Missing in Action

Gluhwein mug ..

Reward : 10^6-body run

Bonn Workshop, 3-5 December 2012

YOUNG CLUSTERS & TIDAL FIELDS

(a love story ;)

Christian Boily, Observatoire astronomique de Strasbourg, France

Historical note -

"yesterday, forming clusters was such an easy game to play.."

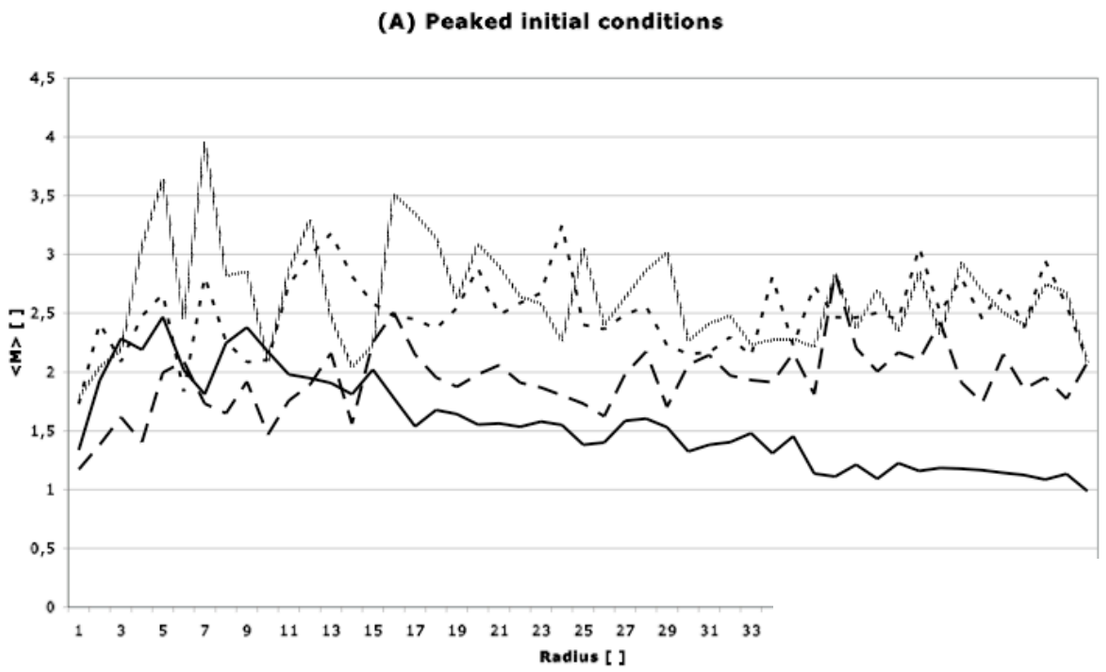
Until the early 1990's :

- Uniform metal abundances (e.g. Richer et al. 1984, etc)
  ∴ single formation epoch, great for stellar evolution synthesis

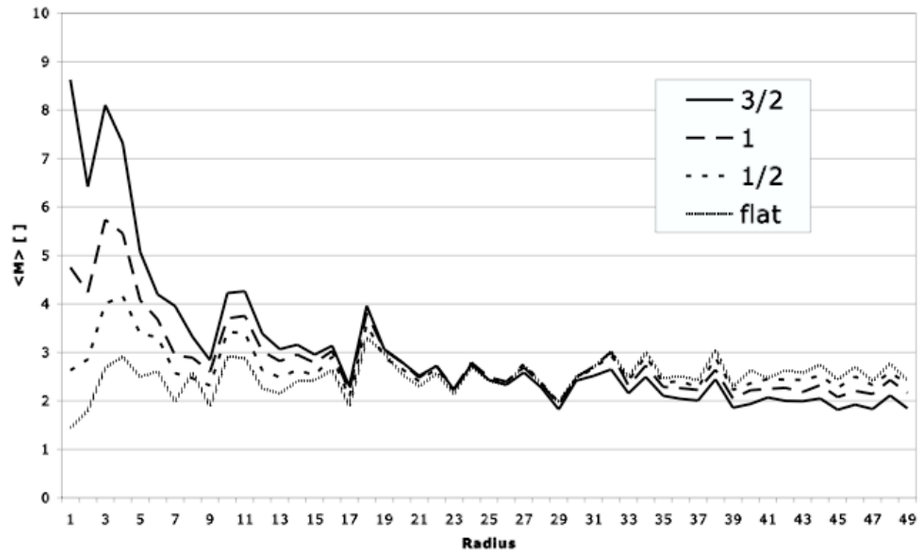
- Star formation through rapid dissipation + seed accretion
  ∴ rapid accretion, "top-hat" model of relaxation

- Examples: Numerous SPH movies, semi-analytic seed accretion

– *easy game to play..”*



r et al. 1984, etc)



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  ∴ rapid accretion, “top-ha

- Examples: Numerous SPH

Some issues for cluster builders -

"formation goes h/h with host galaxy evolution"

- Statistics of GC populations in E galaxies
  ∴ Harris & vdBerg's specific index Sn; dual colour distributions,
  e.g. Forbes et al. 2006.

- Star formation in g-mergers, i.e. galaxy formation
  ∴ Ashman-Zepf picture, classic cases Antennae, ngc 6872

- Account for hte better rendering of today's high-resolution galaxy formation simulations
  ∴ features of tails, filaments @ pc scale

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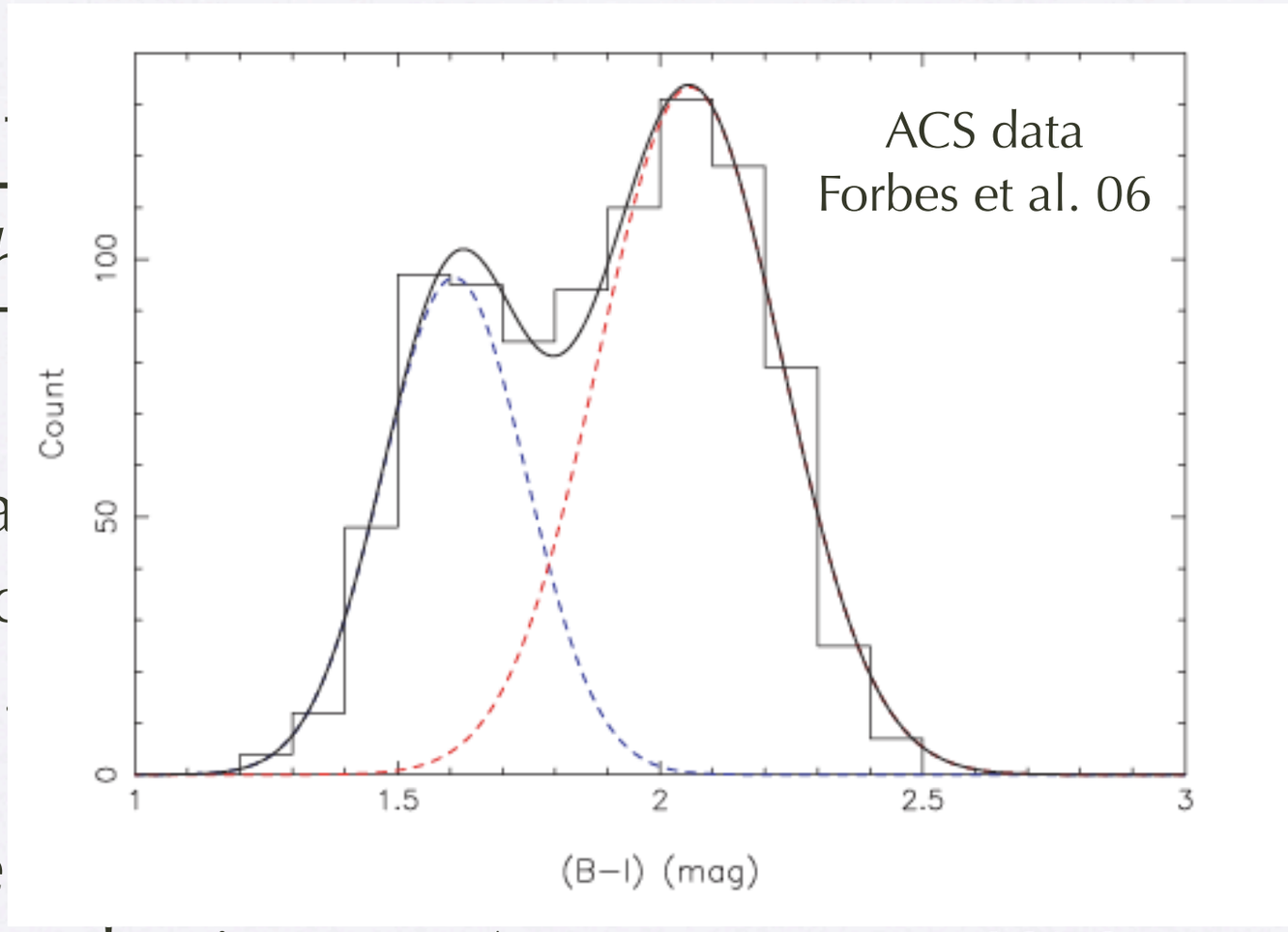

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  ∴ Ha… …colour distributions,

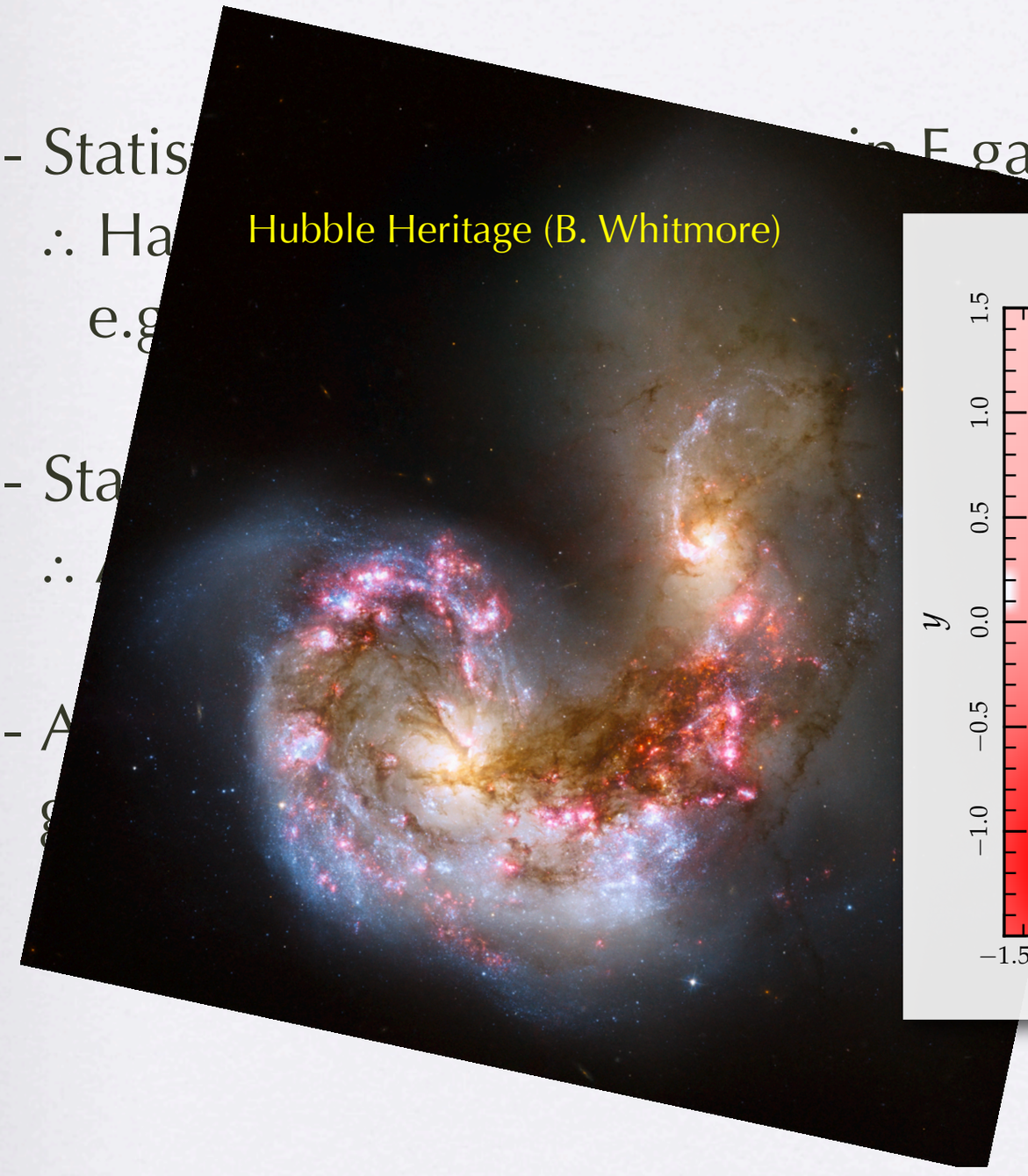
  e.g…

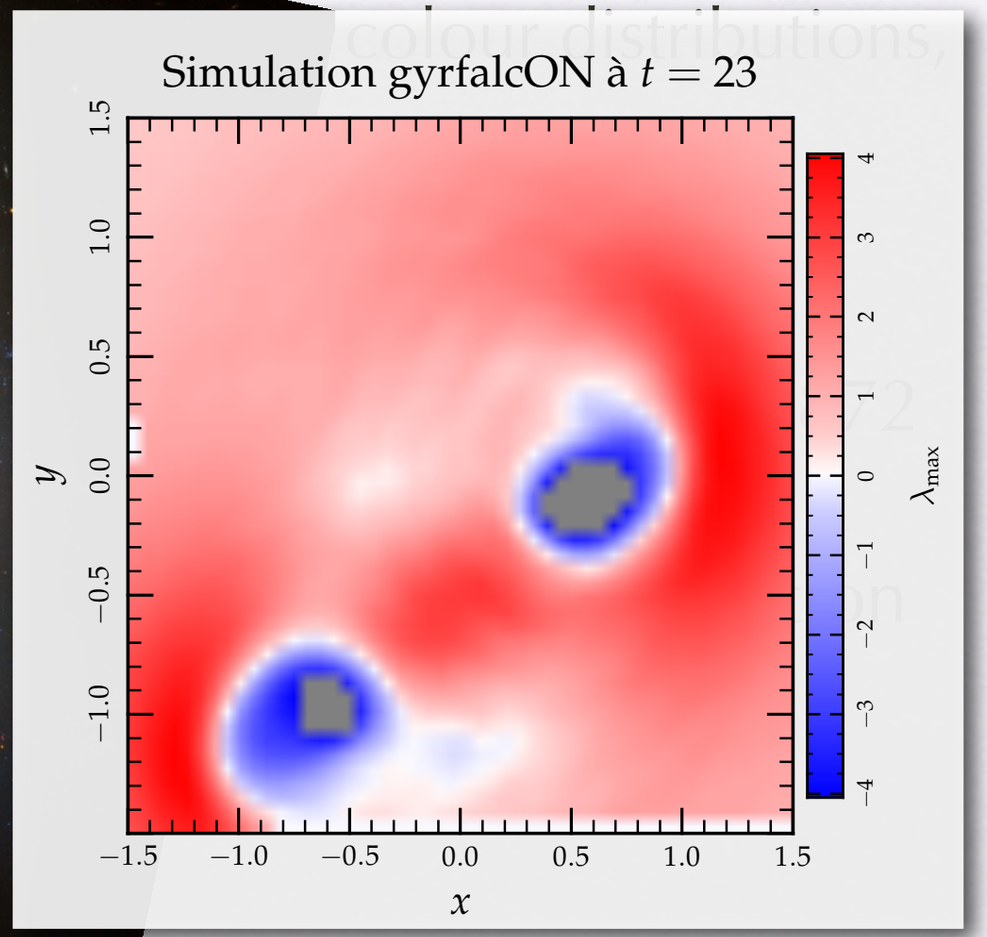
- Sta…

  ∴ …

- A…

  g…





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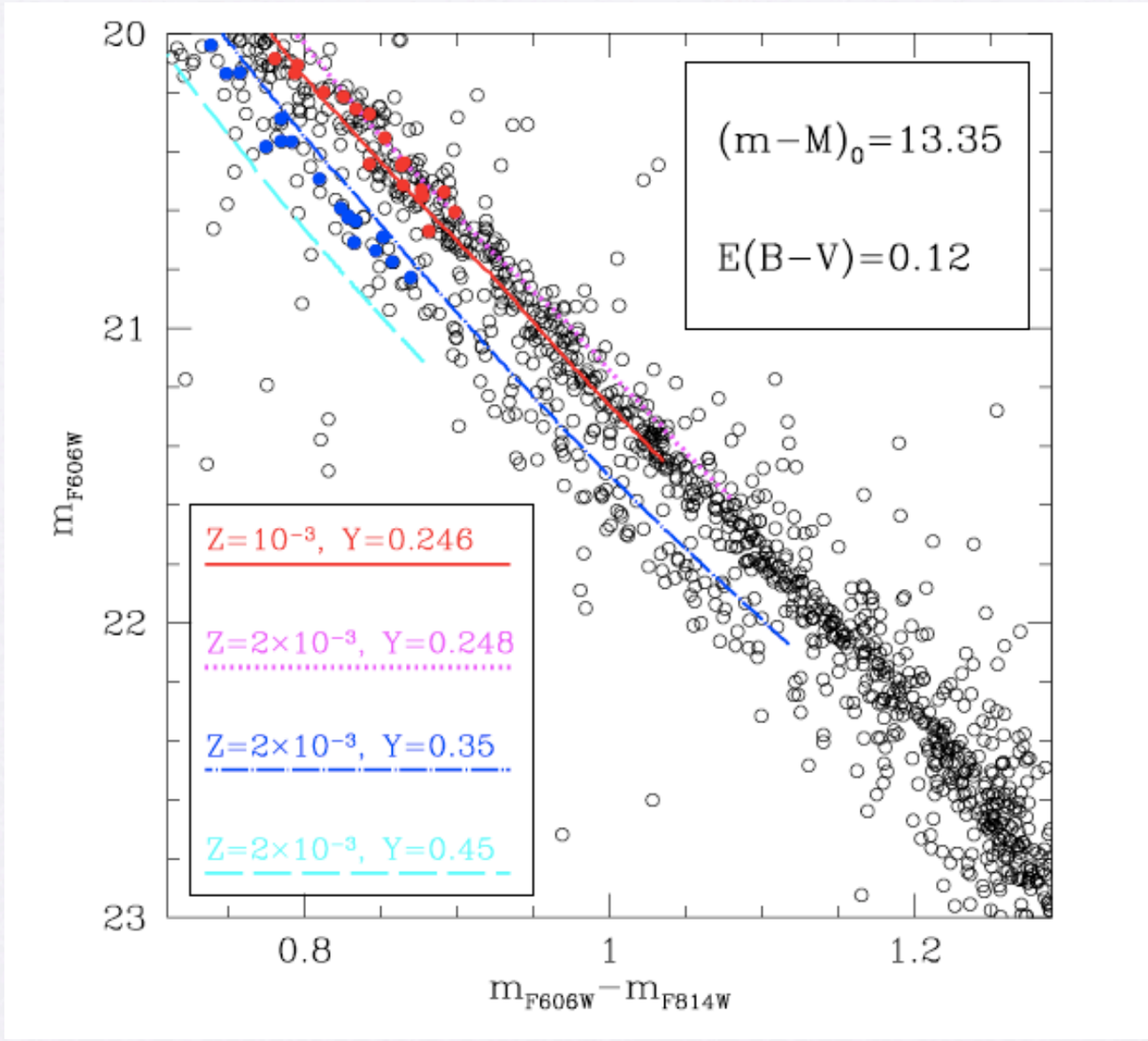
- Multiple MS threads in GC's e.g. Omega-Cen, c.f. Anderson et al. 1997, 2002; Bedin et al. 2004, *etc* ..

- Account for hte better rendering of today's high-resolution galaxy formation simulations
  ∴ features of tails, filaments @ pc scale
  Examples: the Eris simulation, Ramses (AMR) (direct)

More issues for cluster builders - Multiple ☆ populations

Double main sequence of ΩCen (Anderson 1997, 2002; Bedin et al. 2004; more ..)



More issues for cluster builders - *what recipe for star formation?*

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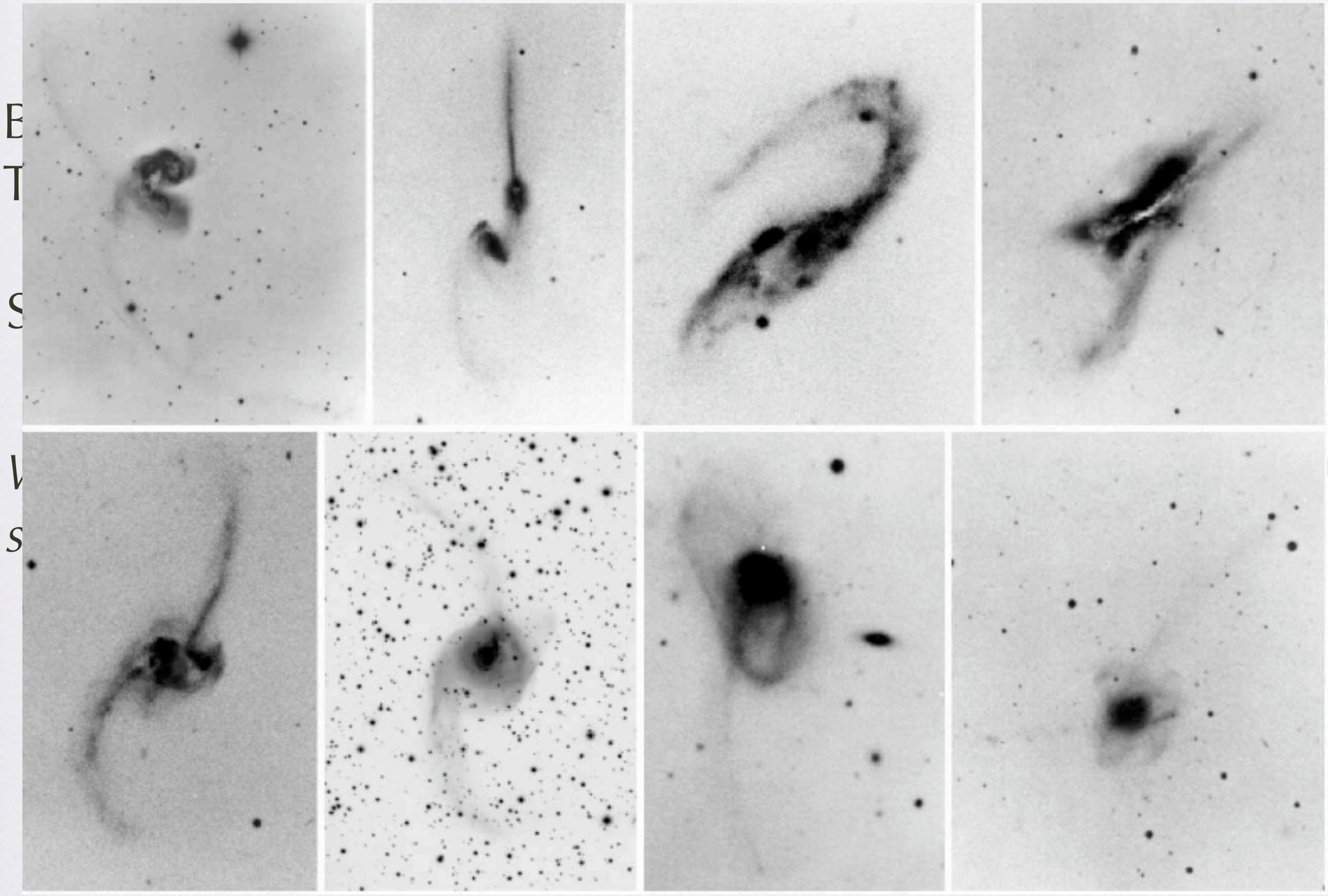


Tuesday, December 4, 2012

More issues for cluster builders - *what recipe for star formation?*

Barnes (2004) :
The Mice, recover star formation sites from nbody/sph

Schmidt SFR law + divergence of the v-field (convergence, really)

What might trigger "inward motion" on cluster-formation scale, say 100 pc?

Where might ★C's form?

Tidal field as "driver"

Roche radius

$$\Delta(\nabla\Phi_x) \approx l_\star \left(\nabla^2\Phi_x\right) = \frac{GM_\star}{l_\star^2}$$

$$\rightarrow l_\star^3 \simeq \frac{GM_\star}{\nabla^2\Phi}$$

3D: tensor form

Shear radius

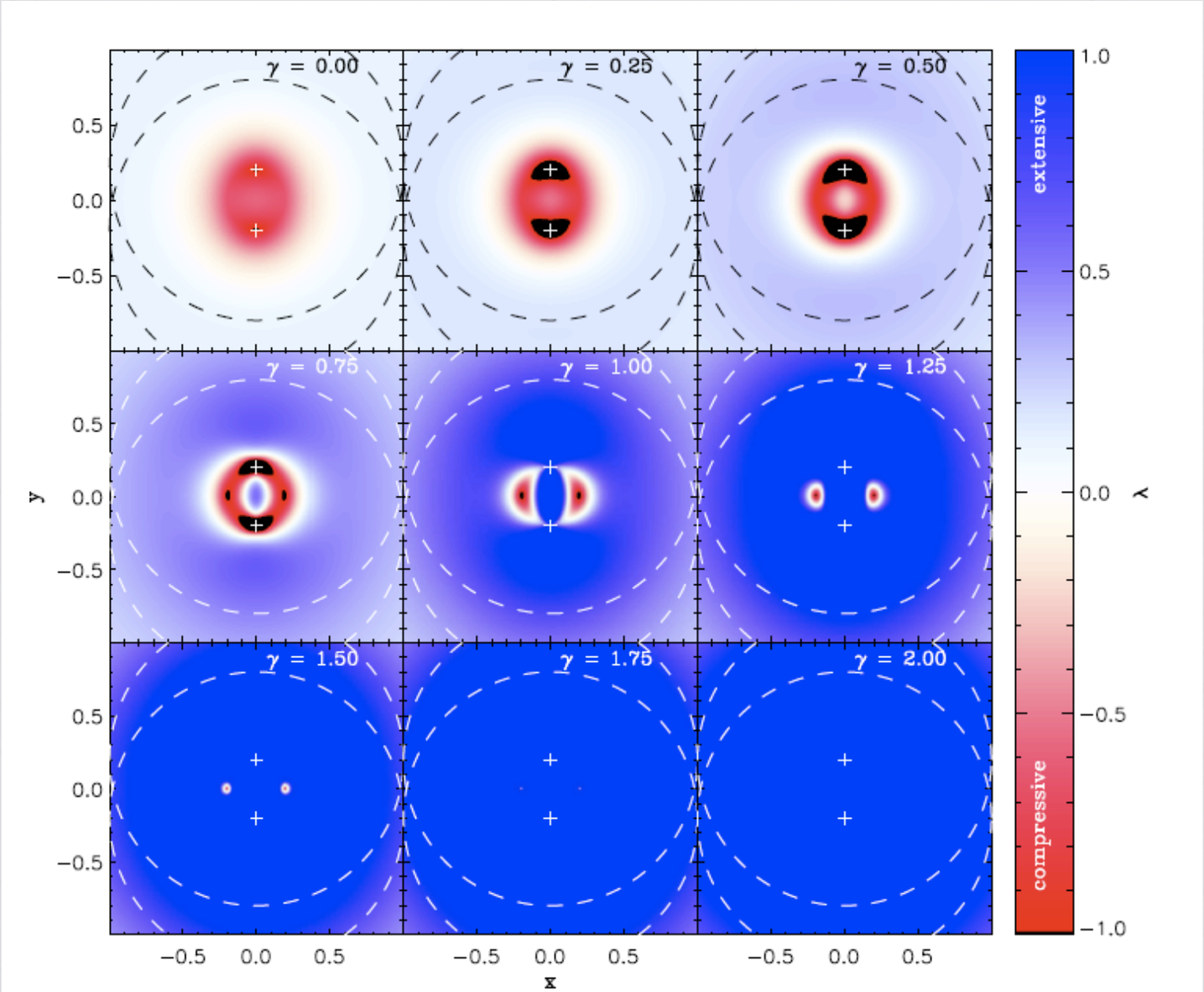
$$\Delta\mathbf{v} \sim \Delta(R\Omega) = \Delta R\Omega + R\Delta\Omega$$
$$= \Delta R(\Omega + R\Omega')$$

$$\rightarrow l_\star \left(\Omega + R\Omega'\right) \simeq \sigma_\star \approx \left(\frac{GM_\star}{l_\star}\right)^{1/2}$$

$$l_\star^3 \simeq \frac{GM_\star}{(\Omega + R\Omega')^2}$$

(equal for circular motion)

Outcome = f(d.f.)


γ = 0.00
γ = 0.25
γ = 0.50
γ = 0.75
γ = 1.00
γ = 1.25
γ = 1.50
γ = 1.75
γ = 2.00
0.5
0.0
−0.5
y
x
extensive
compressive
λ
1.0
0.5
0.0
−0.5
−1.0

Where might ★C's form?

Tidal field as "driver"

* .. where the gas goes .. e.g. ngc 6872 (Bastian et al. 2005)

* .. which is where the potential wants it to go: potential sink + compressive tidal field (i.e. a sound wave, spiral feature)

nt ★C's form?

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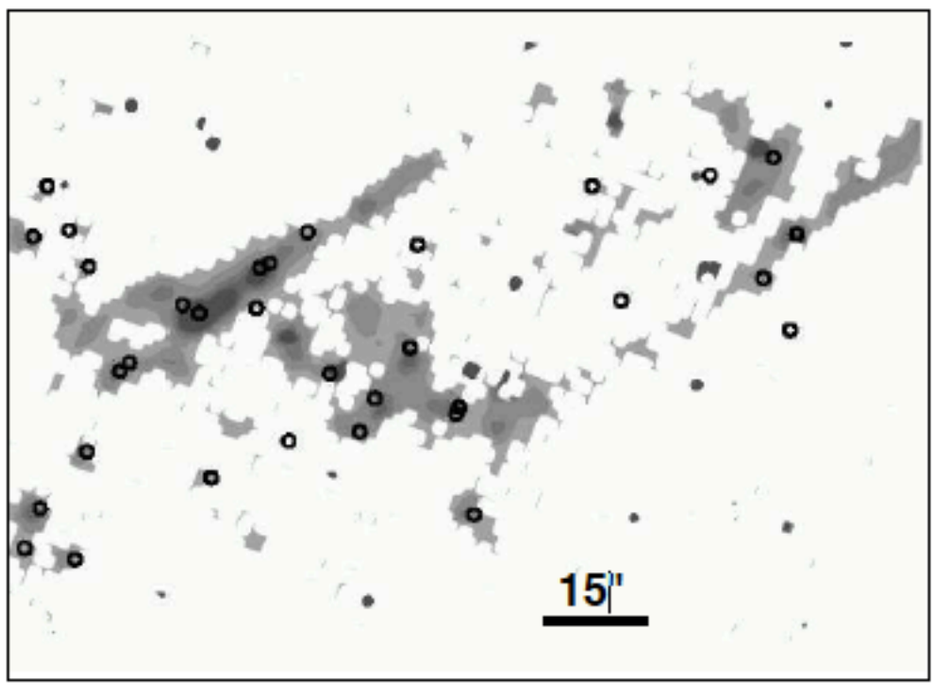

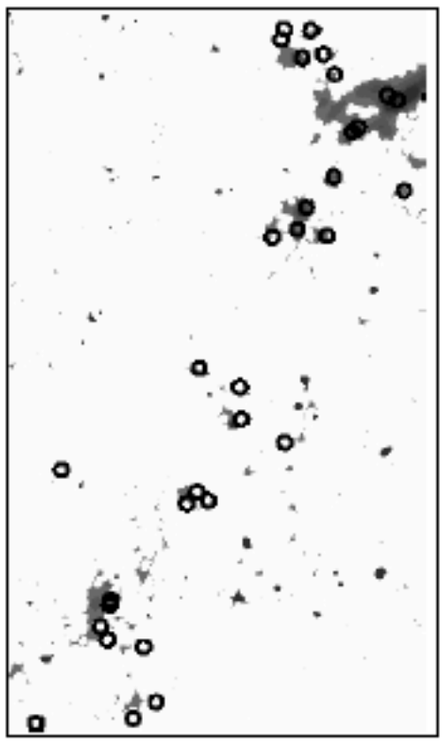

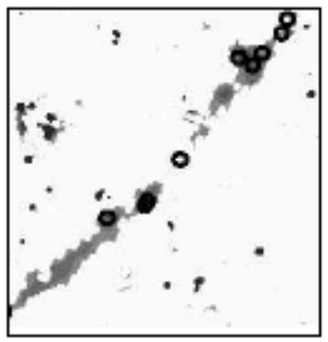

Bastian et al. 2005

Fig. 10. The young (< 10 Myr) massive ($\gtrsim 10^{4.5} M_\odot$)

c 6872 (Bastian et al. 2005)

wants it to go: potential sink +
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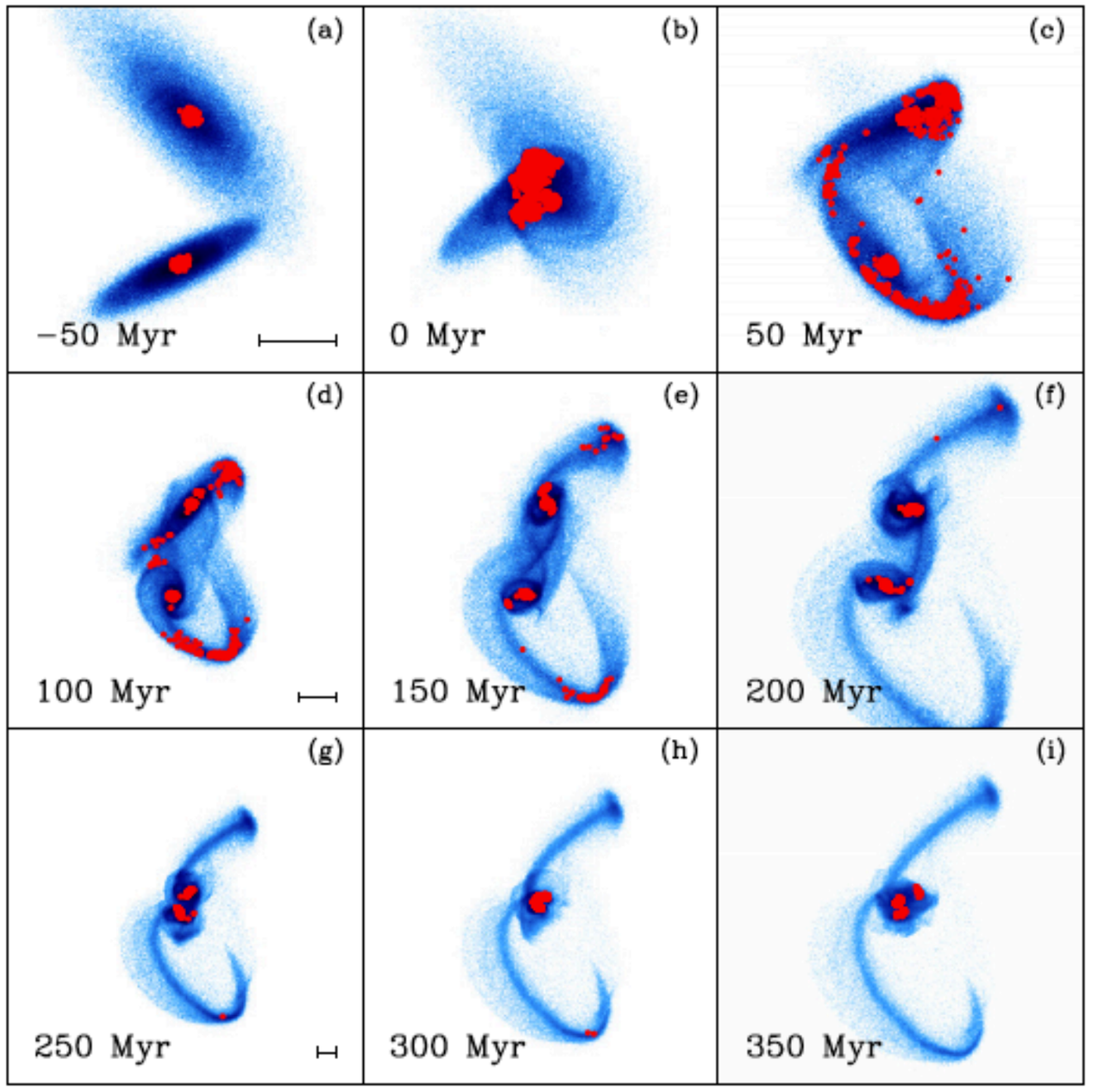

Lifted from Renaud et al. 2009

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Green crosses: nuclei of progenitor galaxies

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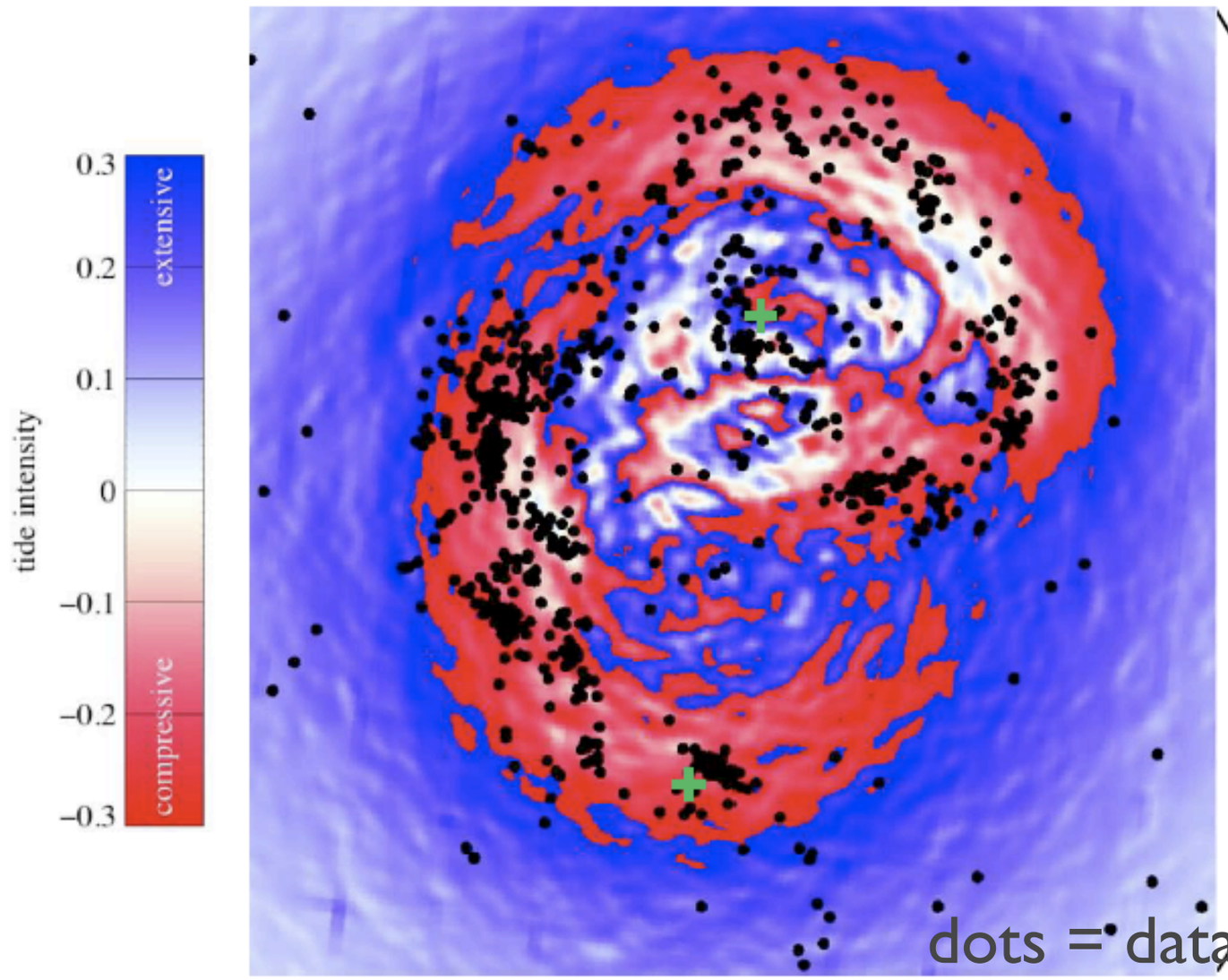
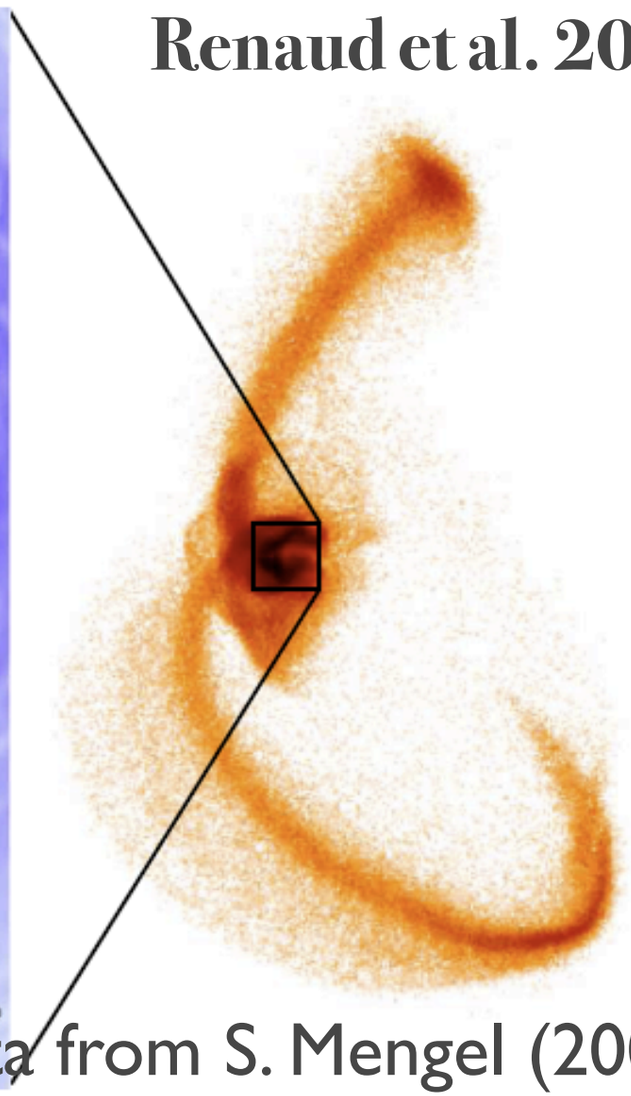




Renaud et al. 2008

dots = data from S. Mengel (2003)

Green crosses: nuclei of progenitor galaxies

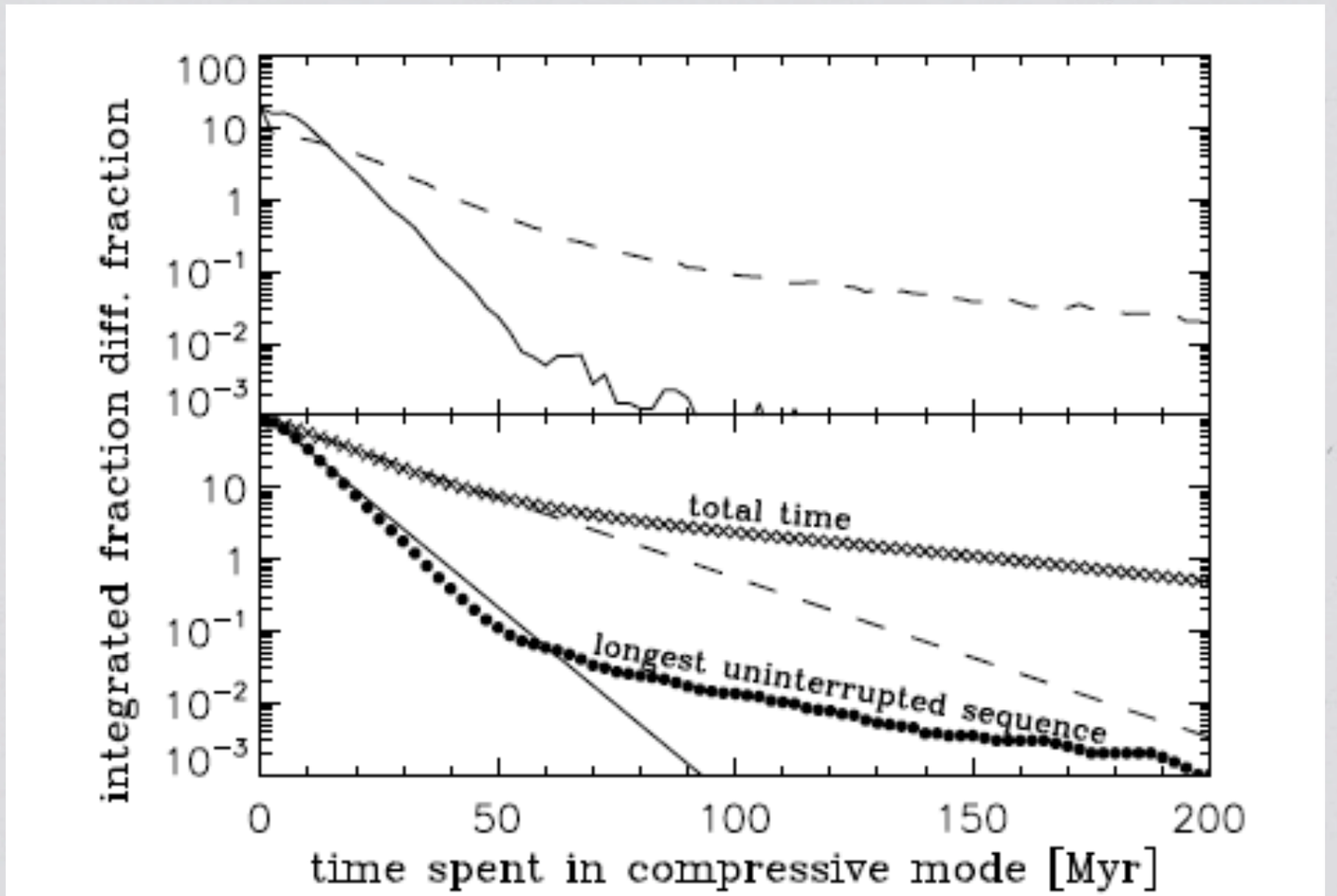
Compressive tidal modes:

statistics point to a log-normal distribution of the duration

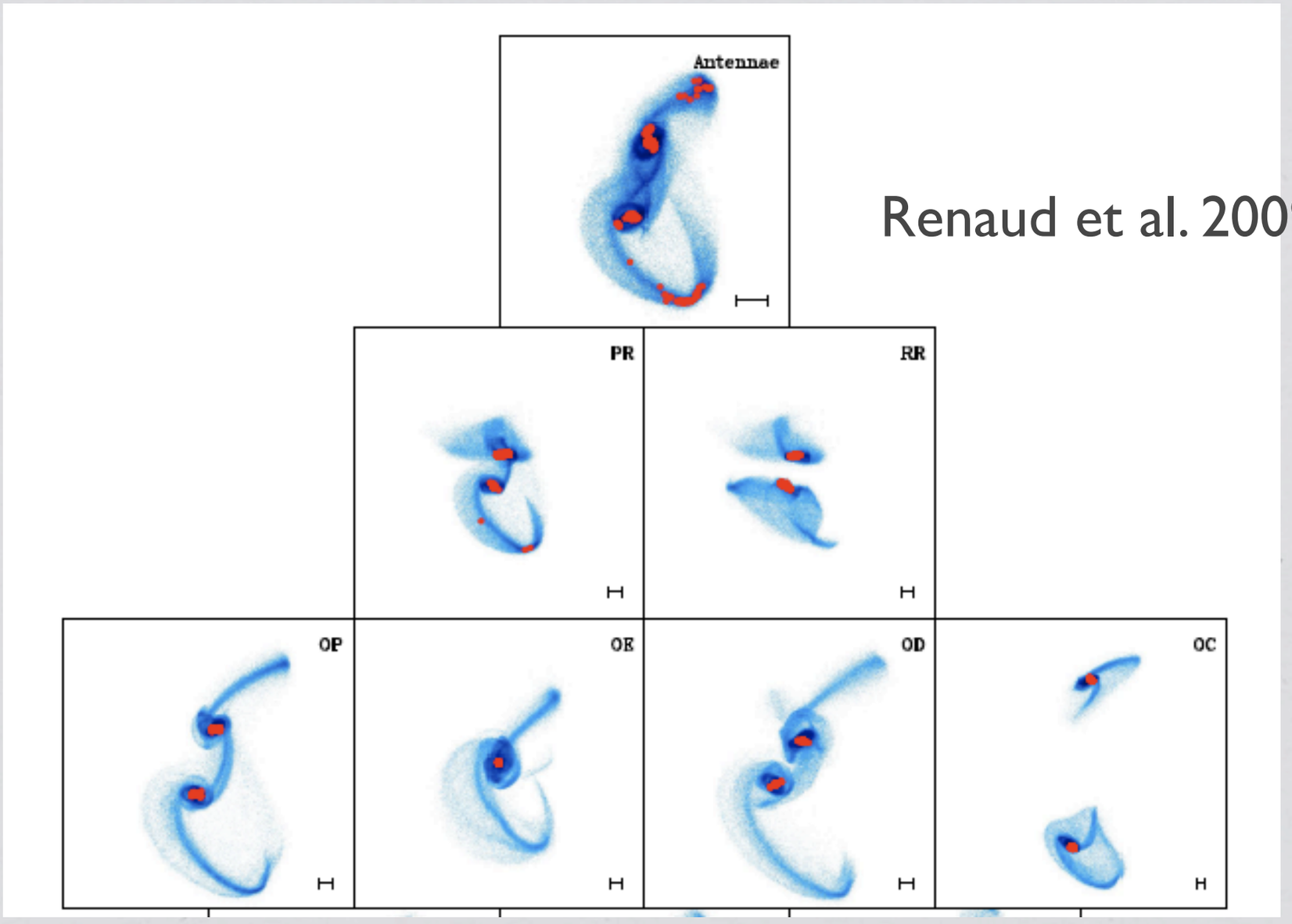
* Characteristic times ~ 10 to 20 Myr

* valid for major mergers, i.e. it is scale free (dry runs)

* *minimal* time scale given that there is *no* dissipation



but … "many" orbital parameters ☹



Renaud et al. 2009 ApJ

Where might ★C's form?

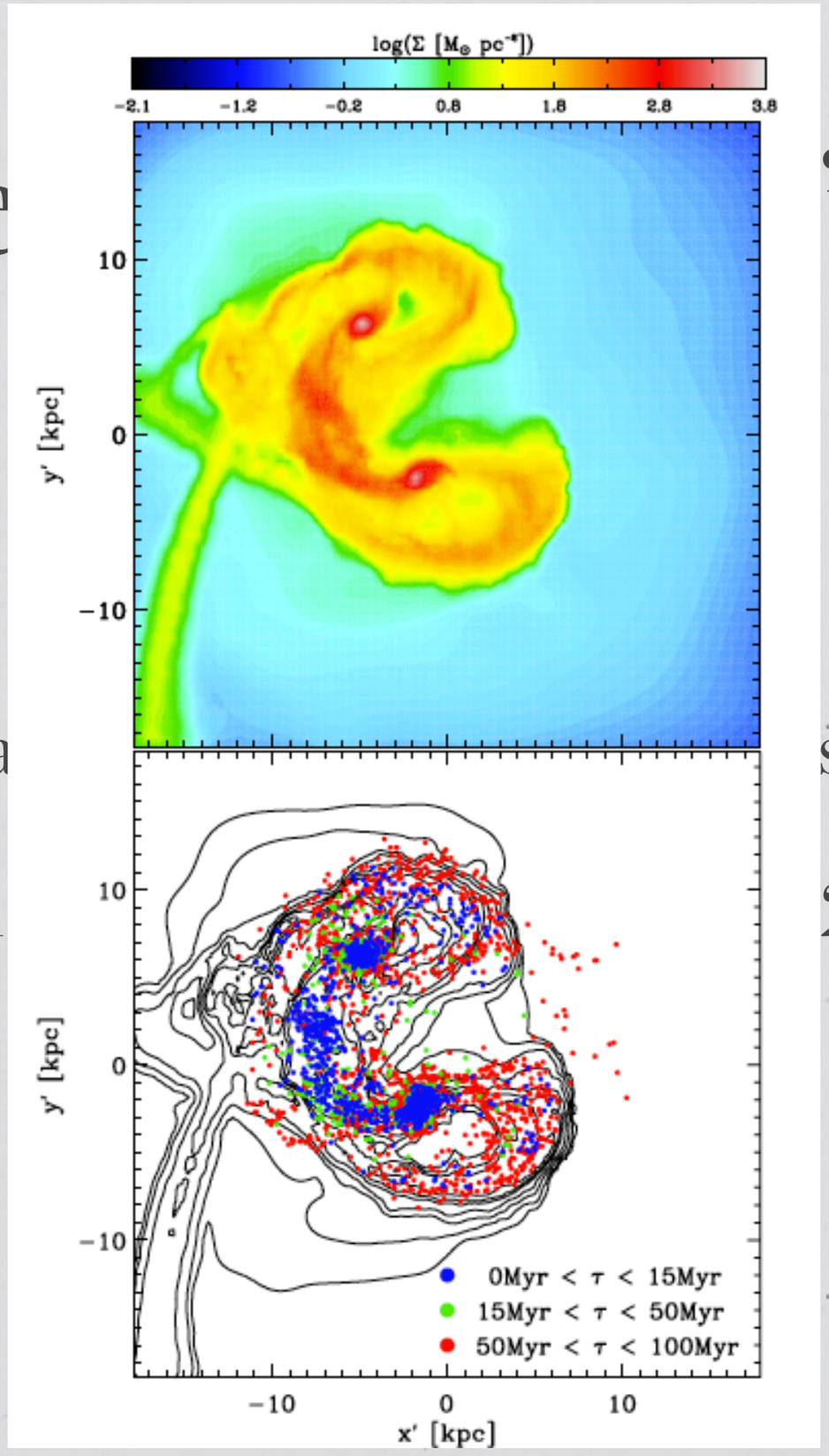
* .. where the gas goes .. ? With gas, is the answer better?

* Example of an sph simulation using Gadget2 (S. Karl et al. 2010)

Whe ’s form?

* .. where the ga swer better?

* Example of an 2 (S. Karl et al. 2010)

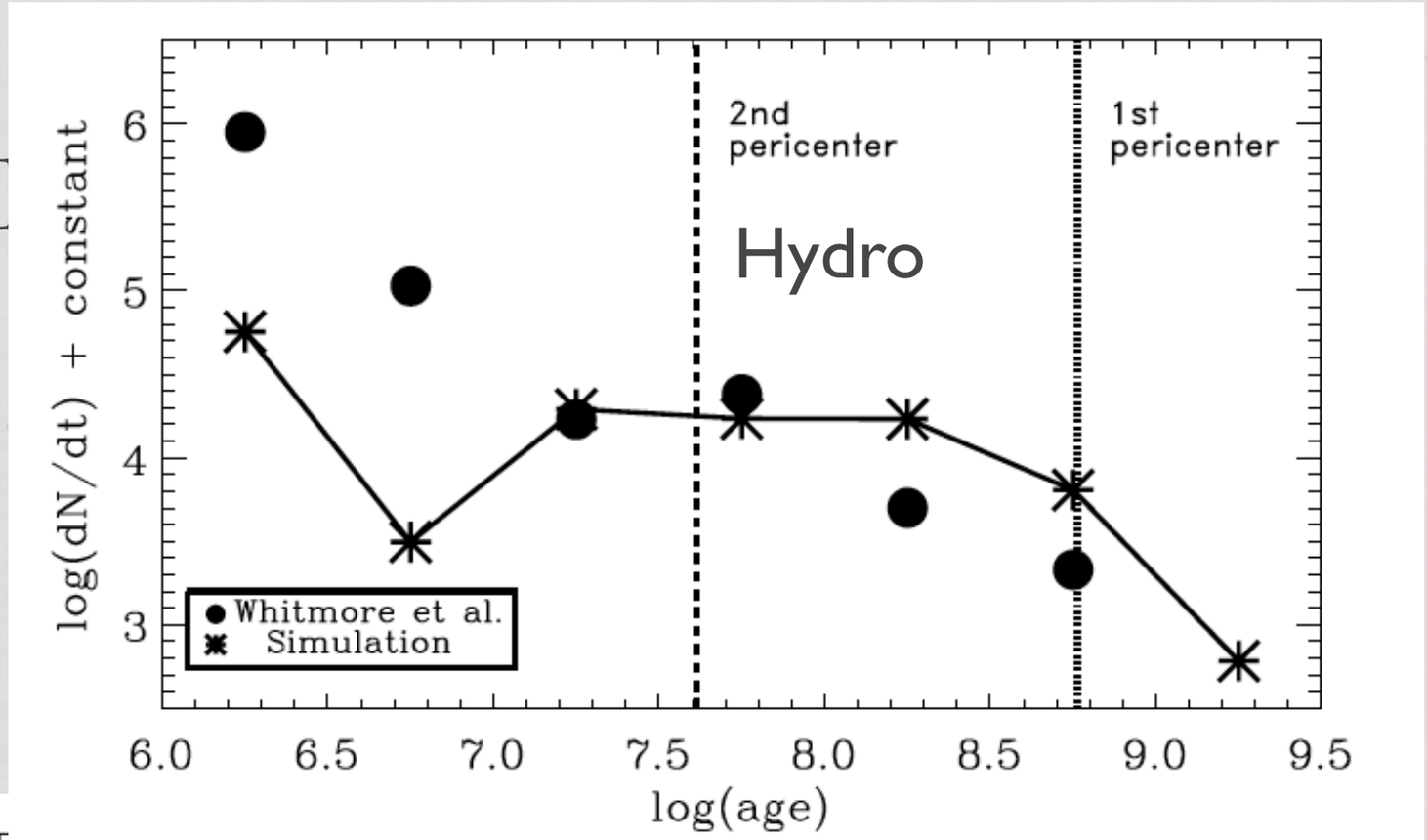


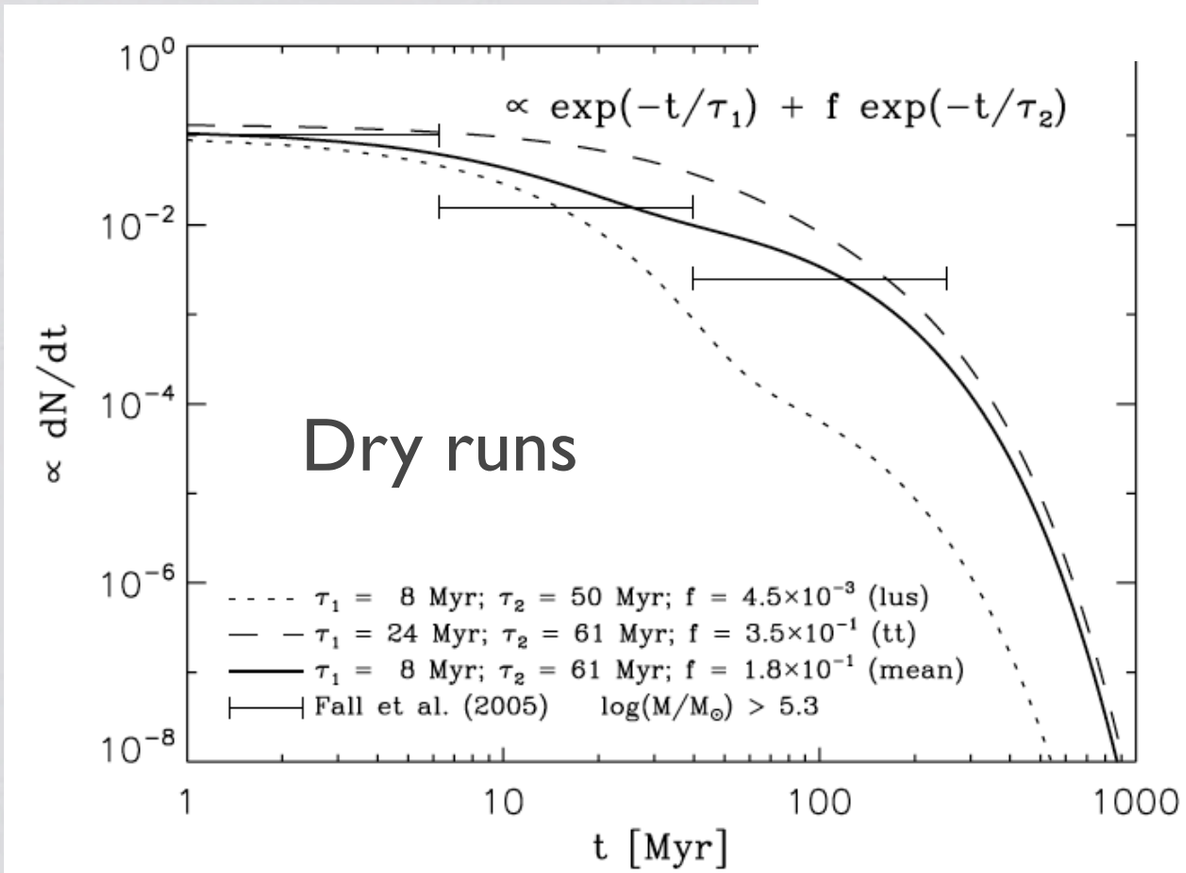
Recovering the SFR of NGC 4038/39

* With gas: number of SHP elements above a threshold in density

* Dry runs: number of bodies in compressive mode at any given time

Recover



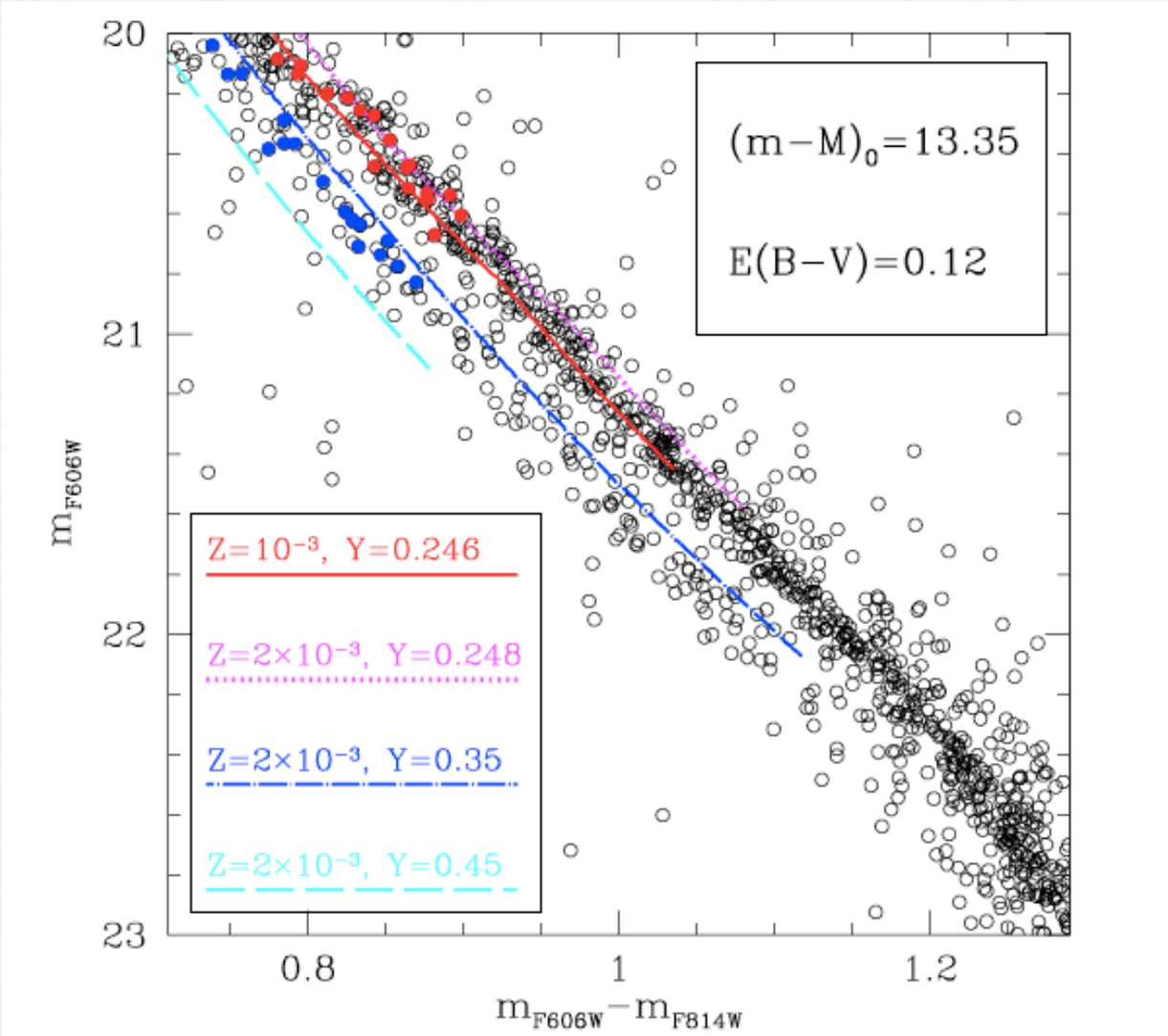


above a threshold in density

pressive mode at any given time

Multiple ☆ populations are (possibly) a result of multiple episodes of tidal compression

Double main sequence of ΩCen (Anderson 1997, 2002; Bedin et al. 2004; more ..)



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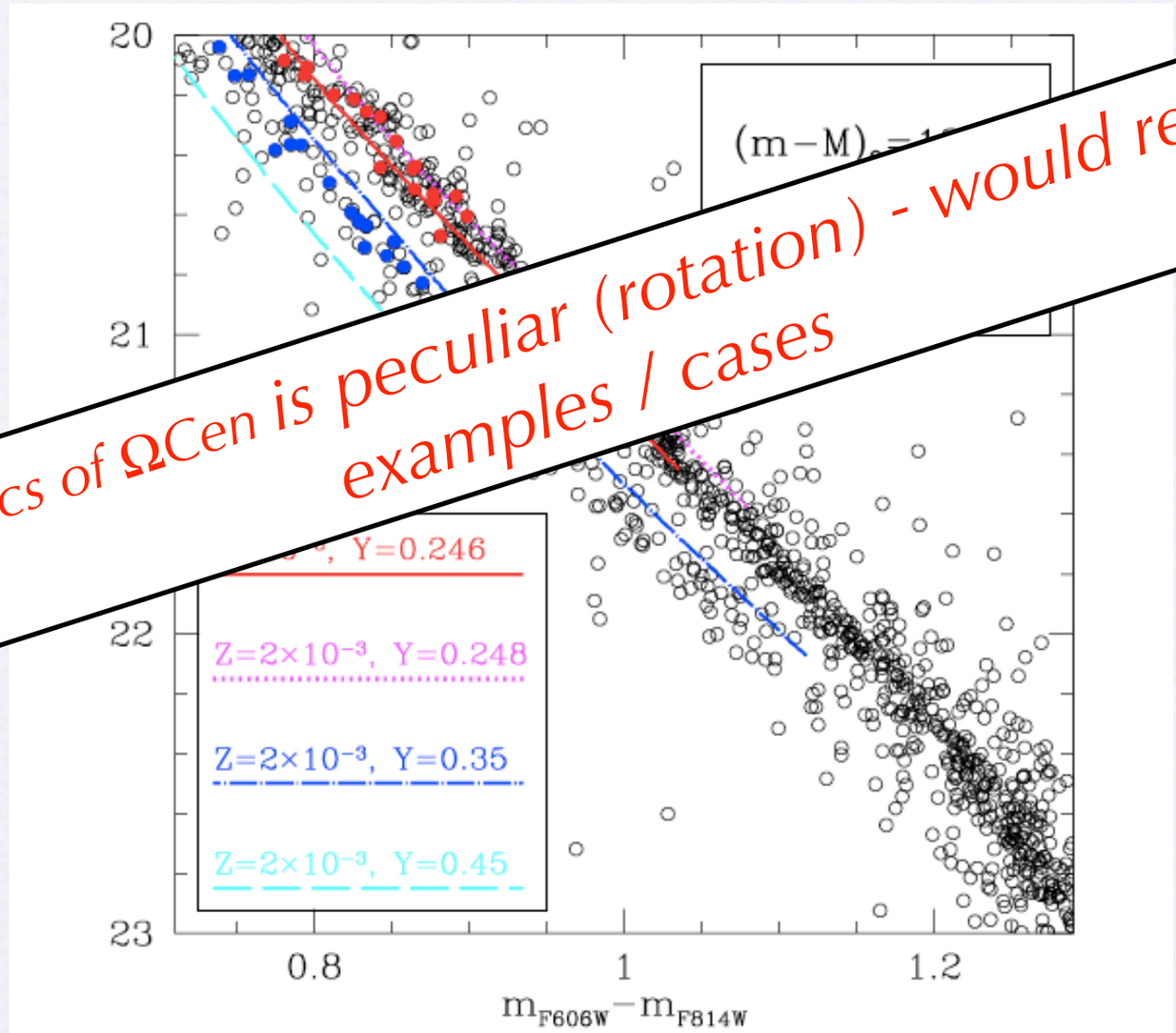

But the kinematics of ΩCen is peculiar (rotation) - would require other examples / cases

Conclusions

- Cluster formation an interplay between local gas dynamics and global galaxy evolution

- The tidal field: compressive modes help trigger the formation of stars (characteristic duration time, magnitude)

- In situ evolution: the *efficiency* with which stars form requires the statistics of turbulence + fragmentation modes