CONSTRaining BLACK Hole and GALaxy Evolution

Francesco Shankar
Massive Dark Objects \( \rightarrow \) observed in all bulged-galaxies \( \rightarrow \) strong link with the host spheroid \( M/n/\sigma \)

Dunlop & McLure; Ferrarese et al.; Gebhardt et al.; Graham et al.; Haring & Rix; Lauer et al.; Magorrian et al.; Marconi & Hunt; FS & L. Ferrarese 2009a,b

What are MDOs? How and why are they connected with spheroids and DM? What is their role in shaping galaxies?

\[ \sigma = k \times V_c \]

\[ V_c + DM \text{ profile} \rightarrow V_{\text{vir}}(z_{\text{vir}}=0) \propto (M_{\text{vir}})^{1/3} \]
SAMs are working hard to understand what is going on...

``our knowledge on the physics of accretion onto BHs and their interaction with galaxies is still poor to draw firm conclusions``
**GOAL:**

- **EMPIRICALLY CONSTRAIN BLACK HOLE EVOLUTION IN A STATISTICAL SENSE**

**TOOLS:**

- **WE USE:**
  - LOCAL BH MASS FUNCTION
  - AGN BOL. LUM. FUNCTION
  - AGN CLUSTERING
  - OBSERVED DUTY CYCLE
First Step: How many SMBH? How Massive?

For all relations used I convolve with a Gaussian weight to account for intrinsic scatter!
Results: systematic uncertainties!
THE ACTIVE EVOLUTION OF BLACK HOLES: THE AGN LUMINOSITY FUNCTION
\[ \Phi(M_{BH}, t) = -\frac{1}{t_{ef} \ln(10)} \int \frac{\partial \Phi(L, z)}{\partial \log L} \frac{dt}{dz} dz \]

\[ L = \lambda L_{\text{Edd}}(M_{BH}) \]

\[ L_{\text{Edd}} = 1.3 \times 10^{38} (M_{BH}/M_{\odot}) \text{ erg/s} \]

\[ t_{ef} \propto \frac{\epsilon}{\lambda} \]

Graham et al.
Do The Relations Evolve with Redshift?

$M_{BH}-\sigma=$constant

$\rho_{\Delta}(t)$, $\rho_{\Delta}(t)$ [M$_{\odot}$ yr$^{-1}$ Mpc$^{-3}$]

$M_{BH}-\sigma \propto (1+z)^{0.33}$

FS, Bernardi, Haiman 2008
Duty cycles:
\[ U(M_{bh},z) = \Phi(L,z)/n(M_{bh[L]},z) \]

Mean Mass Accretion Histories:
Evidence for downsizing
...Same DOWNSIZING....
Broad Eddington ratio Distributions II

Very Narrow $p(\lambda)$

Very Broad $p(\lambda)$
Broad Eddington ratio Distributions III

Very Broad $p(\lambda)$

Very Broad $p(\lambda)+f(z)$
SPECIAL MODELS: $\lambda$-dependent Bolometric Correction

Vasudevan & Fabian 2007
Low Radiative Efficiency + Low Eddington ratios

![Graph showing the rate of change of black hole mass with time.](image1)

Similar Downsizing

Harder to match the local BHMF: \( \lambda < 0.1; \ \epsilon < 0.06 \)
The Effect of SMBH Merging...

Negligible effect on accretion histories and duty cycles:
CONCLUDING on THE LMF

\[ \frac{dm}{dt} \approx 0.5 \]

More Massive+Sub-Edd

Less Massive+Edd

\[ 0.06 < \varepsilon < 0.11 \]

Merging

\( \phi(M_\ast) \, M_\ast \, \text{Mpc}^{-3} \, \text{dex}^{-1} \)

\( \log M_\ast [M_\odot] \)

\( \log 10^5 \)
How to link Clustering to Accretion

From matching the bias in output duty cycle $f_{AGN}$

Rule of thumb: at fixed scatter, high duty cycle massive halos, low numbers

Martini & Weinberg 2001; Haiman & Hui 2001
An Application: The SDSS z~1.5 quasar clustering

Coupling with duty cycle from Continuity Equation breaks some degeneracies!

First Results: large scatter!

Another Application: The SDSS z>3 Quasar Clustering

Duty cycle \( \sim 1 \)

\[
\text{Duty cycle} \sim 1
\]

The Clustering of “MERGING” Halos

We select the halos from the MS which have recently merged
Seeding Central and Satellite Halos with BHs

\[ P_c(M_{bh}) N_c[M_{h}(M_{bh})]/N_{tot} + P_s(M_{bh}) N_s[M_{h}(M_{bh})]/N_{tot} = U(M_{bh}, z) \]

\[ Q = P_s/P_c \]

FS, D. Weinberg, J. Miralda-Escude’ 2009b
SO...WHAT DID WE LEARN ABOUT HOW BHs EVOLVE?

**ACCRETION:** can reproduce the local BH mass function; preferred parameters are $0.5 < \lambda < 1$ and $0.07 < \varepsilon < 0.1$. Multi Edd. Ratios do not change Accreted BHMF.

The *Quasar clustering*, independent constraints on duty cycle, mean L-Mhalo relation, and scatter, small-scales constraints on the BH triggering mechanisms

Constraints are independent of specific models and can then be used in SAMs