGN *flicker* in a $\sim 10^5$ yr cycle resulting in the total 10^{7-9} yr lifetime. We therefore begin to fill in AGN variability between the two extremes.

Breaking up the accretion phases of AGN into many short $\sim 10^5$ yr phases has implications beyond the fact that massive black holes assemble their mass via a large number of individual bursts. Many short phases also means that the AGN central engine swings back and forth between different accretion states. During high-Eddington phases, the AGN will produce predominantly radiative energy and will be visible as a classical quasar or AGN. During the low-Eddington phases, the bulk of the energy is in the form of kinetic energy (Done, Gierliński & Kubota 2007; Alexander & Hickox 2012). In this low-Eddington phase, the AGN is harder to detect, but may still inject (kinetic) energy into the host galaxy. Thus, a full accounting of the AGN lifecycle and the different modes in which an AGN interacts the host galaxy may be vital to a full description of AGN feedback and the galaxy–black hole connection. Ultimately, we will need constraints on the full power spectrum of AGN from days to several Gyrs to understand how black holes influence their surrounding galaxies.

In this paper, we outline the argument for a short AGN lifetime and discuss some implications for our understanding of the galaxy–black hole connection and feedback.

2 ANALYSIS

In this section, we outline our new framework of how existing observations can constrain the duration of an individual AGN phase to $\sim 10^5$ yr, present these observations, and then give an order of magnitude calculation.

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2.1 Framework

Consider the case of a central black hole in a star-forming galaxy. When the black hole begins accreting, it become visible virtually instantaneously as a nuclear source. The accretion disc and surrounding material begin emitting at optical and ultraviolet wavelengths, and the hard X-rays will escape the nuclear region even at very high levels of obscuration. As the AGN phase continues in time, photons from the central engine begin to photoionize the interstellar medium (ISM) of the host galaxy. Due to the geometry of obscuring medium, or torus, the photoionized region usually manifests itself as an ionization cone (Malkan, Gorjian & Tam 1998). Once these galaxy-scale-photoionized *narrow-line regions* (NLRs) are established, the host galaxy can be identified as an AGN as the central engine dominates the photoionization budget of the host galaxy (Baldwin, Phillips & Terlevich 1981; Veilleux & Osterbrock 1987). The NLR is therefore the part of the host galaxy ISM whose emission lines are driven by AGN photoionization. The most prominent AGN line seen in optical spectra is the [O III] λ5007 line, though usually a series of line ratio diagnostics is used. Higher ionization coronal lines are often also found.

From this setup, it follows that there is a significant *time delay* between the start of accretion in the AGN central engine and the time the host galaxy exhibits AGN-like line ratios. To zeroth order, this time delay is on the light travel time from the nucleus to the half-light radius of the host galaxy. Naturally, the properties of the ISM would be an important first-order effect in this time delay as the complex physics of photoionization kicks in, but we believe that estimating the switch-on time using the light travel time across the host galaxy is the dominant effect. As the AGN photoionization travels across the host galaxy, AGN lines become stronger and more apparent over those driven by star formation and shocks in the galaxy, and to the host galaxy spectrum may begin to move into the 'composite' region on emission line diagrams. Ultimately, the AGN will photoionize the ISM and the host galaxy will be classified as a regular AGN.

The non-trivial light travel time of the AGN radiation across the host galaxy thus constrains the *lifetime of the AGN phase* in a statistical sense. Assuming that those AGN host galaxies in a (hard) X-ray-selected AGN sample whose spectra show either pure star formation or composite AGN+star formation lines are those which just switched on, then the combination of the fraction and the light travel time across the host galaxy yields a lifetime for the AGN phase:

$$t_{\mathrm{AGN\ phase}} = \frac{\text{time to photoionize host galaxy}}{\text{fraction of optically elusive AGN}}. \qquad (1)$$

In order to measure the typical duration of the AGN phase, we require estimates of the fraction of the AGN population lacking AGN lines (the optically elusive AGN or XBONGs) and the typical size of the NLR. We caution that this estimate is only true in a statistical sense as it is derived from population statistics, and that there are likely many systematics in both quantities – we discuss those systematics later.

At a later time, once the black hole stops accreting, the ISM may continue producing AGN-like lines as the light echo from the past AGN travels out across the galaxy. At the largest scales, these light echoes have been seen as the quasar light echo 'Hanny's Voorwerp' near IC 2497, and the Voorwerpjes (little Voorwerps; Lintott et al. 2009; Rampadarath et al. 2010; Keel et al. 2012a,b) as well as in some quasars (Schirmer et al. 2013; Davies, Schirmer & Turner 2015). These Voorwerps constrain the 'shut-down' time-scale to 10^4–10^5 yr via the geometry of their spatial extent and the recombination time-scale of the narrow line emission.

We illustrate this AGN phase life cycle in a schematic form in Fig. 1.

Table 1. Literature measurements of 'optically elusive' and XBONG fractions.

AGN/galaxy sample	Optically elusive fraction	Reference
BeppoSAX	4 per cent	La Franca et al. (2002)
Chandra+SDSS	6 per cent	Hornschemeier et al. (2005)
Swift-BAT	6 per cent	Smith, Koss & Mushotzky (2014)
Swift-BAT	5.6 per cent	This work

2.2 Observations

2.2.1 Compilation of 'optically elusive' AGN fractions from the literature

If the life cycle for AGN phases outlined is correct, then the switch-on phase has already been seen: X-ray-selected AGN with host galaxies lacking obvious AGN lines. There is some diversity in terminology and definition of these objects in the literature. These AGN host galaxies can be described as 'optically elusive' or 'optically dull' AGN or as XBONGs (X-ray bright, optically normal galaxies[1]). These classes can sometimes contain AGN host galaxies which are red and dead and therefore do not have a sufficient cold ISM to photoionize and produce strong lines, but these objects make up a minority. Such AGN host galaxies have been reported repeatedly in the literature in a variety of surveys (Comastri et al. 2002; Moran, Filippenko & Chornock 2002; Maiolino et al. 2003; Georgantopoulos & Georgakakis 2005; Rigby et al. 2006; Caccianiga et al. 2007; Cocchia et al. 2007; Smith et al. 2014). Independent of selection and definition, the fraction of such host galaxies is consistently around the ∼5 per cent level as reported by various teams; we report these values in Table 1.

While the details of how AGN are selected on emission line diagrams vary, they share generic features which go back to the original Baldwin et al. (1981) and Veilleux & Osterbrock (1987) which separate star-forming galaxies, AGN, and other non-stellar ionization sources using line ratios. The most common diagram – and the one we use in this paper – is the standard [O III]/H β versus [N II]/H α diagram. Star-forming galaxies are separated using an empirical line of Kauffmann et al. (2003). The 'composite' region where star formation and shocks can mix extends all the way to the extreme starburst line of Kewley et al. (2001). Seyfert AGN and LINERs (low-ionization nuclear emission regions) beyond the extreme starburst line can further be separated (Kewley et al. 2006; Schawinski et al. 2007). In general, AGN photoionized galaxies are identified by having high [O III]/H β line ratios, with a second line ratio such as [N II]/H α separating out other processes such as shocks and evolved stellar populations.

For this paper, we add an independent measurement of the 'optically elusive' fraction. We take the sample of hard X-ray-selected

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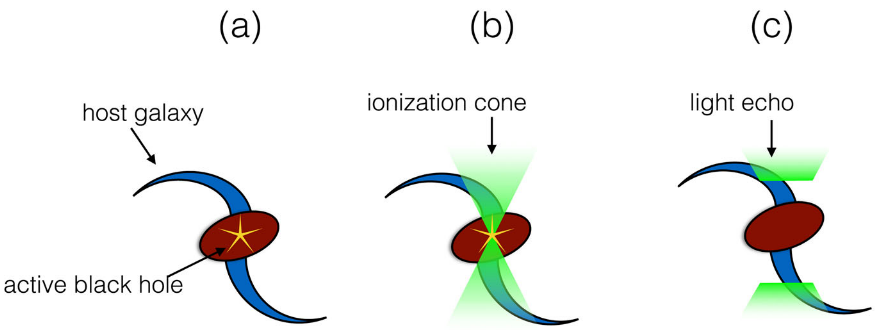
[1] The nomenclature for such objects is not uniform. Some studies reserve the term 'XBONG' for X-ray-selected AGN with host galaxies which show *no* emission lines, as opposed to showing emission lines excited by processes other than AGN.



Central emission (X-rays)	**on**	**on**	**off**
Extended emission (photoionized regions)	**not yet generated**	**on**	**still visible**
Classification	**optically elusive AGN**	**normal AGN**	**light echo/ Voorwerpje**
Duration	**10^4 years**	**10^5 years**	**$10^{4\text{-}5}$ years** **(if screen is present)**

Figure 1. A schematic of the life cycle of AGN. Once the black hole starts accreting (a), the central engine begins emitting in X-rays, but the extended photoionized region on the scale of the galaxy has not yet been lit up; this is the XBONG phase. After the AGN central engine has photoionized the ISM of the galaxy, the AGN is visible as a 'normal' AGN with both nuclear X-ray emission and a galaxy-scale NLR. When the black hole stops accreting, the nucleus stops emitting X-rays, but the light echo from the AGN phase may still travel across the galaxy and to gas reservoirs beyond the galaxy: the galaxy may appear as a Voorwerpje. This cycle may repeat many times to make up a significant black hole growth episode.

AGN detected by *Swift* Burst Alert Telescope (BAT) in the footprint of the Sloan Digital Sky Survey (SDSS) in the redshift interval $0.0165 < z < 0.4$ (Abazajian et al. 2009; Baumgartner et al. 2013). Using emission line diagnostics, we find that 6 out of 107 AGN, 5.6 per cent are classified as composite, meaning they are a mixture of AGN and star formation. We show the resulting classical Baldwin et al. (1981) [O III]/H β versus [N II]/H α diagram in Fig. 2.

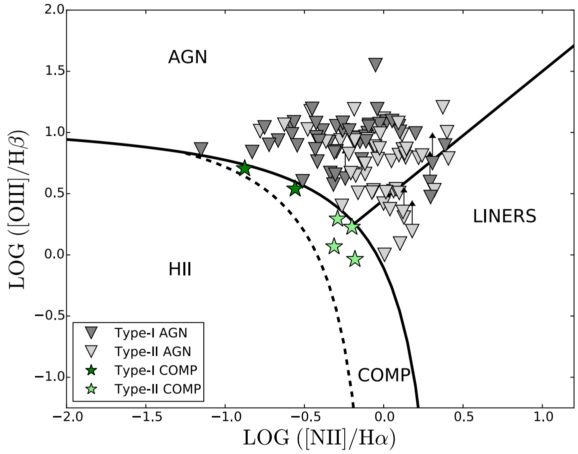


Figure 2. Emission line ratio diagrams for a sample of local hard X-ray-selected AGN observed by *Swift*-BAT and the SDSS in the redshift range $0.0165 < z < 0.4$. 6 out of 107 AGN do not show an NLR yielding an XBONG fraction of 5.6 per cent. This fraction is comparable to those seen in other studies (La Franca et al. 2002; Hornschemeier et al. 2005; Smith et al. 2014).

The SDSS fibres cover the nuclear region of the BAT AGN host galaxies so in our framework, the AGN in these galaxies just switched on and has begun to photoionize the nuclear region, but has not yet overwhelmed the star formation lines. Our measurement is consistent with that of Smith et al. (2014) of a similar sample of *Swift*-BAT AGN, as well as with previous reports despite the heterogeneous nature of samples, selection techniques and definitions.

2.2.2 *Compilation of NLR sizes*

The switch-on time can be derived from the physical scale of the NLR, which to zeroth order scales as the half-light radius of the host galaxy. What do observations show is that the NLRs of luminous AGN are large and at least on scales of several kpc (e.g. Schmitt et al. 2003). Long-slit spectroscopy of obscured AGN by Hainline et al. (2014) shows that the NLR reaches the physical scale of the entire host galaxy as the AGN luminosity increases and tops out, leading to a flattening of the relationship between NLR size and AGN luminosity. Integral field unit studies of AGN host galaxies similarly show large-scale NLRs (McElroy et al. 2015). Based on these observations of NLR sizes, we can take the half-light radius of the host galaxy of a luminous AGN as a reasonable proxy for the expected NLR size.

For this paper, we take the typical half-light radius of the *Swift*-BAT AGN host galaxy sample of ∼5 kpc, which corresponds to ∼16 000 light years. To be conservative, we assume that the typical radius of the NLR is somewhat smaller and take a switch-on time of ∼10 000 yr.

2.3 Estimate of the AGN phase lifetime

We now have estimates of the two quantities that go into the calculation of the AGN phase lifetime. We take the 5 per cent optically elusive fraction, and the 10 000 yr switch-on time-scale: this yields an AGN phase lifetime of

$$t_{\mathrm{AGN\ phase}} \sim \frac{10\,000}{0.05} \sim 200\,000 \mathrm{\ yr} \qquad (2)$$

We stress that this estimate should be seen as an order of magnitude estimate, and that it only applies in a statistical sense. Nevertheless, we believe that this typical lifetime has significant consequences for our understanding of AGN variability and the role AGN play in galaxy evolution. Before we address these, we discuss some of the major caveats to this estimate.

2.4 Caveats

2.4.1 Is there sufficient gas in the host galaxies?

In order to light up an NLR, the AGN radiation needs a sufficiently dense screen of cold gas in the host galaxy to illuminate. One of the hypotheses for the nature of XBONGs is that they are gas-poor, red-sequence galaxies. Correspondingly, their spectra show no strong emission lines *of any kind* while still featuring AGN X-ray emission. For the more distant AGN/XBONG samples, this may be a concern, but for the *Swift*-BAT sample, we can rule out this explanation for most host galaxies: as Koss et al. (2011) report, very few *Swift*-BAT host galaxies are red and gas poor. If such gas-poor AGN hosts[2] are a significant fraction of the total ‘optical elusive’ AGN fraction, this would increase the inferred AGN lifetime. A 50 per cent contamination would double the inferred AGN lifetime. In our sample of *Swift*-BAT AGN, only one object features no emission lines, which implies that this is not a major bias.

2.4.2 Are XBONGs/optically elusive AGN not simply dusty?

Another explanation for the apparent lack of AGN lines in the optical spectra is that XBONGs/optically elusive AGN are particularly dusty and so their AGN lines are not apparent in the optical spectrum. Searches for AGN lines using near-infrared spectroscopy of *Swift*-BAT AGN host galaxies by Smith et al. (2014) find that most XBONGs lack AGN-like lines. Even in the case of two objects with near-IR lines consistent with AGN, star formation remains a possibility. If a significant fraction of optically elusive AGN are in fact normal AGN with dust-obscured NLRs, this would increase the inferred AGN lifetime. As with Section 2.4.1, a 50 per cent contamination would double the inferred lifetime.

2.4.3 Is the assumption of ‘light travel time’ too simplistic?

We assume that we can measure the switch-on time using the light travel time across the host galaxy as the relevant time-scale. This is naturally a simplification as the switch-on process is gradual. More importantly, we are neglecting the well-studies physics of photoionization which certainly modulates the mapping from light travel time to appearance of narrow lines.

How much of a delay can such effects cause? In the central parts of a galaxy, the electron density is high enough that the recombination time-scale is very short. For typical values of density and temperature, the H β recombination time-scale is about $\sim$200 yr (see, e.g. Peterson et al. 2013). It is only in the outer regions of a galaxy where the density drops significantly that the recombination time-scale becomes substantial (as is the case with some Voorwerps, see Keel et al. 2012a,b). Other time-scales which contribute to the delay, such as the time needed to significantly increase the ionization level, or to excite a significant fraction of ions, are expected to be shorter than the recombination time-scale. The host galaxy ISM is likely already largely photoionized due to star formation, so all the AGN ionization front needs to do is change the relative populations in the ions present. In any case, any additional delay between the AGN photoionization front moving though the host galaxy and exhibiting AGN lines would increase the ‘optically elusive’ AGN fraction artificially, and therefore further *decrease* the inferred lifetime.

2.4.4 Could aperture effects be significant?

In a host galaxy with significant star formation, the emission lines from star formation could overwhelm the AGN lines, moving the spectroscopic classification out of the AGN region and into the composite region. This is a particular concern for SDSS fibre spectra as the large physical footprint of the fibre can include such a signal from star formation. Schawinski et al. (2010a) showed using simulations that this dilution effect is significant for low-luminosity AGN around $L[\mathrm{O\,III}] \sim 10^{39}$ erg s^{-1} but ceases to be important for brighter AGN around $L[\mathrm{O\,III}] \gtrsim 10^{40.5}$ erg s^{-1}. Since the *Swift*-BAT AGN are luminous, this dilution effect is unimportant.

Furthermore, not all optically elusive samples are based on fibre spectra: both the La Franca et al. (2002) and the Smith et al. (2014) studies use long-slit spectroscopy and find similar optically elusive fractions as those based on fibre spectra. Ultimately, integral field unit observations will resolve this. AGN during the switch-on phase should exhibit AGN-like lines in the nucleus and lack them at larger radii despite hosting an AGN sufficiently luminous (based on X-ray observations) to photoionize the entire galaxy.

As with the caveats in Sections 2.4.1 and 2.4.2, a significant fraction of AGN misclassified due to aperture effects would increase the inferred AGN lifetime. We note that while all the caveats discussed here could affect the inferred AGN lifetime, the magnitude of the implied changes is on the order of a factor of $\sim$2 and thus have only a moderate effect on our order-of-magnitude estimate of the AGN lifetime.

3 DISCUSSION

We now briefly discuss several consequences of a characteristic lifetime on the order of 10^5 yr for AGN phases. We note that our argument and the resulting AGN lifetime is in broad agreement with other studies, as discussed below.

Siemiginowska & Elvis (1997) presented a simple model for the quasar luminosity function based on the assumption that quasar activity is driven by thermal-viscous instability in the accretion disc. This model yields short bursts of comparable duration to our measurement driven by such instabilities and the resulting model luminosity function matches the observed data very well.

Hickox et al. (2014) have argued that the shorter characteristic time-scale of AGN relative to star formation in galaxies can account for the *apparent* disconnect between star formation and black hole accretion. They propose a simple model for the distribution of Eddington ratios with a functional form of a power law with

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[2] The XBONGs, in some definitions.

an exponential cutoff at high Eddington ratios and allow AGN to vary following this distribution. If star-forming galaxies (i.e. those galaxies with gas) follow this prescription for black hole accretion, the Hickox et al. (2014) model produces a reasonable AGN luminosity function and matches the observed relationship between star formation rate and black hole accretion rate. The model does not constrain the actual AGN phase lifetime, i.e. the time spent at high Eddington ratio in any individual burst; our observational argument now constrains this time.

High-resolution simulations have similarly indicated short AGN lifetimes: Novak et al. (2011) perform very high resolution hydrodynamical simulations of feeding and feedback in elliptical galaxies, resulting in short 10^5 yr AGN bursts. Similarly, Bournaud et al. (2011) and Gabor & Bournaud (2013) find short high-Eddington AGN bursts in simulations of high-redshift gas-rich discs with black holes. In these simulation cases, the enormous short time-scale variability is driven by clumpy and highly variable inflow of gas in the very centre of the galaxy.

All these separate approaches are converging on a picture where short bursts are the norm for black hole growth. It remains however unclear if the burst scale is driven by the fuelling mechanism (such as the clumpiness of the material driven towards the centre), or by instabilities in the accretion disc. We cannot resolve this issue here, but the fact that we can observationally support short individual AGN phases has a number of interesting consequences:

3.1 Black holes accrete mass through many short phases

The first major consequence is that each individual black hole growth phase contributes only very little to the total mass growth of black holes. The Soltan (1982) argument implies characteristic growth times of black holes on the order of 100 Myr–1 Gyr (see also Yu & Tremaine 2002) for reasonable radiative efficiencies η. In order to reconcile the short lifetime of 10^5 yr with a total growth time of 10^{8-9}, the total growth of massive black holes must consist of *many* (100–1000) such short accretion bursts.

3.2 Connection to shorter and longer term variability

The characteristic time-scale of 10^5 yr for the AGN phase must be placed in the context of both shorter and longer term variability as we know AGN exhibit both. On the shorter term side, there is a rich variety of observations on the hour to years time-scale as many local AGN are monitored and sometimes exhibit significant changes in luminosity. This shorter term would be superimposed on the total duration of a 10^5 yr phase, as can be seen e.g. in the simulated light curve of Novak et al. (2011) show in Fig. 3. Taking several 10^5 yr phases, it seems unlikely that these would be randomly distributed. Rather, it is likely that a large number of 100 to perhaps 10 000 make up a longer growth phase of 10^7–10^9 yr. To put it another way, what we previously considered to be an $\sim 10^8$ yr AGN phase, perhaps triggered by a major merger, should be divided into ∼1000 short bursts. In this view, AGN ‘flicker’ in the same sense as a fluorescent lamp[3] does.

3.3 Rapid flickering in AGN may imply changes in accretion state, similar to X-ray binaries

The flickering behaviour for AGN connects the behaviour of massive black holes to that of stellar mass black holes. X-ray binaries exhibit often rapid changes in Eddington ratio and accretion state which changes their appearance and their impact on their environment. The idea that the accretion physics in X-ray binaries and AGN is similar, except that AGN black holes are more massive and therefore change on significantly longer time-scale, has been suggested a number of times (e.g. Maccarone, Gallo & Fender 2003; Falcke, Körding & Markoff 2004; Körding, Jester & Fender 2006; McHardy et al. 2006; Schawinski et al. 2010b). In this framework, the different classes of AGN are closely related: black holes at a given mass rise and fall in Eddington ratio, leading to appearance either as a quasar or a radio galaxy, respectively.

3.4 Time-scale implications for AGN feedback

Dividing a single-sustained AGN phase into numerous short phases alternating between high-Eddington bursts and lower-Eddington troughs points to a new way in which the black hole–galaxy connection works. During each ‘cycle’, the mode via which energy is injected into the system changes: during the high-Eddington peak, the AGN will produce predominantly radiative energy, while during the low-Eddington troughs, the change in accretion mode means that most of the energy is injected in kinetic form (Done et al. 2007; Alexander & Hickox 2012). The AGN flickering cycle thus alternates between radiative and kinetic modes on a short time-scale compared to the dynamical time of the host galaxy. This ‘jackhammer’ effect could be important in driving AGN outflows and feedback. Even if each individual cycle only injects a small amount of energy, repeating the cycle 100–10 000 times could add up to sufficient amounts to unbind the gas reservoir of the host galaxy as required for AGN feedback. In order to approach the binding energy of a massive galaxy of $\sim 10^{60-61}$ erg, each cycle would only have to inject $\sim 10^{56-58}$ ergs.

The short AGN life cycle makes linking AGN activity to outflow phenomena much more challenging. The low-Eddington phase may be difficult or impossible to detect in star-forming host galaxies, and thus the galaxy may not be classified as an AGN, despite the AGN being active. Similarly, a kinetic outflow driven by the low-Eddington phase may persist, perhaps coasting ballistically, until the next high-Eddington burst. Searches for AGN outflows generally target bright AGN, and so might erroneously associate observed outflows with the bright phase, when in fact, the previous faint, low-Eddington phase was responsible.

A short lifetime (compared to the total growth time) for the AGN phase causes a time-scale problem relative to the galaxy. The AGN central engine operate on time-scales comparable only to the central dynamical time of the host galaxy, and orders of magnitude faster than the dynamical time of the whole host galaxy ($t_{\rm dyn} \sim 10^8$ yr for a massive galaxy). The AGN can switch on and off many times on the time the host galaxy at large is able to react to. This is exacerbated by the fact that most tracers of the host galaxy star formation rate and stellar age are dependent on tracers whose time resolution is much worse than the 10^5 time-scale of the AGN. H α is driven by photoionization of OB stars and from the lifetime of these stars alone yields a time ‘smoothing kernel’ of at least 10^6 yr. Ultraviolet emission from young stars and reprocessed infrared extend even further in time as they respond to young stellar populations. Spectral features such as Balmer absorption lines or

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[3] This very useful analogy was first proposed by R. Hickox.

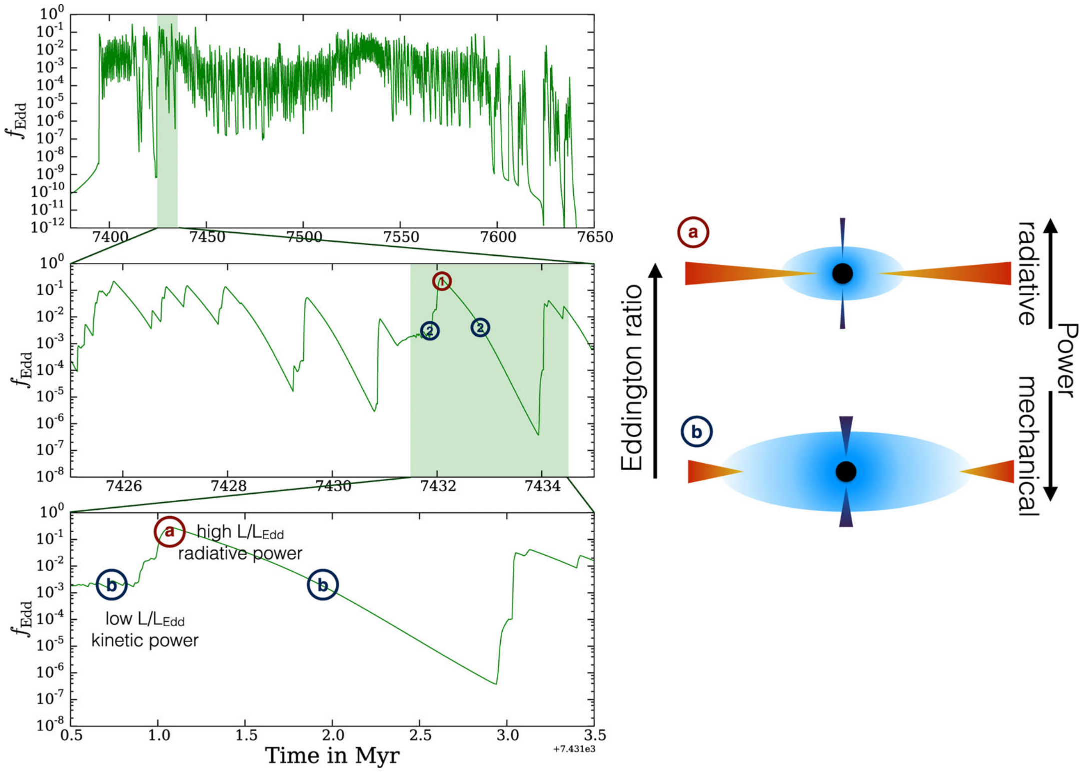

Figure 3. On the left, we show a simulated AGN light curve from Novak, Ostriker & Ciotti (2011). The top panel covers a 250 Myr AGN phase subdivided into many shorter $\sim 10^5$ yr bursts. The middle and bottom panels show zoom-ins of this light curve. This simulated light curve illustrates how the growth history of this black hole is made up of numerous short near-Eddington bursts lasting $\sim 10^5$ yr. On the right, we show a schematic view of an accreting massive black hole following the illustration of Done et al. (2007) for X-ray binaries and adapted for AGN by Alexander & Hickox (2012). During the high-Eddington peaks (a), the black hole shines as an Seyfert/quasar with an optically thick, geometrically thin Shakura & Sunyaev (1973) disc, while during low-Eddington troughs (b), the black hole transitions to a more geometrically thick, optically thin accretion flow (e.g. Narayan & Yi 1994).

the 4000 Å break have even worse time resolution. This mismatch in time-scales may explain why it is so difficult to link AGN to galaxy evolution, and suppression of star formation in particular. The AGN lives and acts of a much shorter time-scale than can be reconstructed from stellar populations.

3.5 The Milky Way black hole

The recent activity of the black hole in the Milky Way centre can be revisited in light of a short AGN flickering cycle. X-ray light echoes in the Galactic Center show moderate-luminosity flares in the last few centuries (Revnivtsev et al. 2004; Ponti et al. 2010), though these were likely too short and not sufficiently luminous to generate narrow lines across the Milky Way. Bland-Hawthorn et al. (2013) show that the Magellanic Stream near the Milky Way was photoionized by an AGN event in the Galactic centre some 1–3 Myr ago, and the duration of the burst is estimated to be 100–500 kyr – the same order of magnitude as the lifetime derived in this paper. Bland-Hawthorn et al. (2013) propose this Galactic Center outburst as the cause of the *Fermi* bubble (Su, Slatyer & Finkbeiner 2010). If this is the case, the flickering cycle exhibited by other AGN should leave similar remnants as the *Fermi* bubble around other galaxies as their black holes switch on and off.

4 SUMMARY

We have presented an observational constraint for the typical AGN phase lifetime. The argument is based on the time lag between an AGN central engine switching on and becoming visible in X-rays, and the time the AGN then requires to photoionize a large fraction of the host galaxy. Based on the typical light travel time across massive galaxies, and the observed fraction of X-ray-selected AGN without AGN-photoionized narrow lines, we estimate that the AGN phase typically lasts $\sim 10^5$ yr. This short lifetime implies that black holes grow via many such short bursts and that AGN therefore 'flicker' on and off. We discuss some consequences of this flickering behaviour for AGN feedback and the analogy of X-ray binaries to AGN.

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