AGN obs

AGNアウトフローの異なる「相」の関係についての考察

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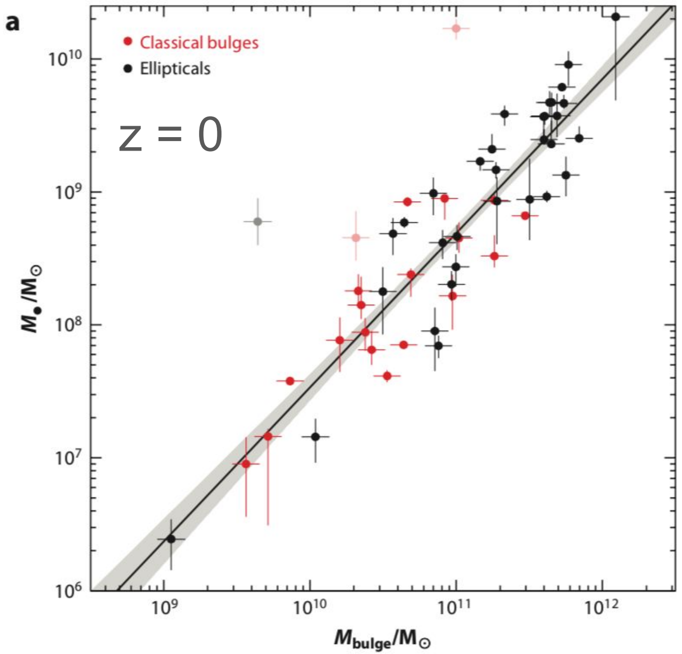
Interpretation

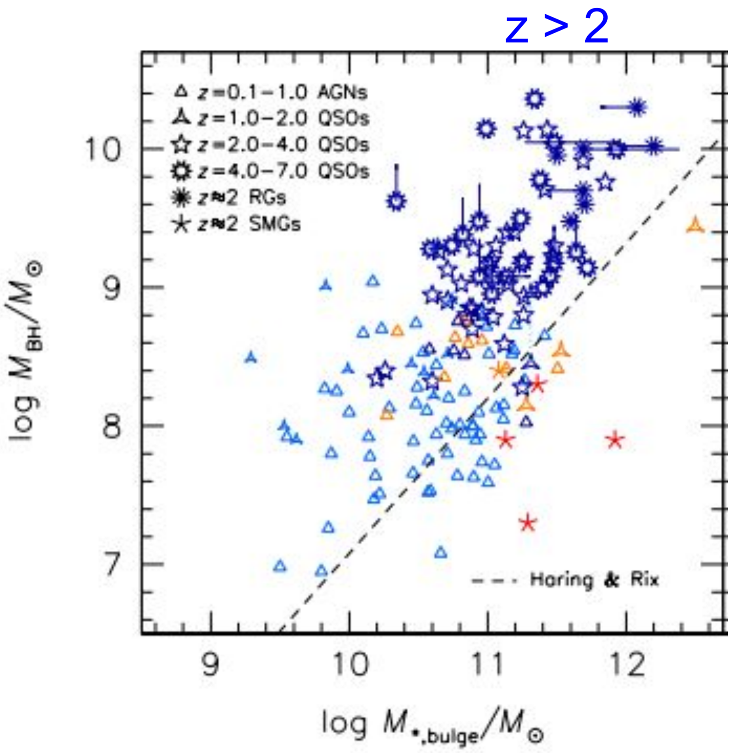
AGNからのアウトフローは、観測的には、X線で観測される降着円盤スケールでの UFOから、可視光で観測される電離ガスのアウトフロー、またミリ波サブミリ波で 観測される低温分子ガスのアウトフローまで、多様な「相」を示すことが知られて いる。それぞれの空間的な広がりやアウトフローが検出される頻度(duty cycle)、mass loading rateやkinetic energy, momentum rateなど鍵となる諸物理量が、どのような 赤方偏移の、どのような種類の活動銀河で観測されているか、現状を整理せよ。その上で、現在観測されているAGNアウトフローは「SMBHと銀河の共進化仮説」 に対して、どのような制限になっているのか(いないのか)議論せよ。今後新たな観測が必要であるとすれば、それは、既存の望遠鏡ないし近未来に予定 されている装置で可能だろうか。もし新しい装置・望遠鏡が必要である場合は、その主な仕様を提案せよ

Science Goal Correlation between AGN outflows and M_{BH}-M_{bulge} relation

1. Studying parameters important for both outflows and co-evolution
2. Studying relations between parameters and outflow phases
3. Proposing observations to estimate the contribution of AGN outflow feedback to M_{BH}-M_{bulge} relation

M_{BH}-M_{bulge} relation





AGN outflows negative (positive) feedback

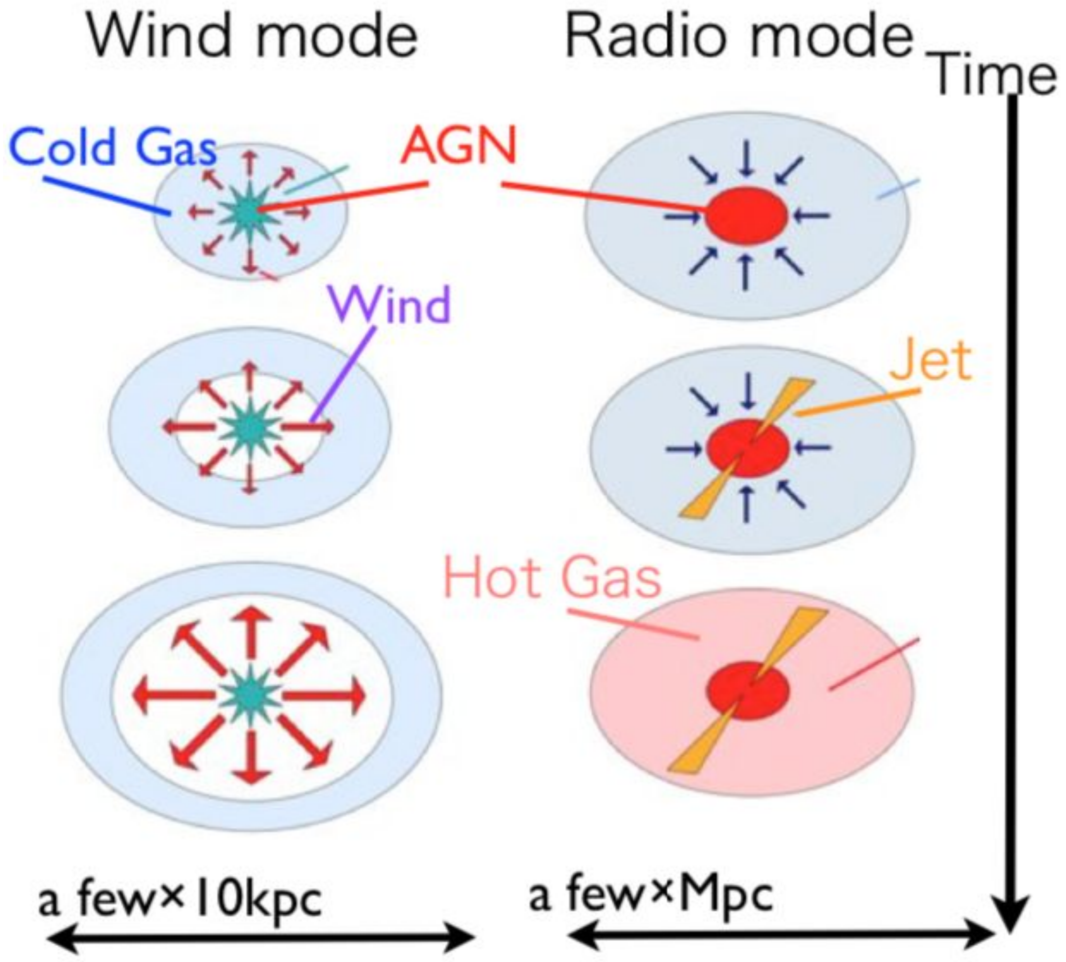
Kormendy & Ho (2014)

AGN outflows?

AGN outflow modes

AGN parameters

- mass loading rate
- star formation
- duty cycle



Two modes feedback:

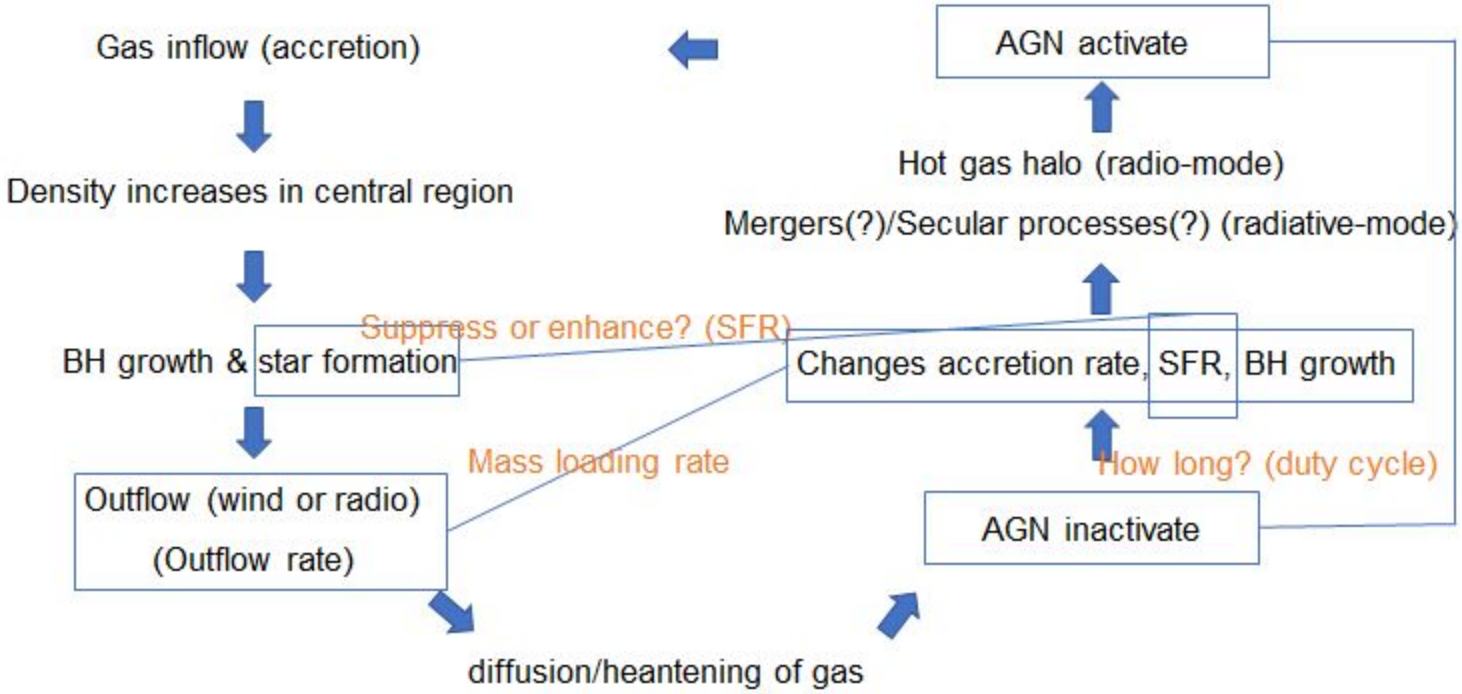
wind mode (radiative mode AGNs, LT): a diffusion in the ambients

radio mode (jet mode AGNs, ET): a heatening in the ambients

UFO happens for both, but differs for LT and ET

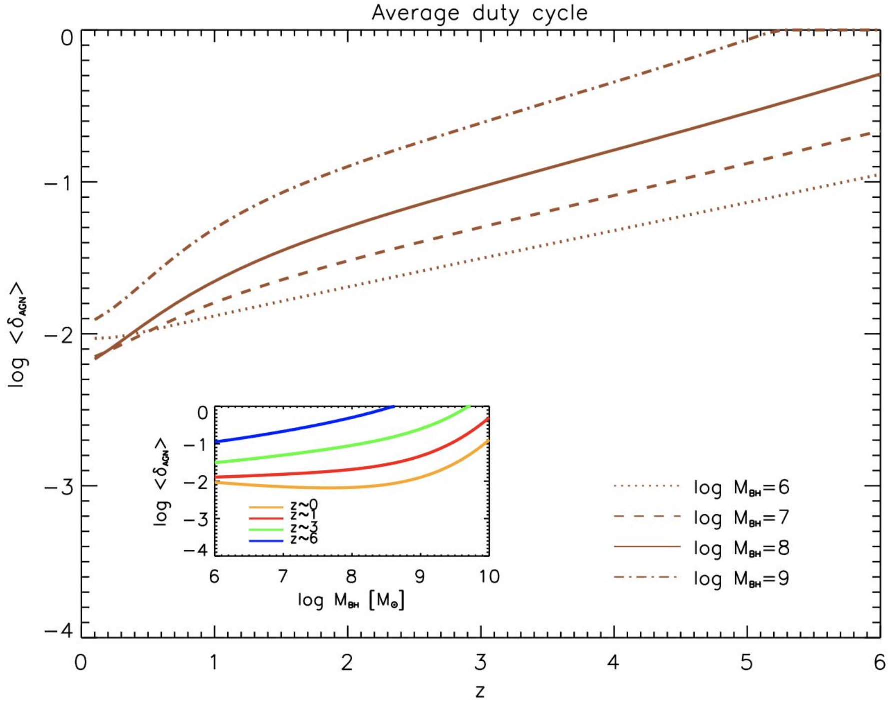
Image credit: 札本佳伸, Wakate 2012

AGN self-regulating mechanism



duty cycle

A **duty cycle** or **power cycle** is the fraction of one period in which a signal or system is active. Duty cycle is commonly expressed as a percentage or a ratio.



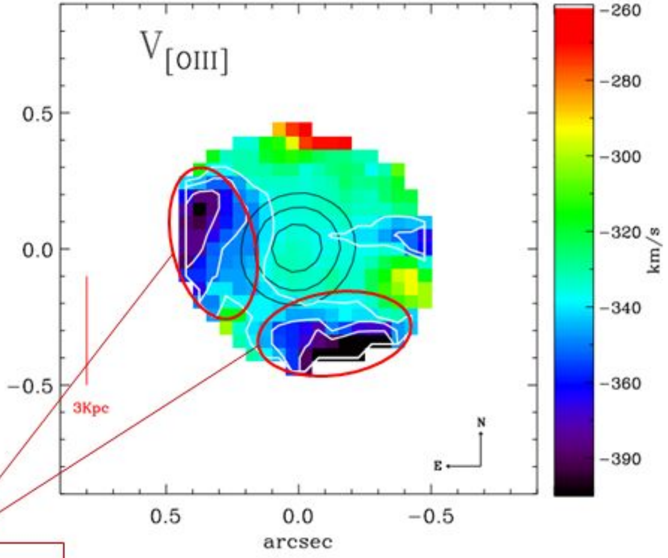
AGNs (quasars) with higher black hole mass and at earlier universe tend to be "turn on" for a longer time, thus have stronger feedback to their environment. (R. Aversa et al. +2015)

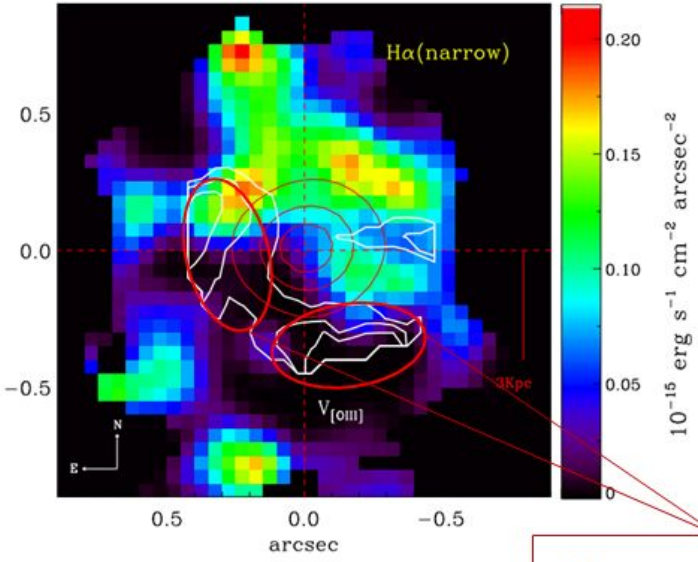
ET ($M_\star \sim 10^{11} M_\odot$): duty cycle 0.001 - 0.01 is sufficient to control gas cooling (Heckman+2014)

Figure 7. The average AGN duty cycle $\langle \delta_{\rm AGN} \rangle$ as a function of redshift z, for different BH masses $M_{\rm BH} = 10^6$ (dotted), 10^7 (dashed), 10^8 (solid), and $10^9\, M_\odot$ (dot-dashed). The inset illustrates the AGN duty cycle as a function of the BH mass at different redshift $z = 0$ (orange), $z = 1$ (red), 3 (green), and 6 (blue).

Observation evidence for suppress on SFR

Negative: Cano-Dıaz et al.2012: VLT, z~2.4 quasar





outflow

SF suppressed

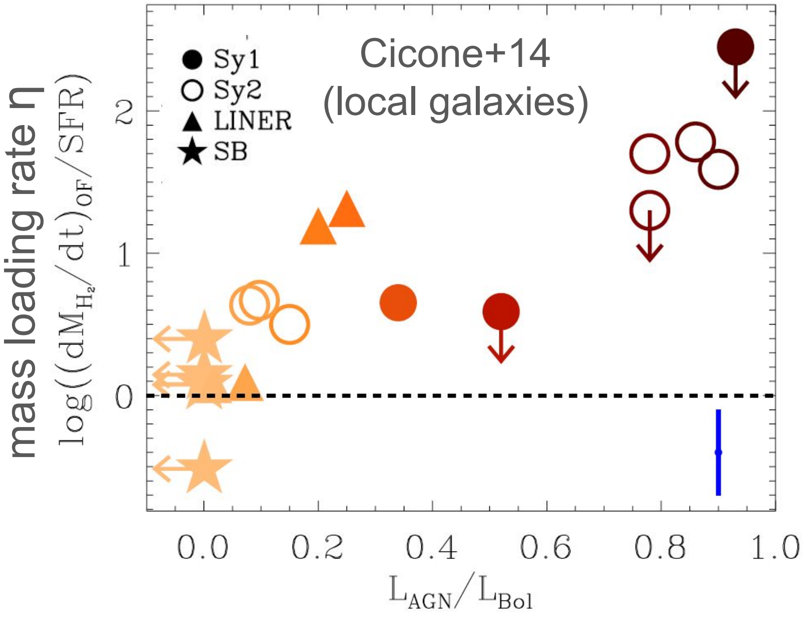
Velocity field of [OIII] (left) and map of narrow component of Hα (right)

In the left, blue regions represent blueshifted, hence, outflow

mass loading rate

mass loading rate η = mass outflow rate [Msun/yr] / SFR [Msun/yr]

molecular outflow (~ kpc scale)

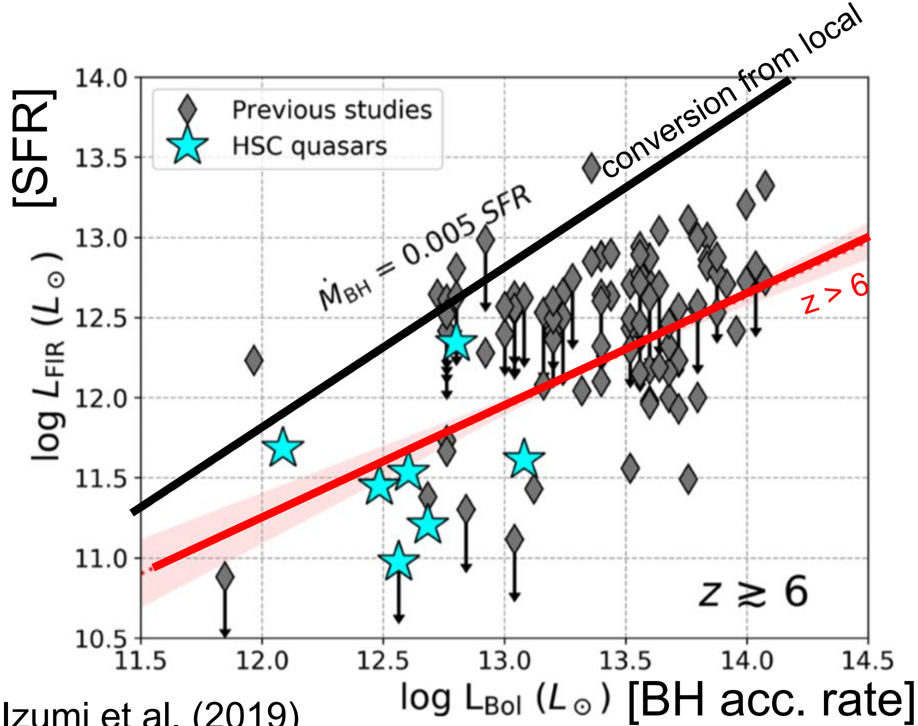


η (starburst) < η (Seyfert)

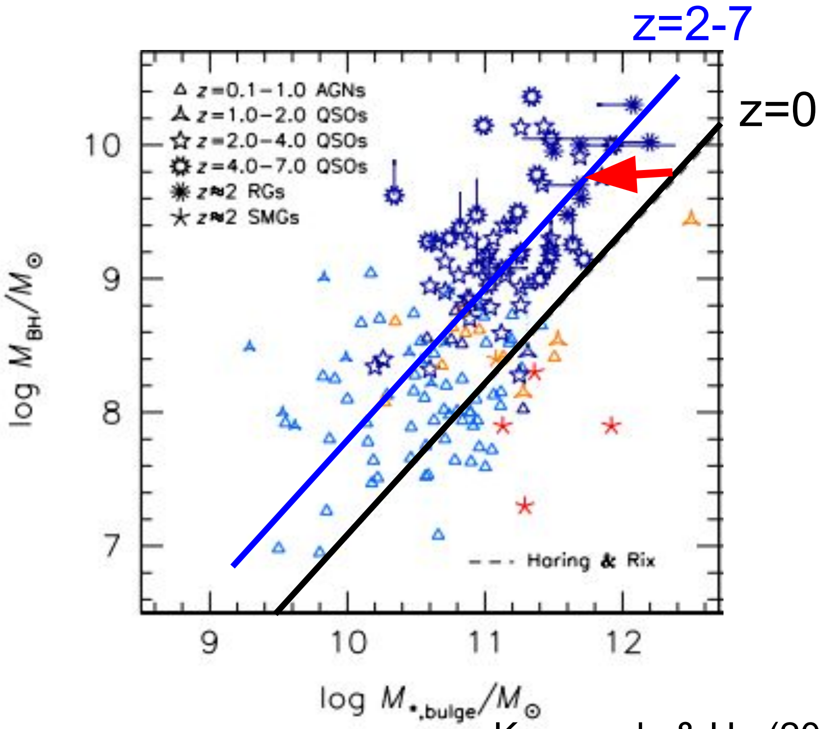
Galaxies including AGN remove the gas at faster rate than a rate of star-forming.

AGN feedback plays an important role in star formation activities in galaxies.

Scenario M-σ relation from low-z to high-z



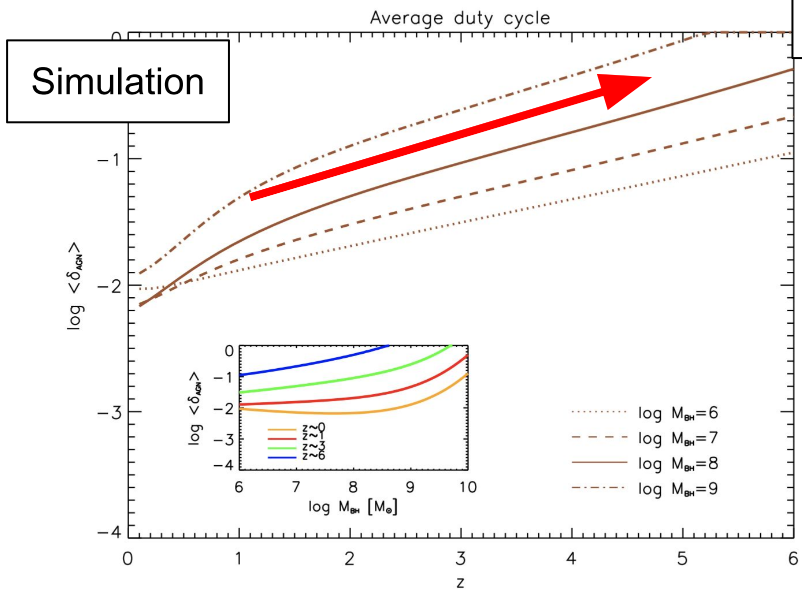
Izumi et al. (2019)



Kormendy & Ho (2014)

High-z SFR is **suppressed** than local → <u>Strong AGN negative feedback</u>?

Longer duty cycle at higher redshift



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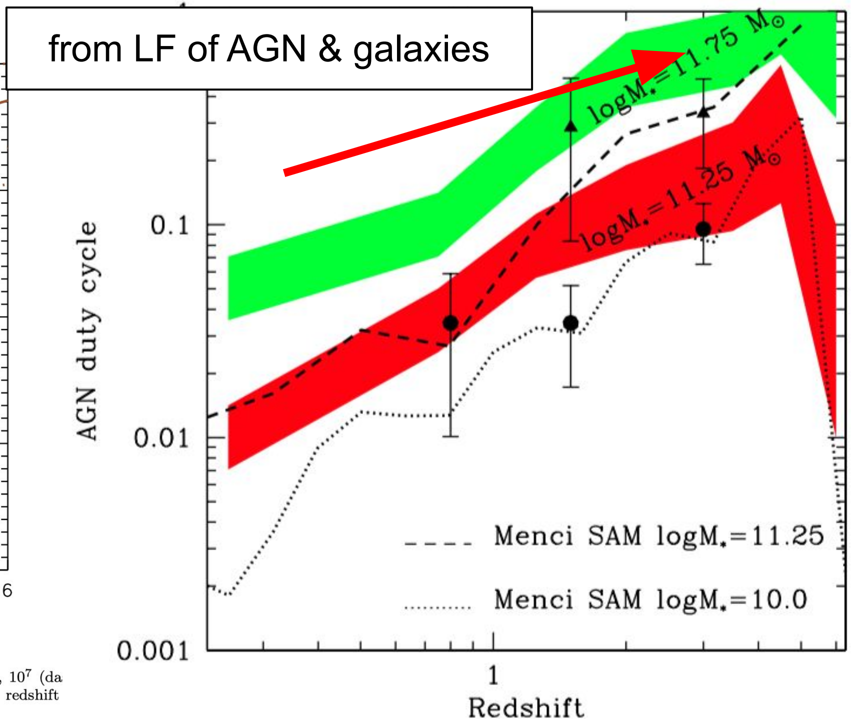


R. Aversa et al. (2015)

Fiore et al. (2012)

Our hypothetical scenario

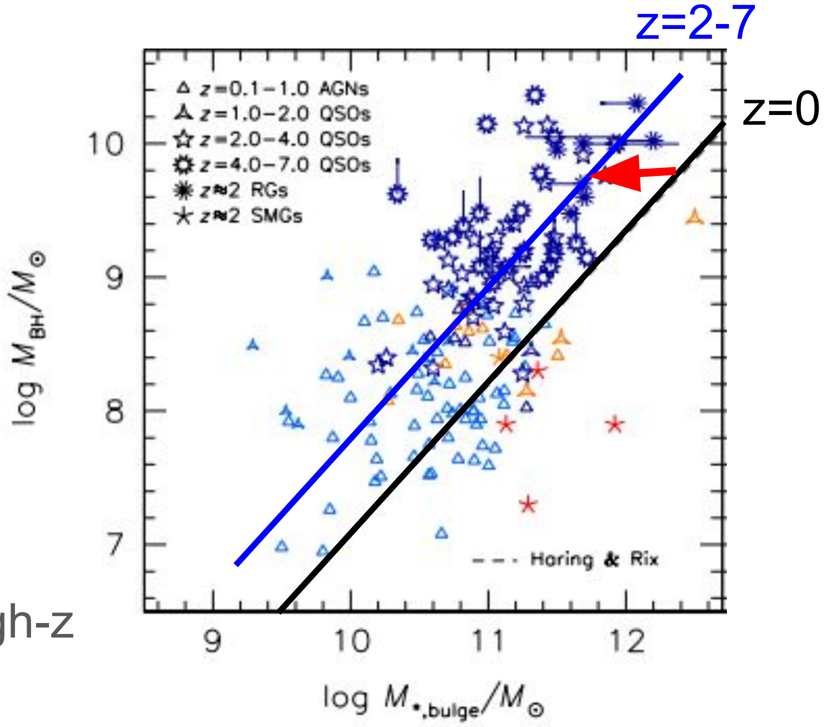
Evolution from z=0 to z=2-7

↓

Stronger AGN feedback at high-z…!?

1. High-z AGNs: longer duty cycle

2. strong/similar mass loading factor at high-z

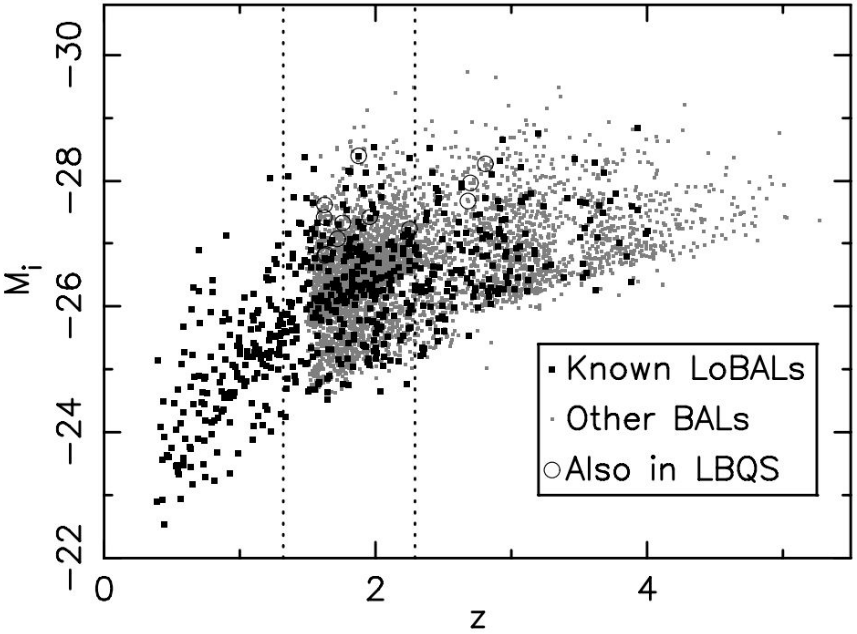


Kormendy & Ho (2014)

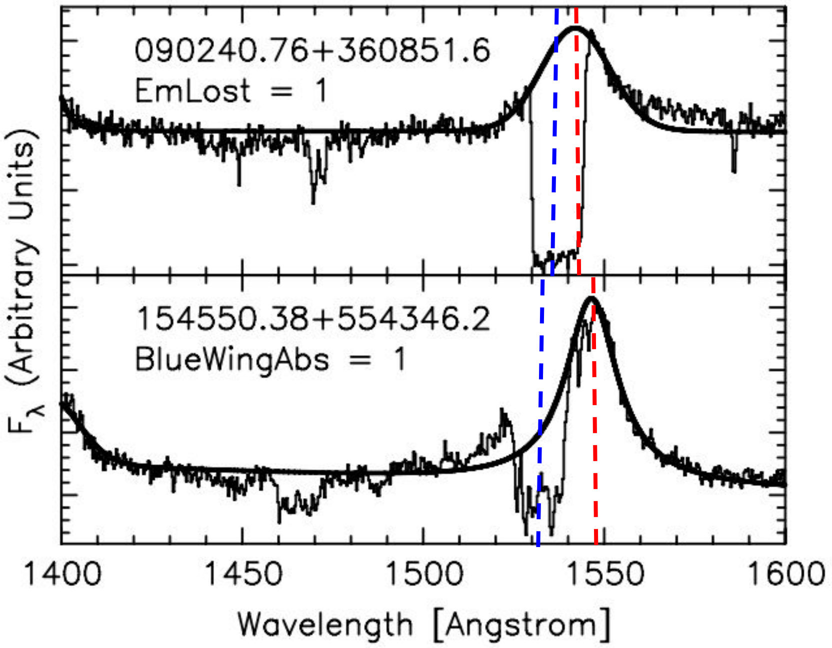
TODO: Confirm high-z molecular outflows are as strong as low-z?

Observation proposal

SDSS → outflow velocity
Subaru/FOCAS IFU → spatial features of outflow
VLT → duty cycle
ALMA → molecular outflow rate



SDSS BAL quasar catalog (Robert et al. 2009)



Observation proposal

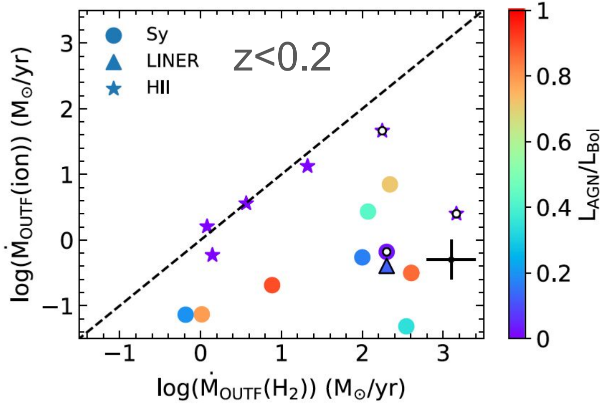
Aim: Comparison of molecular outflow rate between local galaxies and high-z AGNs

molecular gas mass outflow rate

$$\dot{M}_{\rm outf}(\rm H_2) = \frac{v_{\rm outf}(\rm H_2) M_{\rm outf}(\rm H_2)}{r_{\rm outf}(\rm H_2)},$$

v_outf(H2), r_outf(H2), and M_outf(H2) are the velocity, radius, and molecular gas mass of the outflow.

Comparison with local galaxies:
Fluetsch et al. (2019)



Fluetsch et al (2019) used low-J CO (H2 gas tracer) data with ALMA.

→ It's difficult to observe low-J CO in high-z objects with ALMA

(CO(1-0) rest frequency = 115GHz)

We propose the observation of [CI] or [CII] emissions in high-z AGNs with ALMA.

Conclusion

Science Goal Correlation between AGN outflows and M_{BH}-M_{bulge} relation

Focused Question Why is high-z M_{BH}-M_{bulge} relation higher than local?

- Duty cycle: higher at higher-z
- Star-formation: more severe suppress on SFR at high-z?
- Mass loading factor: Molecular outflows are dominant

Our Hypothetical Answer Strong AGN feedback at high-z

Proposal Subaru/FOCAS IFU: spatial feature of outflow

VLT: duty cycle

ALMA [CI] or [CII] observation: molecular gas outflow