Chandra Observation of the Break-out SNR N11L

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Abstract

We analyzed the *Chandra* observation of N11L, and found that

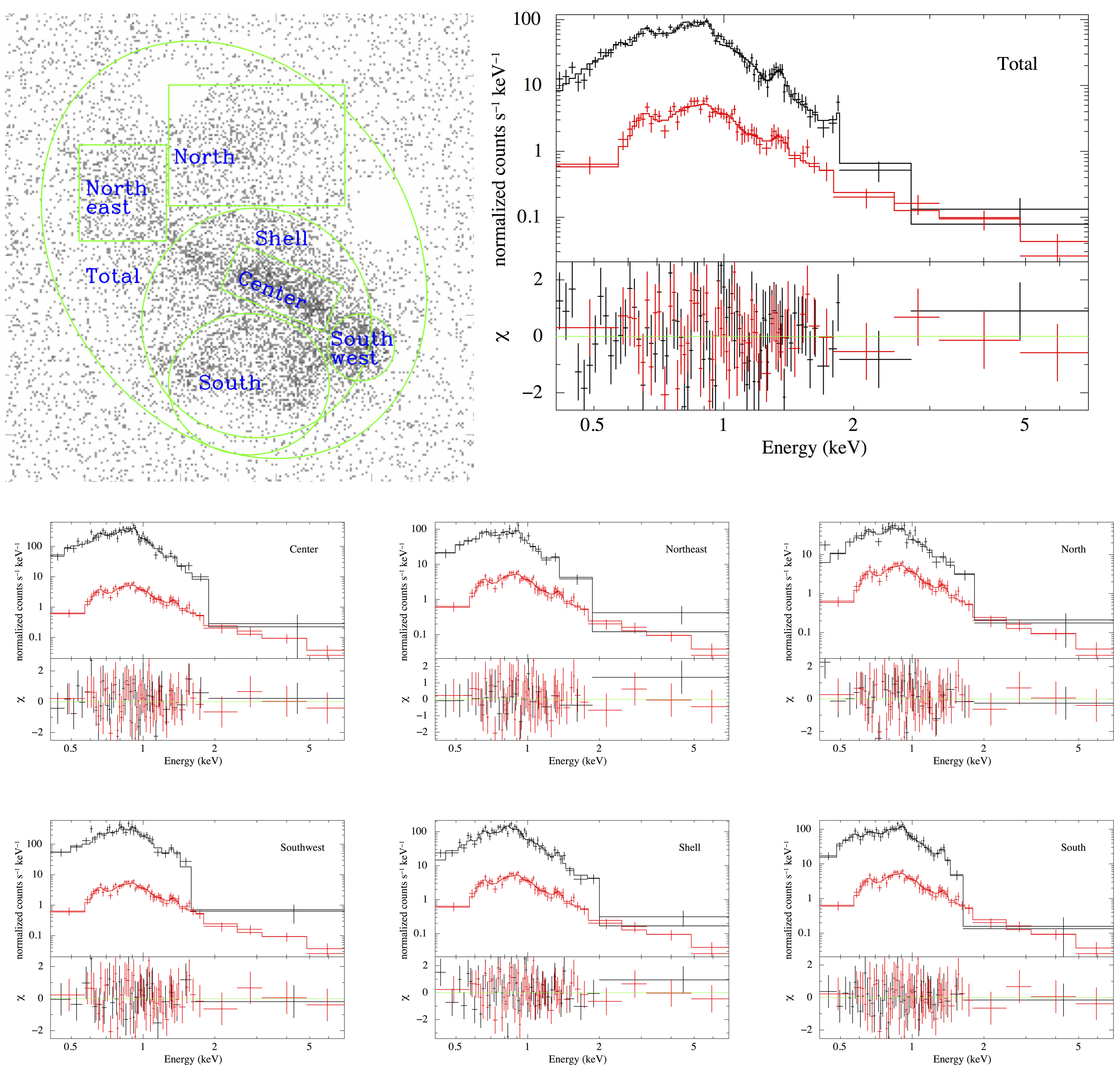
- X-rays mainly distributes in the major shell, with a bright NE-SW ridge; and extends to the north, but still confined by the [O III] filaments;
- spectral fitting result of the plasma in the south region is distinctive from those in the other regions;
- substantial explosion energy is lost during the early stage based on the energy and dynamics arguments;
- the environment is quite inhomogeneous: the physical condition of the X-ray emitter may have been altered by over-density medium at south.

Major Data

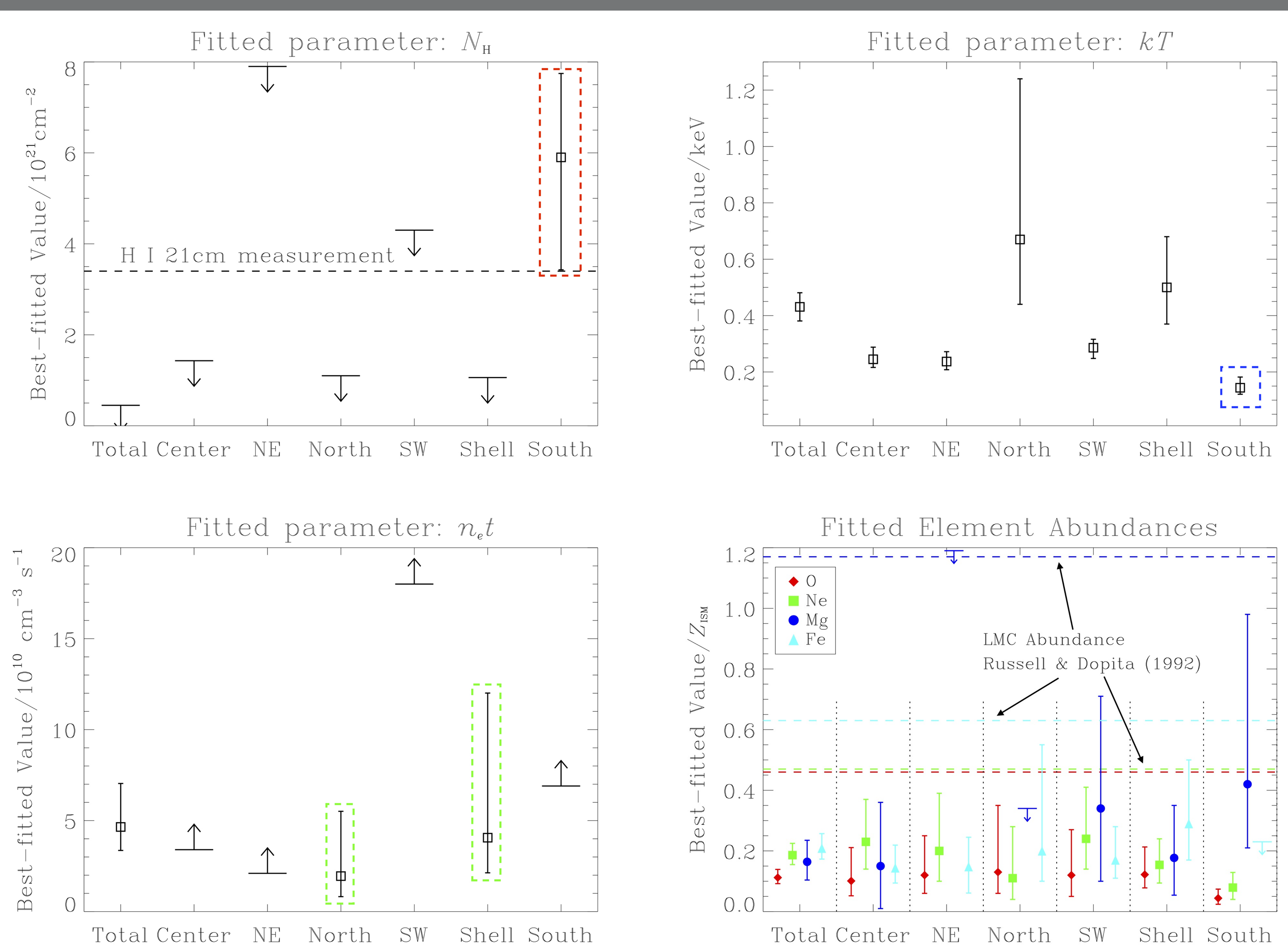
- X-ray: *Chandra* 6 segments of the N11 Project (PI: You-Hua Chu), exposure time: 300 ks in total;
- Optical Image: Hα, [O III], and [S II] images taken by the MOSAIC camera on the CTIO Blanco 4m Telescope.

X-ray Spectroscopic Analysis

The whole and 6 separate parts, double-subtraction, *vnei* modeling:

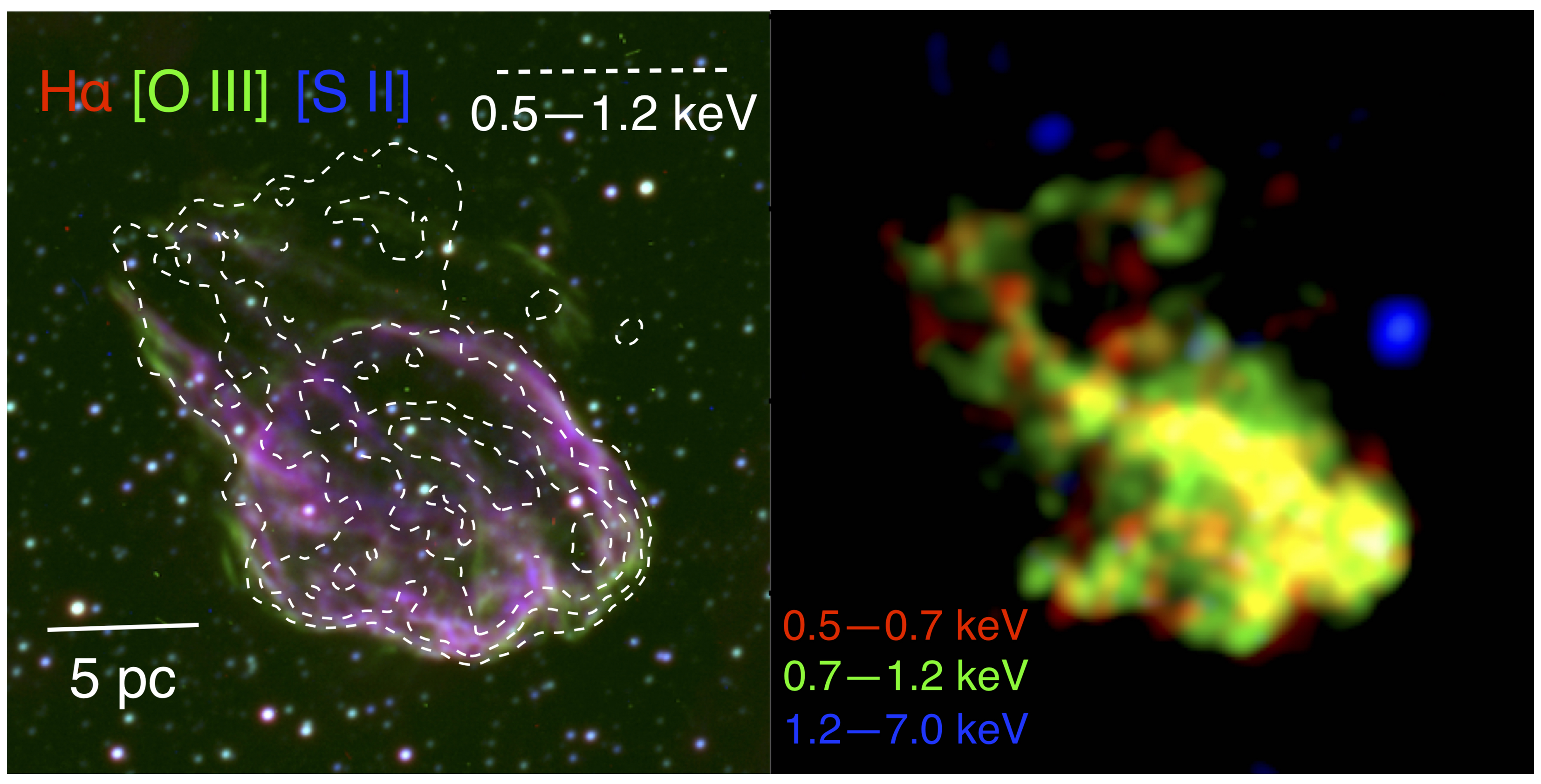


Spectral Fitting Result



- very little LMC absorption except for the South region;
- constrained NEI in the North and Shell region;
- sub-LMC abundance, but consistent with each other.

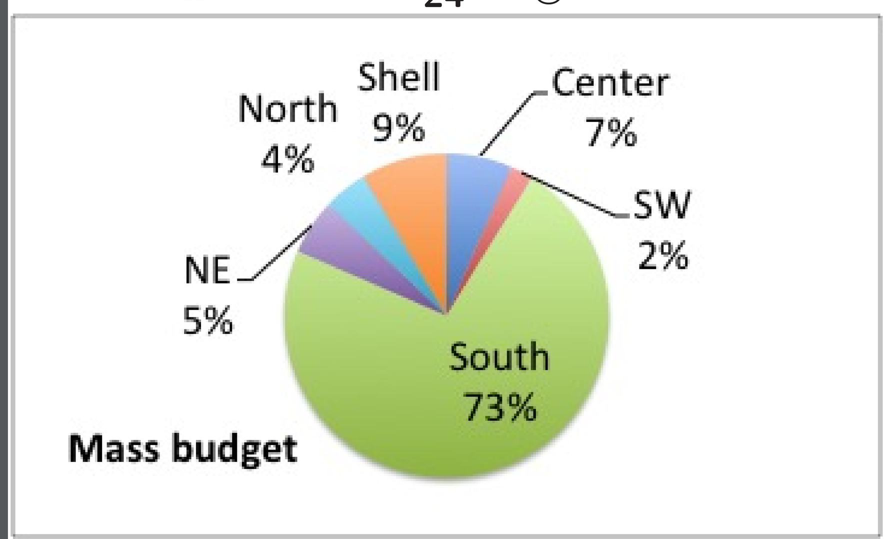
Multi-band Images



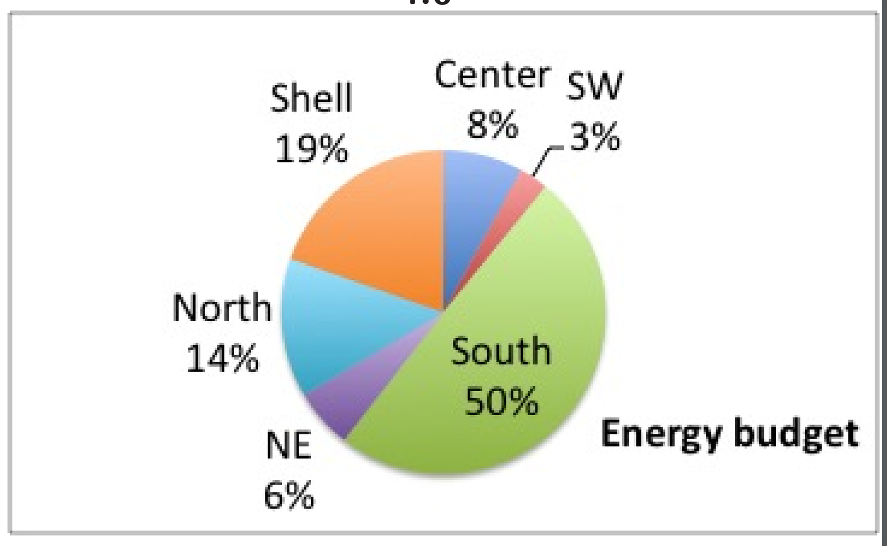
- X-rays predominantly in the major shell and the SE loop-like filaments, with an extension to the north;
- No X-ray spectral variation all across the SNR;
- Bright NE-SW X-ray ridge, peaks at the center and southwest;
- Northern X-ray extension confined by the [O III] filaments;
- [O III] shell located slightly further than Hα and [S II] at south.

Derived Hot Gas Mass and Thermal Energy

total $M_{\rm hot} = 84^{+69}_{-24}\, M_\odot$



total $E_{\rm th} = 8.7^{+11.2}_{-4.0} \times 10^{49}$ ergs



Sedov Age and Explosion Energy

- $kT_{\rm Shell} \sim 0.50$ keV$\Rightarrow$ $v_{\rm exp} \sim 640$ km s^{-1} $\Rightarrow$ $t_{\rm Sedov} \sim 4.0 \times 10^3$ yr, comparable to shock heated age ($n_e t / n_{e,rms}$):
  - 3.2×10^3 yr (**North**), 4.4×10^3 yr (**Shell**)
- Assuming
  1. most of the X-ray emitter is shocked ISM, and
  2. the shell area covers half of them $\Rightarrow$

$$n_0 \sim 0.2 \left(\frac{EM_{\rm Shell}}{1.9 \times 10^{57} {\rm cm}^{-3}}\right)^{1/2} \left(\frac{R}{6.5{\rm pc}}\right)^{-3/2} {\rm cm}^{-3} \Rightarrow$$

the explosion energy

$$E_{\rm tot} \sim 5 \times 10^{49}\,{\rm ergs}$$

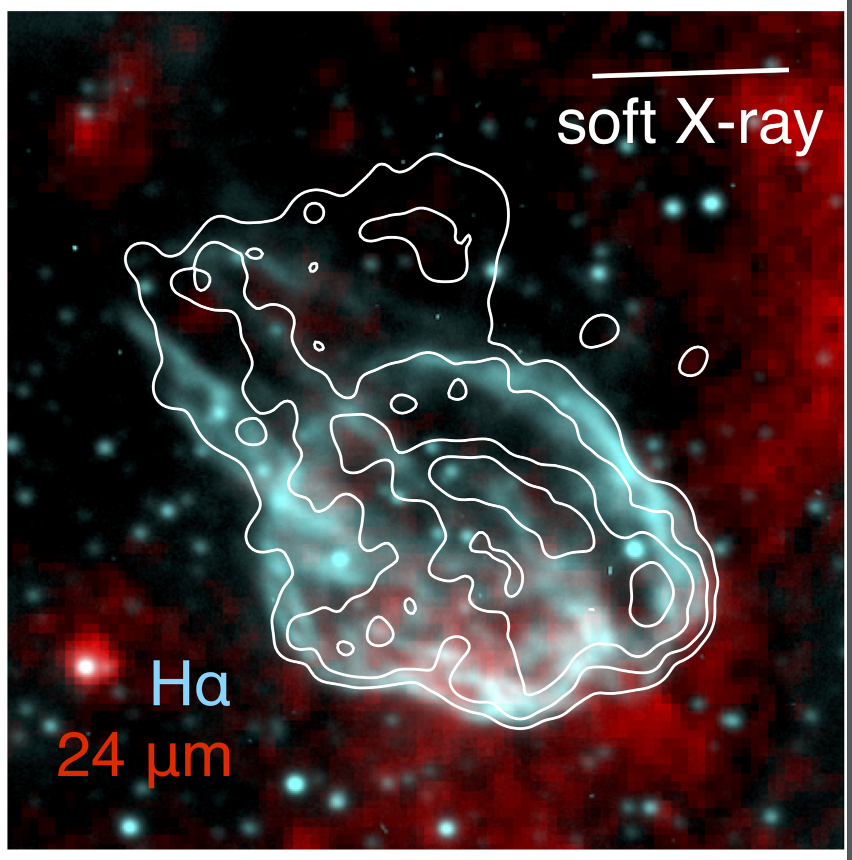
is comparable to the thermal energy.

Substantial explosion energy is lost during the early stage.

Inhomogeneity Environment

At the south part, based on:

- IR studies
  - Enhanced 24μm emission (Seok et al. 2013);
  - ionic emission based on IRS spectra (Williams et al. 2006).
- X-ray analysis
  - lowest kT,
  - major portion of $M_{\rm hot}$ and $E_{\rm th}$,
  - extra absorption in the south region,
    - but uniform H I distribution all across the SNR;
    - extra absorption, if all contributed by molecular gas, is consistent with the non-detection of CO by MAGMA (Wong et al. 2011);



A possible scenario is at south the X-ray emitter is supplemented by molecular cloudlets.