High-resolution observations toward G191.51-0.76

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Abstract:

Herschel and Planck, which operated in the far-IR and sub-mm, could detect cold, dense clouds in emission throughout the Galaxy. This offered the opportunity to search for star forming clumps in the outer Galaxy and to investigate whether their physical structure, fragmentation, star formation efficiency, and gas dynamics are similar to those found in the Inner Galaxy. G191.51-0.76 is a cold core detected with Planck in the outer Galaxy. It has a network of filaments converging into a central massive clump (hub-filament system), and it does not show 70 micron sources making it a precursor of previously reported hub-filament systems such as IRDC SDC13. We observed the continuum and HNC, ^{13}CS and N_2H^+ and HNC (1-0) emission toward G191.51-0.76 with ALMA Band 3 to determine its physical properties, fragmentation and gas dynamics. We identified two main dense fragments, corresponding to the Herschel clumps. They show different evolutionary stages based on their chemical properties. Future deuteration studies will help us to better understand their chemical age and evolution.

The target of this study is PLCKECC G191.51-00.76. We have selected this source from the Planck Early Cold Cores (ECC, Planck Collaboration 2015) catalogue focusing on the objects detected in emission in the outer Galaxy (within the third and fourth quadrants) and which were observed within the Herschel Hi-GAL project. Its T_{dust} is <15K, and it does not show strong evidence for already formed stars (in the form of 70 um point sources). It is located in the galactic anti-center direction. It is associated to the Lynds Dark Clouds at 400pc (Wang et al. 2017).

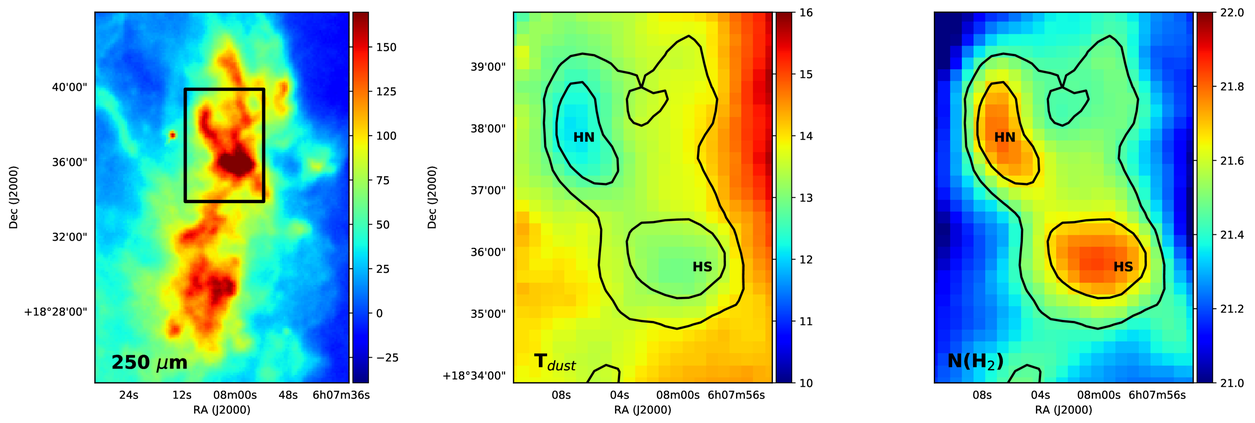


Fig. 1. Left) 250 um image of G191.51-0.76 as seen with Herschel Hi-GAL. Black asterisks indicate the 70 um sources in the area. Middle) Zoom-in figure of the dust temperature image of the cloud with the ALMA observed area in Band 3. Right) Herschel SPIRE based column density image of the observed region. Black contours show the N_1~2.85x10^{21} and N_2~4.57x10^{21} cm^{-2} column density levels (Zahorecz et al. 2016).

APEX and ALMA observations: As part of the ESO E-093.C-0866A project, we observed the ^{13}CO and C^{18}O (2-1) and N_2H^+ (3-2) transitions toward G191.51-0.76 with the APEX SHFI instrument. The region was observed with ALMA in Band 3 as project 2013.1.00584.S.

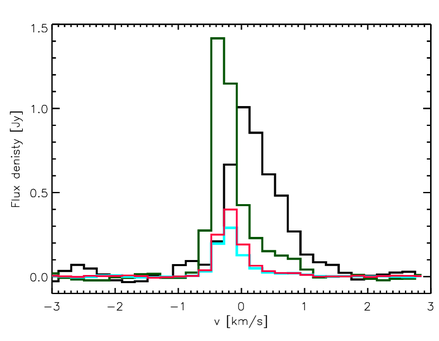
The spectral setup observed high-density gas tracers, see in the Table.

Sensitivity of ~0.1mJy per 3.033"x2.095" beam (with a positional angle of 67°) was achieved in continuum for the combined 12m and 7m array data, no emission was detected. For the spectral lines, we combined the calibrated visibilities from the 7m and 12m array for imaging. We used the CASA feather task to combine the interferometric and single dish TP observations. Images of the line emission with a 10" beam were created and used in this study. A sensitivity of ~10mJy/beam was achieved for the line observations for 0.23km/s bandwidth.

Species	Transition	Frequency [GHz]
HNC	J=1→0	90.663
CH_3CN	J=5→4 K=0,5	91.970
^{13}CS	J=2→1	92.494
N_2H^+	J=1→0	93.173
H_2CS	$J_{K1,K2}=3_{0,3} \rightarrow 2_{0,2}$	103.040
CCS	J=8→7	103.640
SO_2	$J_{K1,K2}=3_{0,3} \rightarrow 2_{0,2}$	104.029
C^{18}O	J=2→1	219.560
^{13}CO	J=2→1	220.398
N_2H^+	J=3→2	279.511

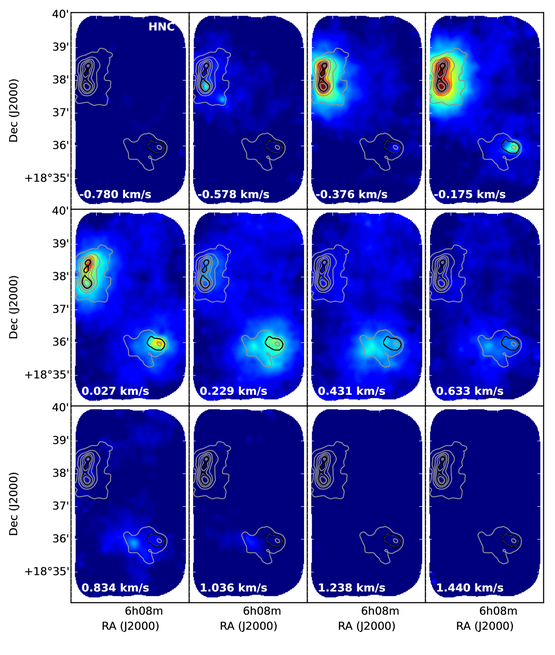
^{13}CO (2-1), C^{18}O (2-1), N_2H^+ (3-2), ^{13}CS (2-1) and HNC (1-0) emission was detected toward G191.51-0.76 with APEX and ALMA.

We identified 4 cores: N_1, N_2, N_3 and S. The FWHM values of the HNC line for them are 0.43 km/s, 0.43 km/s, 0.39 km/s and 0.85 km/s, respectively. Their Virial-masses are: 1.4, 1.6, 2.7 and 5.9 solar mass, respectively.



HNC spectra (top) for the cores and channel maps (right).

S core is the most evolved (no ^{13}CS and strong N_2H^+), N_1 is the youngest.



References and acknowledgement:

Planck Collaboration, 2015, A&A, 594, 28; Wang et al. 2017, ApJS, 230, 5; Zahorecz et al. 2016, A&A, 591, 105

This work was supported by NAOJ ALMA Scientific Research Grant Number 2016-03B. I.J.-S. acknowledges the financial support received from the STFC through an Ernest Rutherford Fellowship (proposal number ST/L004801).