# MODELING CIRCUMPLANETARY DISKS LIKE PROTOPLANETARY DISKS: A MISTAKE?

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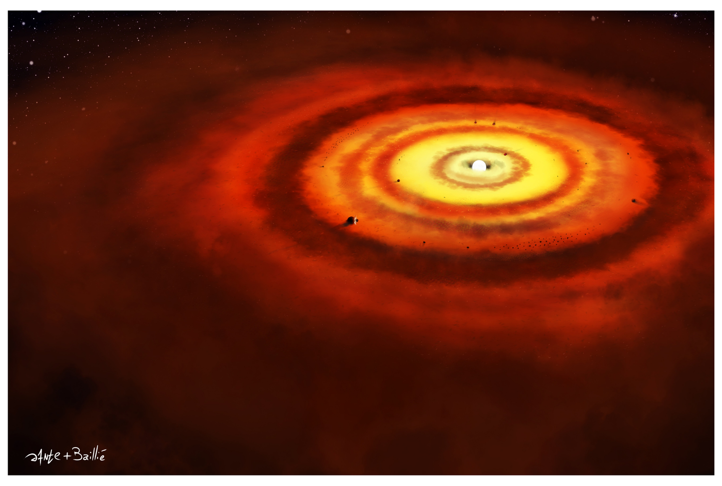
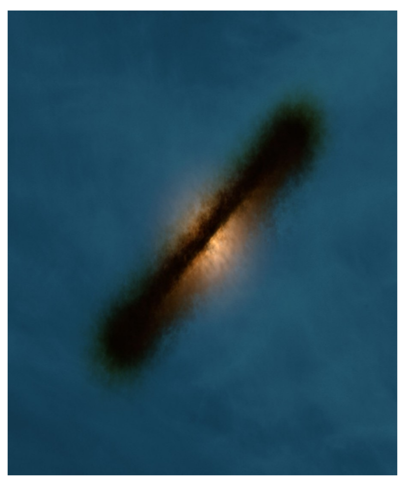


## Abstract

PHYVE is a hydrodynamical code that allows to follow the formation and evolution of protoplanetary disks from the collapse of the molecular cloud to the photoevaporation phase. This code is able to model the surface mass density distribution consistently with the disk radial profile (including the disk composition and geometry). We aim at using this code for modeling circumplanetary disks by considering the protoplanetary disk as the source of infalling material, replacing the molecular cloud that was an initial parameter in the protoplanetary disk simulations. We will simulate the circumplanetary disk radial thermal profile and investigate the crucial parameters differing from protoplanetary disks.

R. Hurt (NASA/JPL-Caltech/IPAC)



## Problematic

**Where and when can satellite embryos survive ?**
**With what size and composition ?**

## Cloud & star model

We interpolate the stellar physical properties from tables of pre-calculated stellar evolutions (Piau et al., 2002, 2011, Marques et al., 2013).

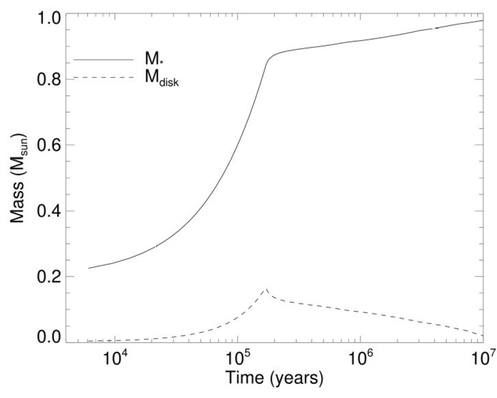


Figure 1 : Star and disk mass evolution.

The disk gains mass from the molecular cloud.
The star gains mass from the molecular cloud and accretion by the disk viscous spreading.

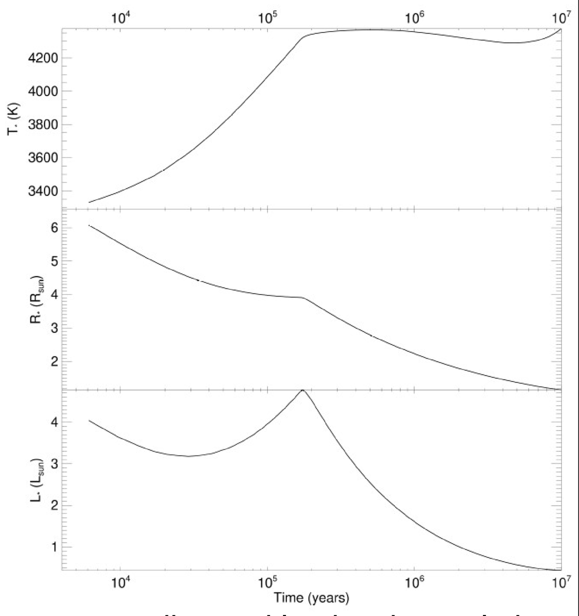
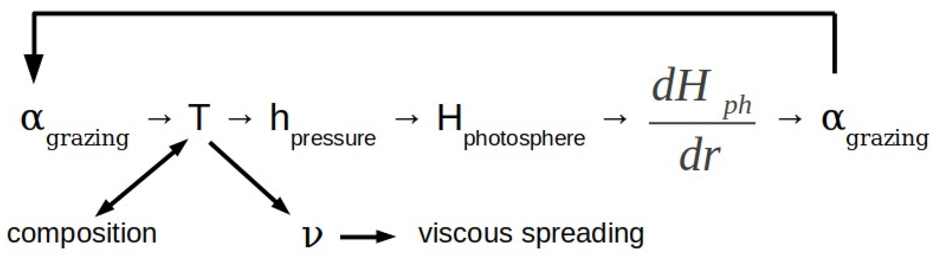


Figure 2 : Stellar temperature, radius and luminosity evolution.

## Disk model

1D + 1D numerical viscous spreading (Lynden-Bell, 1974) hydrodynamical code PHYVE
from Baillié et al., 2014, 2015, 2016, 2019 :

- **heating : irradiation + viscous + cloud + radiative cooling + disk self-shadowing**
- **coupling dynamics ⇄ thermodynamics ($\nu_{turb}$)**
- **coupling temperature ⇄ geometry ($\alpha_{gr}$)**
- **coupling temperature ⇄ composition (opacity)**




| Elements | Condensation / Sublimation Temperature |
|---|---|
| Water ice | 160 K |
| Volatile organics | 275 K |
| Refractory organics | 425 K |
| Troilite FeS | 680 K |
| Olivine, pyroxene ([Fe,Mg] silicates) | 1500 K |

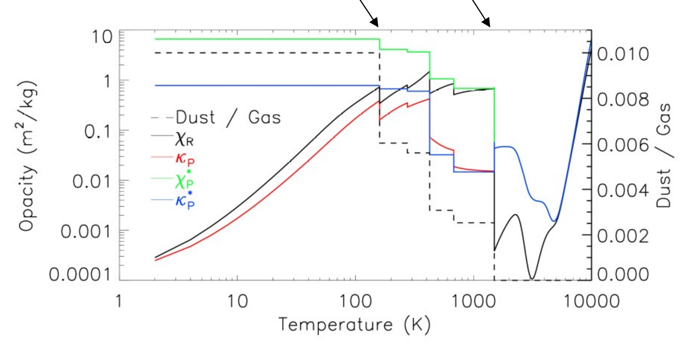


Figure 3 : Opacity variations with local temperature (from Semenov et al., 2003)

## Disk structure and evolution

- The disk grows for **170 kyr** before emptying on the star by viscous spreading
- It gets hotter until the end of the collapse phase and then cools down
- Sublimation lines migrate as the disk evolves

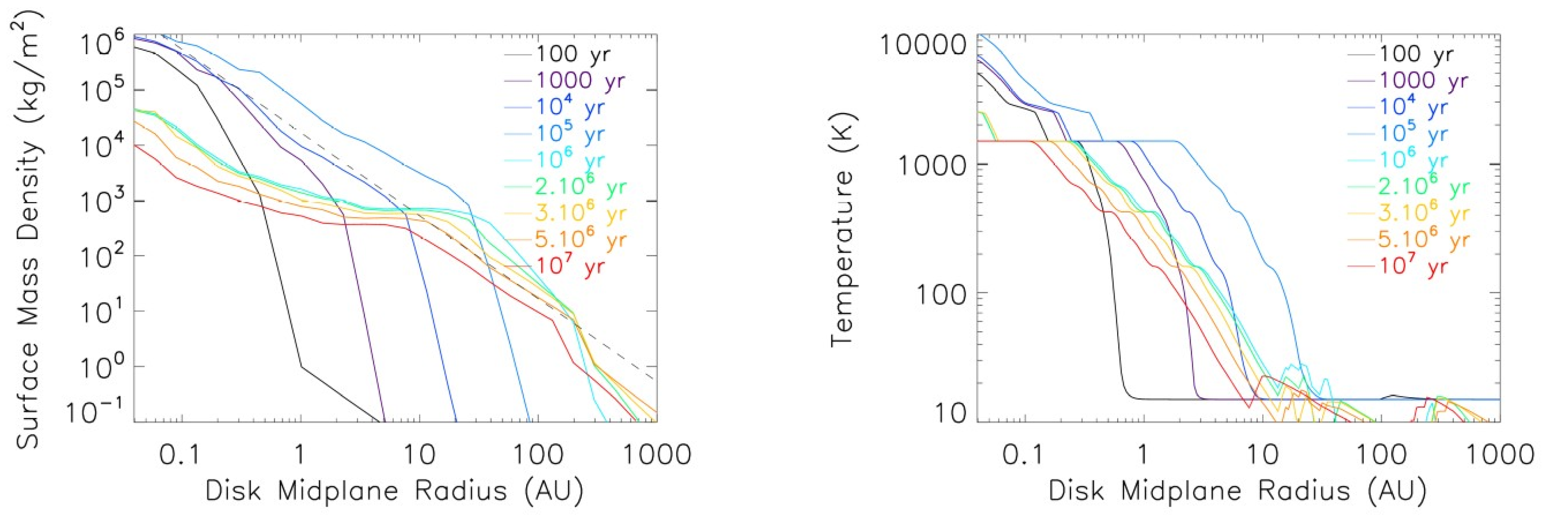


Figure 4 : Evolution of the surface-mass density and temperature radial profiles for disk fed by collapse of the molecular cloud.

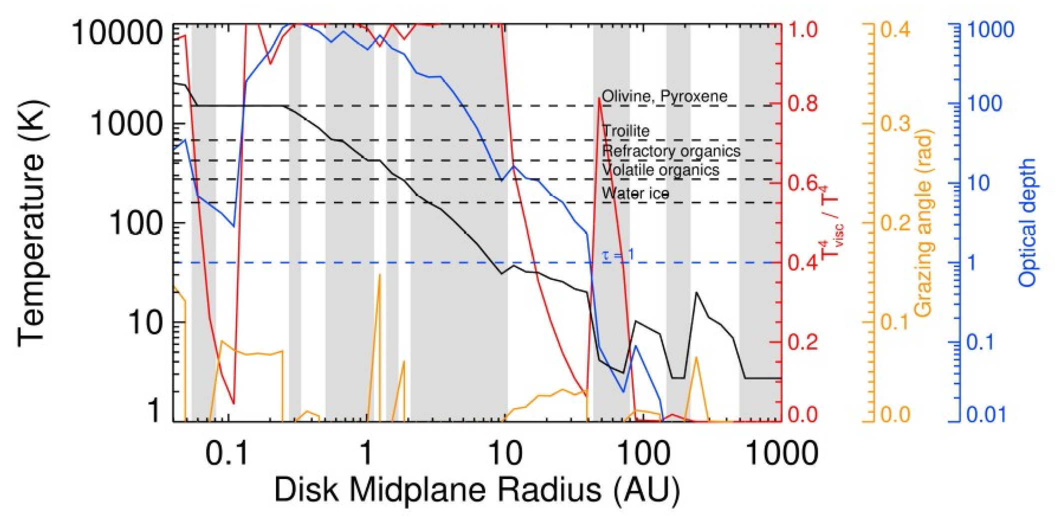


Figure 5 : Mid-plane temperature radial profile after 1 Myr. Shadowed regions in gray. The ratio of the viscous heating contribution over the total heating is presented in red, the grazing angle profile in yellow and the optical depth profile in blue.

- Most of the **inner disk is self-shadowed** (up to the heat transition barrier)
- Sharp edge and positive temperature gradient at the heat transition barrier
- **Enlarged snow and sublimation zones at the temperature plateaux**

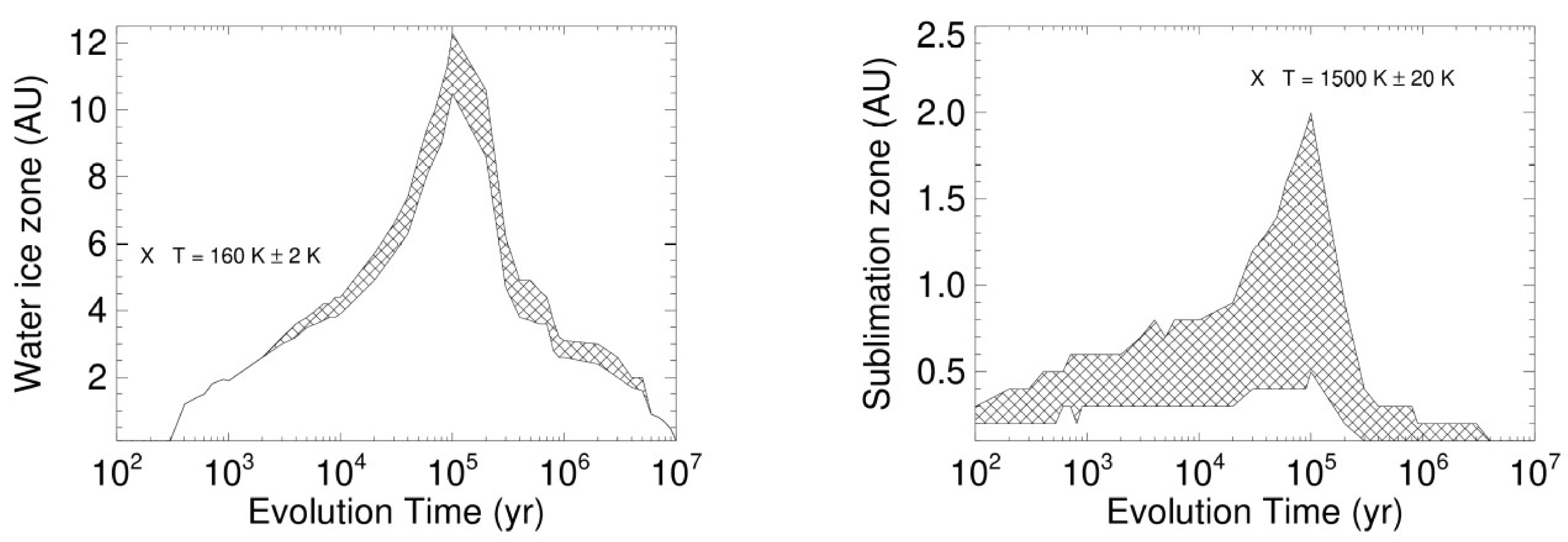


Figure 6 : Time evolution of the snow region and silicates sublimation zone.

**Sublimation lines and therefore traps migrate outward at first and inward after the end of the collapse phase**

## Circumplanetary disk model

We consider a growing CPD and planet around a Zero-Age Main Sequence star.
CPD heating includes :

- PPD external heating (infalling material)
- CPD viscous heating
- Stellar irradiation

Tha angular momentum of the infalling material is the angular momentum of the PPD annulus of infalling gas and dust, taken from Baillie et al., 2019 simulations.

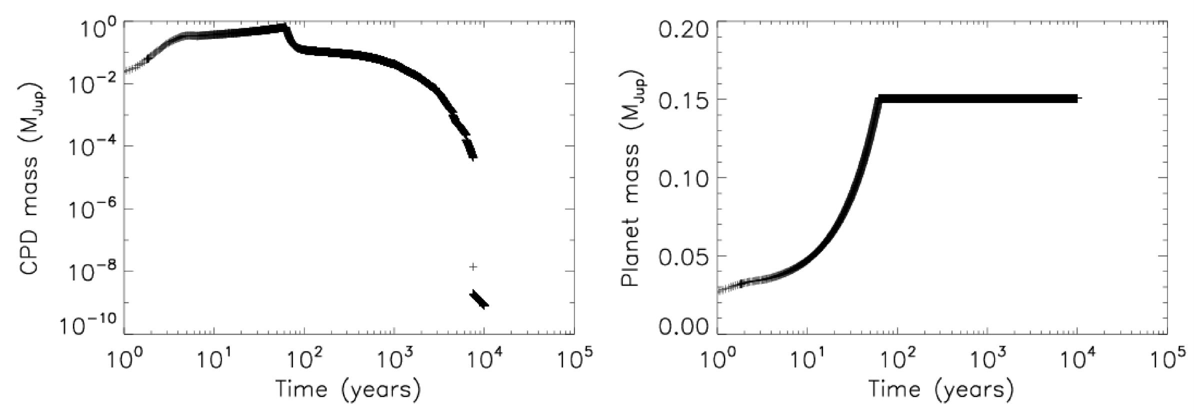
## Initial conditions

Starting from the numerical simulations of a growing star and protoplanetary disk, fed by the collapse of a primordial molecular cloud detailed in Baillié et al., 2019, we chose to consider a snapshot at **4 Myr** (i.e. 1 Myr after the MMSN stage) and locate our CPD **at the snowline (1.7 AU)**.
The infalling material is at **160K**.

The CPD turbulent viscosity is equal to the PPD turbulent viscosity :
$\alpha_{CPD} = \alpha_{PPD} = 10^{-2}$

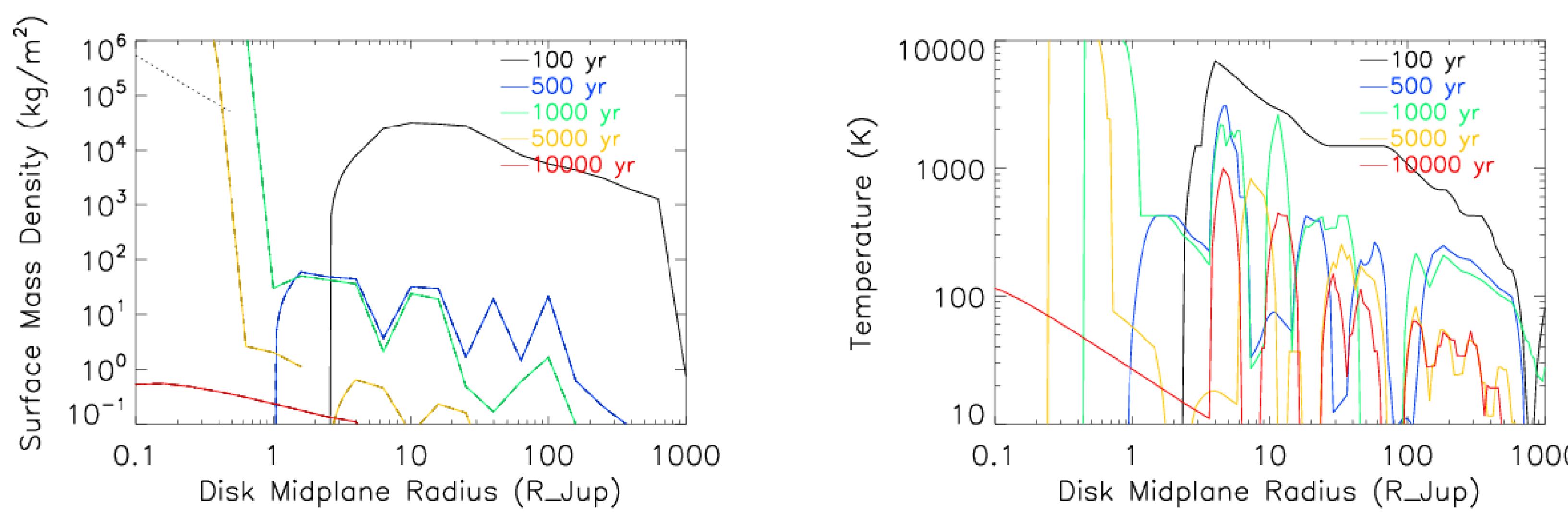
The stellar parameters, and the density profile are inherited from the PPD simulation.

$M_* = 0.95\ M_{Sun}$
$R_* = 1.4\ R_{Sun}$
$L_* = 0.7\ L_{Sun}$
$T_* = 4280$ K
$\Sigma \propto r^{-0.5}$



Additional physical effects:

- Disk self-shadowing
- Adiabatic heating
- Photoevaporation



- **The disk forms in 170 kyr and reaches an MMSN-like stage in 2-3 Myr**
- **Planet traps follow the sublimation lines → « trapped migration »**
- **Modeling the disk formation by the cloud collapse allows to understand the multiple trapping possibilities in the first million years of planet formation**

## Perspectives

- Trapping protosatellites at icelines
- Satellite growth and composition (gas anomaly ? )
- Planet irradiation
- Variable turbulent viscosity, deadzones, stellar evolution

https://perso.imcce.fr/kevin-baillie/migrationmap_movie.html

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