Astronomy 208 v. Y2K Meeting #19

The Hot ISM & The Interaction of X-Rays (High Energy Rad) with the ISM

(Note: More on non-therm em proc next time.)

Last time, in our discussion of SNRs, we showed that

$$\sum V_{SNR} = \text{rate}_{SN} \cdot \tau_{SNR} \cdot V_{SNR}$$

- rate_{SN}: SNR in the Galaxy
- τ_{SNR}: lifetime (how long does each matter)
- V_{SNR}: volume of 1 SNR (average) big ole

$$= \frac{1}{100\,yr} \cdot 3\times10^{6}\,yr \cdot \frac{4}{3}\pi(90\,pc)^3 = 2\times10^{10}\,pc^3$$

Vol of MW $\approx \pi(30\,kpc)^2 * 300\,pc \approx 2.7\times10^{11}\,pc^3$

Fraction of Total Vol that's in "Hot" "SNRs" $\approx 10\%$

$\approx$ McKee & Ostriker model

"SNRs": connections, chimneys, worms

Recall: Energy Deposited/SNR $\approx 10^{51}$ erg

$$\frac{E}{Vol} \approx \text{pressure} \approx \frac{3}{2} n\,kT = \frac{10^{51}}{\frac{4}{3}\pi(90\times3\times10^{18})^3} = 1.8\times10^{-11}$$

$k \cong 1.4\times10^{-16}$

[Note: p/k for ISM actually thought to be $\approx 2\times10^4\ cm^{-3}\,K$]

$\Rightarrow \frac{3}{2} nT \cong 1\times10^5$ $(= P/k)$

$n \approx 1$ $\quad \boxed{T \gtrsim 10^5}$ (still expanding)

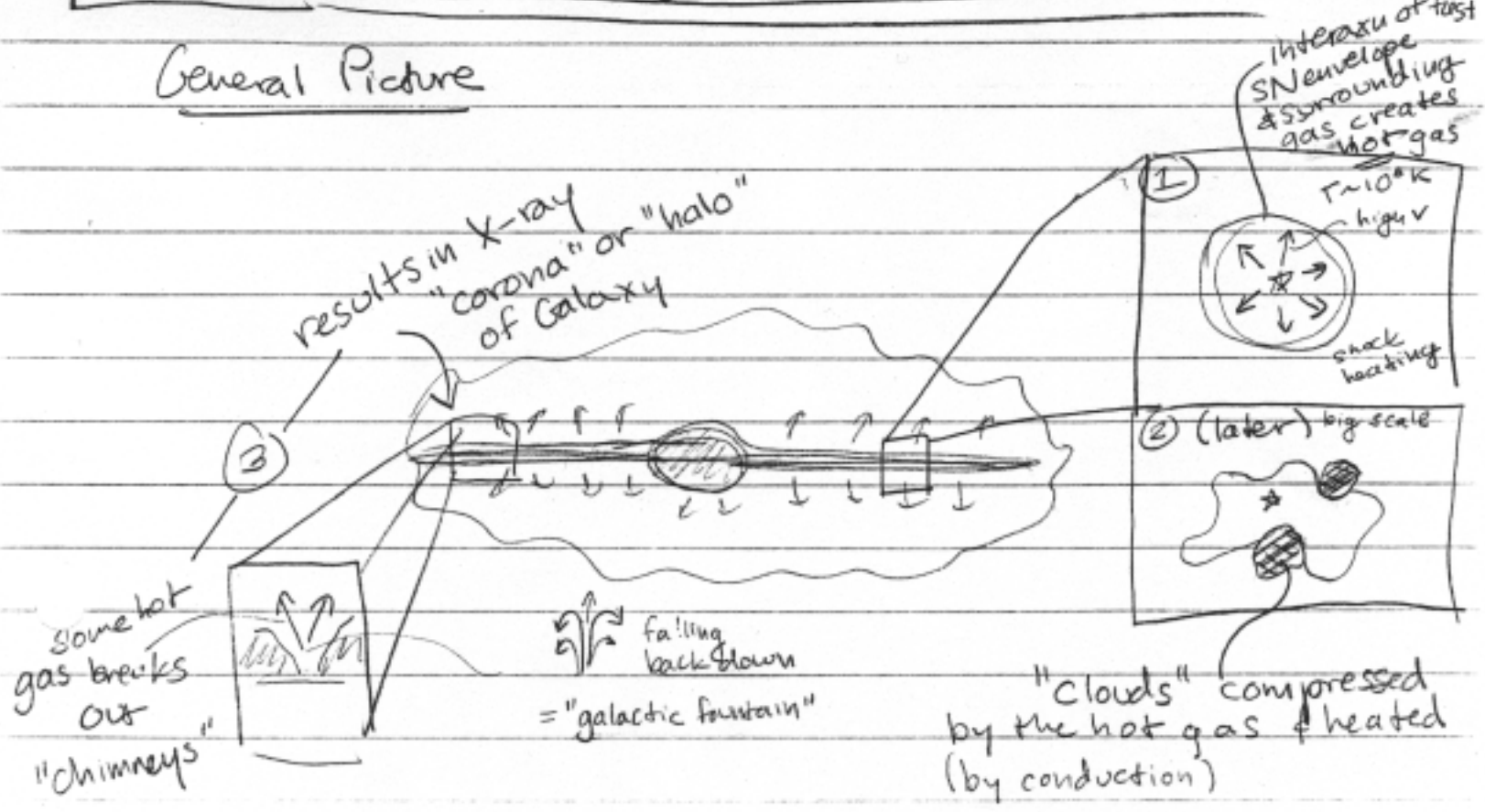
3.6 The "Hot" ISM *

Why should it exist... theories! see Spitzer 1990, ARAA, 28, 71-101.

but here's an important quote from :

"Understanding the processes that occur as the hot interstellar gas evolves in our Galaxy is an ambitious goal that we are far from achieving."

General Picture



History

1962 Shklovsky calculated expansion of non-radiating SNR into ISM

1940's known that T's would be very high behind SN shock, but no way available (then) to obs. this very hot gas

note: resolution of X-ray "telescopes" was very low

1968 start of rocket-borne obsv'ns of diffuse X-rays (Bowyer, Field & Mack 1968)

1973 source of diffuse X-ray emission still unclear — suggestions were about hot gas — was it galactic or intergalactic

1974 ① detection of OVI abs. lines in ISM [Copernicus Obs. ultraviolet] ⟹ major support for idea of hot (soft) X-ray emitting galactic gas

Soft 0.1 to 1 keV

100 to 1000 eV

10^6 to 10^7 K

② detection of Fe XVI from Cygnus Loop, which was strong source of (thermal) free-free ← mostly X-rays @ $T \sim 2\times10^6$ K

③ about 6 SNe shown to have soft X-ray spect consistent w/ thermal radiation @ $2 < \frac{T}{10^6 K} < 15$ (+ a little non-thermal) actually line emission from ionized atoms

post-1974 SNe "believed" as source of hot gas in ISM

Today: "FUSE" Far Ultraviolet Spectral Explorer - launched 6/99

Where do the X-rays come from?

← on a microscopic level

- mixture of ionic emission lines &
- continuum: from the hot plasma (see J. Raymond)
  free-free + some synchrotron

Big problem: DXRB = (local) + (distant) + (extragalactic)

these could be prod. by different processes

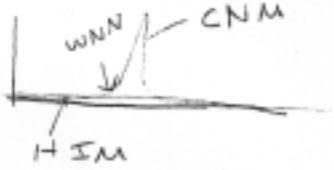
e.g. Xgal could be inverse compton btwn relativ. e^- & CMB ← see handout

In general, though:

X-ray emission modelling → $T \approx 10^6$ $n_e = 3 \times 10^{-3}$ cm^{-3}

$\frac{3}{2} nT \approx 5 \times 10^3$

$\Delta V_{HI}(T=10^6 K) = 2.35 \sqrt{\frac{kT}{\text{atom}}} \cong 200$ km/s



very low density & high-ionization makes this impossible to see in HI

- easier to look @ X-rays directly —
  ROSAT has made a large contribution
  CHANDRA to move
  XMM will do spectroscopy!

note: T from X-rays consistent w/ T needed for OVI UV absorption

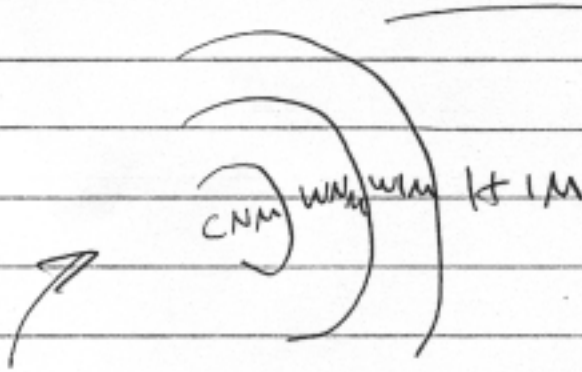
Why does HIM stay hot?

- Density very low collisions infrequent
- Ionization states → mostly just nuclei, no bound e⁻ — not even possible to cool by line radiation (some free-free matters)

WIM ($T \sim 8000$ K) represents transition zone

What is Overall Distribution (even just in the Galaxy) of HIM?

McKee & Ostriker: individual clouds



Convexity/concavity problem: Rosen Bregman & Kelson '96.

or?

cold

hot

soft X from nearby

harder from farther

The general picture is that the Dif XRB is produced in a "Local Bubble" of hot gas w/in ~100 pc of ⊙ T ~ 10^6 K

Absorption lines OVI in the disk } more extended gas @ ~lower T
CIV & NV in halo }

↑ this also produces CIV & OIII emission lines

? Shadows or Holes ?

We're back to Barnard!

How exactly would shadows be made?

How do these high hν photons actually interact with "regular" ISM?