AGN Feedback in the X-ray Surveyor Era

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Gultekin et al. (2009)
Read & Trentham (2005)

Too few low mass galaxies

Too few high mass galaxies

$\alpha = -1.21$

$\phi_* = 2.5 \times 10^{-14}$

$M_* = 1.31 \times 10^{11}$
The Big Questions

- What is the role of AGN feedback across the mass scale of galaxies?
- What are the physical processes mediating this feedback?
- How do feedback processes change over cosmic time?
I : Quasar Mode Feedback
(c) Interaction/"Merger"
- now within one halo, galaxies interact & lose angular momentum
- SFR starts to increase
- stellar winds dominate feedback
- rarely excite QSOs (only special orbits)

(d) Coalescence/(U)LIRG
- galaxies coalesce: violent relaxation in core
- gas inflows to center: starburst & buried (X-ray) AGN
- starburst dominates luminosity/feedback, but, total stellar mass formed is small

(e) "Blowout"
- BH grows rapidly: briefly dominates luminosity/feedback
- remaining dust/gas expelled
- get reddened (but not Type II) QSO: recent/ongoing SF in host high Eddington ratios merger signatures still visible

(f) Quasar
- dust removed: now a "traditional" QSO
- host morphology difficult to observe: tidal features fade rapidly
- characteristically blue/young spheroid

(g) Decay/K+A
- QSO luminosity fades rapidly
- tidal features visible only with very deep observations
- remnant reddens rapidly (E+A/K+A)
- "hot halo" from feedback
- sets up quasi-static cooling

(a) Isolated Disk
- halo & disk grow, most stars formed
- secular growth builds bars & pseudobulges
- "Seyfert" fueling (AGN with M* > 23)
- cannot reden to lie red sequence

(b) "Small Group"
- halo accretes similar-mass companion(s)
- can occur over a wide mass range
- M_{halo} still similar to before: dynamical friction merges the subhalos efficiently

(h) "Dead" Elliptical
- star formation terminated
- large BH/spheroid - efficient feedback
- halo grows to "large group" scales: mergers become inefficient
- growth by "dry" mergers

Hopkins et al. (2008)
Chandra 900ks HETG study of NGC3783 (Kaspi et al. 2002)
PG1211+143 w/XMM : Absorption line from v~0.1c outflow (Tombesi+2010; Pounds+2003)

PDS456 w/NUSTAR : P-Cyg profile from v~0.3c outflow (Nardini+ 2015)
Stratified accretion disk wind

Tombesi et al. (2013)
Future spectroscopic studies of fast outflows…

- Detailed velocity/ionization structure
- Variability \( \rightarrow \) location

Simulated 100ks Astro-H observation of PDF456 (AGN Winds WP, Kaastra et al. 2014)
Zubovas & King (2012)
The $z=0.18$ ULIRG IRASF11119+3257 (Tombesi et al. 2015)

Highly-ionized $v \sim 0.25c$ outflow (Suzaku)

OH 119.23$\mu$m absorption (Herschel)

X-ray Surveyor + ALMA will obtain similar data on $z=2$ quasar
Shocked wind bubble emits in X-rays…
$L_{\text{brems}} \sim 10^{39}$ erg/s (peaking at 200 keV)
$L_{\text{IC}} \sim 10^{41}$ erg/s (peaking at few keV)

Characteristic size of bubble is $\sim \text{kpc}$
Resolvable by X-ray Surveyor out to $z=0.1$
(good candidate; Mrk231 at $z=0.042$)
II : Radio mode feedback
Fabian et al. (2010)

Simionescu et al. (2011)
Fabian et al. (2006)
Turbulent heating in galaxy clusters brightest in X-rays

I. Zhuravleva\textsuperscript{1,2}, E. Churazov\textsuperscript{3,4}, A. A. Schekochihin\textsuperscript{5,6}, S. W. Allen\textsuperscript{1,2,7}, P. Arévalo\textsuperscript{8,9}, A. C. Fabian\textsuperscript{10}, W. R. Forman\textsuperscript{11}, J. S. Sanders\textsuperscript{12}, A. Simionescu\textsuperscript{11}, R. Sunyaev\textsuperscript{4,7}, A. Vikhlinin\textsuperscript{11} & N. Werner\textsuperscript{12}
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Toy model for driving if ICM turbulence by AGN outbursts…
AGN does indeed drive turbulence through g-mode decay, but energy transfer from AGN to ICM turbulence is very inefficient (Reynolds et al. 2015)
Astro-H simulations of Perseus (Astro-H Cluster White Paper)
Unsharp-mask image of Perseus (10arcsec smoothed structure subtracted out)  

Sanders et al. (2006)
Simulated XMIS spectra of 2x2 arcsec$^2$ region of Perseus (500ks)

Assume
150km/s turbulence
150km/s bulk velocity offset
(formally reconstruct these velocities to ±15km/s)
Cygnus A

ROSAT PSPC (Reynolds & Fabian 1995)

Chandra (Smith et al. 2002)
Cygnus A w/NuSTAR (Reynolds et al. 2015)
Best fitting NuSTAR model to Cygnus-A

Solid line = with wind
Dotted line = no wind

- $N_W > 3 \times 10^{23} \text{cm}^{-2}$
- $\log \xi = 3.4 \pm 0.1$
- $V = 20,000 \pm 5000 \text{ km/s}$
The wind in Cygnus A...

- **Assume**
  - Wind subtends $\Omega = \pi$ of the sky as seen by source
  - Velocity is escape speed at launching site

- **Then**
  - Mass flux… $M_{\text{dot}} = 110 \left( \frac{L_{\text{bol}}}{c^2} \right)$
  - Momentum flux… $P_{\text{tot}} = 10 \left( \frac{L_{\text{bol}}}{c} \right)$
  - Kinetic energy flux… $L_K = 0.42 L_{\text{bol}}$

- **Appear to have a strong wind (possibly exercising feedback on galaxy) at same time as we see strong jets (feeding back on cluster)**
Conclusions

- AGN now recognized as a major actor in the story of galaxy evolution
- X-ray Surveyor can bring key contributions
  - Spatial mapping of quasar winds interacting with and clearing ISM
  - Mapping the velocity/temperature/density structure of AGN/ICM interactions on the relevant spatial spatial scales