Observations of AGN Outflows and Their Contribution to Feedback

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Merger Scenario w/ Feedback

- merge gas-rich galaxies
- forms buried AGNs
- feedback expels the gas
- reveals the AGN
- shuts down accretion and star formation

Why No Big Galaxies?

Benson et al. 2003

Number

Observed

Benson et al. 2003

Model 1 = Halo mass function
Model 2 = Cooling
Model 3 = Photoionization
Model 4 = Merging
2 Types of Galaxies

- Red
- Blue

Blue Cloud

Red Sequence

e.g., Faber et al. 2007
Simulations of mergers can reproduce this relationship if 5% of the AGN’s radiated luminosity couples with the gas (0.5% of the rest mass energy).
Is Feedback Really Needed?

- Still have some post-AGN star formation (still some gas).
- Would get red ellipticals from merger anyway.
- M-sigma may just indicate same fuel source.

AGNs may not make red, dead ellipticals – they just make them better.

Wuyts et al. 2010, in prep.
Feedback Mechanisms

- Jets
- Winds
  - radiation pressure
    - line
    - continuum
  - magneto-centrifugal forces
  - thermal pressure
- Radiative Heating

E.g., Begelman 2004
“Quasar” vs. “Radio” Mode

- Quasar mode = cold gas accretion
- Radio mode = hot gas accretion (Croton et al. 2006)

N.B.: AGNs with radio jets aren’t necessarily radio mode objects.

I will strictly be talking about quasar mode.
Clouds (and Torus?) $\Rightarrow$ Disk Winds

Urry & Padovani 1995

Proga 2005 (see also Everett 2005)
Accretion Disk Radiation

Strong X-rays (~ light hours)

Weak X-rays, UV Light, Optical Light (~ light years)

(Gallagher et al. 2002a: Adapted from Königl & Kartje 1994; Murray et al. 1995)
Accretion Disk Wind

UV light from the accretion disk pushes on electrons in the "atmosphere" of the accretion disk and drives a wind. This wind deposits energy into the system.

Gallagher et al. 2002a

Dusty region
Broad Absorption Line Quasars

- Quasars with P-Cygni like absorption troughs reveal much about the nature of the accretion disk wind.
- Weak X-ray (relative to UV) allows stronger winds.

Hall et al. ‘02; Reichard et al. ‘03a,b; Tolea et al. ‘03; Trump et al. ‘06; Gibson et al. ‘08
SED/Shielding Dependence

thinner shield $\Rightarrow$ less X-ray weak

thicker shield $\Rightarrow$ more X-ray weak

larger Rlaunch $\Rightarrow$ lower vterm

(Gallagher et al. 2006; Gallagher & Everett 2007)

smaller Rlaunch $\Rightarrow$ higher vterm

vterm $\sim$ (GMBH/Rlaunch)$^{1/2}$

(cf. Chelouche & Netzer 2000; Everett 2005)
UV Wind Diagnostics

- Crenshaw et al. 1999
- Krolik & Kriss 2001
- de Kool et al. 2001; FIRST J104459.6+365605
- Crenshaw, Kraemer, & George 2003; ARAA
- Moe et al. 2009; SDSS J0838+2955
- Bautista et al. 2010; QSO 2359-1241
- Dunn et al. 2010; SDSS J0318-0600

Campaigns have concentrated on (Fe)LoBALs. Determine distances, outflow rates, kinetic luminosities. Find typical distance are a few kpc. Outflow rates of tens of solar masses/year. Kinetic luminosities of 0.01 $L_{bol}$
\[ \dot{E}_k = \frac{1}{2} \dot{m} v^2 = 4 \rho f R N_H 1.4 M_p v^3 \]

\[ E_k = 5 \times 10^{45} \times f_{0.2} \text{ ergs/s} = 0.02 L_{BOL} \]

\[ \dot{M} = 600 \times f_{0.2} \text{ Solar masses/yr} \]

Moe et al. 2009
Warm Absorber (X-ray) Examples

- Turner et al. 1993
- Reynolds et al. 1995
- Blustin et al. 2005
- Chartas et al. 2010, Saez et al. 2010 (APM 08729+5255)
- Chartas et al. 2003, 2007 (PG1115+080)
- Reeves et al. 2003 (PDS456)
- Pounds et al. 2003 (PG1211+143)
- Dadina & Cappi 2004 (IRAS 13197-1627)
- Zheng & Wang 2008 (CDFS)
- but see Vaughan & Uttley (2008)
Mass outflow rates of 16—64 $M_{\odot}$/year.

Winds are massive and energetic enough to influence galaxy formation (if common).

Argue that most of the mass and energy must be carried away by X-ray absorbers.
Other X-ray Examples

PDS 456; Reeves et al. 2003

PG 1115+080; Chartas et al. 2003/2007
We can use 2 key emission line diagnostics from CIV in the redshift range where BALs are found to learn more about winds.

These help to identify the parent sample of objects from which BALQSOs are drawn.

This will lead to a re-interpretation of the 20% BAL fraction and the realization that strong SED dependences need to be accounted for.
The Baldwin Effect

More luminous quasars have weaker CIV lines (Baldwin 1977).

Seen here from an SDSS sample with 30k quasars.
CIV “Blueshifts”

The peak of CIV emission is generally not at the expected laboratory wavelength (e.g., Gaskell 1982).

Richards et al. 2010
Can form a joint parameter space with these two observations.

Generally speaking radio-loud quasars and BALQSOs live in opposite corners.
2-Component BELR

1. The Disk
   - Dominated by Low-ionization lines
   - Single-peaked due to large distance?

2. The Wind
   - Dominated by High-ionization lines
   - Single-peaked due to radiative transfer effect (Murray & Chiang)
Disk + Wind

(a.)
- X-ray corona
- Black hole
- E > 13.6 eV Radiation supported disk
- E < 13.6 eV Thin disk
- Disk atmosphere
- Shielded region emitting low-ionization lines
- Self-gravitating unstable disk

(b.)
- X-ray emitting corona
- Black hole
- E > 13.6 eV Radiation supported disk
- E < 13.6 eV Thin disk
- Disk atmosphere
- Self-gravitating unstable disk
Filtered Continuum

In the model of Leighly 2004, the disk isn’t just a separate component, it sees a different continuum than the wind (and possibly different from what we see).

Leighly 2004; Leighly & Casebeer 2007
While the disk may see a different filtered continuum for different strength winds, the structure of the wind depends on the intrinsic SED.
More ionizing flux = strong disk component
High radio-loud prob; low BALQSO prob

Less ionizing flux = strong wind component
Low radio-loud prob; high BALQSO prob
CIV Parameter Space

Ionizing SED, Weak LD winds

Less ionizing SED, Strong LD winds

SEDs affects winds, which affects covering fractions.

Mass and accretion rate affect SEDs (i.e., the SEDs evolve).

Radio-Loud 0%

BALQSOs 40%

Richards et al. 2010
Conclusions

There’s plenty of evidence for winds in AGNs and that they can cause feedback effects.

However, we must realize that ALL QUASARS ARE NOT THE SAME!

We need to get away from the nearly religious adherence to:
- The Unified Model
- A Universal SED
- A 20% BAL fraction
- Evolution vs. Orientation