

Starburst Galaxies: Outflow of metals into the IGM



Ann E. Hornschemeier
Goddard Space Flight Center

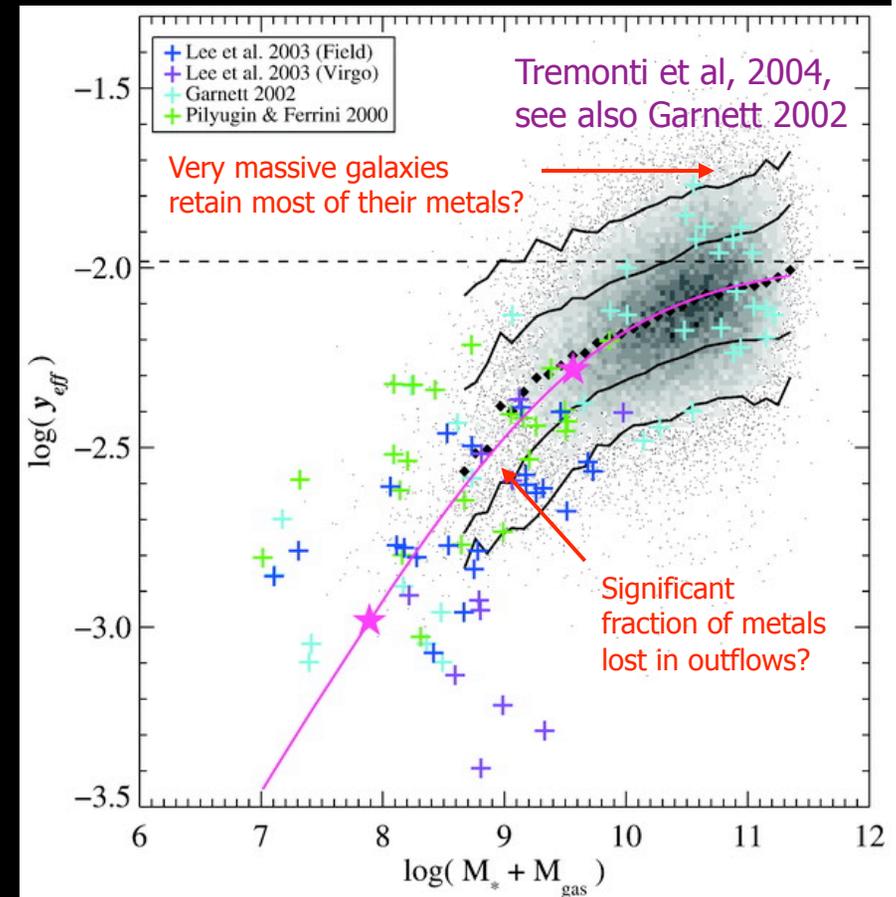
Presented on behalf of
David Strickland, JHU

January 28, 2009

Ann Hornschemeier,
Boston IXO Meeting

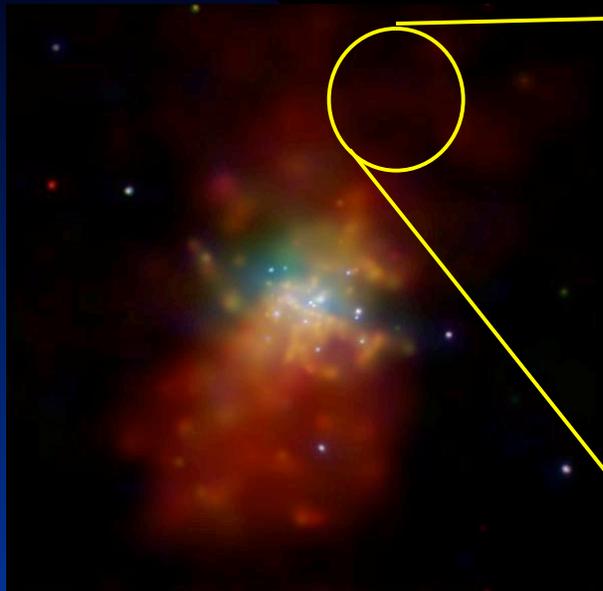
What is the mass outflow rate (metal pollution rate) from starburst galaxies?

- Which galaxies are responsible for the enrichment of the IGM?
- Is the galaxy M-Z relationship (e.g. Tremonti et al 2004) really due to metal-loss via winds?
- Most of the energy and metals in superwinds are in the hot phases (NOT probed by optical/UV spectroscopy).
- Need to measure velocity of hot metal-enriched SN ejecta in superwinds in order to assess whether material will escape.

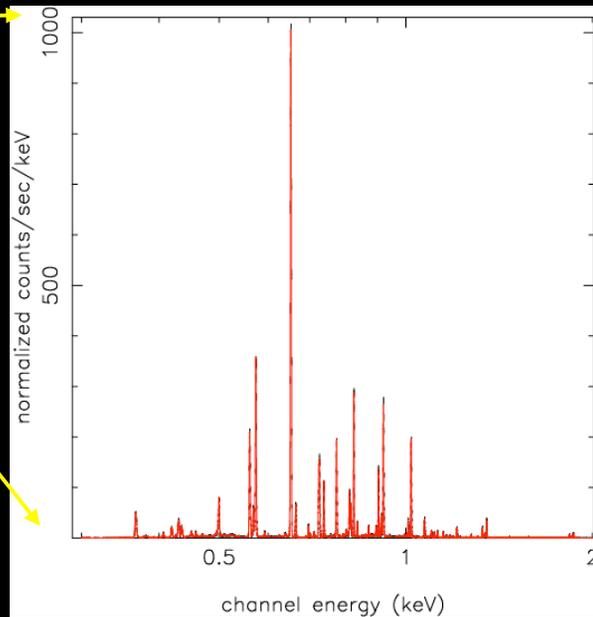


courtesy of D. Strickland (JHU)

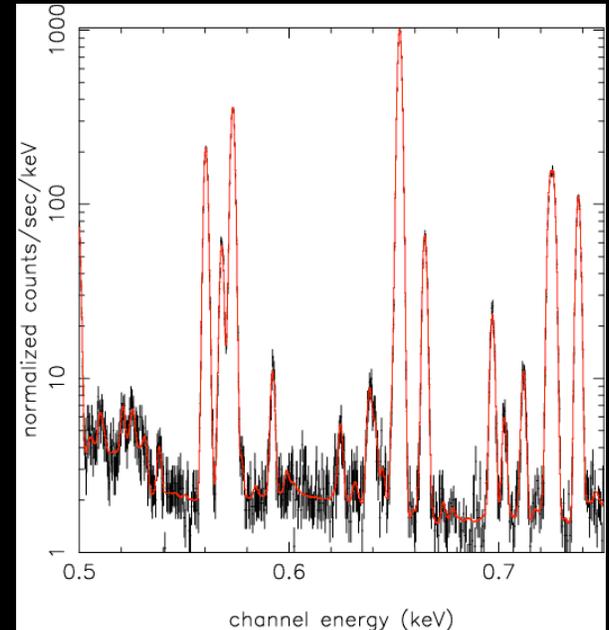
Wind plasma diagnostics with high-resolution X-ray spectroscopy



M82 Chandra central 5x5 kpc
0.3-1.1 keV,
1.1-2.8 keV
2.8-9.0 keV



Simulated ~20 ks IXO NFI northern halo observation, 0.3-2.0 keV.

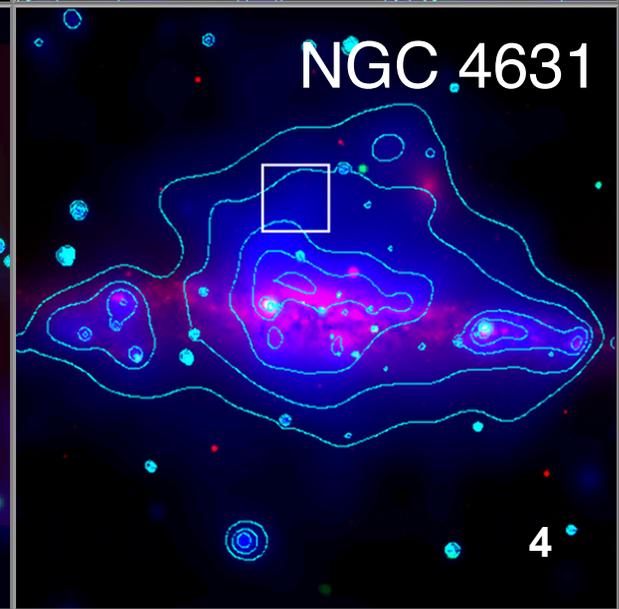
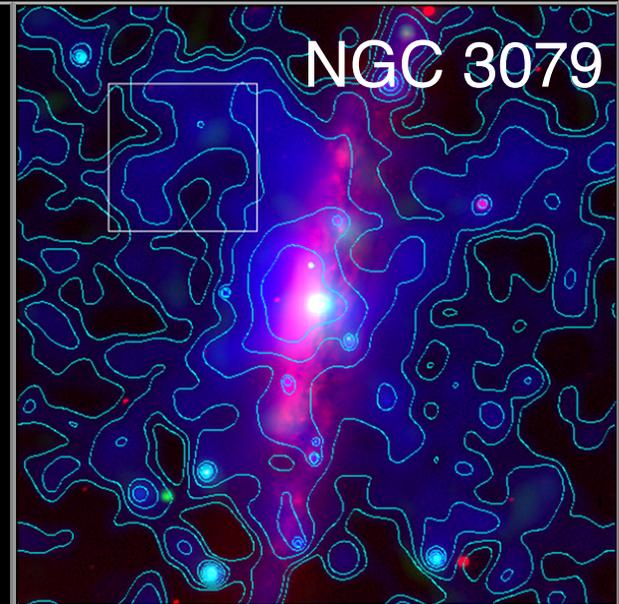
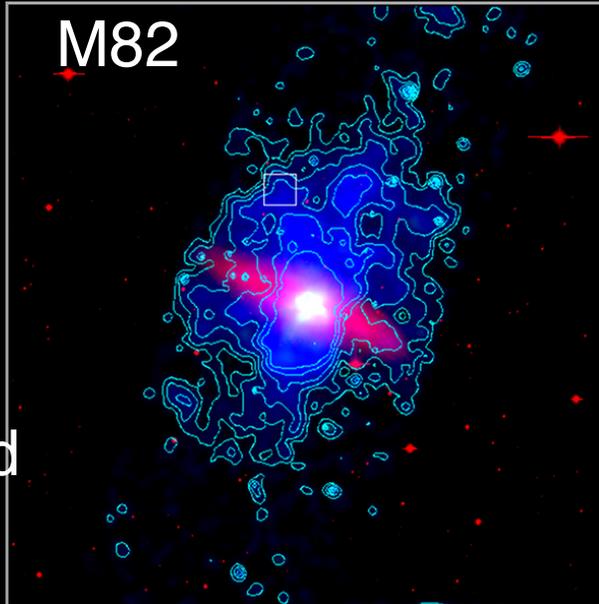


O VII and O VIII region (including Ne IX and Ne X). Well resolved triplet, high S/N in continuum.

Vel. Resolution $\sigma \sim 60-85$ km/s (escape speeds $\sim 300-700$ km/s)

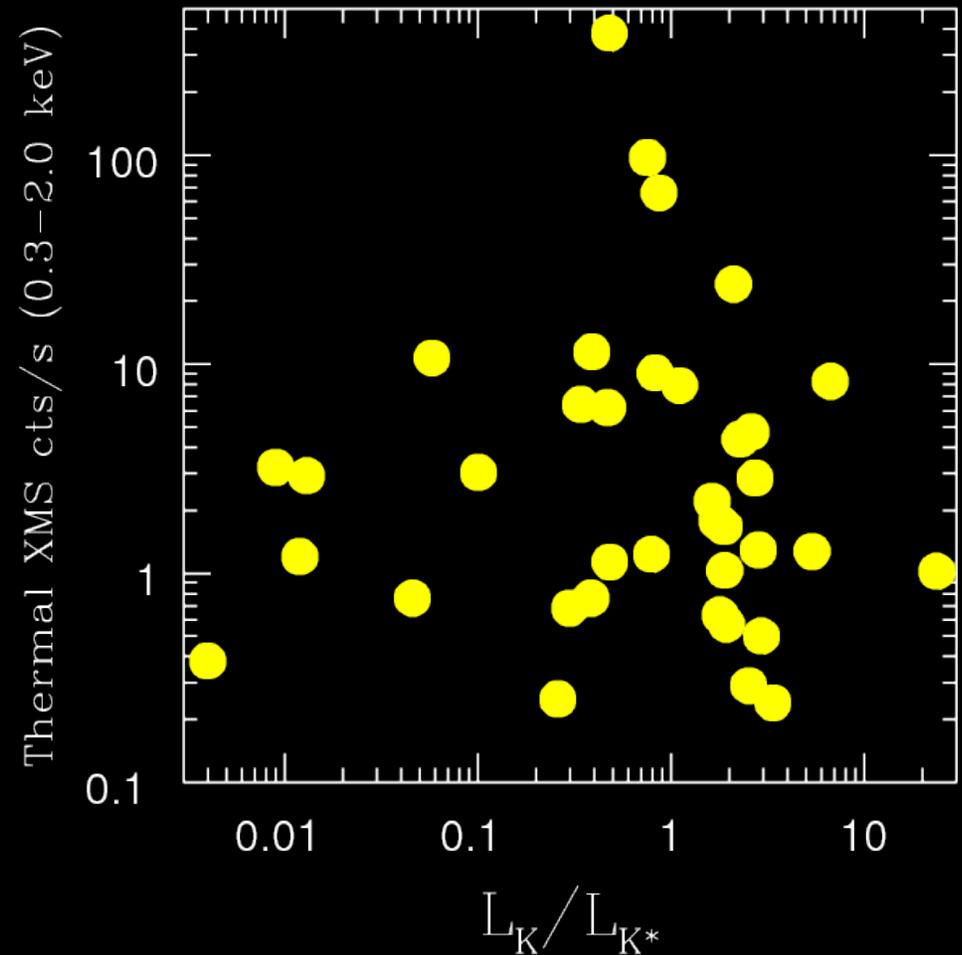
Targets & Observational Strategy

- Starburst sample spanning broad range of galaxy mass.
- Typical angular scales of superwind X-ray nebulae: 0.5 – 10 arcmin.
- Measure velocities in multiple regions per galaxy -> **outflow rates**



IXO Local Starburst Sample

- Predicted total galaxy+wind 0.3-2 keV XMS count rates for diffuse thermal emission (excluding point sources, based on Chandra/XMM)
- 35 representative targets with $D < 200$ Mpc.
- For 50000 cts/galaxy (~ 5 high quality spectra): 1.3 Ms for all 35 starbursts.



Summary

- *Modest* exposures of 35 nearest starburst galaxies will answer the question of how mass/metals escape from galaxies
- Decadal white paper focuses on simulations of these 35 galaxies, will include a link to a more detailed 'simulation webpage'

Thank you!



January 28, 2009

Ann Hornschemeier, Boston IXO Meeting

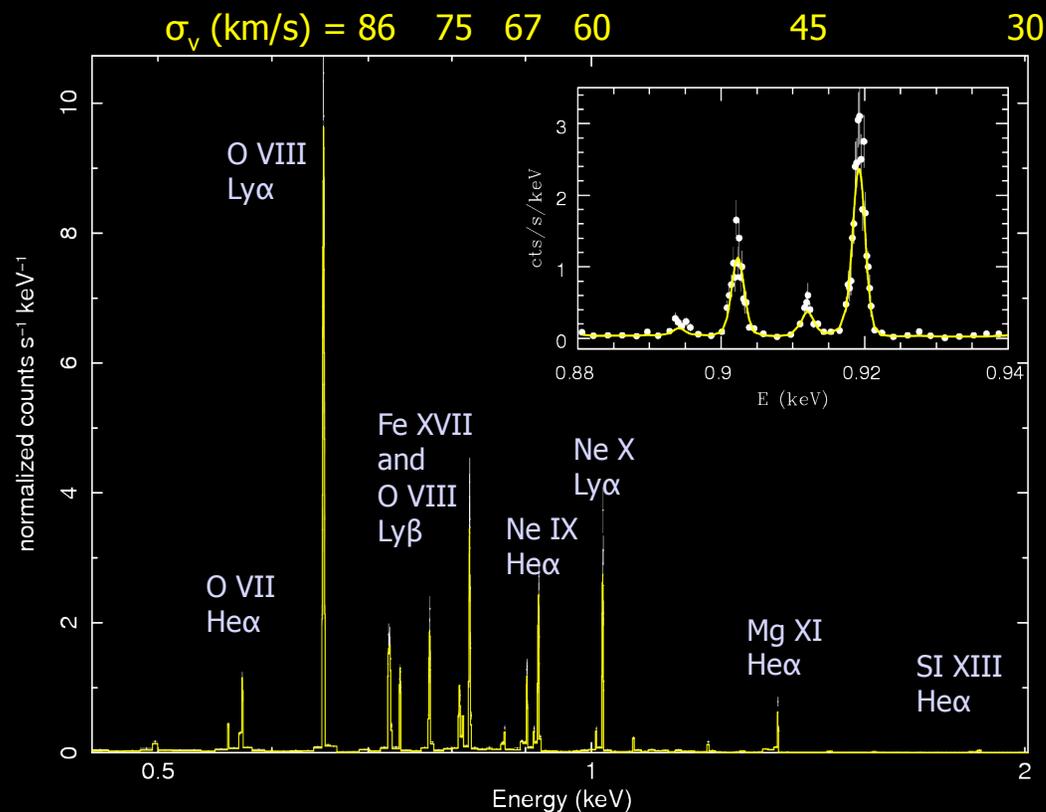
7

IXO XMS spectra of starburst winds (DETAILS)

Escape velocities for local superwind galaxies and Lyman Break galaxies with $M_* > 10^{10} M_{\text{sun}}$ are in the range 300 – 700 km/s

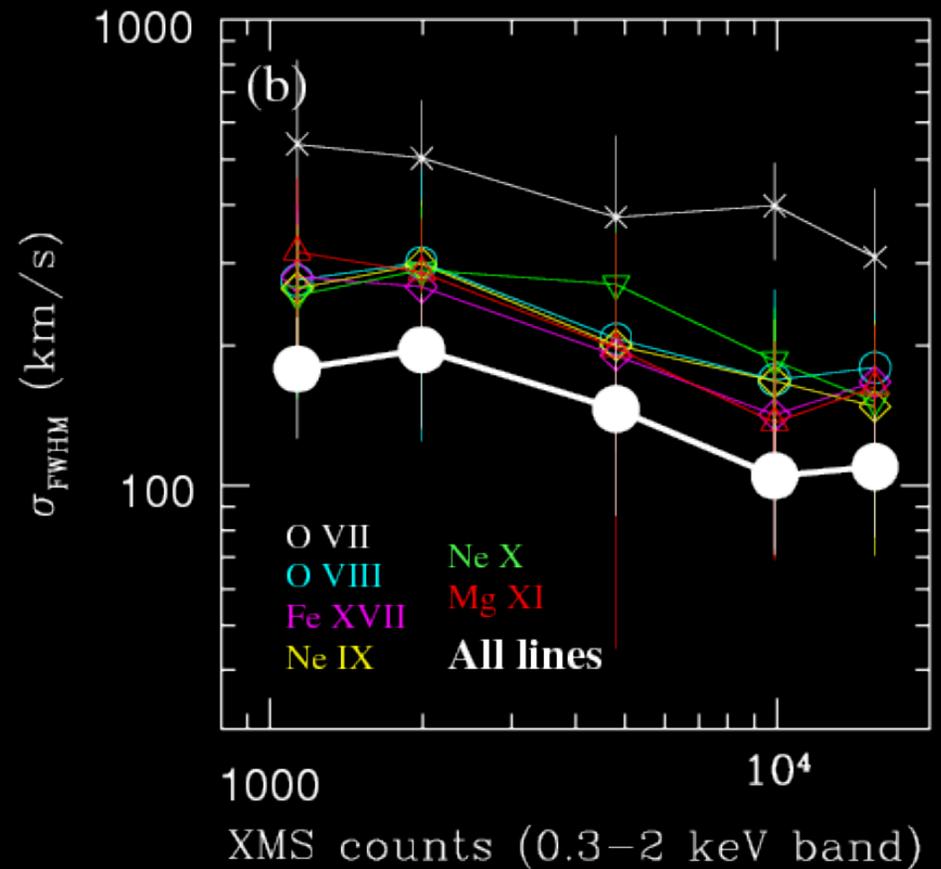
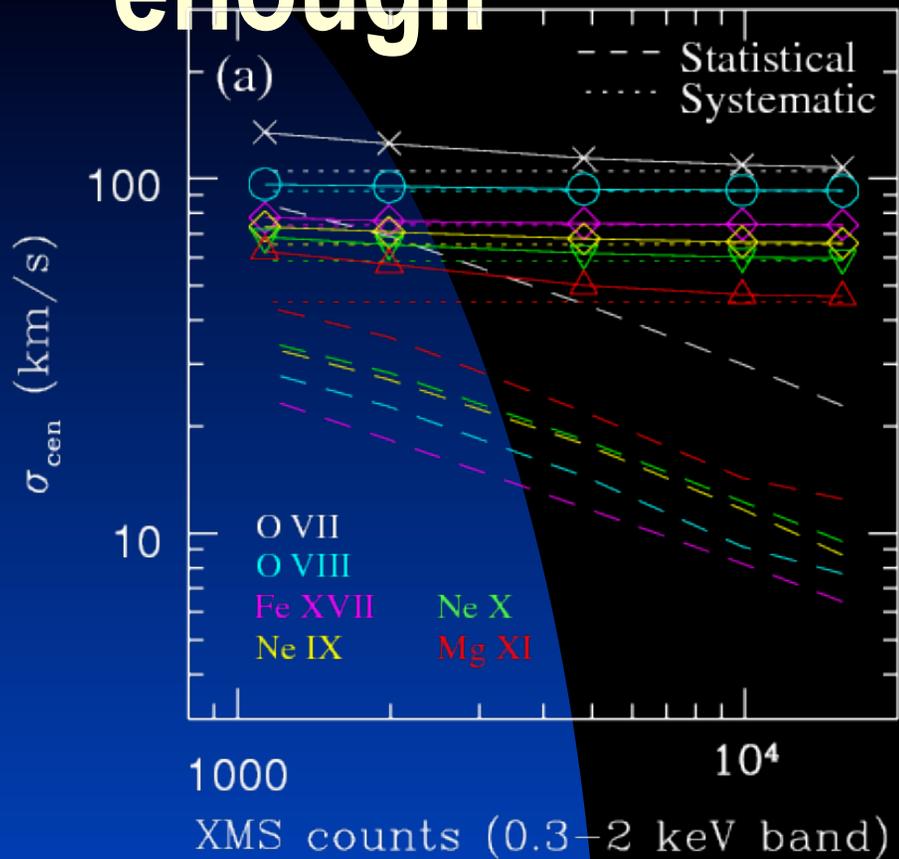
The XMS calorimeter can measure:

1. Individual X-ray line energies (redshifts) to an accuracy of ± 0.2 eV (see σ_v in figure)
2. Line widths to ± 200 km/s (individual soft X-ray lines) or ± 100 km/s (combining all soft X-ray lines) in < 100 ks exposures for even the faintest regions of currently detected superwinds



IXO XMS spectrum with 17000 detected counts (0.3-2 keV). For any line with > 40 counts the line redshift can be determined to the accuracy shown above (this is dominated by the systematic uncertainty in the energy scale).

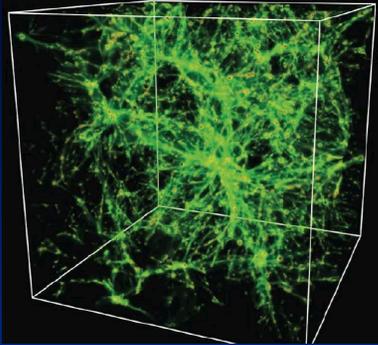
XMS velocity sensitivity: good enough



Caveats: (1) No background assumed.

Life Cycles of Matter and Energy

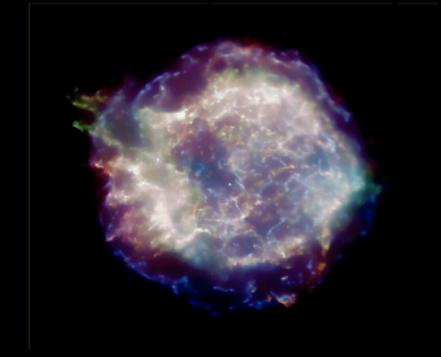
ICM heating and metal "pollution"



Super-winds launched from galaxies



Star formation



Supernovae/
Stellar winds