HOW GOOD IS DUST EMISSION AS A TRACER OF STRUCTURE IN STAR FORMING MOLECULAR CLOUDS?

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PROJECT AIMS

- Create ‘fake’ data of a star forming molecular cloud by building dust emission intensity maps using RADMC-3D
- Degrade this data to better simulate Herschel observations
- Use this data to create maps of column density, N and temperature, T
- Compare these values to the ‘true’ values derived from the simulation input values
- Extract prestellar core locations and masses in both ‘fake’ and ‘true’ maps

MOLECULAR CLOUDS

- A molecular cloud is a cold (<20 K) and dense region of the ISM (Hildebrand, 1983)
- Composed primarily of Molecular Hydrogen (H_2)
- Small dust component (roughly 1% gas mass) also present (Shetty et al, 2009a)
- Gravitational collapse of regions exceeding Jeans' mass can lead to star formation (Jeans, 1902)

$$M_J = \left(\frac{5kT}{GM}\right)^{3/2} \left(\frac{3}{4\pi\rho}\right)^{1/2}$$

WHY IS DUST IMPORTANT?

- Dust occludes sites of star formation
- Dust absorbs/scatters photons
- Absorption results in photons being re-emitted at a longer (sub mm/ IR) wavelength
- Used to determine mass of clouds and the cores within them
- Project assumed one silicate based dust species
    - Also assumed gas and dust temperature uncoupled, so gas neglected as it does not effect the dust temperature at number density $< \sim 10^4$ cm^{-3} (Clark and Glover, 2012)

USING DUST TO TRACE STRUCTURE

$$I_\nu = \frac{N_{H_2}}{R_{dust-gas}} \mu m_p \boxed{\kappa_0 (\frac{\nu}{\nu_0})^\beta} B_\nu(T)$$

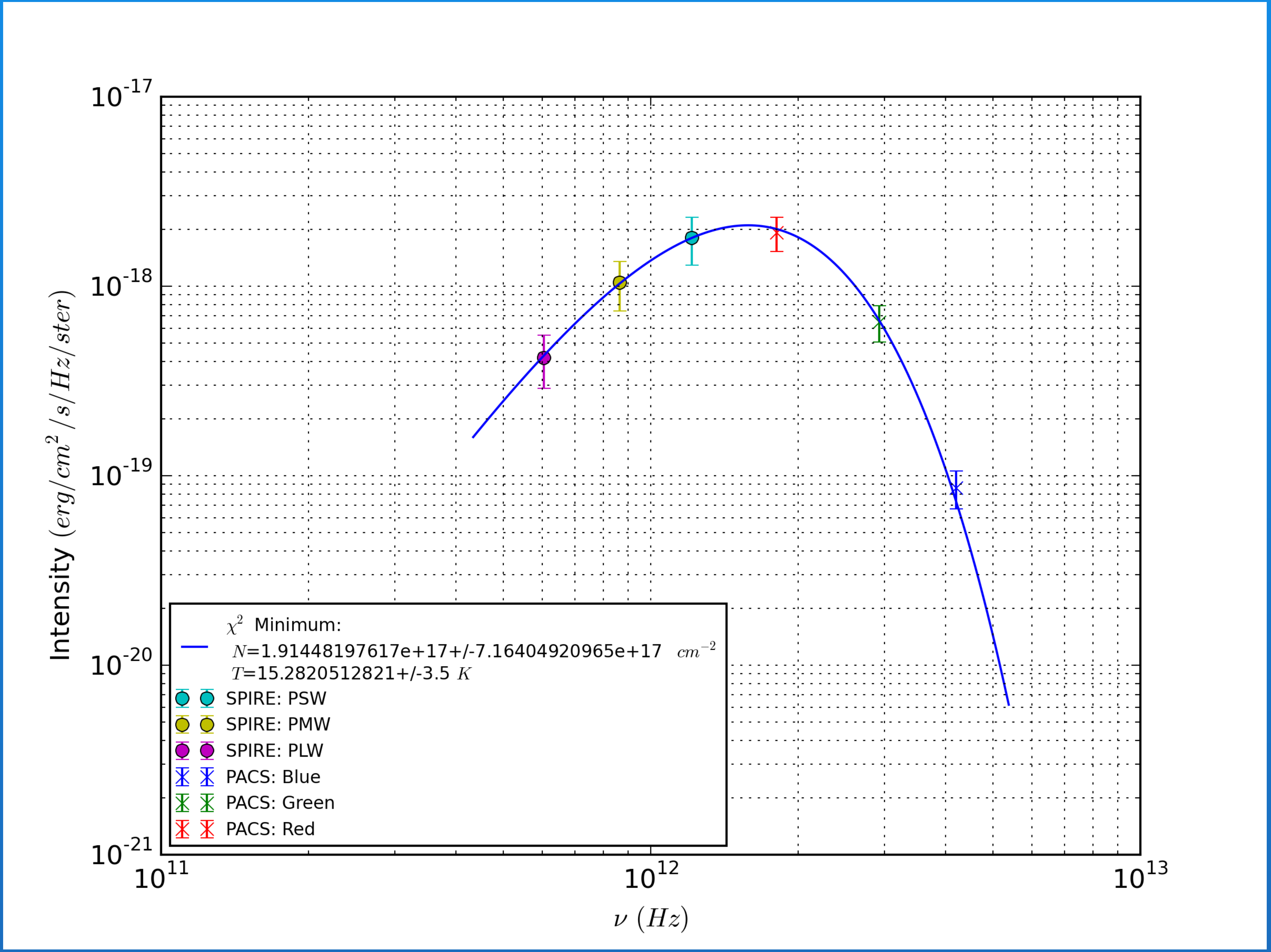
Hildebrand dust opacity

- Systematically varying N and T and finding best fit (goodness of fit assessed via χ^2 minimisation test (Taylor, 1987)) gives the best fit N and T

$$\chi^2 = \sum_i \left(\frac{O_i - E_i}{\sigma_i} \right)^2$$

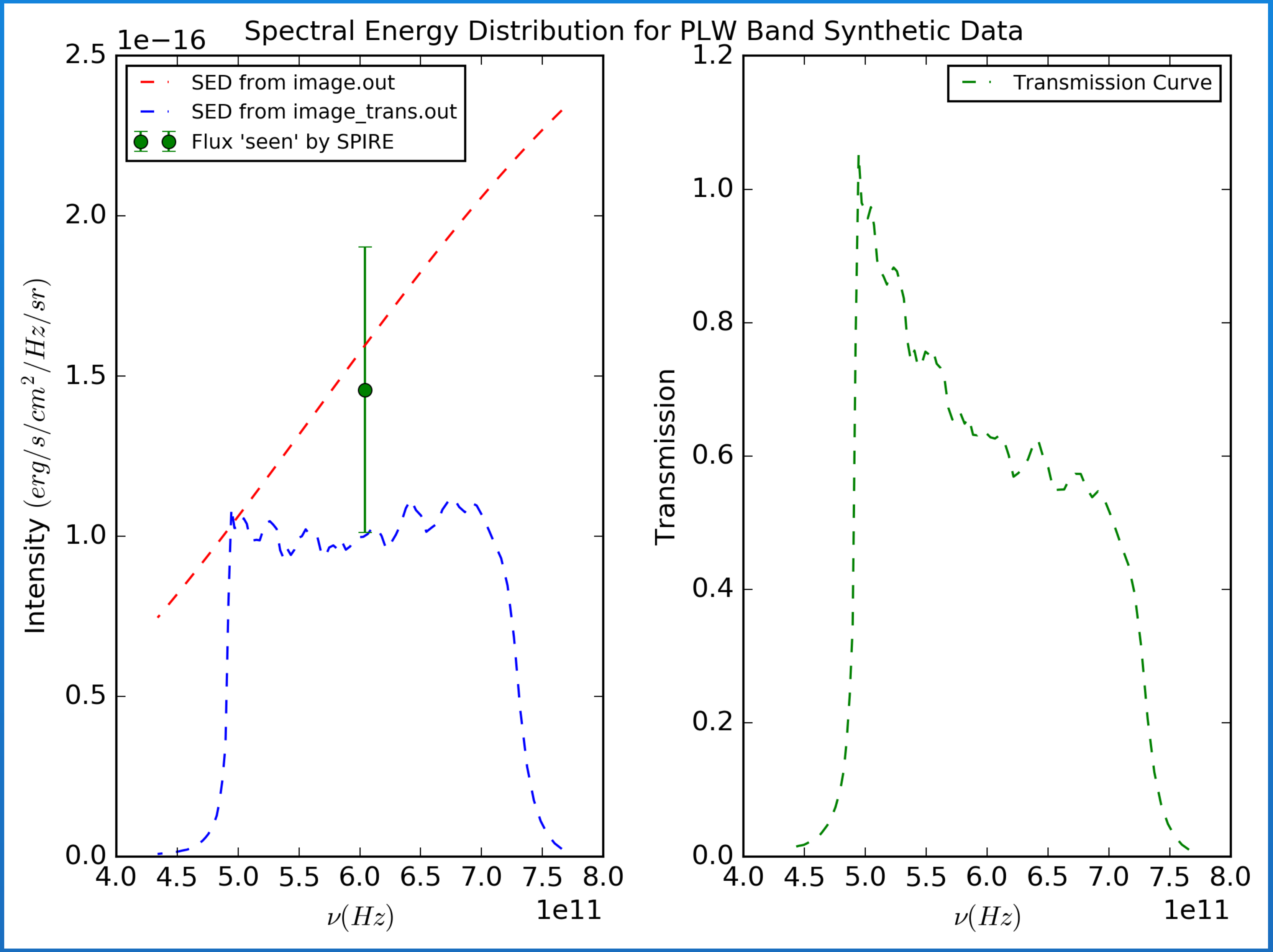
- Shetty et al (2009b) state that N and T suffer from degeneracy: χ^2 prone to underestimating N and overestimating T

USING DUST TO TRACE STRUCTURE: SED



DATA DEGRADATION

$$I_{pix,\nu} = \frac{\sum_{i=0}^{npix} I_{xpix,ypix,\nu_i} T_{\nu_i}}{\sum_{i=0}^{npix} T_{\nu_i}} \quad I_{pix} = \frac{\sum_{\nu} I_{pix,\nu}}{\sum_{\nu} T_{\nu}}$$



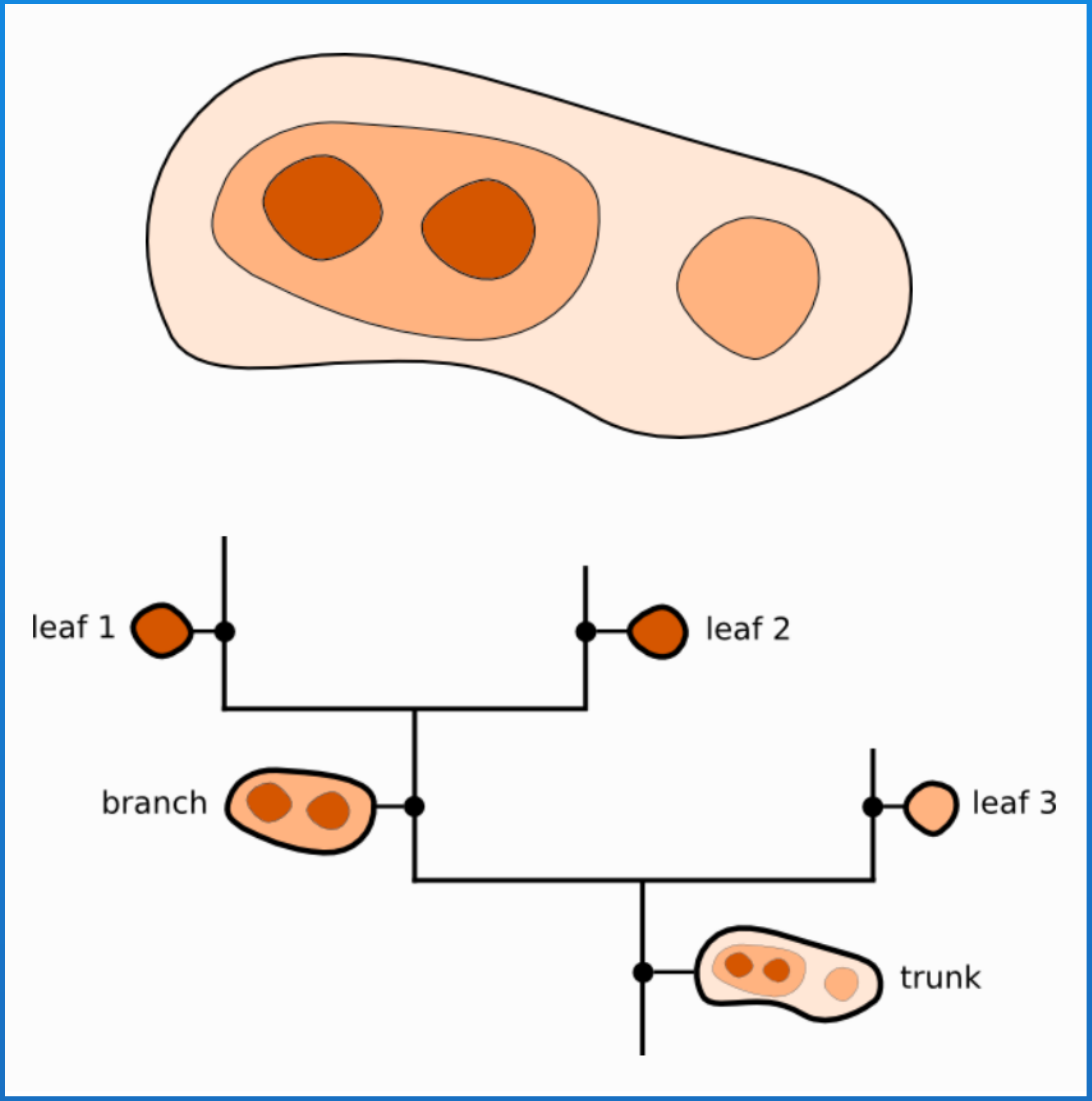
PRODUCING A BENCHMARK

- ‘Real’ observations do not allow the determined N and T to be compared to ‘true’ values
- Use the simulation input parameters as the ‘true’ values, allowing accuracy comparison
- Initial simulation input values (dust density, ρ_i and dust temperature, T_i) extrapolated to N and T

$$N_{true} = \sum_i \frac{\rho_i d_{pix}}{\mu m_p} \qquad T_{true} = \frac{\sum_i T_i \rho_i}{\sum_i \rho_i}$$

DENDROGRAMS

- Dendrogram is a way of highlighting structure in an image
- Project used astrodendro
- 'Leaf' is the point at which structure does not fragment any further



CORE EXTRACTION

- To be considered a core, column density must exceed theoretical estimate, i.e. N > N_{core}

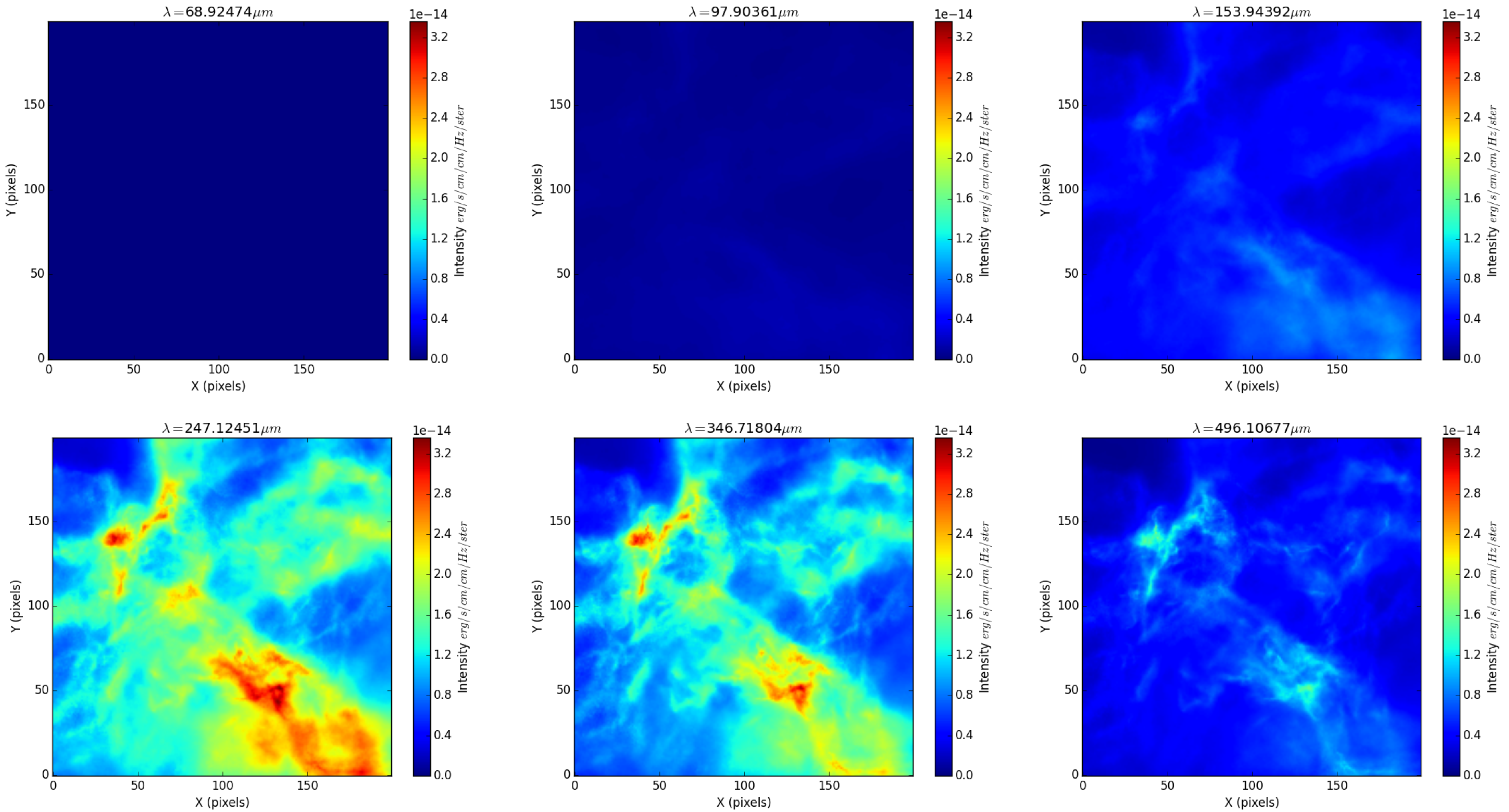
- Theoretical estimate determined using:

$$N_{core} = \frac{M_J}{\mu m_p R_J^2}$$

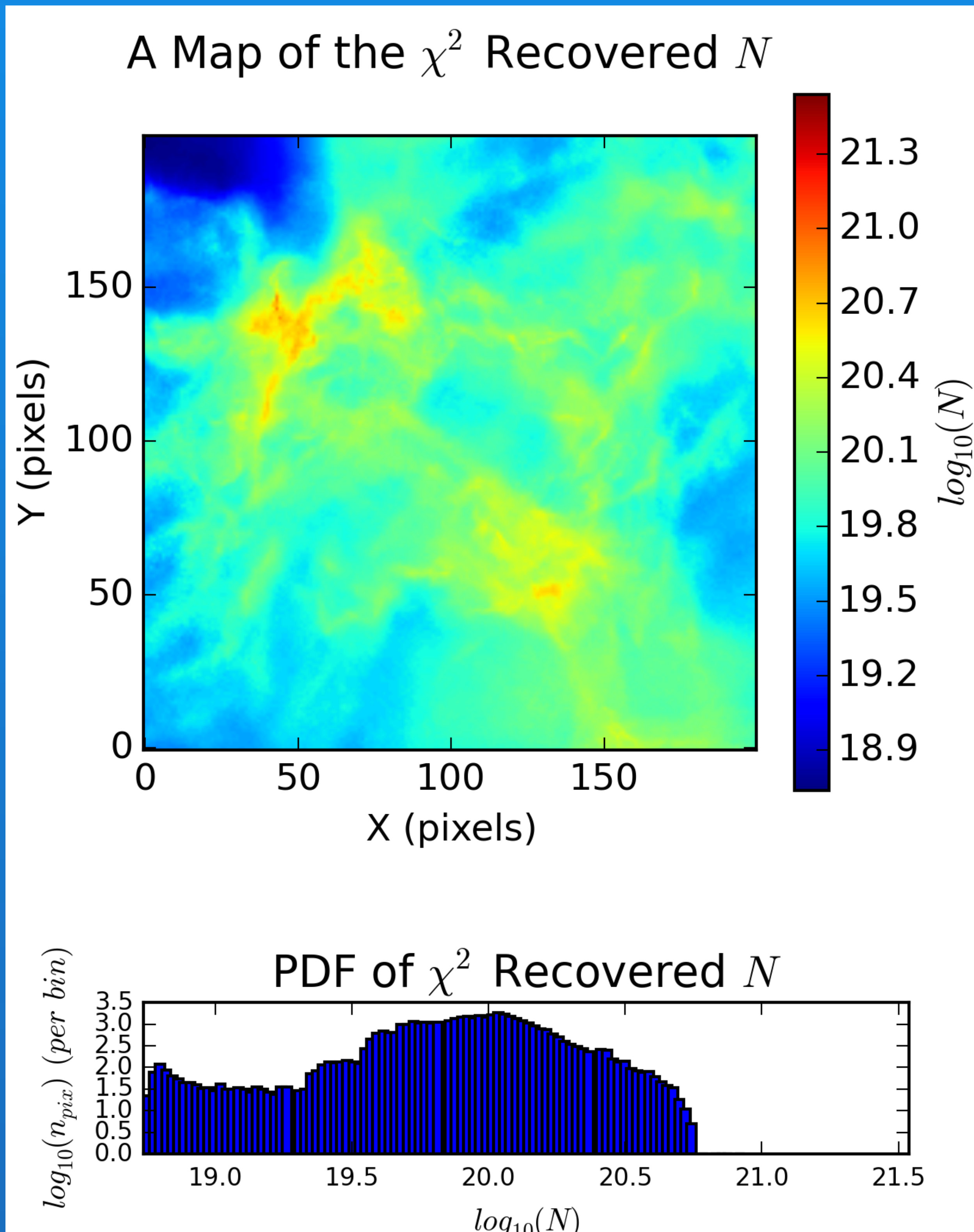
- If regions meets this criteria, determine radius and mass of core using:

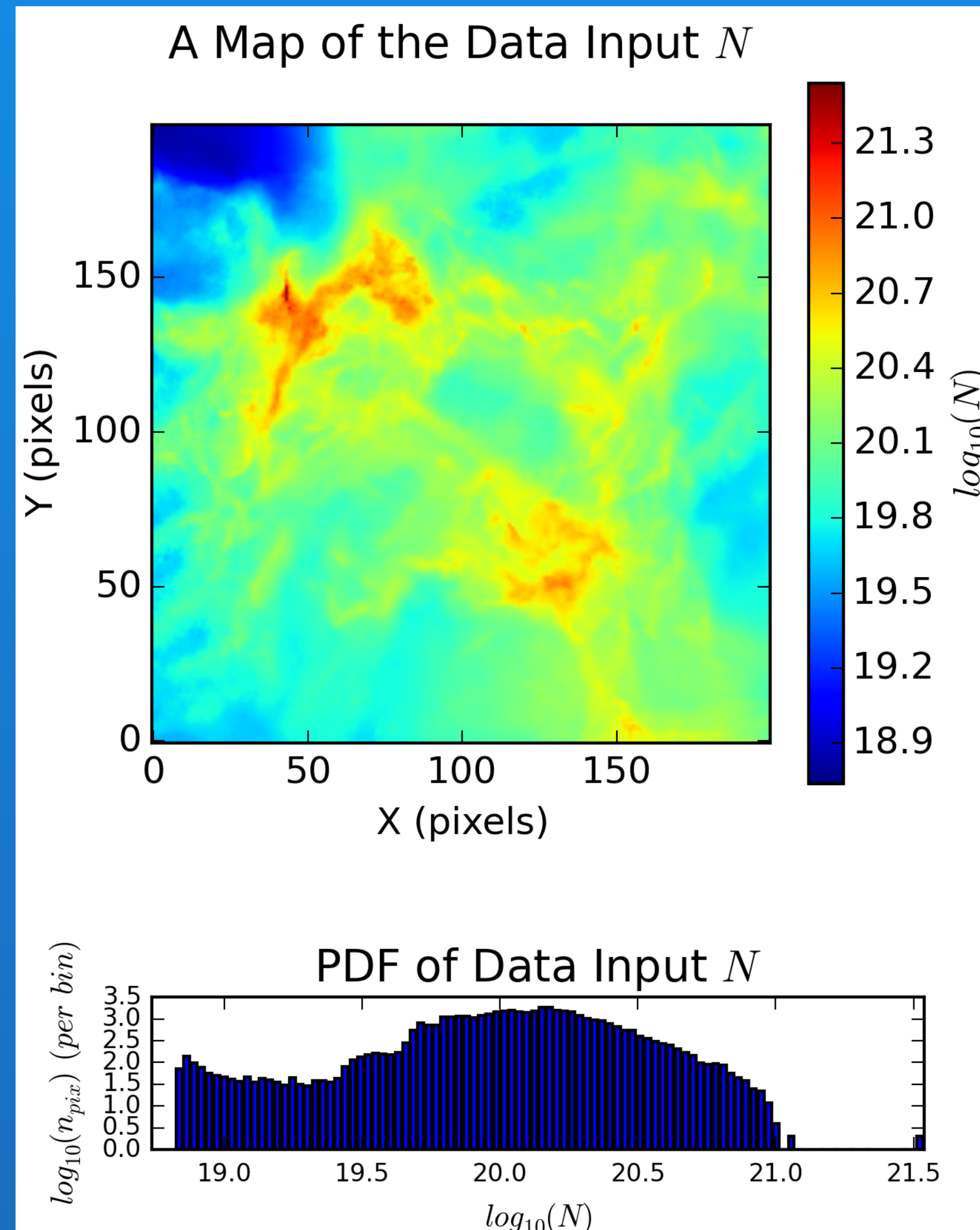
$$R_{core}^2 = \sqrt{\frac{A_{tot}}{\pi}} \qquad M_{core} = N_{H_2} \mu m_p \pi R_{core}^2$$

INTENSITY MAPS

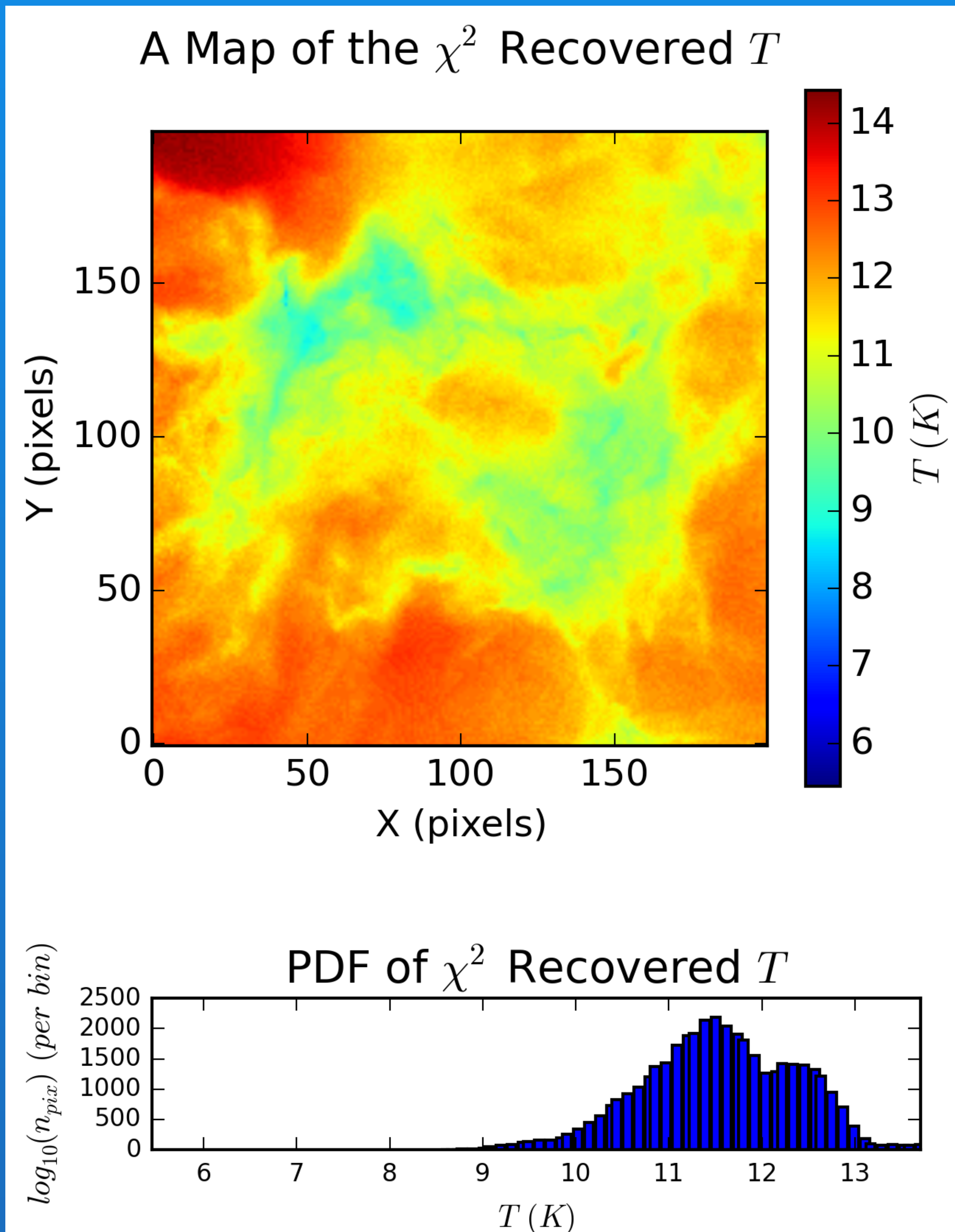


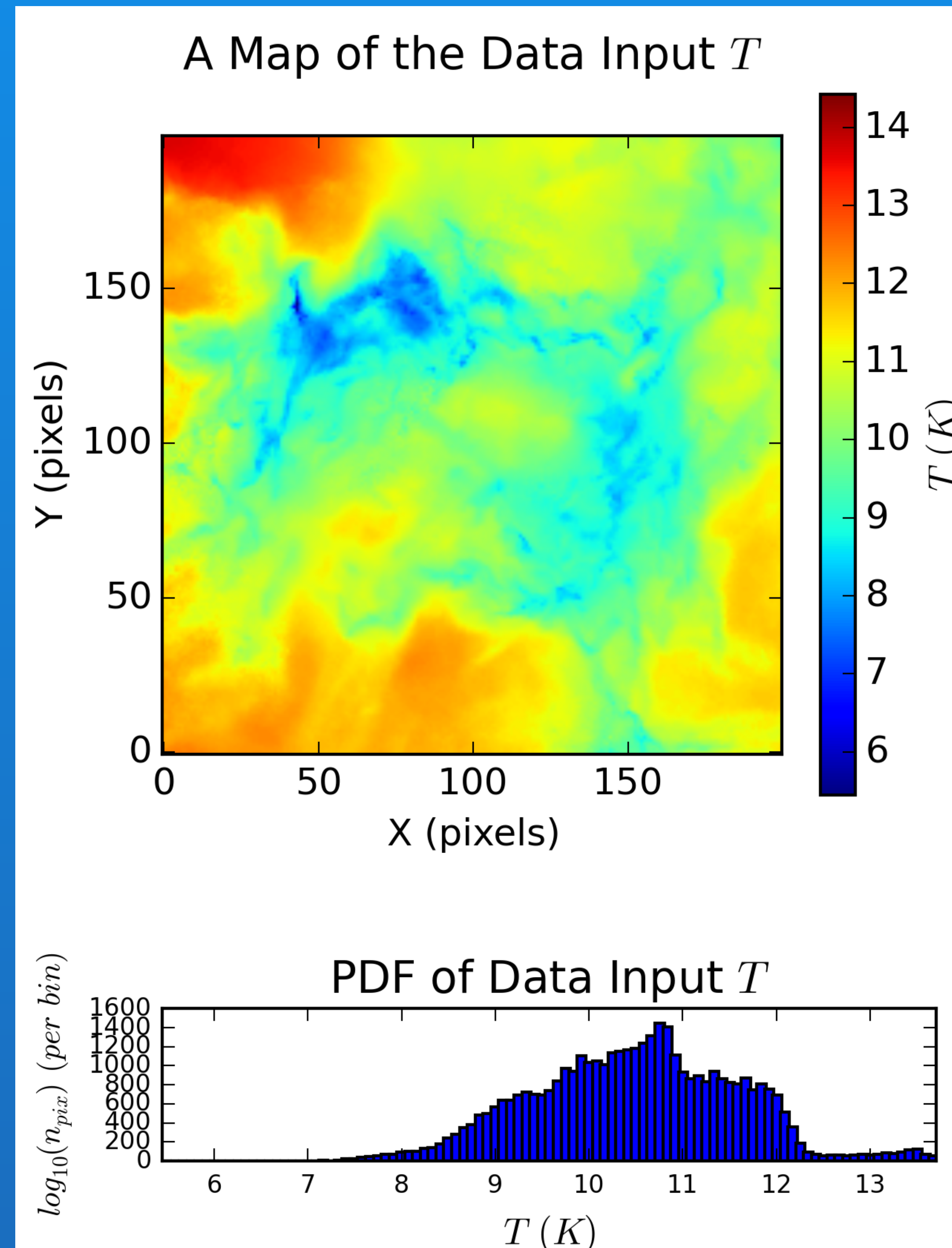
COLUMN DENSITY MAPS



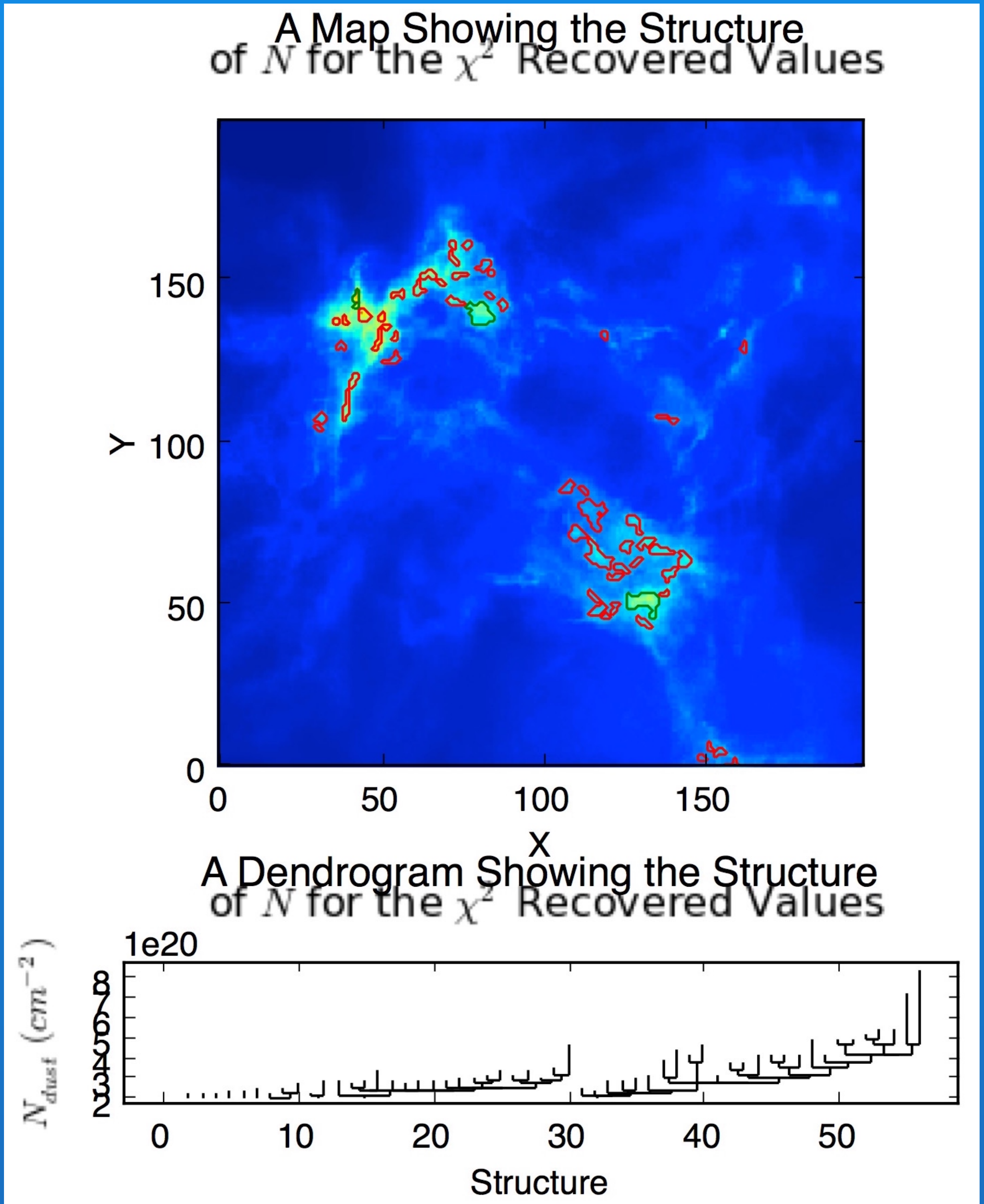


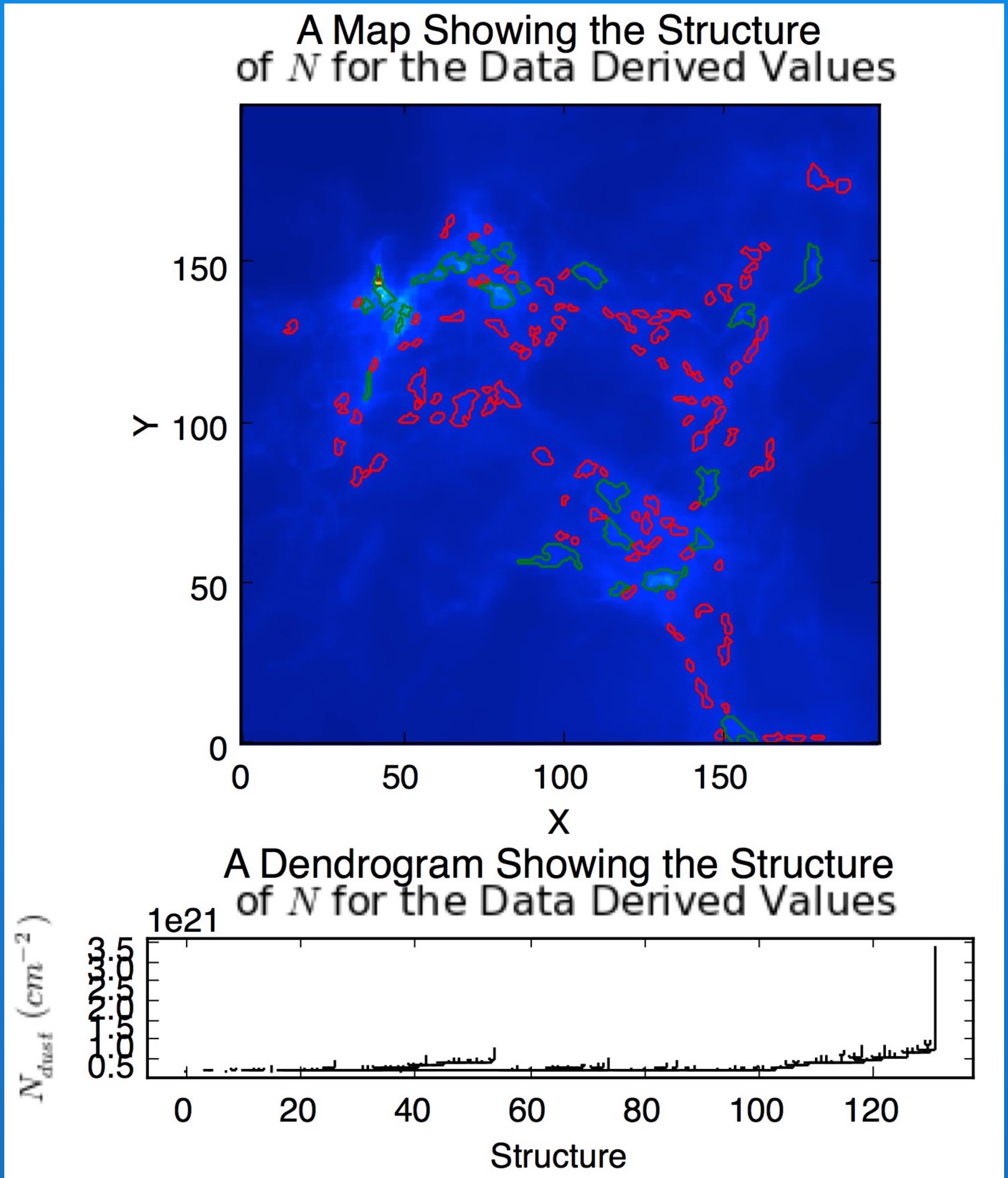
TEMPERATURE MAPS





CORE EXTRACTION





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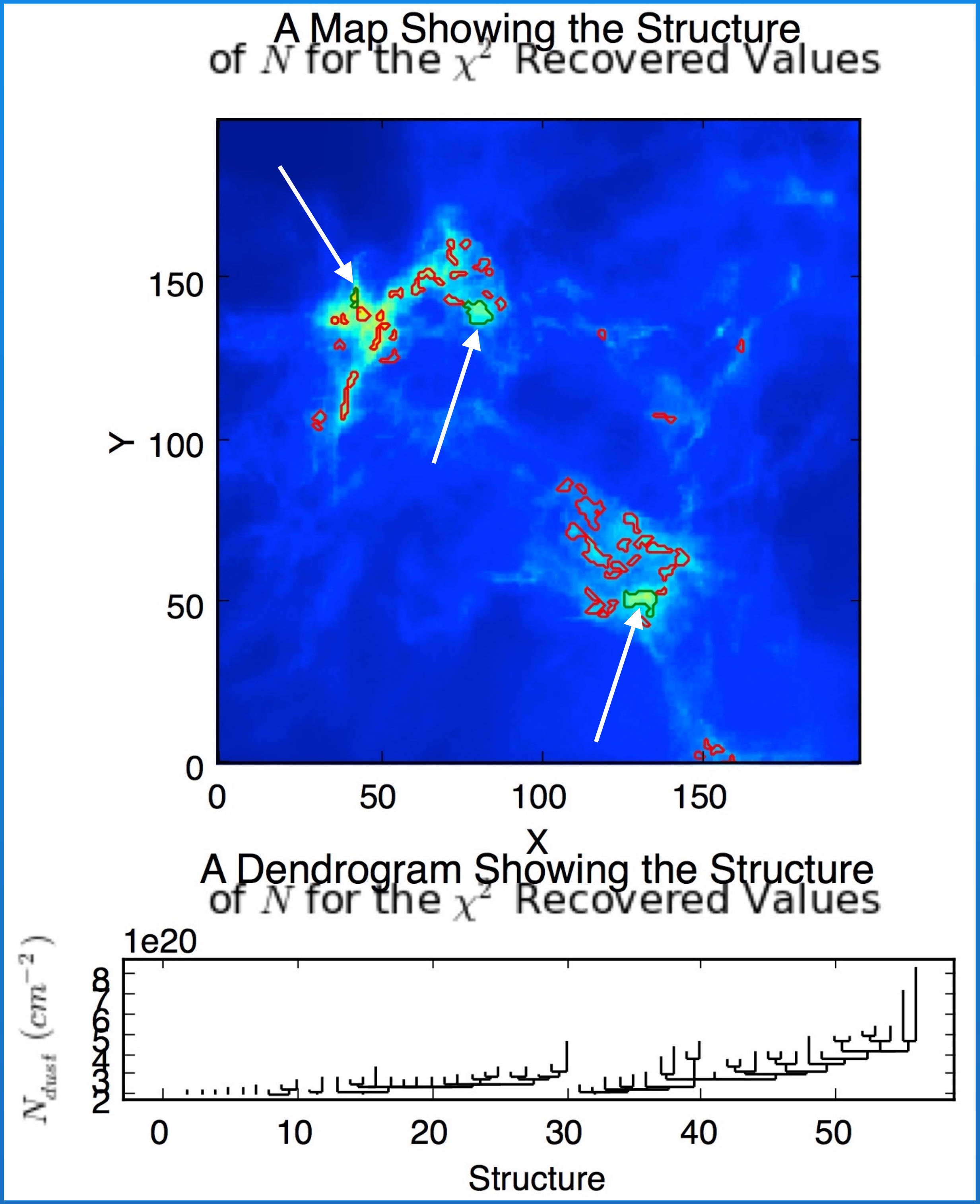

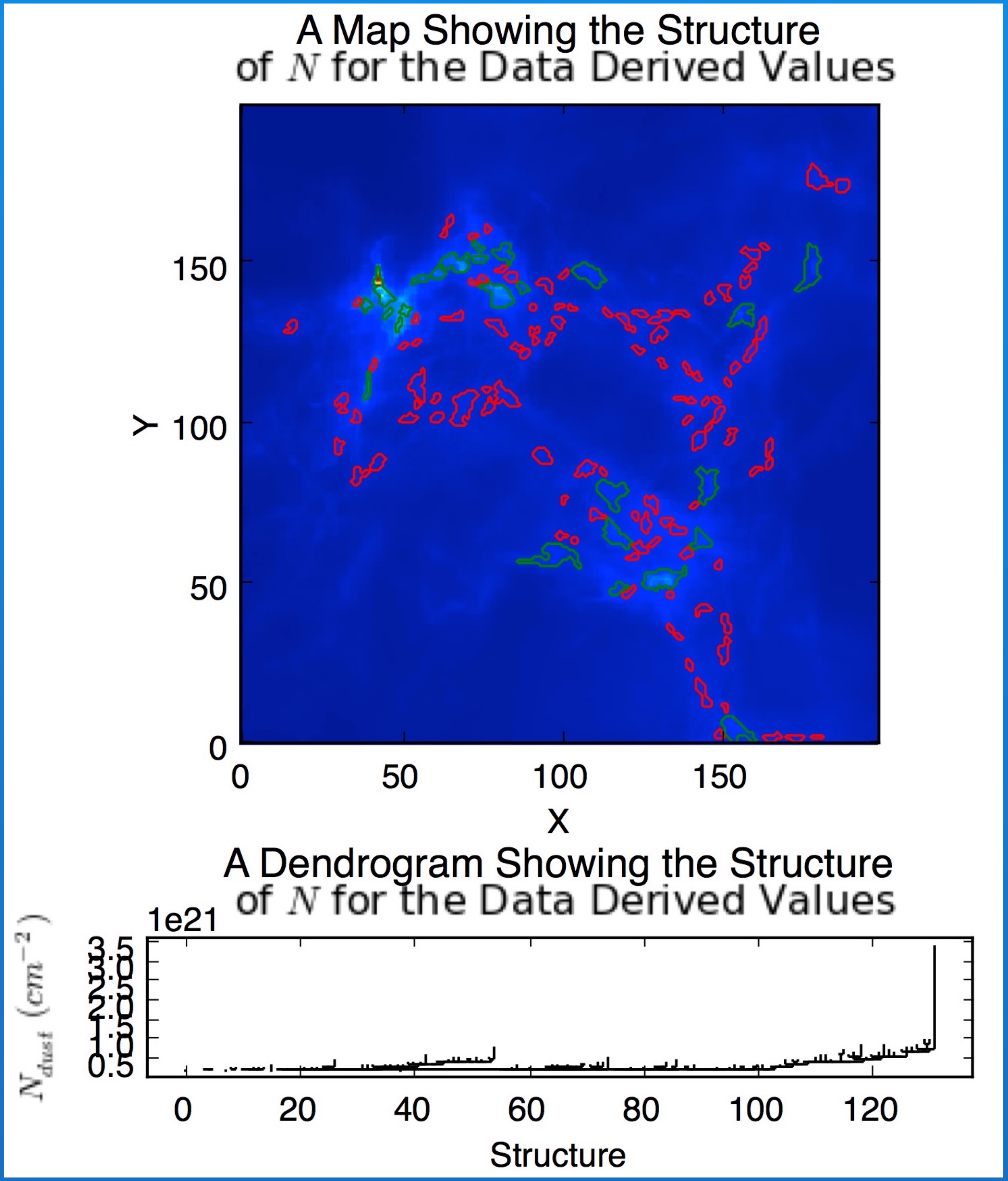

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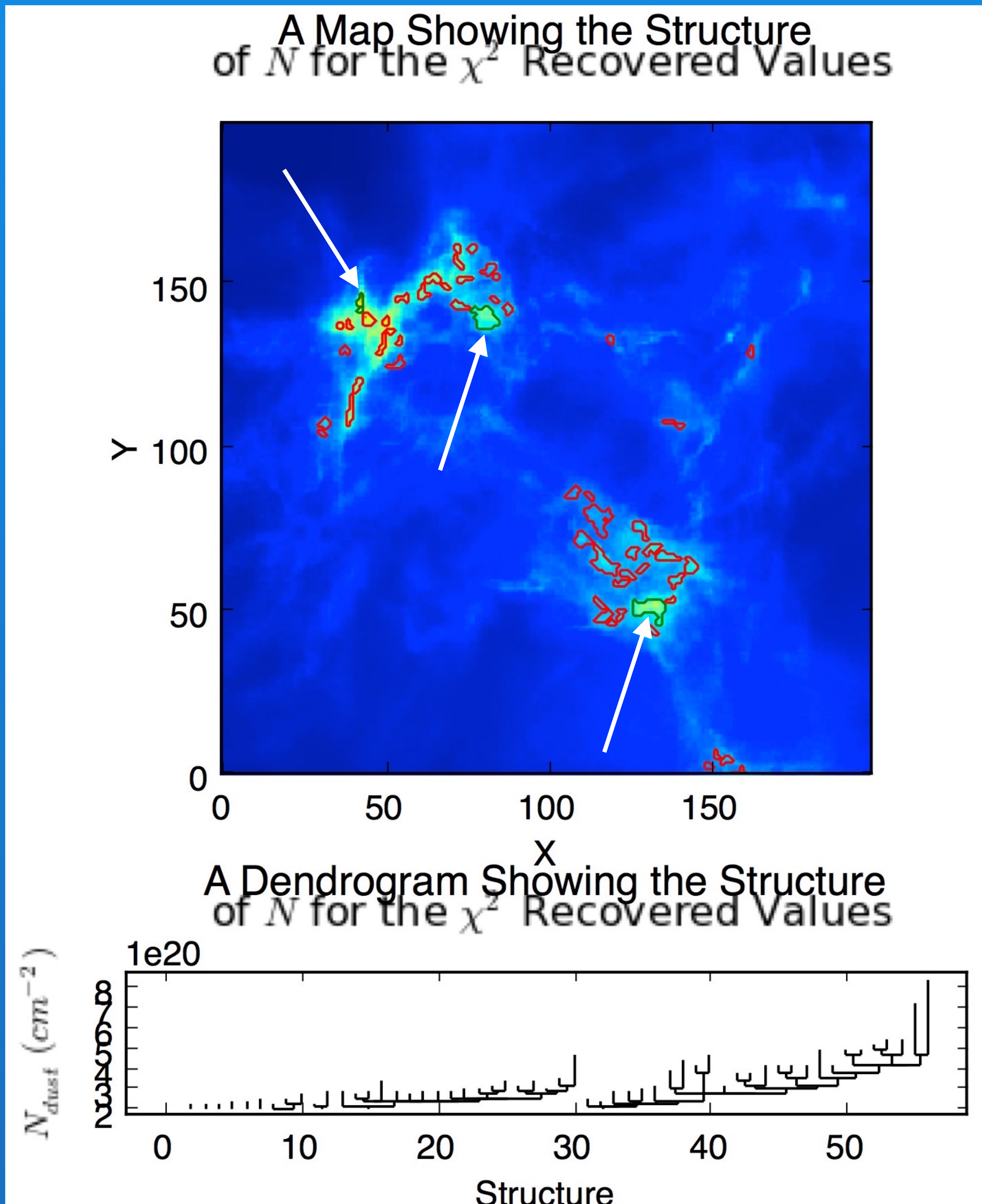
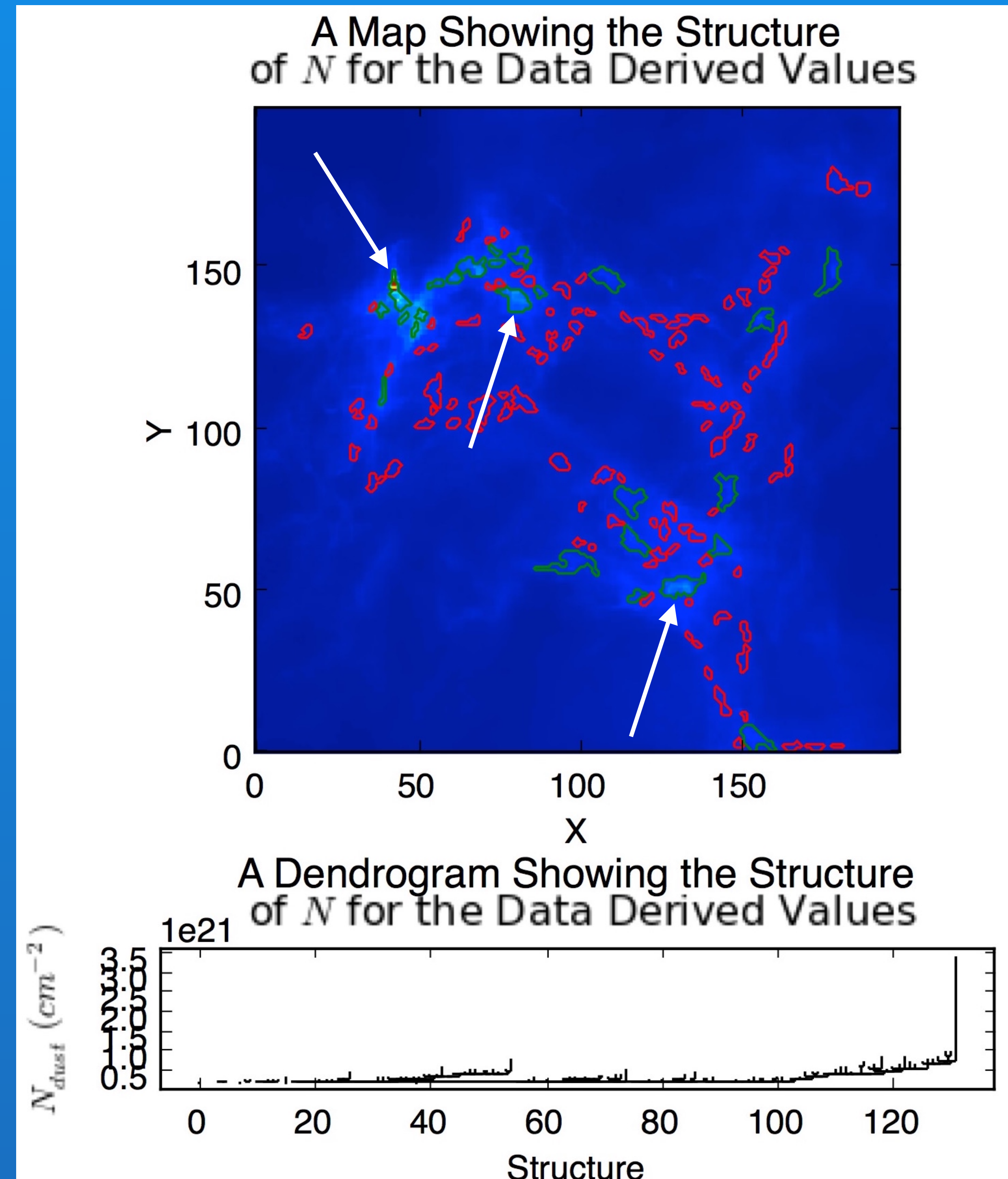
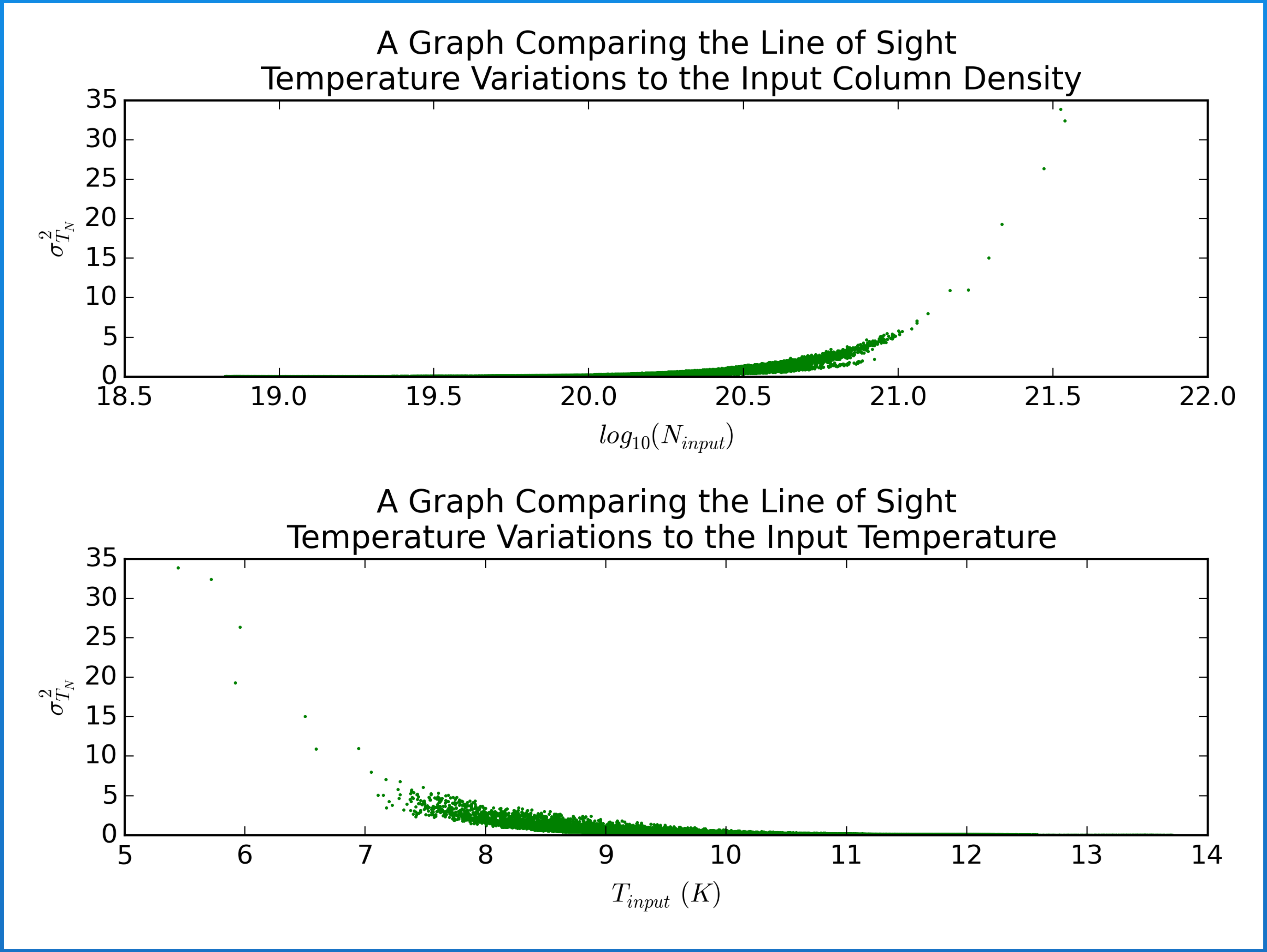




CORE EXTRACTION: MASSES

M_{χ^2}/M_{SUN}	M_{DATA}/M_{SUN}
0.3404 ± 0.3616	0.7016
0.2799 ± 0.3269	0.6241
0.1041 ± 0.07105	0.7974

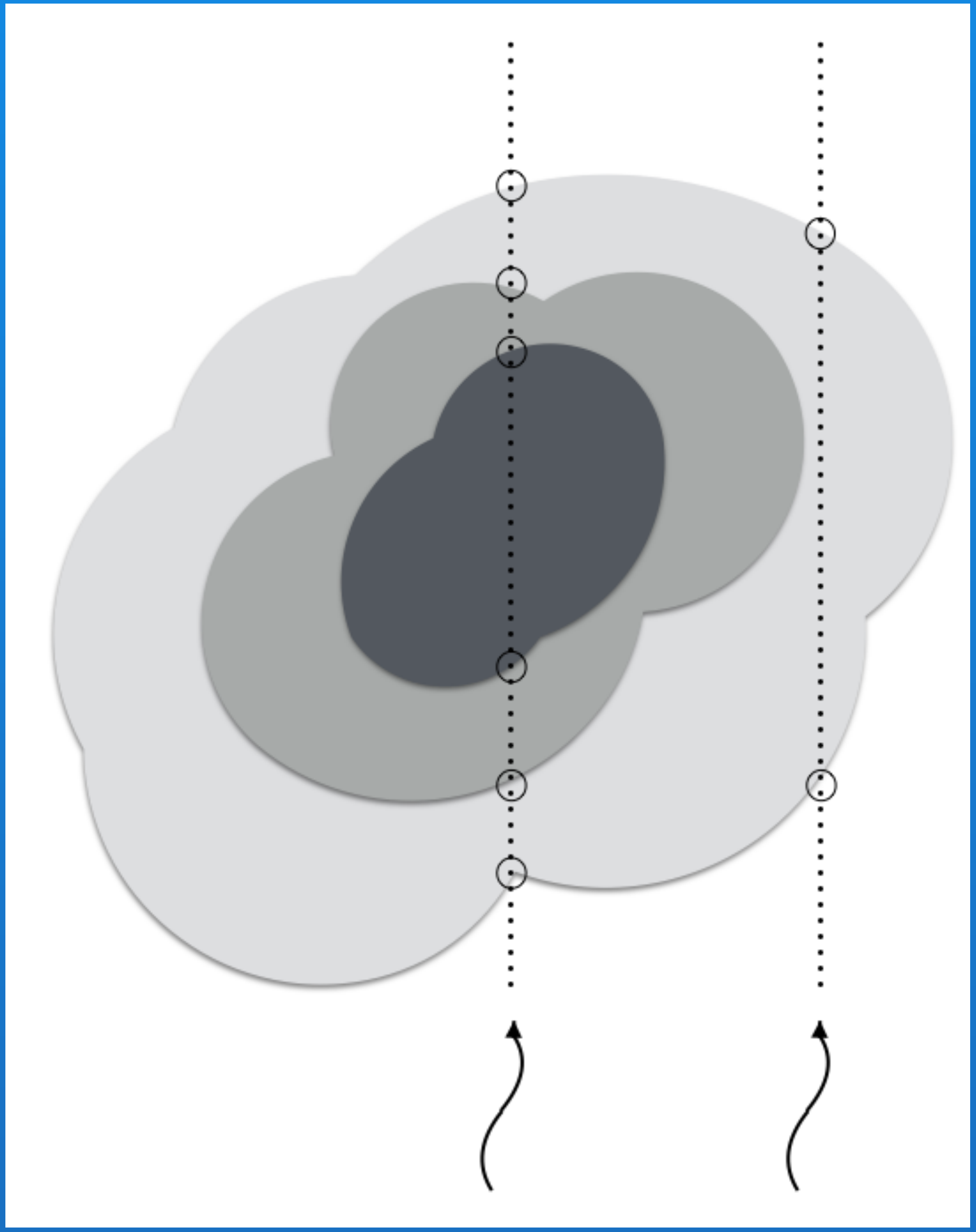
LINE OF SIGHT TEMPERATURE VARIATIONS



$$\sigma^2_{T_N} = \frac{\sum (T_{data} - T_{col})^2 N_{inp}}{\sum N_{inp}}$$

LINE OF SIGHT TEMPERATURE VARIATIONS

- Consider 2 lines of sights
- Central line of sight intersects larger number of density variations than line of sight on the right
- Presents greater opportunity for photon absorb/scatter
    - Therefore less likely to heat the dust in regions of greater column density
    - Produces temperature variations along the line of sight



CONCLUSION

- Clear that line of sight temperature variations are present
  - Renders the single T fit (isothermal line of sight assumption) inaccurate
  - This produces overestimates of T and underestimates of N (when using χ^2 minimisation test)
- Extracted cores number less from χ^2 than from ‘true’ values
  - Knock on effects also observed in the mass: χ^2 masses significantly lower than ‘true’ masses
- Expected power law tail in PDF of N observed
  - Attributed to presence of gravitationally bound material

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