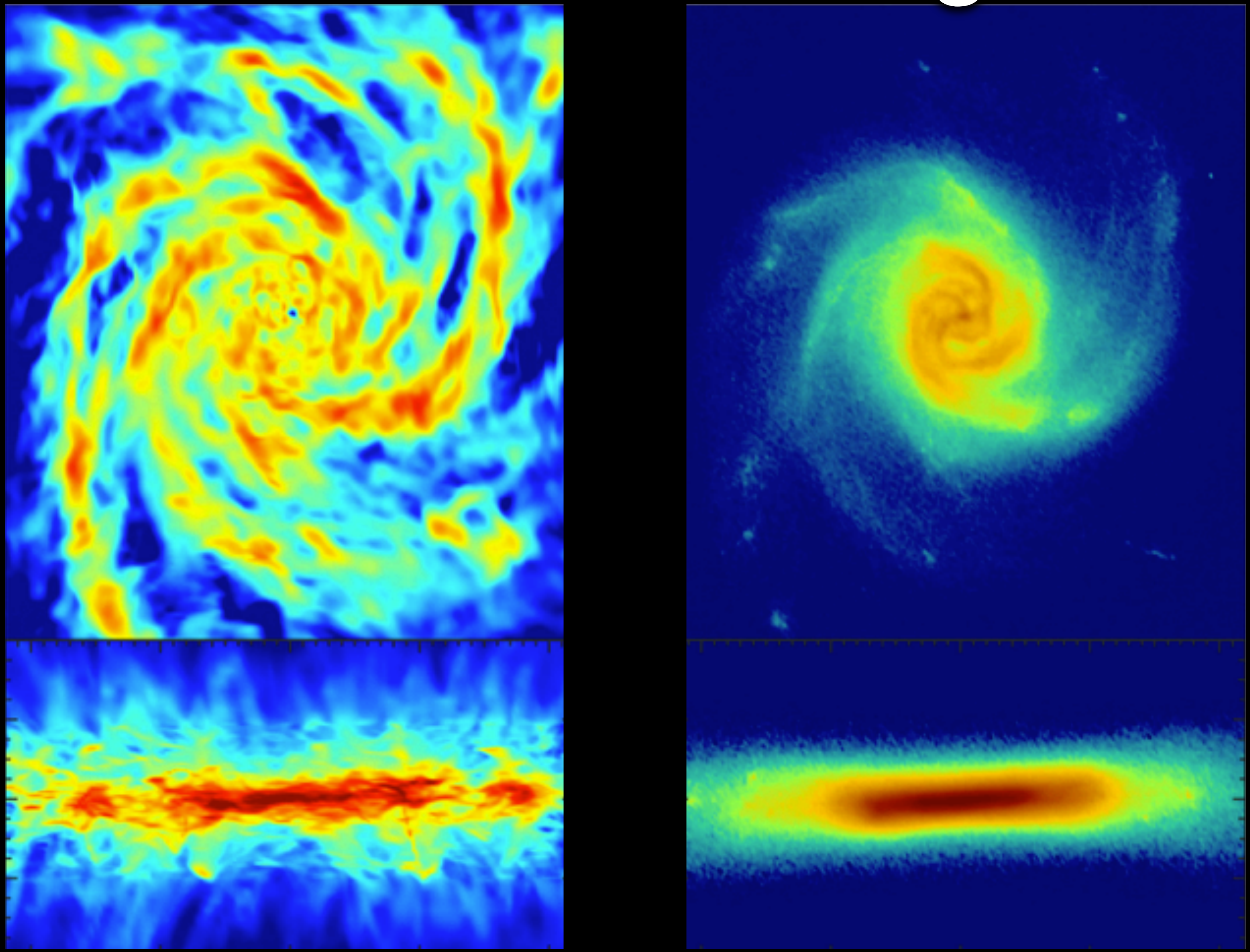
Chemo-dynamical modeling of thick/thin galactic disks



Sergey Khoperskov[1]

Misha Haywood[1], Paola Di Matteo[1], Owain Snaith[2], Matt Lehnert[3], Francoise Combes[4]

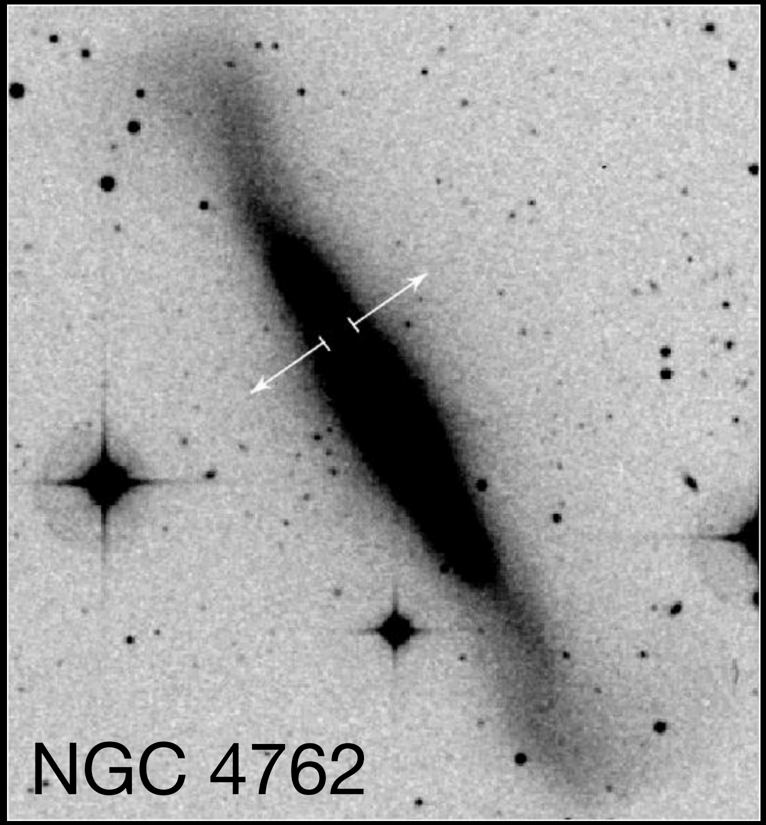
[1]GEPI, Observatoire de Paris, Meudon, France, [2]KIAS, Seoul, South Korea, [3]IAP, Paris, France, [4]LERMA, Observatoire de Paris, Paris, France

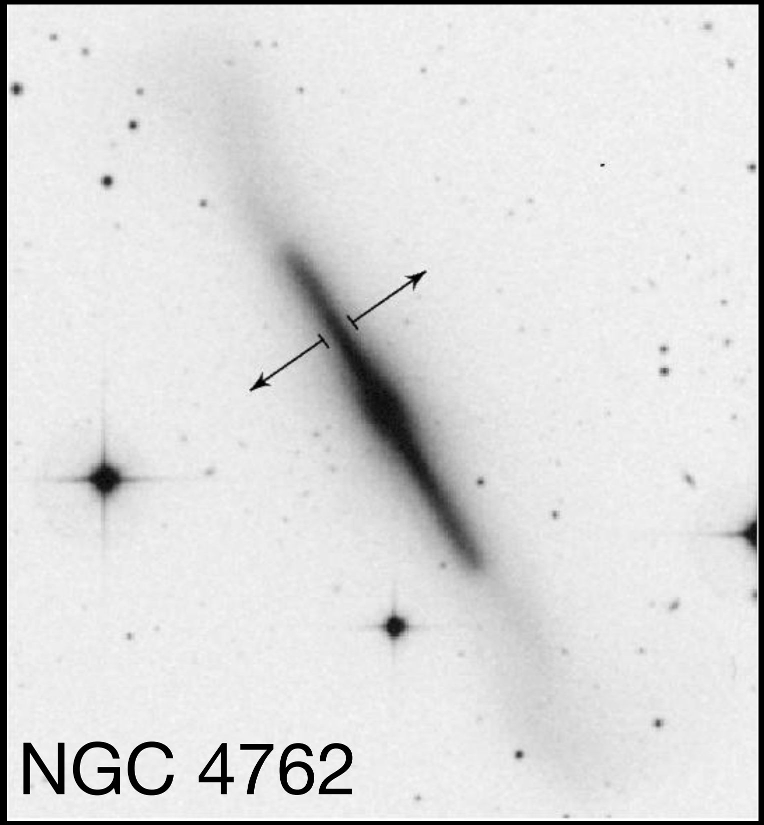
Galactic disks

Most spirals have two disk components

Thicker disk:
very common in other galaxies
appears to be old (> 6-10 Gyr)
moderately metal-poor

Thin disk:
relatively younger
moderately metal-rich
dynamically colder

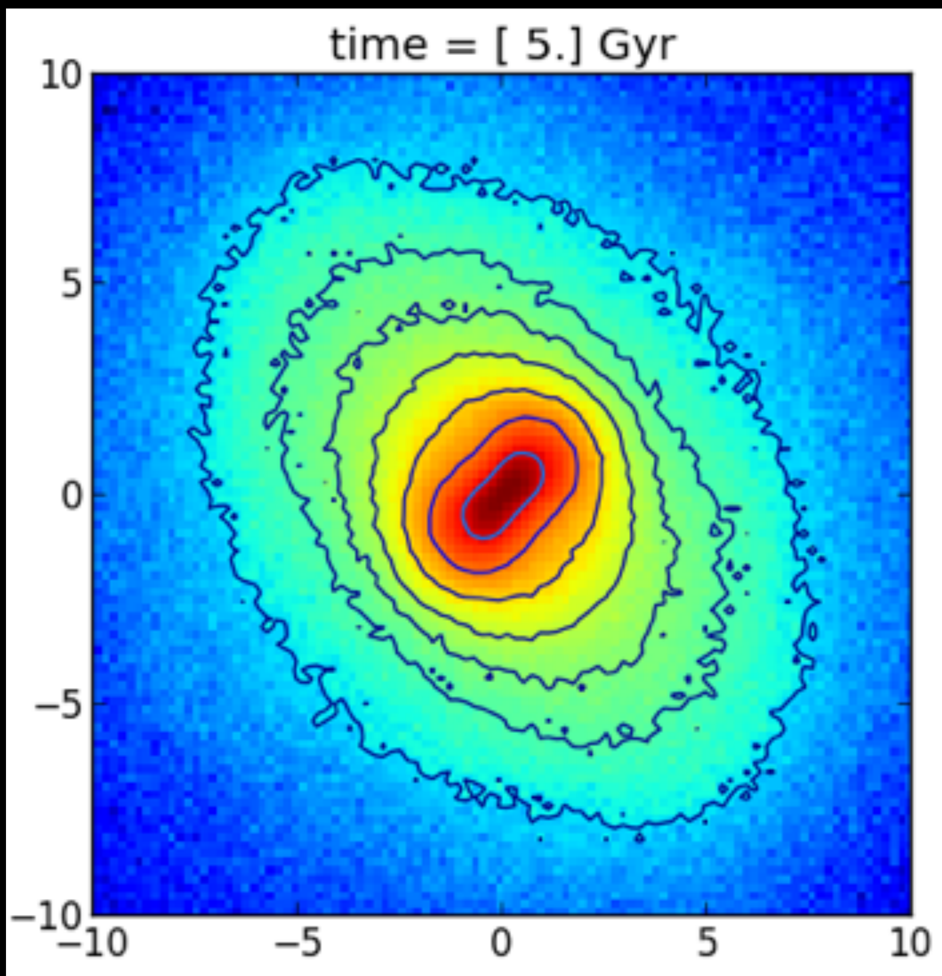


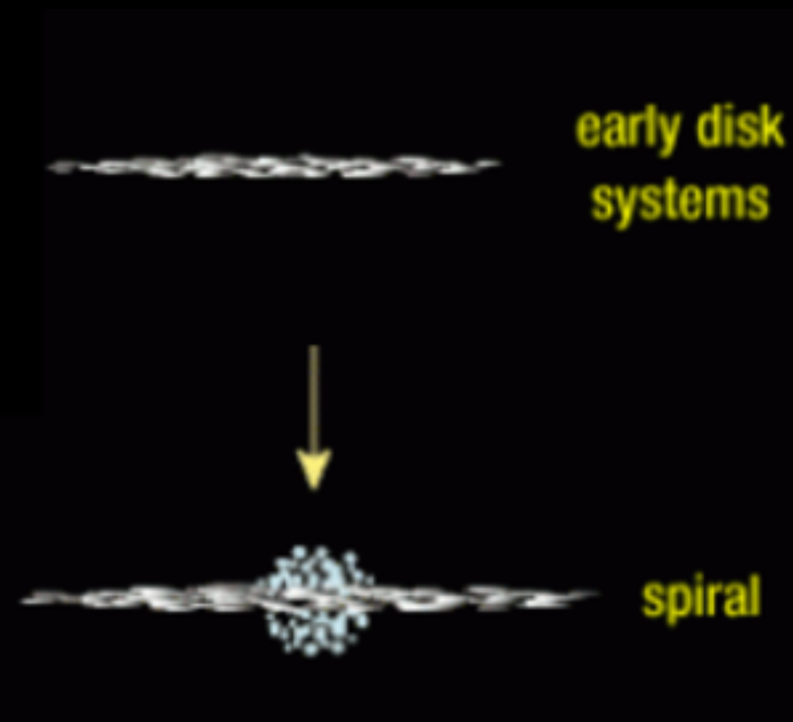


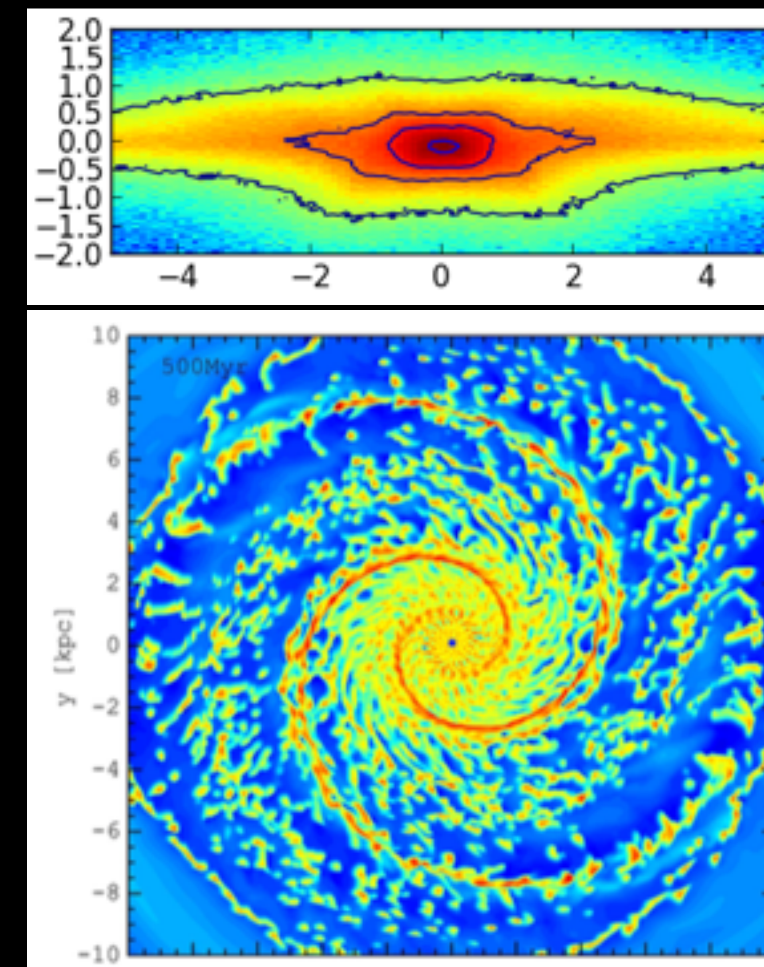
Thick disk recognizable as a relict of the early galaxy

ISM conditions at epoch of galaxy formation: density, chemical composition, turbulence

- Secular evolution affects galactic disk dynamics
- Dynamical information can be vanished through disk heating processes







- The detailed abundance pattern reflects the chemical evolution of the gas from which the aggregate formed.

- Disks formation/evolution are still recognizable by their chemical signatures

Thick disk formation

- Gas rich mergers (e.g. Brook+ 2004, 2005). The thick disk stars are born in-situ
- Accretion of satellites (e.g. Abadi+ 2003). Thick disk stars come in from outside
- Perturbation by merging satellites (e.g. Di Matteo+ 2011). The orbital energy of the satellite goes into thickening the disk
- Formation in turbulent gas-rich thick gas disk (e.g. Bournaud+ 2009). Dissolution of giant gas agglomeration in clumpy galaxies (Kroupa 2002, Bournaud+ 2008).

Outline

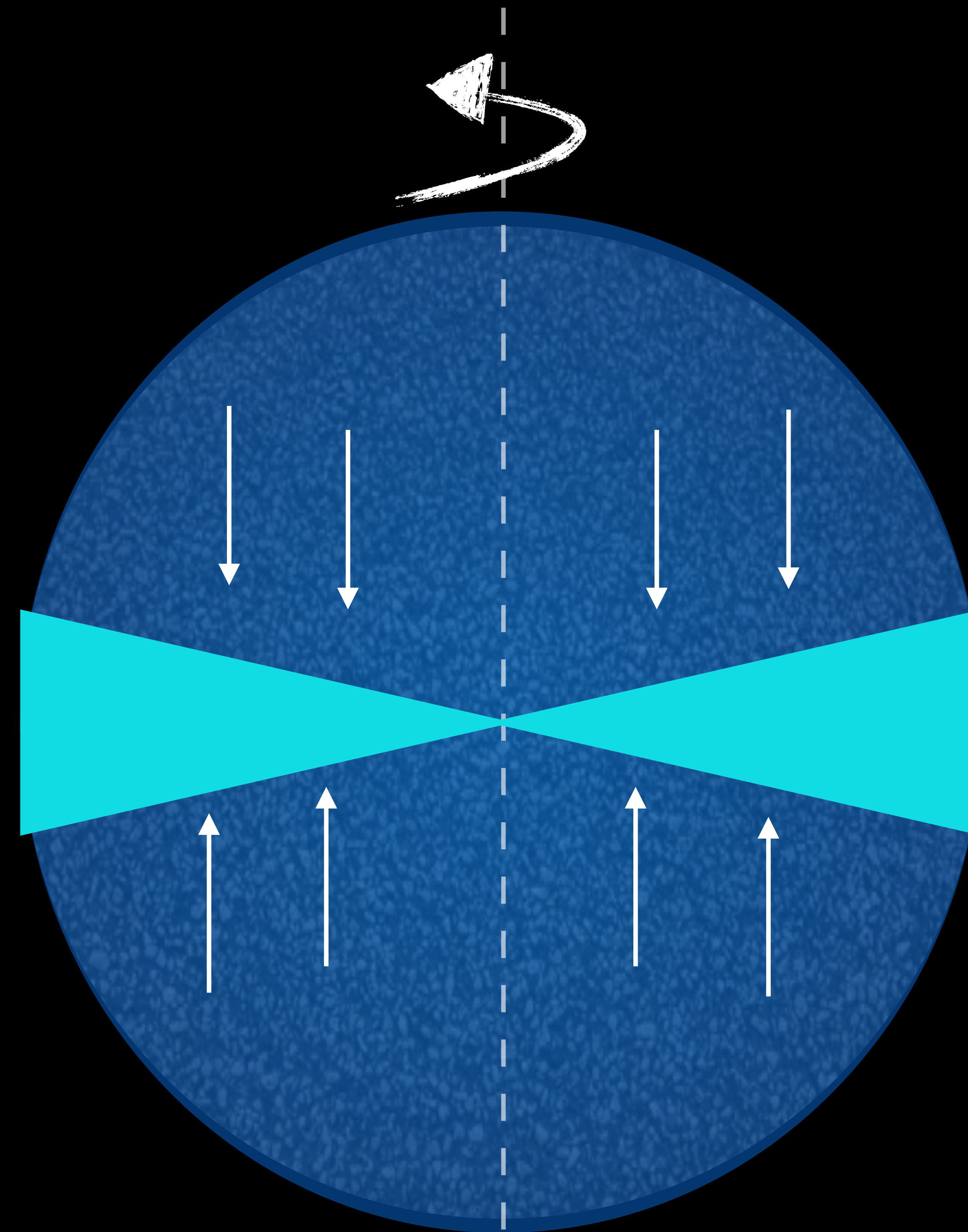
Starting from turbulent gas rich disk…

- can we reproduce realistic thick / thin disks?
- what do we need to separate thin and thick disks formation phases?
- chemical evolution?

Model

live DM halo
rotating gaseous halo
$T_{ini} \sim 10^5 - 10^6$ K

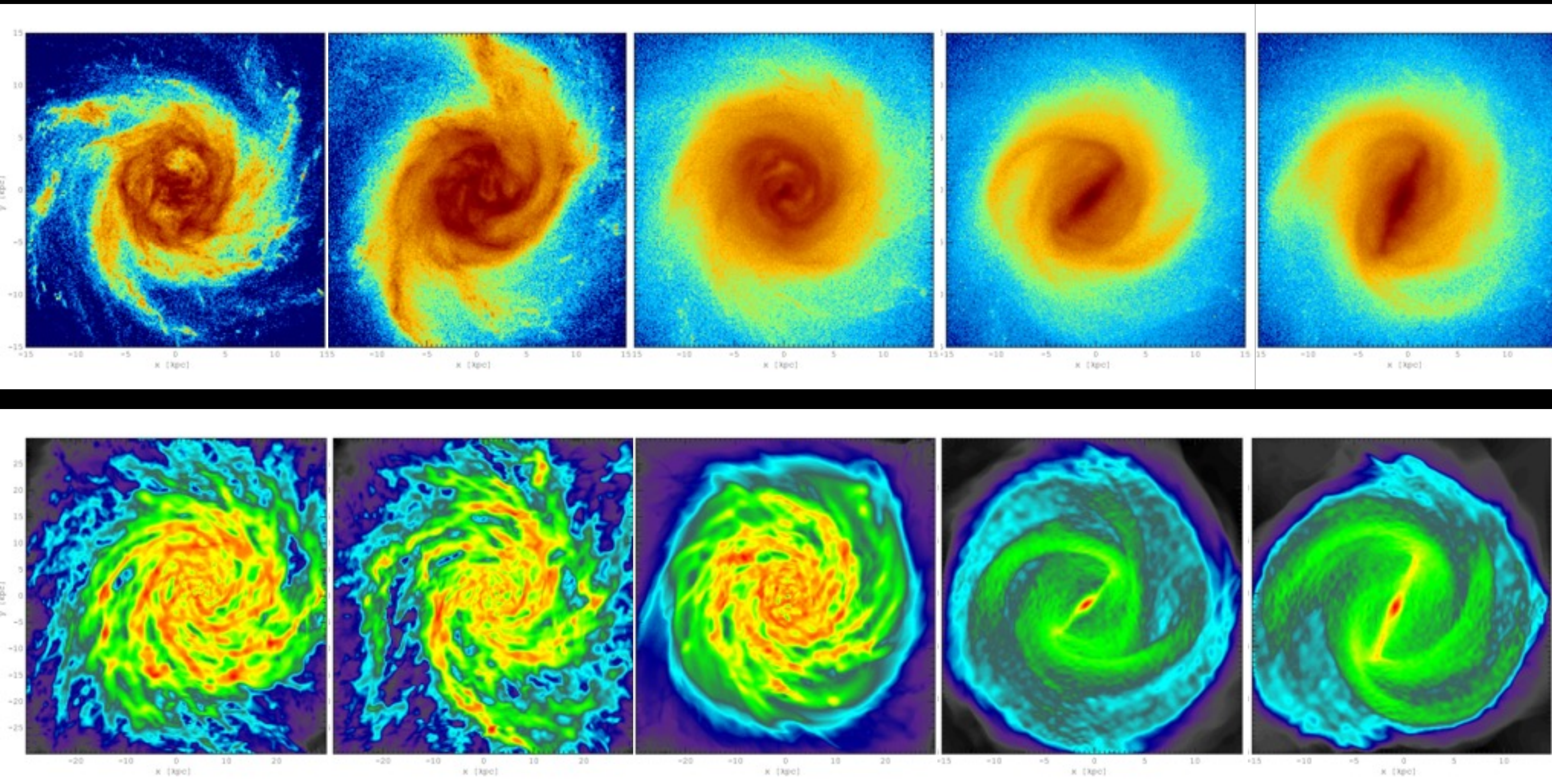
- Gasdynamics (grid based)
  - static mesh refinement
  - TVD MUSCL, 2nd order in time, 3nd in space
  - Riemann solvers (HLLC)
  - passive scalars advection
    - (H, He, Si, Fe, Mg, O… 8 species in total)
  - radiative cooling/heating (metallicity dependent)
  - stellar feedback (only thermal:
    - SNI, SNII, AGB stars, metallicity dependent)
  - star formation ($T<100$ K, $M^{*}_{ini}>10^3\ M_{o}$, div $V<0$)
- Stellar component (N-body)
  - stellar yields
  - mass loss
  - IMF (Kroupa 2001)
- Dark matter (N-body)
- Gravity: TreeCode
  ($\theta=0.5$, $\Delta t=10^4$ yr, AVX instructions)
  Khoperskov & Berczik in prep



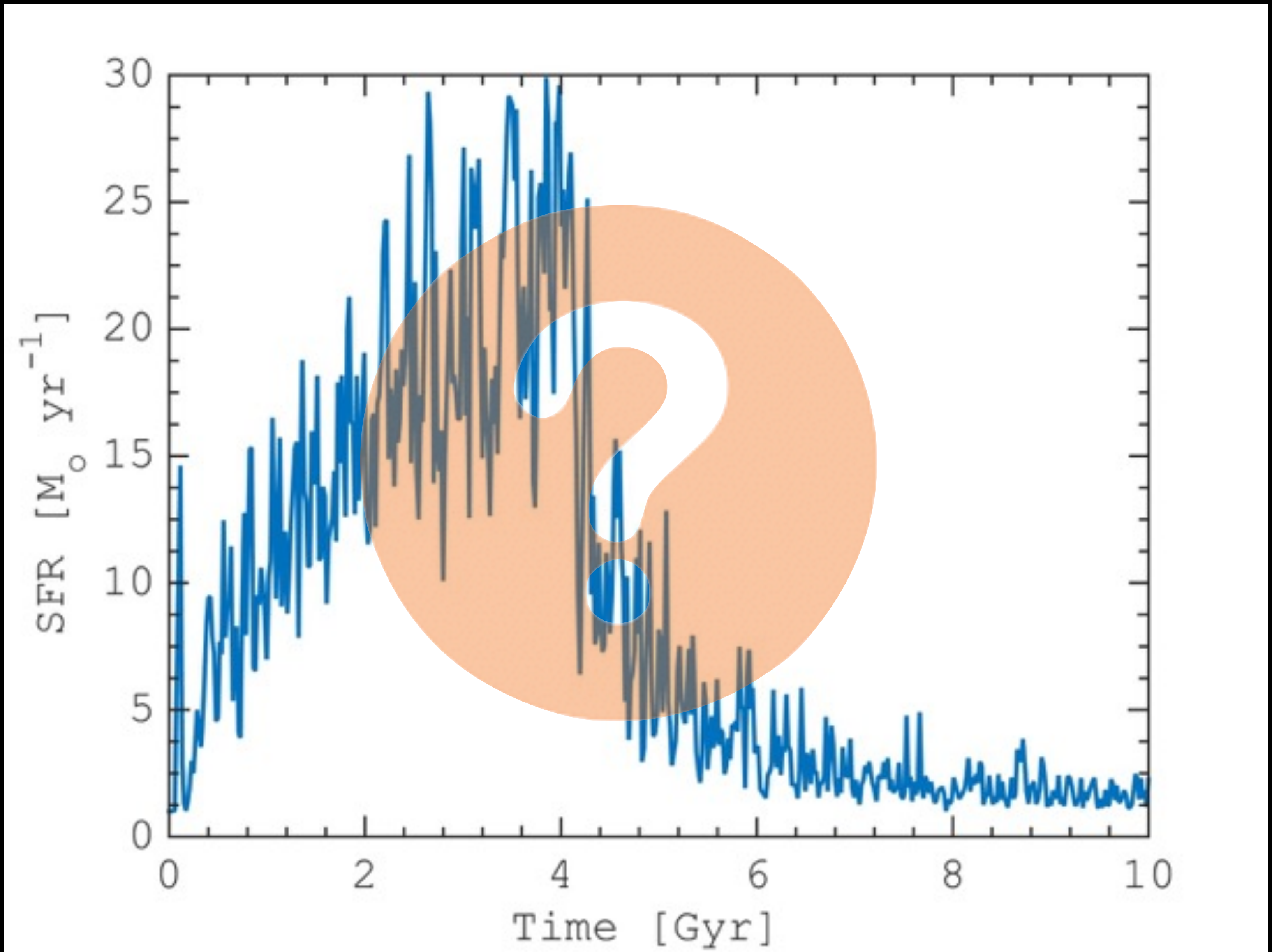
similar to Cole+2013,
Aumer & White 2013, Marasco+ 2015

Stellar disk formation

0.5 Gyr 1 Gyr 3 Gyr 4 Gyr 10 Gyr



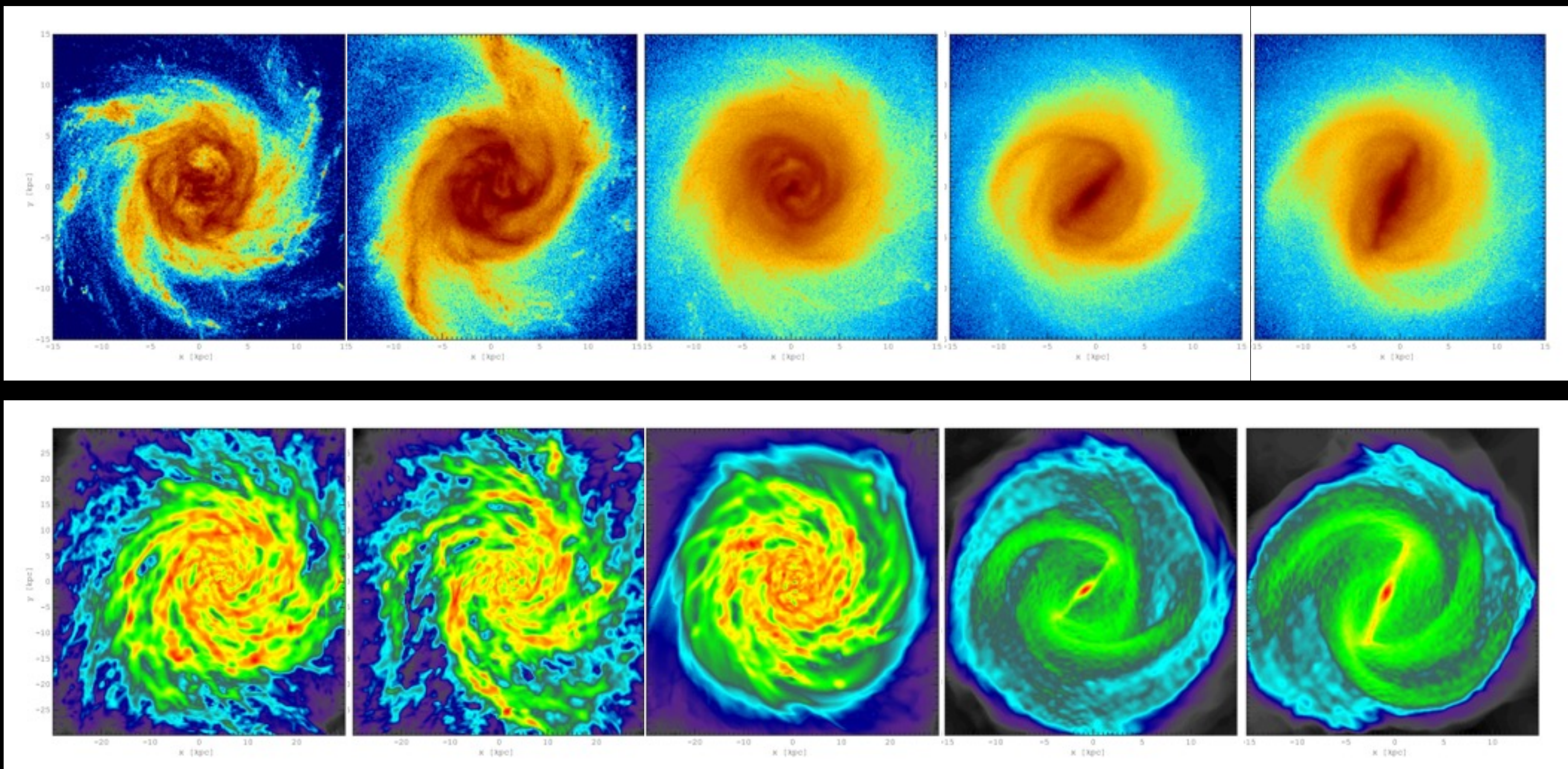
Star formation history



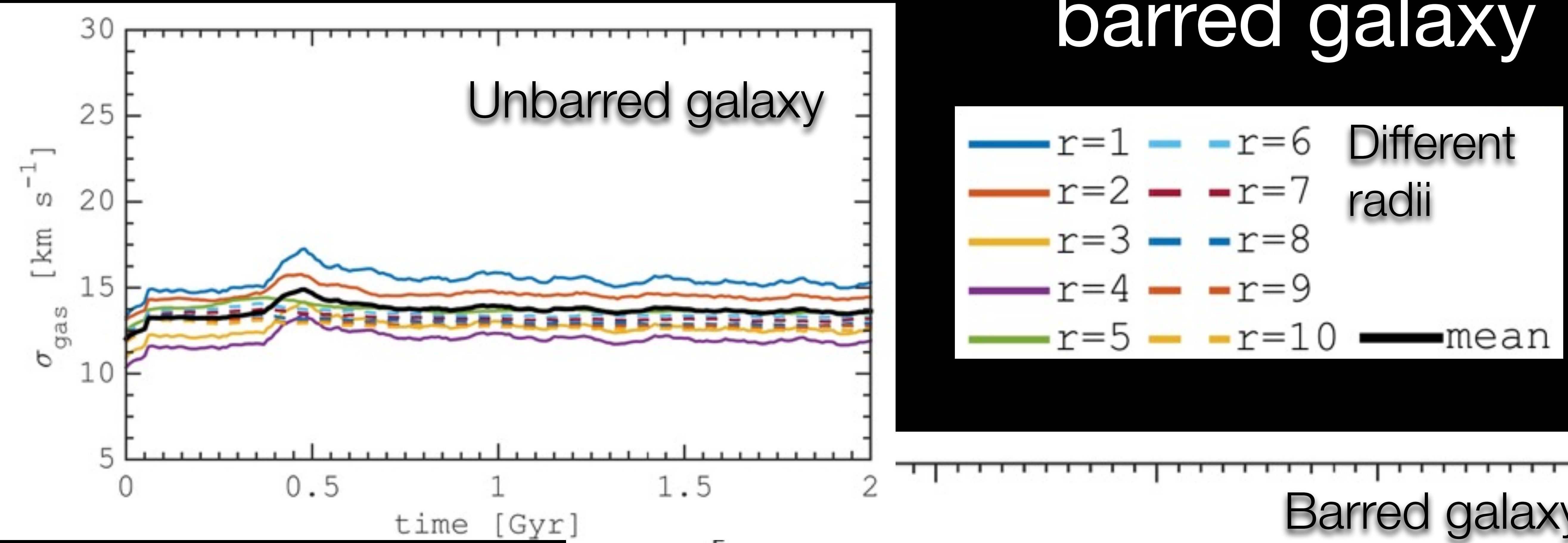
Rapid decrease of star formation rate

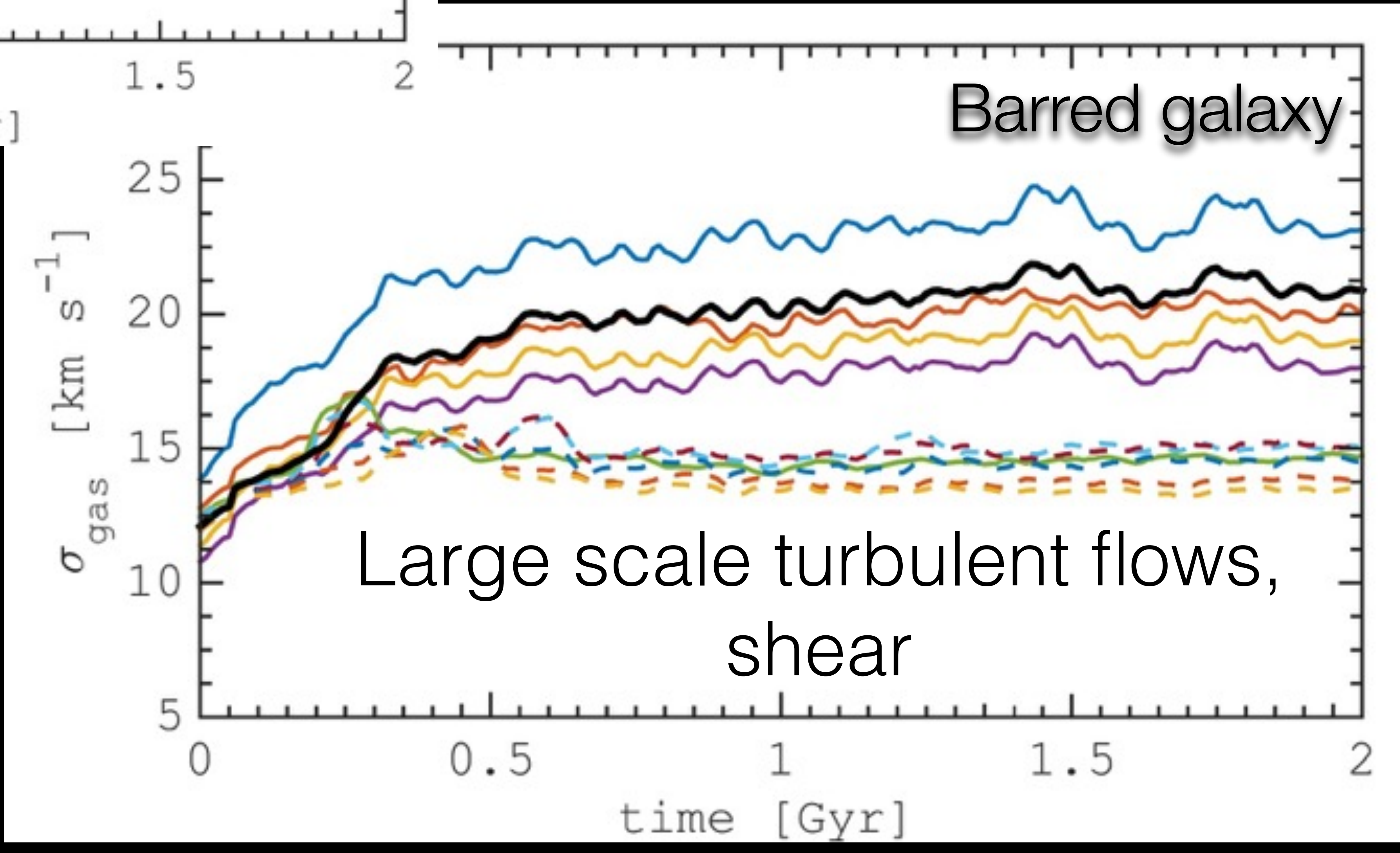
Stellar disk formation

0.5 Gyr 1 Gyr 3 Gyr 4 Gyr 10 Gyr



Gas velocity dispersion in a gas-rich barred galaxy





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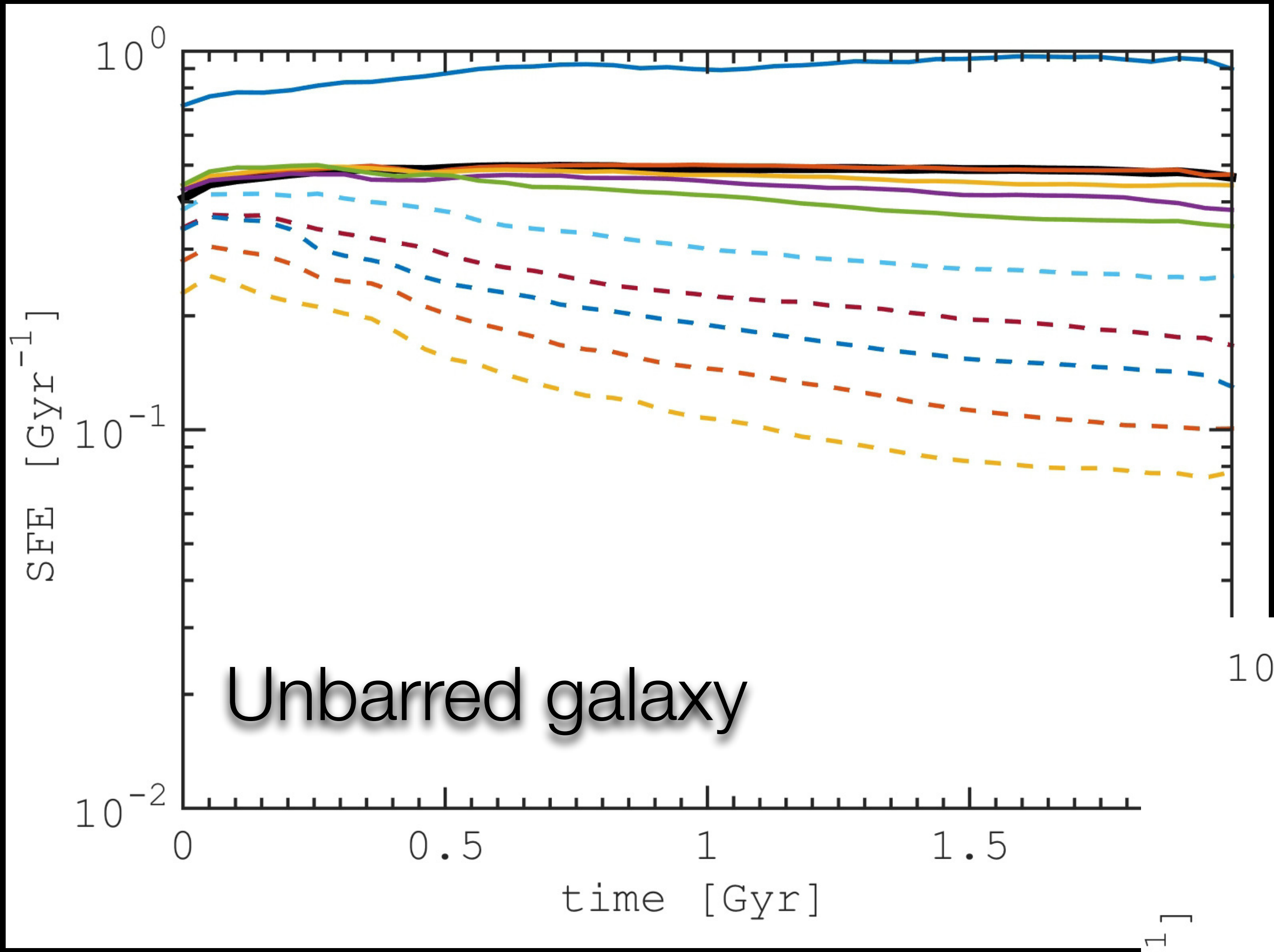
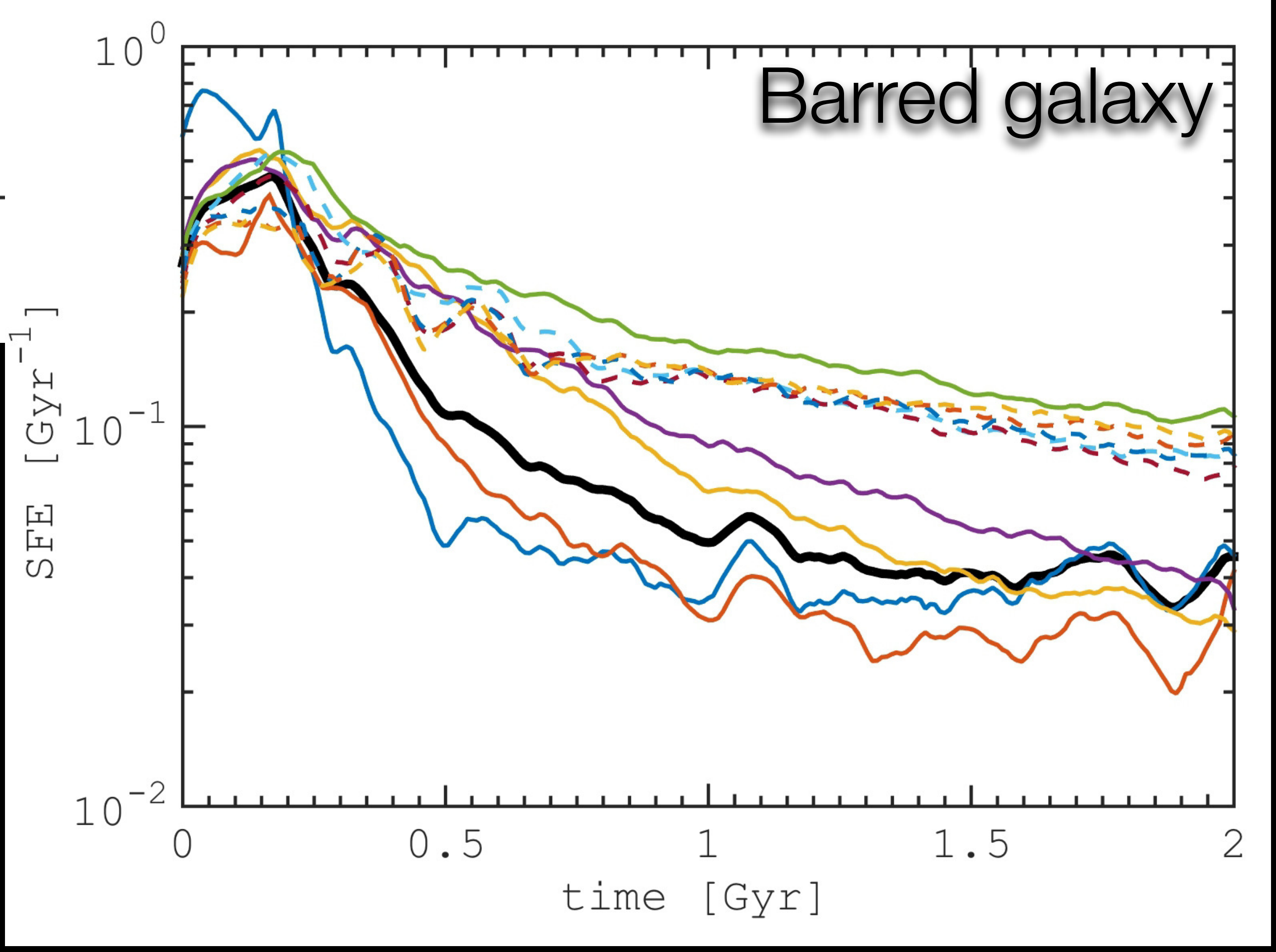
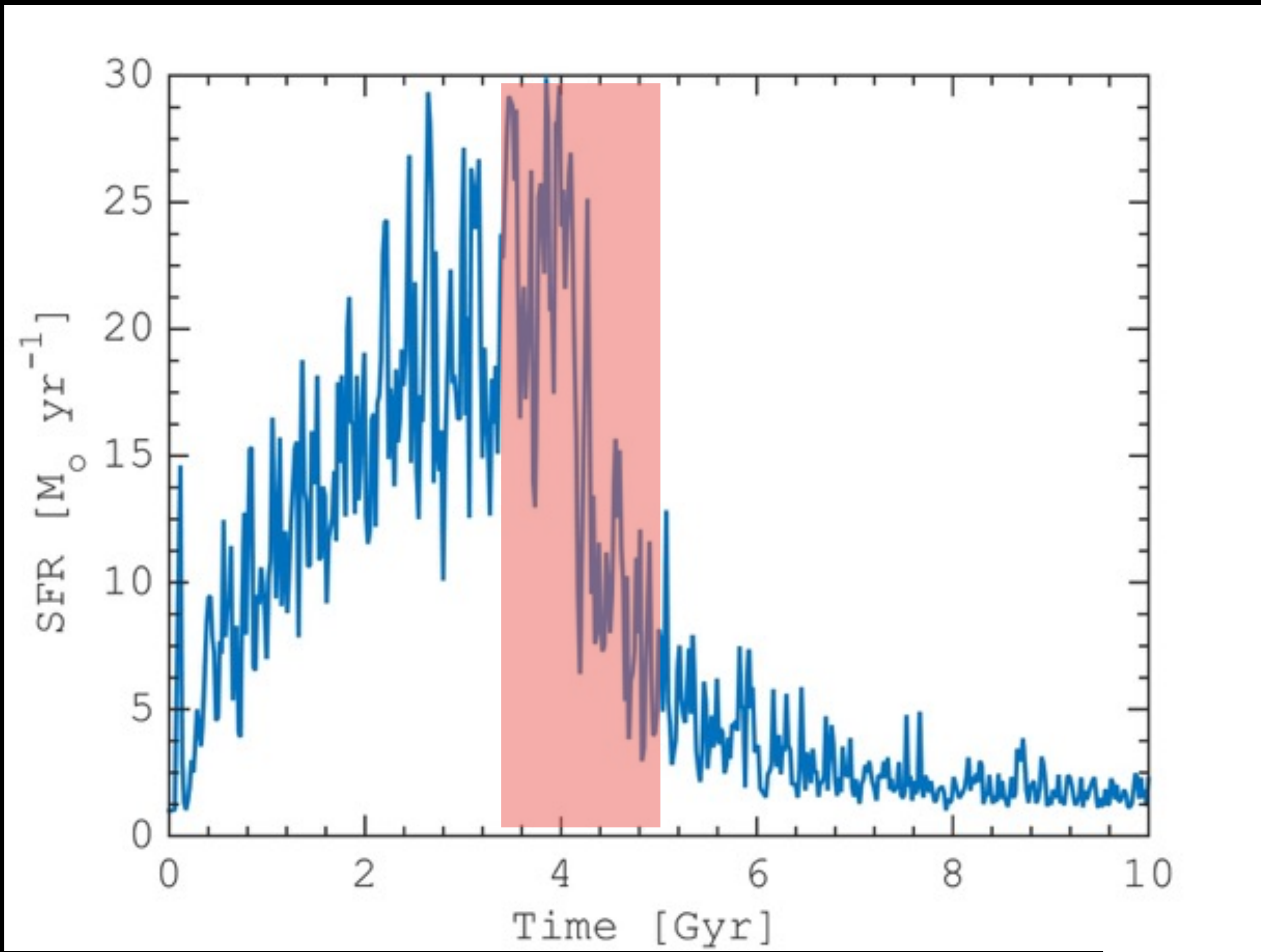
Star formation efficiency in a gas-rich barred galaxy





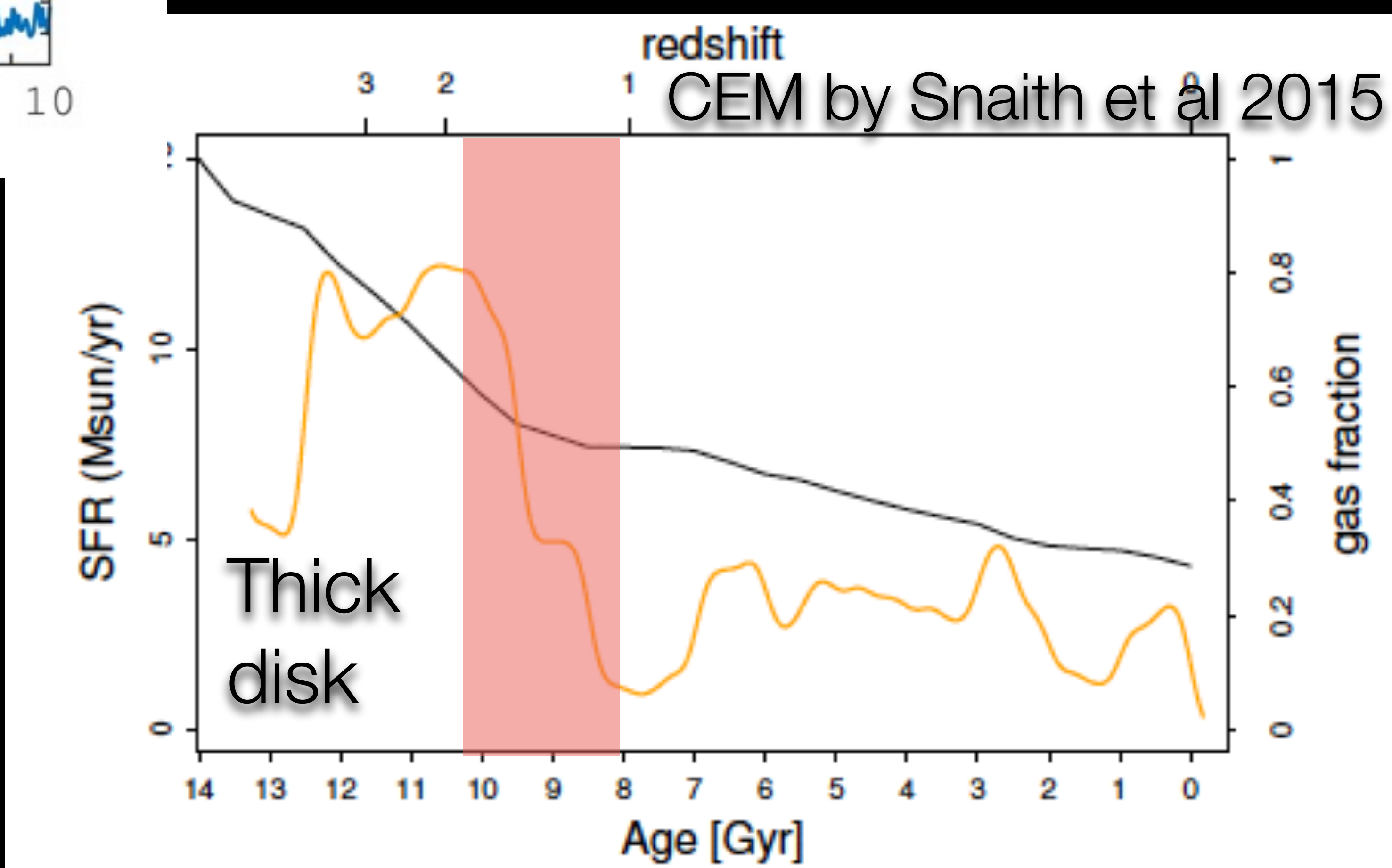
SK, Haywood, Di Matteo + 2017

Star formation history

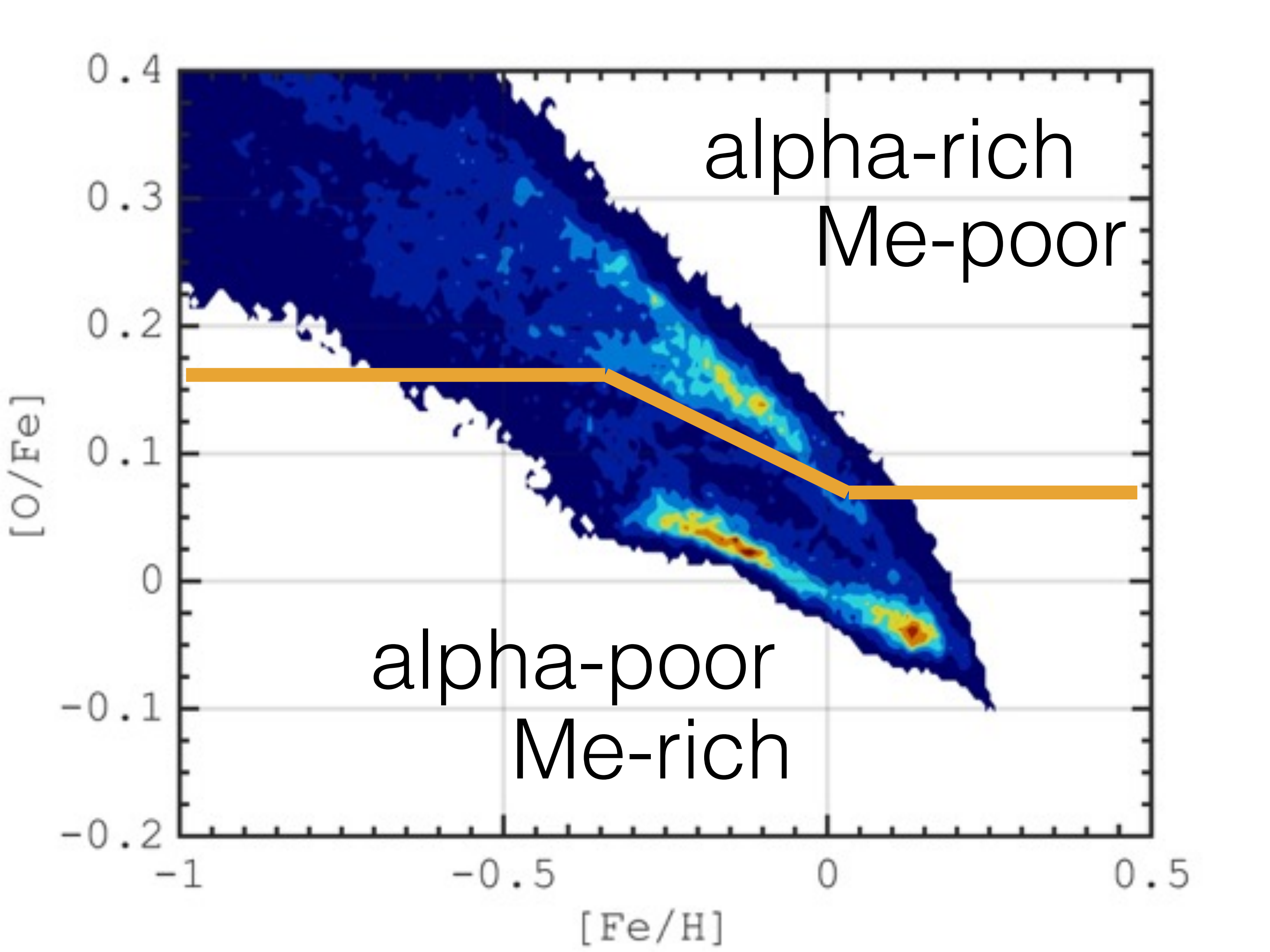


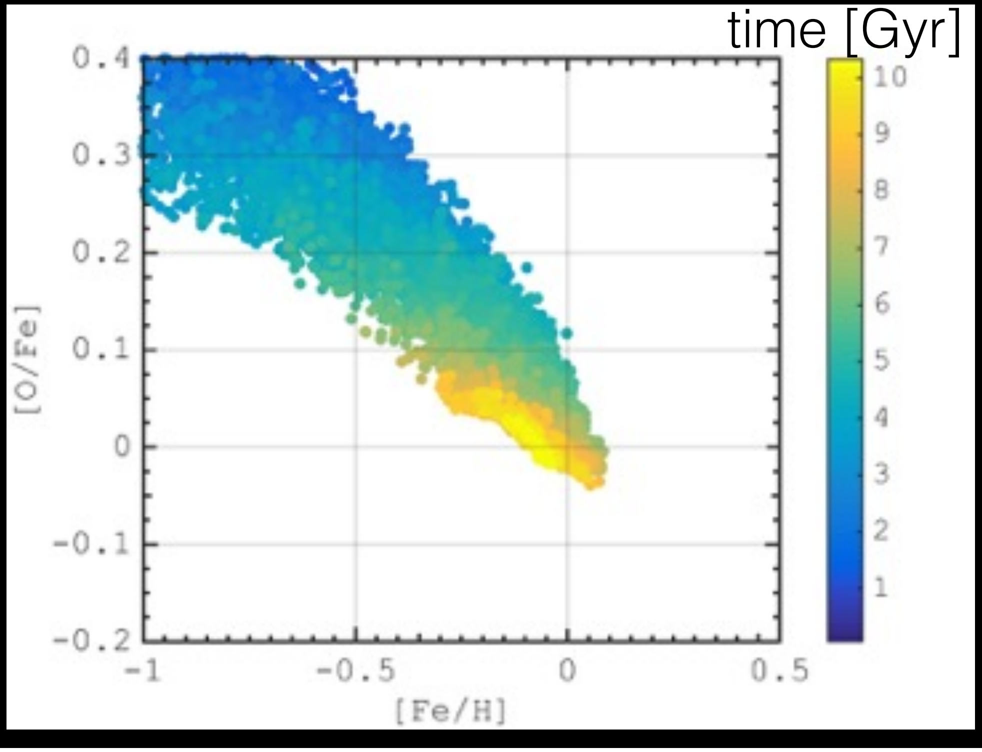
MW star formation history

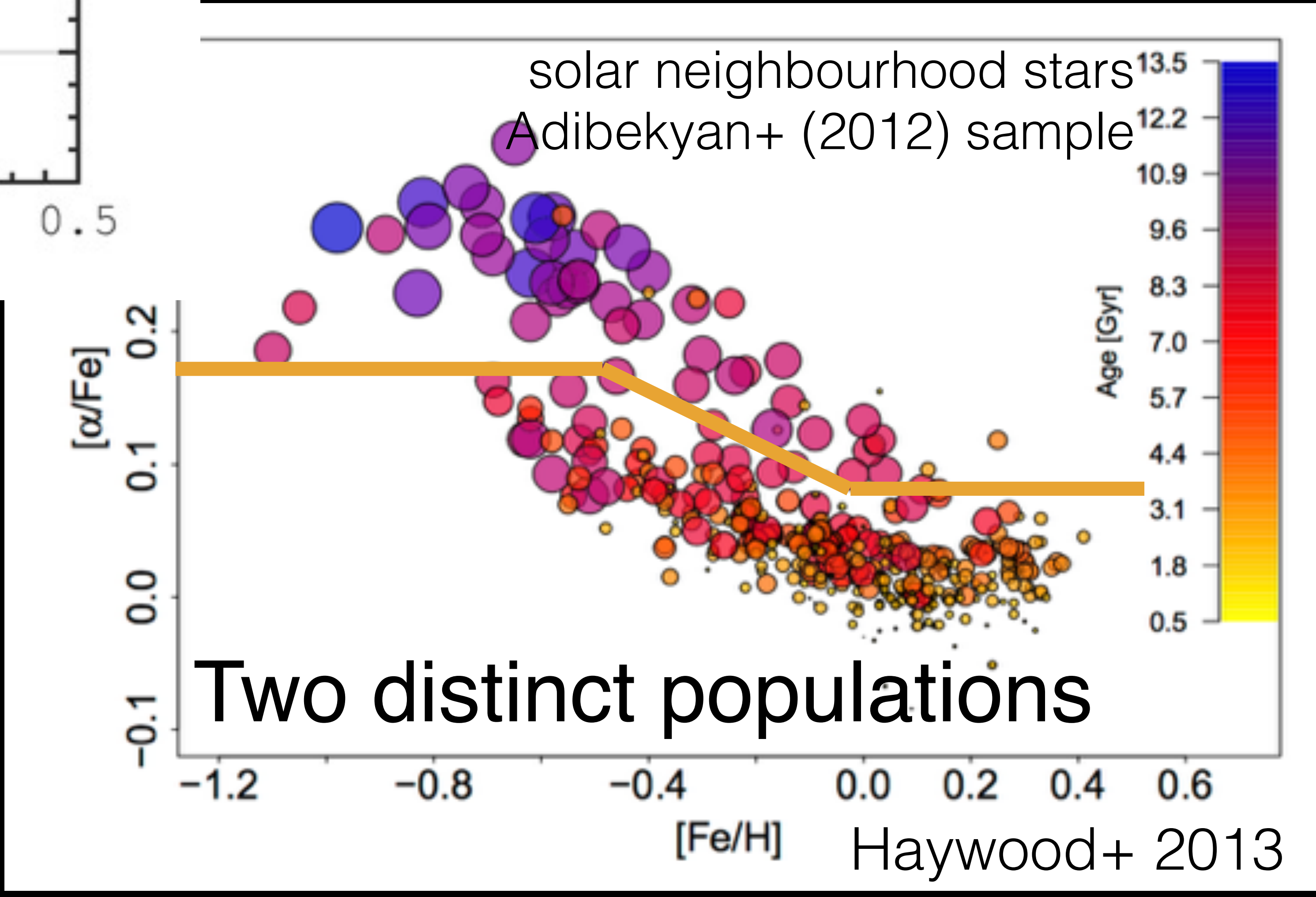
Rapid decrees of SF
can be explained
by the formation
of a bar in a gas-rich disk



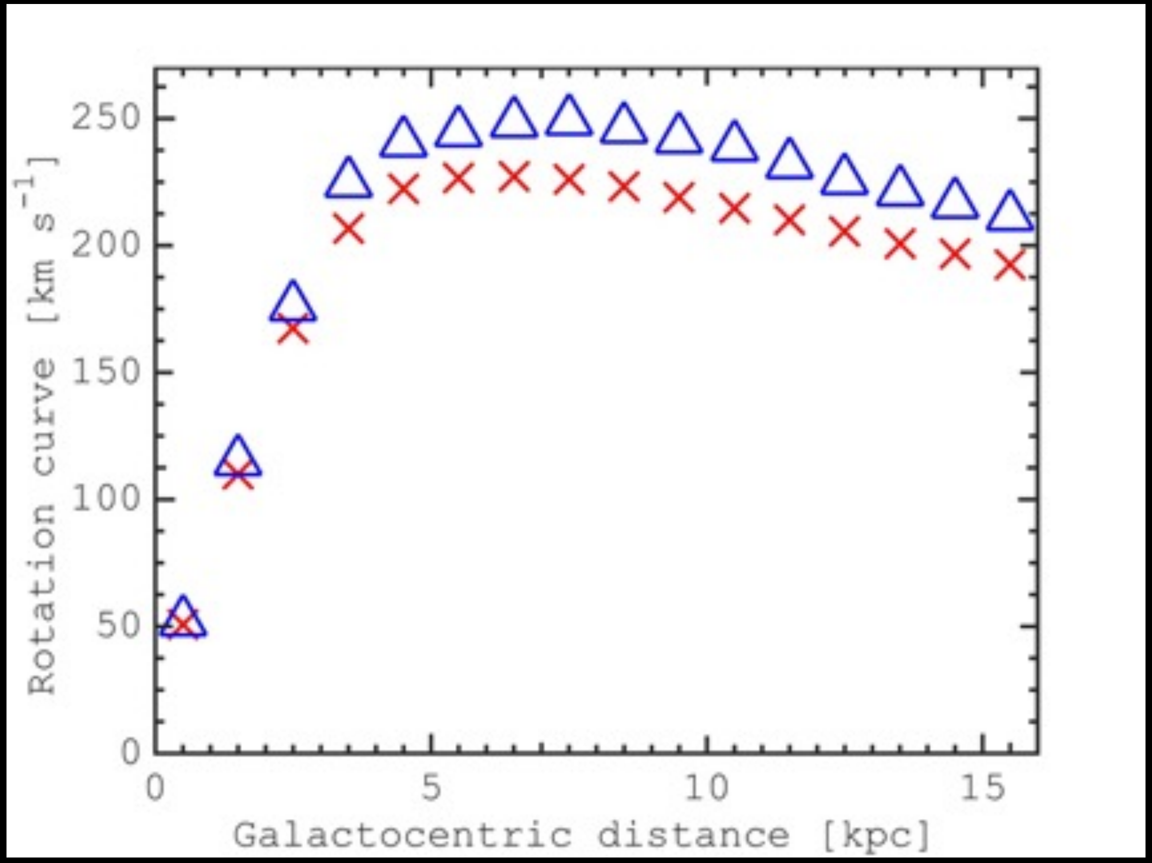
Chemical evolution





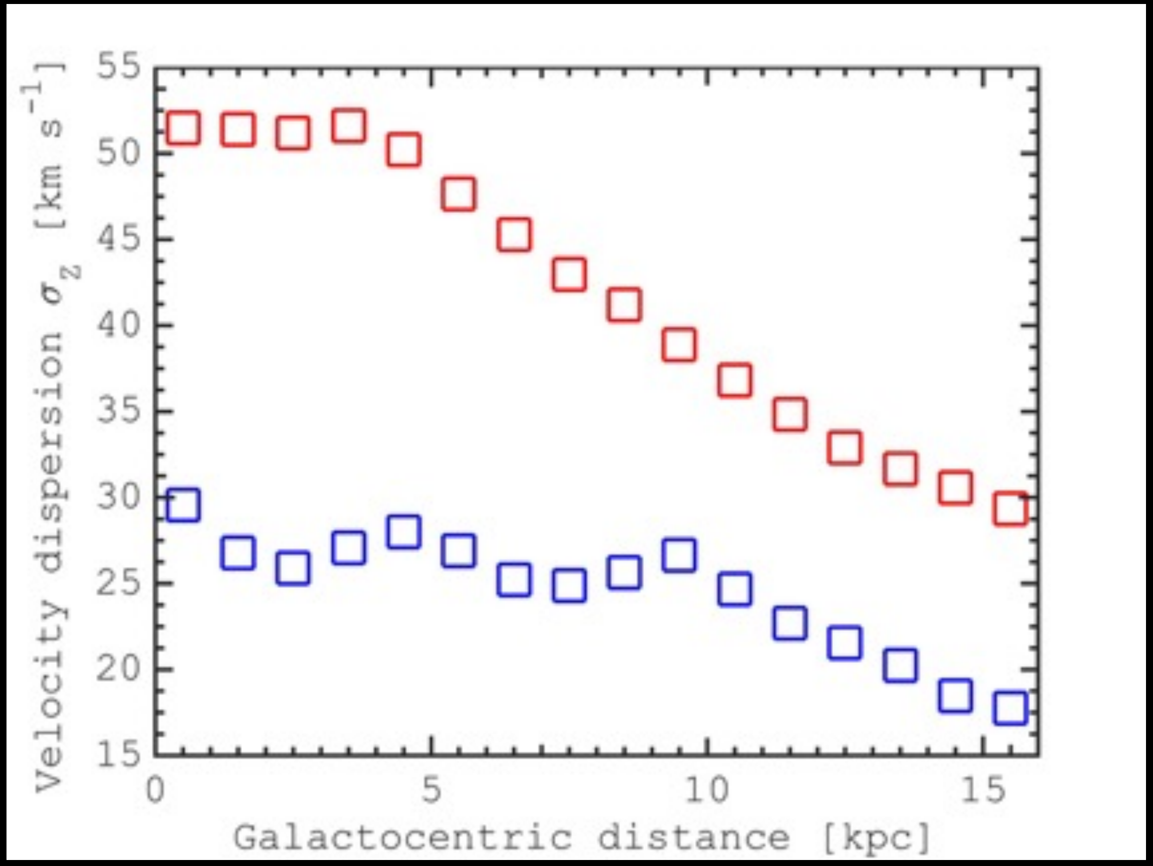


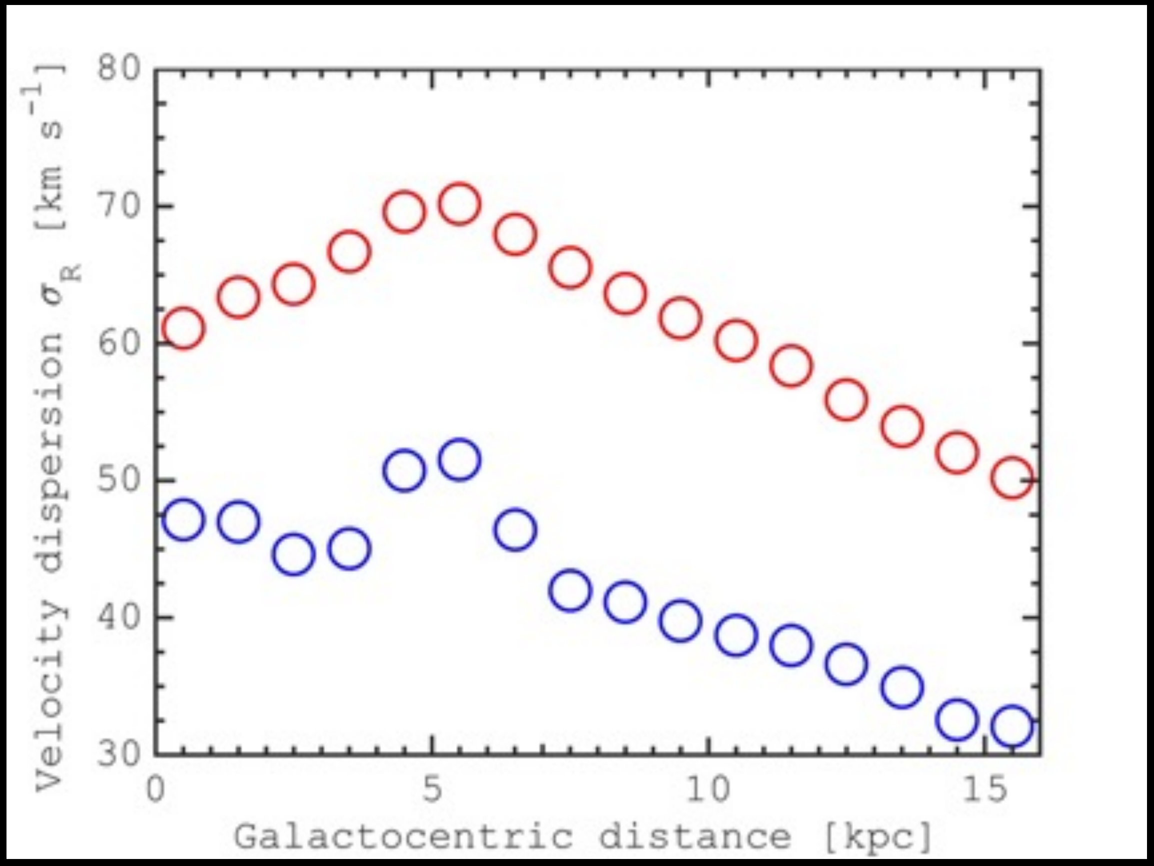
Disks kinematics



([O/Fe]>0.1)

([O/Fe]<0.1)





Alpha-enriched disk rotates slower and it is kinematically hotter

Summary

- The thick disk formed in a well mixed turbulent gaseous disk which gave rise to a steep and monotonic chemical enrichment lasting a few Gyr

- Thin disk is the result of slow (and long) star formation

- Formation of the bar can separate these two phases decreasing global star formation rate. This provides evidence for the existence of two different epochs of star formation in the galaxy, which we have defined as the epochs of thick disk and thin disk formation.

- The transition between the two epochs is imprinted in [α/Fe] variation as a function of time/space/metallicity