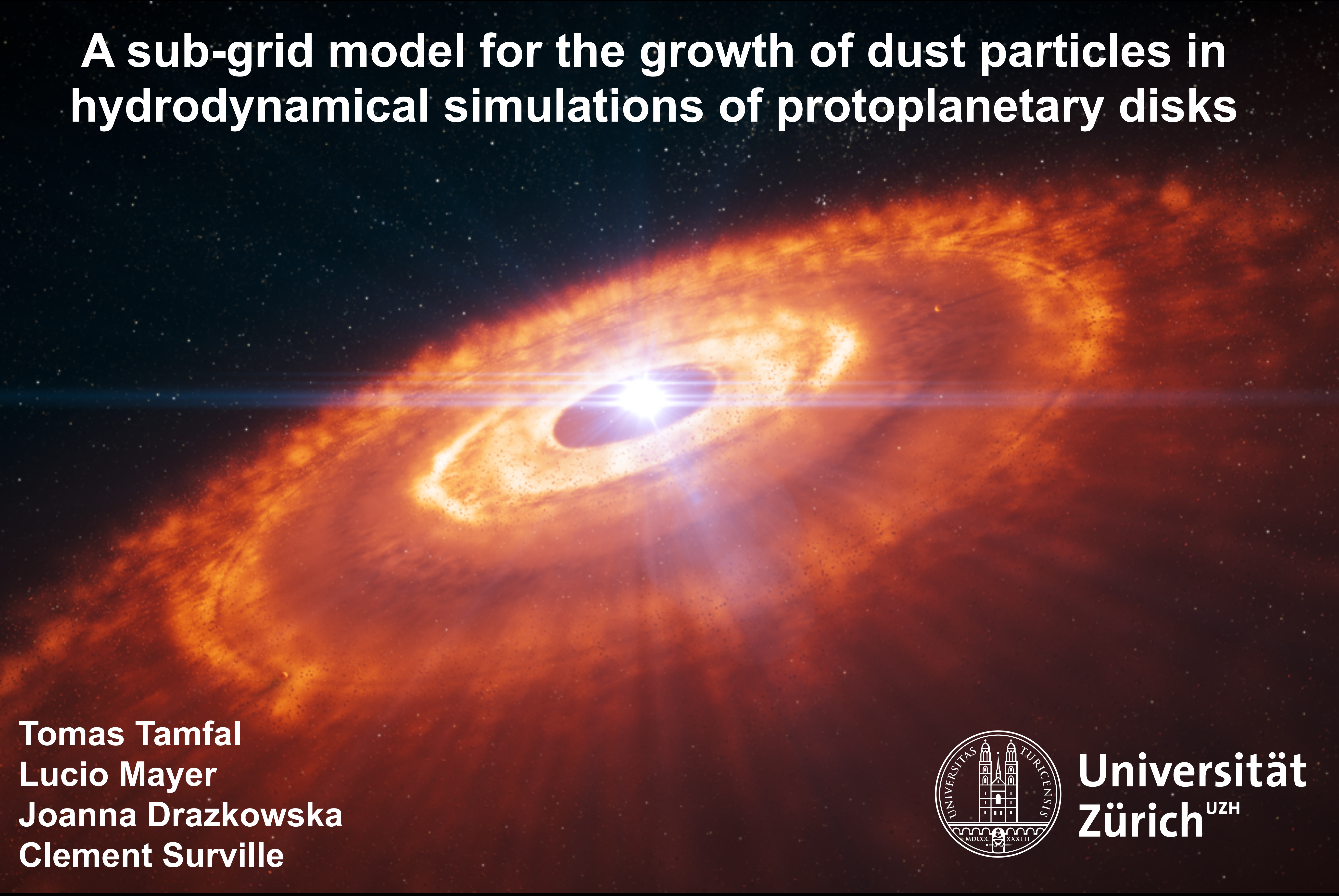
A sub-grid model for the growth of dust particles in hydrodynamical simulations of protoplanetary disks

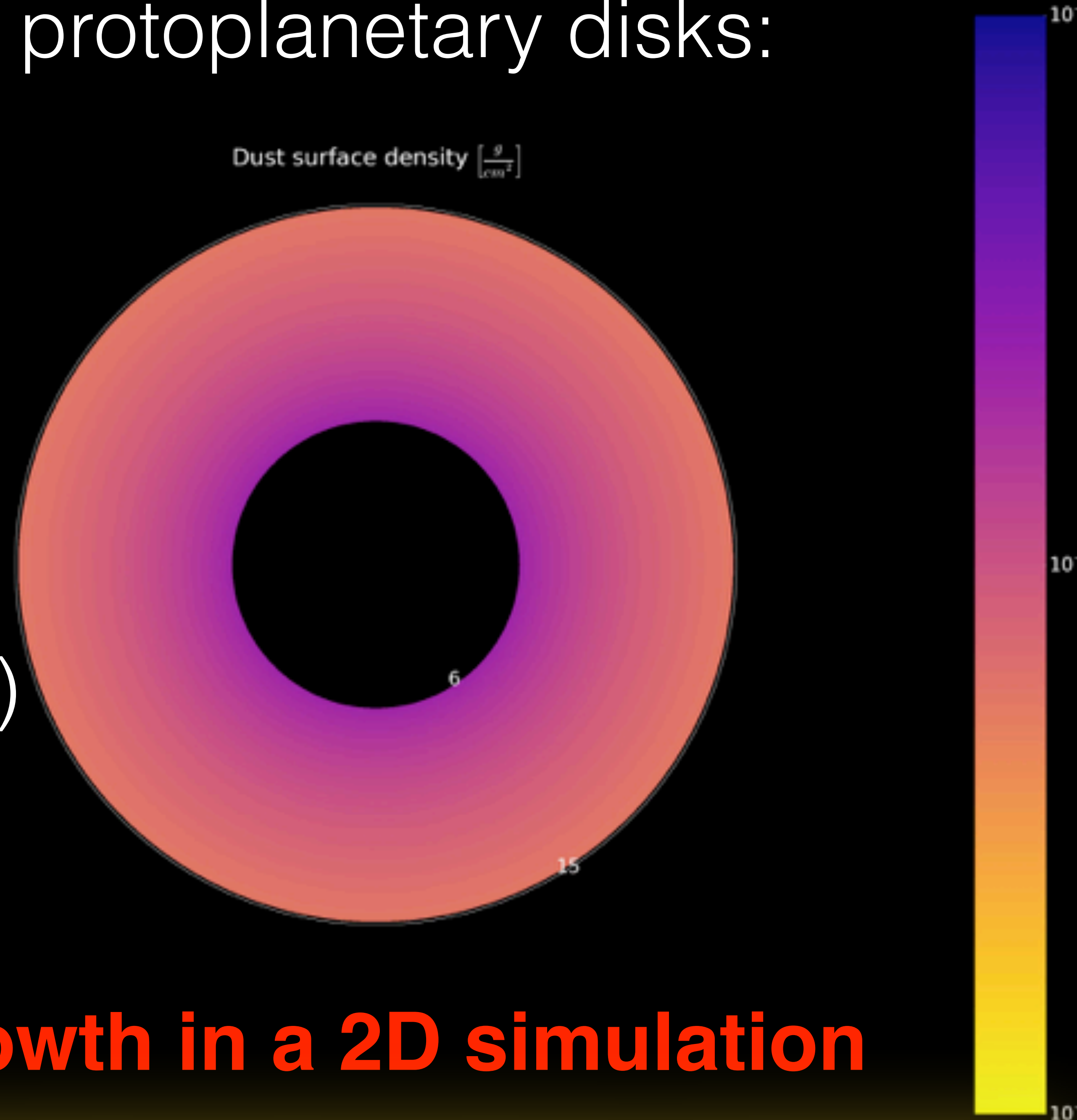


Tomas Tamfal
Lucio Mayer
Joanna Drazkowska
Clement Surville

Universität Zürich[UZH]

Introduction & hydrodynamical code

Current simulations of protoplanetary disks:



- 2D fluid dynamical simulations *(e.g. RoSSBi)*
- Fixed dust size (i.e. no coagulation)

Goal:

Implement dust growth in a 2D simulation

RoSSBi: Explained by Clement Surville

Method

Idea: *(based on Birnstiel et al 2012)*

- Determine maximum particle size from full 1D simulations
- Find semi analytical expressions of maximum sizes

$$a_{\max} \propto f(\Sigma_{g,d}, P, \rho_s, \ldots.)$$

- Compare with full simulations and find coefficients

$$a_{\max} = C_{\text{experimental}} \cdot f(\Sigma_{g,d}, P, \rho_s, \ldots.)$$

What are the maximum values?

✓ **a_{drift}:**

Drift limited size

✓ **a_{df}:**

Drift induced fragmentation

✓ **a_{frag}:**

Turbulence induced fragmentation

New size

MIN → a_1

✓ **a_{ini}:**

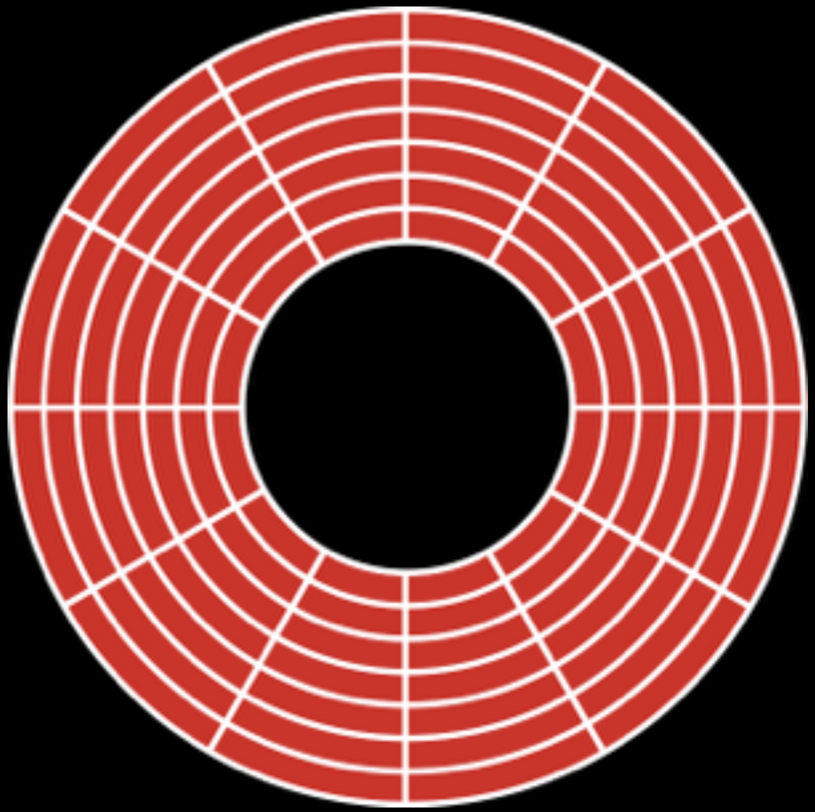
Simulation of the initial growth

Maximum size

MIN → a

Implementation

Algorithm *in RoSSBi*:



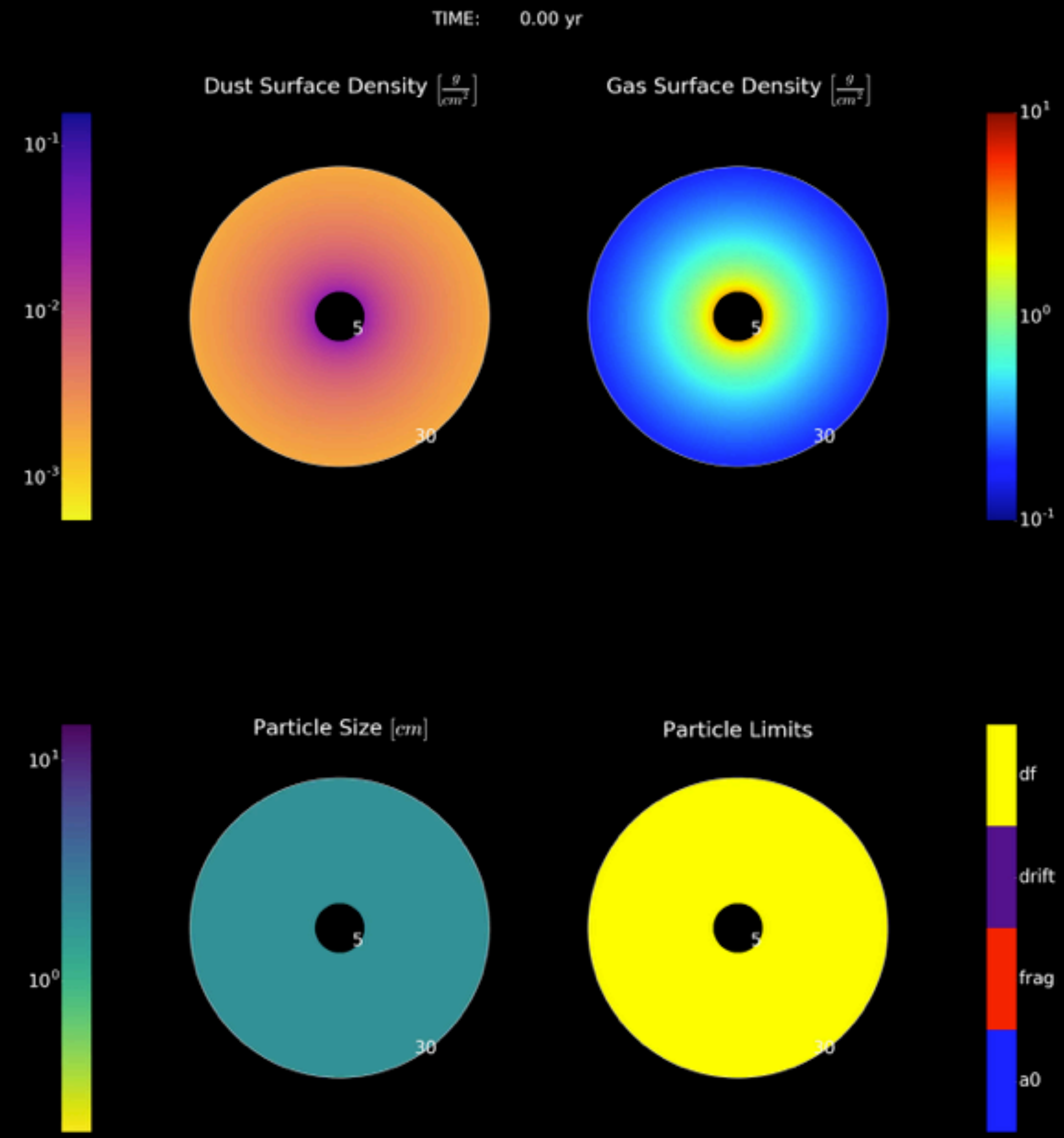
- 2D Disk
- Go through each cell and find the maximum size of the particles
- Dust density is governed by maximum size

Results

Details:

- Planet 1.6 earth mass
- Disk: 5 - 30 AU
- Starting dust size 2 cm
- Dust to gas: 10^-2
- Gas model:

$$\Sigma_g = 1780 \left(\frac{r}{AU}\right)^{-1} \left[\frac{g}{cm^2}\right]$$



Comparison *(RoSSBi vs RoSSBi)*

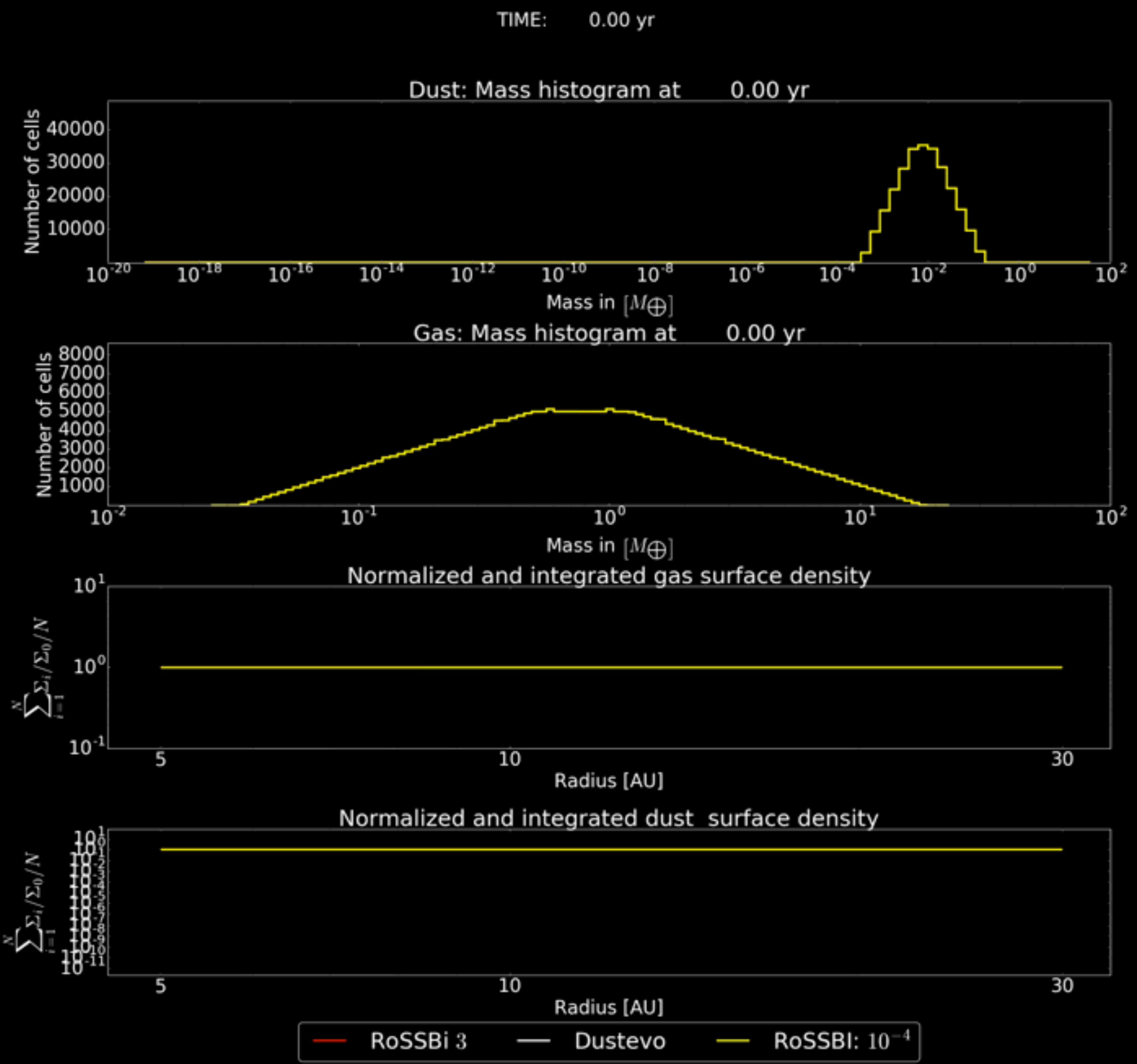
Comparison: *RoSSBi vs RoSSBi (& growth)*

• Planet:	*Jupiter mass*
• Disk:	*5 - 30 AU*
• Particle size 1:	*3 cm*
• Particle size 2:	*10^-4 cm*
• Particle size 3:	10^-4 cm
• Dust to gas:	*10^-2*
• Gas model:	*Minimum Mass Solar Nebula*

Comparison *(RoSSBi vs RoSSBi)*

Comparison:

- *Jupiter mass*
- *5 - 30 AU*
- *3 cm*
- 10^-4 *cm*
- 10^-4 cm
- *10^-2*
- *MMSN*



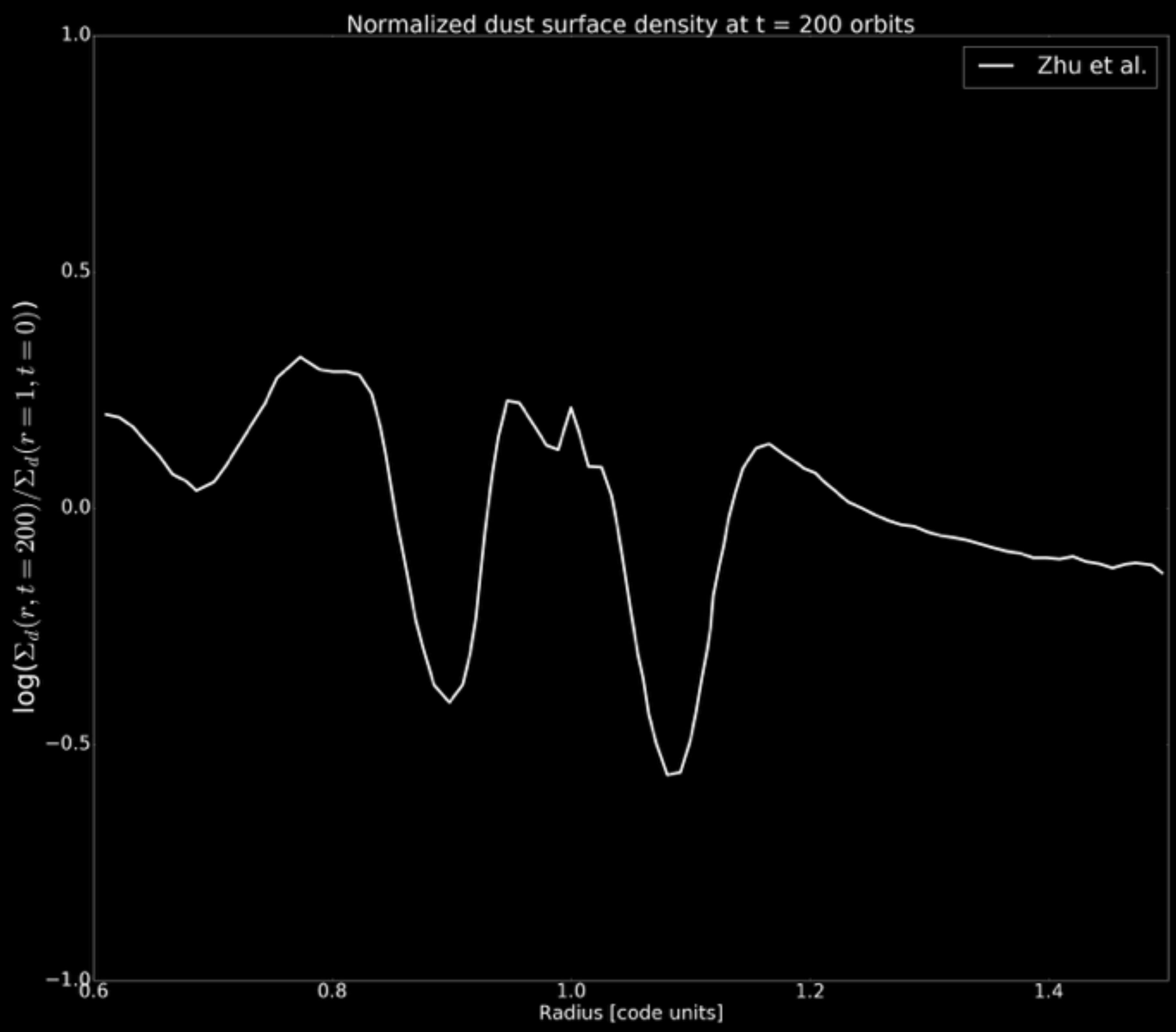
Comparison *(RoSSBi vs cylindrical ATHENA)*

Comparison: *RoSSBi vs ATHENA (Zhu et al. 2012)*

- Planet: *1.6 earth masses*
- Disk: *0.5 - 3.0 [Code units]*
- Particle size: *2 cm*
- Gas model: $\Sigma_g = 1780 \left(\frac{r}{AU}\right)^{-1} \left[\frac{\mathrm{g}}{\mathrm{cm}^2}\right]$
- Evolution time: *200 orbits (~ 6000 yr)*
- Dust to gas: *10^-2*

Comparison *(RoSSBi vs cylindrical ATHENA)*

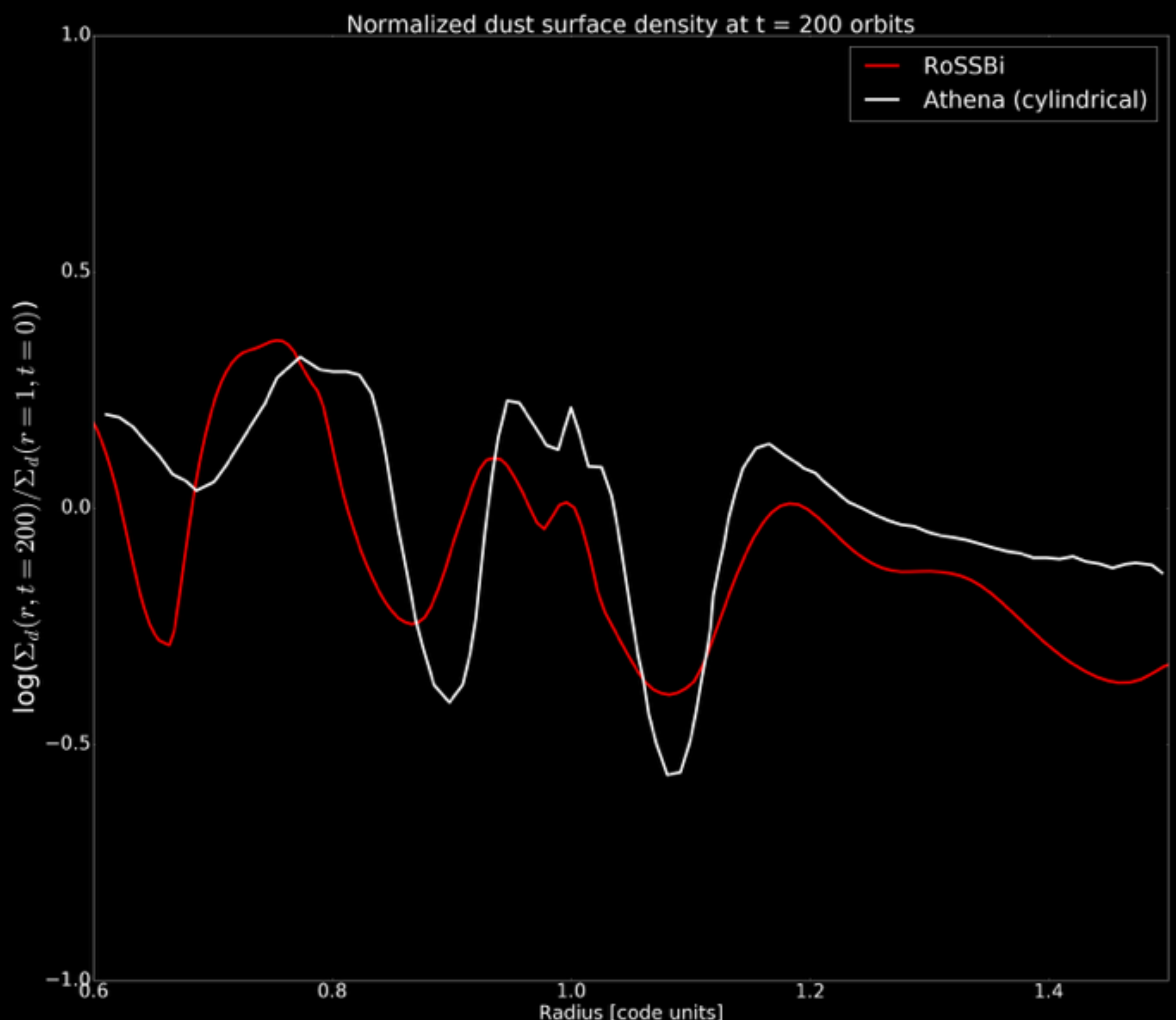
Outline:



Comparison *(RoSSBi vs cylindrical ATHENA)*

Outline:

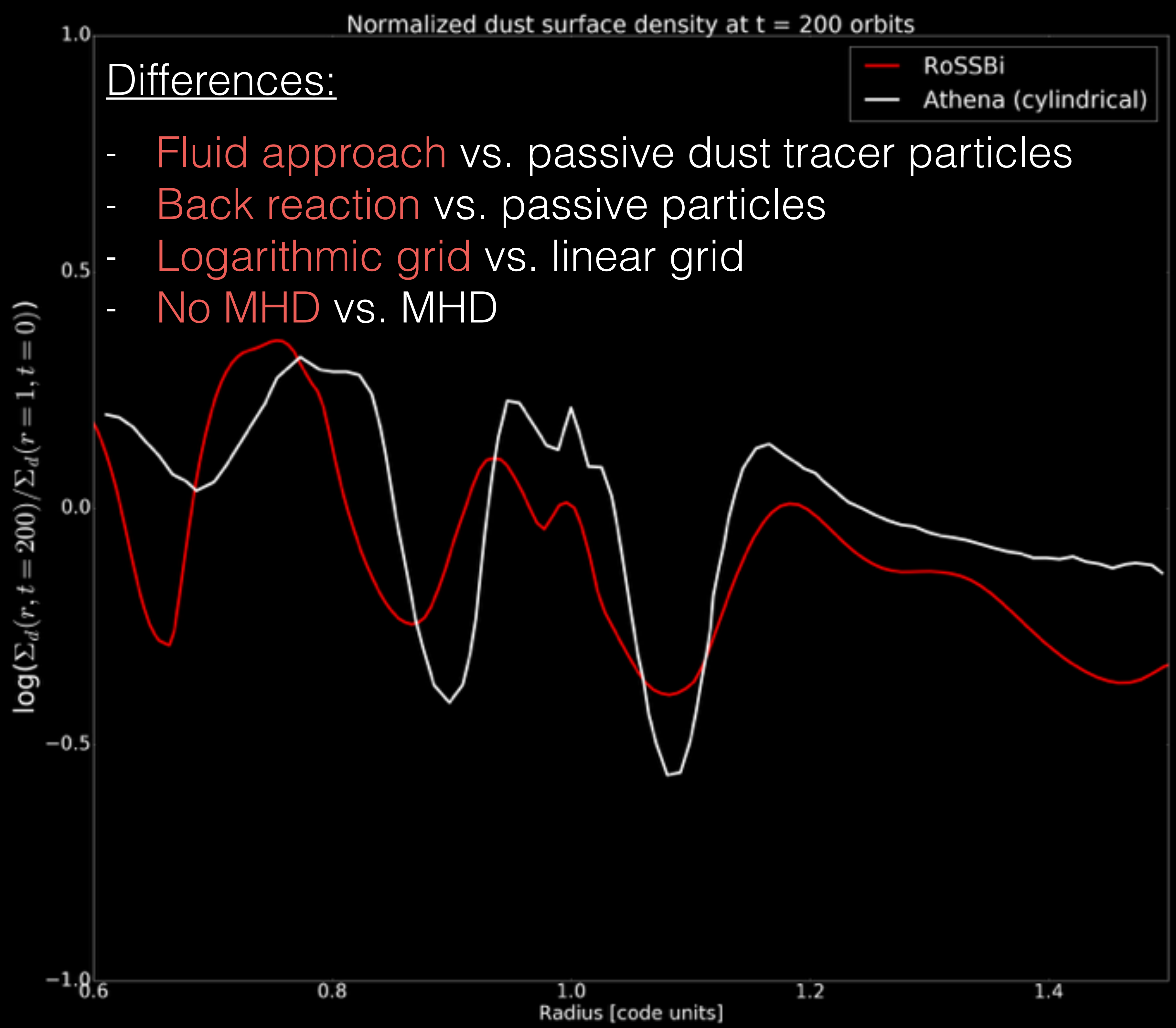
i. Introduction & hydrodynamical code
ii. Dust coagulation
iii. Results
iv. Summary



Outline:

i. Introduction & hydrodynamical code
ii. Dust coagulation
iii. Results
iv. Summary

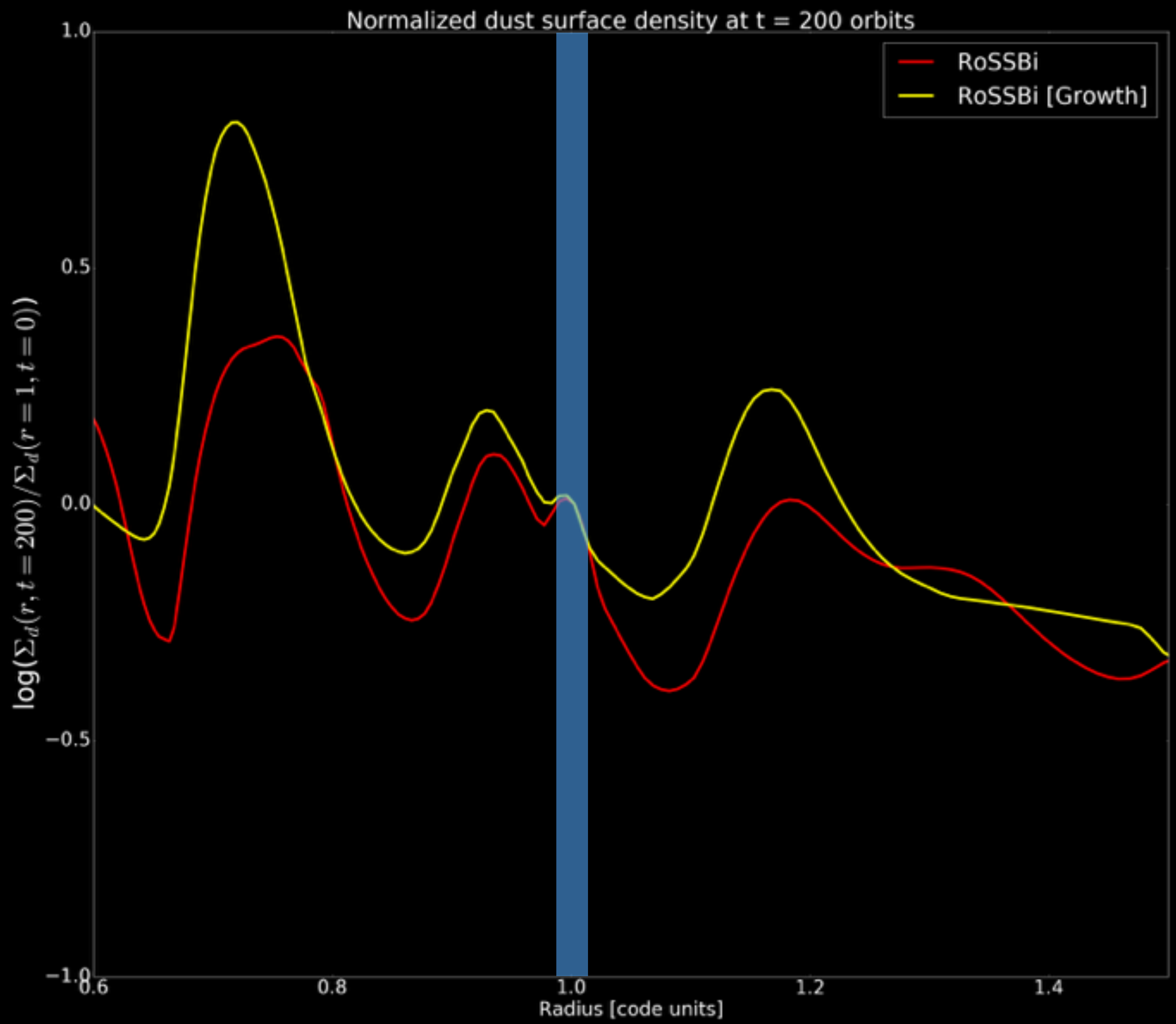
Comparison *(RoSSBi vs cylindrical ATHENA)*



Differences:

- Fluid approach vs. passive dust tracer particles
- Back reaction vs. passive particles
- Logarithmic grid vs. linear grid
- No MHD vs. MHD

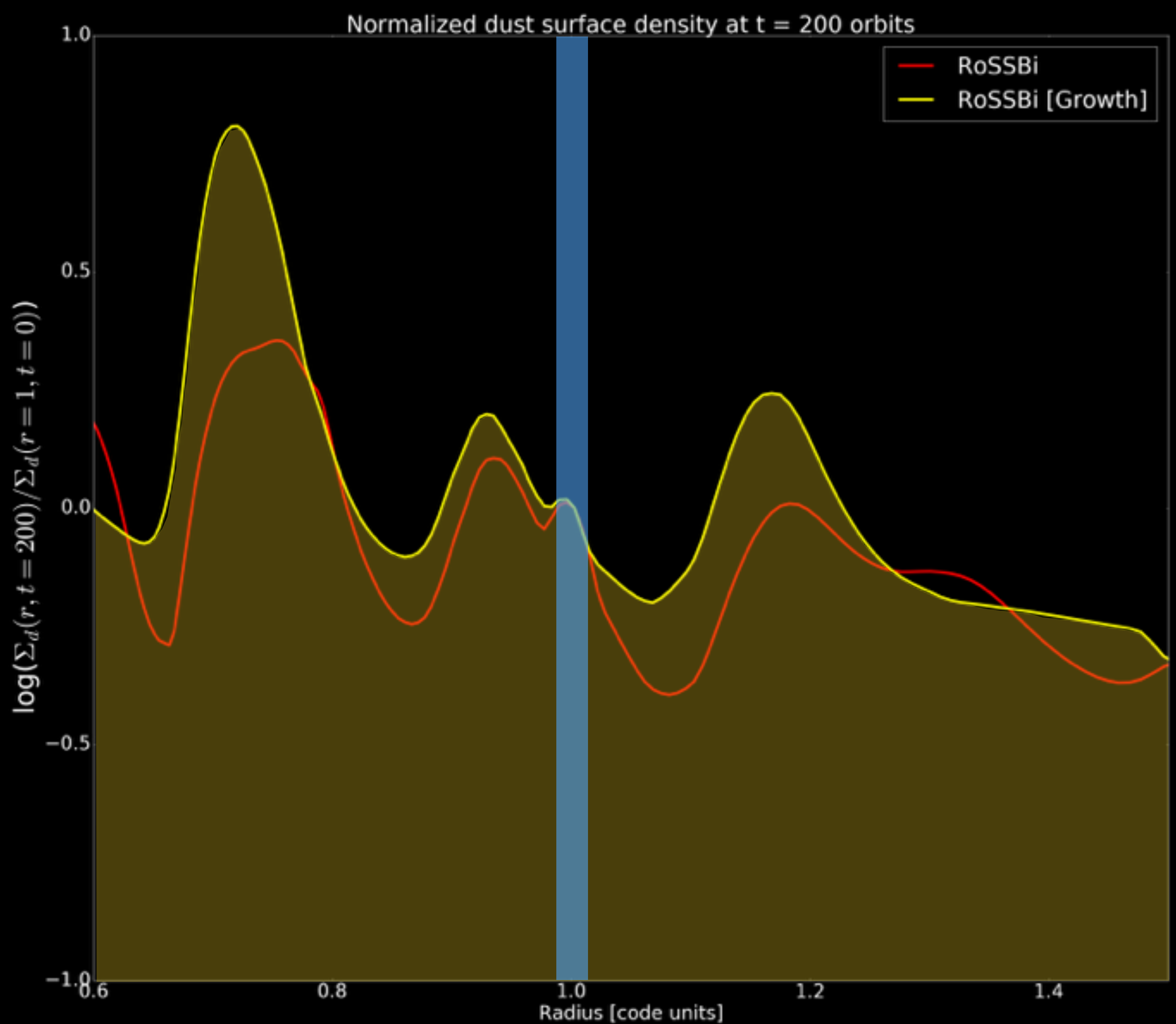
Comparison *(RoSSBi vs cylindrical ATHENA)*



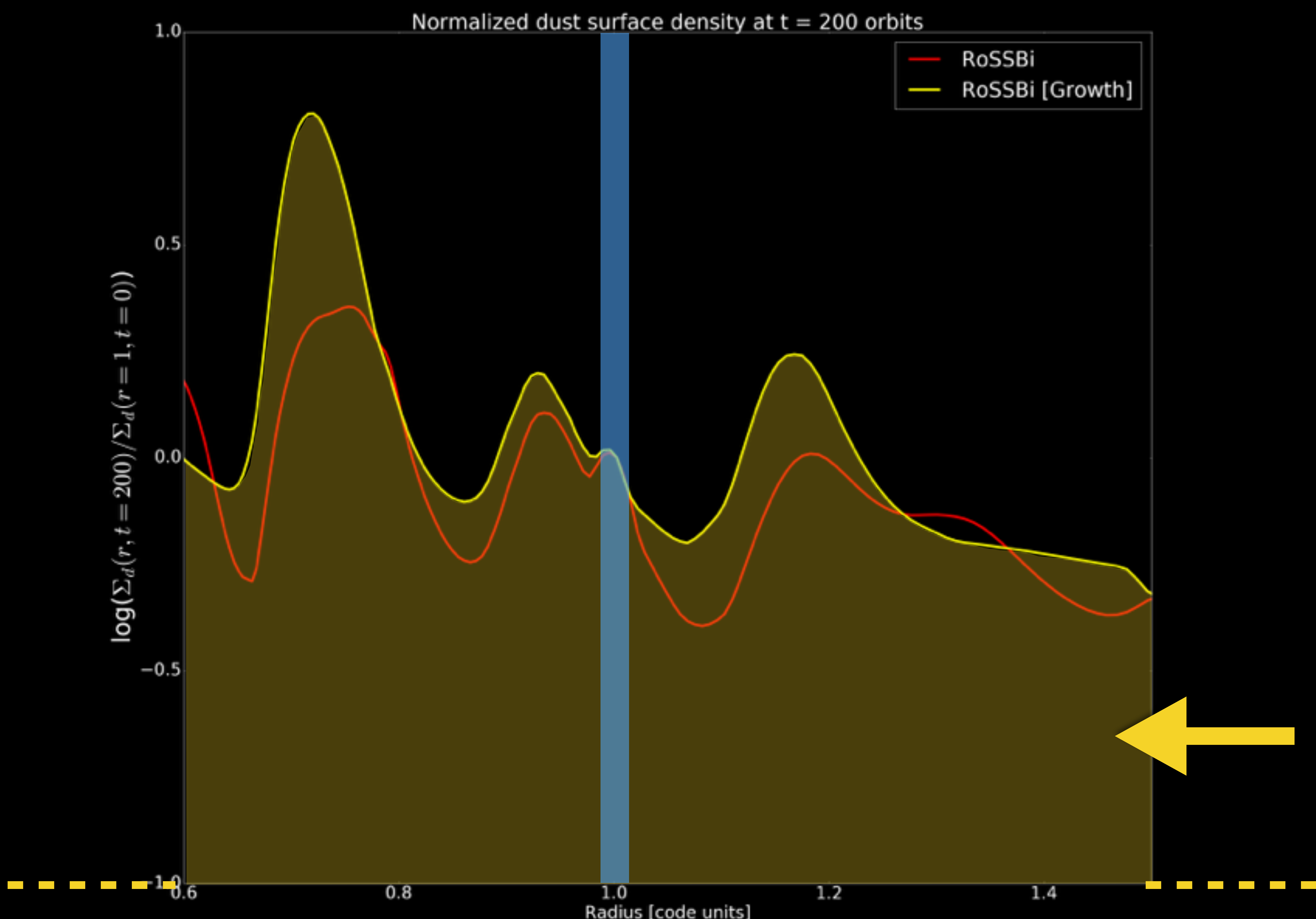
Comparison *(RoSSBi vs cylindrical ATHENA)*

Outline:

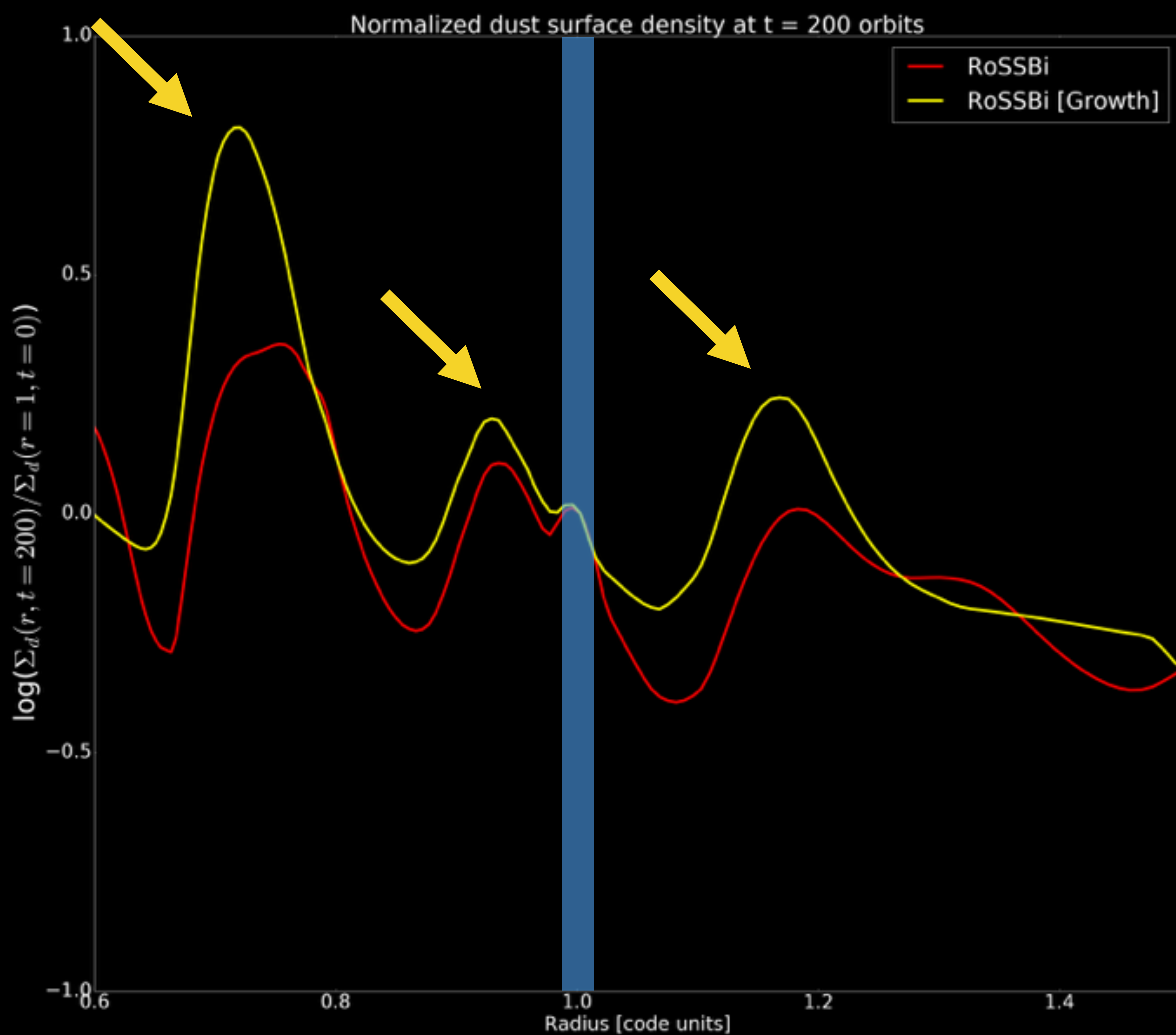
- i. Introduction & hydrodynamical code
- ii. Dust coagulation
- iii. Results
- iv. Summary



Comparison *(RoSSBi vs cylindrical ATHENA)*



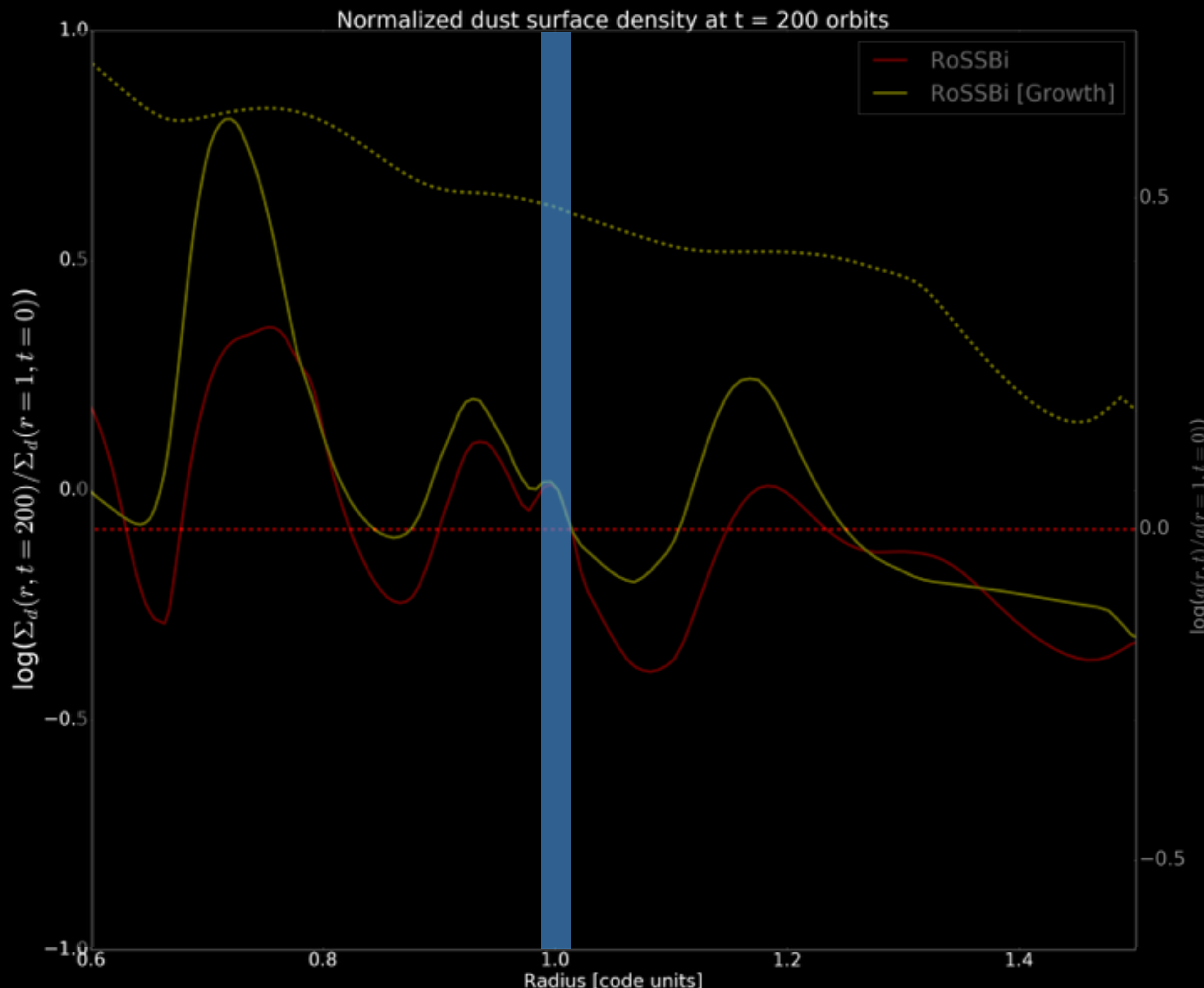
Comparison *(RoSSBi vs cylindrical ATHENA)*



Comparison *(RoSSBi vs cylindrical ATHENA)*

Outline:

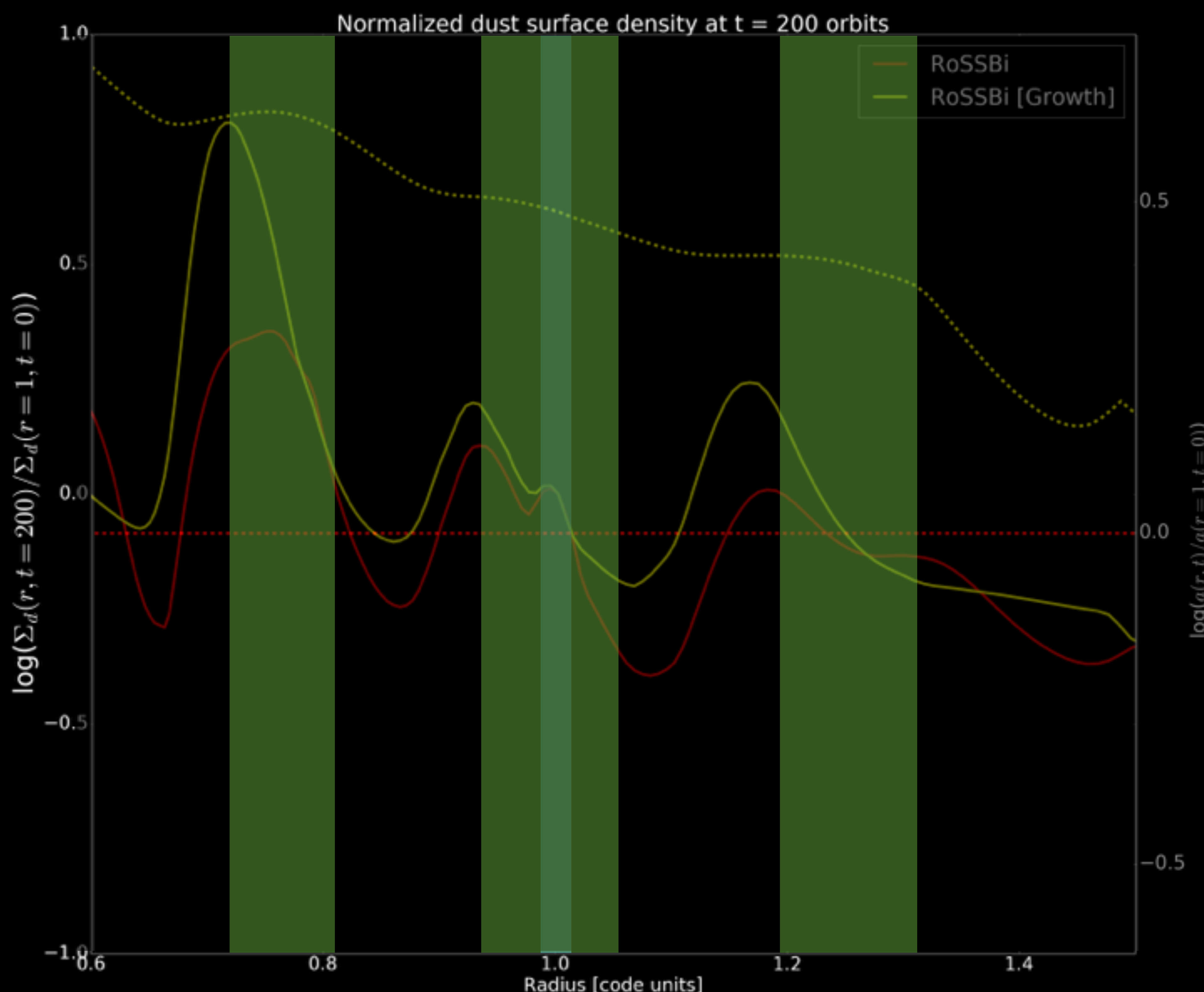
i. Introduction & hydrodynamical code
ii. Dust coagulation
iii. Results
iv. Summary



Comparison *(RoSSBi vs cylindrical ATHENA)*

Outline:

i. Introduction & hydrodynamical code
ii. Dust coagulation
iii. Results
iv. Summary



Summary

Take home messages:

- Dust growth is important!
- A variable dust size affects the evolution of protoplanetary disks.
- *For fixed dust simulations: Intermediate dust size.*

Outline:

THANK YOU FOR YOUR ATTENTION!