

# Small-scale turbulence in giant elliptical galaxies

**Norbert Werner**

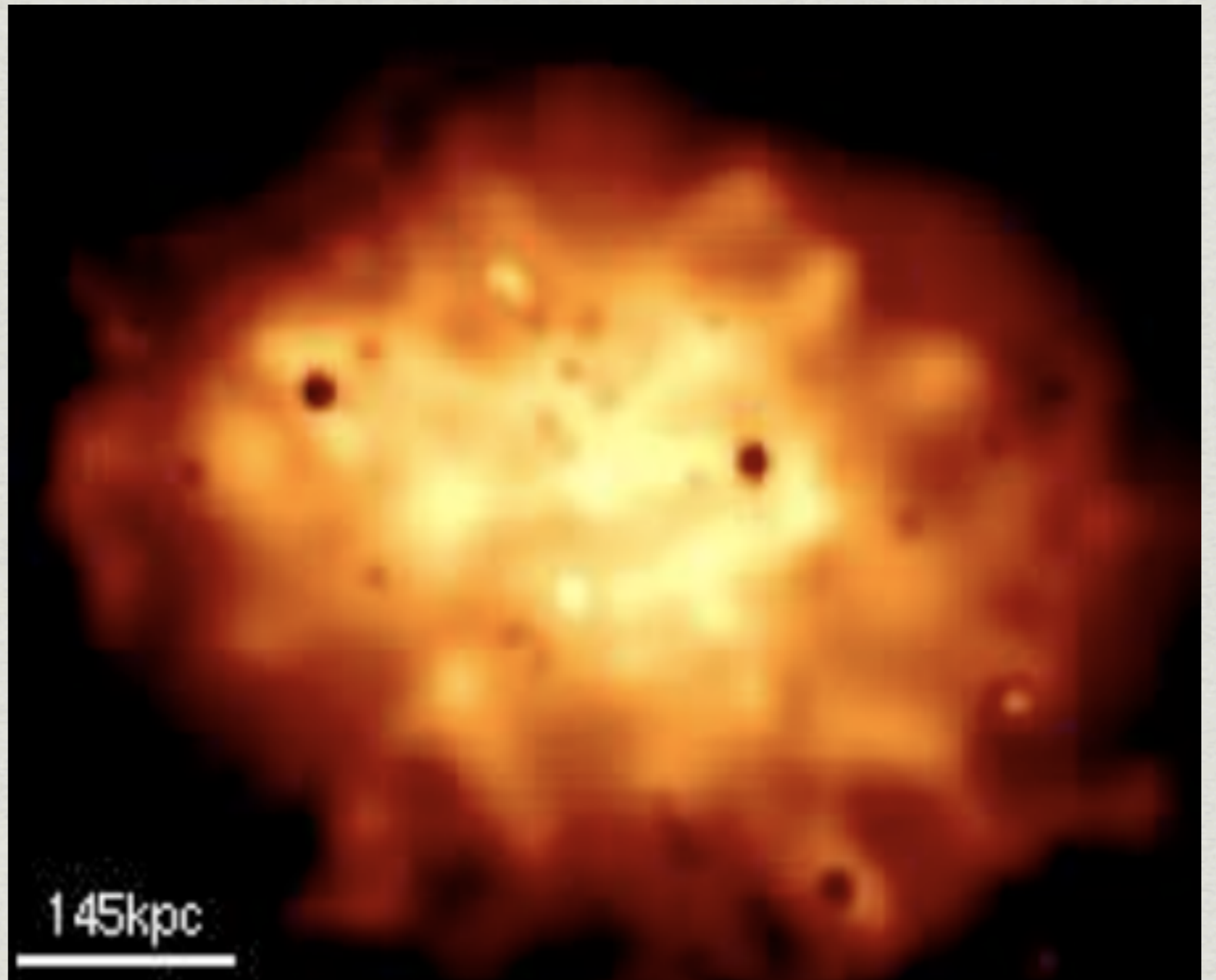
**I. Zhuravleva, E. Churazov, A. Simionescu, S. W. Allen, W. Forman, C. Jones,  
J. S. Kaastra**

# Intro: motivation

- \* Galaxy clusters in principle excellent cosmological probes
- \* But accurate mass measurements necessary
- \* X-ray mass measurements rely on the assumption of hydrostatic equilibrium in the hot gas
- \* Turbulent pressure can bias mass measurements low
- \* Turbulent line broadening will be probed by Astro-H & IXO
- \* What can we do until then?

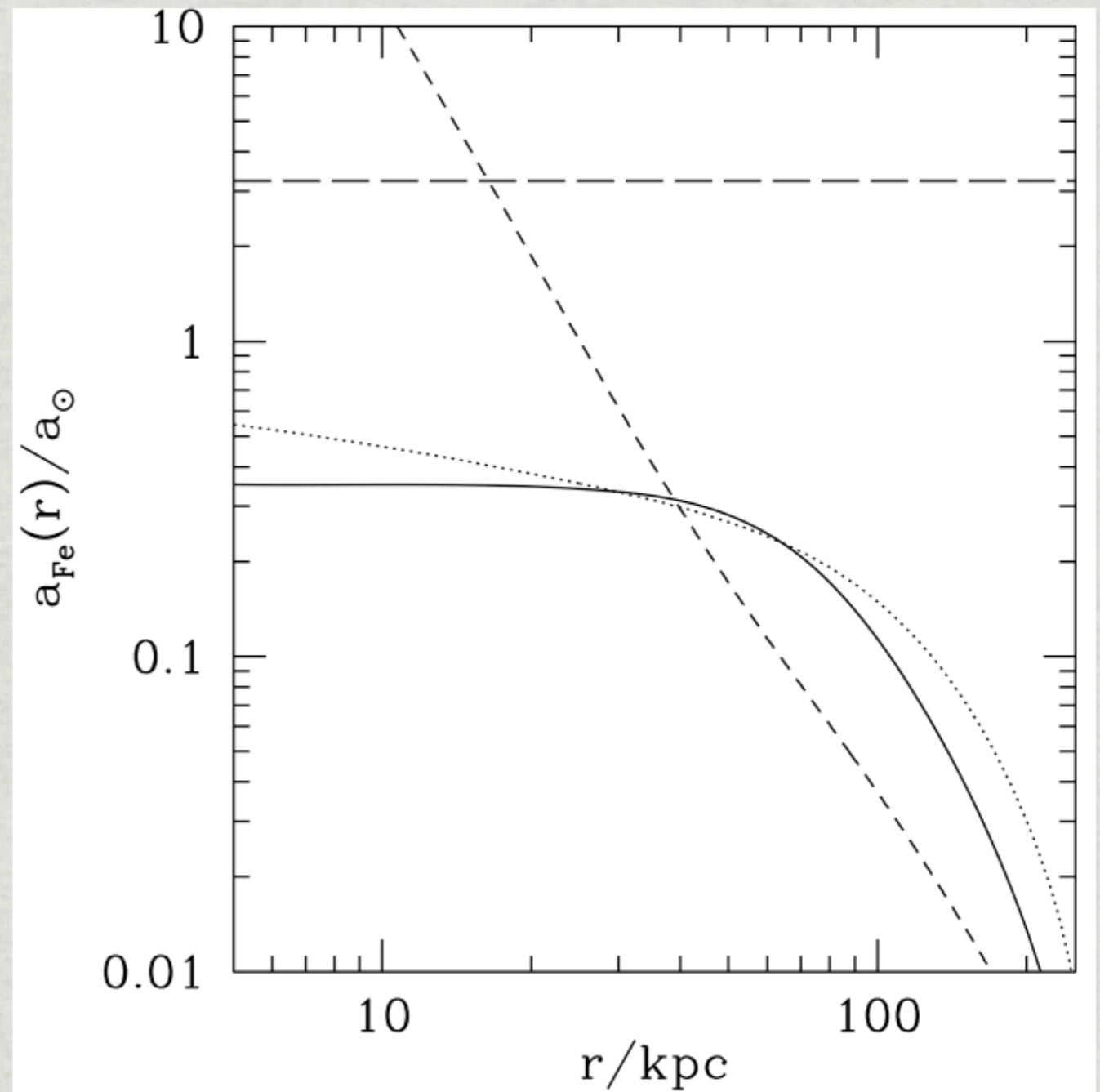
# Pressure maps of Coma

- ✱ on 40-90 kpc scale consistent with Kolmogorov spectrum
- ✱  $P_{\text{turb}} > 0.1 P_{\text{thermal}}$

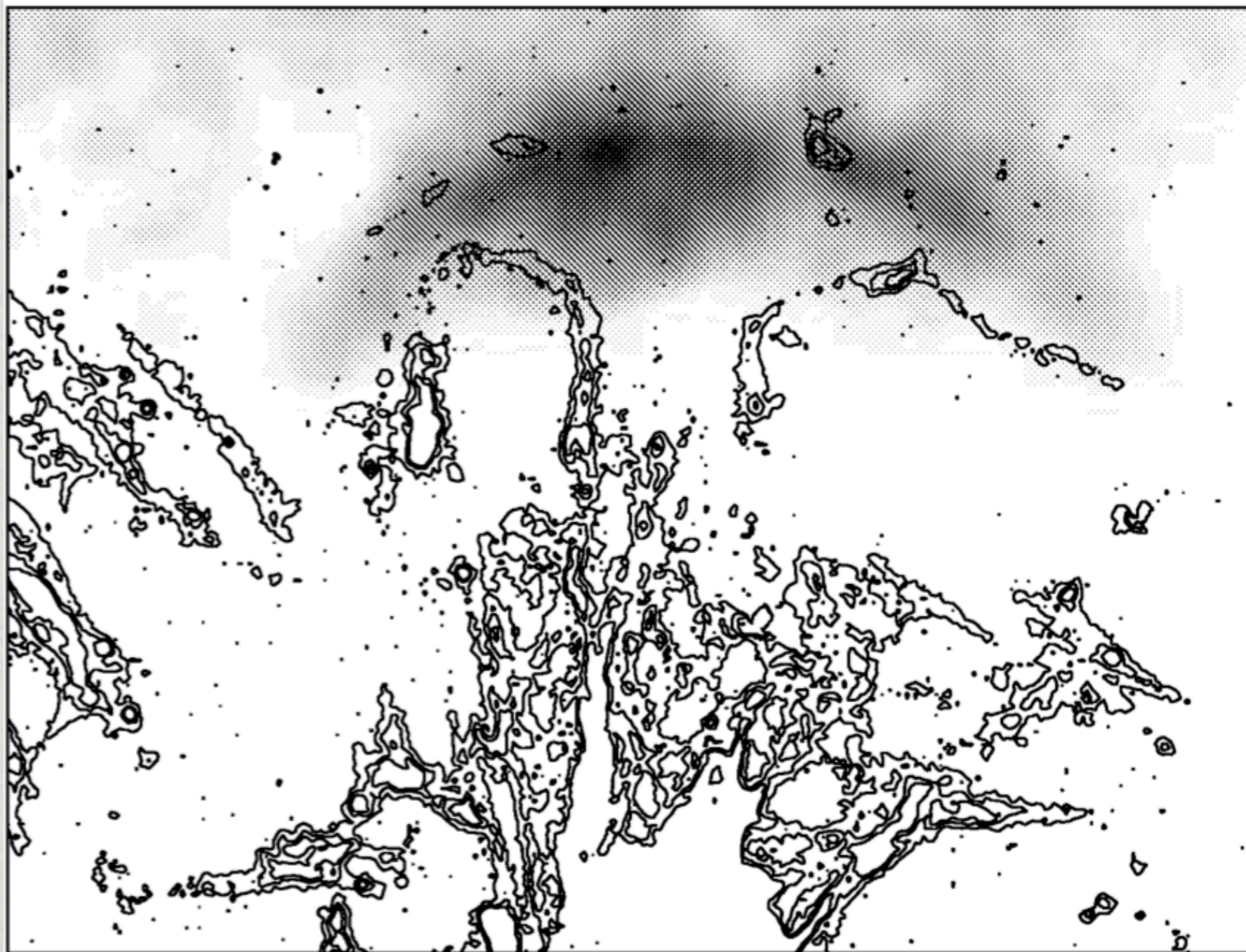


# Spread of metals as indicator of turbulence

- \*  $V_{\text{turb}} \sim 400 \text{ km/s} \sim 0.45 \text{ sound speed}$



# Halpha filaments as tracers of gas motions



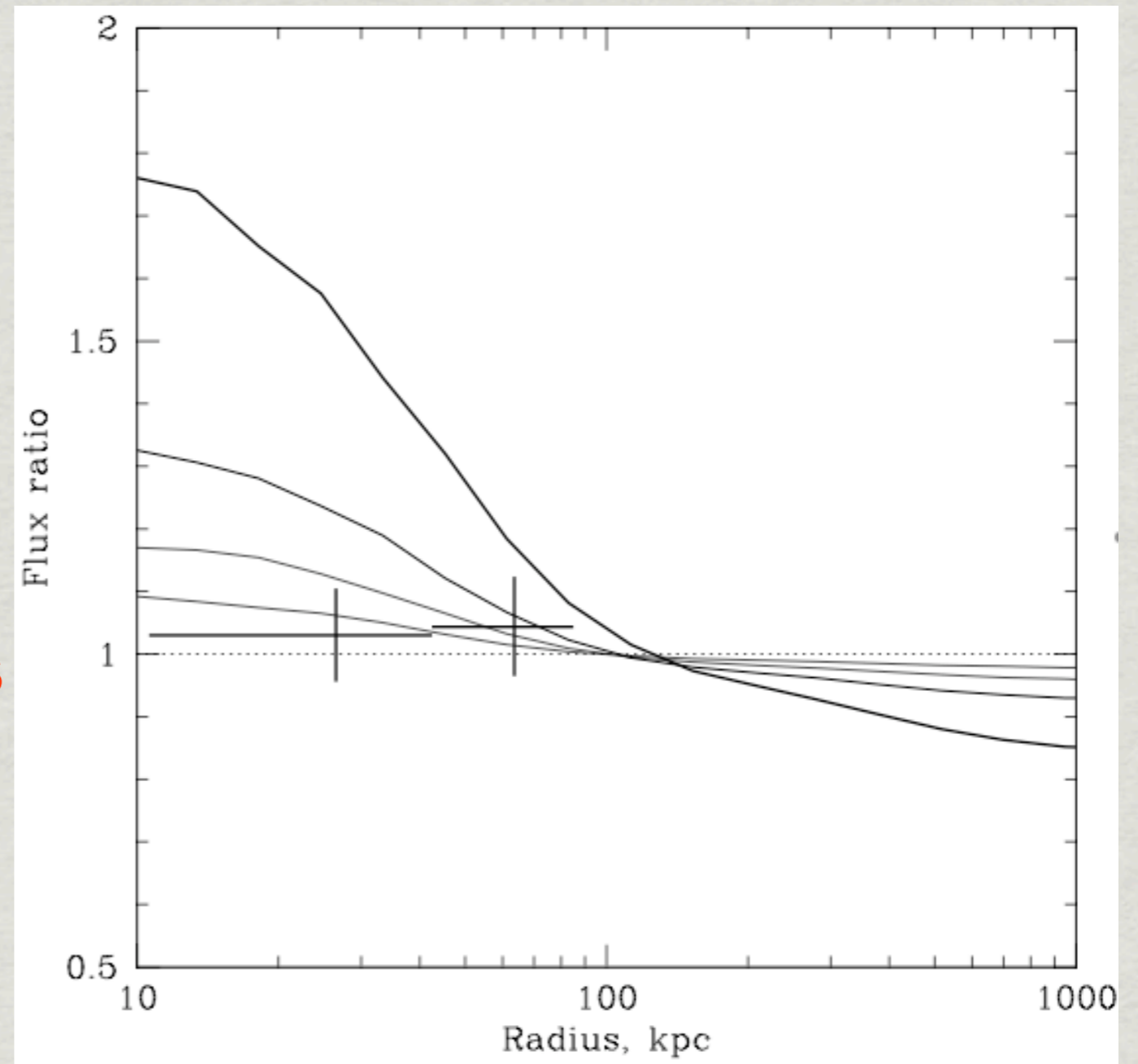
# Resonant scattering

- \* Hot plasma in galaxies and ICM assumed optically thin
- \* Generally true but not for strong resonant lines
- \* Depends on characteristic velocity of internal motions
- \* The effect is usually relatively weak and difficult to detect

$$\tau = \frac{4240 f N_{24} \left( \frac{n_i}{n_Z} \right) \left( \frac{n_Z}{n_H} \right) \left( \frac{M}{T_{\text{keV}}} \right)^{1/2}}{E_{\text{keV}} \left\{ 1 + \frac{0.0522 M v_{100}^2}{T_{\text{keV}}} \right\}^{1/2}}$$

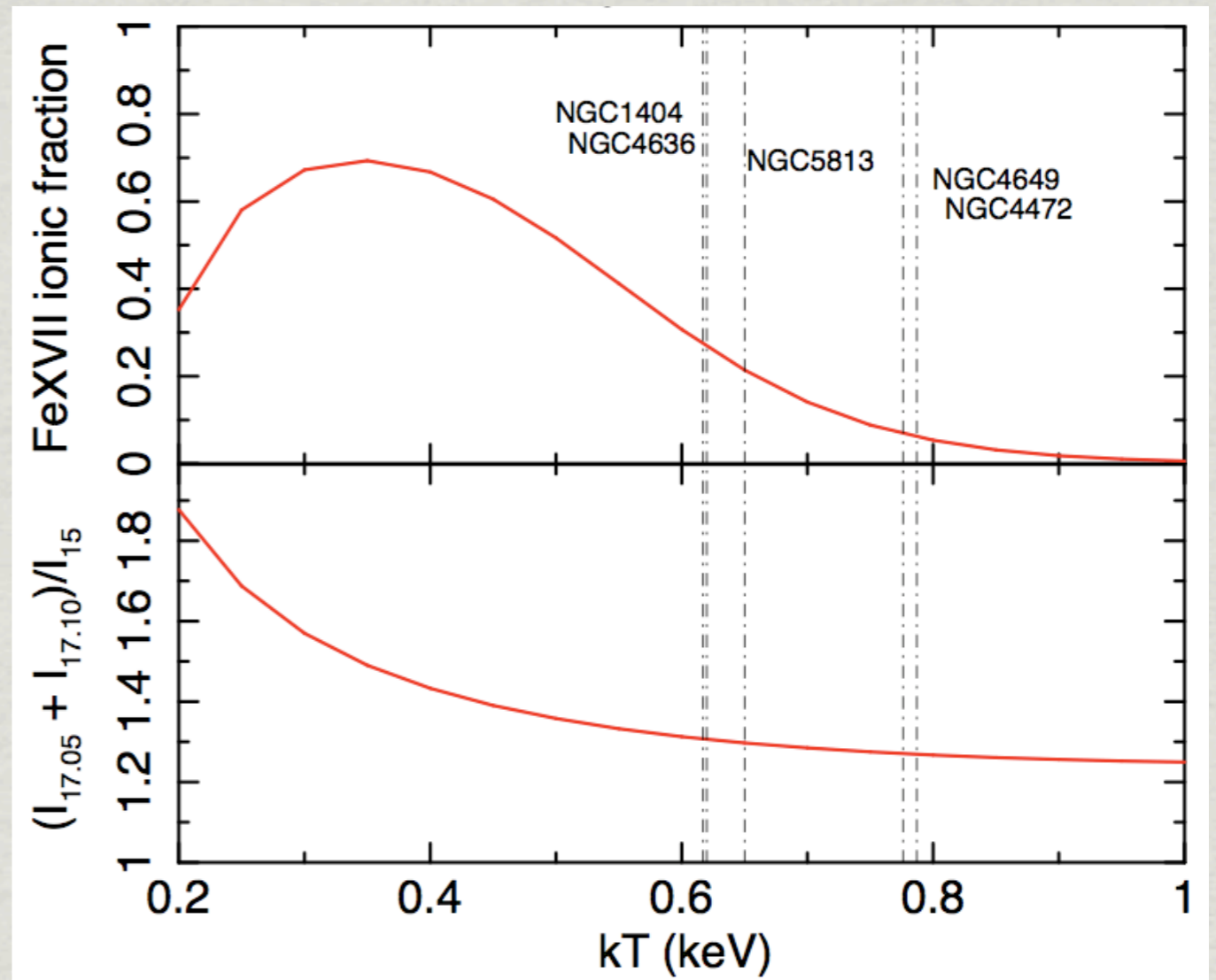
# Resonant scattering in Perseus

- \* no resonant scattering in the 6.7 keV Fe-K line
- \* on scales  $< 100$  kpc differential gas motions  $> 0.5$  sound speed



# The power of Fe XVII as diagnostic tool

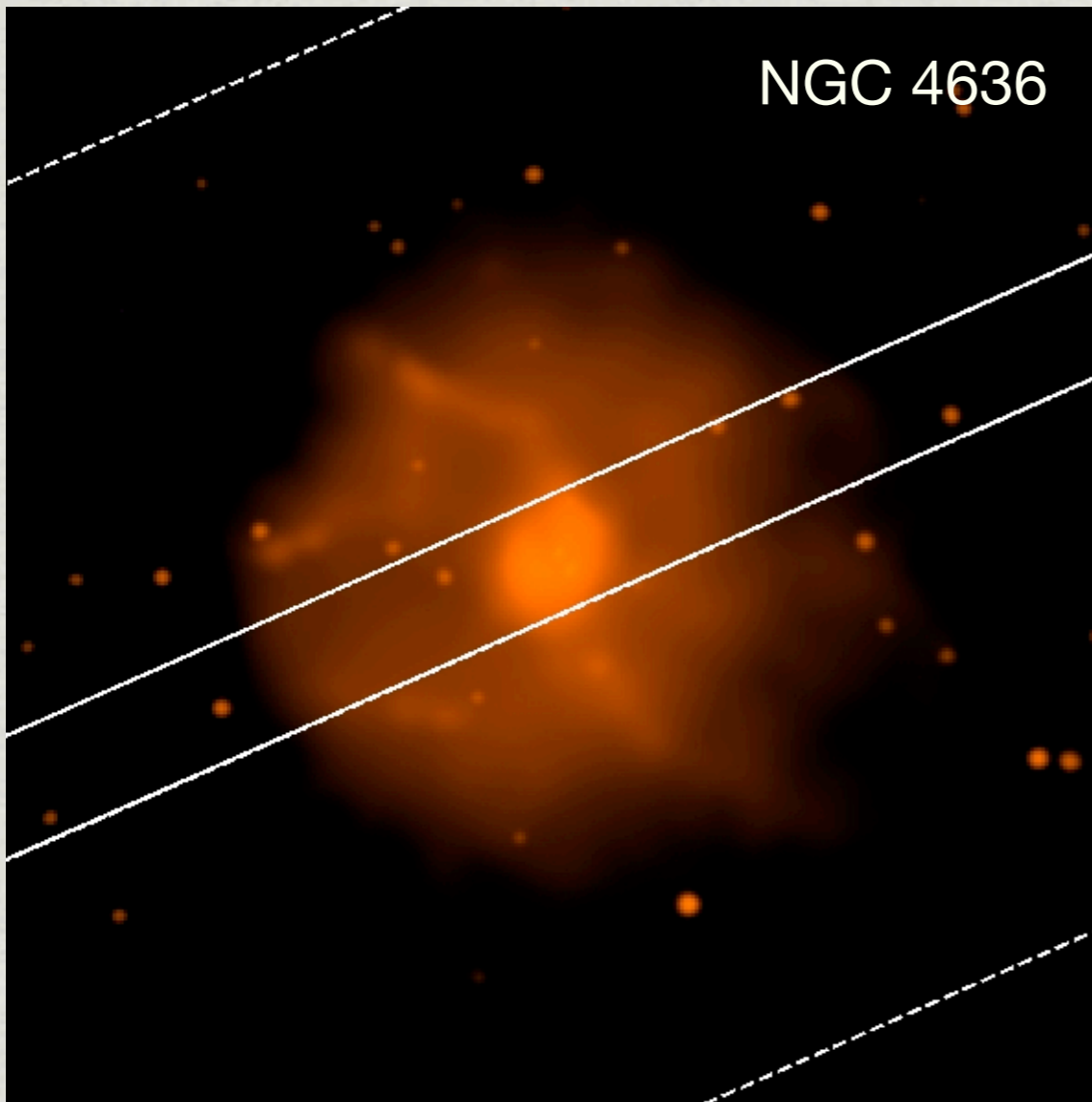
- \* 2 prominent features:  
at 17 Å and 15 Å
- \* 15 Å line optically thick  
17 Å lines optically thin
- \* Same ion of same  
element - ratio  
insensitive to biases



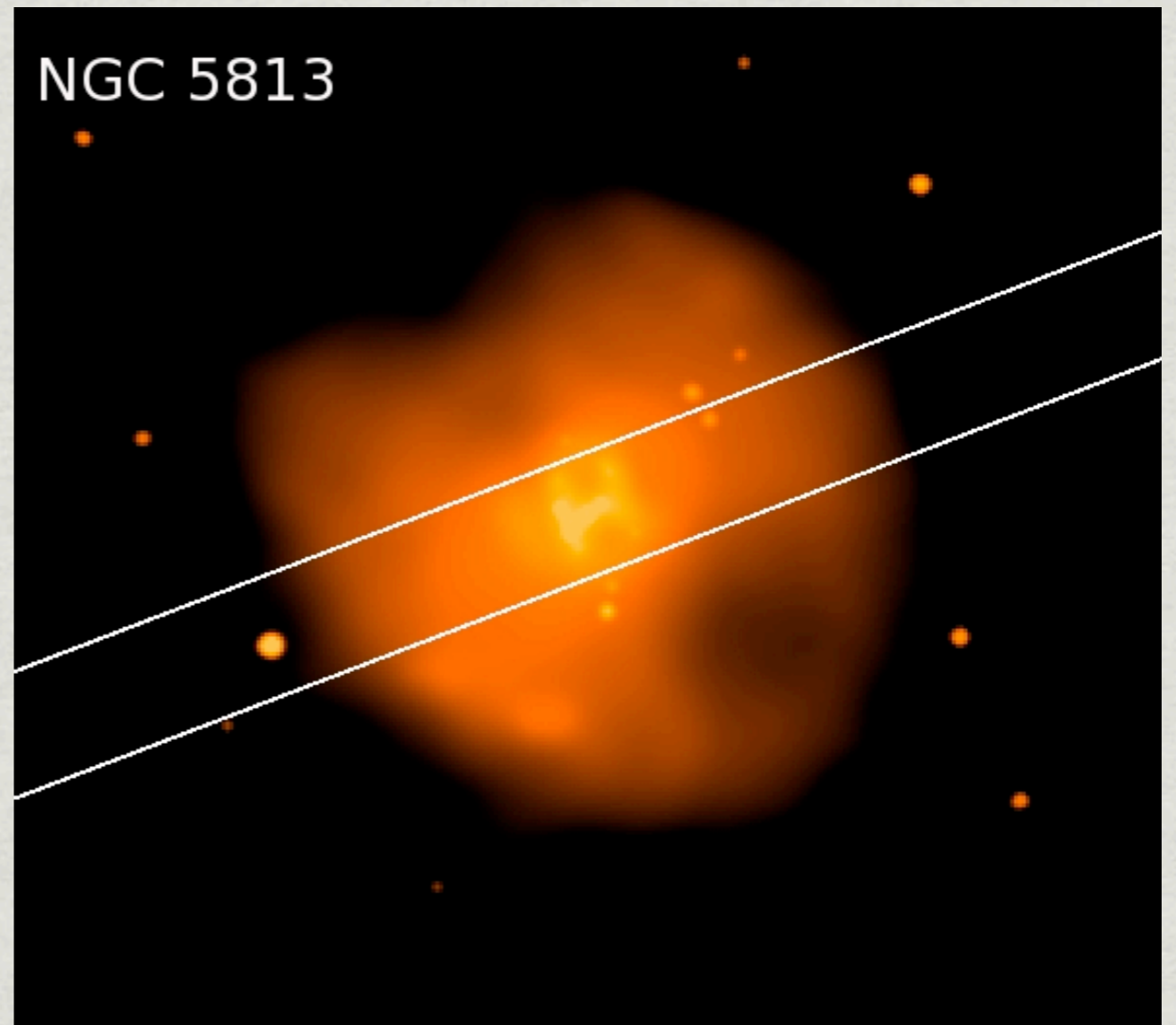


# Disturbed galaxies

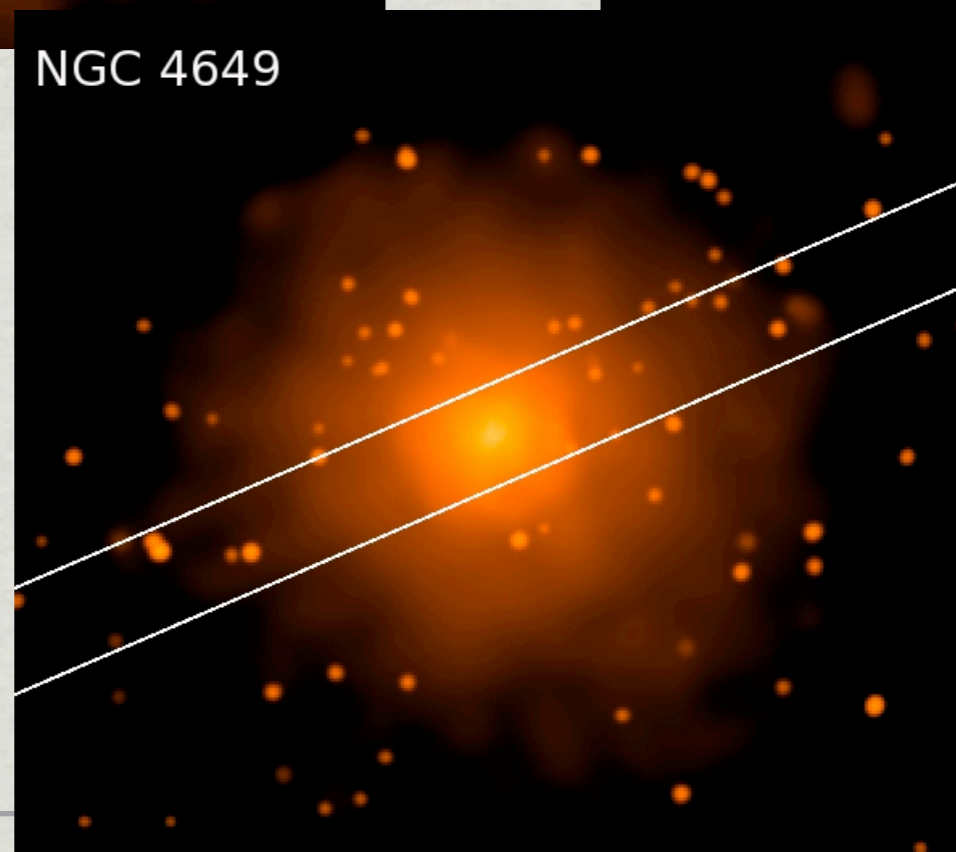
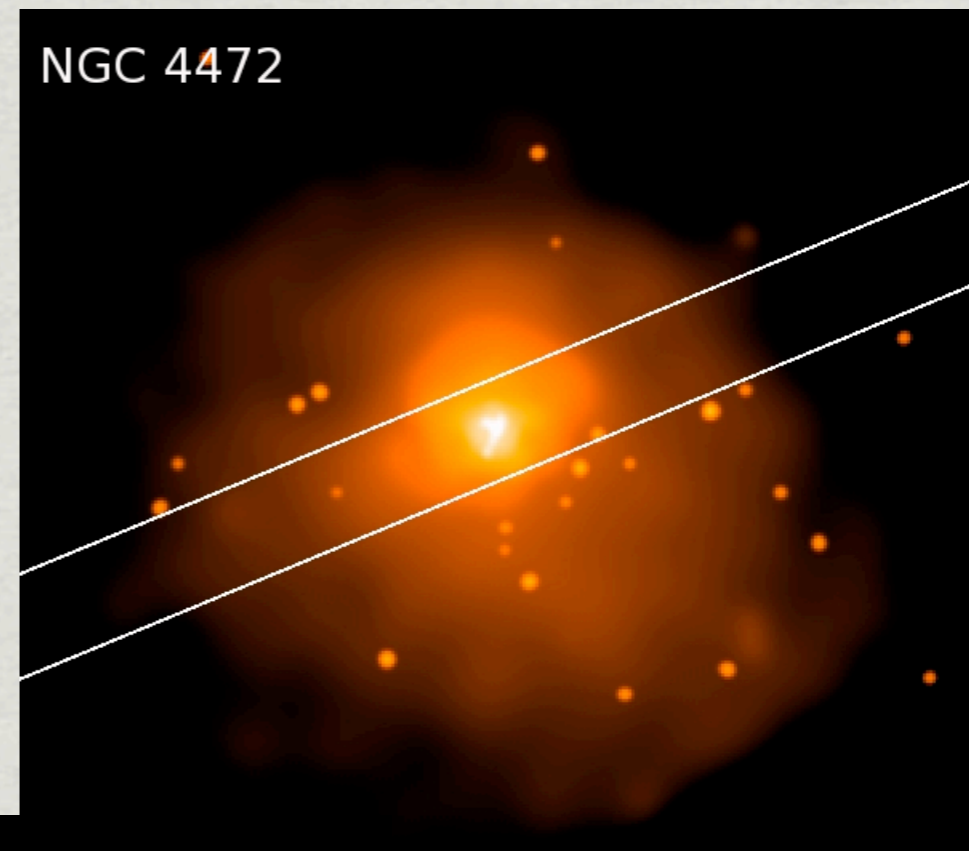
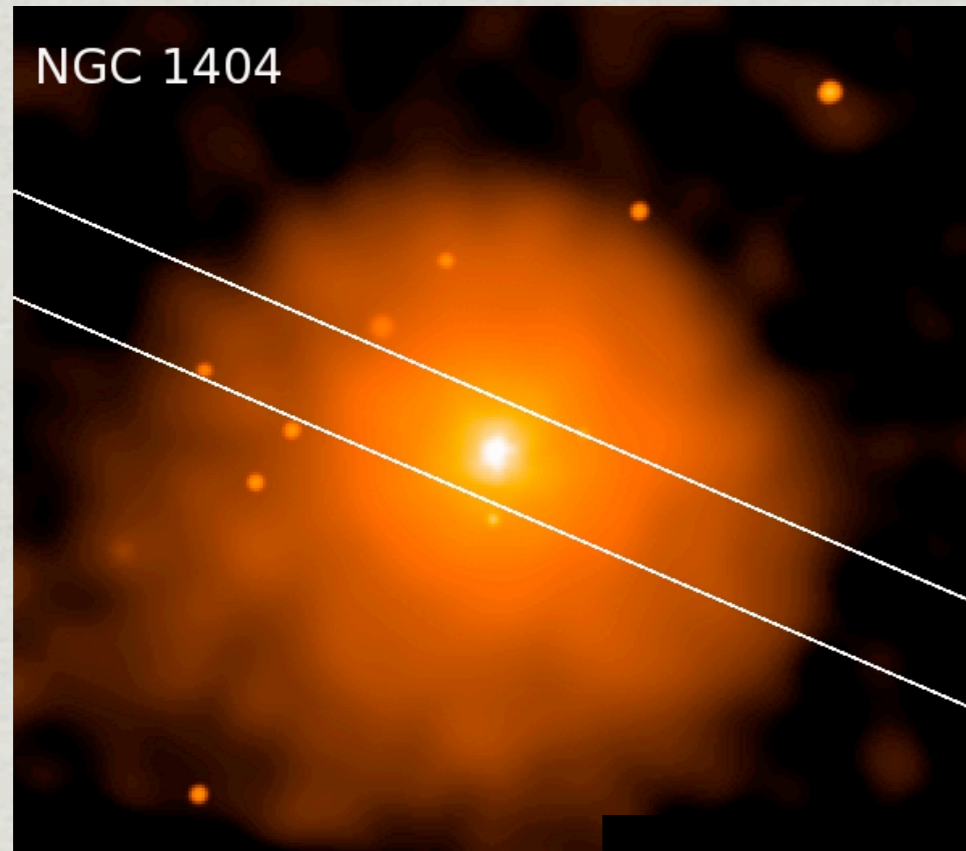
NGC 4636



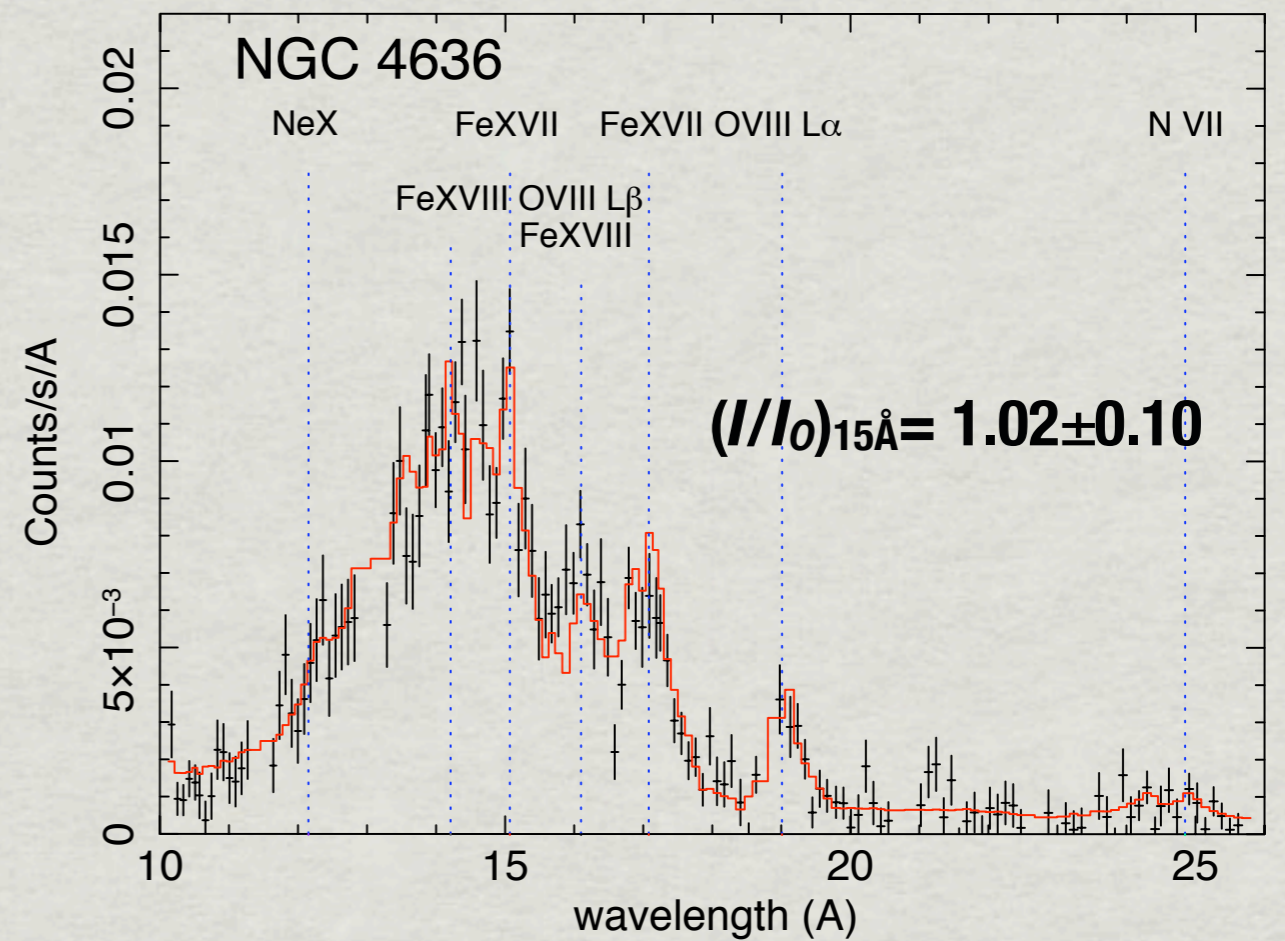
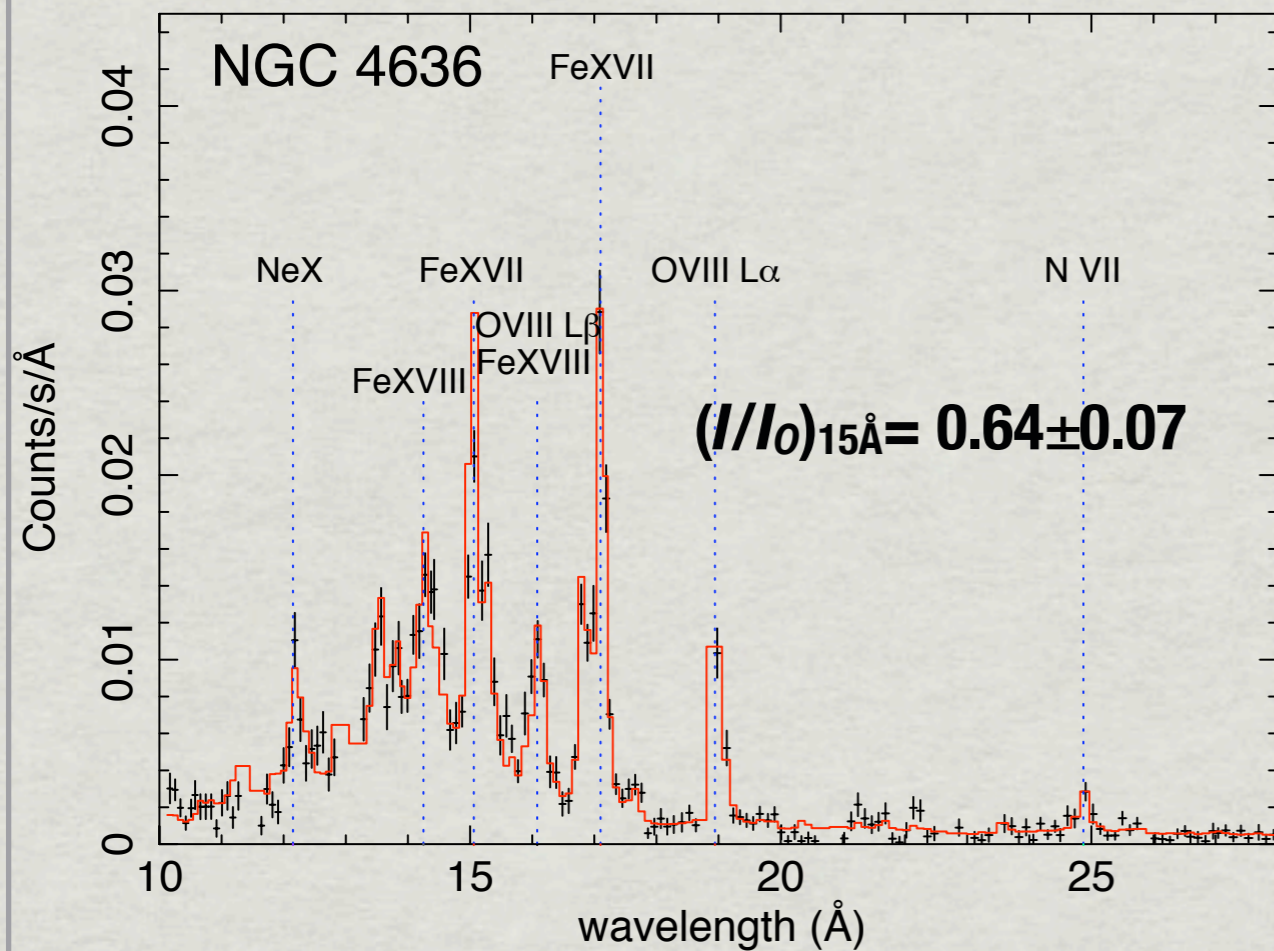
NGC 5813



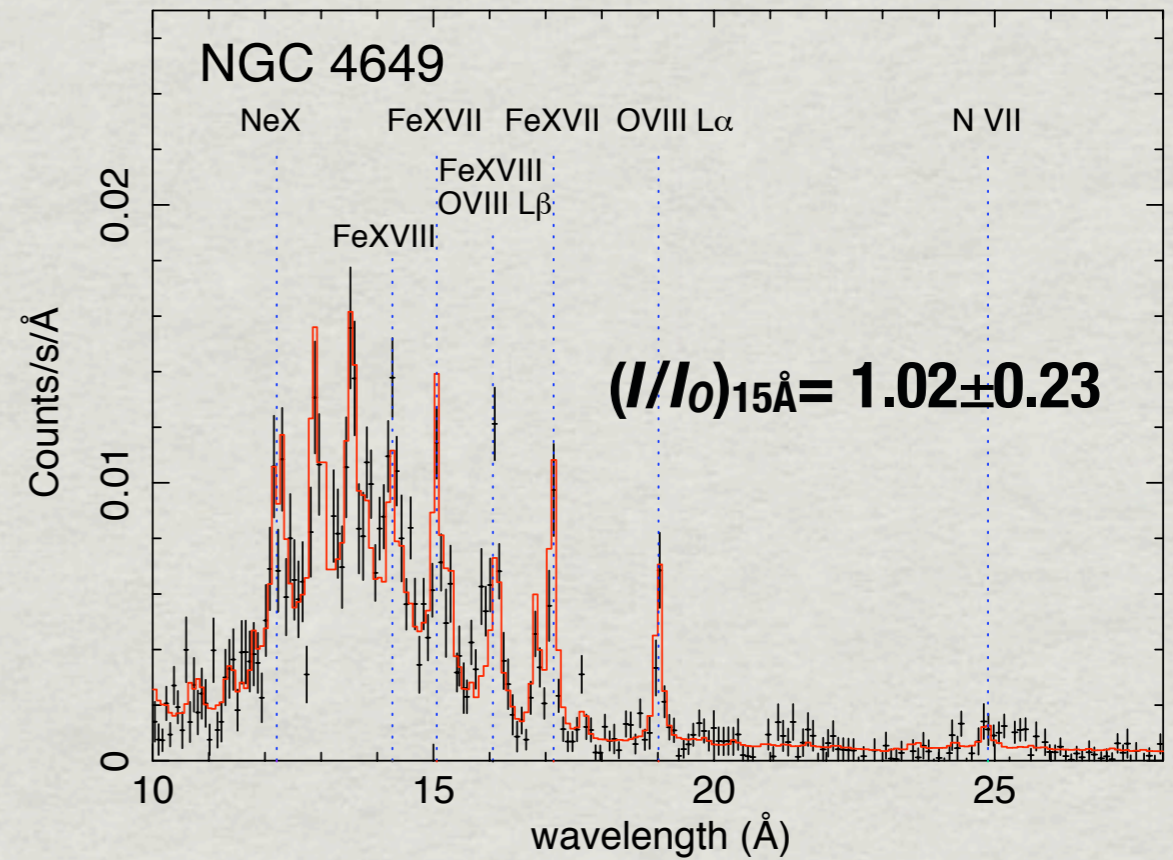
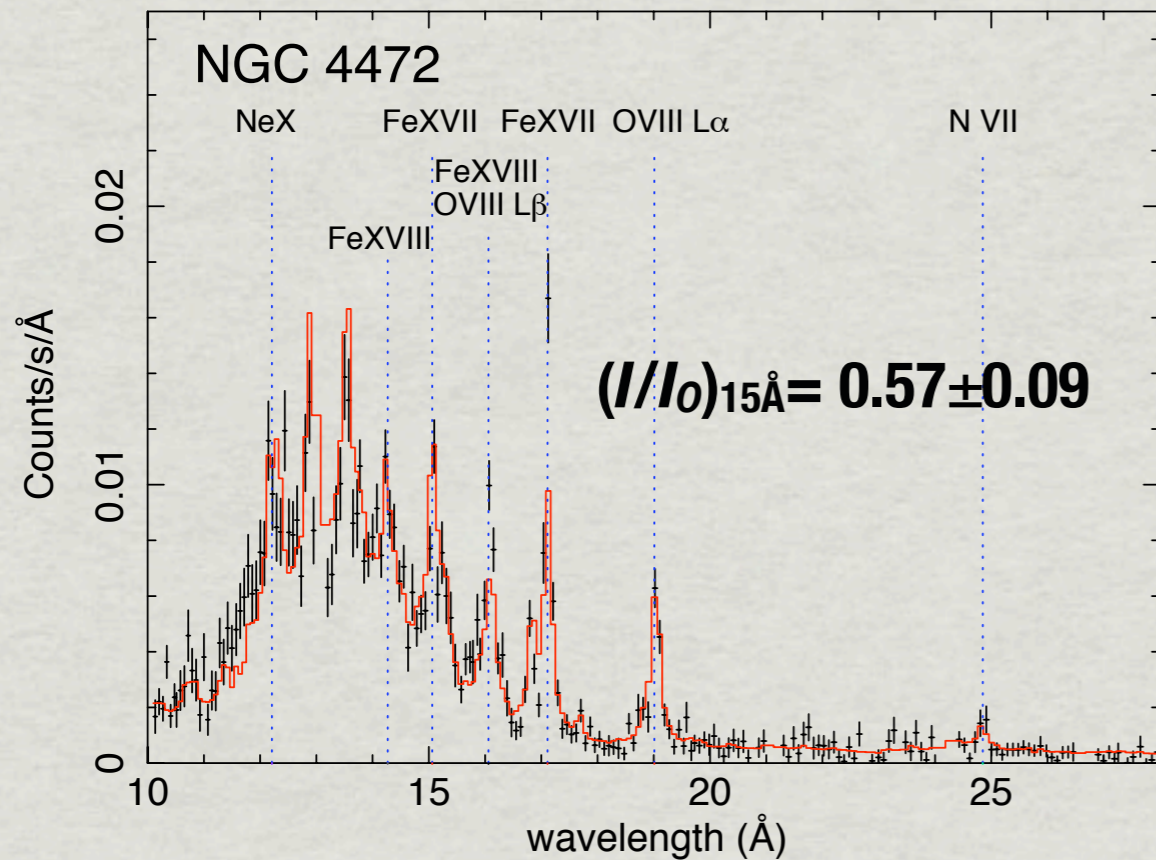
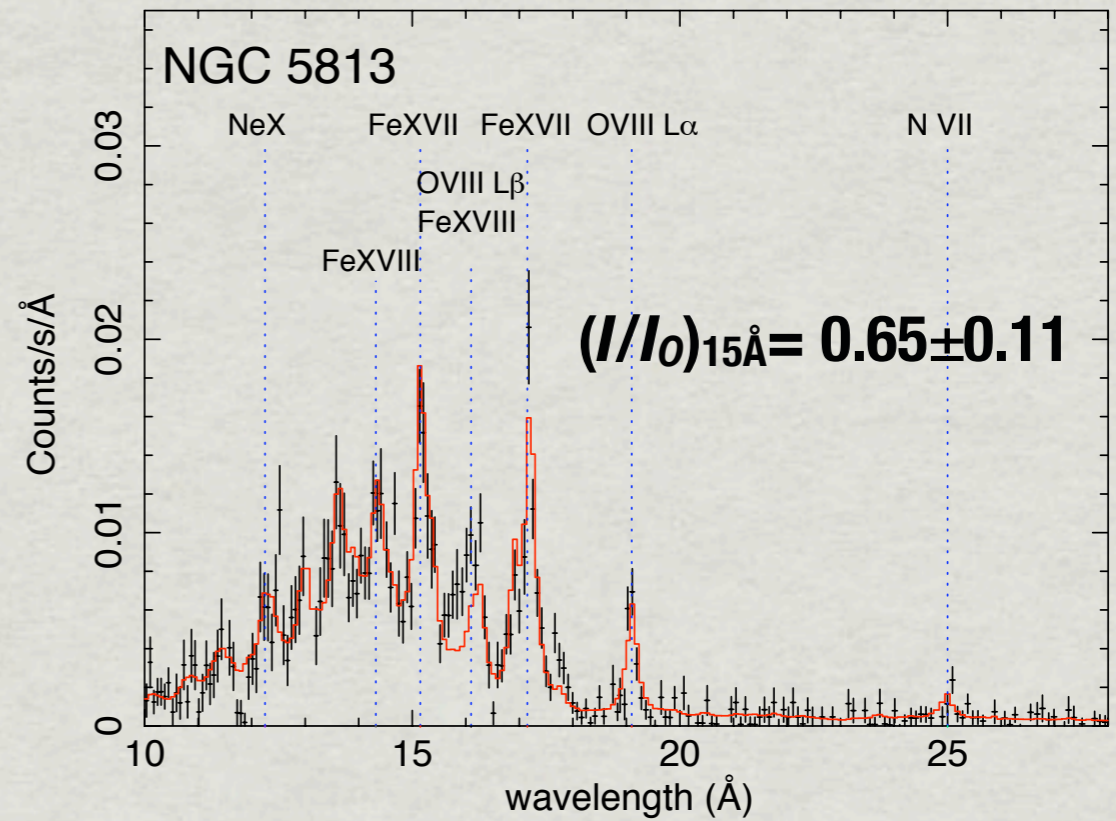
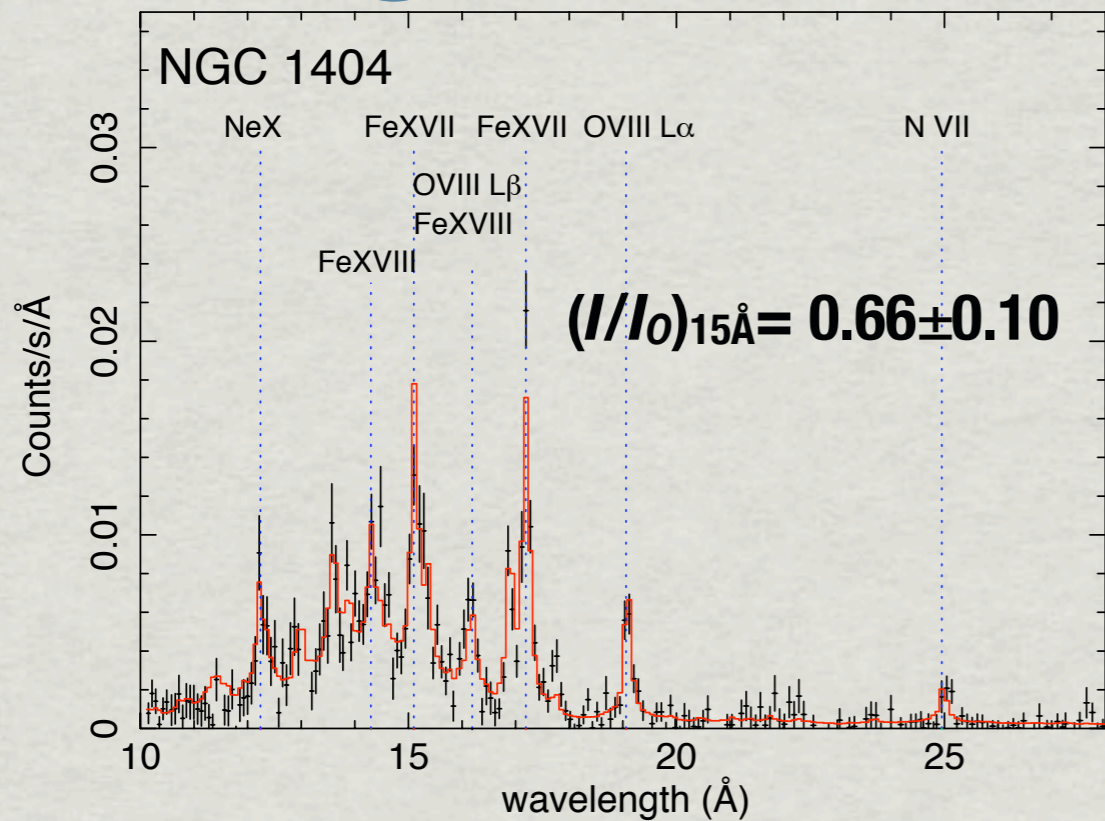
# Relaxed galaxies



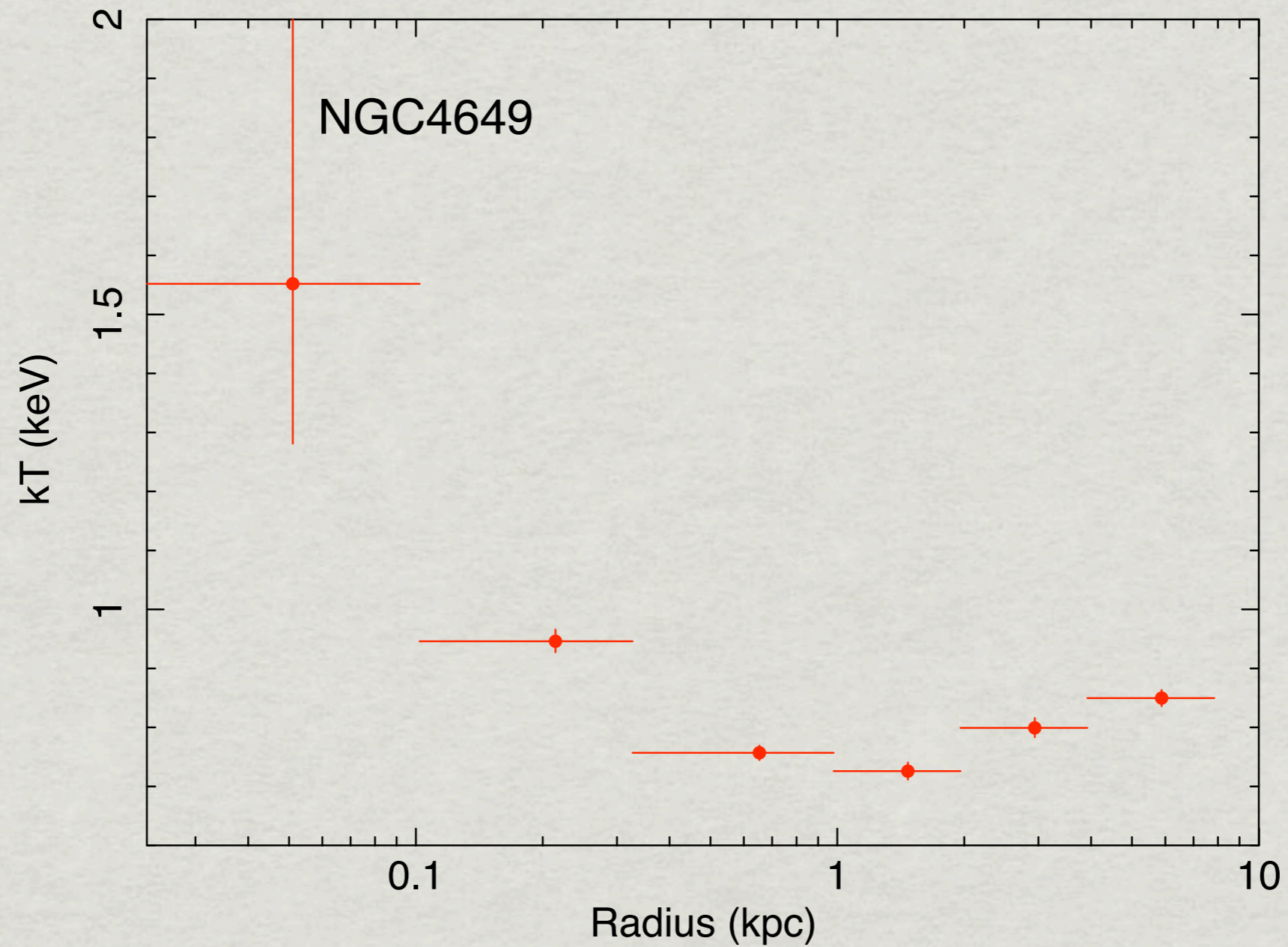
# Resonant scattering in NGC 4636



# High-resolution spectra

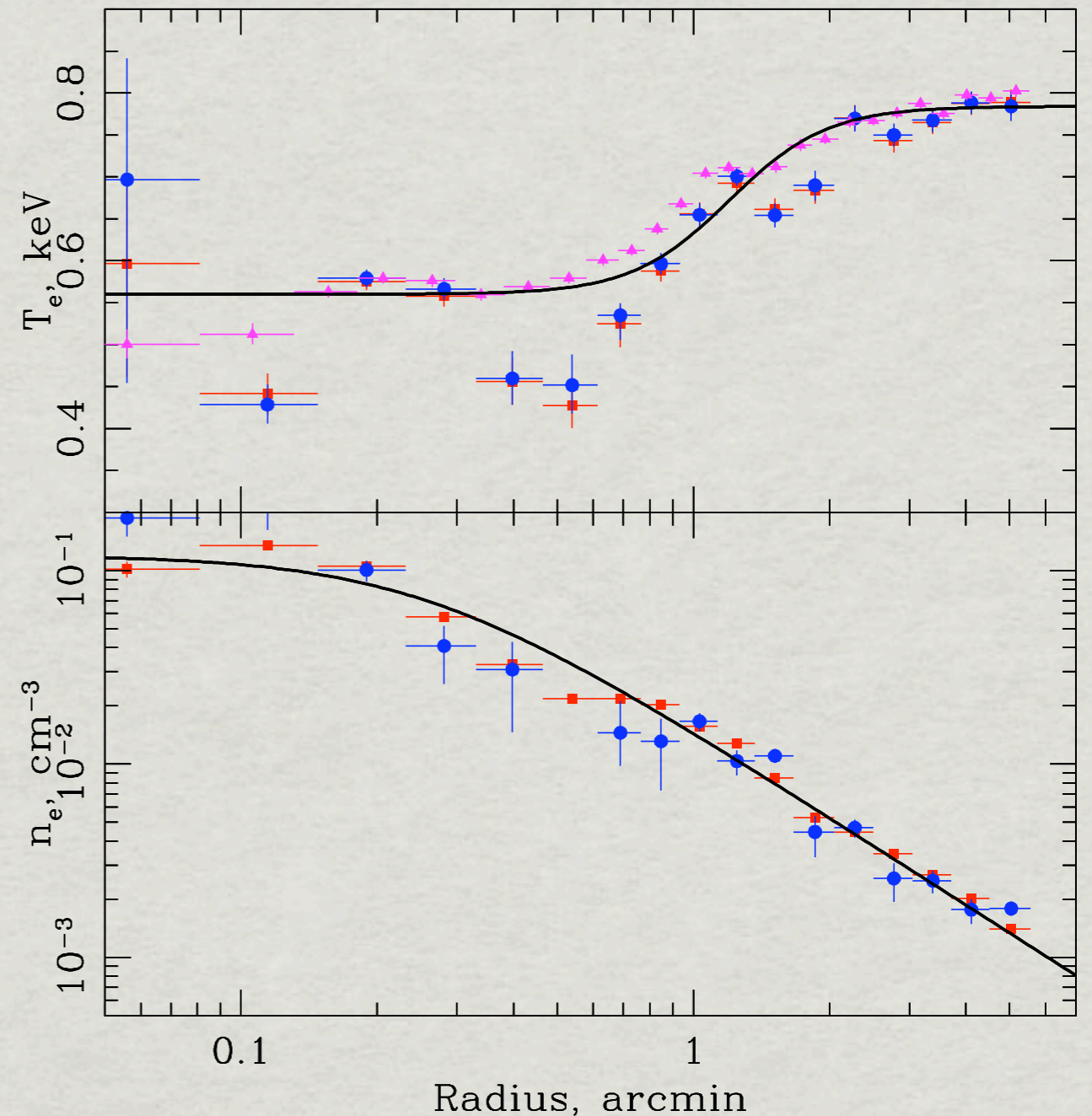


# Why not in NGC 4649?

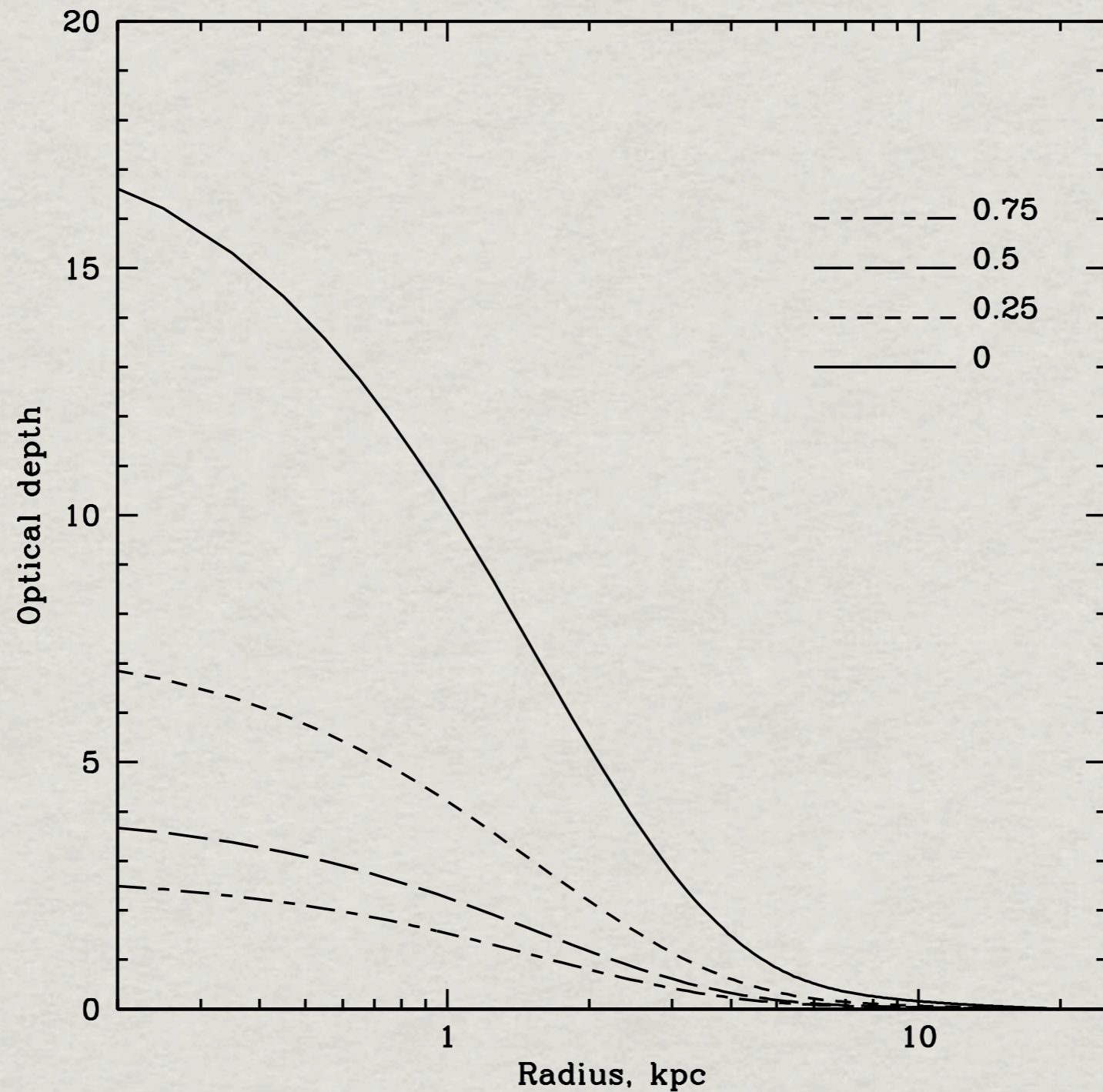


# Model of resonant scattering in NGC 4636

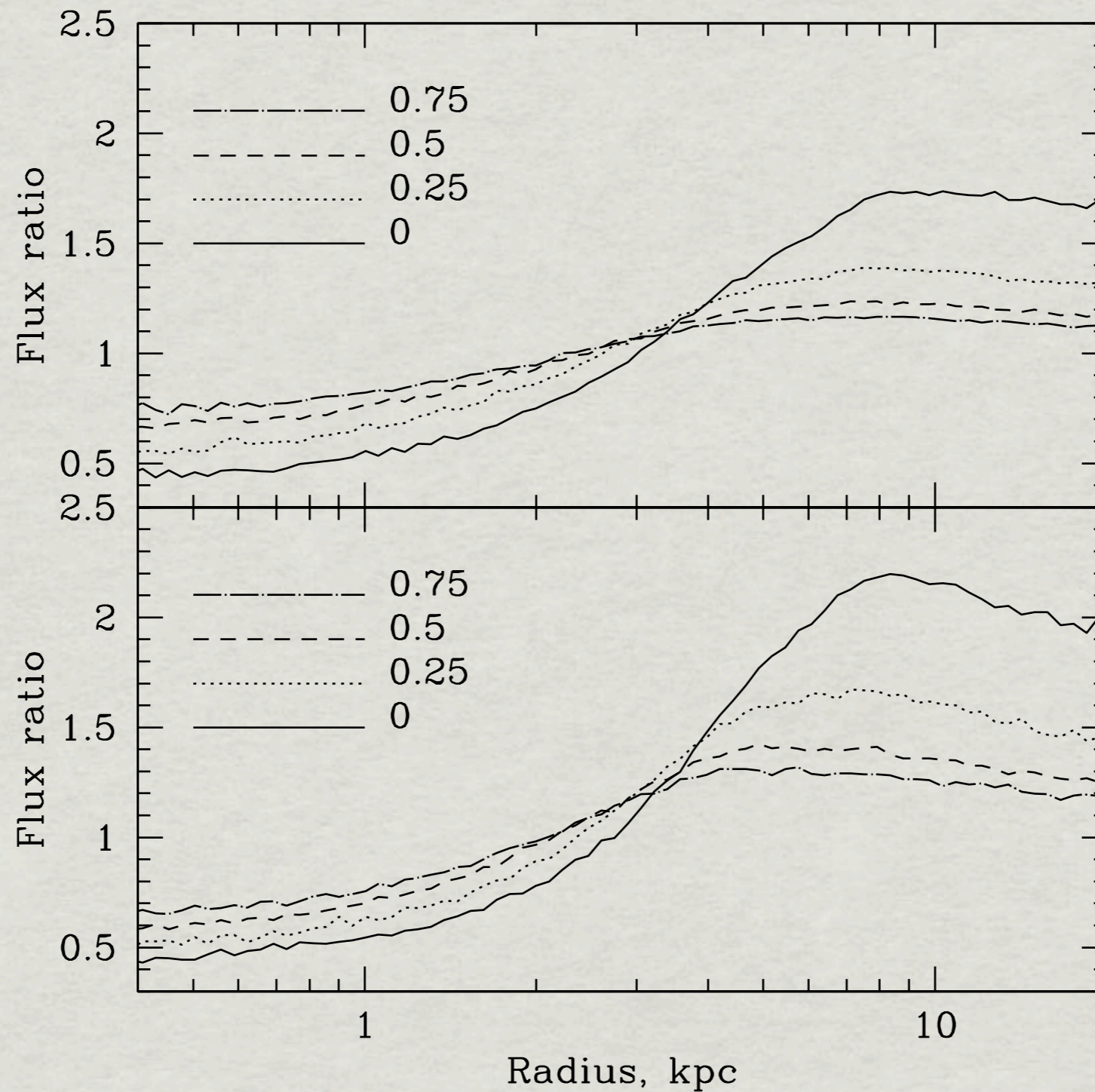
- \* Monte-Carlo simulations (Churazov et al. 2004)
- \* Halo modeled as spherical shells
- \* Model density and temperature profiles determined using deprojected Chandra data



# Expected optical depth



# Expected line profiles $I/I_0$





# Turbulent velocities

- \* for  $M=0.00$ ,  $l/l_0=0.69-0.71$
- \* for  $M=0.25$ ,  $l/l_0=0.76-0.78$
- \* for  $M=0.50$ ,  $l/l_0=0.80-0.82$
- \* measured  $l/l_0=0.64\pm 0.07$
- \*  $M=0.25$  ruled out at the 90% confidence level
- \*  $M=0.50$  ruled out at >95% confidence level

# Turbulent pressure

- \* Turbulent pressure  $< 5\%$  of thermal pressure at 90% confidence level
- \* At 95% confidence level turbulent pressure  $< 20\%$
- \* Consistent with Churazov et al. (2008) non-thermal pressure in elliptical galaxies  $< 10\%$
- \* Good news for cosmology

**THANK YOU FOR THE NICE MEETING!**