Probing black hole-galaxy co-evolution from de-biased scaling relations

FRANCESCO SHANKAR

With: V. Allevato, M. Bernardi, A. Lapi, R. Sheth, P. Grylls, C. Marsden, L. Zanisi, and many more…
WHAT I WILL DISCUSS:

Local Scaling Relations: Slopes, Normalizations, Scatters

Discussion of biases: Observed vs ‘Intrinsic’ relations

Consequences: X-rays Basic models, AGN feedback, Accretion, Gravitational waves
Local Scaling Relations: Slopes, Normalizations, Scatters
BH-galaxy scaling relations

\[ M_{\text{BH}} \sim M_{\text{star}} \]

\[ L_{K,\text{bulge}} (L_{\odot}) \]

\[ M_{\text{BH}} \sim \sigma^{4-5} \]

\[ \sigma \ (\text{km/s}) \]

Kormendy & Ho 13
The $M_{\text{BH}}$-$\sigma$: The most fundamental?
The $M_{BH}-\sigma$: The most fundamental?

Repeated for $Re$, $n$, $M_{bulge}$, and also in hosts of AGN
Take-home message I:
Stellar velocity dispersion is more fundamental!
Discussion of biases: Observed vs ‘Intrinsic’ relations
One major problem!

$M_{BH}/M_{sun}$

$L_{K, bulge} (L_{sun})$ vs $\sigma (km/s)$

Kormendy & Ho 13
A case study: The Illustris simulation (Horizon also!)

$z = 0$

$log\left(\frac{M_{BH,\text{central}}}{M_\odot}\right)$

$log\left(\frac{M_{\star,\text{HM}}}{M_\odot}\right)$

Sijacki+15
A case study: The Illustris simulation (Horizon also!)
Another major problem!

Hosts of SMBHs are OUTLIERS!!

SDSS, early-type galaxies

Shankar+16
The ‘sphere of influence’ of a SMBH

\[ r_h \sim \frac{G M_{BH}}{\sigma^2} \sim 11 \left( \frac{M_{BH}}{10^8 M_{\text{Sun}}} \right) \left( \frac{\sigma}{200 \text{ km/s}} \right)^2 \text{ pc} \]

“...defined as the region of space within which the gravitational potential of the SMBH dominates over that of the surrounding stars.”

Implications?
As an example, a SMBH of \( M_{BH} \sim 3 \times 10^7 \text{ Msun} \) placed at the distance of the Virgo cluster (\( \sim 15 \text{ Mpc} \)), would shrink to a projected radius of 0.07”, beyond the reach of even HST (\( \sim 0.1" \))!
-1- Assume BHs’ hosts follow SDSS
-2- Assume underlying $M_{BH}-\sigma$ (residuals)
-3- Cut above the resolution limit

$$r_{lim} < r_h \sim \frac{GM_{BH}}{\sigma^2}$$
Take-home message II:
Be cautious with ‘raw’ scaling relations!
Consequences: Basic models, AGN feedback, Accretion, Gravitational waves
AGN feedback? Which one?
Thermal AGN feedback does not work!

$\log M_{\text{BH}} - \log M_{\text{STAR}}$

$r = 0.72$

$\propto \sigma^{0.9\pm0.8}$

$r = 0.15$

Barausse, FS, et al. 2017
\[ \log M_{BH} \quad (MBH-\sigma) + (\sigma-M_{star}) \]
Shankar+19b, Nature Astronomy, resubmitted

X-ray/Optical AGN from Krumpe+15
AGN ARE NOT (GRAVITATIONALLY) BIASED!!

Shankar+19

[Graph showing the relationship between log(MBH) and log(Mstar) with data points from different studies and models.]
\[ \dot{M}_{BH} \propto \frac{1 - \varepsilon}{\varepsilon} L \]
Local ratio from K&H

Shankar+19 in prep, Suh+19 submitted, Carraro+19 submitted, ...
characteristic Amplitude GWs at $f=1/yr$
Take-home message III: From de-biased scaling relations more radiative efficiency, less evolution, less GWs!
What I have discussed:

Local Scaling Relations:
Slopes, Breaks, Scatters

Discussion of biases:
Observed vs ‘Intrinsic’ relations

Consequences:
Basic models, AGN, Accretion, Gravitational waves