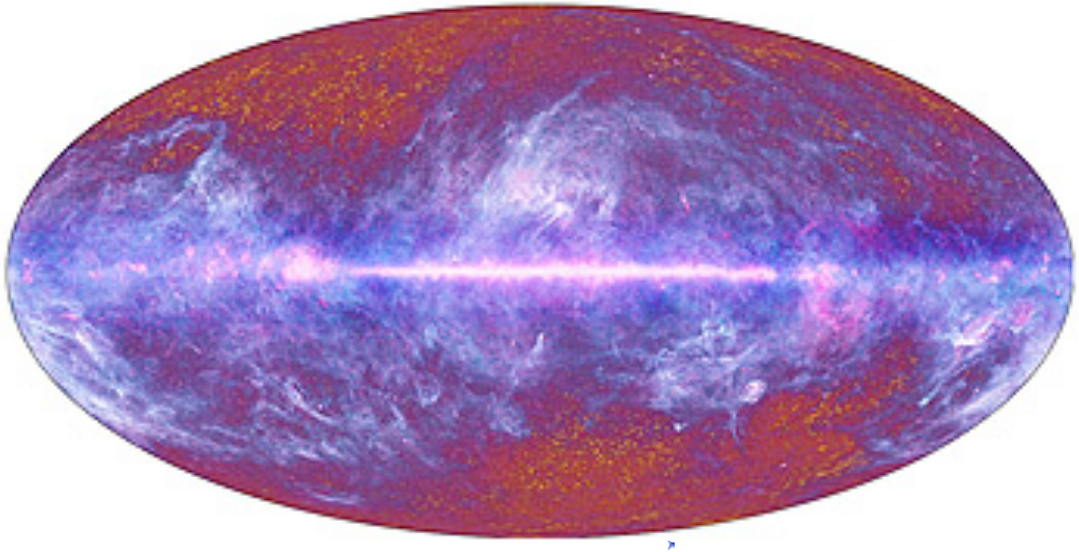
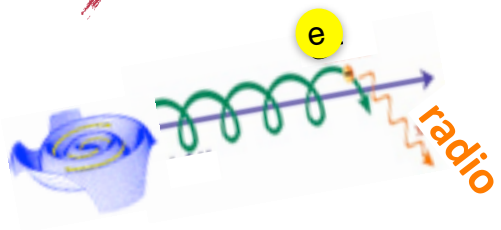
Planck, Fermi, & the “dark” gas

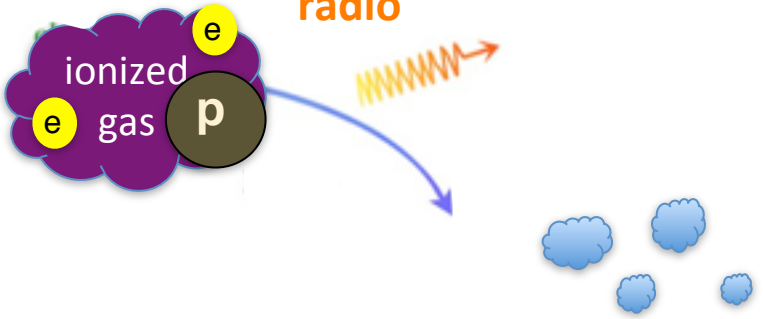
Isabelle Grenier
AIM, Paris Diderot & CEA Saclay
on behalf of both collaborations

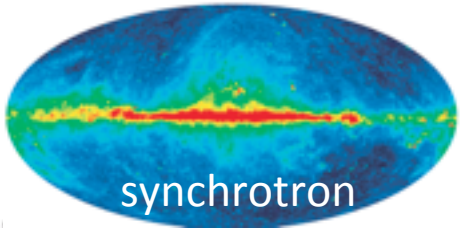
the microwave sky

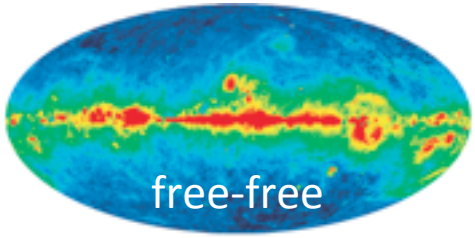


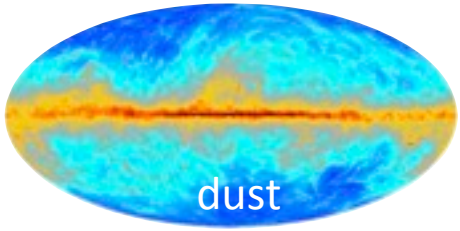
PLANCK
30 GHz to 857 GHz

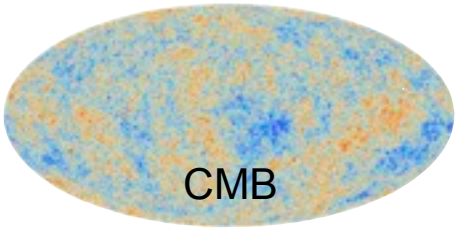






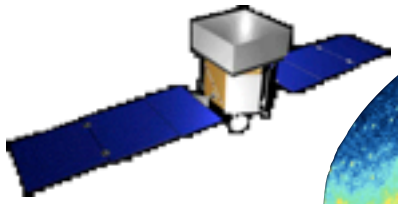


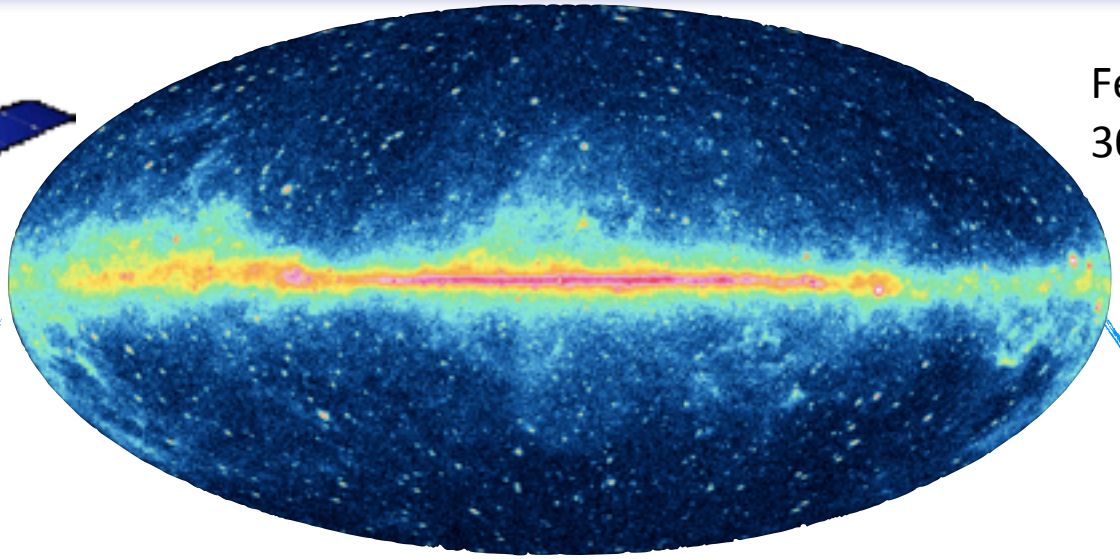




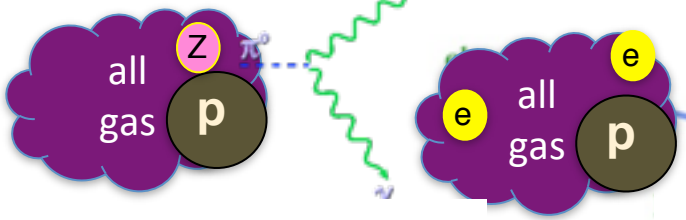
+ sources + spinning dust

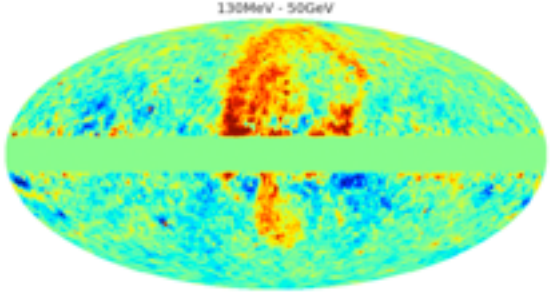
the 4-year γ-ray sky

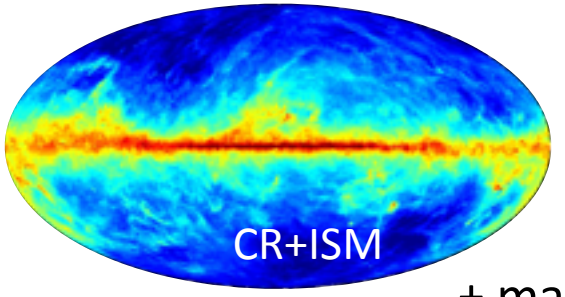


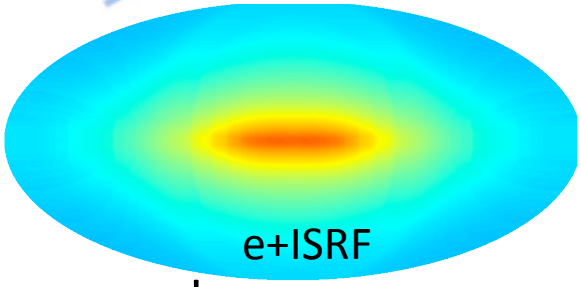


Fermi LAT
30 MeV to 300 GeV



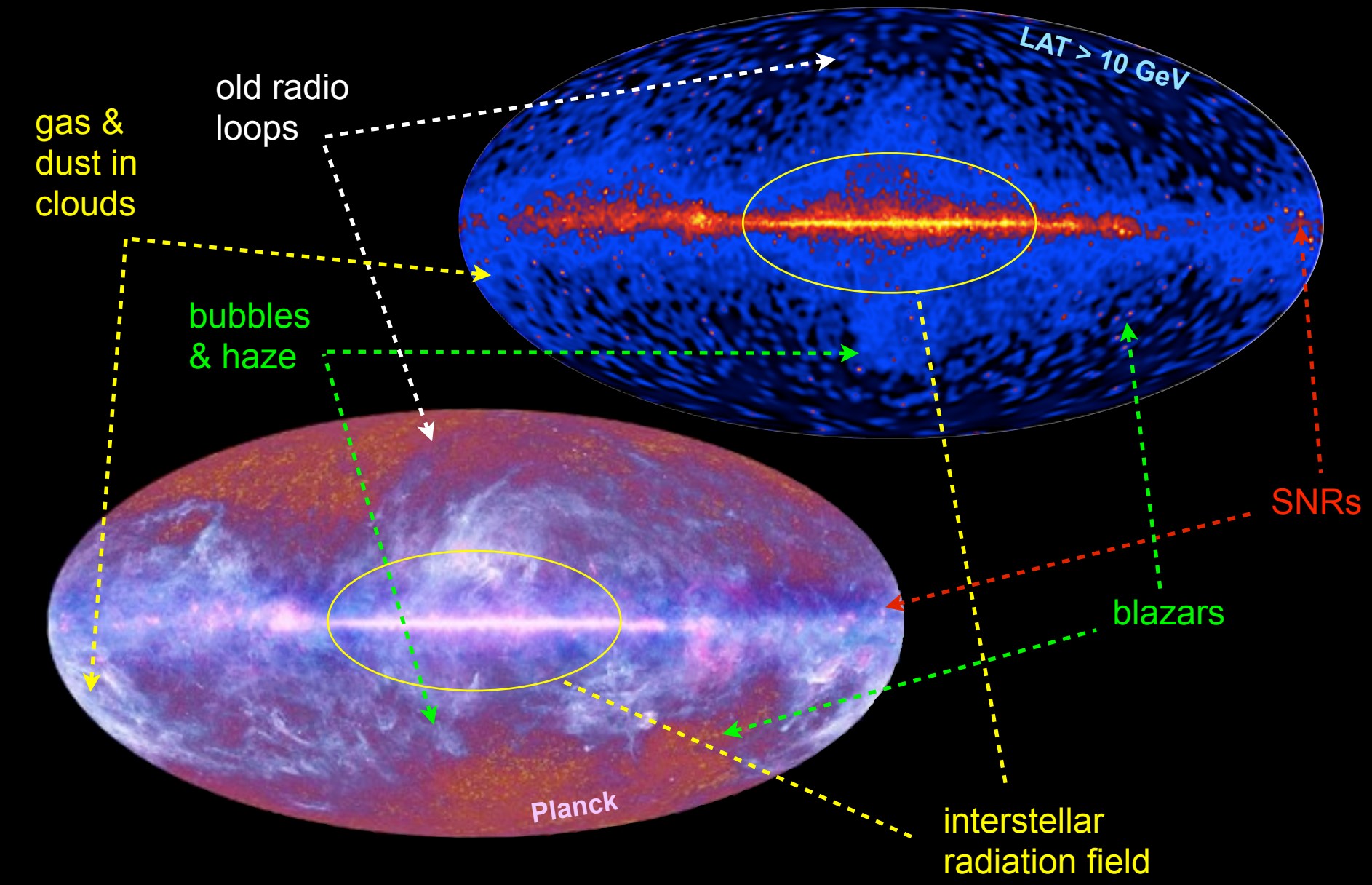






+ many sources !

Fermi Planck multiple synergies



$e^{\pm}$ spectrum & total B field

- low-energy electron break

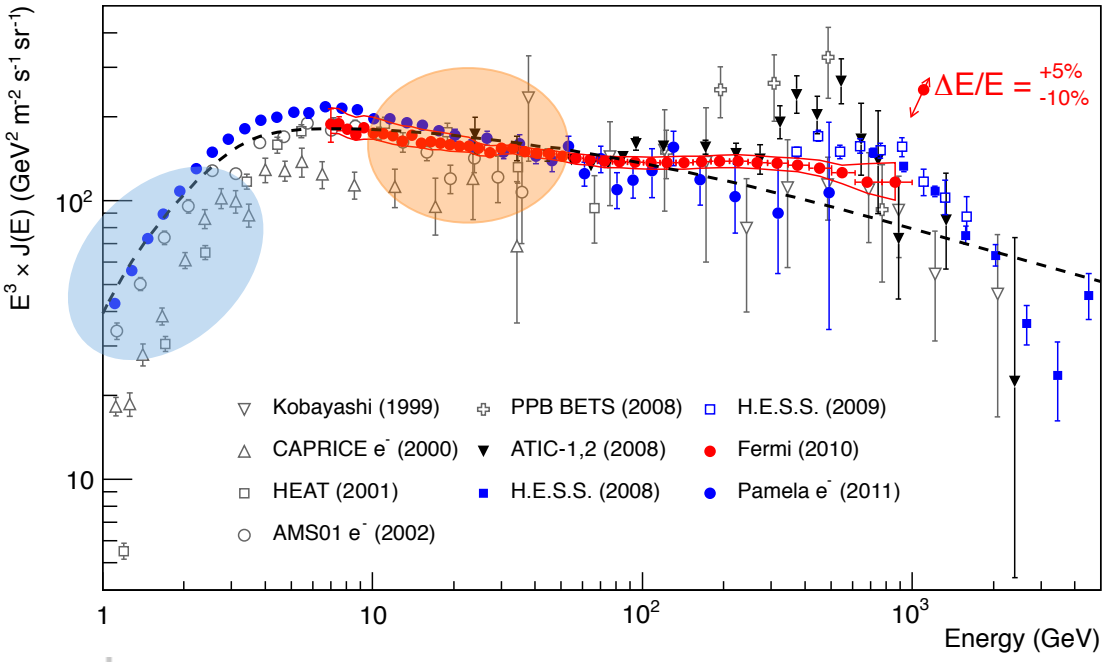
  $E_e^{-1.6}$ | $E_e^{-2.5}$ | $E_e^{-2.2}$

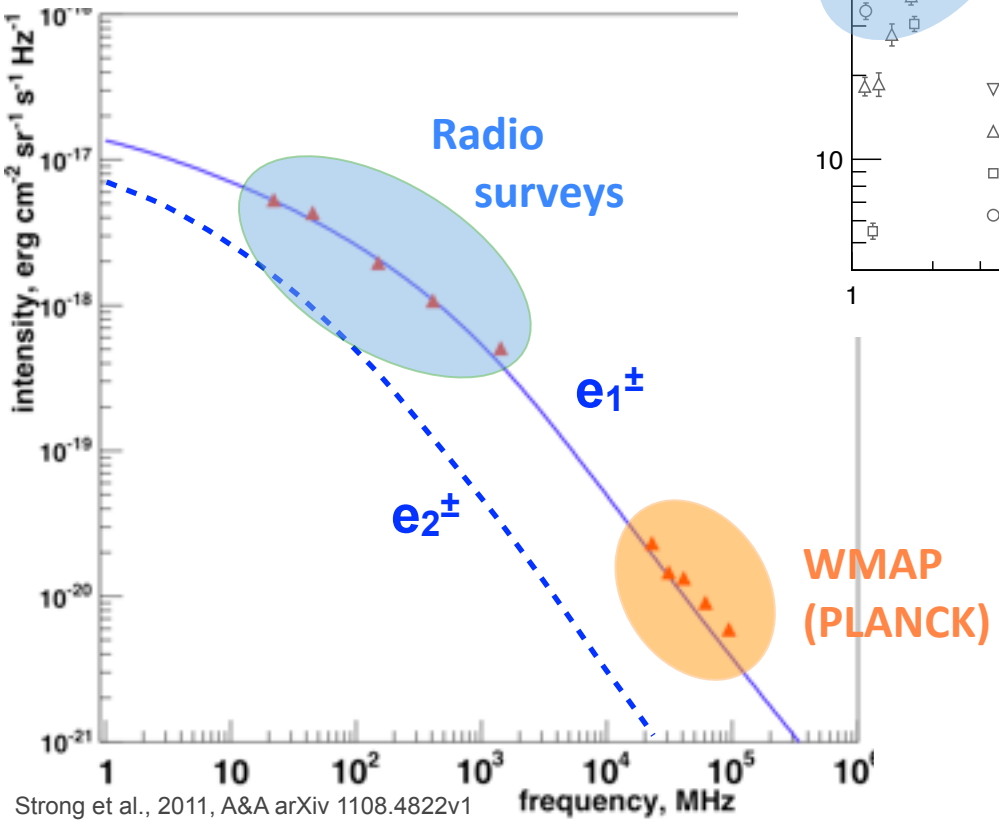
  4 GeV **50 GeV**

- $E_e^{-2.2}$ steeper than in SNRs
- significant $e_2^{\pm}$ contribution at low energy

- $B_{rand} \sim 7.5\ \mu G\ e^{-R/30\ kpc}\ e^{-z/4\ kpc} > B_{reg} \sim 2\ \mu G$

Ackermann+ 2010, PRL 82, 092004





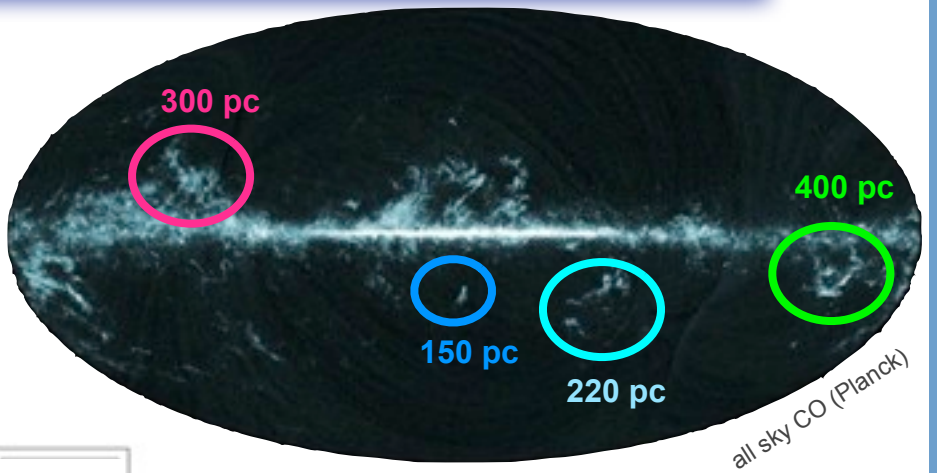
Strong et al., 2011, A&A arXiv 1108.4822v1

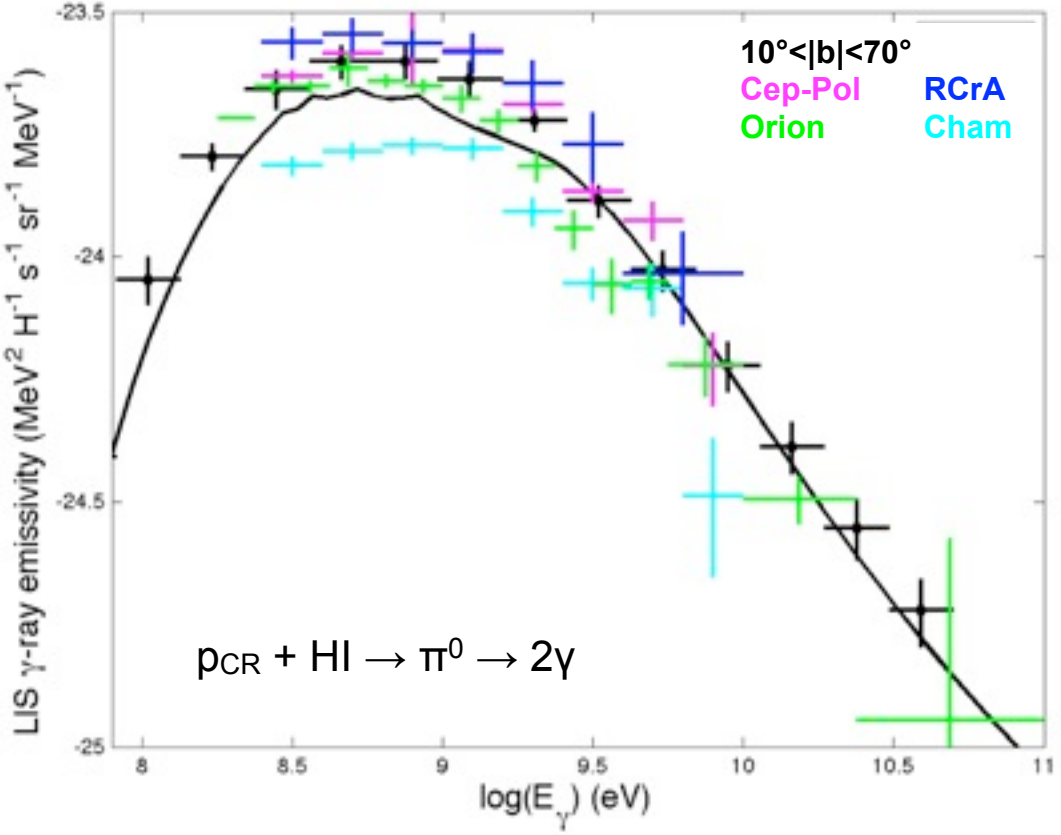
remote synchrotron
⇒ e spectrum in the ISM

remote vs. local electrons
⇒B field

local CR nuclei

- < 0.5 kpc scale CR spectrum consistent with our local knowledge of e and nuclei spectra (and solar demodulation)
- < 20% variations inside the Gould Belt

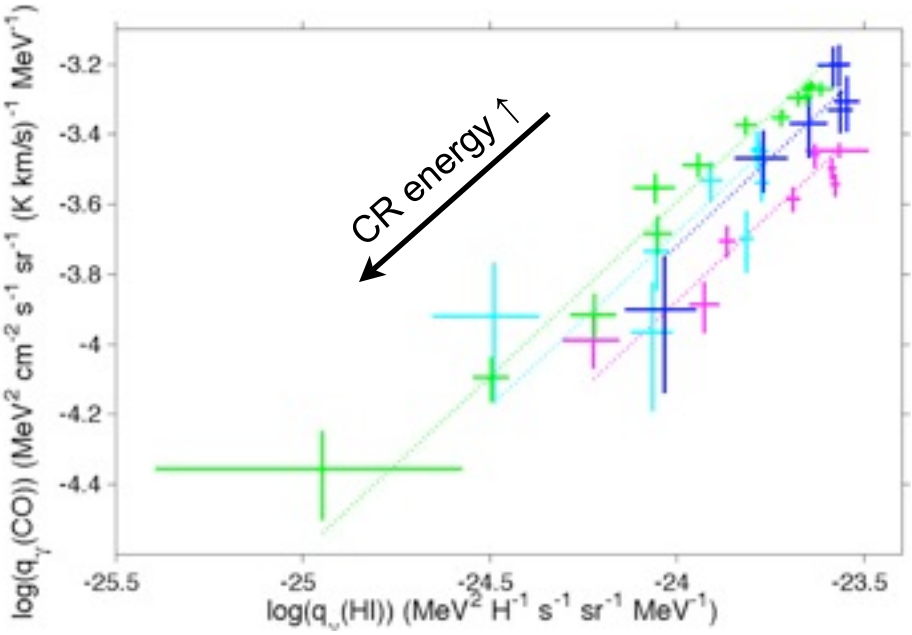


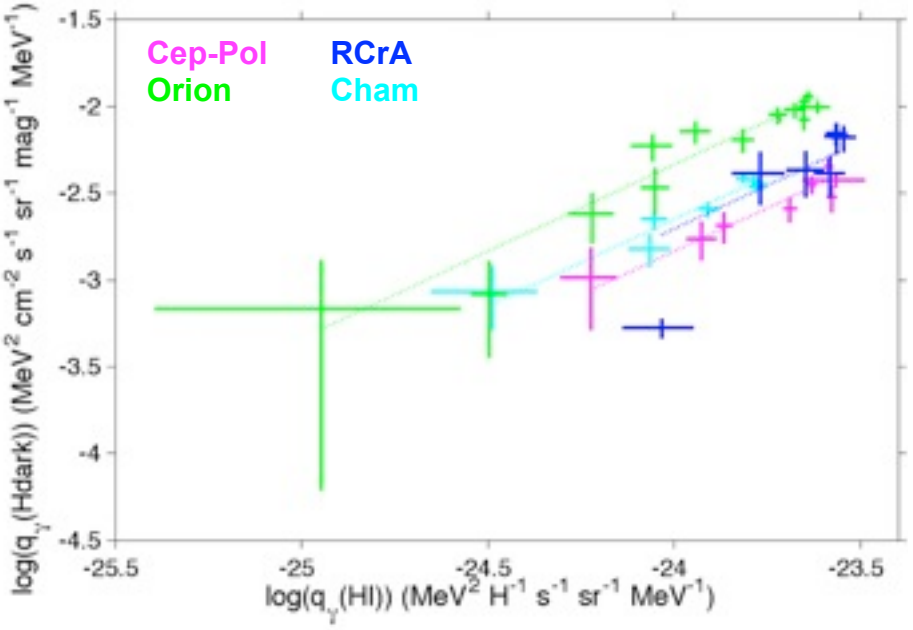


Ackermann+ 2012, ApJ, 755, 22
Ackermann+ 2012, ApJ, 756, 4
Casandjian+ in preparation

cosmic-ray penetration inside clouds

- no apparent spectral change ⇒ on average, uniform penetration to
  - the denser HI/H_2 dark phase
  - the very dense CO cores
  - down to pc scale, at the current precision





CO-bright H_2 phase

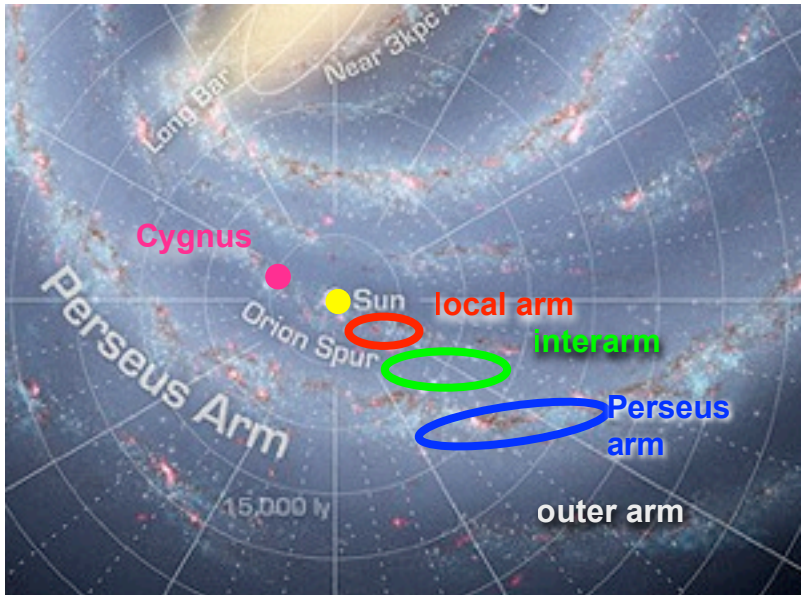
dark gas phase

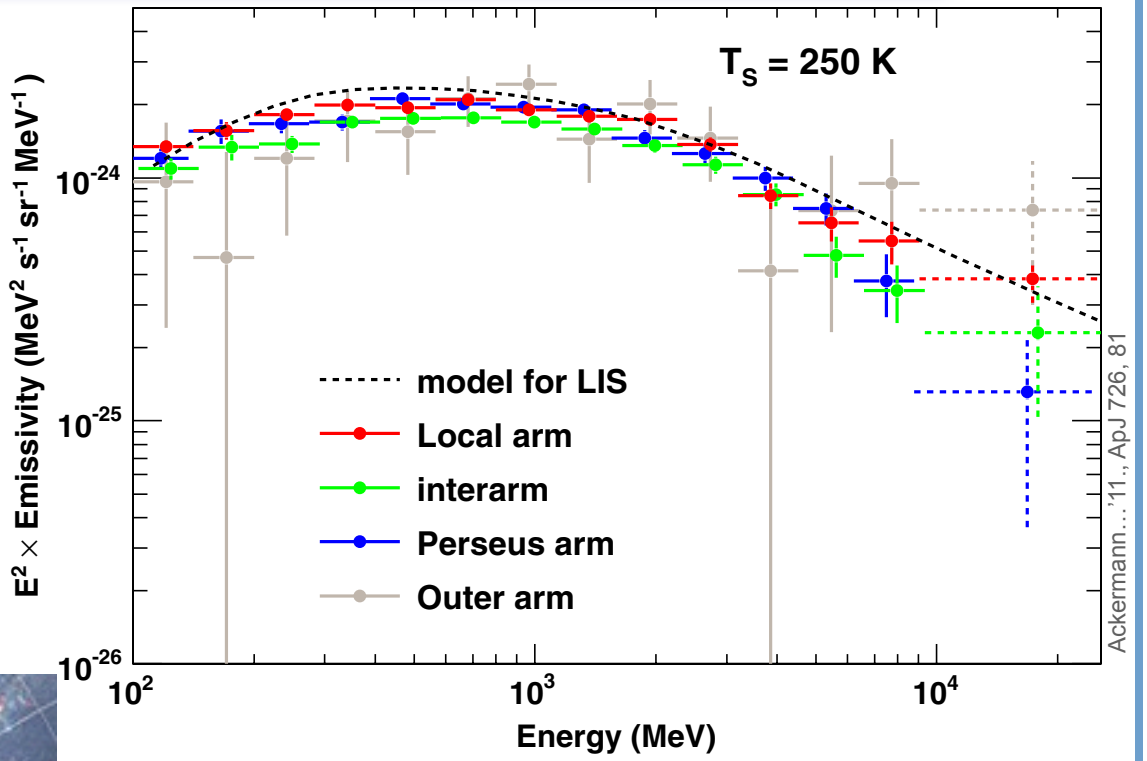
Ackermann+ 2012, ApJ, 755, 22
Ackermann+ 2012, ApJ, 756, 4

CR spectrum across spiral arms

- consistent with LIS spectrum
  comparable in clouds
  with $10^3 < M < 8\ 10^6\ M_\odot$

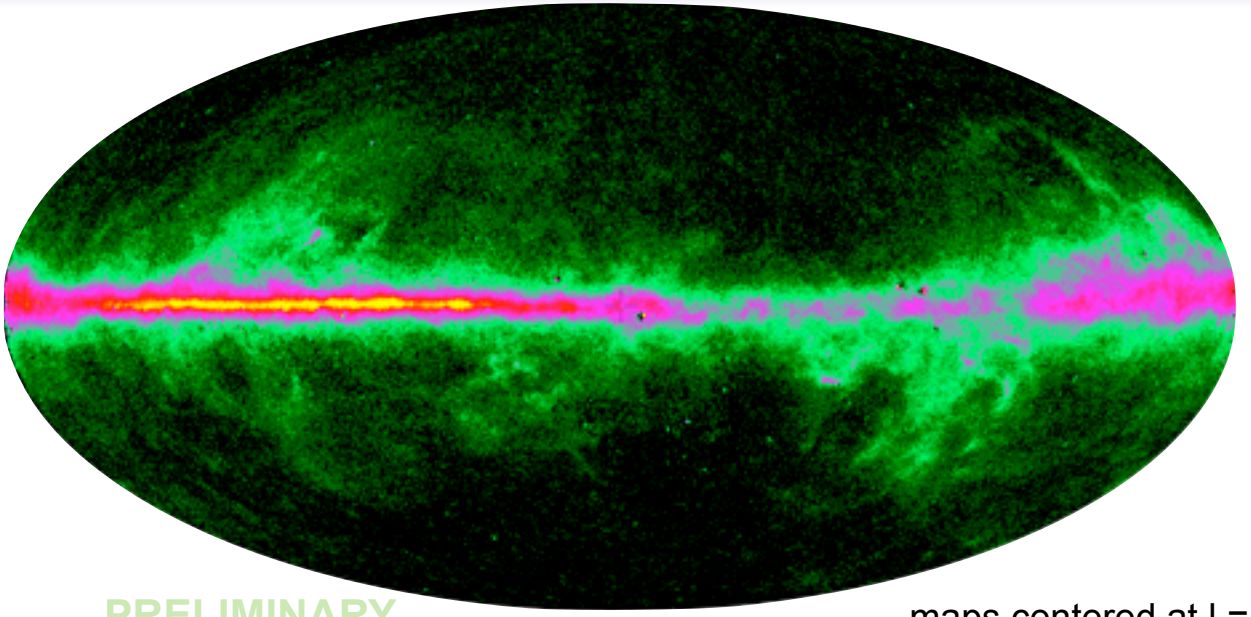
- little arm/interarm contrast
  => loose coupling with the
  kpc-scale surface density of gas
  or star formation





- shallow gradient in the outer Galaxy
  too shallow even for a large halo size
  - large amounts of missing gas ?
  - non-uniform diffusion?

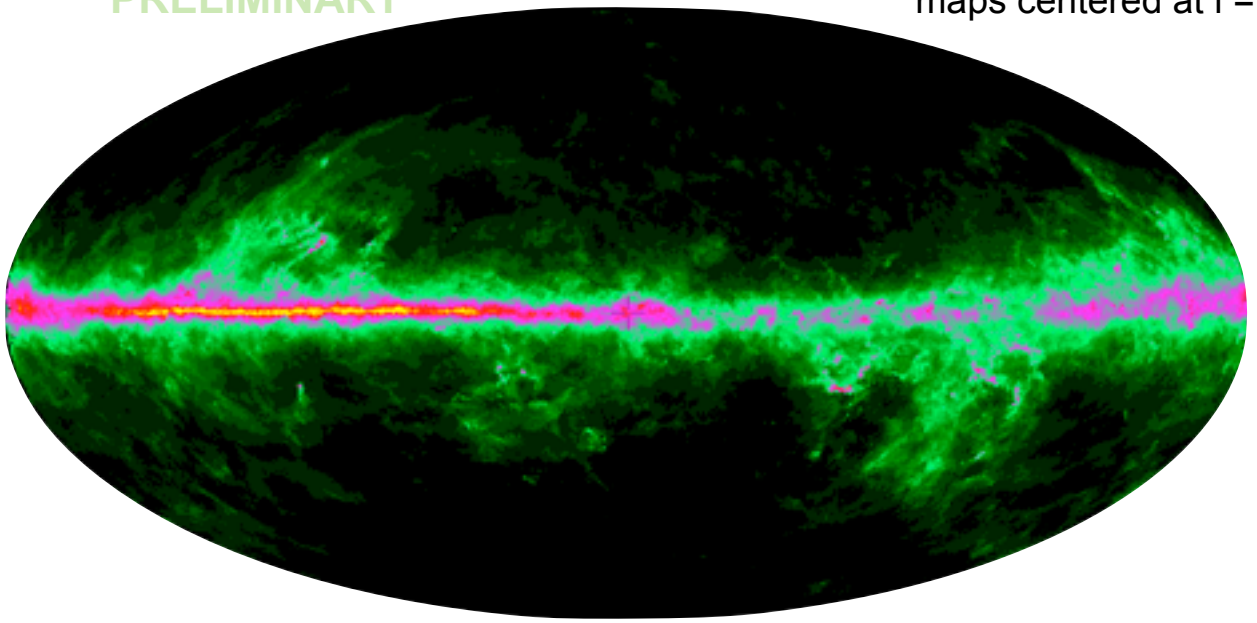
the total ISM in 2013



0.6 - 7 GeV photons
Fermi LAT diffuse model, in prep.

PRELIMINARY

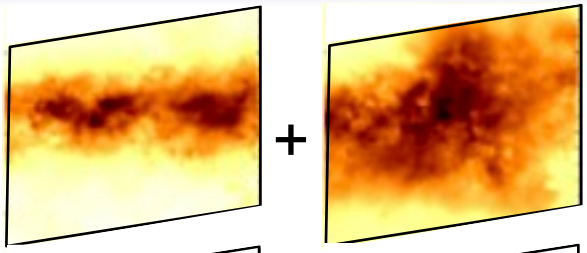
maps centered at l = 270°



dust optical depth
Planck et al. 2013, in prep

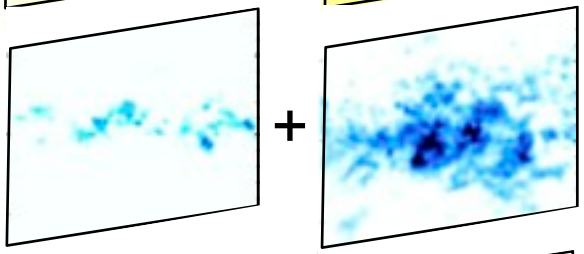
interstellar γ rays and dust

- CRays in HI: N(HI) $\frac{dN_{CR}}{dV}$



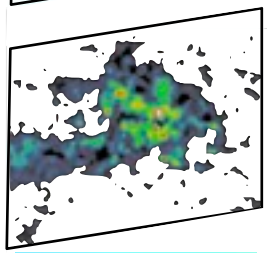
$\frac{\tau_{dust}}{NH}$ dust in HI

- CRays in H_2: $X_{CO} = \frac{N(H_2)}{W(CO)}$



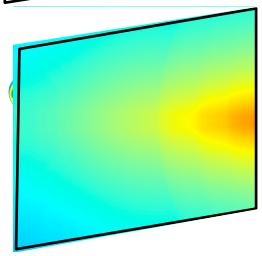
$X_{CO} = \frac{N(H_2)}{W(CO)}$ dust in H_2

- CRays in dark neutral gas: $I_\gamma - a\,N(HI) - b\,W(CO)$



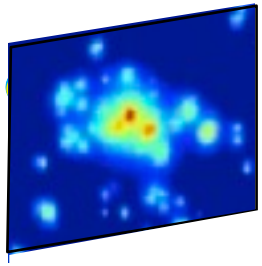
$\tau_{dust} - a'\,N(HI) - b'\,W(CO)$ dust in dark gas

- Galactic inverse Compton



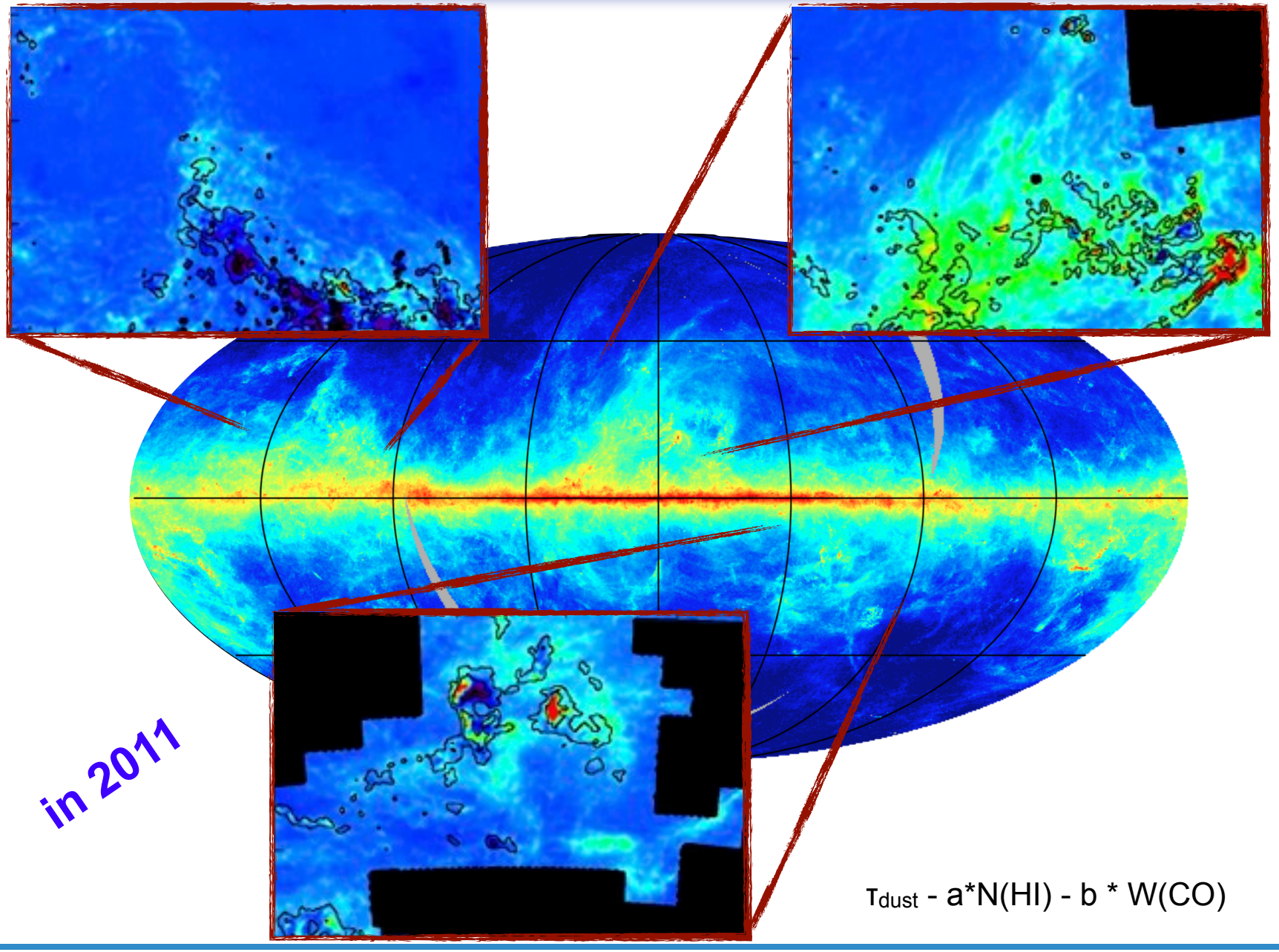
ISRF + CMB

- γ-ray sources

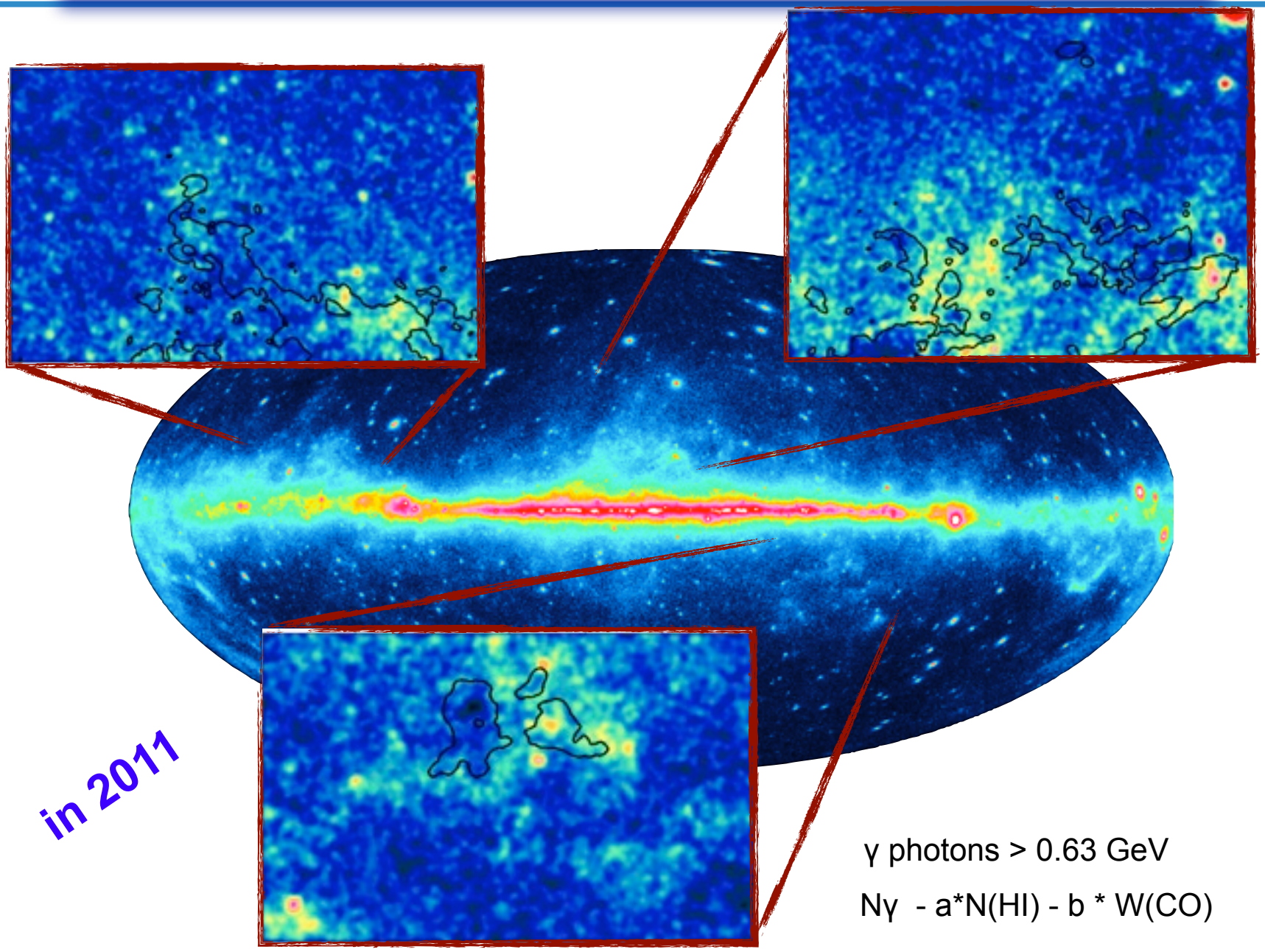


IR sources

chasing unseen gas with dust



chasing unseen gas with cosmic rays

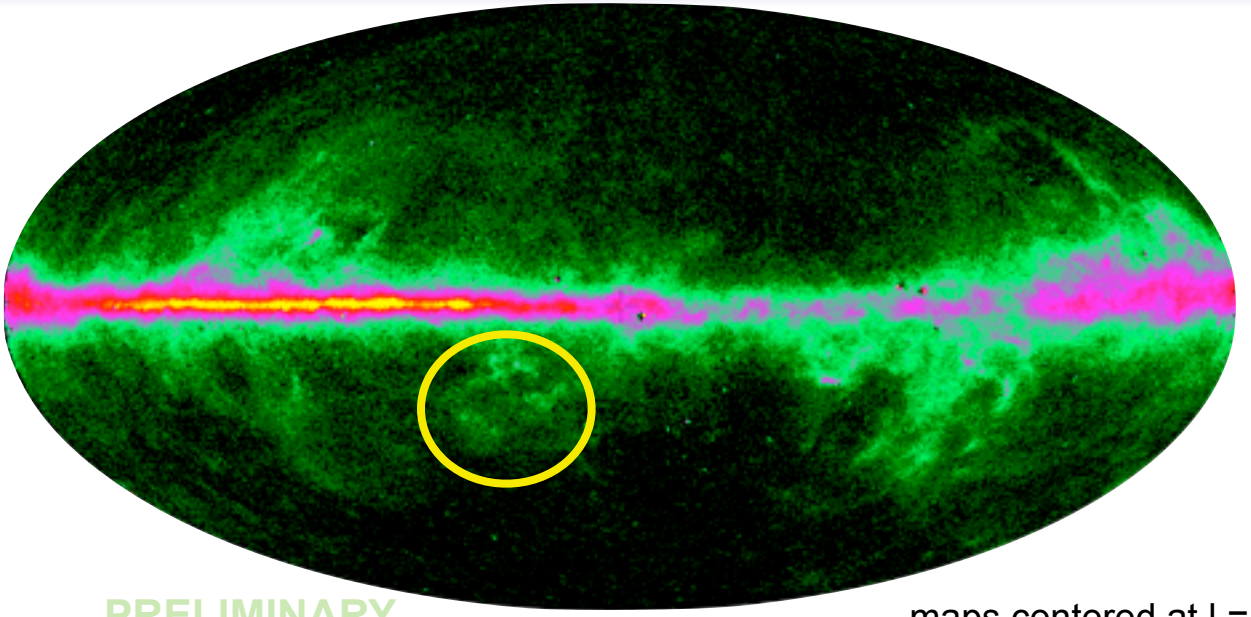


in 2011

γ photons > 0.63 GeV

Nγ - a*N(HI) - b * W(CO)

the total ISM in 2013



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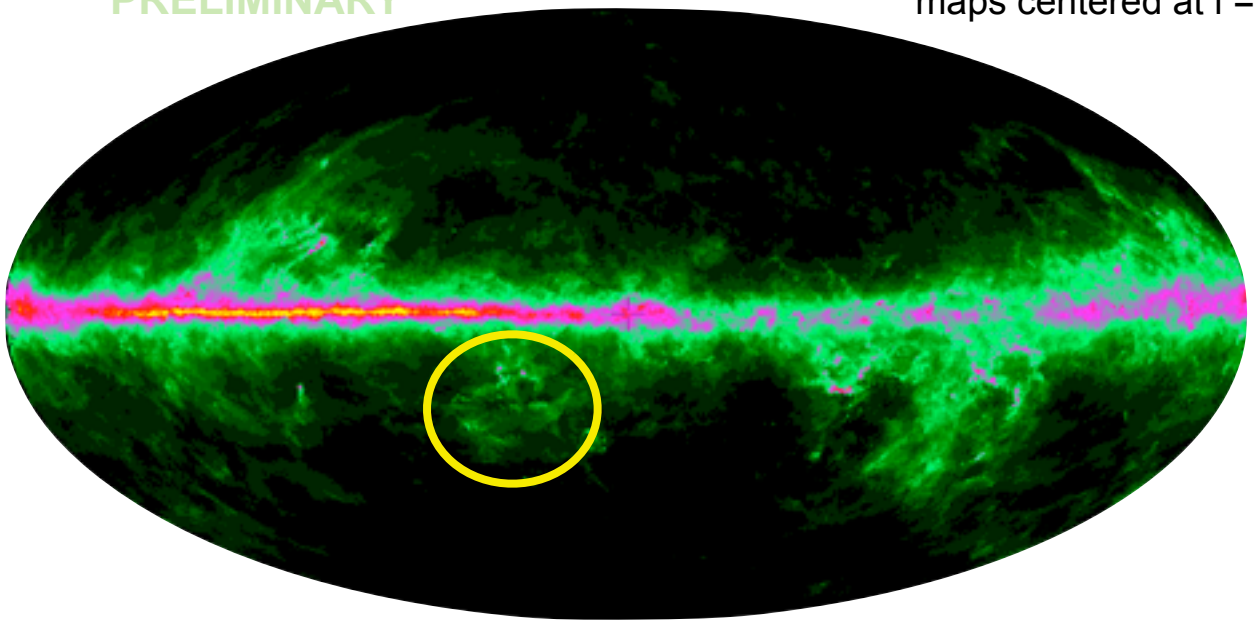
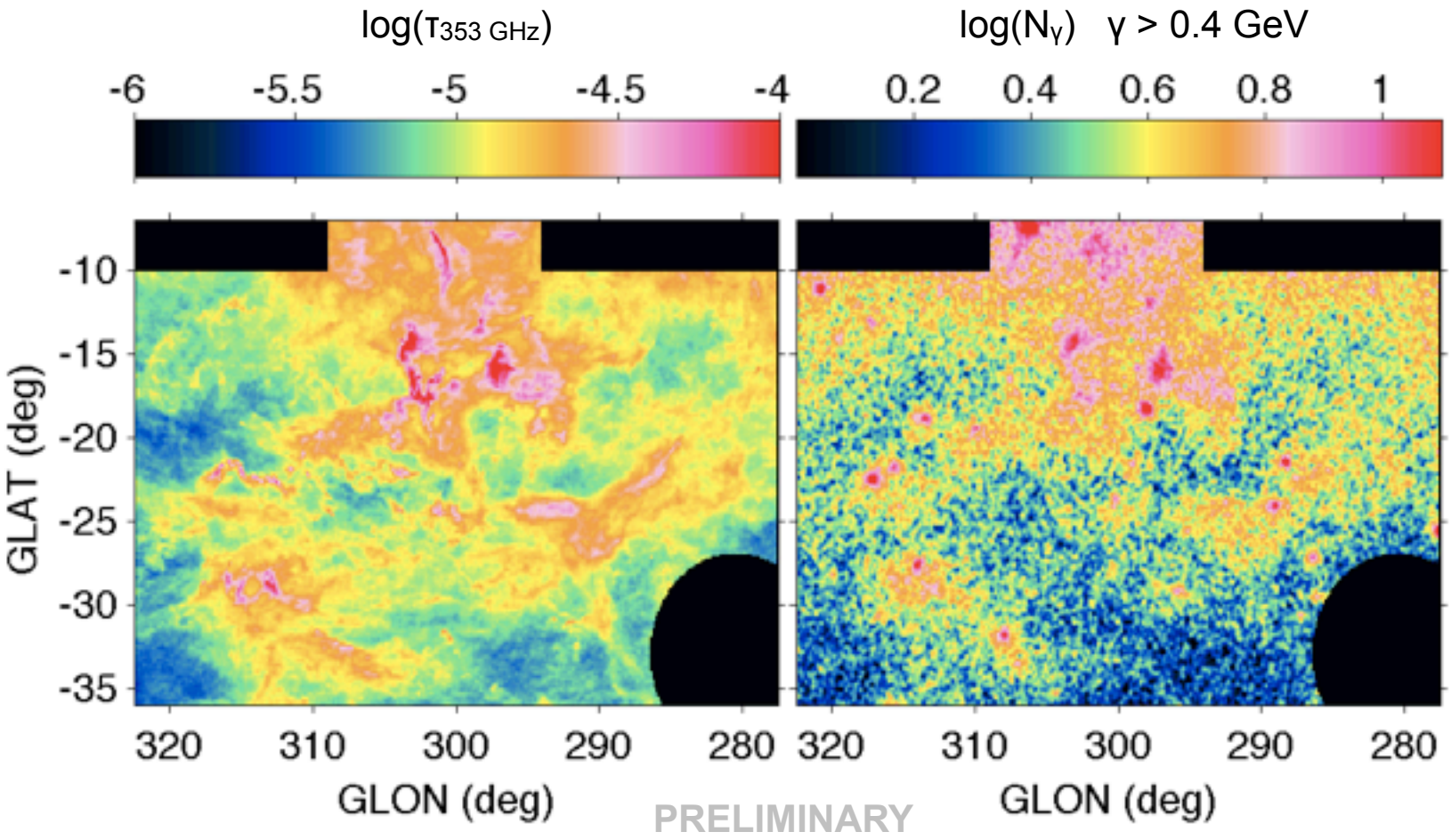
PRELIMINARY

maps centered at l = 270°



dust optical depth
Planck et al. 2013, in prep

gas tour of the Chamaeleon



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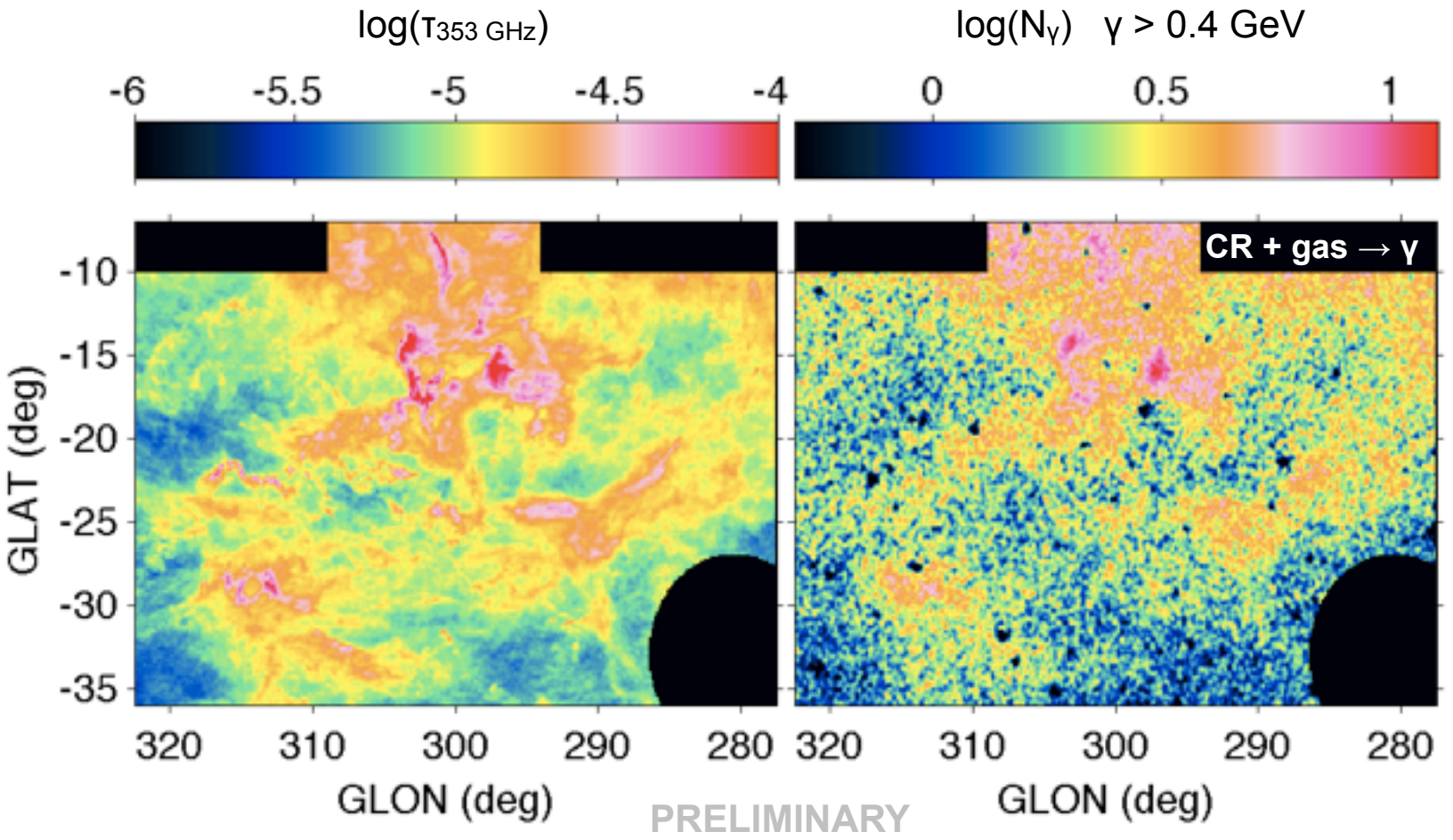
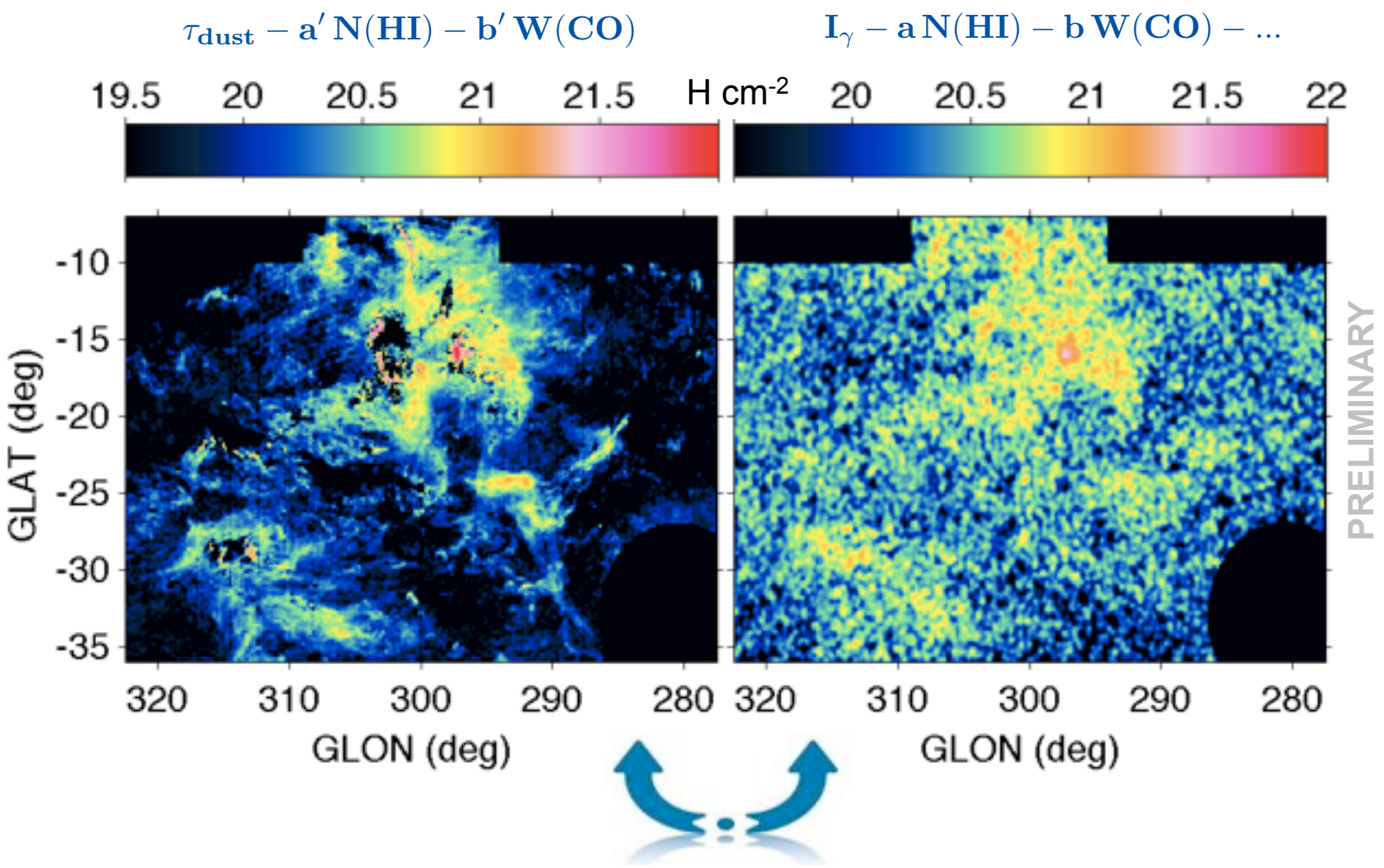


- all γ rays spawn by cosmic-ray interactions in the gas (sources subtracted)

extended dark-gas clouds

- as independently traced by dust and γ rays

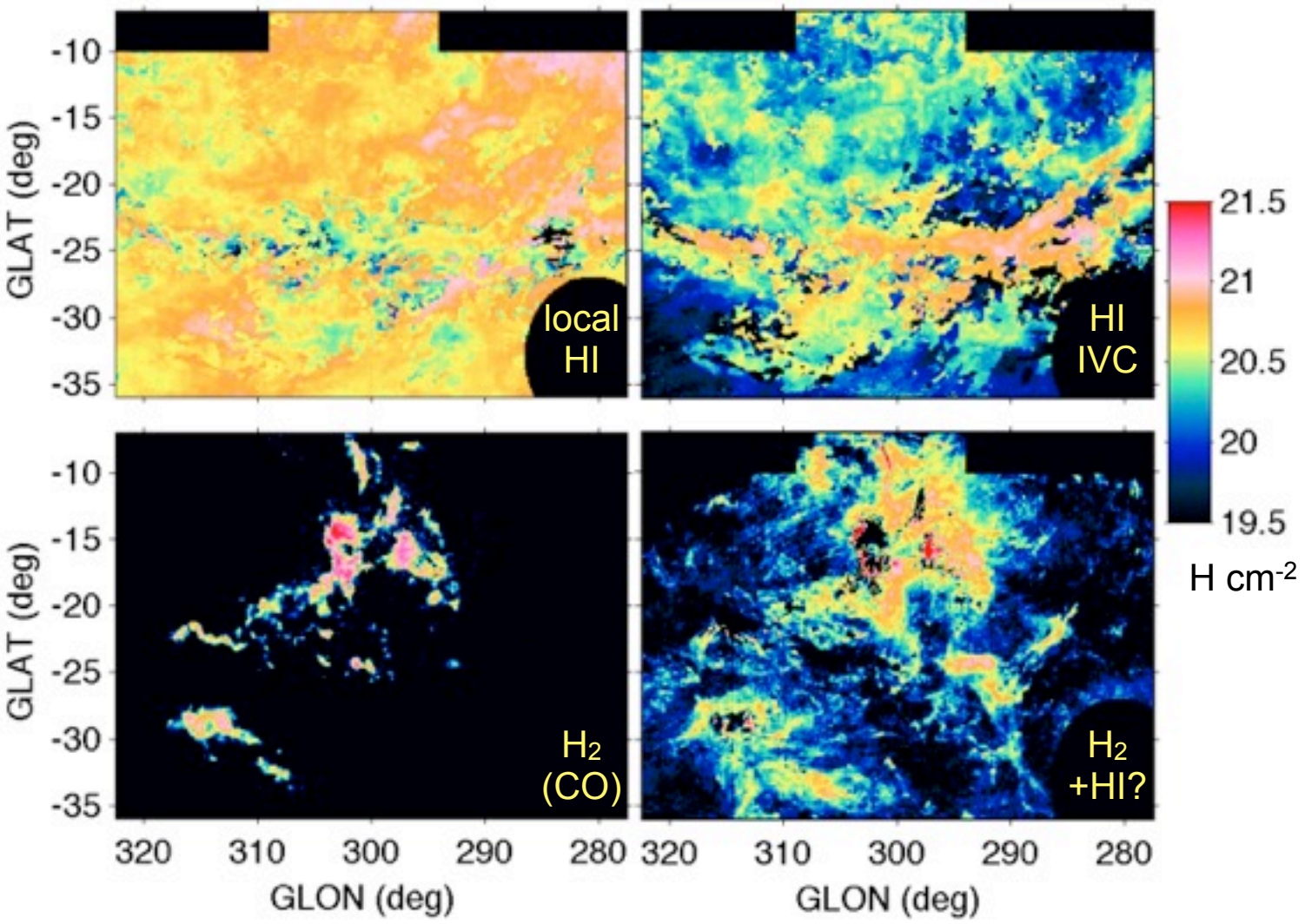


τ_{dust}/NH in the dark phase

joint NH decomposition

- neutral dark gas = major constituent of the Chamaeleon

between the HI and CO phases, to tens of pc away from CO



PRELIMINARY

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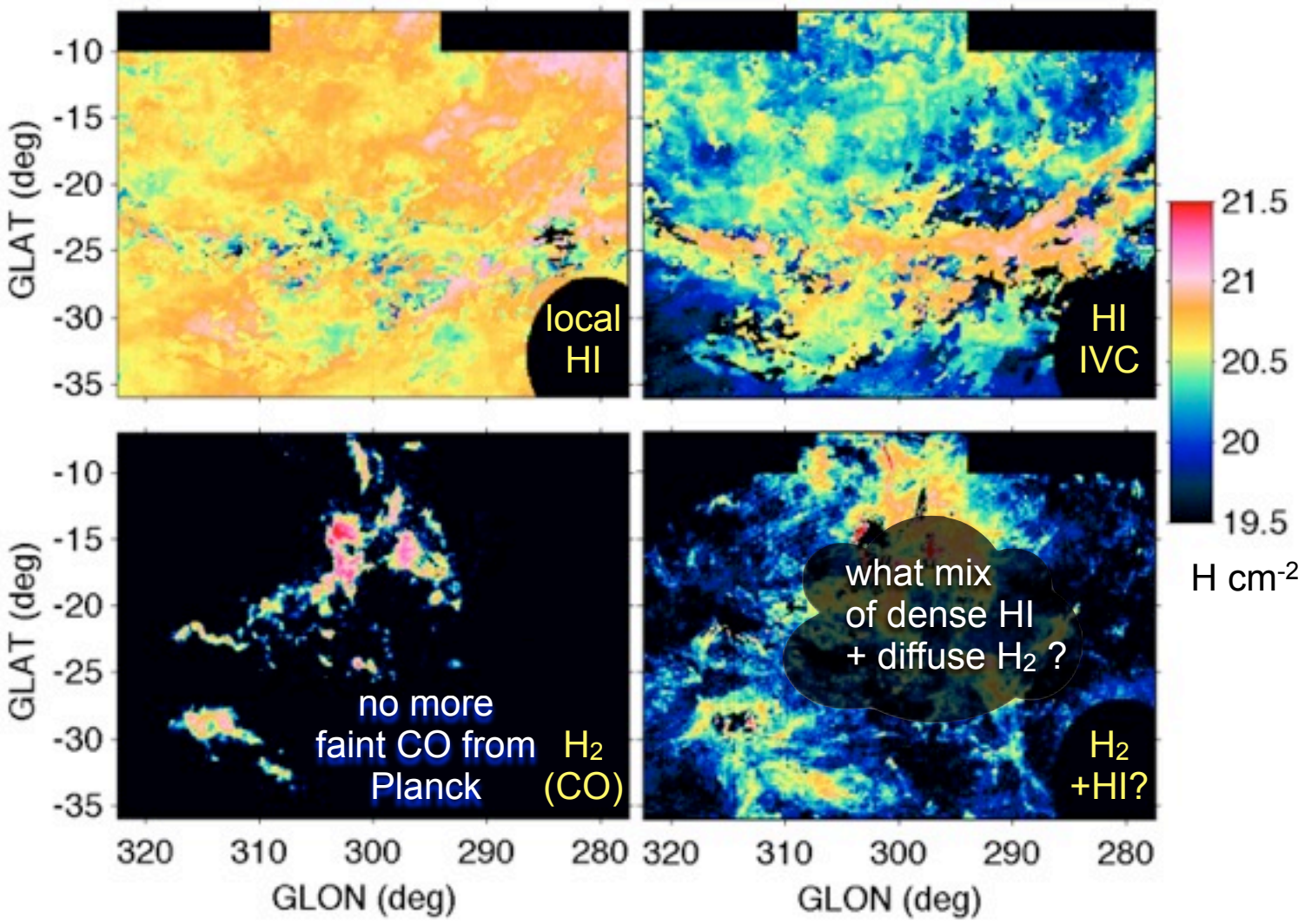
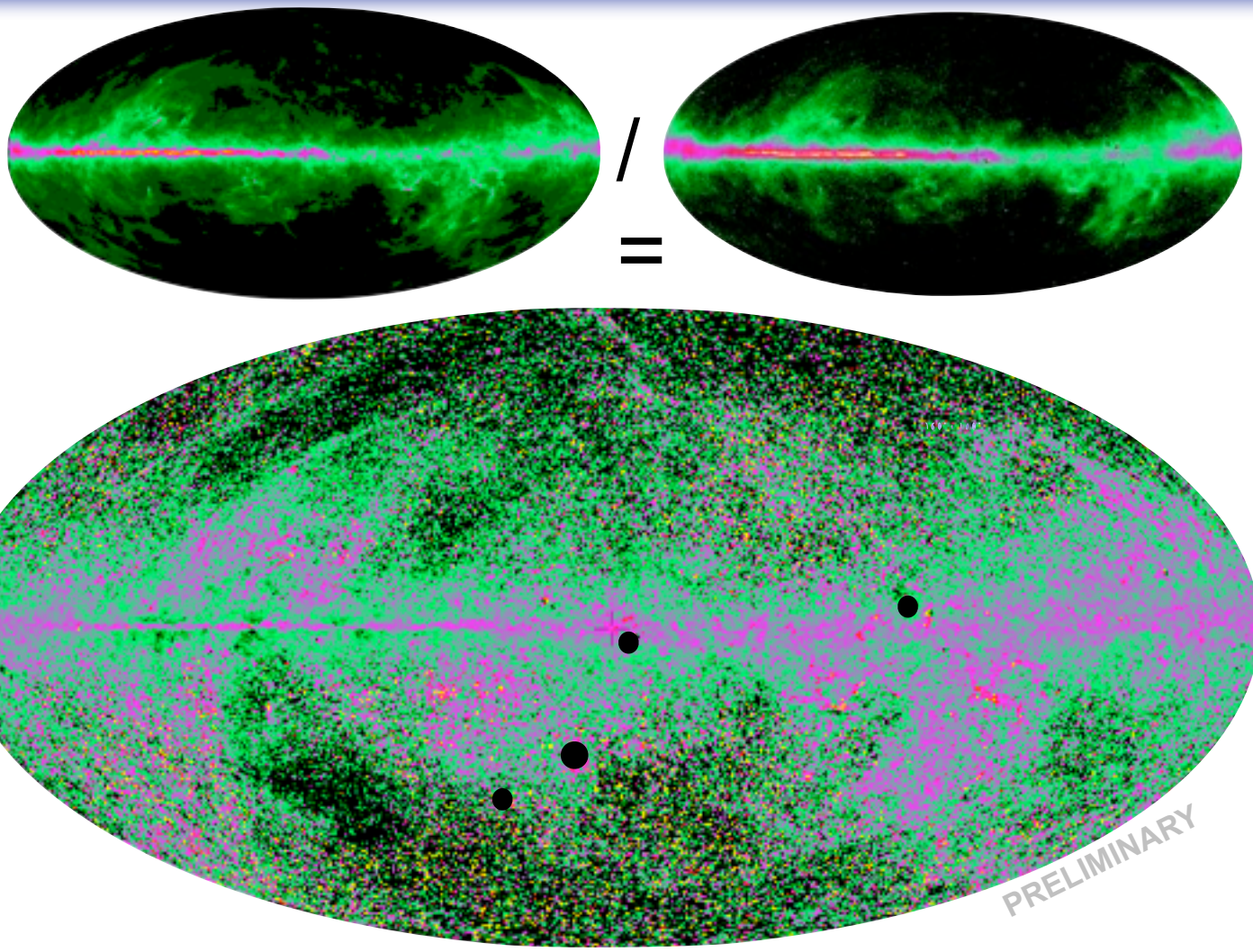


PRELIMINARY

variations in the τ_{353}-to-γ flux ratio

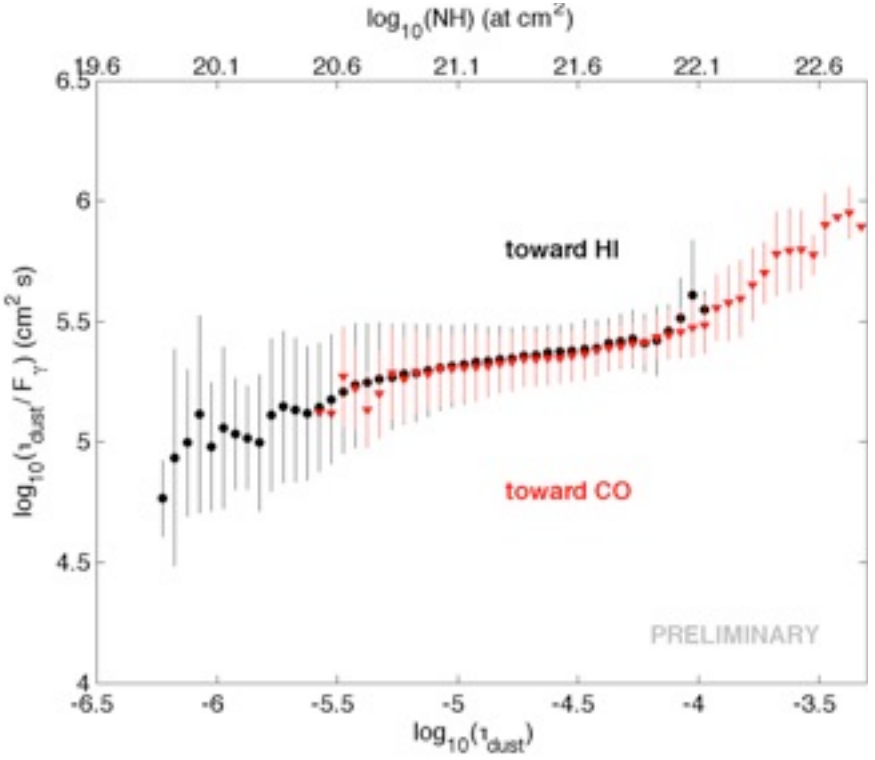


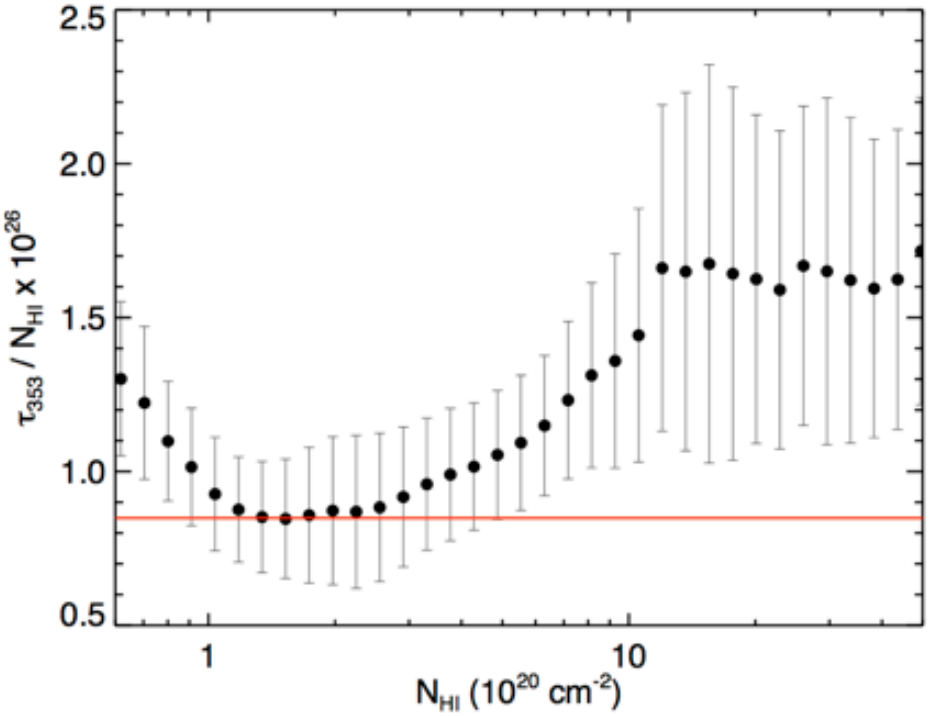
maps centered at l = 270°

- ratio increasing from the diffuse HI, to dense HI and dark-neutral gas, to the denser CO-bright phase

variation of τ_{353}/NH with total NH?

- if the γ rays trace the total gas in the local ISM (off the Gal. plane)
- assumption valid at the precision level of the current γ-ray data





N(HI) > 3.5 10^{20} cm^{-2}
conversion factor between scales: τ/NH = 8.5 10^{-27} cm^2/H
probably factor ~ 2 too low for the dense HI here since

variation of τ_{353}/NH with total NH?

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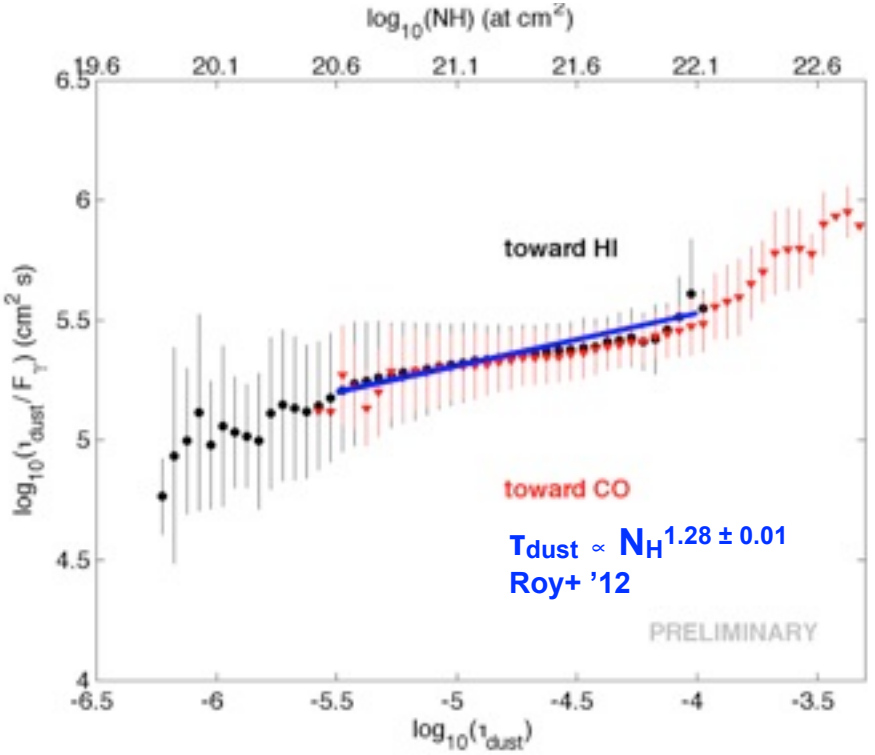

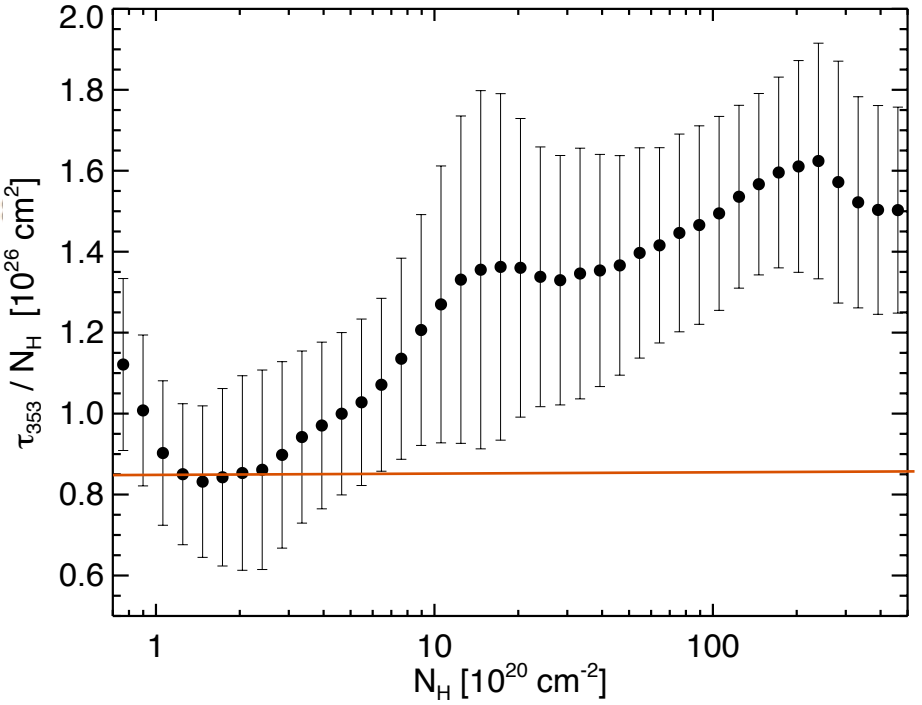

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probably factor ~ 2 too low for the dense HI here since

NH = N(HI) + 2X W(CO)
X = 1.5 10^{20} cm^{-2} K^{-1} km^{-1} s

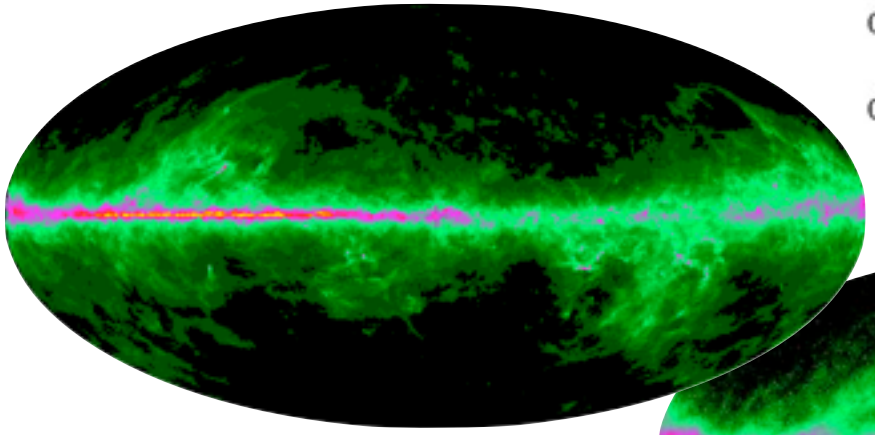
interstellar “tensions”

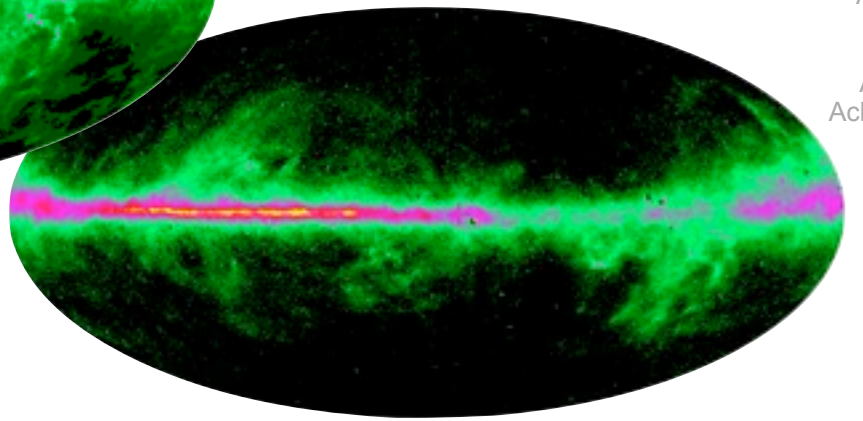
- τ_{dust}/NH increases by factor > 4
  from diffuse HI to dense CO-bright H_2 ?

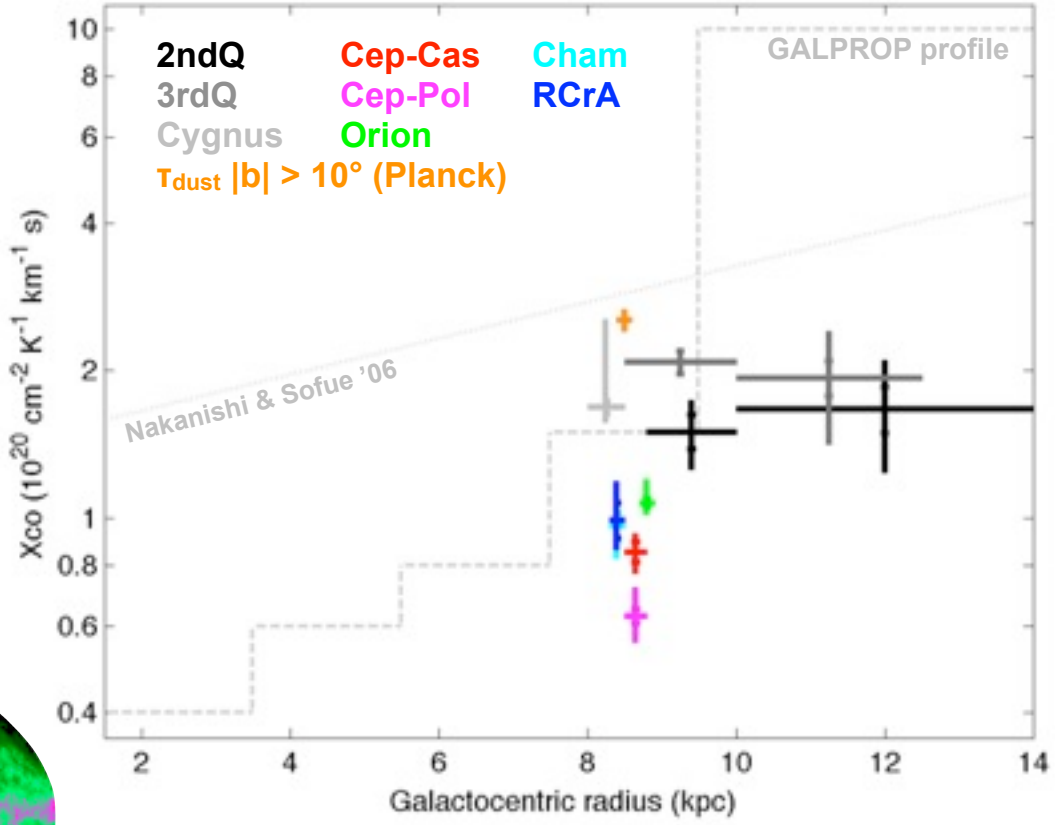
- $X_{CO dust} \approx 2\, X_{CO\gamma}$
  - dust evolution ?
  - cosmic-ray exclusion ?

- $X_{CO\gamma}$(kpc-scale) ≈ 2 $X_{CO\gamma}$(pc-scale) value ?

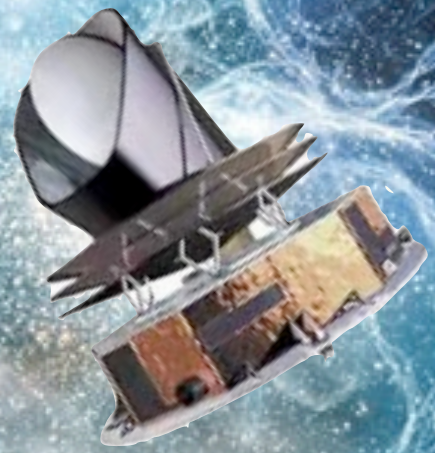
- answers hiding in those maps & SEDs:
  stay tuned !







Ackermann+ ‘12, ApJ, 755, 22
Abdo+ ‘10, ApJ 710, 133
Ackermann+ ‘12, ApJ, 756, 4
Ackermann+“11., ApJ 726, 81
Ackermann+ ‘12, A&A, 538, A71
Planck+ ‘11, A&A 536, A19



Thanks to many !