A disc galaxy model applied to the chemo-dynamics of the bar-bulge region and to the outer regions of the disc

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Major mergers : « Constrained », or «Dynamical», or «Detailed » simulations, with partly «idealised» initial conditions. Includes gas, SF, feedback and cooling.

Improvements:

– Include a hot gaseous halo
– A better modelling of the progenitors (resemble galaxies at intermediate redshifts)
– A more complete comparison of simulation final results with nearby galaxy properties (morphological, kinematical, photometrical, chemical)
– Better resolution simulations :
  N_{total} 5.5M (standard resolution SR) - 27.5M (high resolution HR)
  Standard mass resolution : (m_baryonic = 5x10^4 Msun, m_DM = 2x10^5 Msun)
  and linear resolution 25 pc.
  High resolution m_baryonic = 10^4 Msun
– Over 200 simulations

Merger occured 8 – 10 Gyr ago

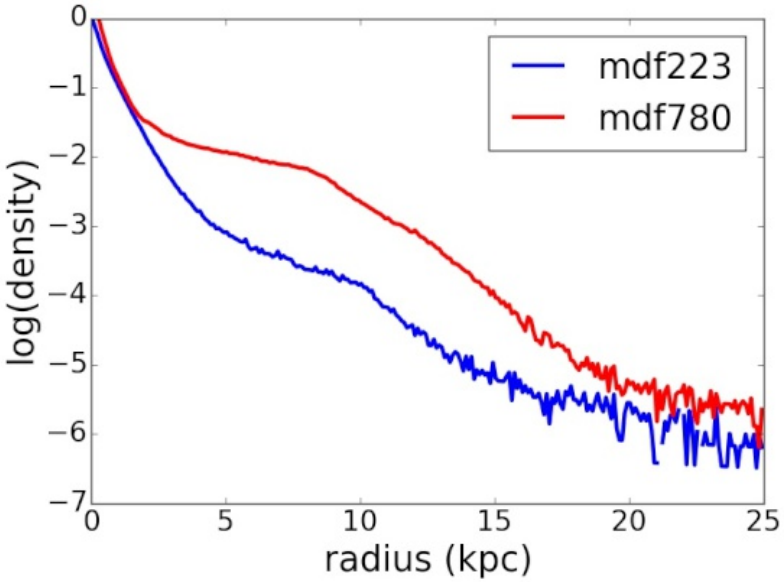
Most of this talk is from :
EA, Rodionov, Peschken, Lambert (ARPL16 = ApJ, 2016)
Rodionov, EA, Pescken (RAP16, subm.)
Peschken, EA, Rodionov (PAR16, subm.)
EA, Peschken, Rodionov (APR16, subm.)
EA, Rodionov, Prantzos (ARP16, in prep.)

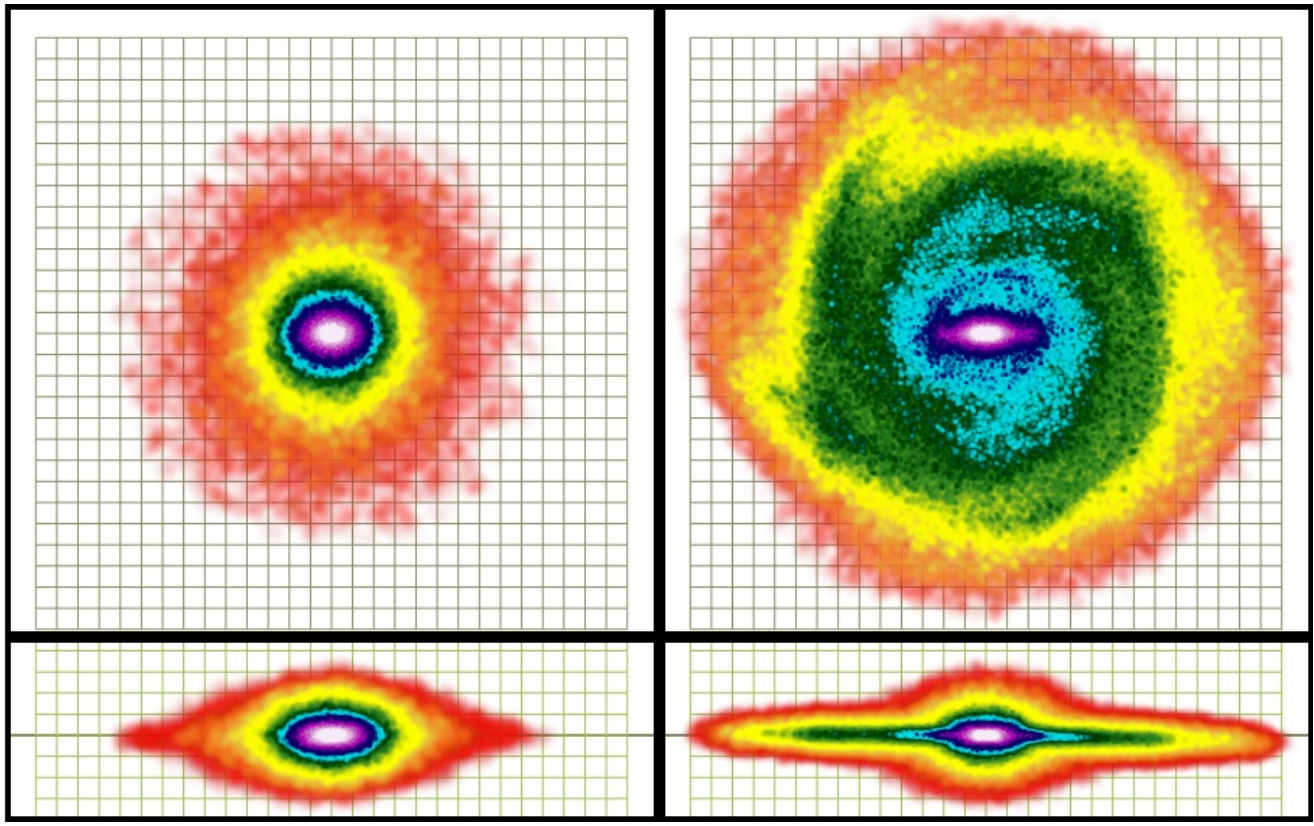
The effect of hot gas in the halo

Progenitor galaxies have the basic properties of galaxies at intermediate redshifts : smaller, more gas rich, less relaxed

Morphology!

At z=0 :





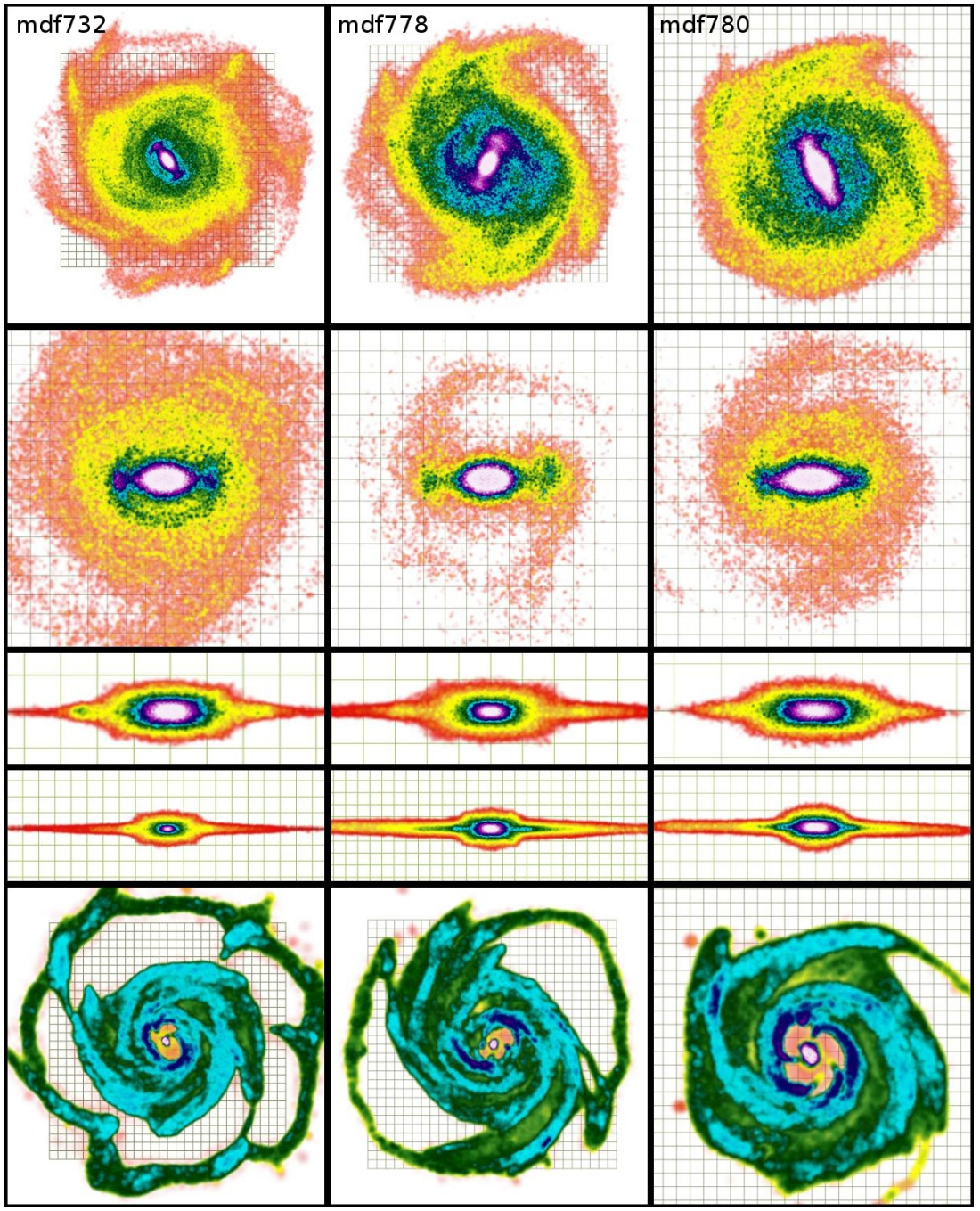
without
with

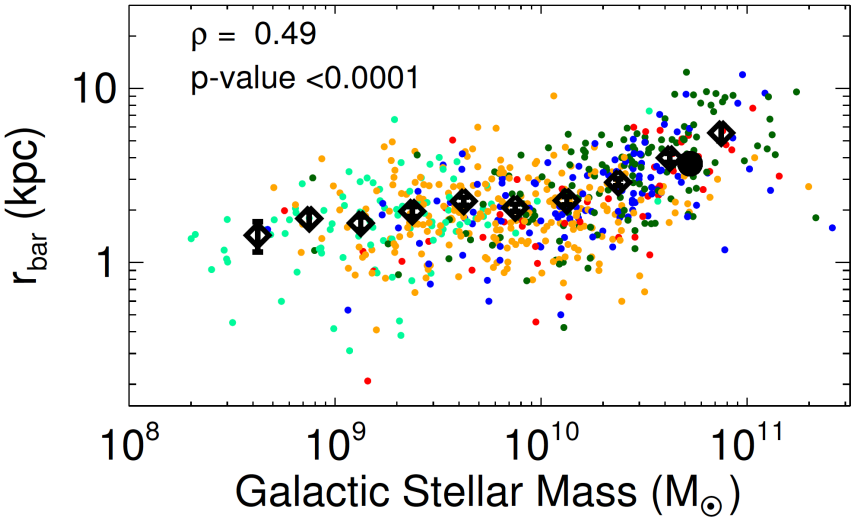
Without gaseous halo

With gaseous halo

ARPL16

Morphologies





Observations : S4G,
Diaz-Garcia et al 2015

Our 3 fiducial simulations :
Black filled circle

Good agreement with local universe galaxies

ARPL16

Formation of thick disc, some spheroidal component like a possible classical bulge or stellar halo

<---------- merger driven ---------->

Violent relaxation

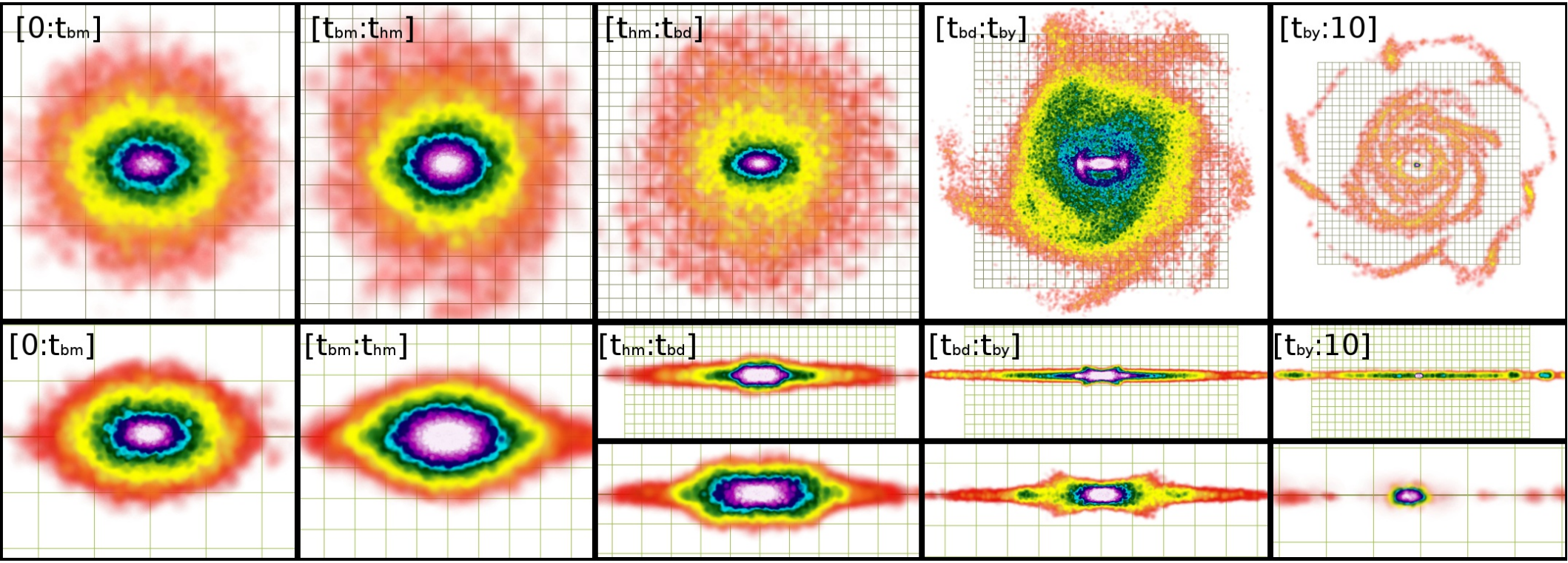
Born before the merging

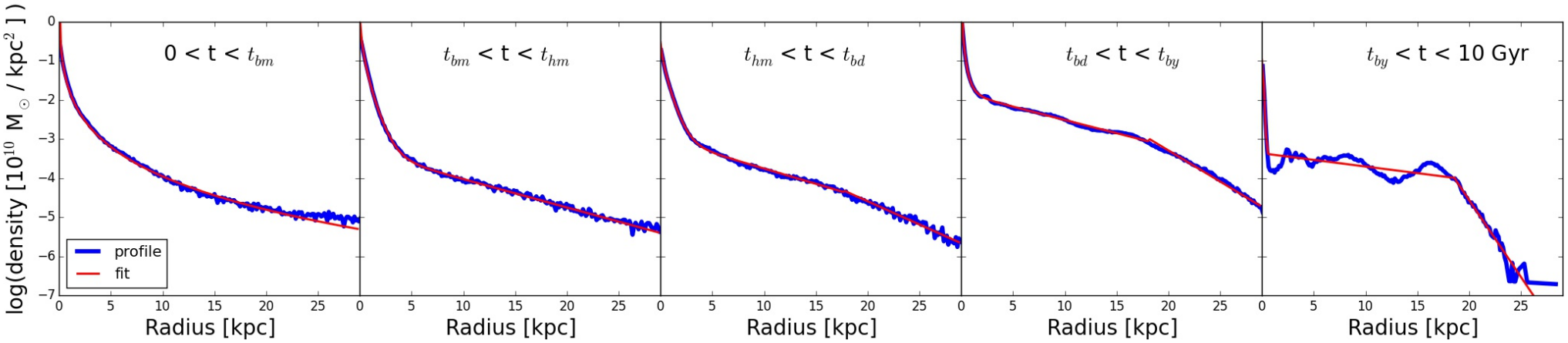
lots of shuffling

During the merging

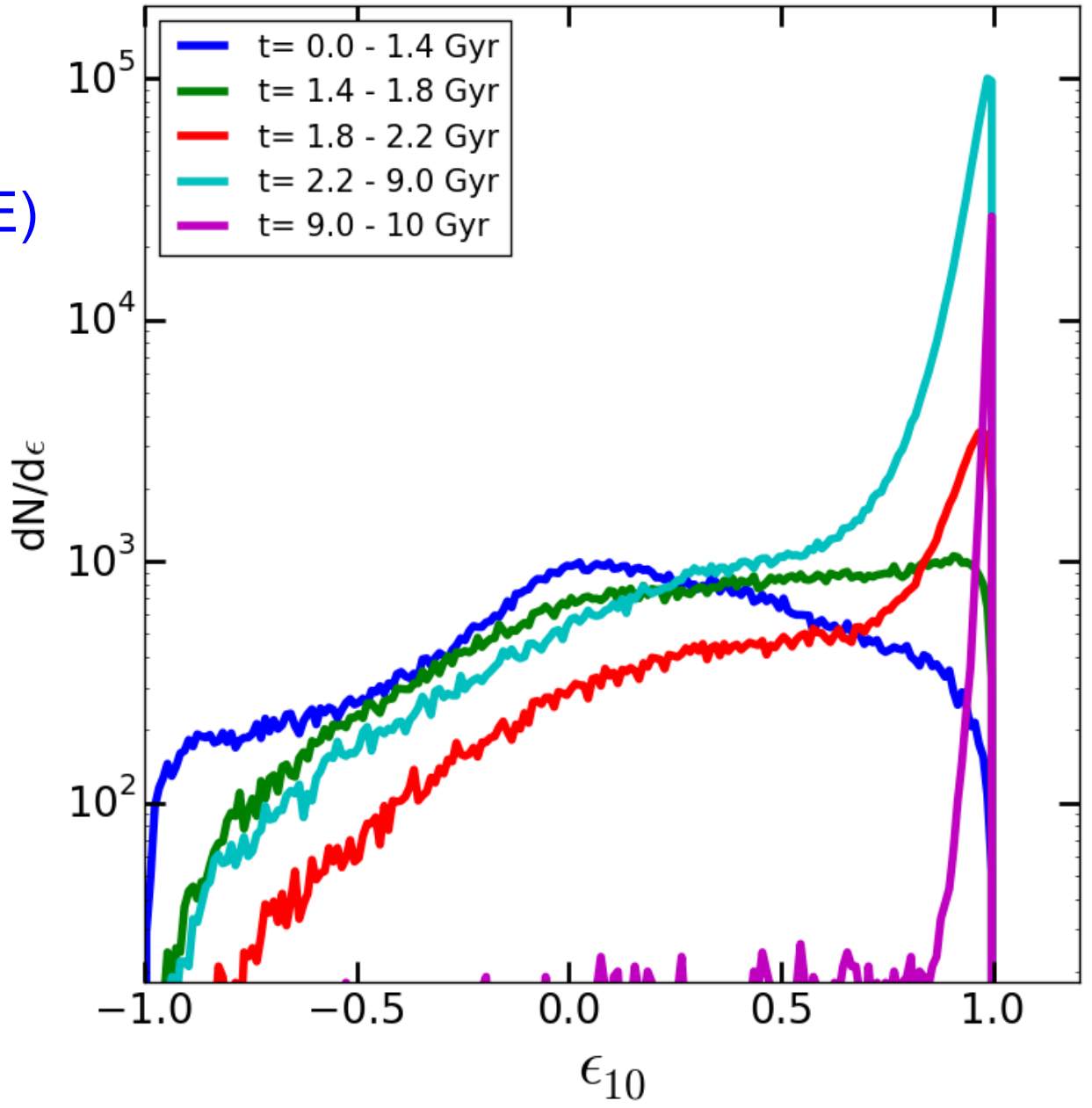
Formation of the thin disc and of its Structures (bar, spirals, rings ...)

<---------- secular ---------->





Circularity = Jz/Jz_circ(E)



Continuous sequence, not separate entities

ARPL16

Classical bulge mass to total stellar mass

It is possible to reach low values compatible with spiral galaxies

The three examples here : 10 – 20%

Morphology (bars, ansae, B/P/X structure, rings, spirals ….)

Surface density radial profiles

Type II and Type III

Rinner, Router, Break radius

As a function of population age

Evolution with time

Thick disk properties (in progres)

Kinematics (in progress)

Rotation curves

Chemical abundances (preliminary comparison with MW)

Whatever comparisons with observations we have tried so far work fine.

More tests in progress

Part I

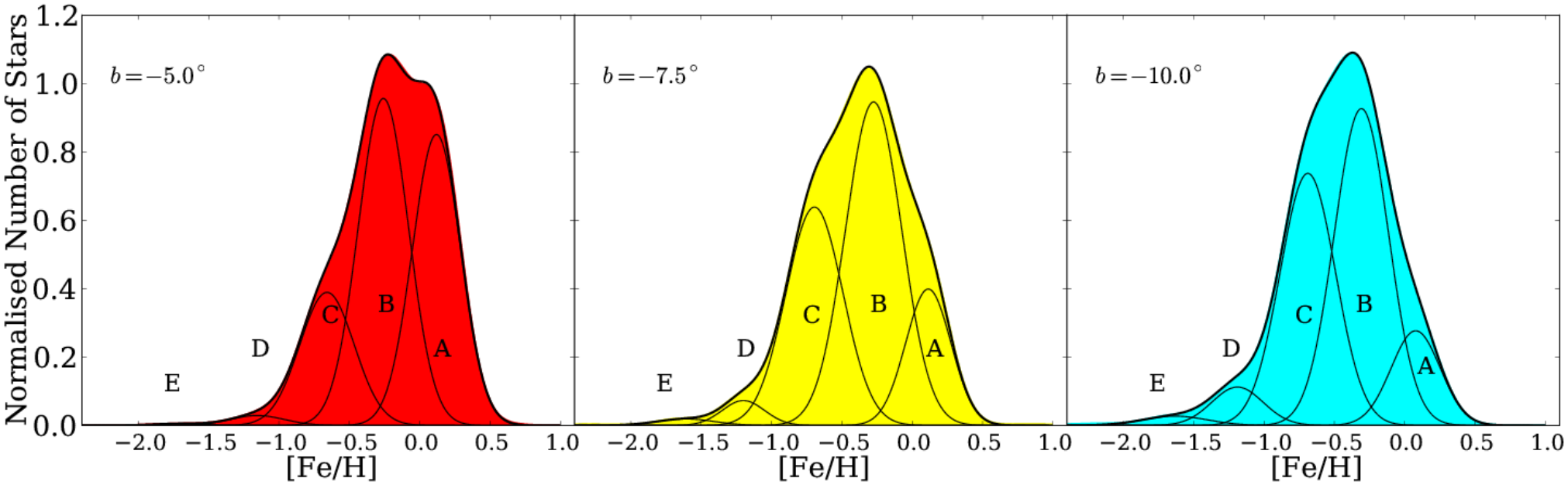
Modelling the link between kinematics and metallicity

We do not use an 'ersatz' (substitute)

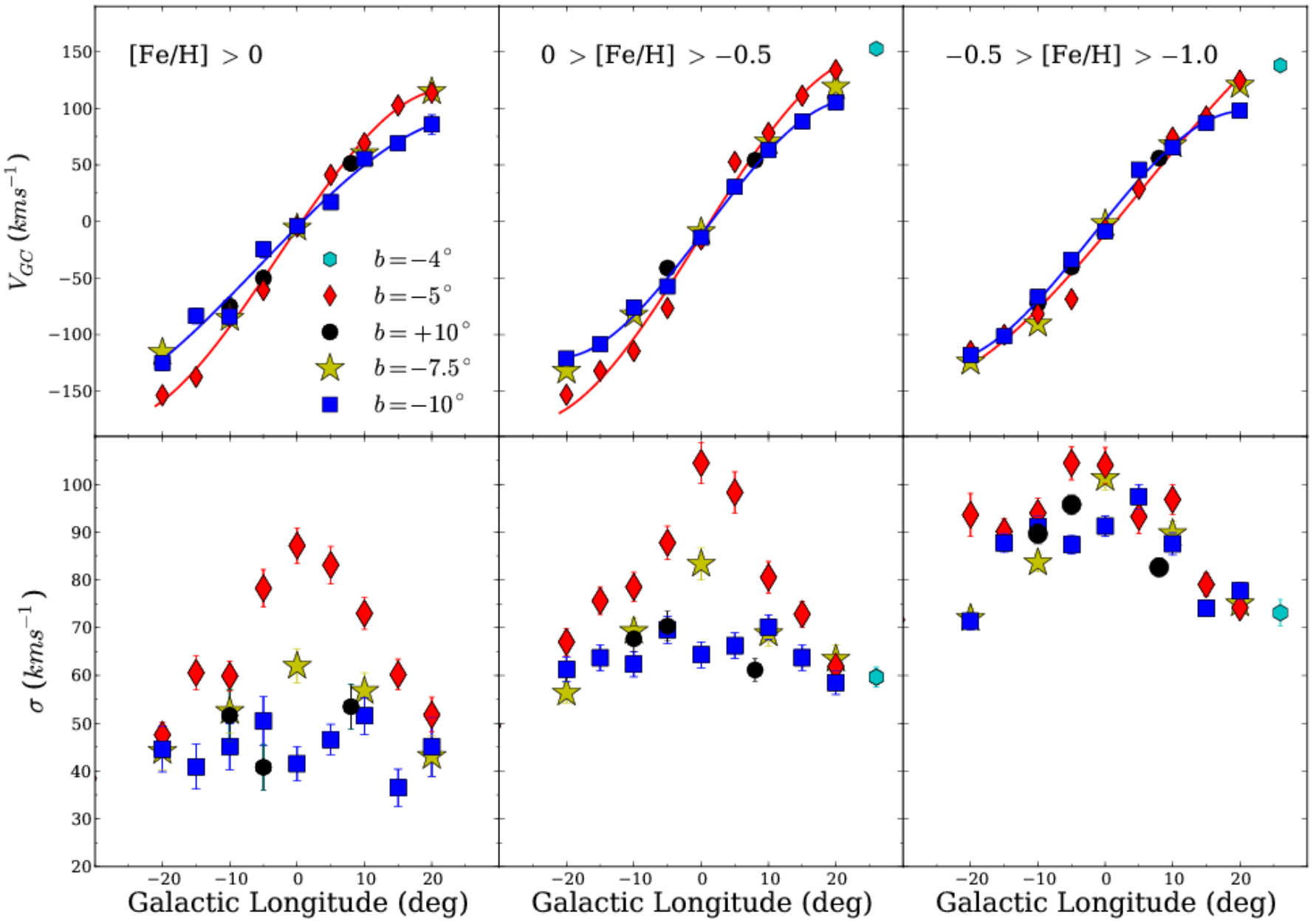
We Introduce chemical evolution
SSP formalism (with yields calculated as in Kubryk et al. 2015)
We do NOT rely on the instantaneous recycling approximation
Instead we apply a finite lifetime to each 'star' as a function of its mass
We then redistribure the ejecta to the nearby gas particles

Some of the following is work in progress

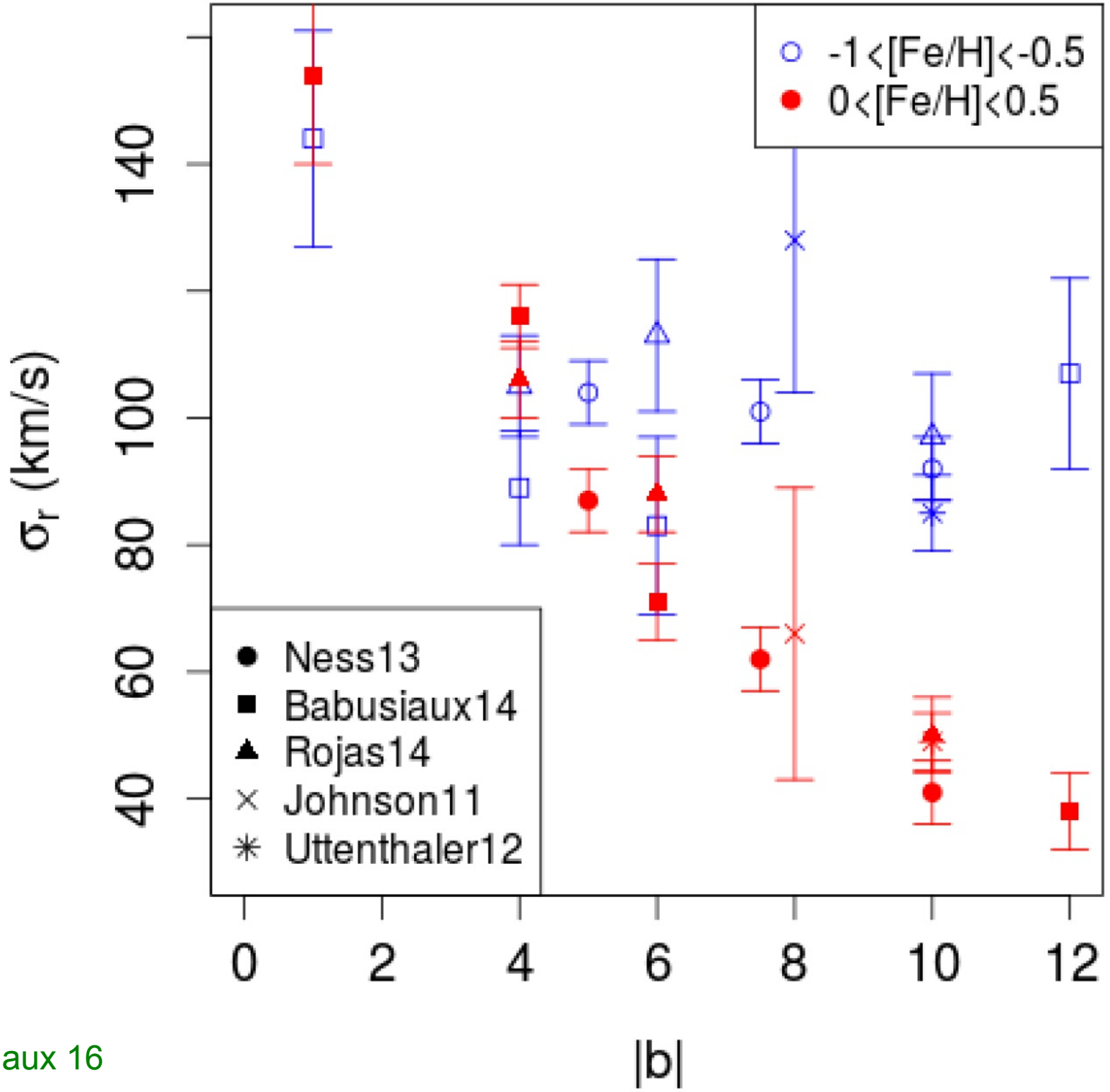
Collaborators : S. Rodionov, N. Prantzos



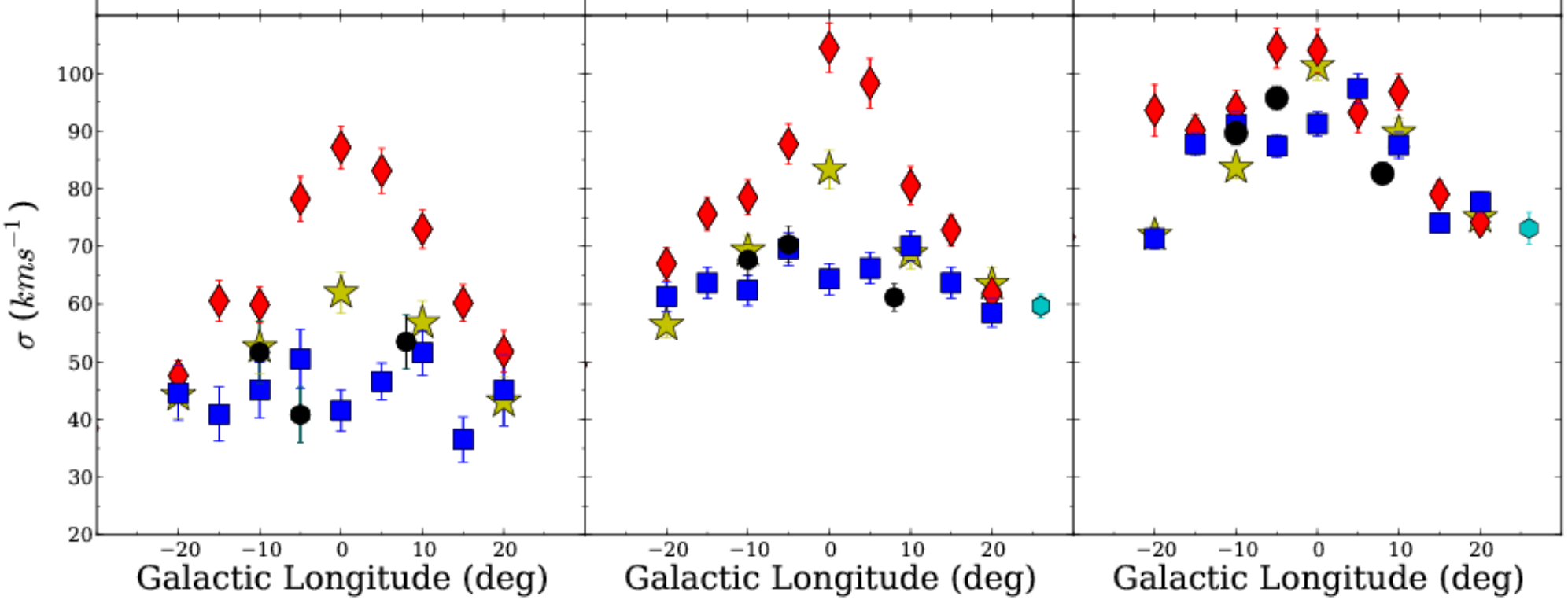
Ness et al. 2013a

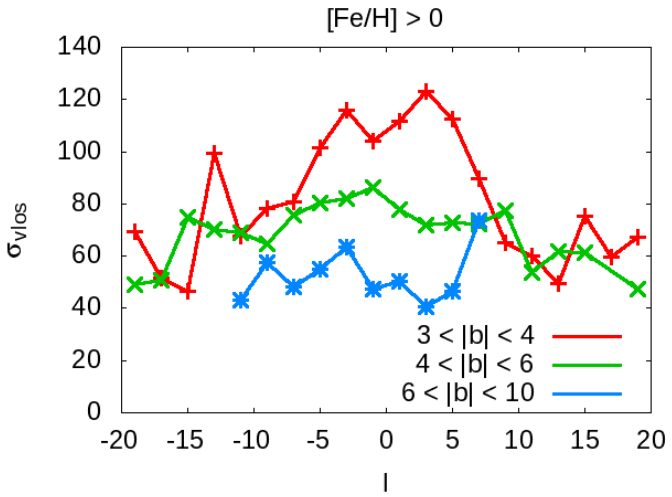


Ness et al. 2013b

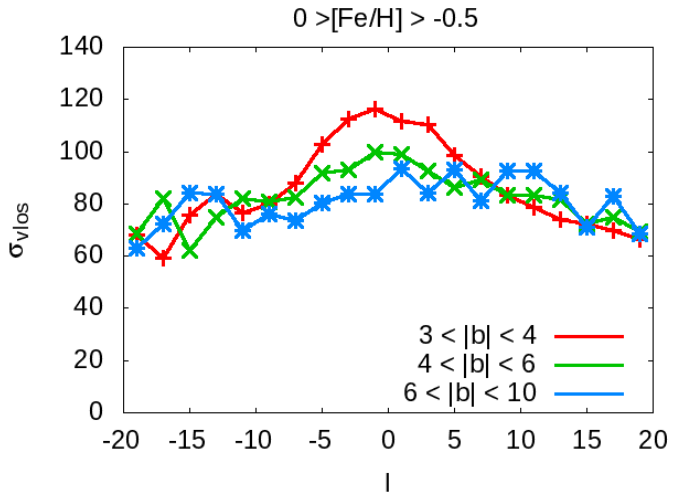


Babusiaux 16

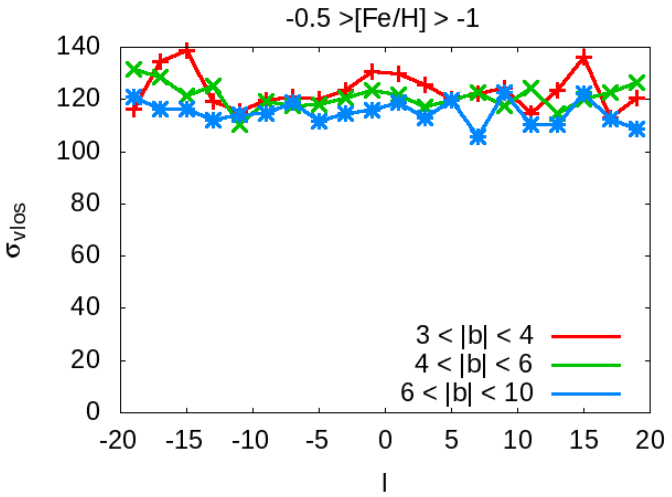




[Fe/H] >0

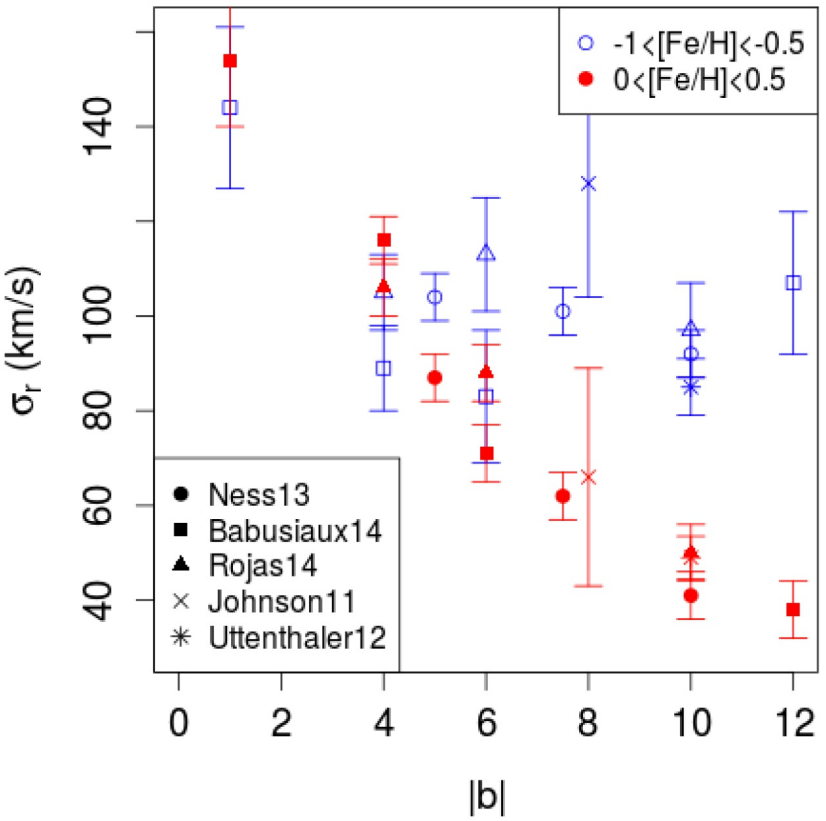


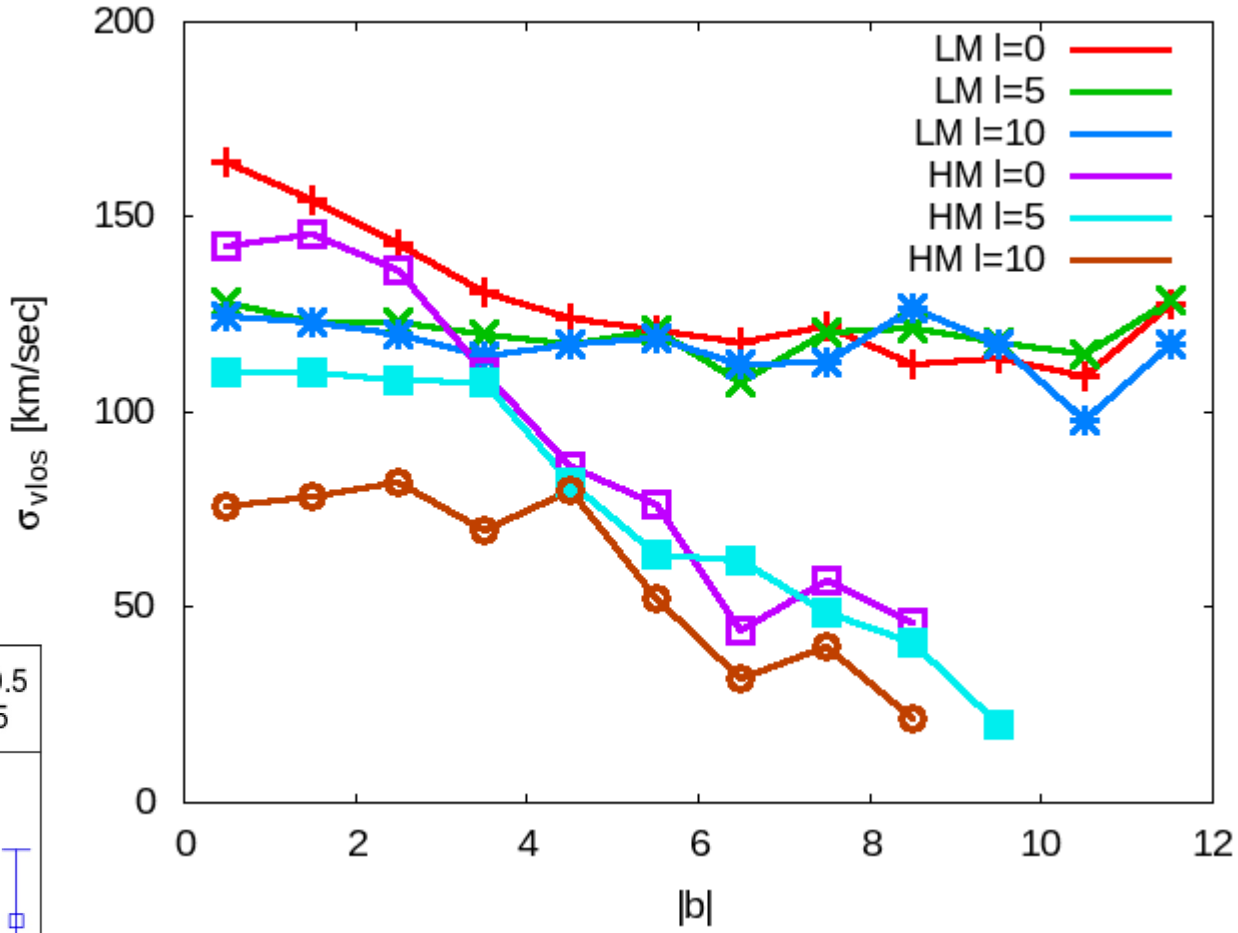
0>[Fe/H]>-0.5



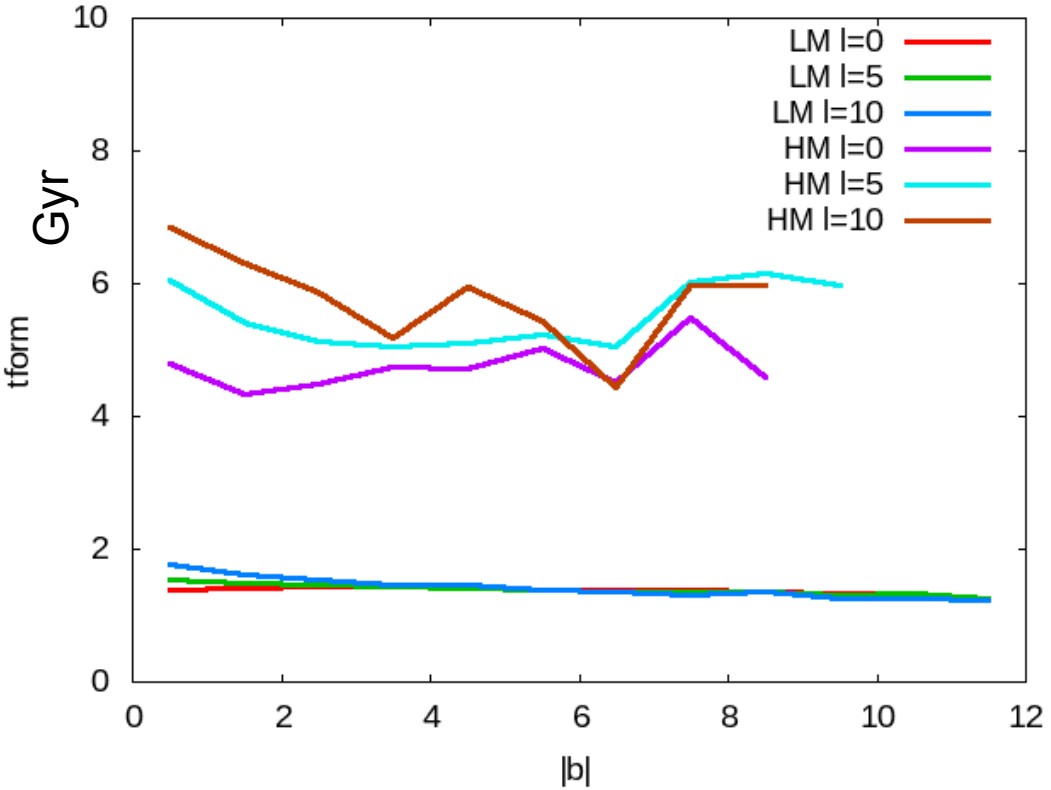
-0.5>[Fe/H]>-1.0

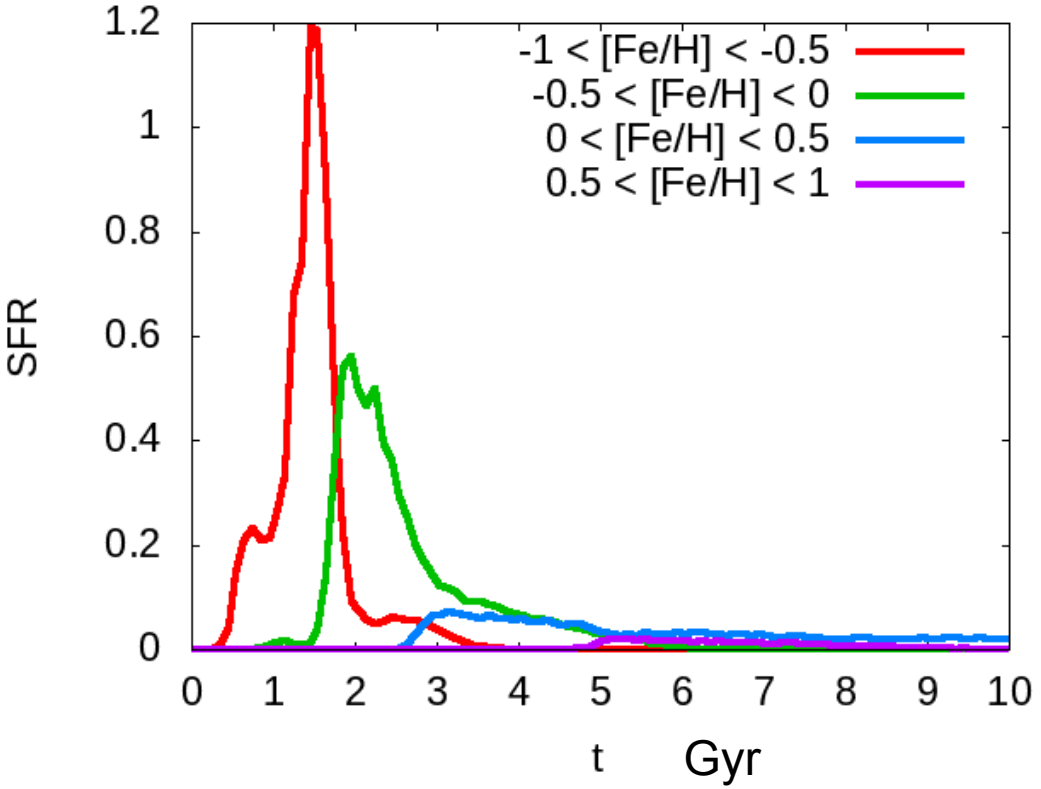
ARP16 Qualitatively very good agreement, and even quantitatively only 20% off


-1<[Fe/H]<-0.5
0<[Fe/H]<0.5
Ness13
Babusiaux14
Rojas14
Johnson11
Uttenthaler12
σr (km/s)
40
60
80
100
140
0
2
4
6
8
10
12
|b|

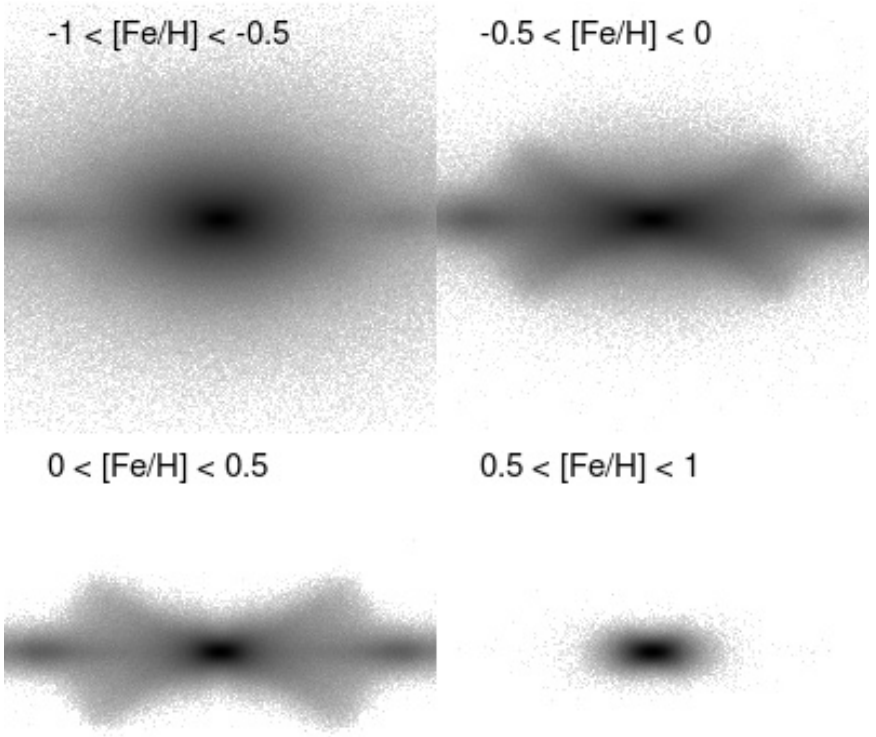

LM l=0
LM l=5
LM l=10
HM l=0
HM l=5
HM l=10
σvlos [km/sec]
0
50
100
150
200
0
2
4
6
8
10
12
|b|

ARP16


LM l=0
LM l=5
LM l=10
HM l=0
HM l=5
HM l=10
tform
Gyr
|b|
0
2
4
6
8
10
12

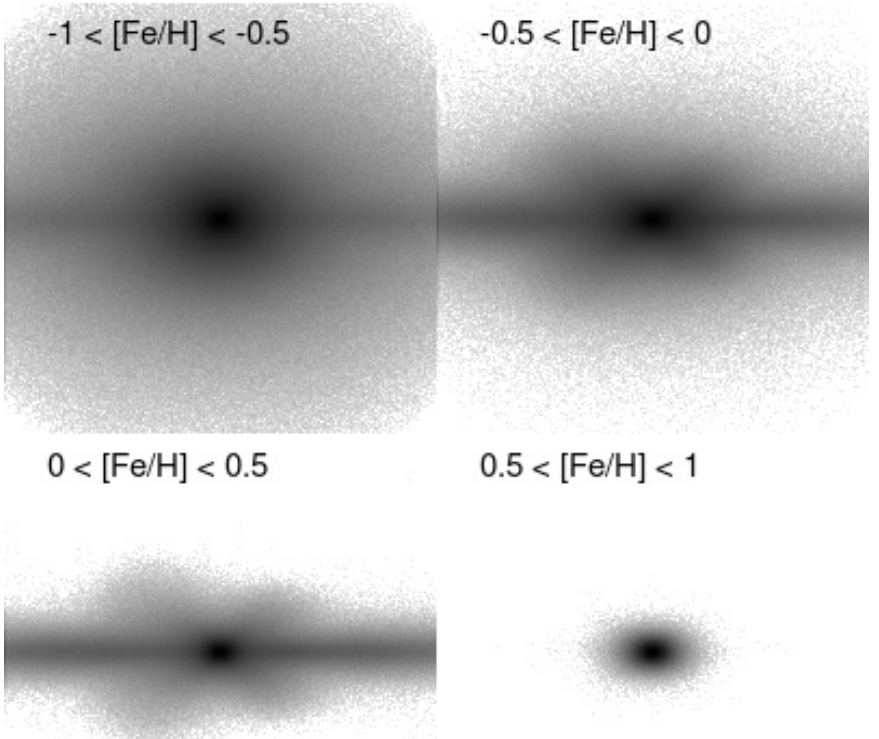

-1 < [Fe/H] < -0.5
-0.5 < [Fe/H] < 0
0 < [Fe/H] < 0.5
0.5 < [Fe/H] < 1
SFR
t
Gyr
0
0.2
0.4
0.6
0.8
1
1.2
0
1
2
3
4
5
6
7
8
9
10

ARP16

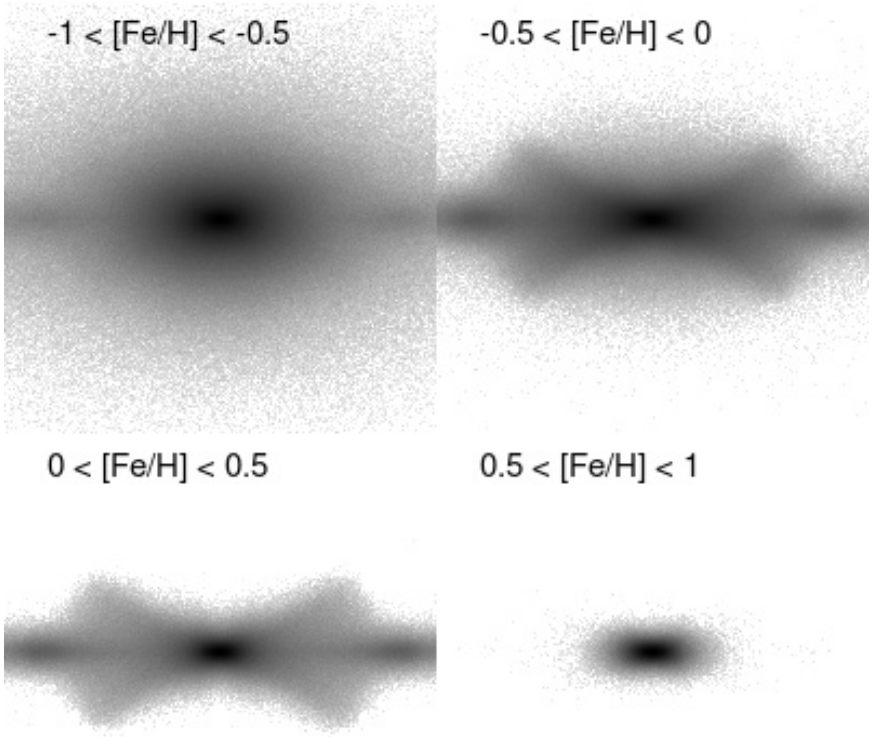


(-3.5, +3.5 kpc)

ARP16



Ness & Lang 16

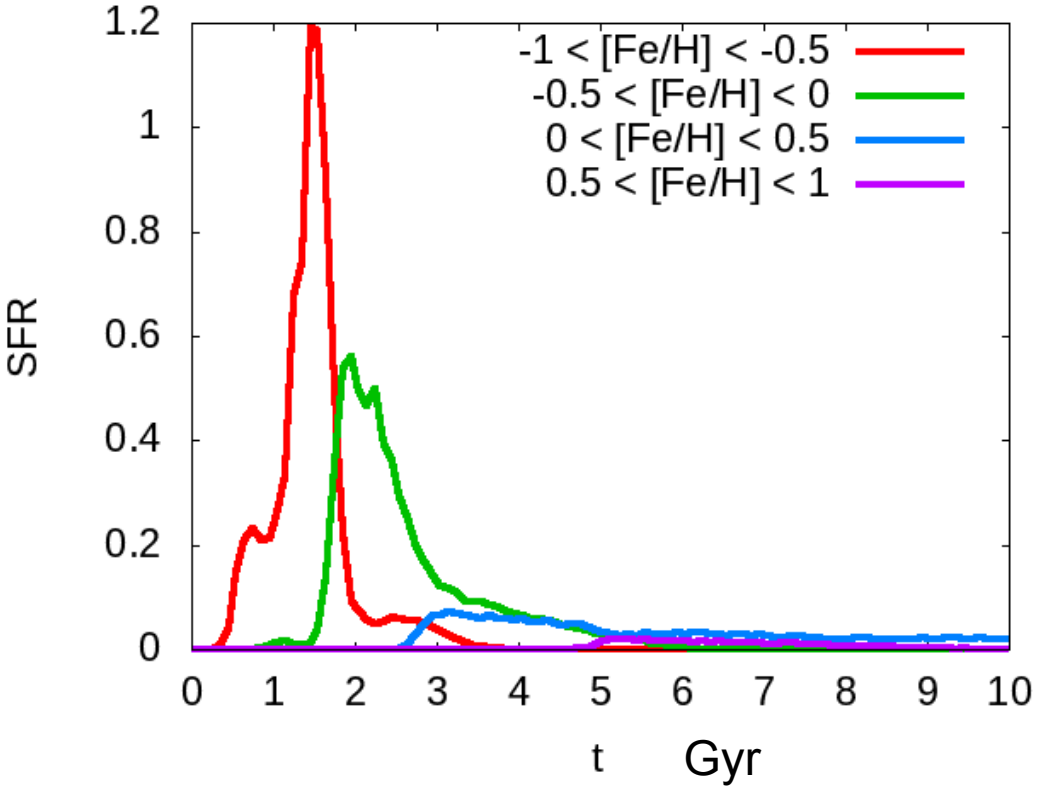


So (most of the) thick disc stars and (if present) the classical bulge stars are formed early on and in a relatively short time range

Thin disc forms later on and much more spread out in time

Agree with Freeman's talk and Matteucci's comment yesterday

Most of the ===> because some of the thin disc has time to thicken a bit



ARP16

To summarise part I :

There are several components in the bar/bulge region

This makes it seem complex

It is natural that there is a relation between kinematics and metallicity

Simulations help us in disentangle this 'complexity'

Comparison with the MW should be considered as qualitative, NOT quantitative. It would pretentious to say that we had a full MW model

How much classical bulge there is can be best obtained from the metallicity generalised histograms, NOT the kinematics

Yet another way of forming thick discs …..

Part II

Projected radial density profiles

Collaborators :
N. Peschken, S. Rodionov

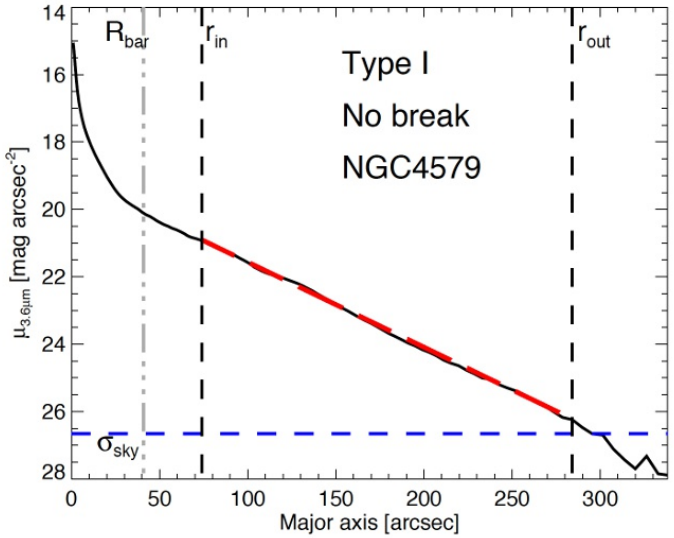
THREE TYPES OF BREAKS OBSERVED

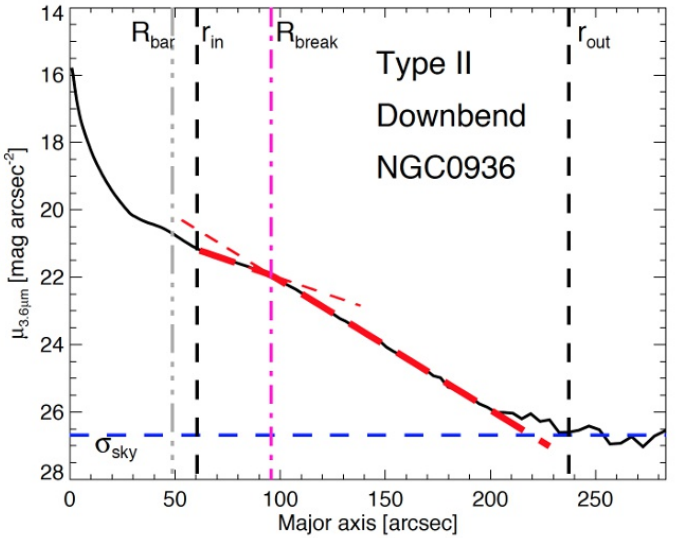
What are these breaks due to ?

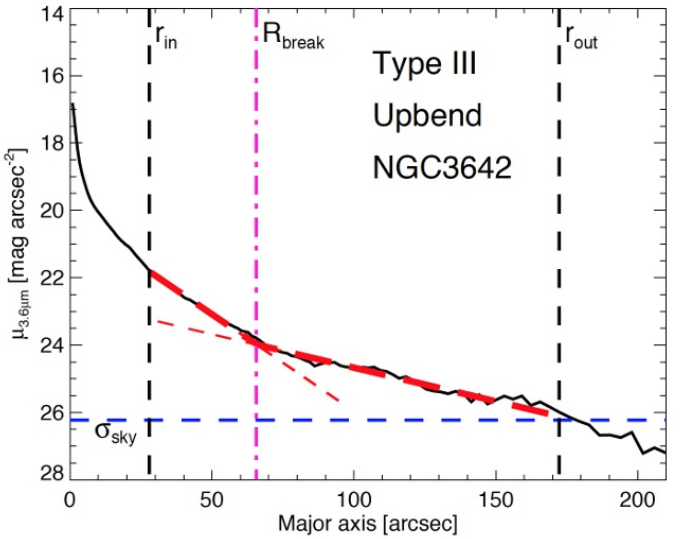
No truncation
The least frequent type

Truncations
The most frequent type

Antitruncations





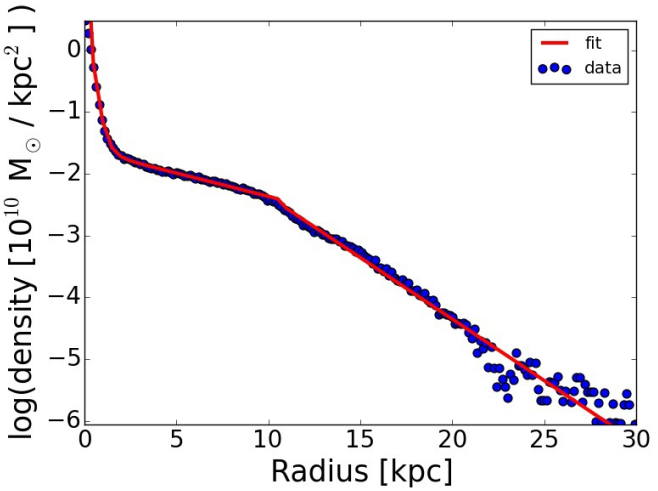


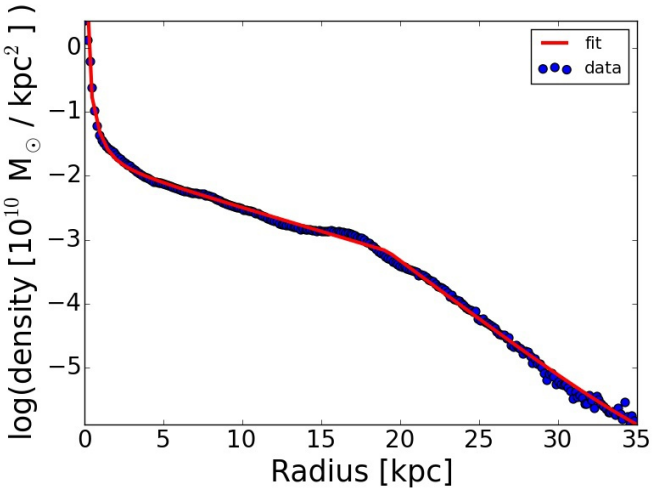
Freeman 70, van der Kruit & Searle 81, Pohlen + 02, Perez 2004, Trujillo & Pohlen 05, Pohlrn & Trujillo 06; Erwin + 05, 08, Azzollini, Trujillo & Beckman 08, Bakos, Trujillo & Pohlen 08, Gutierez + 11, Comeron + 12, Maltby + 12, Martin-Navarro + 12, Munoz-Mateos + 13, Laine et al. 14, Kim + 14, etc

(figure from Laine et al. 14)

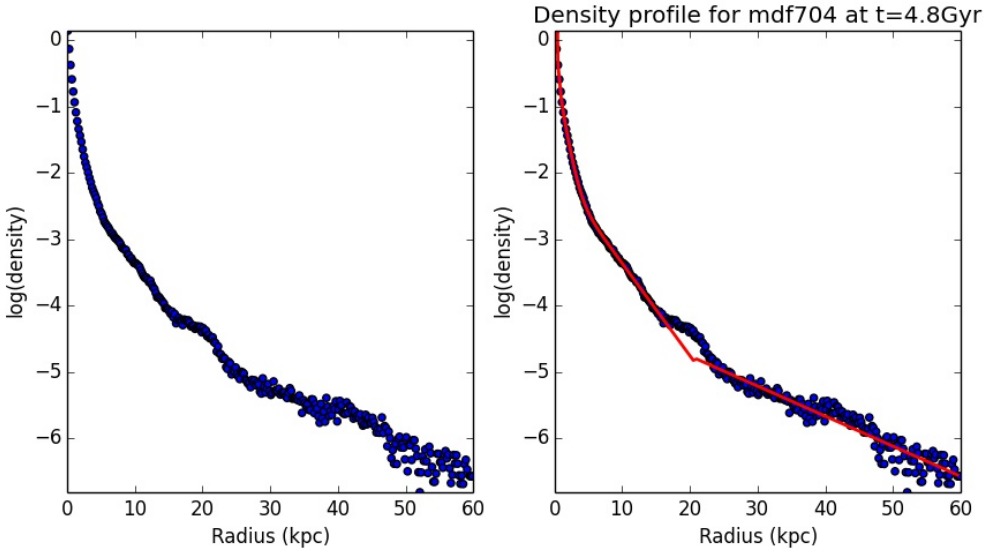
No type I (but see RaDES, Few et al. 2012)

Type II
(most cases)



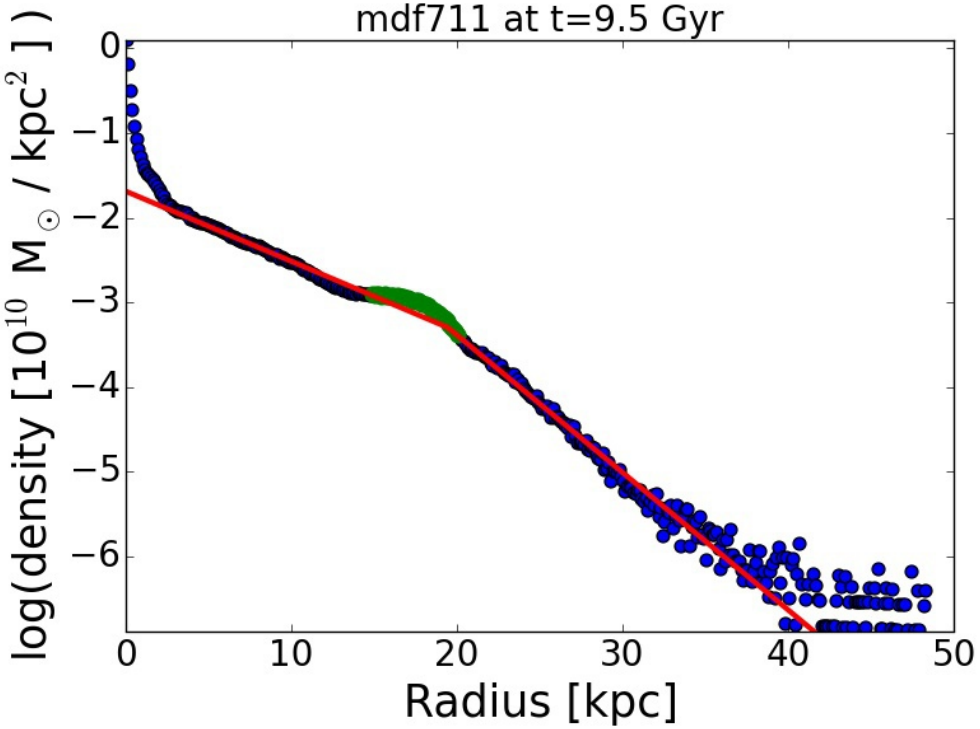


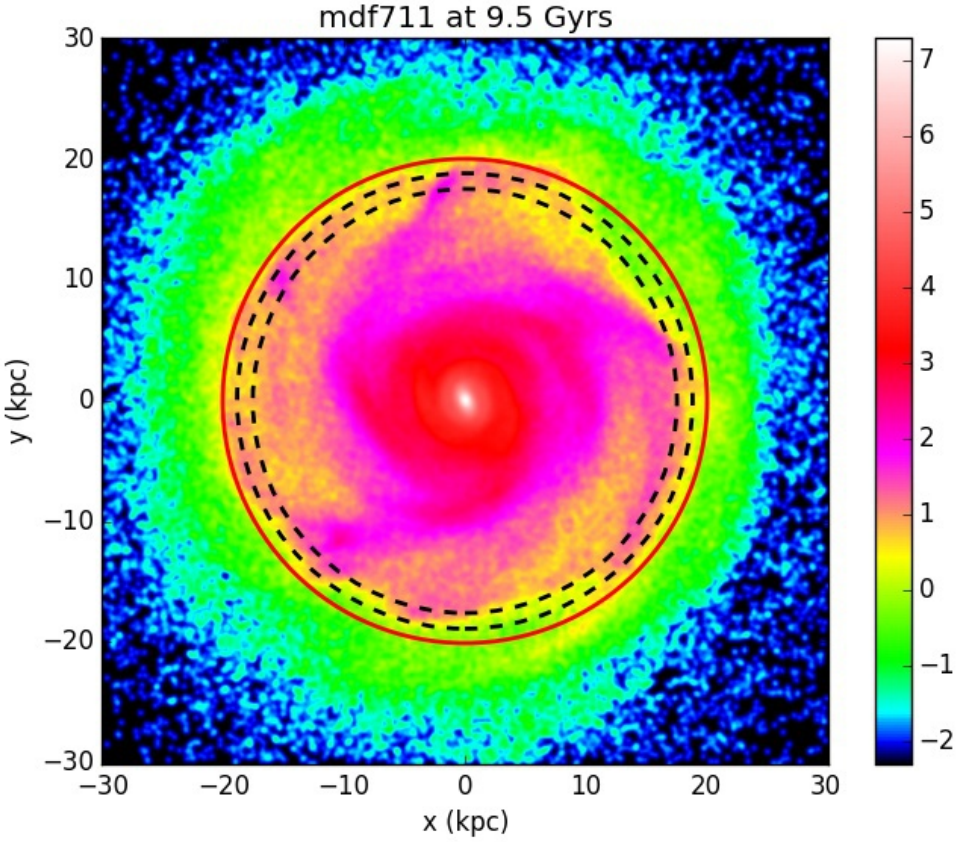
Type III

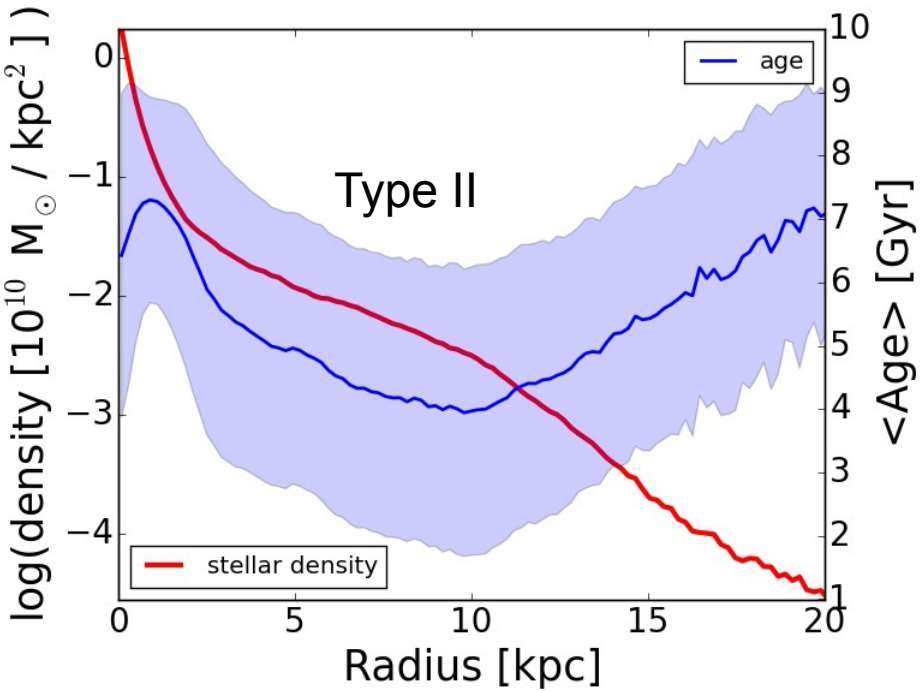


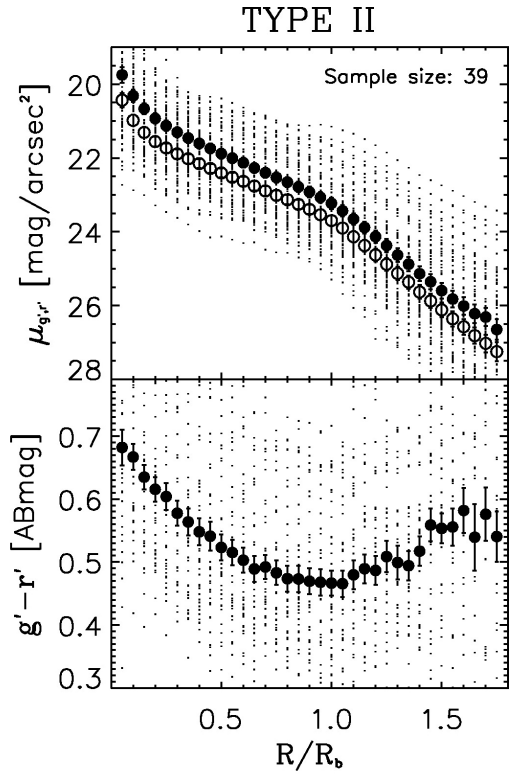
Comparison with observations for inner and outer disc scale lengths shows good agreement

APR16


mdf711 at t=9.5 Gyr
log(density [10^10 M⊙ / kpc^2])
Radius [kpc]
0
−1
−2
−3
−4
−5
−6
0
10
20
30
40
50


mdf711 at 9.5 Gyrs
y (kpc)
x (kpc)
30
20
10
0
−10
−20
−30
7
6
5
4
3
2
1
0
−1
−2





e.g. Azzollini et al. 08A, 08b, 09
But see also Ruiz-Lara et al. 15
Etc
Roskar et al. For simulations

The end