Observational studies of star formation and protostellar disc dynamics

Maria Giulia Ubeira Gabellini[1,2,3], Giuseppe Lodato[1], Massimo Robberto[2,5], Leonardo Testi[3], Anna Miotello[4,6], Stefano Facchini[6], Nicola da Rio[7], Carlo Manara[8], Leonardo Ubeda[2]

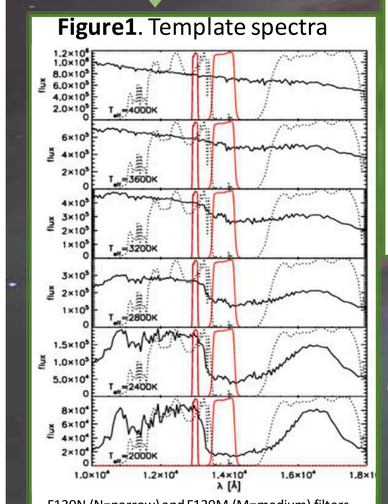
1. Dipartimento di Fisica, Università Degli Studi di Milano, Via Celoria, 16, Milano, Italy. 2. Space Telescope Science Institute, Baltimore, MD, United States. 3. European Southern Observatory (ESO), Garching, Germany. 4. Leiden Observatory, Leiden University, Leiden, The Netherlands. 5. Johns Hopkins University, Baltimore, MD, United States 6. Max-Planck-institute für extraterrestrische Physik, Garching, Germany. 7.University of Florida, Gainesville, FL, United States. 8. European Space Research and Technology Centre (ESA/ESTEC), Keplerlaan 1, 2201 AZ Noordwijk, The Netherlands.

The sub-stellar mass function in the Orion Nebula Cluster

Motivation:

A 52-orbit Hubble Treasury Program is currently under way to investigate a fundamental question of star formation: **the low- mass tail of the Initial Mass Function (IMF), down to a few Jupiter masses**. The aim of this project is to discover and classify all brown dwarfs and planetary-mass objects in the field, extending the IMF down to lowest masses formed by gravitational collapse. The program targets the Orion Nebula Cluster (ONC).

Figure1. Template spectra



F130N (N=narrow) and F139M (M=medium) filters

Figure2. Color-color diagram

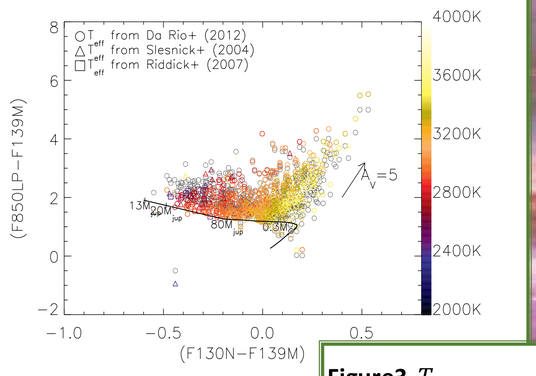


Figure3. $T_{effective}$ - color relation calibration

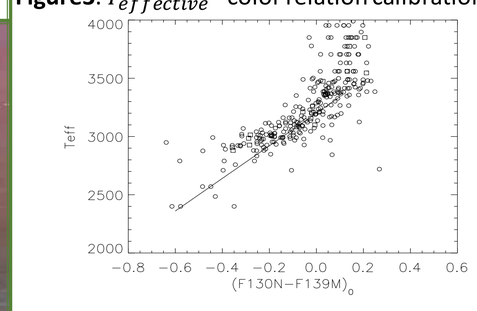


Figure 4. H-R Diagram

4a. Baraffe models[1]

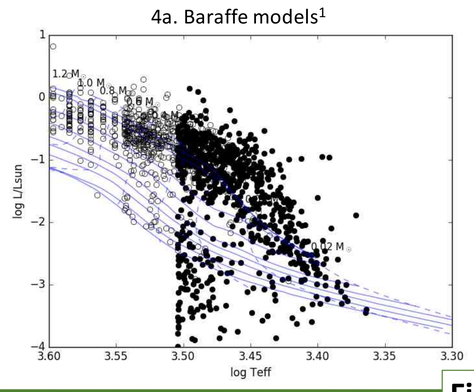


Figure 6. Completeness

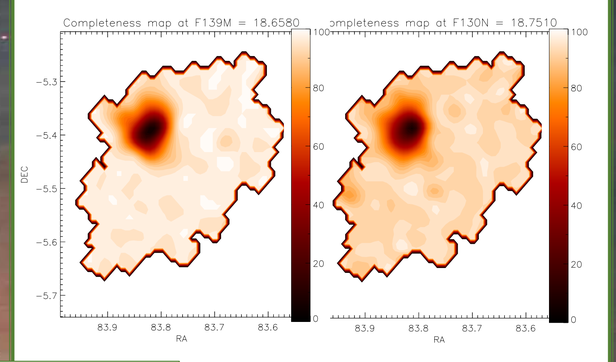
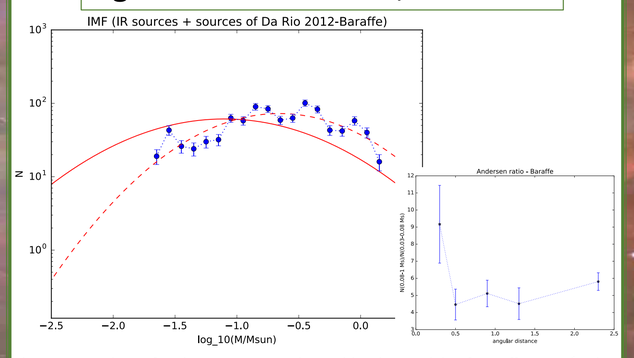


Figure 5. IMF and STAR/BDs



The measured IMF for the entire ONC, derived by the models of Baraffe 1998 [1]. The IMF of the ONC detected by us is almost similar to the "system" mass function of Chabrier (2003) [2] (dashed red line in the figure). The Andersen ratio represents the distribution of stars and BDs in the field.

Strategy:

We used the Wide Field Camera 3 (WFC3-IR) on Hubble to observe the full ONC in 2 filters:

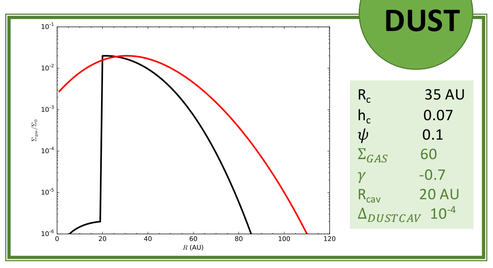
- **F139M**: centered on the 1.4μm H_2O absorption feature, increasingly prominent as the effective temperature of a star drops below ~3500K (spectral-type M2, see Figure 1).
- **F130N**: provides a measure of the adjacent line-free continuum that can be used to create a reddening-free spectroscopic index.

Conclusion:

I have extracted photometry for more than 5,000 sources, and I complemented it by data at 0.85micron taken in a previous HST survey. Using a color-color diagram (Fig. 2), and the theoretical pre-main-sequence evolutionary tracks (Fig. 4), we derived age and mass of each source, and therefore the IMF (Fig. 5). The IMF of the ONC turns out to be almost similar to the "system" mass function of Chabrier (2003)[3]. Finally, I refined the analysis deriving the completeness map (Fig. 6) in the two WFC3 filters, which will be used to give a more complete result of the IMF profile.

The gaseous and dusty disc around the CQ Tau protostar

DUST

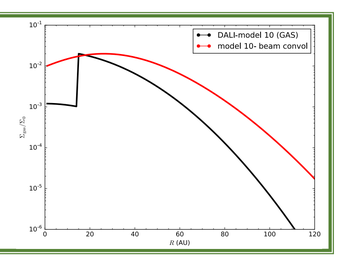


R_c	35 AU
h_c	0.07
ψ	0.1
Σ_{GAS}	60
γ	-0.7
R_{cav}	20 AU
$\Delta_{DUSTCAV}$	10^{-4}

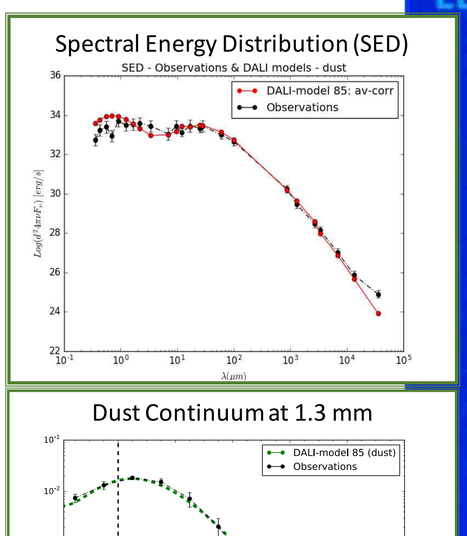
Motivation:

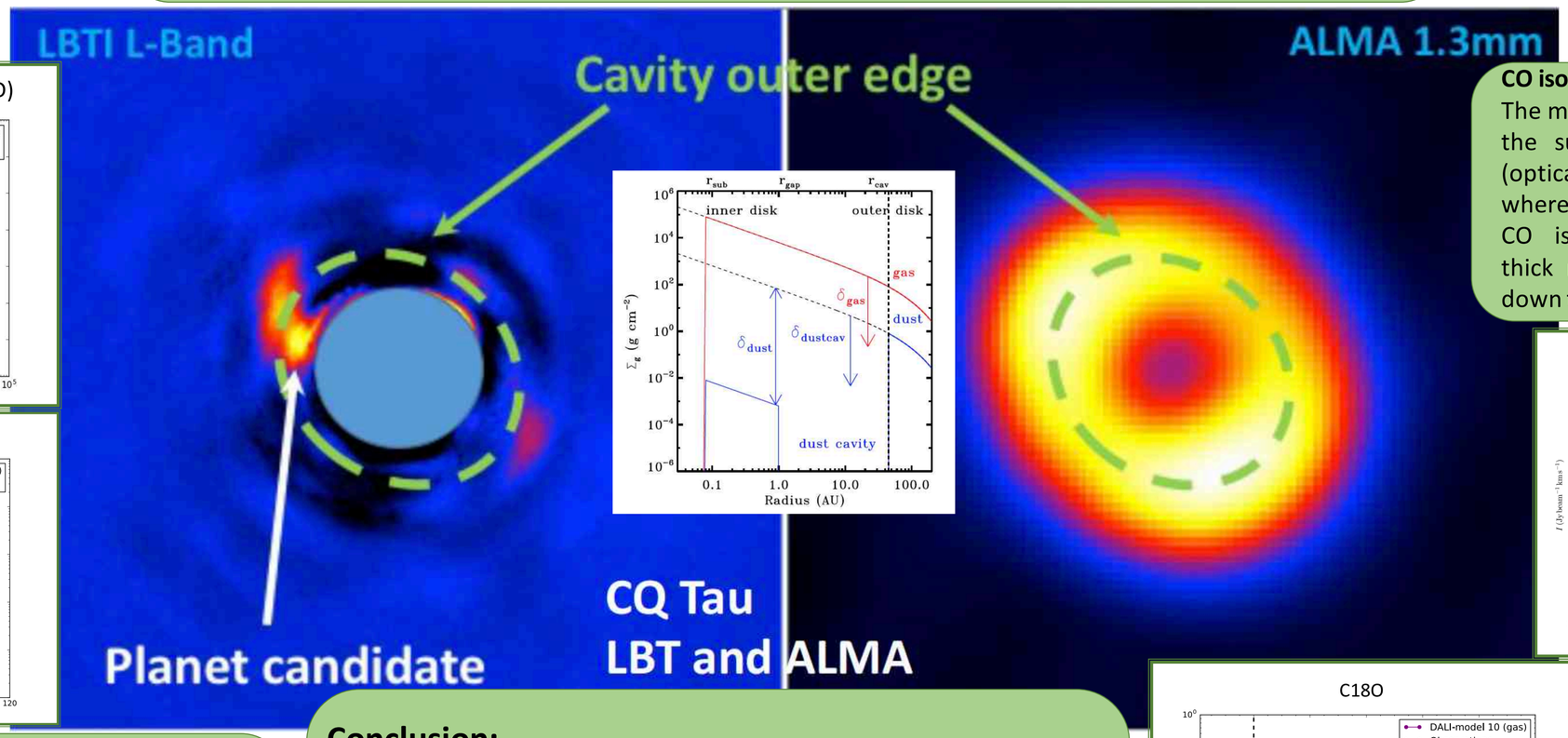
In this project we have studied the dust and gas distribution around pre-main-sequence stars using the Atacama Large Millimeter Array (ALMA). We focused on **finding the best model's parameters to fit the high angular resolution observations of the protoplanetary disk around CQ Tau**, a young (5Myr), nearby (d =100 pc), intermediate mass (M = 1.5 Msun) star. In this system there is the clear evidence of the presence of an inner cavity in the disk dust distribution with an outer radius of 30 AU. Moreover, thanks to an excellent LBTI/L-band dataset for the CQ Tau system, there is the evidence of a massive planet candidate just outside the outer edge of the cavity as imaged with ALMA.

GAS



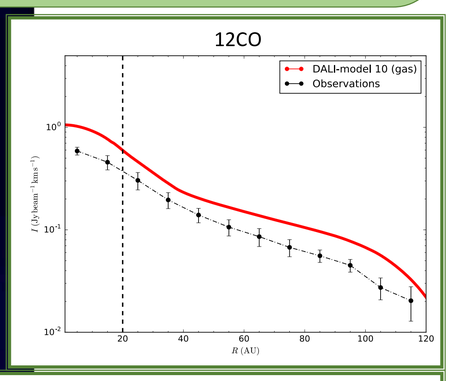
R_c	35 AU
h_c	0.07
ψ	0.1
Σ_{GAS}	25
γ	0
R_{cav}	15 AU
Δ_{GAS}	0.05

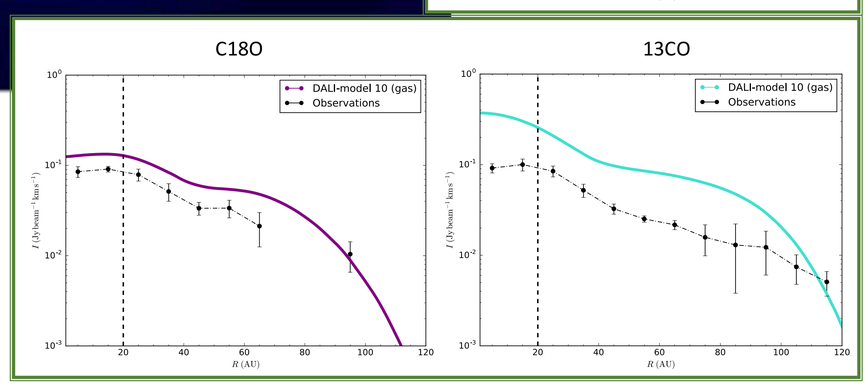




CO isotopologues:

The main isotopologue, ^{12}CO only traces the surfaces of protoplanetary Disks (optically thick at low column densities); whereas, ^{13}CO and $C^{18}O$ (less-abundant CO isotopologues) become optically thick much deeper and trace the gas down to the midplane of the disk.





Strategy:

We used the physical-chemical modeling tool DALI (Bruderer 2013[3]), that solves for the chemical structure, the radiative transfer and the thermal balance within the disc. Our data include the thermal continuum produced by cold dust, and line emission maps in different isotopologues of the CO molecule (12CO, 13CO and C18O), that need to be fitted simultaneously.

Conclusion:

We modelled CQ tau as a disk where there is a sharp ring of dust (just outside the supposed planetary orbit) and a broader extent of the gas. Moreover, dust has a larger cavity than gas.

As soon as we will be confident with the gas modelling, we will run hydrodynamic simulations to addressed if the disk structure could be influenced by the planetary candidate.

References:

1. I. Baraffe, G. Chabrier, F. Allard, and P. H. Hauschildt. Astronomy and Astrophysics, 337:403–412, 1998
2. G. Chabrier. Astronomical Society of the Pacific, 115:763–795, 2003. doi: 10.1086/376392.
3. S. Bruderer, S. 2013, A&A, 559, A46