Star formation modes, gradients, and (no) stellar migration

in simulated dwarf galaxies

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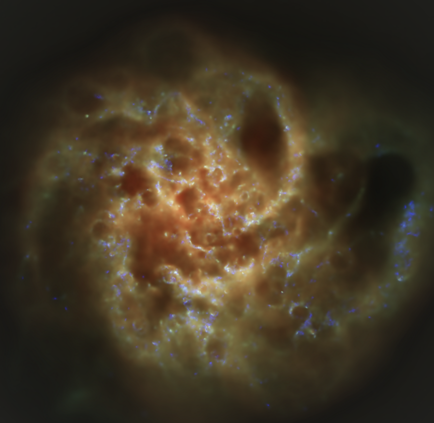
Who we are…



THE HARDWORKING SIMULATORS

- Joeri Schroyen
- Annelies Cloet-Osselaer

THE SUPERVISORS

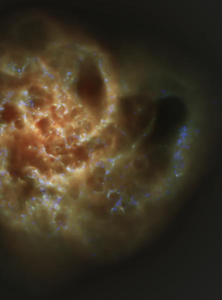
- Sven De Rijcke
- Mina Koleva

What we do...

Nbody-SPH simulations of dwarf galaxy formation and evolution

- Adapted version of **Gadget2** (Springel 2005)

additions: radiative cooling
star formation
feedback
metal enrichment



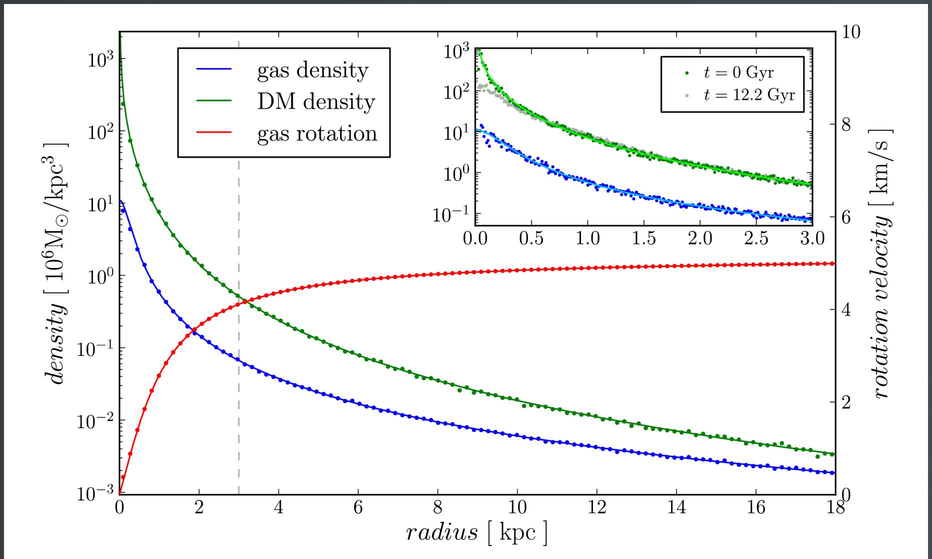
Our own little cluster
"Ithildin"

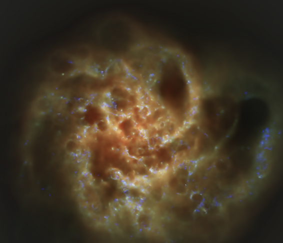
- Valcke et al. (2008, 2011)
- Schroyen et al. (2011)
- Cloet-Osselaer et al. (2012)

The models

Isolated dwarf galaxy simulations

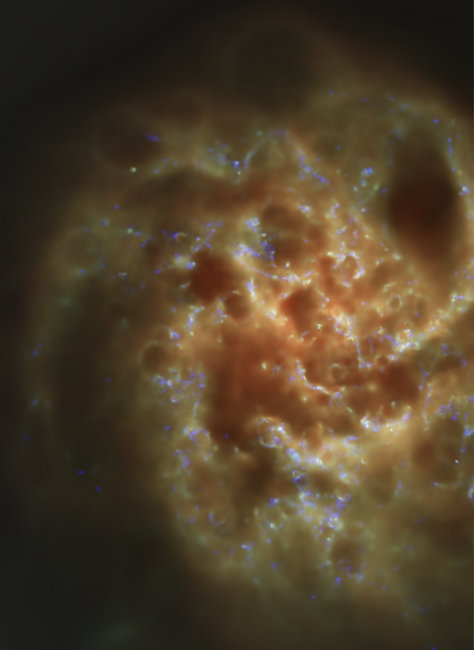
- Dark matter halo : NFW profile (talk Annelies)
- Gas sphere : Pseudo-isothermal
- Rotation curve (gas) : arctangens (to 5 km/s)





- Total mass range = 2.5 - 30 x $10^8 M_\odot$
- Particle numbers =
  200k DM + 200k gas
- Runtime = 11.7 Gyr

The models



Star formation prescriptions :

- Convergence : $\vec{\nabla}.\vec{v} \leq 0$
- **Density threshold** : $\rho_{gas} \geq \rho_{crit}$

Classic

- **Low** threshold : $\rho_{crit} = 0.1\ cm^{-3}$

  (Katz, Weinberg & Hernquist 1996, Stinson 2006, Valcke 2008, Revaz 2009, ...)

  Temperature : $T_{gas} \leq T_{crit} = 15000K$

NEW

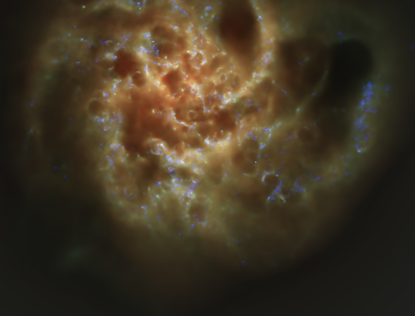
- **High** threshold : $\rho_{crit} = 100\ cm^{-3}$ ("DG1" - Governato 2010)

  => extension of cooling curves below 10^4 K

  => increase feedback efficiency (Cloet-Osselaer et al. 2012)

  (degeneracy in SF parameters - talk Annelies)

More realistic description of cold, star-forming clouds



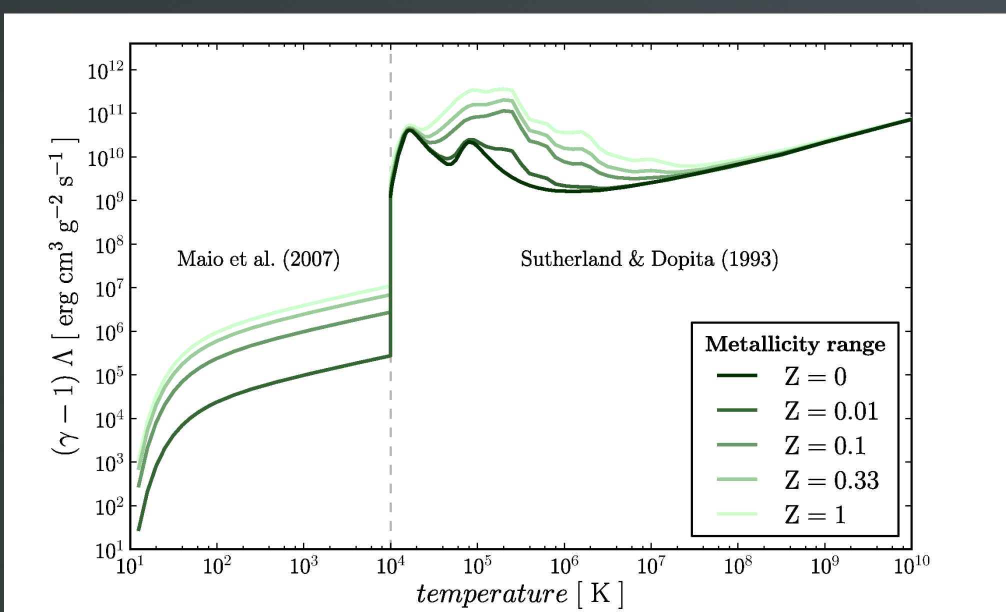
The models

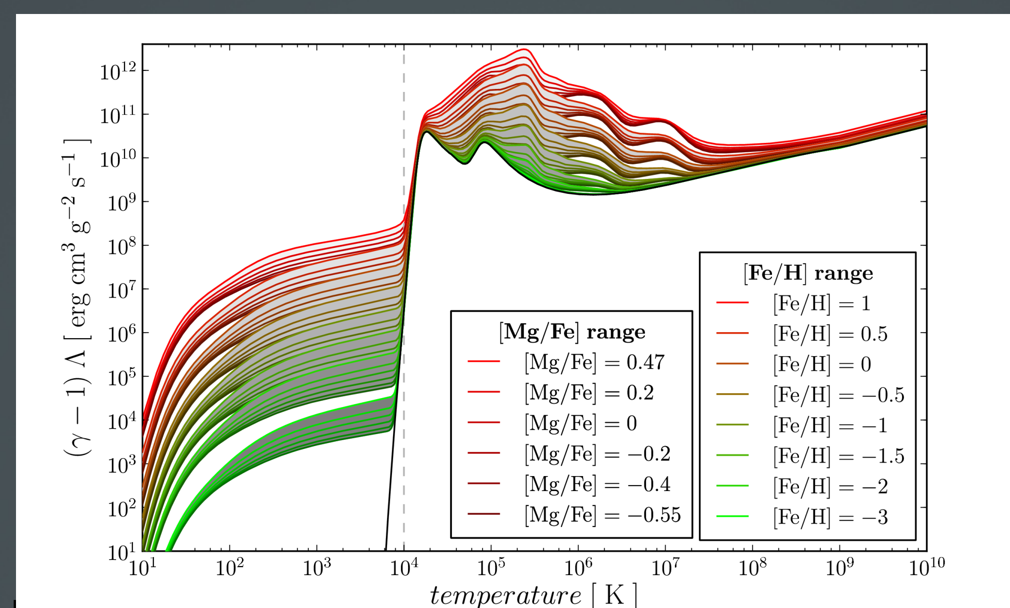
Radiative cooling

- Metallicity ($Z/Z_\odot$) dependent cooling curves (Sutherland & Dopita 1993)
- For high density threshold : extension below 10^4 K

  A) stitch on extra curves (Maio 2007)

  B) new full-range consistent calculations (talk Sven De Rijcke)





De Rijcke et al. (in preparation)

Star formation modes

Angular momentum = second parameter (after mass)

centrifugal barrier differentiates between SF modes

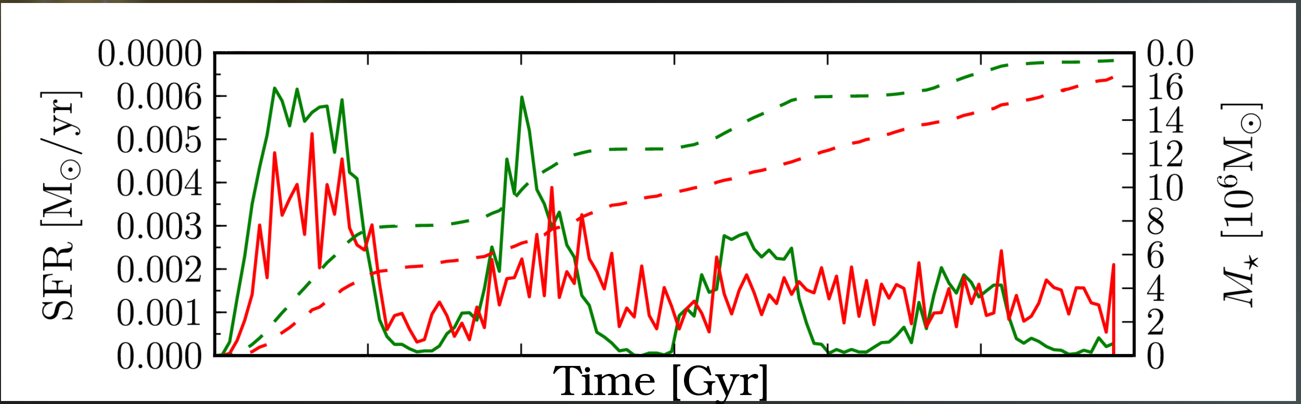
- Non-rotating => centralized and bursty

  gas falls in very centrally → concentrated SF → blowout → repeat

- Rotating => extended and continuous

  rotation prohibits direct infall → extended SF across galaxy

  → no global blowout, only local ('bubbles') → continuous SF



Reminiscent of

BCD / dIrr dichotomy

Schroyen et al. (2011)

Low density SF threshold

Star particles

- Yellow : < 20 Myr **"Hα"**
- Red : > 40 Myr "FUV"
  < 100 Myr

Schroyen et al. (2011)

High density SF threshold

Star particles

- Yellow : < 20 Myr "Hα"
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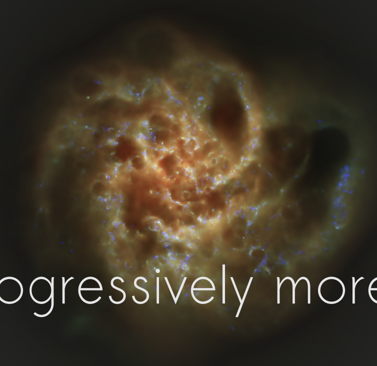
  < 100 Myr

Schroyen et al. (2011)

Gradients

Radial stellar metallicity profiles

consequence of the **star formation modes**



- Non-rotating => negative gradient

  SF burst centrally concentrated + bursts progressively more centralized

  ⇨ **build up of gradients**

- Rotating => flat profile

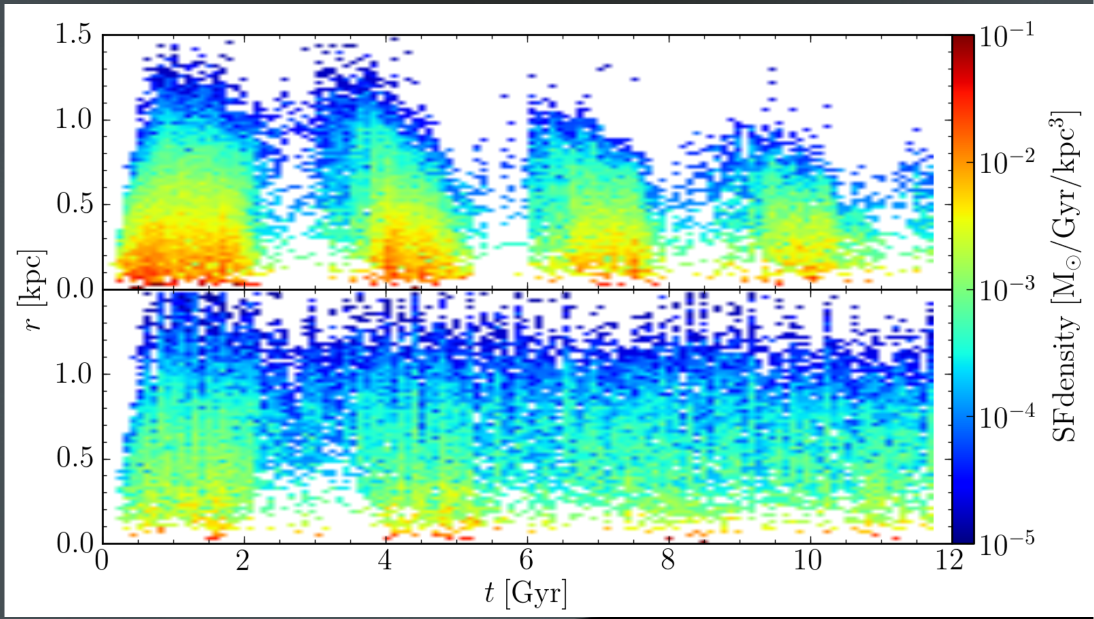
  spatially extended SF

  \+

  SF-area does not shrink

  ⇩

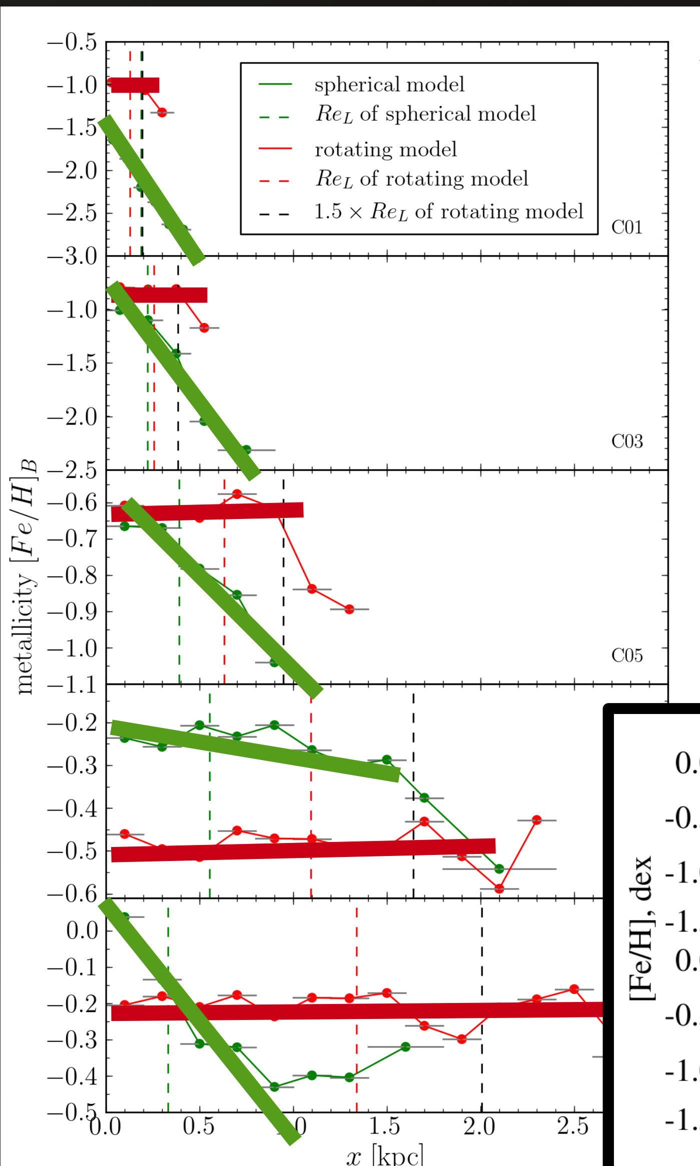
  chemical homogeneity



Schroyen et al. (2011)

Gradients

Schroyen et al. (2011)

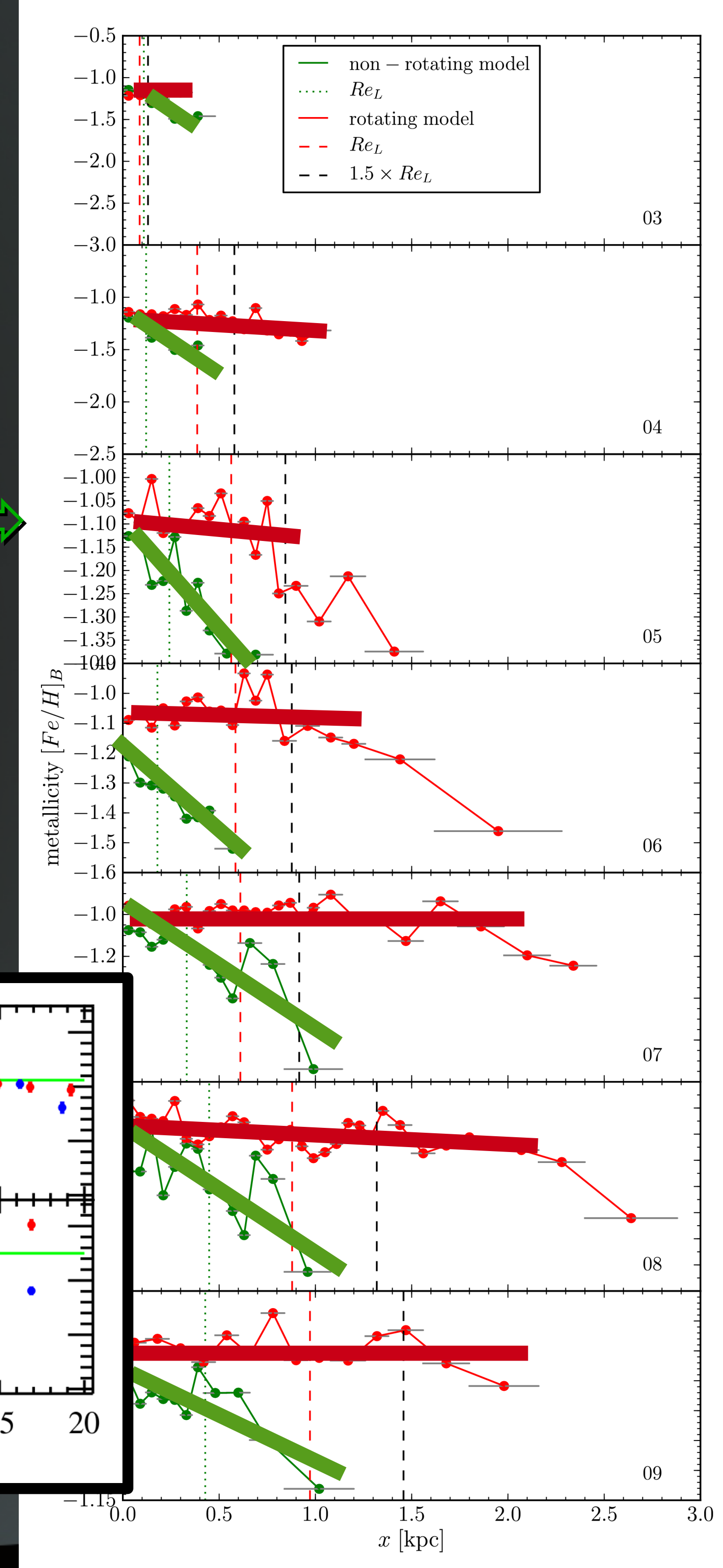


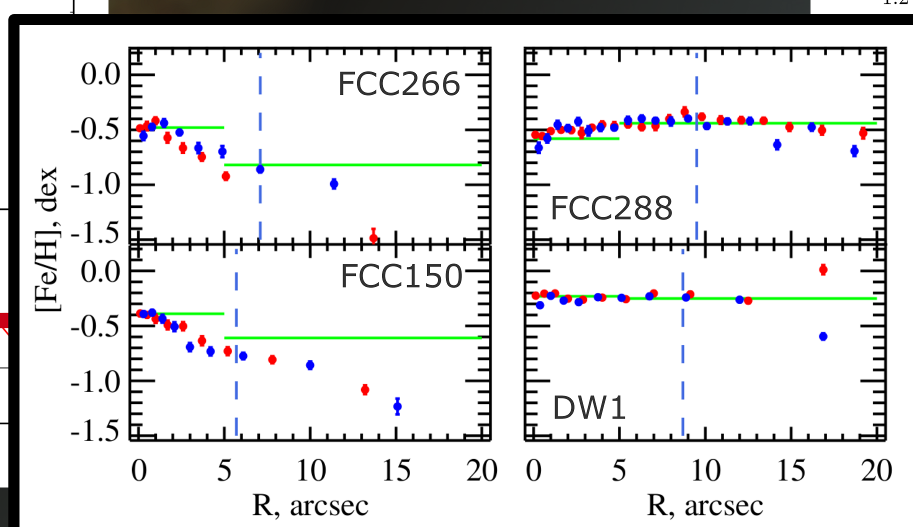
⇦ *Low*

density threshold

HIGH ⇨

Explains observed dichotomy in stellar metallicity profiles (talk Mina Koleva)





Koleva et al. (2009)

Gradients

Stability and evolution

recent doubts on survival of gradients in stellar populations

- Revaz et al. (2011) : *simulations*

  gradients are **destroyed** on **dynamical timescale**

  ⇨ gradients have to be **re-formed** in every SF episode

⇳

- Battaglia et al. (2006,2011), Tolstoy (2004), Koleva et al. (2009),... :

  observations

  gradients do **exist** (in abundance) and are **observed**,

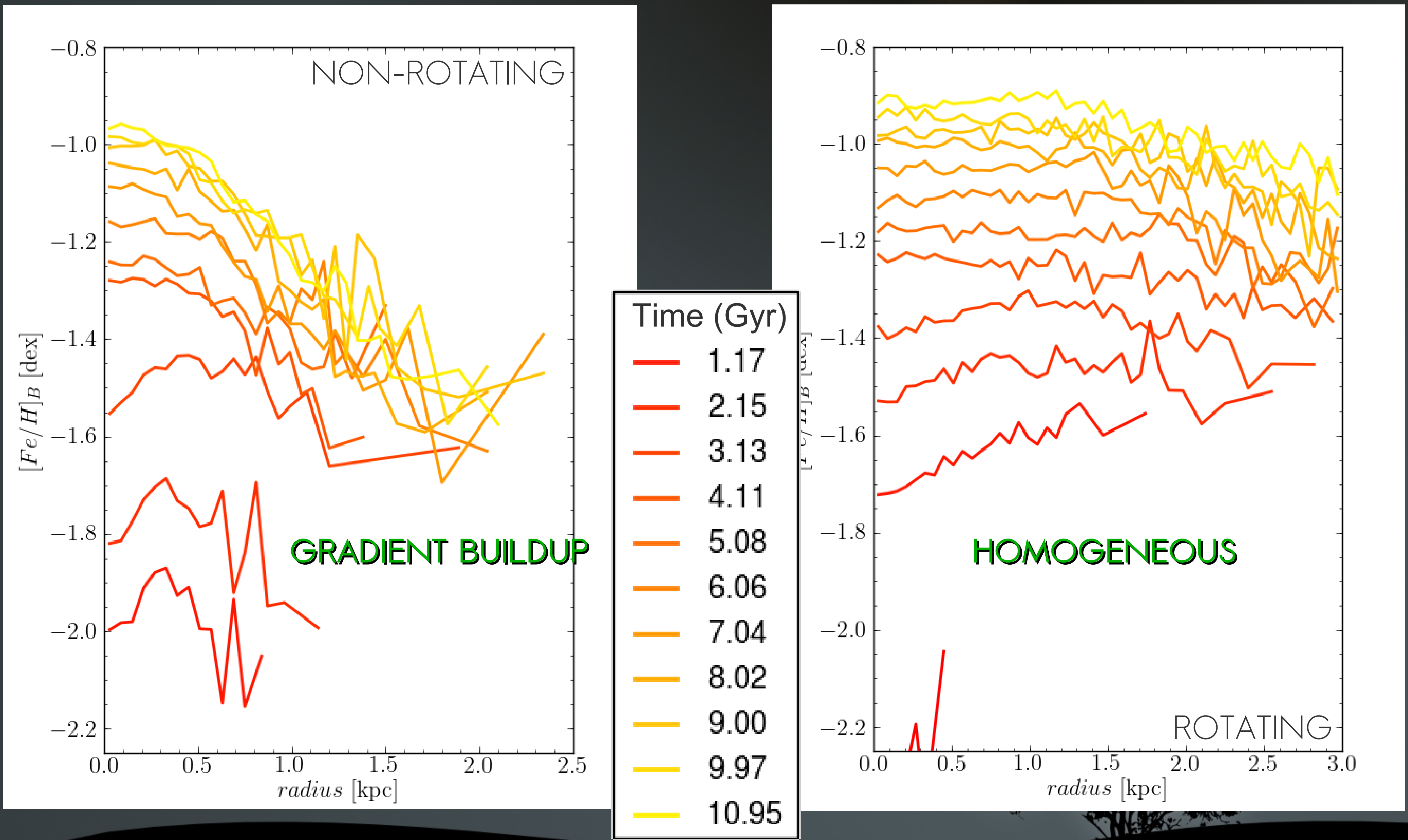
  also in the **old populations** (see talk Mina Koleva)

=> investigate whether in our simulations the stellar orbits get disturbed so drastically and on such short timescales

Schroyen et al. (2012-in prep)

Gradient evolution

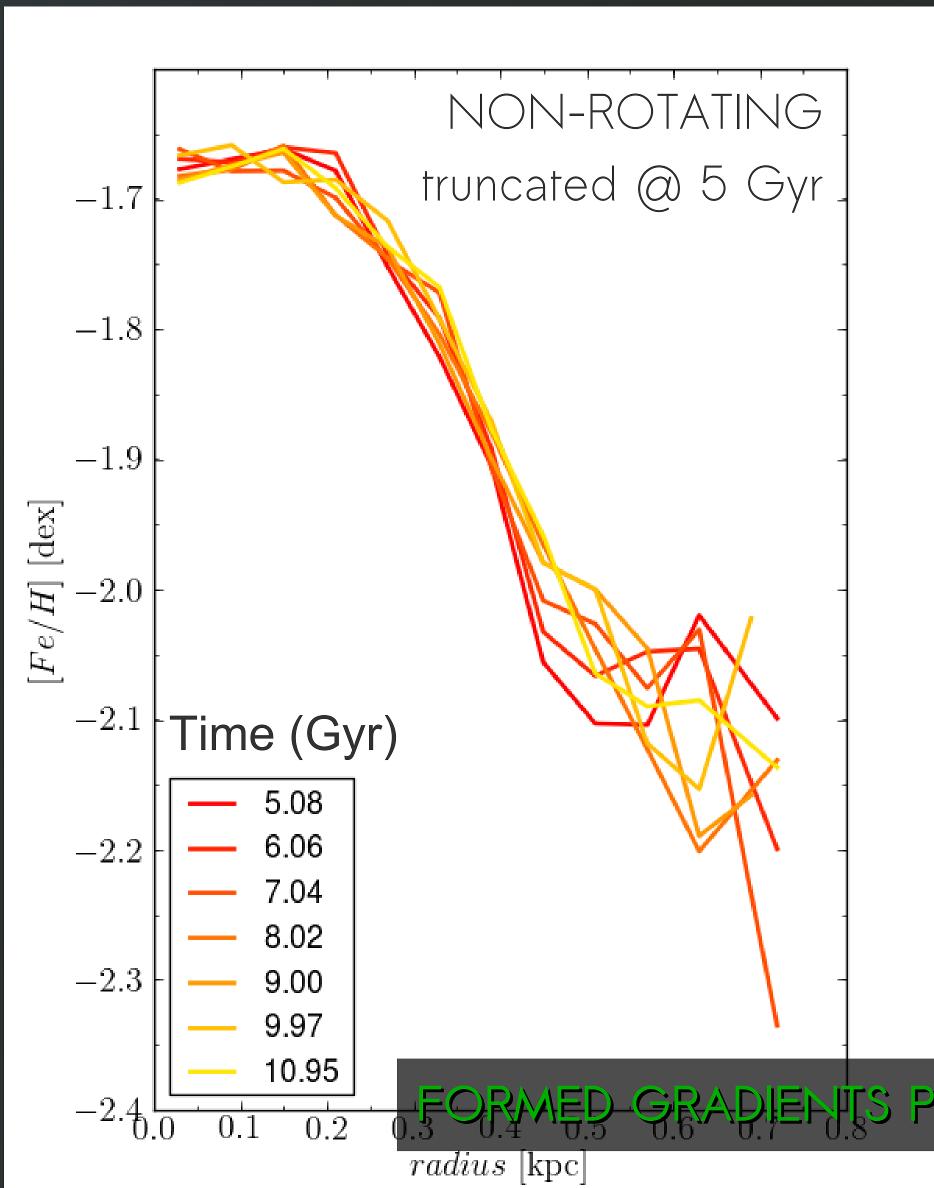
FULL EVOLUTION

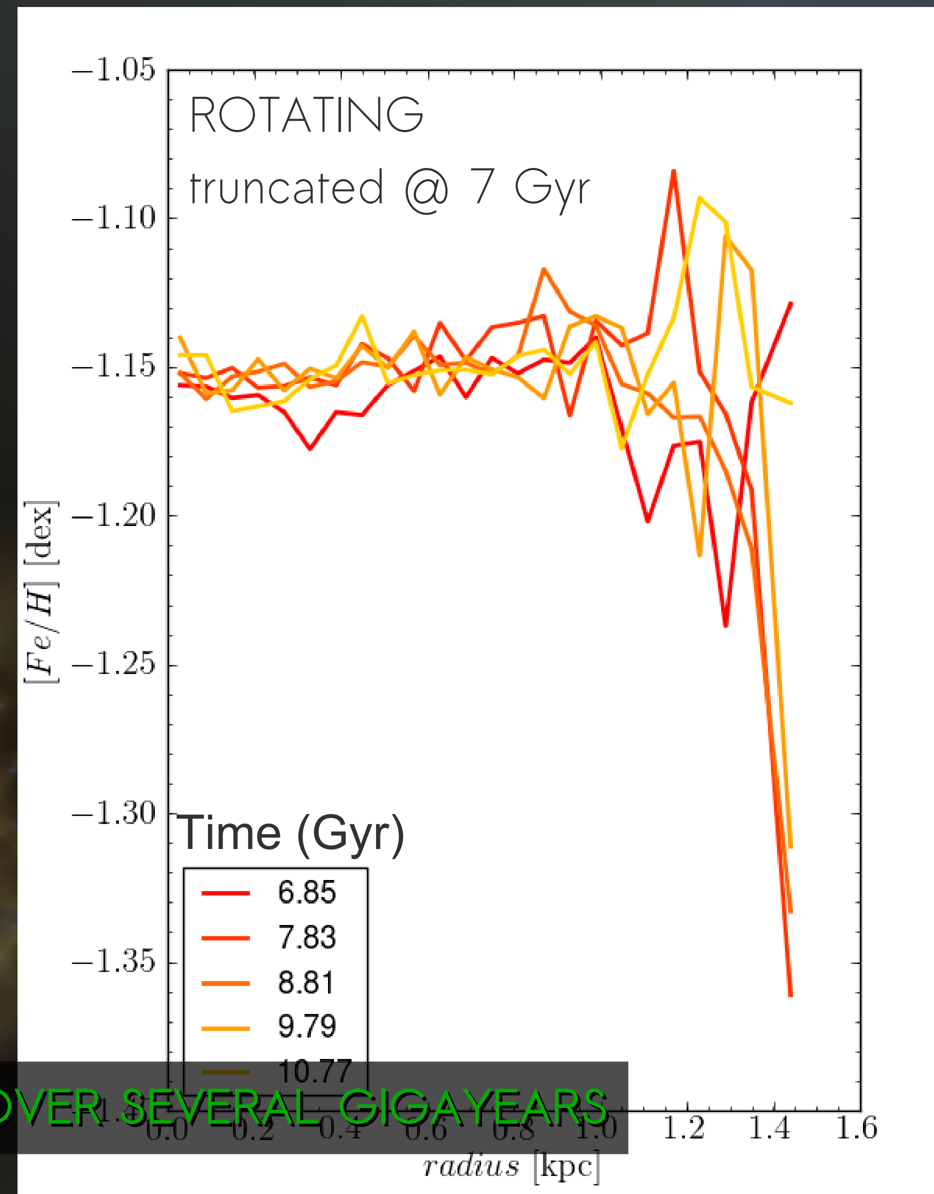


Schroyen et al. (2012-in prep)

'TRUNCATED SF' SIMULATIONS

Gradient evolution





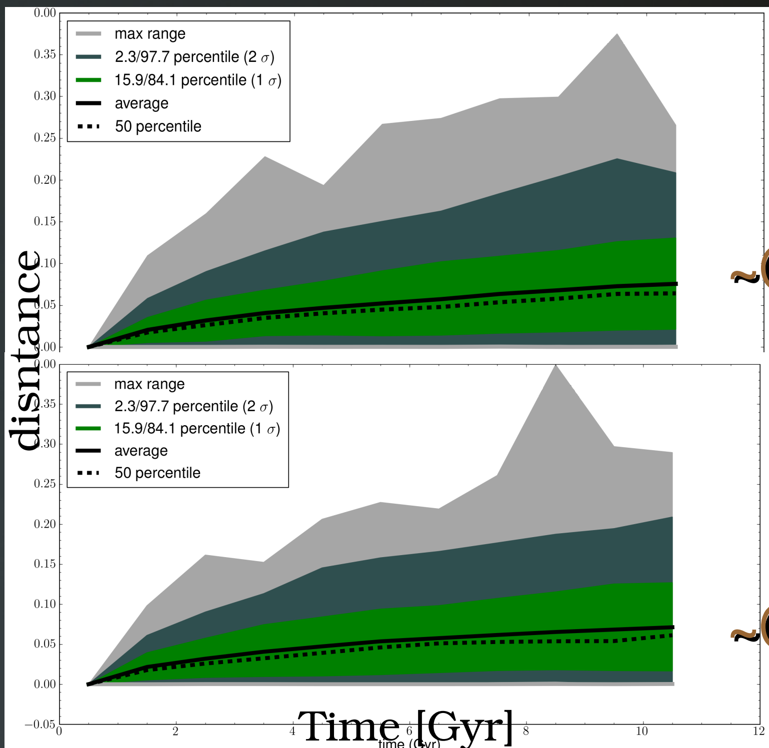
FORMED GRADIENTS PERSIST OVER SEVERAL GIGAYEARS

Schroyen et al. (2012-in prep)

Stellar migration (?)

LDT

HDT



non-rotating

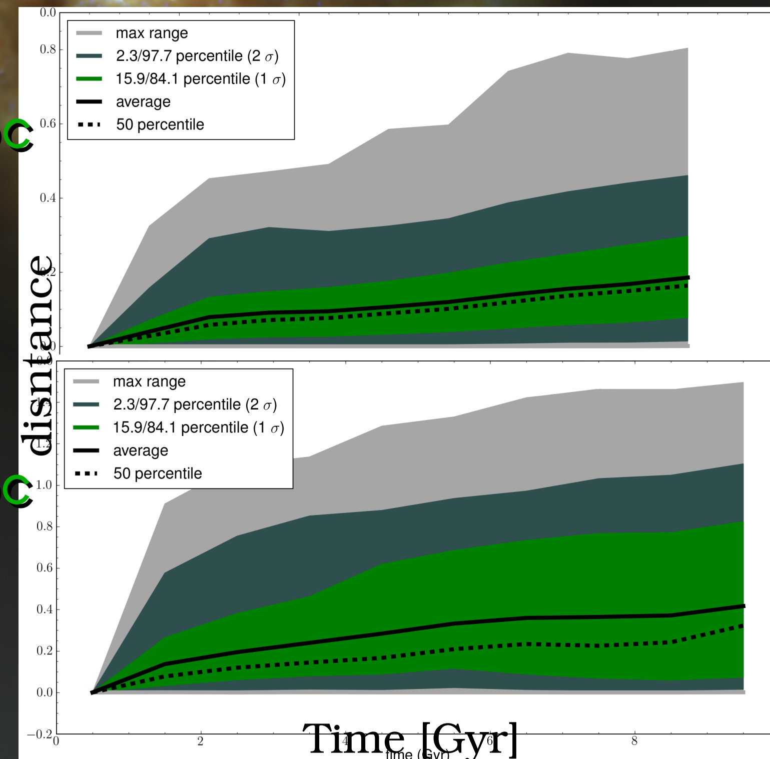
~0.25 kpc

~0.1 kpc

rotating

~0.35 kpc

~0.1 kpc



Stellar migration is limited

- Gradients can survive for **several Gyr**
- SF density threshold has influence => more **scattering** of stellar particles off **dense gas clouds**

Schroyen et al. (2012-in prep)

Stellar migration (?)

Connection to stellar migration in giant spirals

a totally different story...

Roškar et al. (2011) : *simulations*

Spiral patterns can significantly influence angular momentum through the **corotation scattering mechanism** (Selwood & Binney 2002)

Stellar migration is a key component in kinematical galaxy evolution

⇕

Dwarf galaxies :

Stellar migration is not an important effect in this mass scale

Transient spiral structures visible in gas, but not effective

No spiral structure in stellar body of DG **in our mass range** (10^6-$10^8 M_\odot$)

Schroyen et al. (2012-in prep)

Conclusions

Star formation modes :

angular momentum = second parameter in DG evolution

differentiates between **central/bursty** and **extended/continuous** SF

Gradients :

flat / negative gradient dichotomy consequence of SF modes

stability : gradients survive several gigayears

Stellar migration :

very limited stellar migration - contrary to giant spirals

influence from SF prescriptions (density threshold)

=> enhanced scattering off dense clouds

Schroyen et al. (2011)

Schroyen et al. (2012-in prep)