# Pillars Project

***Mélanie Chevance, Vital Fernandez, Niall Tyndall, Ronin Wu***

## ***Introduction and conclusion of our project***

The goal of this project is to investigate the impact of the geometry of a cloud on the emission from the HII regions and the photo-dissociation regions (PDR). To do this, we simulated clouds of different covering factor and/or different filling factor, with the same density and physical size, ionized by the same source. We combine several smaller clouds to have the same mass as a bigger cloud and study the transmitted/reflected continua as well as emission line ratios. We conclude that the clouds of different clumpiness, as governed by the filling factor, have different molecular gas fraction since the PDR starts deeper in the cloud when the cloud has lower filling factor.

## Main continua predicted by Cloudy:

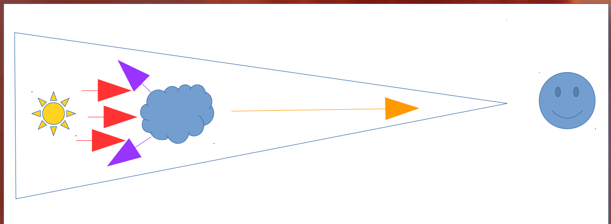
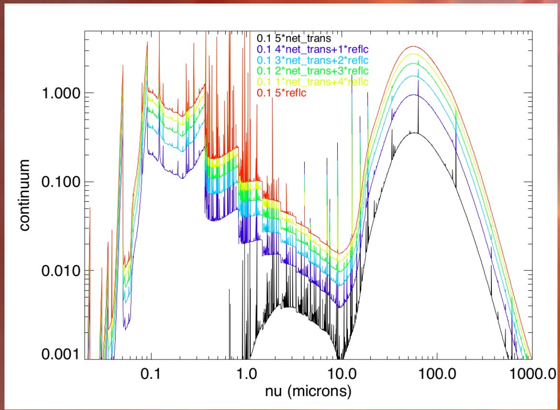


**Figure 1.** An simple indication of the components predicted by Cloudy. The main components investigated in our project includes the incident (red arrows), the reflected (purple arrows), and the total transmitted (orange arrow) components.

When using "save continuum" command in Cloudy, a few different components are recorded in the output file. These components include the full spectrum of the incident light from the heating source, which is defined by the user, of the light reflected by the surface of the cloud with pre-defined geometry, and of the total transmitted light through the cloud.

## Case I: Clouds of different sizes




In Case I, we experimented configurations of clouds composed of several units. Each unit is defined to have the same hydrogen number density, 10^4 cm-3, the same thickness, ~1 pc, and the same distance, ~3 pc, to the heating source, an O4 star. The results of our experiment is shown in Figure 2.

**Figure 2**. When a unit of cloud is exactly in between the observer and the heating source, the observer sees the total transmitted spectrum. When a unit of cloud is behind the heating source, the observer sees the reflected spectrum from it. All spectra in the figure are from clouds which are composed of 5 units of cloud. The black line show the configuration when all units are between the observer and the heating source. As the units are gradually moved behind the heating source (purple, cyan, green, yellow, and, red), the observed spectra become more dominated by the reflected spectrum.

## Case II : Clumpy clouds

The filling factor characterizes the presence of small clumps in the cloud. It affects the radiative transfer, as the photons can penetrate deeper into the cloud in a low-filling factor case (see Figure 3.

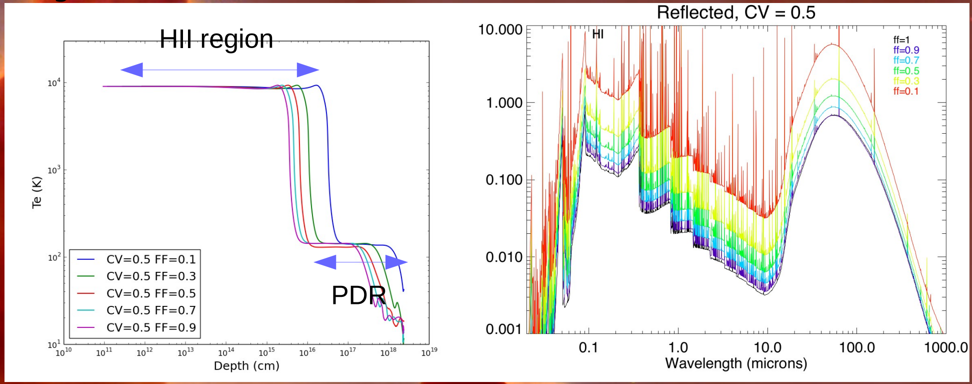



**Figure 3**. **(Left)** The electron temperature as a function of depth in the clouds of different filling factors. As the filling factor gets lower, the ionizing photons can reach deeper in the clouds. However, the temperature distributions indicate that our simulations well include the HII region and photo-dissociation PDR. **(Right)** Assuming the clouds are all behind the heating source, with respect to the observer, combining different clouds of the same mass give different observed spectra. This is also true when the clouds are all between the observer and the heating source.

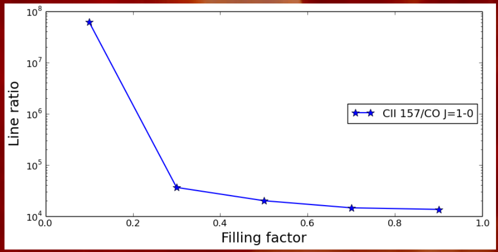



**Figure 4**. We investigate the ratio of CII 158 micron and CO J=1-0 ([CII]/CO) from the clouds of different filling factors. As the filling factor increases, the molecular gas starts forming in smaller depth. This leads to smaller [CII]/CO.