Aims. We aim to study the interstellar medium (ISM) and cosmic-rays (CRs) in local HI clouds in the 3rd Galactic quadrant.

Methods. We evaluated the total gas column density $N(H_{tot})$ by investigating the correlations among 21 cm survey data (HI4PI), Planck dust models (optical depth at 353 GHz $\tau_{353}$ and radiance $R$), and Fermi-LAT $\gamma$-ray data.

Results & Prospects. We found $N(H_{tot,\gamma})/\tau_{353}$ and $N(H_{tot,\gamma})/R$ depend on dust temperature $T_d$ in the North region, and $N(H_{tot,\gamma})/\tau_{353}$ is not constant over $\tau_{353}$ in the South region. We will examine the systematic uncertainties and discuss ISM and CRs properties.
Objective of the Study

- An accurate estimate of $N(H_{\text{tot}})$ is crucial to understand the ISM and CRs.
- Considerable amount of ISM gas is not properly traced by HI and CO line surveys [1]. The distribution of this “dark gas” can be estimated by dust data, but the procedure has not been established yet.
- We studied mid-latitude region of the 3rd quadrant using Fermi-LAT $\gamma$-ray data (as a robust tracer of $N(H_{\text{tot}})$), HI4PI data [2], and Planck dust models [3], in order to examine the following ISM properties and implications on CRs:
  - (a) $T_d$ dependence of dust-emission to gas ratio [4]
  - (b) Non-linearity of dust-emission to gas ratio [5][6]
$W_{\text{HI}}$-Dust Relations

- North: $T_d$ dependence is seen and is larger in the $W_{\text{HI}}$-$\tau_{353}$ relation
- South: $T_d$ dependence is weak, but a non-linear relation is observed
- We used linear relations which follow trends in high $T_d$ & low $W_{\text{HI}}$ area to construct initial $N(H_{\text{tot}})$ template maps from $\tau_{353}$ and $R$
Results and Prospects

- We fit $\gamma$-ray data with a linear combination of gas template maps and other components (isotropic, inverse Compton, sources etc.)
- Under the assumption of a uniform CR density, emissivity should not depend on $T_d$ (North) and should be constant over $\tau_{353}$ (South), if $N(H_{tot}) \propto \tau_{353}$ or $R$
- North: We prepared $T_d$-sorted maps and found a positive $T_d$ dependence for $\tau_{353}$, likely due to an overestimate of $N(H_{tot})/\tau_{353}$ in low $T_d$ area (similar trend seen in [4])
- South: We prepared $\tau_{353}$-sorted maps and found negative $\tau_{353}$ dependence, likely due to an overestimate of $N(H_{tot})/\tau_{353}$ in high $\tau_{353}$ area (similar trend seen in [5][6])
- Future plan: examine the systematic uncertainties and discuss ISM and CR properties

Scale factors to the model for the local interstellar spectrum [7]

References: