Relation between winds and jets in radio-loud AGN

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Ionised winds in AGN

Warm-absorber winds
Outflows of photoionised gas from the nucleus
Multiple ionisation and velocity components
Ionised winds mostly studied in radio-quiet AGN

- Large campaigns on Seyferts
- Sample studies

How about ionised winds in radio-loud AGN?

- Ballantyne+05
- Reeves+09
- Torresi+12
- Tombesi+14
- Di Gesu & Costantini 16
Questions:

- Differences between ionised winds in RL and RQ AGN?
- Are wind and jet parameters related?
- Common or different origin and driving mechanism?

We carried out an XMM-Newton spectroscopic study of Type-1 RL AGN
Sample selection

- Started with Quasars and Active Galactic Nuclei Catalogue (Véron-Cetty & Véron 2010)

- Selected radio-loud Type-1 AGN

  Radio-loudness parameter: \( R = \frac{F_{6\text{cm}}}{F_{\text{opt}}} \)

  Radio-loud AGN: \( R > 10 \)

- Selected those with XMM-Newton observations

- Selected those with RGS S/N > 3 per resolution element for high-resolution X-ray spectroscopy

16 radio-loud Seyfert-1 AGN
Modelling of the X-ray spectra

X-ray continuum:
- Power-law (primary X-ray continuum)
- Modified black body (soft X-ray excess)
- Reflection component

X-ray absorption:
- Milky Way neutral ISM absorption
- Host galaxy neutral ISM absorption
- Photoionised absorption by the wind

column density ionisation parameter outflow velocity

Modelled with SPEX (Kaastra et al.)
Wind-jet relation in RL AGN

As the radio jet becomes stronger, the wind becomes weaker.

Significant inverse correlation between NH and R

\[ r_s = -0.83 \]
\[ p_{null} = 0.00007 \]

As the radio jet becomes stronger, the wind becomes weaker.
Origin of the NH-R relation?

- No dependence on the inclination angle
- Not preferentially equatorial winds
- Similar to UFOs in RL AGN (Tombesi+14)
Origin of the NH-R relation?

Mehdipour & Costantini (2019)

Not an ionisation effect

NH of the warm absorber does not decrease with the ionisation parameter
Origin of the NH-R relation?

No dependence on the Eddington luminosity ratio

- Sub-Eddington AGN
- Not caused by widely different accretion rates
Wind-jet relation in RL AGN

Significant inverse correlation between \( NH \) and \( R \)

\[ r_s = -0.83 \]
\[ p_{\text{null}} = 0.00007 \]

Suggests common mechanism behind both winds and jets: magnetic driving

Mehdipour & Costantini (2019)
Anti-correlation between winds and jets in BHBs

- Wind-jet bimodality seen in BHBs

- Wind transition across states suggested to be a magnetic wind

- Different magnetic field configurations drive winds and jets

- Similar wind-jet behaviour in BHBs and RL AGN

Wind absorption seen when jet is weak
- Neilsen & Lee 09
- Ponti+12
- Miller+12
As the jet becomes stronger the wind becomes weaker in RL AGN

Mehdipour & Costantini (2019)
Conclusions

- Inverse relation between radio loudness of the jet and column density of the ionised wind

- Inclination, ionisation, or luminosity effects are not responsible for the relation

- It is linked to the magnetic driving mechanism of both winds and jets in RL AGN

- Analogous to the wind-jet bimodality seen in stellar mass black holes

- Larger sample size needed for a more general characterisation (deeper XMM, XRISM, ATHENA)
Supplementary slides
Radio-loud AGN sample

Mehdipour & Costantini (2019)

Table 1. Properties of the 16 radio-loud AGN in our sample.

<table>
<thead>
<tr>
<th>Object</th>
<th>Class</th>
<th>$z$</th>
<th>$B$</th>
<th>$F_{\text{mid-IR}}$</th>
<th>$F_{6\text{cm}}$</th>
<th>$R$</th>
<th>$i$</th>
<th>$M_{\text{BH}}$</th>
<th>$F_{\text{soft}}$</th>
<th>$F_{\text{hard}}$</th>
<th>$L_{X}$</th>
<th>$L_{\text{bol}}$</th>
<th>$\lambda$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1H0323+342</td>
<td>S1n</td>
<td>0.063</td>
<td>15.72</td>
<td>na</td>
<td>0.30 (d)</td>
<td>130</td>
<td>13 (i)</td>
<td>0.36 (v)</td>
<td>21.7</td>
<td>0.53</td>
<td>0.81</td>
<td>0.278</td>
<td>2.08</td>
</tr>
<tr>
<td>3C 59</td>
<td>S1.8</td>
<td>0.111</td>
<td>16.80</td>
<td>na</td>
<td>0.02 (d)</td>
<td>22</td>
<td>na</td>
<td>7.94 (w)</td>
<td>6.59</td>
<td>0.36</td>
<td>0.86</td>
<td>0.538</td>
<td>3.88</td>
</tr>
<tr>
<td>3C 120</td>
<td>S1.5</td>
<td>0.033</td>
<td>15.72</td>
<td>0.54 (b)</td>
<td>0.36 (e)</td>
<td>154</td>
<td>21 (m)</td>
<td>0.69 (x)</td>
<td>19.4</td>
<td>3.03</td>
<td>5.27</td>
<td>0.309</td>
<td>2.33</td>
</tr>
<tr>
<td>3C 273</td>
<td>S1.0</td>
<td>0.158</td>
<td>13.05</td>
<td>0.60 (b)</td>
<td>0.36 (e)</td>
<td>1407</td>
<td>20 (n)</td>
<td>65.9 (y)</td>
<td>1.77</td>
<td>5.34</td>
<td>7.93</td>
<td>9.16</td>
<td>97.4</td>
</tr>
<tr>
<td>3C 382</td>
<td>S1.0</td>
<td>0.058</td>
<td>16.50</td>
<td>0.09 (b)</td>
<td>0.15 (d)</td>
<td>128</td>
<td>40 (o)</td>
<td>11.5 (z)</td>
<td>8.96</td>
<td>2.03</td>
<td>3.44</td>
<td>0.544</td>
<td>4.07</td>
</tr>
<tr>
<td>3C 390.3</td>
<td>S1.5</td>
<td>0.056</td>
<td>16.06</td>
<td>0.22 (b)</td>
<td>0.12 (e)</td>
<td>70</td>
<td>33 (o)</td>
<td>2.87 (aa)</td>
<td>4.41</td>
<td>2.10</td>
<td>3.48</td>
<td>0.459</td>
<td>3.36</td>
</tr>
<tr>
<td>4C +31.63</td>
<td>S1.0</td>
<td>0.298</td>
<td>15.85</td>
<td>0.07 (b)</td>
<td>1.40 (d)</td>
<td>676</td>
<td>10 (p)</td>
<td>20.0 (ab)</td>
<td>12.0</td>
<td>0.28</td>
<td>0.45</td>
<td>3.28</td>
<td>29.0</td>
</tr>
<tr>
<td>4C +34.47</td>
<td>S1.0</td>
<td>0.206</td>
<td>15.58</td>
<td>0.05 (b)</td>
<td>0.37 (d)</td>
<td>139</td>
<td>35 (q)</td>
<td>3.16 (ac)</td>
<td>3.36</td>
<td>0.70</td>
<td>0.86</td>
<td>2.19</td>
<td>16.4</td>
</tr>
<tr>
<td>4C +74.26</td>
<td>S1.0</td>
<td>0.104</td>
<td>15.13</td>
<td>0.14 (b)</td>
<td>0.32 (g)</td>
<td>79</td>
<td>40 (e)</td>
<td>41.7 (ad)</td>
<td>23.1</td>
<td>0.85</td>
<td>2.46</td>
<td>1.41</td>
<td>10.4</td>
</tr>
<tr>
<td>ESO 075-G041</td>
<td>S1</td>
<td>0.028</td>
<td>14.78</td>
<td>0.12 (c)</td>
<td>13.4 (h)</td>
<td>2416</td>
<td>10 (s)</td>
<td>na</td>
<td>2.90</td>
<td>0.49</td>
<td>0.67</td>
<td>0.023</td>
<td>0.31</td>
</tr>
<tr>
<td>III Zw 2</td>
<td>S1.2</td>
<td>0.089</td>
<td>15.96</td>
<td>0.13 (b)</td>
<td>0.43 (d)</td>
<td>233</td>
<td>21 (q)</td>
<td>0.72 (c)</td>
<td>7.13</td>
<td>0.39</td>
<td>0.72</td>
<td>0.251</td>
<td>1.94</td>
</tr>
<tr>
<td>Mrk 6</td>
<td>S1.5</td>
<td>0.019</td>
<td>15.16</td>
<td>0.55 (b)</td>
<td>0.10 (d)</td>
<td>26</td>
<td>9 (f)</td>
<td>1.80 (ac)</td>
<td>9.80</td>
<td>0.17</td>
<td>1.51</td>
<td>0.026</td>
<td>0.23</td>
</tr>
<tr>
<td>Mrk 896</td>
<td>S1n</td>
<td>0.027</td>
<td>15.27</td>
<td>0.13 (c)</td>
<td>0.04 (i)</td>
<td>11</td>
<td>24 (a)</td>
<td>0.12 (af)</td>
<td>4.03</td>
<td>0.54</td>
<td>0.37</td>
<td>0.021</td>
<td>0.15</td>
</tr>
<tr>
<td>PKS 0405−12</td>
<td>S1.2</td>
<td>0.574</td>
<td>15.09</td>
<td>0.09 (b)</td>
<td>1.99 (j)</td>
<td>477</td>
<td>na</td>
<td>29.5 (ad)</td>
<td>4.16</td>
<td>0.39</td>
<td>0.43</td>
<td>13.4</td>
<td>112</td>
</tr>
<tr>
<td>PKS 0921−213</td>
<td>S1</td>
<td>0.053</td>
<td>16.50</td>
<td>na</td>
<td>0.42 (b)</td>
<td>369</td>
<td>na</td>
<td>0.79 (w)</td>
<td>5.75</td>
<td>0.41</td>
<td>0.68</td>
<td>0.083</td>
<td>0.67</td>
</tr>
<tr>
<td>PKS 2135−14</td>
<td>S1.5</td>
<td>0.200</td>
<td>15.63</td>
<td>0.11 (b)</td>
<td>1.33 (b)</td>
<td>525</td>
<td>na</td>
<td>44.7 (ag)</td>
<td>5.22</td>
<td>0.36</td>
<td>0.60</td>
<td>1.21</td>
<td>10.2</td>
</tr>
</tbody>
</table>

Radio jet information taken from the literature

X-ray modelling of the wind done by us using the SPEX code (Kaastra et al.)
## Ionised wind parameters

**Table 3.** Best-fit parameters of the ionised AGN wind and the neutral ISM gas in the host galaxy of the radio-loud AGN in our sample, derived from our modelling of the *XMM-Newton* observations.

<table>
<thead>
<tr>
<th>Object</th>
<th>Wind $N_H$</th>
<th>Wind log $\xi$</th>
<th>Wind $v_{out}$</th>
<th>Neutral $N_H$</th>
<th>C-stat/d.o.f.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1H 0323+342</td>
<td>9 ± 2, 7.2 ± 0.7</td>
<td>2.17 ± 0.02, 0.15 ± 0.12</td>
<td>−830 ± 170, −880 ± 120</td>
<td>&lt;0.01</td>
<td>2296/1488</td>
</tr>
<tr>
<td>3C 59</td>
<td>40 ± 2, 81 ± 8</td>
<td>1.20 ± 0.05, 2.42 ± 0.03</td>
<td>−3530 ± 130, −1000 ± 120</td>
<td>&lt;2</td>
<td>2036/1477</td>
</tr>
<tr>
<td>3C 120</td>
<td>14 ± 3</td>
<td>2.65 ± 0.04</td>
<td>−2160 ± 360</td>
<td>&lt;0.02</td>
<td>1949/1496</td>
</tr>
<tr>
<td>3C 273</td>
<td>0.7 ± 0.2</td>
<td>1.90 ± 0.08</td>
<td>−3670 ± 170</td>
<td>&lt;0.01</td>
<td>2588/1532</td>
</tr>
<tr>
<td>3C 382</td>
<td>7 ± 2</td>
<td>2.44 ± 0.06</td>
<td>−1350 ± 370</td>
<td>&lt;0.02</td>
<td>1805/1467</td>
</tr>
<tr>
<td>3C 390.3</td>
<td>3.7 ± 0.6, 11 ± 5</td>
<td>1.63 ± 0.11, 2.77 ± 0.06</td>
<td>−1550 ± 160, +50 ± 100</td>
<td>&lt;0.2</td>
<td>1847/1481</td>
</tr>
<tr>
<td>4C +31.63</td>
<td>11 ± 3</td>
<td>−0.00 ± 0.20</td>
<td>−960 ± 200</td>
<td>&lt;0.3</td>
<td>1783/1423</td>
</tr>
<tr>
<td>4C +34.47</td>
<td>31 ± 11</td>
<td>2.12 ± 0.05</td>
<td>−1500 ± 210</td>
<td>&lt;0.3</td>
<td>1546/1398</td>
</tr>
<tr>
<td>4C +74.26</td>
<td>36 ± 3, 68 ± 8</td>
<td>1.69 ± 0.04, 2.46 ± 0.04</td>
<td>−1490 ± 90, −3000 ± 500</td>
<td>&lt;0.09</td>
<td>1986/1511</td>
</tr>
<tr>
<td>ESO 075–G041</td>
<td>7 ± 1</td>
<td>−0.03 ± 0.11</td>
<td>−210 ± 180</td>
<td>&lt;0.05</td>
<td>1832/1415</td>
</tr>
<tr>
<td>III Zw 2</td>
<td>7 ± 4</td>
<td>2.07 ± 0.13</td>
<td>−1780 ± 670</td>
<td>&lt;0.2</td>
<td>1763/1468</td>
</tr>
<tr>
<td>Mrk 6</td>
<td>116 ± 8</td>
<td>1.38 ± 0.06</td>
<td>−4000 ± 500</td>
<td>27 ± 4</td>
<td>2287/1449</td>
</tr>
<tr>
<td>Mrk 896</td>
<td>73 ± 6</td>
<td>2.23 ± 0.02</td>
<td>−130 ± 150</td>
<td>&lt;0.2</td>
<td>1679/1429</td>
</tr>
<tr>
<td>PKS 0405–12</td>
<td>6 ± 2</td>
<td>1.71 ± 0.17</td>
<td>−130 ± 200</td>
<td>&lt;0.05</td>
<td>1715/1465</td>
</tr>
<tr>
<td>PKS 0921–213</td>
<td>8 ± 3</td>
<td>1.92 ± 0.12</td>
<td>−3540 ± 360</td>
<td>&lt;0.2</td>
<td>1700/1458</td>
</tr>
<tr>
<td>PKS 2135–14</td>
<td>5 ± 3</td>
<td>2.14 ± 0.08</td>
<td>−1240 ± 530</td>
<td>&lt;0.1</td>
<td>1831/1414</td>
</tr>
</tbody>
</table>

Mehdipour & Costantini (2019)
Relation between parameters

Mehdipour & Costantini (2019)

$r_s = -0.32$
$p_{null} = 0.23$

$r_s = -0.42$
$p_{null} = 0.11$

$r_s = -0.15$
$p_{null} = 0.63$
AGN sample

Mehdipour & Costantini (2019)
SED model of NGC 5548

Mehdipour+15a

NGC 5548 (Summer 2013)

I R V B U
UVW1
UVM2
UVW2
1793 Å 1750 Å
1735 Å 1480 Å
1367 Å 1160 Å

disk/warm corona

hot corona

reflection

RGS
EPIC–pn
NuSTAR
INTEGRAL