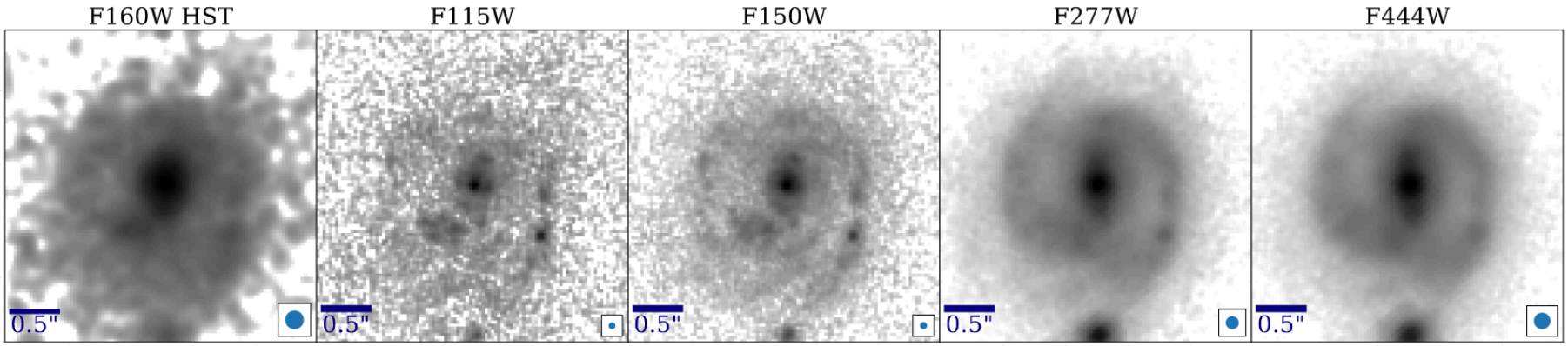
When do disks become bars?

Elena D'Onghia
University of Wisconsin-Madison

nearby universe

z~2 with JWST



Guo et al. arXiv:2210.08658

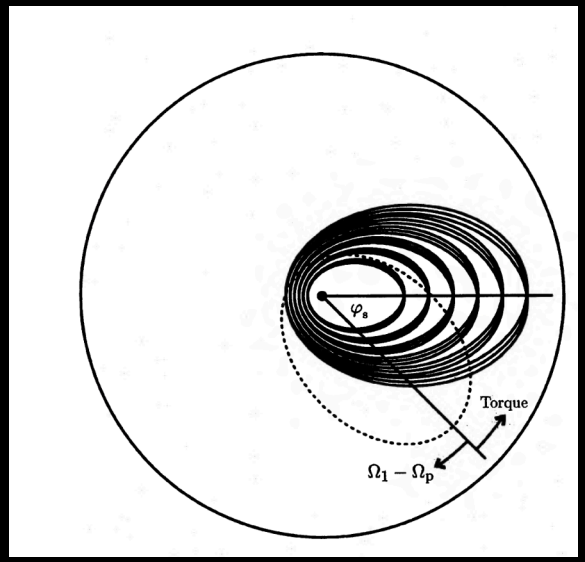
Statement of problem

- 65% of nearby disk galaxies have bars
- Why do bars exist?
- A theory should be able to provide a global disk stability criterion

Physical basis

- bi-symmetry

$$m\frac{2\pi}{\kappa} = \ell\frac{2\pi}{\Omega - \Omega_a}.$$



- m=2 ; l=1 (orbit close with 2 lobes after 1 turn)

Lynden-Bell (1979)

(Local) criterion to bar instability

(swing amplification-toomre 1981)

- two parameters define disk instability:

  1) $Q = \kappa\sigma_R / 3.36 G\Sigma$

  2) $X = \lambda/\lambda_c \;\; ; \;\; \lambda_c = 4\pi G\Sigma/\kappa$

disks stabilized by increasing Q (e.g. random motion)

or X (dark halo or bulge)

Global criterion of disk stability

- Disk is exponential
- Disk self-gravitating and in external field
- Two parameters:

  1) t=T/W (ordered/disordered motion)

  2) M_central/M_disk

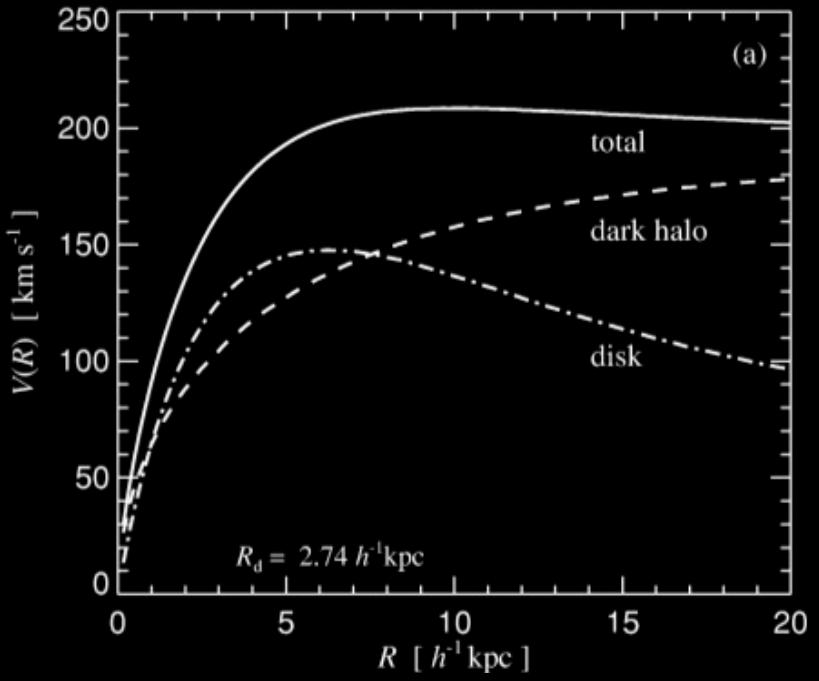
We study the stability/Instability regions in this plane!

Note that….

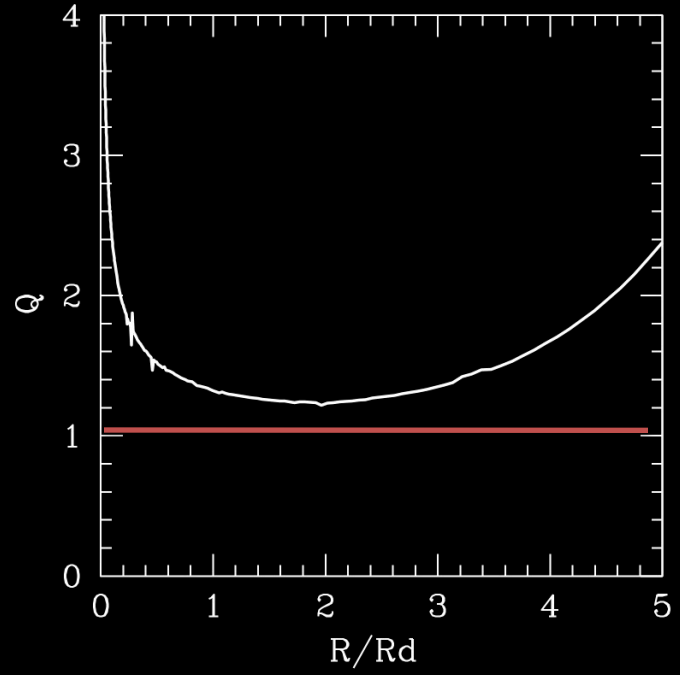
- A cold disk is bar unstable if $t>0.12$ (Ostriker-Peebles 72)
- Solar system is never bar unstable!
- Other cases are unclear!

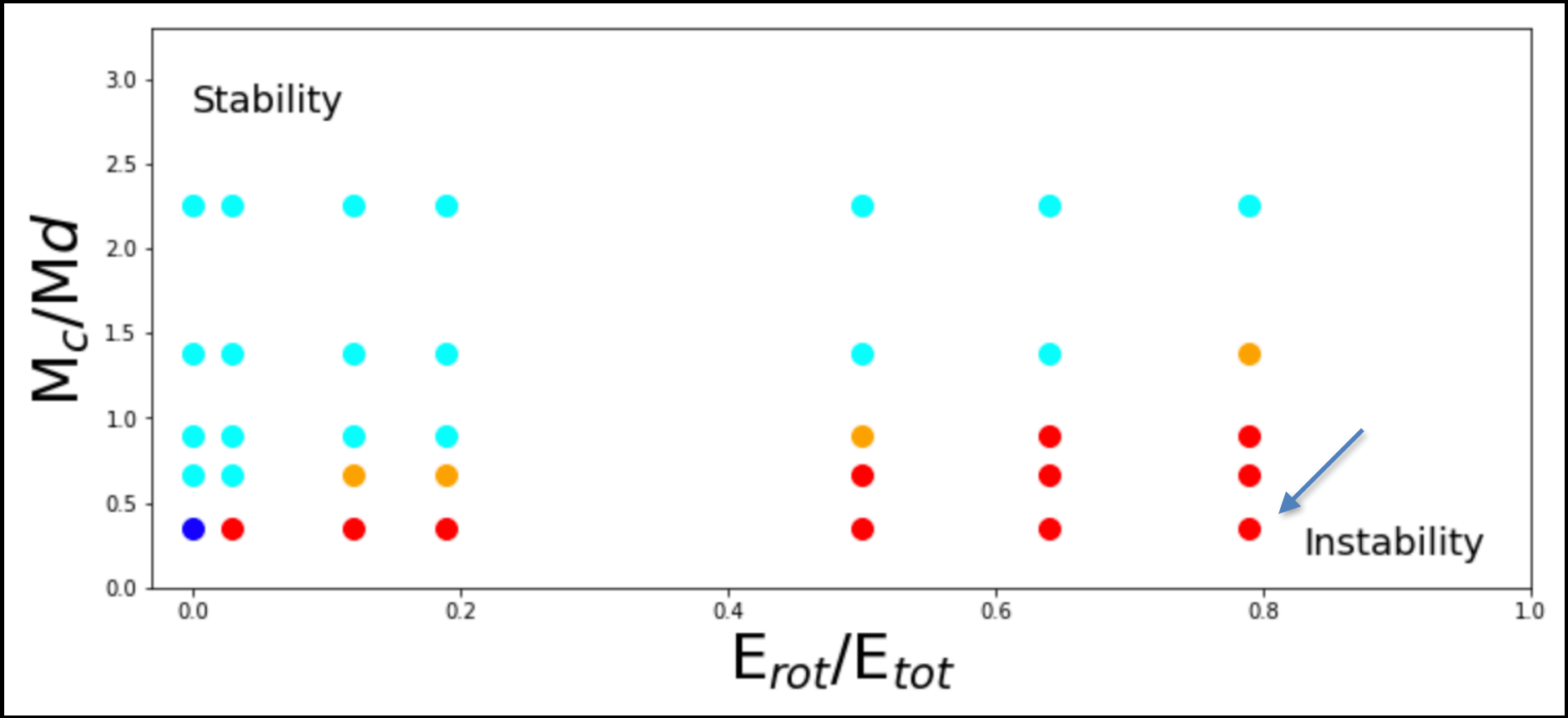
Galaxy N-body Models

Springel, Di Matteo & LH (2005)



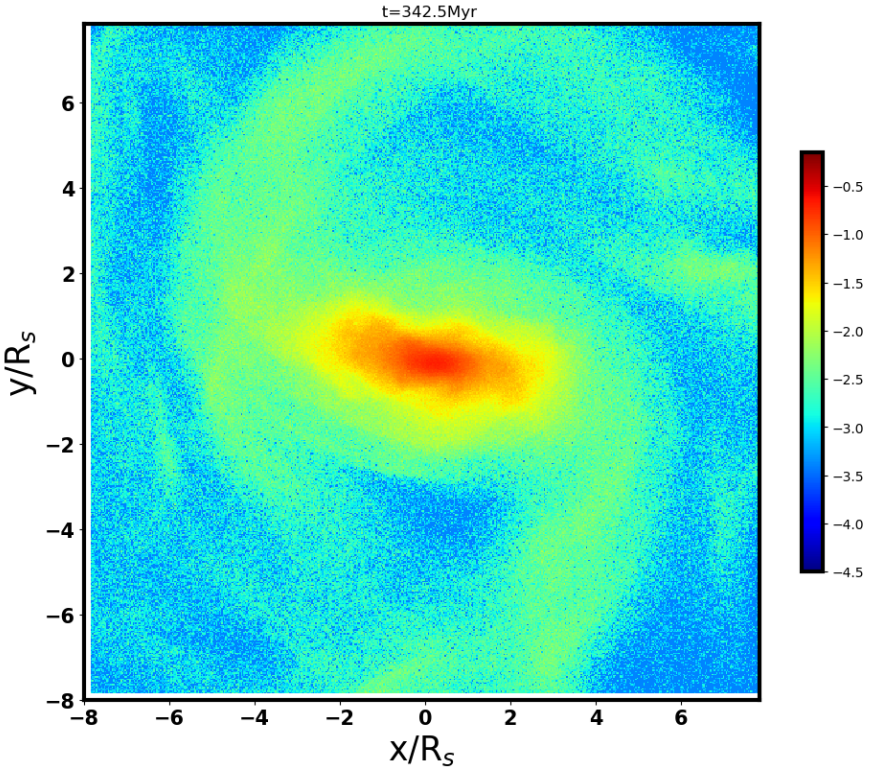
- Present study:
  - self-gravitating stellar disks
  - no gas, no bulges (add later)
  - live halo
  - $N_* \approx 10^7$ to suppress noise
  - exponential disks
  - Toomre $Q = \varkappa\ \sigma_R / 3.36\ G\ \mu_0 > 1$
  - We introduce counterrotating stars

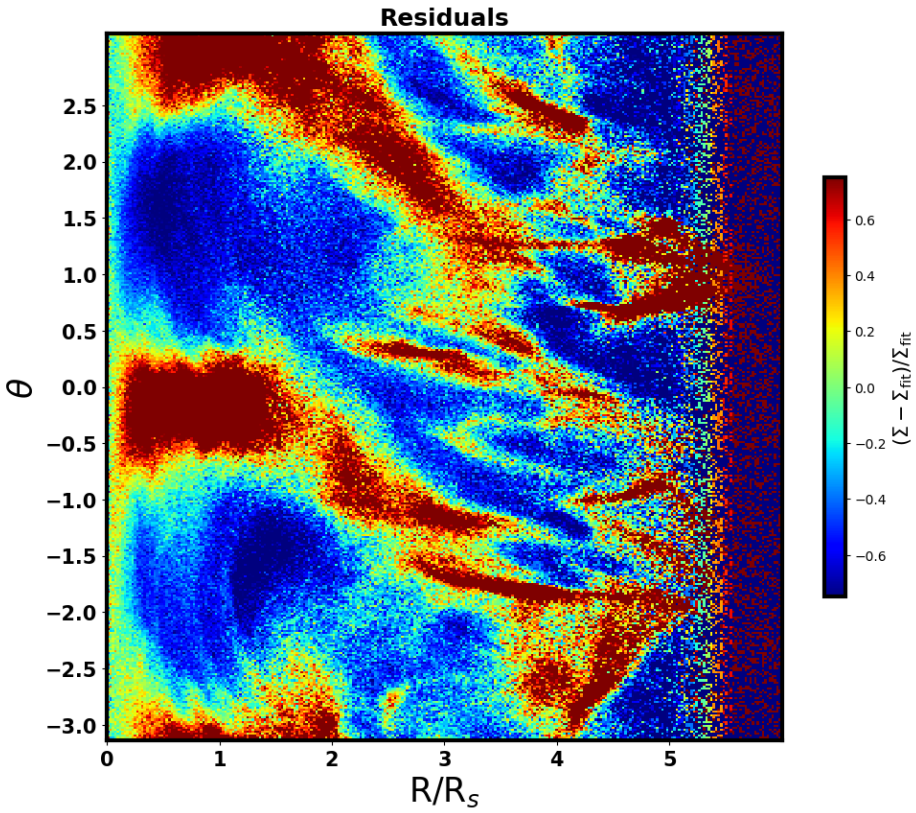




D'Onghia & Ostriker, 2022 in prep

Most unstable disk

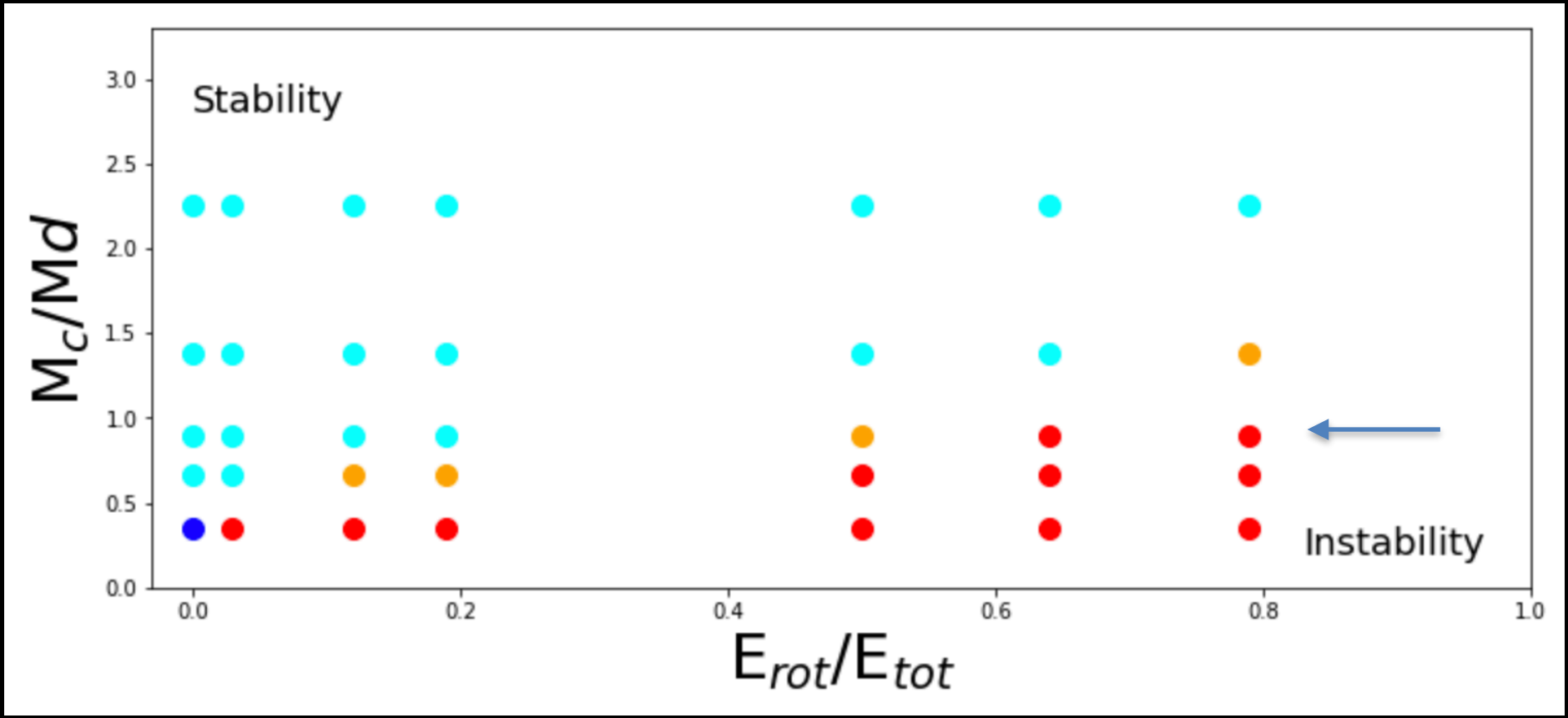




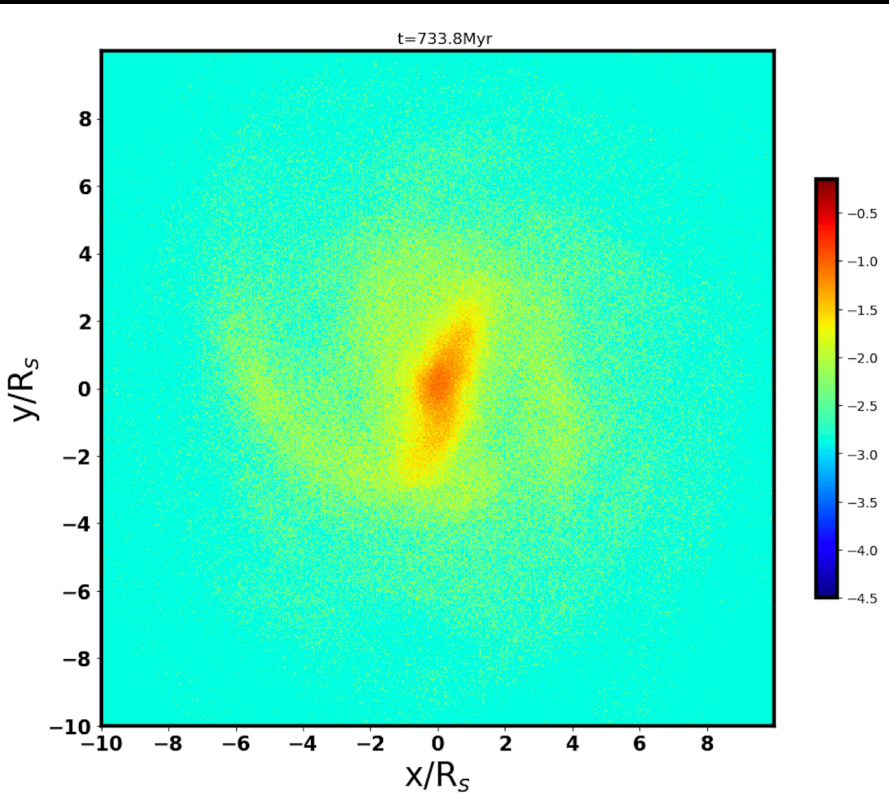
- Disk fraction ~70%
- no counterrotating stars

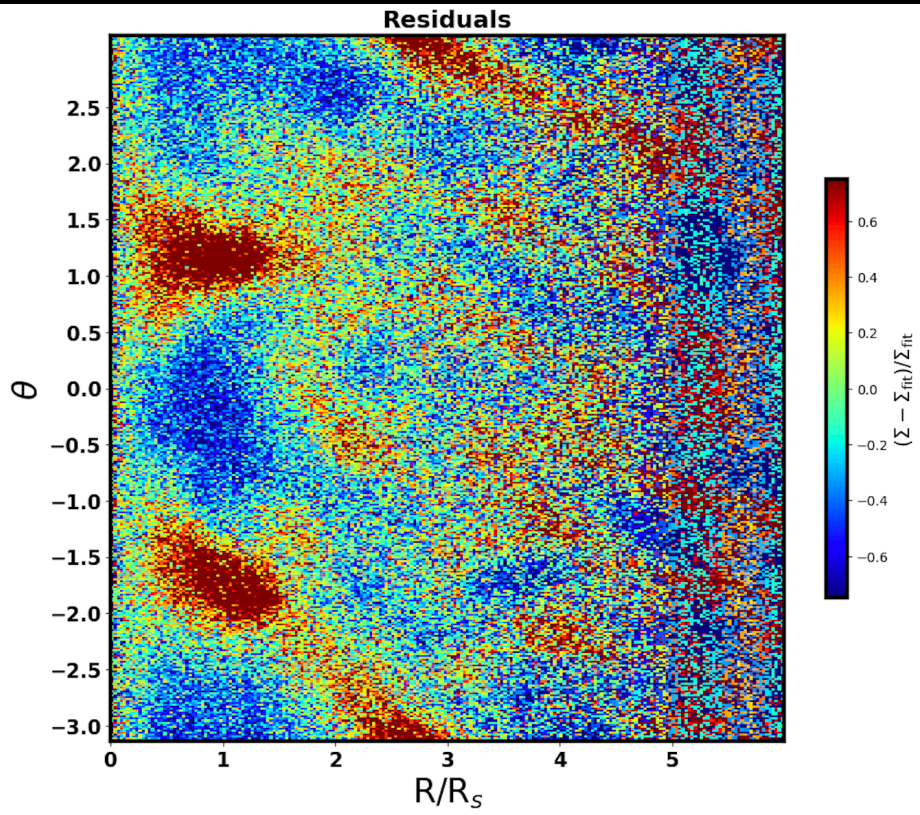
D'Onghia & Ostriker, 2022 in prep

Milky Way-like Galaxy



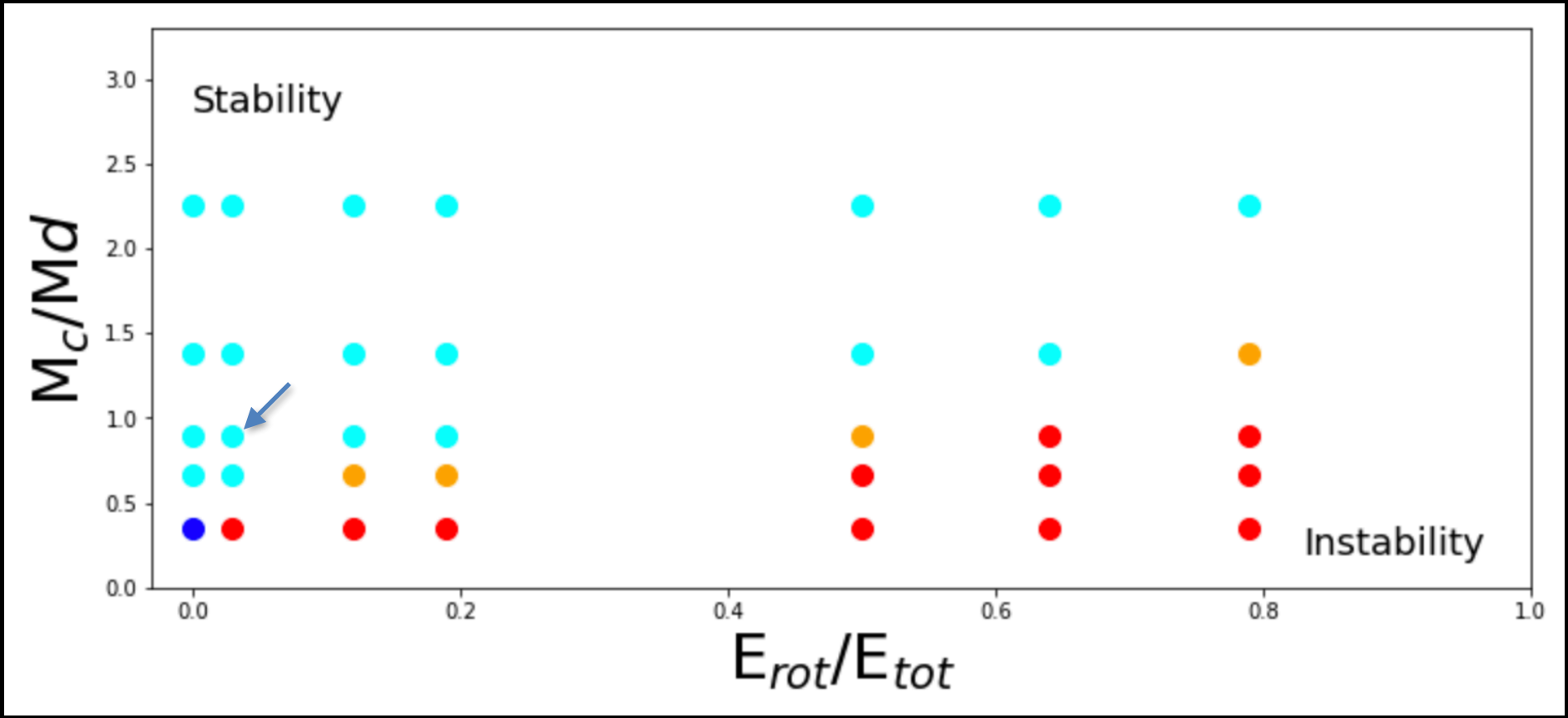
Milky Way-like galaxy



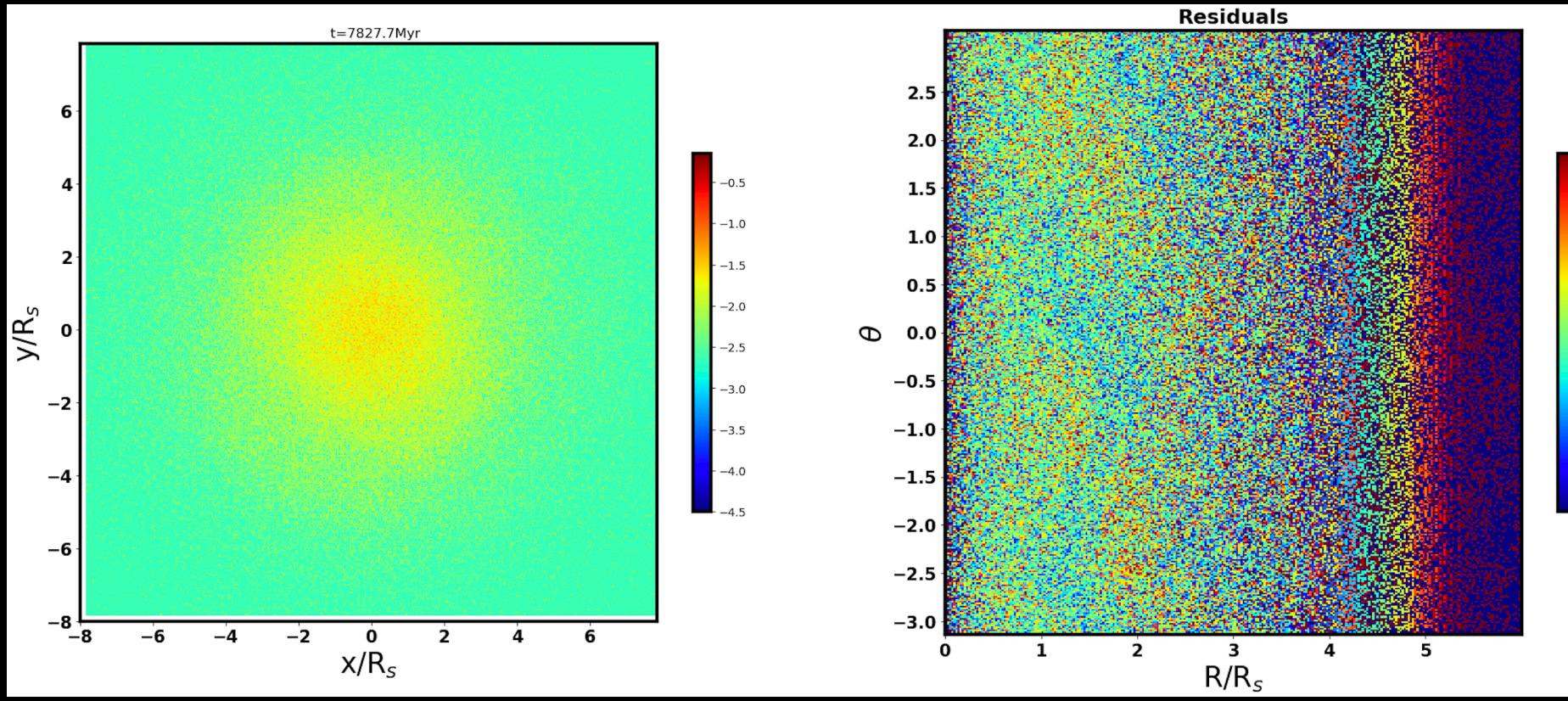


- Disk fraction ~40%
- no counterrotating stars

Milky Way-like Galaxy



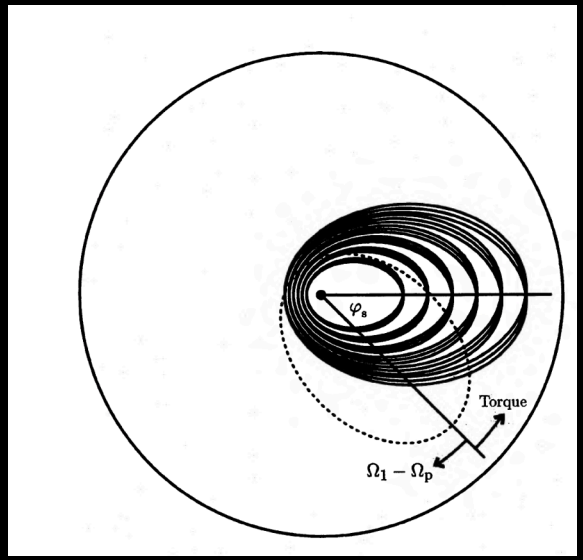
Milky Way-like galaxy



- Disk fraction ~40%
- 40% counterrotating stars

We learned

- mean rotation rate, <Ω>, is crucial in disk stability
- retrograde stars reduce <Ω> and increase stability



D'Onghia & Ostriker, 2022 in prep

Contributions

- 2 global parameters regulate bar formation
- results are valid also for thick disks
- gas affects bar formation—> high redshift galaxies
- Results extended at any scale