Modelling the protoplanetary disc in the Bok globule CB26

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1. Introduction

A Bok globule is a small, opaque and isolated cloud. CB26 is a small cometary-shaped Bok globule located about 10° north of the Taurus/Auriga dark cloud at a distance of 140 pc [1], [2].
In 1997 Launhardt & Henning [3] found an unresolved 1.3 mm continuum source. Interferometric observations 2001 by Launhardt & Sargent [1] showed that the major fraction of thermal dust emission at millimeter wavelength has its source in a young protoplanetary disc with a diameter of about 400 AU and a mass of about 0.1 $M_\odot$.
This disc is seen almost edge-on and the central star ist not visible. However, the spectral energy distribution suggests a Class 1 Young Stellar Object with $L \geq 0.5\,L_\odot$.

Optical image of the CB26 region, based on Hα, [S II] and I-Band observations. The inlay zooms in on the south-western rim of the Bok globule. For this image observations in the near infrared at 1.25 μm, 1.65 μm and 2.2 μm have been combined. The disc here appears as the apparent void that intersects the bipolar nebula.

Figure adopted from [4].

2. Our goal

Following the example given by the model for the Butterfly star [5], the purpose of our project is to model the density distribution of the disc and the envelope and to get constraints on the inclination angle, the mass of the disc and on the grain size ditribution of the dust particles constituting the disc. In order to do so, we explore the parameter space with the radiative transfer code `MC3D` for the best fit with available data.

3. Means of Simulation

Our model for CB26 consists of multiple parts:

- A protoplanetary disc, responsible for the mm emission and the dark [illegible] the NIR.
- An infalling envelope, accounting for the scattered light structure in [illegible]
- A central star as the heating source.

As for the first part, we use the following density distribution for a [illegible] disc

$$\rho = \rho_0 \left(\frac{R_*}{r}\right)^{\alpha} e^{-\frac{1}{2}\left[\frac{z}{h(r)}\right]^2} \quad \text{with} \quad h(r) = h_0 \left(\frac{r}{R_*}\right)^{\beta}$$

adopted from [8]. Here r and z are the usual cylinder coordinates, R_* is the stellar radius and the function $h(r)$ is known as the scale height. The values ρ_0 and h_0 are used to model the disc mass. This leaves α and β to warp the disc according to data needs.
For the second part, we will adopt the denisity profile, resulting from mass infall under consideration of evelope rotation by [9].
The dust grains in these two parts are modeled by spheres. As for the chemistry, we assume a model consisting of to distinct populations, that is silicate and graphite with 62.5% and 37.5% relative abundances, respectively.
For the grain size distribution we assume a power law

$$n(a) \sim a^{-3.5} \quad \text{with} \quad a_{min} < a < a_{max}.$$

This distribution coincides with the commonly used distribution for the interstellar matter [10]. A smaller exponent indicates grain growth, one goal of this project is to show if this is needed match observations.
Since the star, the third model component cannot be observed, we adopt usual parameters of a T Tauri star, that is $L = L_\odot$ and $T_* = 4000\,K$, where the stellar luminosity is a fitting parameter.
The main simulation tool is the radiative transfer code `MC3D` by Wolf ([11], [12]). This code is based on the Monte Carlo method and solves the radiative transfer problem self-consistently. It is used in a two step process. First, the temperature distribution in the dust due absorption of stellar radiation is computed. Then, in a second step, observable quantities, such as SEDs, λ-dependent maps and polarization maps are derived.

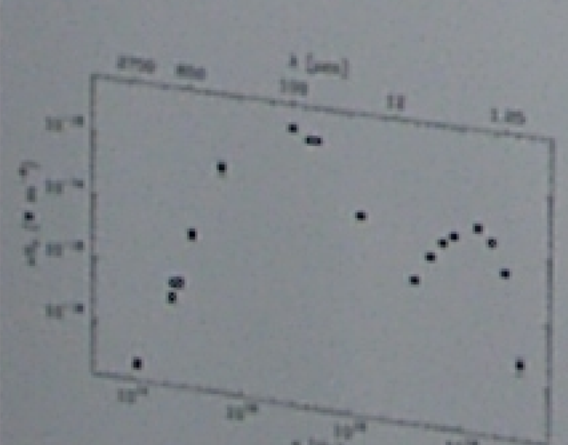
4. Available Data

In the case of CB26 one is in the fortunate situation, that many observational data has recently become available ([6], [7]):

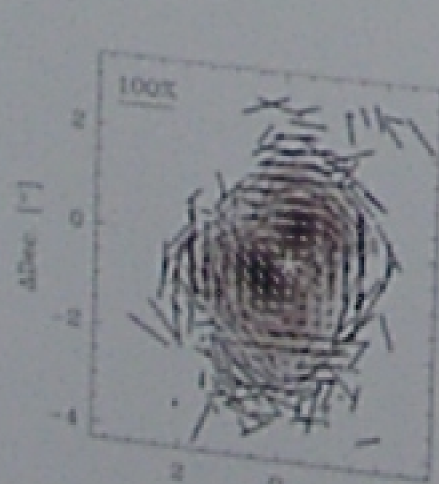
- Ground-based NIR and polarimetry
- HST NICMOS NIR
- Submm dust continuum images (single-dish, SCUBA, IRAM 30m)
- Interferometric mm continuum maps (1.1mm SMA, 1.3 & 2.7mm OVRO)
- SED, including IRAS, ISO, and Spitzer data

Map at 1.25 μm taken with HST/NICMOS 2. The dark lane in the biploar structure is the protoplanetary disc. The map's length and height corresponds to 6″.

Map at 1.3 mm taken with OVRO. The map's length and height corresponds to 10″.



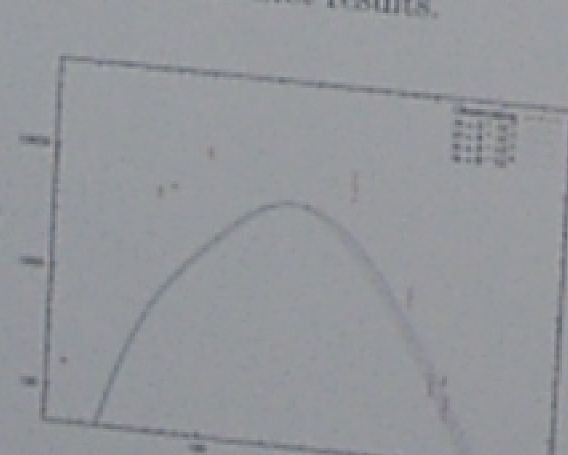
Spectral engergy distribution, obtained by combining all data.



Map at 2.2 μm with polarization vectors overlay. The central star marks the source of the pattern, i.e. the star.

5. First results

Despite the fact that the study of the parameter space ist not complete yet, we are able to present some first results.



The SED in the mm domain allows an estimate of the disc dust mass. We got a minimum dust mass of $\approx 3 * 10^{-3} M_\odot$. The obvious difference between data and simulation at lower wavelengths is due to the envelope, which has not been included in simulations yet.

Map (*left*) of the simulated disc at 1.3mm. The map's length and height corresponds to 12″. This is the simulational equivalent to the upper right picture in box 4.
Density profile (*right*) of the simulated disc. Shown is a cut trough the disc center perpendicular to the midplane. One nicely can see the 'flaring' of the disc in its out parts.

Outlook: The next step will be to add the envelop to our model in order to reproduce the scattered light feature.

6. References

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Questions, suggestions, ideas ? Contact the auther: `jsauter@mpia.de`