The ISM

(Diffuse Emission in Galaxies)

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Xray Emission from Galaxies

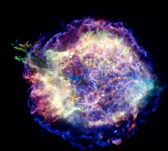
Point Sources

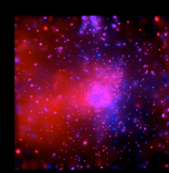
LMXB HMXB

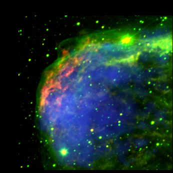
Population Studies

Diffuse Emission

SNR | SFR | Bubbles | Super-Bubbles | Un ID'd







Due to single stars

Multiple SW
& SNE

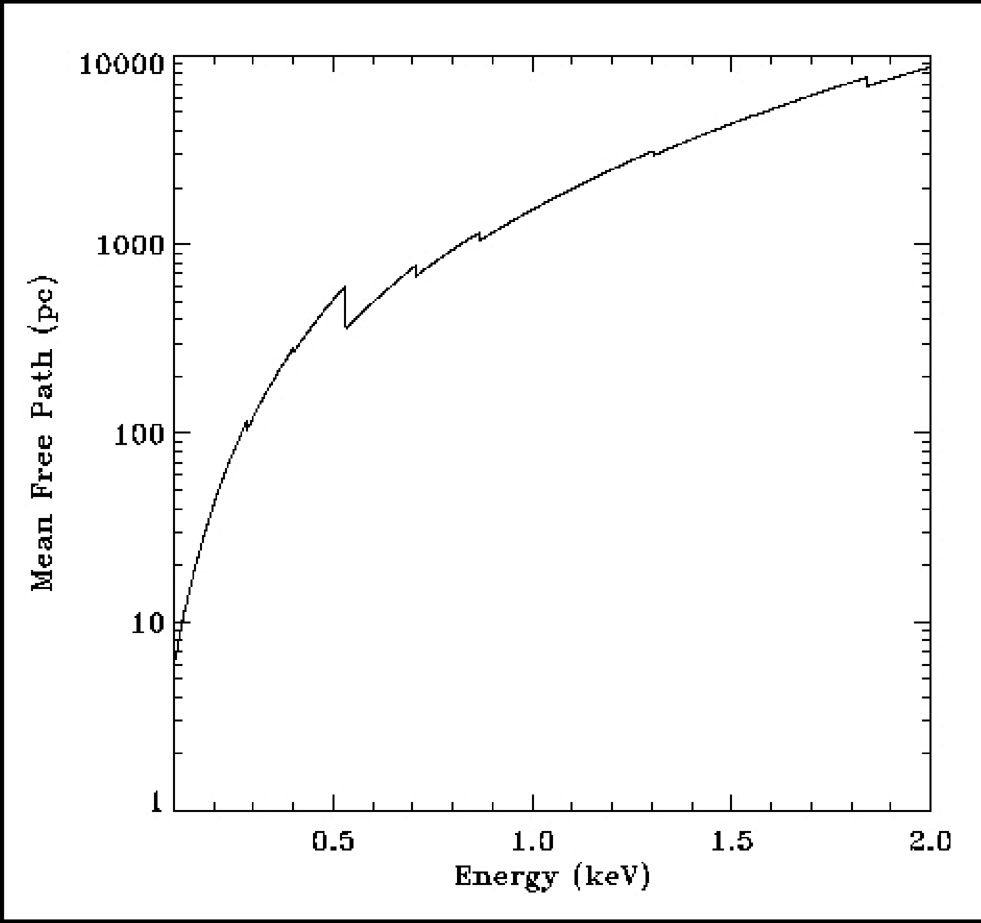
Large Scale Emission
(multiple degrees
or larger)

Outline

- Diffuse Emission in the Milky Way
  - Large Scale Emission (LHB, Galactic Halo, Etc.)
  - Super Bubbles
  - Star-Forming Regions
- Diffuse Emission in Other Galaxies
  - Global Correlations

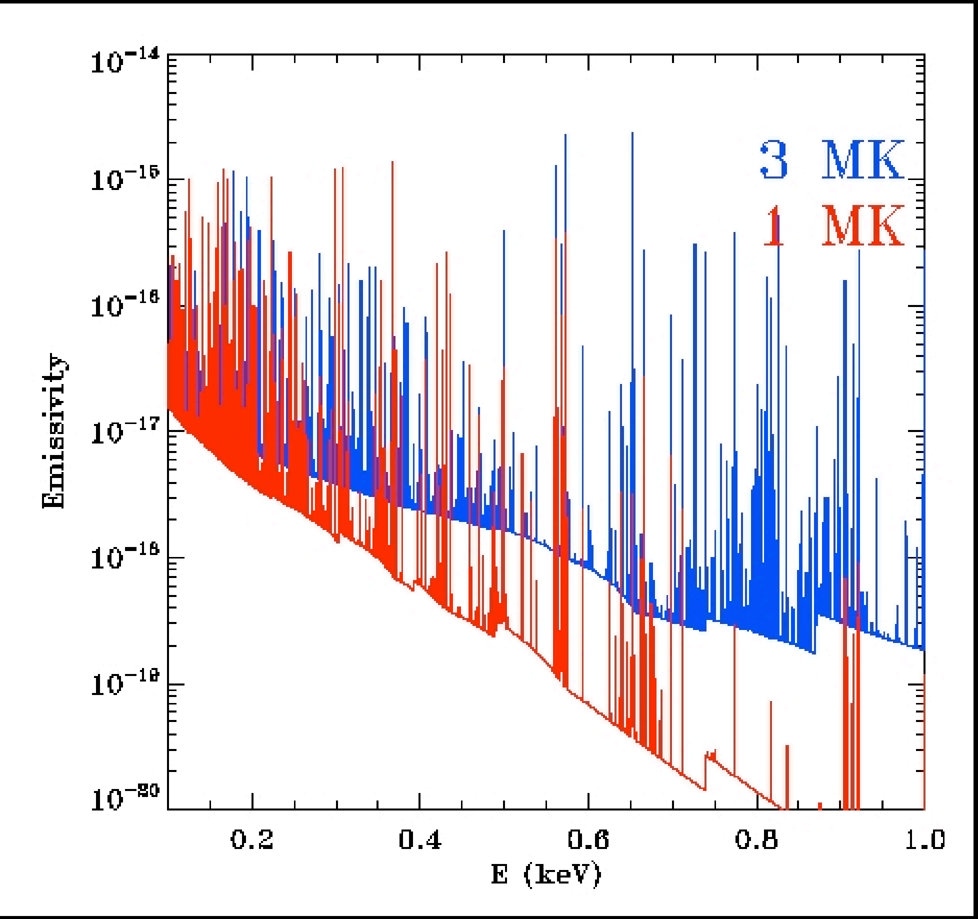
Fundamentals of X-ray Astronomy

- X-ray Absorption Cross-Section is $E^{-2/3}$
  - Lower energy photons more readily absorbed
  - One can see further at higher energies



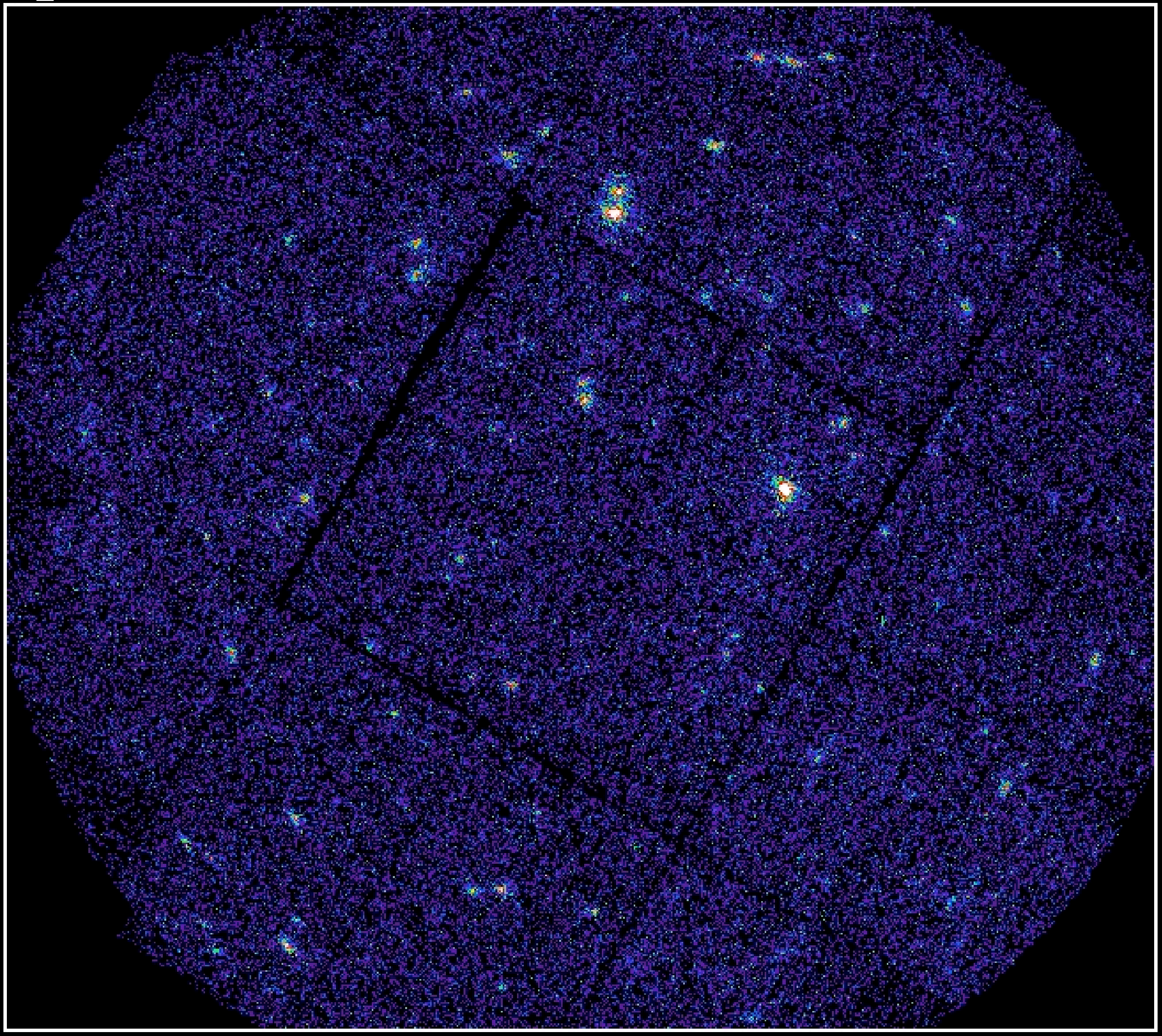
Fundamentals of X-ray Astronomy

- Typical hot ISM T~10^6K _emission below 0.7 keV
  - Most parts of the hot ISM hidden from us
- Most of what we see at low E is local!



Diversion I

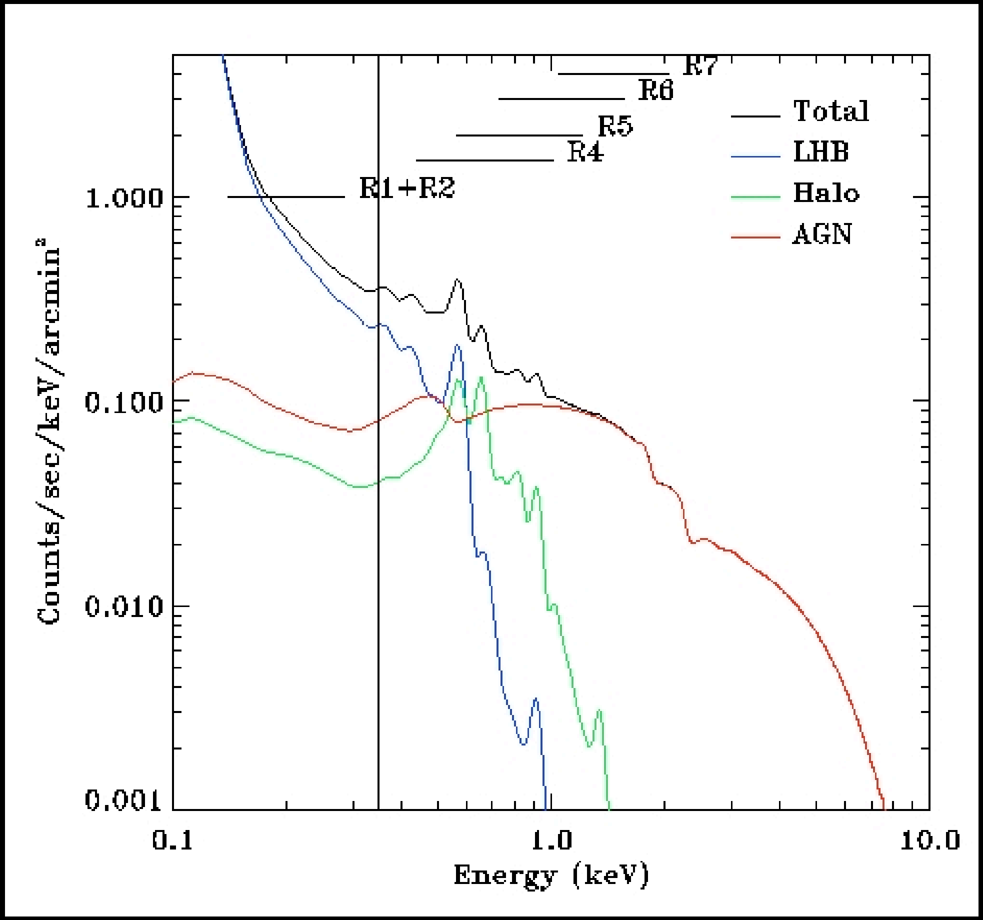
- A high Galactic latitude, bulk of sources are AGN
- Deep exposures reveal more & fainter sources



Diversion I

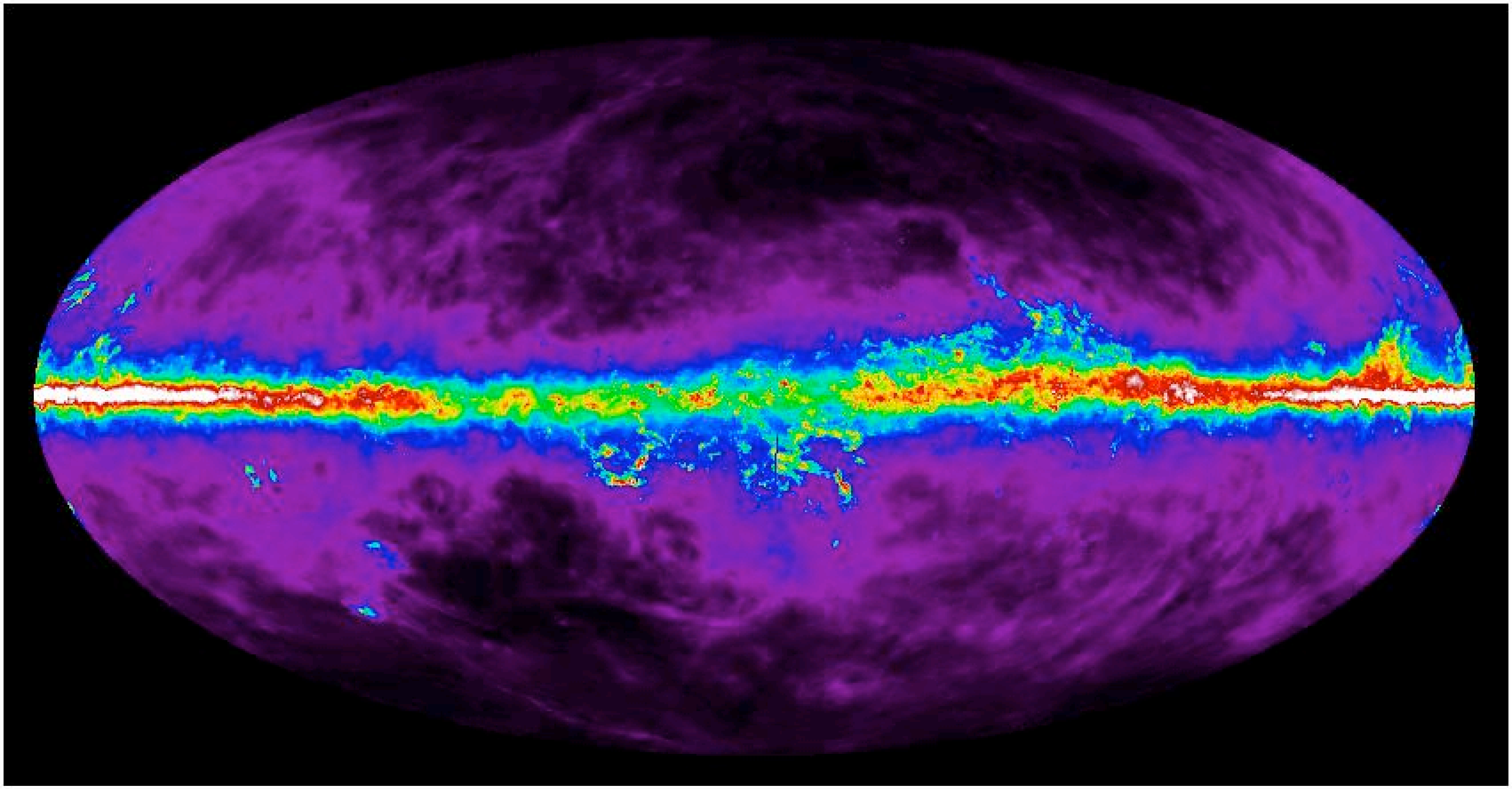
- Does _AGN=total X-ray surface brightness?

  Yes, but…answer depends upon the energy.

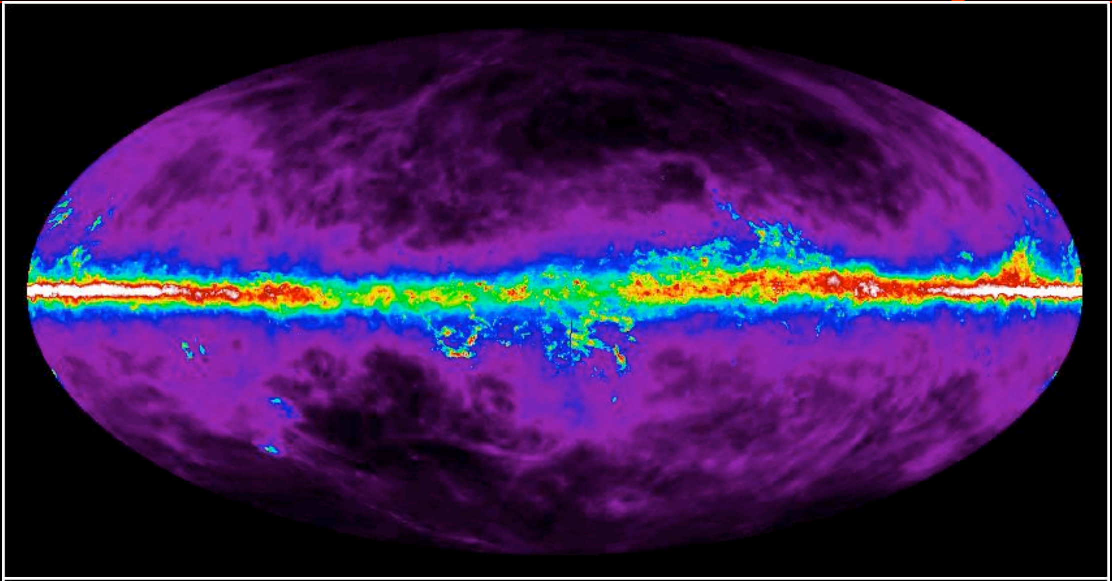


A Model of the Sky

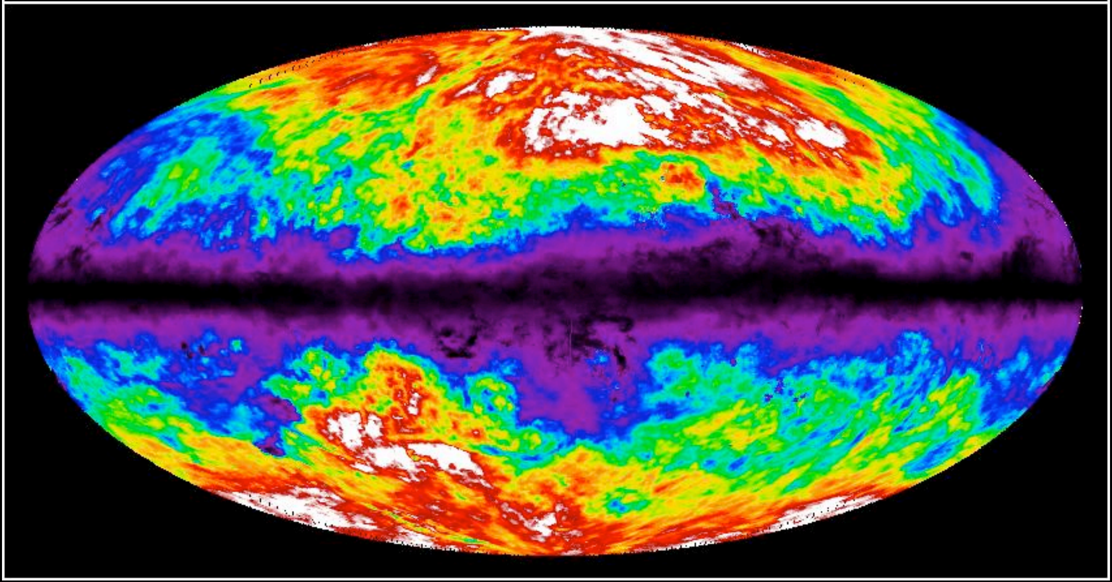
- Consider a map of the absorbing column due to neutral and molecular gas in the Milky Way.
- If all of the emission is due to AGN, what does the sky look like?



A Model of the Sky

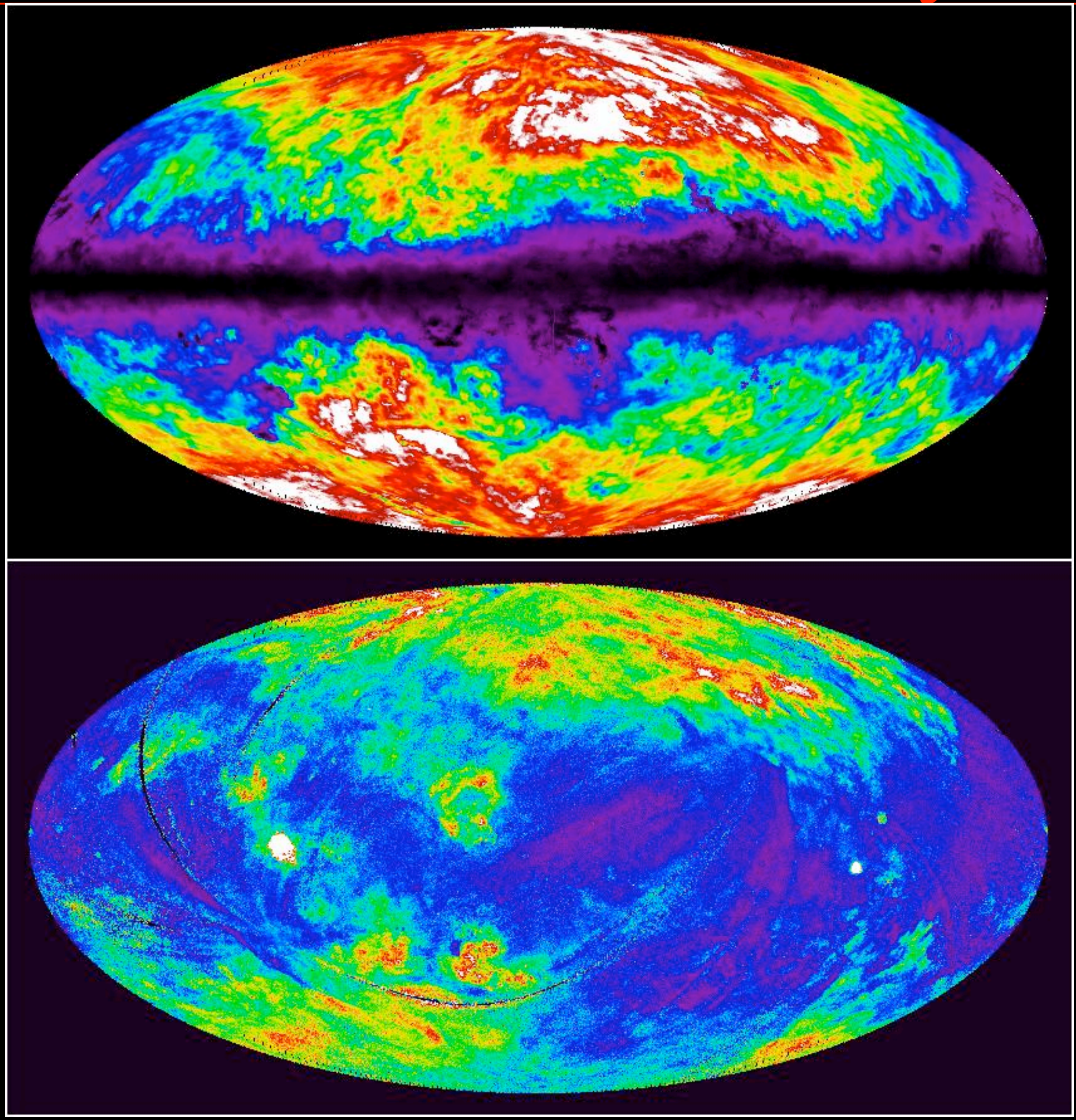


Absorption



_ keV em.

A Model of the Sky

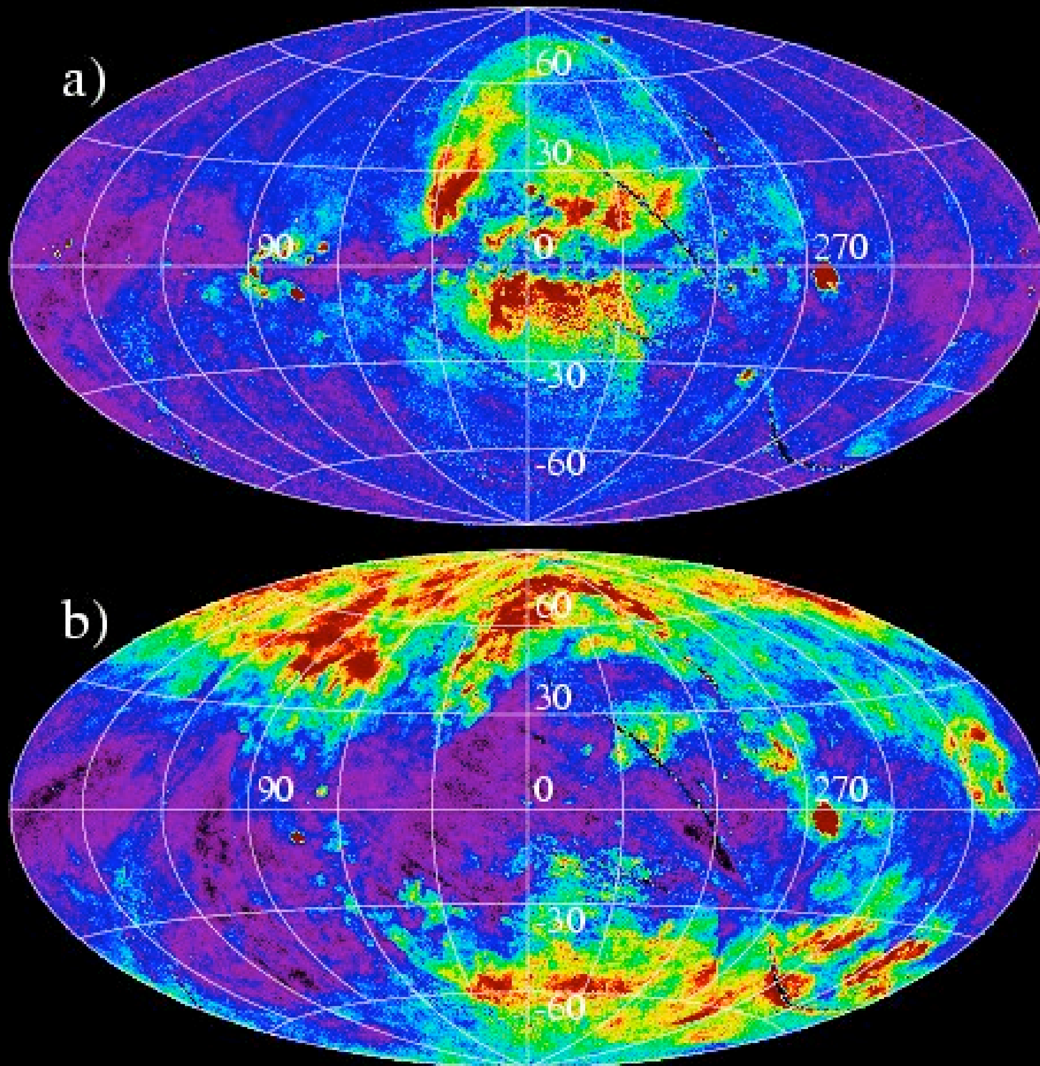


Model

Observed

R12= _ keV

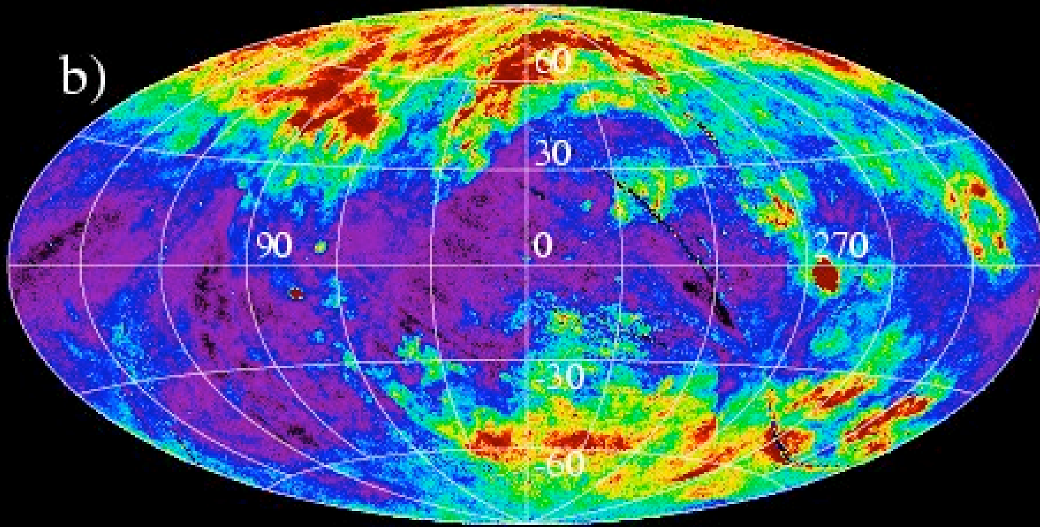
The Observed Sky



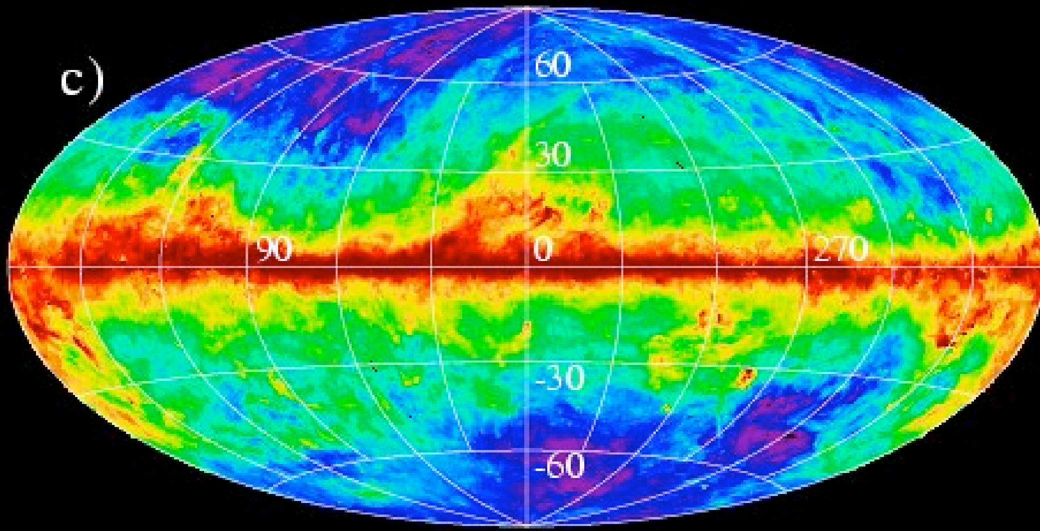
_ keV

_ keV

The Observed Sky



1/4 keV



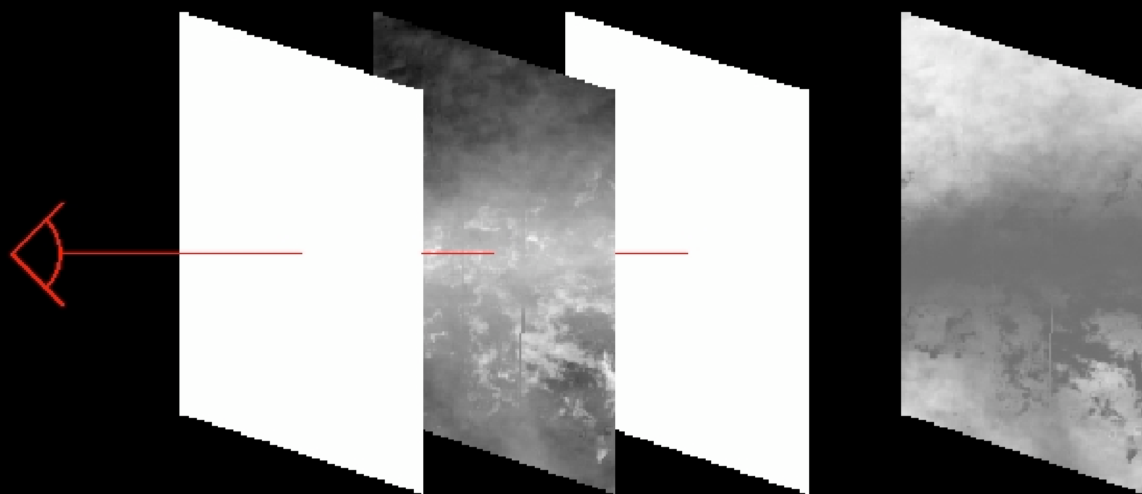
100μm

The Observed Sky

- At _ keV and _ keV there is diffuse local emission
  - Not identifiable with any single SN, SNR, or SFR
- Distribution in _ keV and _ keV bands is different
  - (not just an effect of absorption)
- Distance to emission (and thus its mass) is unknown.

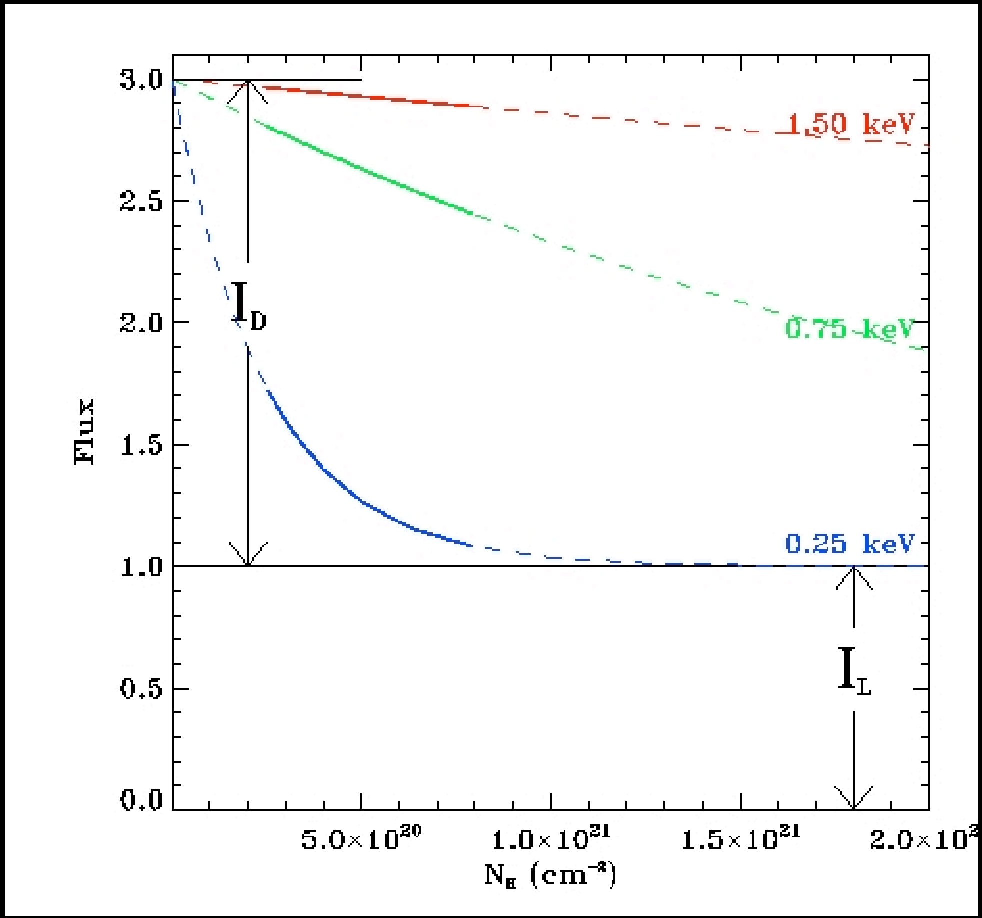
Diversion II

- Assume:
  - Uniform local emission
  - A screen of absorption
  - Uniform distant emission



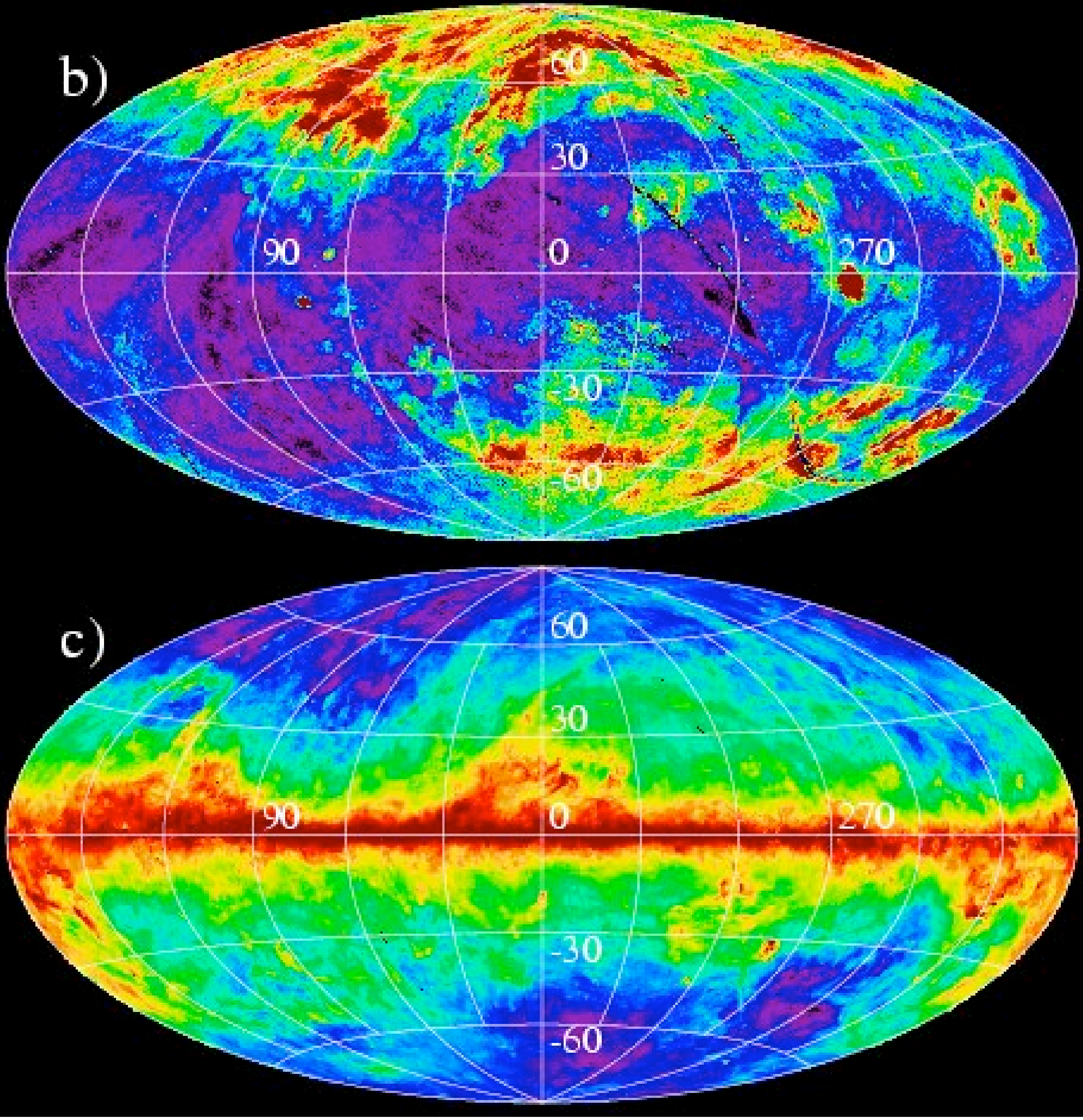
Diversion II

- If _=_N_H varies with position
  - Anticorrelation of _ and surface brightness
  - By fitting anticorrelation
    - Can determine
      - I_L and I_D

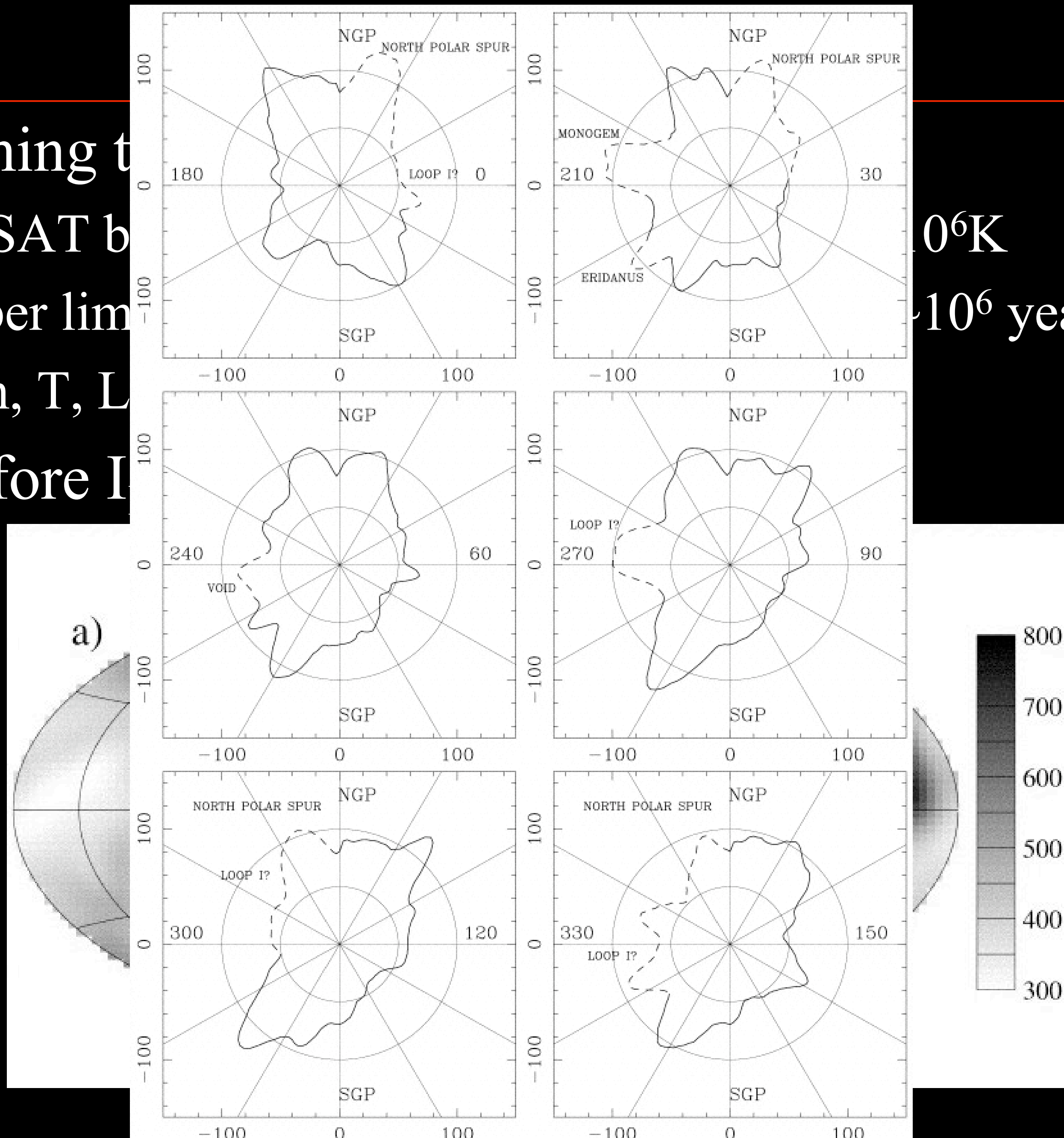


LHB

- From ... ions
- Give...
  - _ upp...
  - _ low...



- Assuming t
  - ROSAT b ... 0^{6}K
  - Upper lim ... 10^6 years
    - _ n, T, L
- Therefore I



LHB

The Local Hot Bubble:

- Irregular region filled with $T=10^6$K emission
- Inside a larger(?) region (Local Cavity)
  - With below average density of neutral material
- Controversy: contamination by very local emission
  - The heliosphere is X-ray bright
  - Accounts for some unknown fraction of "LHB" emission
  - Some truly LHB emission does exist

LHB

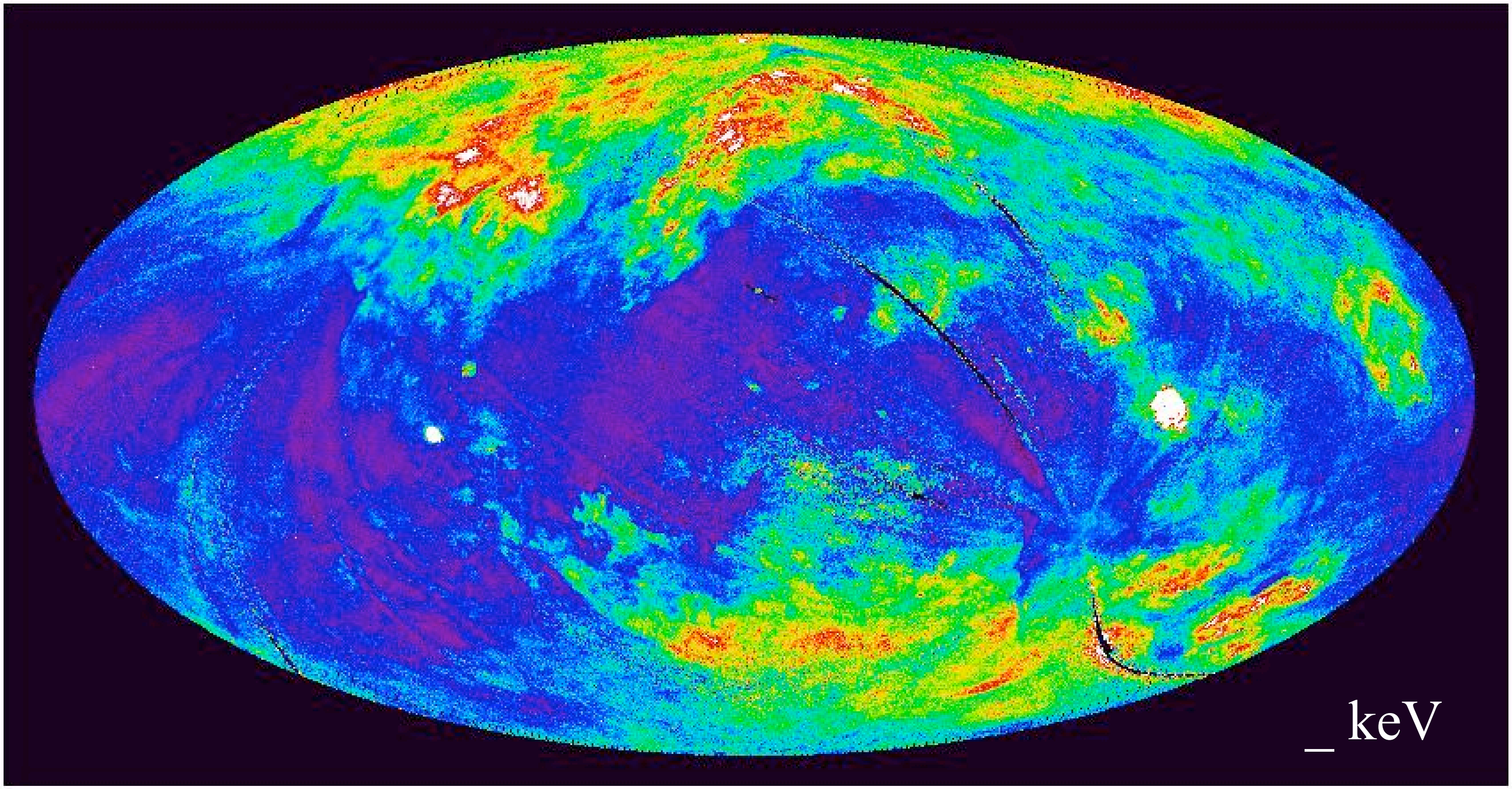
The Local Hot Bubble:

- At $T \sim 10^6 K$, emission is so low-energy that we can't see similar bubbles further away than a few 100 pc.
- Could be a major component of galactic X-ray emission
- Bulk of emission below Chandra/XMM bandpass

Galactic Halo

At high Galactic latitude the I_D component is the halo.

- In some directions the halo emission is substantial



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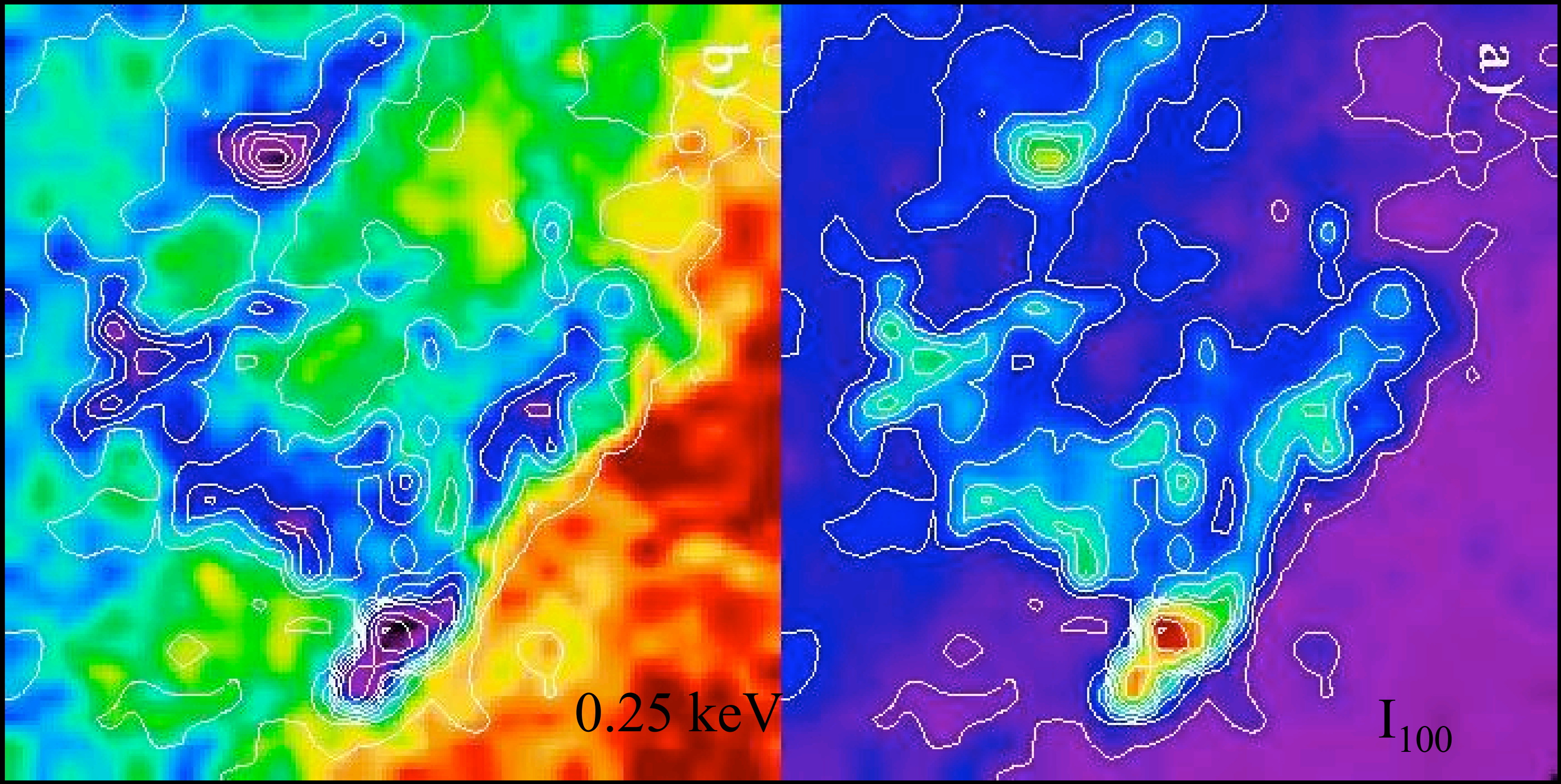
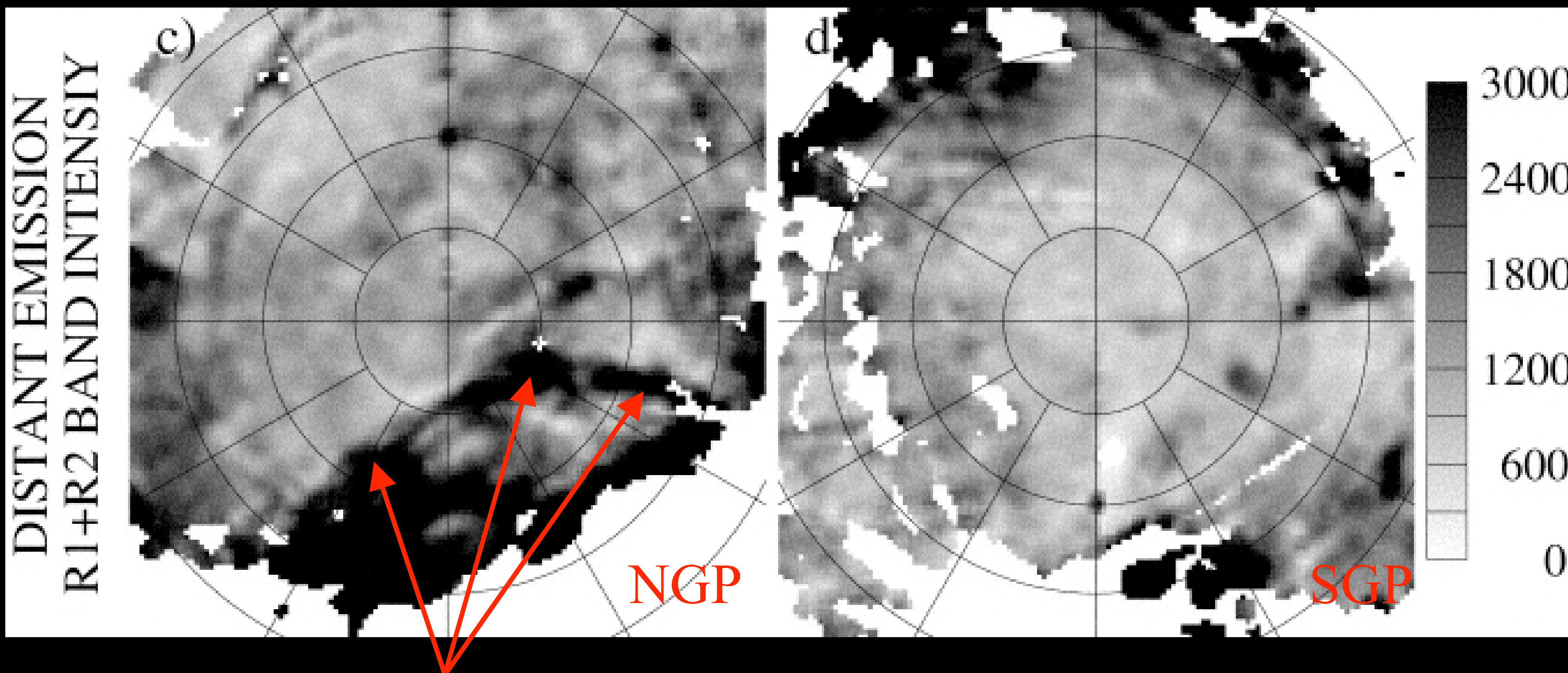


Galactic Halo

At high Galactic latitude the I_D component is the halo.

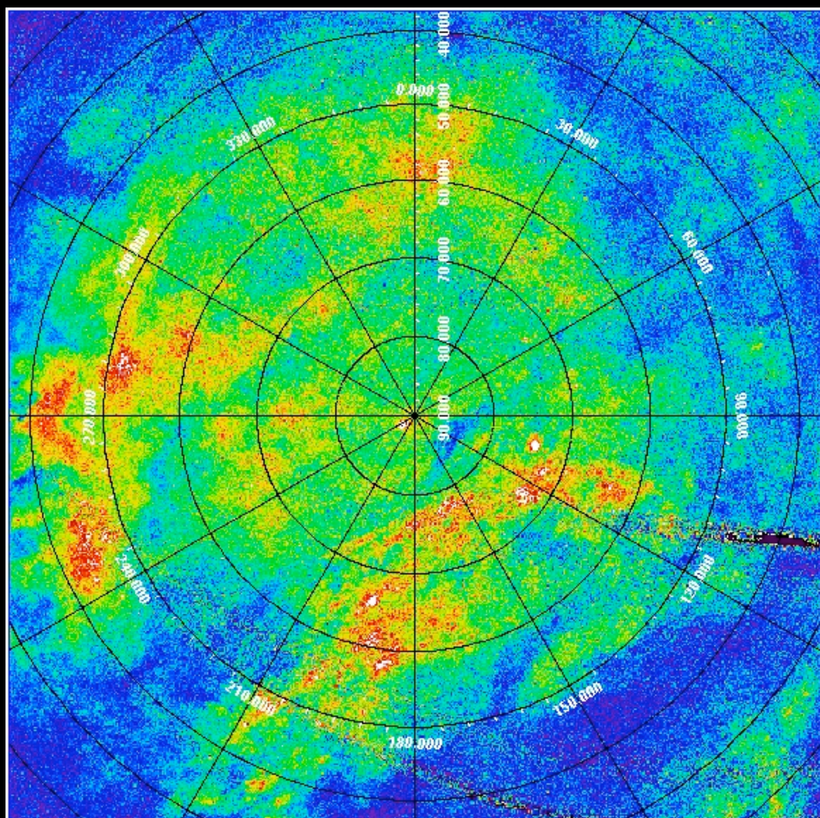
- Distant emission at _ keV is mottled



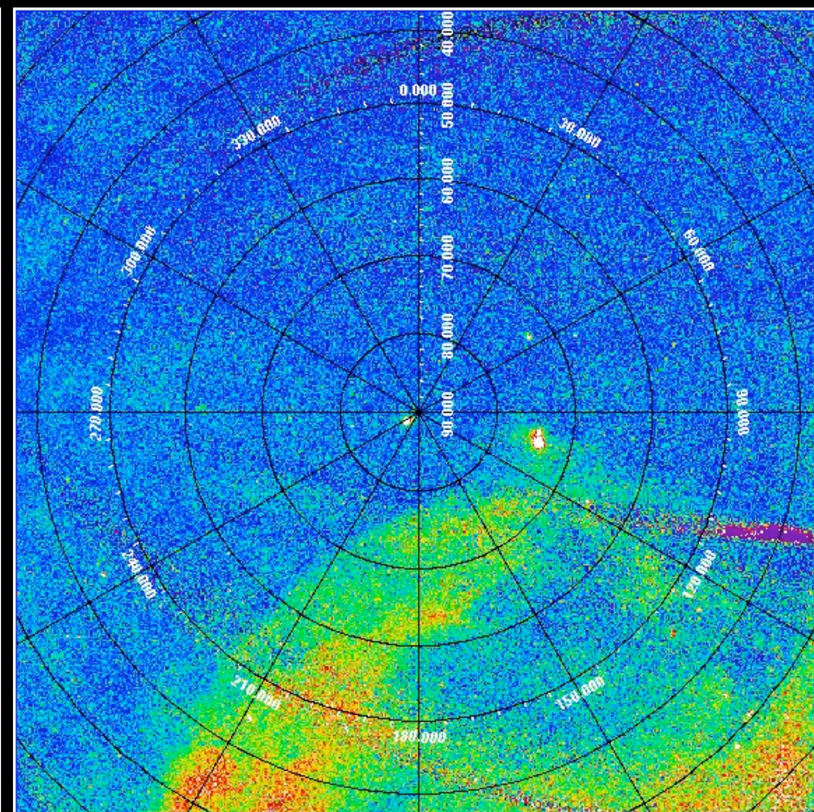
Galactic Halo

At high Galactic latitude the I_D component is the halo.

- Emission at _ keV is smoother than at _ keV



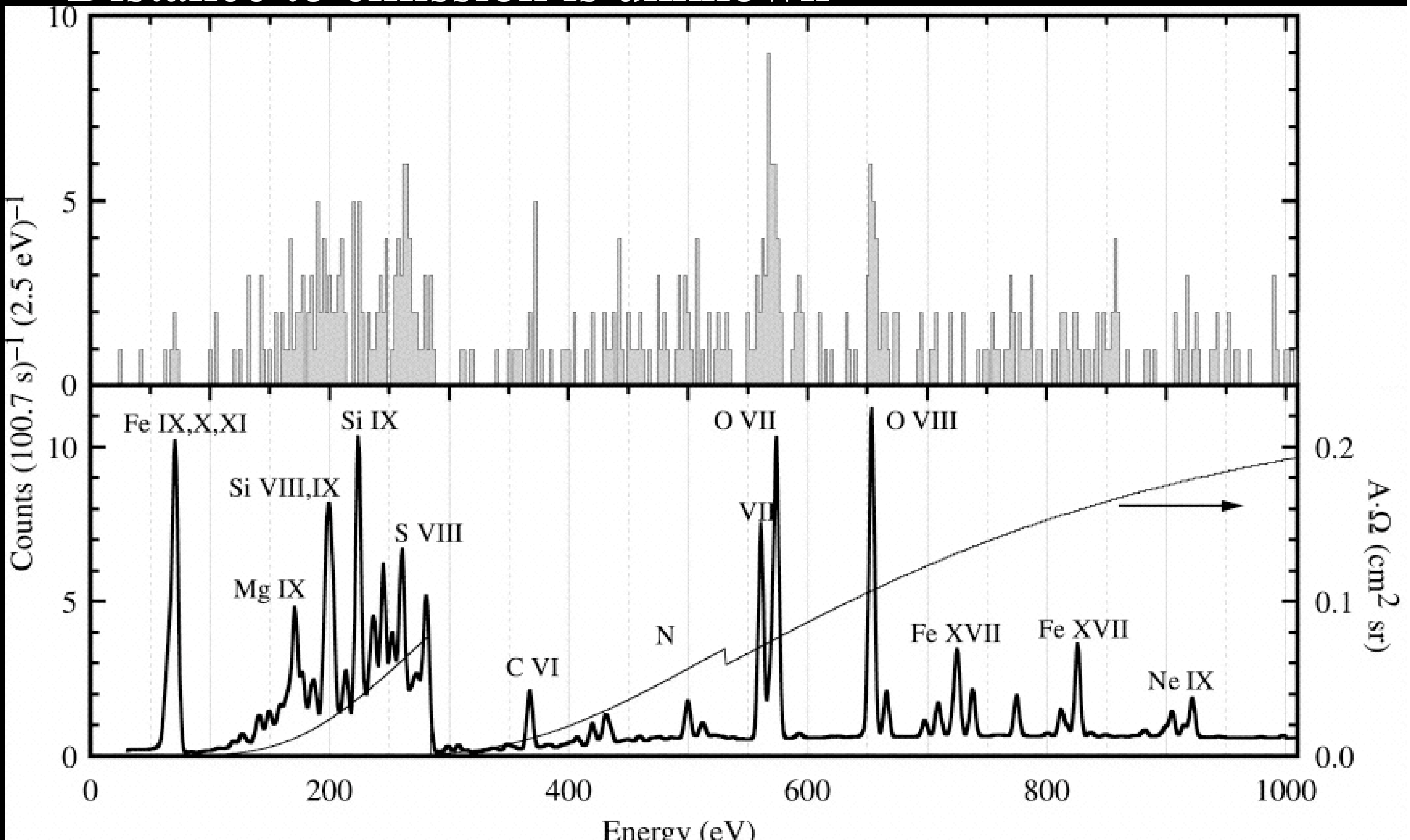
_ keV



_ keV

Galactic Halo

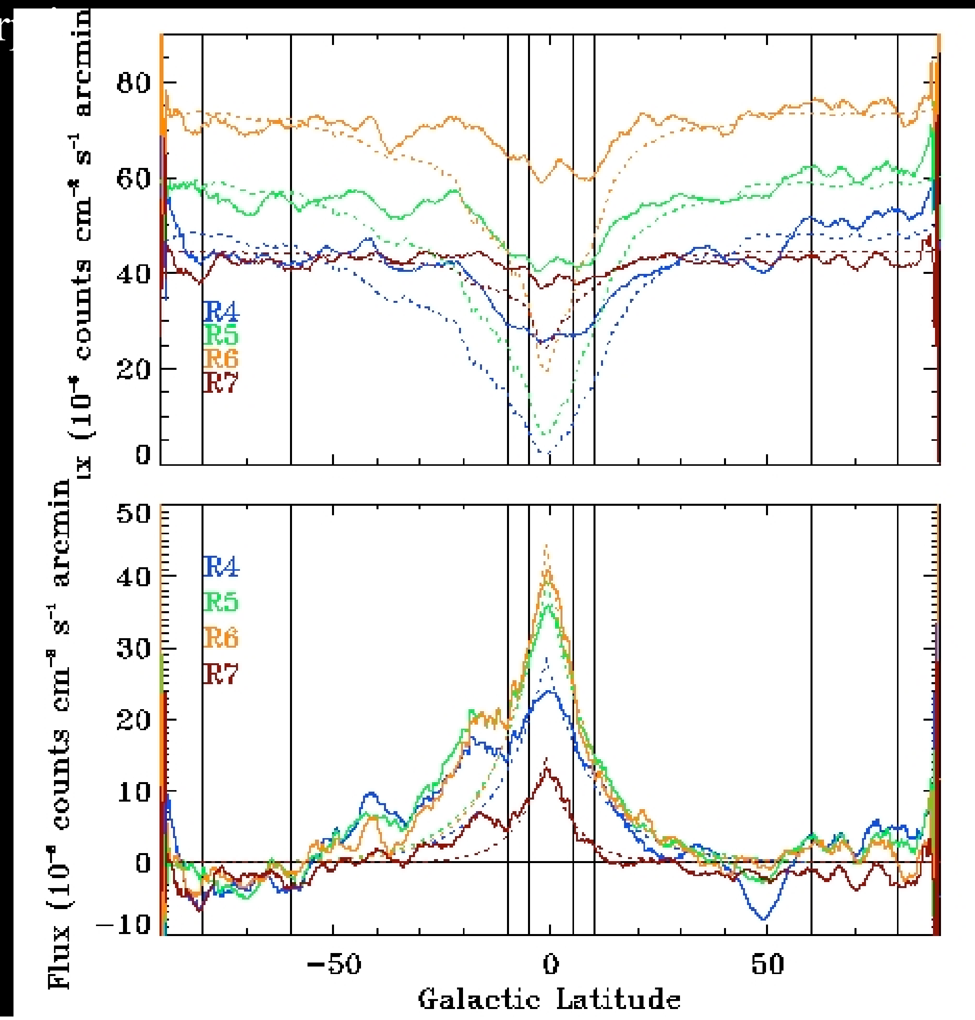
- Distance to emission is unknown



Galactic Disk Emission

In this image of the Galactic anticenter at _ keV,

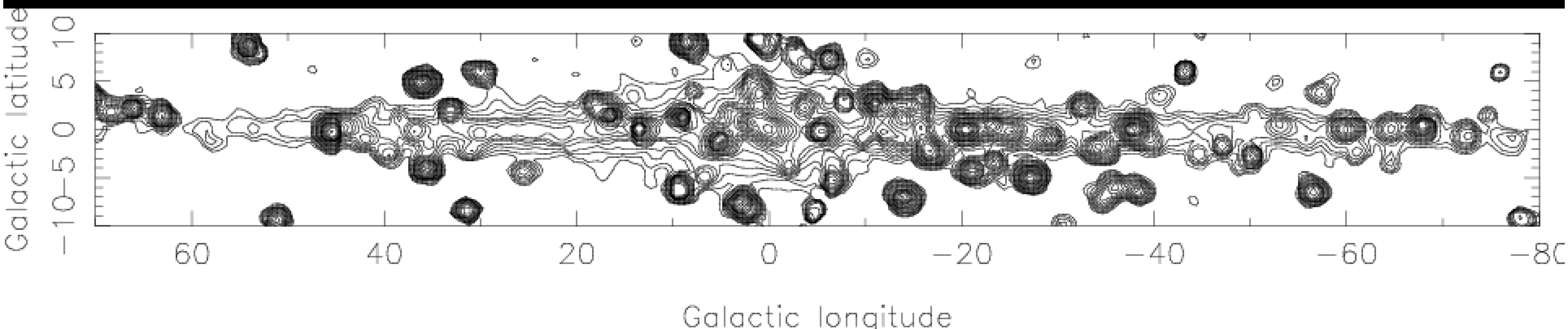
- The disk absorption is less than expected if all emission were extragalactic
  - There must by X-ray emission due to the Galactic disk
  - Must “exactly” balance the absor
- Stars can provide some fraction
  - Source population unclear
  - Spatial distribution is unclear (due to emission and abs. being intermixed along LOS.)
- kT~0.6 keV



Galactic Ridge Emission

Hard (kT~7.0 keV) Emission along the Galactic plane:

- Truly diffuse emission or unresolved point sources?
  - Seemingly diffuse component has same distribution as the near IR _ distribution is stellar _ due to point sources
  - Identification of point source population problematic(?)
  - Spectrum of emission is problematic(?)

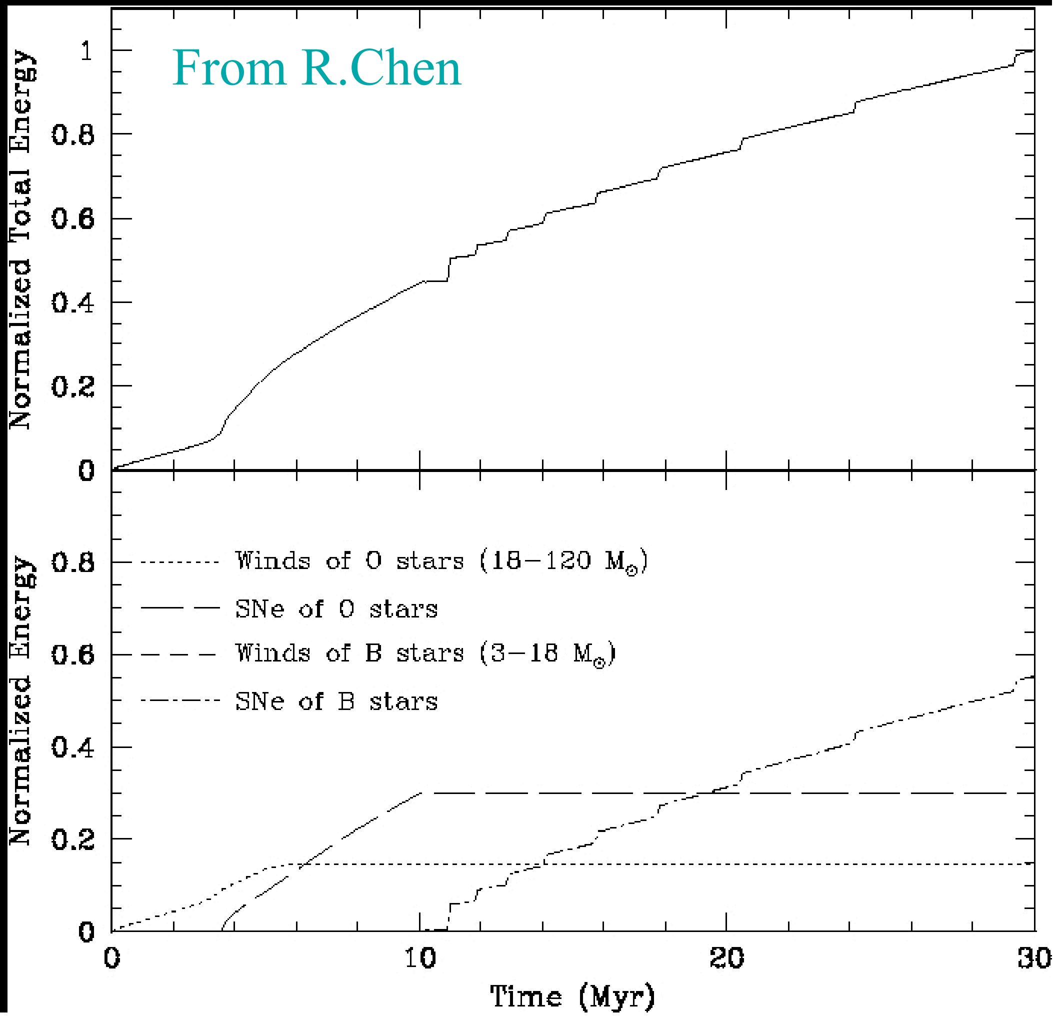


Star-Forming Regions

From pop. synthesis models, expected source of X-rays:

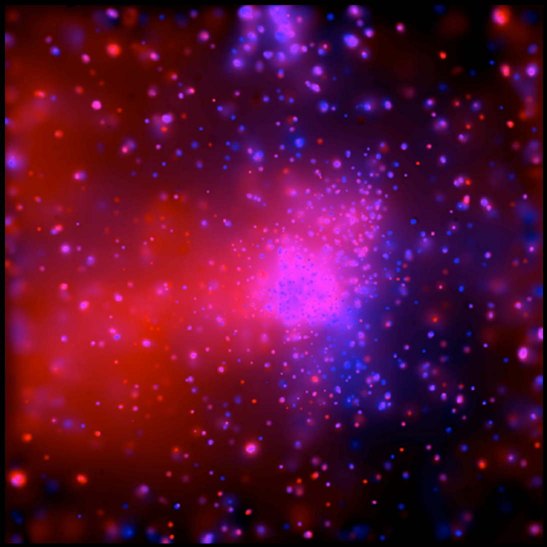
- O star winds >>> B star winds
- O star SNe ~ B star SNe

  (depends on age)



Star-Forming Regions

Observed SFRs (without SNe):



M17 Shows plenty of diffuse emission

~30 OB stars

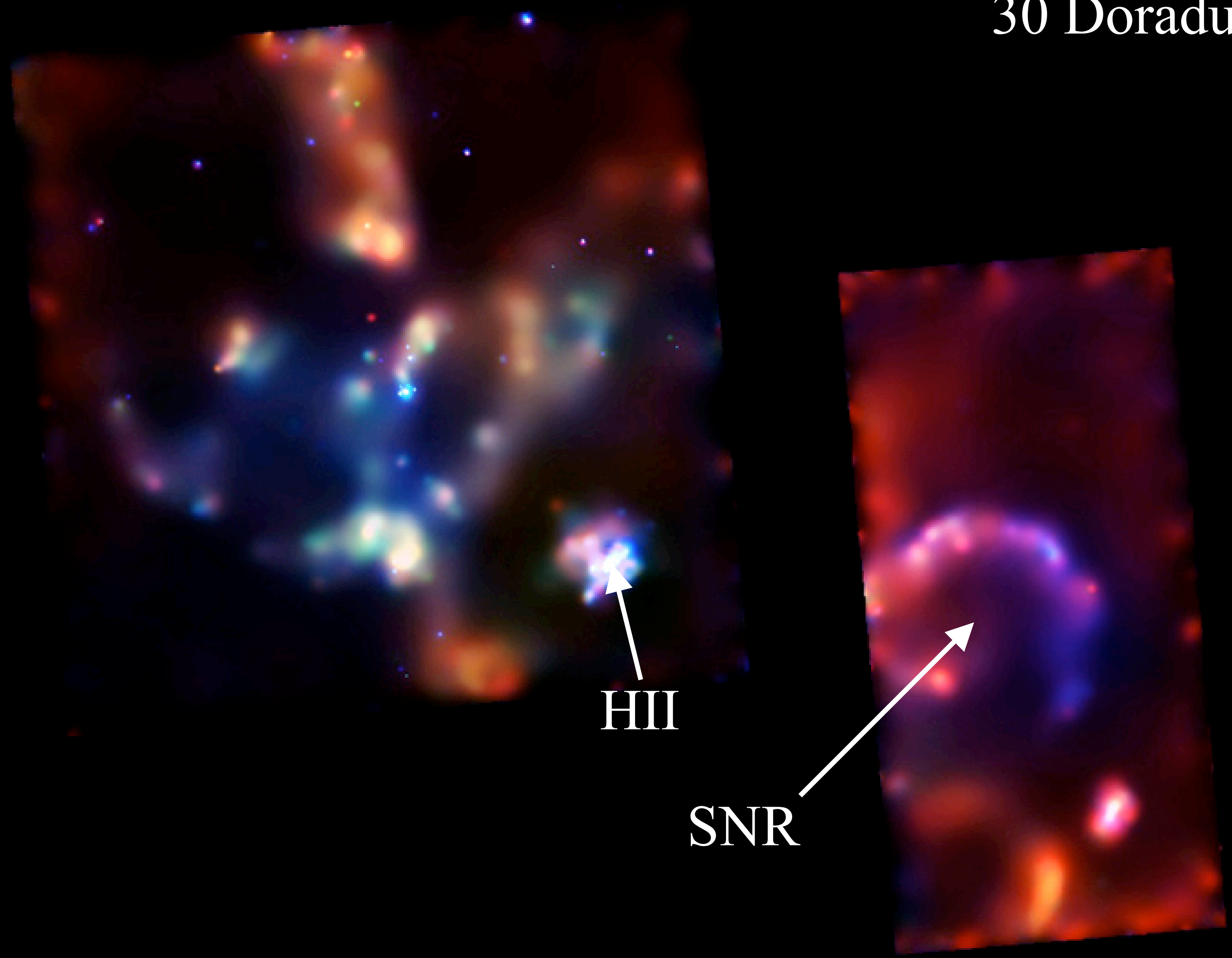
While Orion does not.

~5 OB stars

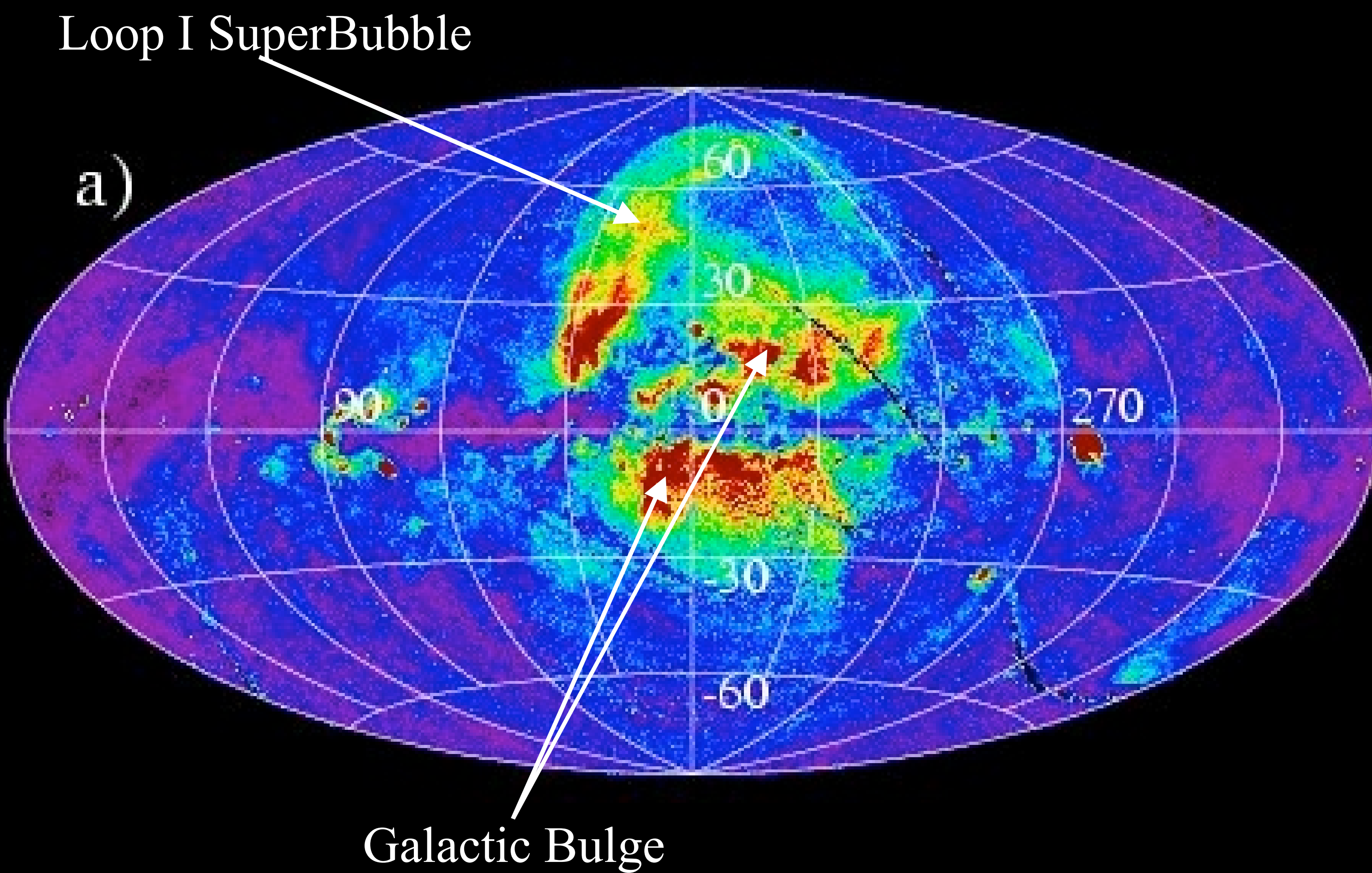
Star-Forming Regions

Somewhat older SFR: What a mess!

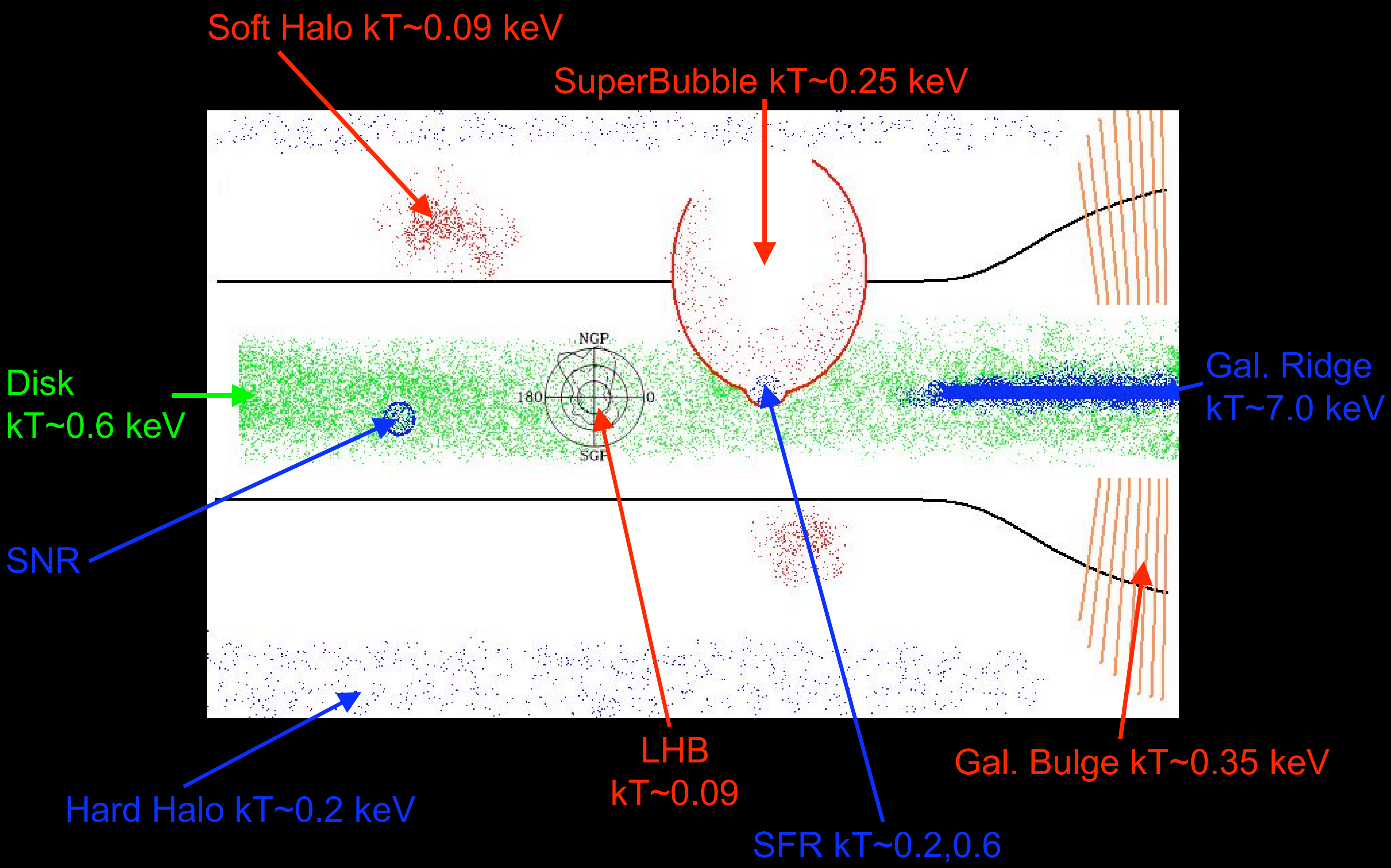
30 Doradus



Miscellaneous



Milky Way Summary



Milky Way Summary

What is the filling factor?

- Is it a pervasive hot medium with embedded cool clouds?

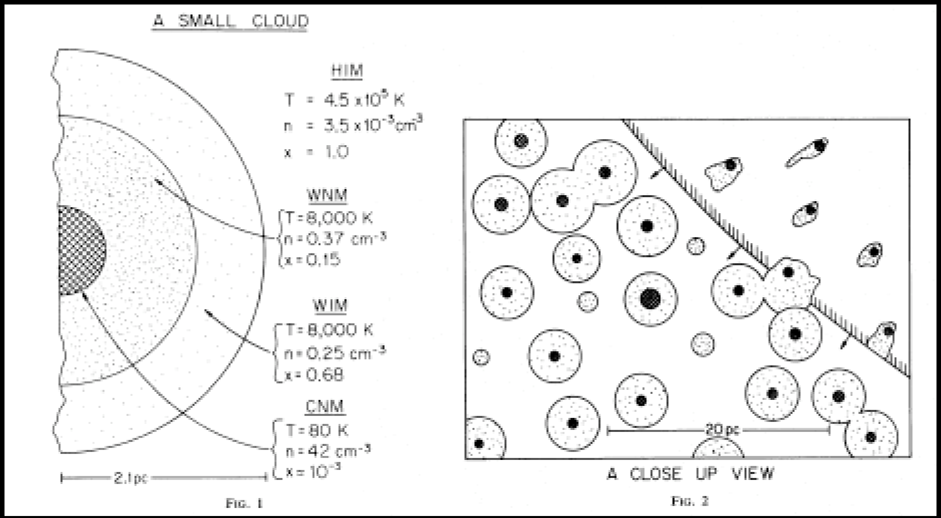


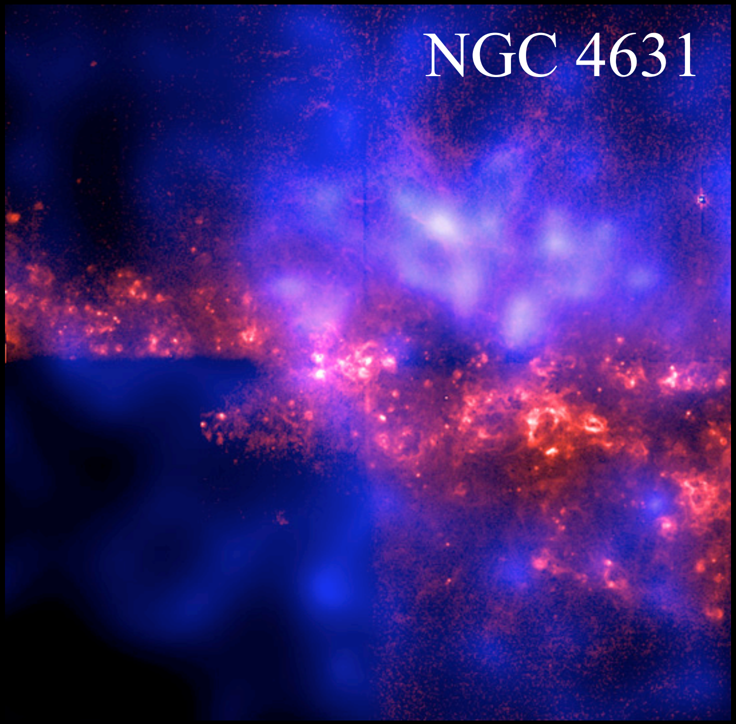
FIG. 1 FIG. 2

- Is it restricted to hot bubbles in a pervasive cool medium?

Other Galaxies

Two Opposed Views

Star Formation



Dominates is Late-Type Spirals

Galactic Potential

Only the most massive galaxies

Other Galaxies

Global Correlations among X, B, H, 12μm, FIR, 6cm:

- Many correlations depend on morphology

  Reflecting differences in SFR, bulge vs. disk, AGN prob.
- 12μm, FIR, 6cm correlated (star formation)
  - Small dust grains, Large dust grains, thermal free-free
  - Linear correlations
- B, H correlated (stellar populations, IMF)
  - Young massive stars, All ages of low mass stars
  - Non-linear correlations
- But B,H not correlated well with 12μm,FIR,6cm

Other Galaxies

How is X correlated?

- Early-type galaxies – X and B weakly correlated
  - Non-linear correlation
- Late-type galaxies – X and FIR strongly correlated
  - L_X/L_B correlated w/ L_{60}/L_{100} correlated with SFR
  - X, FIR, 6cm all have linear correlations

Other Galaxies

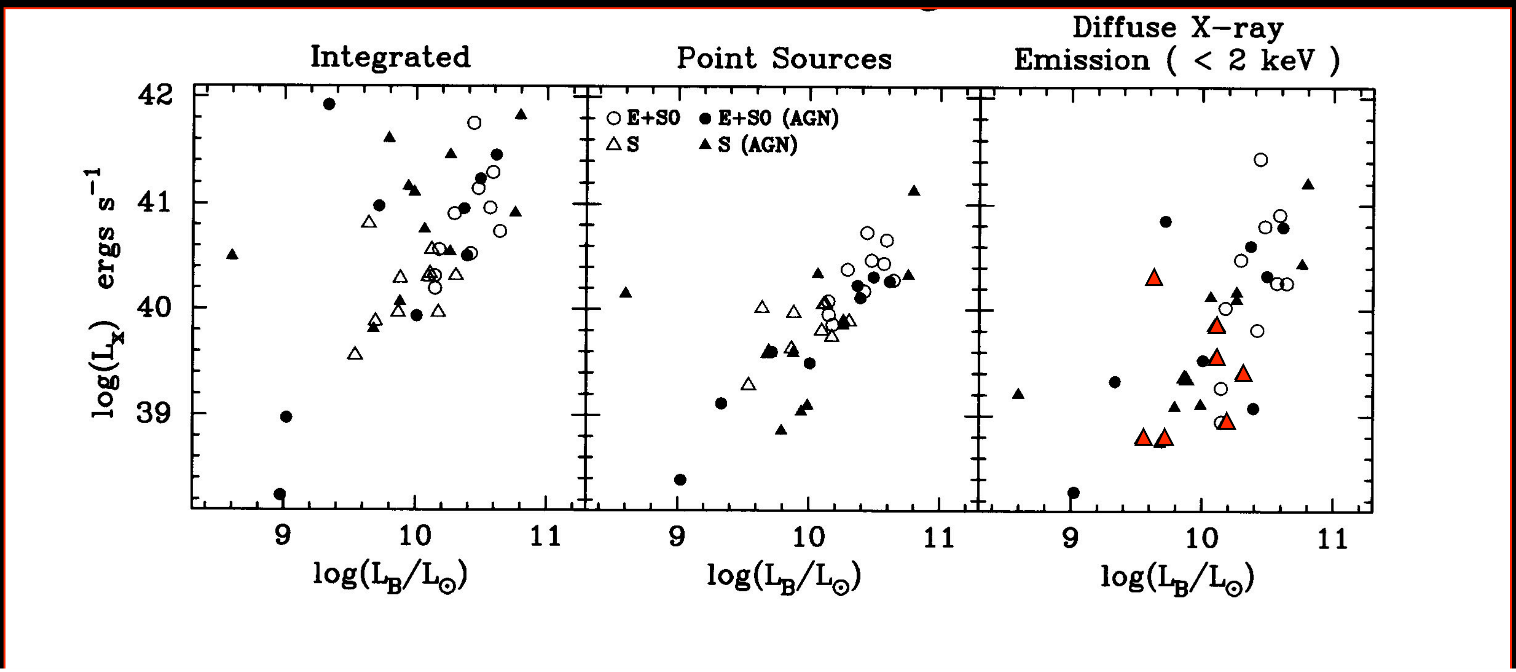
Why?

- Point sources:
  - HMXB: end products of massive star formation } B
    - Short-lived, appear shortly after star formation
  - LMXB: end products of low mass star formation } B/H
    - Long lived, appear long after star formation
- Diffuse emission:
  - Halo: determined by mass of the system }H
  - Star formation: stellar winds & SNR }FIR
  - Other components }?
- AGN:

Other Galaxies

What about the individual components X?

- Point source emission correlated non-linearly with B
  - Roughly consistent with expectations
- Diffuse emission only weakly correlated with B
  - Complicated since X-ray/FIR emission is immediate while the B-band emission lasts for as long as B stars.



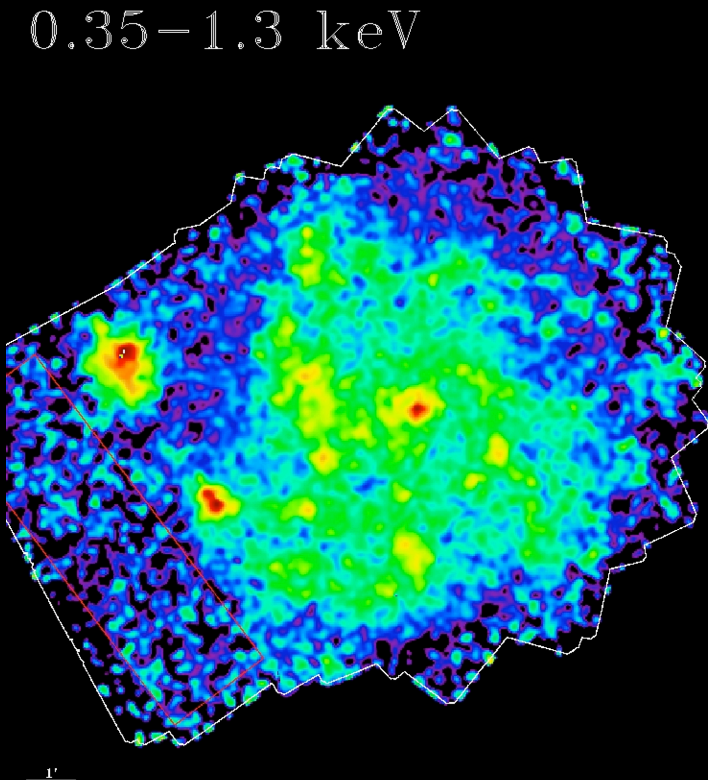
Other Galaxies

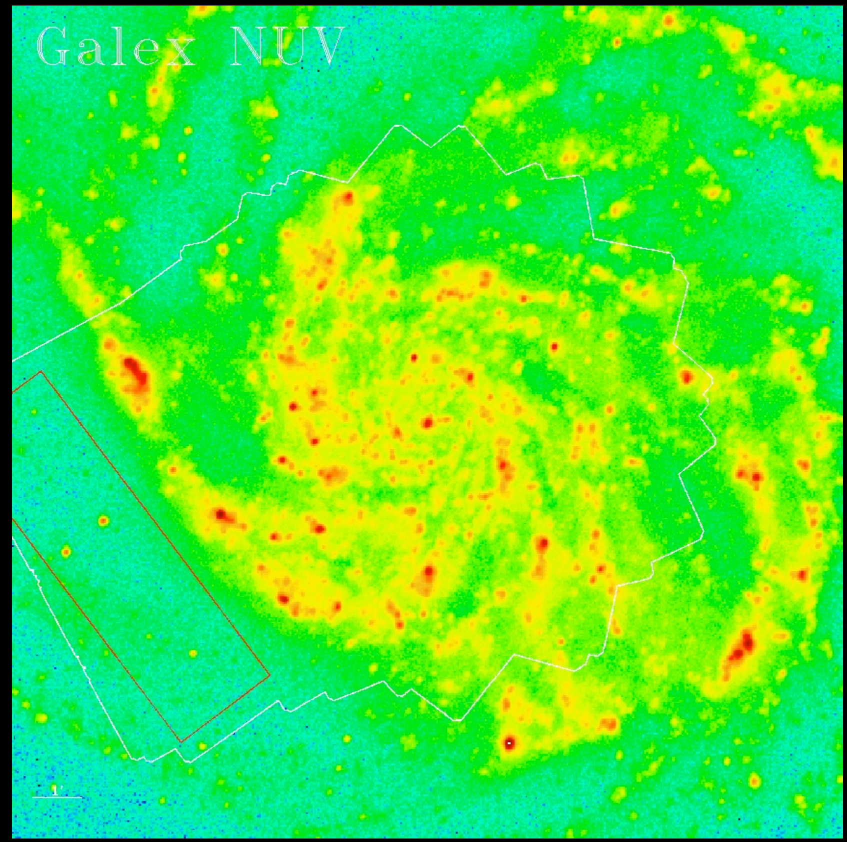
Bottom line:

- X-ray emission from early-type galaxies dominated(?) by point source populations with possible contribution from hydrostatic halo and other, minor diffuse sources.
- X-ray emission from late-type galaxies dominated by star formation/hot ISM
  – Concentrating on ISM _ concentrating on late-type disks

Diffuse Emission in Sc-Sd

Spatial distribution of the X-ray follows that of UV

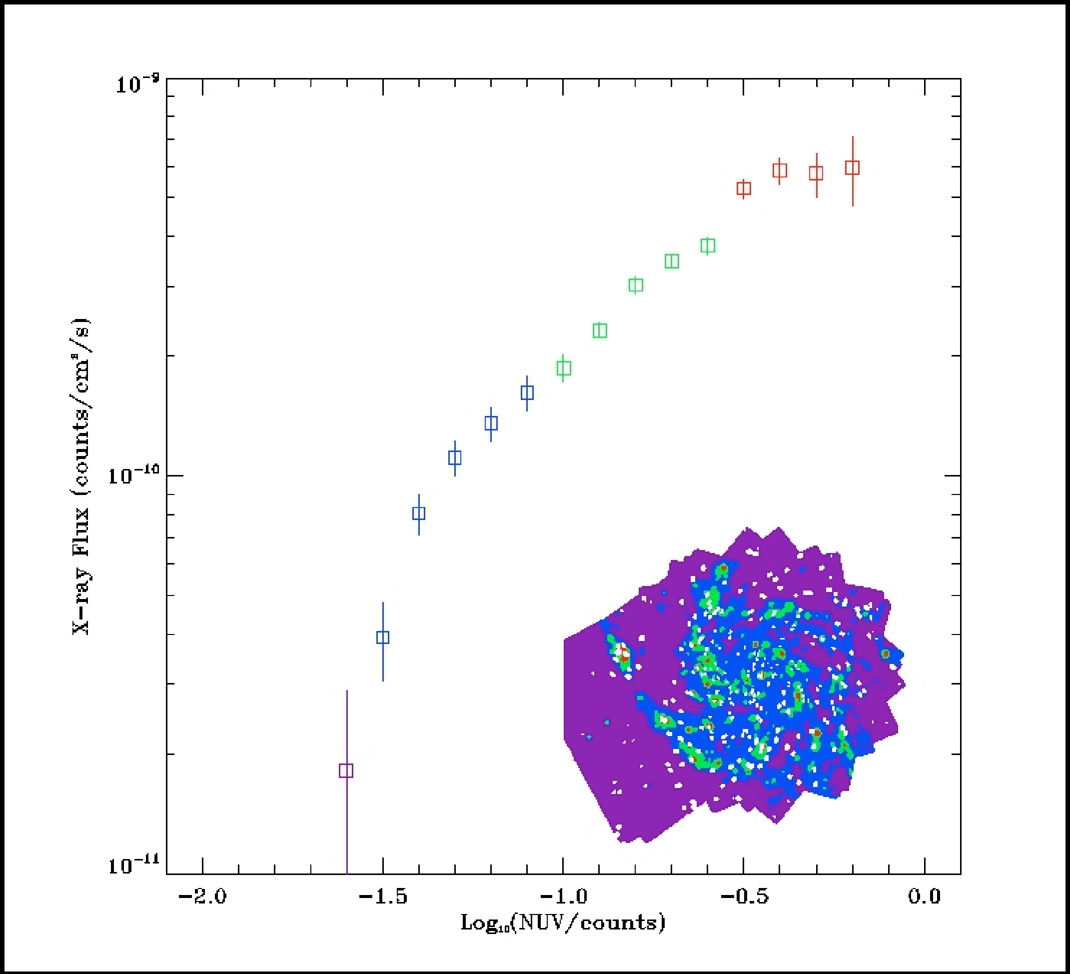




Diffuse Emission in Sc-Sd

X-ray surface brightness correlated with UV

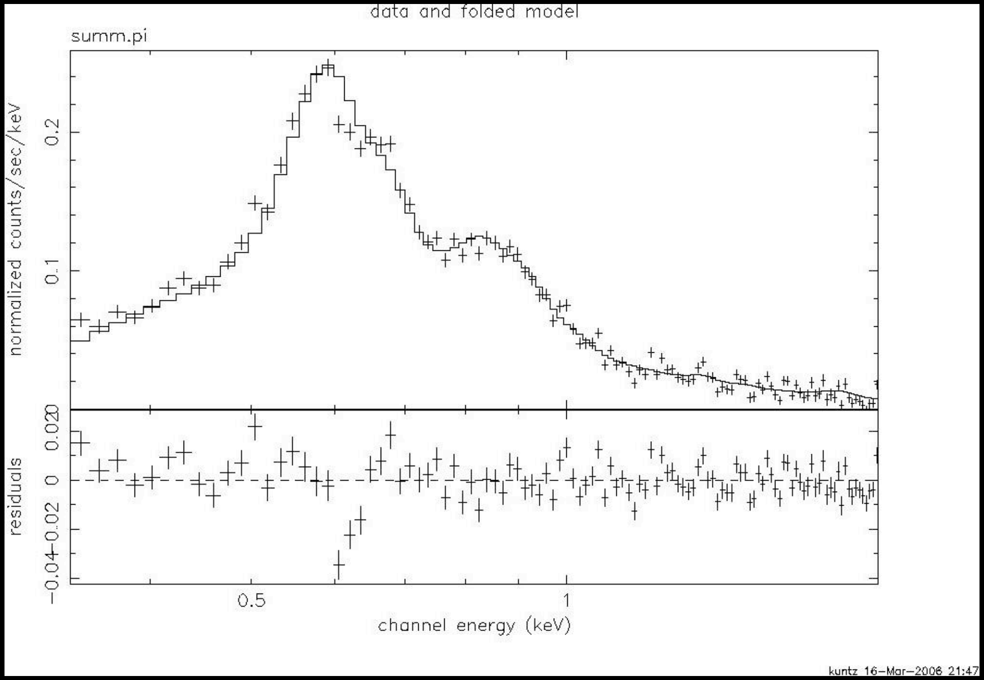
- Trend may not be universal



Diffuse Emission in Sc-Sd

Spectrum fit by two thermal components:

- kT~0.2 keV and kT~0.6 keV



Diffuse Emission in Sc-Sd

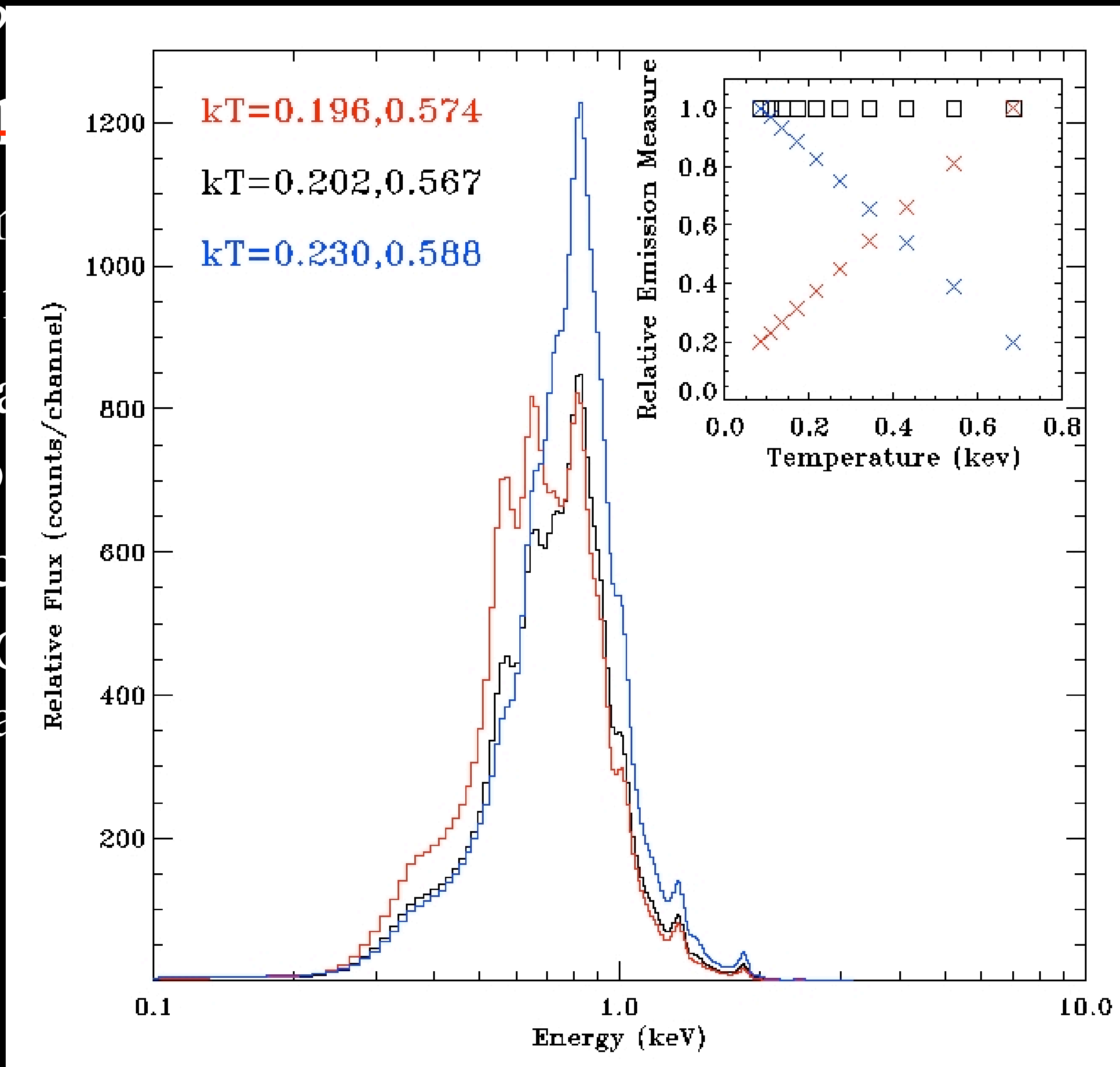
- Most late type galaxies have similar 2 temperature structure
- Ratio of emission strengths may vary with Hubble type.

Galaxy	T_S	T_H	N_H/N_S	Hubble
M61	0.25	0.79	3.33	Sbc
M83	0.25	0.61	0.63	Sc
N1637	0.3	0.7	1.43	Sc
M101	0.20	0.75	0.35	Scd
N2403	0.18	0.73		Scd
N6946	0.25	0.70	0.14	Scd
N3184	0.13	0.43		Scd

Diffuse Emission in Sc-Sd

Why?

- ~~Infl~~
- Sim ... ning
  reg
- Cha ... mission
  pro
- Lac
  – C ... =(0.2,0.6)
  a



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