PROCEEDINGS OF SCIENCE

Study of the Interstellar Medium and Cosmic Rays in local H I Clouds

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Aims. We aim to study the interstellar medium (ISM) and cosmic-rays (CRs) in a mid-latitude region in the third Galactic quadrant (Galactic longitude l from 200° to 260° and latitude $|b|$ from 22° to 60°). The region is expected to be dominated by local H I clouds since it is located at high latitude and free of know large molecular clouds.

Methods. We evaluated the total gas column density $N(\mathrm{H_{tot}})$ by investigating the correlations among 21 cm survey data (HI4PI), *Planck* dust thermal emission models (optical depth at 353 GHz τ_{353} and radiance R), and *Fermi*-LAT γ-ray data in the region studied. In the South region, we first masked areas containing an intermediate velocity cloud or the Orion-Eridanus superbubble, and that with a ratio of the integrated H I 21-cm line intensity to dust emission significantly different from that seen in the rest of the region. We then fit the γ-ray data with a linear combination of gas template maps based on *Planck* dust models and other components to obtain the total gas column density $N(\mathrm{H_{tot,\gamma}})$.

Results & Prospects. We found that $N(\mathrm{H_{tot,\gamma}})/\tau_{353}$ and $N(\mathrm{H_{tot,\gamma}})/R$ depend on dust temperature T_d in the North region, indicating that that neither τ_{353} nor R were proportional to $N(\mathrm{H_{tot}})$. We also found that $N(\mathrm{H_{tot,\gamma}})$ is not proportional to τ_{353} but shows non-linear relation in the South region. We will examine the systematic uncertainties and discuss ISM and CR properties inferred from γ-ray data.

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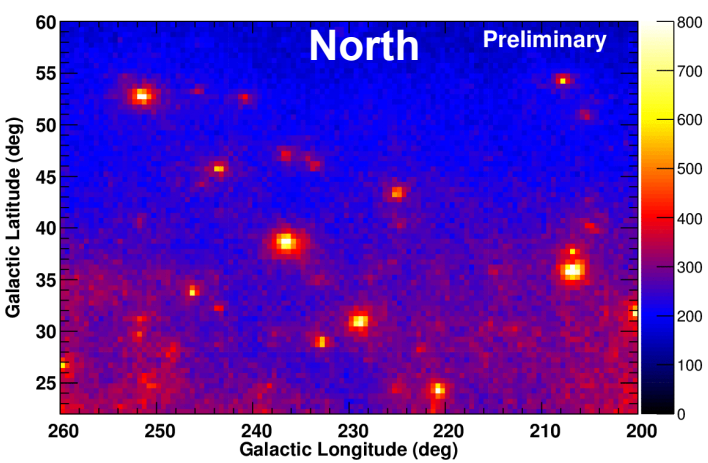
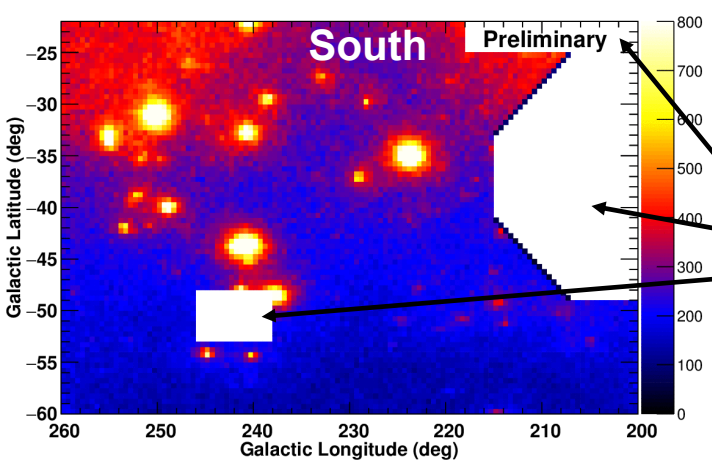
Objective of the Study

- An accurate estimate of $N(H_{tot})$ 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 γ-ray data (as a robust tracer of $N(H_{tot})$), 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]





8 years, P8R2_CLEAN_V6, 0.1-25.6 GeV

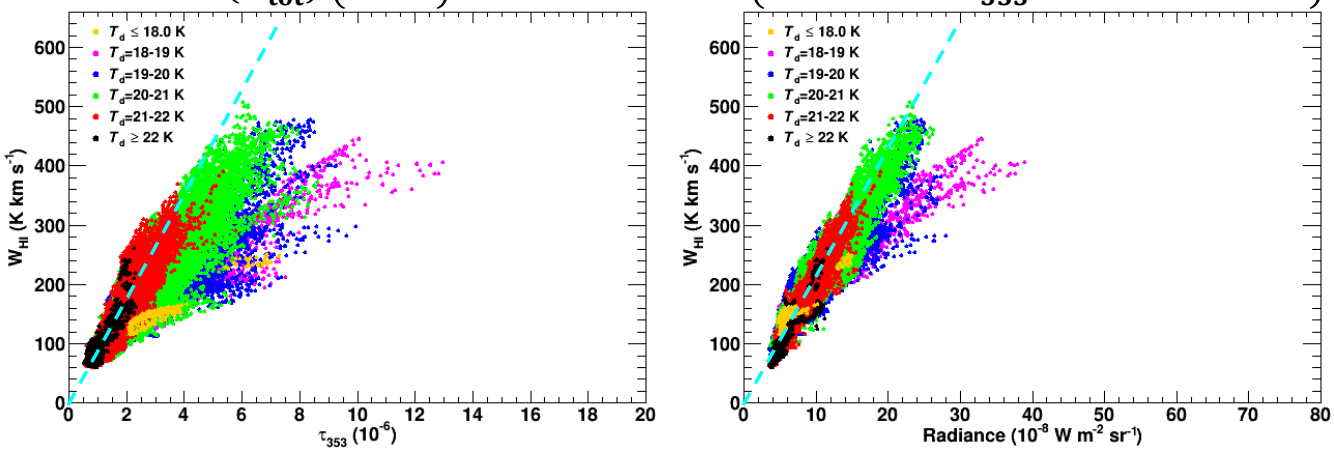
Several areas are masked
- a peculiar W_{HI}-dust relation
- the Orion-Eridanus superbubble
- an intermediate velocity cloud

W_{HI}-Dust Relations

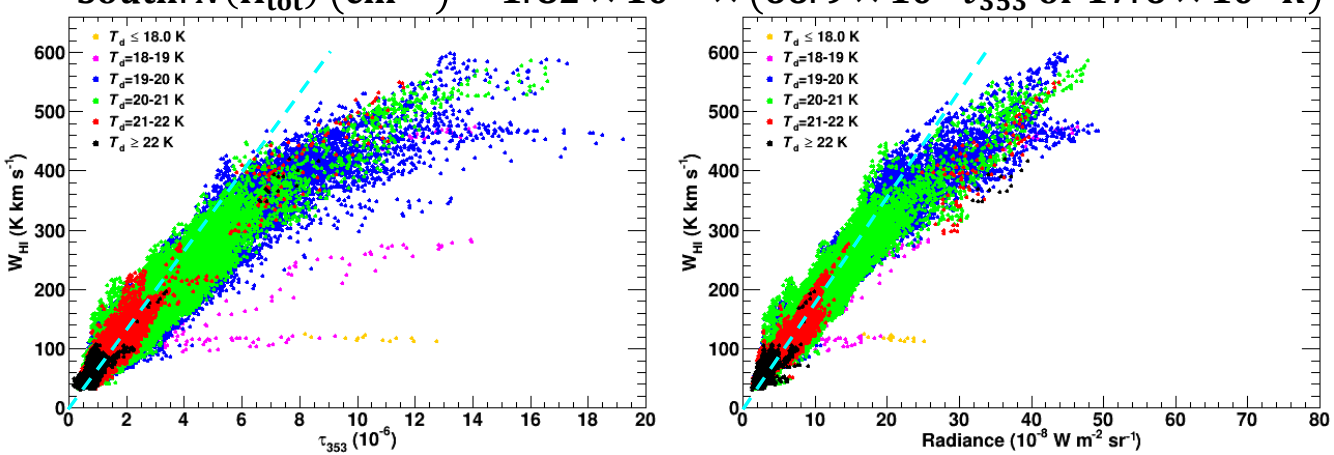
- North: T_d dependence is seen and is larger in the W_{HI}-τ_{353} relation
- South: T_d dependence is weak, but a non-linear relation is observed

- We used linear relations which follow trends in high T_d & low W_{HI} area to construct initial $N(H_{tot})$ template maps from τ_{353} and R

$$\text{North: } N(\mathrm{H_{tot}})\ (\mathrm{cm^{-2}}) = 1.82 \times 10^{18} \times \left(87.2 \times 10^{6}\ \tau_{353} \text{ or } 21.1 \times 10^{8}\ R\right)$$



$$\text{South: } N(\mathrm{H_{tot}})\ (\mathrm{cm^{-2}}) = 1.82 \times 10^{18} \times \left(66.9 \times 10^{6}\ \tau_{353} \text{ or } 17.6 \times 10^{8}\ R\right)$$

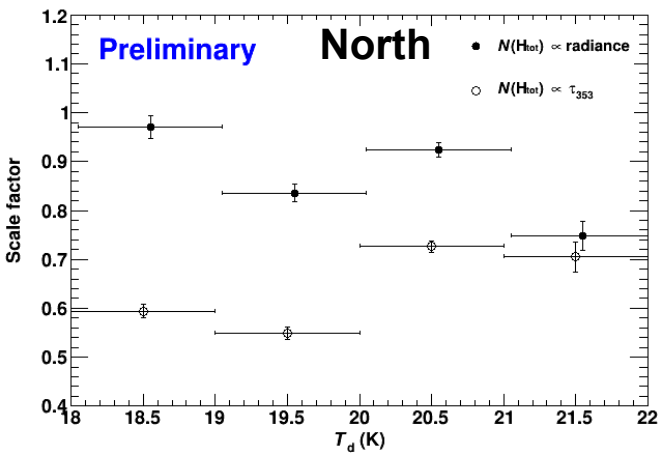


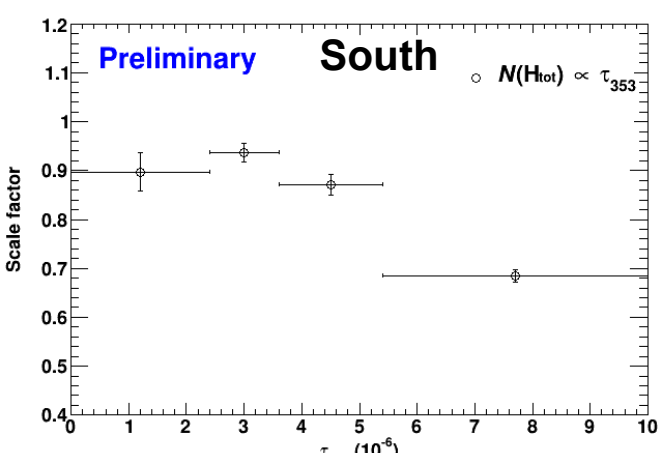
Results and Prospects

- We fit γ-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 τ_{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 τ_{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 τ_{353}-sorted maps and found negative τ_{353} dependence, likely due to an overestimate of $N(H_{tot})/\tau_{353}$ in high τ_{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:
[1] Grenier+05, Science 307, 1292 [2] HI4PI Collaboration 2016, A&A 594, 116
[3] Planck Collaboration XI 2014, A&A 571, 11 [4] Mizuno+16, ApJ 833, 278 [5] Roy+13, ApJ 763, 55
[6] Planck Collaboration XXVIII 2015, A&A 582, 31 [7] Abdo+09, ApJ 703, 1249