The OVRO Ophiuchus Pre-stellar (OOPS) Survey:
An investigation of discs and the initial conditions of planet formation

J. Bulger[1], J. Patience[1], H. Arce[2], S. Corder[3], J. Koda[4], C. Pinte[5], J. L. Monin[5], J.Carpenter[6], M. Enoch[7]

[1]University of Exeter, [2]Yale University, [3]NRAO-ALMA, [4]Stony Brook University, [6]LAOG, Grenoble, [5]California Institute of Technology, [7]University of California, Berkeley

email: joanna@astro.ex.ac.uk

Abstract

We present 3.4 mm survey of circumstellar material around a flux limited sample of members in the ρ Ophiuchus star forming region. Continuum emission is detected for 26 of the 34 targets. With these detections and previous measurement we estimate key disc parameters such as disc masses, radii and dust properties. A number of the discs show evidence of grain growth, an important initial step for planet formation.

Molecular line emission of HCN(1-0) and HCO$^+$(1-0) has been observed for all the sources, the results of which will provide insight into the nature of outflows of the disc gas. From HCO$^+$(1-0) emission, we have detected a velocity pattern showing a Keplerian disc, for a Class I source. With follow up observations of this source, we intended to test the evolutionary models of pre-mainsequence stars.

Introduction

Star formation occurs within optically thick molecular clouds of gas and dust.

The evolutionary stages of star formation and associated YSO classifications is shown in Figure 1.

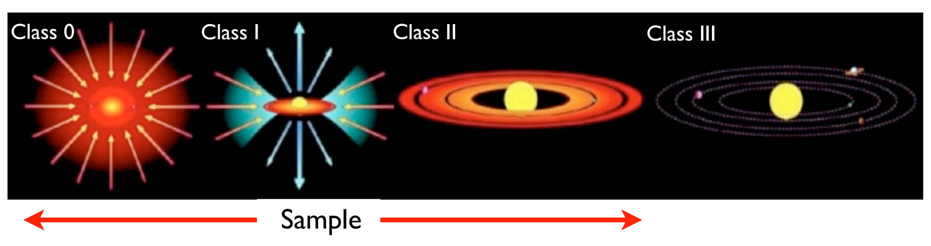


Figure 1: A depiction of the evolutionary stages of star formation (Shu et al. 1987). A molecular cloud undergoes collapse leading to the birth of a star, of which the prenatal gas and dust that resides in a circumstellar envelope and disc, is dissipated through outflows and planet formation.

Observations carried out in the sub-millimetre and millimetre regime are sensitive to dust emission, throughout the entire discs of YSOs.

Spectral energy distributions (SEDs) in this regime allow the properties of disc structure, i.e radius, disc mass and spectral opacity index, to be constrained.

These properties are critical in aiding our understanding the early conditions in protoplanetary discs and the viability of planet formation.

The Sample

Our sample consists of 34 targets in the ρ Ophiuchi cloud, the nearest site of on going clustered star formation.

These targets consist of:

- 6 Starless clumps with peak flux emission ≥ 85 mJy/beam at 1.3mm.
- 2 Class 0,
- 11 Class I,
- 14 Class II YSOs with peak flux emission ≥ 70 mJy/beam at 1.3mm.
- 1 Class II YSO, spatially resolved in IR, but previously unobserved at millimetre wavelengths.

Observations were carried out using the 6 dish interferometer at the Owens Valley Radio Observatory (OVRO), positioned in three configurations with baselines ranging from 20-240 m.

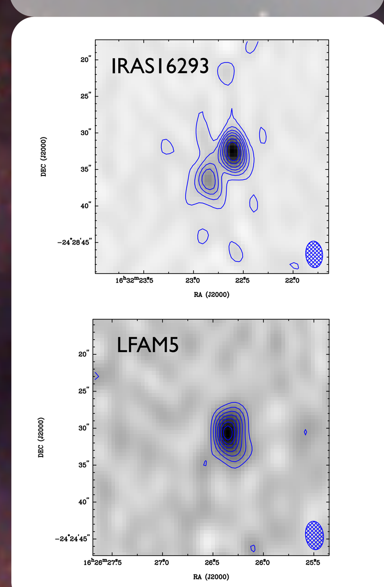
Observations of both 3.4mm continuum emission and molecular line emissions of HCN(1-0) and HCO$^+$(1-0).

Continuum maps and SEDs

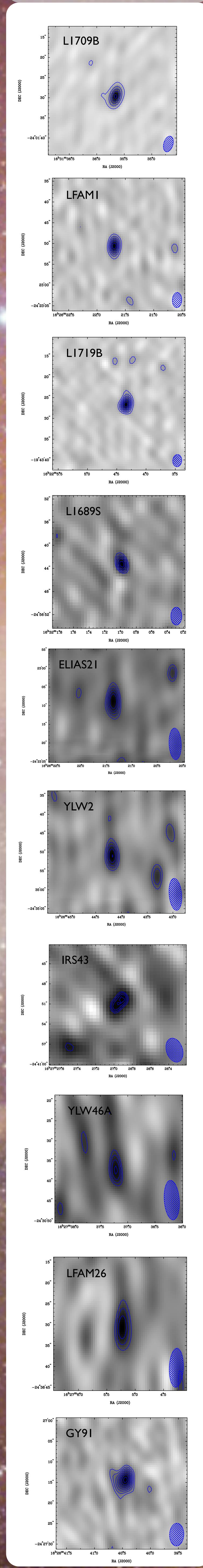
3.4 mm continuum emission maps are shown below for the 26 sources detected at 3σ.

SED fitting of the Class II sources has been carried out with MCFOST. The axis plots are of log ν F (W/m²) against log λ (μm)

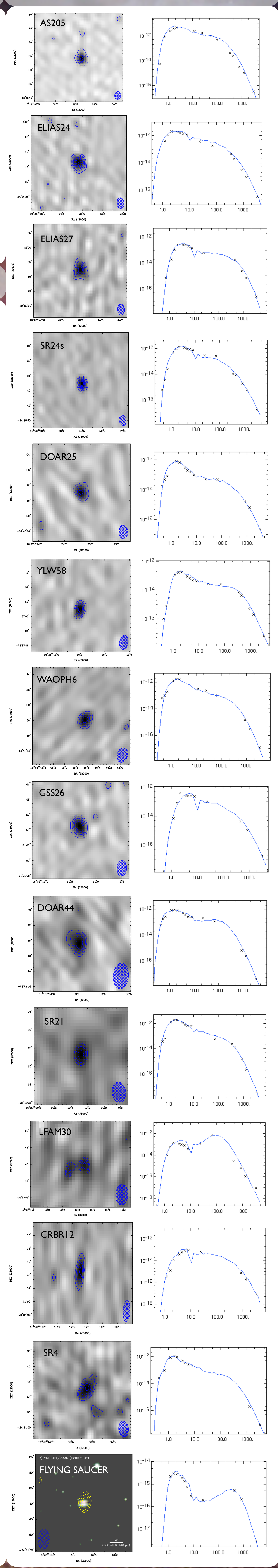
Class 0



Class I



Class II



Results

Continuum emission

Continuum emission is detected at a 3σ level for 26 of the 28 YSOs.

Peak emission fluxes range from 3-180 mJy as shown in Figure 2.

• Typical rms noise levels of 1.2 mJy. • Typical beam sizes of 3".7×2".3.

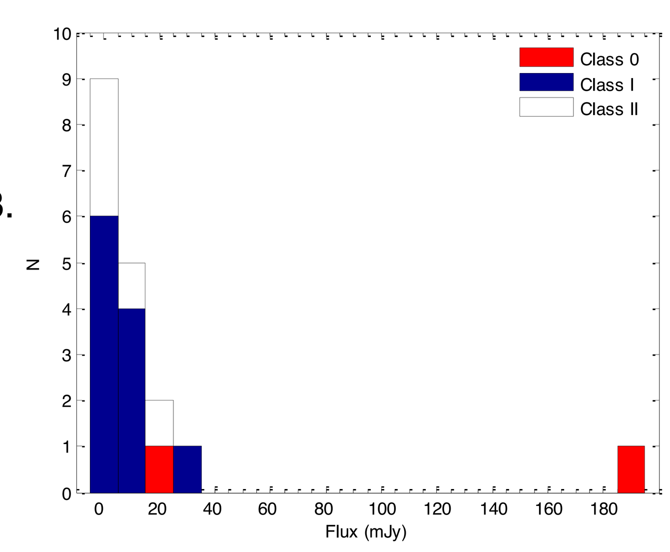


Figure 2: Distribution of measured fluxes at 3.4 mm, across the YSO classes.

SED Fitting

Fitting has been carried out with MCFOST (Pinte et al. 2006), a 3D radiative transfer model.

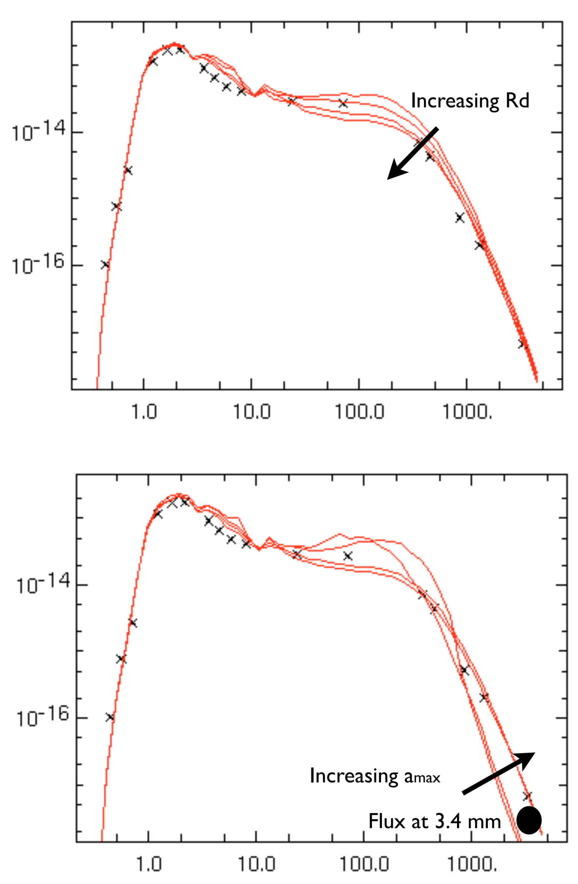


Figure 3: SEDs of YLW 58. The top plot shows how the distribution is effected by varying the disc radius. The bottom plot shows how the distribution is effected by varying the maximum grain size. The axis plots are of log ν F (W/m²) against log λ (μm)

Disc Parameters

Currently, initial fits have been carried out on the Class II targets, which range in spectral type G3-M8.

The following disc parameters have been used to obtain the current fits:

{i, Rd, a_{max}, M_d, p, and f}

where i is the disc inclination, Rd is the outer disc radius, M_d is the disc mass, p is the surface density exponent and f is the flaring exponent.

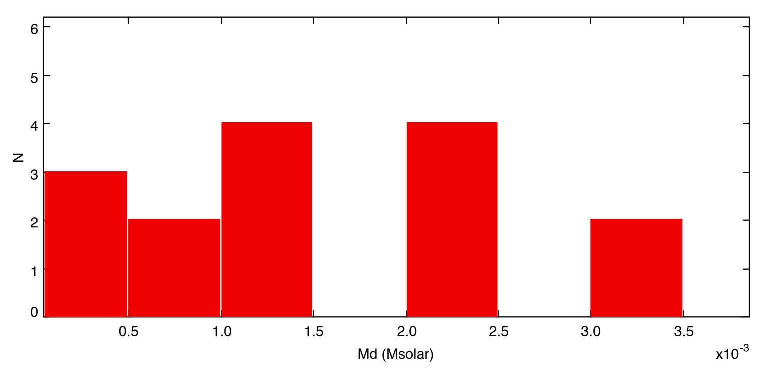


Figure 4: Distribution of the disc masses obtained from the modelled SEDs of the Class II targets.

The plots shown below indicate that no correlation between the fitted disc parameters are identified.

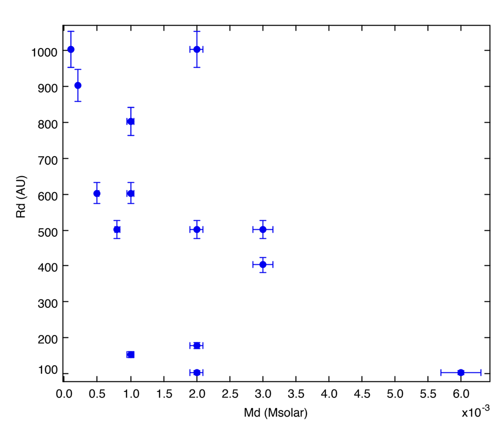


Figure 5: Plot of outer disc radius (AU) against disc mass (M☉).

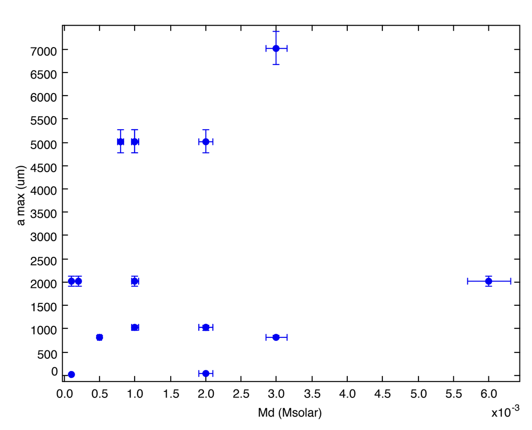


Figure 6: Plot of maximum grain size (μm) against disc mass (M☉)

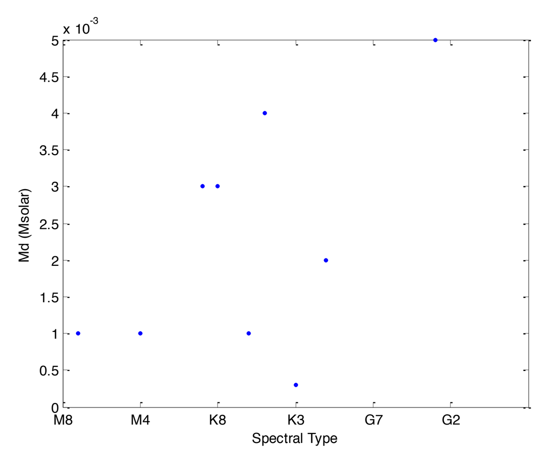


Figure 7: Plot of disc mass (M☉) against spectral type.

Future Work

The SED fitting of the Class 0 and Class I YSOs will be carried out.

χ^2 calculations will be used to determine the best fit model to the observations across a grid of disc parameters.

From initial inspection of the molecular line data, the velocity pattern of the HCO$^+$(1-0) emission from an embedded Class I YSO - L1689s, shows a Keplerian disc, as can be seen in the maps to the right.

This observation will allow the mass the of the central star to be directly calculated.

If it is possible to determine the spectral type of this source with spectroscopic observations, this will provide a test of evolutionary models.

Molecular line emission