Constraining variations of dust properties in circumstellar disks with mm observations

F. Trotta(Arcetri/ESO), L.Testi(ESO/Arcetri), A.Isella(Caltech), L.Ricci(ESO), A.Natta(Arcetri)

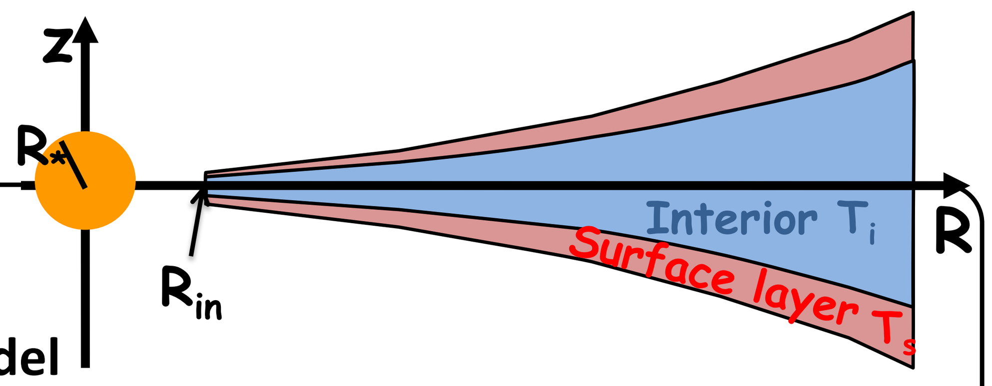
Introduction

Grain growth in protoplanetary disks is the first step towards the formation of the rocky cores of planets. Models predict that grains grow, migrate and fragment in the disk and predict varying dust properties as a function of radius, disk age and physical properties.

To constrain grain growth and migration in protoplanetary disks high-angular resolution observations at more then one (sub-)mm wavelength are currently being performed to detect possible radial variations of the dust properties.

We present initial results of including radial dependent grain growth at the midplane of two layers passive disks. Our models predict variations of the disk emission as a function of radius as a consequence of the different grain distribution as a function of radius. The aim is to compare the prediction of these models against spatially resolved multi-frequency observations of the disk around RY Tau.

Disk Model



We adopt the **two-layer disk model** of *Chiang&Goldreich (1997)* with the modifications of *Dullemond, Dominik &Natta (2001).* These models solve the radiation transfer in a simple way, and allow a self-consistent computation of the geometry of the disk.

For the disk surface density we use a **similarity solution** for a viscous Keplerian disk (*Lynden-Bell & Pringle 1974*)

$$\boxed{\Sigma(R,t) = \Sigma_{tr}\left(\frac{R_{tr}}{R}\right)^{\gamma} e^{-\frac{1}{2(2-\gamma)}\left[\left(\frac{R}{R_{tr}}\right)^{(2-\gamma)}-1\right]}}$$

This has the characteristic of falling off exponentially at large disk radii.

For the dust grain model we assume **compact spherical grains** made of (vol. perc.) 27% silicates and 73% carbonaceous where the components are homogeneous and structured in spherical shells.

To estimate the optical behavior of our composite particles we use **Bruggeman mixing model** to derive an average dielectric function ε_{av} representing the mixture as a whole and then we use ε_{av} in the **Mie theory** to derive the the absorbtion efficiency of the grains.

We have included in our model the possibility to have a radial variation of the grain size distribution. We adopt for the grain size distribution a **truncated Power-Law parametrization:**

$$\boxed{n(a,R) \propto a^{-q(R)}} \qquad a_{\min}(R) < a < a_{\max}(R)$$

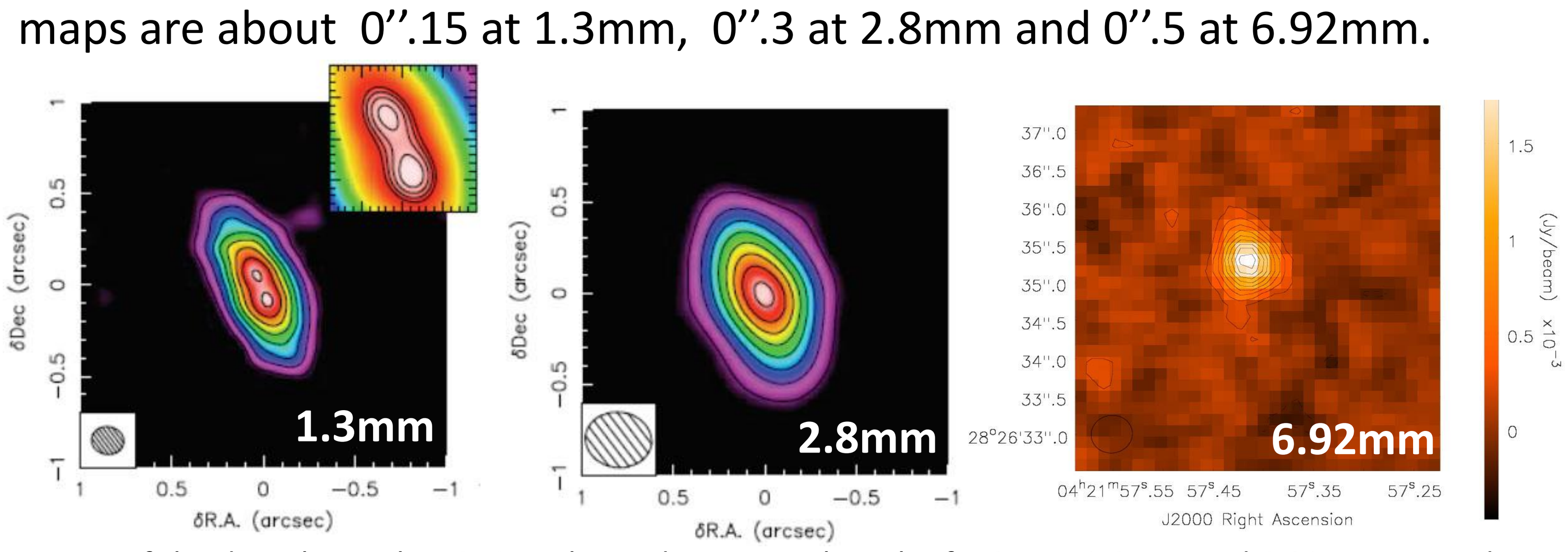
For the maximum grain size we adopt a **Power-Law Profile**

$$\boxed{a_{\max}(R) = a_{0\max}\left(R/R_{0\max}\right)^{b_{\max}}}$$

and we assume for the minimum grain size and index q a constant value along the Radius, respectively $a_{min}(R)$=0.005 μm and the q(R)=3

Observations

We use high angular resolution observations of the thermal dust emission from the circumstellar disk around the young star RY Tau at 1.3mm and 2.8mm from the CARMA interferometer *(Isella, Carpenter, Sarget 2010)* and at 6.92 from the VLA interferometer. The angular resolutions of the maps are about 0''.15 at 1.3mm, 0''.3 at 2.8mm and 0''.5 at 6.92mm.



Maps of the dust thermal emission obseved at a wavelength of 1.3mm, 2.8mm and 6.92mm toward RY Tau.

Method

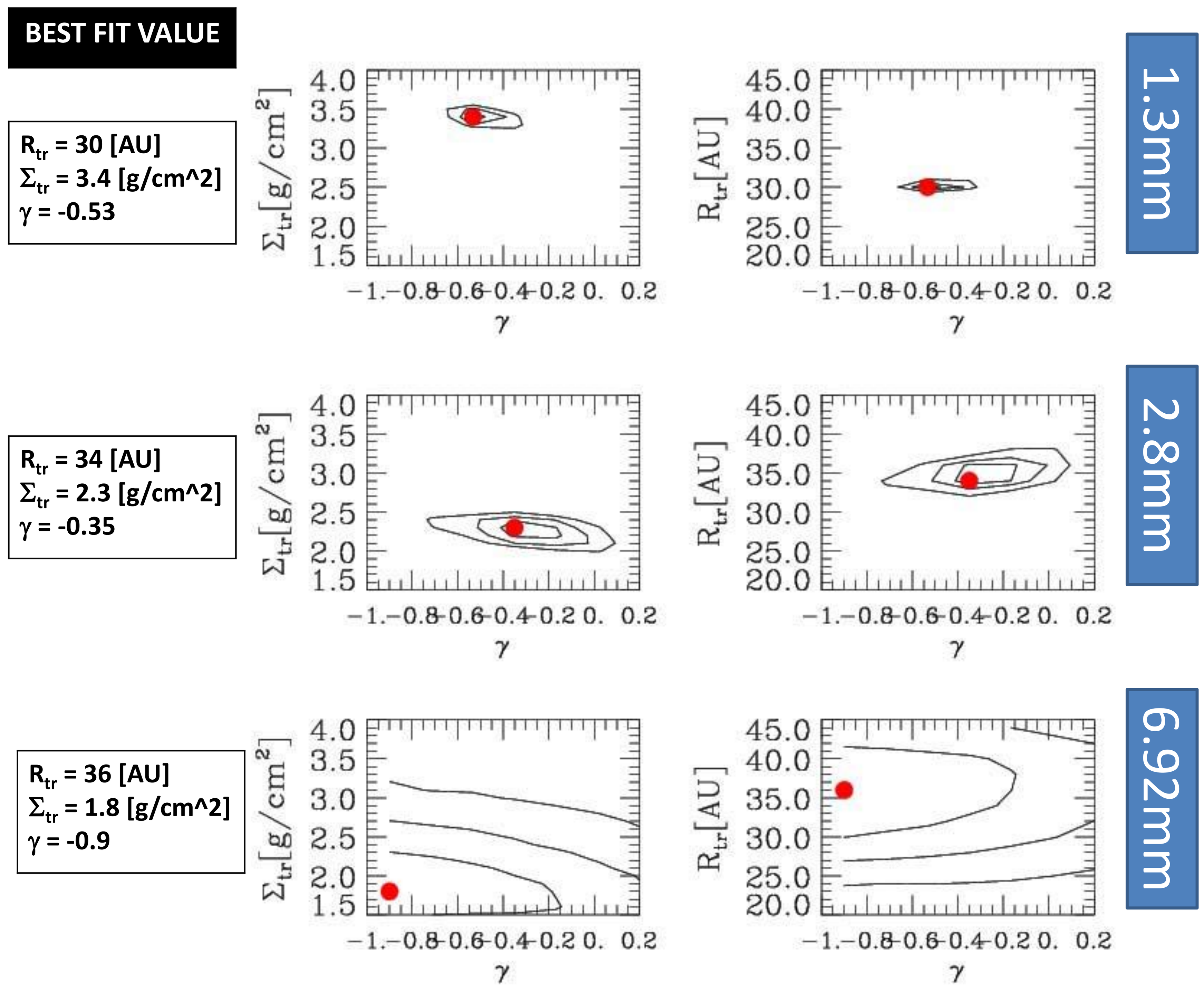
We produced model images corrisponding to different sets of parameters: disk inclination, position angle, index(b_{max}) and normalization(a_{0max}) of the maximum grain size (Power Law) Radial Profile, index(γ), transition radius(R_{tr}) and surface density at transition radius(Σ_{tr}) of the surface density (Similarity solution) Profile.

For each model, the disk images at each wavelength are Fourier trasformed and sampled at the appropriate positions on the (u,v) plane corrisponding to the observed samples and at each wavelength we computed the χ^2 value. This procedure was repeated on a wide grid of model parameters to contruct a χ^2 hypercube.

In order to find the best fitting model, the cube is then searched for the minimum of the χ^2 as a function of all parameters. The procedure is repeated indipendently for all three datasets at the 3 wavelenghts and the best fitting model is derived indipendently at each wavelenght.

Results

As first step we compare our result with that of *(Isella, Carpenter, Sarget 2010).* So we fix the value for the inclination at **66°**, the position angle at **24°** and we take a constant radial profile (**b_{max}=0**) of the maximum grain size with **a_{0max}=0.03cm**. In the intensity profile calculation we take into account also the contribution of free-free emission from the ionized gas.



χ^2 hypercube projectons on the (γ,R_{tr}) and (γ,Σ_{tr}) planes and the corrispetive best fit values for the different wavelengths

The best fit values we found are ~ in agreement with the *Isella*'s result. We add also a new high-resolution observation at 7mm from the VLA interferometer. We are currently running a new fit using a range of values also for b_{max} and a_{0max} with the aim to constrain the radial variation of grain size distribution (under our Power-Law assumption)

Conclusions and Future Prospects

We have presented an initial result of the comparison between the prediction of our disk models against spatially resolved multi-frequency observations of the disk around RY Tau. Our result are in agreement with the precedent work of *(Isella, Carpenter, Sargent 2010).*

The investigation of the radial variation of the dust properties is still strongly limited by the relatively poor angular resolution and sensitivity of the current facilities. Observations with higher angular resolution and sensitivity are needed to place more stringent constrains on the radial variation of the dust opacity. For these purposes, the EVLA and ALMA arrays will play a crucial role in the next future.