SED-Fitting of Pre-Stellar Clumps in the Census of High- & Medium-Mass Protostars (CHaMP) Survey: First Look

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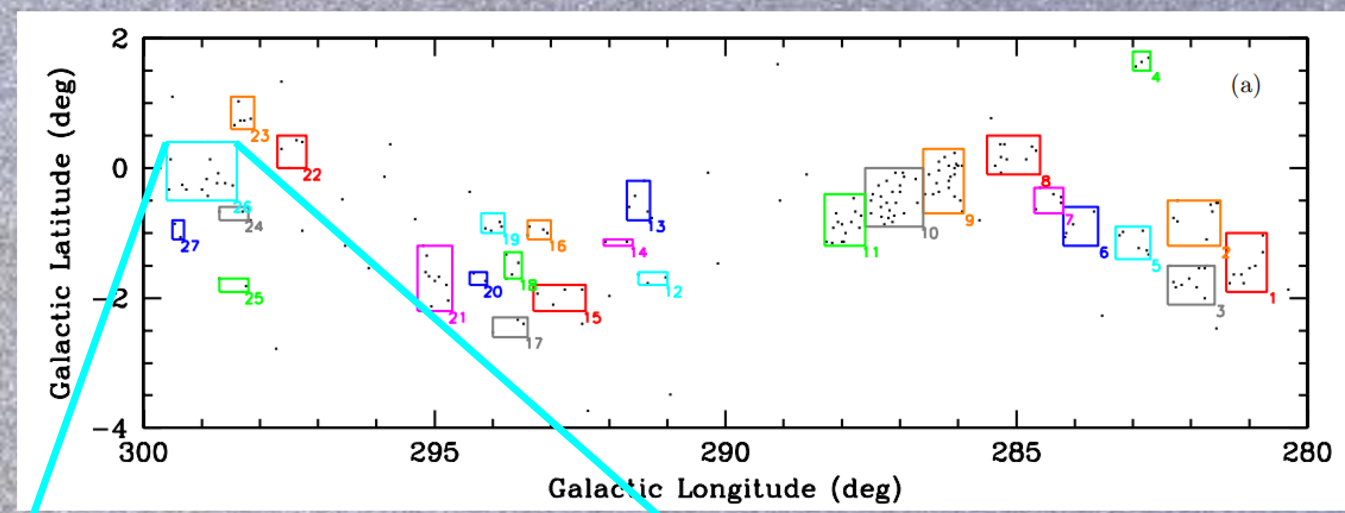
Rationale

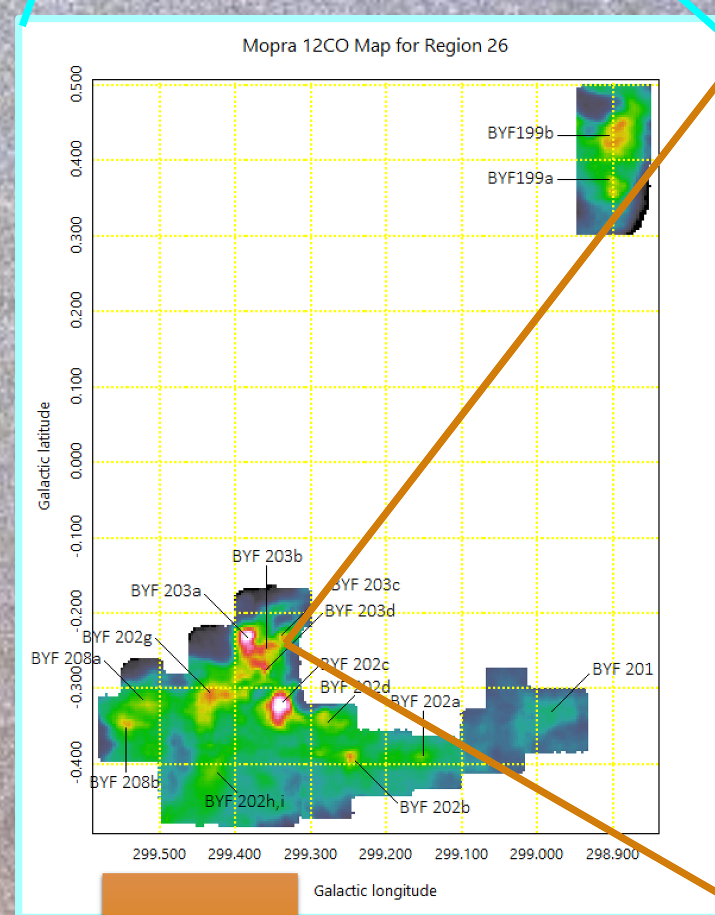
We seek to derive the temperatures and column densities of H_2 using dust emission as a tracer, and compare these to similar quantities derived from ^{12}CO emission to compare the effectiveness of the two H_2 tracers and detect variations in the abundance of ^{12}CO throughout the Census of High- and Medium-mass Protostars (CHaMP). The physical and chemical properties of high-mass star-forming clouds are poorly understood compared to low-mass star-forming regions. Results from Barnes+2015, Kong+2015, and Narayanan and Krumholz 2014 suggest the amount of H_2 not traced by CO ("CO-dark" gas) may be overstated due to improper characterization of the conversion from ^{12}CO line intensity to H_2 column density, as I_{CO} and N_{CO} may be better related by a power law than a constant X_{CO} factor. Here we use data from Herschel PACS and SPIRE, APEX LABOCA, and MIPS 24um to start testing those results independently.

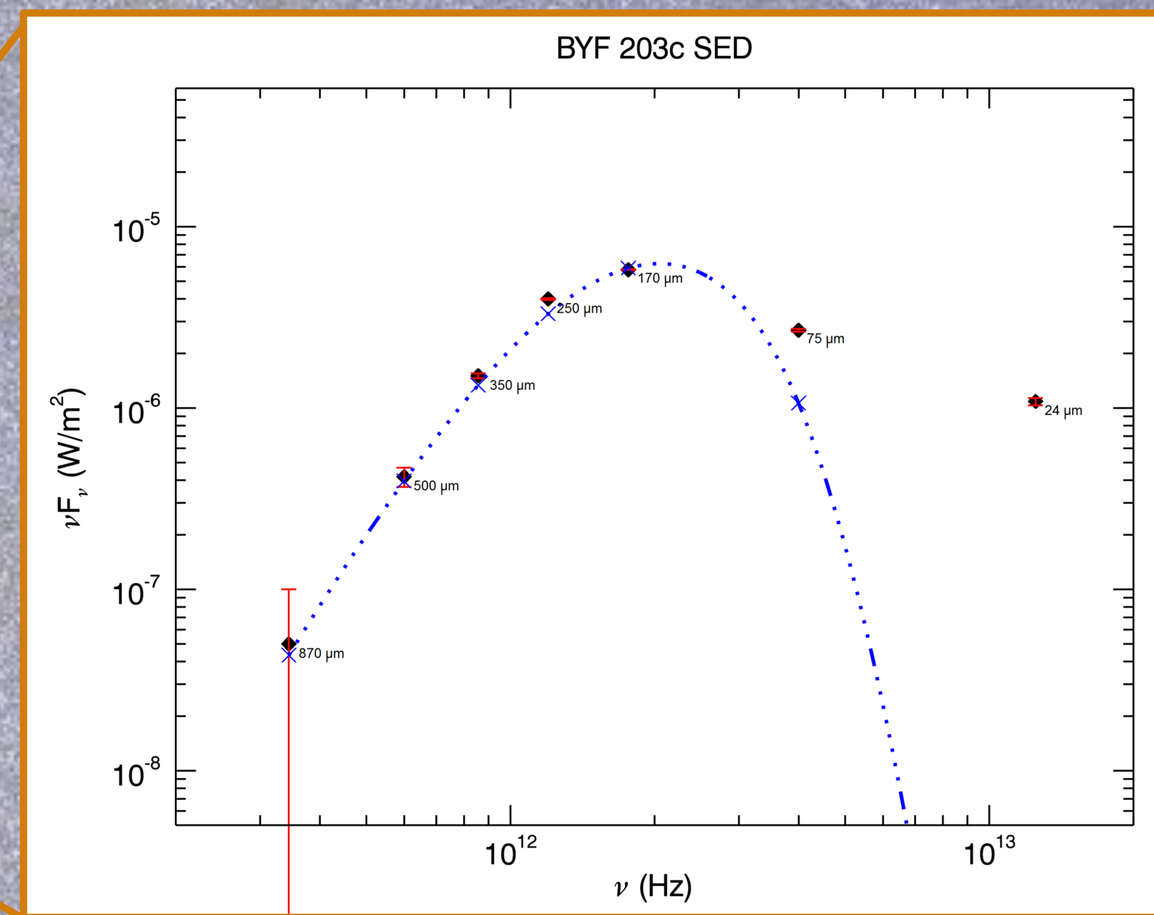


Left: Map of the CHaMP survey area, with 27 areas of interest identified. Here we focus on Region 26

Below left: Mopra ^{12}CO J(1→0) maps of Region 26 with clumps labeled

Below: Sample SED fit. PAH emission at high frequencies will be addressed later





Methods

We begin by choosing a test region—Region 26 (see above, right)—convolving the data to 37", and fitting pixel-by-pixel single-temperature greybody spectral energy distributions to dust emission of the form:

$$F(\nu,T) = \frac{N\kappa_0 \mu m_H}{\delta}\left(\frac{\nu}{\nu_0}\right)^{\beta} B(\nu,T), \text{ where}$$

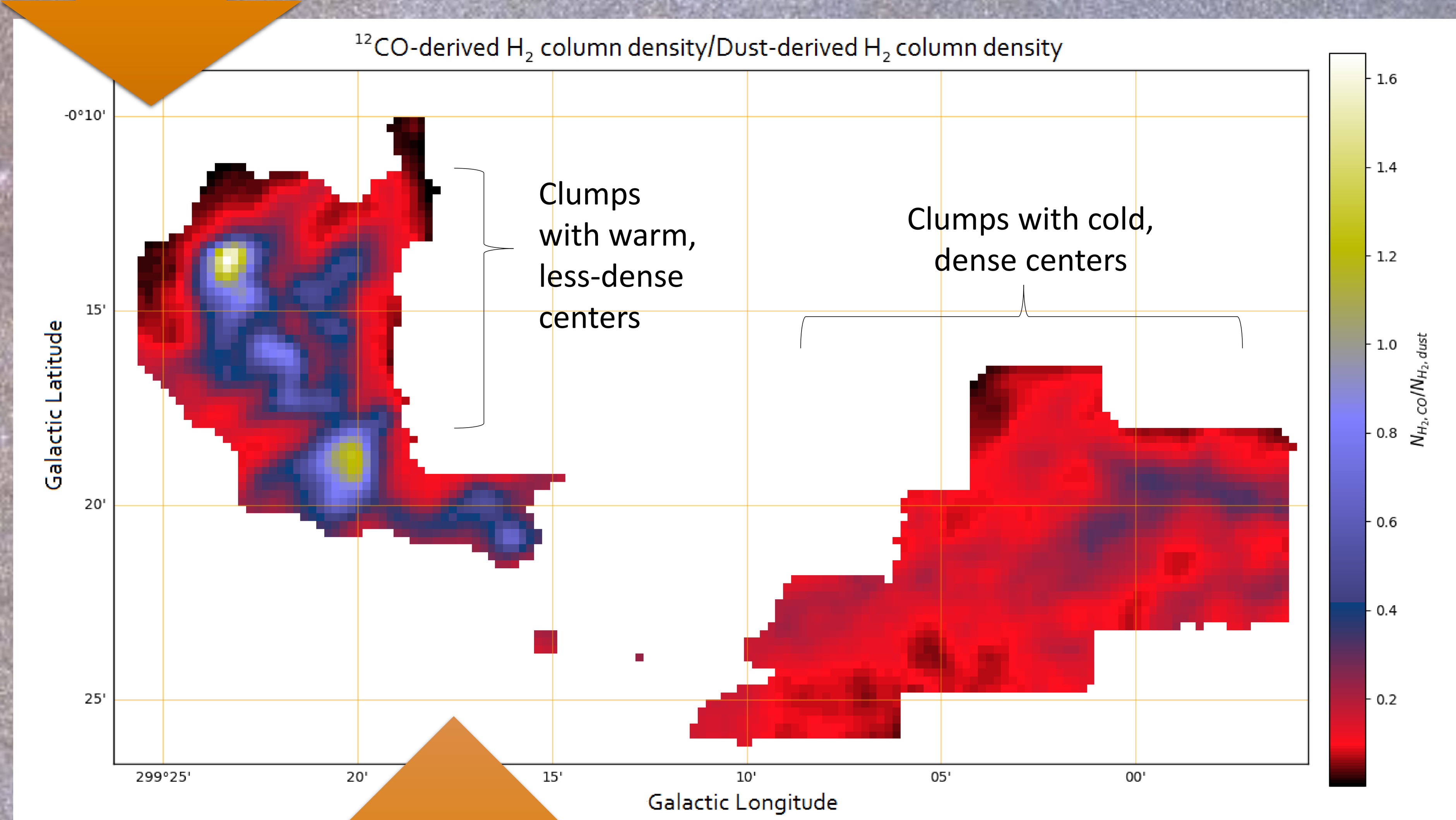
- **N** = H_2 column density,
- $\boldsymbol{\kappa_0}$ = dust opacity at a fiducial frequency $\boldsymbol{\nu_0}$ (0.55 m^2/kg at 250 μm*)
- **β** = dust emissivity index (fixed at 1.8*),
- **δ** = gas-to-dust ratio (fixed at 162†)
- **μ** = mean molecular weight per H_2 molecule (~2.8), and
- $\mathbf{m_H}$ is the mass of the hydrogen atom.

Diffuse background was crudely filtered by subtracting the minimum positive flux value at each wavelength over a relatively featureless area identified by visual inspection‡. Only **T** and **N** were allowed to vary, as **T** and **β**, and **N** and **δ**, are degenerate, and since **β** is tied to $\boldsymbol{\kappa_0}$ and $\boldsymbol{\nu_0}$.

*Values from Planck Papers XIX & XXIX. Values from Herschel publications, with β=2.0 and κ_0=0.192 m^2/kg at 350 μm, were also tested, with slightly worse results

†From Zubko+2004, mean over all observation-based models

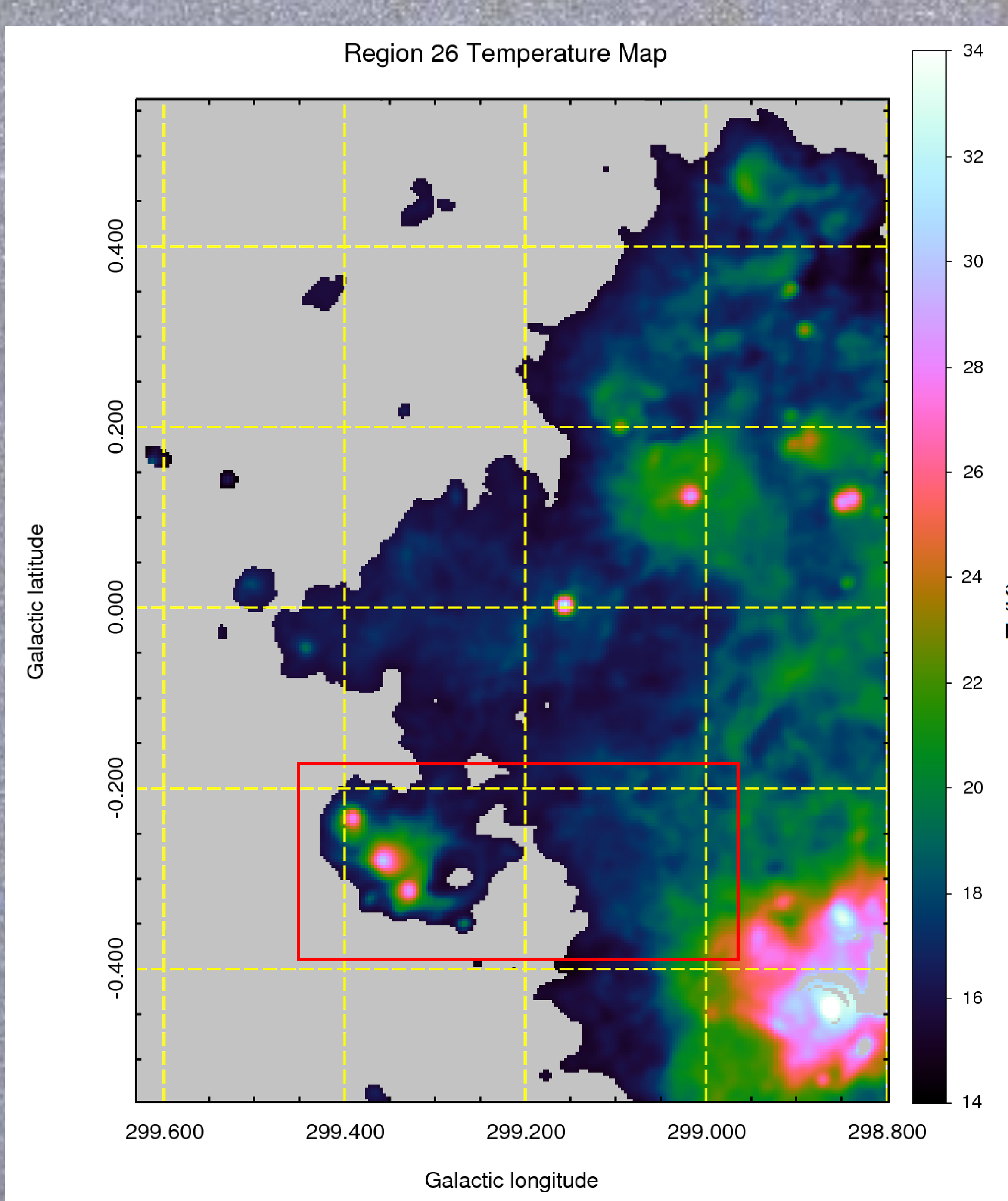
‡Subtracting the mean or median over the same area removed too many structures of interest

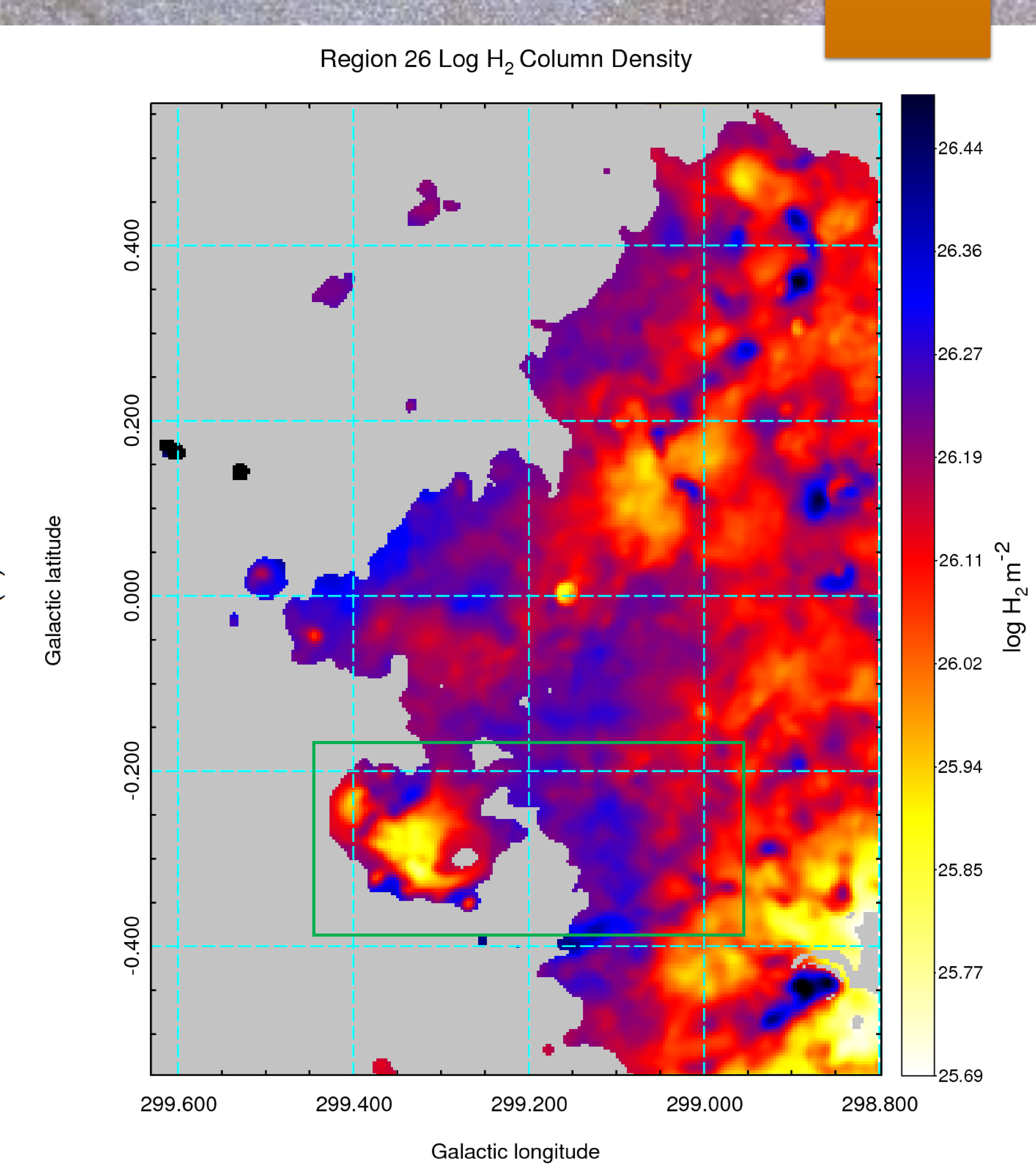


Above Right: Map of the ratio of dust-derived column density ($N_{H2,dust}$) to column density derived from ^{12}CO-emission ($N_{H2,CO}$) using a power-law I_{CO} to N_{CO} conversion and assuming $N_{CO} = 10^{-4}\ N_{H2}$. Field of view corresponds to red (left) and green (right) boxes in the maps below.

Below Left: Map of fitted blackbody dust temperature. Statistical errors are 0.2—1.1 K.

Below Right: Map of fitted $\log(N_{H2,dust})$. Statistical errors are ~0.01 dex.





Preliminary Results

- 2D structure of ^{12}CO maps recovered where data exist for both ^{12}CO and dust emission
- Mode of $\log(N_{H2}) \approx 26.2\ m^{-2}$; for high-mass star-forming regions, $\log(N_{H2})$ typically varies from 25.6 to 26.4 m^{-2} (Battersby+2017)
- Plot of $N_{H2,CO}/N_{H2,dust}$, with N_{CO} calculated using the power law prescription from Barnes+2015 for optically thick ^{12}CO, suggests:
  - Except where ^{12}CO is either optically thin or starting to dissociate into CI, **$N_{H2,CO}/N_{H2,dust}$ traces variations in CO abundance across the cloud relative to the standard 10^{-4} CO to H_2 number density conversion**. As the plot above shows, the correlation with $H_{2,dust}$ and temperature is not straightforward
  - **The inverse, $N_{H2,dust}/N_{H2,CO}$, effectively traces variations in the traditional X_{CO} factor across the cloud**
  - Gas-to-dust ratio may be varying instead, or also. Nonlinear least-squares fitting can't break the degeneracy with $N_{H2,dust}$, but an MCMC algorithm might.

References

Barnes, P. J., Muller, E., Indermuehle, B., et al. 2015, ApJ, 812, 6
Battersby, C., Bally, J., Svoboda, B., 2017, ApJ 835, 2, 263
Bianchi, S. 2013, A&A 552, A89
Kong, S., Lada, C. J., Lada, E. A et al. 2015, ApJ, 805, 58
Magrini, L., Bianchi, S., Corbelli, E., et al. 2011, A&A, 535, A13
Narayanan, D. & Krumholz, M., 2014, MNRAS 442, 2, p.1411-1428
Planck Collaboration, 2011, A&A, 536, A19 (Paper XIX)
Planck Collaboration, 2016, A&A, 586, A132 (Paper XXIX)
Zubko V., Dwek E., Arendt R. G., 2004, ApJS, 152, 211