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Infrared Space Astronomy Group

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Modelling of early stage massive star formation – work in progress

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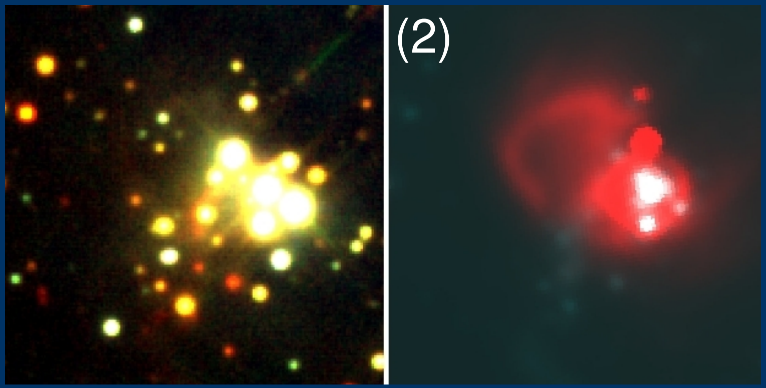
Outline

- ISOSS massive star formation regions: Findings & Ideas
- Radiative transfer modelling
- Dust opacities
- Wrap-up

Analysis of ISOSS star-forming regions

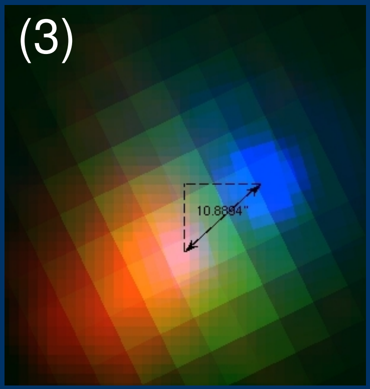
(1) MIR sources associated with submm cores:

- Embedded young accreting protostars?
- Accretion luminosity?
  - → Radiative transfer modelling
  - → Investigation of jets/outflows



(2) NIR/MIR sources:

- Young clusters?
  - → SED fitting to YSO model grid
  - → Mass distributions



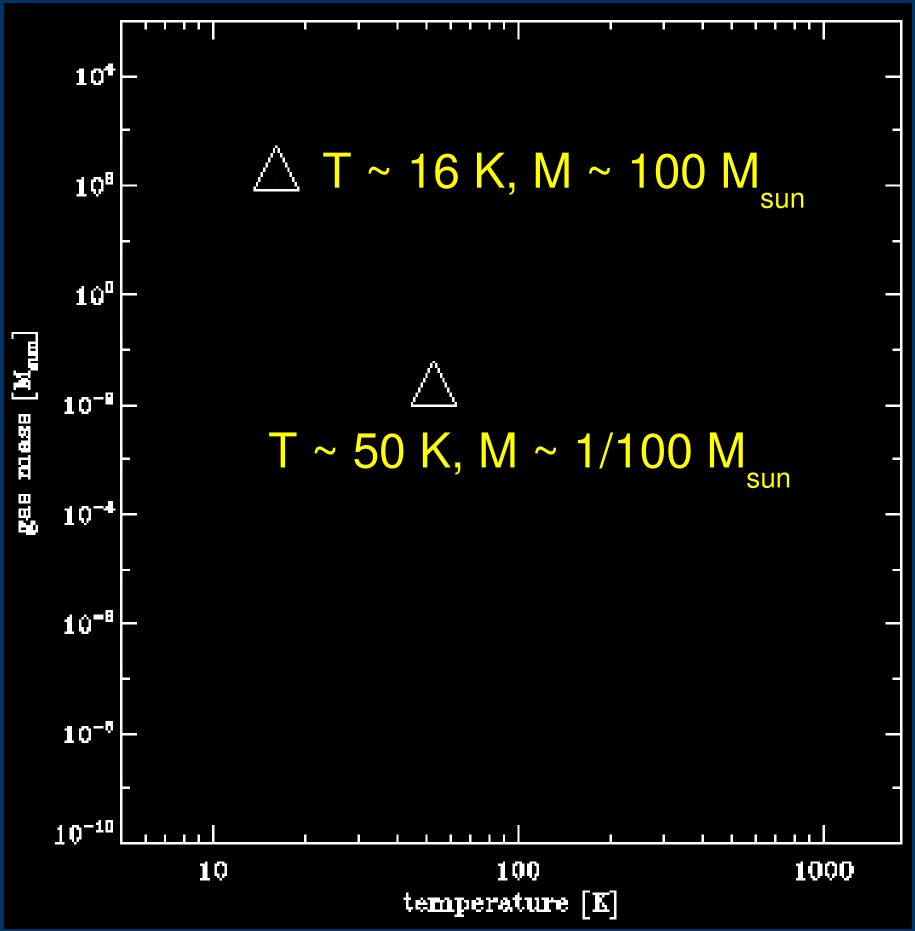
(3) Submm cores without clear NIR/MIR counterpart:

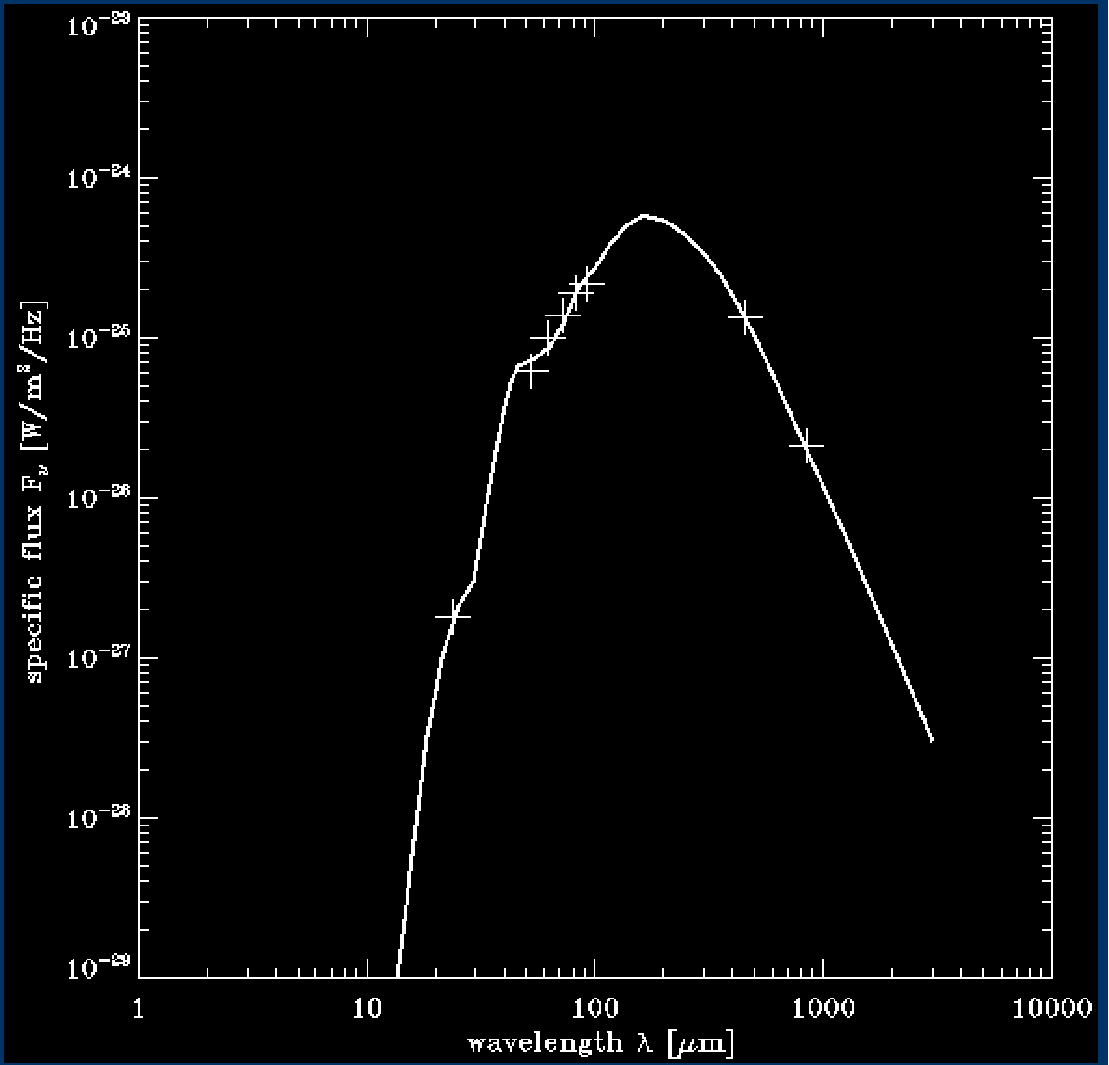
- Prestellar cores?
  - → High angular resolution needed

SED modelling

SED for ISOSS J18364-0221E:

- Assuming dust opacity (Ossenkopf & Henning 1994)
- Fit blackbody emission





- n = 10^6 /cm³
- 2 components
- 99% of mass in cold component
- But: optically thin?
  → Radiative Transfer

Radiative Transfer

Changes in radiation intensity due to

Emission, Absorption, Scattering

$$\frac{dI_\nu}{ds} = \epsilon_\nu - \kappa_\nu \rho I_\nu + \iint \sigma_\nu(\Omega, \nu') \, I_{\nu'} \, d\nu' \, d\Omega$$

Applied to dust configurations:

- Emission thermal: only temperature dependent
- Absorption per dust mass: opacity κ
- Scattering: Isotropic or angular dependence

Steps:

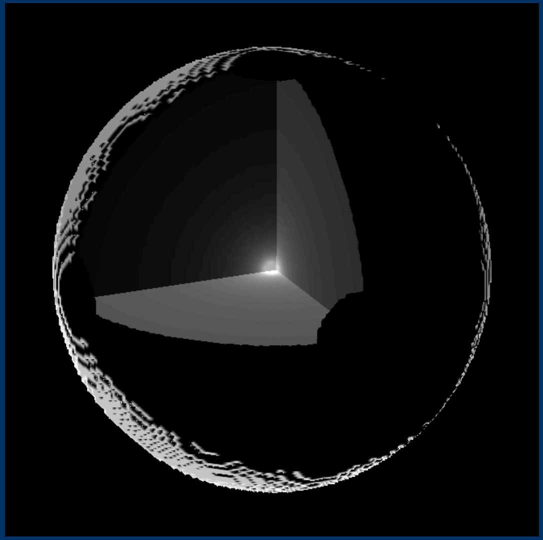
- Assume dust configuration, source parameters, ...
- Determine thermal equilibrium dust temperature
- Follow photon propagation until detector

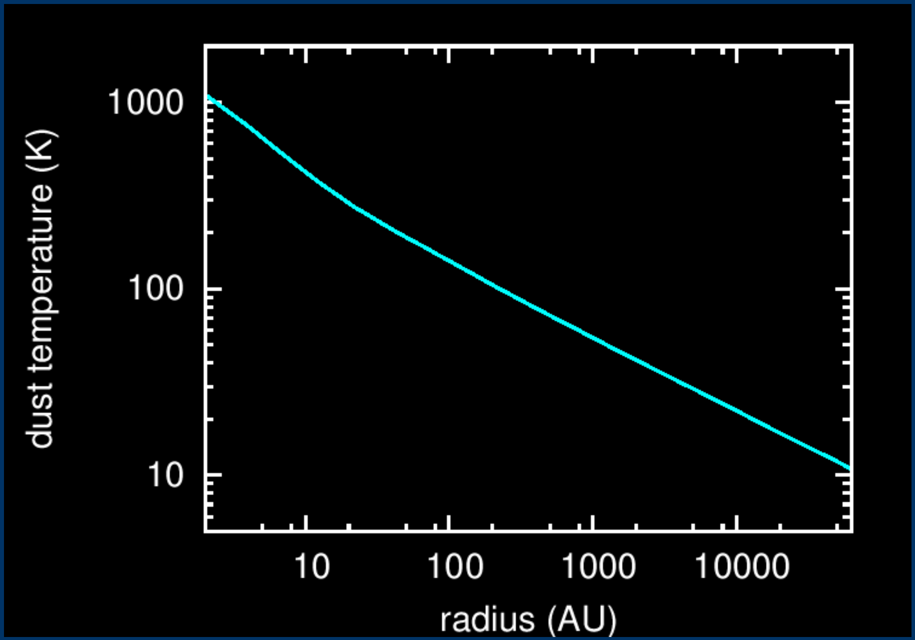
Radiative Transfer modelling

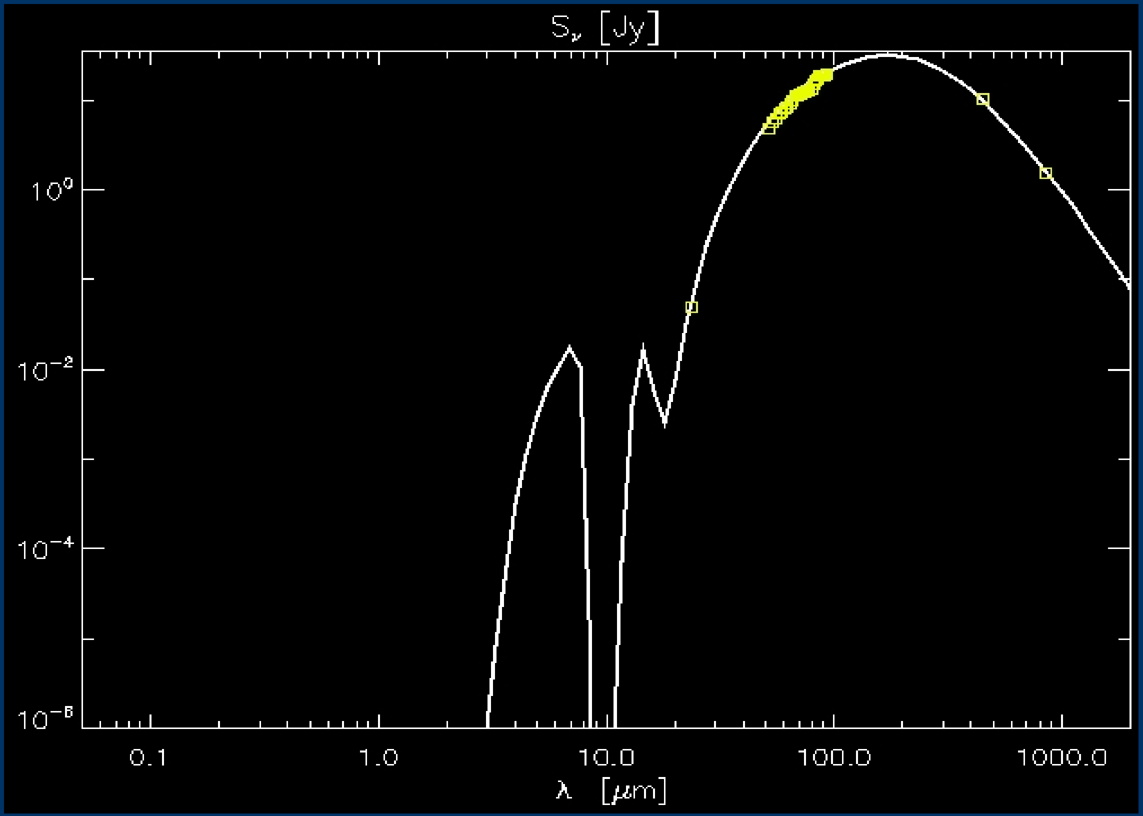
mc3d-Code of S. Wolf: 1d dust configuration

6 parameters:

- Temperature, radius of star
- Inner, outer radius of dust envelope
- Dust density profile exponent $\rho \sim r^{\text{something}}$
- Dust mass in envelope







Grid of radiative transfer YSO models

- Robitaille et al. 2006/2007, Code: Whitney et al. 2003
- 20 073 2d YSO models: central star, disk and envelope
- 10 viewing angles → 200 730 spectra
- > 16 parameters

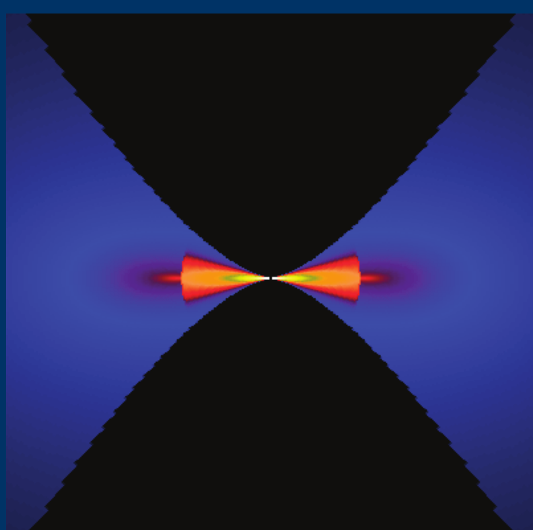
Fitting JHK + IRAC 1-4 + MIPS 24µm

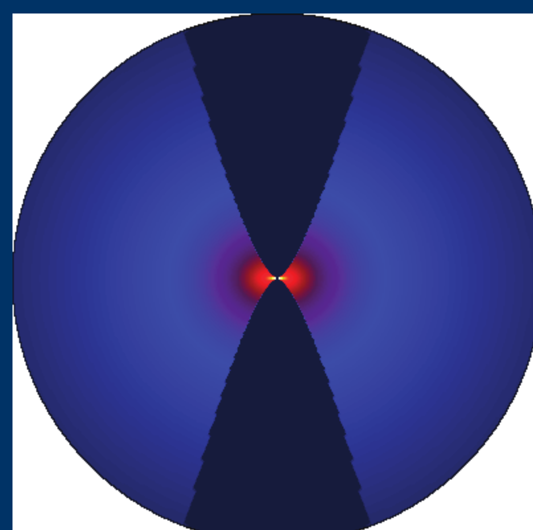
Objectives:

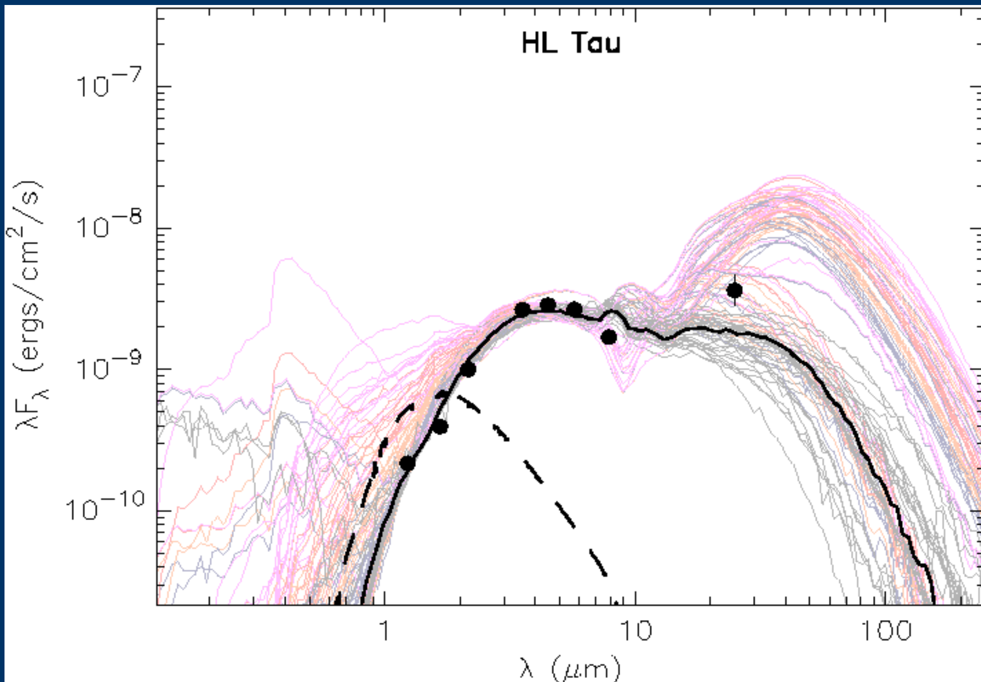
→ Constraints on masses / ages

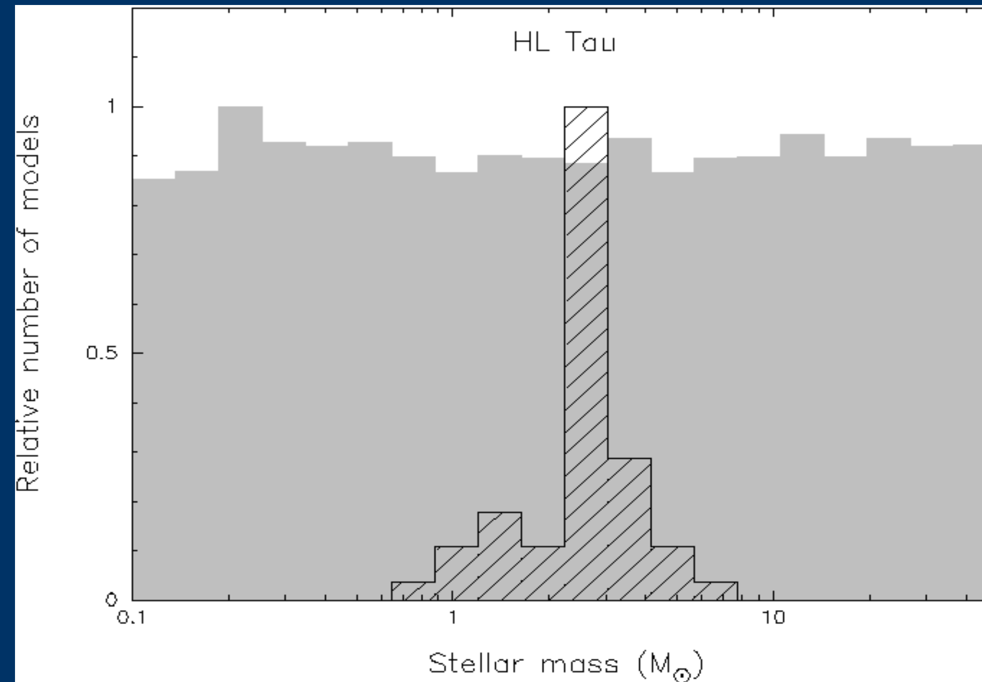
→ Mass distributions in very young clusters

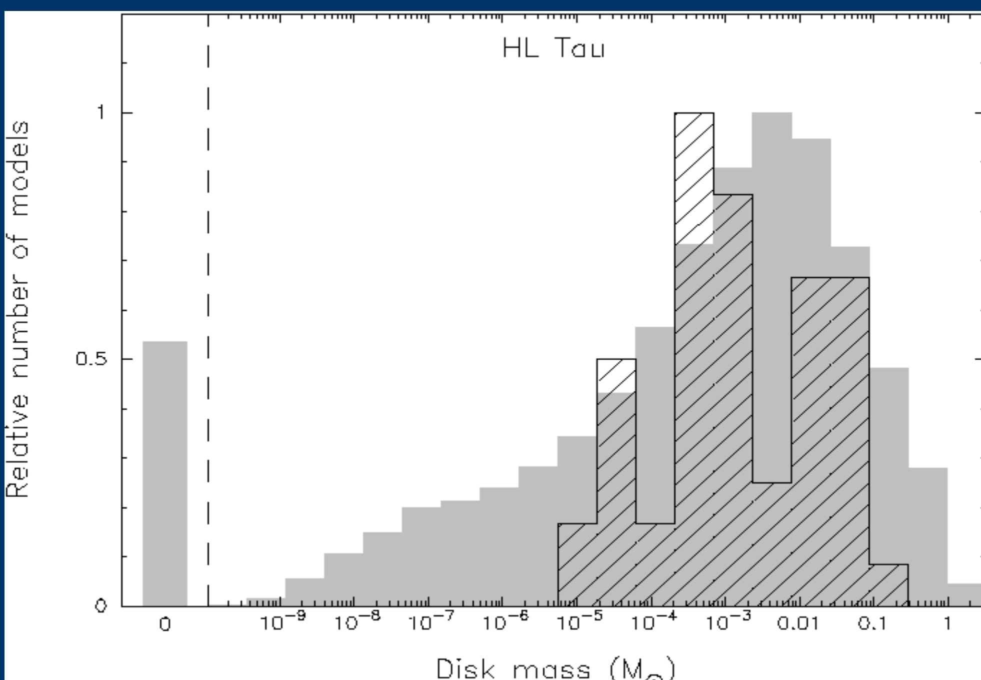
Whitney et al. 2003

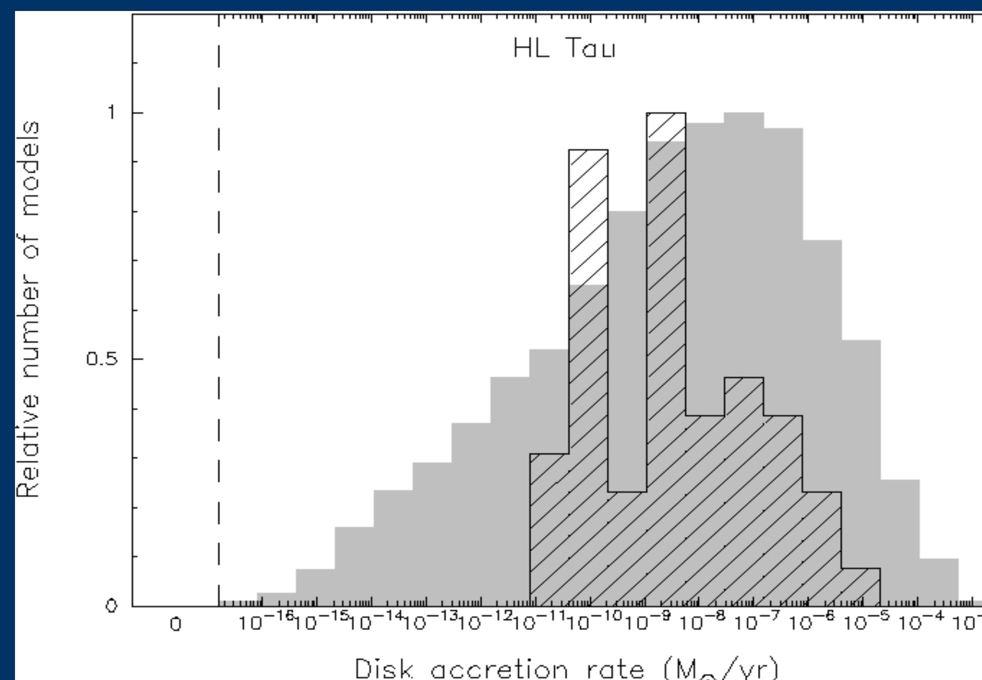





HL Tau
λF_λ (ergs/cm^2/s)
10^{-7}
10^{-8}
10^{-9}
10^{-10}
1
10
100
λ (μm)


HL Tau
Relative number of models
1
0.5
0
0.1
1
10
Stellar mass ($M_\odot$)


HL Tau
Relative number of models
1
0.5
0
0
10^{-9} 10^{-8} 10^{-7} 10^{-6} 10^{-5} 10^{-4} 10^{-3} 0.01 0.1 1
Disk mass ($M_\odot$)

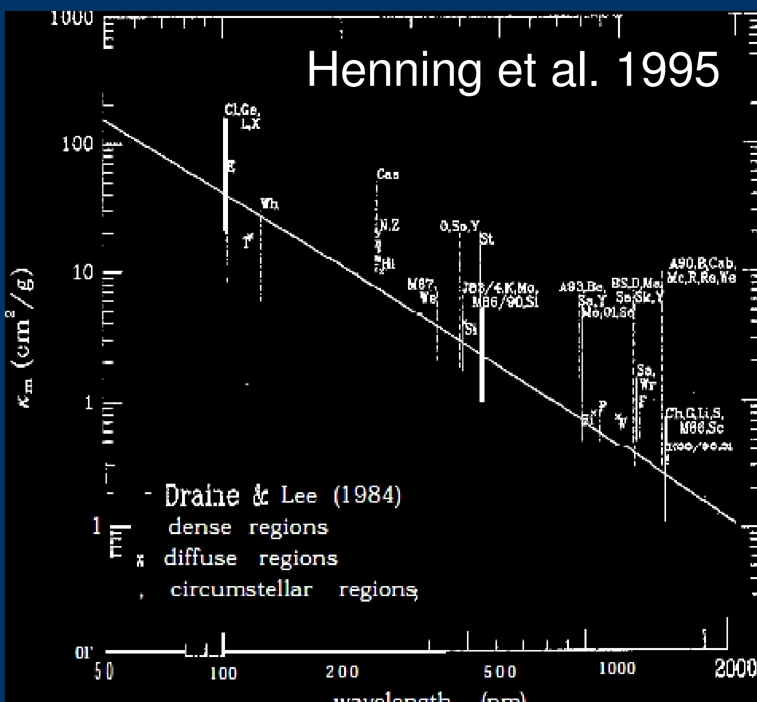

HL Tau
Relative number of models
1
0.5
0
0
10^{-16} 10^{-15} 10^{-14} 10^{-13} 10^{-12} 10^{-11} 10^{-10} 10^{-9} 10^{-8} 10^{-7} 10^{-6} 10^{-5} 10^{-4} 10^{-3}
Disk accretion rate ($M_\odot$/yr)

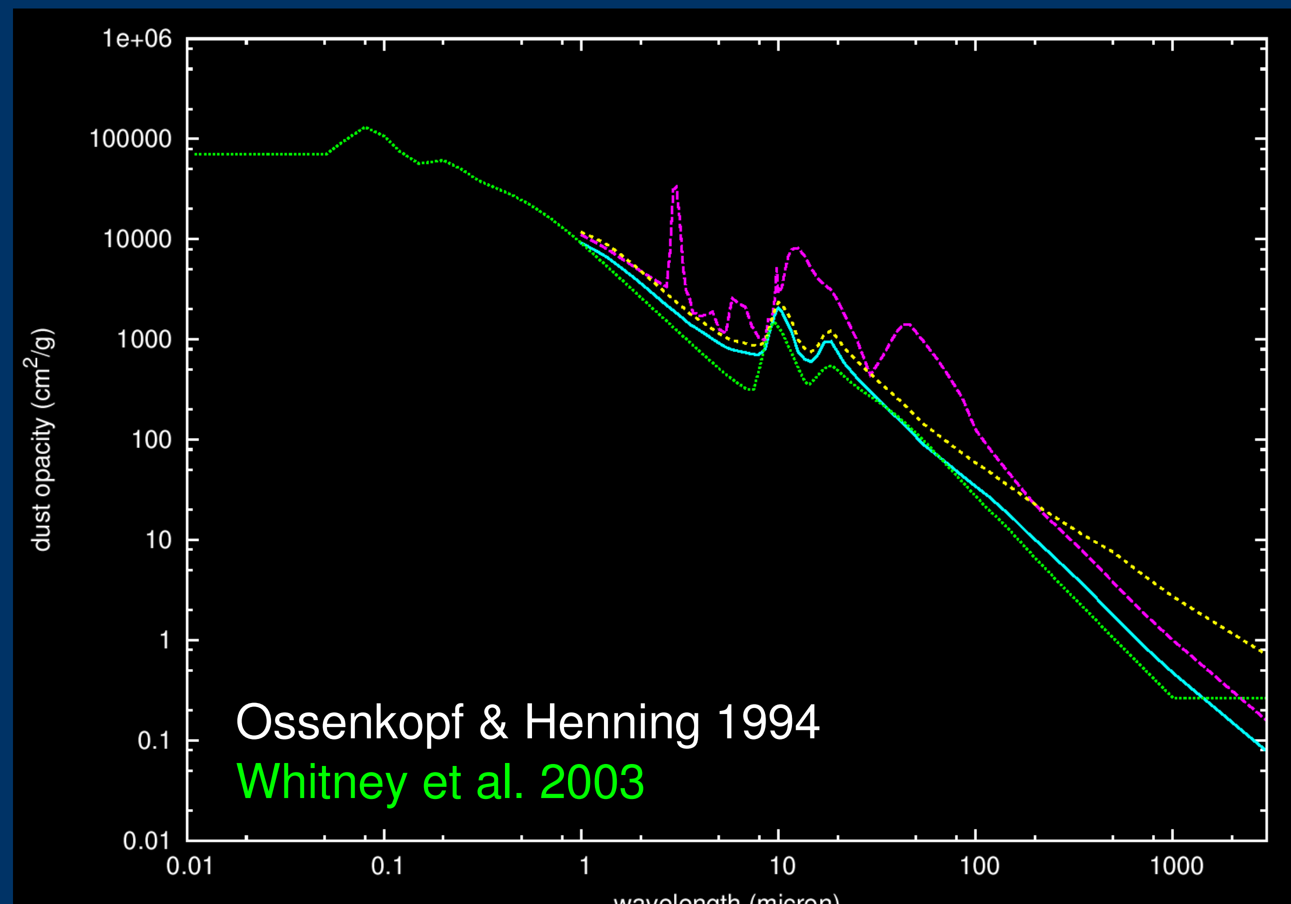
Different dust models – different masses

Dust models → Opacitiy $\kappa(\lambda)$ → Scattering / absorption per mass

Dust constituents:

- Silicates → Features at 10µm, 18µm
- Amorphous carbon
- Ice mantles
- Coagulation





Wrap-up

Interpretating multi-wavelength observations of ISOSS massive star-forming regions:

- Different evolutionary stages
  - Prestellar cores
  - Protostellar objects
  - Young clusters
- Radiative transfer models
  - Dust configuration in submm cores
  - Mass distributions of young clusters
- There exist different dust models...

Thank you for the attention!