UNIVERSITY OF WARSAW

STABILITY OF HYPERMASSIVE NEUTRONS STARS AGAINST A PROMPT COLLAPSE

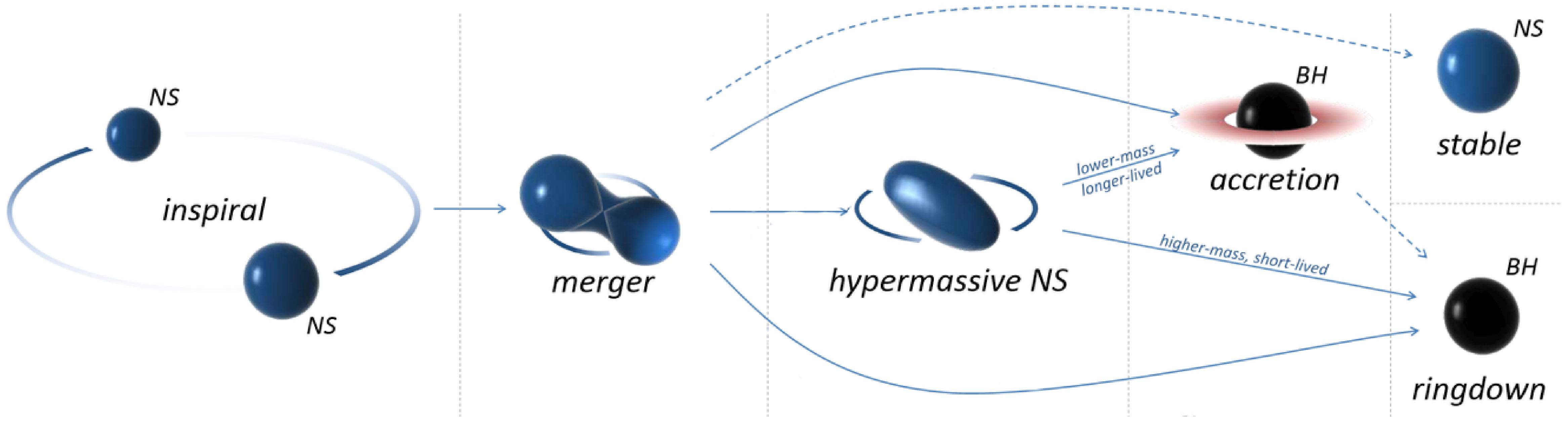
Paweł Szewczyk

in collaboration with: Dorota Rosińska, Pablo Cerda-Duran

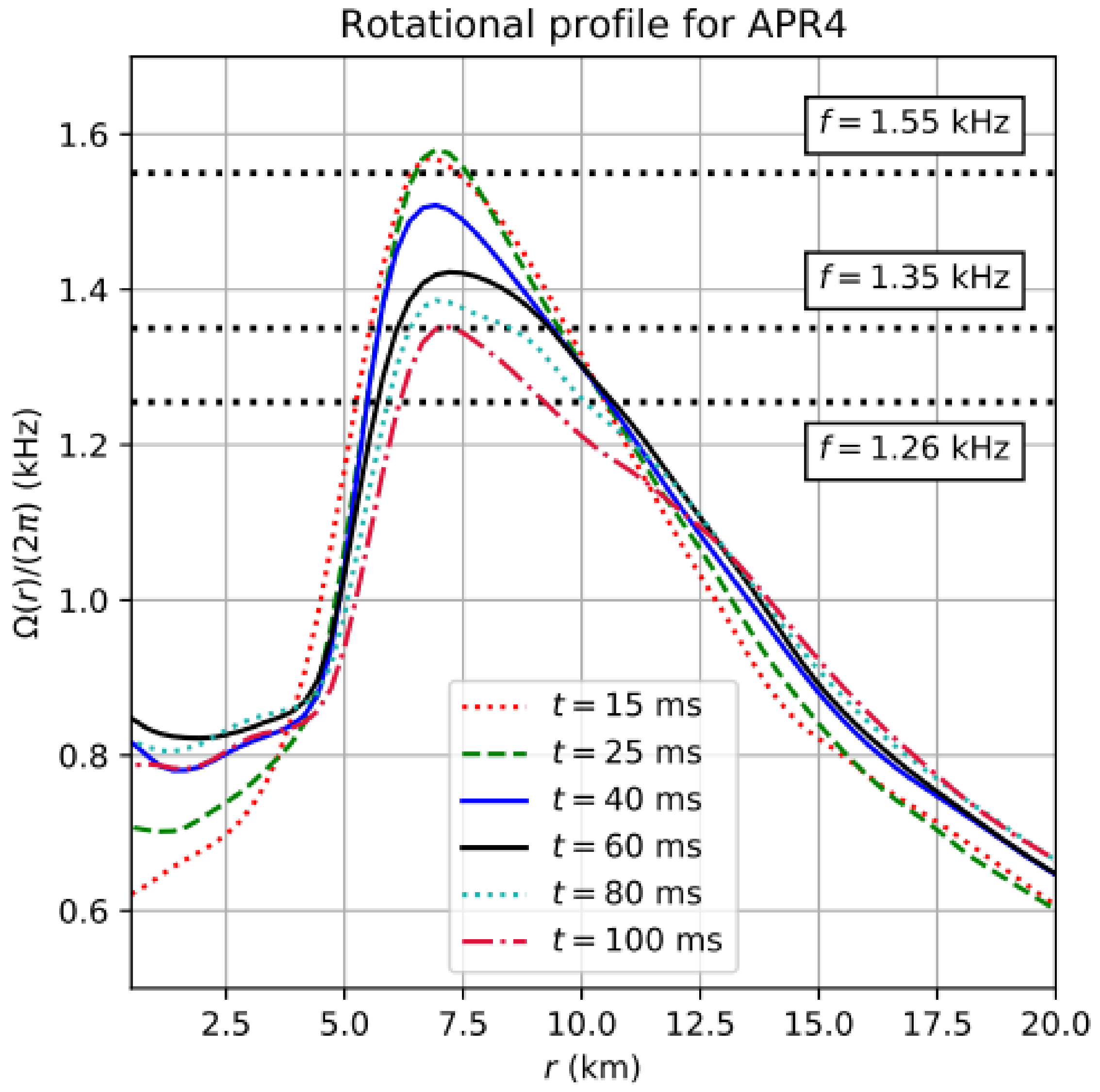
Introduction

- **Differential rotation allows for more massive neutron stars (NS)**
- What is the maximum mass?
- Are the most massive HMNS dynamically stable?
- Where is the stability limit?
- What can we learn from the dynamics of HMNS? How?

BNS merger remnants

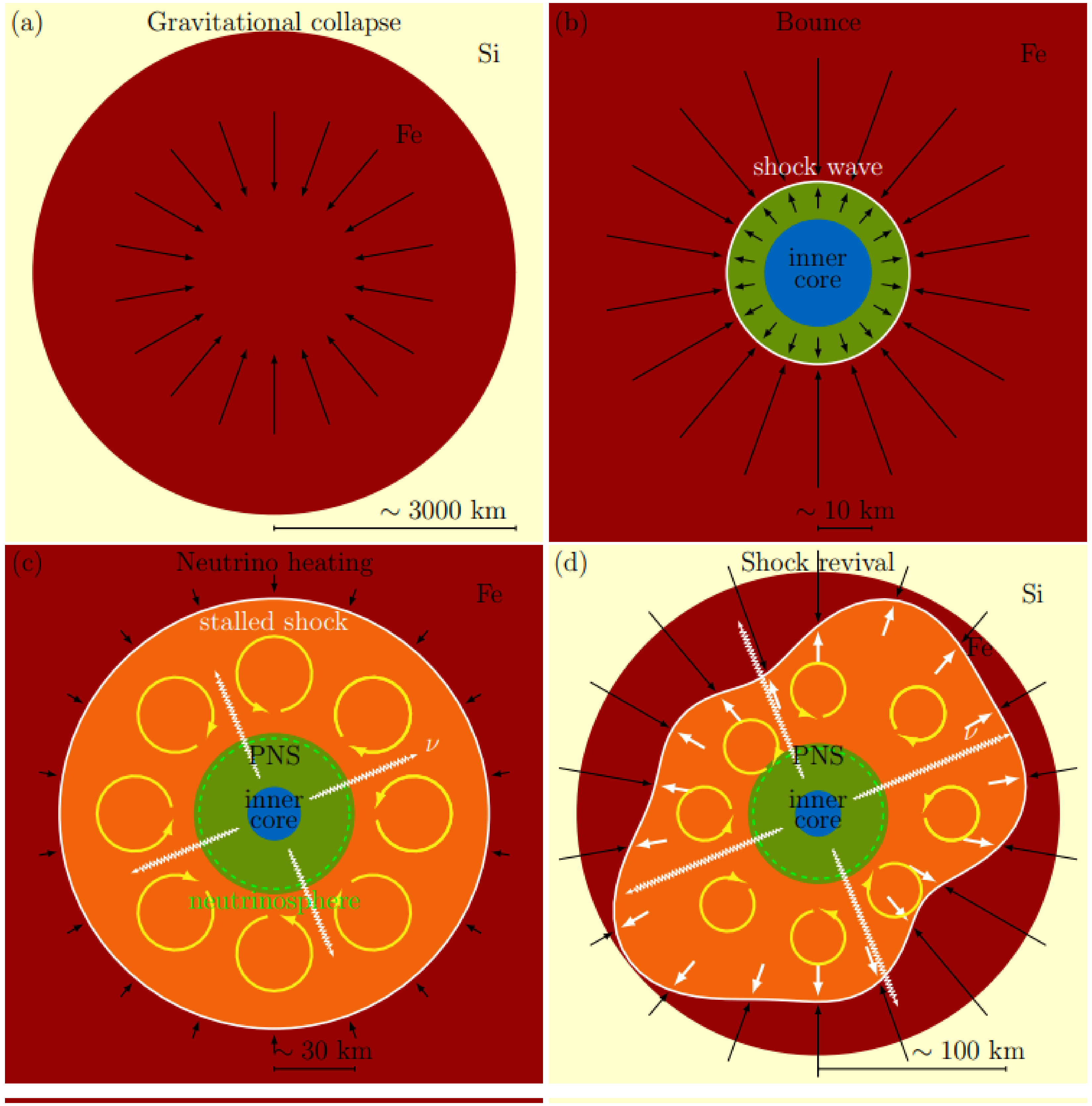


Bartos, Brady & Marka (2013)

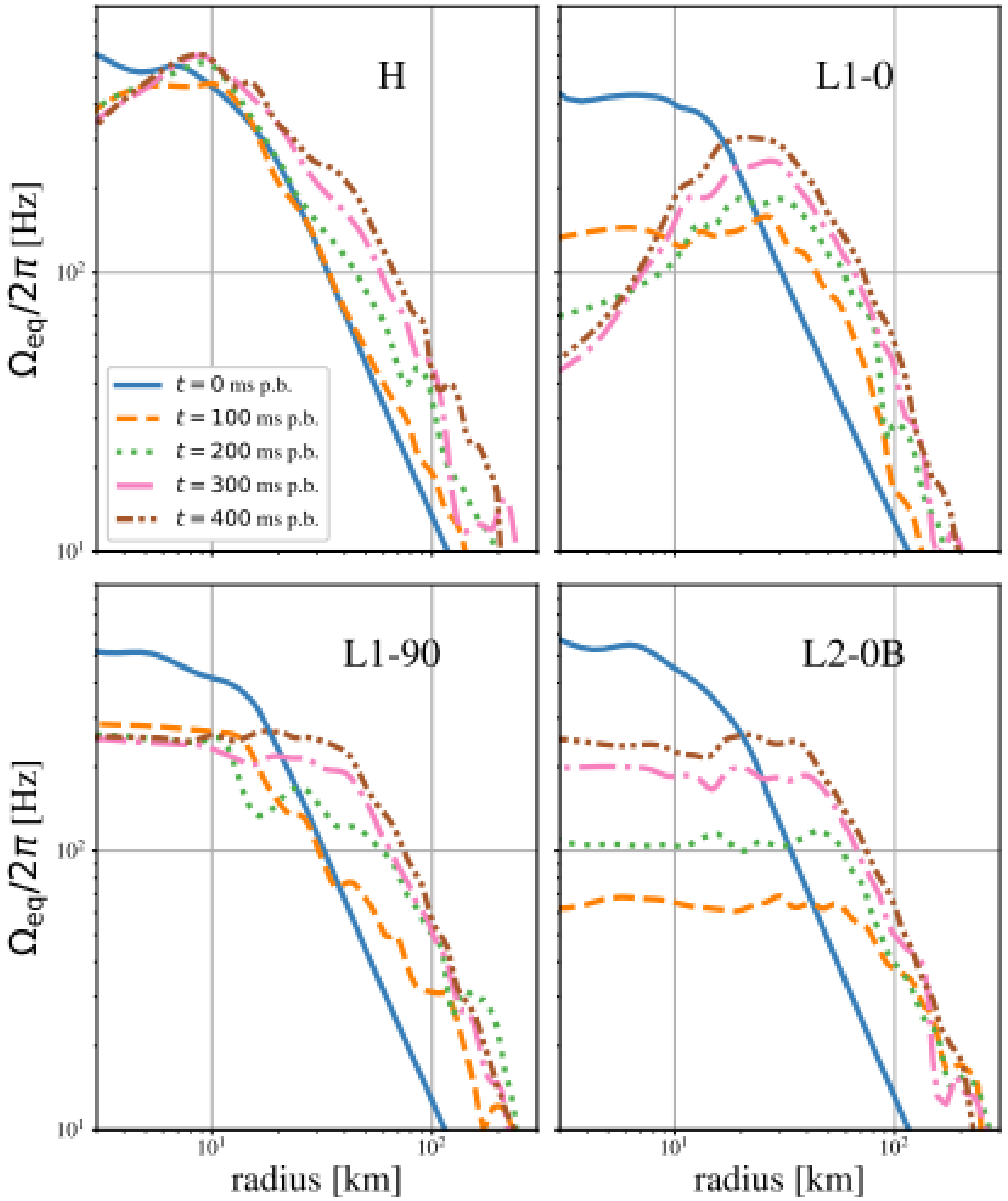


De Pietri et al. (2020)

Core-collapse remnants



Cerda-Duran & Elias-Rosa (2018)

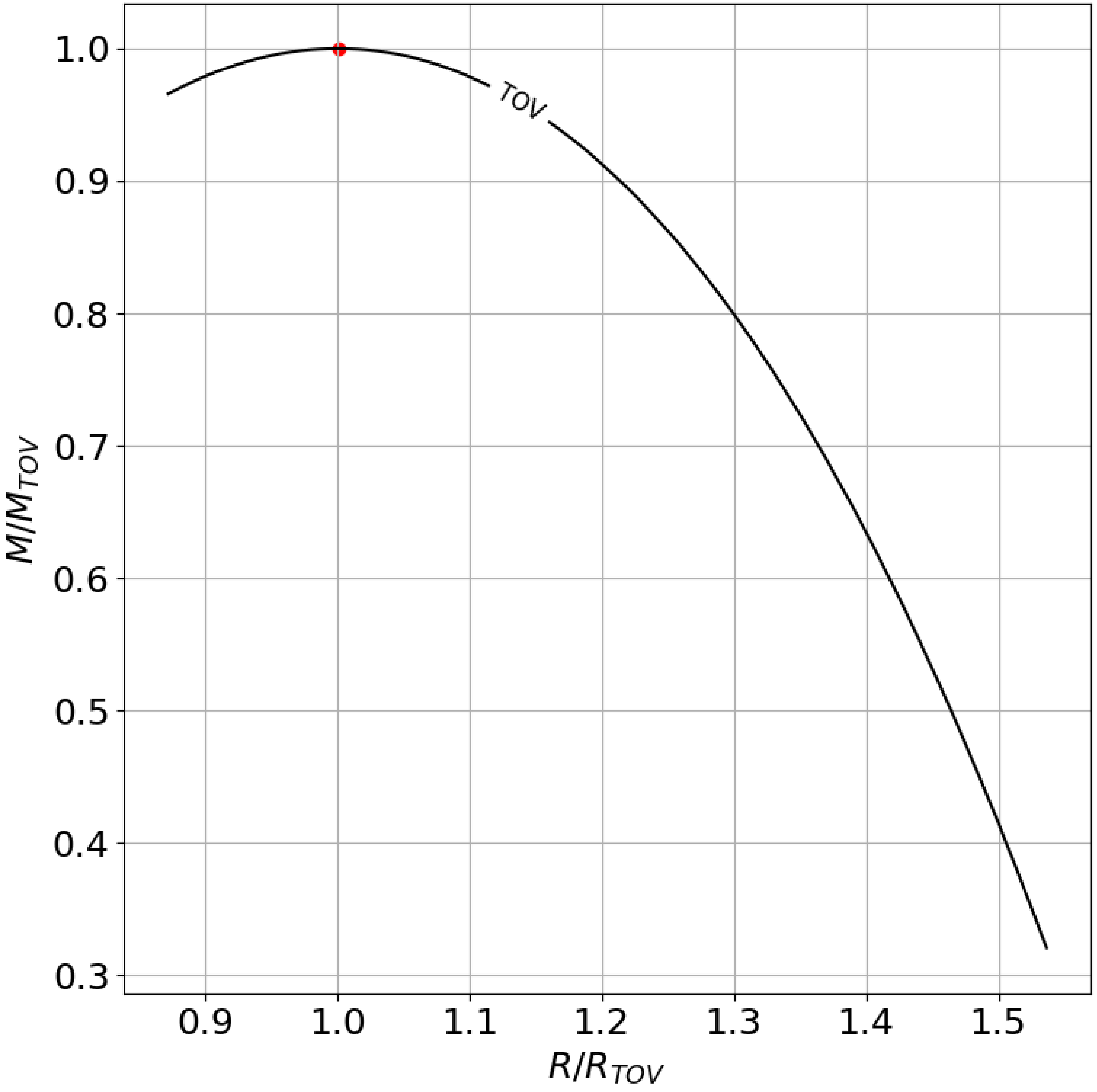


Bugli et al. (2023)

Maximum mass of NS

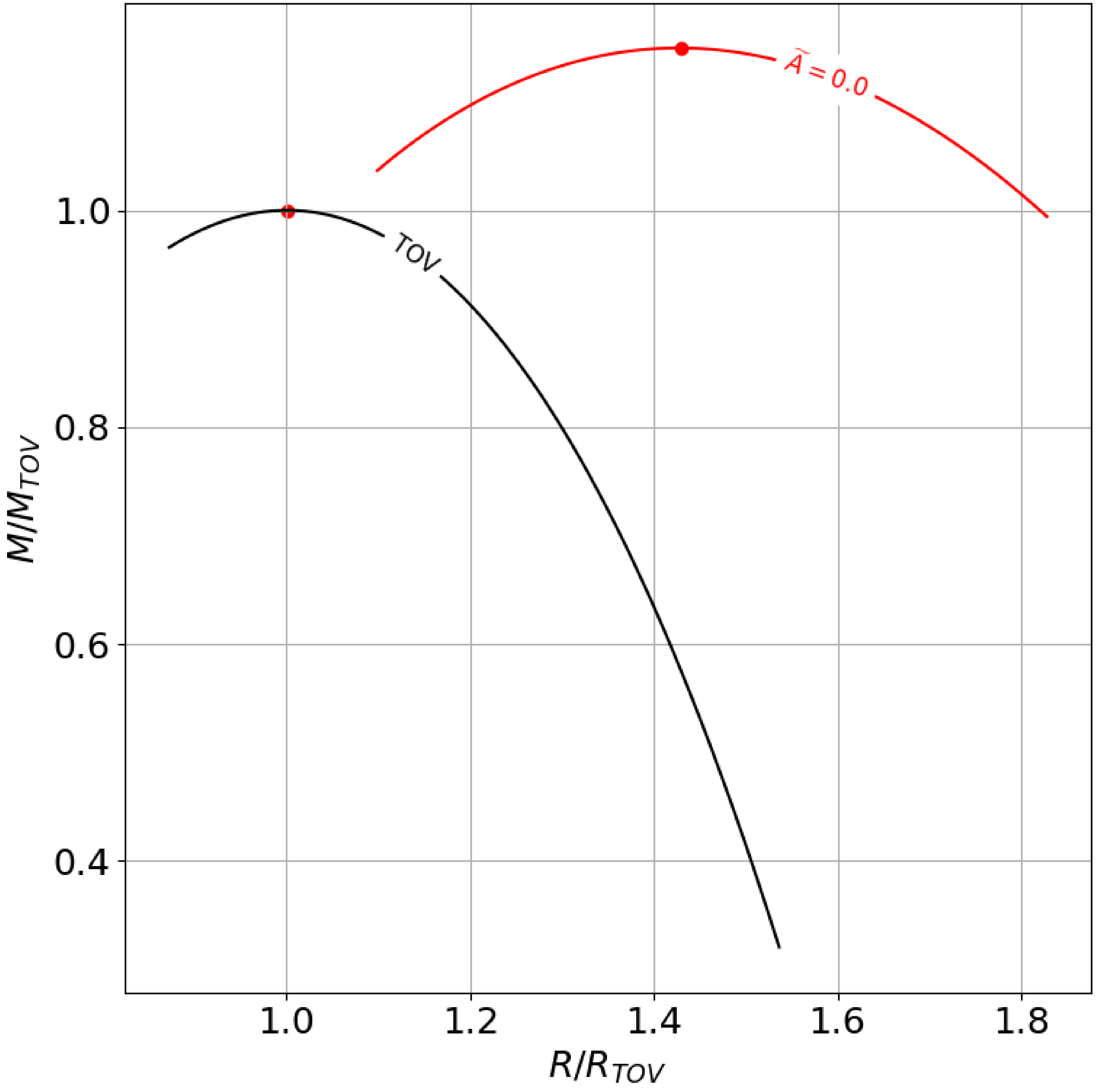
- Limit of mass exists for non-rotating NS (TOV limit)

- 2 - 2.5 solar masses



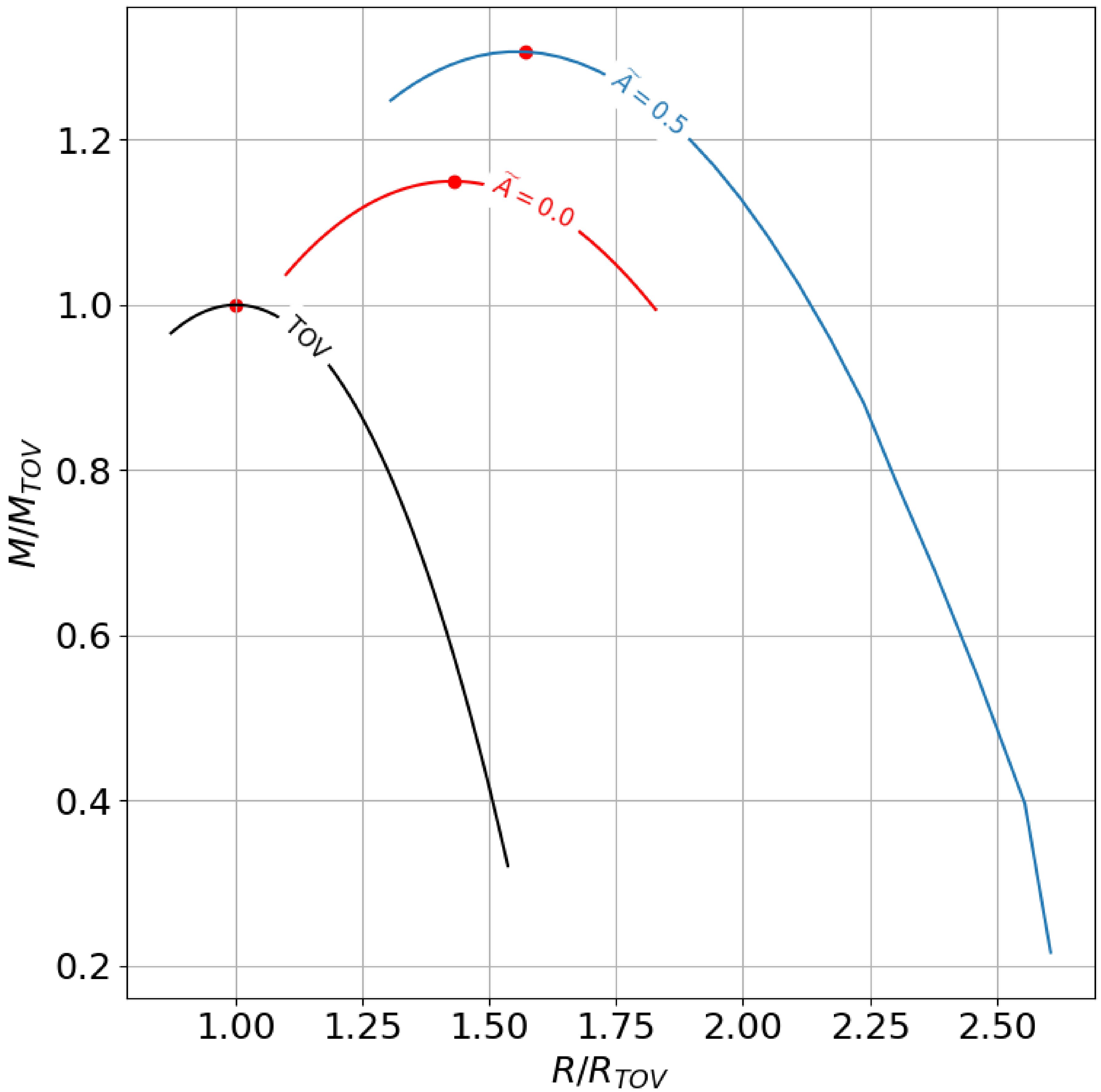
Maximum mass vs rotation

- Limit of mass exists for non-rotating NS
- **Rigid rotation** can increases the limit by ~20%

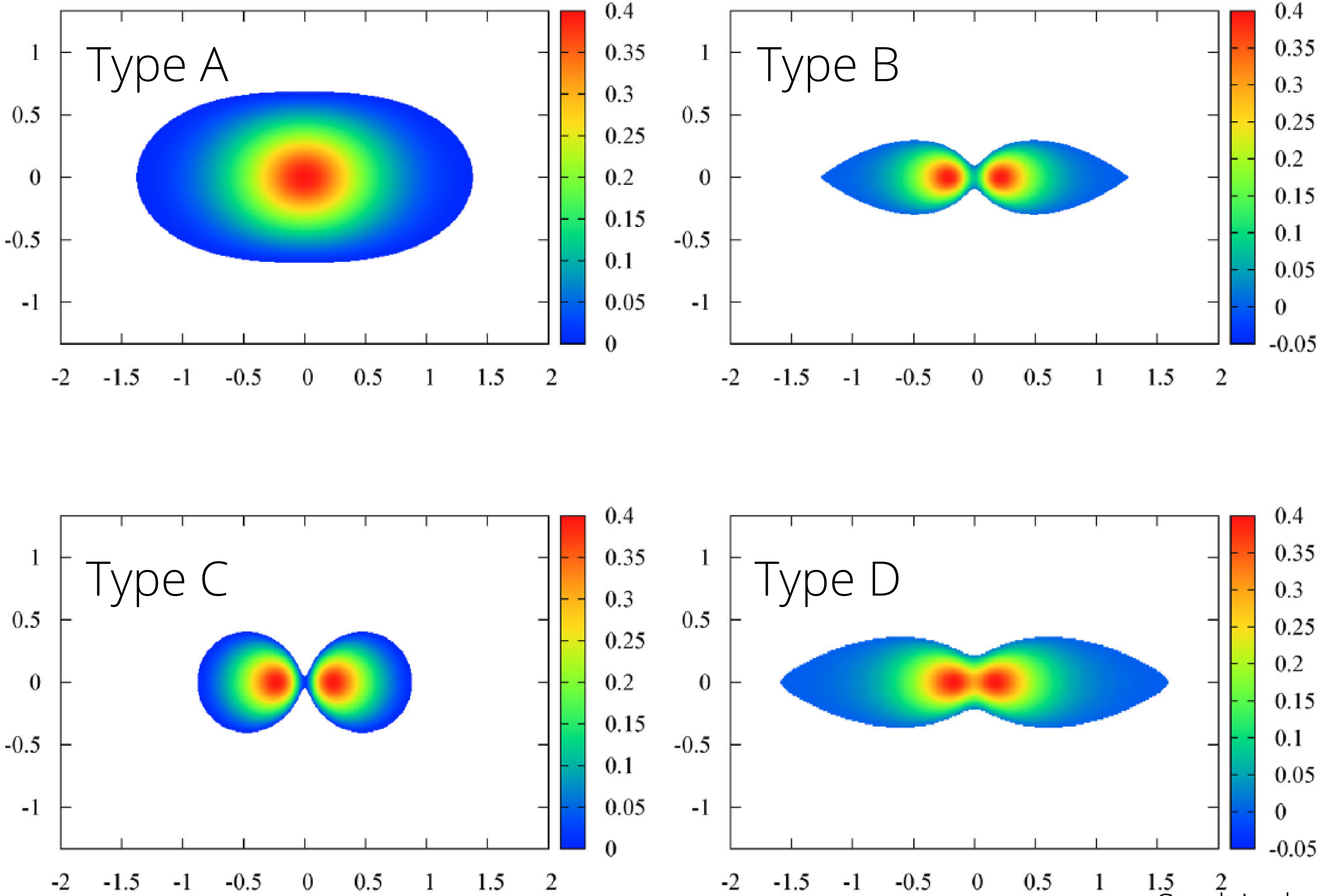


Maximum mass vs differential rotation

- Limit of mass exists for non-rotating NS
- **Rigid rotation** can increases the limit by ~20%
- **Differential rotation** increases the limit even further. By how much?



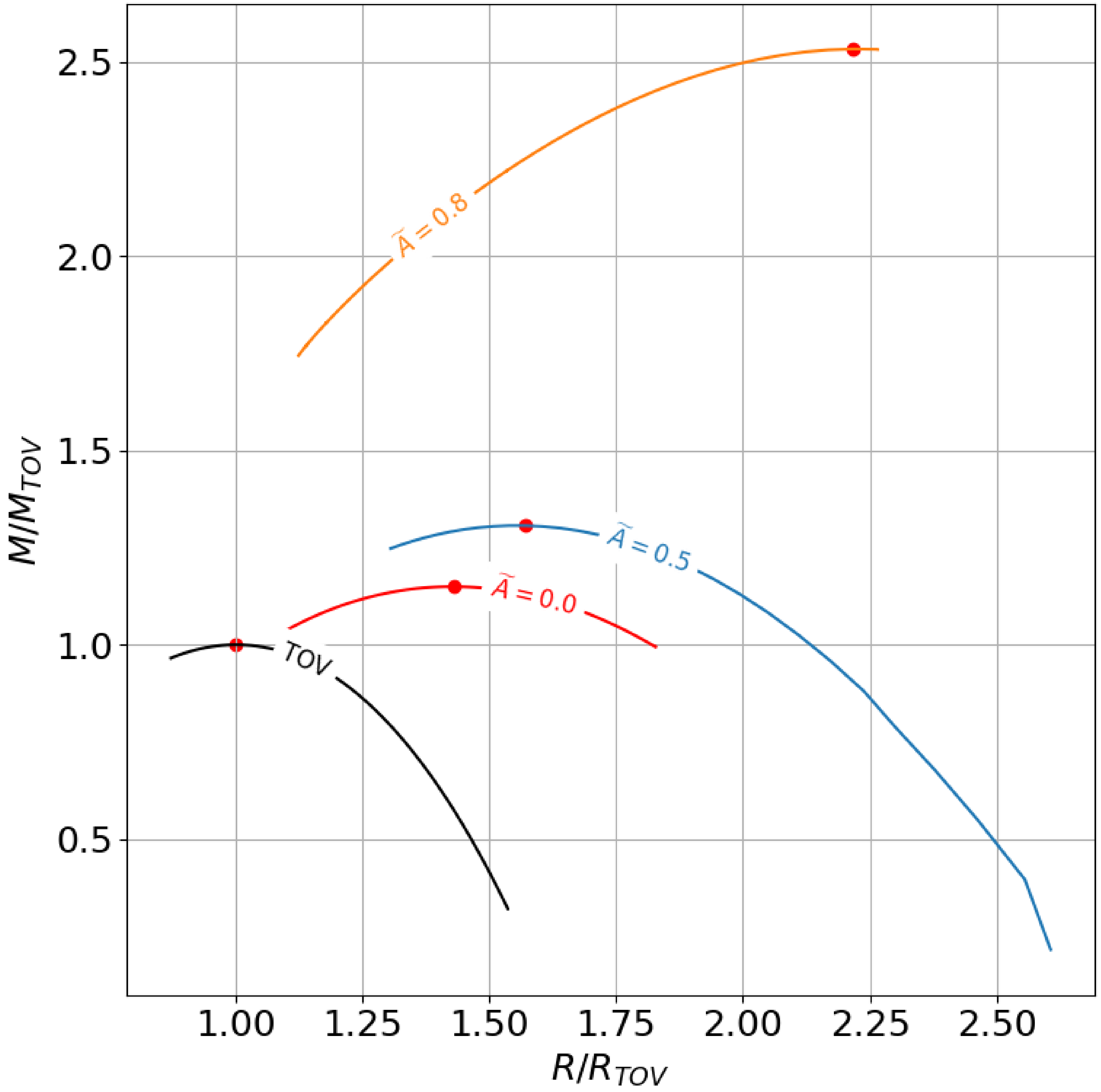
Different types of solutions



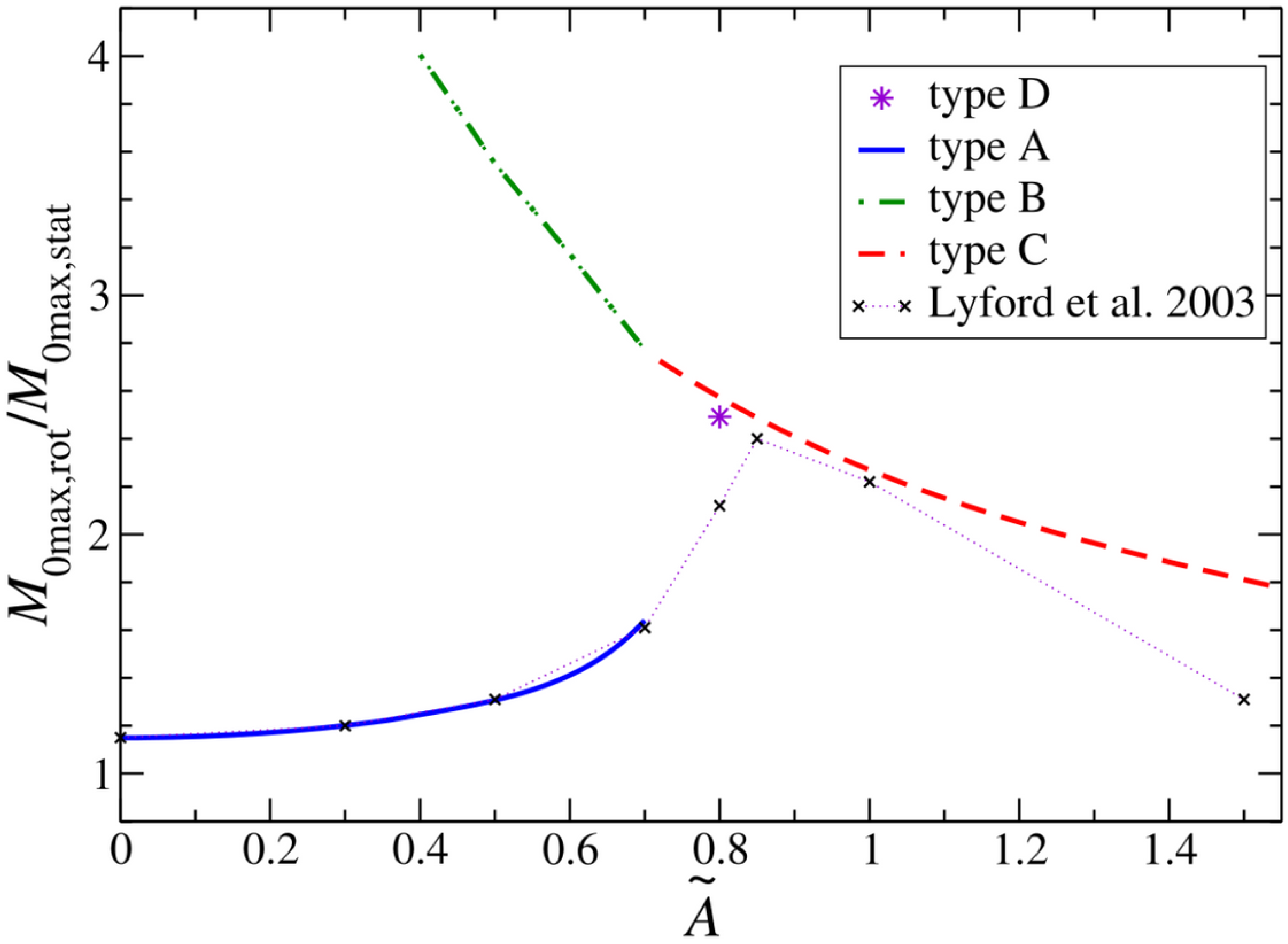
Studzinska et al. (2016)

Maximum mass

- Limit of mass exists for non-rotating NS
- **Rigid rotation** can increases the limit by ~20%
- **Differential rotation** increases the limit even further
- More than 2 times the TOV limit

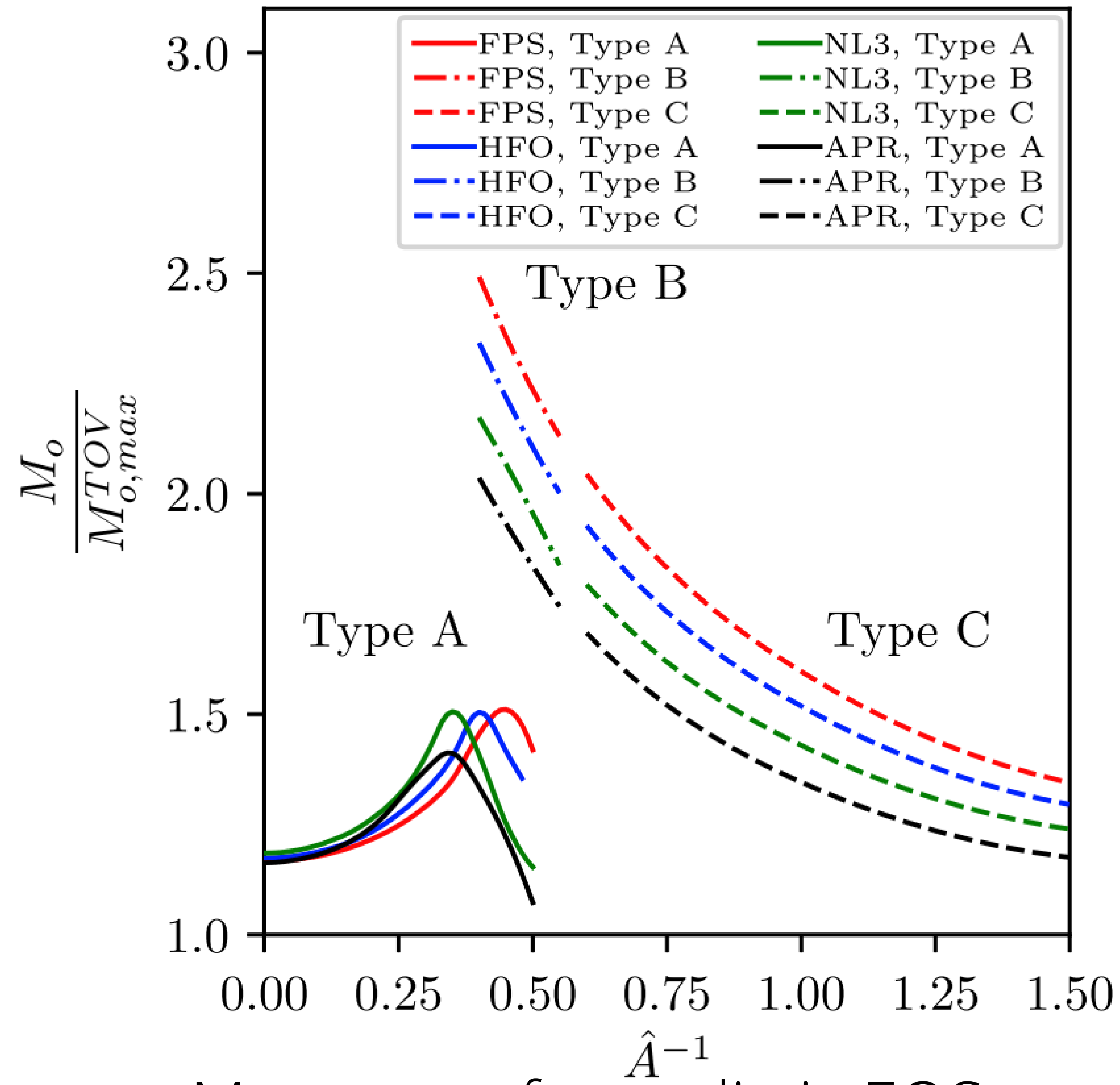


Effects of rotation on maximum NS mass

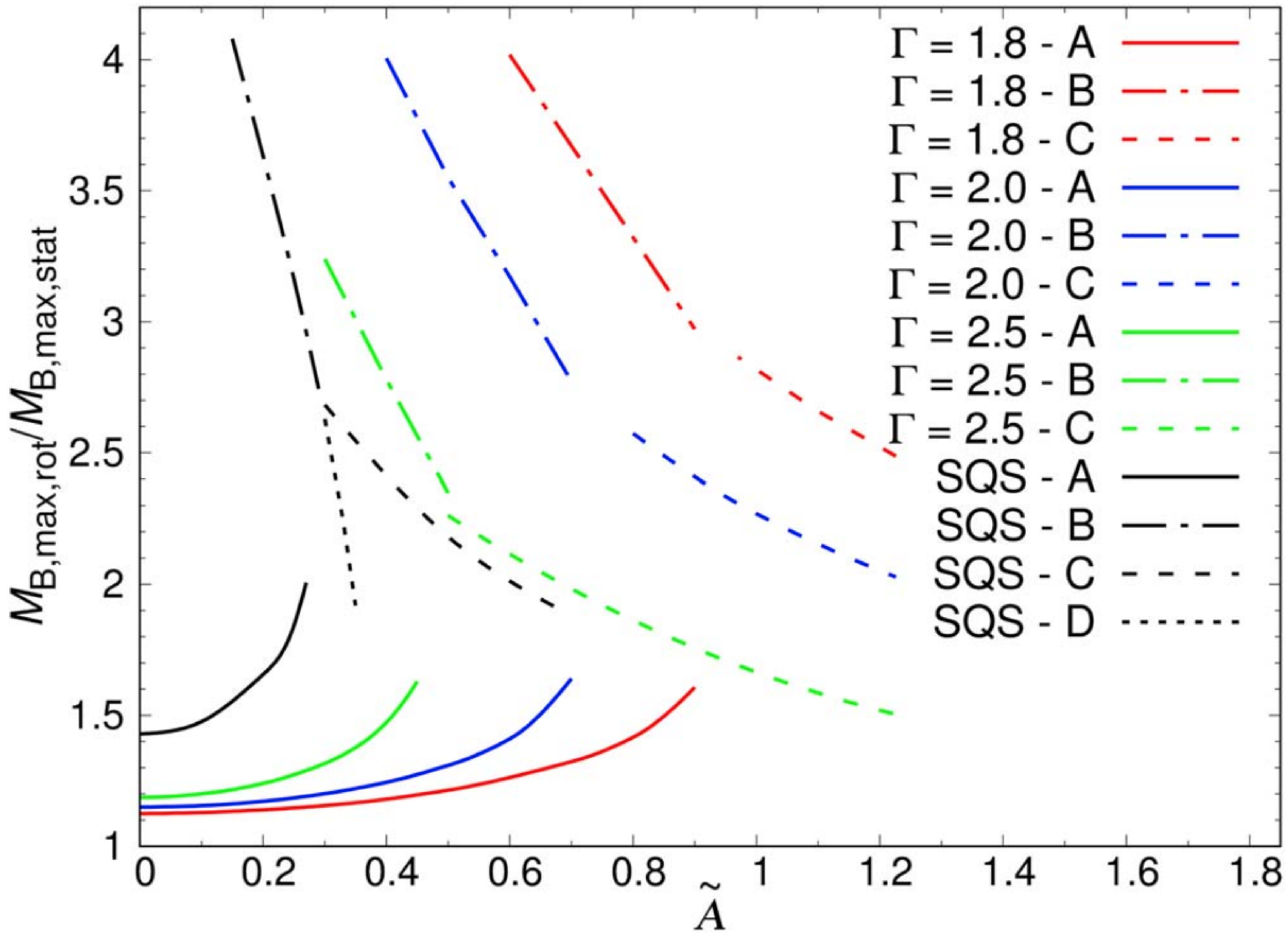


- **Differential rotation** leads to larger possible masses than rigid rotation
- Maximum mass at a **moderate** degree of differential rotation
- Similar properties for different polytropes (Studzińska et al. 2016), strange stars (Szkudlarek et al. 2019) and realistic NS EOS (Espino and Paschalidis 2019)
- Are massive configurations dynamically stable?

Effects of rotation on maximum NS mass



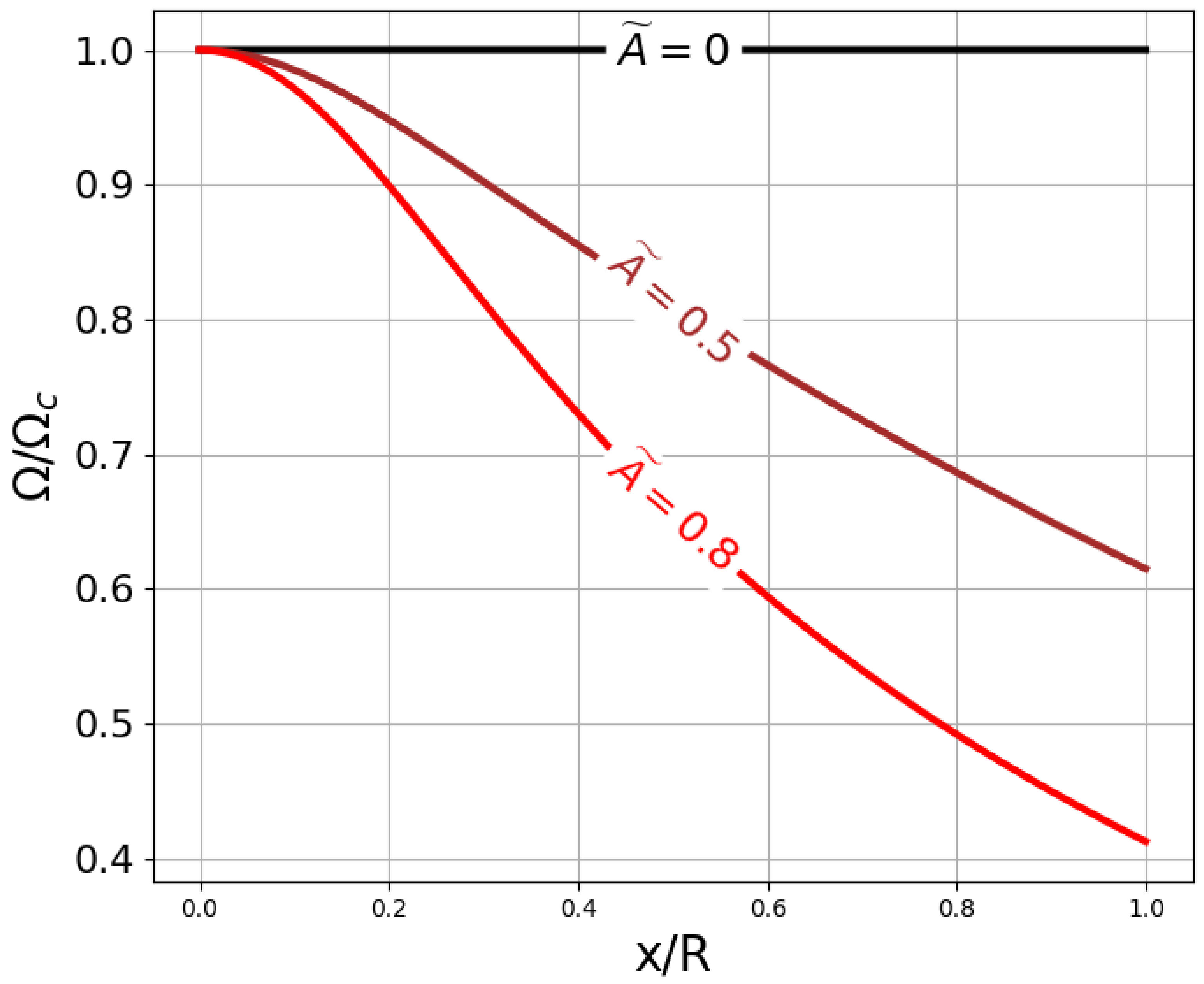
Max. mass for realistic EOS
(Espino & Paschalidis 2019)



Max. mass for polytropes and strange stars
(Szkudlarek et al. 2019)

Methodology

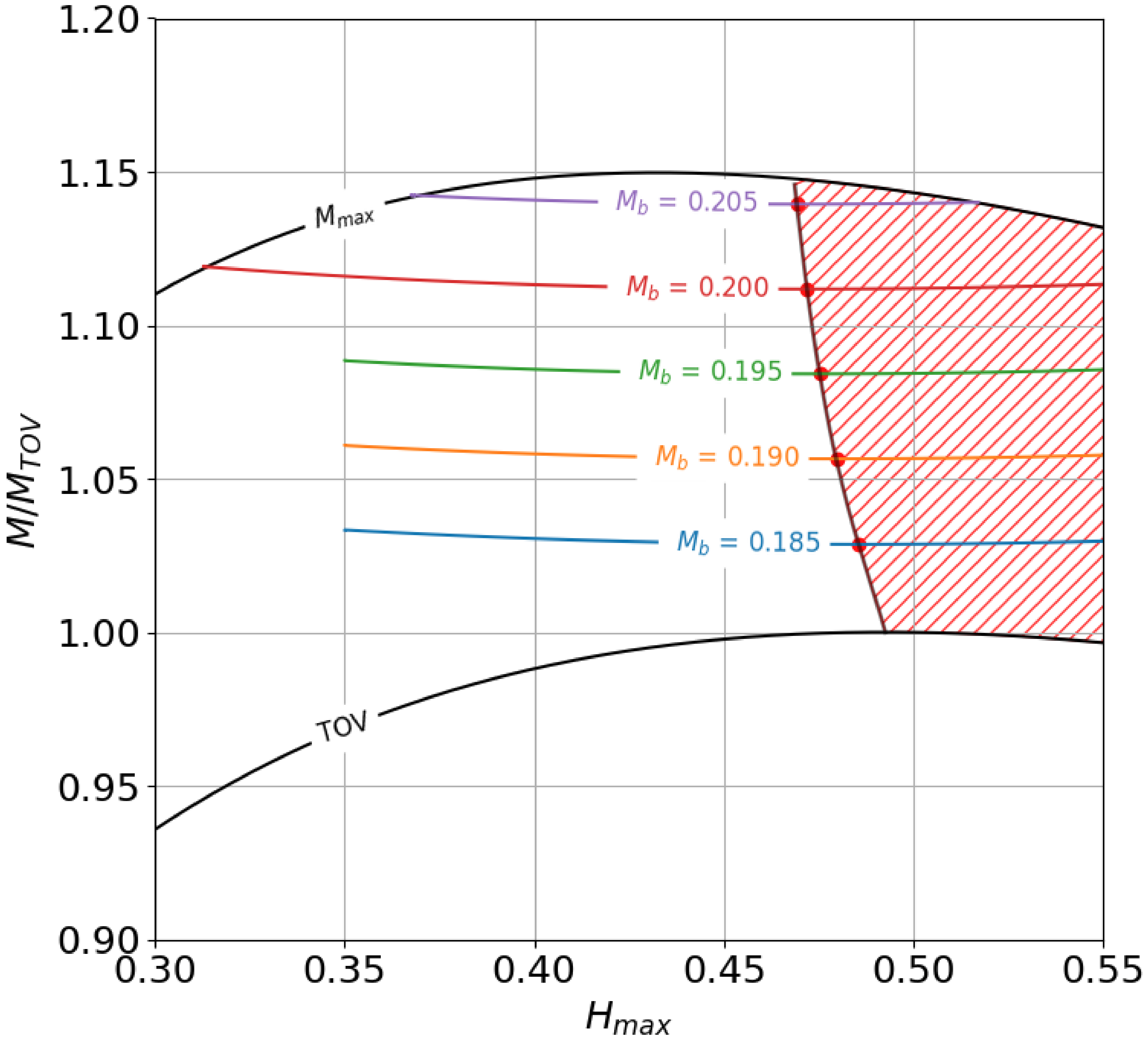
- Relativistic **FlatStar** code for axisymmetric stationary NS models with differential rotation (Ansorg, Gondek-Rosinska, Villain 2009)
- **Polytropic EOS** ($P = K\rho^2$)
- **j-const** (KEH) rotation law (Komatsu et al. 1989), consistent with core-collapse remnant
- **CoCoNuT** code for 2D hydrodynamics
- **Cactus** framework for 3D hydrodynamics



Rotation profiles in equatorial plane for different degrees of dif. rotation

Turning point criterion for instability

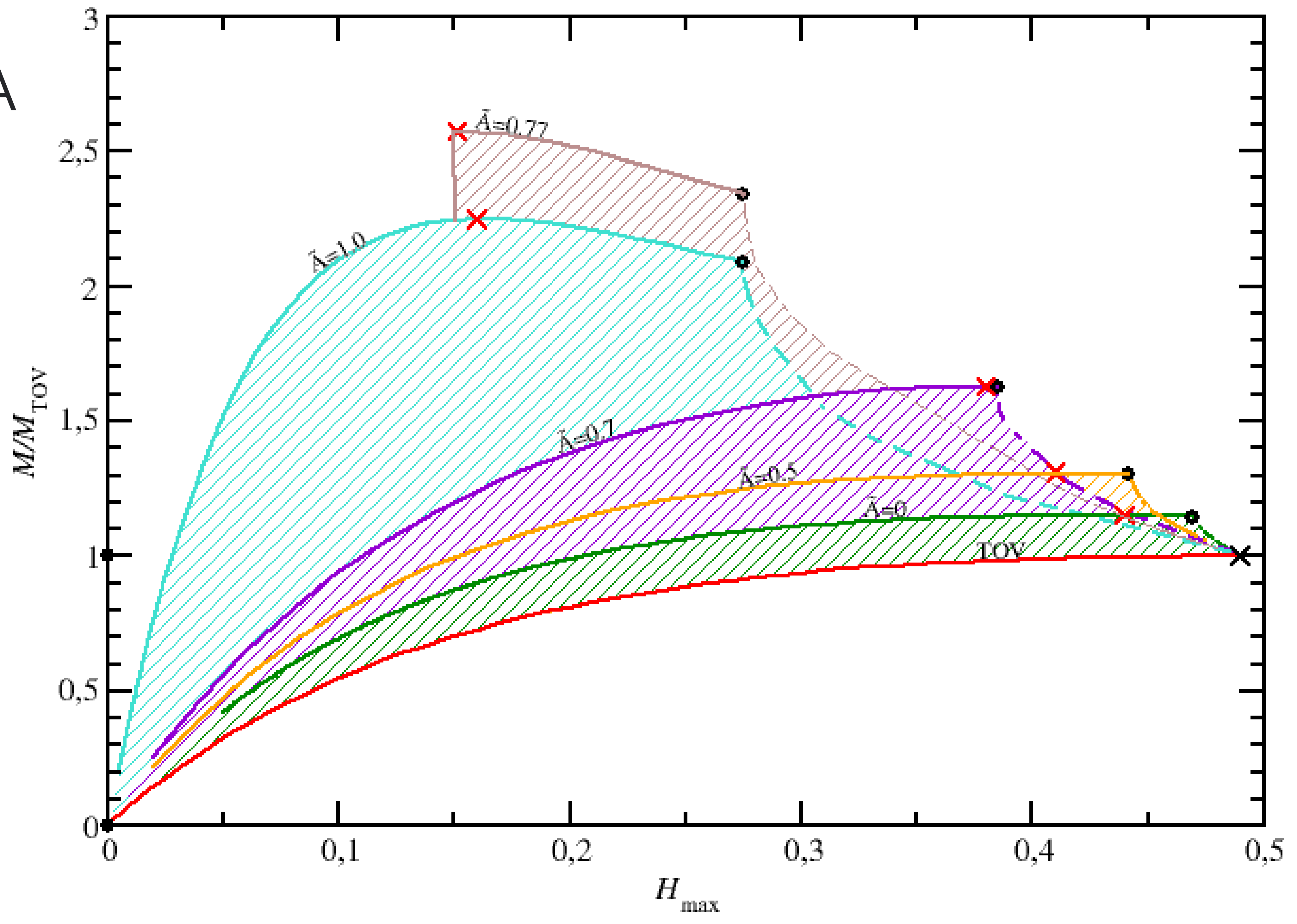
- Minimum of **gravitational mass** on sequences of fixed rest mass marks the onset of instability
- **Sufficient** criterion of dynamical instability for rigid rotation (Friedman, Ipser, Sorkin 1988)



Turning point criterion for instability

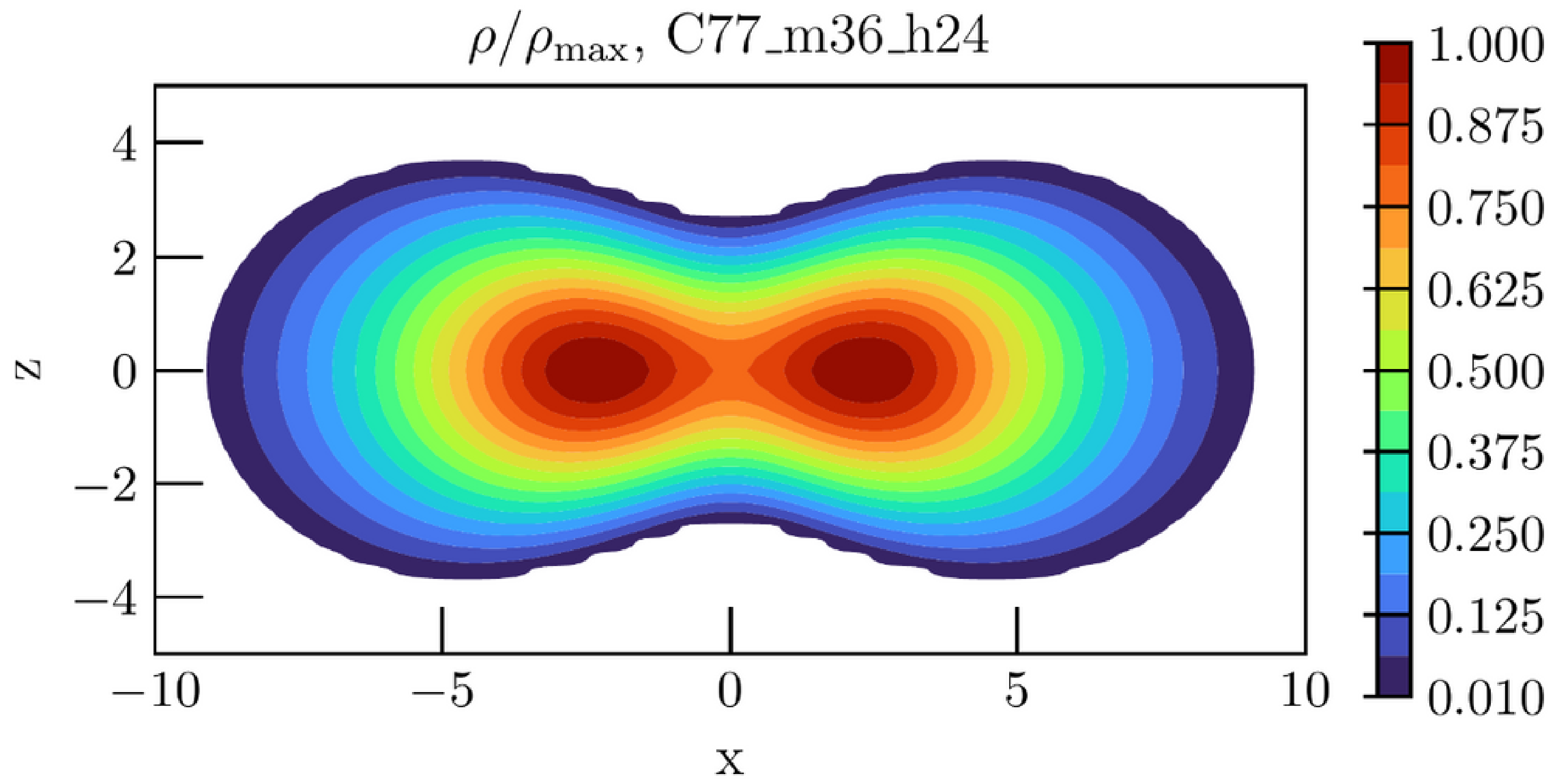
Estimated regions of stability (types A and C)

Rosinska et al. (in prep.)



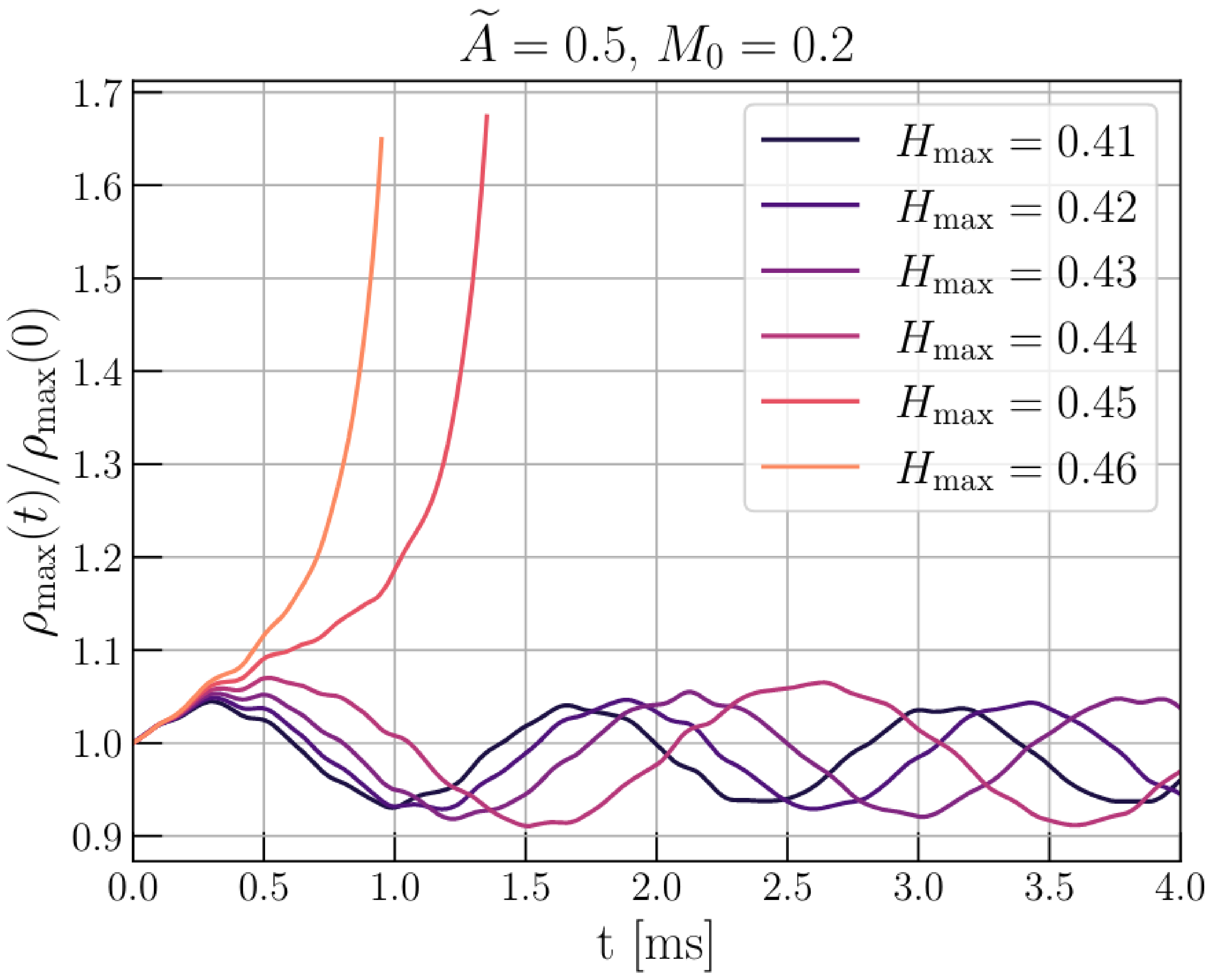
2D simulations: numerical scheme

- Initial data calculated by FlatStar
- CoCoNuT code (relativistic hydrodynamics, dynamical space-time evolution)
- Axial symmetry
- CFC approximation
- Additional radial perturbations
- 10ms length



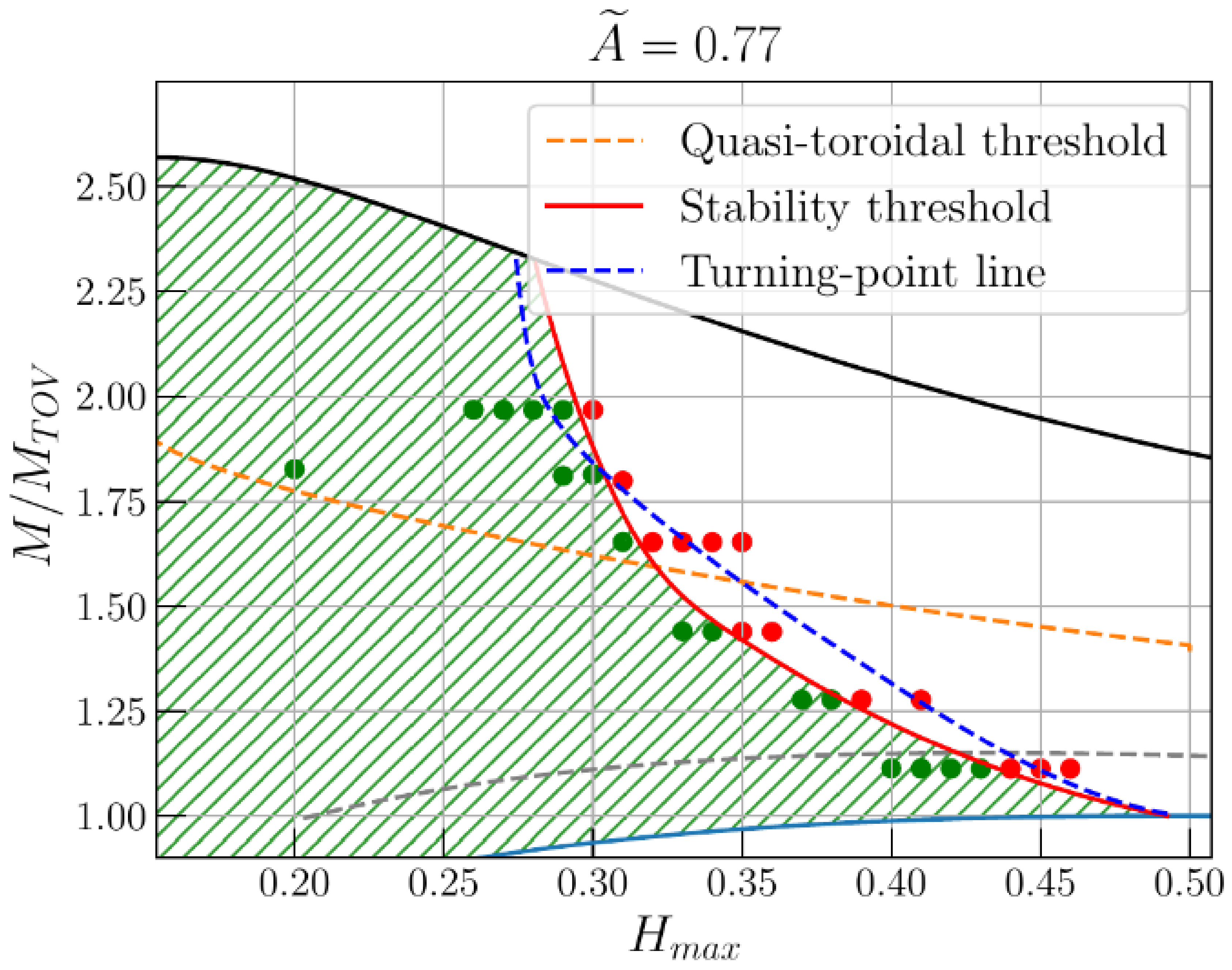
Initial data calculated by FlatStar (meridional cut)

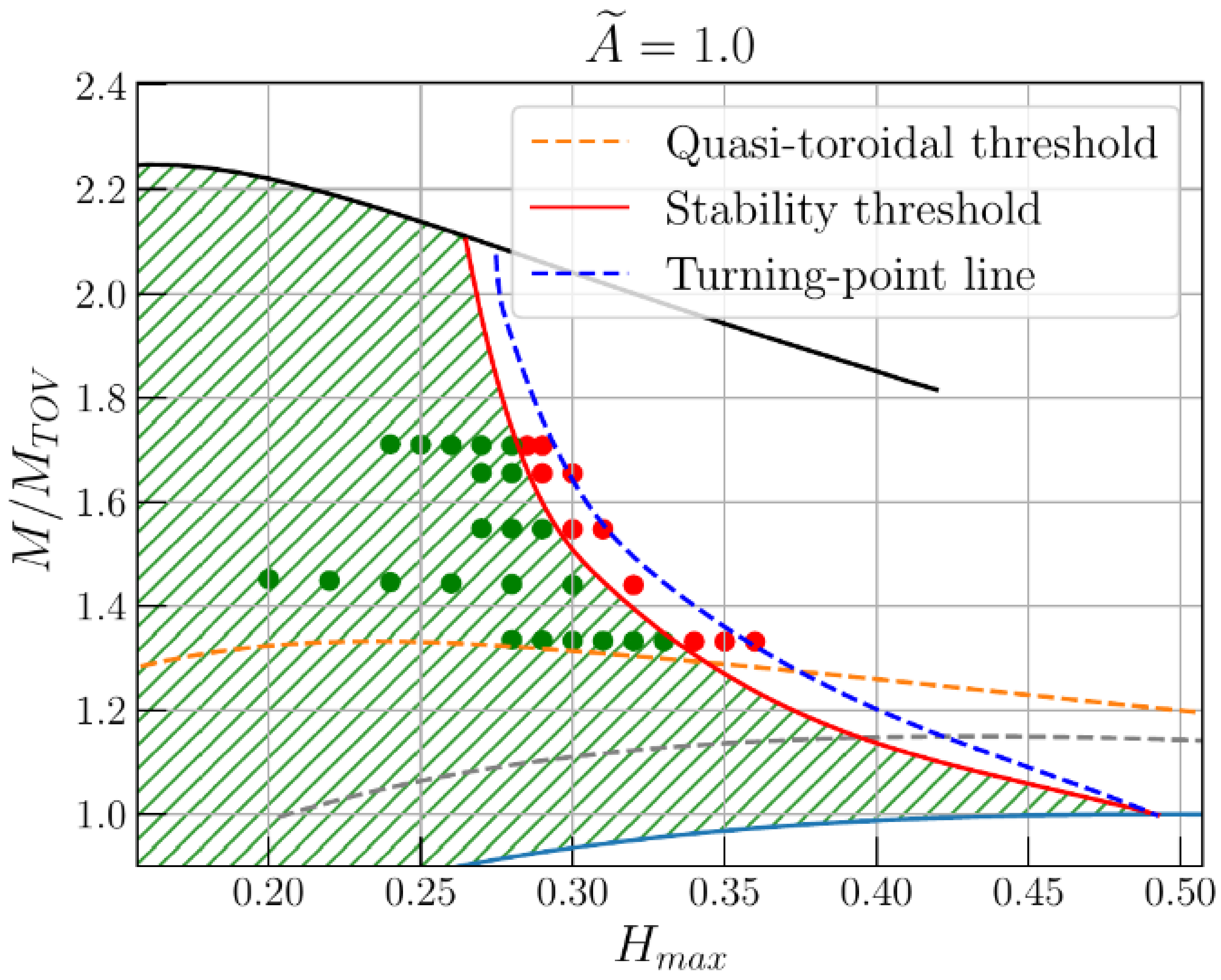
2D simulations



Maximal density evolution for stable and unstable cases

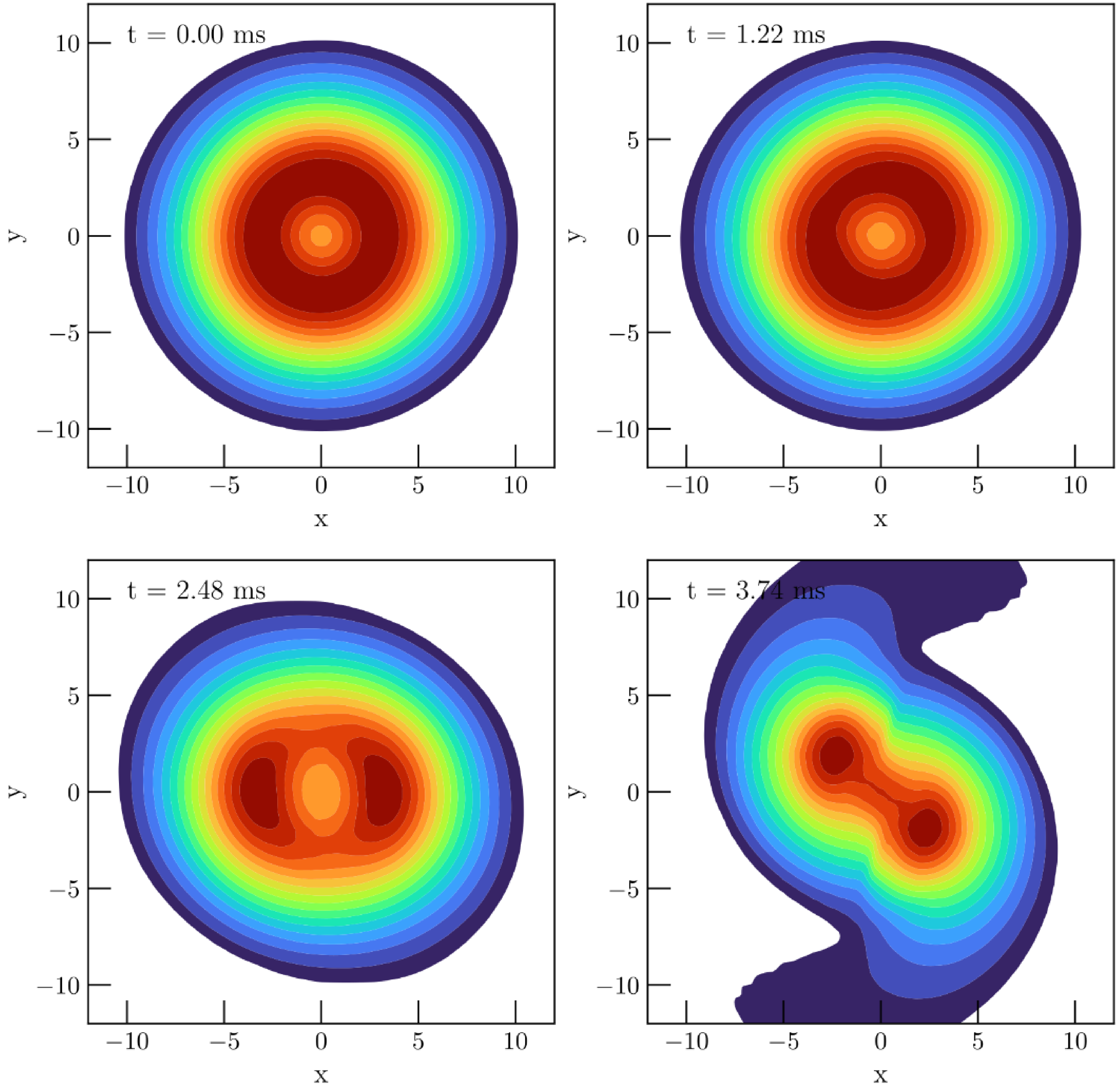
Stability limit for differential rotation (with axial symmetry)





Szewczyk, Gondek-Rosińska, Cerda-Duran (in prep)

Non-axisymmetrical instabilities



Evolution of density profile in equatorial plane with nonaxisymmetrical perurbations (work in progress)

Summary

- Massive NS can be stabilized by **differential rotation**
- Maximum mass for a stationary solution is ~4M_TOV
- We found stable configurations with M=2M_TOV
- Most massive configurations are **stable** against quasi-radial perturbations

Future work:

- 3D simulation (non-radial modes), GW emission
- Realistic EoS
- Types B and D