Study of γ rays from Molecular Cloud Regions

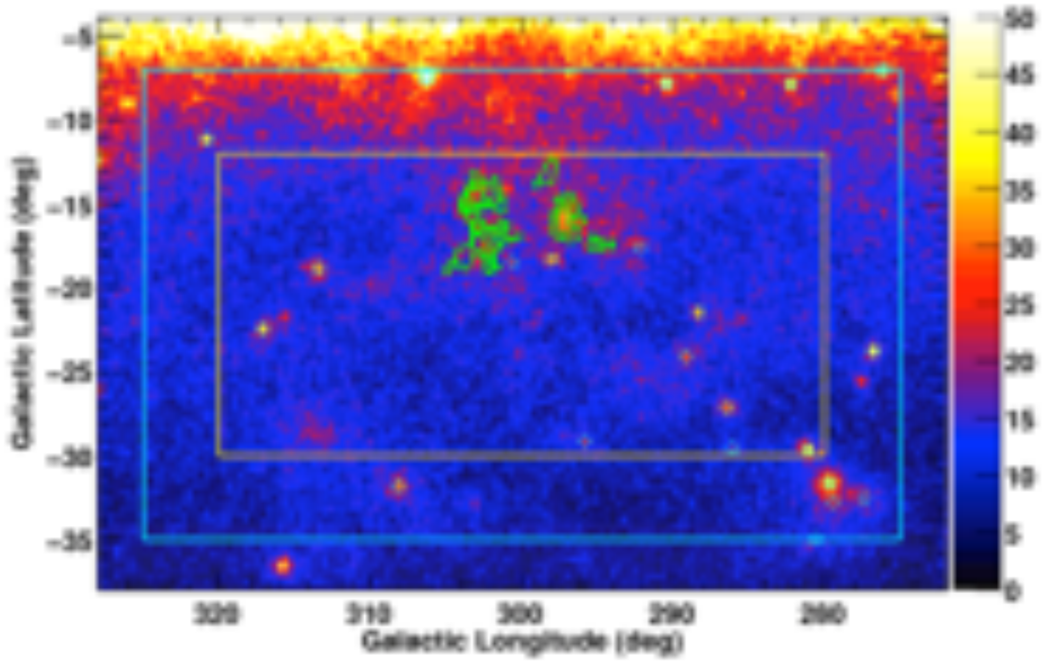
γ rays ∼ CRs x ISM (or ISRF)

(Ackermann+12)

Diffuse GeV γ rays are powerful probe to study the ISM

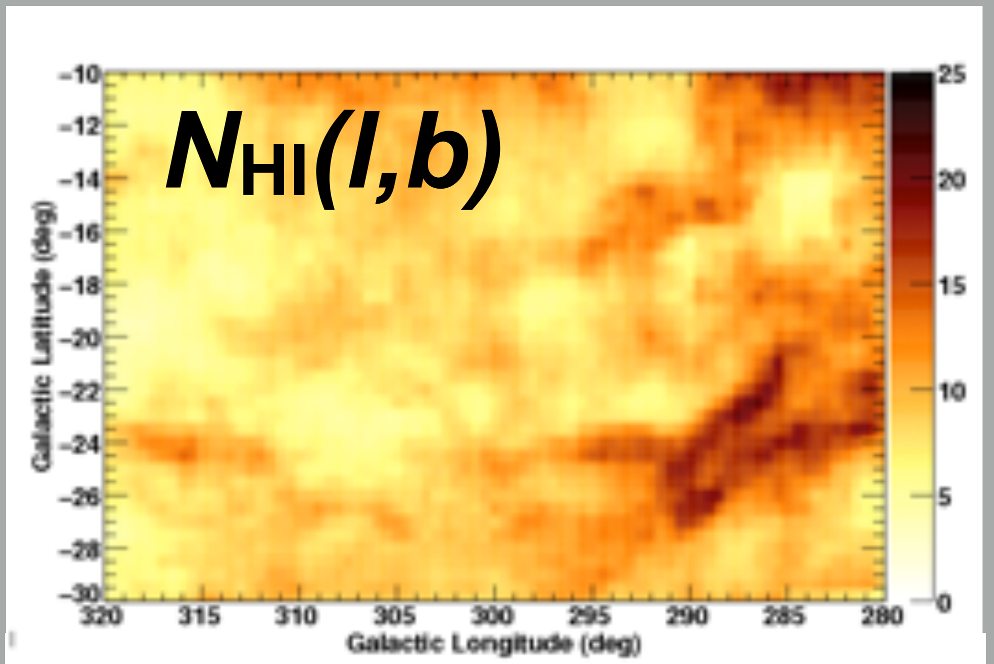
- **γ-ray production does not depend on the chemical and thermodynamic state of the ISM**
- **A good tracer of the total gas column density**

γ ray (l,b,E)

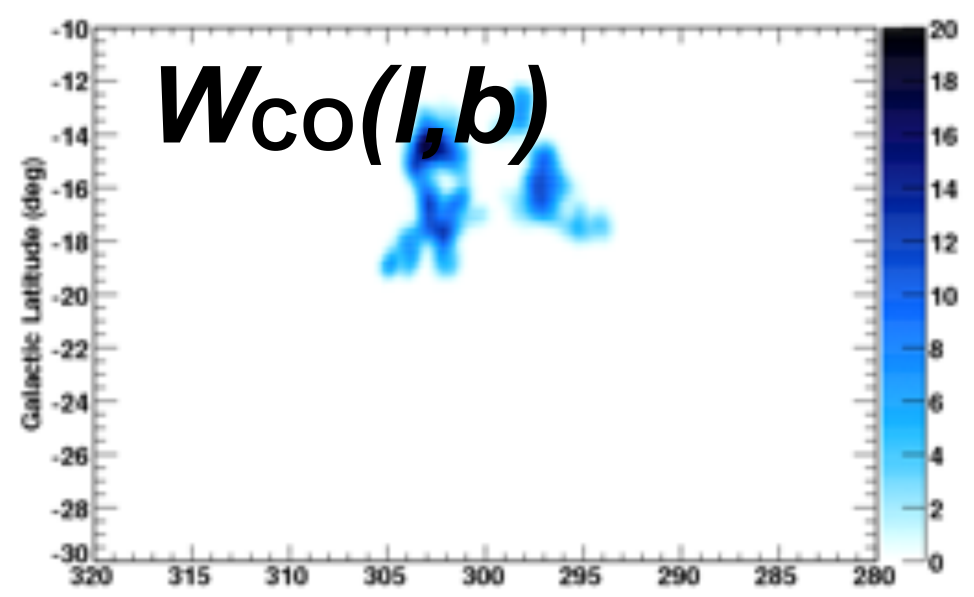


=

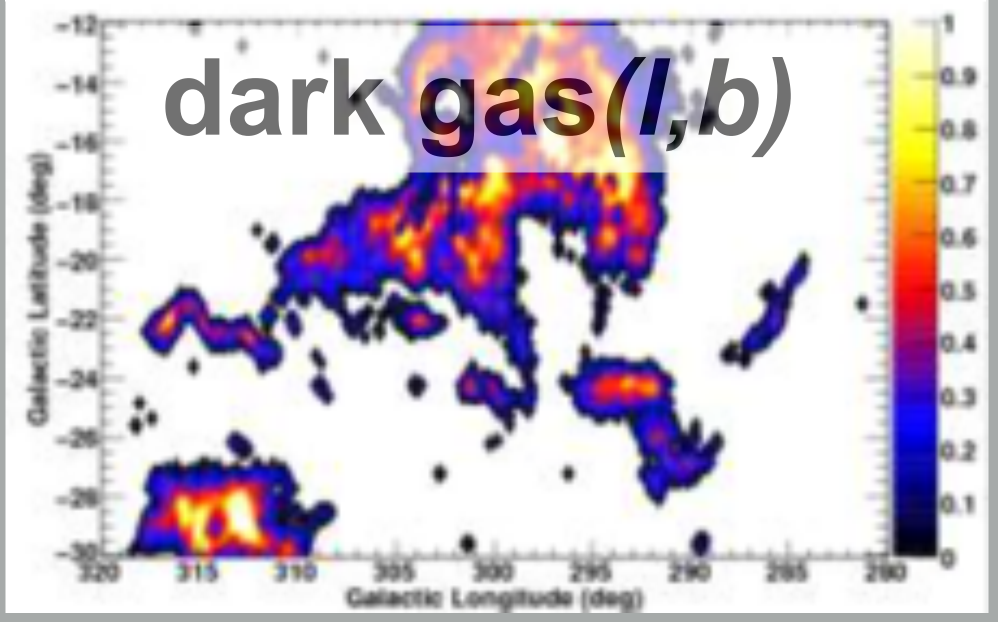
$q_{HI}(E)$ x



+ $q_{CO}(E)$ x



+ $q_{dark}(E)$ x



+ background emission (IC, Isotropic and point sources)

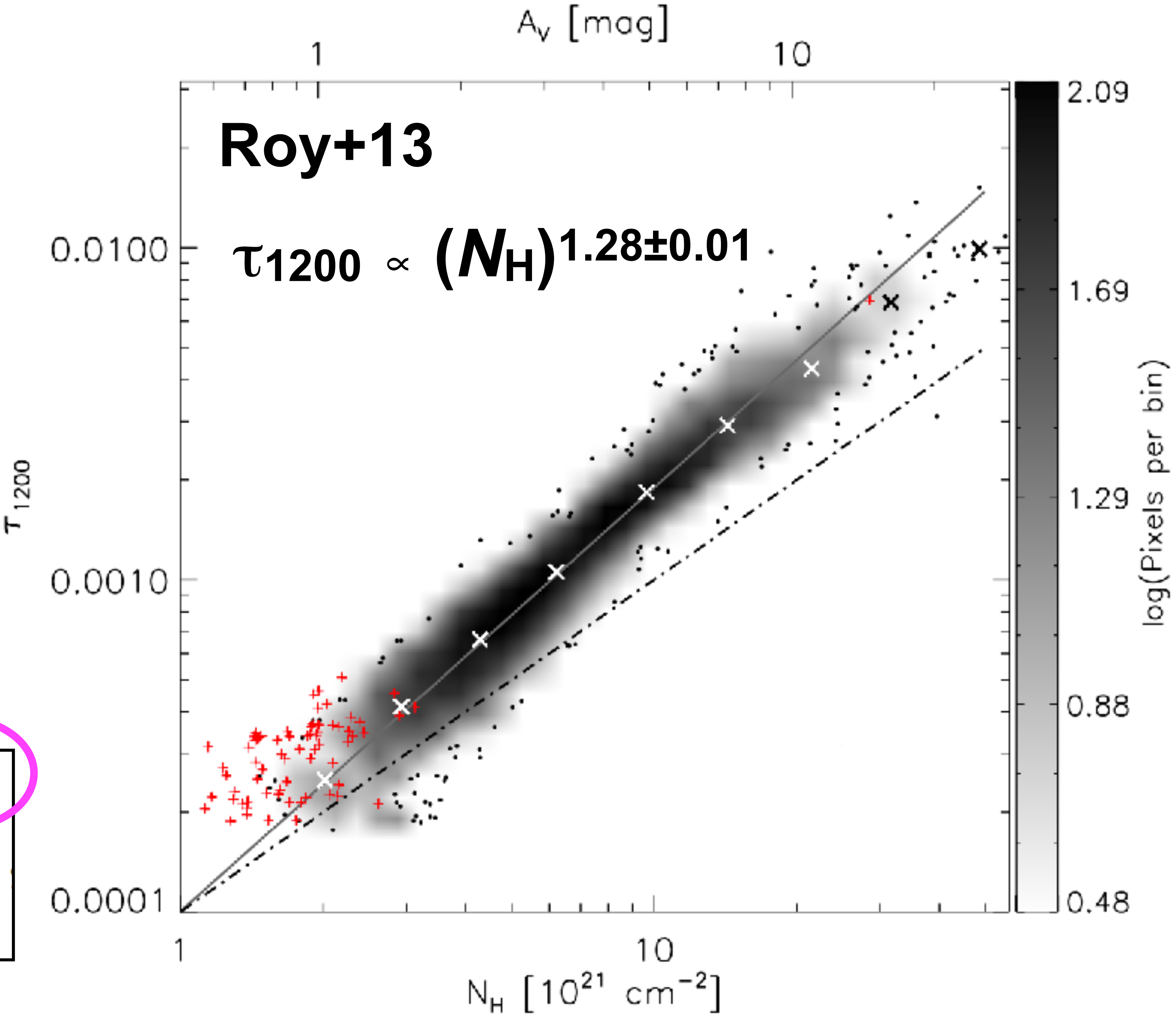
"Conventional γ-ray analysis" (e.g., Ackermann+12)

- **Fit γ-ray data with linear combination of three gas maps under the assumption that CRs uniformly thread the ISM**
- **"dark gas" (gas not traced by standard HI and CO observations) map is inferred by dust extinction map**

$N_{\rm H}$ Model and γ-ray Analysis

- **Fukui+15 suggested $N_{\rm H}$ model based on linear function of the thermal dust optical depth τ_{353}**
- **Roy+13/Okamoto+17 found nonlinear relation in Orion/Perseus molecular clouds**

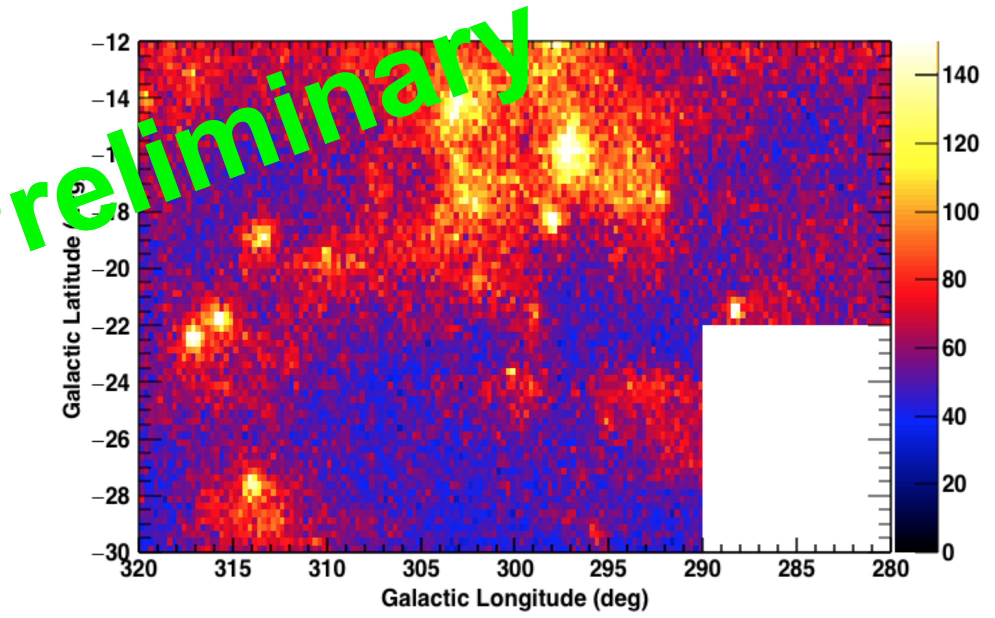
- **We examined several $N_{\rm H}$ models as function of τ_{353} with linear/nonlinear relations by fitting them to γ-ray data in the Chamaeleon region**



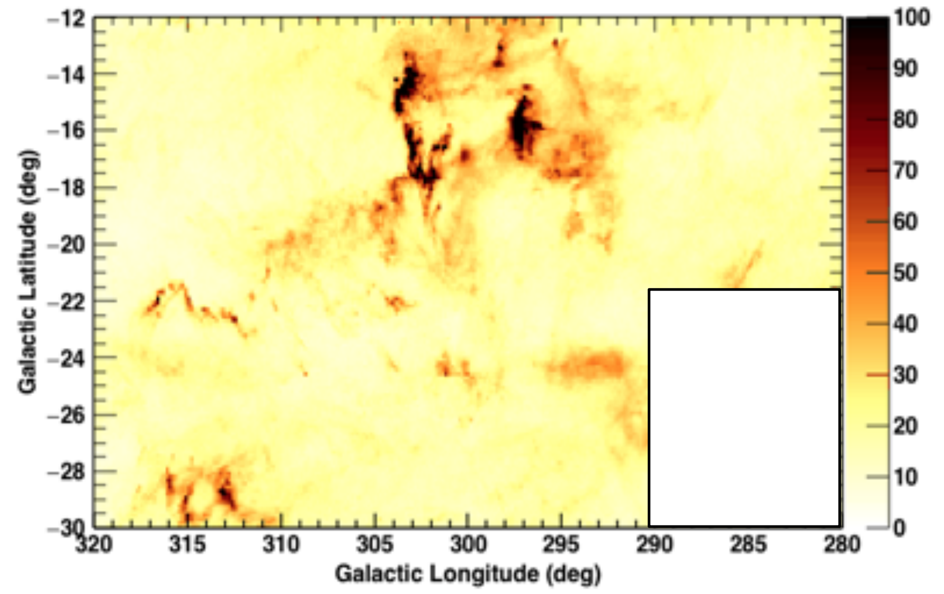
(Reddening data obtained with 2MASS)

γ ray (*l*,*b*,*E*)
~7years (0.25-100 GeV)
P8R2_CLEAN_V6

$$\frac{N_{\rm H}(l,b)}{N_{\rm H,ref}} = \left(\frac{\tau_{353}(l,b)}{\tau_{353,\rm ref}}\right)^{1/\alpha}$$

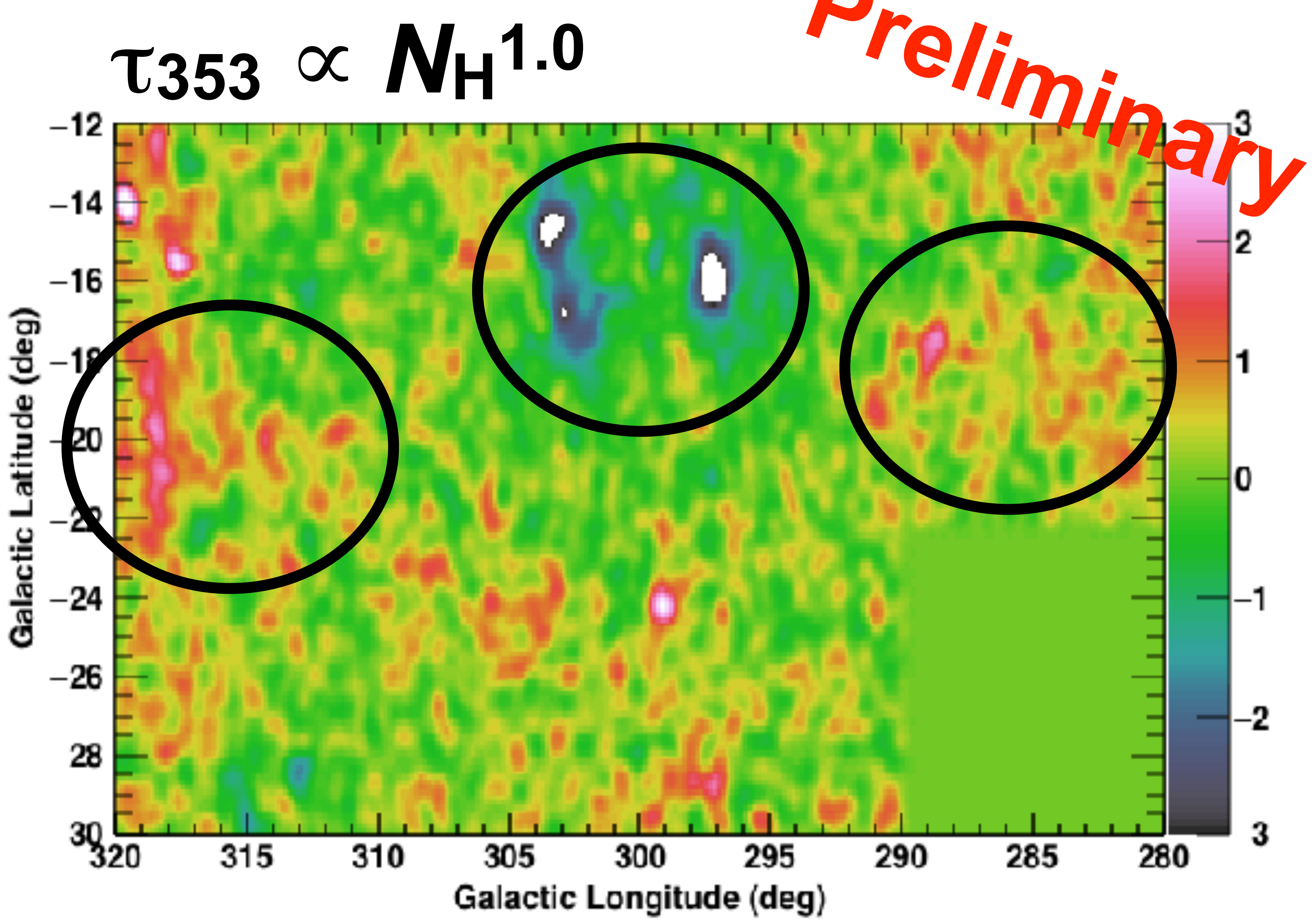


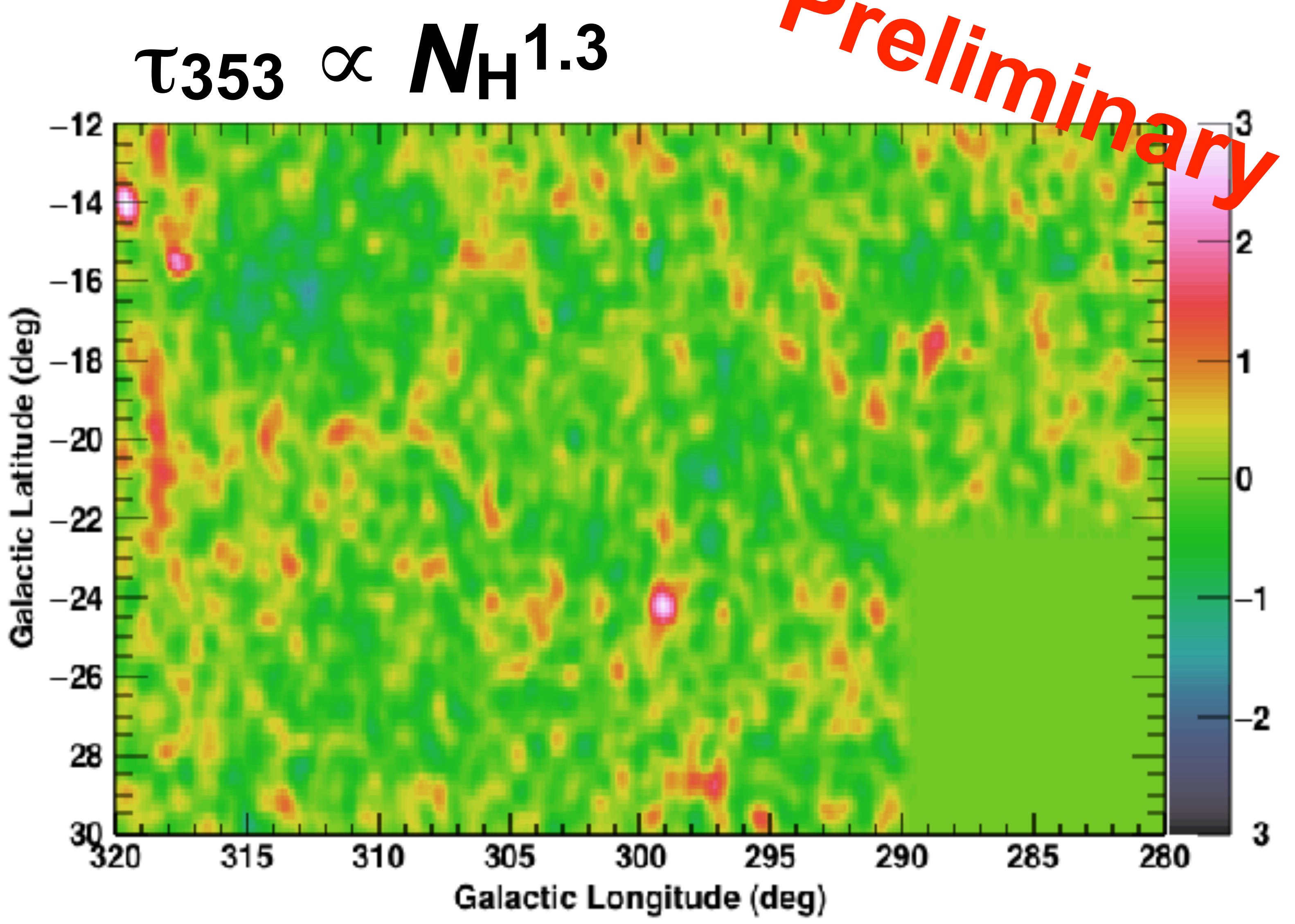
= $q_{\rm H}(E)$ x

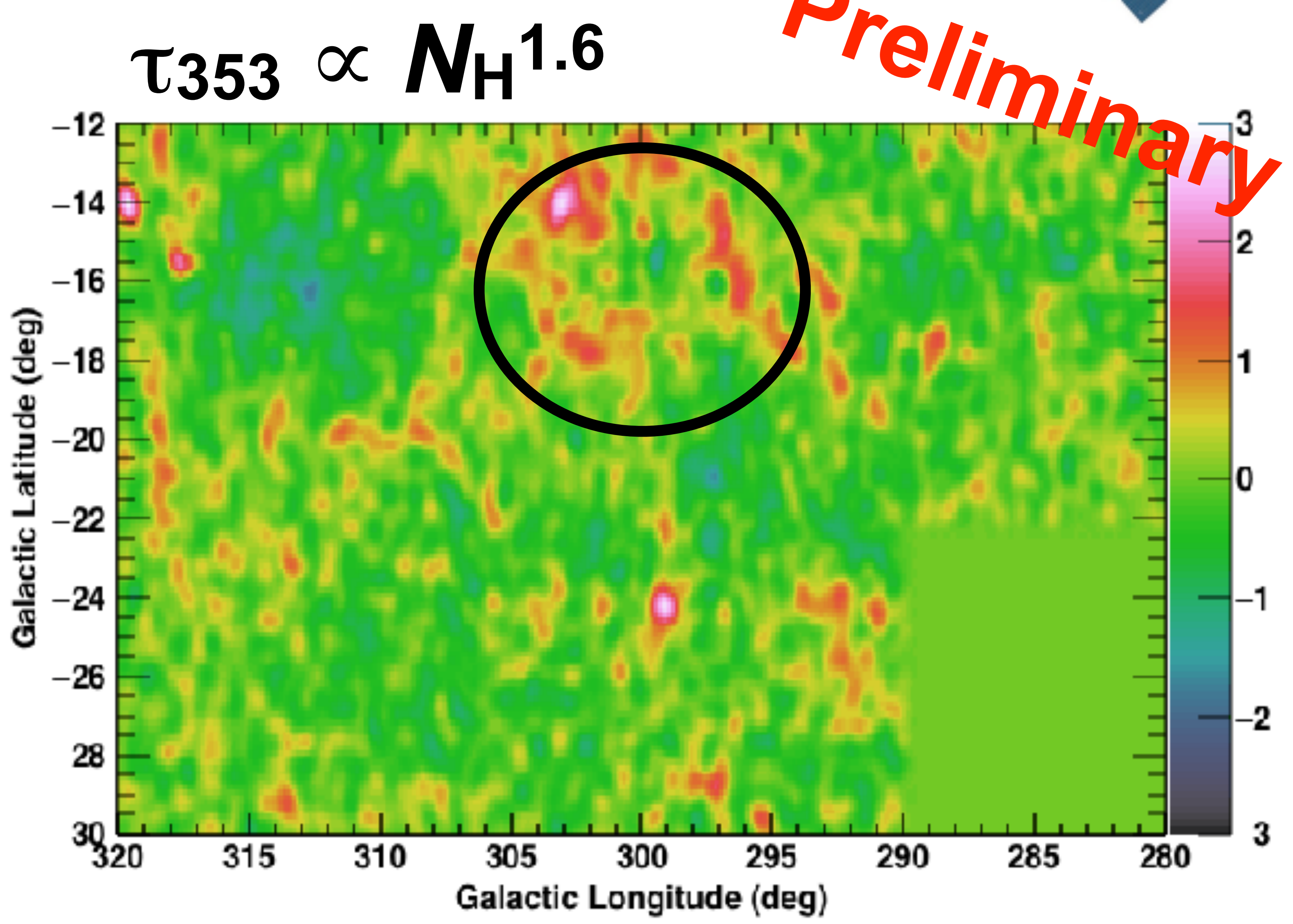


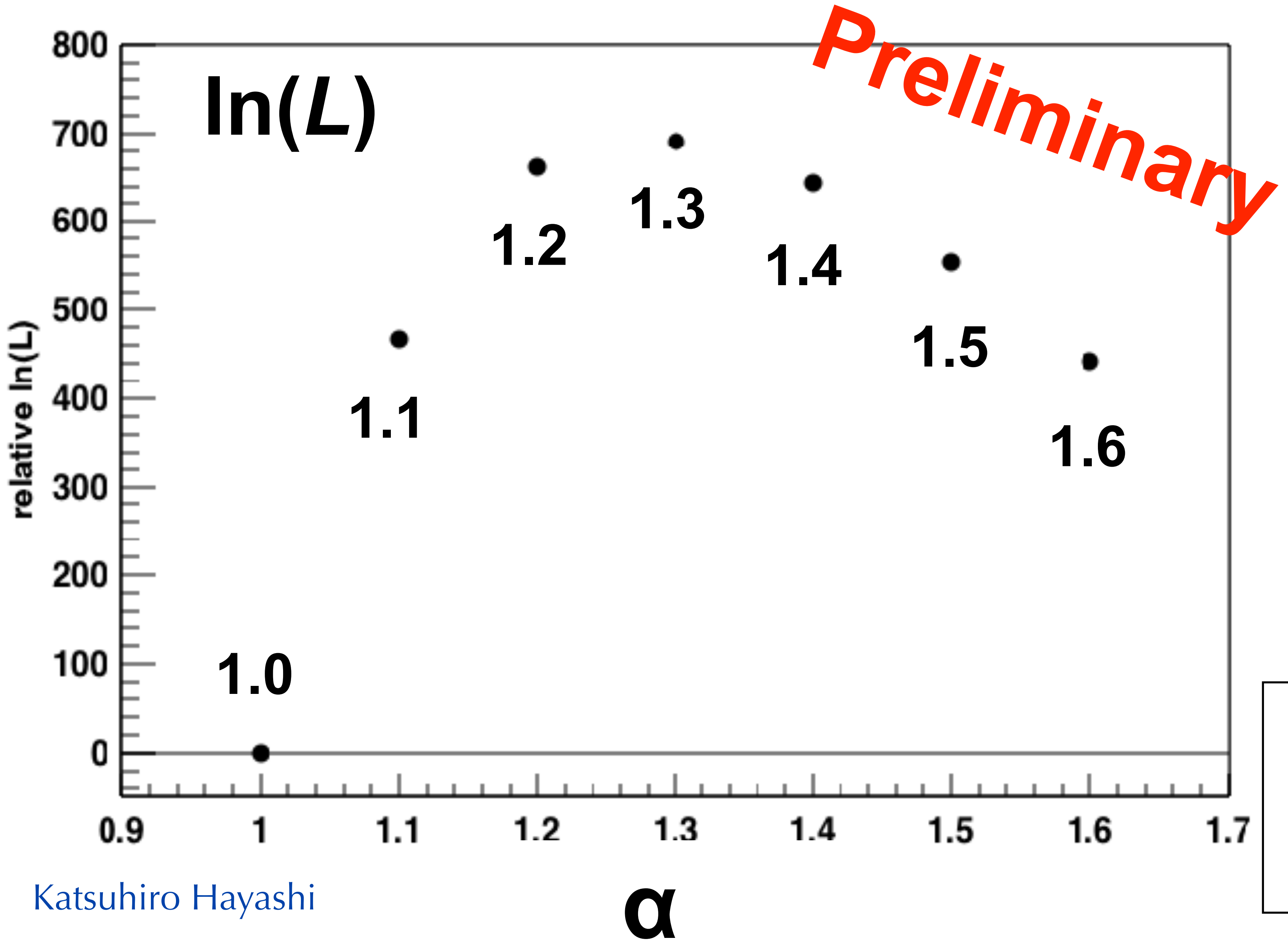
$$+ I_{\rm IC}(l,b,E) + I_{\rm iso}(E) + \sum_j {\rm PS}_j(l,b,E)$$

Results (Residual Maps)









- **Residuals in standard deviation (σ)**
- **Significant positive and negative residuals are seen in the models of $\tau_{353} \propto N_H^{1.0}$ and $\propto N_H^{1.6}$**
- **$\tau_{353} \propto N_H^{1.3}$ model provides the best fit to γ-ray data; lower residuals and the highest ln(*L*)**
- **The nonlinearity may suggest grain evolution in the molecular cloud complex**

References: Ackermann et al. 2012, ApJ, 755, 22
Okamoto et al. 2017, ApJ, 838, 13
Roy et al. 2013, ApJ, 765, 55
Fukui et al. 2015, ApJ, 798,6
Planck Collaboration XXVIII, 2015