Powering the faint end of the AGN LF

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The AGN luminosity function

Hard X-ray
Soft X-ray
Optical
Emission Line
Mid-IR

Hopkins et al. 2007
MOTIVATION: Interpret the knee of the AGN luminosity function

$\log(\Phi(L))\ [\text{Mpc}^{-3}\ \log(L)^{-1}]$

$z = 1.50$  
$z = 0.10$

$\log L_{\text{bol}}\ [\text{cgs}]$

Hopkins et al. 2007
MOTIVATION: Interpret the knee of the AGN luminosity function

What kind of SMBH are hiding behind low luminosities AGN?

- Massive BH with low accretion rate
- Small BH with standard accretion rate
COMPARISON: prediction of models

Semi-analytical models where AGN activity is ALWAYS triggered by galaxy major-mergers:
→ Need of a power-law decay to reproduce a rising LF at faint magnitudes
  Cattaneo et al. (2001)
→ Numerical simulations of galaxy mergers which incorporate BH growth find that quasar lifetime is longer for lower luminosity AGN (and reproduce the luminosity dependent density evolution LDDE observed for AGN). Hopkins et al. (2006)
SAMPLE: The VIMOS VLT Deep Survey

Faint galaxy redshift survey

Goal:
Evolution of galaxies, AGN and large scale structures.

Institutes:
LAM (Marseille), LATT (Toulouse) OABo/IRA (Bologna), IASF/OABr (Milan), OAC (Napoli), OAR (Roma)

Spectroscopic follow-up @ESO with VIMOS
Faint galaxy redshift survey

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→ Spectroscopic follow-up @ESO with VIMOS

$I_{AB} < 24$ : VVDS-Deep Le Fèvre et al. 2005
11 000 spectra in 0.6 deg$^2$

$I_{AB} < 22.5$ : VVDS-Wide Garilli et al. 2007
30 000 spectra in 4.5 deg$^2$
The VIMOS VLT Deep Survey

**Deep sample I<24**

- 0226-04
  - ~0.5 deg²
  - 9,600 spectra

- CDFS
  - ~0.15 deg²
  - 1,700 spectra

**Wide sample I<22.5**

- 1400+05
  - ~0.9 deg²
  - 6,000 spectra

- 1003+01
  - ~0.6 deg²
  - 4,000 spectra

- 2217-00
  - ~3.0 deg²
  - 20,000 spectra
Public data release

VVDS Imaging Survey: $UBVRIJK$

- **0226-04**
  - ~0.5 deg$^2$
  - 9,600 spectra

- **CDFS**
  - ~0.15 deg$^2$
  - 1,700 spectra

- **2217-00**
  - ~3.0 deg$^2$
  - 20,000 spectra

http://cencos.oamp.fr/
SAMPLE: The VIMOS VLT Deep Survey

→ Faint spectroscopical sample sample of 300 AGN

→ Free of morphological/colour selection;

→ $I_{\text{AB}} < 22.5$ & $I_{\text{AB}} < 24$: Deep counterpart of SDSS ($i^* < 19$) and 2Qz ($bj < 20.8$) and spectroscopical equivalent to COMBO-17 (192 AGN, $z > 1.2$, $R < 24$)

→ $0 < z < 5$

→ FORS follow-up spectroscopy of most of degenerate redshifts (single broad emission line objects).

Gavignaud et al. 2006
SAMPLE: The VIMOS VLT Deep Survey

→ Faint spectroscopical sample sample of 300 AGN

\[ \log(\Phi(L)) \text{ [Mpc}^{-3} \text{ log(L)}^{-1}] \]

\[ z = 1.50 \]

\[ z = 0.10 \]

Hopkins et al. 2007 + Bongiorno et al. 2007
Weighing Black Holes

Assuming that the gas motion in the BLR is dominated by gravity

**Virial Relation:** \( M_{BH} \sim f R V^2 \)

**Size of the broad Line Region:**
Line emission is delayed by
\( R \sim c t \)
from the continuum variation

**Broad Emission Line width**
FWHM, \( \sigma \)

Reverberation mapping
Weighing Black Holes

Assuming that the gas motion in the BLR is dominated by gravity

**Virial Relation:** \( M_{BH} \sim f R V^2 \)

**Size of the broad Line Region:**
Line emission is delayed by \( R \sim c t \) from the continuum variation

*Peterson & Wandel 1999*

Is the virial assumption meaningful?
→ Indeed for different lines \( R \sim V^{-1/2} \)

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**Broad Emission Line width**
FWHM, \( \sigma \)
Weighing Black Holes
Scaling relations:
→ L can be used as a surrogate for R

Weighing Black Holes
Weighing Black Holes

Assuming that the gas motion in the BLR is dominated by gravity

**Virial Relation:** \( M_{BH} \sim f R V^2 \)

**Size of the broad Line Region:**

\[ R \sim L^{-0.5} \]

**For Mg II:**

\[
\log M_{BH} = 2 \log \text{FWHM}_{1000} + 0.62 \log (L_{44,3000}) + 6.51
\]

Mc Lure & Dunlop (2004)

**For C IV:**

\[
\log M_{BH} = 2 \log \sigma_{1000} + 0.53 \log (L_{44,1350}) + 6.73
\]

Vestergaard & Peterson (2006)

**Luminosity dependent bolometric corrections:**

\[ f_{bol}(3000 \text{ A}) \sim 6.5 \]

\[ f_{bol}(1350 \text{ A}) \sim 4 \]
Observed wavelength = 5500 – 9200 Å
<table>
<thead>
<tr>
<th>z</th>
<th>Mg II: 1.1 &lt; z &lt; 2.0</th>
<th>C IV: 2.5 &lt; z &lt; 4.3</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.0-3.6</td>
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<td>3.6-3.1</td>
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<td>0.4-0.1</td>
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</tbody>
</table>
We exclude objects with:

- absorption line (C IV);
- with S/N < 7.
Sample of 118 AGN 
(29 + 89 )

C IV : 2.5 < z < 4.3

Mg II : 1.1 < z < 2.0
RESULTS: $M_{\text{BH}}$ and $L/L_{\text{Edd}}$
RESULTS: Possible biases

- Host galaxy contamination ?
- Incertitude on the index $\alpha$ to estimate $R$ from $L$
RESULTS: Possible biases

- Host galaxy contamination

We use the multi-wavelength data available in F02 to estimate the host contamination

*Bongiorno et al. 2007*
RESULTS: Possible biases

- Host galaxy contamination?

This would lead to overestimated $M_{BH}$ and overestimated $L/L_{EDD}$

→ Our results are conservative
RESULTS: Possible biases

• Host galaxy contamination?
  → Our result are conservative

• Incertitude on the index $\alpha$ to estimate $R$ from $L$
  Values in the literature from 0.4 to 0.8:
  → it is affecting our results
COMPARISON: other surveys

McLure et al. 2004
Kollmeier et al. 2006
Netzer et al. 2007.
COMPARISON: other surveys

McLure et al. 2004
Kollmeier et al. 2006
Netzer et al. 2007
Wisotzki et al. in prepa.
CONCLUSION

- Optical sample of faint AGN free of colour and morphological biases;
- Evidence for a population of half-starved black holes, at ~1 magnitude fainter than the knee of the LF.

FUTURE WORK

- Study the optical variability (with CFHTLS) and the host galaxies (with HST) of these faint AGN.
F02P031_020254511 flags : spec 0, nois 0, mask 0

Iteration No. 10
\[ z = 1.747, z_{\text{MgII}} = 1.748 \]

\[ X^2_{\text{gent}} = 6.85 \]
\[ X^2_{\text{EL}} = 4.71 \]

FWHM = 3540 \pm 131, (\pm 140) \text{ km/s} \]
\[ \lambda_{\text{obs}} = 7688.8, (\pm 0.3) \text{ Å} \]

\[ \text{med(FeII)} = 2.52 \times 10^{-18} \]
\[ X^2 = 6.75, X^2_{\text{EL}} = 8.88 \]