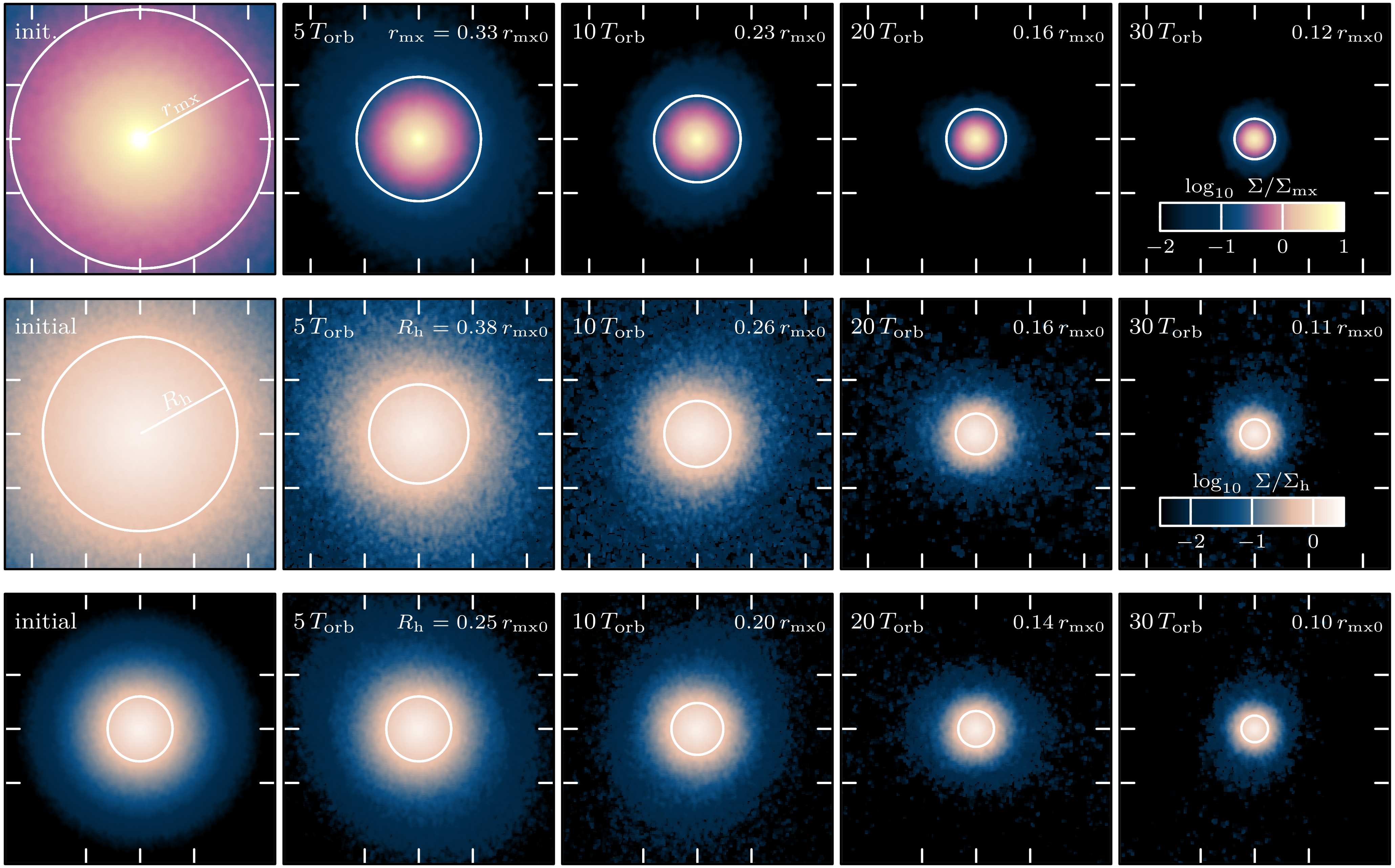
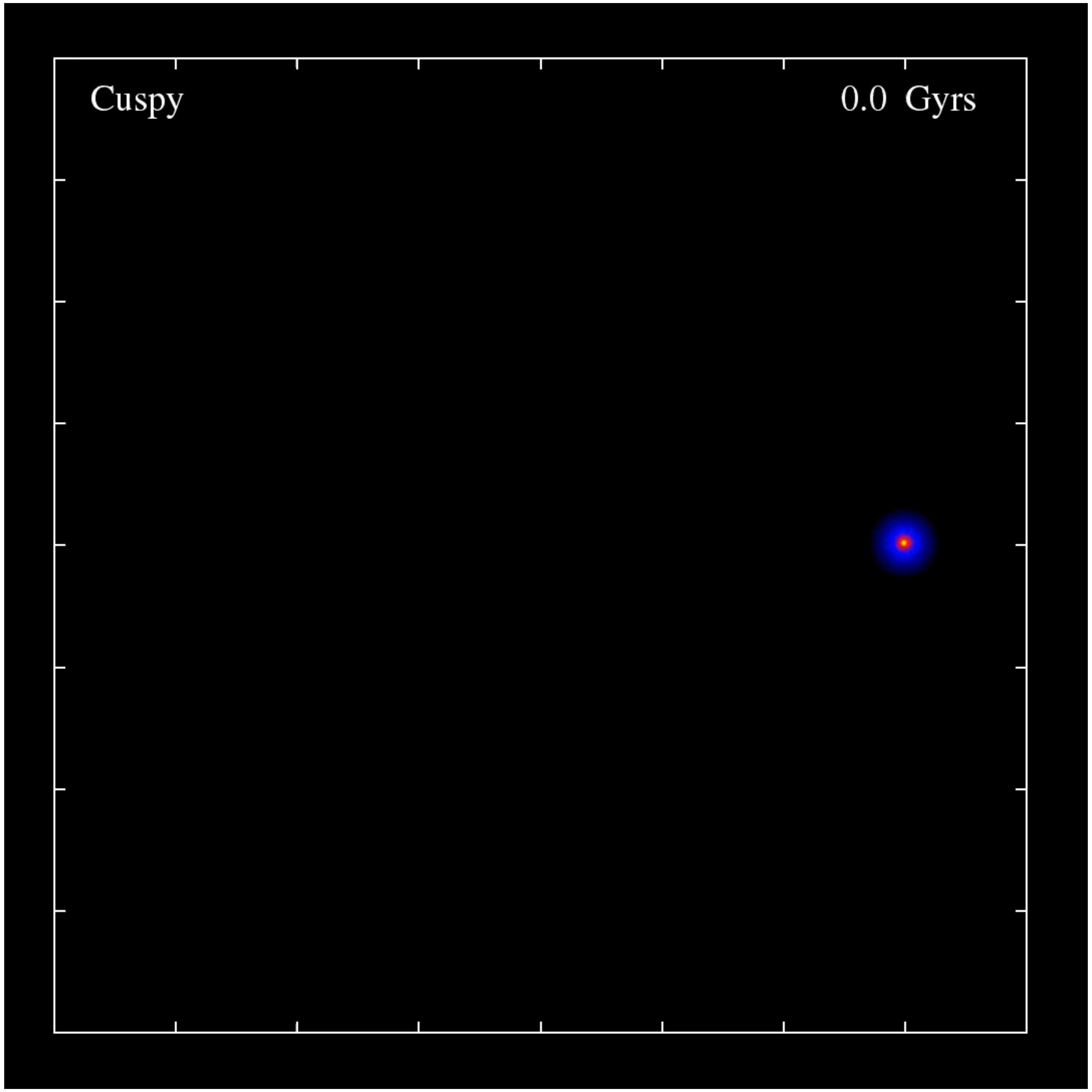
Tidal Stripping of Subhalos with Linear Response Theory



Simon Rozier

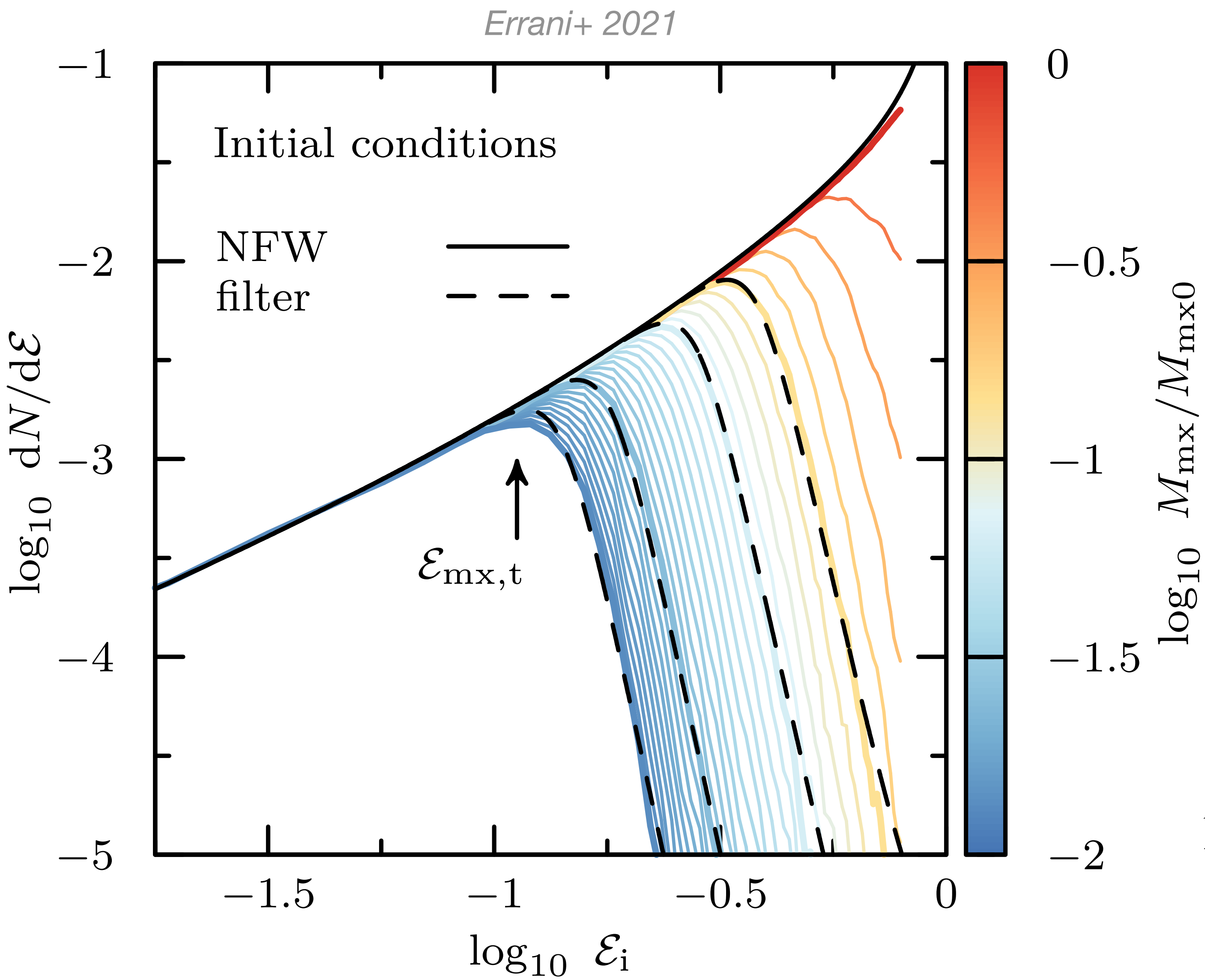
NftD 2021 - 23/11/2021

Idealised scenario

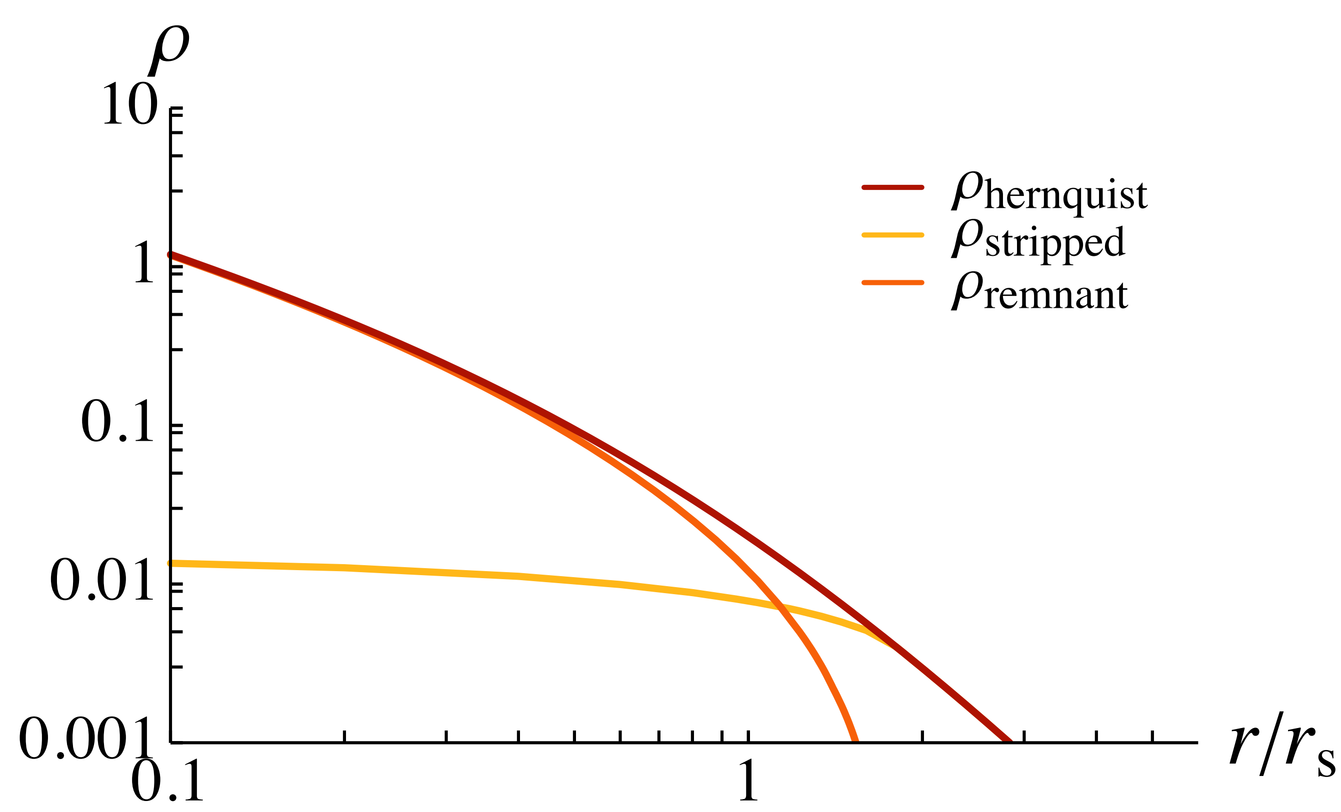


- Tidal shock at pericentric passage: **instantaneous mass removal**
- **Relaxation** during the rest of the orbit, to a **new equilibrium**

Model for mass removal



- Which fraction of the cluster is removed at the tidal shock? **Cut in energy *E*.**

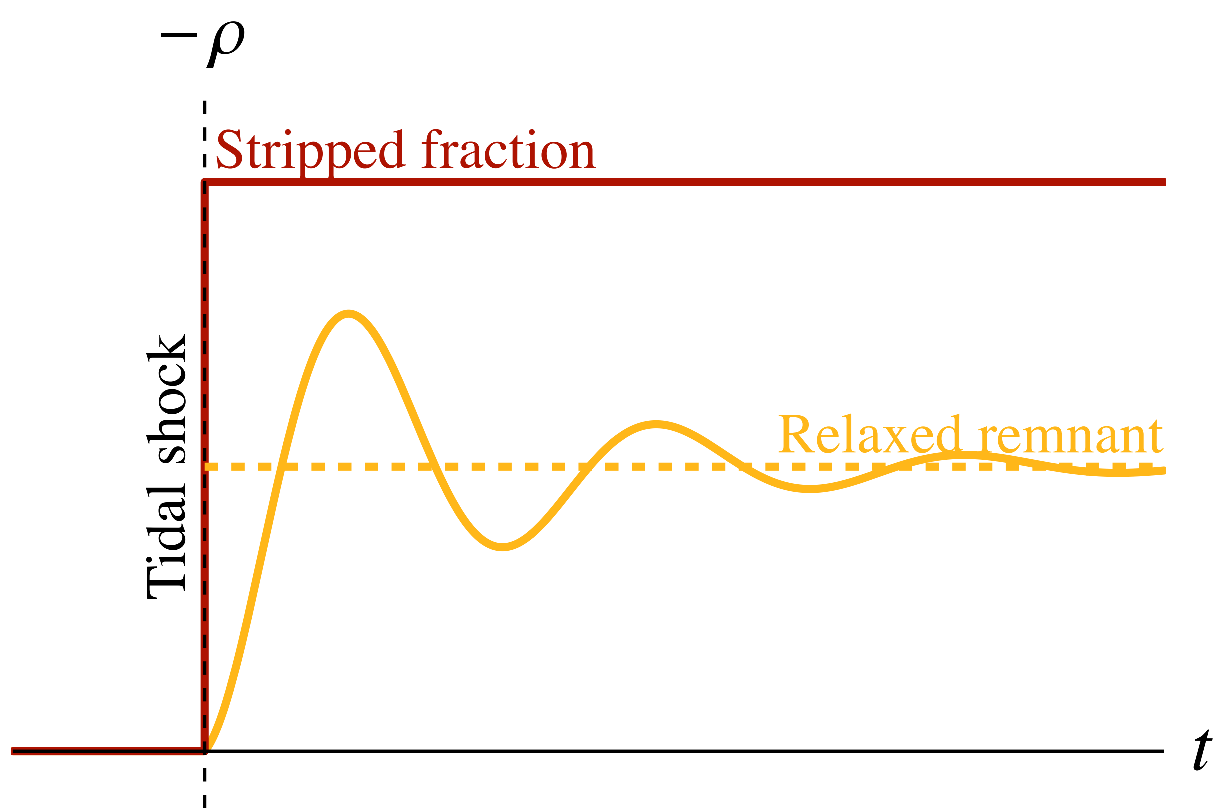


- Hernquist sphere, all particles removed above E_{tr}=-0.36 (most bound: E=-1; escaping: E>0)

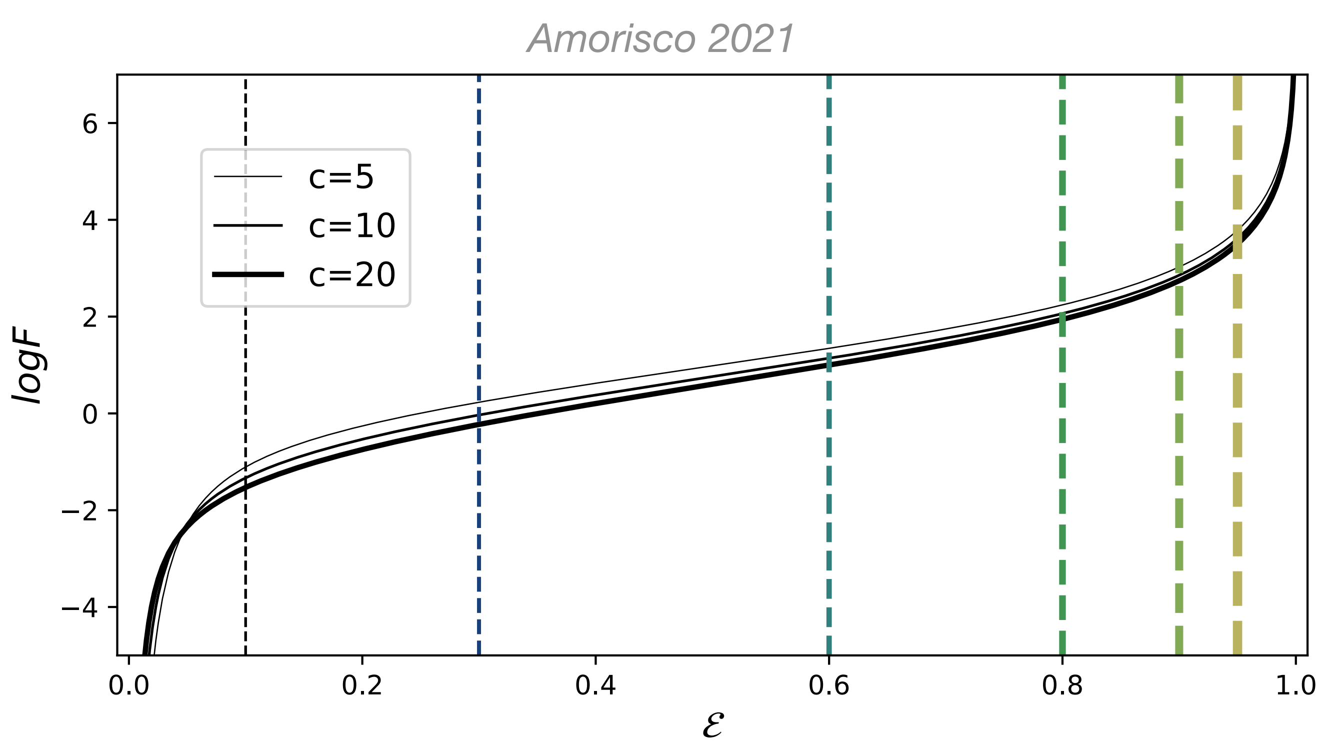
Model for relaxation

Hypotheses:

- Surviving particles **initially unaffected** by the tidal shock: they remain on the same orbits.
- The orbits are later perturbed by the absence of the tidally stripped fraction: **relaxation to a new equilibrium.**

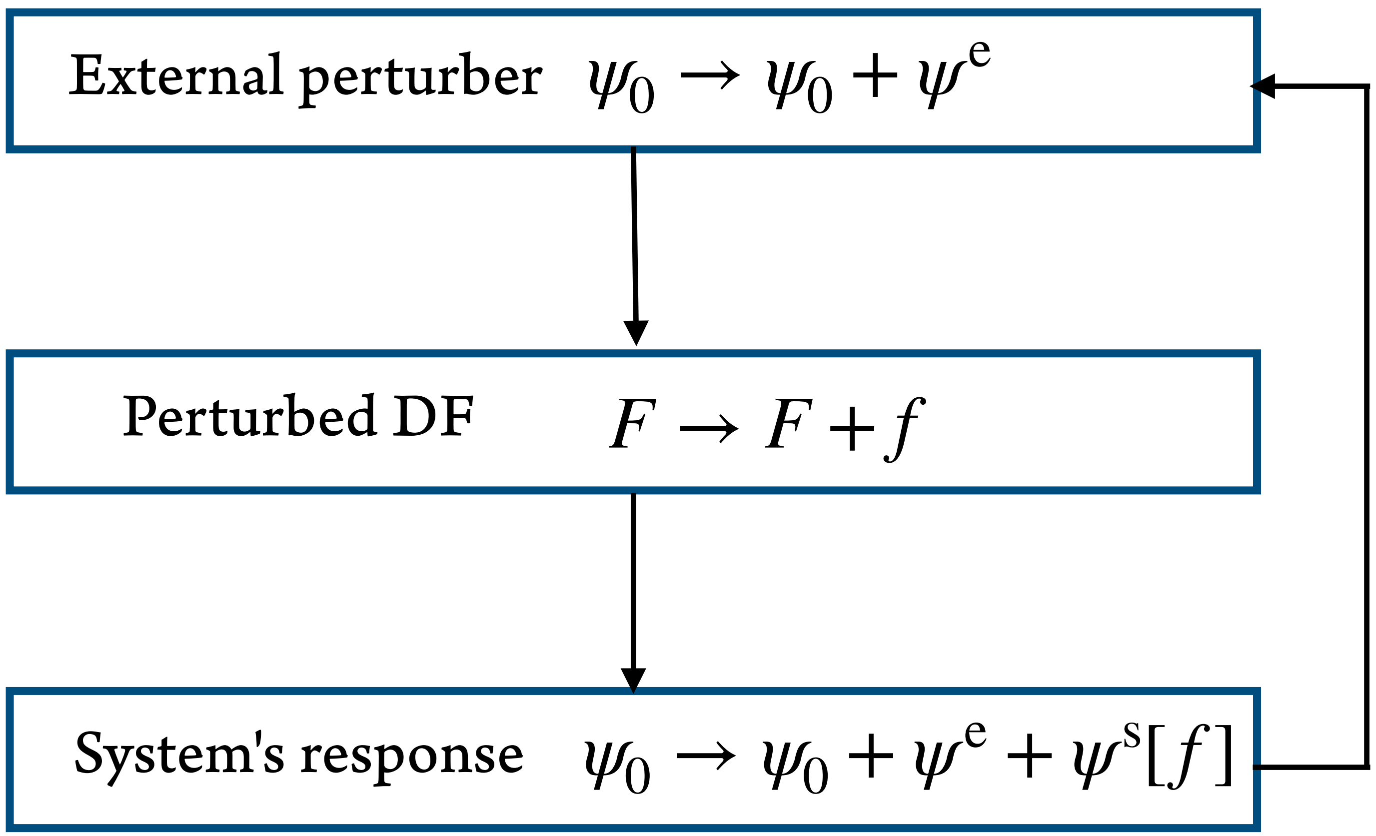


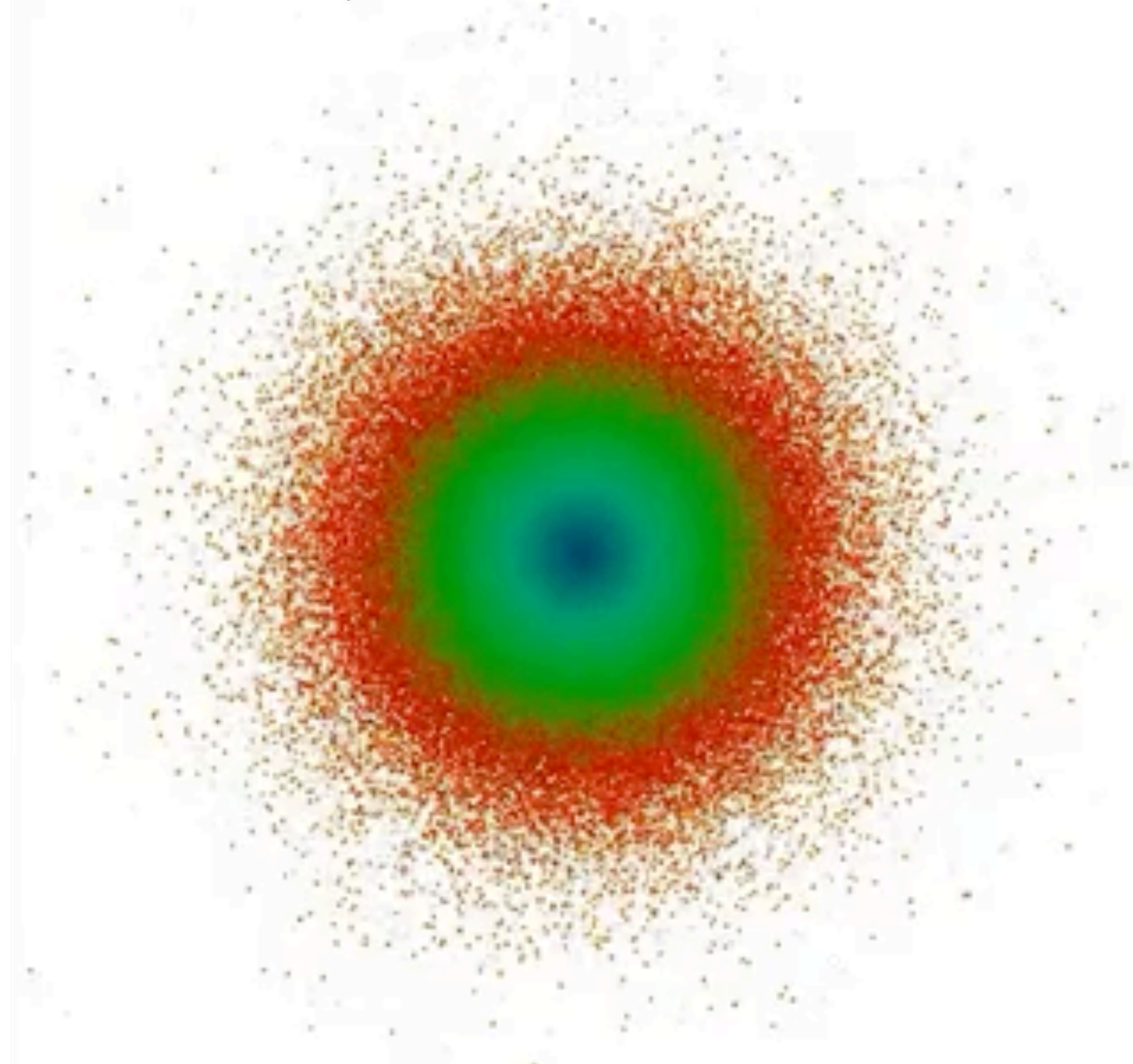
Recent work based on similar hypotheses: Amorisco 2021. Relaxation is performed using **isolated N-body simulations.**



Linear Response Theory

How does a stellar system **respond** to an **external perturbation**?





S. Chakrabarti

Linearised collisionless Boltzmann equation

$$\frac{\partial f}{\partial t} + \mathbf{\Omega}(\mathbf{J}) \cdot \frac{\partial f}{\partial \boldsymbol{\theta}} - \frac{\partial F}{\partial \mathbf{J}} \cdot \frac{\partial (\psi^{\mathrm{e}} + \psi^{\mathrm{s}})}{\partial \boldsymbol{\theta}} = 0$$

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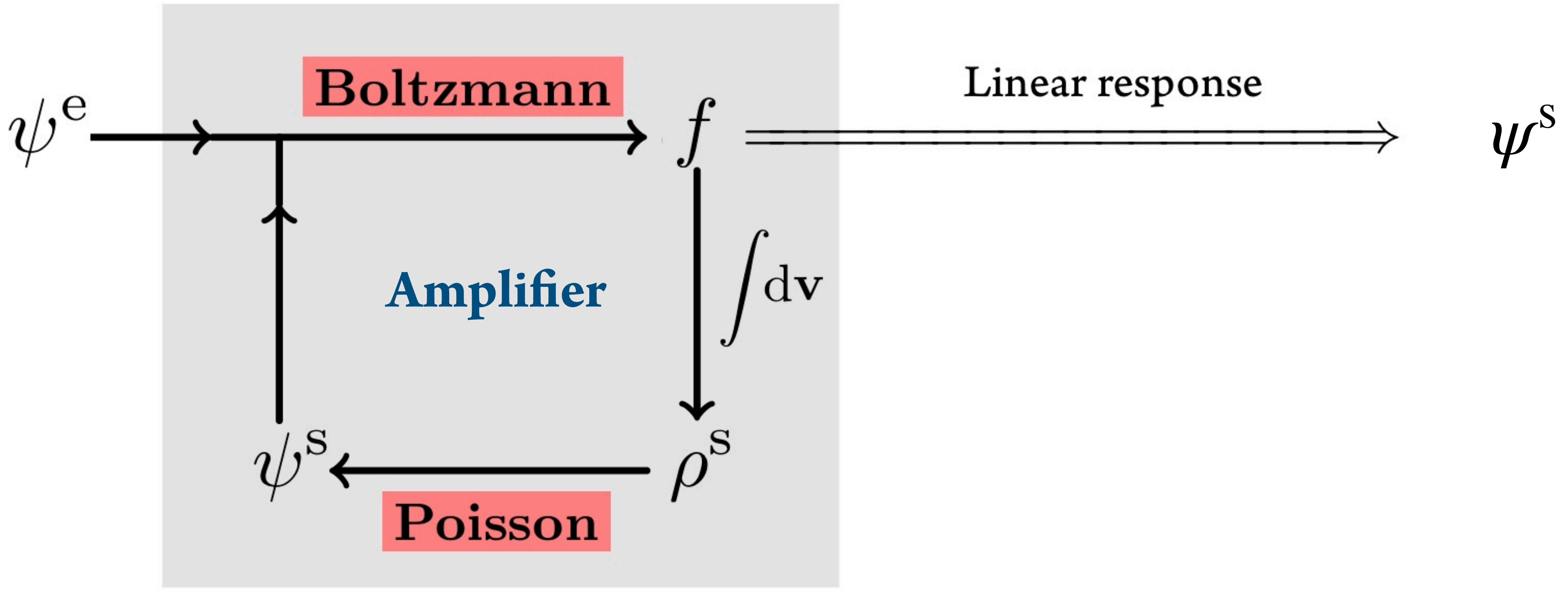

Poisson

$$\Delta \psi^{\mathrm{s}} = 4\pi G \rho^{\mathrm{s}}$$

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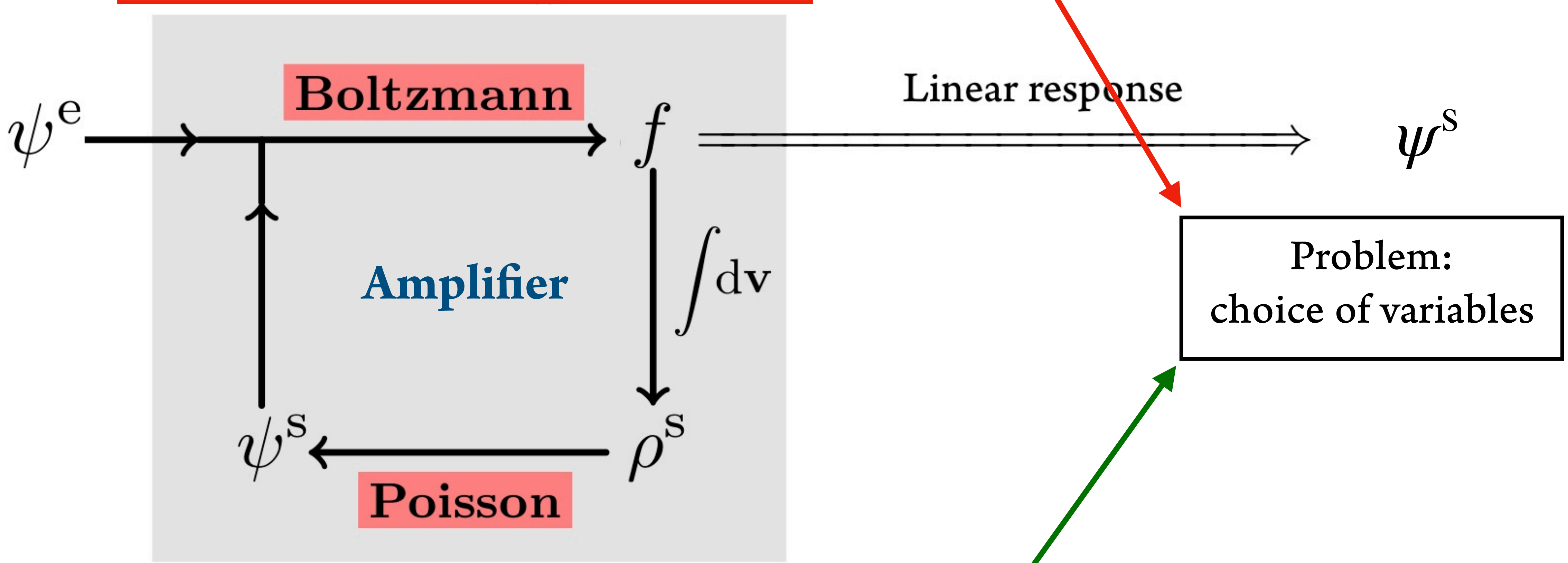
Easier in $(\boldsymbol{\theta}, \mathbf{J})$



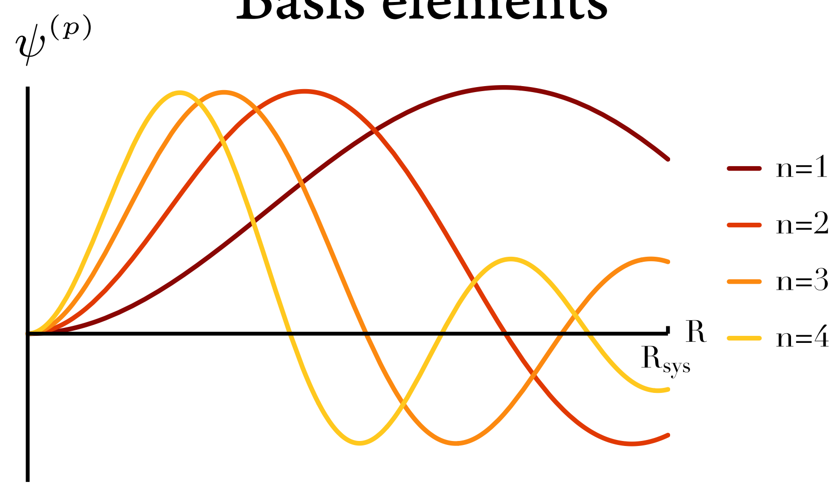
Poisson

$$\Delta \psi^{\mathrm{s}} = 4\pi G \rho^{\mathrm{s}}$$

Easier in $(\mathbf{x}, \mathbf{v})$

Projection on a basis *Kalnajs 1976*

Basis elements



The basis **solves the Poisson equation**

$$\psi^{\mathrm{e}}(\mathbf{x}, t) \longrightarrow \mathbf{b}(t)$$

$$\psi^{\mathrm{s}}(\mathbf{x}, t) \longrightarrow \mathbf{a}(t)$$

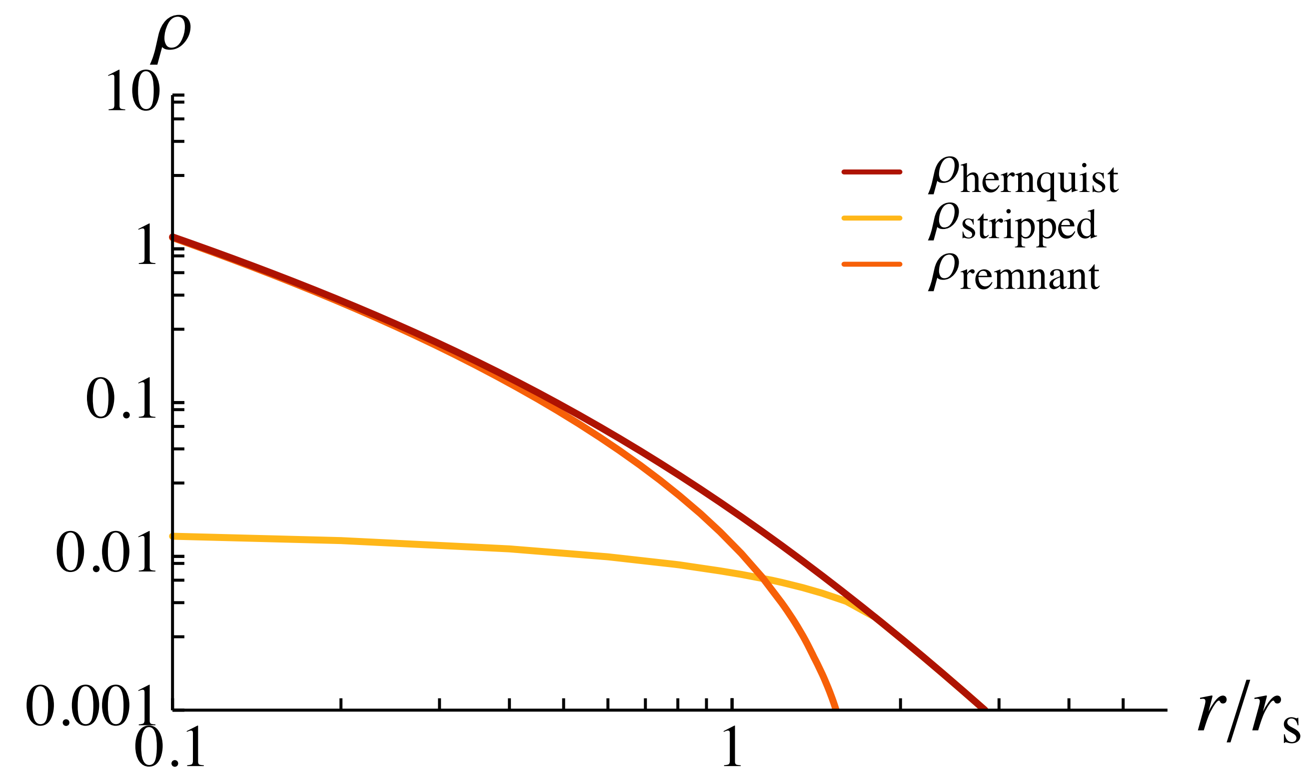
$\mathbf{M}(t)$ Response matrix

$$\mathbf{a}(t) = \int_0^t \mathrm{d}\tau\, \mathbf{M}(t-\tau) \cdot (\mathbf{a}(\tau) + \mathbf{b}(\tau))$$ ⟶ Linear **Response**

$$\mathbf{M}_{pq}(t) = -\,\mathrm{i}\,(2\pi)^3 \sum_{\mathbf{n}} \int \mathrm{d}\mathbf{J}\, \mathbf{n} \cdot \frac{\partial F}{\partial \mathbf{J}}\, \psi_{\mathbf{n}}^{(p)*}(\mathbf{J})\, \psi_{\mathbf{n}}^{(q)}(\mathbf{J})\, \mathrm{e}^{-\mathrm{i}\,\mathbf{n}\cdot\boldsymbol{\Omega}\, t}$$

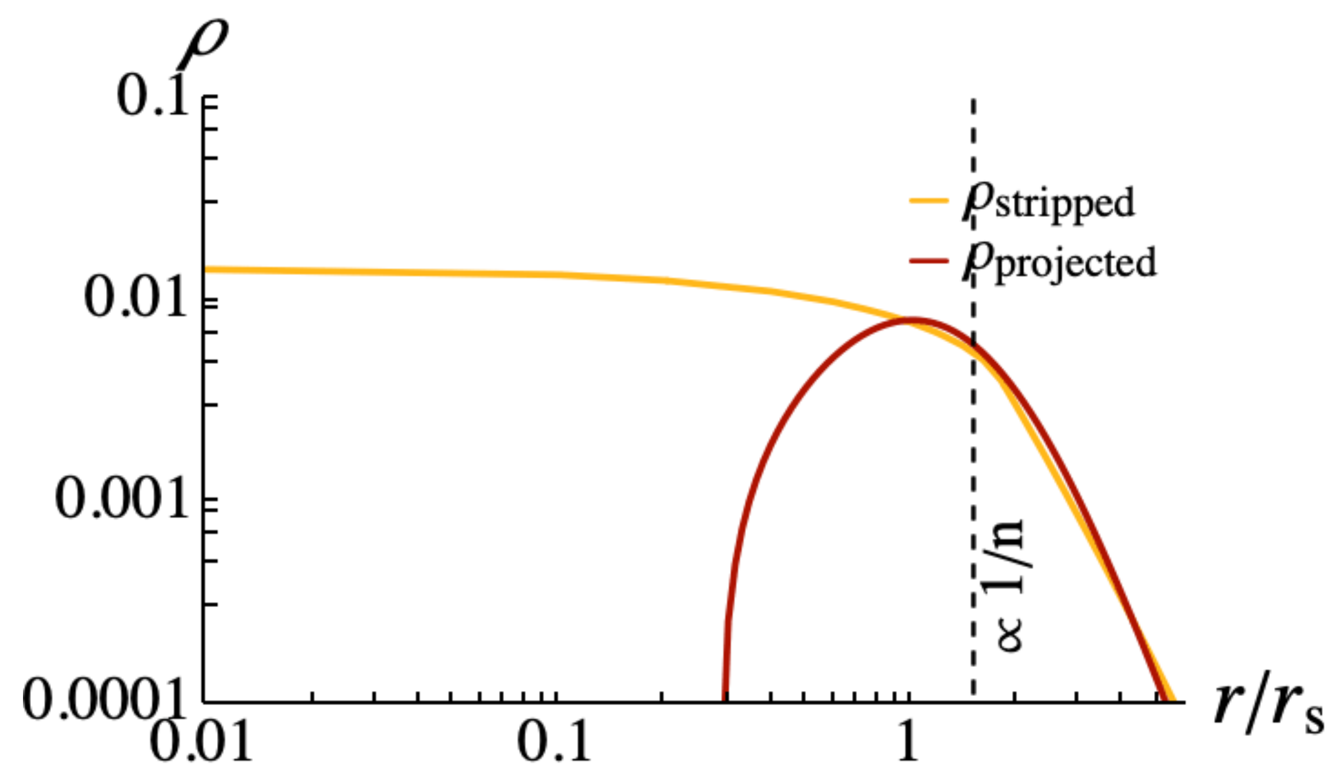
Application to our model

- Background potential ψ_0: classical Hernquist sphere
- Relaxing system $F(E)$: surviving fraction (once the stripped fraction is removed)
- External perturber ψ^{e}: stripped fraction (negative density)



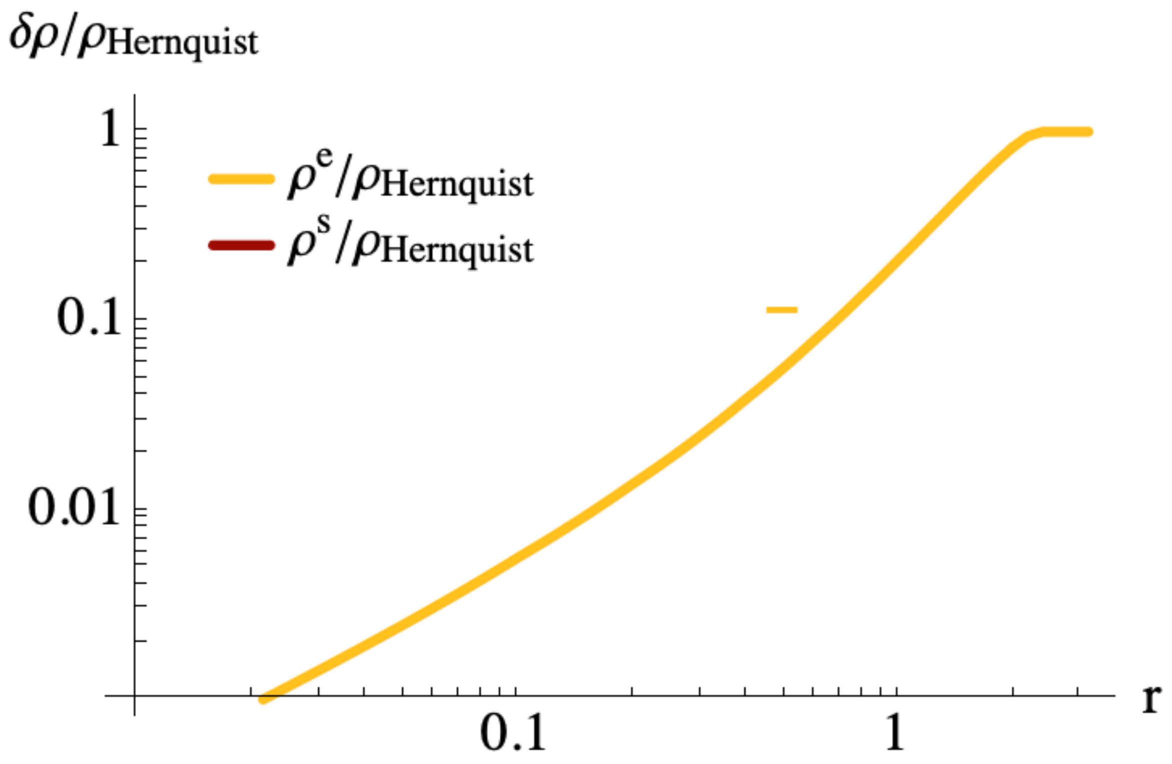
- Perturber ρ^{e}: projection onto the basis.

The quality of the reconstruction depends on the number of basis elements, especially at the centre.

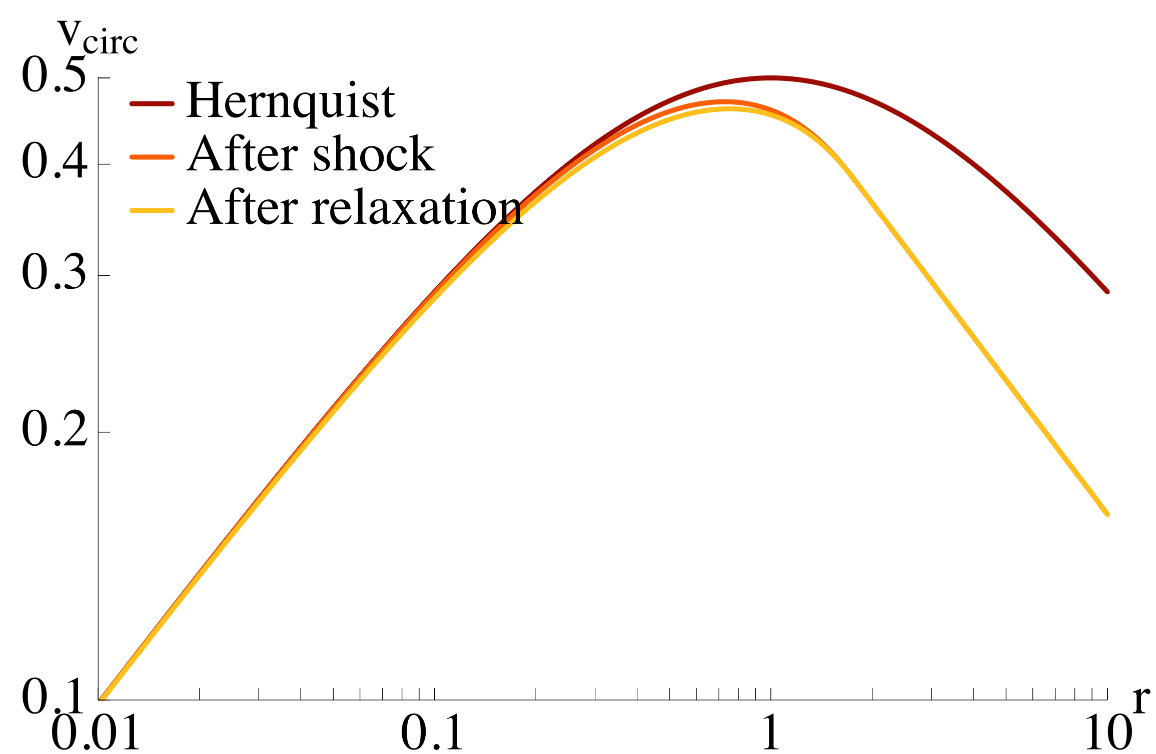


Response of the surviving halo

- <u>Response</u> ψ^s: the surviving halo quickly reaches a relaxed state. Mass is transferred from the centre to the outskirts.

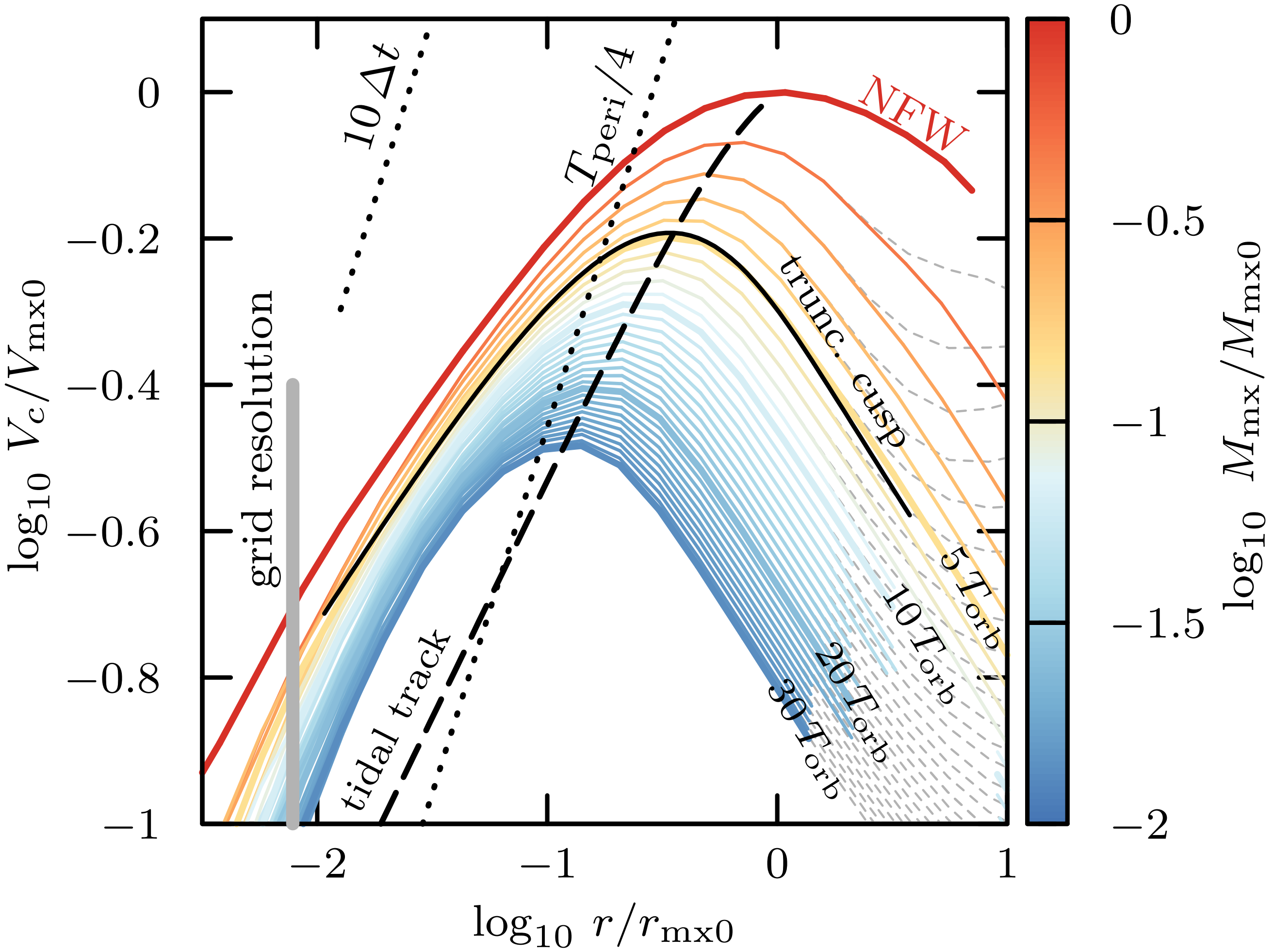


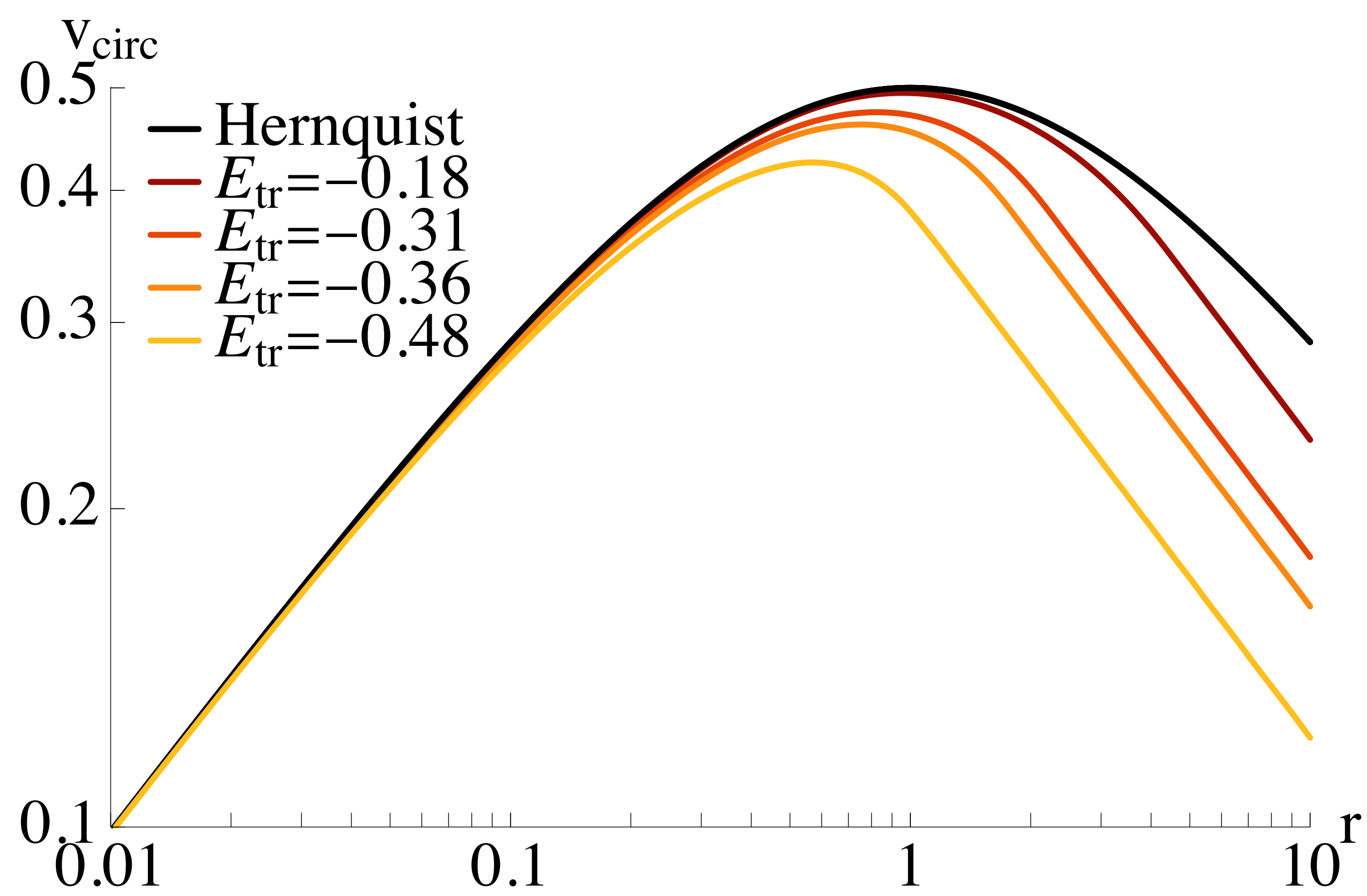
- The evolution of the v_{circ} curve is mostly due to the tidal shock. But not only.



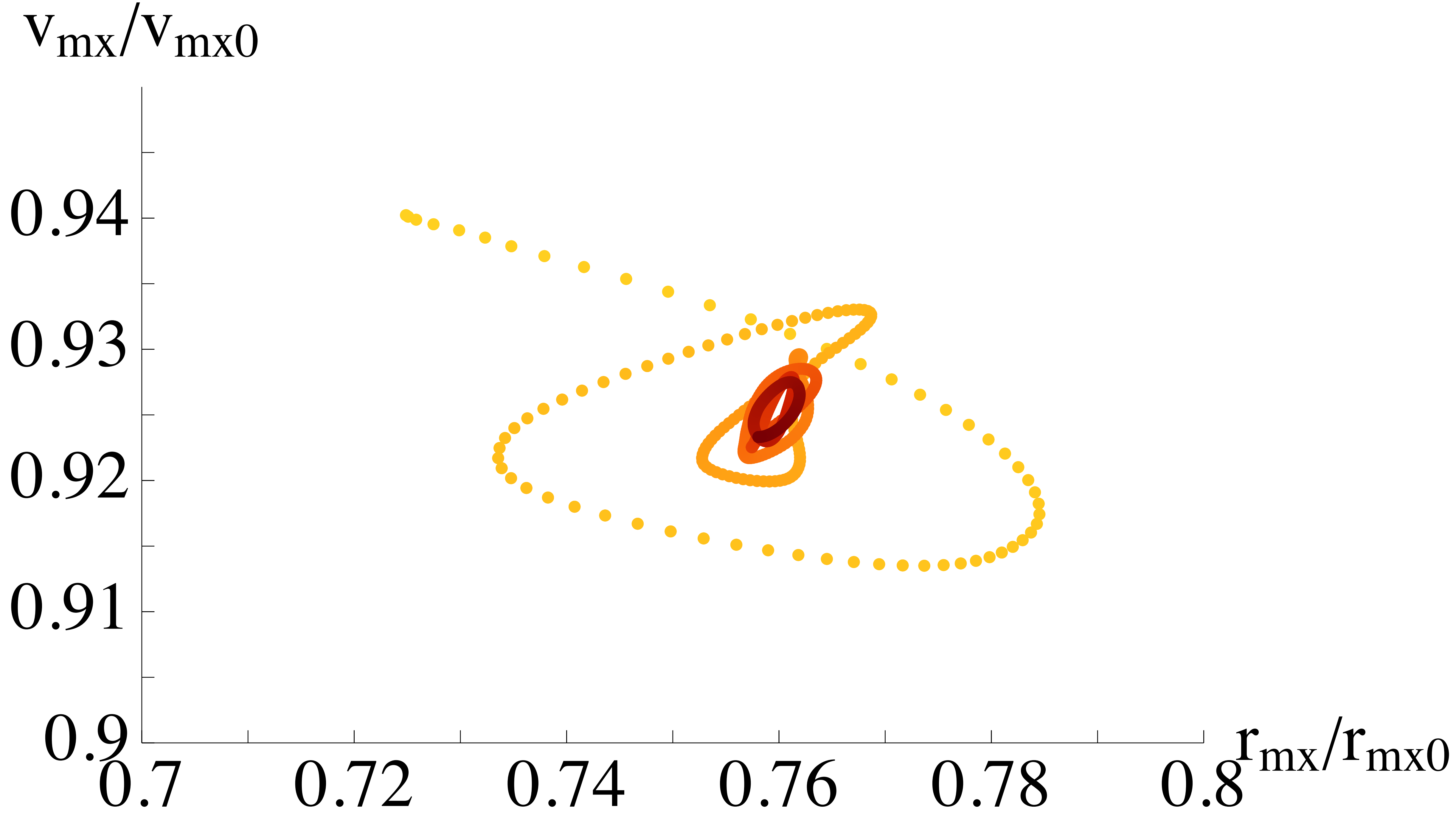
Rotation curves VS stripped fraction

Errani+ 2021



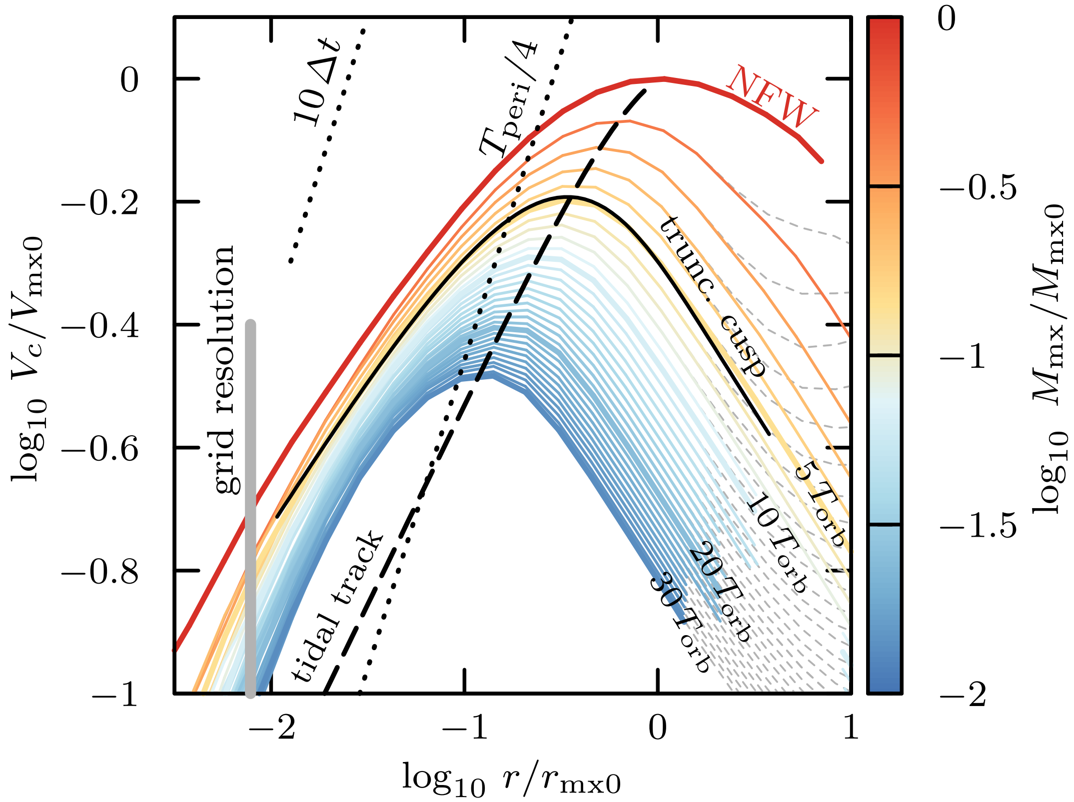


$r_{mx} - v_{mx}$ evolution during relaxation

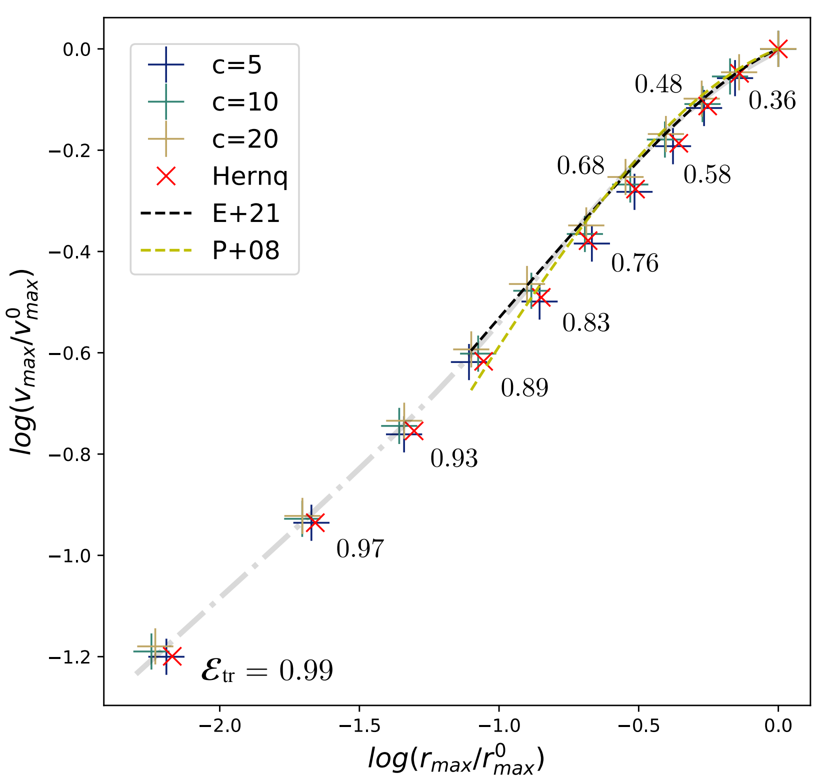


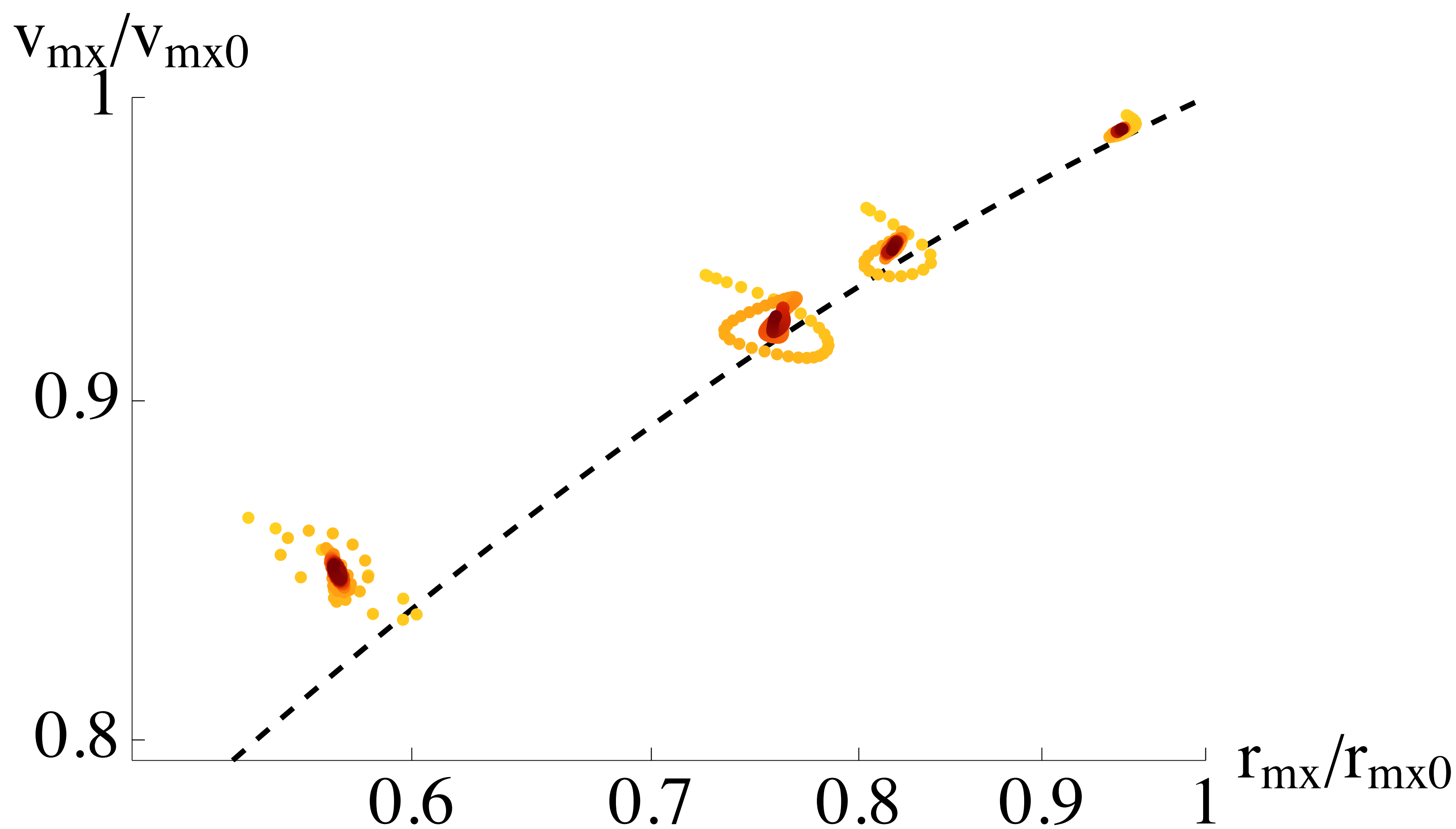
Tidal tracks

Errani+ 2021



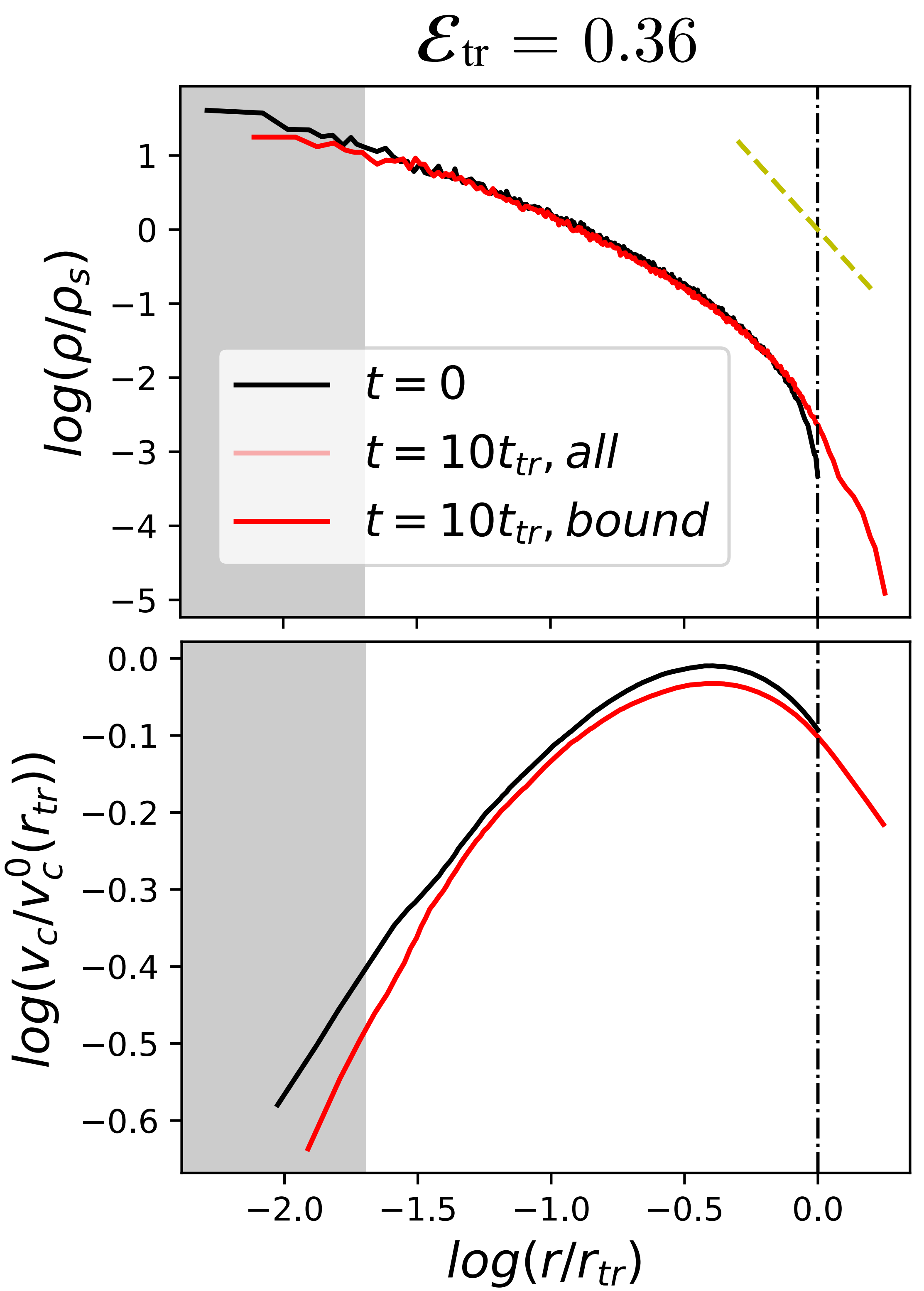
Amorisco 2021



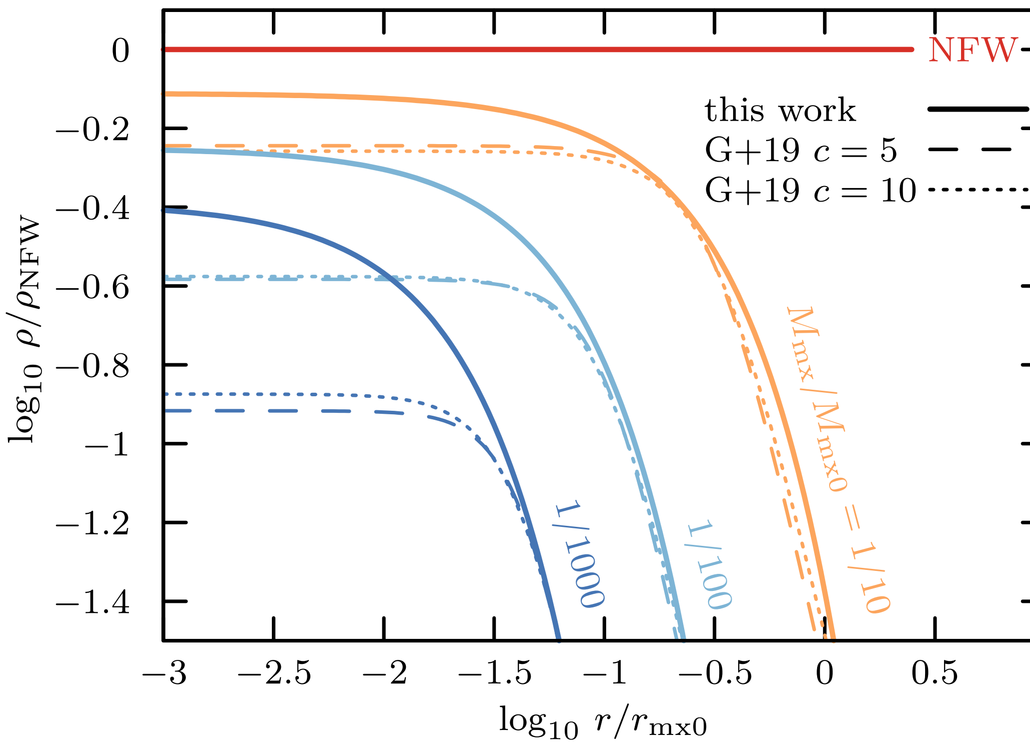


An issue: central density

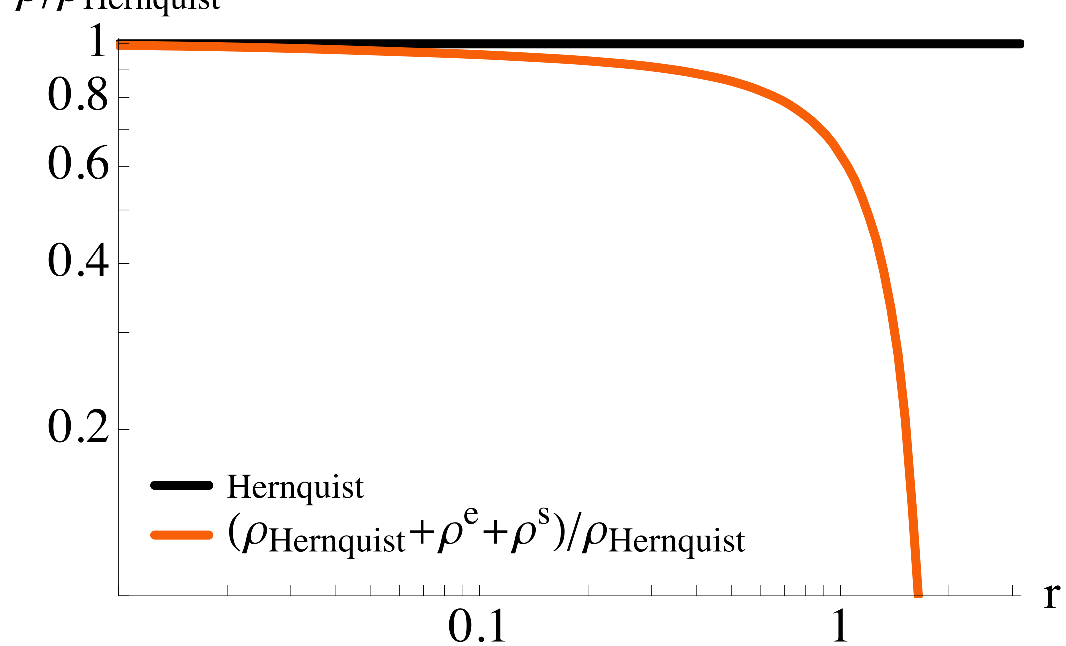
Amorisco 2021



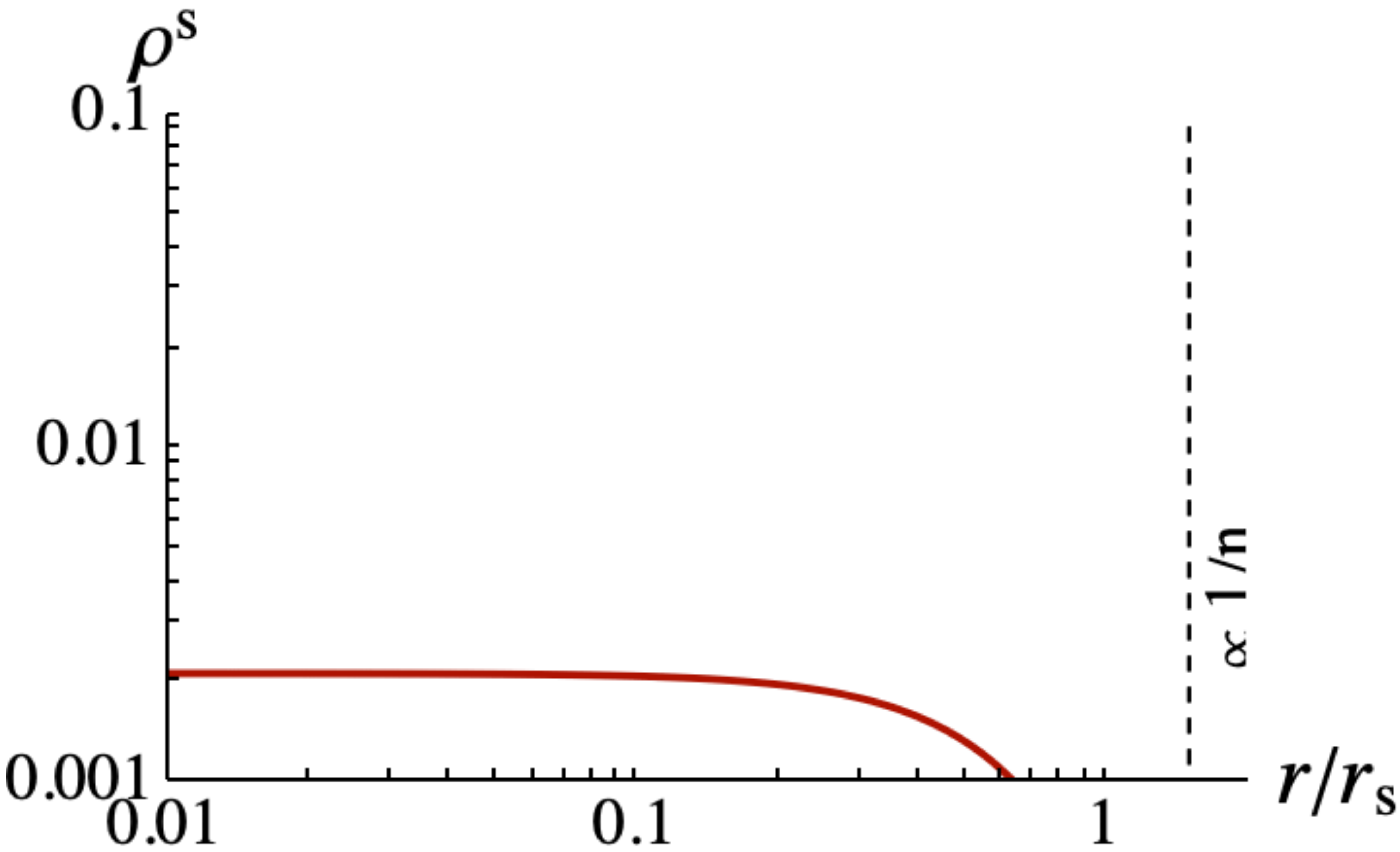
Errani+ 2021a



This work



But: resolution issues



Conclusions

SIMPLE MODEL

seems to do a good job at reproducing tidal stripping.

MATRIX METHOD

seems to do a good job at computing relaxation at lower numerical cost.

STRONG TIDAL SHOCK REGIME

makes the linear method fail.

CENTRAL BEHAVIOUR

requires more resolution.

Thanks for your attention