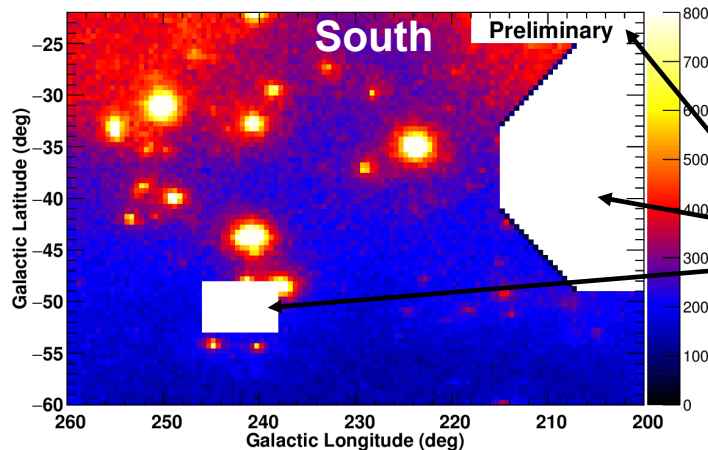
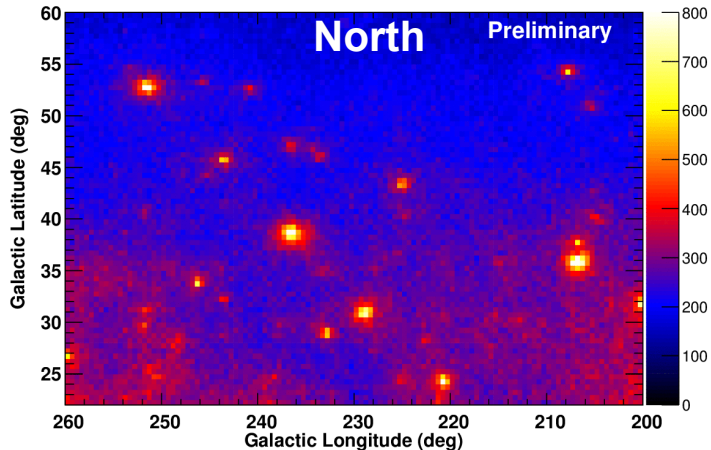


# Objective of the Study

- 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 3<sup>rd</sup> 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]



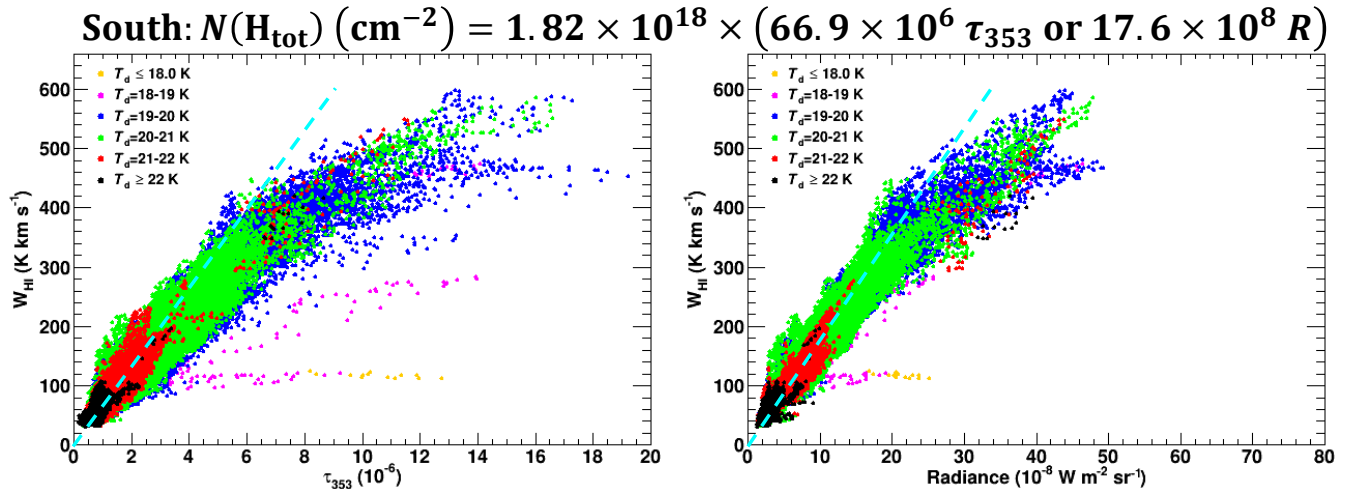
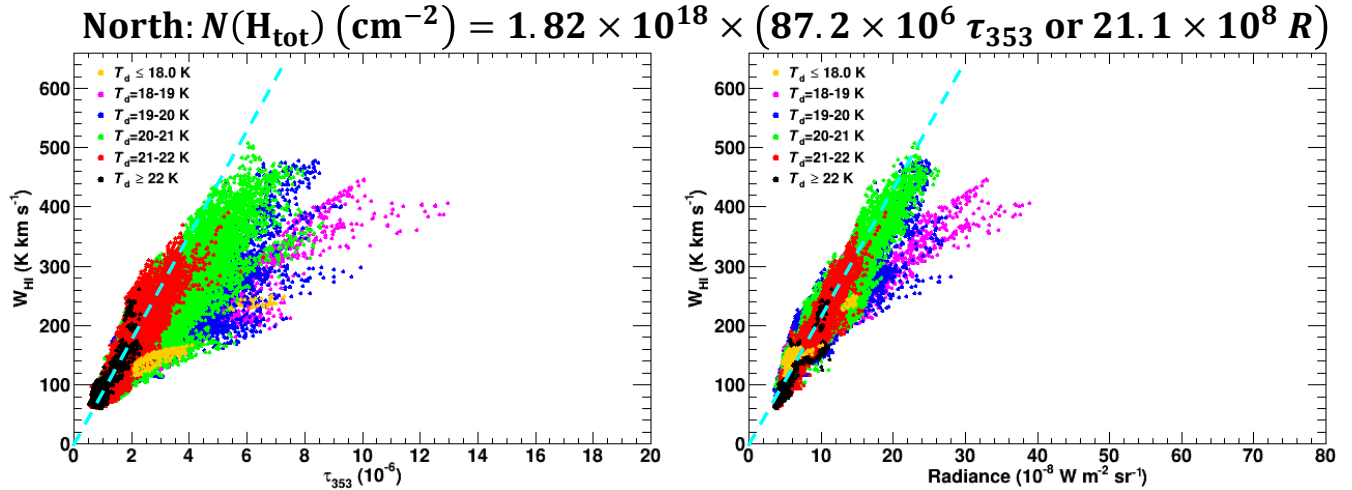
8 years, P8R2\_CLEAN\_V6, 0.1-25.6 GeV

Several areas are masked

- a peculiar  $W_{\text{HI}}$ -dust relation
- the Orion-Eridanus superbubble
- an intermediate velocity cloud

# $W_{\text{HI}}$ -Dust Relations

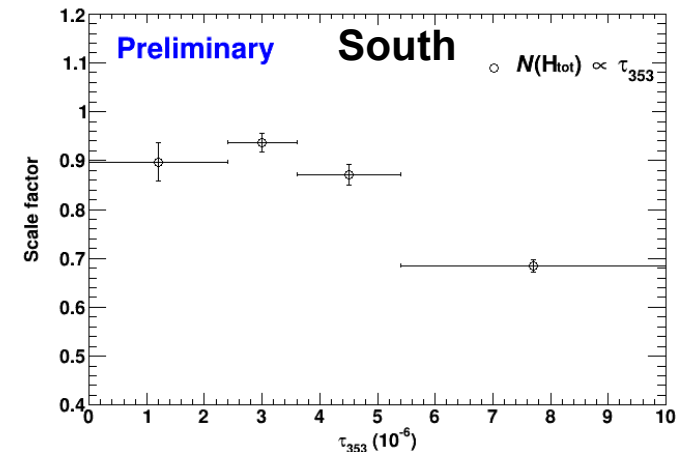
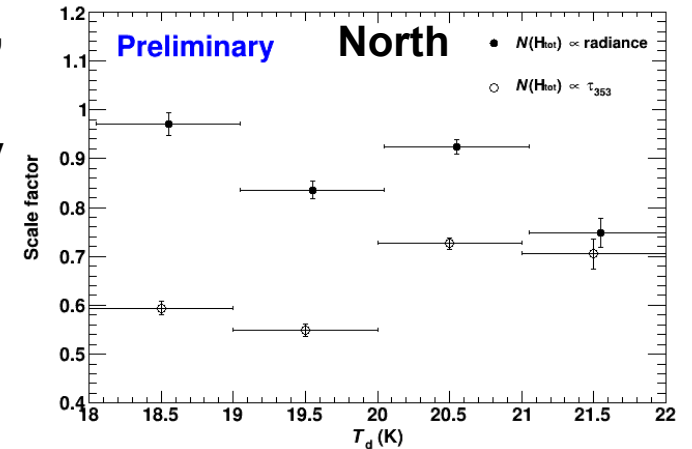
- North:  $T_d$  dependence is seen and is larger in the  $W_{\text{HI}}-\tau_{353}$  relation
- South:  $T_d$  dependence is weak, but a non-linear relation is observed
- We used linear relations which follow trends in high  $T_d$  & low  $W_{\text{HI}}$  area to construct initial  $N(\text{H}_{\text{tot}})$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

- [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