Planck intermediate results. XXV. The Andromeda Galaxy as seen by Planck

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The Andromeda Galaxy (M31) is one of a few galaxies that has sufficient angular size on the sky to be resolved by *Planck*. We use colour ratios to investigate the dust heating method in M31, finding that the dust seen by Planck is heated by the diffuse stellar population. We fit SEDs to the individual pixels, measuring the dust temperature and mass before and after rescaling the SEDs to consider just the dust heated by the diffuse stellar population. We also measure the integrated SED, finding a large amount of free-free emission, and a 2.3σ marginal detection of AME.

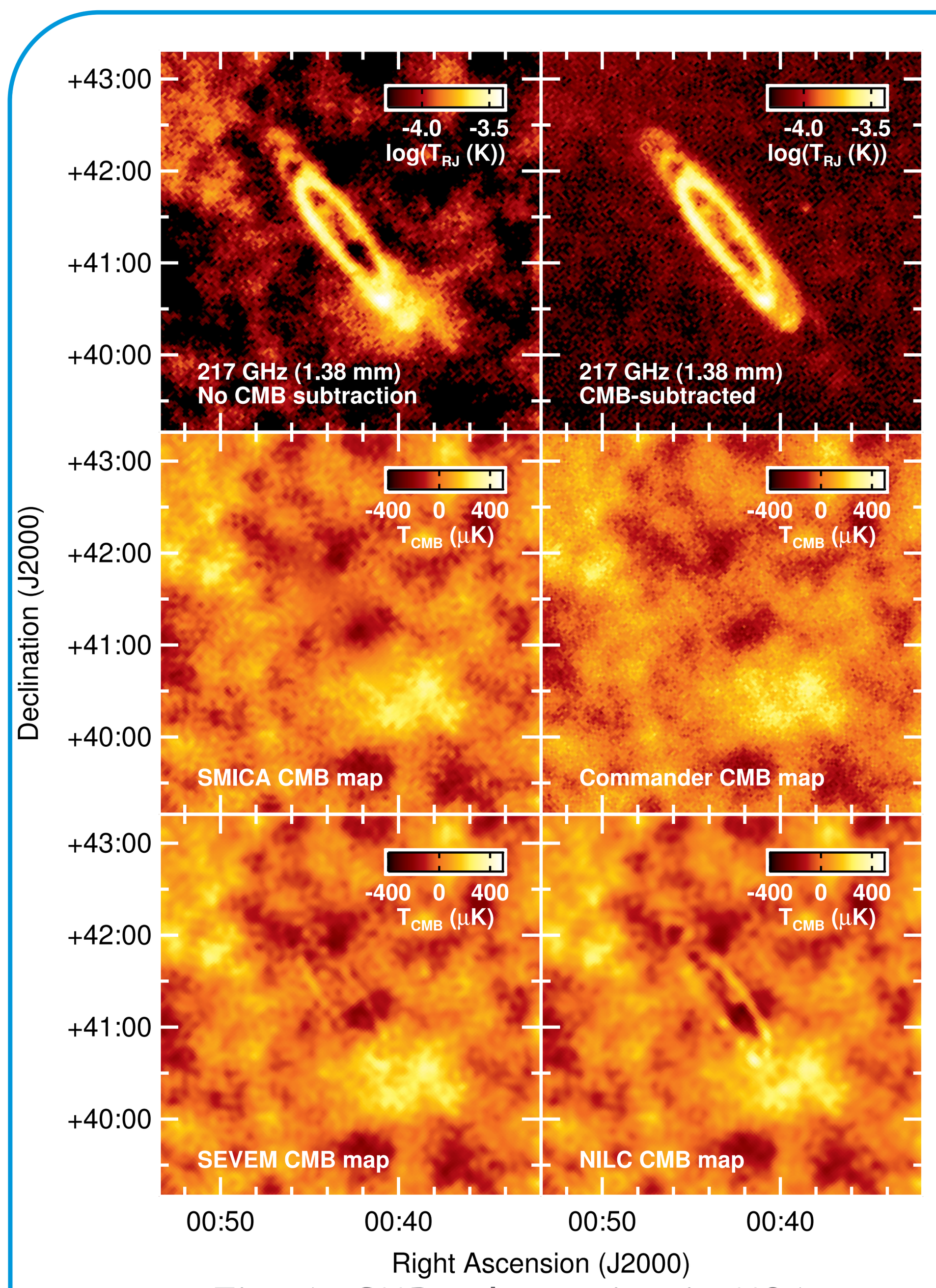


Fig. 1: CMB subtraction in M31

Accurate CMB subtraction is important for M31 given the similarities in angular scales between M31 and the CMB. Fig. 1 shows the different *Planck* CMB maps in the M31 region, and the SMICA CMB-subtracted 217 GHz (1.38 mm) map.

Fig. 2 shows the CMB-subtracted *Planck* maps. *Planck* has detected M31 in all wavebands and clearly resolves multiple spiral arms and sub-features at >100 GHz (<3 mm). A number of features are clearly visible, such as the outermost spiral arm structures at 545/857 GHz (550/350 μm; bottom-right of each panel), as well as NGC 205 and a bright background quasar.

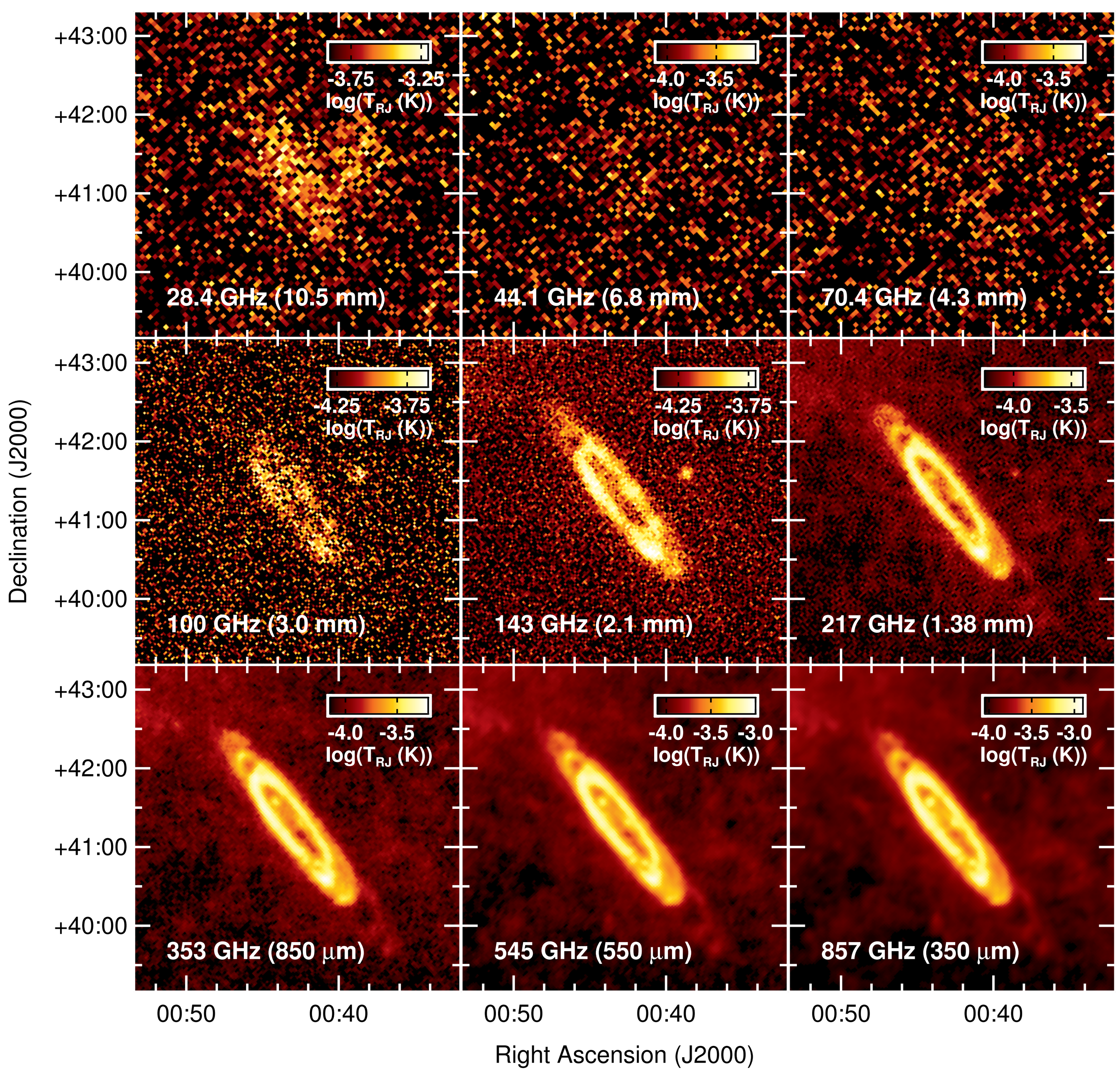


Fig. 2: CMB-subtracted maps at all *Planck* bands.

The integrated SED of M31, shown in Fig. 3, is well-fitted with a global dust temperature of 18.2 ± 1.0 K, a spectral index of 1.62 ± 0.11, and a significant amount of free-free emission at 20–60 GHz, which when converted into a star formation rate (SFR) agrees well with the Hα SFR of 0.4 $M_\odot\,yr^{-1}$. We find a 2.3σ marginal detection of spinning dust emission, with a 30 GHz amplitude of 0.7 ± 0.3 Jy, compared to the ~1 Jy expected from Galactic AME-100 μm ratios.

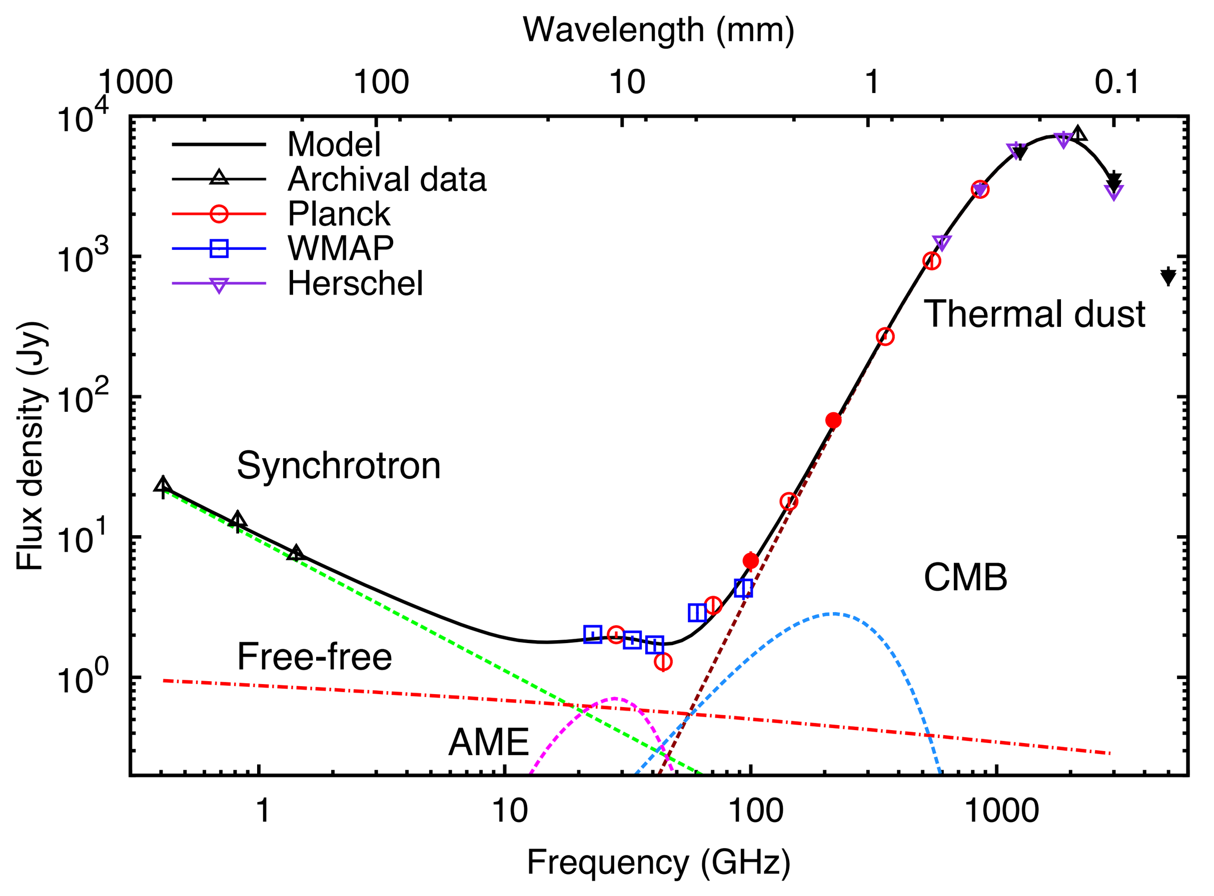
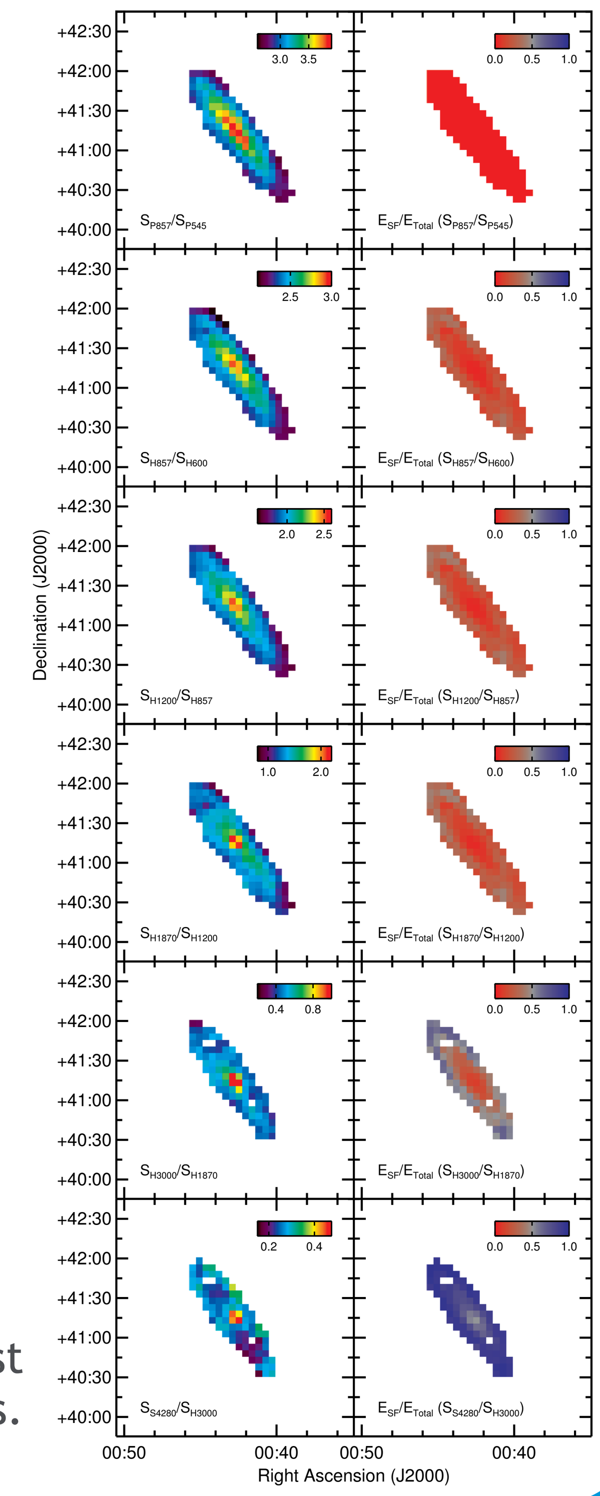


Fig. 3: The integrated SED of M31.

We investigate the dust heating mechanism across M31. By comparing the colour ratios between *Planck* and Herschel bands with Spitzer 3.6 and 24 μm data, we find that dust dominating the longer wavelength emission (>0.3 mm) is heated by the diffuse stellar population (as traced by 3.6 μm emission), with the dust dominating the shorter wavelength emission heated by a mix of the old stellar population and star-forming regions (as traced by 24 μm emission).

Fig. 4 shows the colour ratios for various bands (top row), and the fraction of the emission that is attributable to star formation in each colour ratio (bottom row) for the *Planck* and Herschel data; only the last ratio is dominated by the star-formation contribution.



Right: Fig. 4: Identifying the dust heating mechanisms.

We also fit spectral energy distributions (SEDs) for individual 5′ pixels and quantify the dust properties across the galaxy, taking into account the different heating mechanisms. Two examples of these are shown in Fig. 5 for pixels in the nuclear region (top) and the northern edge of the 10 kpc ring (bottom). Red points are the flux densities measured in the pixels; blue points are the flux densities after rescaling using the colour ratios to only fit the cold dust contribution. In the nuclear region these two are the same; in the ring there is a difference between the two, which represents a decrease in temperature from 16.2 K to 15.5 K, and a 10 % increase in dust mass.

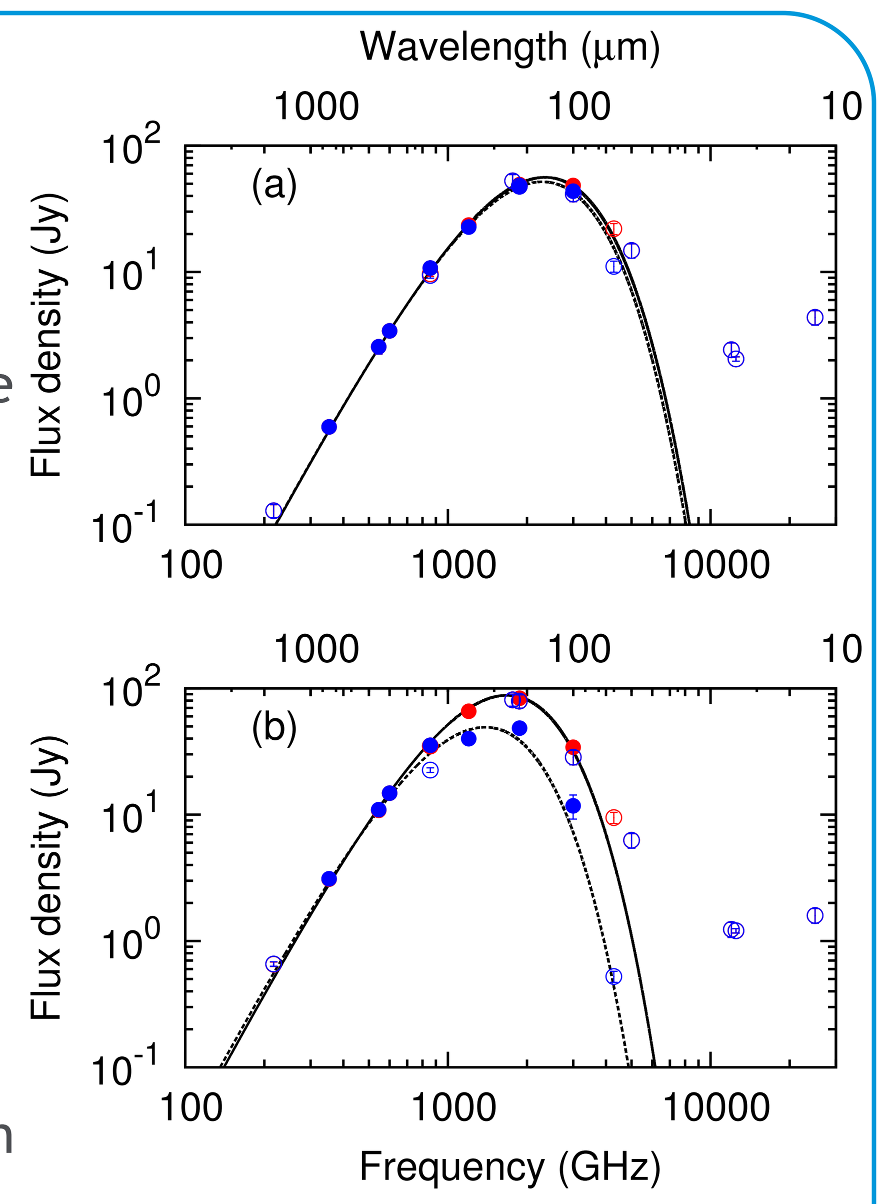


Fig. 5: SEDs of individual pixels.

The fitted dust parameters for the rescaled SEDs, with a fixed spectral index of 2.0, are shown in map form in Fig. 6. We find that there is a linear decrease in temperature with galactocentric distance for dust heated by the old stellar population, as would be expected, with temperatures ranging from around 22 K in the nucleus to 14 K outside of the 10 kpc ring. We have also used a variable spectral index to fit the data, and find that the spectral index traces the heating from the old stellar population rather than measuring the dust grain properties.

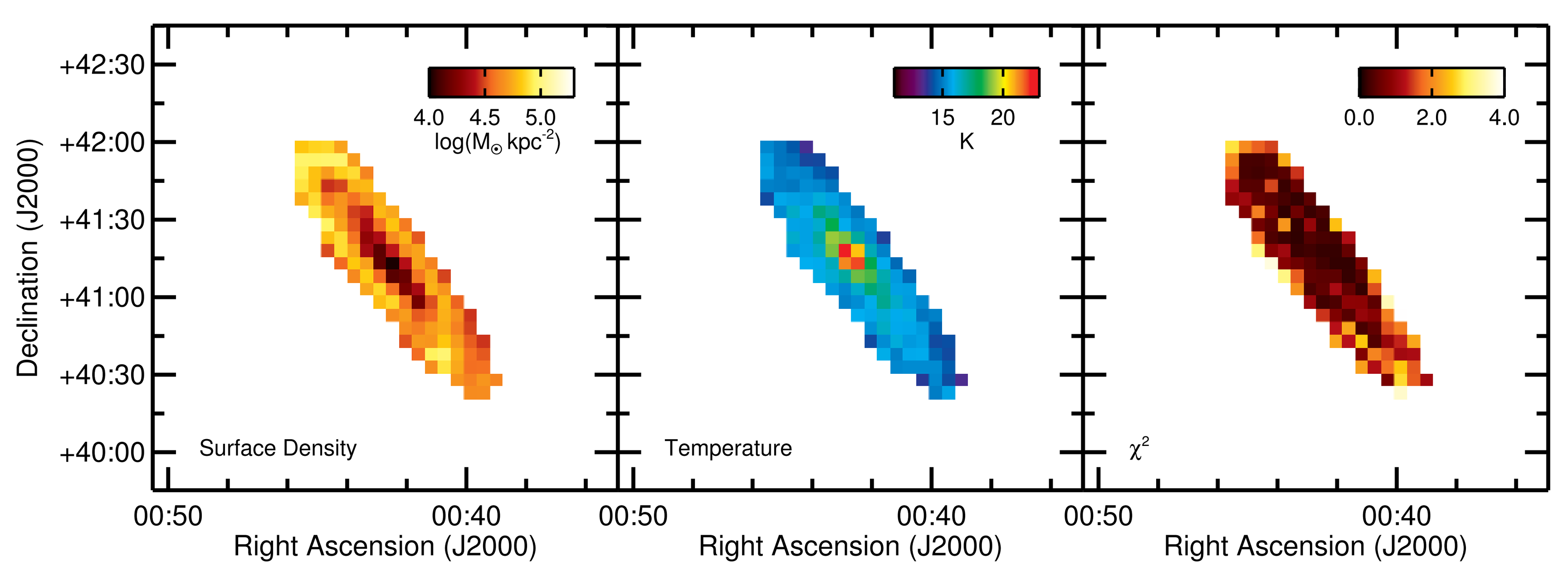


Fig. 6: Fitted dust parameters to the cold dust.

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