CI/CO Abundance Ratio of Shock-Excited Gas in the Magellanic Supernova Remnant N63A

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Abstract

Atomic carbon line emission (CI) is considered a reliable tracer for inferring the distribution of H_2 in galaxies, comparable to low-J CO line emission, However, the modification of the CI/CO abundance ratio under environments where cosmic-ray-induced and/of shock-induced destruction of CO molecules occurs efficiently is not fully understood. Therefore, we conducted high-resolution and high-sensitivity observation of [CI] and CO line emissions toward the pre-and post-shocked molecular clouds in the Magellanic supernova remnant (SNR) N63A using ALMA. N63A offers an excellent opportunity to study the variation of the CI/CO abundance ratios through cosmic-ray and shock-induced destructions of CO, free from contamination along the line of sight. As a result, we found a correlation between the CI/CO ratio and CO column density in these clouds, suggesting the dominance of ultraviolet (UV) radiation influencing the ratio across all clouds. We also fund that the CI/CO that the CI/CO abundance ratio in pre-shocked molecular clouds exhibited a wider scatter compared to that in the post-shocked regions, suggesting the environmental factors (e.g., cosmic-ray abundance, supernova shocks), We shows detailed results in this poster.

1. Introduction

❖ **SNR N63A**

- **SNR in the LMC**
- **Embedded within large HII region**
- **Provide various environments**
  1. Photo-ionized region (W)
  2. Shock-ionized region (W)
  3. Only-affected by cosmic-ray region (NE,E close to shell)
  4. Normal LMC environment (NE,E far from shell)

Aim of this study

Measure the variations of CI/CO abundance ratio to test "weather CI is really reliable tracer of H_2"

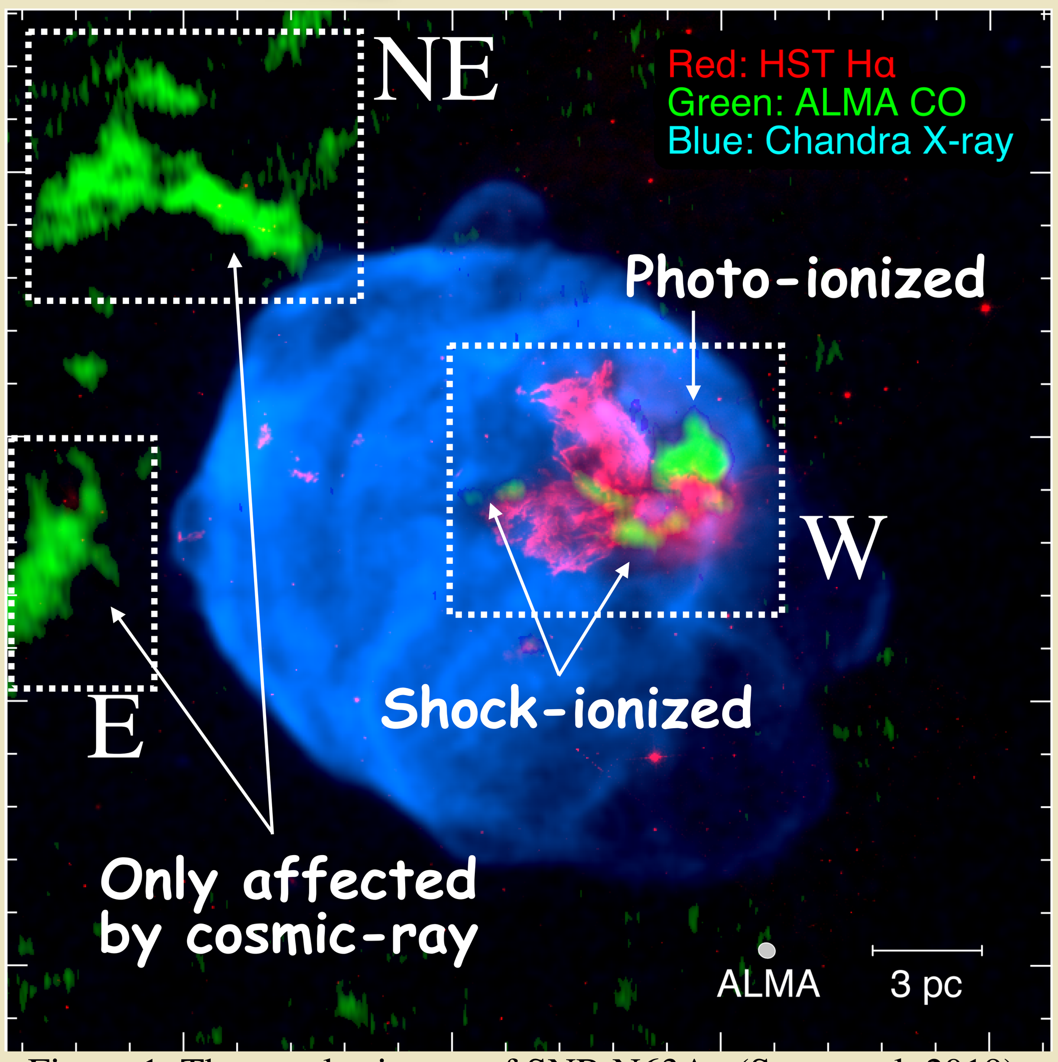


Figure 1: Three-color image of SNR N63A (Sano et al. 2019)

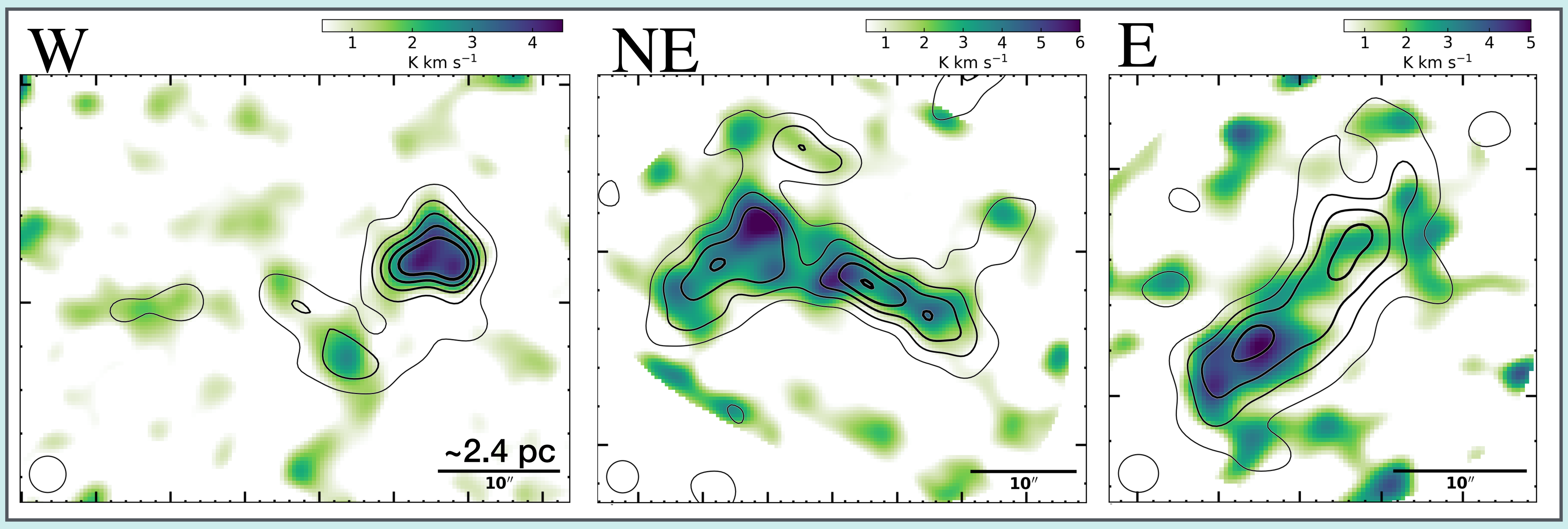
2. ALMA Observation

❖ **[CI](1-0) mapping observation toward W, NE, and W region**

- **Project: 2021.2.00030.S (PI: Hidetoshi Sano)**
- **Parameters**
  - Antenna: ACA, TP
  - Spatial Resolution: ~2 arcsec (~ 0.5 pc at the LMC)
  - Velocity Resolution: 0.4 km/s
  - Mapping Coverage
    - W region : ~ 45" x 35" (~ 11 pc x 9 pc)
    - NE region : ~ 25" x 25" (~ 6 pc x 9pc)
    - E region : ~ 25" x 25" (~ 6 pc x 6pc)
  - RMS (smoothed 3 arcsec)
    - W region : 0.26 K
    - NE region : 0.20 K
    - E region : 0.48 K

3. Results & Discussion

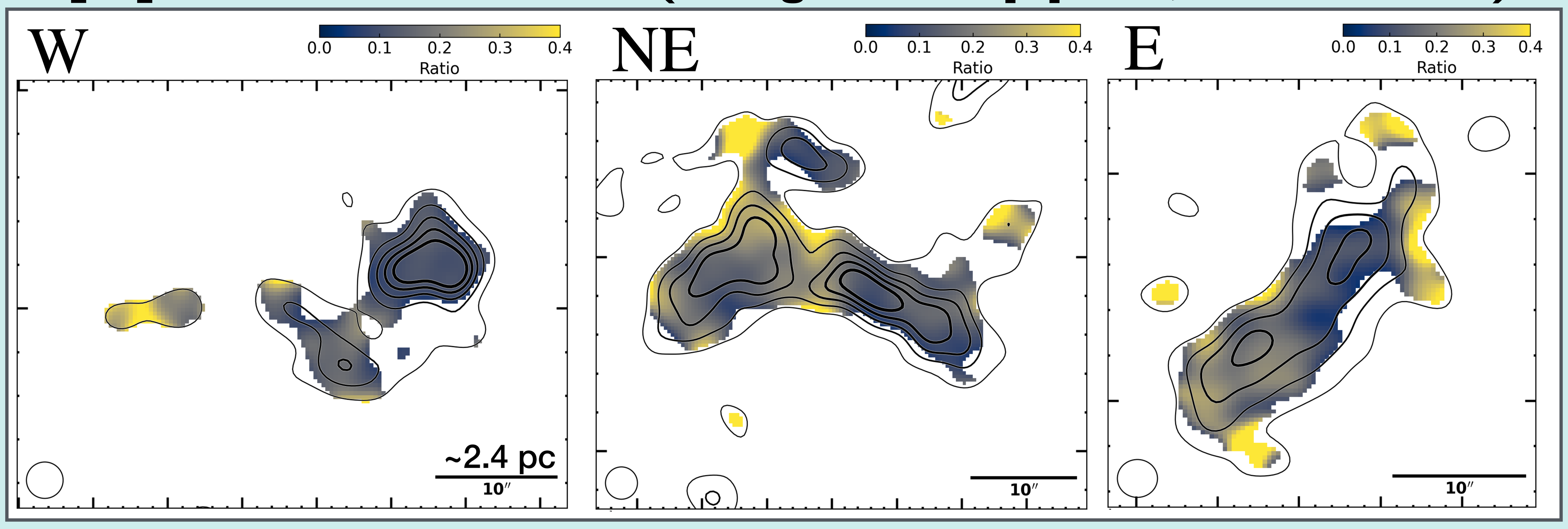
❖ **[CI] Distribution (Back ground: [CI], Contour: ^{12}CO)**



- **The overall distribution of the [CI] emission in all 3 regions is similar to that of the $^{12}CO(1-0)$ emission**
- **In both NE and E regions, [CI] emission appears relatively weak near the shell**

Figure 2: [CI](1-0) integrated intensity distribution of all 3 regions (left: W, middle: NE, right: E). Black contours show $^{12}CO(1-0)$ integrated intensity distributions (3, 8, 13, 18, and 23σ).

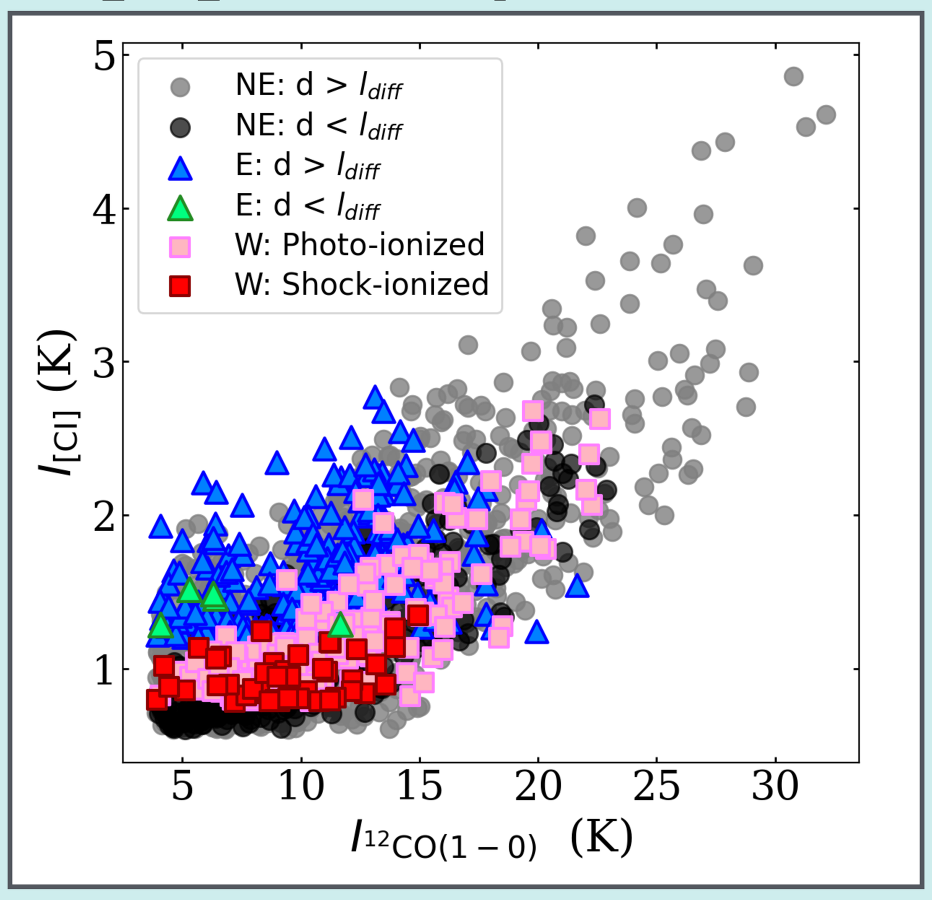
❖ **[CI]/CO ratio distribution (Background: $N_{[CI]}/N_{CO}$, Contour: N_{CO})**



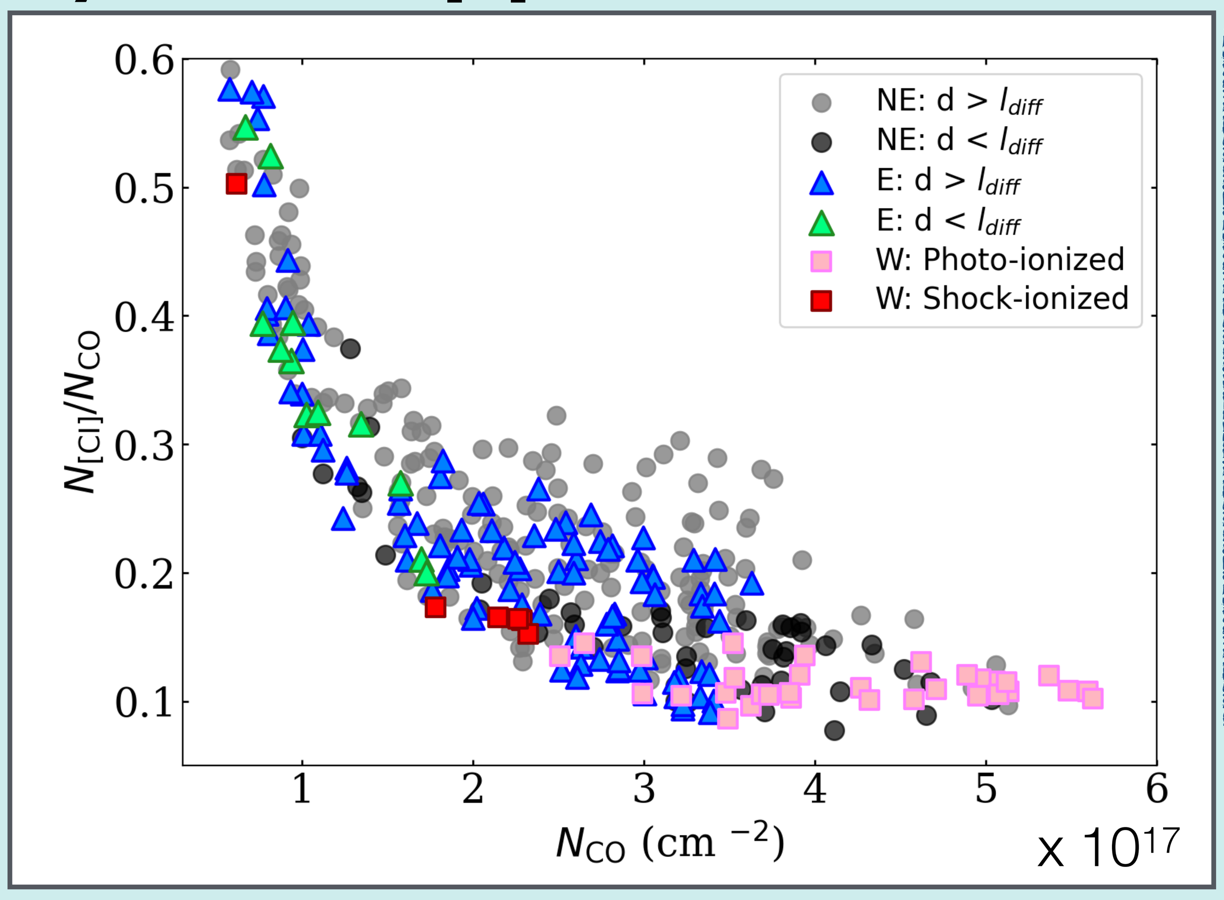
- **$N_{[CI]}$: ~ 1.0 x 10^{16} - 1.0 x 10^{17} cm^{-2}**
  - Derived with LTE assumption (e.g., Izumi et al. 2021)
  - Averaged value: 1.3 x 10^{16} cm^{-2} (W)
    4.2 x 10^{16} cm^{-2} (NE)
    3.6 x 10^{16} cm^{-2} (E)
- **N_{CO}: ~ 1.0 x 10^{17} - 1.0 x 10^{18} cm^{-2}**
  - Derived with Xco factor (e.g., Fukui et al. 2021)
  - Averaged value: 2.0 x 10^{17} cm^{-2} (W)
    2.1 x 10^{17} cm^{-2} (NE)
    1.5 x 10^{17} cm^{-2} (E)
- **CI/CO abundance ratio ($N_{[CI]}/N_{CO}$)**
  - Averaged value: 0.16 (W)
    0.21 (NE)
    0.21 (E)

Figure 3: Ratio of [CI]/CO column density distribution of all 3 regions (left: W, middle: NE, right: E). Black contours show ^{12}CO column density distributions (3, 8, 13, 18, and 23σ).

❖ **[CI] intensity vs. CO intensity**



❖ **$N_{[CI]}/N_{CO}$ vs. N_{H2}**



- **Correlation between $N_{[CI]}/N_{CO}$ and N_{H2} (N_{CO})**
  - Suggesting dominance of UV radiation influencing the ratio across all clouds
    → Whole regions are affected by large HII region ?
- **Wider scattering in pre-shocked regions (NE +E)**
  - Especially, wider scattering (relatively higher $N_{[CI]}/N_{CO}$) is seen at NE and E regions away from the SNR shell with distance of larger than cosmic-ray diffusion length (l_{diff} ~ 4.5 pc)
    → Suggesting environmental factor ?
    (e.g., cosmic-ray abundance, supernova shock)

Figure 4 (left): Point-by-point correlations between [CI] and ^{12}CO
Figure 5 (right): Point-by-point correlations between [CI]/CO column density ratio and CO column density