CENTRE FOR ASTROCHEMICAL STUDIES

The dynamics of a young protostellar core

Ammonia emission in the Barnard 59 core

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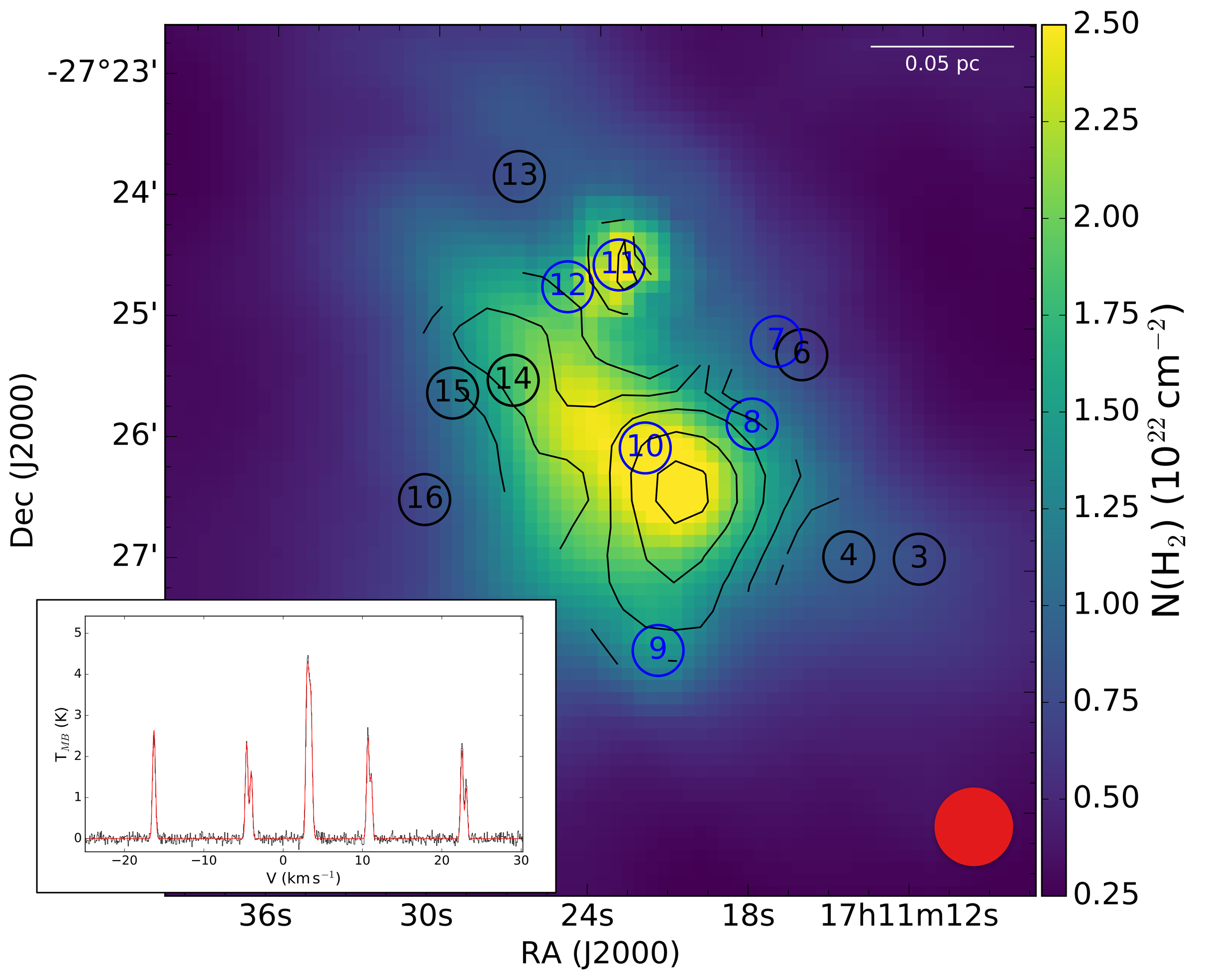
Introduction

B59 is the only part of the Pipe hosting active star formation, with about 20 known YSOs (Brooke et al., 2007), some of which -B11 in particular- are very young and are driving outflows (Duarte-Cabral et al., 2012).
We have investigated the core Barnard 59, at the very western end of the Pipe Nebula, using ammonia data of (1,1) and (2,2) inversion transitions, acquired as part of the GAS survey (Friesen, Pineda et al., 2017) at GBT. The data were smoothed to a 40'' beam size and regridded in order to increase the SNR. Spectra have been fitted according to standard NH_3 LTE analysis using GAS scripts. The free parameters are column density (presented in Panel 1), excitation (T_{ex}) and kinetic temperature (T_K, shown in Panel 2), V_{lsr} and velocity dispersion σ_V. Herschel SPIRE data of the Pipe Nebula have been used to derive T_{dust} and H_2 column density (Panels 1 and 3).
Our new data allowed us to obtain an unprecedented and comprehensive view of the dynamics and kinematics of B59, investigating in detail the YSOs feedback in the parental core (see Panel 4).

1. H_2 and NH_3 column densities



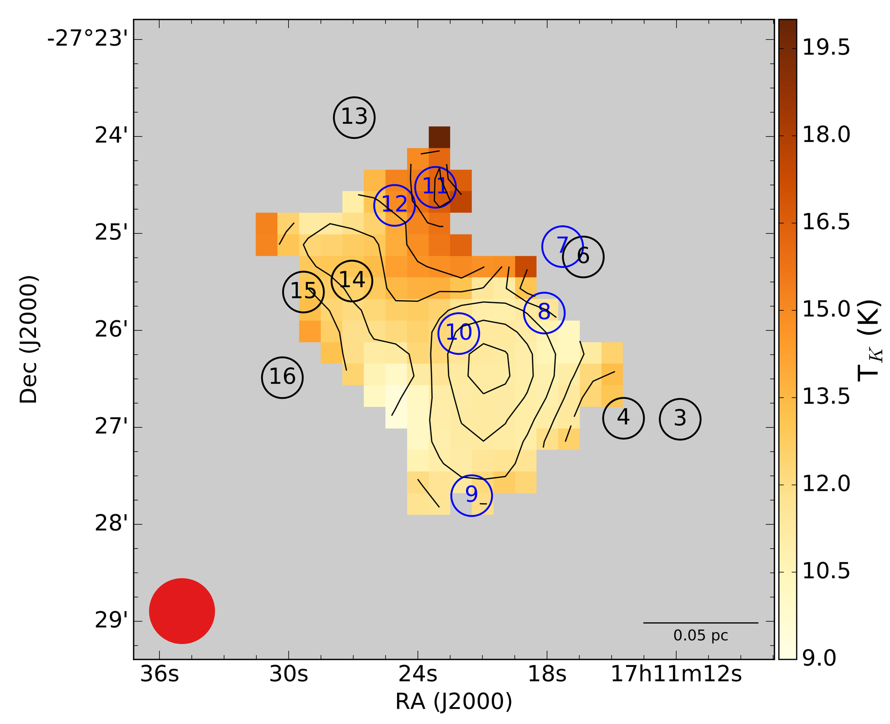
Main panel: $N(H_2)$ with log[$N(NH_3)$] contours (levels: [14.0,14.2,14.4,14.6,14.75]). YSOs positions are shown as numbered circles. Blue represents class 0/I, while black class II sources. *Bottom left:* Observed spectrum (black) and best-fit model (red) at the (1,1) emission peak.

- NH_3 is a good tracer of the cold gas, following well the H_2 structure;
- There is no correlation with the position of the YSOs, except for B11. The latter has a dense dusty envelope, which is not very prominent in ammonia;
- The mean ammonia abundance in the core is $X(NH_3)=(3.7\pm0.4)10^{-8}$.

2. Kinetic Temperature

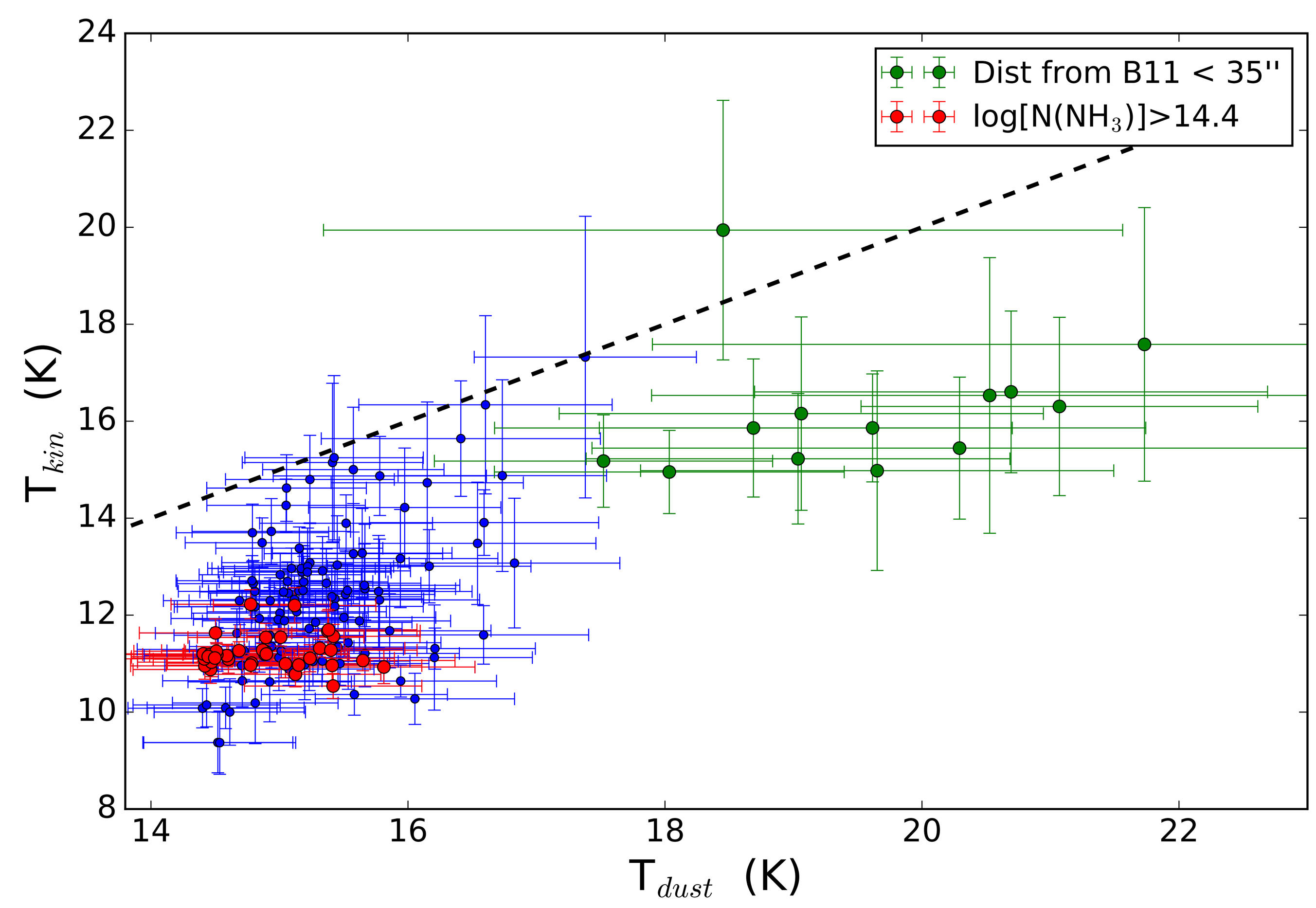
The T_k map shows that:

- The core densest part is also the coldest, with typical values of cold cores heated by external radiation field (Zucconi et al., 2001; Evans et al., 2001);
- T_K increases towards north, reaching 16-18 K at B11 position, suggesting that the young source is affecting the surrounding gas;
- These higher temperatures can explain NH_3 partial depletion in this area: at $T_{dust} \approx 20$ K (see Panel 3) CO starts to evaporate from dust grains, reducing the formation of ammonia precursors (Rodgers & Charnley, 2008).



Kinetic temperature map across the core. $N[NH_3]$ contours and symbols are the same as in the previous image.

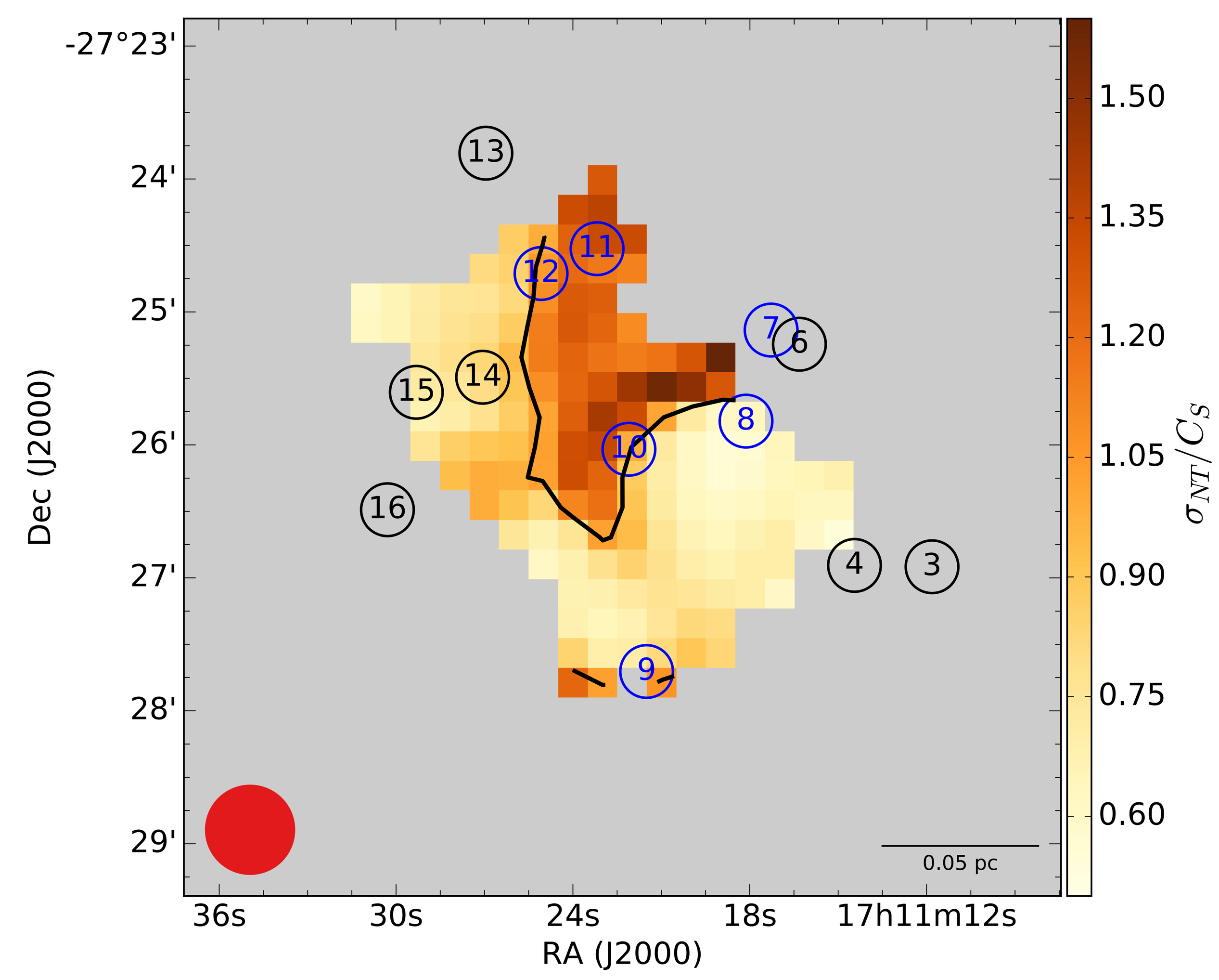
3. Dust and gas temperature



The scatter plot shows kinetic temperature versus dust temperature. The key features are:

- T_K is always $< T_{dust}$, due to a less dense and warmer back/fore-ground medium;
- Points from the cold core (in red) show an almost isothermal source, with $T_K \approx 11$ K;
- The region surrounding B11 (green points) is the hottest in both variables, requiring an extra source of heating (the YSO itself) besides the standard radiation field. This is in agreement with the possible partial release of CO in the gas phase, which can reduce NH_3 formation (see Panel 2).

4. Turbulence in the core



σ_{NT}/C_s map across Barnard 59 with YSOs positions indicated. The black line shows where the ratio is equal to 1.0, corresponding to the transition from subsonic to supersonic turbulence.

The σ_{NT}/C_s ratio was computed calculating thermal and non thermal velocity dispersion components and sonic speed from the T_k and σ_V maps. It is interesting to notice that:

- The densest and coldest part of the core is characterised by subsonic motions, and the ratio does not show much variation across it;
- The transition to mildly supersonic ones is sharp (within a beam size);
- There seems to be a correlation with YSOs evolutionary stages: class II sources are associated with subsonic motions, while younger objects are found in trans/super-sonic regions. This is likely due to the fact that class II objects are not embedded in the cloud and thus do not affect its energetics.

References

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