Discovery of Ultra-Fast Outflows (UFOs) in Radio-Loud AGN

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Thank you to:

- Francesco Tombesi
- James Reeves, Valentina Braitto, Lucia Ballo, Max Cappi

- Group Publications:
Ionized gas in radio-quiet AGN

Warm gas in NGC3783 (Kaspi et al. 2002)

Ultra-Fast Outflow (UFO) in PG1211+143 (Pounds et al. 2003; Pounds & Page 2006)
**UFOs common in radio-quiet AGN**

Tombesi et al 2010, A&A, subm:

**XMM Survey of z<0.1 Seyfert galaxies (44 sources, 104 spectra)**
Around the BH in radio-loud AGN

- Until recently, little or no evidence for ionized diffuse gas on sub-pc scales
- Are the central engines of RL AGN “empty”?  
- Powerful radio jet sweeping away material
- Jet only mediator of energy with large-scale environment
  → “radio mode” feedback
Tales of change

Deep Chandra & XMM gratings:

• First detection of warm absorber on kpc-scales in 3C382 (Reeves et al. 2009; Torresi et al. 2010)
• Evidence for emitter & absorber in 3C445 on sub-pc scales (Reeves et al. 2010)
Broad-Line Radio Galaxies
Suzaku observes BLRGs

Our Program: BLRGs at $z<0.1$
- 3C 390.3: 100 ks
- 3C 382: 100 ks
- 3C 445: 120 ks
- 3C 111: 100 ks
+ BAT spectrum from 9 months survey (Tueller et al. 2008)

In GTO Program:
- 3C 120: 160 ks  (Kataoka et al. 2007)
Absorption features in 7-10 keV

Uniform spectral analysis:
- Reduction and analysis of all XIS-FI spectra in the 4-10keV
- Baseline model: absorbed power-law + Gaussian Fe K emission lines
- Absorption lines search with energy-intensity contour plots
- Detection probability from extensive Monte Carlo simulations
• detected absorption lines E>7keV in 3/5 sources
• unresolved Fe XXV K-shell and Fe XXVI Lyman series lines
• common blue-shifted velocity of lines ~0.04-0.15c (UFOs)

<table>
<thead>
<tr>
<th>Source</th>
<th>ID</th>
<th>E (keV)</th>
<th>σ (eV)</th>
<th>EW (eV)</th>
<th>Δχ²/Δν</th>
<th>F-test</th>
<th>MC</th>
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<tbody>
<tr>
<td>3C 111</td>
<td>Lyα</td>
<td>7.26+0.03</td>
<td>10</td>
<td>-31 ± 15</td>
<td>13/2</td>
<td>99.9%</td>
<td>99%</td>
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<tr>
<td></td>
<td></td>
<td>8.69+0.13</td>
<td>390</td>
<td>-154 ± 80</td>
<td>40/3</td>
<td>&gt;99.9%</td>
<td>&gt;99.9%</td>
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<tr>
<td>3C 390.3</td>
<td>Lyα</td>
<td>8.11+0.04</td>
<td>10</td>
<td>-32 ± 16</td>
<td>14.6/2</td>
<td>99.9%</td>
<td>99.5%</td>
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<tr>
<td>3C 120a</td>
<td></td>
<td>≡7.25</td>
<td>10</td>
<td>&gt; -29</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≡7.54</td>
<td>10</td>
<td>&gt; -32</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≡8.76</td>
<td>500</td>
<td>&gt; -160</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>3C 120b</td>
<td>Kα</td>
<td>7.25+0.03</td>
<td>10</td>
<td>-10 ± 5</td>
<td>9.4/2</td>
<td>99%</td>
<td>91%</td>
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<tr>
<td></td>
<td>Lyα</td>
<td>7.54+0.04</td>
<td>10</td>
<td>-12 ± 6</td>
<td>10/2</td>
<td>99.3%</td>
<td>92%</td>
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<td>Kβ-Lyβ</td>
<td>8.76+0.12</td>
<td>360</td>
<td>-50 ± 13</td>
<td>18/3</td>
<td>99.9%</td>
<td>99.8%</td>
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<tr>
<td>3C 382</td>
<td></td>
<td>≡8</td>
<td>10</td>
<td>&gt; -20</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>3C 445</td>
<td></td>
<td>≡8</td>
<td>10</td>
<td>&gt; -45</td>
<td>...</td>
<td>...</td>
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</tbody>
</table>

(a) Parameter held fixed during the fit.
(b) Equivalent width lower limit at the 90% level.
UFOs in BLRGs!

<table>
<thead>
<tr>
<th>Source</th>
<th>$\log \xi$</th>
<th>$N_H$</th>
<th>$v_{out}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>3C 111</td>
<td>5.0 ± 0.3</td>
<td>$&gt; 20^a$</td>
<td>+0.041 ± 0.003</td>
</tr>
<tr>
<td>3C 390.3</td>
<td>$5.6^{+0.2}_{-0.8}$</td>
<td>$&gt; 3^a$</td>
<td>+0.146 ± 0.004</td>
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<tr>
<td>3C 120a</td>
<td>…</td>
<td>…</td>
<td>…</td>
</tr>
<tr>
<td>3C 120b</td>
<td>3.8 ± 0.2</td>
<td>1.1$^{+0.5}_{-0.4}$</td>
<td>+0.076 ± 0.003</td>
</tr>
<tr>
<td>3C 382</td>
<td>…</td>
<td>…</td>
<td>…</td>
</tr>
<tr>
<td>3C 445</td>
<td>…</td>
<td>…</td>
<td>…</td>
</tr>
</tbody>
</table>

(a) Lower limit at the 90% level.
Discussion

UFOs parameters

- Distances $r < 0.01$-$0.1$ pc ($<10^2$-$10^5$ $r_s$)
- $v_{ufo} > v_{esc}$ not always, some blobs might fall back
- $L_{bol}/L_{Edd} \sim 0.01$ (3C111) – 1 (3C120, 390.3)
- $M_{out}/M_{acc} \sim 0.1$-$1$ for covering factor $\sim 0.6$
- $E_k \sim 10^{44}$-$10^{45}$ erg s$^{-1}$ $\sim 0.1$ $L_{bol}$ ($\sim 0.1$-$1$ $P_{jet}$)
- Similar to Seyferts (Tombesi et al. 2010b)
Unified model of inflow/outflow in AGN by Ohsuga et al. (2009)

R-MHD simulations of inflow/outflow in AGNs. Three different modes controlled by density parameter. Massive and fast disk winds/outflows driven by radiation pressure. Collimated jets along polar axis driven by magnetic forces. **Disk winds and jets not mutually exclusive; UFOs in both RQ and RL AGNs.**
Open Questions

• What is the true covering factor of the gas?
  - mass and energy carried
  - role of wind for large-scale feedback in RL

• What are physical & dynamical characteristics of outflows in RL?
  - need to study line profile & variability

• Is there a link between jet and outflow in AGN?
  - correlated multiw. variability monitoring, e.g. GRS1915
The role of IXO - the XMS

Flux limits

- 2-10keV flux limits for 5σ detection of narrow absorption lines in the 3-11keV
- Different EWs, exposure times and responses
- Lines of \( \text{EW}=10\text{eV} \) (50eV) in \( \approx6-9\text{keV} \) for \( \approx10^{-12}(10^{-13}) \) erg s\(^{-1}\) cm\(^{-2}\) (expo 100ks)
- Spectral variability on time-scales of \( 5(10) \) ks for \( \approx10^{-11}(10^{-12}) \) erg s\(^{-1}\) cm\(^{-2}\)

Realistic spectra simulations

- Simulations of highly ionized and massive absorbers
- FeXXV/XXVI K lines detectable with high significance
- Line details (profile, energy, broadening) measured with high accuracy (>30 times Astro-H)
- Extend search for UFOs to fainter sources
- Time variability, dynamics of absorbers

Flux limits (EW=10eV) (Tombesi et al. 2009)

log\(5=3\) erg s\(^{-1}\) cm, \(N_H=10^{23}\) cm\(^{-2}\), \(v_t=1000\)km/s (Tombesi et al. 2009)
Conclusions

• X outflows with moderately relativistic velocities: new component of radio-loud AGN
• Link wind-jet-disk

• IXO (& multiw obs): major player for its physics