# IRAM 30 m observations of Serpens Main and Barnard 1b: gas temperatures and UV radiation around low-mass protostars

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During the earliest stages of star formation, the protostar is surrounded by a dense, collapsing envelope. In order to characterise the physical and chemical processes around protostars, observations at long-wavelengths are needed to overcome the dust extinction. At submillimeter range, there are many rotational lines of key molecules which are the tracers of the gas temperatures, densities, and the UV/X-ray radiation. Here, we analysed molecular emission from low-mass protostars in the Serpens Main and Barnad 1 regions using IRAM 30 m single dish telescope. Maps in HCN, CN, CS and their isotopologues revealed the presence of UV radiation associated with outflows from deeply-embedded protostars. We found that the strength of the UV radiation in these regions is a few times higher than the average interstellar UV field. In this way, we gained new insights into physical and chemical processes around low-mass protostars.

## 1 Introduction

According to the NASA Exoplanet Archive, there are more than 3,500 confirmed exoplanets discovered so far. Yet, how those exoplanets formed is still an open question. One of the pending questions is whether UV radiation affects the formation of stars and planets at the deeply embedded stages. UV radiation influences the chemistry and temperature of the material and thus may decrease the efficiency of star formation (Stäuber et al., 2007). It could be also the key to understanding the shape of the initial mass function and the binary fraction. Here, we aimed to estimate the strength of the UV field in the surroundings of low-mass protostars.

Recent observations with *Herschel* at far-infrared are interpreted as tracing regions affected by UV radiation(Karska et al., 2017). The UV radiation can be also studied using ground-based telescopes e.g. by comparing the ratio of CN and HCN molecules. At the presence of the UV field, the HCN molecules photodissociates into CN radical. Therefore, the ratio of the CN and HCN molecules can serve as a tracer of the UV radiation.

## 2 Observations

We analysed molecular emission from selected, well-studied low-mass protostars situated in the Serpens Main and Barnard 1 star forming regions, only 230 pc and

| Serpens Main | Barnard 1 |
|---|---|
| CN 1-0 | CN 1-0 |
| HCN 1-0 | HCN 1-0 |
| CS 3-2 | CS 3-2 |
| $C^{34}S$ 3-2 | |
| $H^{13}CN$ 2-1 | |
| $H^{13}CN$ 1-0 | $H^{13}CN$ 1-0 |

Table 1: Targeted rotational lines observed in Serens Main and Barnard 1 star forming regions with IRAM.

429 pc away. Both regions are large molecular clouds with star formation rates of $57\,M_\odot\,yr^{-1}$ and $96\,M_\odot\,yr^{-1}$, respectively (Evans et al., 2009).

In our analysis, we used the data from IRAM submillimetre telescope. It is a 30 m single dish antenna located at the altitude of 2850 m in order to reduce the amount of water vapor. IRAM operates at 70˘350 GHz frequency range. It is equipped with a high resolution and broad band EMIR receiver that has been provided high quality spectra of targeted lines: HCN, CN, CS and their isotopologues. Molecules used in the analysis are shown in Tab. 1.

## 3 Results

Using CLASS, a dedicated software for IRAM observations, we obtained spatial maps of HCN and CN emission around protostars in the studied regions (see also Gładkowski et al. in this volume). In order to identify regions where the UV radiation is at play, we calculated ratios of CN and HCN emission for each positions on the map. Under the influence of dissociating UV photons, HCN molecule disintegrates into CN radical. Thus, we expect higher CN/HCN ratio in the regions with stronger UV field. Fig. 1 presents CN/HCN ratio maps for two Serpens Main sources and Barnard 1b source. The directions of molecular outflows are adopted from the CO 6-5 observations by Yıldız et al. (2015). By analysing the map of Serpens sources, we found an increased CN/HCN ratio associated with the SMM4 outflow. The CN/HCN ratio can be estimated about 0.8-0.9. Similar features do not appear in the surroundings of the SMM3 source. The Barnard 1b outflows show the high CN/HCN ratio of about 0.9-0.95. In both maps the contribution from other protostars in the neighbourhood can be also detected.

The strength of the UV radiation can be estimated by comparing our results with the modeled CN/HCN ratio as the function of the UV field strength, gas temperature and total hydrogen density. Stäuber et al. (2007) modeled protostellar envelopes containing an inner source of UV radiation. Assuming the gas temperature of 300-400 K and hydrogen density $n_{\rm H} = 10^6\,{\rm cm}^{-3}$ (Karska et al., 2013), the observed CN/HCN ratios correspond to the UV field of about 10 times the average interstellar value. Although the Stäuber et al. (2007) model does not include outflow cavities, the results agree with that estimated from *Herschel* observations (Benz et al., 2016; Karska et al., 2017). They confirm the presence of the UV radiation around low-mass protostars.

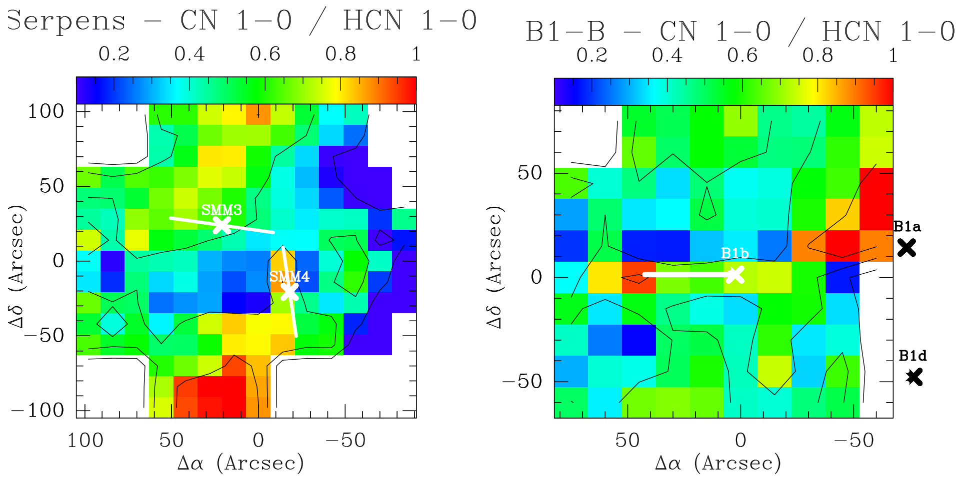


Fig. 1: Spatial maps of CN/HCN relative emission for Serpens SMM3 and SMM4 sources (left) and Barnard 1b source (right). Molecular outflows are marked with white colour.

## 4 Conclusions

HCN and CN emission is detected around low-mass protostars in the studied regions. Based on the CN/HCN ratios and the model of dense envelopes irradiated by UV (Stäuber et al., 2007), we estimated that UV fields in these objects are a few times stronger than the average field in the interstellar medium. Thus, the UV radiation cannot be neglected in models of star formation.

*Acknowledgements.* AM and MŻ acknowledge support from the Torun Astrophysics/Physics Summer program (TAPS 2017). AK and MG are supported by the Polish National Science Center grant 2016/21/D/ST9/01098.

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