X-ray Surveyor
Feedback Science Working Group

Co-chairs:
Chris Reynolds & Megan Donahue
Outline

• Membership
• Driving Science Questions
• First thoughts on X-ray Surveyor’s Impact
• Experience from Hitomi
• Next steps...
## SWG membership

- **Megan Donahue (MSU)**  
  Cluster-scale feedback
- **Chris Reynolds (UMd)**  
  ICM-Jet interaction / AGN winds
- **Nahum Arav (VT)**  
  AGN winds / BALQSOs
- **Laura Brenneman (CfA)**  
  Accretion and BH spin
- **Larry David (CfA)**  
  Cluster feedback
- **Oleg Gnedin (U.Mich)**  
  Cosmological Simulations / Feedback
- **Julie Hlavacek-Larrondo (Montreal)**  
  Cluster scale feedback over cosmic time
- **Edmund Hodges-Kluck (U.Mich)**  
  CGM, ICM and radio-galaxies
- **Brian McNamara (Waterloo)**  
  Cluster feedback
- **Jon Miller (U.Mich)**  
  Disk winds across BH mass scale
- **Paul Nulsen (CfA)**  
  Cluster feedback
- **Scott Randall (CfA)**  
  AGN-ICM feedback
- **Eric Schlegel (UT)**  
  Feedback across scales
- **Dan Schwarz (CfA)**  
  AGN Jets
- **Aneta Siemiginowska (CfA)**  
  Jet-ISM interactions
- **Gregory Sivakoff (Alberta)**  
  Accretion-jet connection in XRBs
- **Francesco Tombesi (UMd)**  
  AGN winds
- **Grant Tremblay (Yale)**  
  Galactic-scale feedback/multiwaveband
- **Shuo Zhang (MKI)**  
  BH jets and Sgr A*
I : Driving Science Issues

• Manifestations of feedback
  – Galactic SF rate $<<$ cold gas mass / dynamical time
  – Too few low-mass galaxies
  – Too few high-mass galaxies
  – $M_{BH}$-sigma relation
  – Lack of cooling catastrophe in relaxed clusters

• Injection/cycling of mass, energy, and metals into hot ISM/CGM/IGM

• The baryons ain’t missing – there’re just hot!

Compared to number of parent dark matter halos
How efficient is galaxy formation?

\[ \frac{\dot{N}}{\dot{N}_{\text{total}}} = 0.16 \]

\[ M_{\text{baryons}} = 0.16 \, M_{\text{total}} \]
How efficient is galaxy formation?

\[ \frac{dN}{dM} \text{ (Objects per cubic Mpc)} \]

\[ f = \frac{M_*}{M_{\text{total}}} \]

\[ f_b = 0.16 \]

\[ M_{\text{baryons}} = 0.16 \, M_{\text{total}} \]

\[ M_* \text{ Disks} \]

\[ M_* \text{ Spheroids} \]

\[ M_* \text{ BCGs} \]
Galactic Scale Stellar Feedback

- Key issue is cycling of mass, energy and metals from galaxy into circumgalactic medium (CGM).
- To make progress...
  - Imaging spectroscopy of hot baryonic halos
  - Absorption spectroscopy of hot IGM
  - Next generation models that predict state of CGM/IGM given physical feedback prescriptions
  - Connection to Baryon Cycling SWG

8/21/16
Galactic Scale AGN Feedback

• Key issue is coupling of the AGN to the ISM/CGM
• Relative roles & physics of
  – Radiation
  – Winds
  – Jets
  "Quasar mode"
• What is the cosmic history of these processes?
  – Obvious connection to AGN Populations SWG
The $z=0.18$ ULIRG IRASF11119+3257 (Tombesi et al. 2015)

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

Characteristic size of bubble is \(~\text{kpc}\)
Resolvable by X-ray Surveyor out to \(z=0.1\)
(good candidate; Mrk231 at \(z=0.042\))
Cluster-scale feedback

• Key issue is the nature of AGN-ICM coupling and the physics behind the self-regulation
• Role of
  – Turbulence
  – Shocks / sound waves
  – Sloshing
  – Bubble/ICM mixing
• Need to consider the ICM as a plasma (i.e. worry about plasma instabilities, thermal conduction, viscosity)
  – Obvious connection to Plasma Physics SWG

Edge-detection Chandra image of Perseus (Sanders, Fabian... 2016)
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 ±20km/s)
Hitomi Collaboration (2016)

The diagram shows a spectrum with various emission lines labeled for elements such as Cr XXIII, Mn XXIV, Fe I, Fe XXV, He x, and others. The spectrum is labeled as "CCD spectrum" and "Hitomi SXS."
Hitomi Collaboration (2016)

Fe XXV He α

$z = 0.01756$

$\sigma_v = 164 \text{ km s}^{-1}$

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Fe XXVI Ly α

Fe XXV He β
Fe XXV Kα complex

The 2 most commonly used spectral models

- **SPEX**
- **APEC**

Counts s⁻¹ keV⁻¹

Energy (keV)
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 ±20km/s)

Constraints all driven by resonance line!
• Perseus is has highest surface brightness of any diffuse source on the Sky.

• Even then, it is challenging to collect enough photons to simultaneously use ~arcsec spatial resolution AND calorimeter spectral resolution!

• But spatial resolution crucial for...
  – Separation of AGN & ICM for high-z clusters
  – ...

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X-ray Surveyor STDT
The Path Forward...

• Will pull team together and start regular telecons after the XRS f2f
• Initial list of tasks...
  – ICM imaging spectroscopy (rigorous assessment of XRSs capabilities in light of Hitomi data)
  – CGM emission & absorption studies (end-to-end simulations)
  – Hot ISM in other galaxies / connections to CGM
• Interface with other SWGs
  – Baryon cycling
  – First Accretion Light
  – Evolution of structure
  – Plasma physics SWG
Questions?