AGN Feedback in the X-ray Surveyor Era

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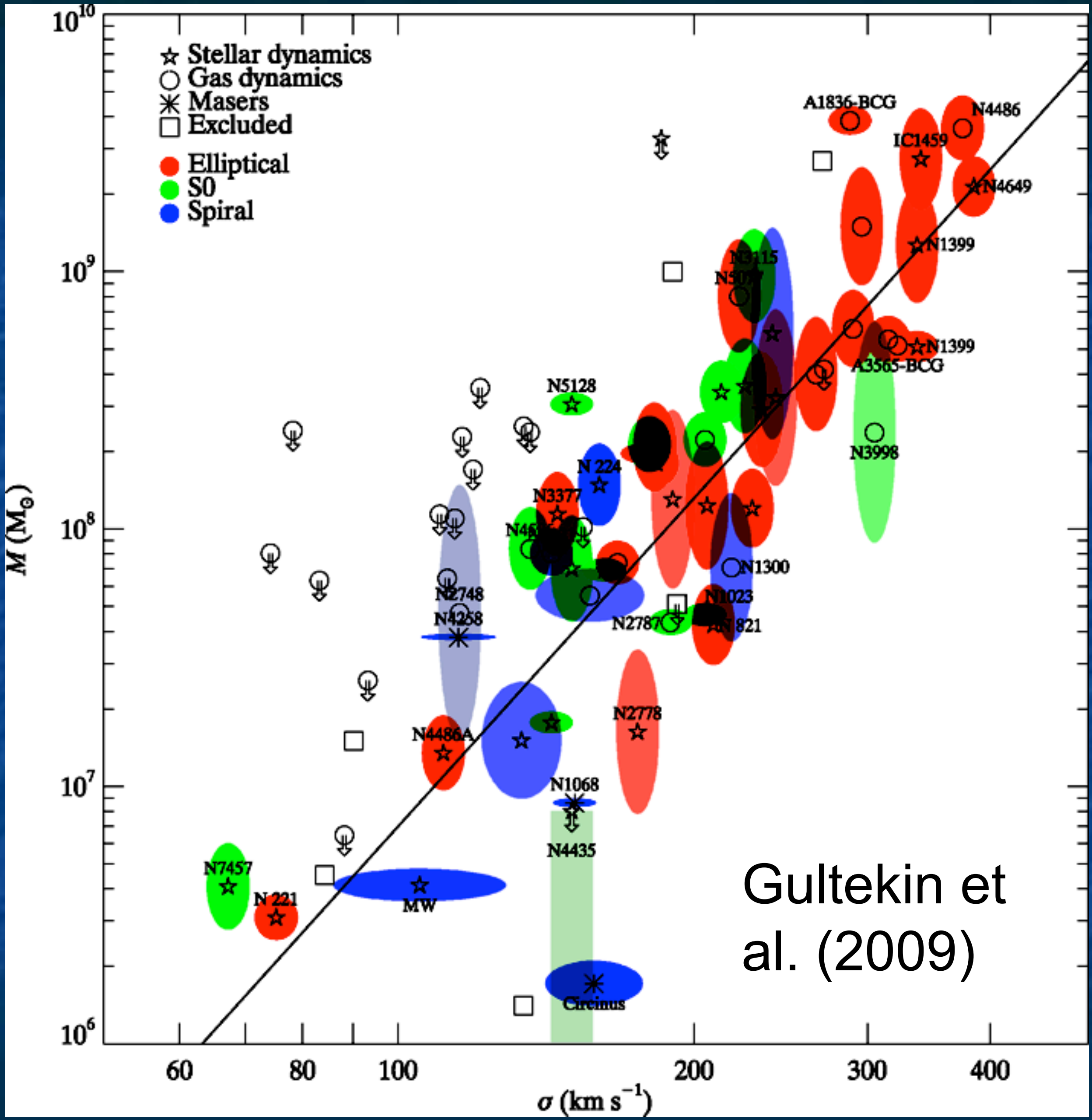
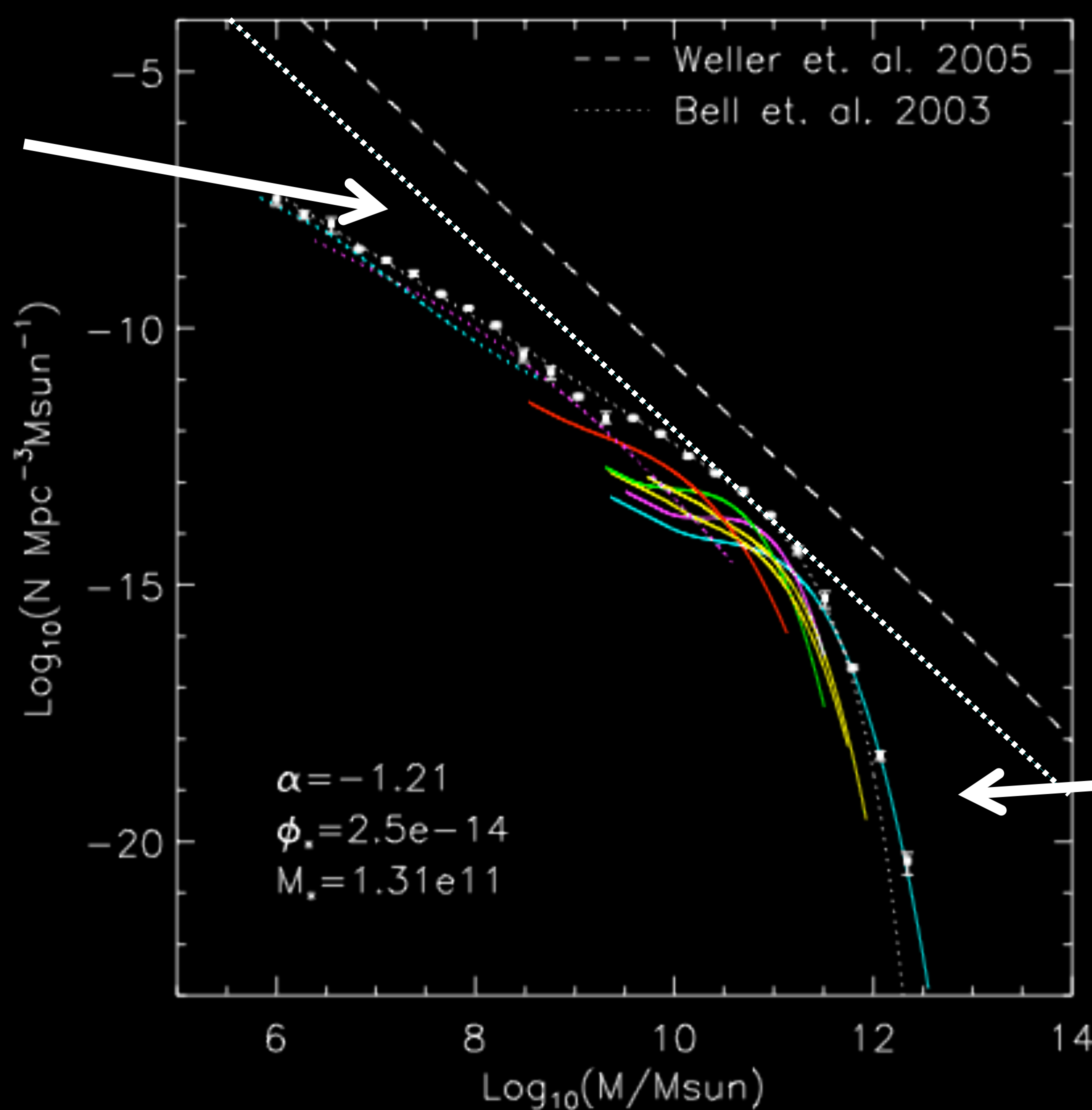

Stellar dynamics
Gas dynamics
Masers
Excluded
Elliptical
S0
Spiral
A1836-BCG
N4486
IC1459
N4649
N1399
N3115
N5077
N1399
A3565-BCG
N5128
N3998
N 224
N3377
N1300
N2748
N4258
N1023
N2787
N821
N4486A
N2778
N1068
N4435
N7457
N 221
MW
Circinus
M ($M_\odot$)
σ (km s^{-1})
Gultekin et al. (2009)

Read & Trentham (2005)

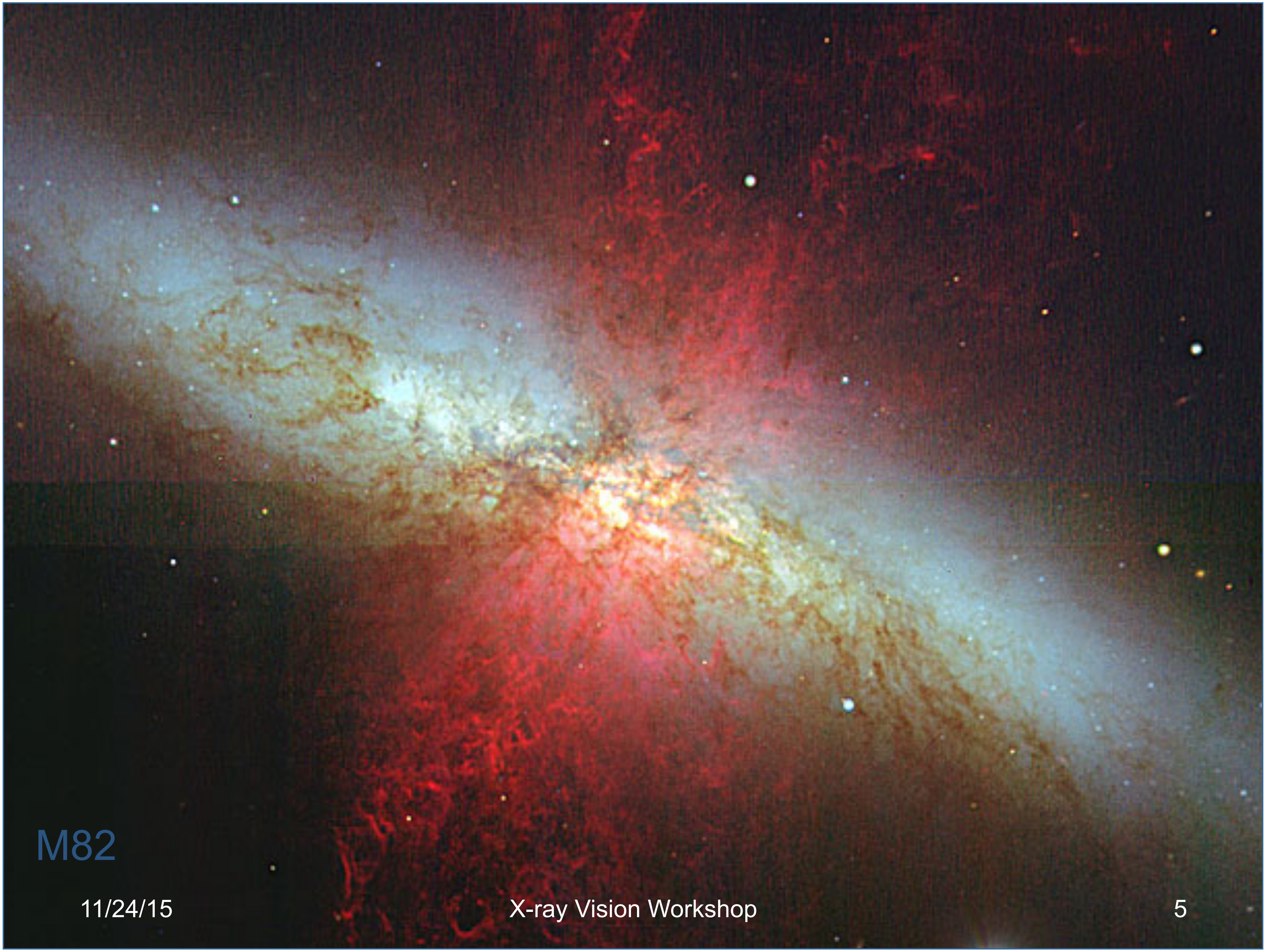
Too few low mass galaxies



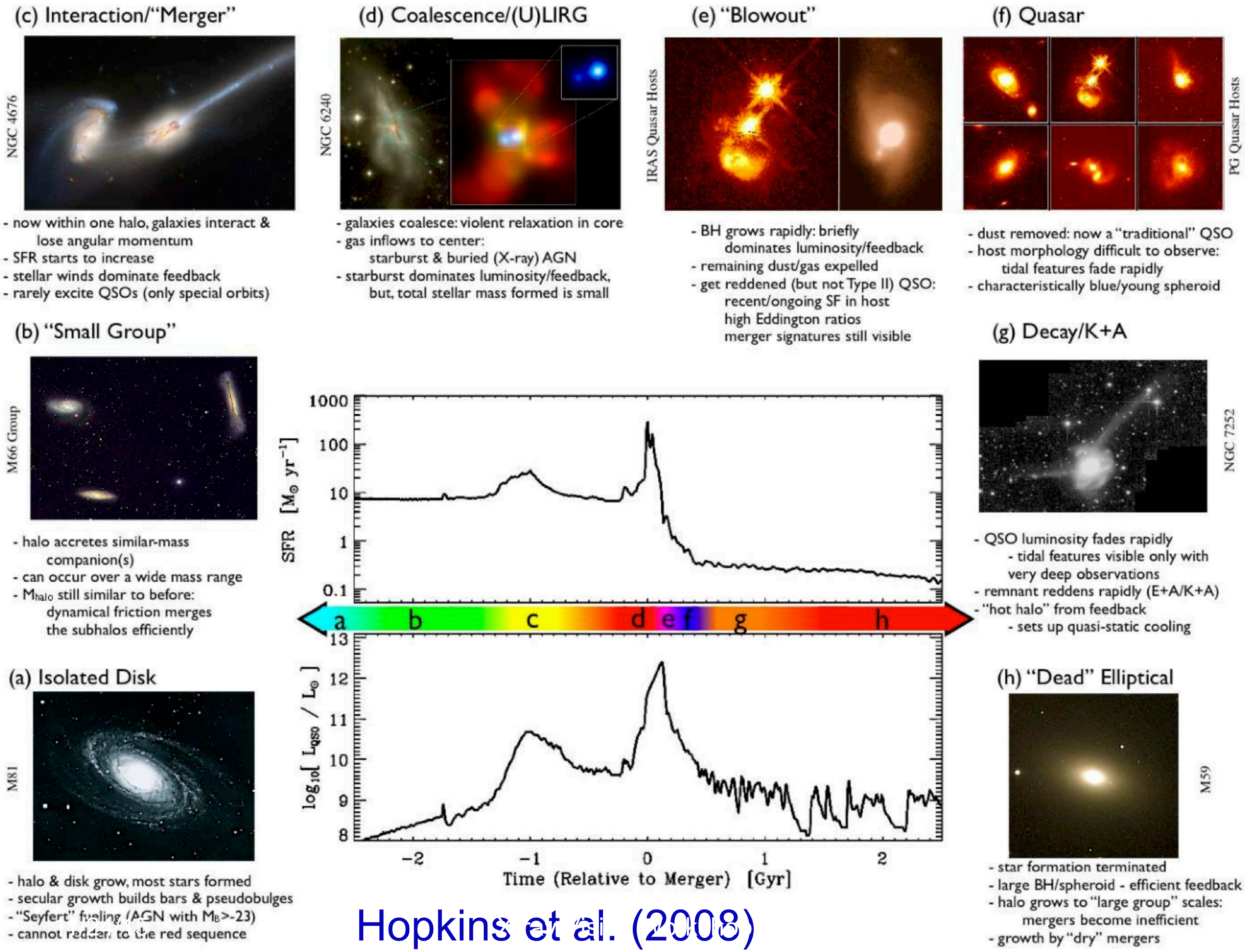
Too few high mass galaxies

The Big Questions

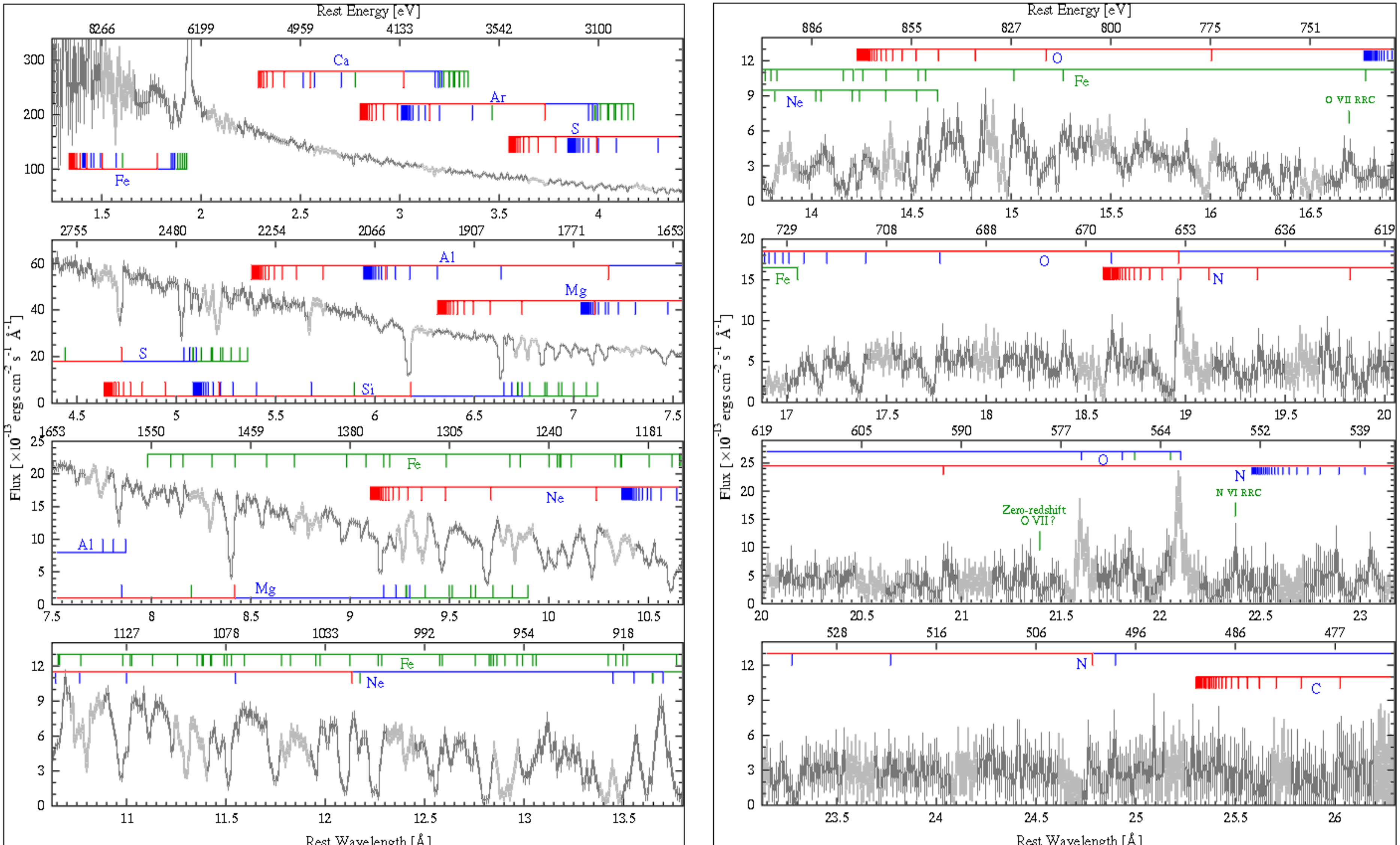
- What is the role of AGN feedback across the mass scale of galaxies?
- What are the physical processes mediating this feedback?
- How do feedback processes change over cosmic time?


M82

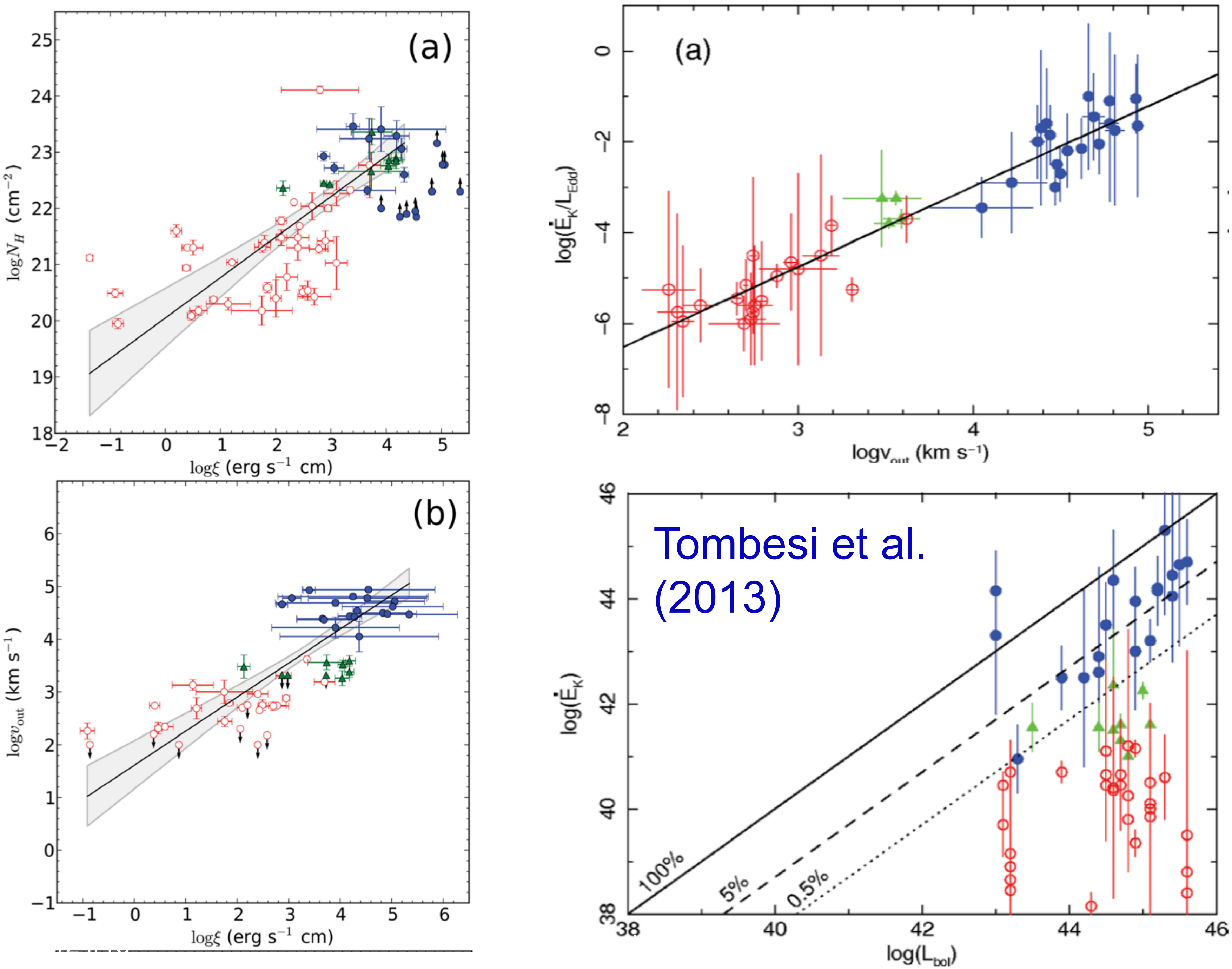
I : Quasar Mode Feedback



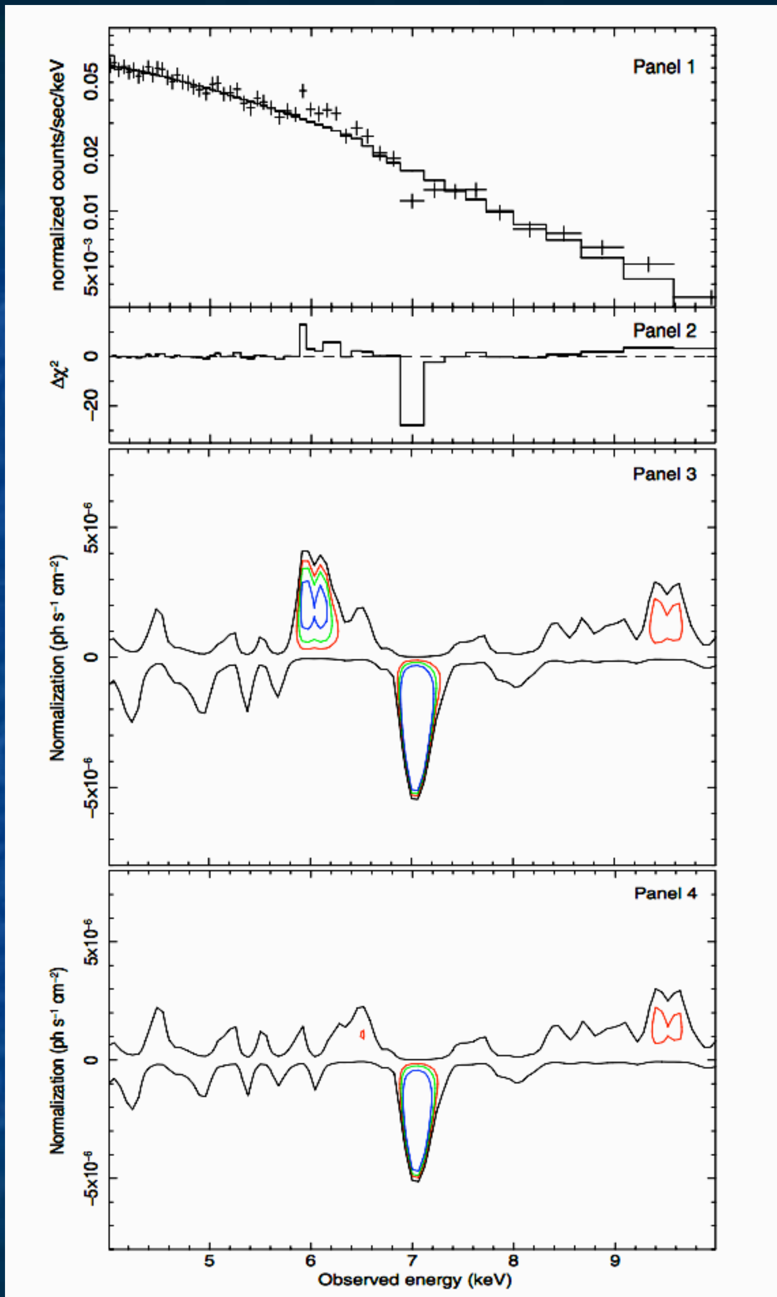
Hopkins et al. (2008)



Chandra 900ks HETG study of NGC3783 (Kaspi et al. 2002)

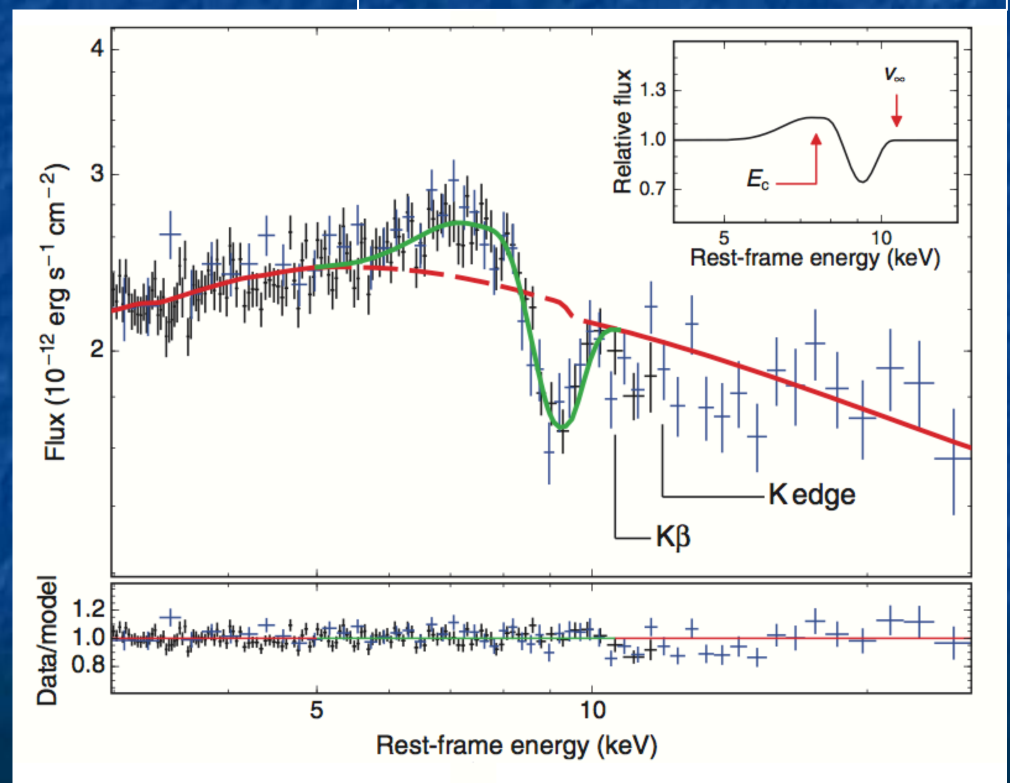


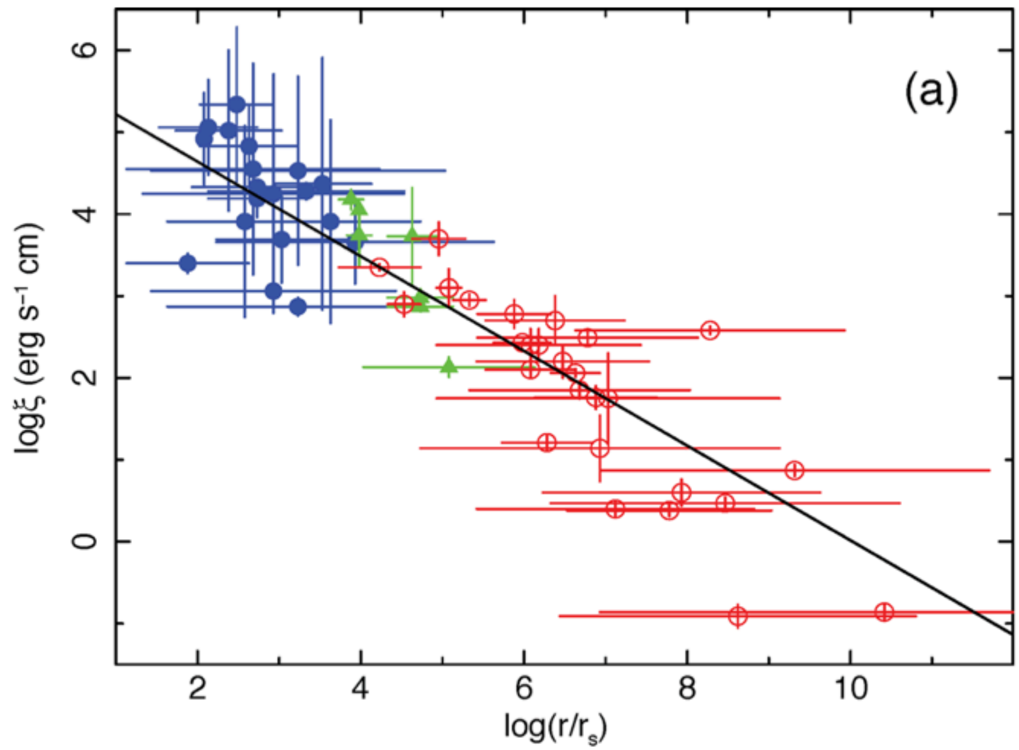
(a)
$\log N_H$ (cm^{-2})
$\log\xi$ (erg s^{-1} cm)
(b)
$\log v_{out}$ (km s^{-1})
$\log\xi$ (erg s^{-1} cm)
(a)
$\log(\dot{E}_K/L_{Edd})$
$\log v_{out}$ (km s^{-1})
Tombesi et al.
(2013)
$\log(\dot{E}_K)$
$\log(L_{bol})$
100%
5%
0.5%

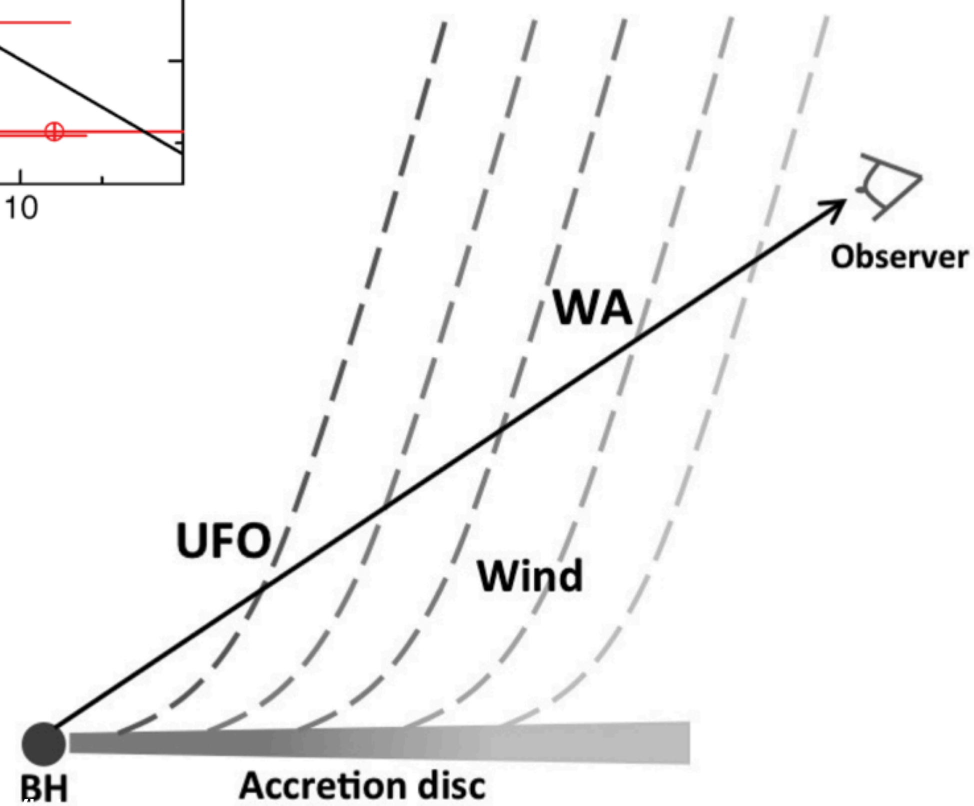


PG1211+143 w/XMM : Absorption line from v~0.1c outflow (Tombesi+2010; Pounds+2003)

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





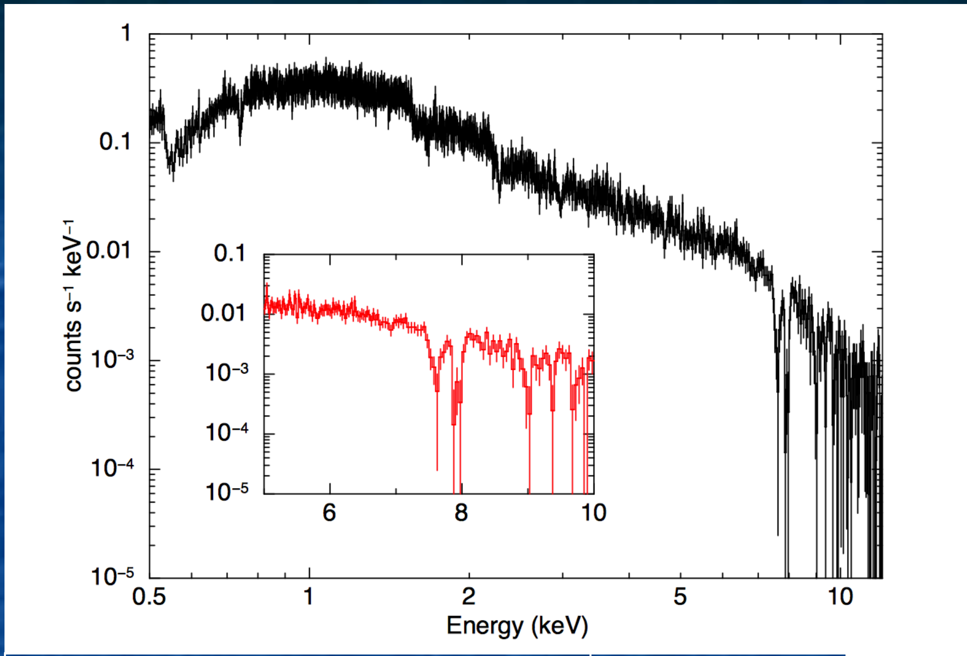


Stratified accretion disk wind

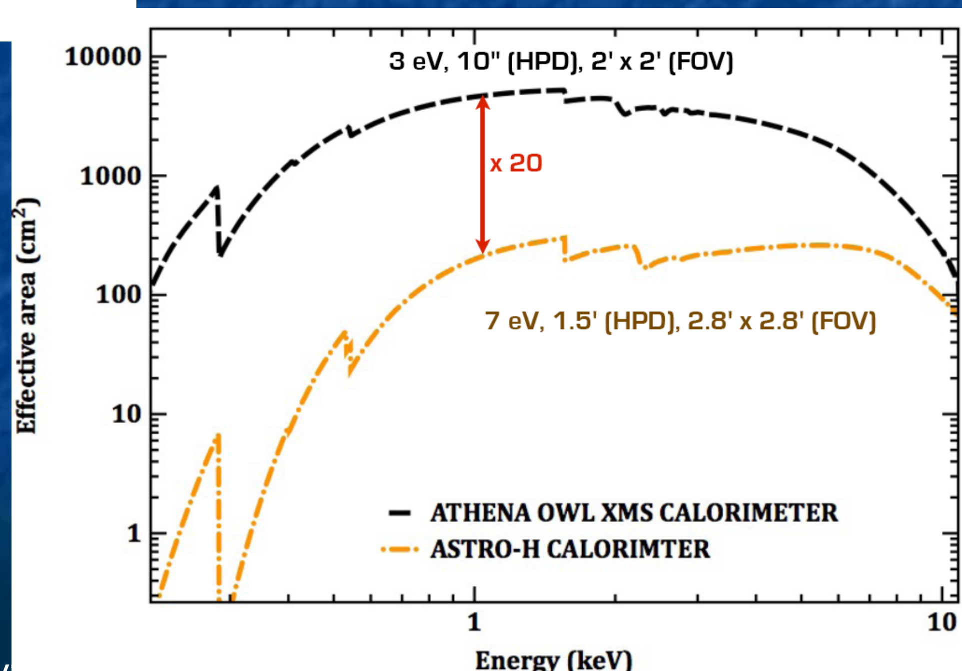
Tombesi et al. (2013)

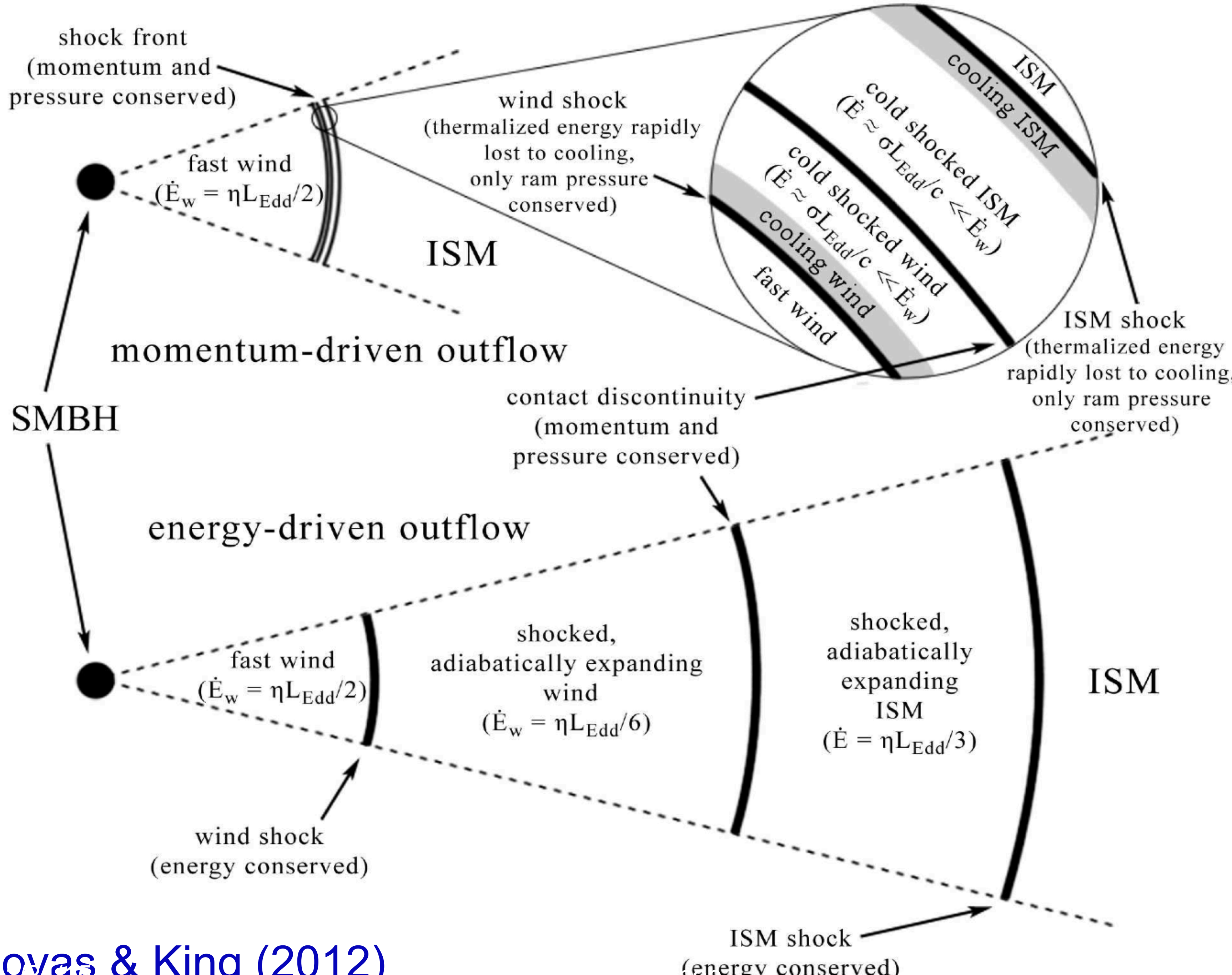
Future spectroscopic studies of fast outflows…

- Detailed velocity/ ionization structure
- Variability ➔ location



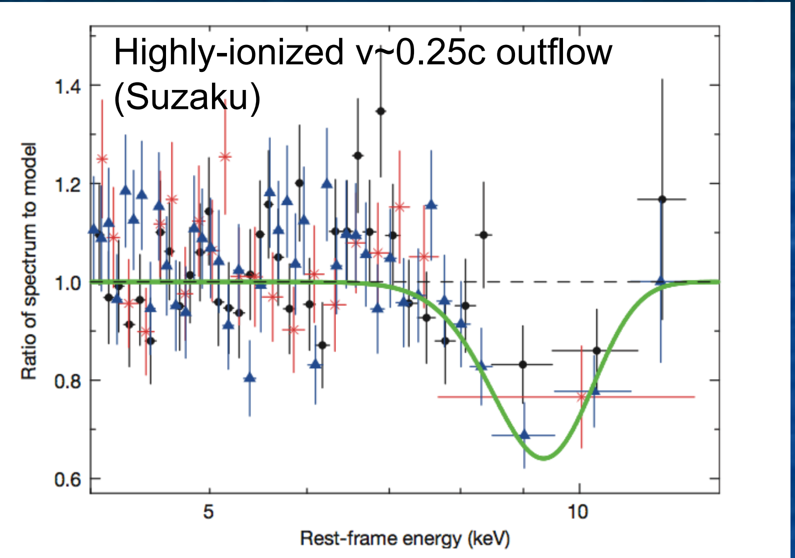
Simulated 100ks Astro-H observation of PDF456 (AGN Winds WP, Kaastra et al. 2014)

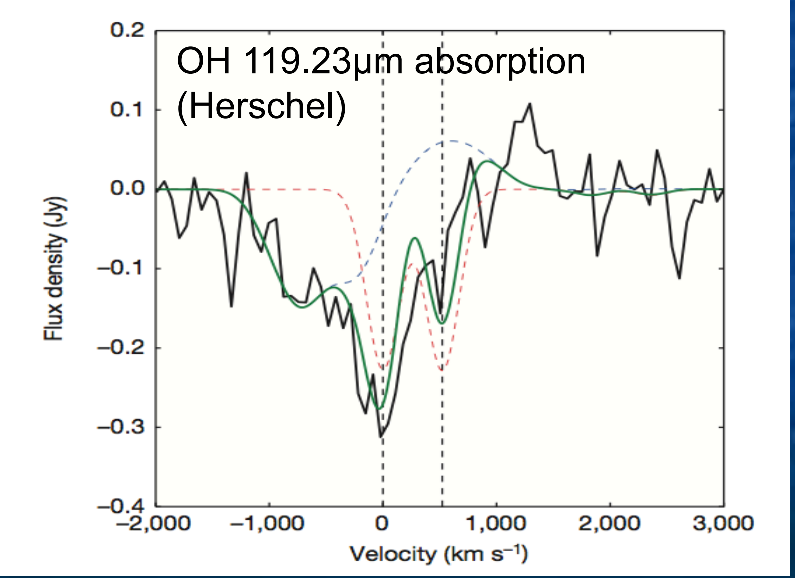




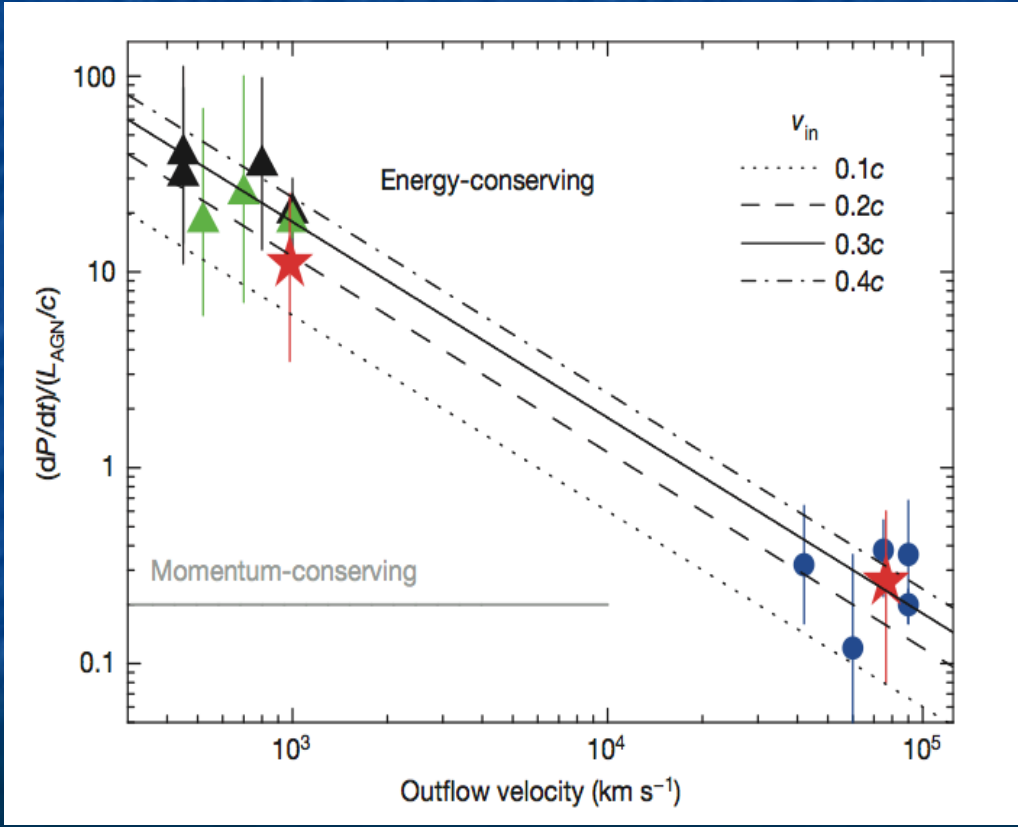
Zubovas & King (2012)

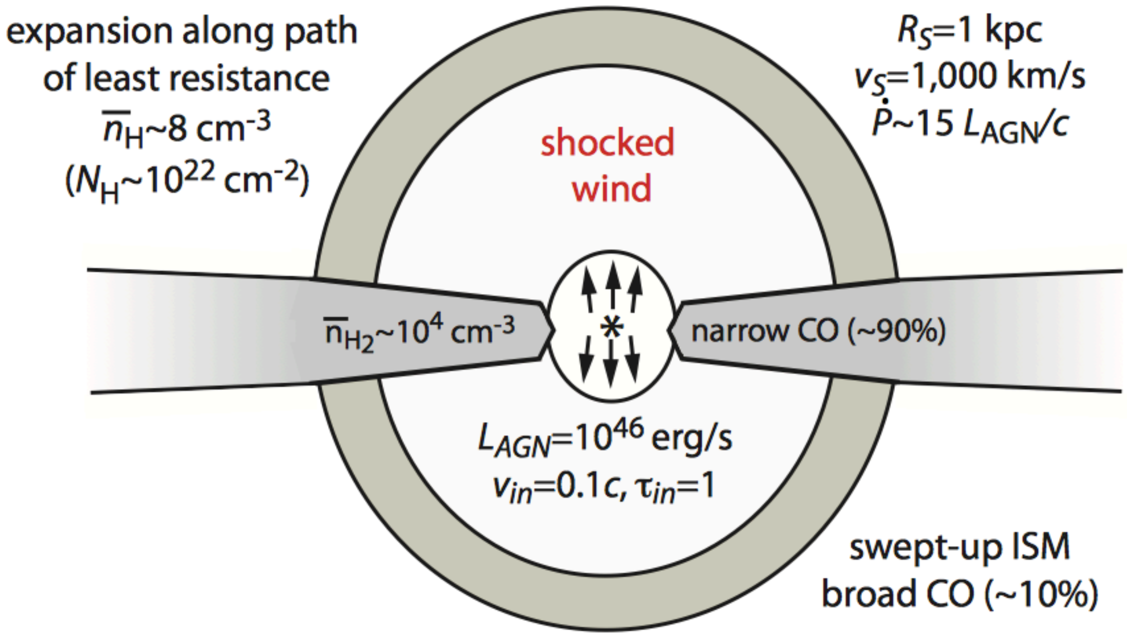
The z=0.18 ULIRG IRASF11119+3257 (Tombesi et al. 2015)





X-ray Surveyor + ALMA will obtain similar data on z=2 quasar





Faucher-Giguere & Quataert (2012)

Shocked wind bubble emits in X-rays…

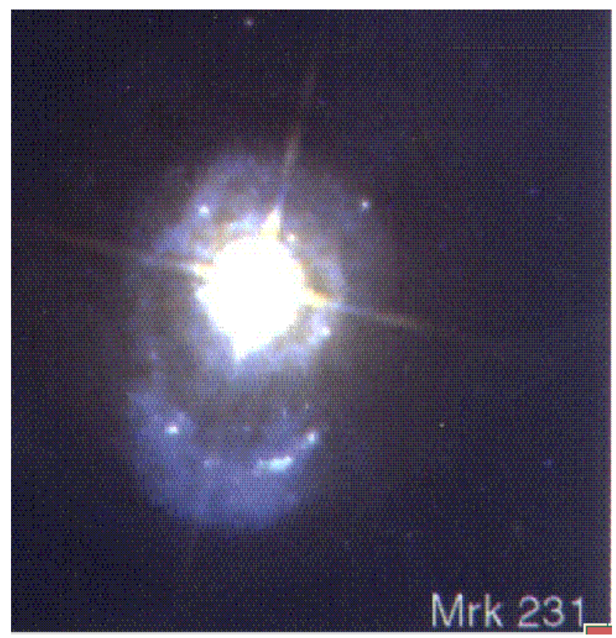
L_{brems}~10^{39} erg/s (peaking at 200keV)

L_{IC}~10^{41} erg/s (peaking at few keV)

Characteristic size of bubble is ~kpc

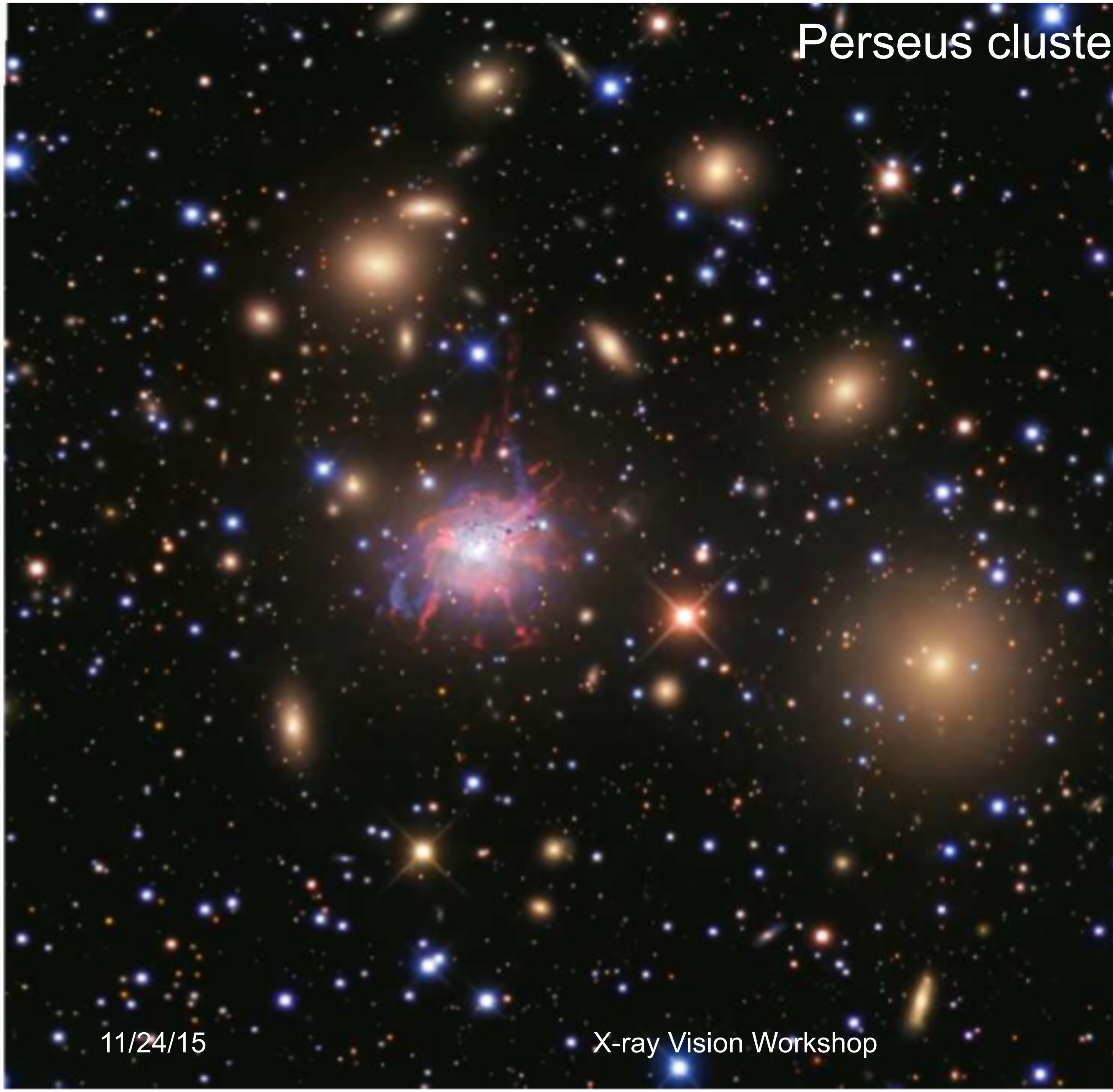
Resolvable by X-ray Surveyor out to z=0.1

(good candidate; Mrk231 at z=0.042)

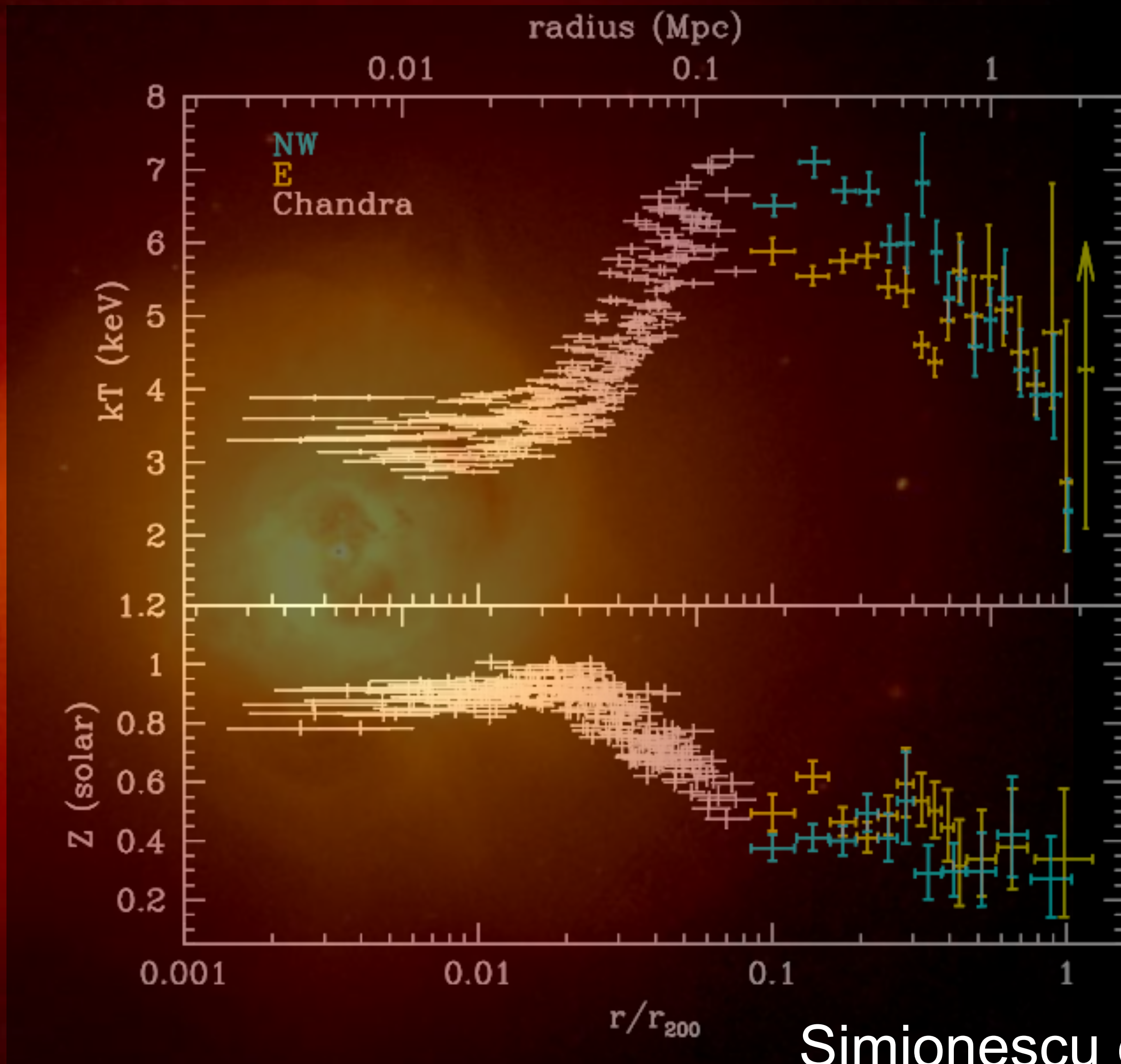


II : Radio mode feedback

Perseus cluster (Jay GaBany)

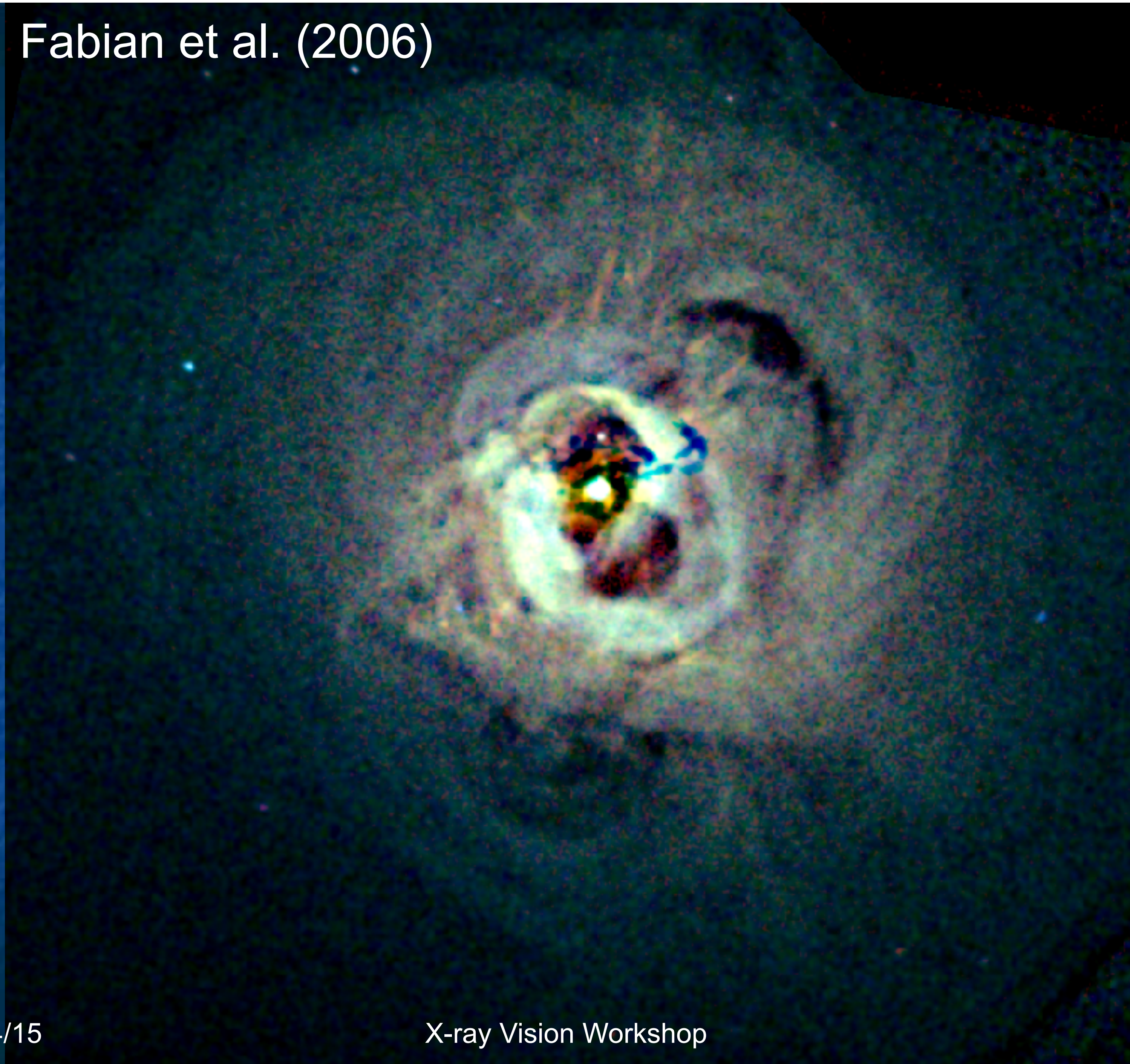


Fabian et al. (2010)



Simionescu et al. (2011)

Fabian et al. (2006)



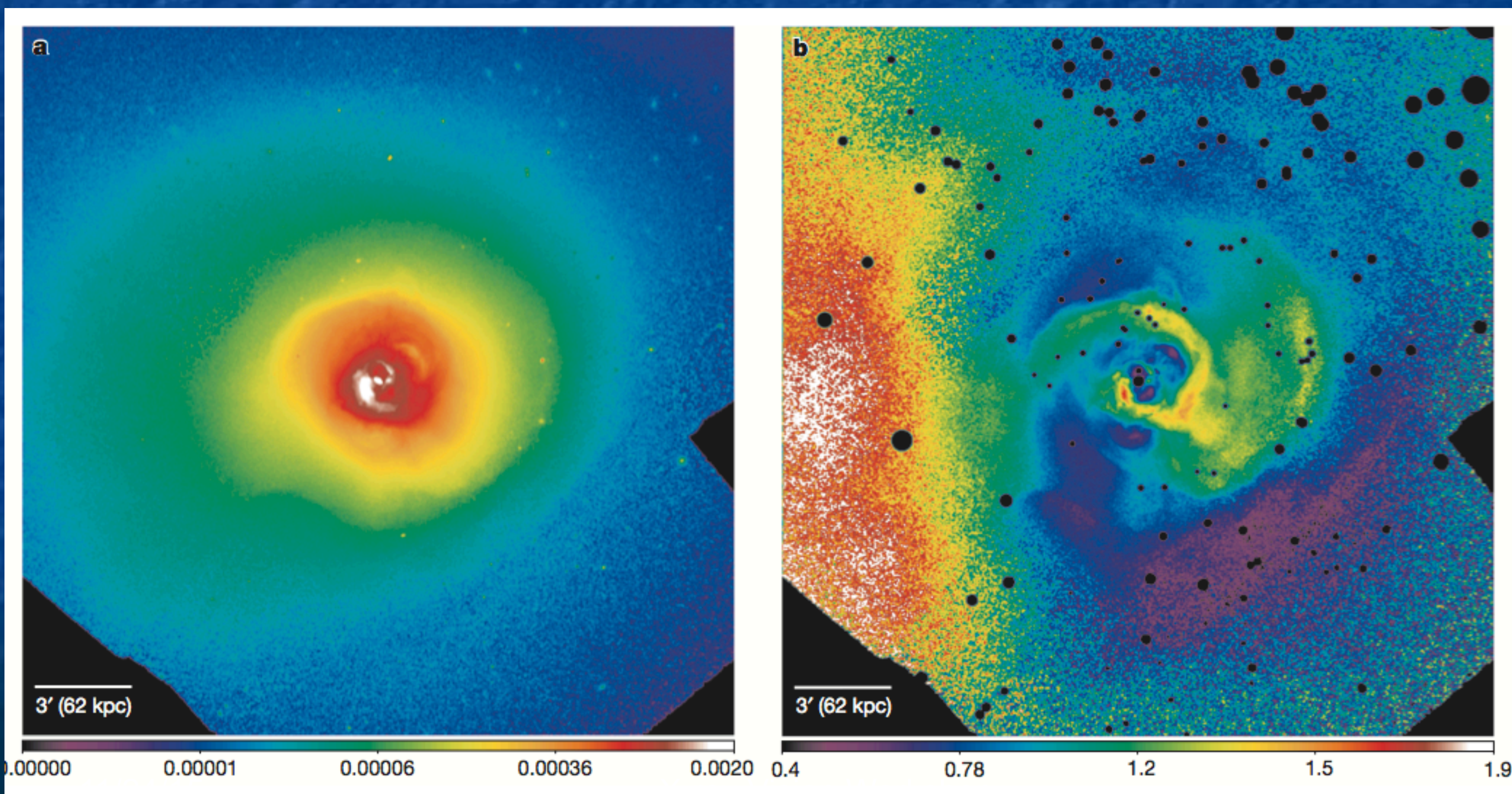
LETTER

doi:10.1038/nature13830

Turbulent heating in galaxy clusters brightest in X-rays

I. Zhuravleva[1,2], E. Churazov[3,4], A. A. Schekochihin[5,6], S. W. Allen[1,2,7], P. Arévalo[8,9], A. C. Fabian[10], W. R. Forman[11], J. S. Sanders[12], A. Simionescu[13], R. Sunyaev[3,4], A. Vikhlinin[11] & N. Werner[1,2]

Zhuravleva et al. (2014)



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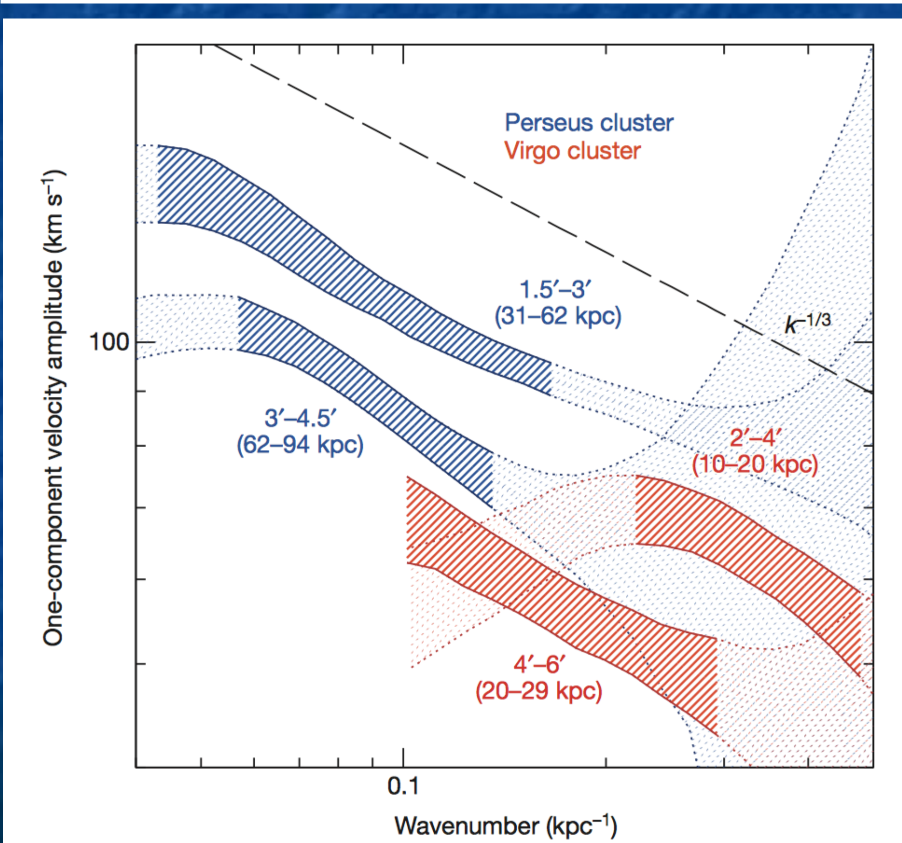
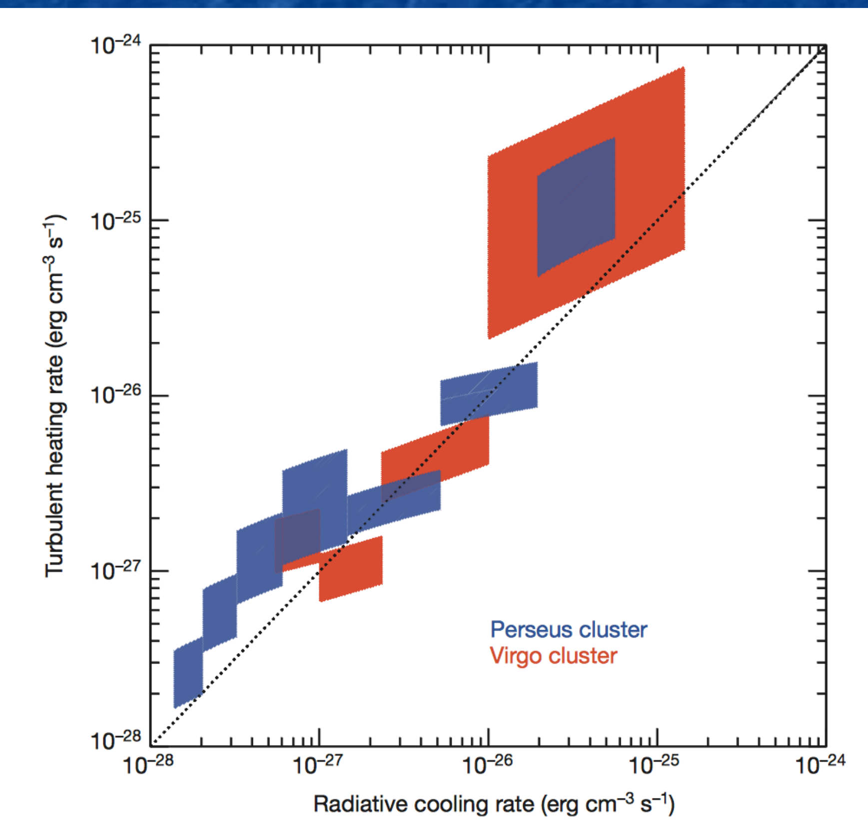
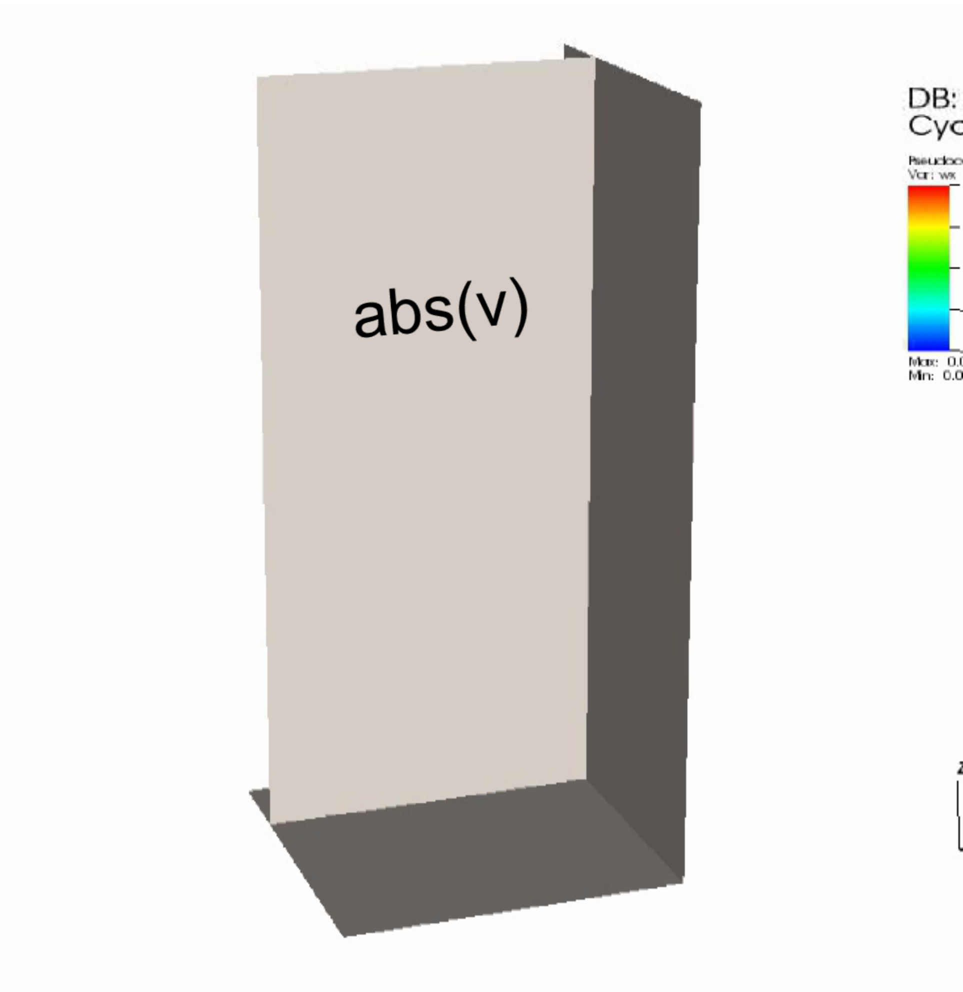
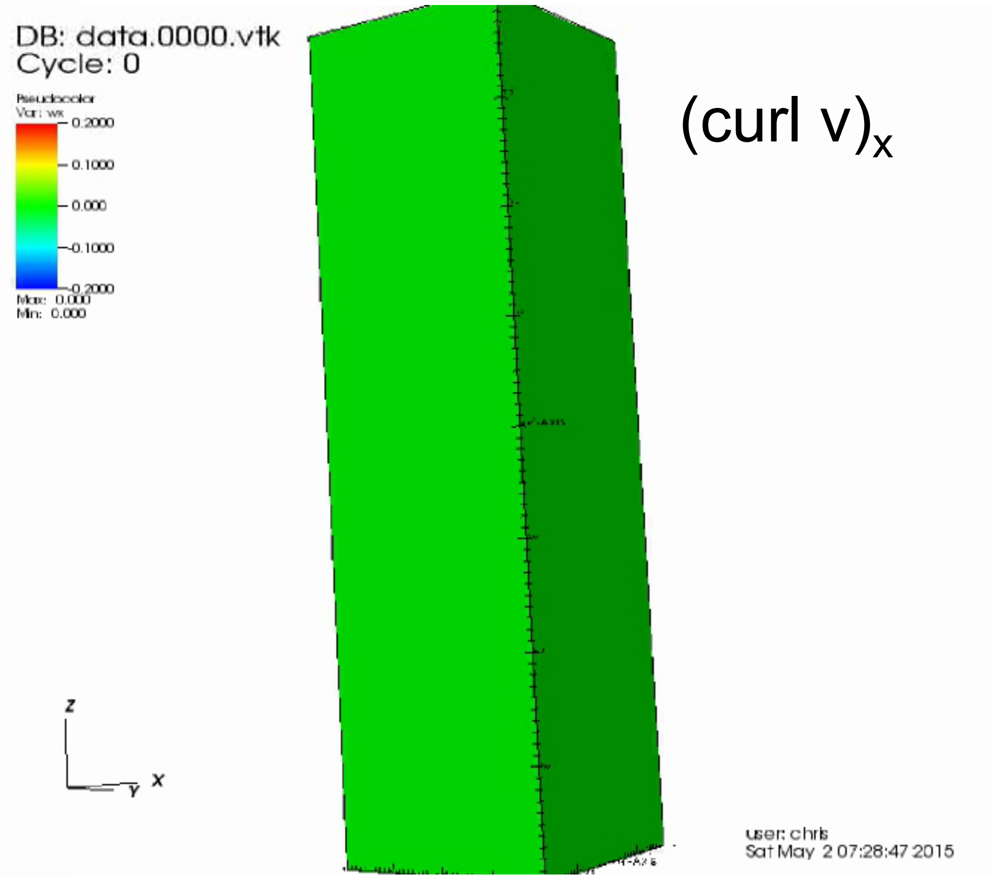
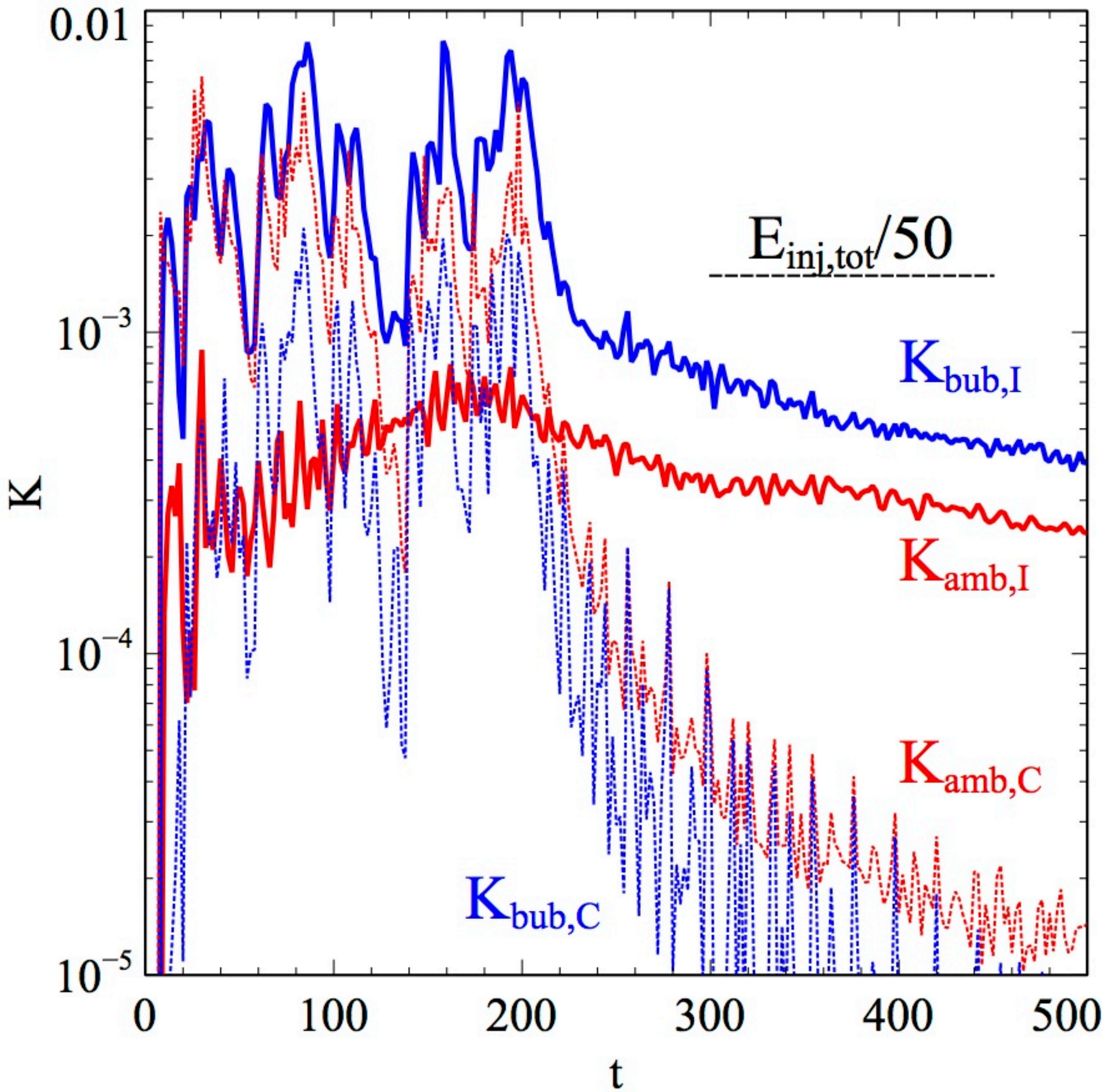




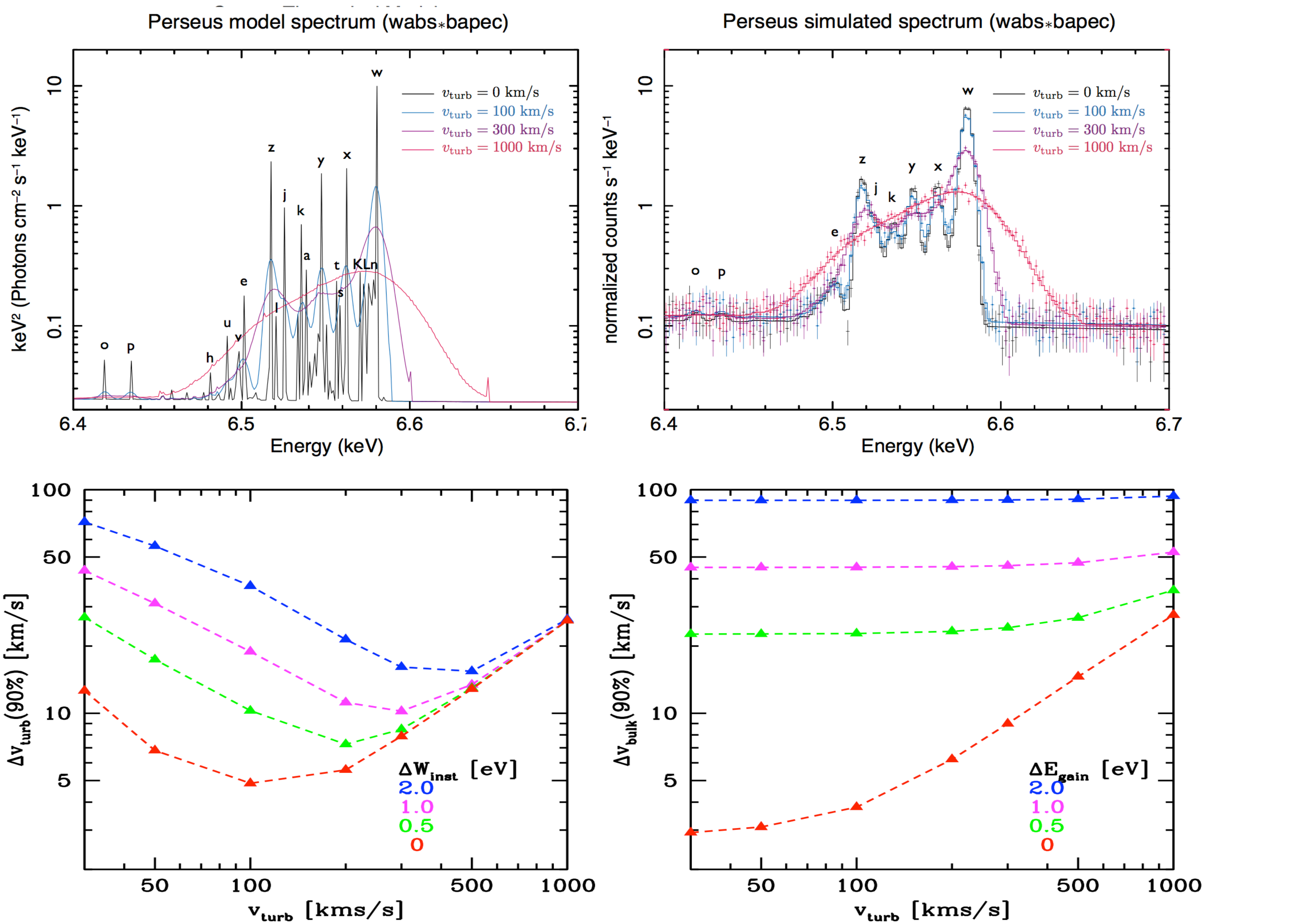




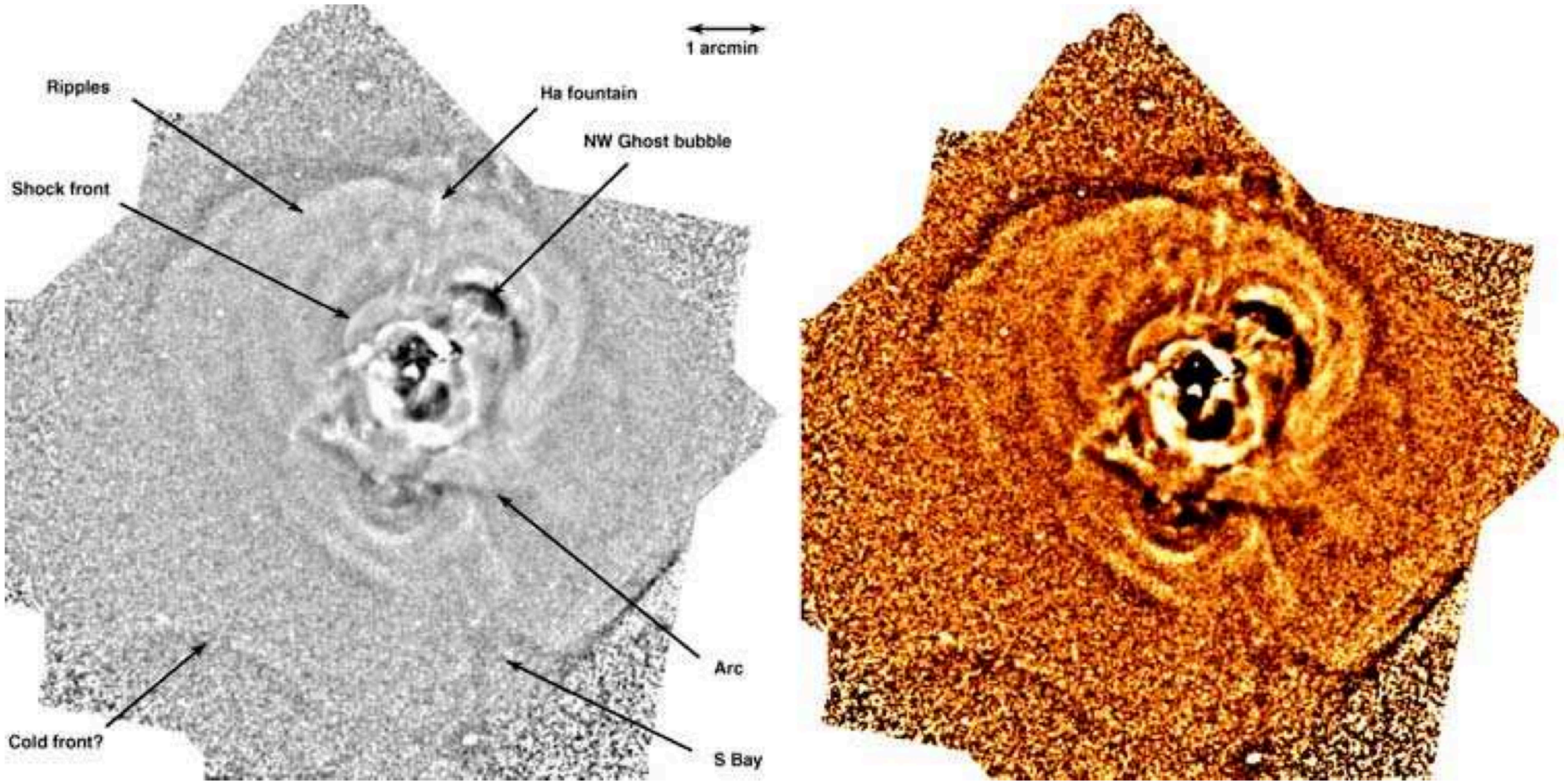
Toy model for driving if ICM turbulence by AGN outbursts…
AGN does indeed drive turbulence through g-mode decay, but energy transfer from AGN to ICM turbulence is very inefficient (Reynolds et al. 2015)



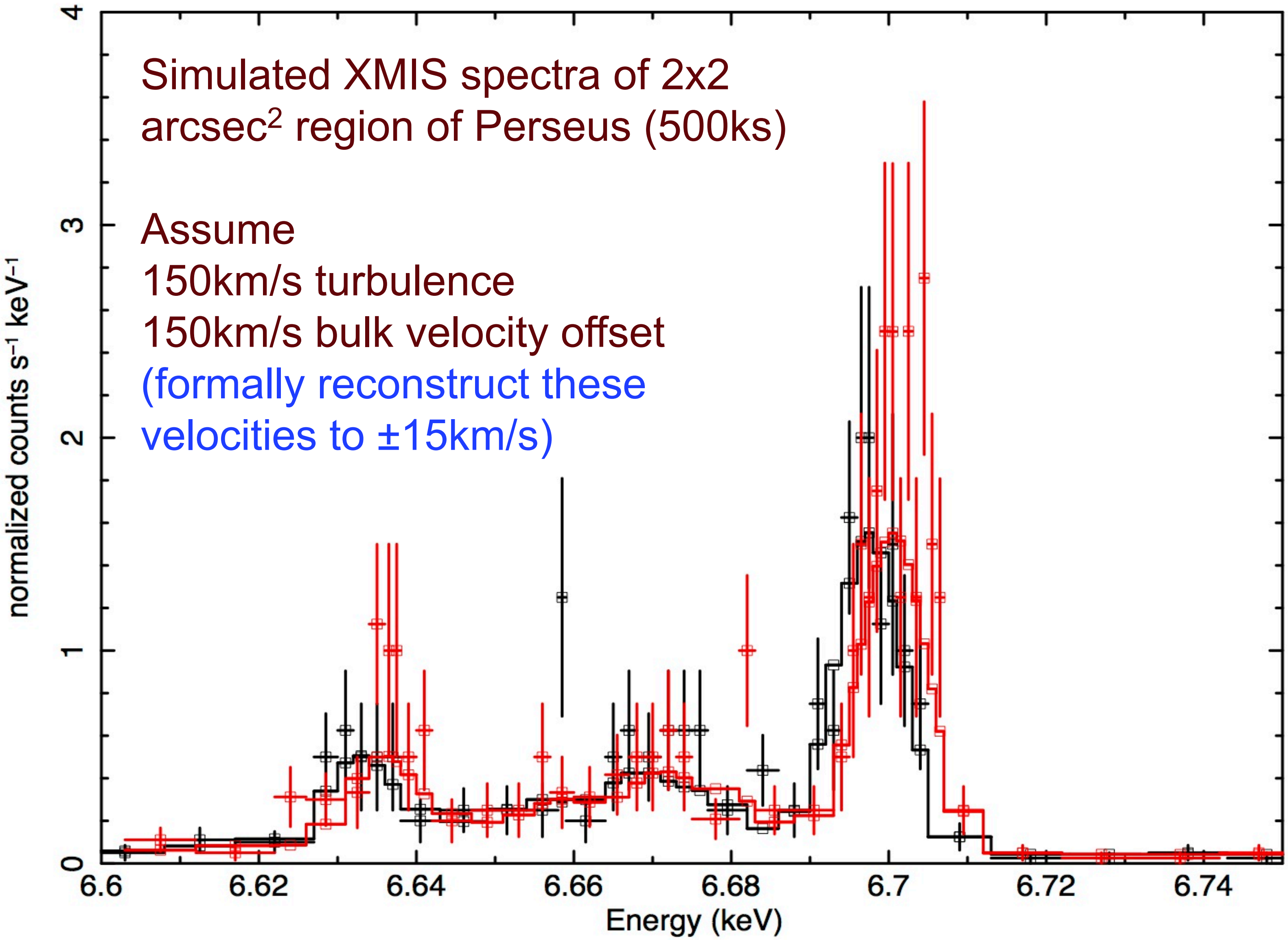
0.01
10^{-3}
10^{-4}
10^{-5}
K
0
100
200
300
400
500
t
$E_{inj,tot}/50$
$K_{bub,I}$
$K_{amb,I}$
$K_{amb,C}$
$K_{bub,C}$

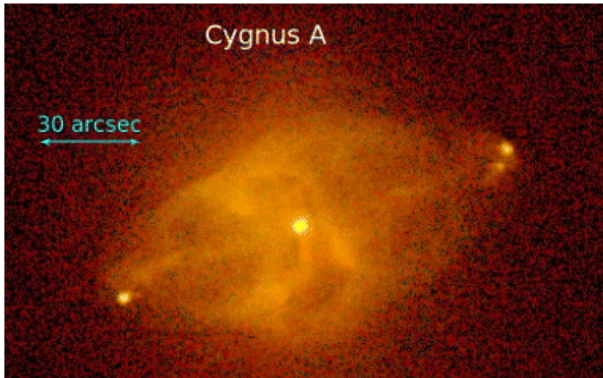


Astro-H simulations of Perseus (Astro-H Cluster White Paper)

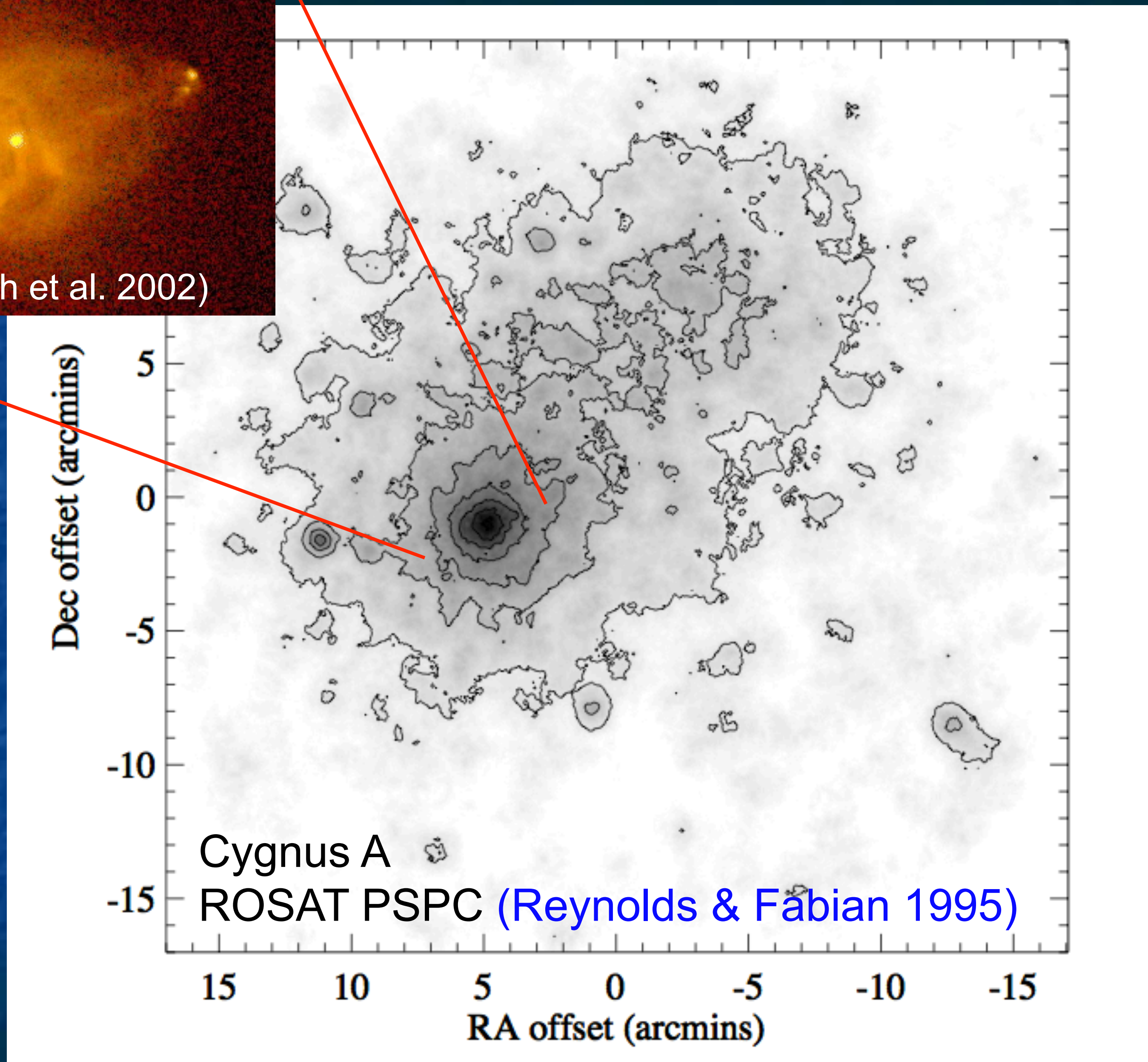


Unsharp-mask image of Perseus (10arcsec smoothed structure subtracted out) Sanders et al. (2006)


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)
normalized counts s^{-1} keV^{-1}
Energy (keV)
0
1
2
3
4
6.6
6.62
6.64
6.66
6.68
6.7
6.72
6.74

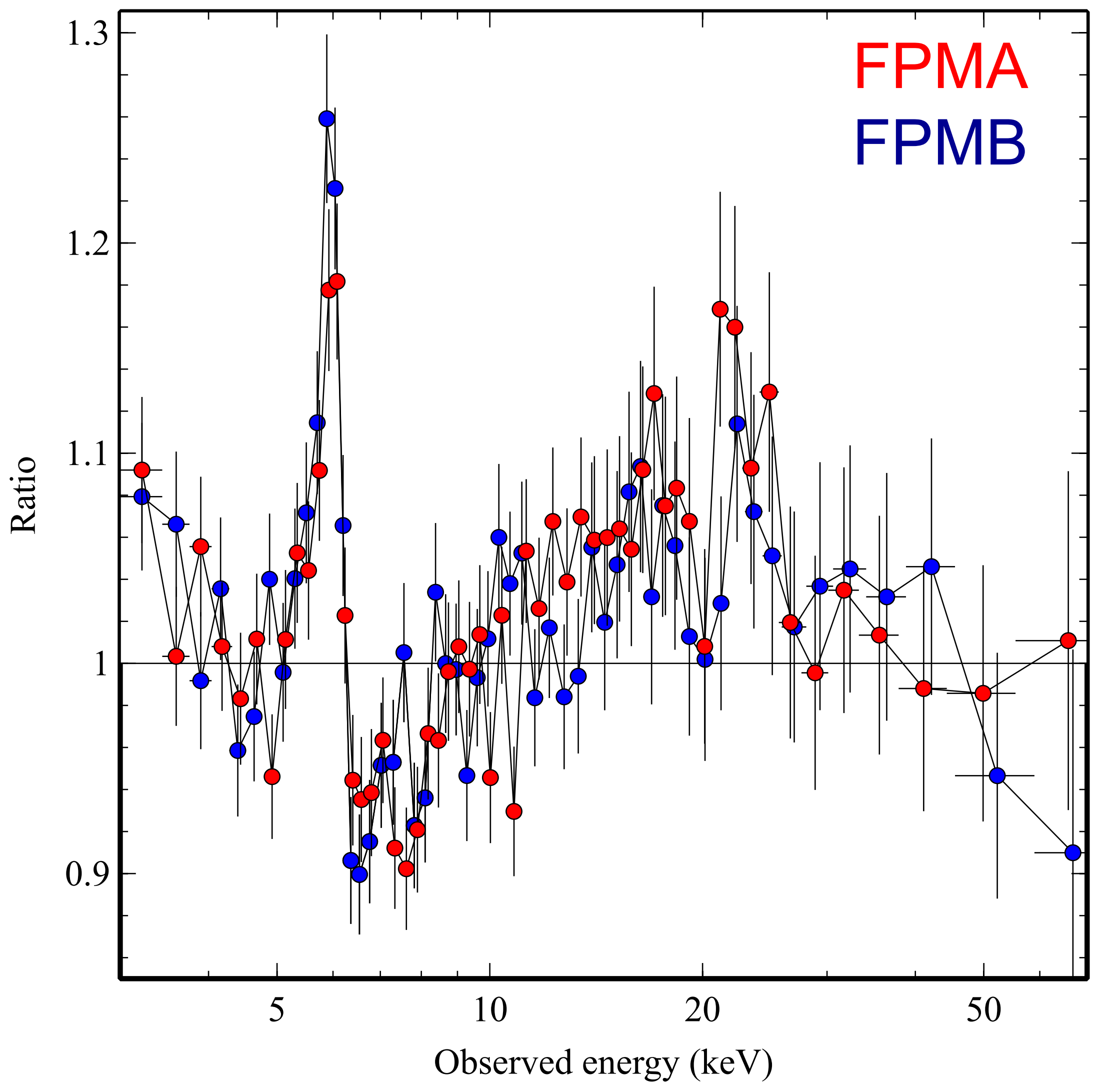


Chandra (Smith et al. 2002)

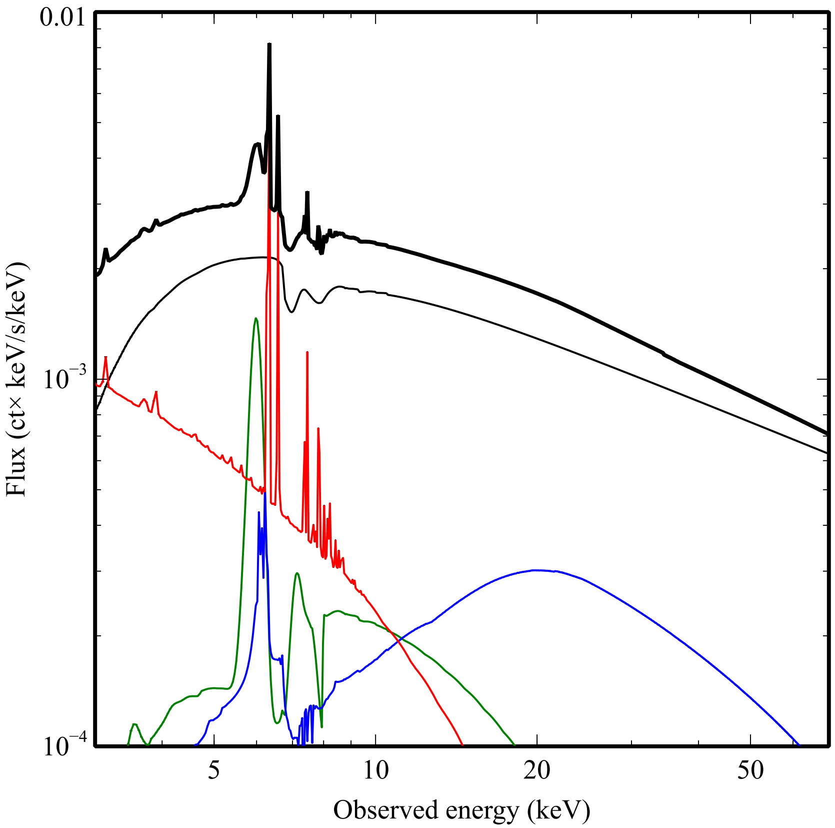


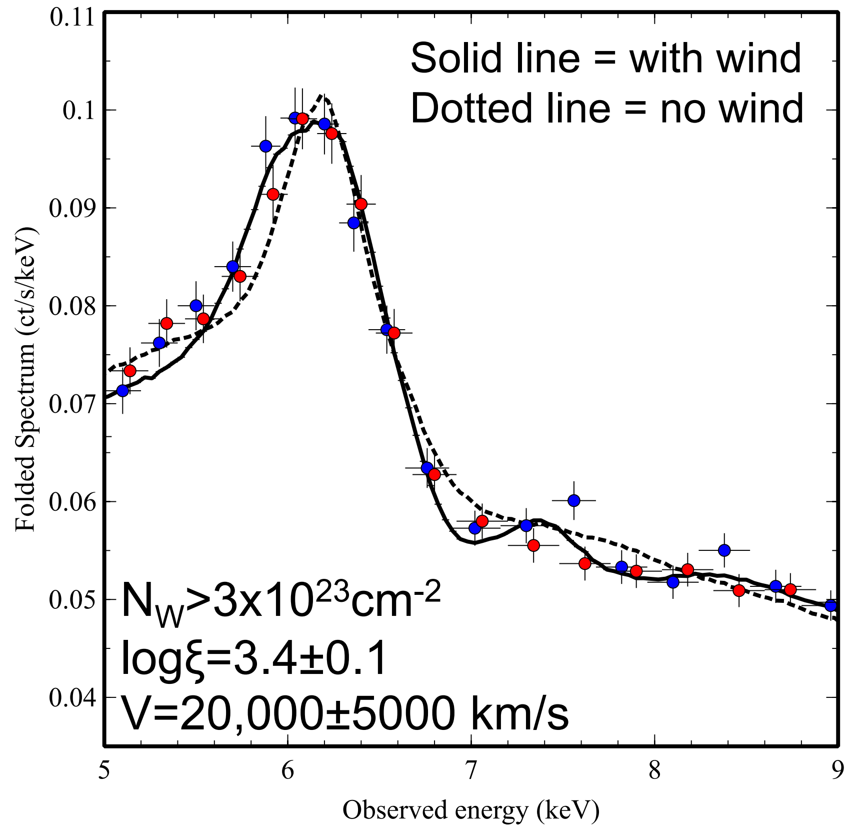
Cygnus A
ROSAT PSPC (Reynolds & Fabian 1995)

Cygnus A w/NuSTAR (Reynolds et al. 2015)



Best fitting NuSTAR model to Cygnus-A





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… $M_{dot} = 110\ (L_{bol}/c^2)$
  - Momentum flux… $P_{tot} = 10\ (L_{bol}/c)$
  - Kinetic energy flux… $L_K = 0.42\ L_{bol}$
- 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