Bayesian SED Fitting of YSOs in Cygnus-X

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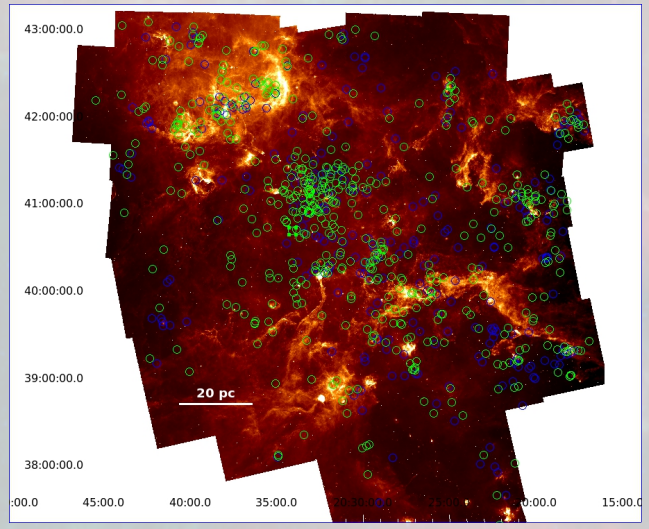
Overview

We have developed a Monte Carlo fitter based on the grid of SED models presented in Robitaille et al. 2006 to find the best fitting model parameters and their associated probability distribution functions (PDFs) for a large sample of YSOs in the Cygnus-X star forming region. Our aim is to understand the model degeneracies and their impact on the determination of physical parameters in a real sample of young stars for which we have an independent determination of the parameters. We focus on how these degeneracies and the error weighting affects the derived mass, age, and visual extinction of the sample. We find that within the priors defined by the model grid, different SED shapes are subject to different types of degeneracies, and might lead to misleading values of the parameters.



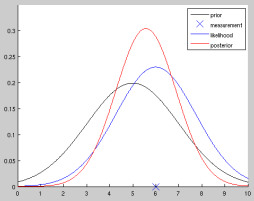
IRAC 8μm map of the Cygnus-X region, one of the most active sites of massive star formation in the galaxy. Shown in circles are the 843 YSOs (mostly Class II objects) selected for the present study. For all of them we have r′, i′ (IPHAS), J, H, K (UKIDSS or 2MASS) photometry, as well as IRAC (all bands) and MIPS 24μm aperture photometry. Photospheres, PAH dominated sources (mostly galaxies) and AGN candidates have been excluded. The classification has been done according to the method described in Gutermuth et al., 2008. The sources are indicated by blue (Class IIa) or green (Class IIb) circles.

Fitting

We use a Monte Carlo Markov Chain (MCMC) to step over the parameter space defined by the model grid. At each point we calculate the reduced χ^2 value associated to the fit to a particular SED and retrieve the value of the probability (assuming observational errors are Gaussian) as:

$$P(p_0) = \sum_{p \neq p_0} e^{-1/2\,\chi^2_{\rm red}}$$

We use a Metropolis-Hastings algorithm to sample the PDF associated to each of the model parameters. The priors are set by the original sampling in the grid. We also allow for a 20% uncertainty in the distance to Cygnus-X, that we have assumed to be 1.4 kpc, and for external extinction with A_V values between 0 and 10 magnitudes. These two priors are uniform and flat, but can be updated with, i.e., independent extinction maps, etc.



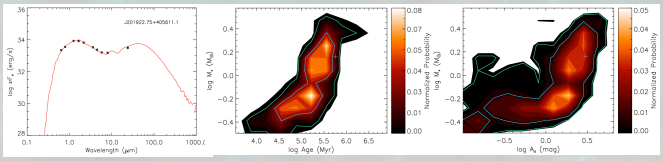
Solutions are marginalized posterior probability distribution functions (PDFs) for the model parameters.

We record both the best fit value and the peak of the marginalized PDF for each parameter

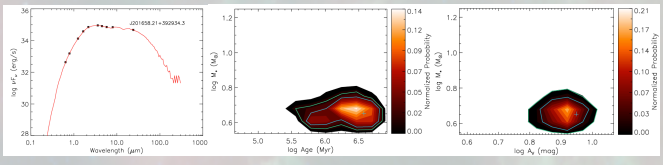
Sample fits and PDFs

In general, we can separate Class II YSOs in Cygnus-X into two groups according to the shape of their SEDs: objects with significant warm ($\lambda \sim 5$-10 μm) emission and large extinction in the optical (Class IIb), and less extincted objects with dimmer relative fluxes in the IRAC bands (Class IIa). Class IIb objects show better constrained PDFs for mass, age and A_V as compared to Class IIa objects. For Class IIa objects the models give a clear mass-age degeneracy (observed in the PDFs). This is a statistical trend in our sample. Two examples of best fits and PDFs are shown below. The blue crosses represent the best fit values.

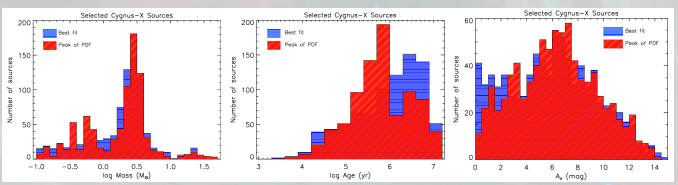
Class IIa SED



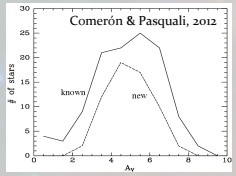
Class IIb SED



Statistics

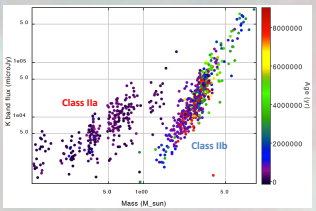


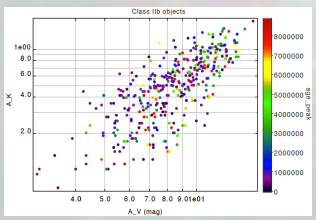
The prominent low mass ($M < 1M_\odot$) wing of the distribution is probably due to the mass-age degeneracy observed in the PDFs. We argue that such degeneracy leads to an underestimation of the YSO mass for sources with Class IIa SEDs. This results prevails if uniform errors are used for the fitting. Including the optical points seems to help in the determination of the A_V values towards the sources, as suggested by direct comparison with independently derived extinction values.



The A_V distribution obtained by these authors using the Cardelli et al. (1989) extinction law.

Photometric indicators





The two separated mass populations are more clearly seen in this plot of model-derived mass vs. K-band flux. Class IIb objects have a tighter correlation with near-infrared fluxes, and their derived A_V values are correlated with the observational, 2MASS-calibrated, K_S band extinction values obtained using the color index (H–K) as described in Gutermuth et al. 2005. Such correlation is not seen as clearly for the Class IIa objects. We see a similar behaviour in the Perseus region (see poster 1K083).

Our study suggests that model degeneracies jeopardize some of the parameters derived with SED fitting, specially for Class IIa YSOs. Independent spectroscopic studies are required to properly constrain basic parameters.

References

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