Cosmic Feedback from AGN

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Possible effect of central black hole on host galaxy

\[ E_{\text{BlackHole}} > 30 \times E_{\text{Galaxy}} \]

- Energy released by growth of Black Hole
- Gravitational Binding Energy of Host Galaxy

2 major modes for the interaction:
- Kinetic (radio/jet) and Radiative (quasar)
KEY QUESTIONS

1) Understanding the energy flow in cool cores of clusters, groups and ellipticals:
   (Velocity field, bulk motions, shocks, turbulence...)

2) Understanding the energy and mass outflow of AGN:
   (Mass and energy components, velocity structure, variability, ionization structure...)

Resolution is very important!

10" bars
Discovery of Ripples in Centaurus Cluster
Sanders & Fabian 08
M84 Finoguenov+08
Hydra A
Larry David
900ks Chandra image of Perseus cluster
Fabian+06
Today’s Nature
Do we expect this to be very turbulent?
Images have wider appeal than spectra.
Cavagnolo+08

![Graph showing the relationship between $L_{\text{H}^\alpha}$ and $K_0$ with data points for 'Ha' and 'No Ha' categories.](image)
Wind Outflow
(Model by Proga & Kallman04, Spectrum by N Schurch, at 62 deg)

Con-X in red, XMM in black
### AGN with reported fast outflows

<table>
<thead>
<tr>
<th>Name</th>
<th>Type</th>
<th>v/c</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>H 1413+117</td>
<td>BALQSO</td>
<td>2.56 0.23 and 0.67</td>
<td>(Chartas et al. ApJ, 2007, 661, 678)</td>
</tr>
<tr>
<td>•PG 1115+080</td>
<td>BALQSO</td>
<td>1.72 0.1 and 0.4</td>
<td>(Chartas et al. ApJ, 2003, 595, 85)</td>
</tr>
<tr>
<td>PG 1211+143</td>
<td>NLS1</td>
<td>0.081 0.13</td>
<td>(Pounds et al. MNRAS, 2003, 345, 705) (1) (2)</td>
</tr>
<tr>
<td>PG 0844+349</td>
<td>Sey 1</td>
<td>0.064 0.2</td>
<td>(Pounds et al. MNRAS, 2003, 346, 1025) (3)</td>
</tr>
<tr>
<td>Mrk 509</td>
<td>Sey 1</td>
<td>0.034 0.1-0.2</td>
<td>(Dadina et al. A&amp;A, 2005, 442, 461)</td>
</tr>
<tr>
<td>IRAS13197-1627</td>
<td>Sey 1.8</td>
<td>0.0165 0.11</td>
<td>(Dadina and Cappi, A&amp;A, 2004, 413, 921)</td>
</tr>
<tr>
<td>IC 4329a</td>
<td>Sey 1</td>
<td>0.016 0.1</td>
<td>(Markowitz et al. 2006, ApJ, 646, 783)</td>
</tr>
<tr>
<td>MCG-5-23-16</td>
<td>Sey 1.9</td>
<td>0.0085 0.1</td>
<td>(Braito et al. 2006, AN, 327, 1067)</td>
</tr>
<tr>
<td>MCG-6-30-15</td>
<td>Sey 1.2</td>
<td>0.0077 0.007</td>
<td>(Young et al. 2005, ApJ, 631, 73)</td>
</tr>
<tr>
<td>NGC 1365</td>
<td>Sey 1.8</td>
<td>0.0055 0.017</td>
<td>(Risaliti et al. 2005, ApJ, 630, 129)</td>
</tr>
</tbody>
</table>

(1) Disputed by Kaspi et al., who claim the outflow may arise from a lower velocity, depending on the specific identification of lines in the spectrum.

(2) Pounds & Page 2006 (astro-ph0607099) confirm the high velocity outflow in PG 1211+143. Reeves et al 2008 (astro-ph08011578) use a variability argument to show that the iron K shell absorption in PG 1211+143 is not due absorption from local IGM gas but is most likely associated with a fast outflow.

(3) Disputed on the basis of background subtraction in the EPIC/PN spectrum (Brinkman et al. 2005)

Likely that ALL AGN have outflows but influence at present unclear
PDS456  (Suzaku: J Reeves+)
PDS456  (J Reeves+)

True continuum
XMM 2001 in red
Effect of radiation pressure on dusty gas

Feedback Successful here
SWIFT-BAT data from Mushotzky, Winter+
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X-rays are most direct probe of crucial volume-filling component
• X-ray absorption lines can be used to constrain the properties of quasar outflows ($N_H$, $n_e$, $\xi$, $v$, $f_c$, $n_e$, $\dot{M}$, $\varepsilon_k$)

• Mass outflow rates in APM08279 (~5 $M_\odot$/y) and PG 1115 (~5 $M_\odot$/y) is found comparable to their accretion rates.

• Fraction of bolometric energy released in the form of kinetic energy

  $\varepsilon_K \sim 0.09 (-0.05, +0.07)$, APM 08279+5255
  $\varepsilon_k \sim 0.64 (-0.40, +0.52)$, PG1115+080
Quasar Outflows: Observations

$z = 3.91$

$z = 2.56$

$z = 1.72$

**APM 08279+5255** (Chartas et al. 2002)

**PG 1115+080** (Chartas et al. 2003)

**H 1413+117** (Chartas et al. 2007)
0.75c so flow within 25deg of l.o.s. (George Chartas)