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.

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.

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.

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.

Derived Hot Gas Mass and Thermal Energy
total \( M_{\text{hot}} = 84_{-24}^{+69} \times 10^{24} M_\odot \)
total \( E_{\text{th}} = 8.7_{-4.0}^{+11.2} \times 10^{49} \text{ ergs} \)

Sedov Age and Explosion Energy
\[ kT_{\text{Shell}} \sim 0.50 \text{ keV} \Rightarrow v_{\text{exp}} \sim 640 \text{ km s}^{-1} \Rightarrow t_{\text{Sedov}} \sim 4.0 \times 10^3 \text{ yr}, \]
comparable to shock heated age \( (n_0 t/\sigma)_{\text{rms}} \): \( 3.2 \times 10^3 \text{ yr} \) (North), \( 4.4 \times 10^3 \text{ yr} \) (Shell)

Assuming
1. most of the X-ray emitter is shocked ISM, and
2. the shell area covers half of them
\[ n_0 \sim 0.2 \left( \frac{EM_{\text{Shell}}}{1.9 \times 10^{57} \text{ cm}^{-3}} \right)^{1/2} \left( \frac{R}{6.5 \text{ pc}} \right)^{-3/2} \text{ cm}^{-3} \Rightarrow \]
the explosion energy \( E_{\text{tot}} \sim 5 \times 10^{49} \text{ ergs} \)
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 \( M_{\text{hot}} \) and \( E_{\text{th}} \),
- 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.