HI motivation

- Is HI sometimes optically thick?
  - how can we tell?
  - if yes, by how much is N(HI) underestimated?
  - where at?
- Galaxy-wide N(HI) distribution function
- Can we actually separate CNM vs. WNM?
- PAH-emission and dust correlation with HI

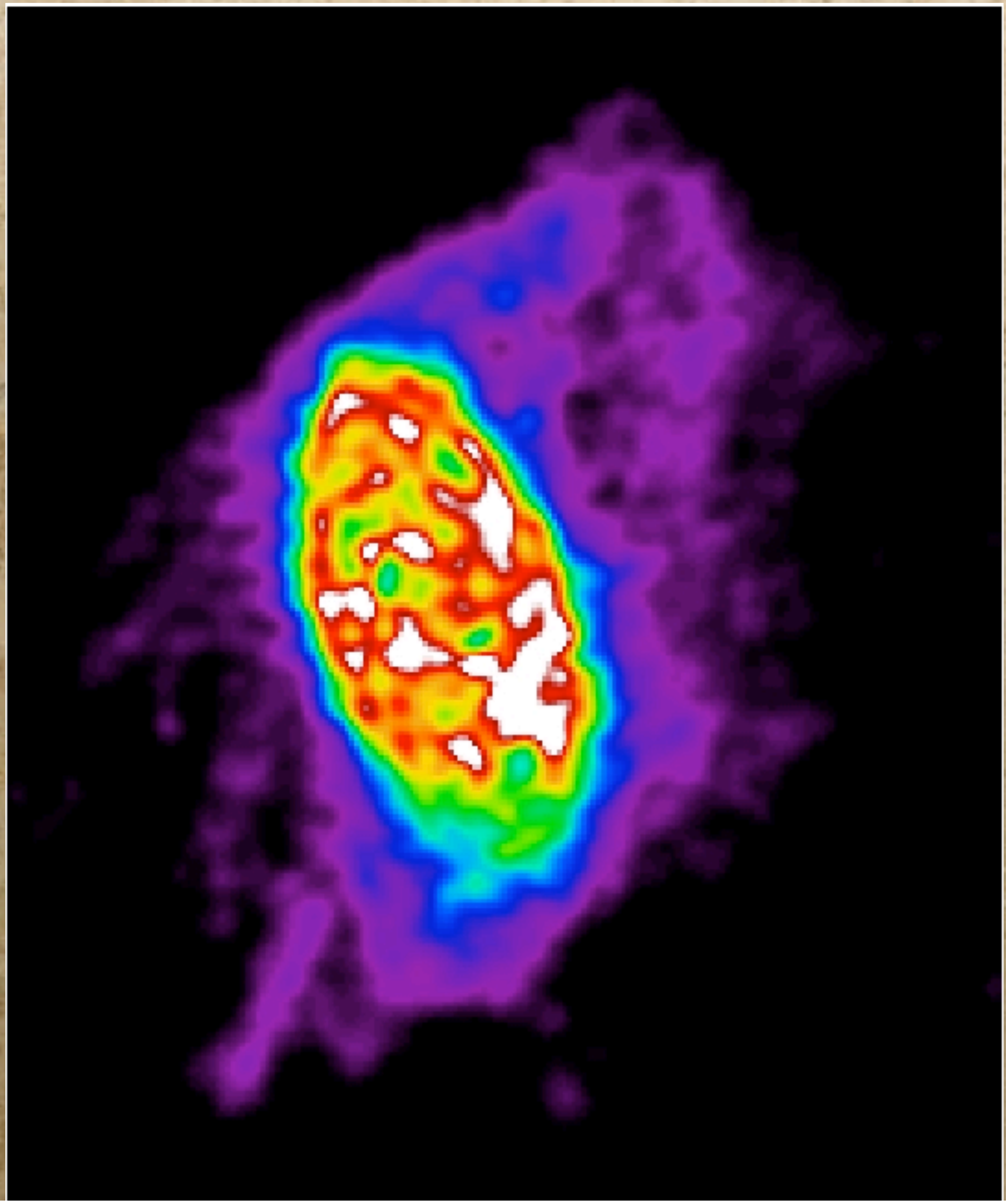
HI motivation

- Is HI sometimes optically thick? Yes
  - how can we tell? Line profile modeling
  - if yes, by how much is N(HI) underestimated? Up to 10x
  - where at? Clumps within high brightness filaments
- Galaxy-wide N(HI) distribution function
  - Complex form : Modeled as turbulent medium
- Can we actually separate CNM vs. WNM?
  - Promising method based on masking peak Tb image
- PAH-emission and dust correlation with HI
  - Dust/gas ratio declines with radius/decreas.met.
  - Remarkable morphological agreement with Peak Tb

M33 HI database overview

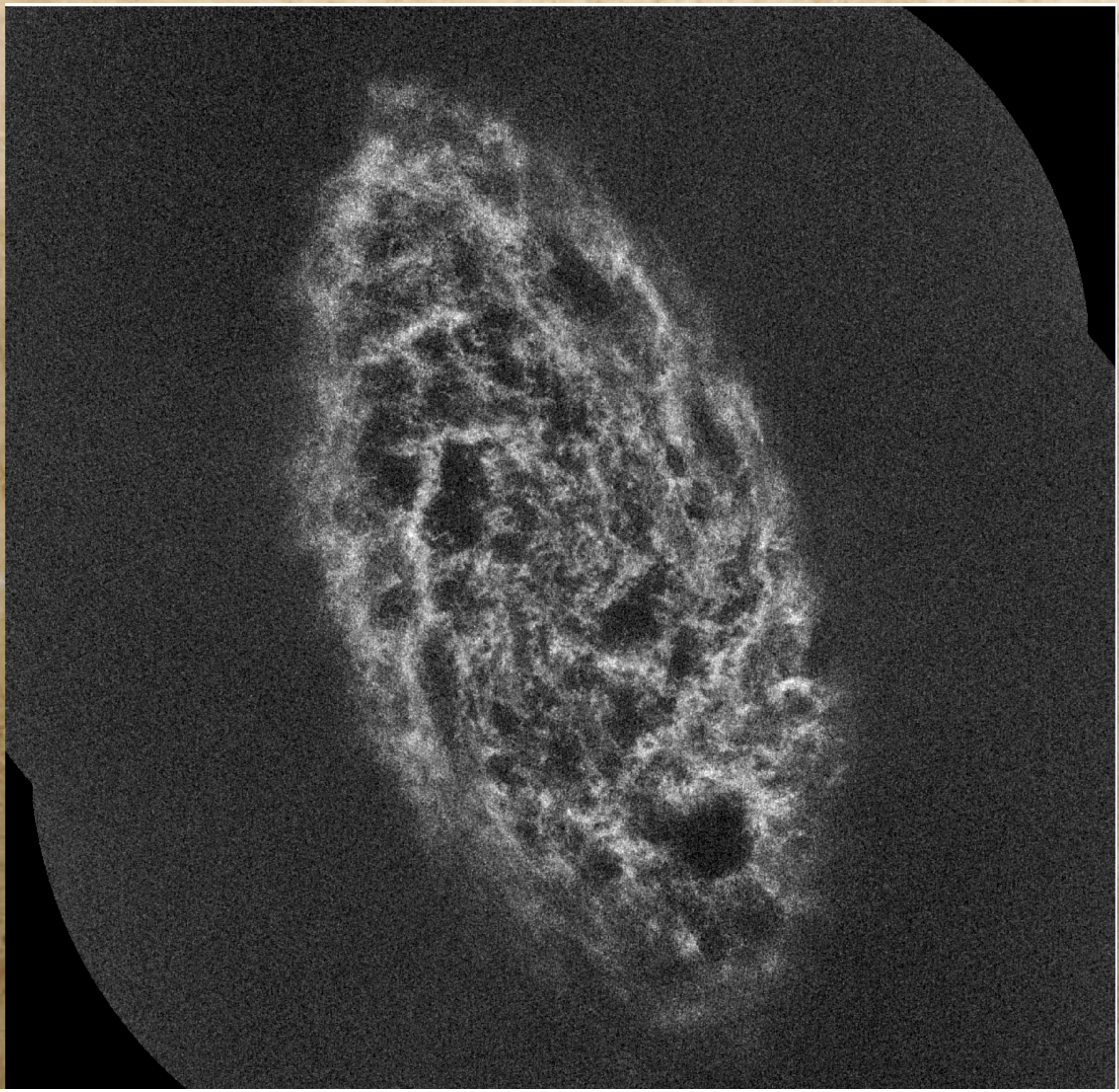
- VLA synthesis survey
  - main disk (B-array, CS-array)
    - 6 pointings : 48 hrs total
    - 5" (20 pc), 1.3 km/s resolution
  - wide-field (D-array only)
    - Tiled with 99 pointings : 8 hrs
    - 2.9 x 3.8 deg (2.3 x 3.0 deg full sens.)
    - 45" (183 pc), 1.3 km/s resolution
- GBT total power survey
    - 5 x 5 deg on-the-fly map
    - 9.1' (2.2 kpc), 1 km/s resolution
- VLA+GBT products
  - Joint deconvolution in miriad
  - Many resolutions available
    - All permutations of 5, 10, 20, 60, 130" and 2.6, 7.8,12.8, 23 km/s

- 1.8e9 Msun with 20% outside of sf disk (putman'09)
- max r=22 kpc (@ 840 kpc)

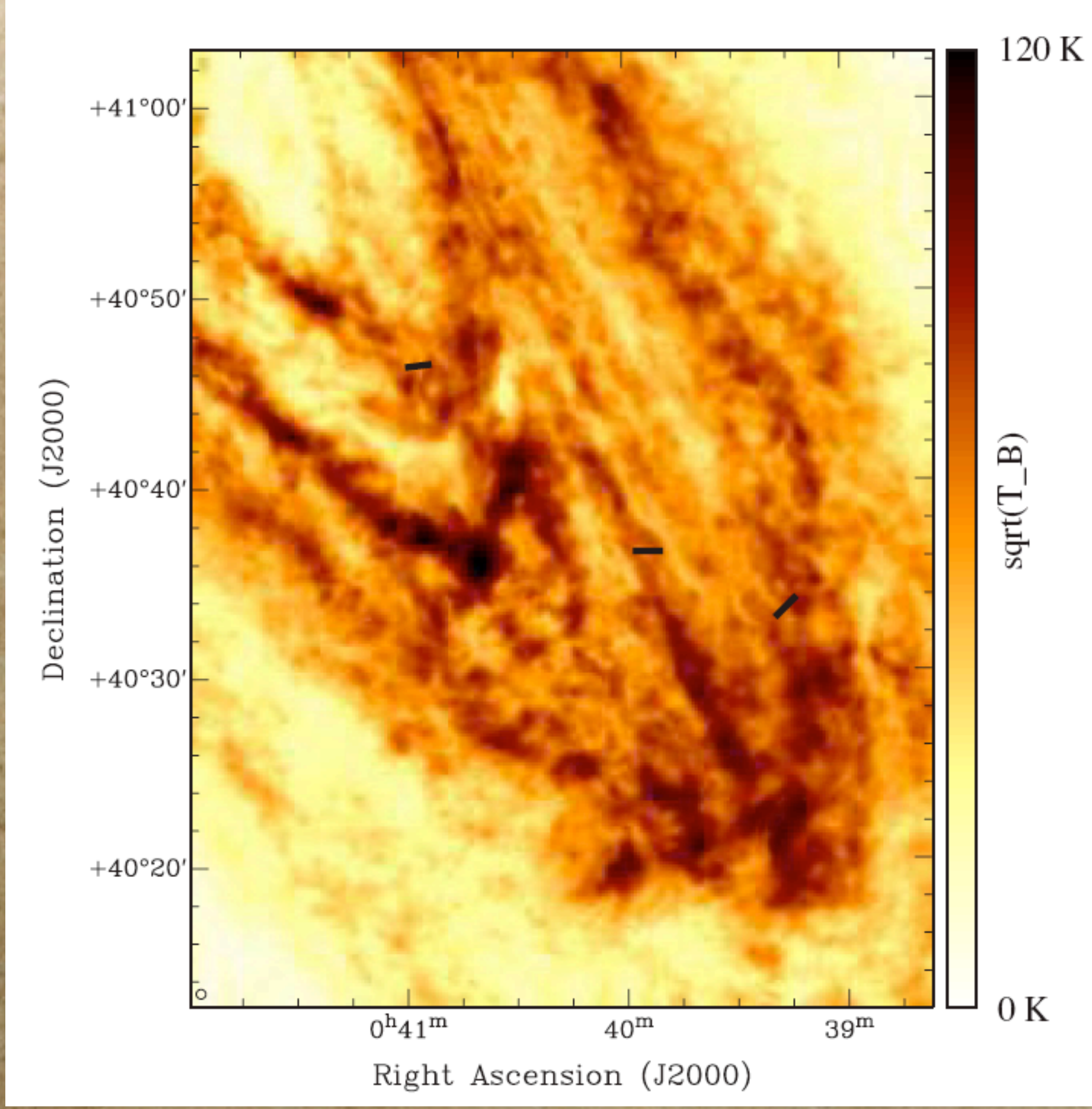


N(HI)
VLA+GBT
130" res.

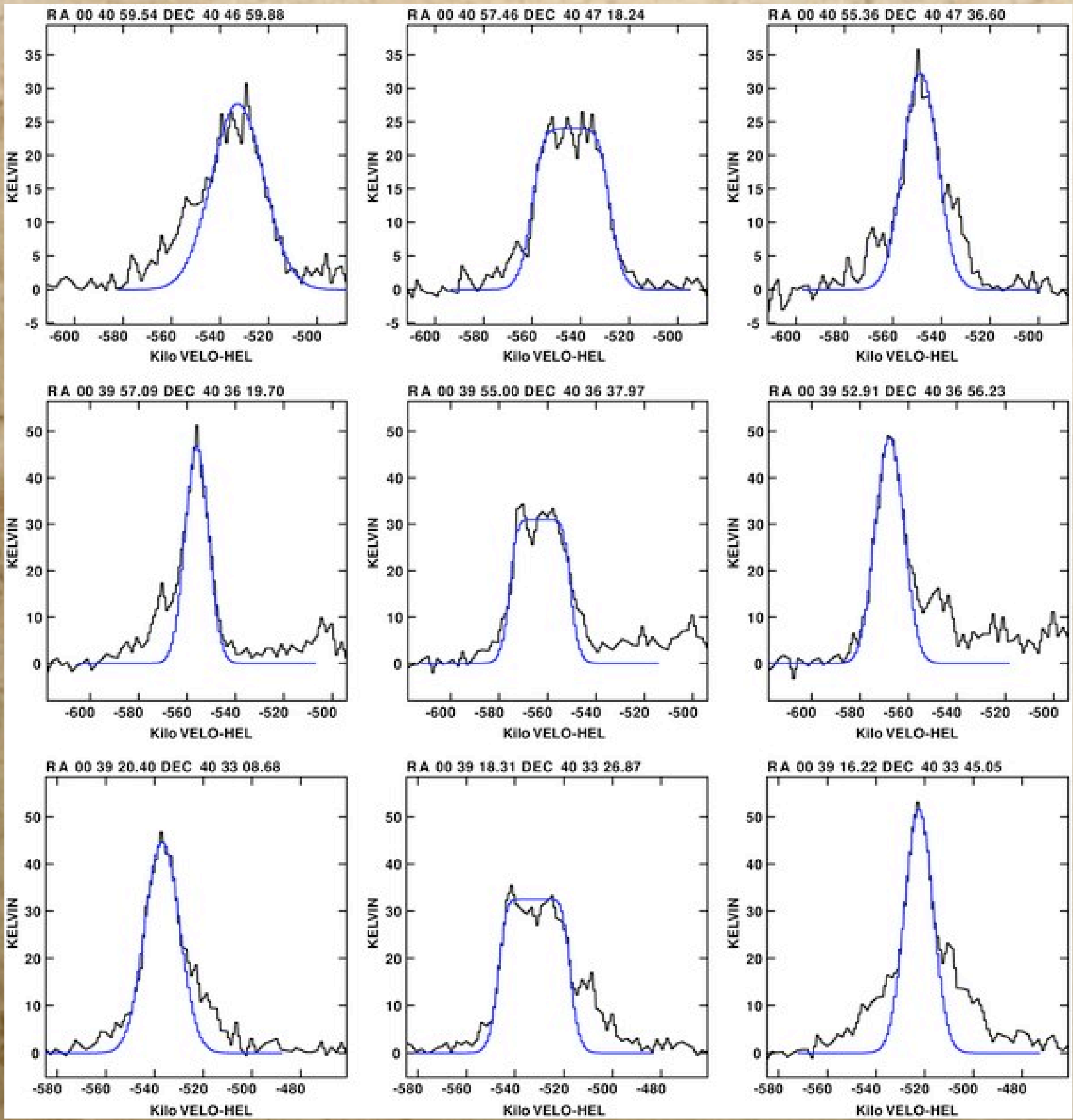
- Peak Tb : 5” resolution



- Peak Tb Filamentary minima (in M31!)

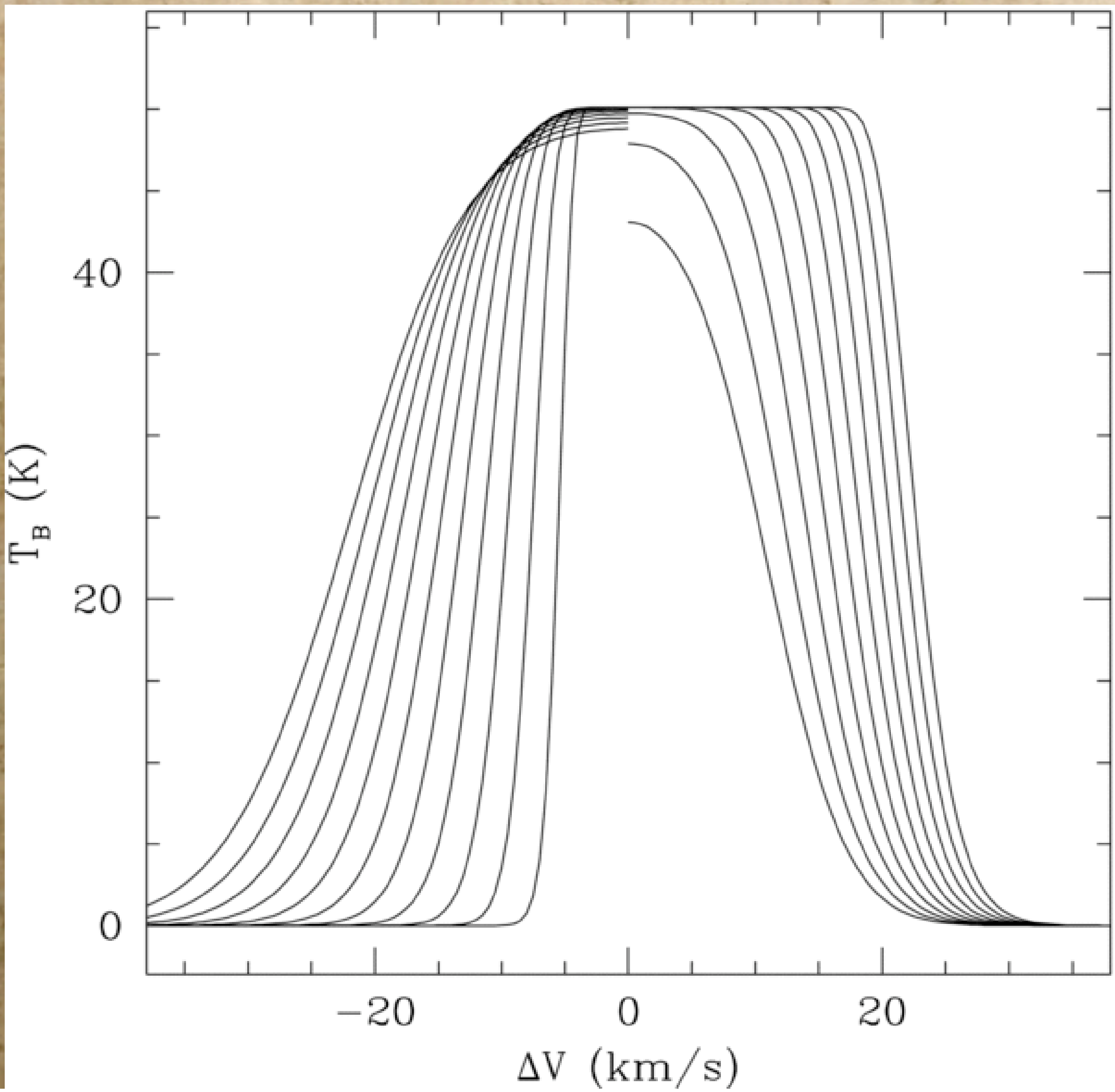


- Cross-cuts over Peak Tb Filamentary minima



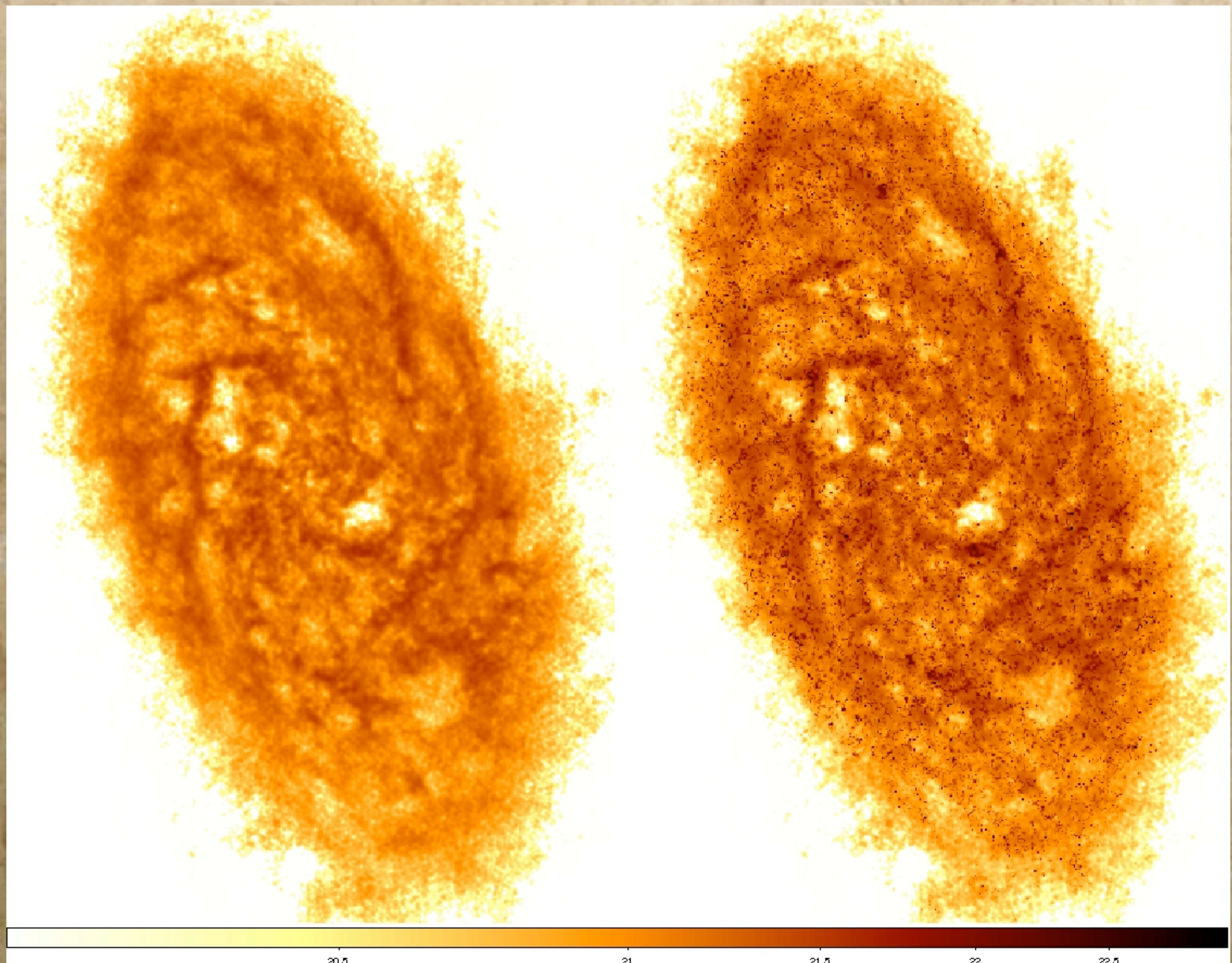
- Model spectra used for fitting datacube

(LEFT) "half"-spectra with increasing σ_{NT} = 2-12 by 1 km s^{-1} at a fixed log(NHI) = 22, log(T_S) = 1.7
(RIGHT) sequence of increasing log(NHI) = 21.5-23.5 by 0.2 at a fixed log(T_S) = 1.7, σ_{NT} = 7 km s^{-1}



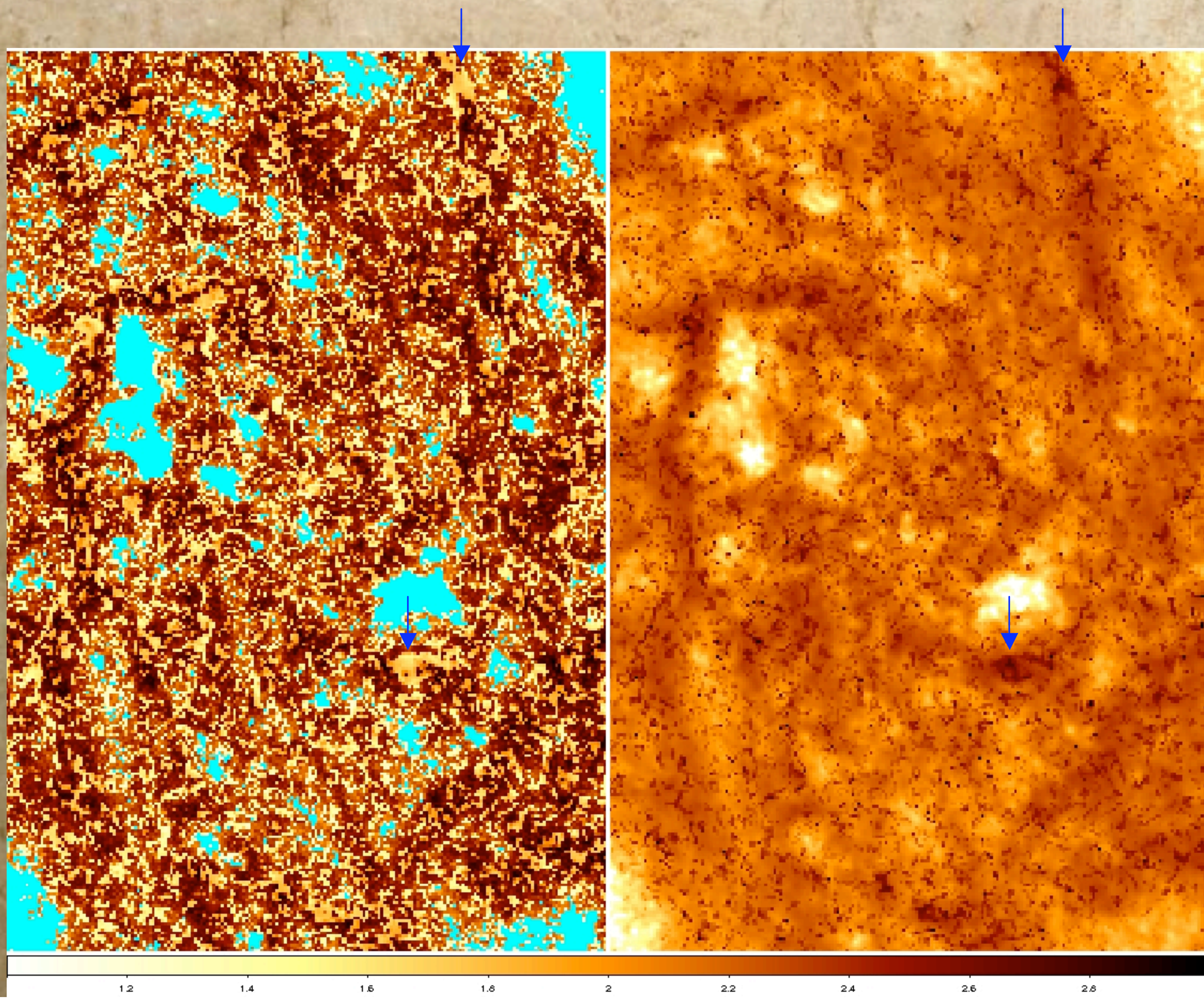
Braun et al. 2009

- Observed vs. opacity-corrected N(HI)

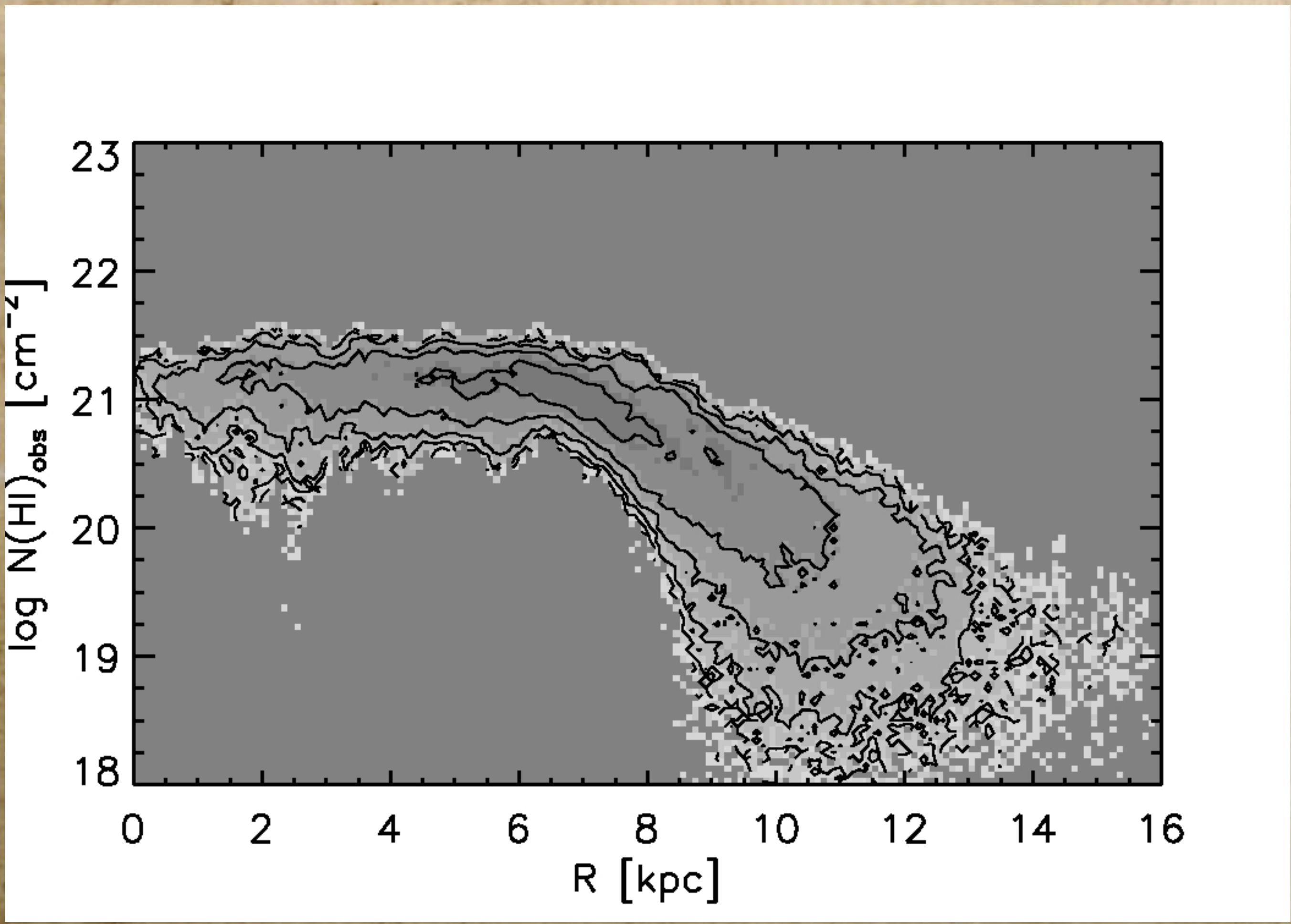


- Sqrt-scaled from log N(HI) = 20 to 23 [cm-2]

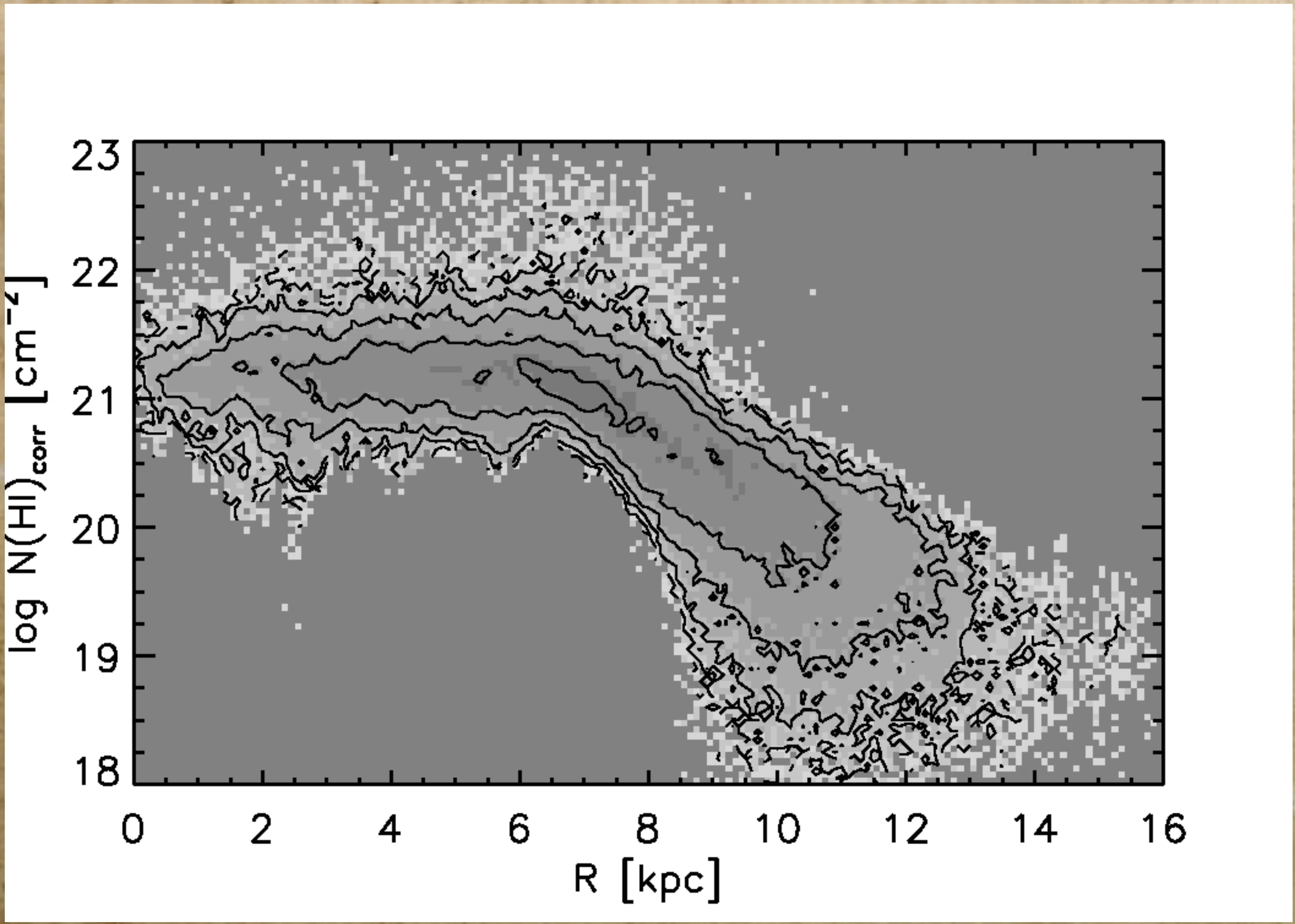
- Log (T_S) vs opacity-corrected N(HI)
  - High-opacity regions are cooler than surroundings and typically lie on HI ridges



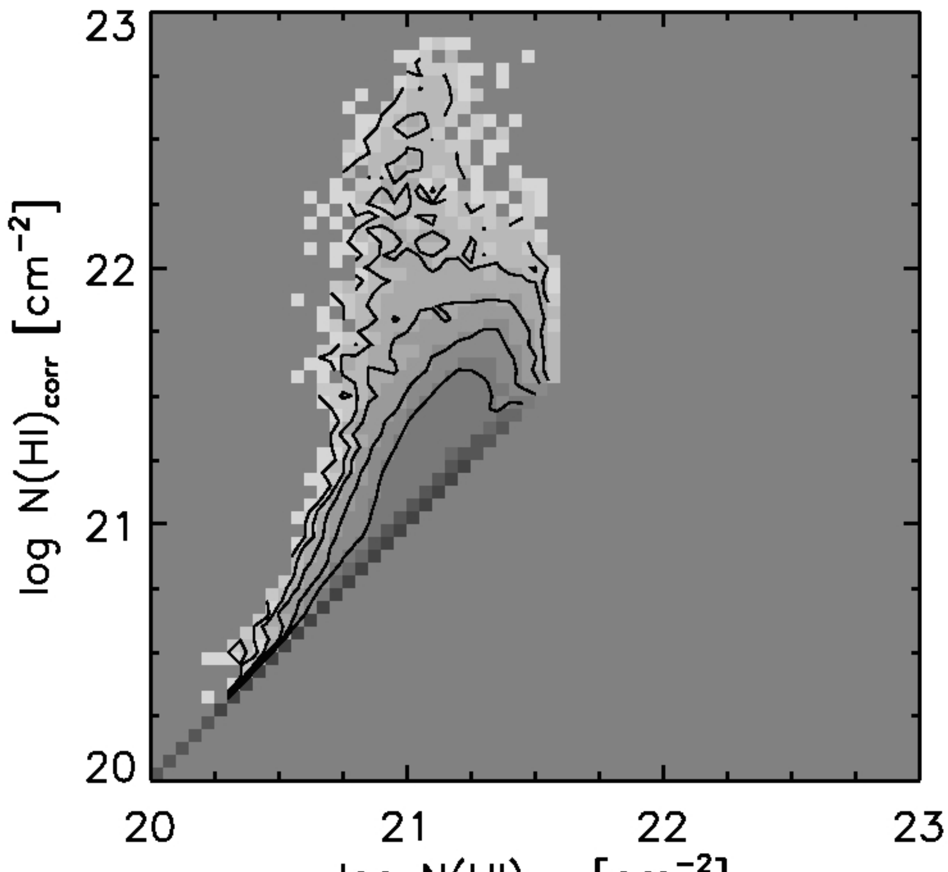
- Observed N(HI) vs. radius
  - Narrow range of N(HI) : near log N(HI) = 21.2
  - Downturn at R = 7 kpc, warped disk model needed beyond



- Opacity-corrected N(HI) vs. radius
  - Opaque sightlines confined to main disk
  - Substantial increase in "dynamic range" of gas distr.

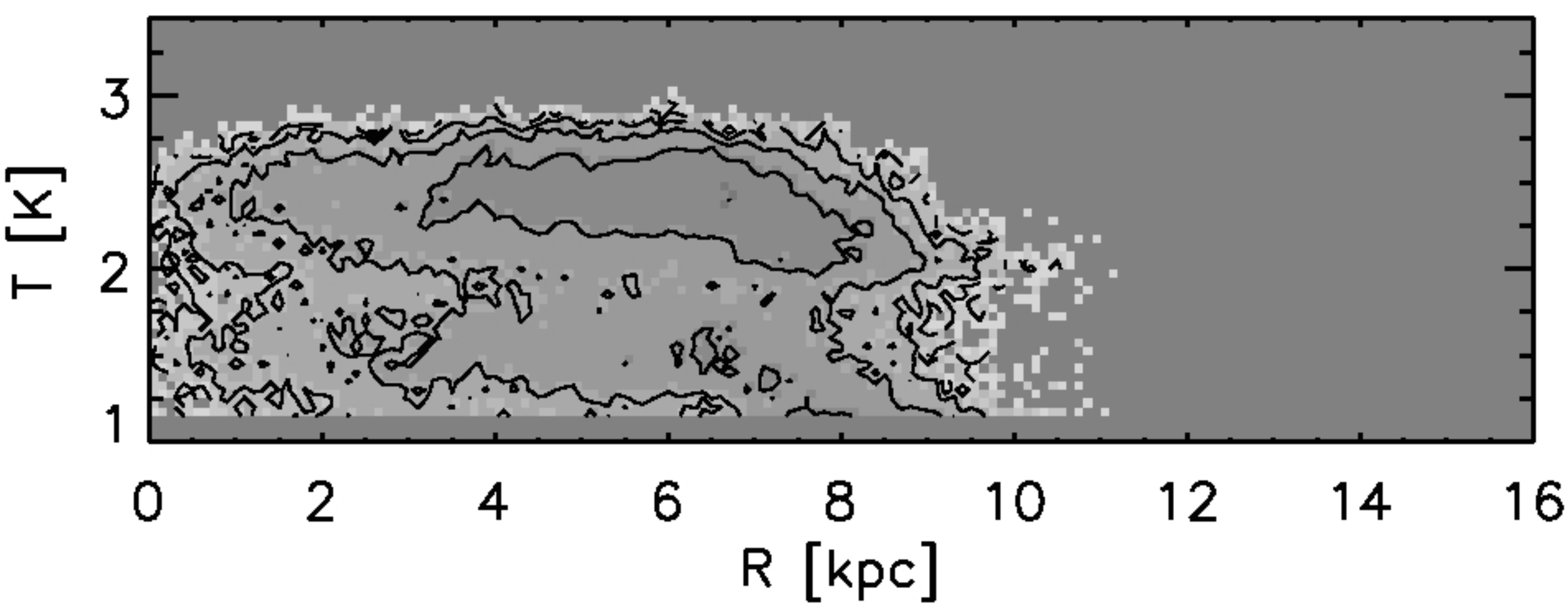


- Distrib. of corrected vs. observed N(HI)
  - Opaque sightlines above log N(HI) = 20.5
  - 10x Local increase, typical peak log N(HI) = 22

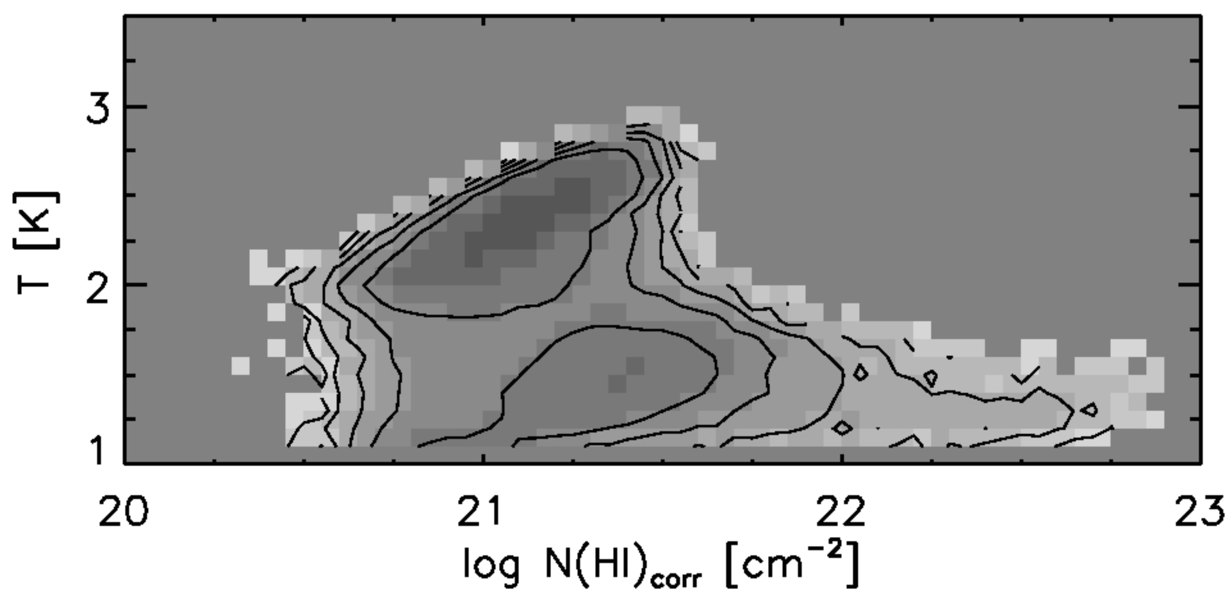


Temperature vs. radius

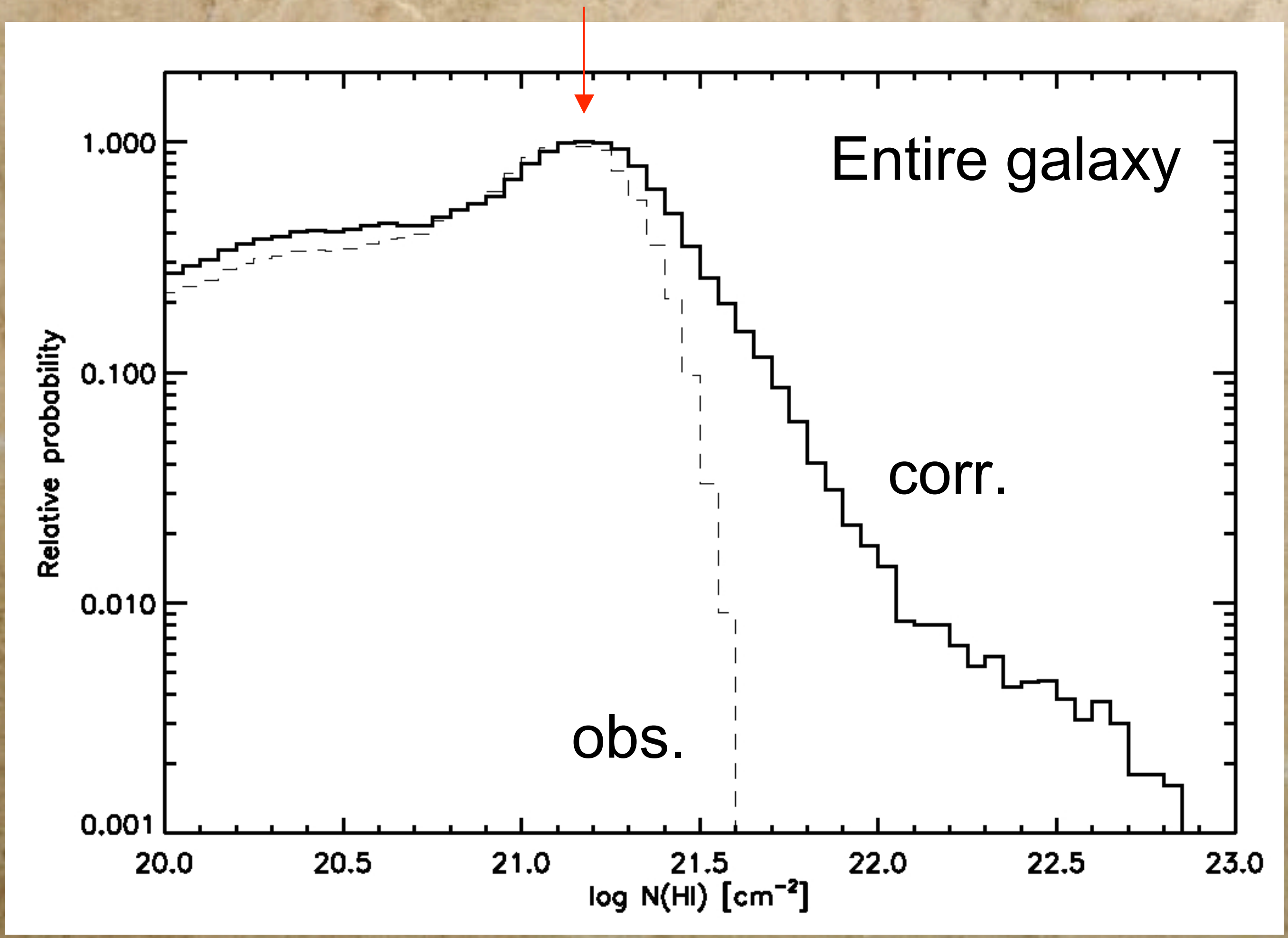
- Opaque sightlines represented in cool ridgeline
- Cool component temp declines slightly with rad.
  - 40 K at 4 kpc, 25 K at 7 kpc



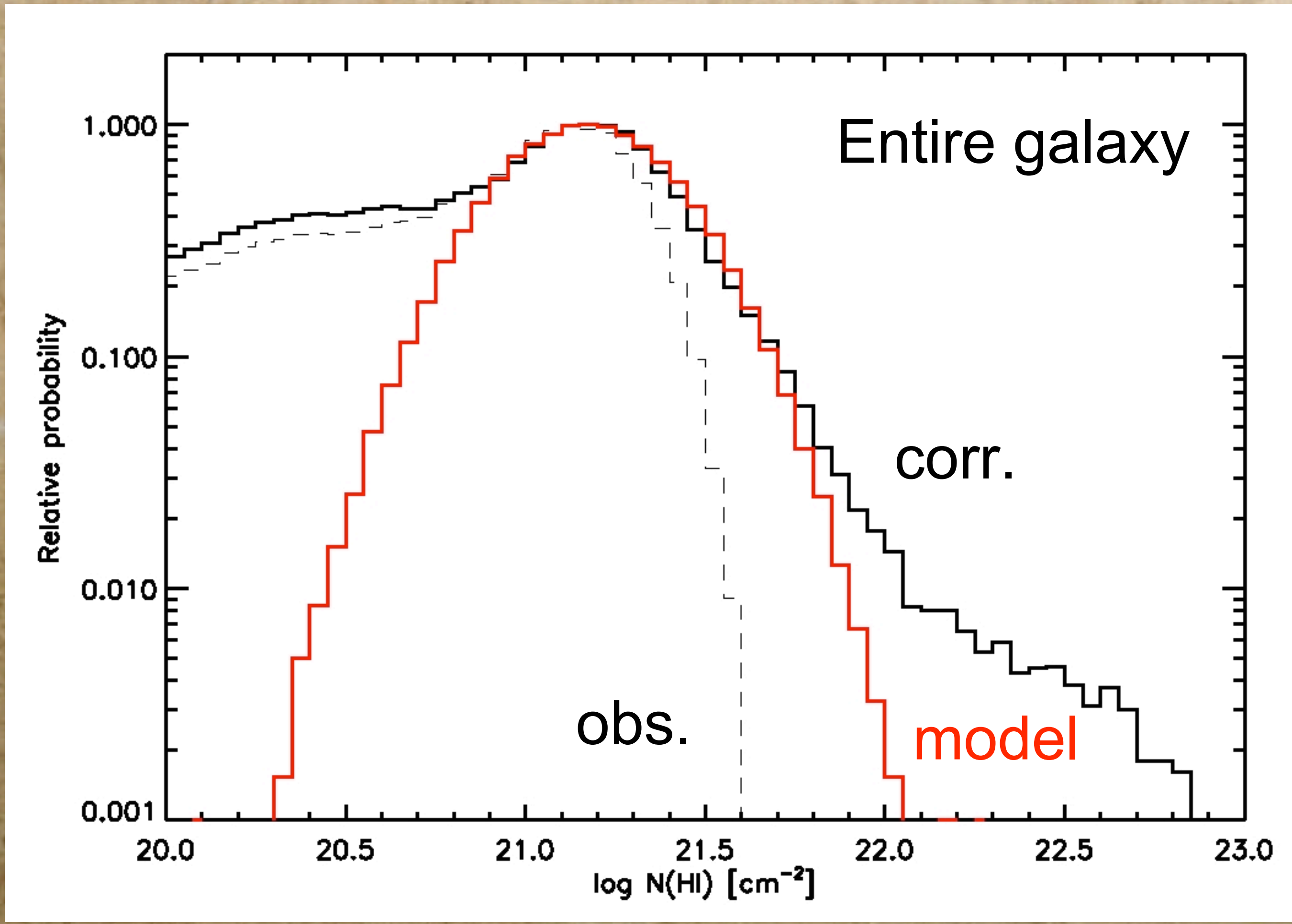
- Temperature vs. opacity-corrected N(HI)
  - Bimodal distribution
    - dominated by high T / low opacity sightlines
  - High N(HI) sightlines form a tail at low T
    - Signals a phase transition? Pre-molecular??

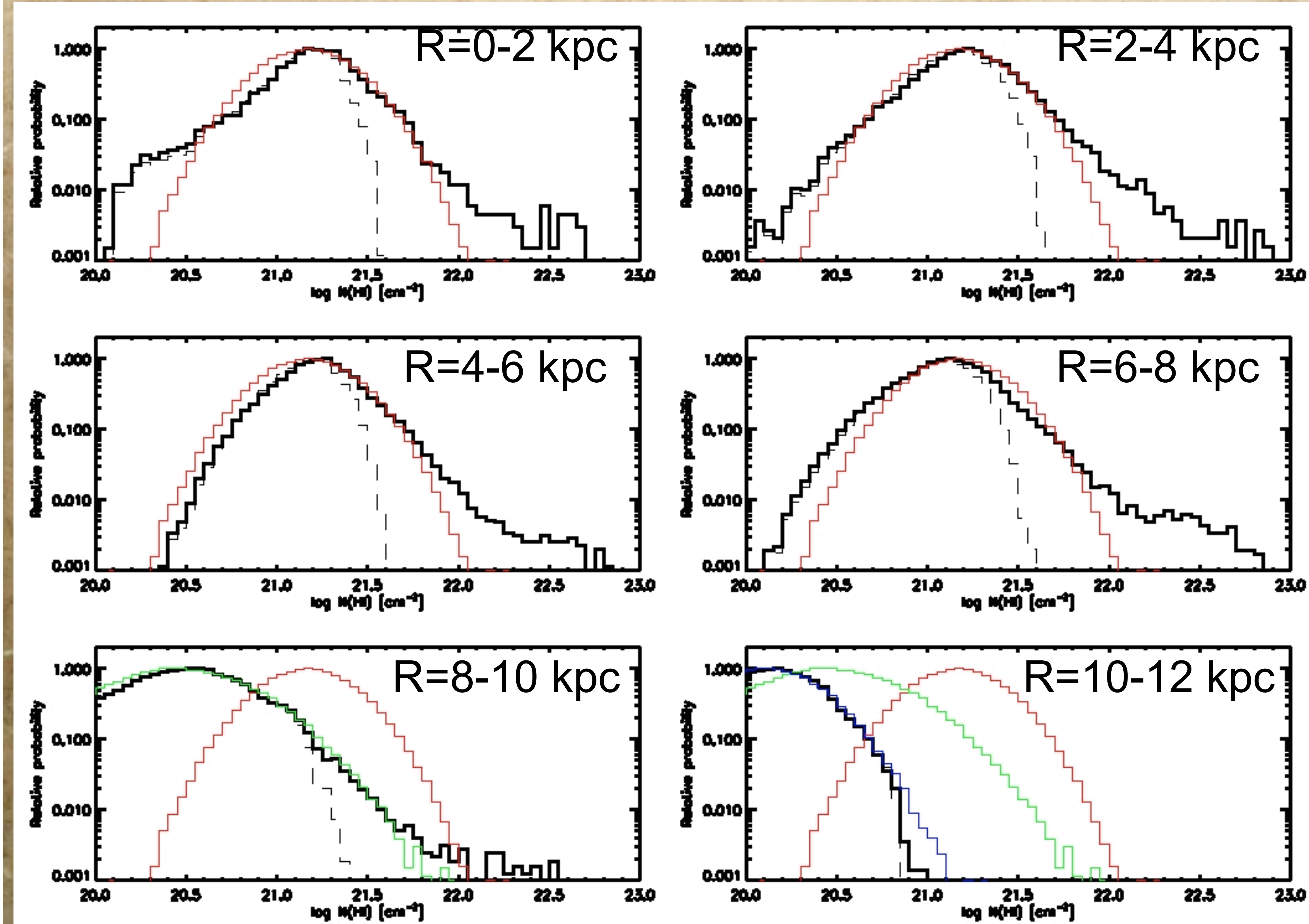


- Distribution of opacity-corr. N(HI)
  - 81 pc (20") resolution resolves HI superclouds
  - Preferred log N(HI) regardless of correction
  - Complex distribution well above noise floor



- Distribution of opacity-corr. N(HI)
  - 81 pc (20") resolution
  - Modeled by Log-normal N(HI) distribution such as associated with a turbulent medium



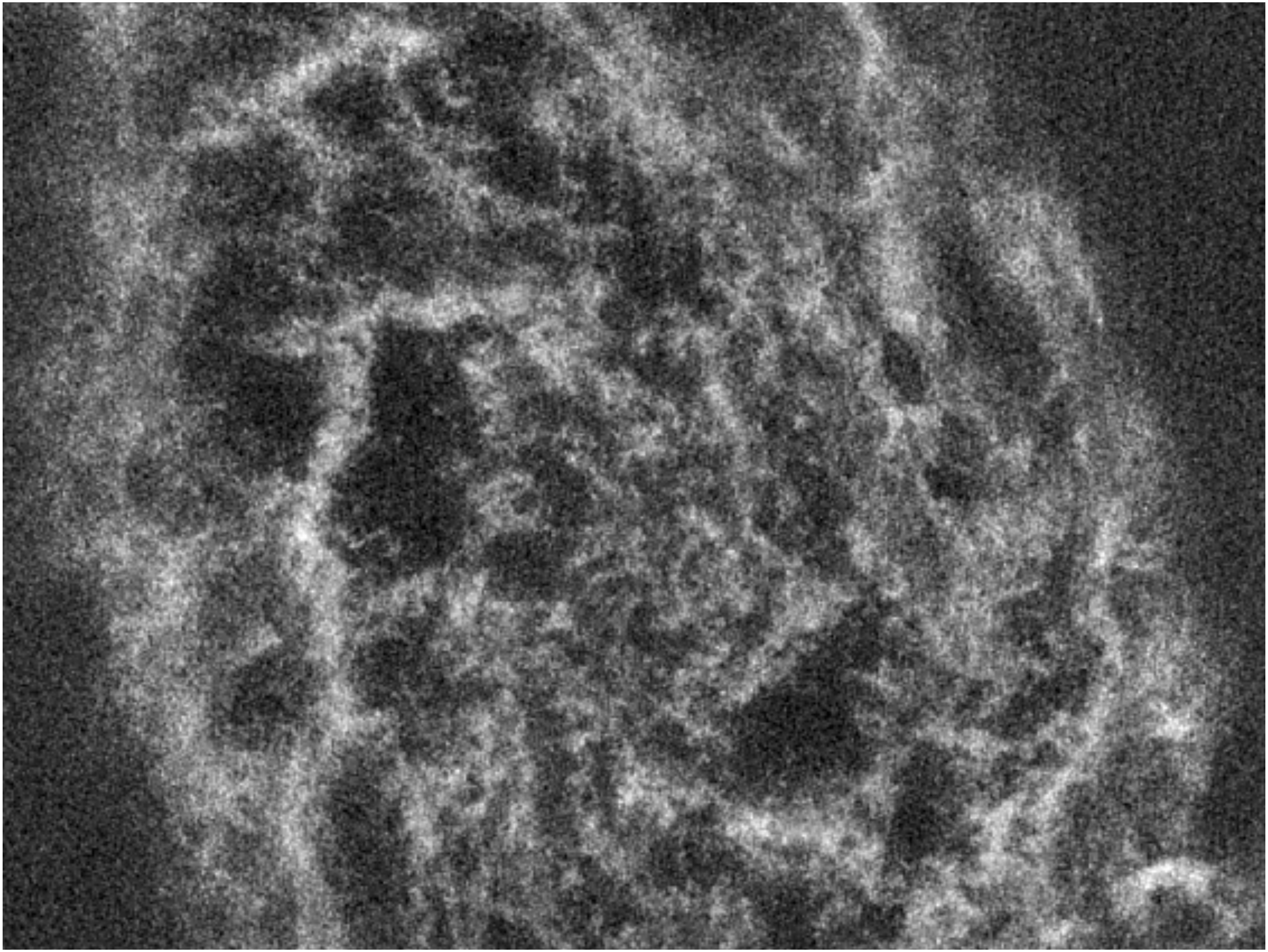


R=0-2 kpc
R=2-4 kpc
R=4-6 kpc
R=6-8 kpc
R=8-10 kpc
R=10-12 kpc
Relative probability
log N(HI) [cm⁻²]
1.000
0.100
0.010
0.001
20.0
20.5
21.0
21.5
22.0
22.5
23.0

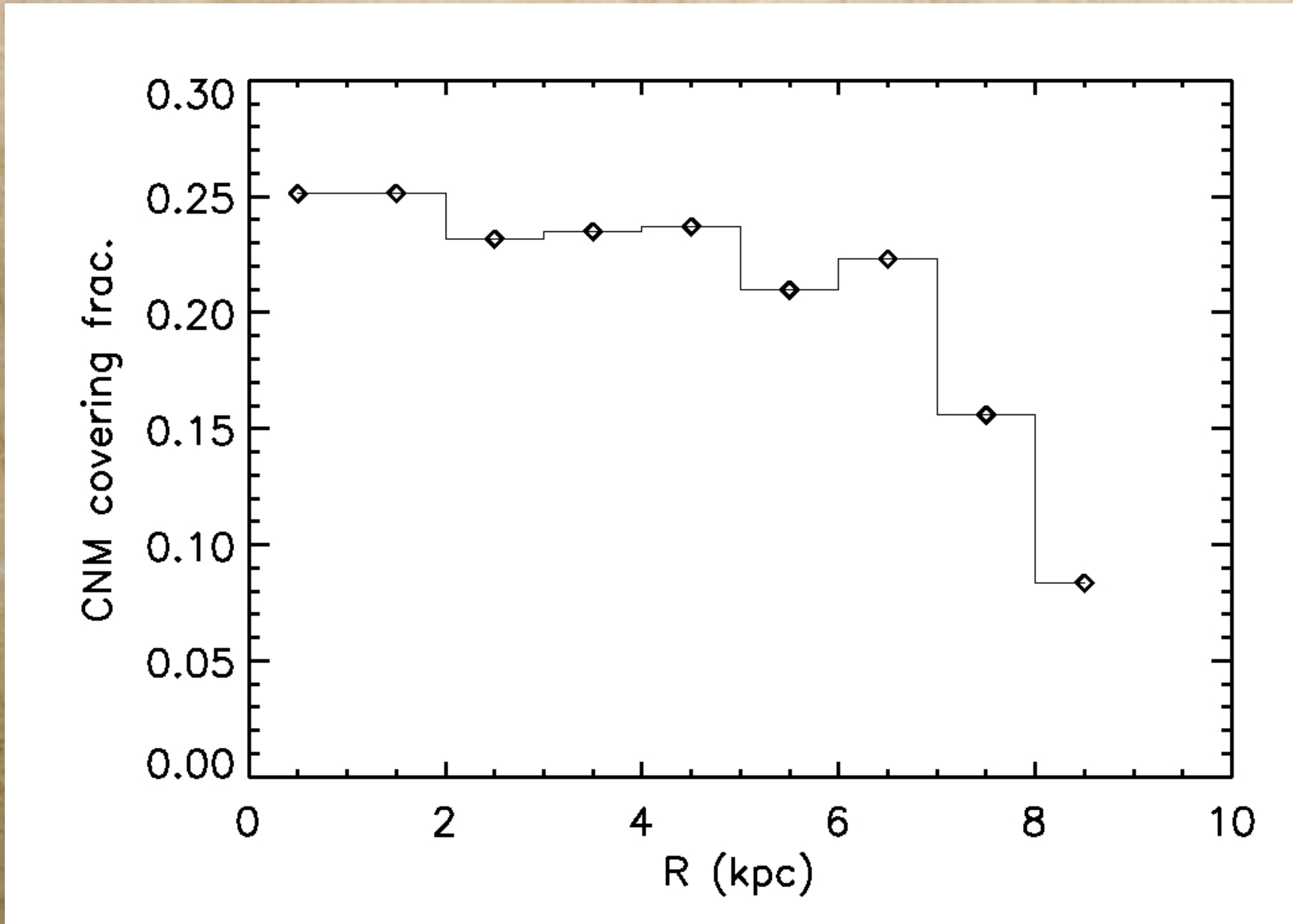
- CNM vs. WNM - - The problem of isolating them from each other
  - Current modeling method treats all sightlines independently
    - Poorly suited for study of diffuse component
  - CNM is well traced by high-brightness network seen in peak Tb image

  - PROPOSED METHOD:
    - Mask high-pass filtered peak Tb image
    - Pixels not in mask sample the diffuse WNM
    - Iterative interpolation of these sample points to estimate WNM contribution to datacube

  - OUTPUTS:
    - CNM covering fraction
    - CNM fractional flux

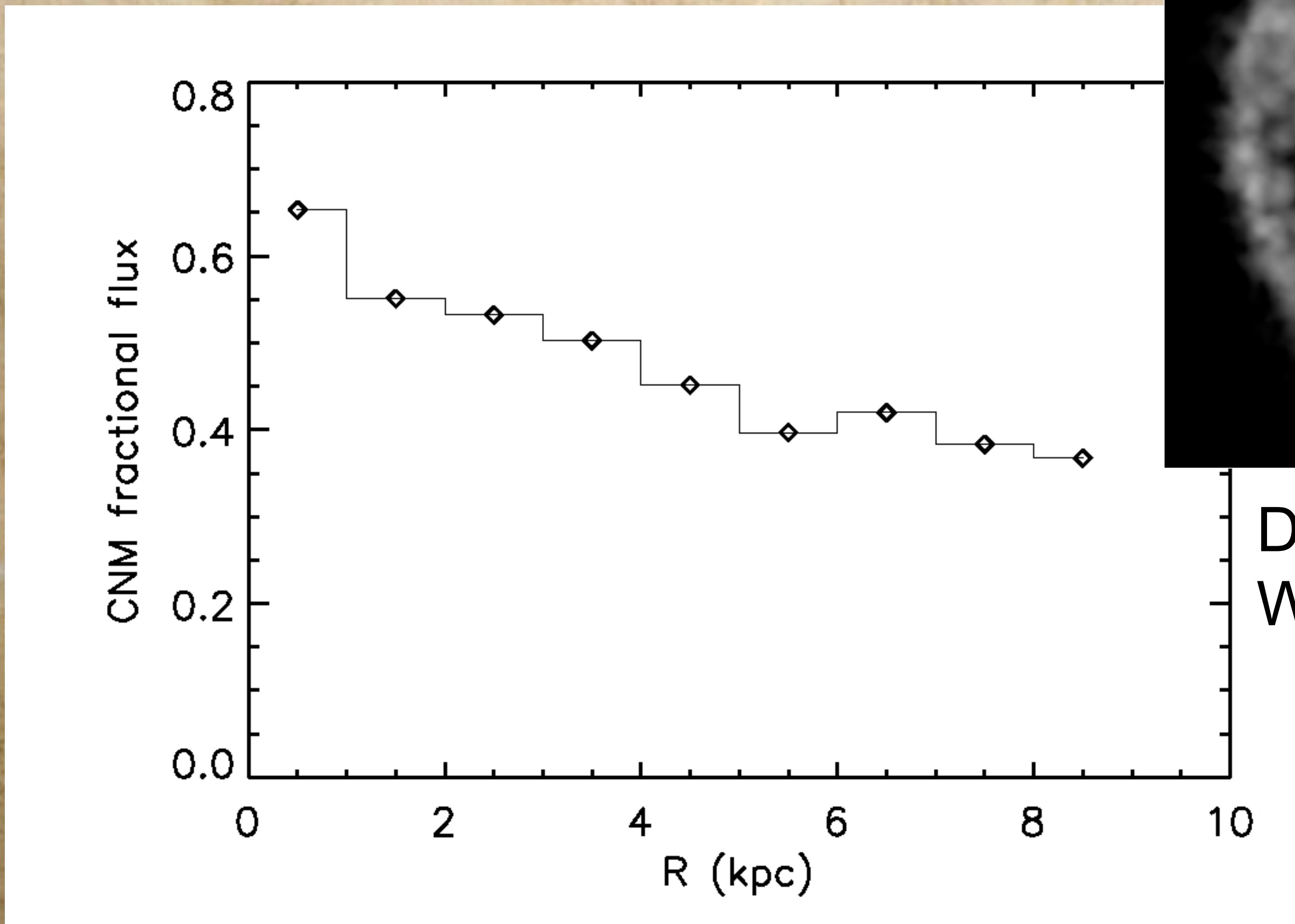


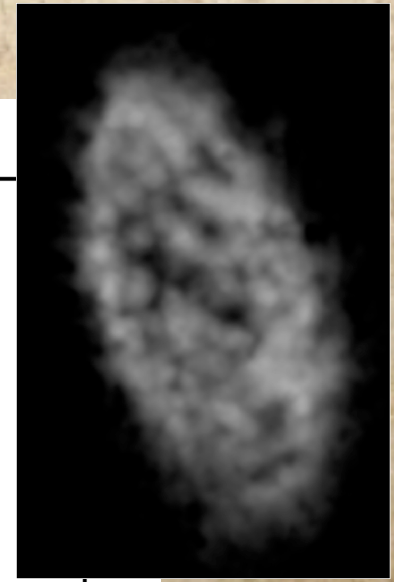
- CNM covering fraction vs. radius (Peak Tb-masked)



- Covering frac. is about 25% throughout main disk
- Drops precipitously at R = 7 kpc : related to SF edge?

- CNM fractional flux vs. radius *(provisional!)*

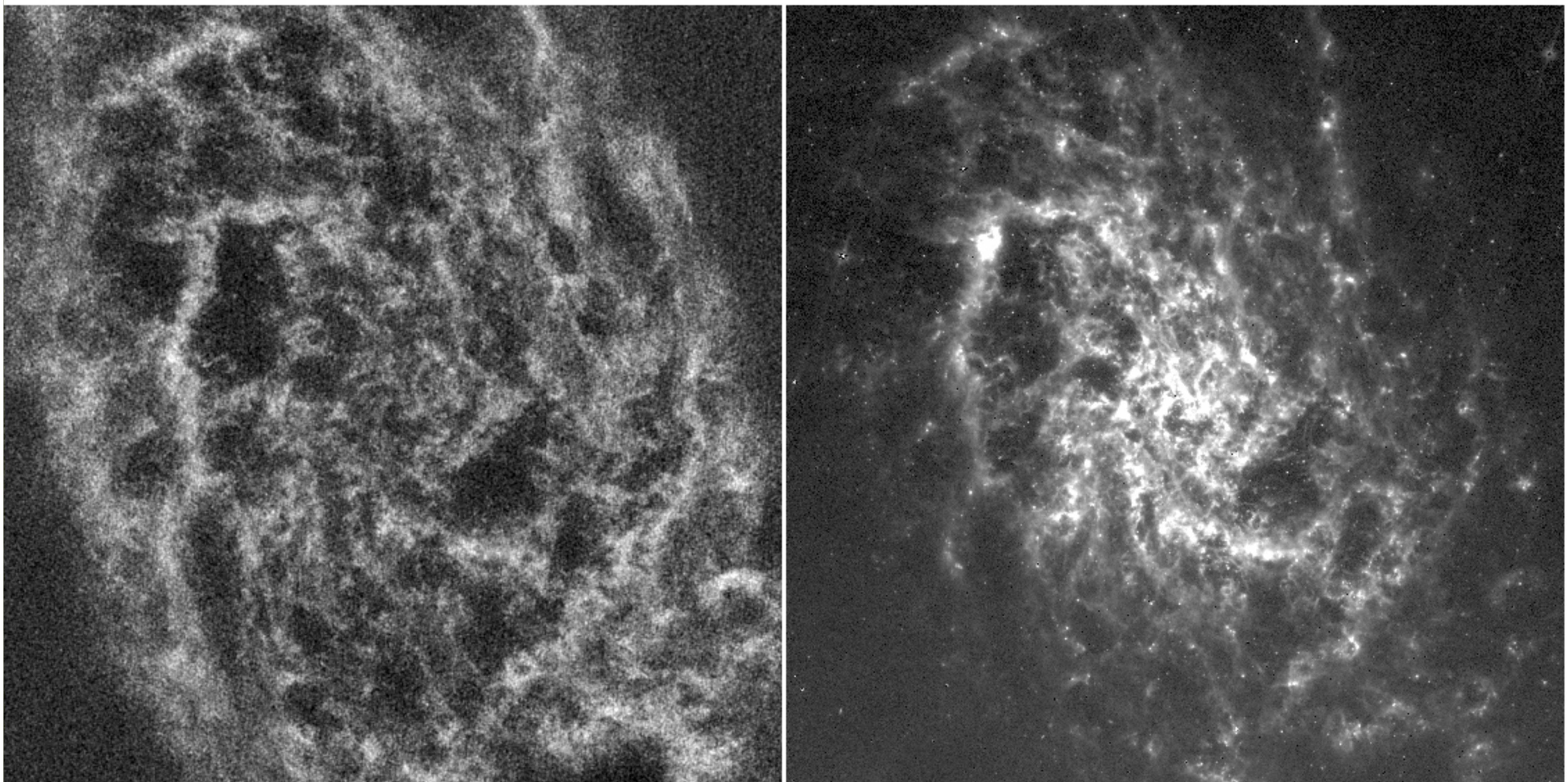




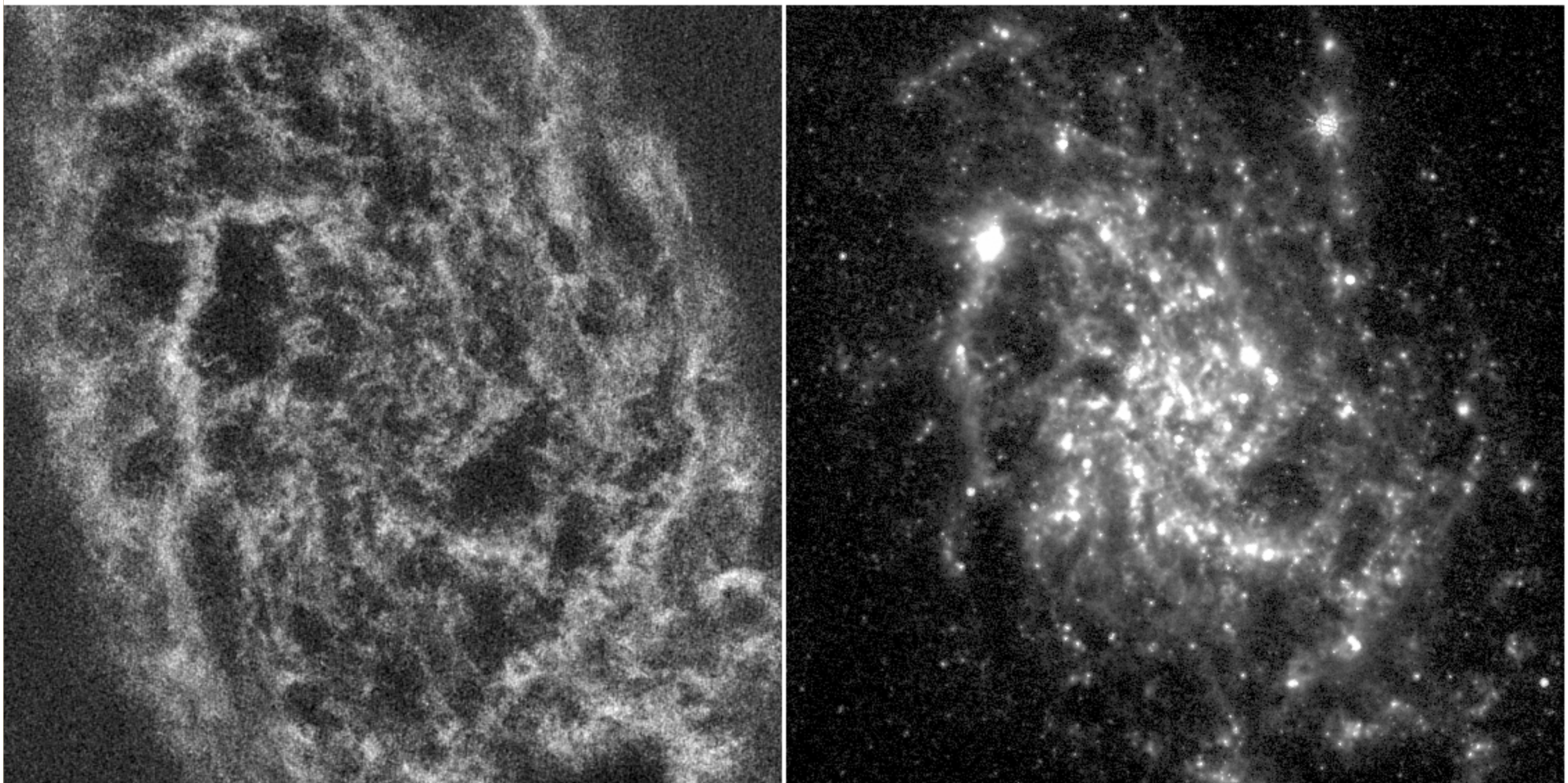
Diffuse WNM

- Smooth decline with radius 0.65 -> 0.4 from center to edge of main disk

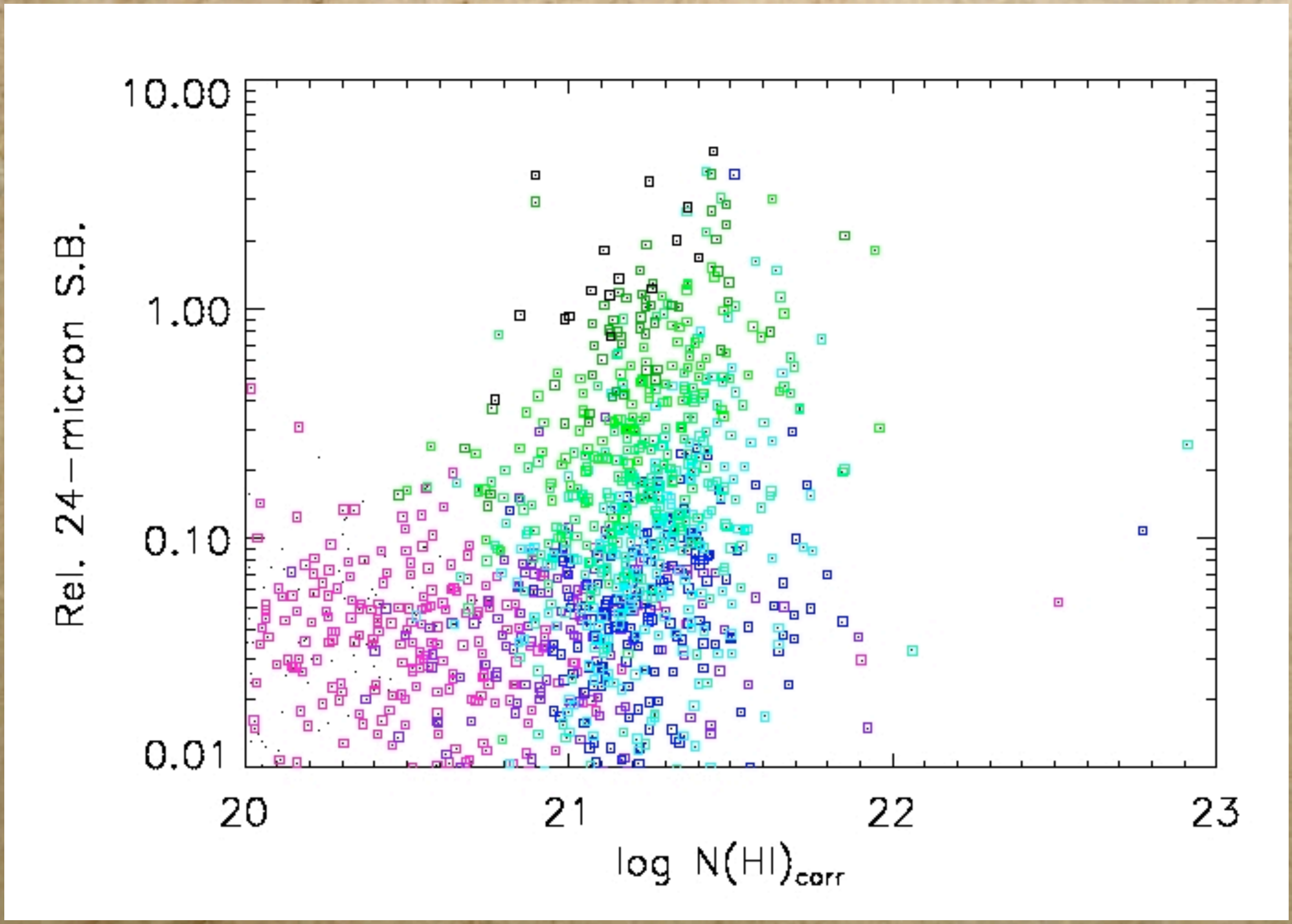
- Peak Tb - PAH correlation
  - Morphologically better match than with N(HI)
  - Suggests PAH originates in CNM (more than WNM)
  - Radial decline in dust/gas ratio



- Peak Tb - 24-micron correlation
  - Morphologically better match than with N(HI)
  - Same radial trend as PAH



- Radial decrease in dust/gas due to metallicity?
  - M33 has small metallicity gradient but with significant local deviations
  - Suggests that some scatter in d/g is real



  - Color indicates increasing radius (black, dark green, light green, cyan, blue, magenta)

Open Questions - M33 HI

- Dust/gas ratio
  - Spitzer/Herschel SED fit, VLA to measure locally
- Contribution of PDRs
  - Locally important?
- *Star formation law w.r.t. HI*
  - Schimdt law... best with mol. gas
  - Using only CNM does HI correl. improve?
- *HI-CO transition (details vs. prediction)*
- Updated warped-disk model, rotation curve
- *Details of HVC Population*