NIKA2 Observations and 3D Modeling of L1506C, a prestellar core in the making

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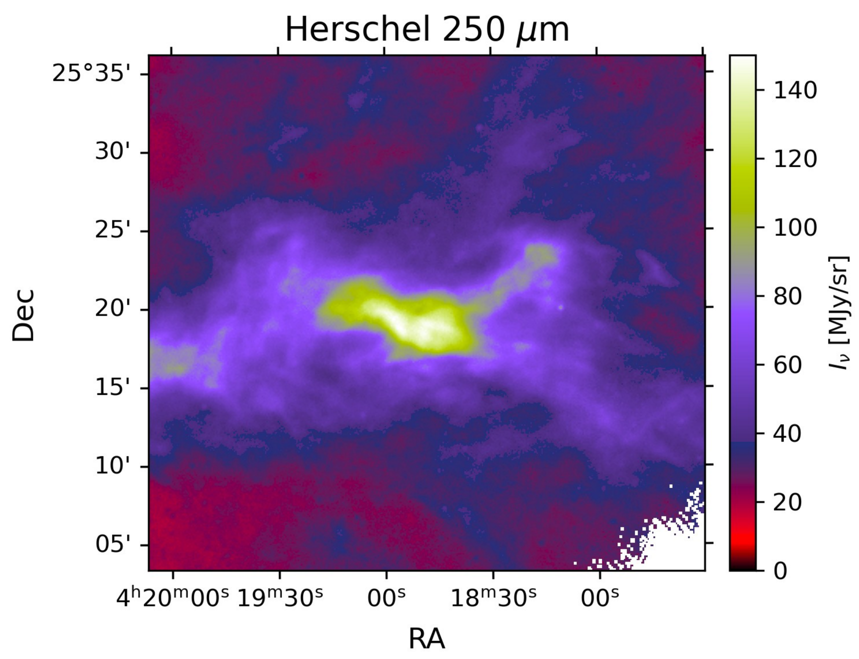
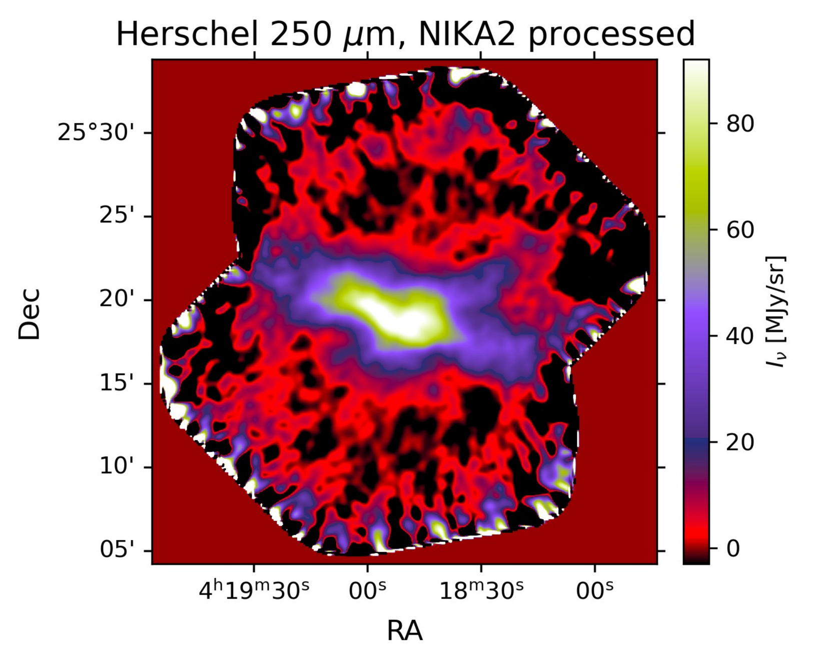
MOTIVATION

Stars are formed by the collapse of cores within molecular clouds but the precise mechanisms driving this process remain poorly understood. At the initial stage of star formation, structures such as filaments, condensations, and prestellar cores are formed and can be studied with the observation of thermal dust emission in the far-infrared (FIR) and millimeter (mm) wavelength range. Consequently, the estimated core properties derived from these observations are strongly influenced by the assumed dust properties. Therefore, it is essential to first characterize the dust properties thoroughly to study the initial conditions of star formation accurately.

DATA AND METHODOLOGY



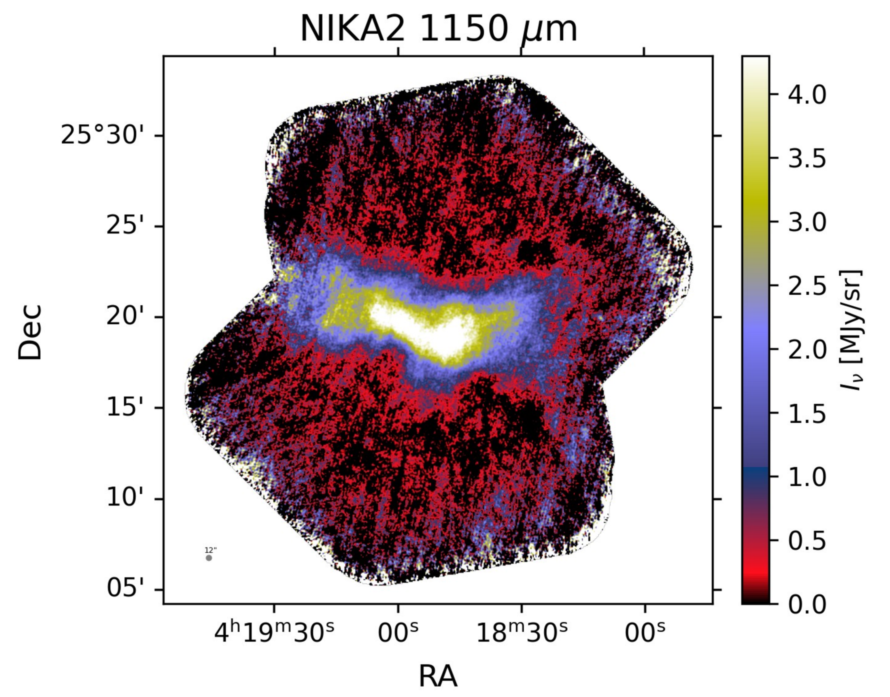
Herschel 250μm before filtering



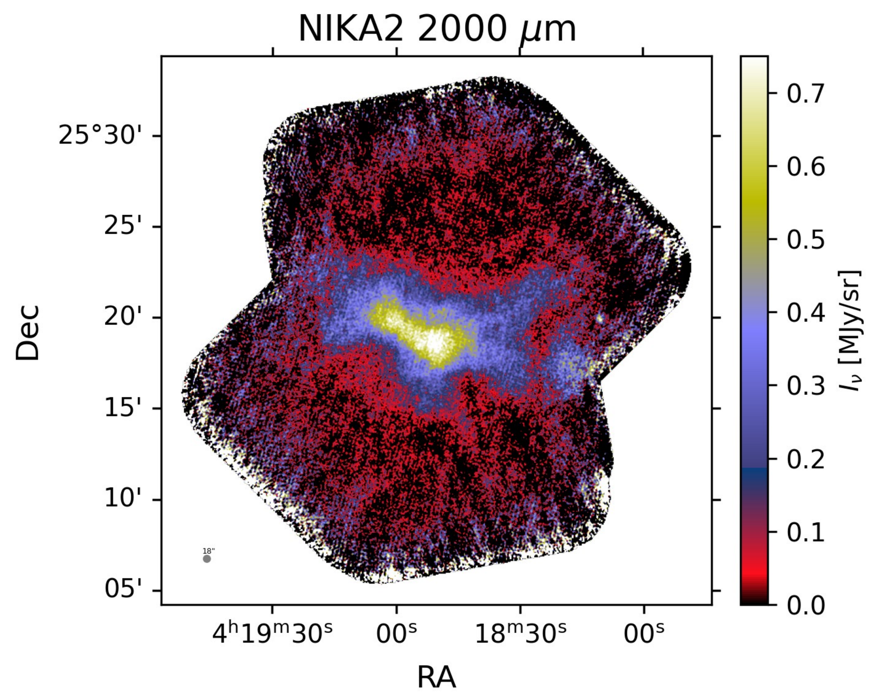
Herschel 250μm after filtering

We used both ***Herschel* FIR** observations (SPIRE and PACS 160 μm) and new complementary observations in the **mm** wavelength with the **NIKA2** camera of the IRAM-30m telescope that better traces the emission of cold and large grains. To combine these space-born and ground base data, we used the innovative method scanam_nika[4] to filter out the extended emission that is observed with *Herschel*. This ensures that the two data sets are consistent with each other so that dust spectral energy distributions **(SED) on the whole spectral range** (160 μm – 2 mm) can be constructed. The SEDs analysis are performed with both MBB fits and the dust modeling software DustEM[5] using THEMIS(2)[6,7] dust models, after convolving all maps to 36" resolution. We also used WirCAM data in the *J*, *H*, *K* bands for extinction measurements. The data are also **modeled in 3D** with the radiative transfer code SOC[8] using THEMIS(2) dust models.

TARGET: L1506C



NIKA2 1.15 mm map (beam size 12")

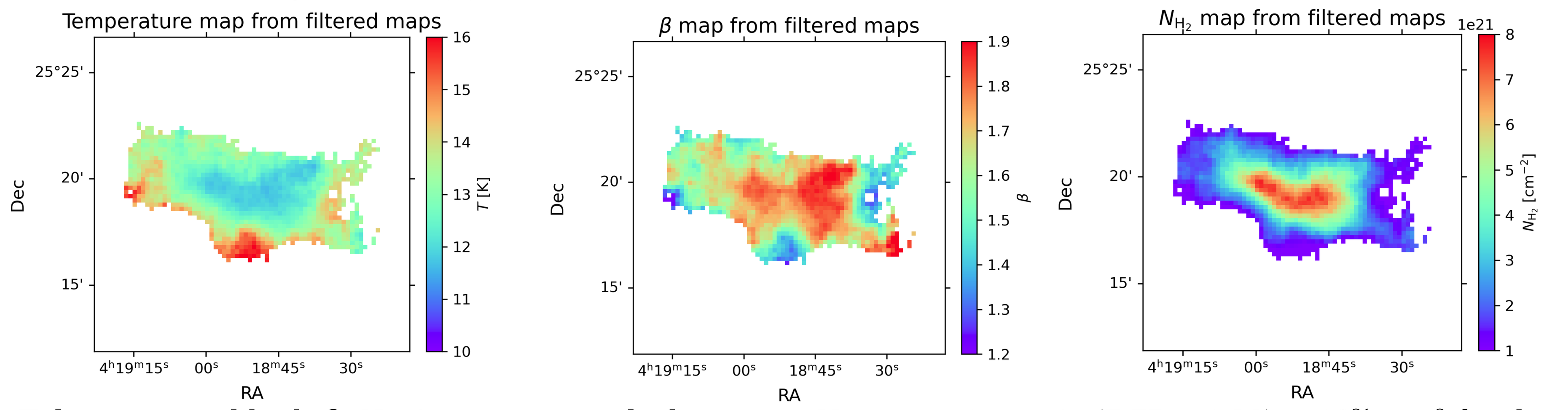


NIKA2 2 mm map (beam size 18")

L1506C is a fragment of the long filament L1506 in the Taurus molecular cloud (D ~ 140pc) . It is contracting with a low density $n_{H2} \leq 5 \times 10^4$ cm^{-3}, suggesting that it is in the process of **forming a prestellar core**[1]. Previous observations have revealed a significant increase in dust opacity in the densest part compared to the surrounding diffuse filament, which was interpreted as a result of **grain growth**[2,3].

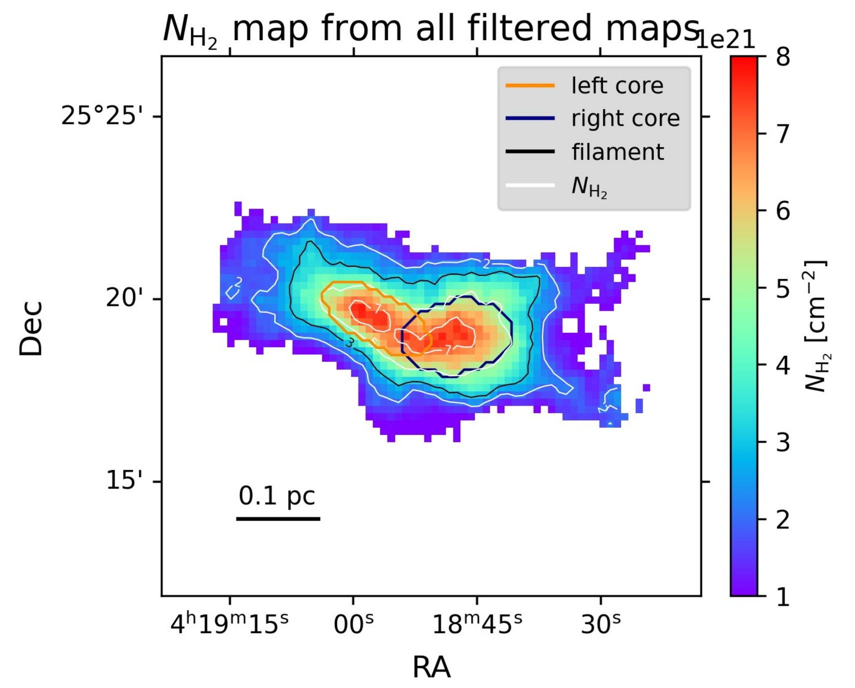
RESULTS: MAPS FROM MBB FIT

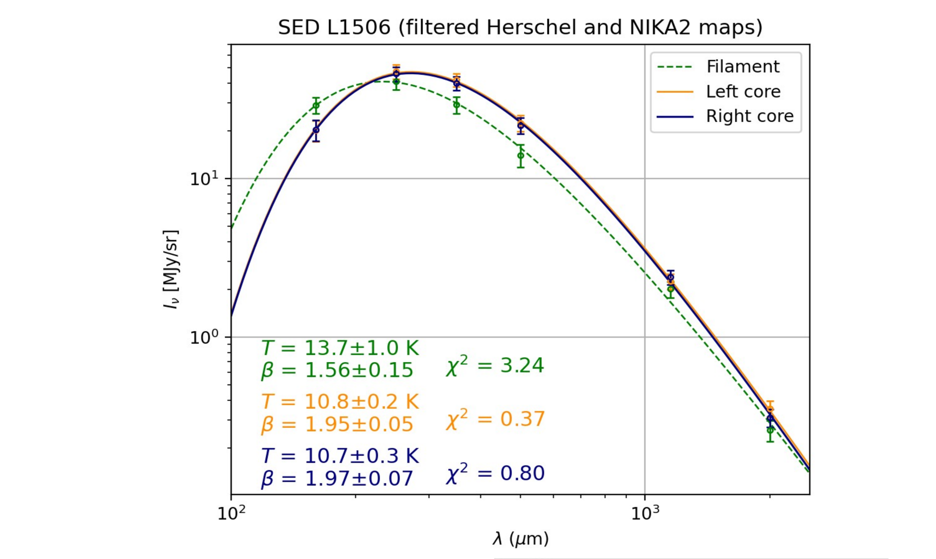
SEDs of L1506C are fitted pixel by pixel with a modified black body (MBB) function: $I_\nu \propto \nu^\beta B_\nu(T)$, with both the spectral index β and temperature T as free parameter. We focused on the area with SNR > 4 at all wavelength bands. The column density map is then calculated based on the fitted T and β with the following function: $N_{H2} = I_{250} / \mu m_{H2} \kappa_{250} B_\nu(T)$, with κ_{250} from Beckwith et al. (1990, B90 hereafter)[9].



T decreases and both β, N_{H2} increase towards the center. N_{H2} at maximum is (7.75 ± 1.29) × 10^{21} cm^{-2} for the left core and (7.67 ± 1.38) × 10^{21} cm^{-2} for the right core, which are not dense. T seems to be hotter at the southern edge, which might be due to anisotropic irradiation field or asymmetric cloud profile. These possibilities will be studied with 3D modeling. Typical T/β uncertainties are ±3.9K/±0.4 on the map edges and ±0.2K/±0.1 in the center.

RESULTS: CORE PROPERTIES





left core	filtered maps (B90)
$n(H_2)$ [cm^{-3}]	(5.17 ± 0.75) × 10^4
N_{H_2} [cm^{-2}]	(5.80 ± 0.84) × 10^{21}
M [$M_\odot$]	0.79 ± 0.12

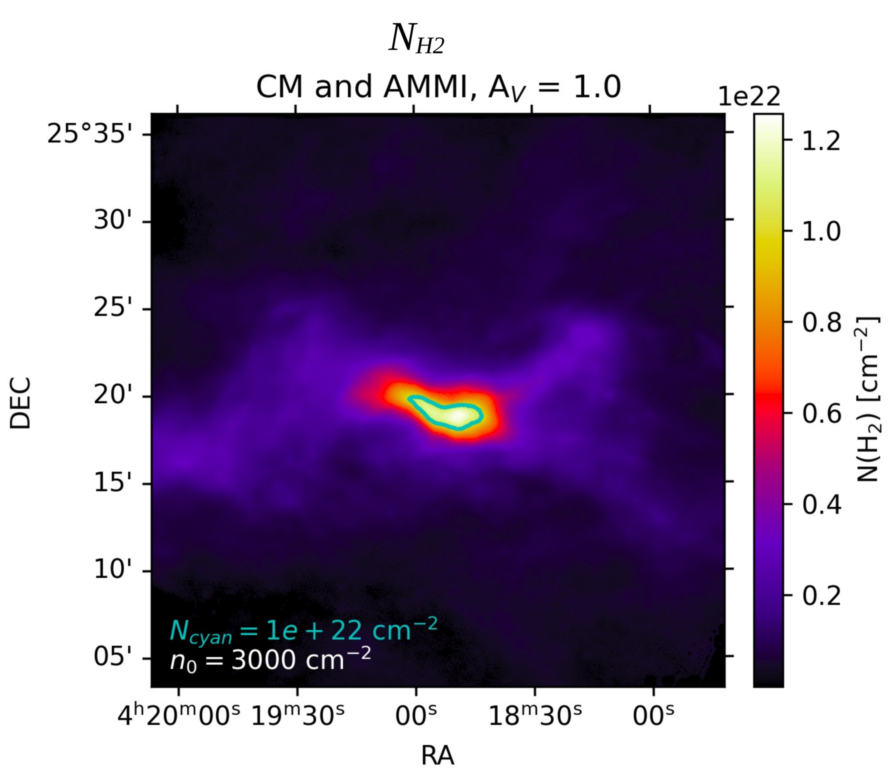
right core	filtered maps (B90)
$n(H_2)$ [cm^{-3}]	(3.49 ± 0.65) × 10^4
N_{H_2} [cm^{-2}]	(5.70 ± 1.06) × 10^{21}
M [$M_\odot$]	1.03 ± 0.19

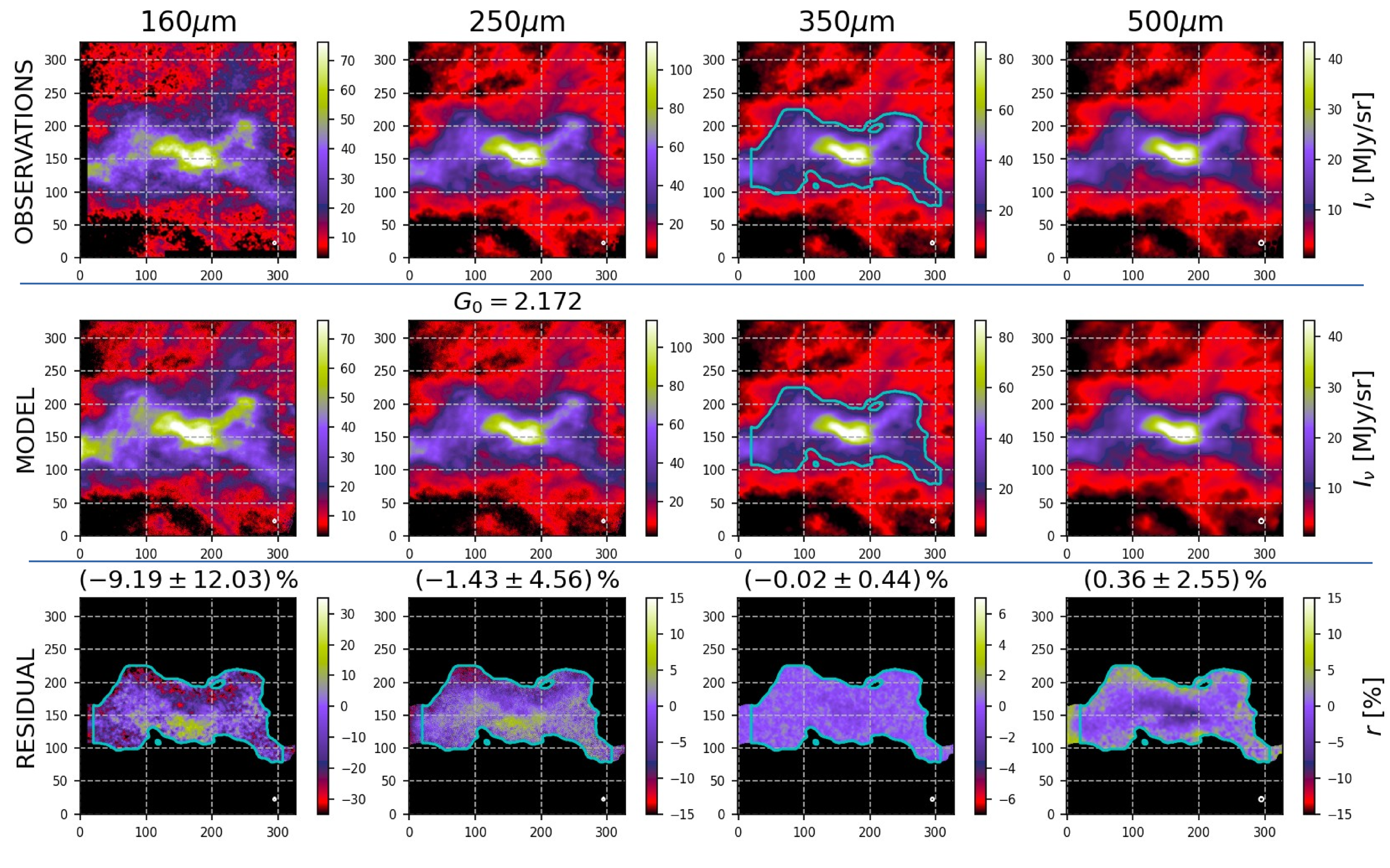
L1506C seems to fragment into two cores at the scale of *Herschel* and NIKA2. We manually fitted two ellipses according to N_{H2} (white inner contours) and define them as the left and right core with $N_{H2} \geq 5 \times 10^{21}$ cm^{-2}. We also defined an outer filament region with $N_{H2} \leq 3 \times 10^{21}$ cm^{-2} (regions outside the black contour). The SED of the three sources are fitted with MBB function.

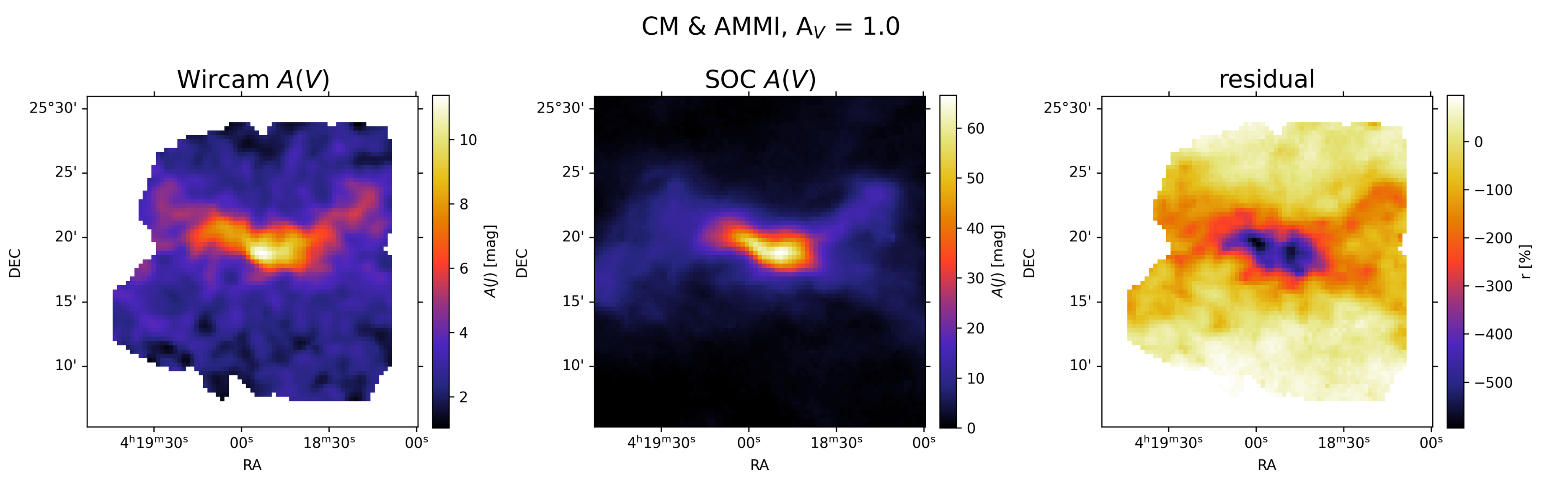
The two cores have similar T and β values, with masses smaller than their virial mass (1.5 M$_\odot$ for the left and 1.7 M$_\odot$ for the right core), indicating that the collapse has not yet started. The filament has higher T and lower β than the cores, showing that dust has **different properties** at these regions that might indicate **possible grain growth** in the dense part. β of the filament is close to the value of the diffuse interstellar medium[10].

RESULTS: RADIATIVE TRANSFER MODELING

We also used the 3D radiative transfer modeling software SOC[8] to model the cloud. The cloud density profile is modeled with a Plummer function with r_0=0.04 pc and r^{-2}. The cloud is modeled with two dust components from the THEMIS dust model[6]: diffuse-type dust in the outskirts (CM) and icy aggregates in the center (AMMI) with a transition threshold n_0 = 3000 cm^{-3}. The radiation field is the ISRF[11] attenuated by an outer extinction A$_V$ = 1 mag. SOC adjusts 1) the density structure by fitting the observed intensity at 350 μm and 2) G$_0$ by the intensity fraction between 250 μm and 500 μm. The input *Herschel* SPIRE maps are at their nominal resolution (18", 25", 36" respectively), while the PACS map is smoothed to 18".







The modeled cloud shows **good agreement** with the *Herschel* maps. The modeled N_{H2} and n_{H2} (3.4×10^4 cm^{-3} at maximum) both agree with estimation from molecular line observations ($N_{H2} \leq 2 \times 10^{22}$ cm^{-2} and $n_{H2} \leq 5 \times 10^4$ cm^{-3})[1]. However, **A(*V*) is strongly overestimated** by a factor up to 6.7 compared with Wircam observation. This is due to the fact that in the current model, the LOS structure is dominated by aggregates with high A(V)/N_H = 2.6×10^{-21} cm^2 (5.3×10^{-22} cm^2 for diffuse dust)[12].

CONCLUSIONS AND PERSPECTIVES

- It is **difficult to simultaneously constrain both emission and extinction**.
  - Perform modeling over a grid parameters values, e.g., cloud shape, dust properties, n0, anisotropic irradiation field, A$_V$, etc.
  - Compare modeled emission at 1.15mm and 2mm with the NIKA2 observations
- Millimeter observations help reveal **evidence of grain growth** in L1506C and better constrain cloud properties
  - Extend the study to other prestellar cores at different galactic positions with various environments

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