The Global Hot ISM: New Perspectives

Q. Daniel Wang et al.

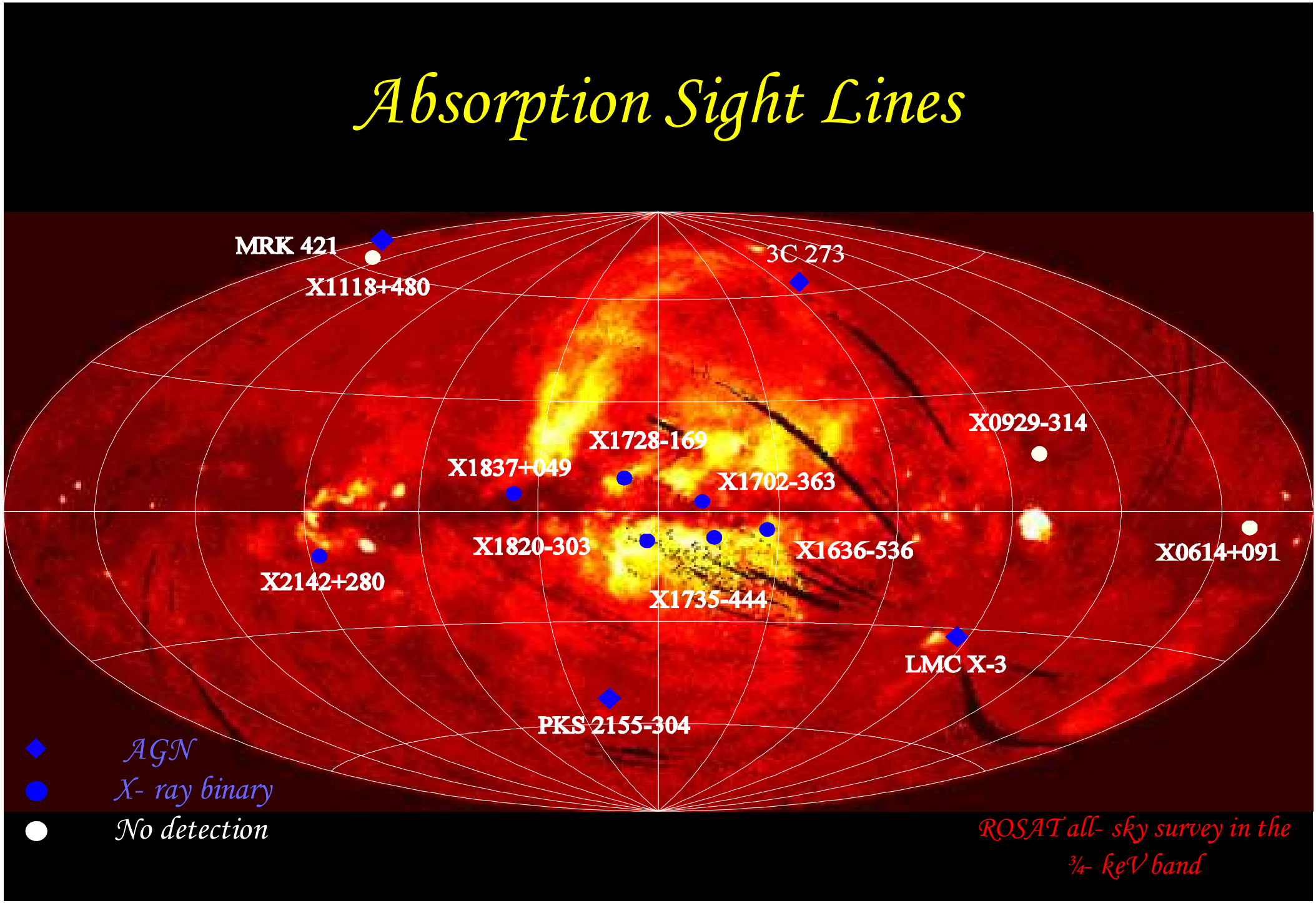
Absorption spectroscopy:

- *Add the depth*
- *Measure the column density, thus the mass*
- *Direct line diagnostics*
- *Independent of cool gas absorption*

External views:

- *Global properties*
- *Relationship between various components*
- *Dependence on galaxy properties and environment*

Absorption Sight Lines

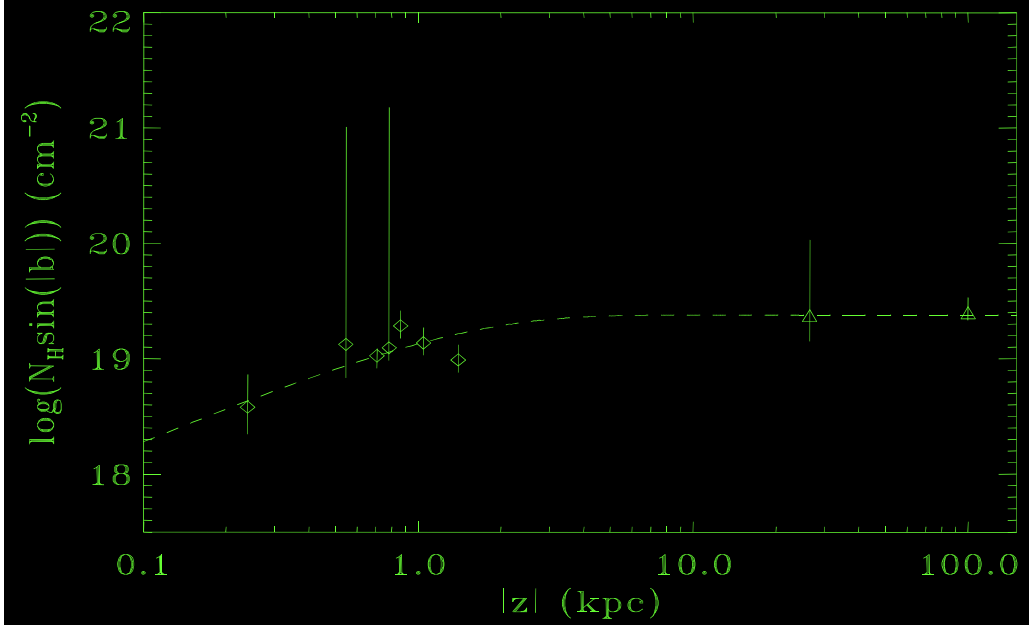


More Sources Global HISM distribution

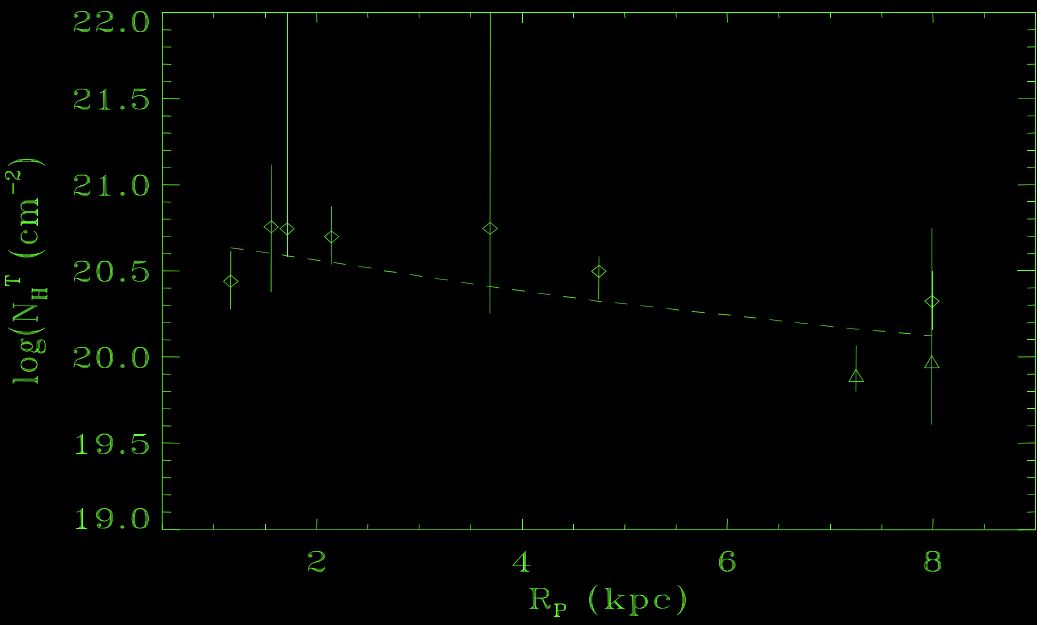
- *LMXBs with $|b| > 2^{o}$ and S/N > 7 per bin at ~0.6 keV*
- *Excluding sources with identified intrinsic emission/absorption features*
- *Ten LMXBs with 17 observations (6 with the LETG) are selected*

Yao & Wang 2005

Global distribution models



Disk model



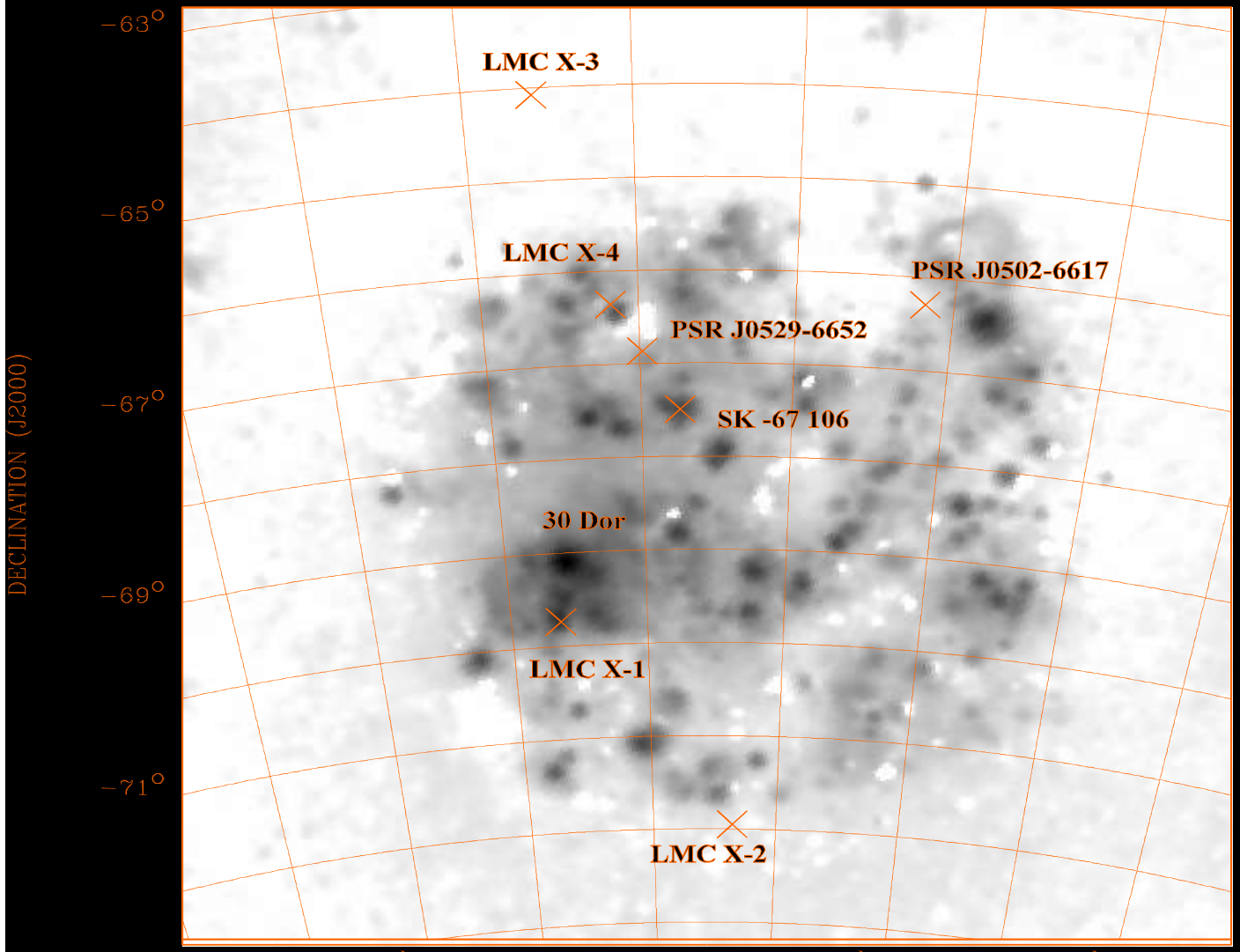
Sphere model

- n_H = 5.0(- 1.8,+2.6)x10^{-3} cm^{-3} exp[- |z|/ 1.1(- 0.5,+0.7) kpc]
- Total N_H~1.6 x10^{19} cm^{-2}

- n_H = 6.1(- 3.0,+3.6)x10^{-2} cm^{-3} exp[- R/ 2.7(- 0.4,+0.8) kpc]
  ~3 x 10^{-3} cm^{-3} at the Sun
- Total N_H~6.1 x10^{19} cm^{-2}
- M_H~7.5(2.5- 16)x10^{8} Msun

X- ray absorption is primarily around the Galactic disk within a few kpc!

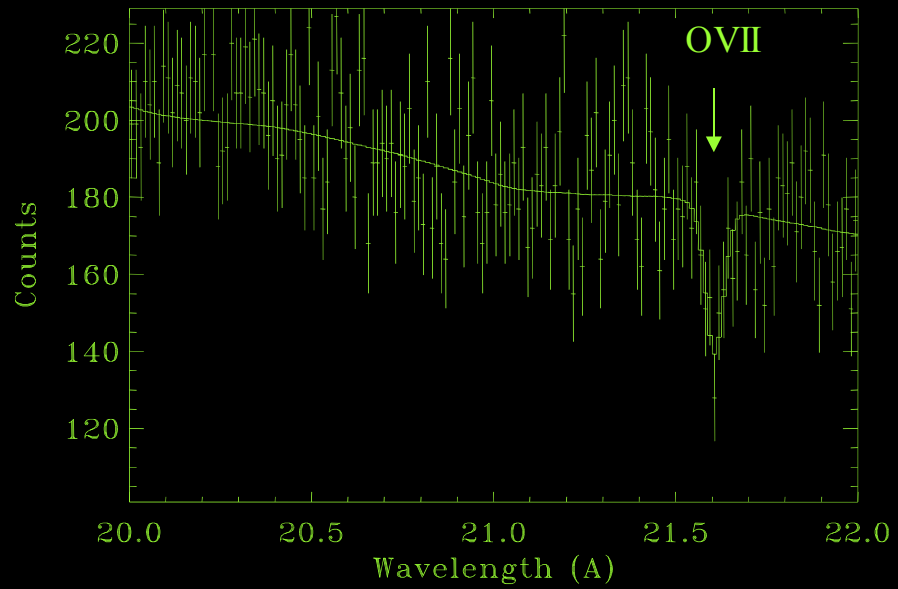
LMC X- 3 as a distance marker

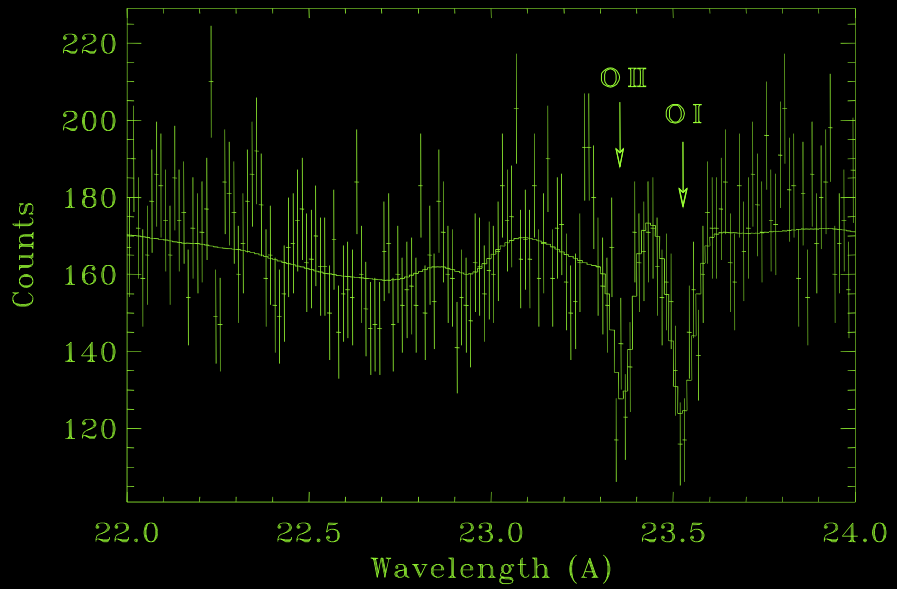


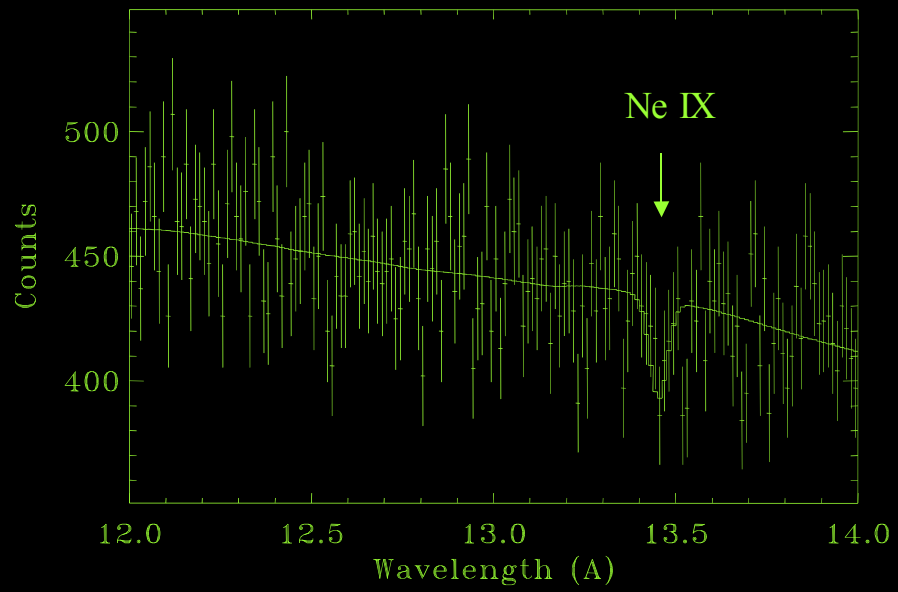
- *BH X- ray binary, typically in a high/soft state*
- *Roche lobe accretion*
- *50 kpc away*
- *V_s = +310 km/s*
- *Away from the LMC main body*

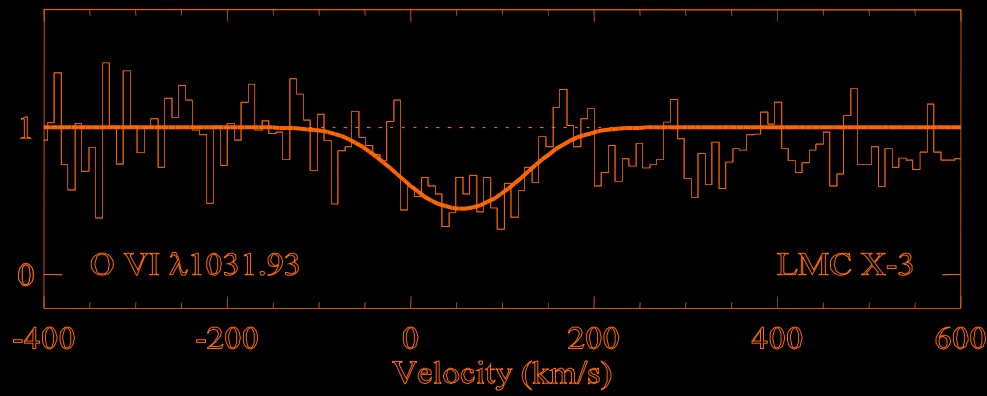
Wang et al. 2005

LMC X- 3: absorption lines









The EWs are about the same as those seen in AGN spectra!

Summary: Galactic hot ISM

- *No significant X- ray absorption beyond the LMC (~< 10^{19} cm^{-2}, assuming the solar abundance)*
- *A thick Galactic disk with a scale height 1- 2 kpc, ~ the values of OVI absorbers and free electrons*
- *Mean T ~ $10^{6.3+-0.2}$ K, ~ $10^{6.1}$ K at solar neighborhood*

External Perspective: NGC 3556 (Sc)

- Active star forming
- Hot gas scale height ~ 2 kpc
- L_x ~ 1% of SN mech. Energy input

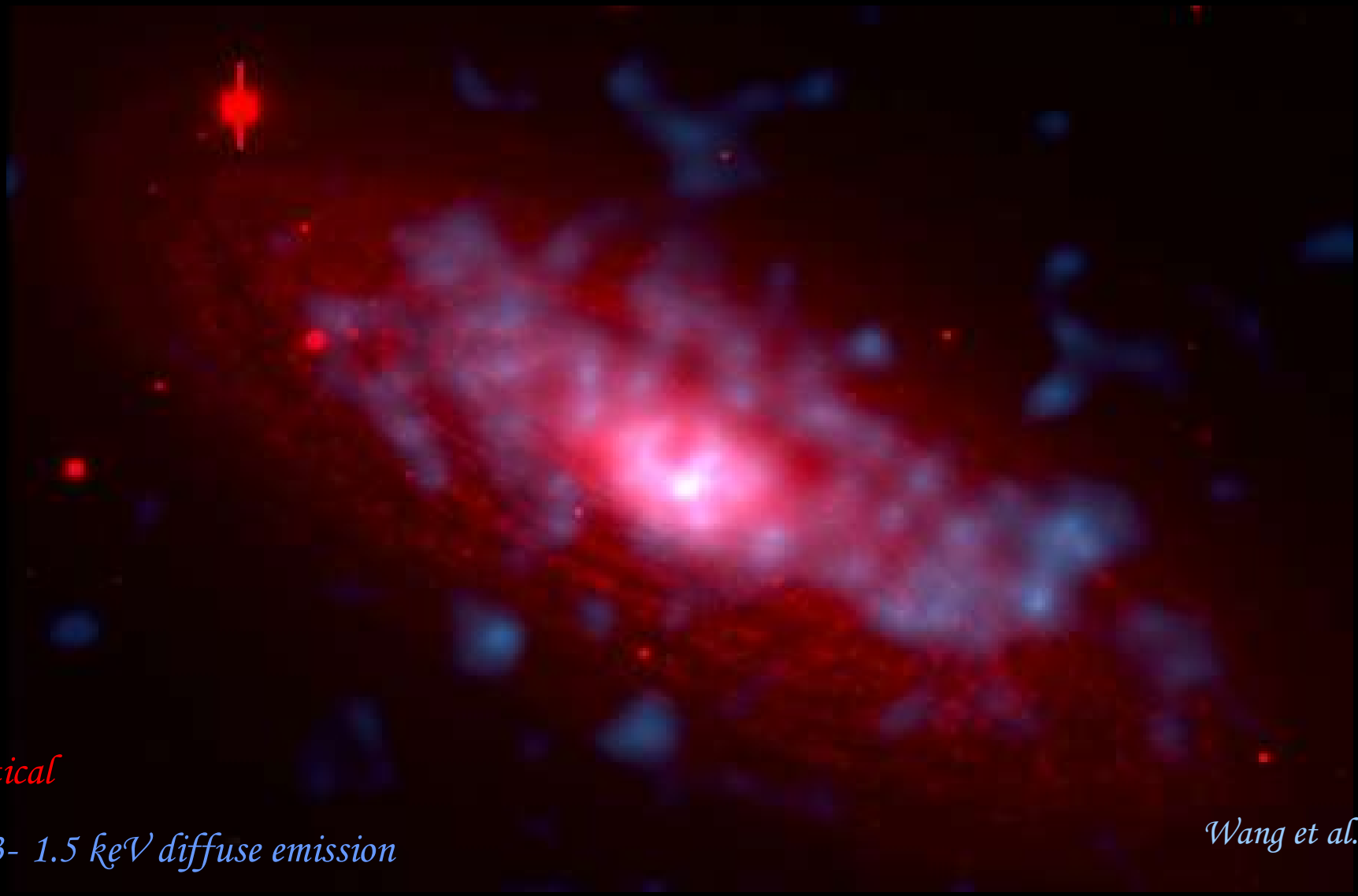
Red – optical

Green – 0.3- 1.5 keV band

Blue – 1.5- 7 keV band

Wang et al. 2004

NGC 2841 (Sb)

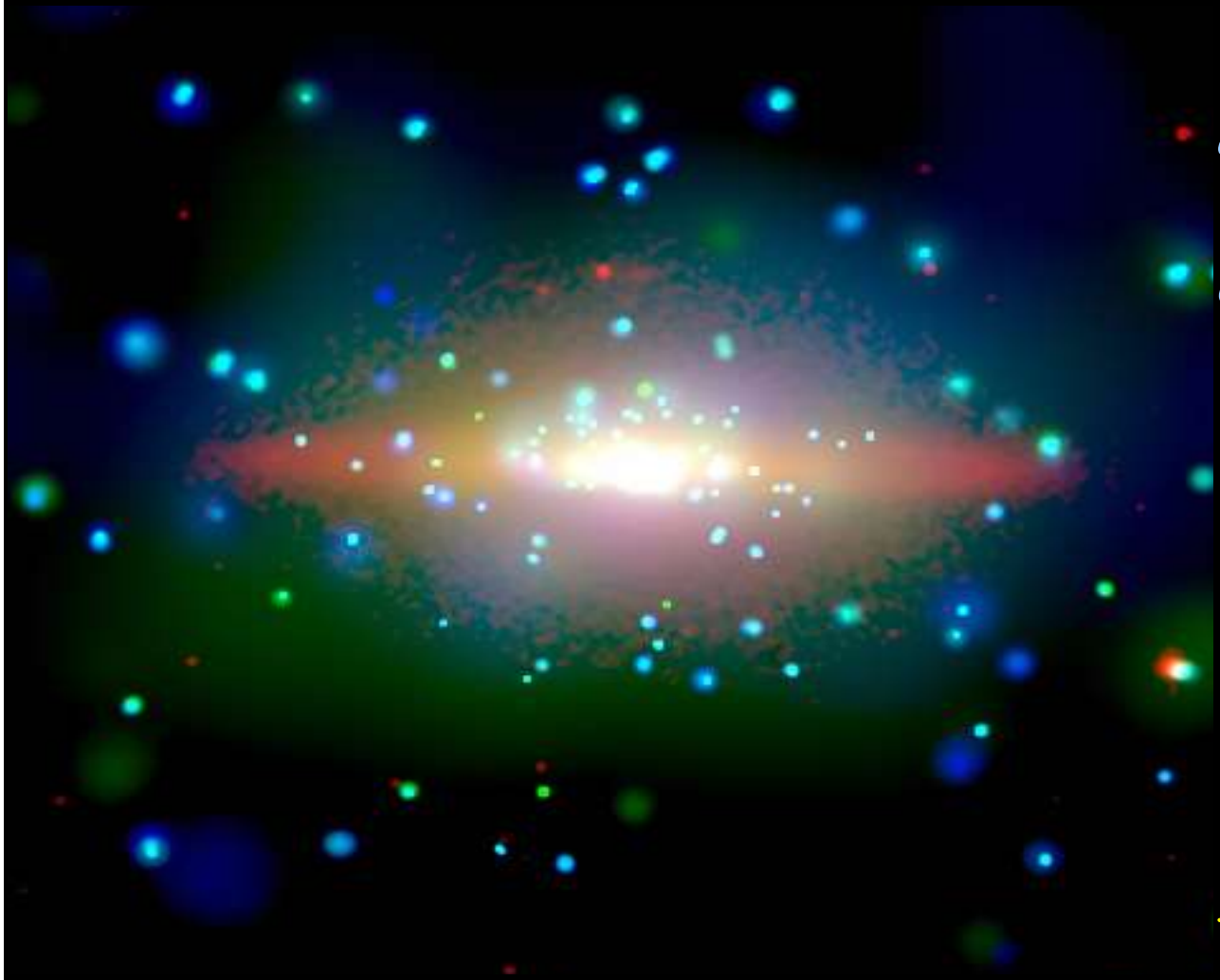


Red: optical

Blue: 0.3- 1.5 keV diffuse emission

Wang et al. 2006

NGC 4594 (Sa)



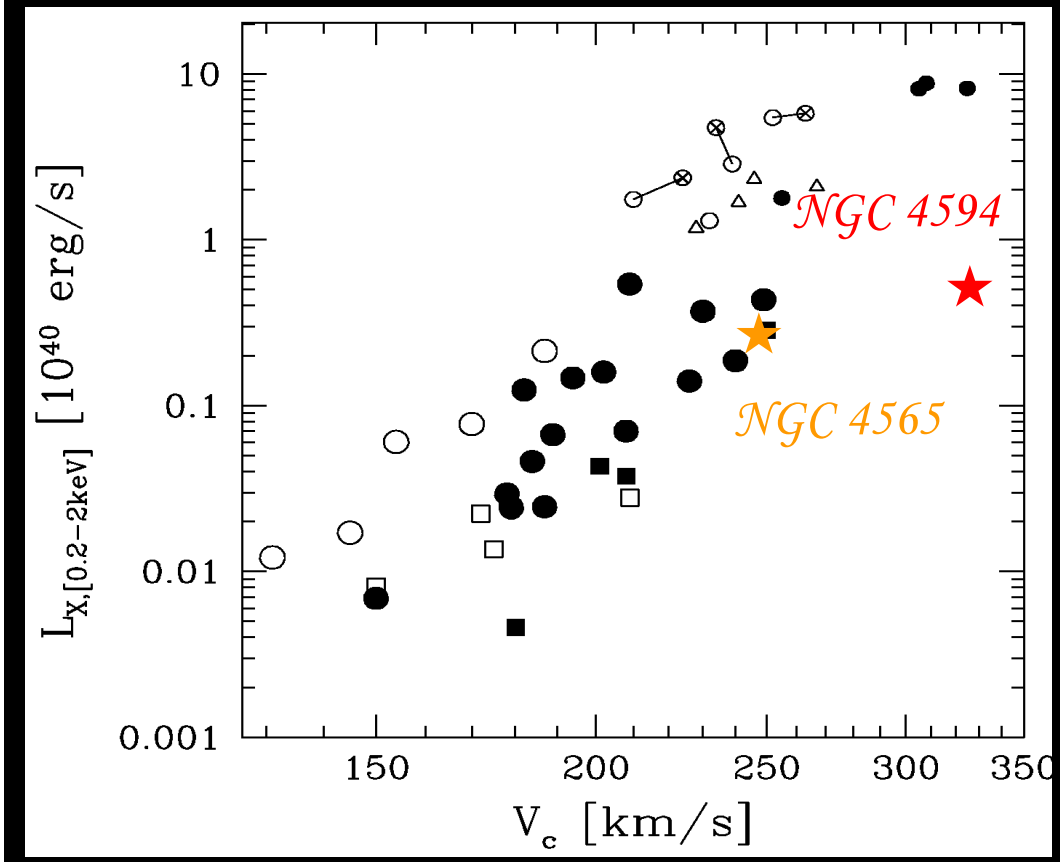
- Lx ~ 2% of Type Ia SNe energy alone
- Not much cool gas to hide or convert the energy
- Mass and metals are also missing!
  - Mass input rate of evolved stars ~ 1.3 M_{sun}/yr
  - Each Type Ia SN 0.7 Msun Fe

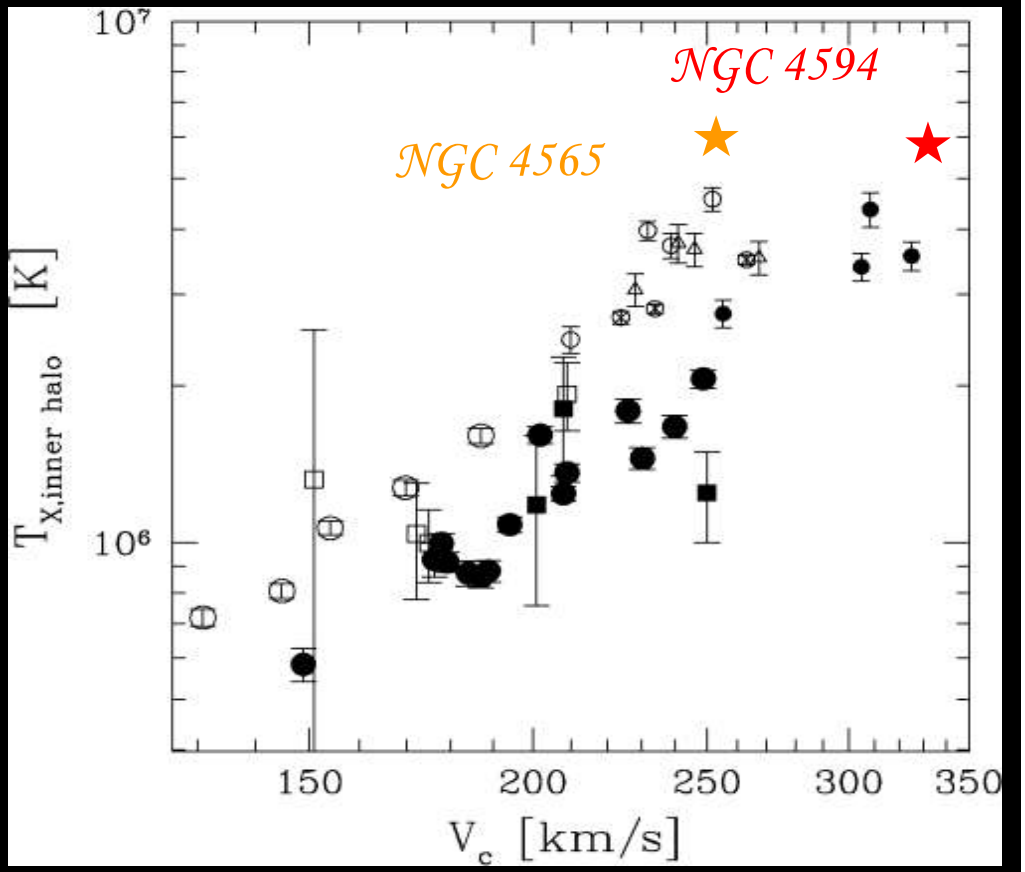
Missing stellar feedback in early- type disk galaxies!

Red: optical; Green: 0.3- 1.5 keV; Blue: 1.5- 7 keV

Wang & Li 2005

Galaxy formation simulations vs. observations: missing accreted IGM





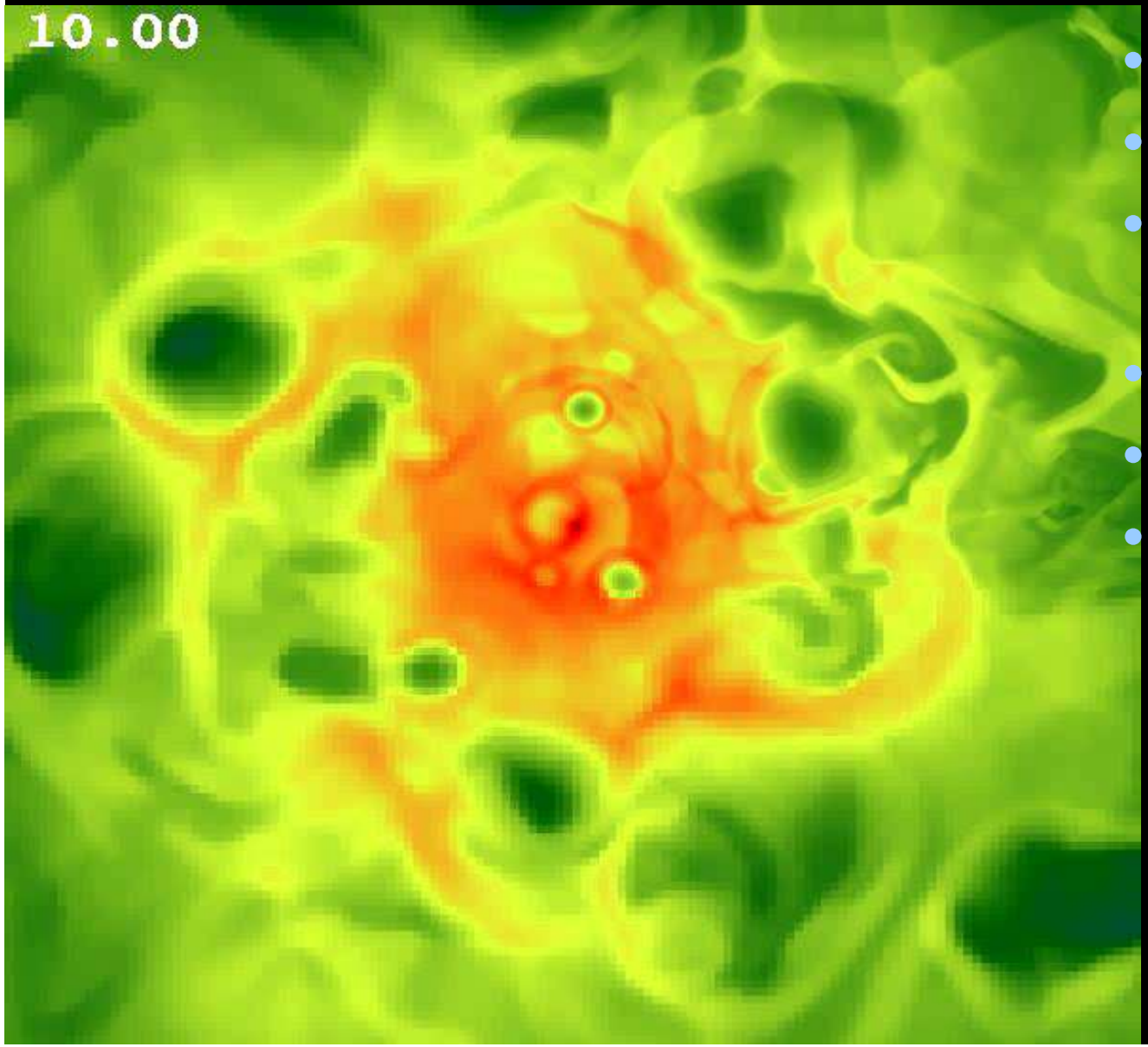
Toft et al. (2003)

Summary: Nearby galaxies

- Good News
  - At least two components of diffuse hot gas:
    - Disk – driven by massive star formation
    - Bulge – heated primarily by Type- Ia SNe
  - Characteristic extent and temperature similar to the Galactic values
- Bad news
  - Missing stellar feedback, at least in early- type spirals.
  - Little evidence for X- ray emission or absorption from IGM accretion
    - - - maybe good news for solving the over- cooling problem.

Are these problems related?

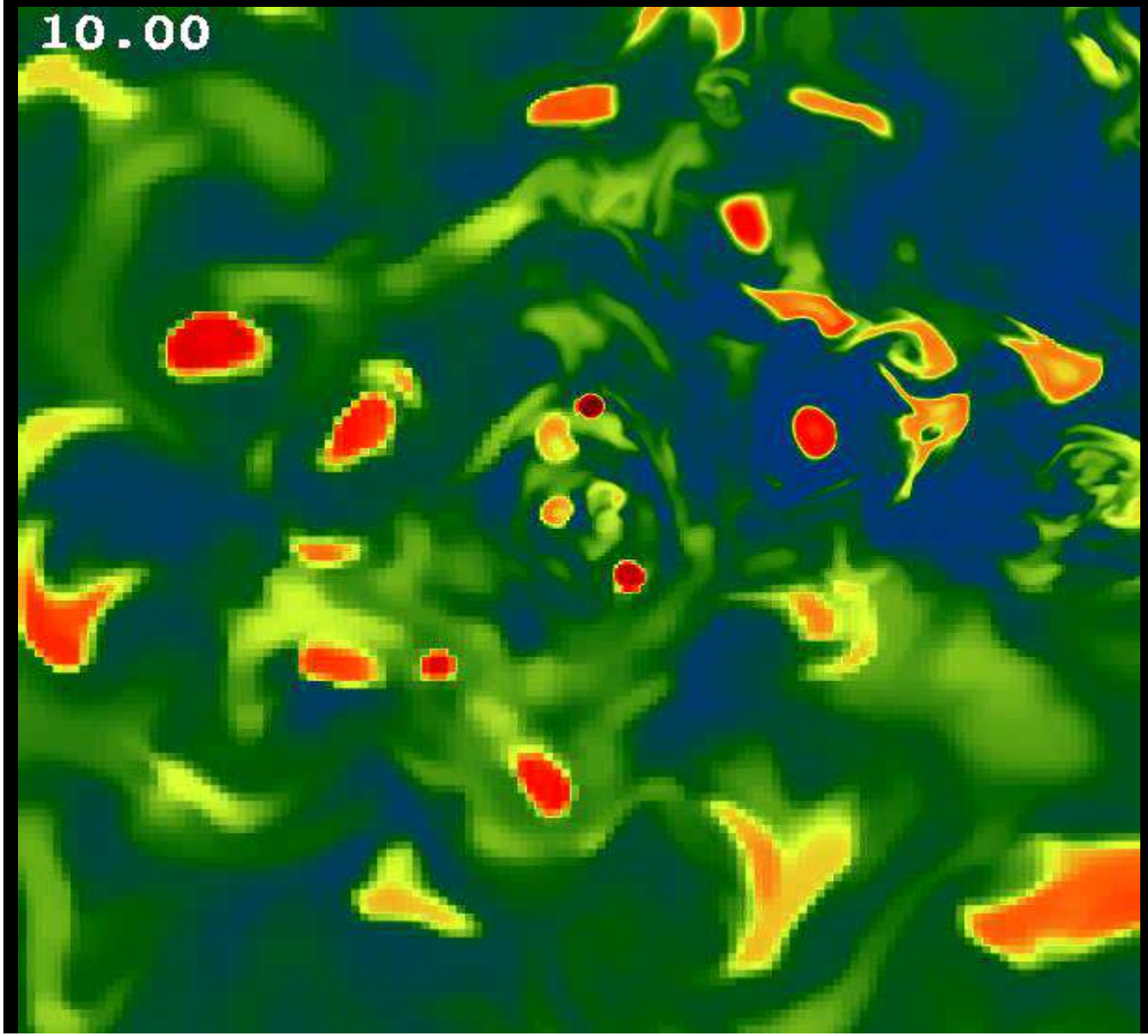
Galactic bulge simulation: density



- *3x3x3 kpc^3 box*
- *SN rate ~ $4x10^{4}$ /yr*
- *Mass injection rate ~0.03 Msun/yr*
- *Logarithmic scale*
- *Statistical steady state*
- *~ adiabatic*

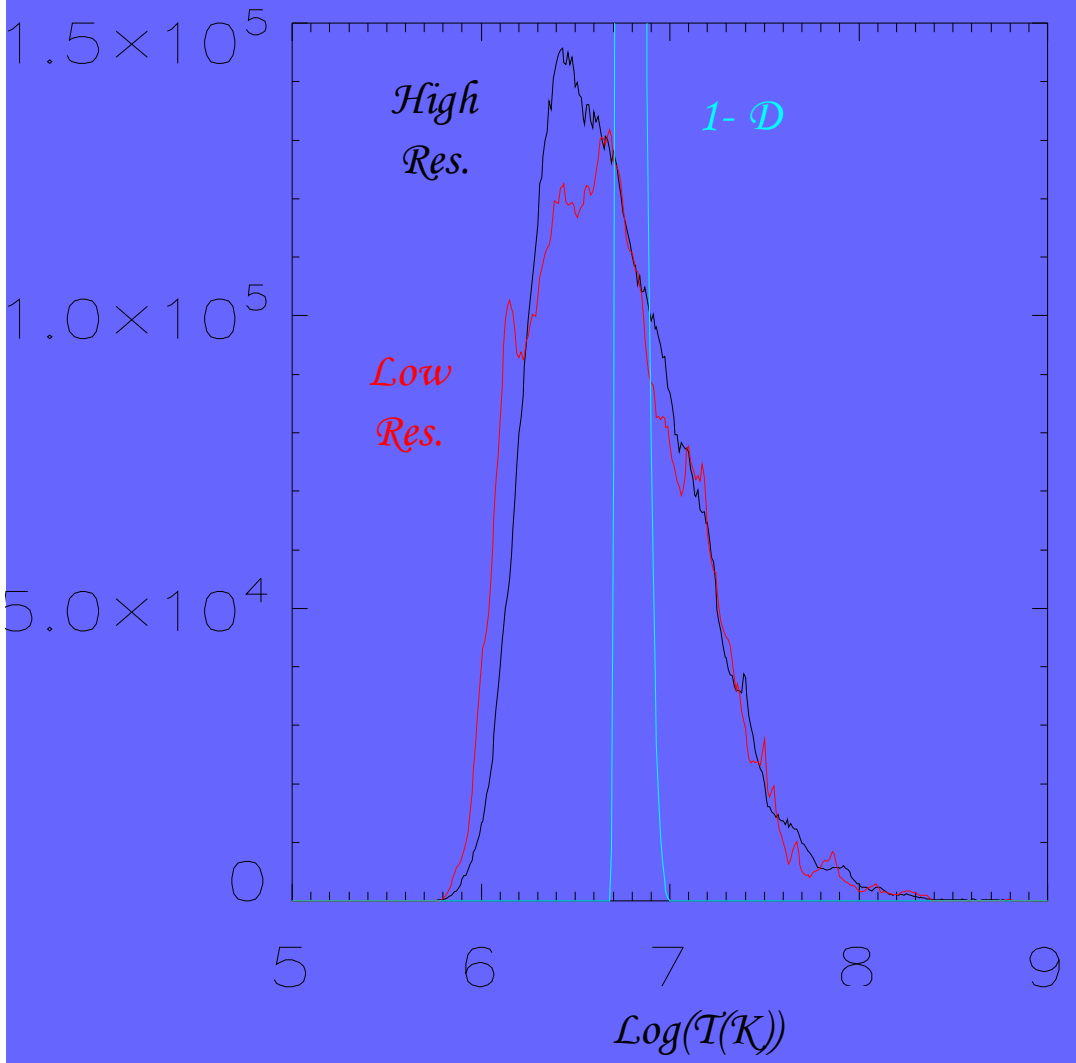
Tang et al. 2005

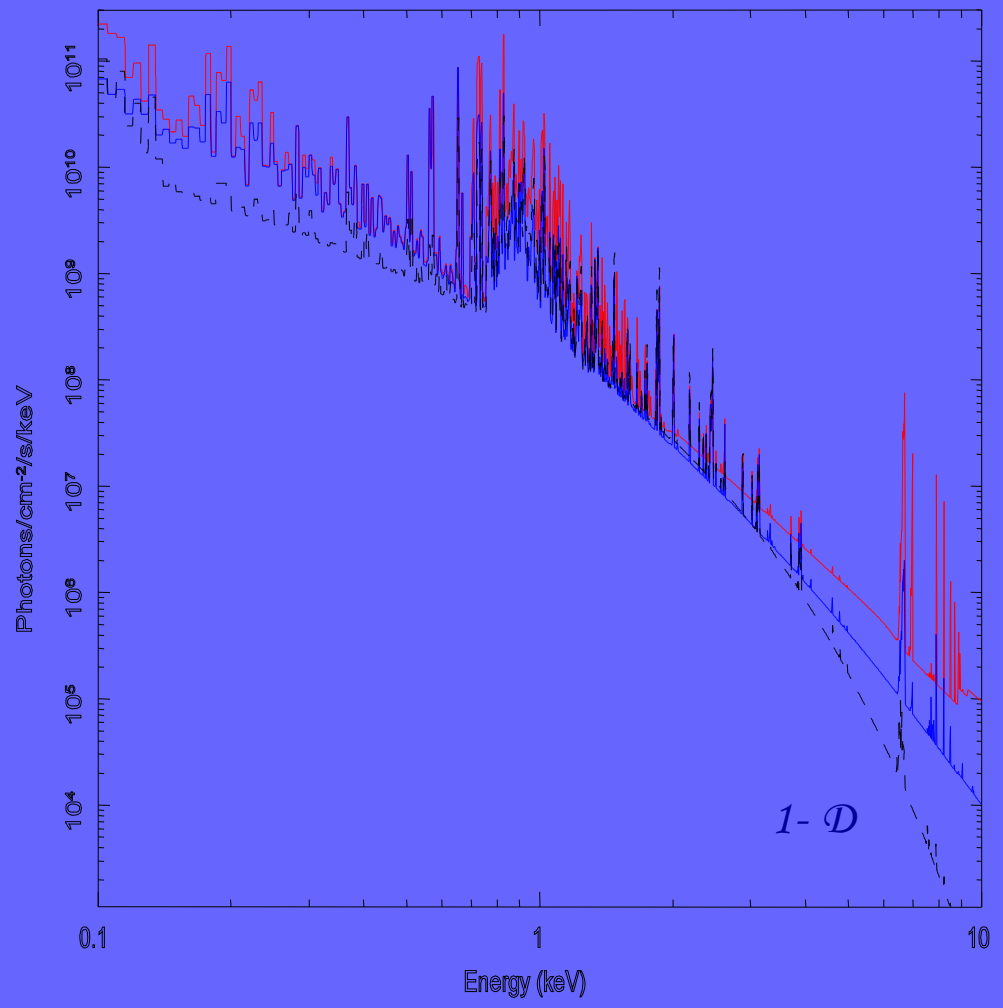
Galactic bulge simulation: Fe



- *Fe- rich ejecta dominate the high- T emission*
- *Not well- mixed with the ambient medium*
- *May cool too fast to be mixed with the global hot ISM*

Non- uniformity effects





What we do not know:

- *Filling factor*
- *Physical and chemical states*
- *Kinematics*

- *Overall spatial distribution*

- *Heating, transporting, and cooling*
- *Effects on galaxy formation and evolution*

Sample of normal disk galaxies

Galaxy Name	Hubble Type	D (Mpc)	Incl. ang. (deg)	Exp. Time (ks)
N4244	Sd/LSB	3.6	85	60
N4631	Sd	7.5	85	60
N3556	Sc	14.1	80	60
N4565	Sb	13.4	87	60
N4594	Sa	8.9	84	19

All with low Galactic foreground absorption ($N_H < 3 \times 10^{20}$ cm^{-2})