Fermi LAT observations of high- and intermediate-velocity clouds: implications for cosmic rays

Luigi Tibaldo
ltibaldo@slac.stanford.edu

KIPAC SLAC

Seth Digel

on behalf of
the *Fermi*-LAT collaboration

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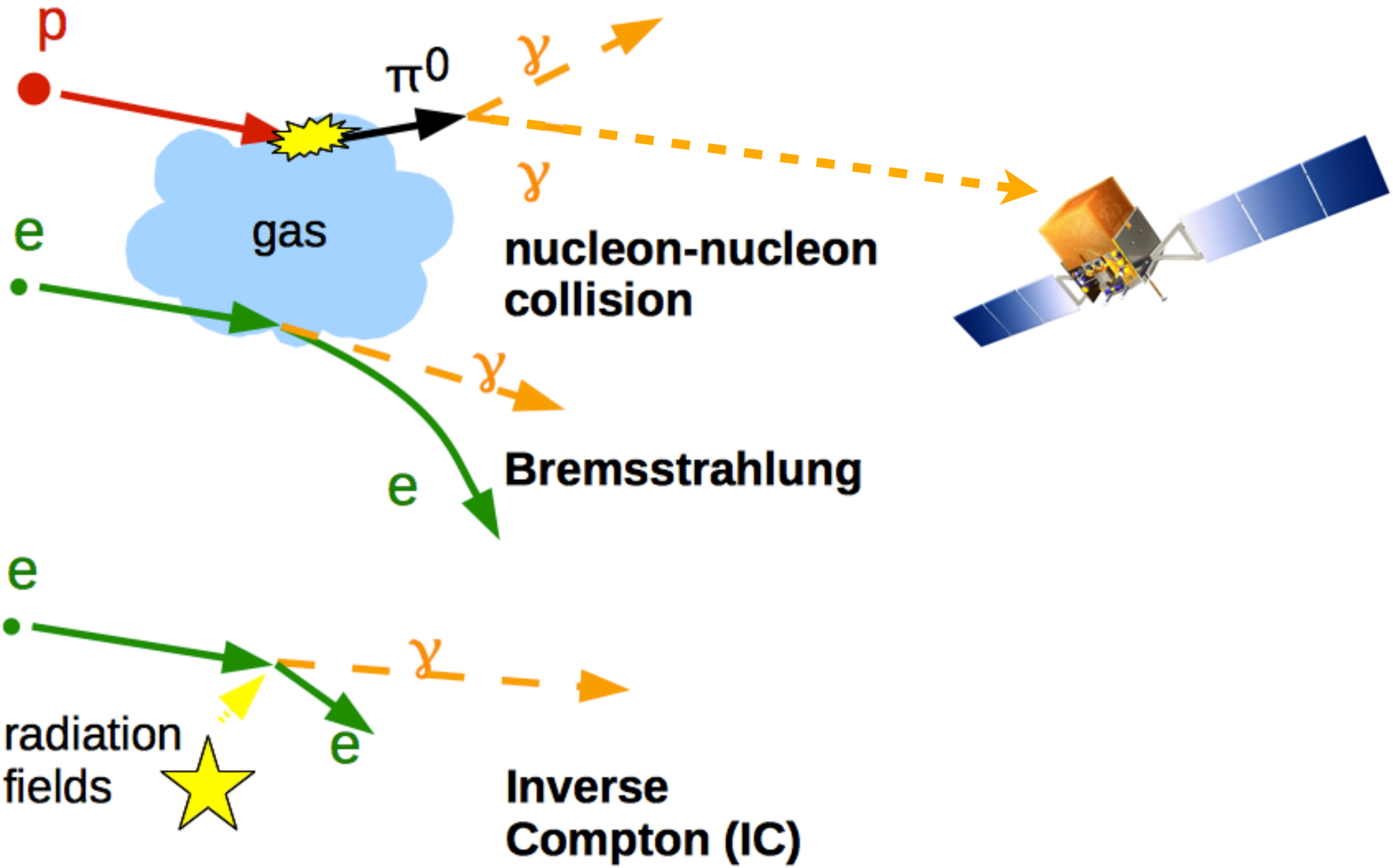
The Galactic cosmic-ray paradigm

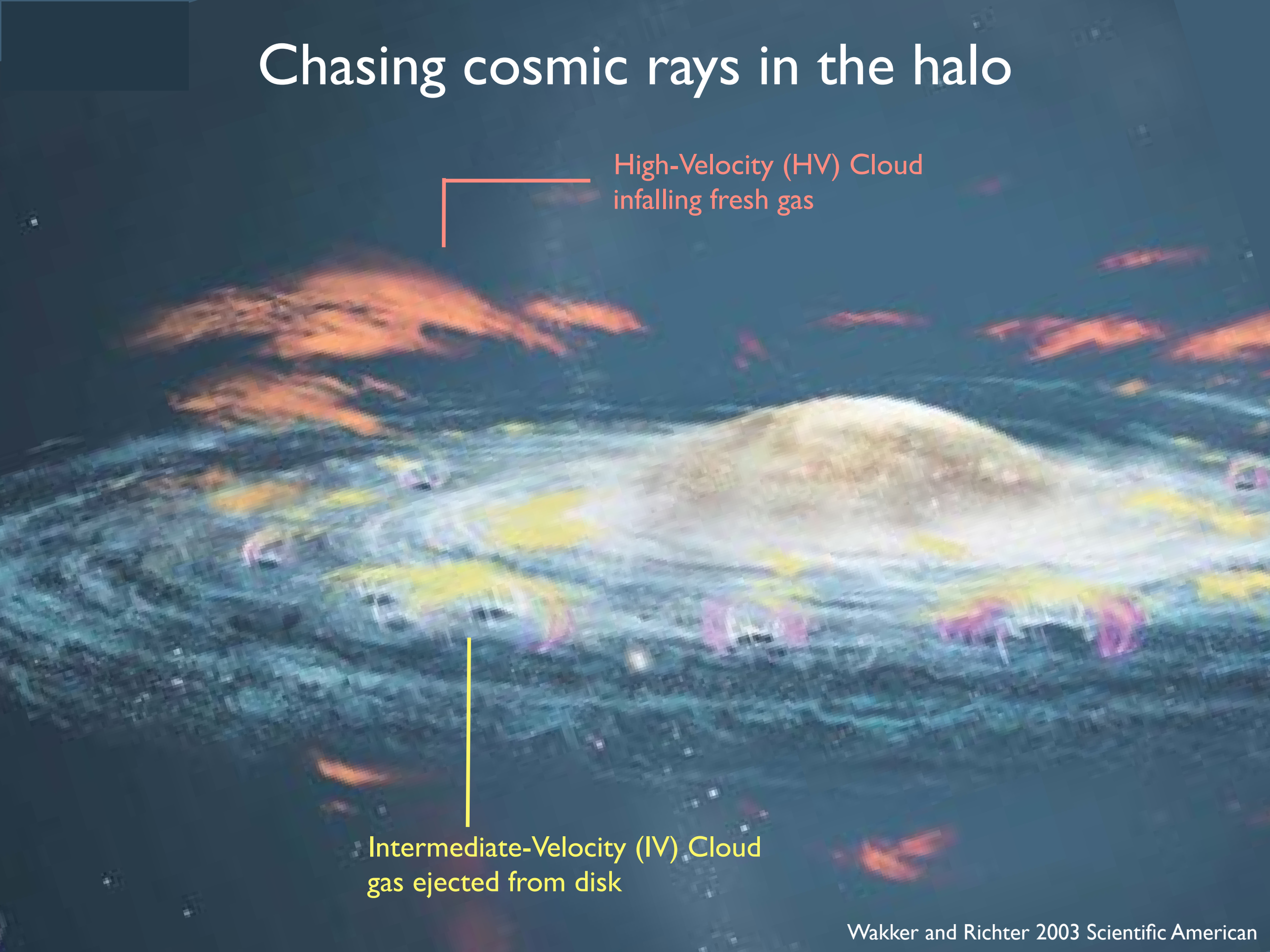
below 10^{15} eV

- origin in the disk of the Milky Way
- propagate in > kpc halo (indirect evidence)

γ rays as a charged particle tracer

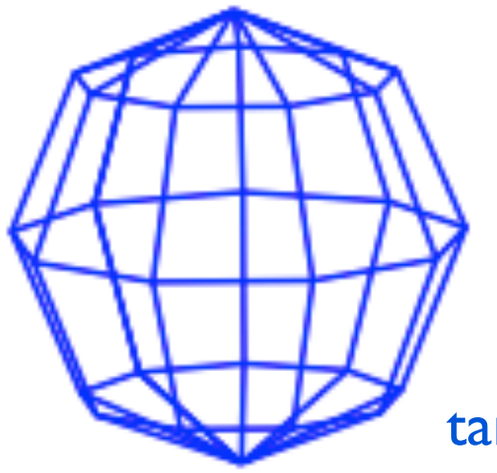


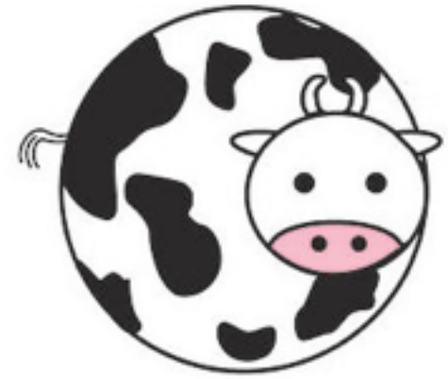
Chasing cosmic rays in the halo



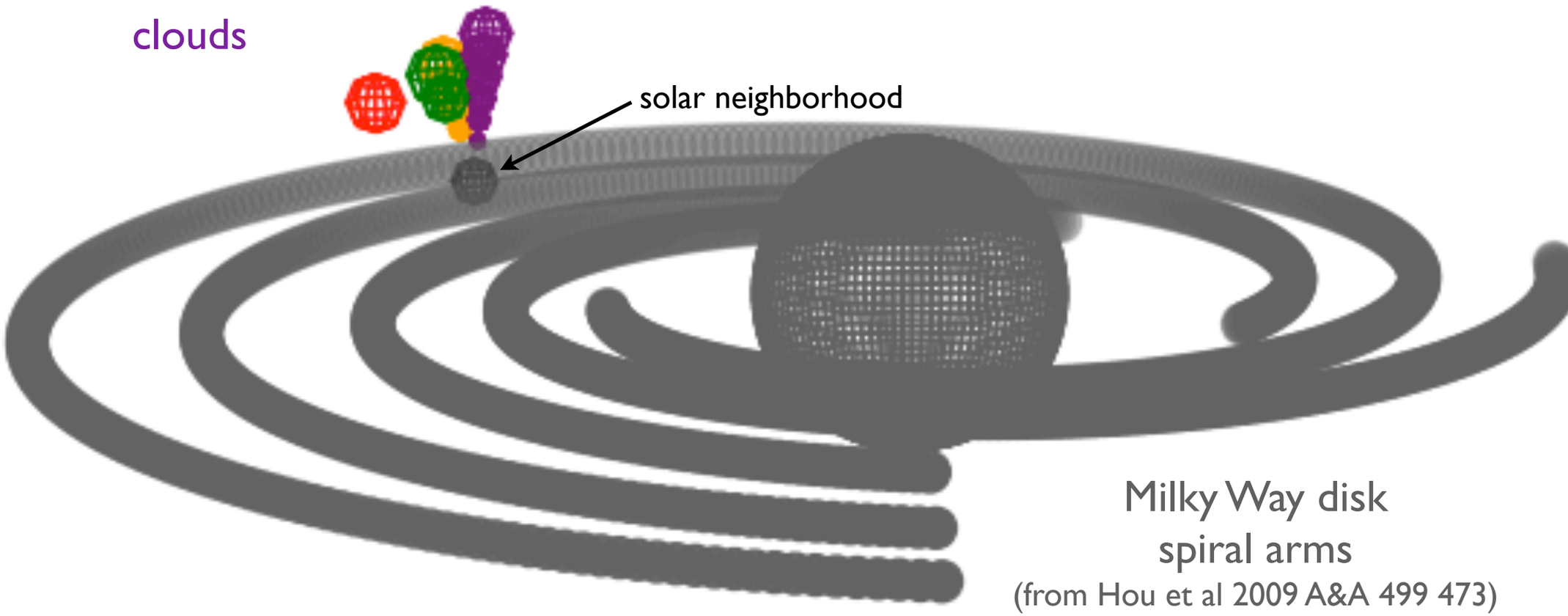
Wakker and Richter 2003 Scientific American

Target selection





target
HV and IV
clouds



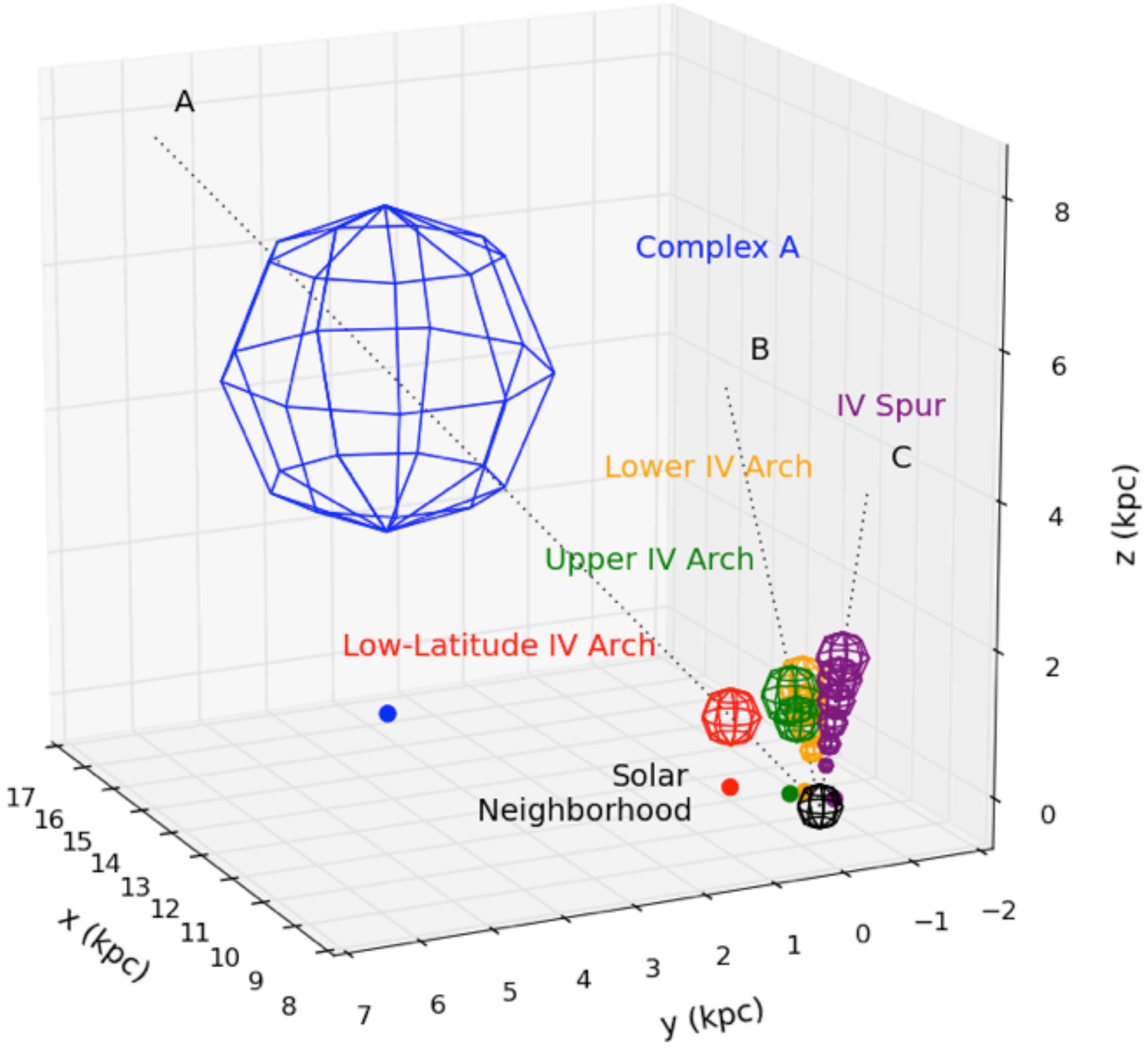
Milky Way disk
spiral arms
(from Hou et al 2009 A&A 499 473)

selection criteria

- distance/altitude bracket (stars)
- mass - distance detectable by the LAT

Meet the targets

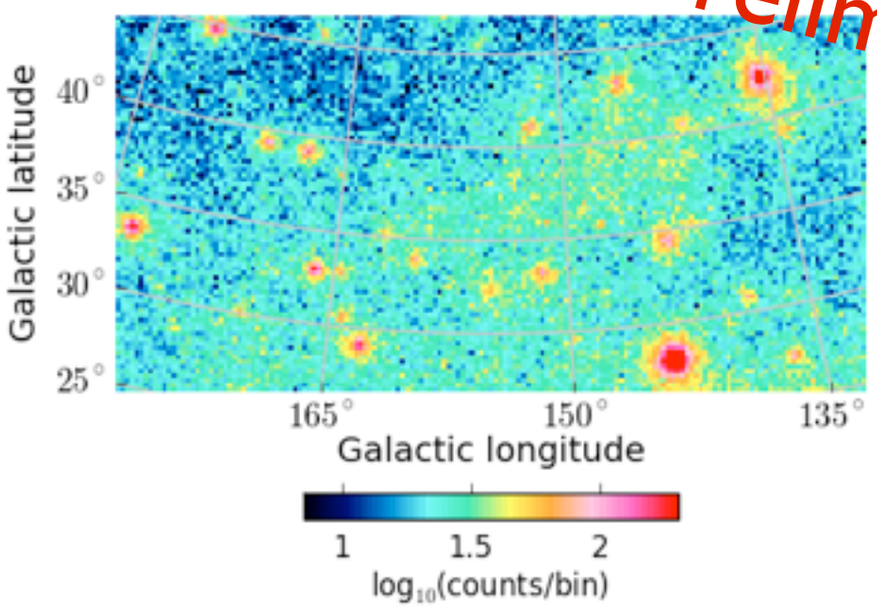
distance/altitude brackets
Wakker 2001 ApJS 136 463



Analysis method

γ rays

Preliminary



= LAT PSF ⊗ exp ·

interstellar medium tracer data
LAB HI survey
CfA CO survey
Planck dust thermal emission model

scaling factor
γ-ray emissivity
cosmic rays

[$x_{HI,1}$ ·

local HI

+ $x_{HI,2}$ ·

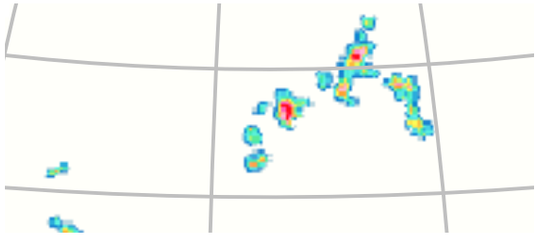
HI Low-Latitude IV Arch

+ $x_{HI,3}$ ·

HI Complex A

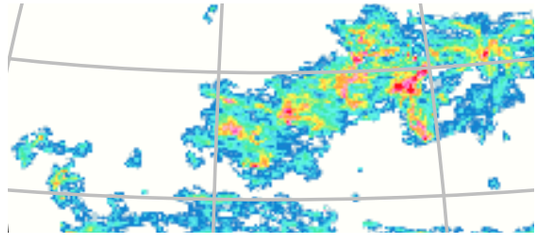
+ x_{CO} ·

CO (traces local H_2)



+ x_{DNM} ·

dust excess
(traces dark neutral medium)



] · $q_{LIS}(E)$ +

γ-ray emission rate
(emissivity)
per H atom per dE
in Local Interstellar Space
Casandjian (2014)

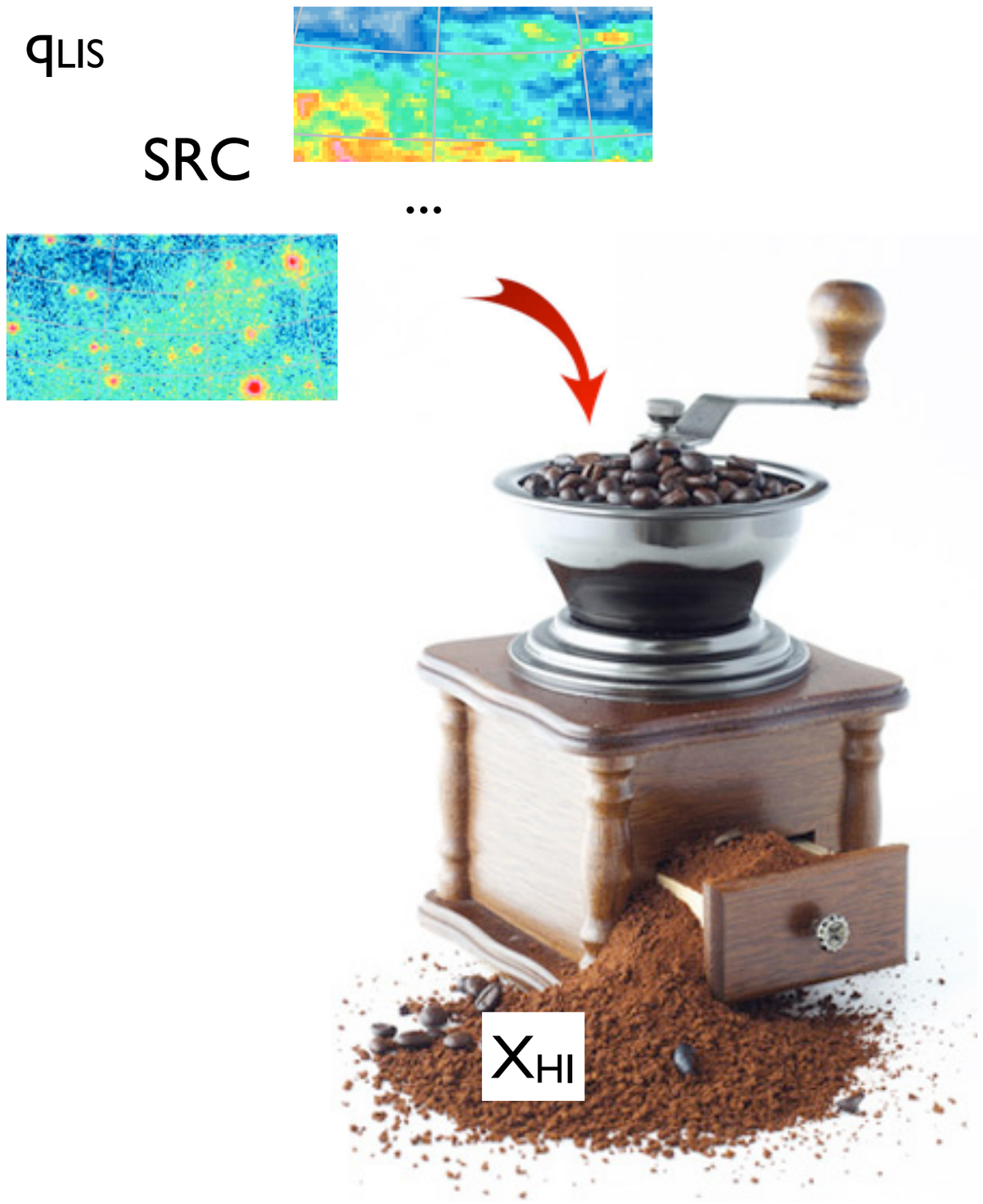
+ IC(l,b,E) + Isotropic(E) + 3FGL

LAT analysis

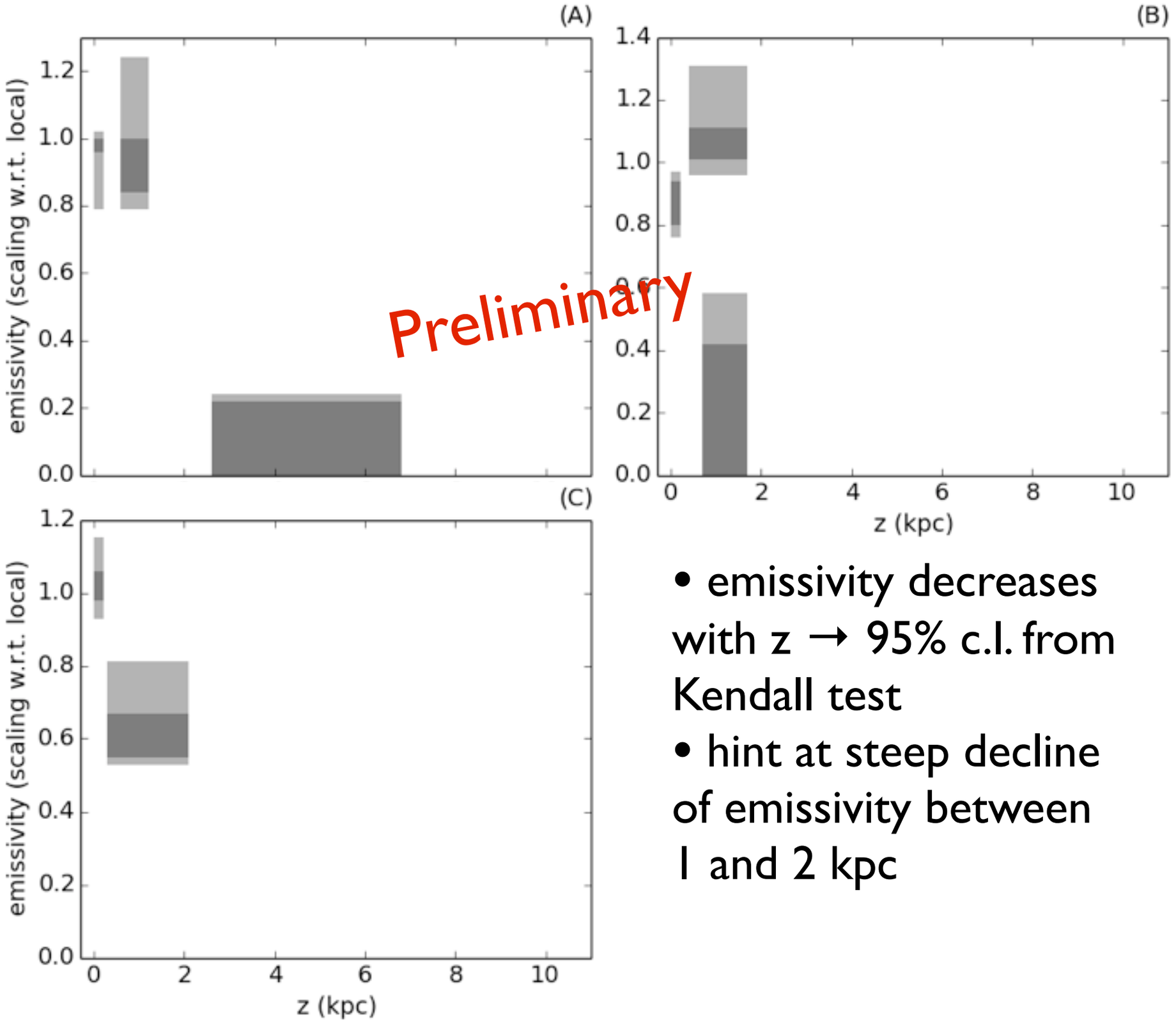
- 73 months of P7REP data
- binned likelihood analysis

300 MeV - 10 GeV

- systematics:
  - uncertainties in model input
  - jackknife
  - LAT instrument response

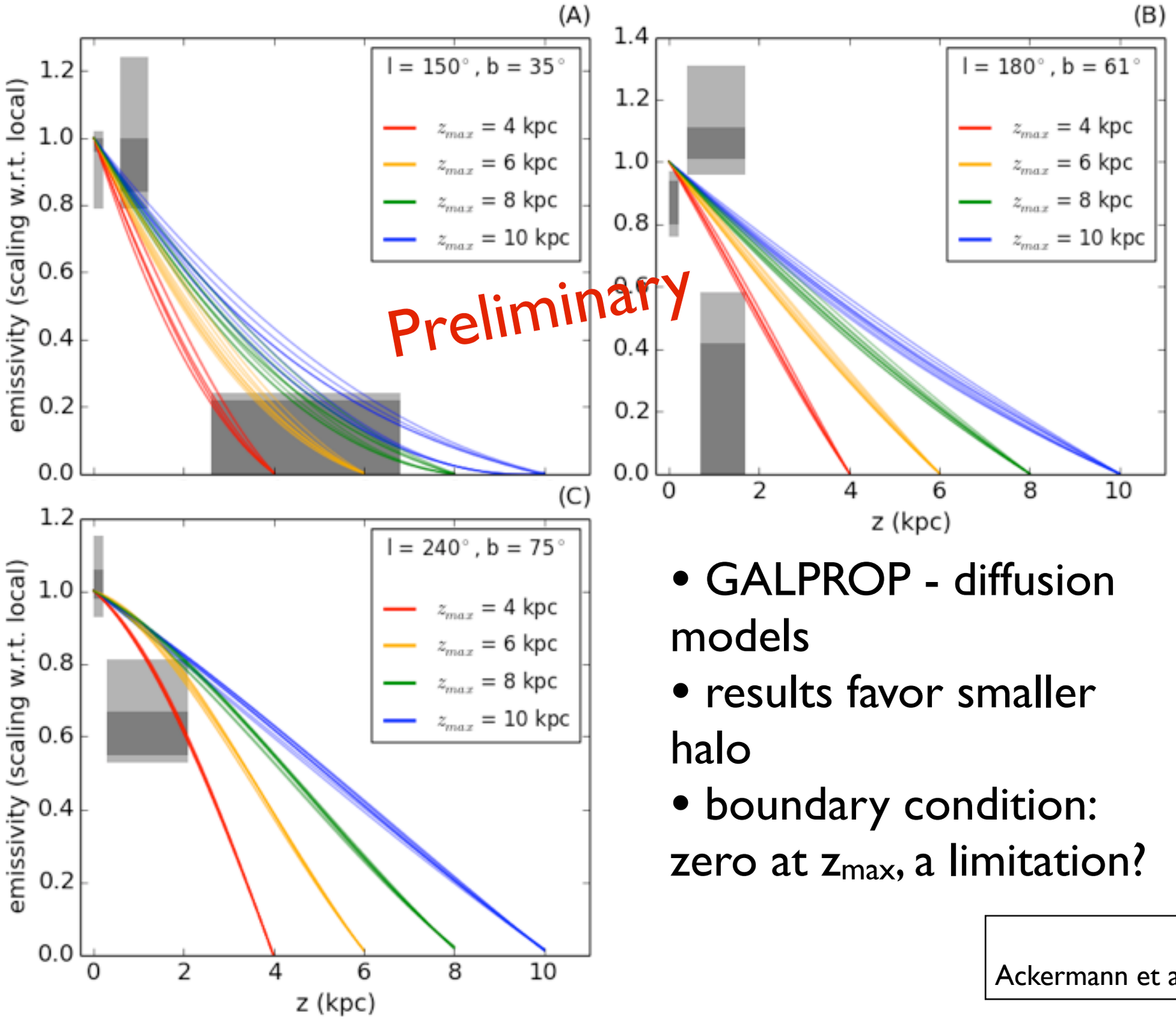


Comparison to propagation models



- emissivity decreases with z → 95% c.l. from Kendall test
- hint at steep decline of emissivity between 1 and 2 kpc

Comparison to propagation models



- GALPROP - diffusion models
- results favor smaller halo
- boundary condition: zero at z_{max}, a limitation?

models from
Ackermann et al 2012 ApJ 750 3

Final remarks

- HV and IV clouds are suitable targets to measure cosmic rays in the Milky Way halo with LAT data
- decrease of cosmic-ray densities with distance from the disk at 95% c.l. → corroborates origin in the disk
- hint at steep decline of densities between 1 kpc and 2 kpc above the disk
- can constrain cosmic-ray propagation and outflow into extragalactic space