

# Can spiral galaxies form in major mergers ?

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$S + S \implies E$  (Toomre + Toomre 1972, Toomre 77, Barnes, Hernquist etc etc)

Observations:

$S$  (with gas) +  $S$  (with gas)  $\implies S$

Hammer et al. (2007, 2009a, 2009b, 2010, 2012, 2013, 2014),  
Puech et al (2006, 2007a, 2007b, 2008, 2009, 2010a, 2010b, 2014),  
Flores et al. (2006), Yang et al. (2008, 2009, 2014), Wang et al. (2012),  
Delgado-Serrano et al. (2010), Rodrigues et al. (2012), Fouquet et al (2012, 2014),  
Peirani (2009), Pawlowski et al. (2014)

Simulations (and criticism thereof):

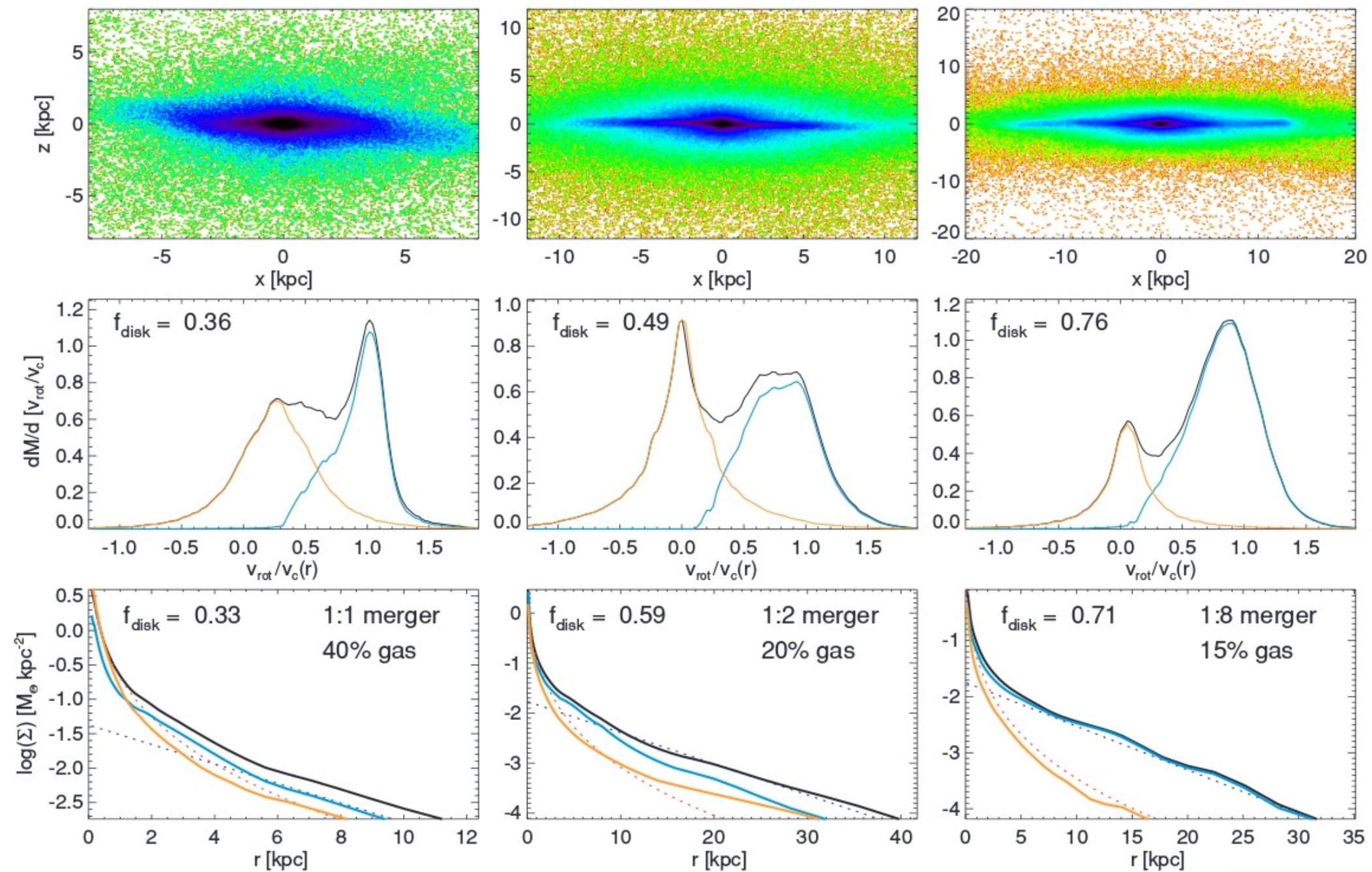
$S$  (with gas) +  $S$  (with gas)  $\implies$  galaxy with a disc component, or lenticular but .....

Barnes 2002, Springel & Hernquist 2005, Cox et al. 2006, Robertson et al. 2006,  
Governato et al. 2007, Bournaud & Elmegreen 2009, Covington et al. 2009,  
Hopkins P. et al. 2009a, 2009b, 2010, 2011, Borlaff et al 2015, Querejeta et al 2015a,b etc

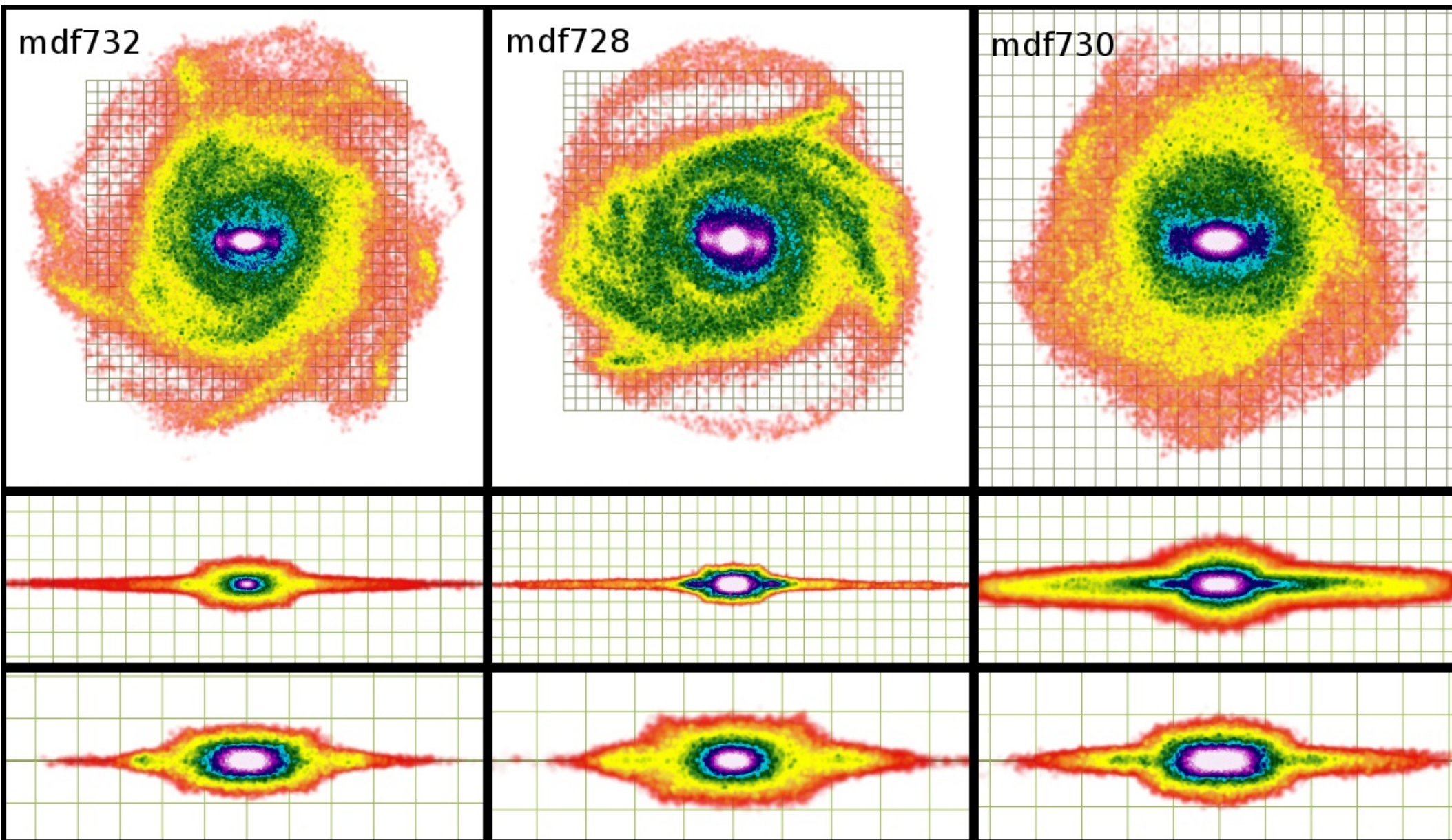
Improvements :

Technically superior, More realistic gas physics, More realistic ICs

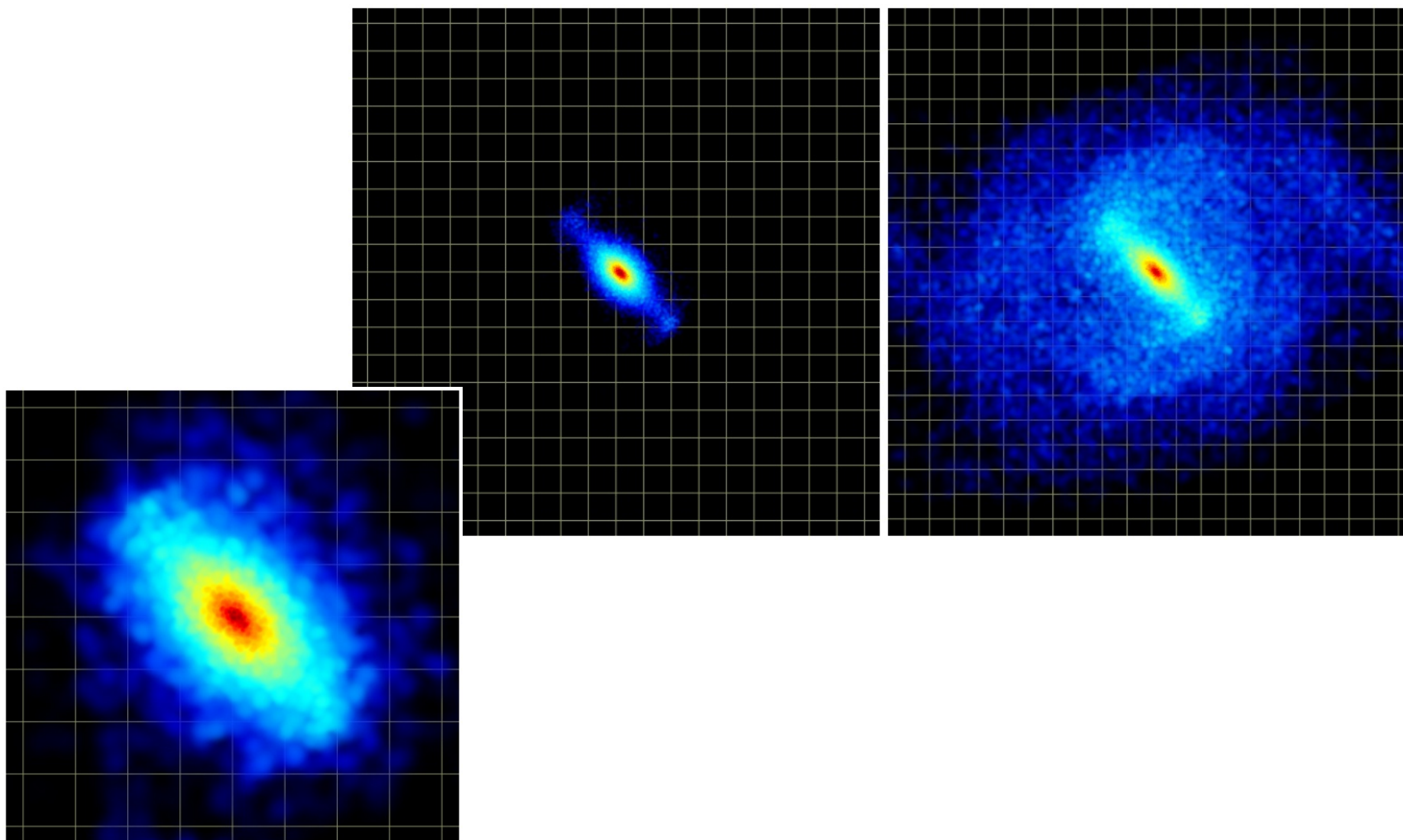
We make a detailed and complete comparison with observations

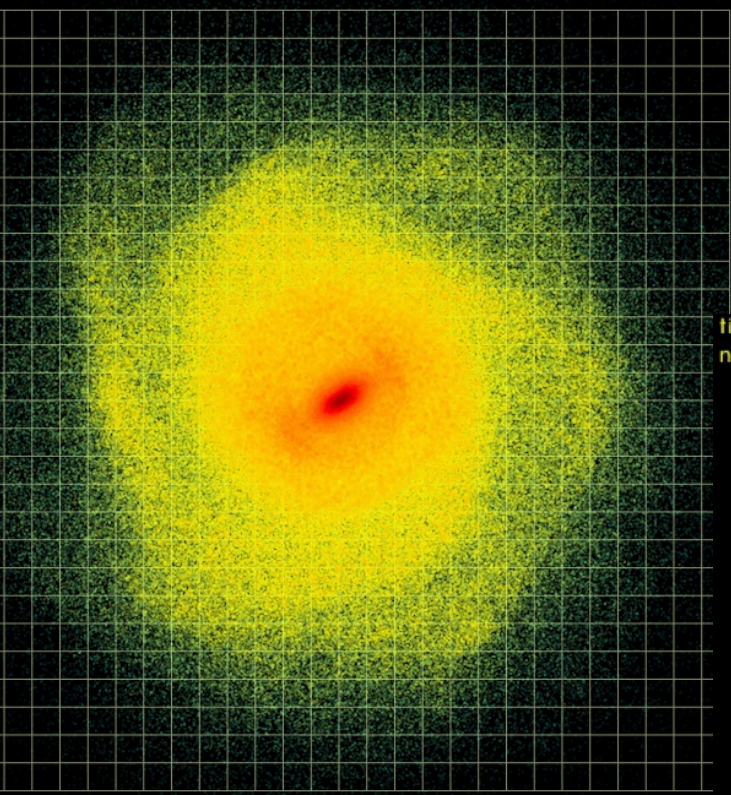


# Morphologies



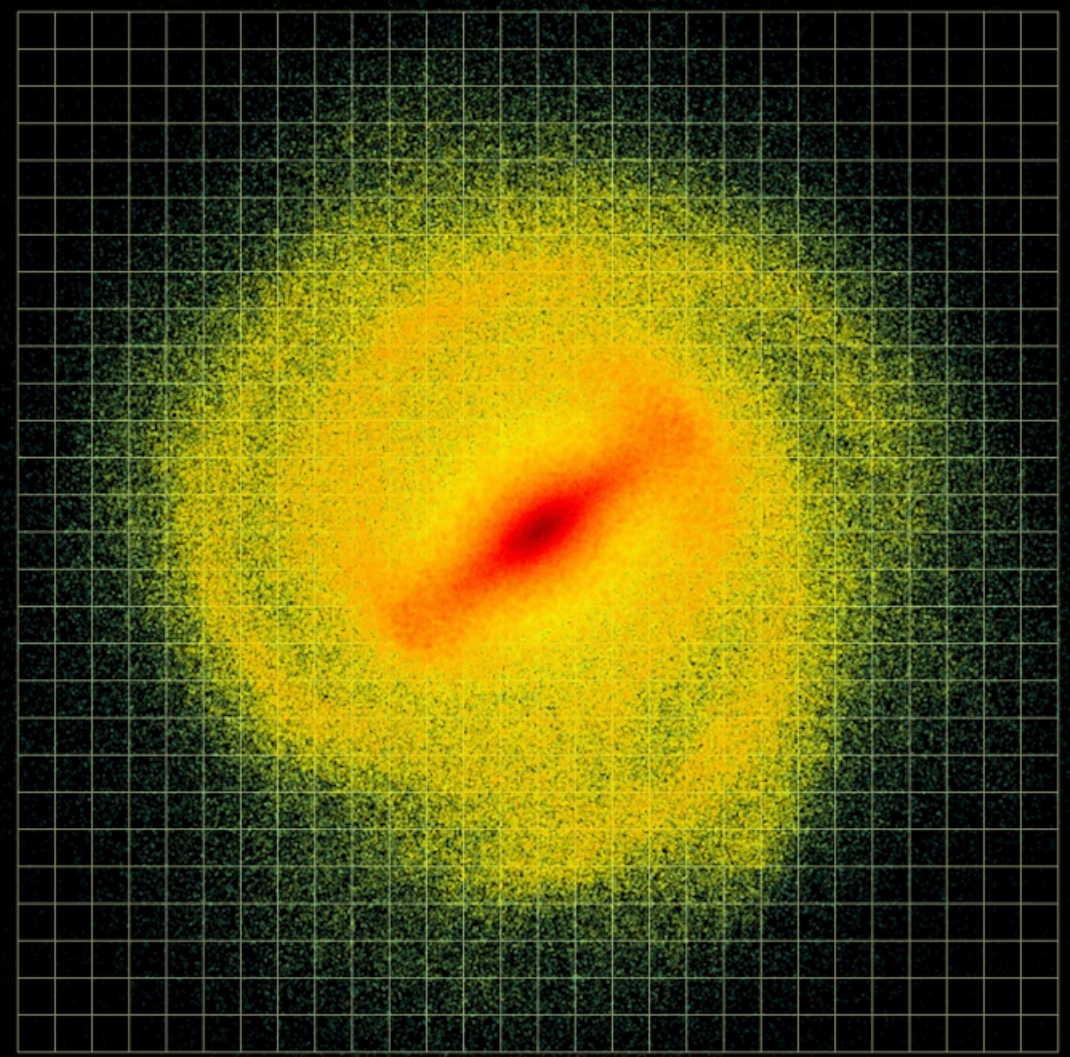
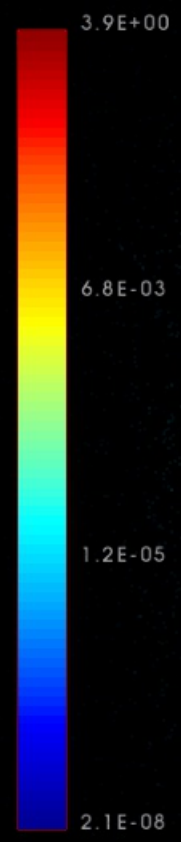
Compare bars with those of idealised simulations (pre-existing discs)





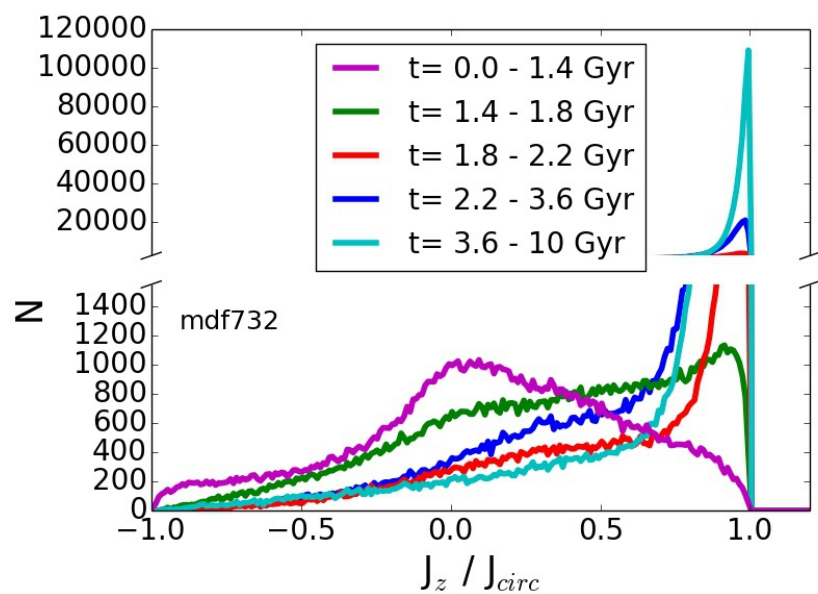
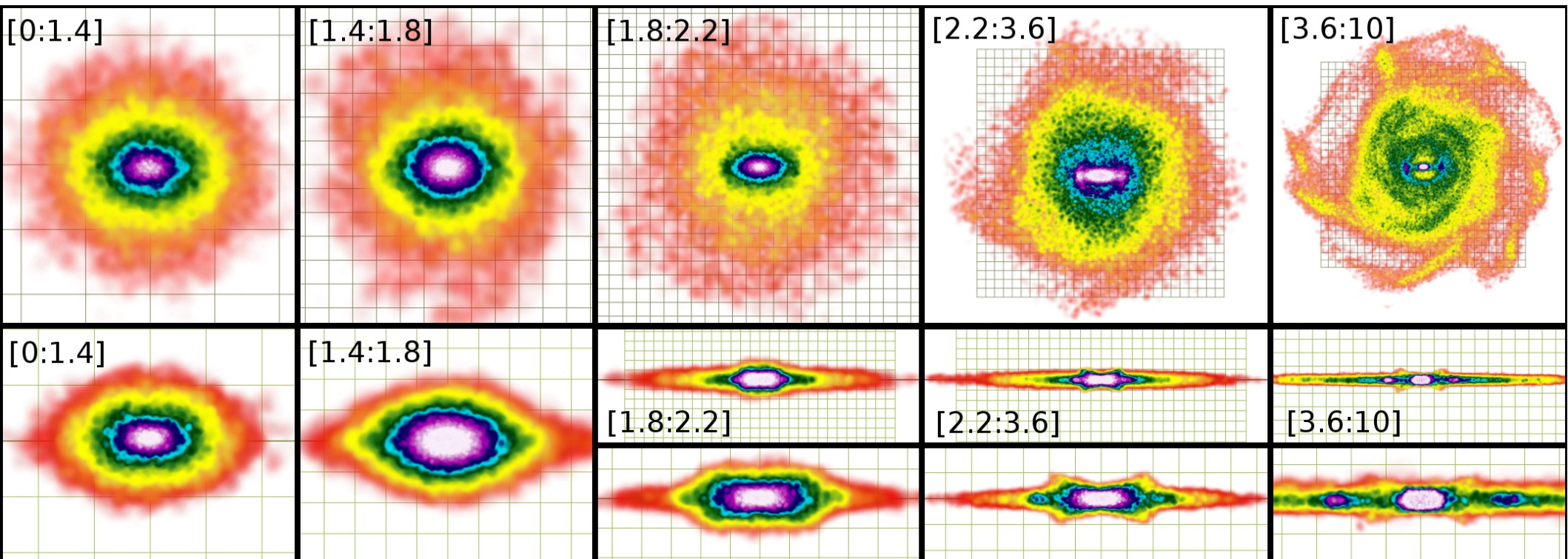
time : 2.5000  
nbody : 1057948

Perspective



Zoom : -39.9566  
Rot : 0.00 0.00 0.00

At  $t=10$  Gyr, but consider separately different populations (different ages)



Athanassoula et al 2015

B/T (bulge to total baryonic mass ratio)

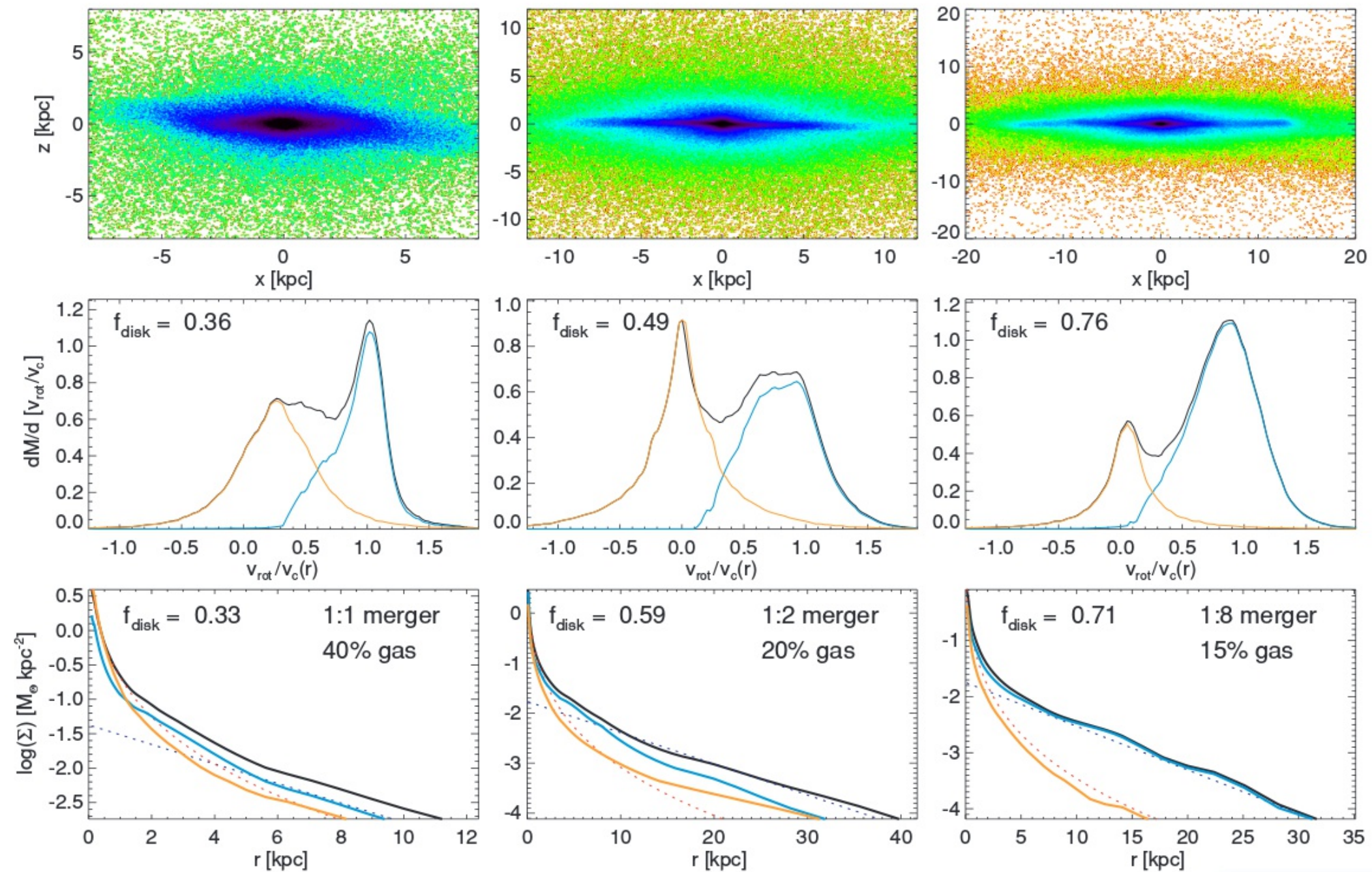
From kinematics

0.15 (mdf728), 0.16 (mdf732) and 0.25 (mdf730)

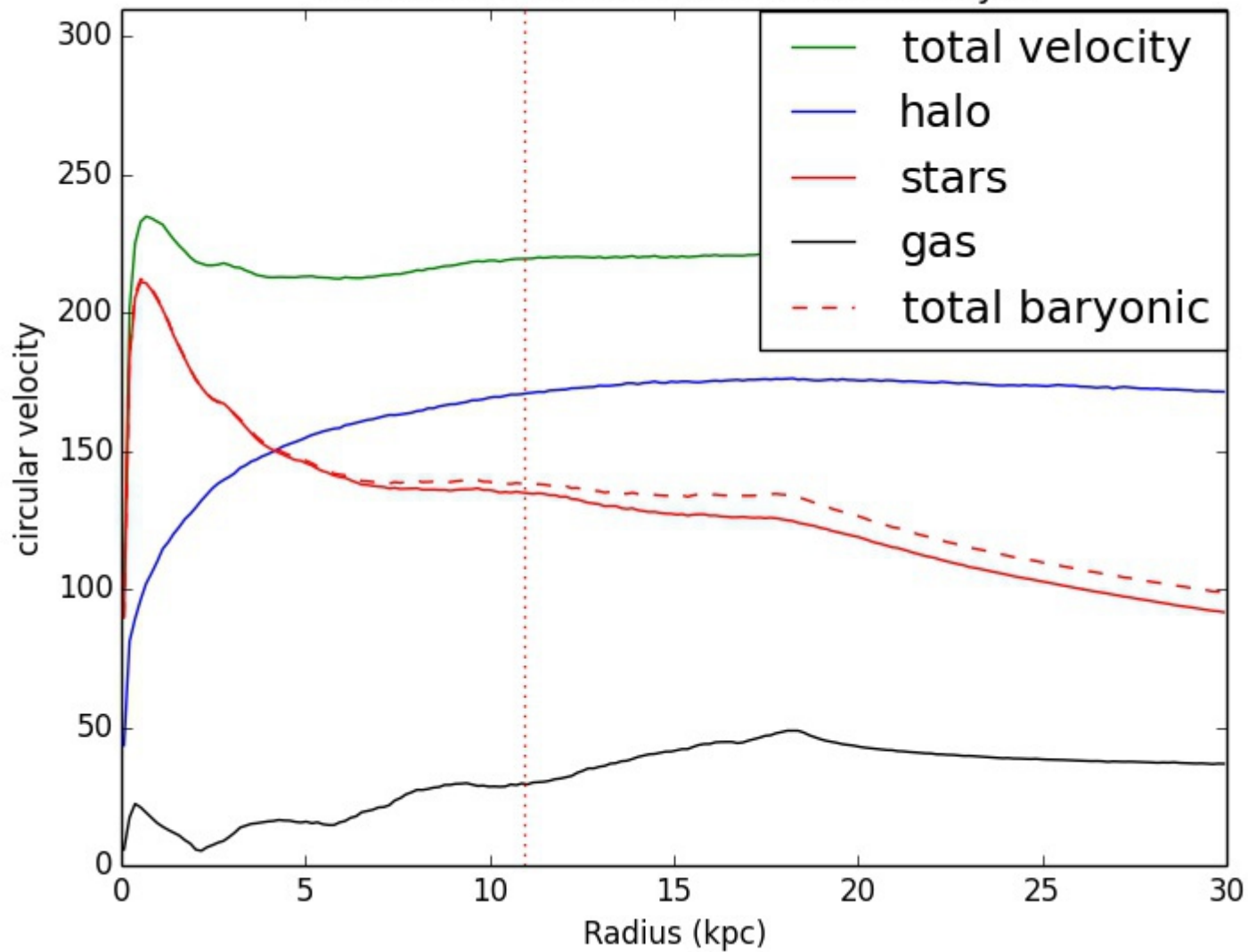
From decompositions

0.12 – 0.15 (mdf728), 0.14 – 0.20 (mdf732) and 0.21 – 0.27 (mdf730)



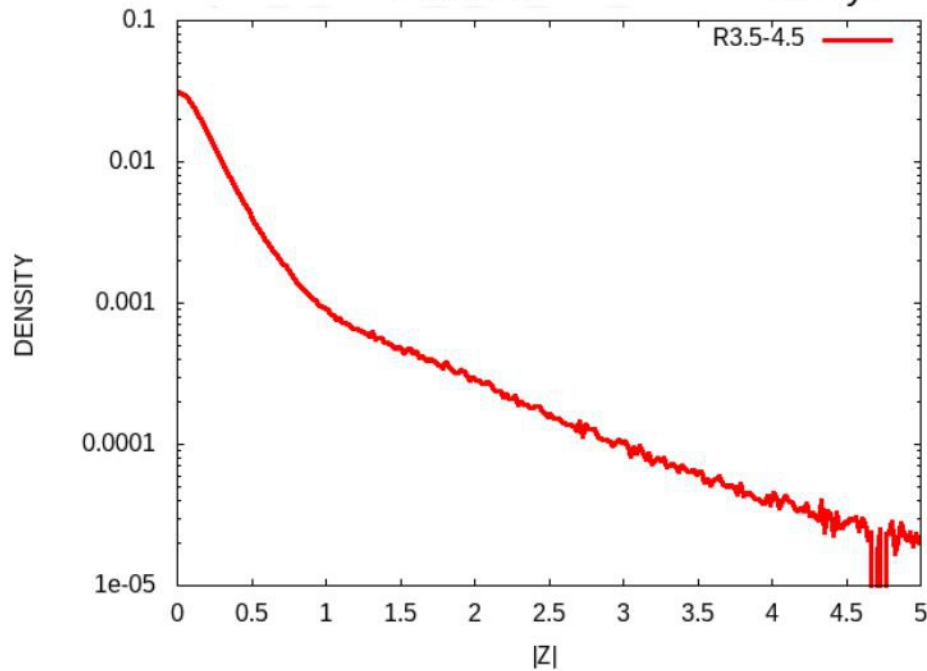


Rotation curve for mdf958 at t=10 Gyrs

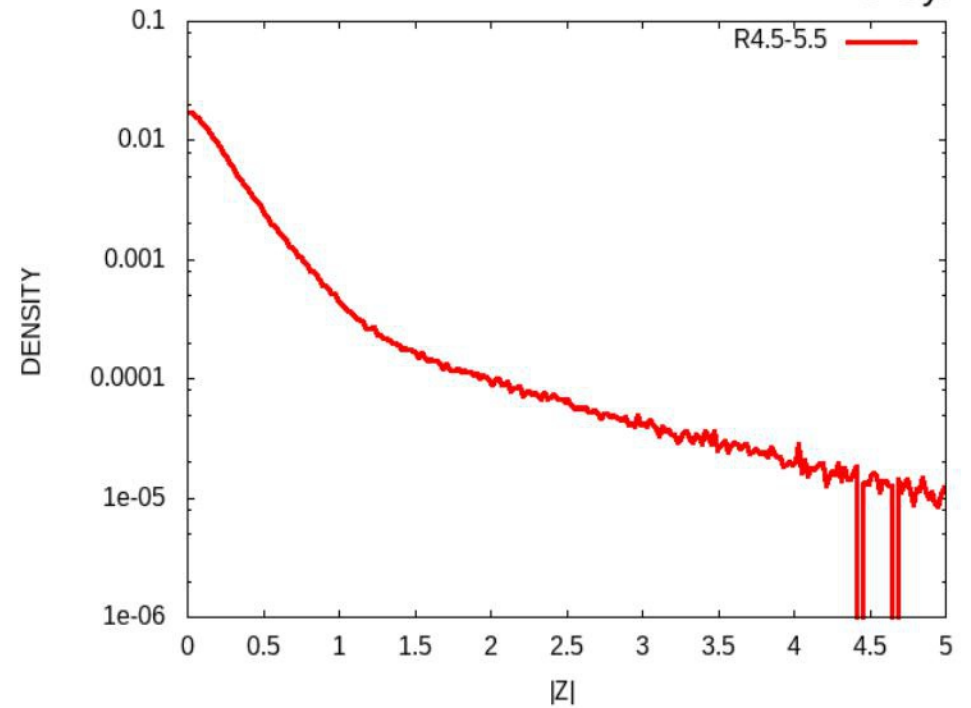


# Thick discs: Vertical density profiles

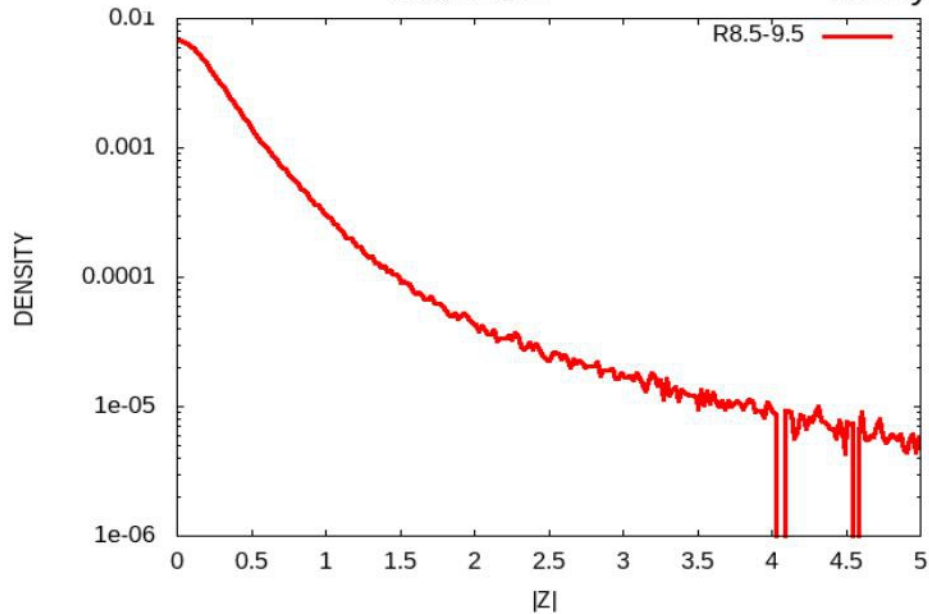
mdf730 10 Gyr



mdf728 8 Gyr

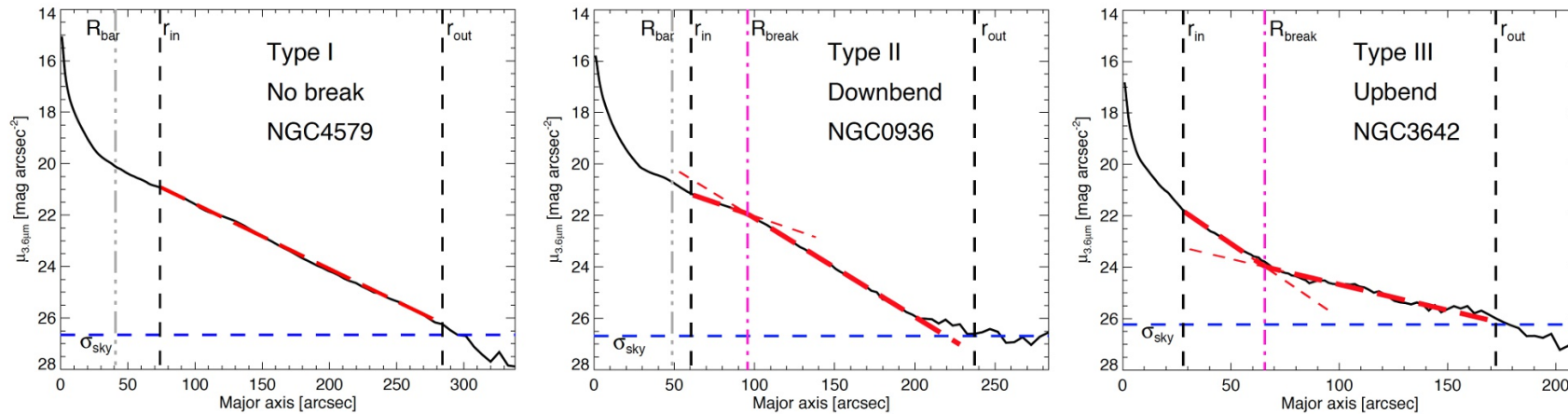


mdf732 10 Gyr



For observations :  
Comeron et al. 2011 a,b,c, 2012

## THREE TYPES OF BREAKS OBSERVED

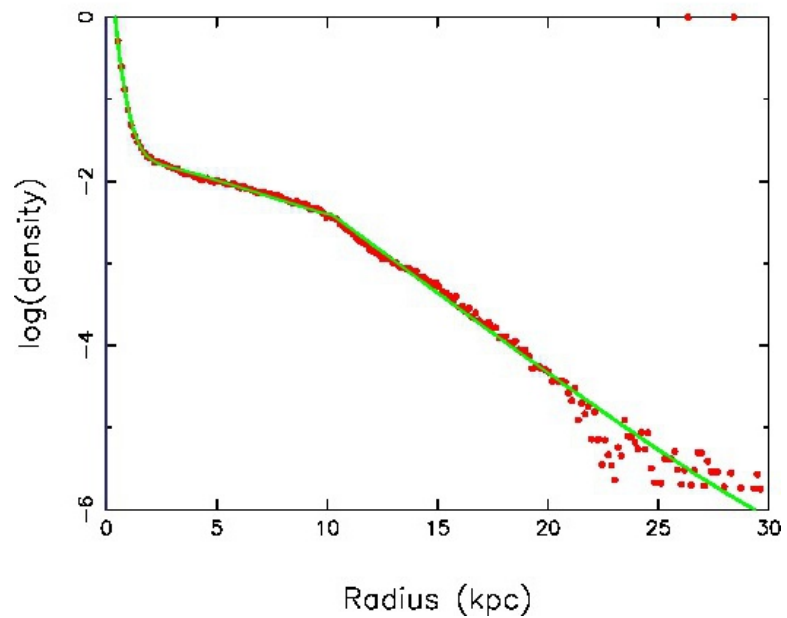


Freeman 70, Pohlen & Trujillo 06; Erwin, Pohlen, Beckman 08, Munoz-Mateos et al. 13, Laine et al. 14 (figure from Laine et al. 14)

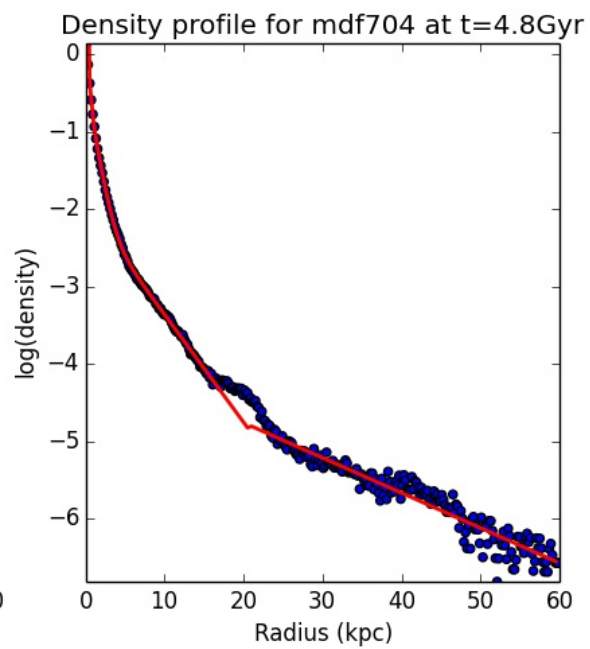
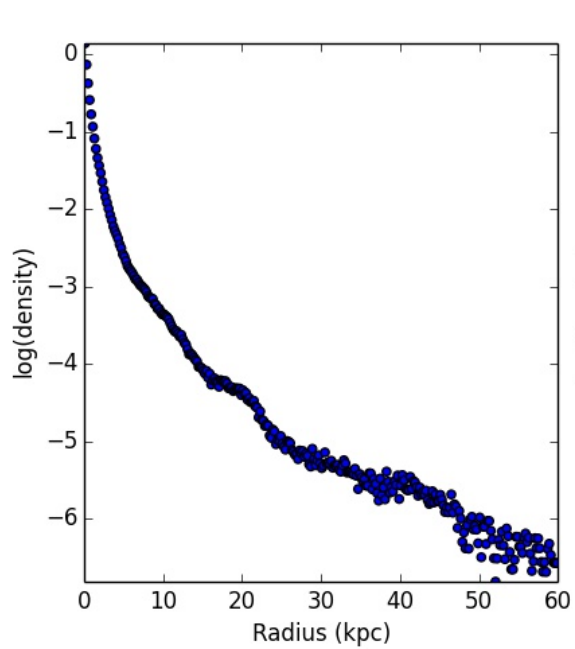
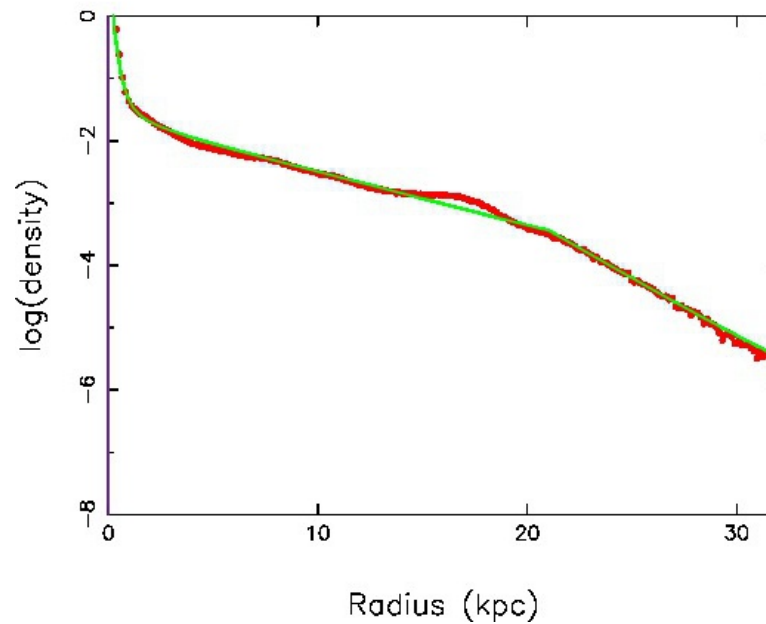
Can reproduce all three types of profiles

Results for the inner and outer disc scale lengths and for the break radii are of the right order of magnitude

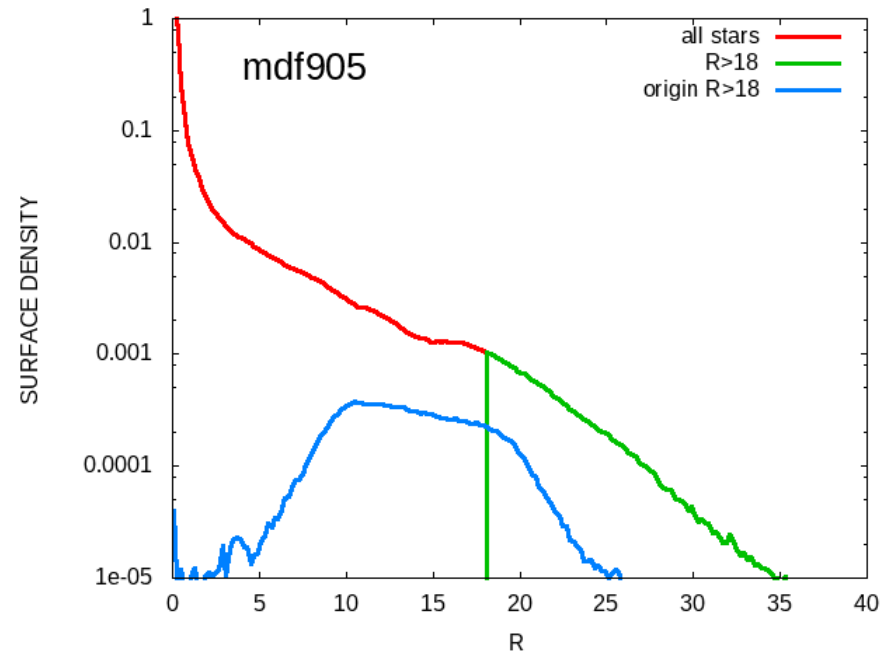
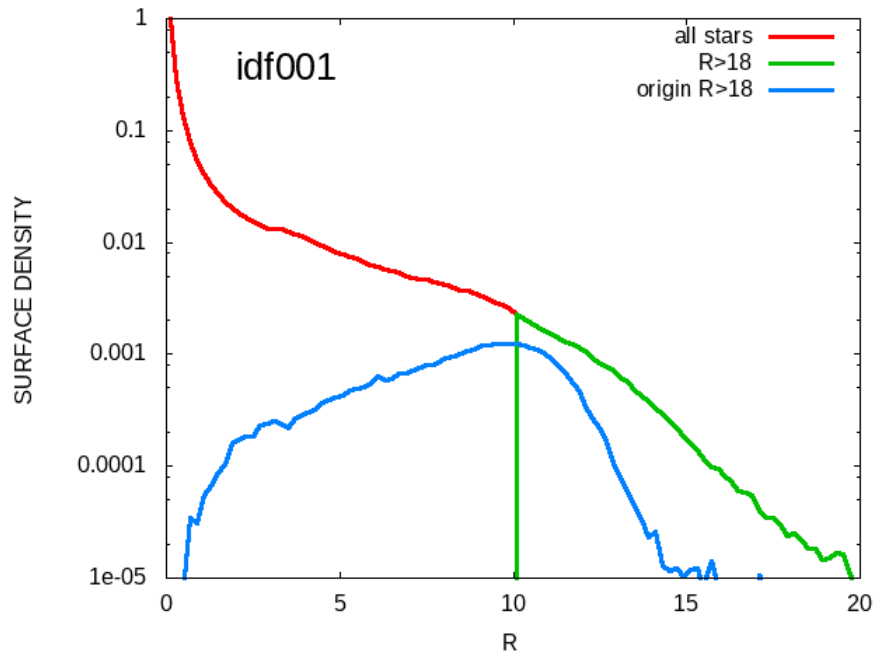
mdf855\_normalstars\_2000\_ring



mdf896\_normalstars\_1760\_ring

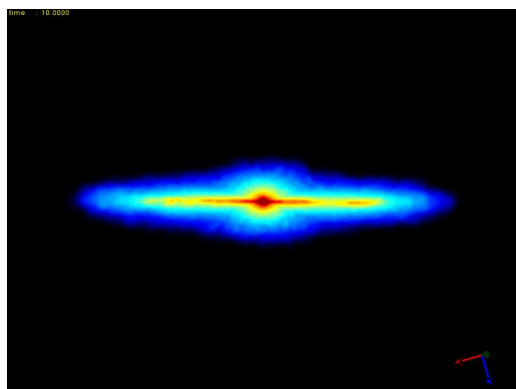
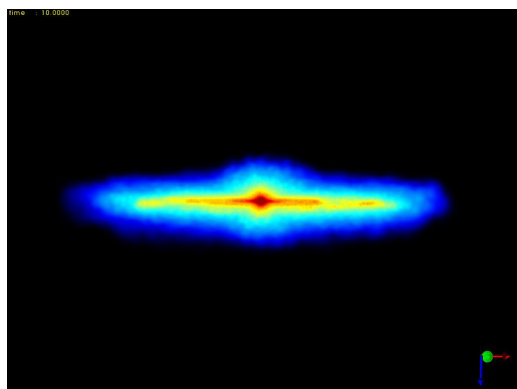
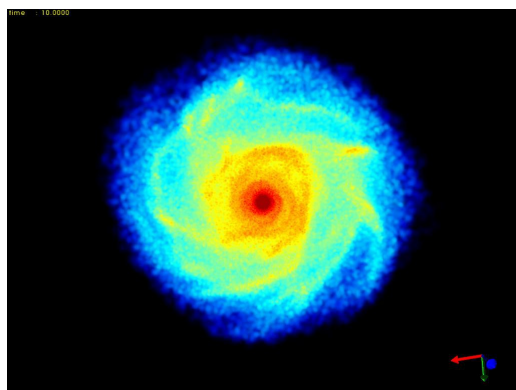
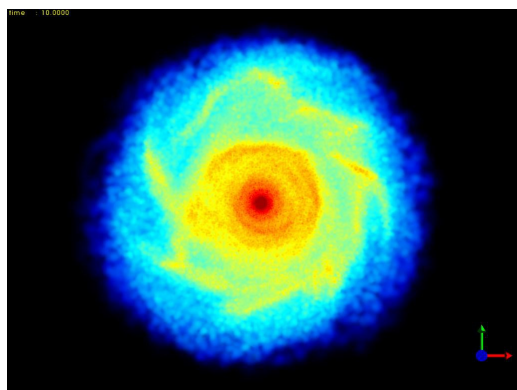


# Migration and formation of breaks

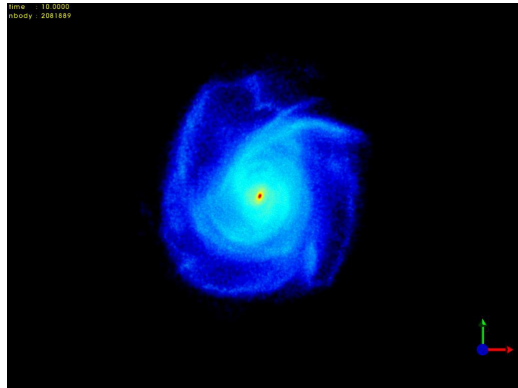


See also Roskar et al. 2008 (with simple collapse)

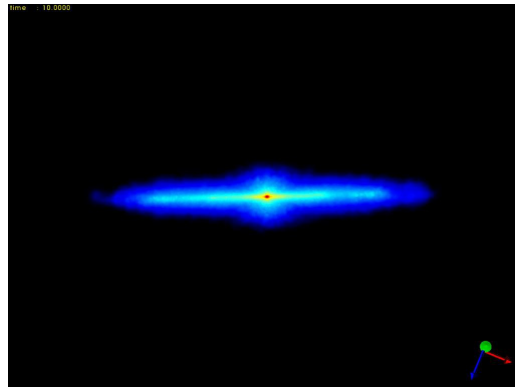
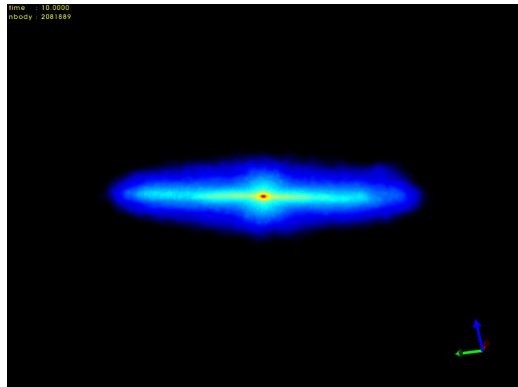
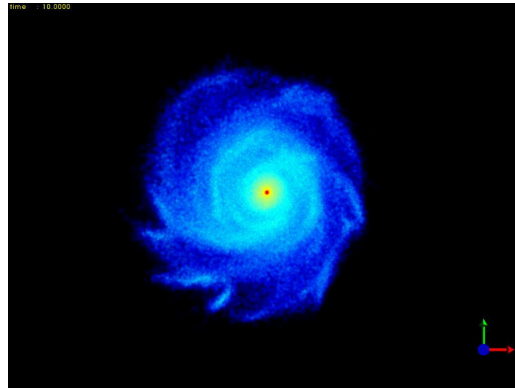
Face-on and edge-on views if discs initially in the orbital plane, or at 60 degrees from it



Both galaxies at 0 degrees



One at 90 degrees





## Conclusions

Major mergers can form spiral galaxies whose properties and parameters are in good agreement with observations.  
Detailed comparisons.

But not all spirals are necessarily formed this way.  
(What fraction? This work can't say)

Anything but ... THE END