The Common Origin of Stars Clusters and UCDs

a numerical perspective

Florent Renaud

University of Surrey

I WOULD LIKE TO SAY

Thank you
to the SOC

Gracias
to the LOC

Danke
to the 2 ~~pet~~ workshop boys

Important Disclaimer

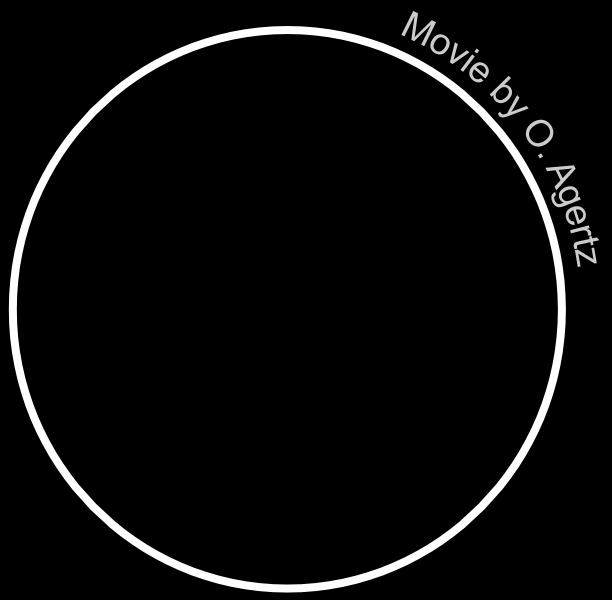
I don't know anything about UCDs

I just happen to find tiny things in my galaxy simulations

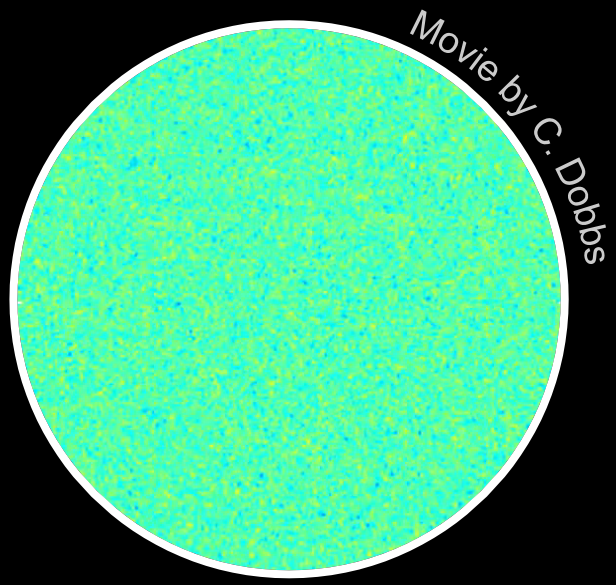
WHY IT IS NOT SO STRAIGHTFORWARD?

- Half-light radius of UCDs ~ 10-100 pc
- Must describe this with several (> 10) elements (cells, particles)
- Required resolution: 1 pc – 10 pc

Cosmological simulations
do not resolve galactic disks
(~ 100 pc)



Galaxy simulations
barely resolve molecular complexes
(~ 20 pc)



That's soooo 2012!

The Antennae

Renaud, Bournaud & Duc (2015)

THE ANTENNAE

gas

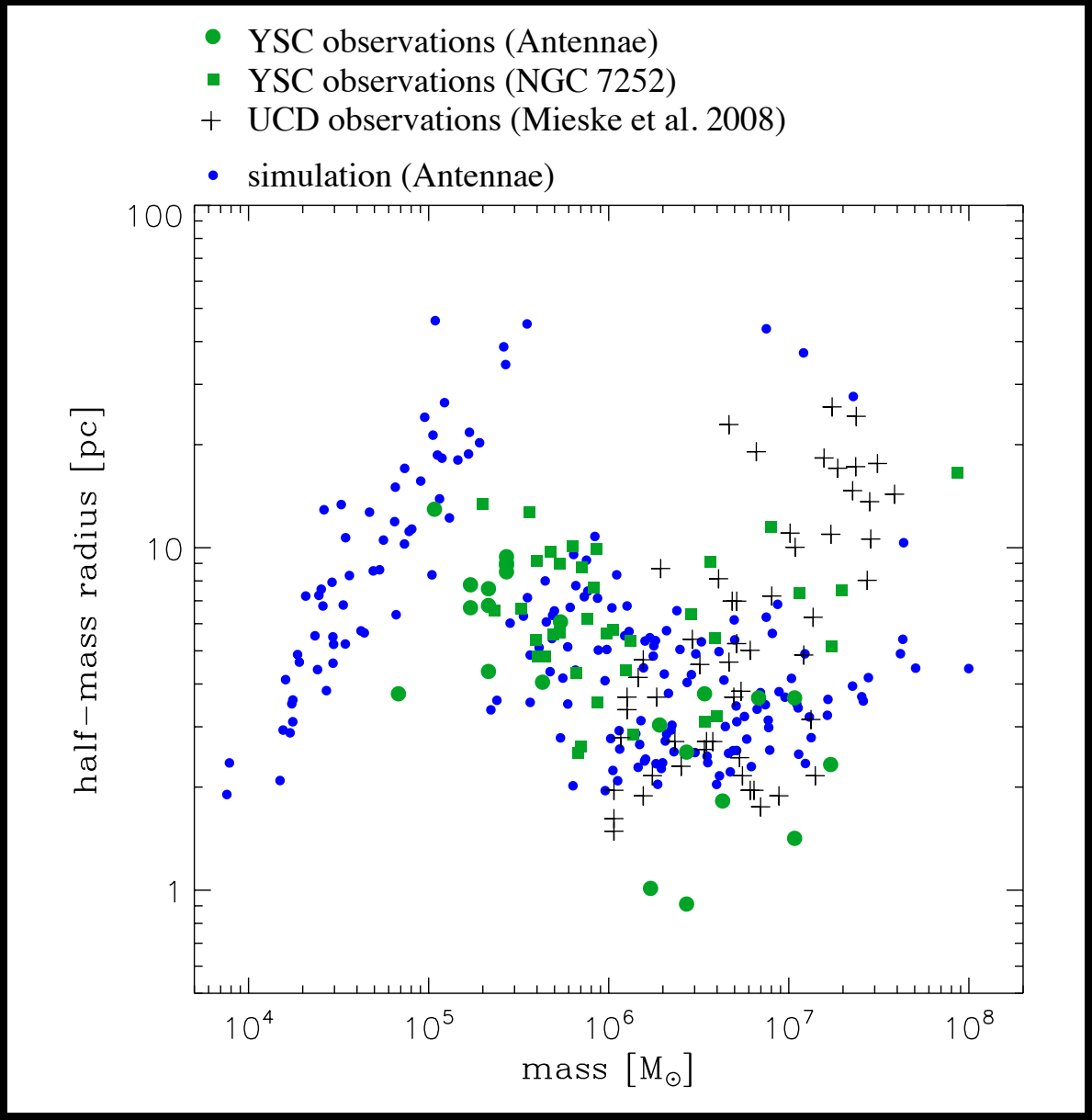
new stars

2 kpc

1 pc resolution = able to resolve r_h of compact systems (UCDs, YSCs)

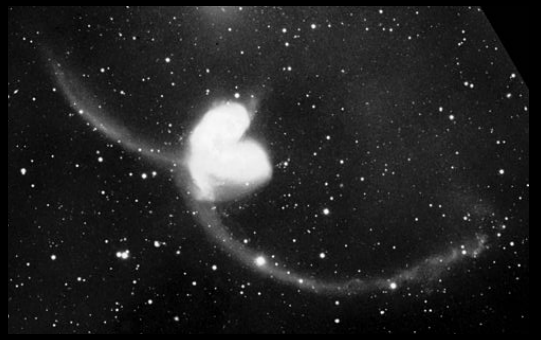
RAMSES code (heating/cooling, star formation, feedback: HII+radiative pressure+SNe)

Young Star Clusters and Ultra Compact Dwarfs



in the Antennae

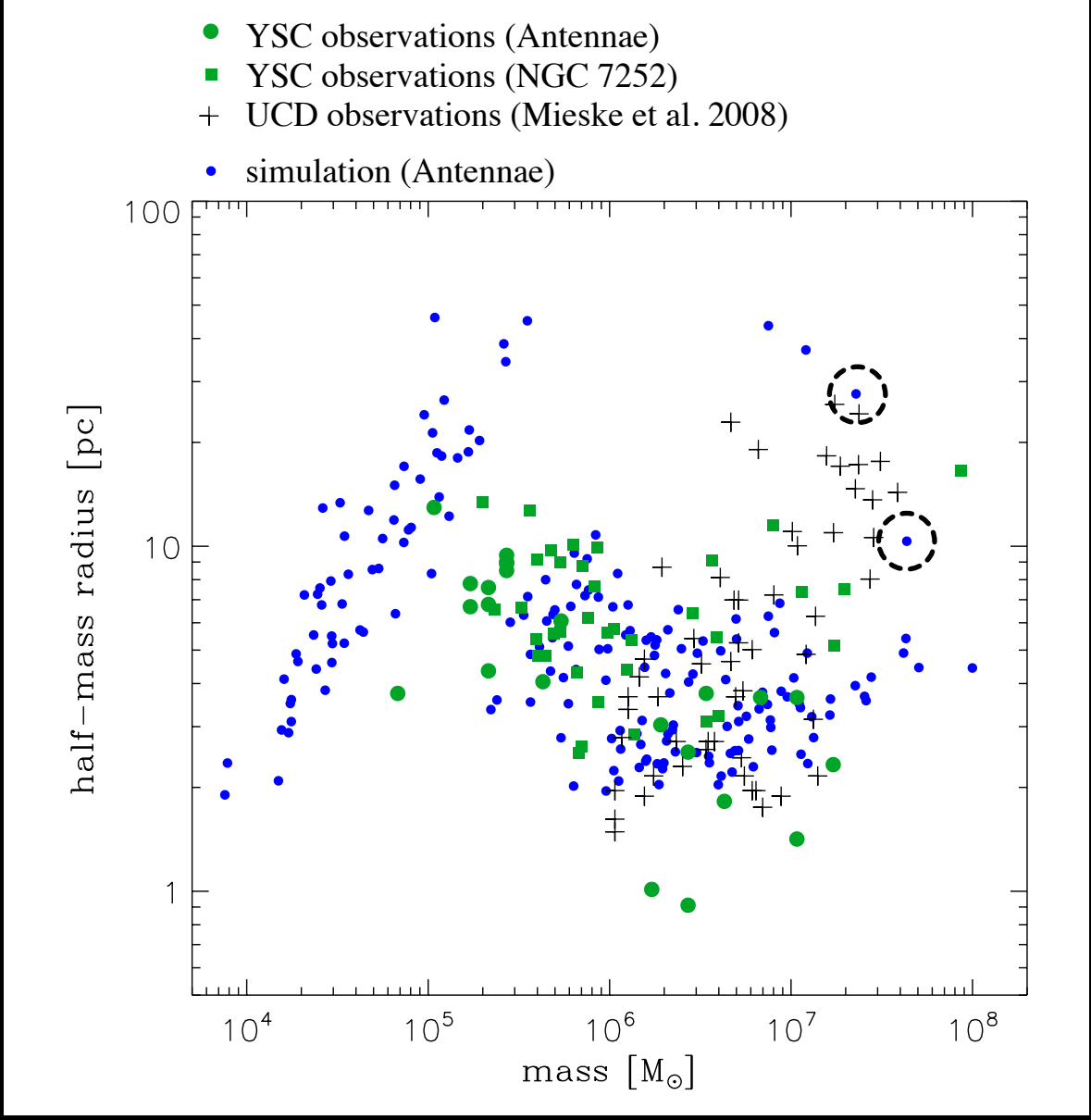
Mengel et al. (2008)
Bastian et al. (2009)



in NGC 7252

Bastian et al. (2013)

UCD-LIKE OBJECTS



- compact (4 pc) all its life
- but fly through the center of the merger and get extended

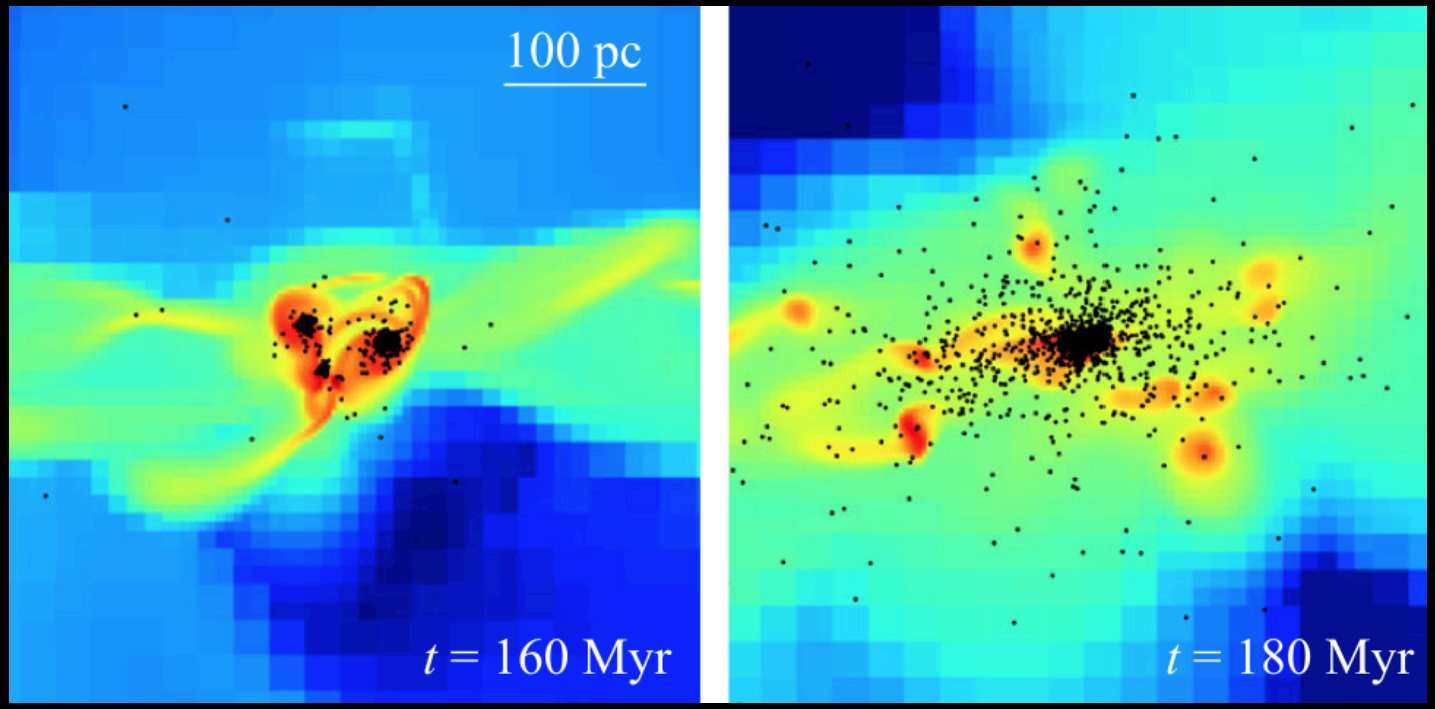
- massive cloud
- forms at 4 kpc
- 1.5 $M_\odot$/yr for 30 Myr

Hierarchical Formation

No need for hierarchical sub-clouds

Fellhauer & Kroupa (2005)
Bonnell et al. (2003)

Altough they exist



Mass to Light Ratio

Massive UCDs have a high M/L Hasegan et al. (2005)

Dark Matter?
unlikely
Goerdt et al. (2008)
Murray et al. (2009)

IMF?

Black Hole?
maybe
Frank et al. (2011)
Mieske et al. (2013)

Top-heavy + stellar evolution
Dabringhausen et al. (2009)

Bottom-heavy
Mieske & Kroupa (2008)

... as in massive E-type galaxies
Van Dokkum & Conroy (2010, 2012)

How to get a bottom-heavy IMF?

➔ Strong + Compressive turbulence
Chabrier et al. (2014)

A Quick Reminder about Turbulence

Local velocity field =

net motion
(*average*)

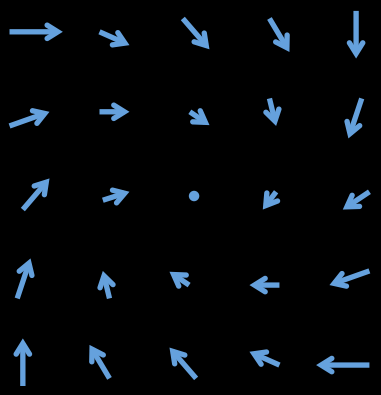
$\langle v \rangle$

Move it!

+

solenoidal
turbulence
(*curl*)

$\nabla \times v$

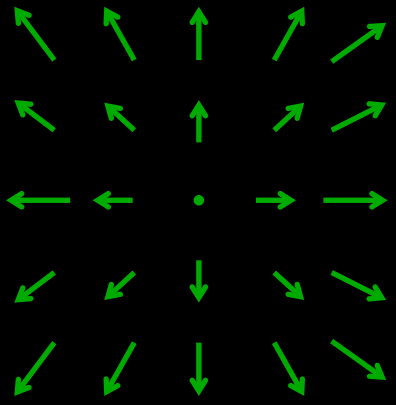


Mix it!

+

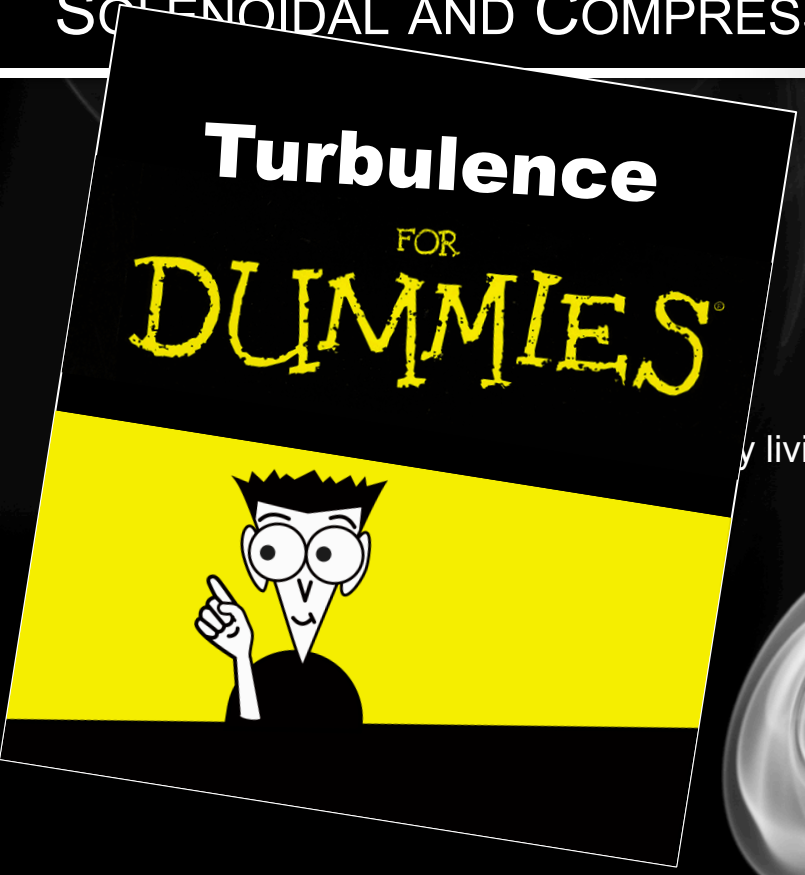
compressive
turbulence
(*divergence*)

$\nabla \cdot v$



Pinch it!

Solenoidal and Compressive Turbulence



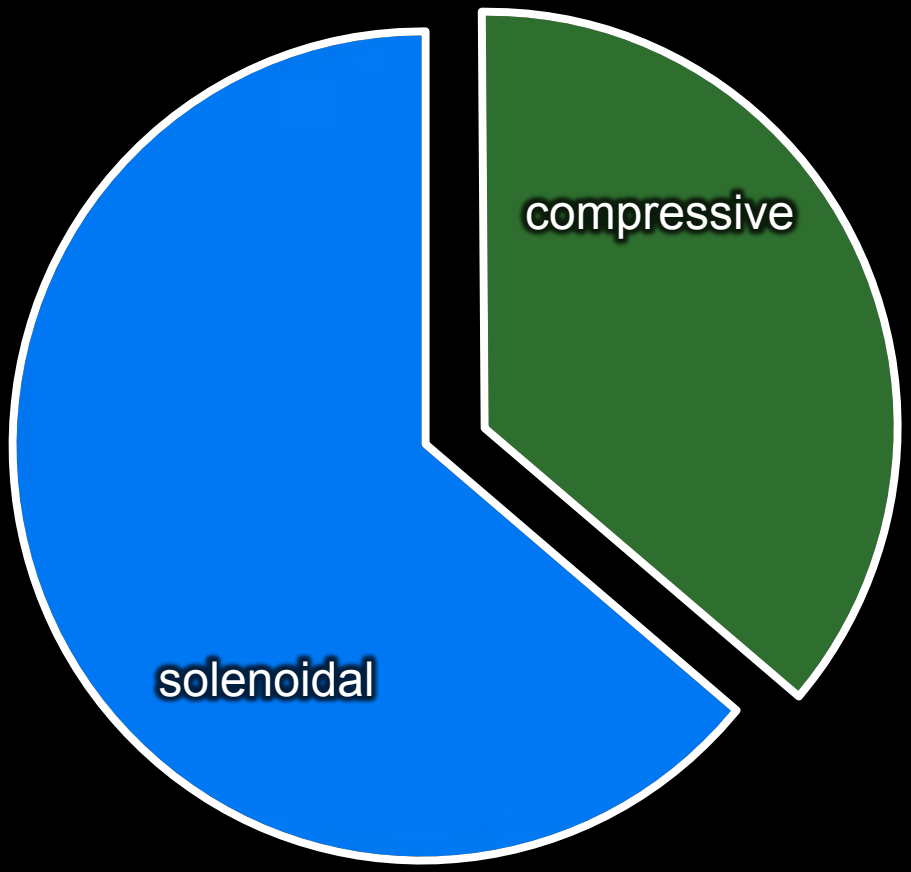
y living room

compressive
turbulence

*"If you understand turbulence,
you are doing something wrong."*

solenoidal
turbulence

Solenoidal and Compressive Turbulence

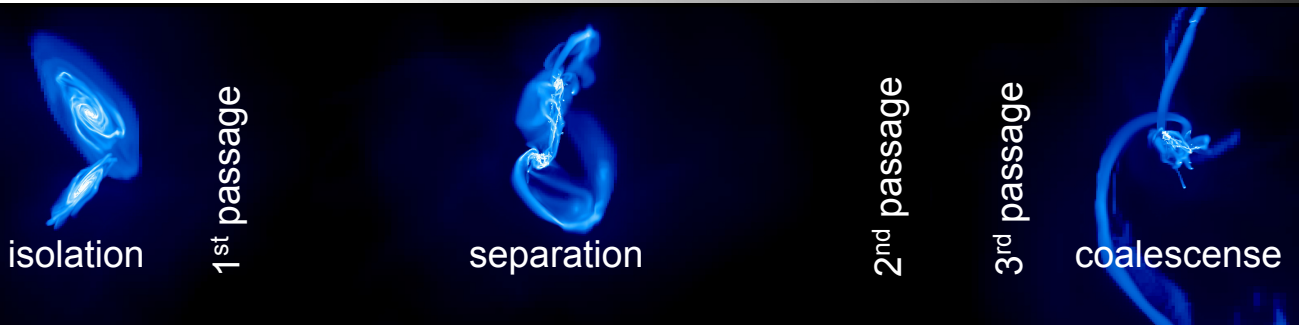


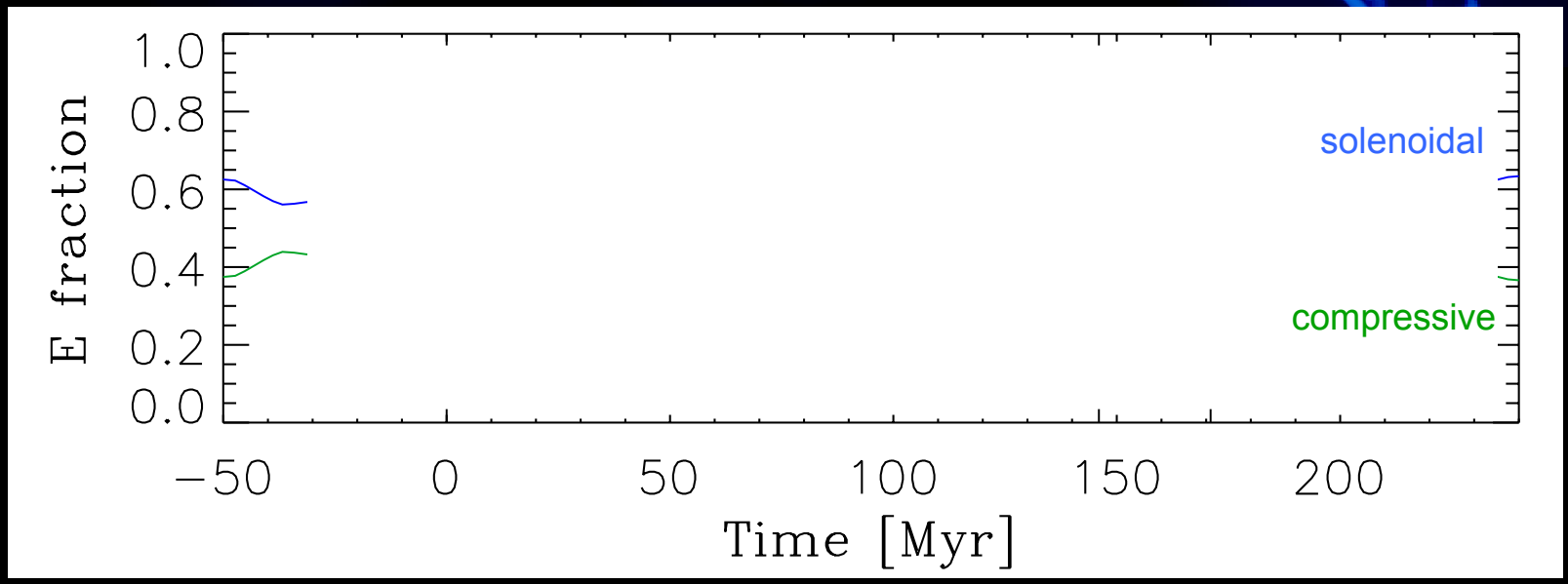
"Natural" turbulence energy budget
(no external forcing)

Federrath et al. (2010)

In a Merger

Renaud et al. (2014)

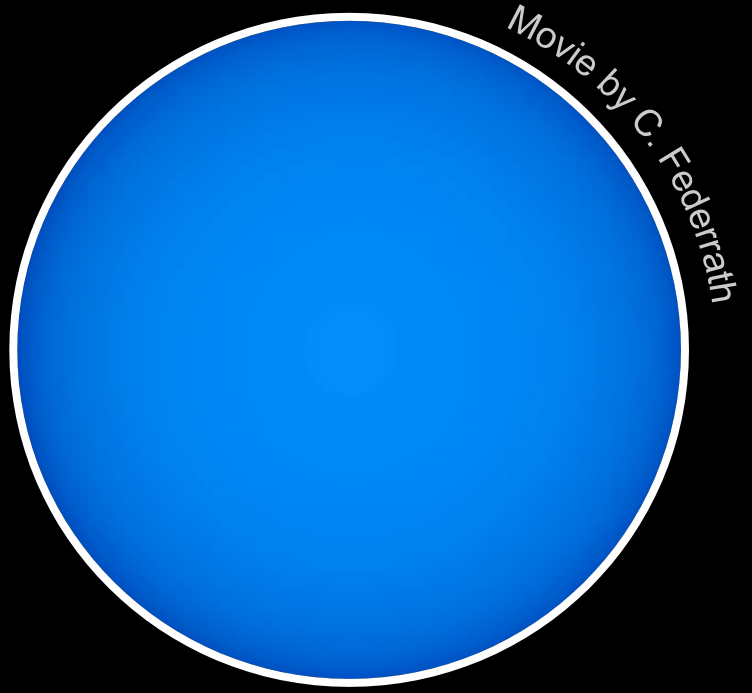




- Change the nature of turbulence
- Change how the ISM fragments
- Explain the extended starbursts

At small scale

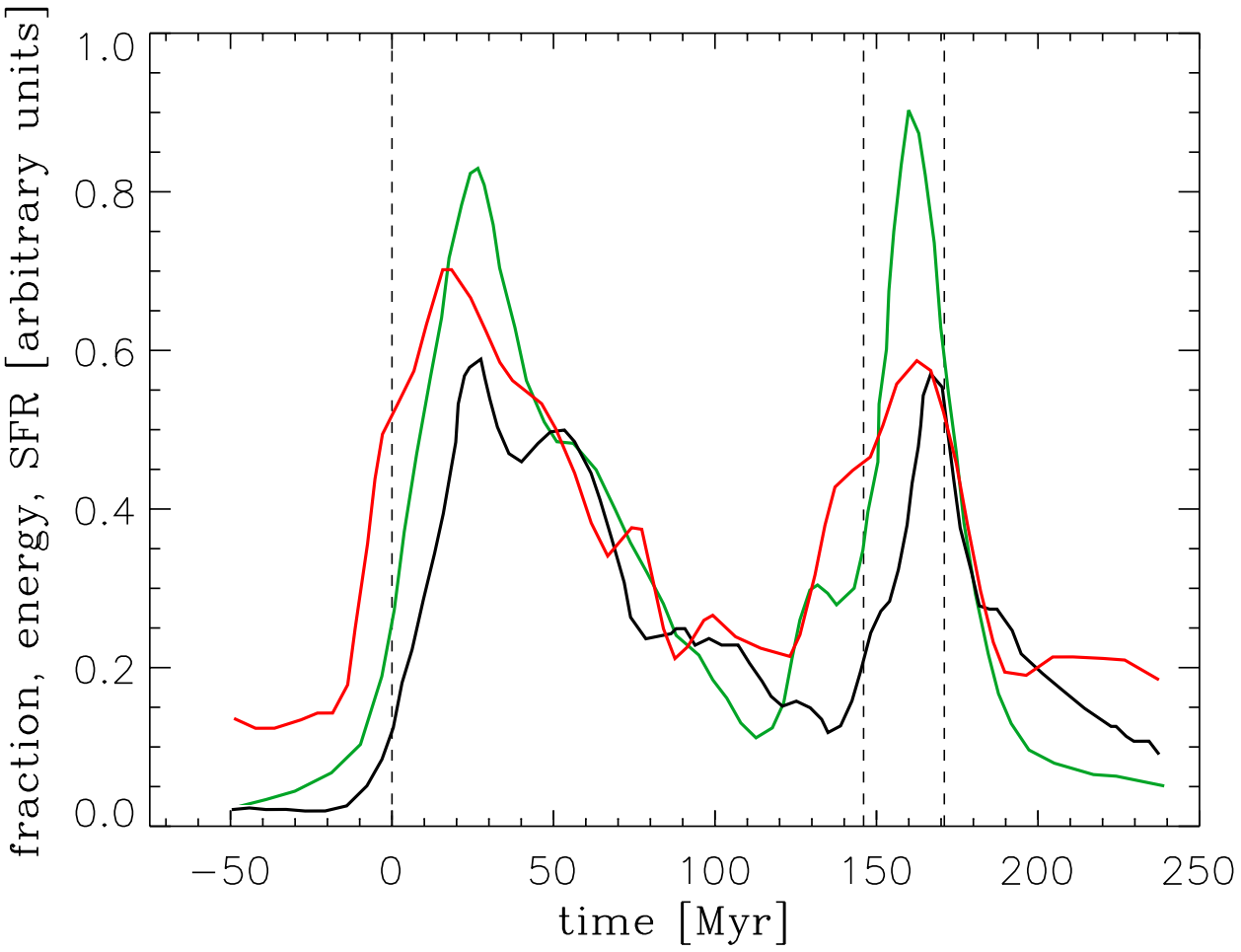
Renaud et al. (2014)



- Possibly change the nature of turbulence
- Possibly change how the ISM fragments
- **Possibly** change the IMF (to bottom-heavy)

TIME EVOLUTION

Renaud et al. (2014)



tides → turbulence → SF

20 – 30 Myr

compressive tides (gas mass fraction)

compressive turbulence (energy)

SFR

SUMMARY

Galaxy major mergers can form massive YSCs and UCDs

No need for hierachical formation

IMF *possibly* altered in mergers

which could explain the M/L of UCDs

What about the evolution?

I still don't know anything about UCDs