Galactic flows and the formation of stellar clusters

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Disclaimer

I am not Ian Bonnell!

For any difficult questions about this talk see iab1@st-and.ac.uk

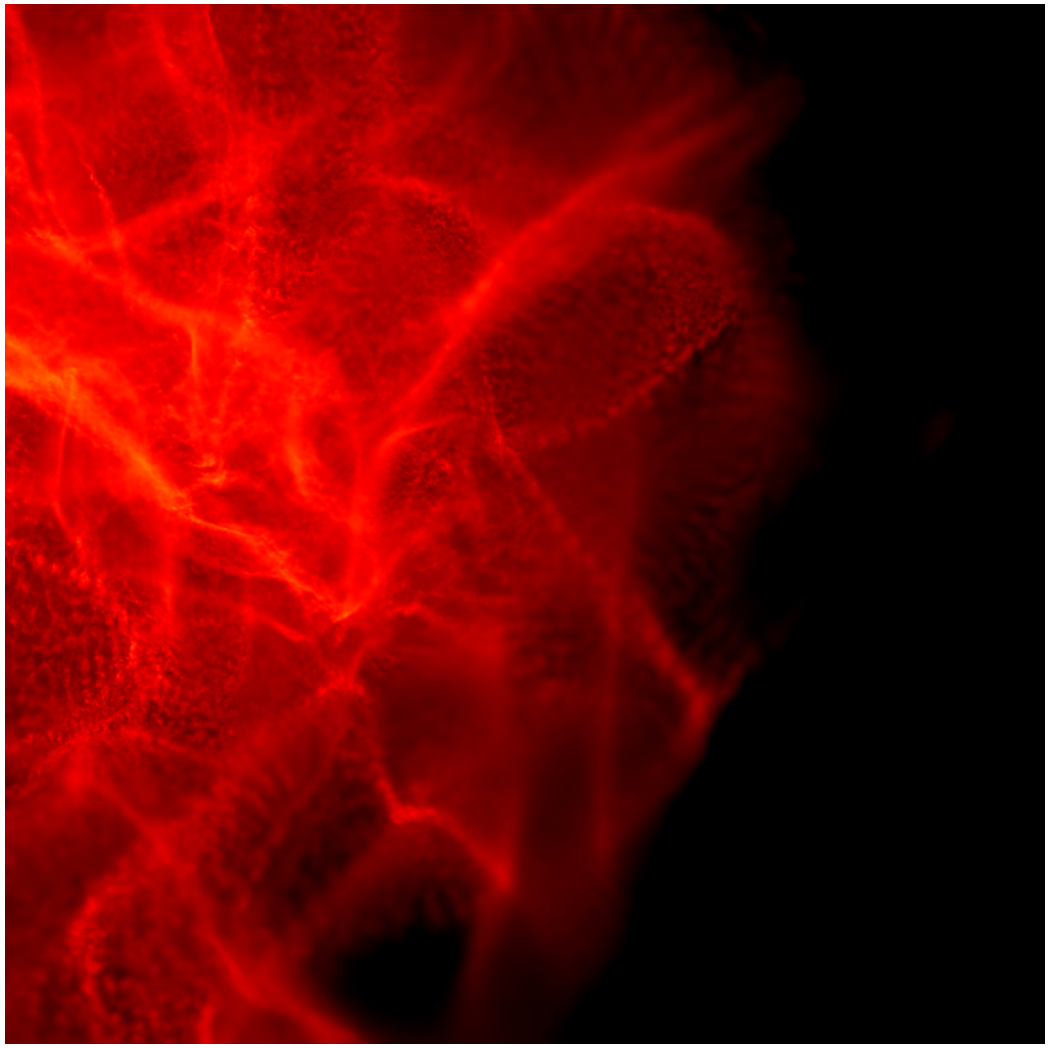
Formation of stellar clusters

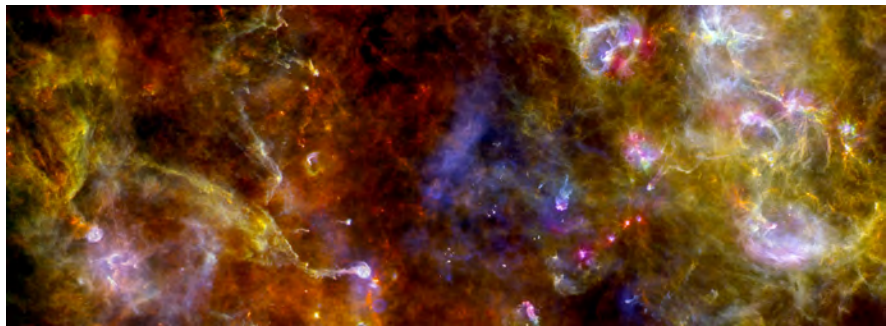
Fragmentation in filaments ~ Jeans length

clusters grow at intersection of filaments

Filaments feed gas and stars into cluster

Clusters grow through Hierarchical mergers

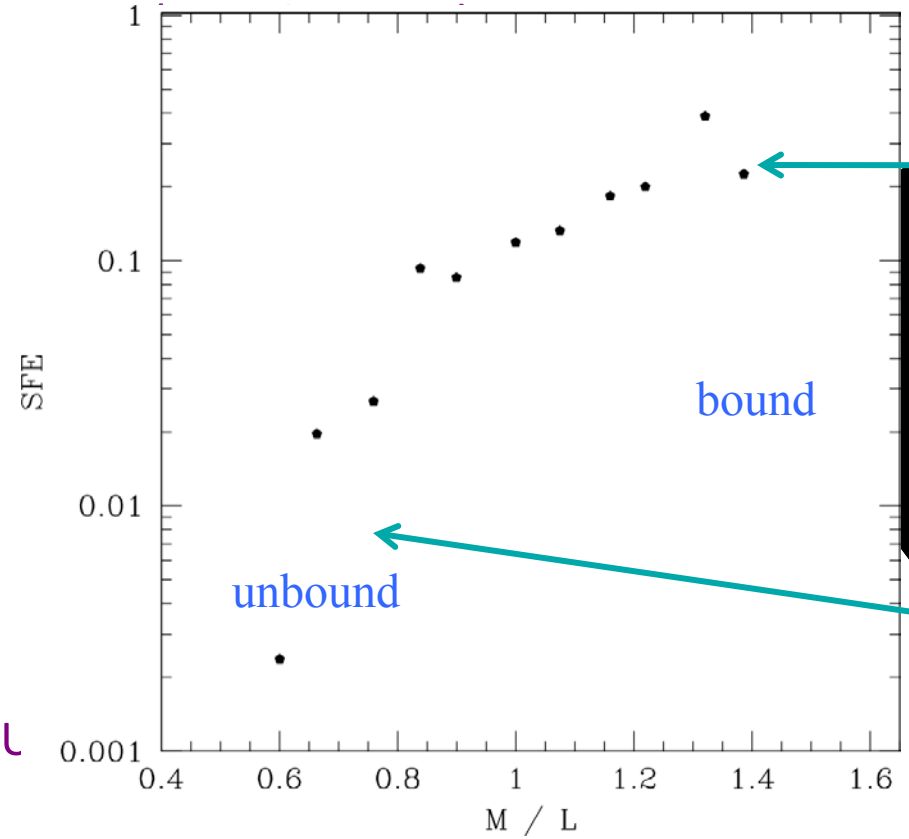




Bonnell et al 2011

SF efficiencies and clustering

- Bound conditions produce stellar clusters and full IMF



- L
  - See Clark et al 2008

bound
clustered
SFE ~10-30 %

distributed
SFE

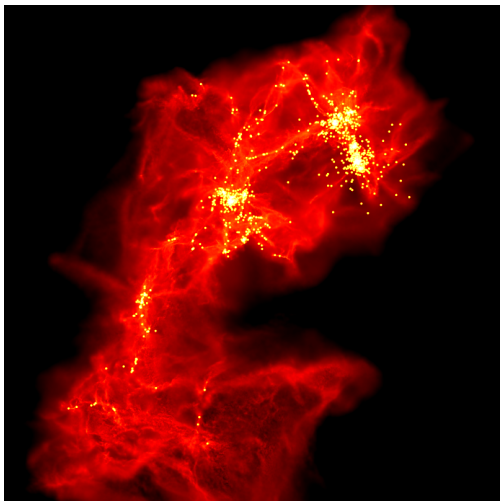
Bonnell et al. 2011

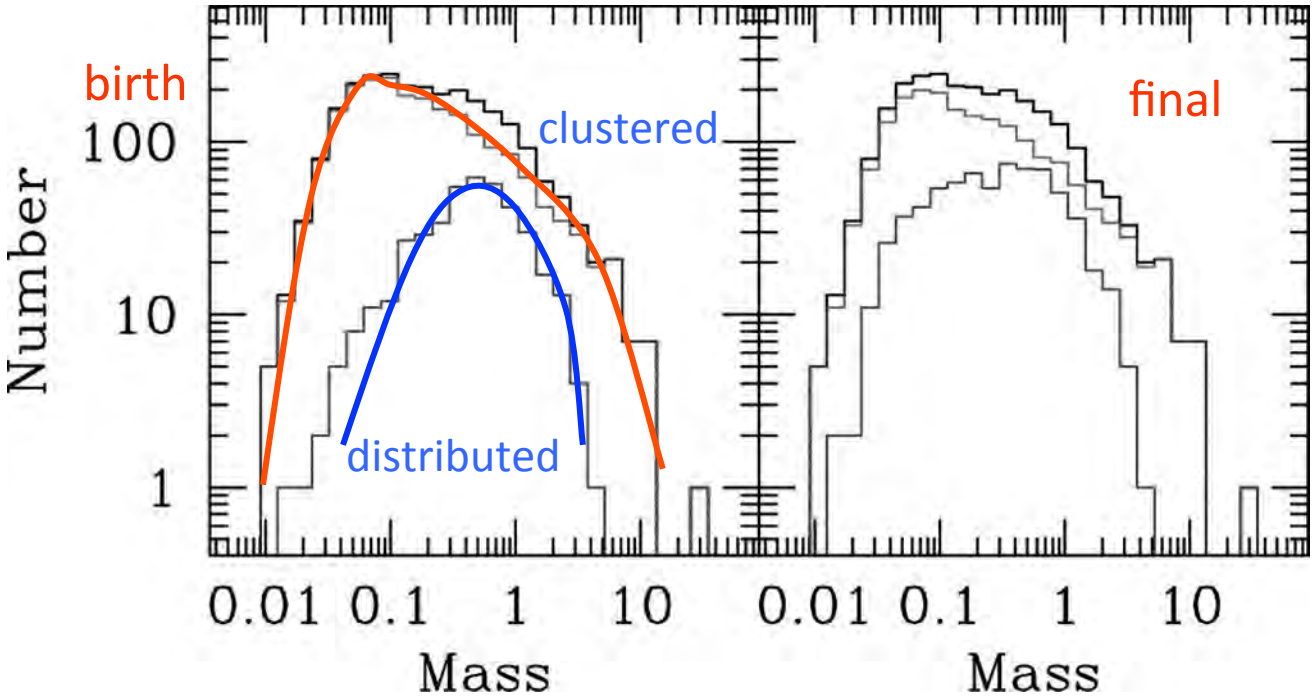
IMF depends on birth environment

- Stellar clusters
  - Full IMF
  - Form from Bound conditions SFE 20-40 %

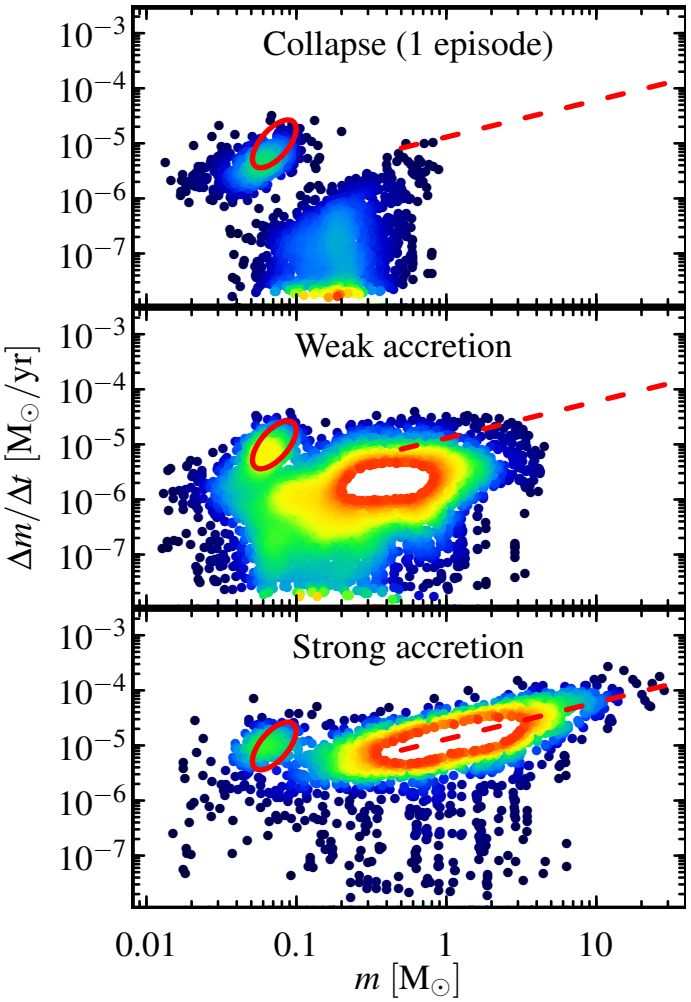
Clark et al 2007; Bonnell et al 2011

- **Distributed SF**
  - **No high-mass, few low mass stars**
    - **Flat/Peaked IMF**
  - **Unbound regions**
    - **Low SF efficiencies**



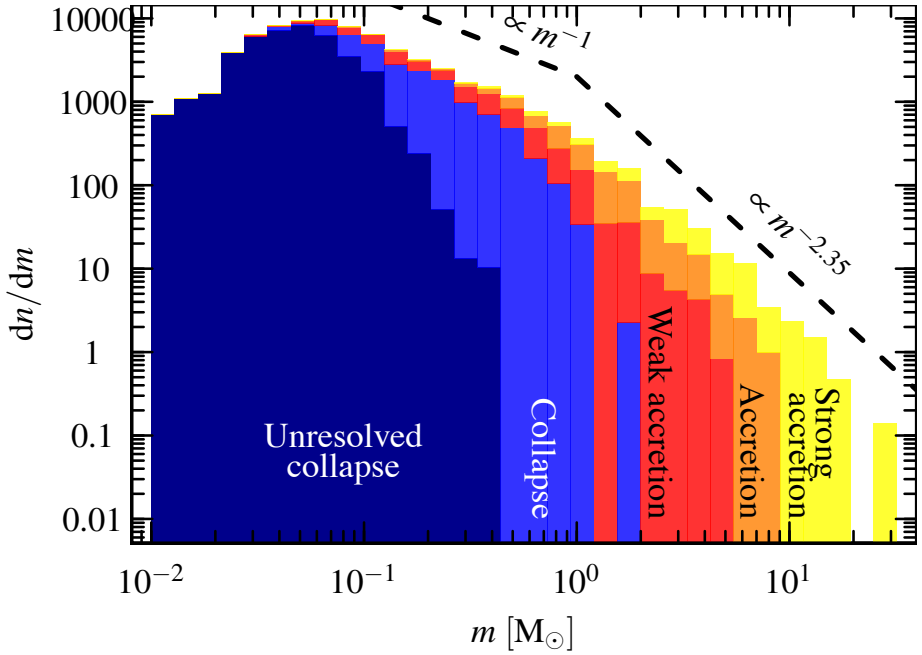


Accretion in Clusters



- Higher mass stars formed through accretion
  - Tidal radius accretion

$$\dot{M} \propto M^{2/3}$$

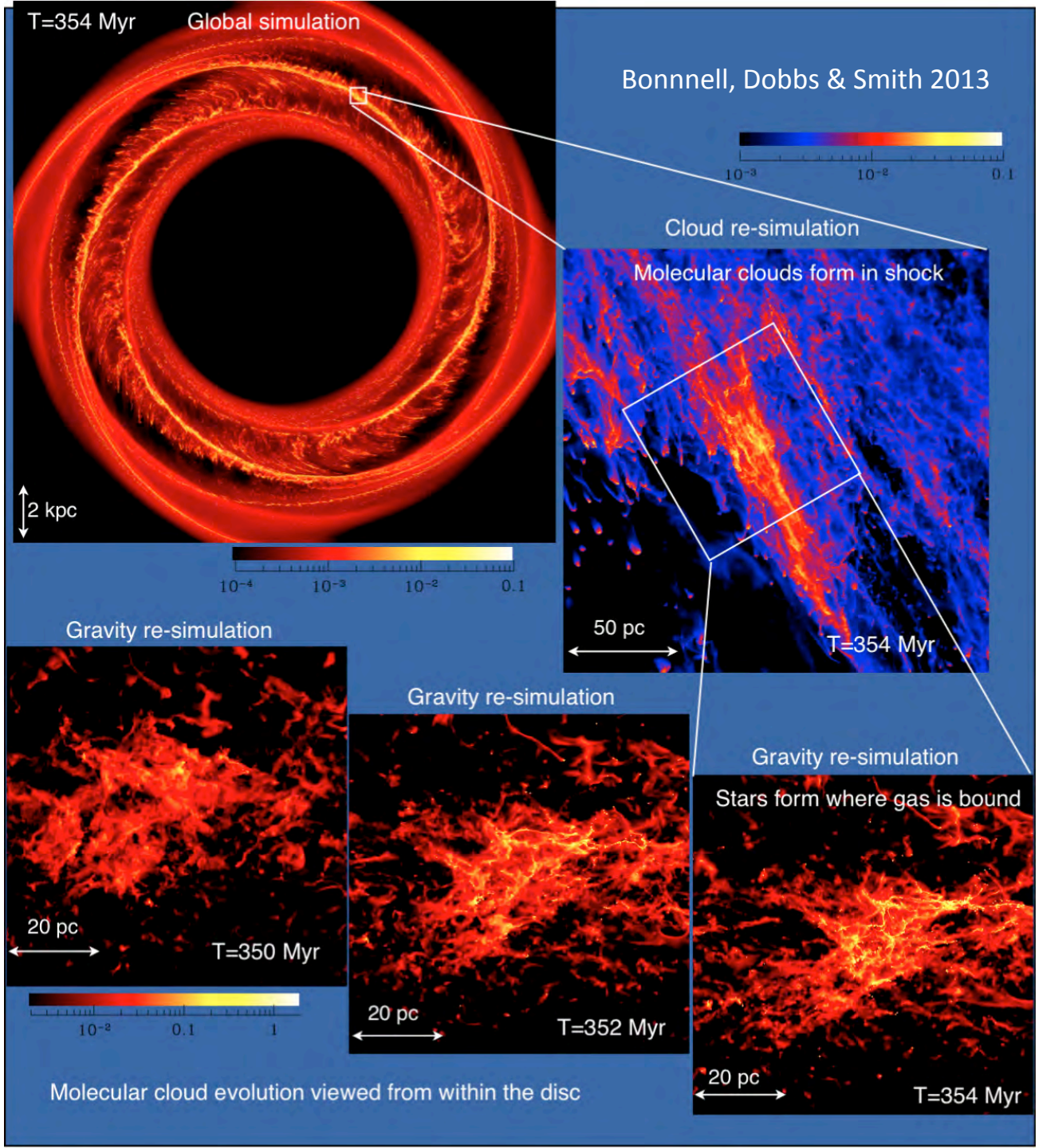


Maschberger et al 2014

Realistic initial conditions for star formation

Global disc simulation
25 million SPH particles
2 x 10^9 M_{sun} gas

(Koyama & Inutsuka 2002)



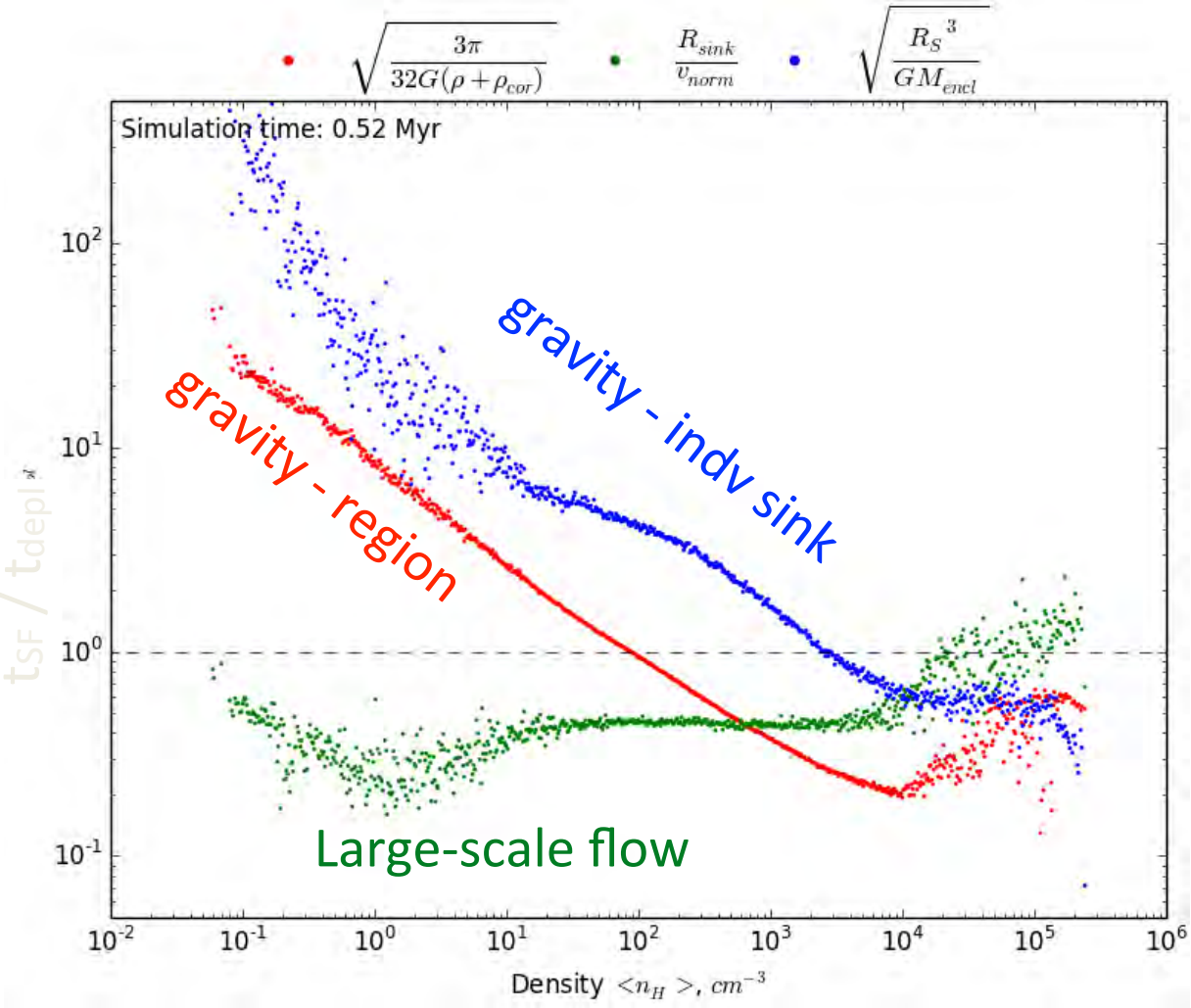
What drives star formation ?

Compare theoretical timescales with simulated SF times

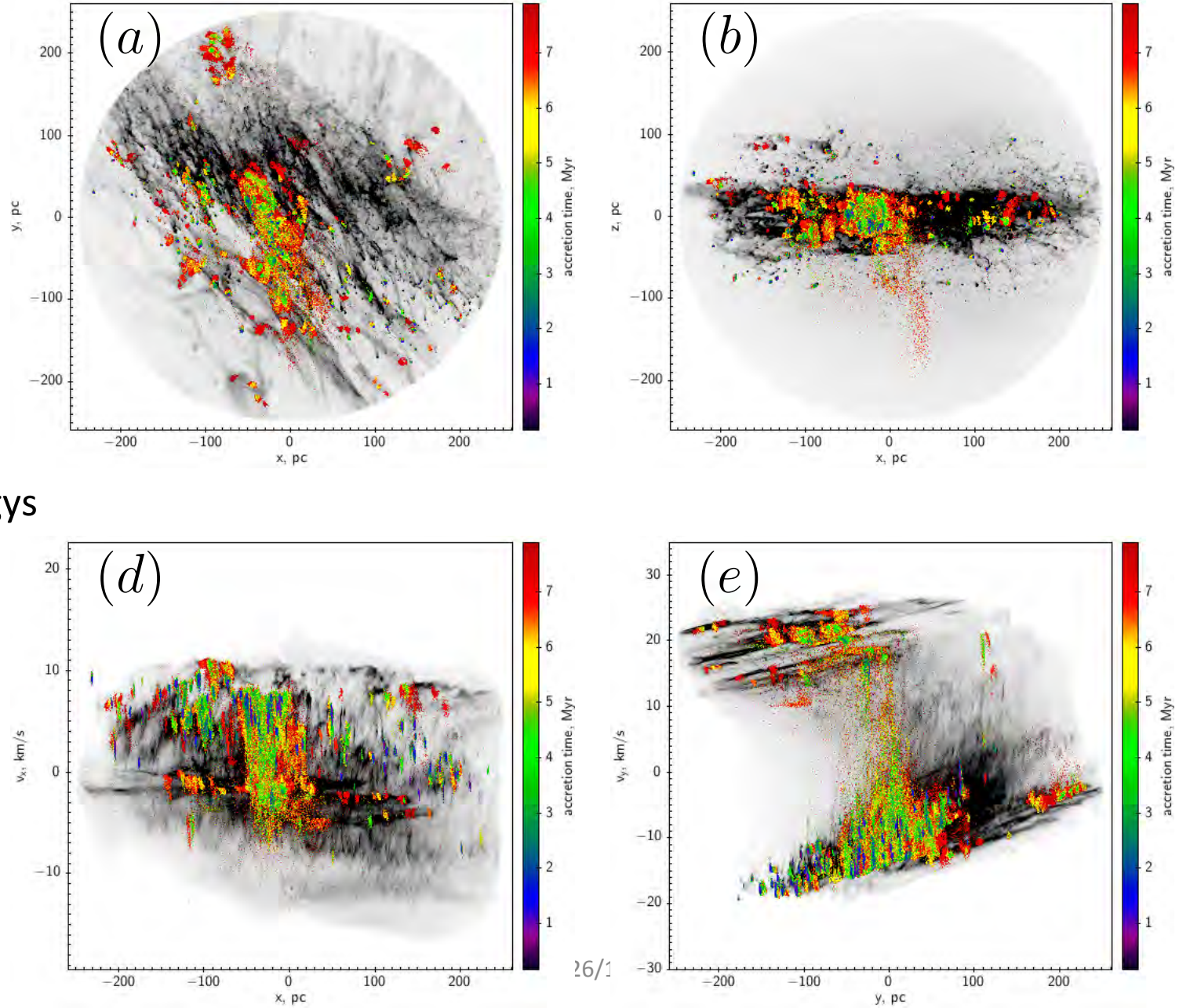
1) Galactic flows dominate on large scales (~10+ pc)

2) Self-gravity of forming cluster dominates on smaller scales,

3) For Densities > 10^3 cm^{-3}



Triggering Star Formation



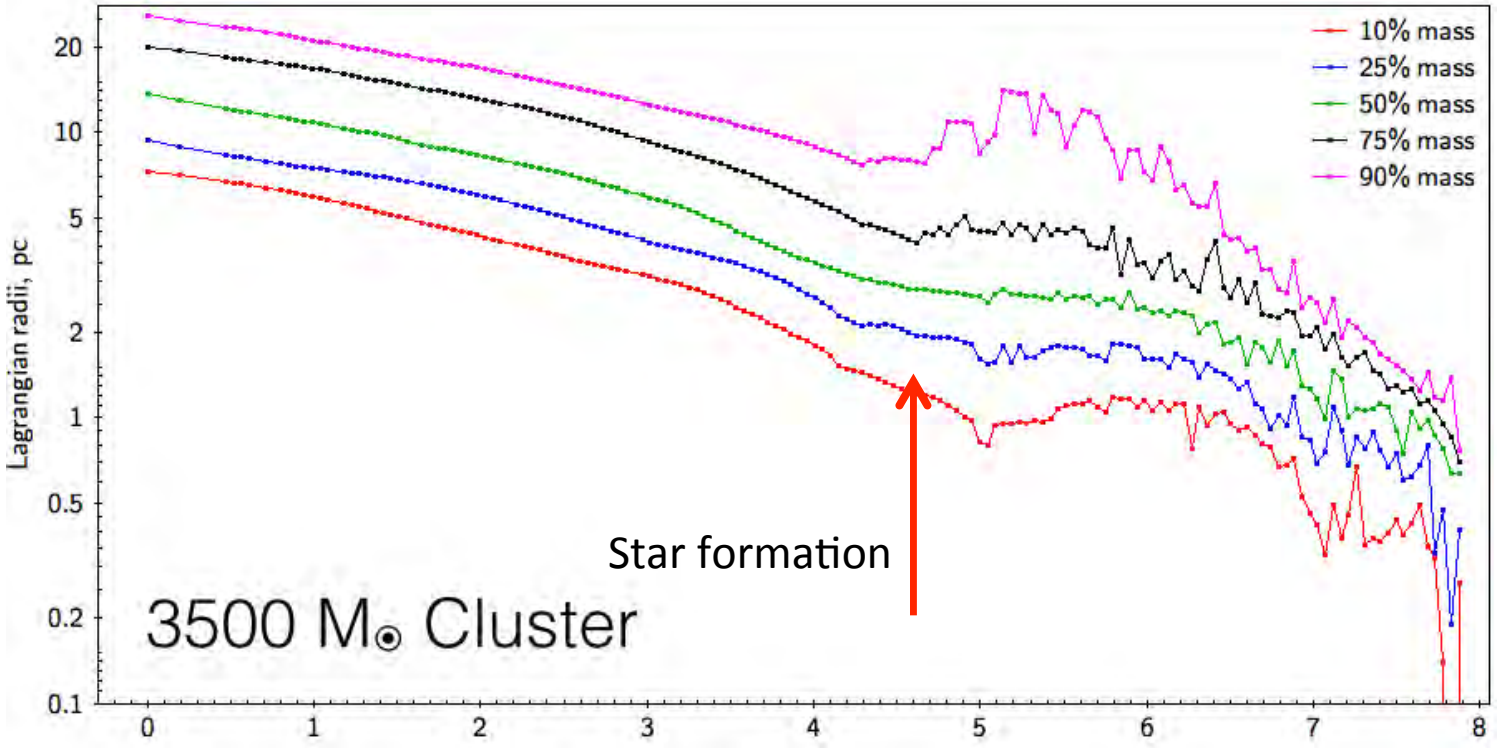
R. Smilgys

velocities

Colours : Depletion times

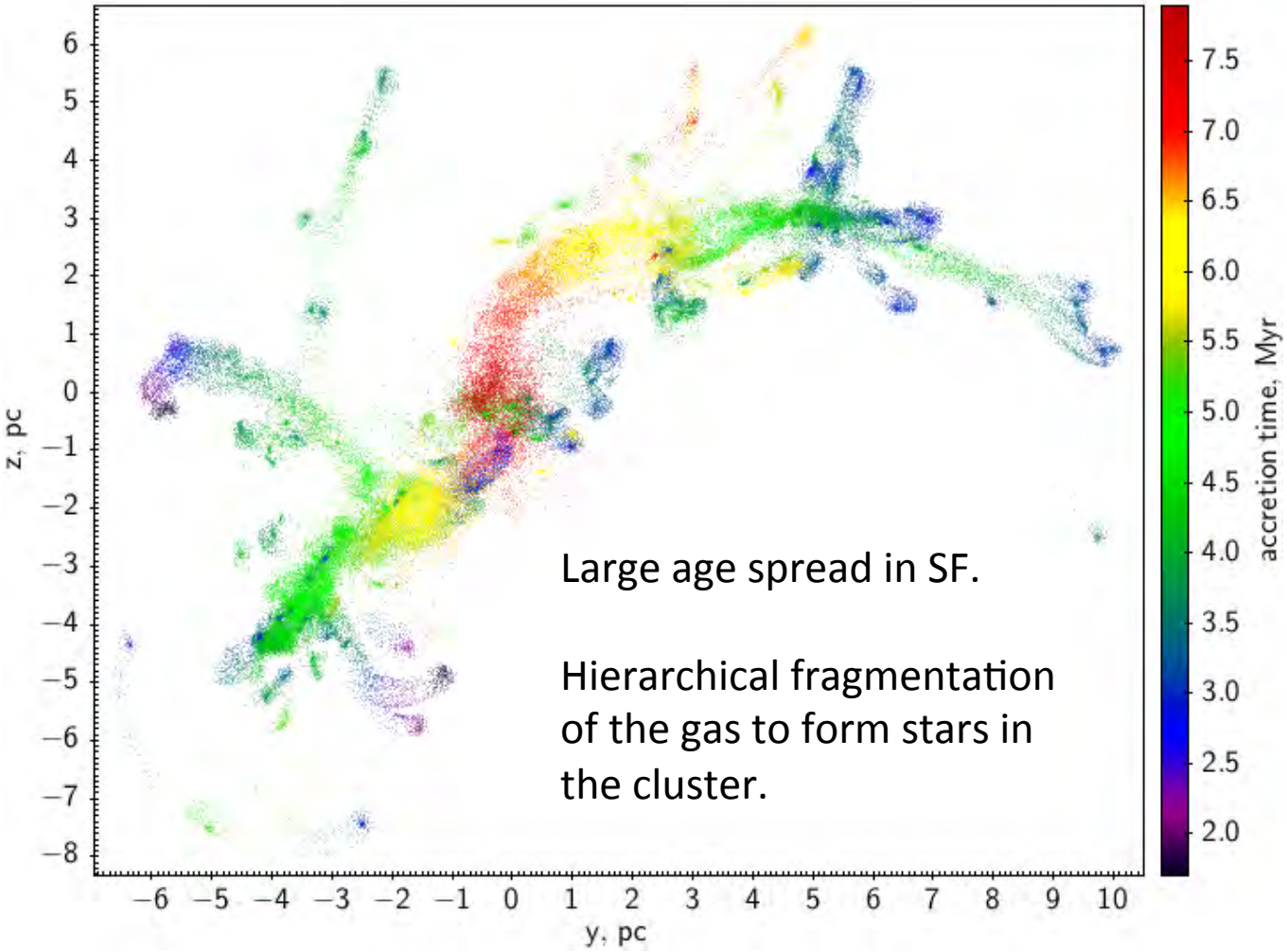
Formation of Stellar Clusters

Stellar clusters gather gas from large distances
~few 10s of pc
Cluster formation and star formation are simultaneous.



Time in Myr

Formation history of a 19000 M_o cluster



Can ionisation disrupt clouds?

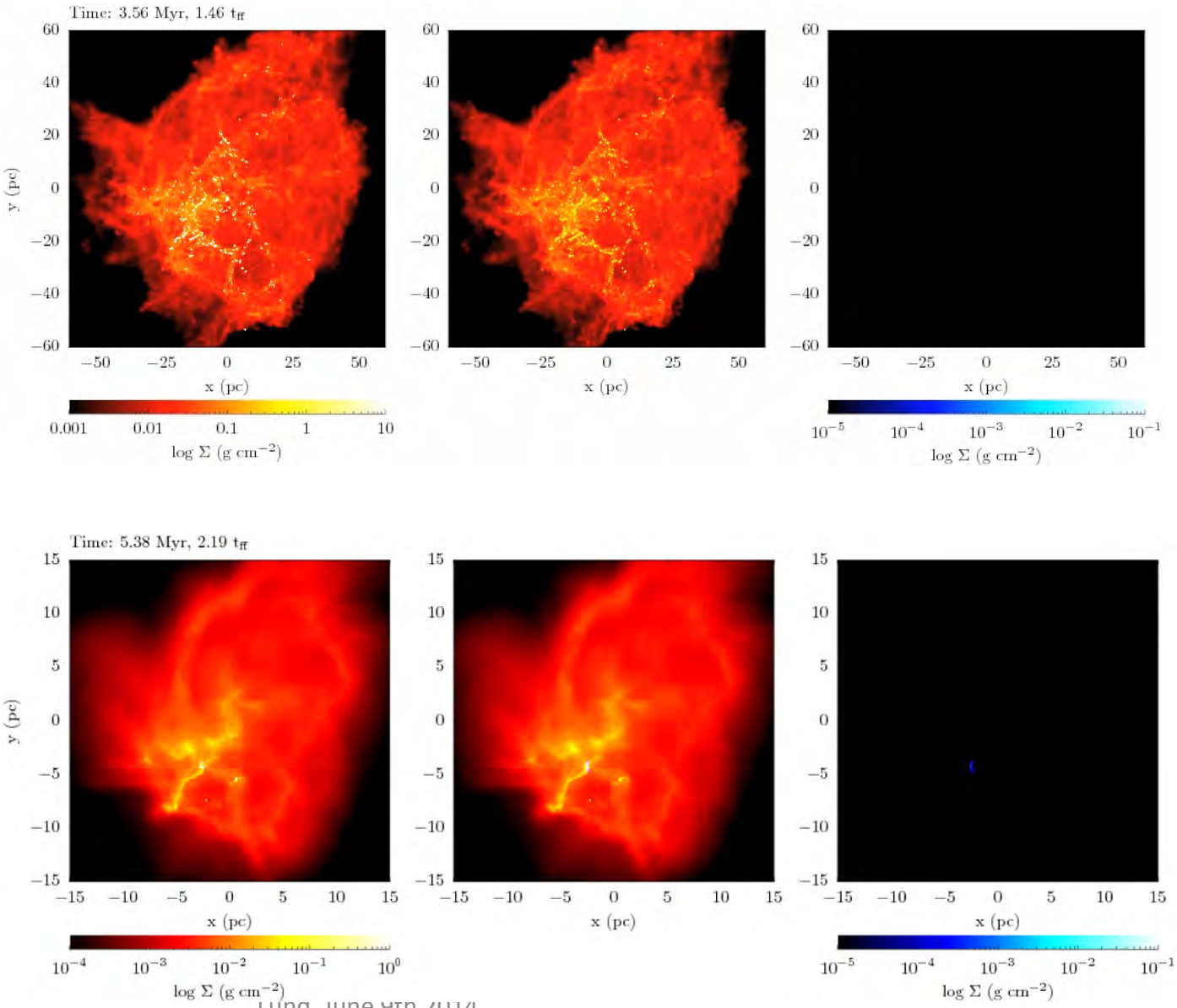
High-mass, large v_{esc}

High density gas unaffected

Ionisation fills pre-existing bubbles

Lower-mass, low v_{esc} clouds

Ionisation dynamically important



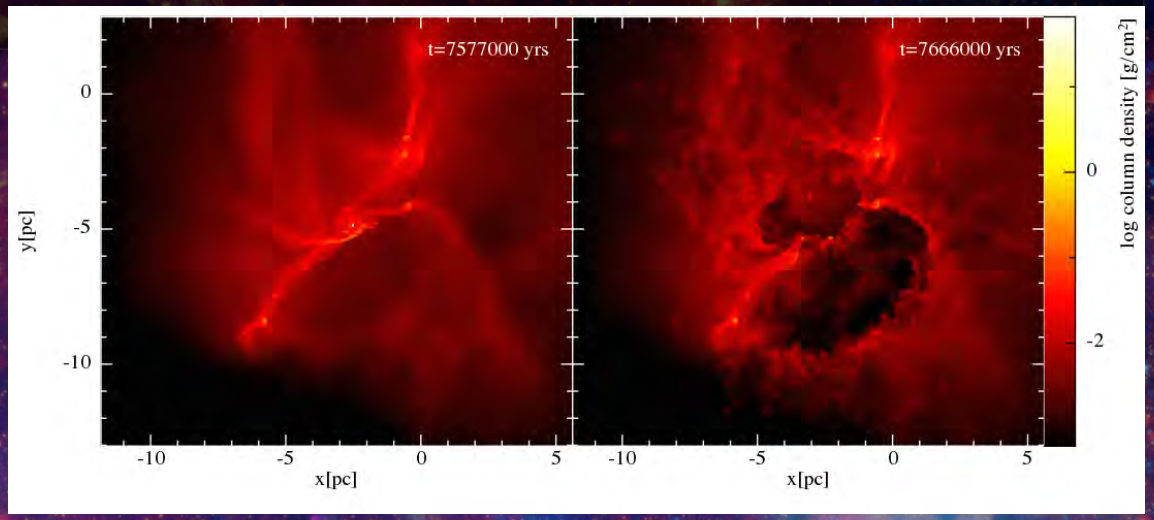
Dale, Ercolano & Bonnell 2012

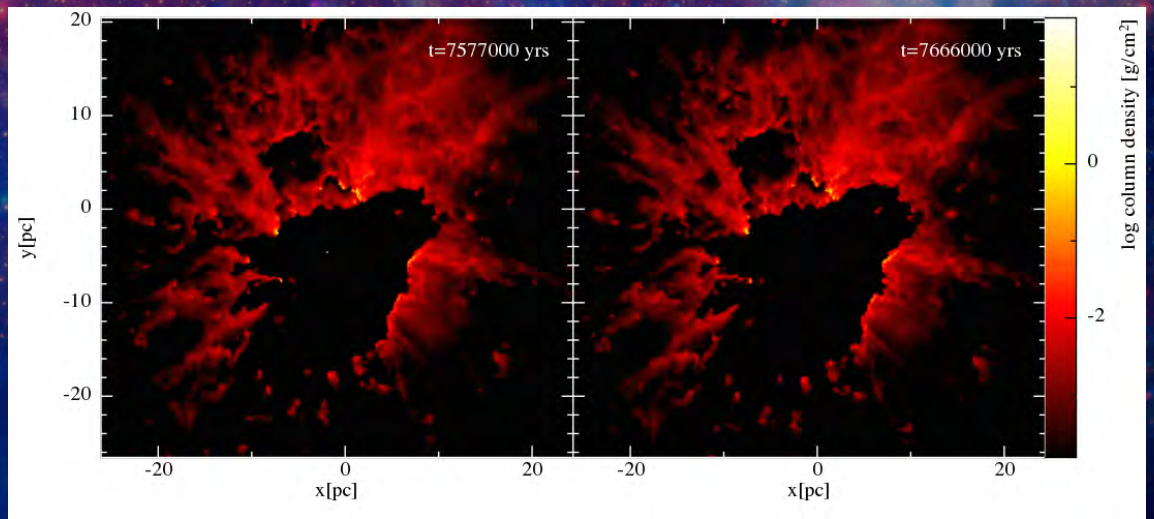
Supernova feedback

- Initial conditions as published in Dale et al. 2014 and included no feedback (control), ionisation only, and dual feedback from both ionisation and winds.
- SN inserted with 10^{51} ergs split equally between thermal and kinetic energy at the location of the most massive sink particle.

Before and after the supernova:

- Control (top) – large bubble driven into the gas
- Dual feedback (bottom) – almost no change!





Summary

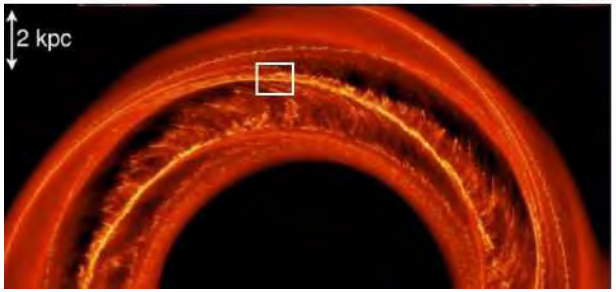
- Large-scale Shocks and cooling can trigger star formation
  - Realistic molecular clouds (structures/dynamics)?
    - Large scale turbulence driving
    - Need not be globally bound : low star formation efficiencies
  - Study galaxy star formation rates
  - Clusters form from several to 10's pc scales
    - Assembled by large scale flows
    - Clusters form in bound regions (global infall)
    - Age spreads up to several Myrs
    - Massive stars accrete as

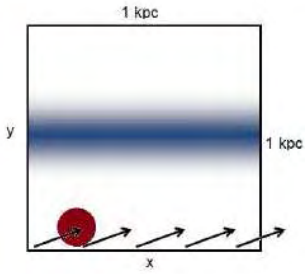
$$\dot{M} \propto M^{2/3}$$

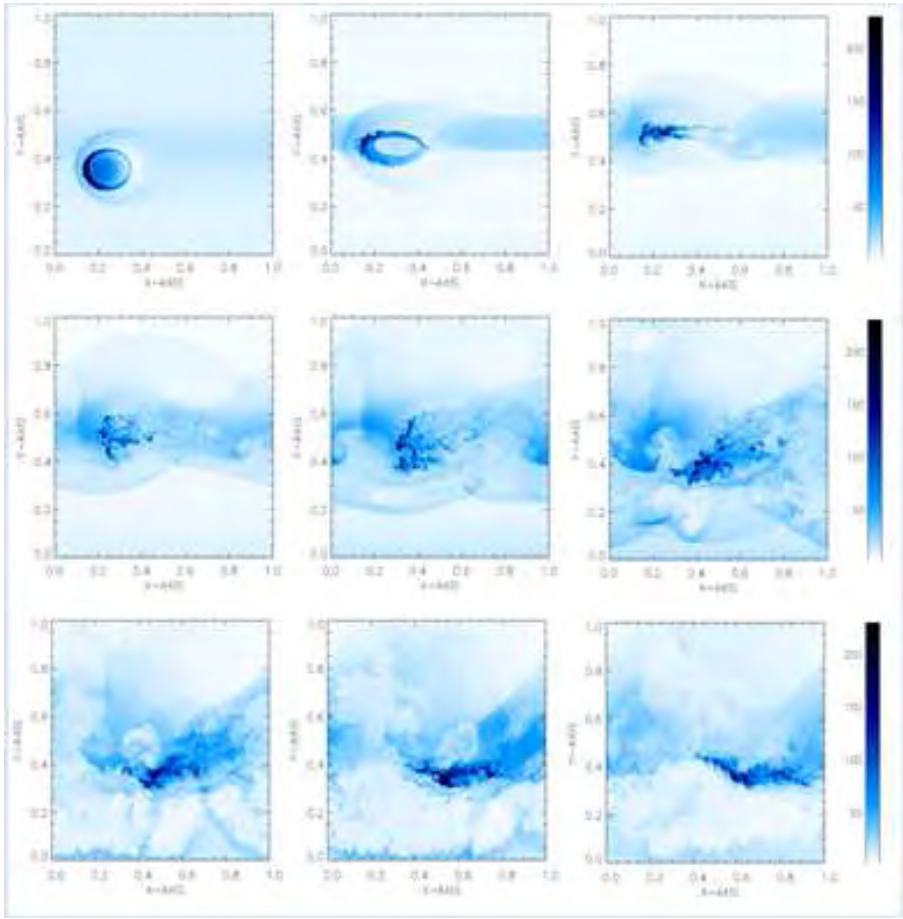
- Ionising Feedback factor of 2 decrease n SFR

Spiral arm driven turbulence

Falceta-Goncalves et al 2014







Single cloud-arm interaction

100 cm^{-3} cloud self-shocking
- cooling
- KH-instabilities

Drives turbulence