Active Galactic Nuclei as cosmological probes

Elisabeta Lusso

Junior Research Fellow (CoFund)

G. Risaliti (Uni. of Florence-INAF), S. Bisogni (INAF Arcetri/Harvard CfA), E. Nardini (INAF Arcetri), F. Salvestrini (DIFA-INAF), C. Vignali (DIFA), M. Elvis (Harvard CfA), M. Salvati (INAF Arcetri), F. Civano (Harvard CfA), R. Gilli (OaBo-INAF),

Treasures Hidden in High Energy Catalogues
IRAP, Toulouse (France), May 22, 2018
The power of optical/UV+X-ray catalogues: Active Galactic Nuclei as standard candles

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The disc-corona synergy

Photons s\(^{-1}\) keV\(^{-1}\)

Energy (keV)

10\(^{-3}\)

10\(^{-4}\)

10\(^{-5}\)

10\(^{-6}\)

X-RAY

Corona

Disc

optical

UV
Our starting point: The X-ray/UV non-linear relation in AGN

\[ \log(L_X) = \beta + \gamma \log(L_{UV}) \]

\( \gamma \approx 0.6 \ (\sigma \approx 0.35) \)

**Goal:** Evaluate the dispersion of the relation to the intrinsic degree

**Method:** take into account contaminants, systematics, evolution of the slope with time, etc
SMBH accretion physics
intrinsic dispersion of the UV/X-ray relation

2153 quasars selected from the Sloan Digital Sky Survey DR7 with X-ray observations from 3XMM-DR5

1. Reddening and host galaxy contamination
2. Uncertainties on X-ray fluxes do to unreliable source counts
3. X-ray absorption
4. No radio loud (based from FIRST only)
5. No BAL quasars
6. Eddington Bias

743 quasars with “clean SED”

SMBH accretion physics
intrinsic dispersion of the UV/X-ray relation

\[ \gamma \approx 0.6 \text{ with } \sigma \approx 0.24!! \]

SMBH accretion physics
physical origin of the UV/X-ray relation

SDSS-DR7 + 3XMM-DR6 + MIXR (Mingo+2015)

Observed: \( \log L_X \sim 0.61 \log L_{UV} + 0.54 \log \text{FWHM} \)

Predicted: \( L_X \sim L_{UV}^{0.57} \text{FWHM}^{0.57} \)


Elisabeta Lusso Junior Research Fellow
SMBH accretion physics

The $\Gamma_x - \lambda_{edd}$ relation: SDSS-DR7+3XMM-DR7

Lusso et al., in prep.

$N = 362$

$\gamma = 0.252 \pm 0.046$

$K = 2.280 \pm 0.038$

$\delta = 0.07$ ($\sigma_{\Delta\Gamma_x} = 0.32$)

$E(B-V)<0.1$, offaxis<6 arcmin, cts(EPIC)>250
SMBH accretion physics

The $\Gamma_{X}$-$\lambda_{edd}$ relation: SDSS-DR7+3XMM-DR7

Lusso et al., in prep.

Detailed source-by-source analysis of the “outliers”

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Treasures Hidden in High Energy Catalogues, May 22
Cosmology with quasars

The distance modulus

\[ \log(L_X) = \beta + \gamma \log(L_{UV}) \]

\[ \log(F_X) = \beta' + \gamma \log(F_{UV}) + 2(\gamma - 1)\log D_L(z, \Omega_M, \Omega_{\Lambda}) \]

The non-linear \( L_X \)-\( L_{UV} \) relation as a way to measure quasar distances

Cosmology with quasars

The Quasars Hubble Diagram


~800 quasars

Excellent agreement with SNe @ z=0.3-1.4

Type 1a SN: Supernovae Cosmology Project (Sullivan+11, Suzuki+12)

See also: Risaliti & Lusso (2017, AN, 201713351)
Bisogni, Risaliti, and Lusso (2017, FrASS, 4, 48B)
Cosmology with quasars

The Quasars Hubble Diagram


Test cosmological models in a poorly explored redshift range i.e. $z>2$

Type 1a SN: Supernovae Cosmology Project (Sullivan+11, Suzuki+12)

See also: Risaliti & Lusso (2017, AN, 201713351)
Bisogni, Risaliti, and Lusso (2017, FrASS, 4, 48B)
Cosmology with quasars

Results

Open Universe
($\Omega_L$ and $\Omega_M$ fitted simultaneously),
QSOs only:
$\Omega_M = 0.22^{+0.10}_{-0.08}$
$\Omega_L = 0.92^{+0.18}_{-0.30}$

Open, QSOs + SNe:
$\Omega_M = 0.28^{+0.04}_{-0.04}$
$\Omega_L = 0.73^{+0.08}_{-0.08}$

Planck 2015 results
$\Omega_M = 0.308\pm0.012$
$\Omega_L = 0.692\pm0.012$

Quasars are complementary (i.e. orthogonal) to supernovae

Cosmology with quasars
The Quasars Hubble Diagram

~2000 quasars SDSS+3XMM catalogue
Risaliti & Lusso (2017, AN, 201713351)
Cosmology with quasars
Test of cosmology

$w_0-w_a$ plane where $w=w_0+w_a(1+z)$, $w=-1$ no evolution,
Accelerating expansion of the universe for eq. of state $w<-1/3$

Risaliti & Lusso (2017, AN, 201713351)
To summarise

Archives still hide a potential treasure e.g. SDSS-DR14+3XMM-DR8/CSC2

1. The non-linear $L_X$-$L_{UV}$ relation is extremely tight
2. and it is based on sound physical grounds
   

3. The $\Gamma_X$-$\lambda_{edd}$ relation: using $\Gamma_X$ to establish $\lambda_{edd}$ among samples of high-redshift AGN 
   (red herring?)
   
   Lusso et al., in prep.

4. Quasar are standard candles and can be used to measure the dark matter and energy content in the Universe
   
   Risaliti & Lusso 2015