Thin vs thick disks

Main questions

➔Characteristics of the two disks, mass ratio, scale and height

➔Metallicity vs abundance, degree of rotation

➔Scenarios of formation: when? High z?
Turbulent clumpy disks, heating, companions

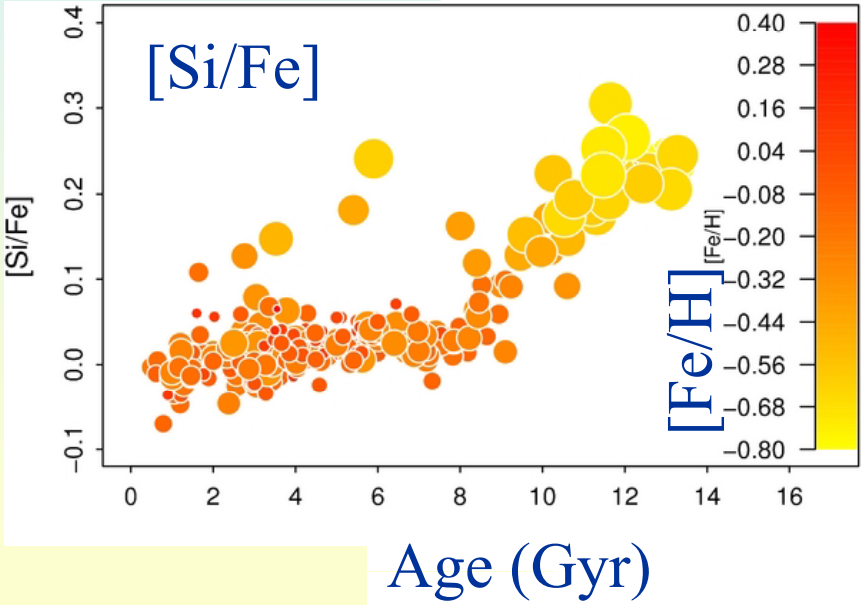
➔Role of the radial migration

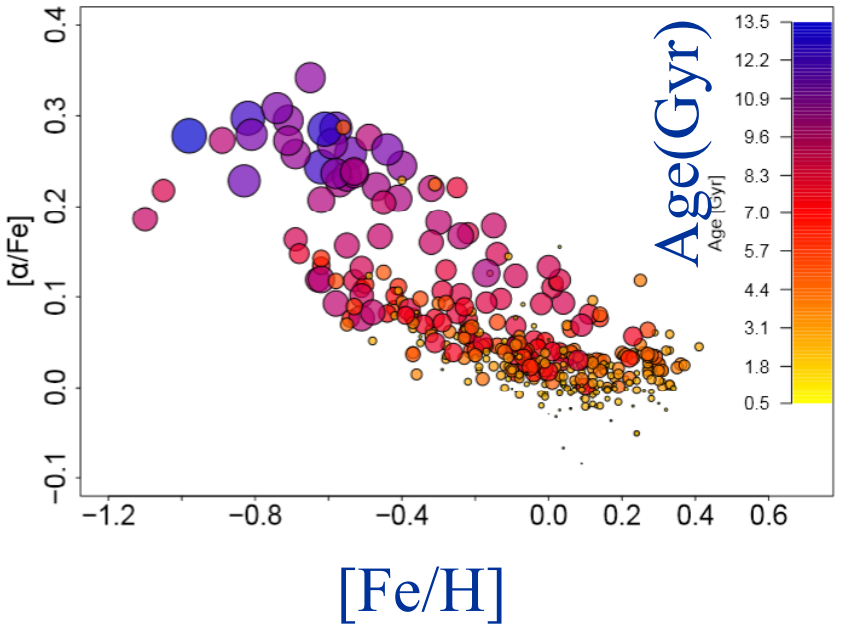
Round Table Discussion
20 September 2016

Mass, scale, height (exp)

Thin: Scale: 2.5-3kpc Height: 220-450pc ➔ 300±50pc
Thick: Scale: 2.2-2.8kpc Height: 700-1450pc ➔ 900±180pc
M_T/M_t~0.5 Comparable scales (Comeron et al 2012)

Appears that the thick disk is smaller in radius, and of comparable mass (15% surface brightness at Sun)



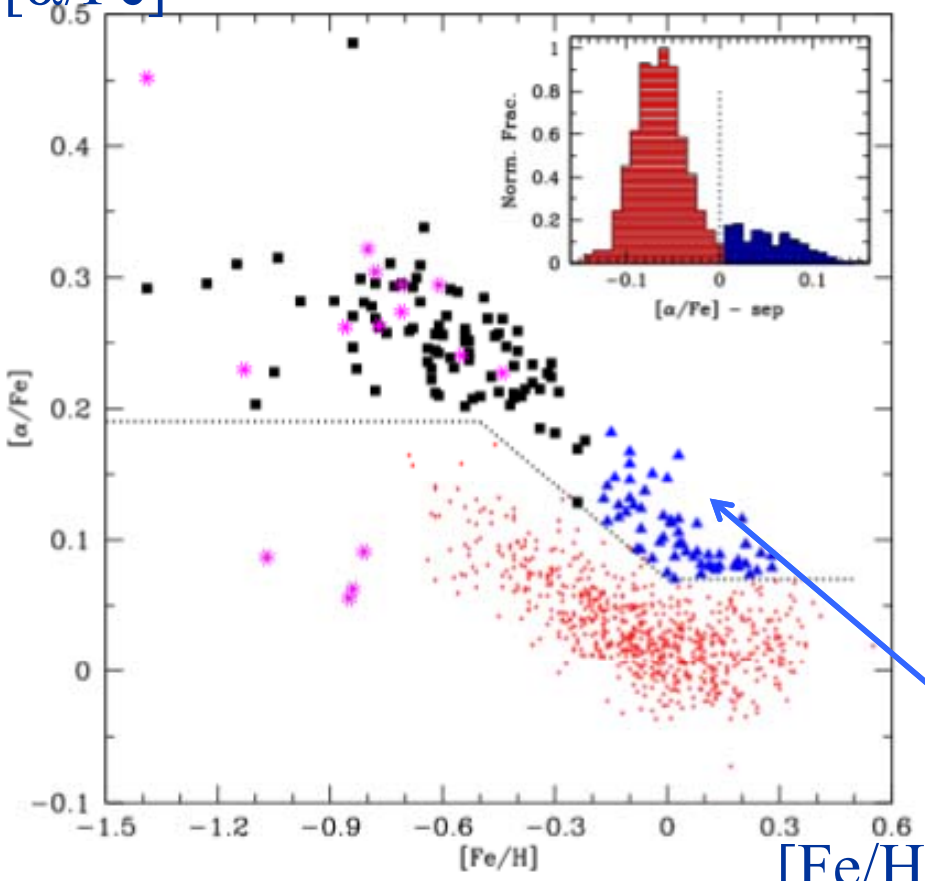


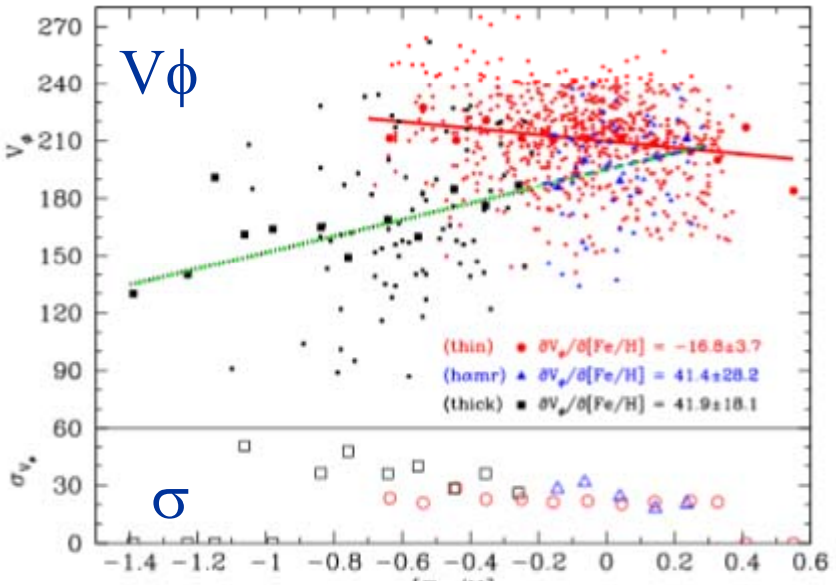
Solar neighborhood: Haywood et al 2013

Abundance- metallicity relation

Solar neighborhood FGK dwarf stars

[α/Fe]





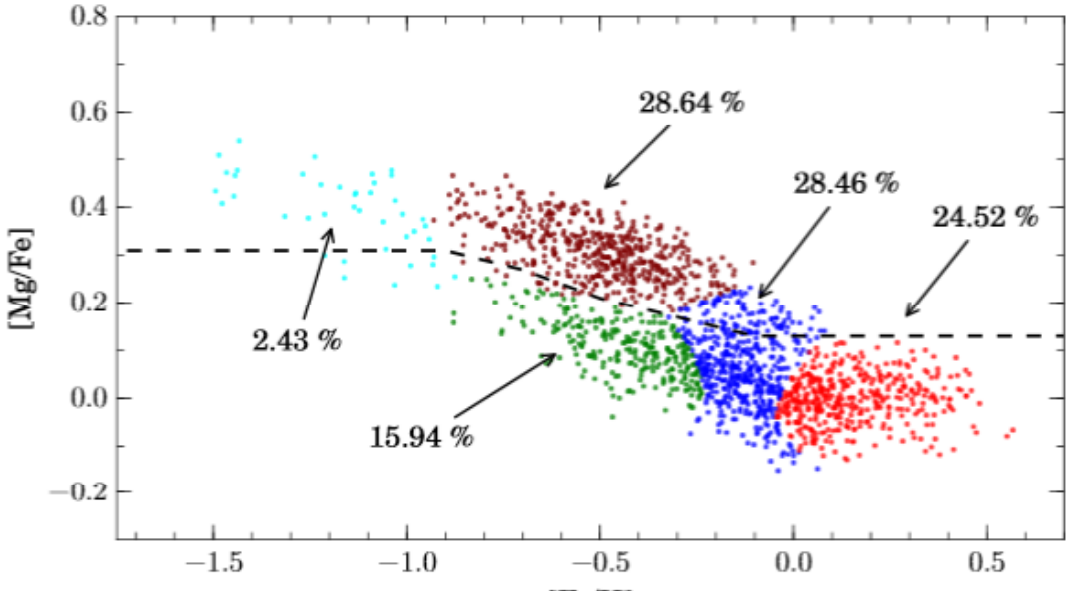
[Fe/H]

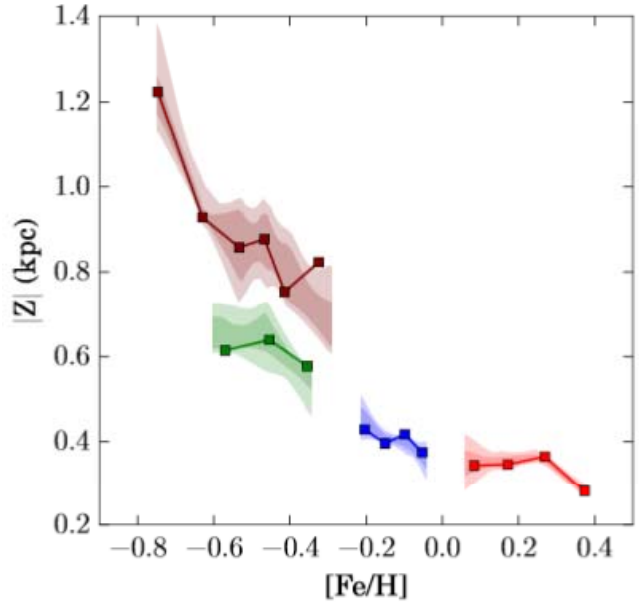
HAMR

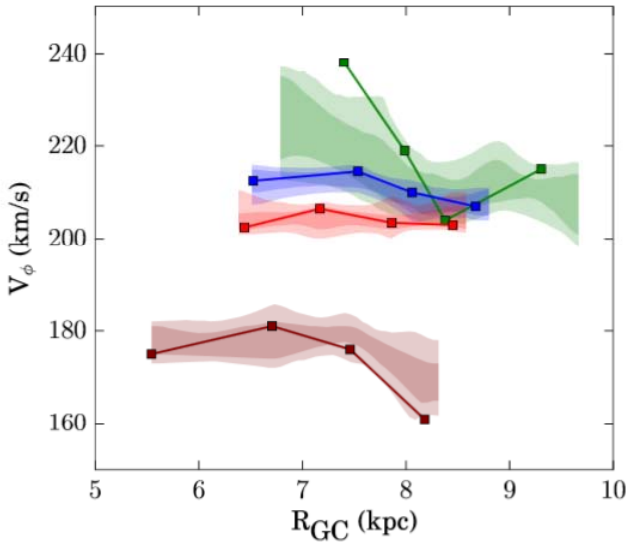
[Fe/H]

Adibekyan et al 2013

Components of the thin disk





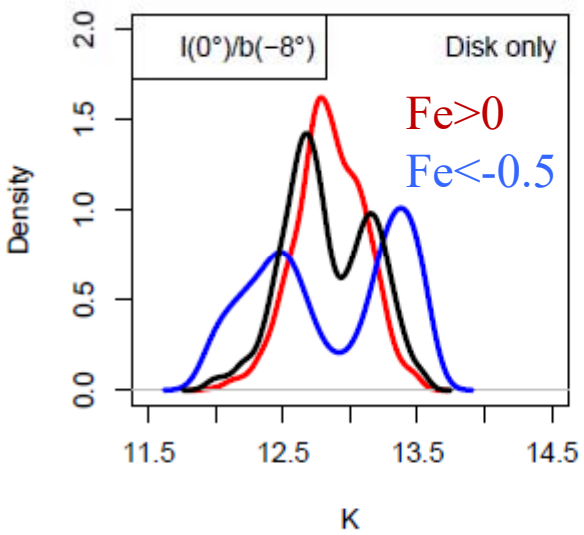


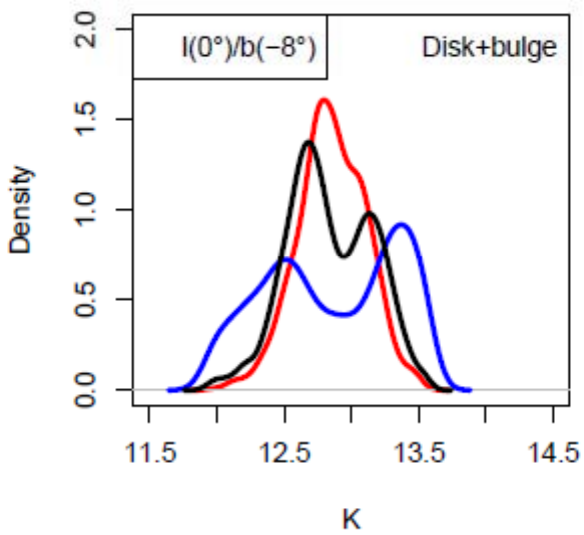
GAIA-ESO survey: the metal-poor end of the thin disk is at larger radii,
Elevated height, and higher Vrot
➔Different from inside out?
Quiet evolution, enriched by outflows from the thick disk?

Rojas-Arriagada et al 2016

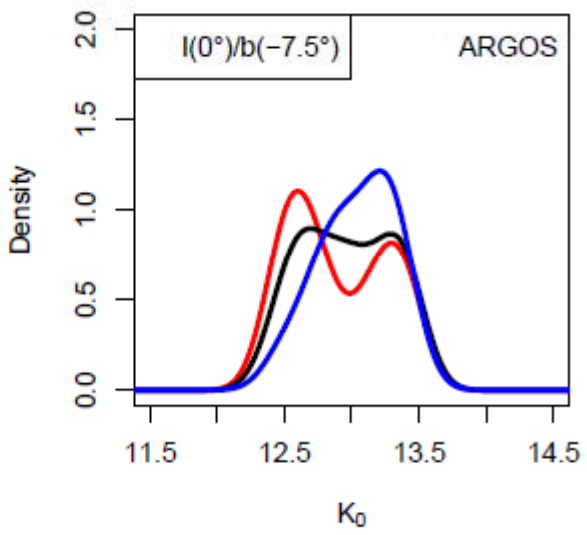
Bulge or thick disk?

Red clump stars in K





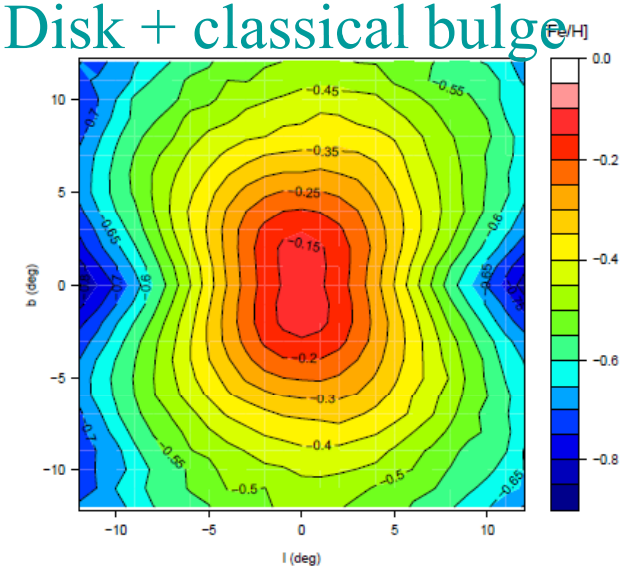
Ness et al 2013



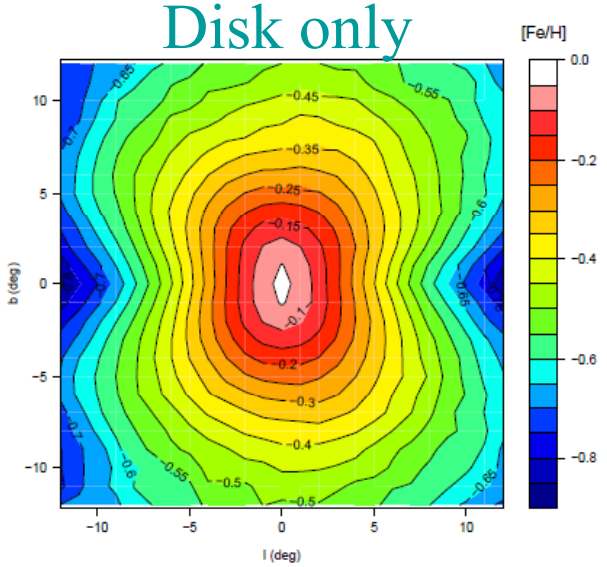
Detailed kinematics with metallicity

➔Not only a thin disk could be a thick disk
Di Matteo et al (2015)

Disk + classical bulge



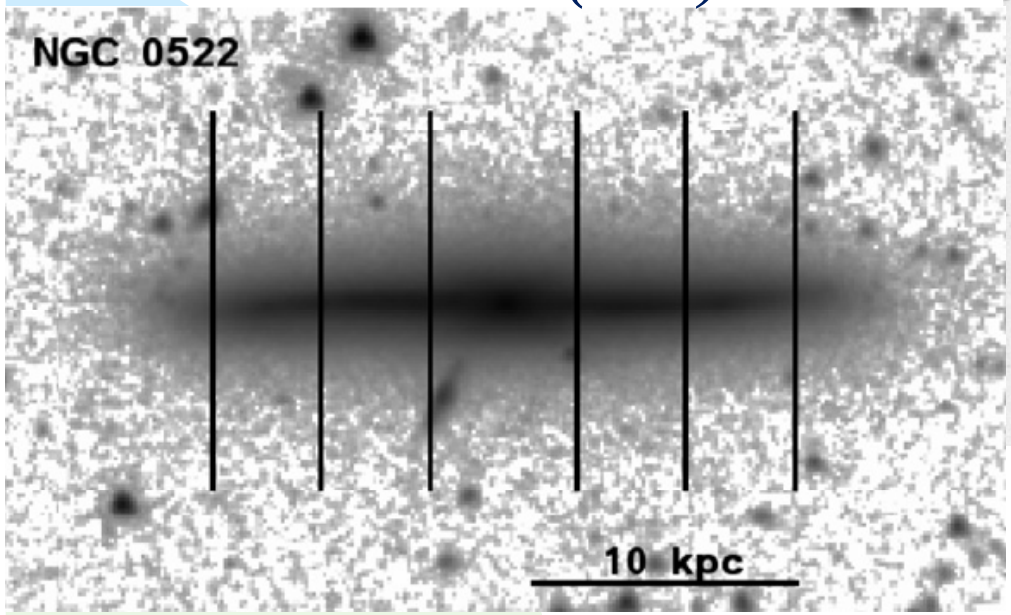
Disk only



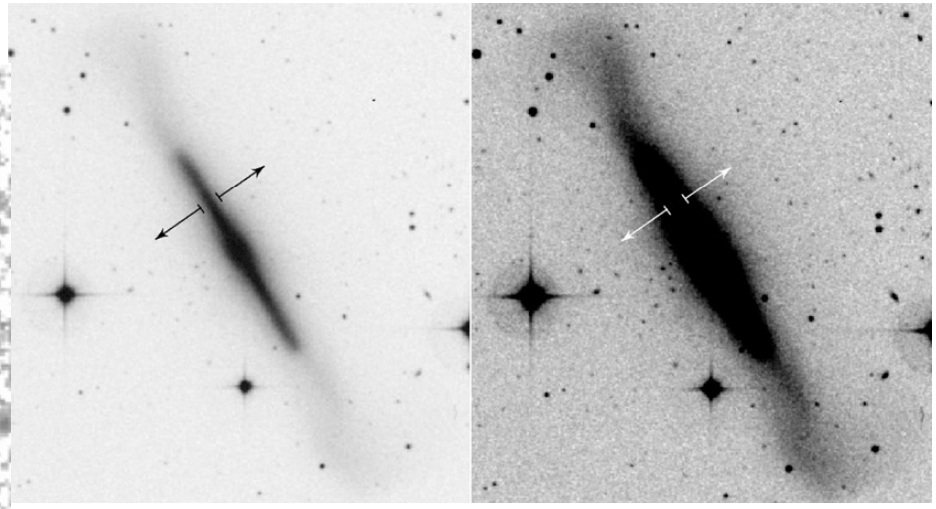
Thick disk

Same type and size as MW

Comeron et al 2011 (S4G)



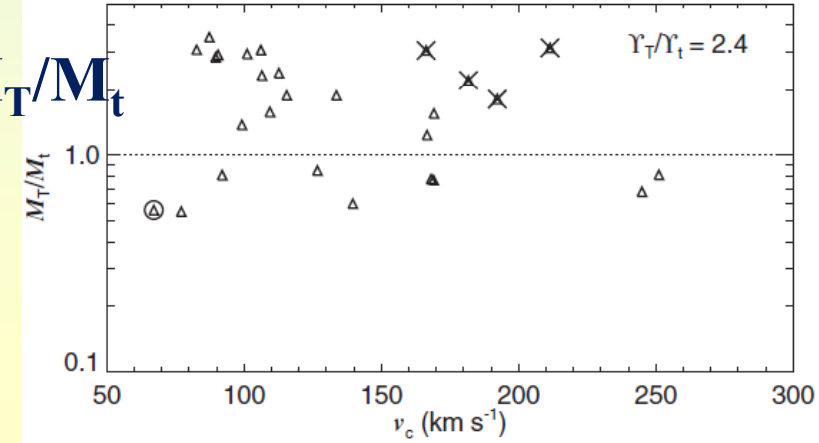
Tsikoudi 1980

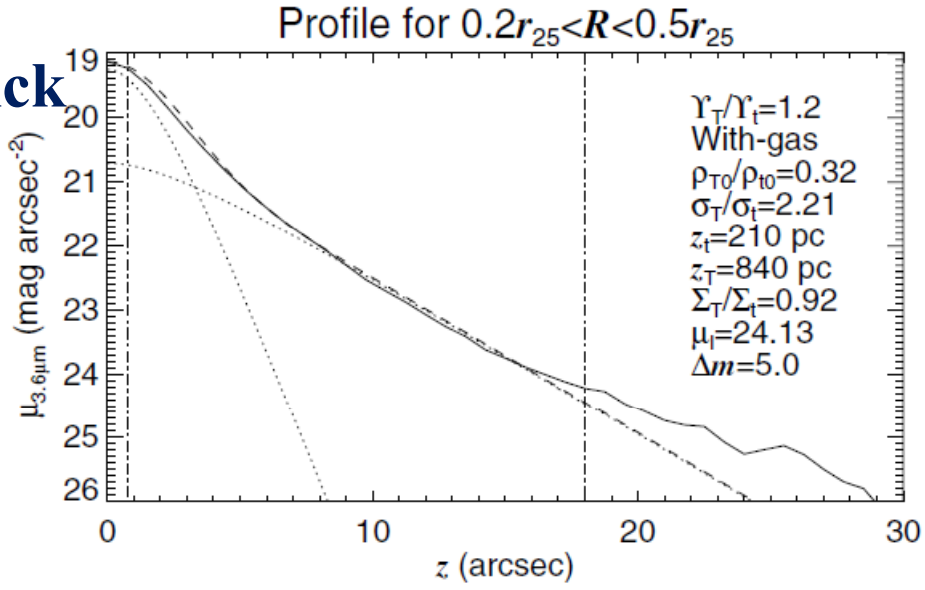


zt= 250pc, zT= 900pc

Comparable masses in thin and thick

M_T/M_t





Formation of the thick disk

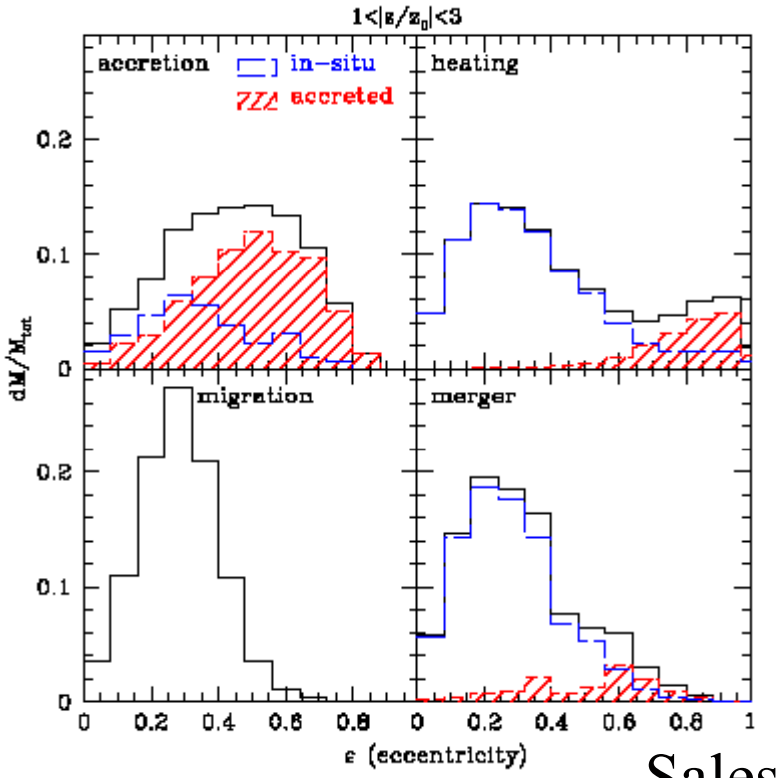
At least 4 scenarios:

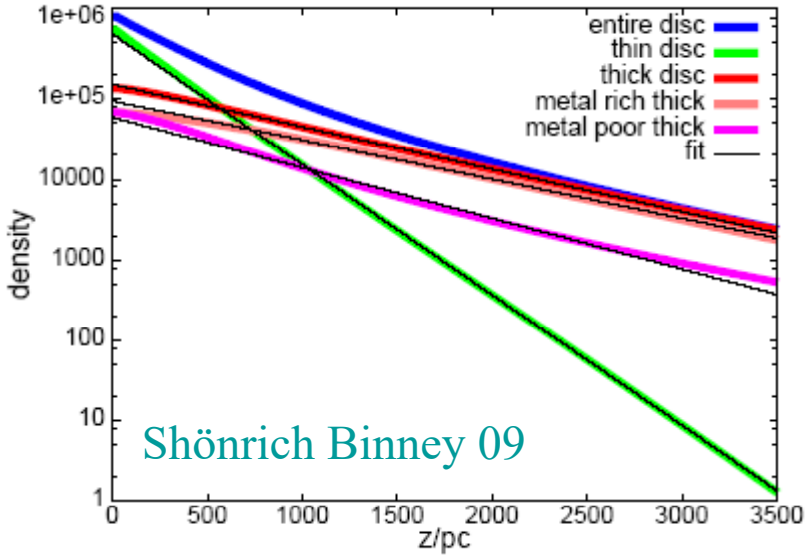
1) Accretion and disruption of satellites (like in the stellar halo)

2) Disk heating due to minor merger (also secular)

3) Radial migration, via resonant scattering

4) In-situ formation from thick gas disk (mergers, or clumpy galaxies)





➔Orbit excentricity of stars could help to disentangle

Sales et al 2009 cf di Matteo et al 2011

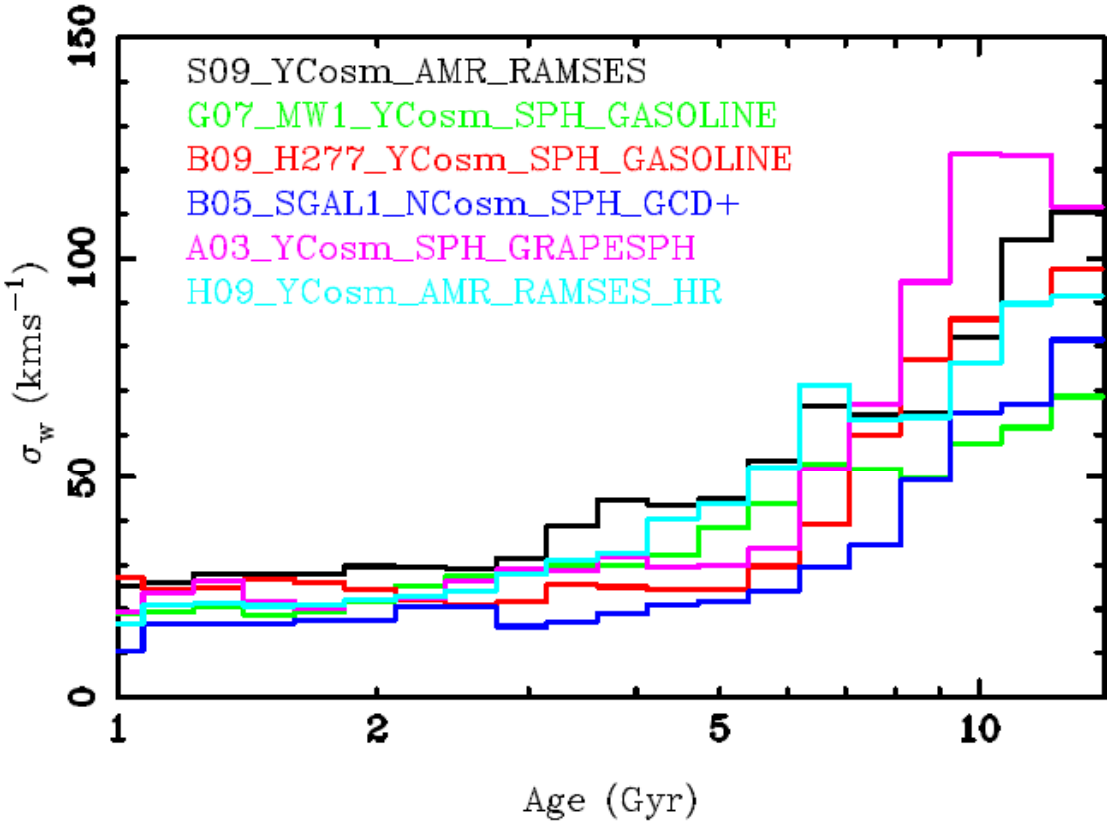
Disk Heating

➔Rapid, due to mergers
➔Slow due to secular evolution

Presence of thin and thick disks as two independent components
Thick disks could be due to mergers and/or turbulent ISM at high z

House et al 2011

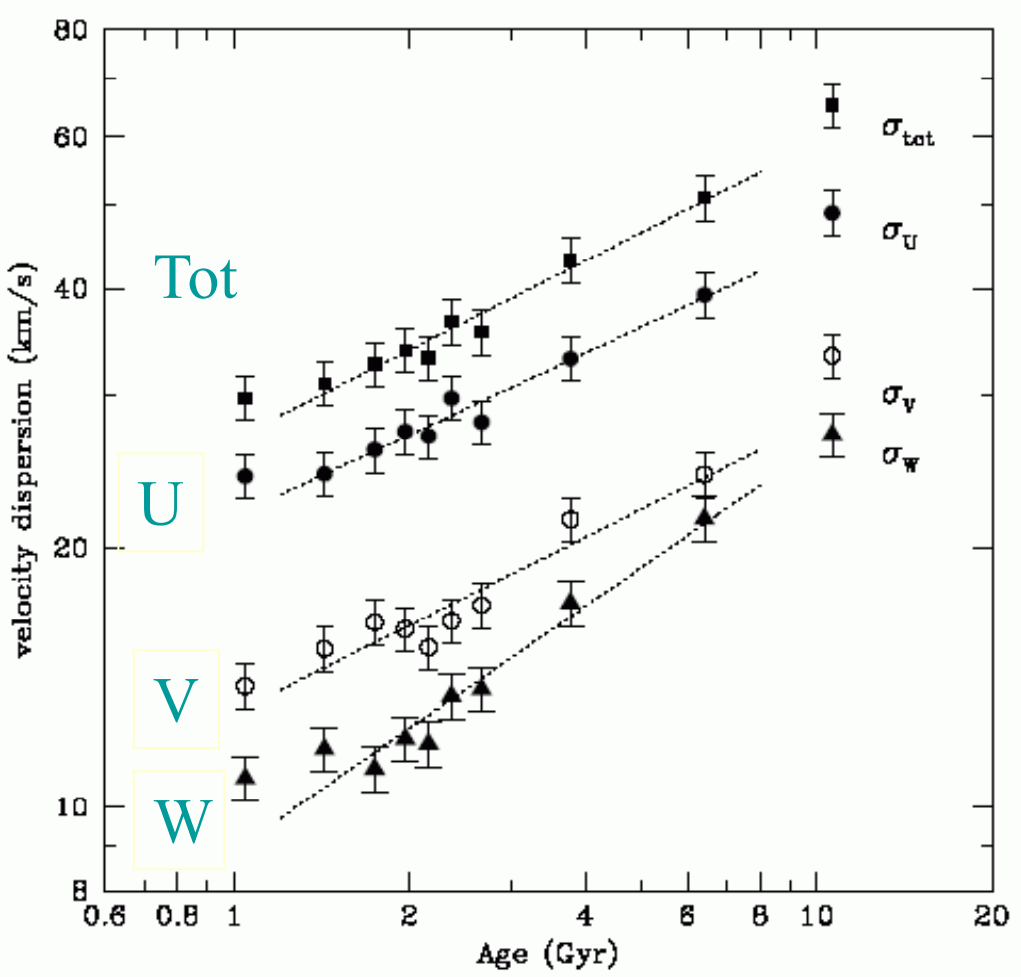
Too hot in simulations
High σ floor
Due to low ρ threshold



There is no discontinuity for the thick disk for oldest stars

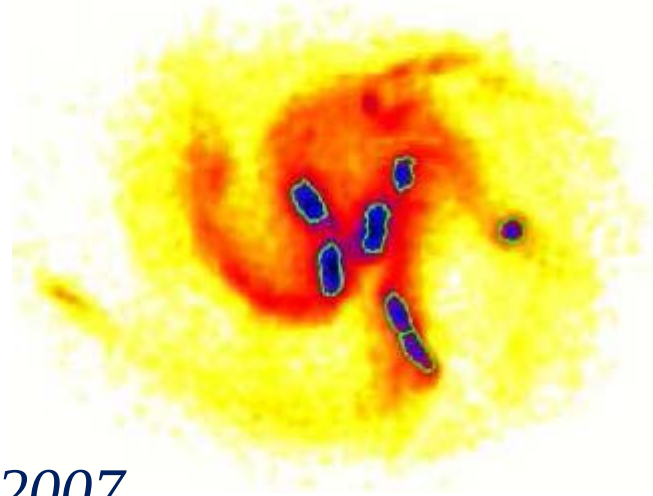
Sample
about 2800 stars

Nordstrom et al. 2004



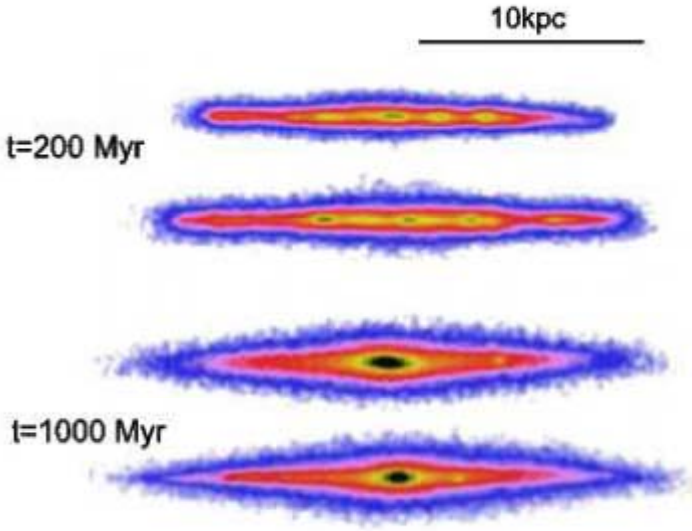
Disk heating continues after 2 Gyr

Formation in clumpy galaxies



Rapid formation of exponential disk
and bulge, through dynamical friction
Noguchi 1999, Bournaud, Elmegreen et al 2007

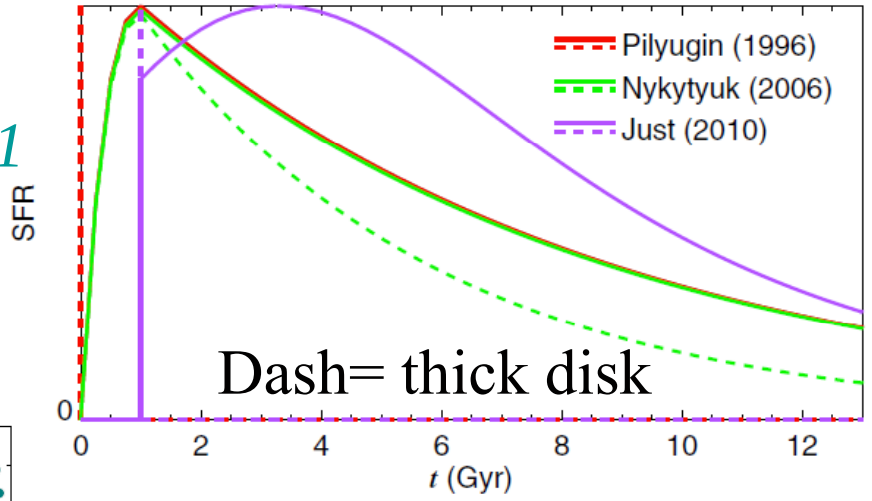
Chain galaxies, when edge-on

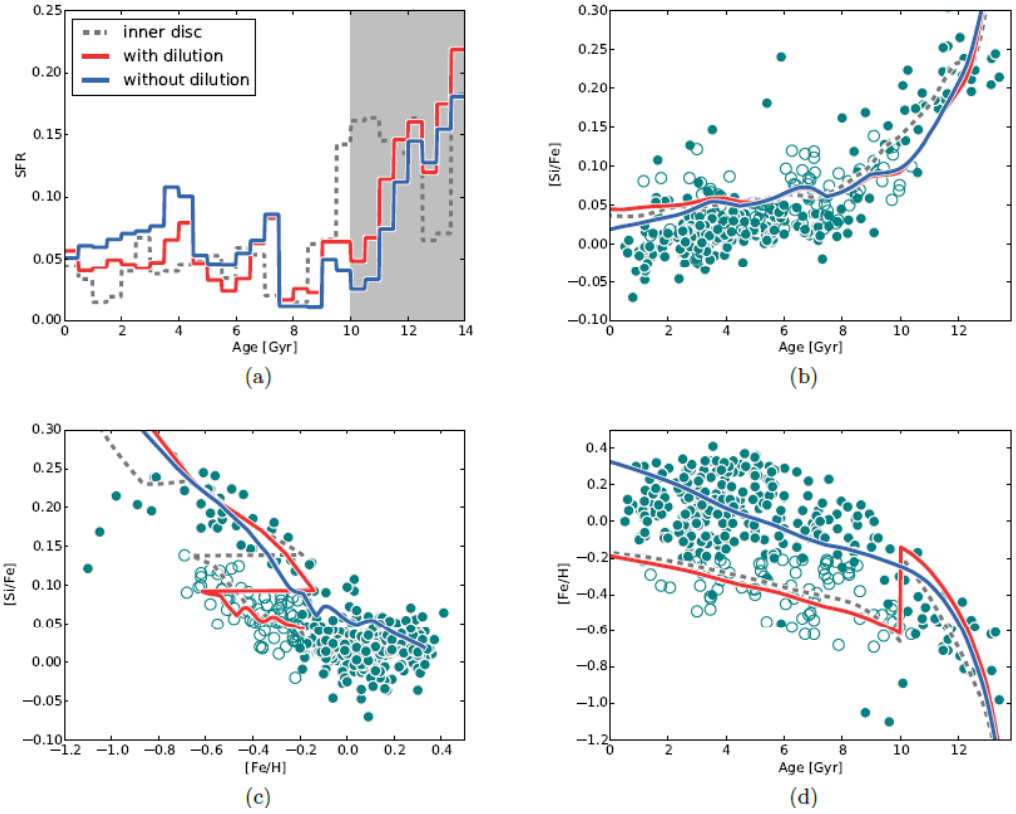


Turbulent clumpy disks form thick disks
with uniform scale height rather
than the flared thick disks
generated by minor mergers

Star Formation History (SFH)

Comeron et al 2011

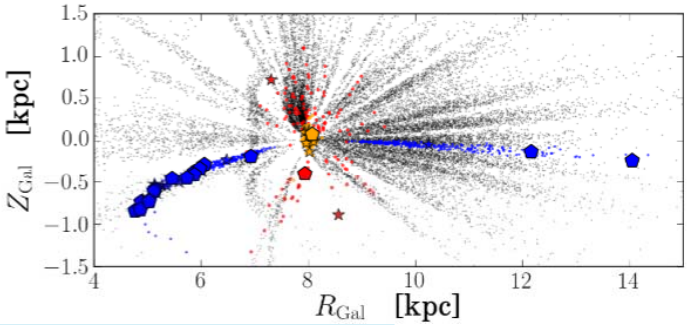




Snaith et al 2015:

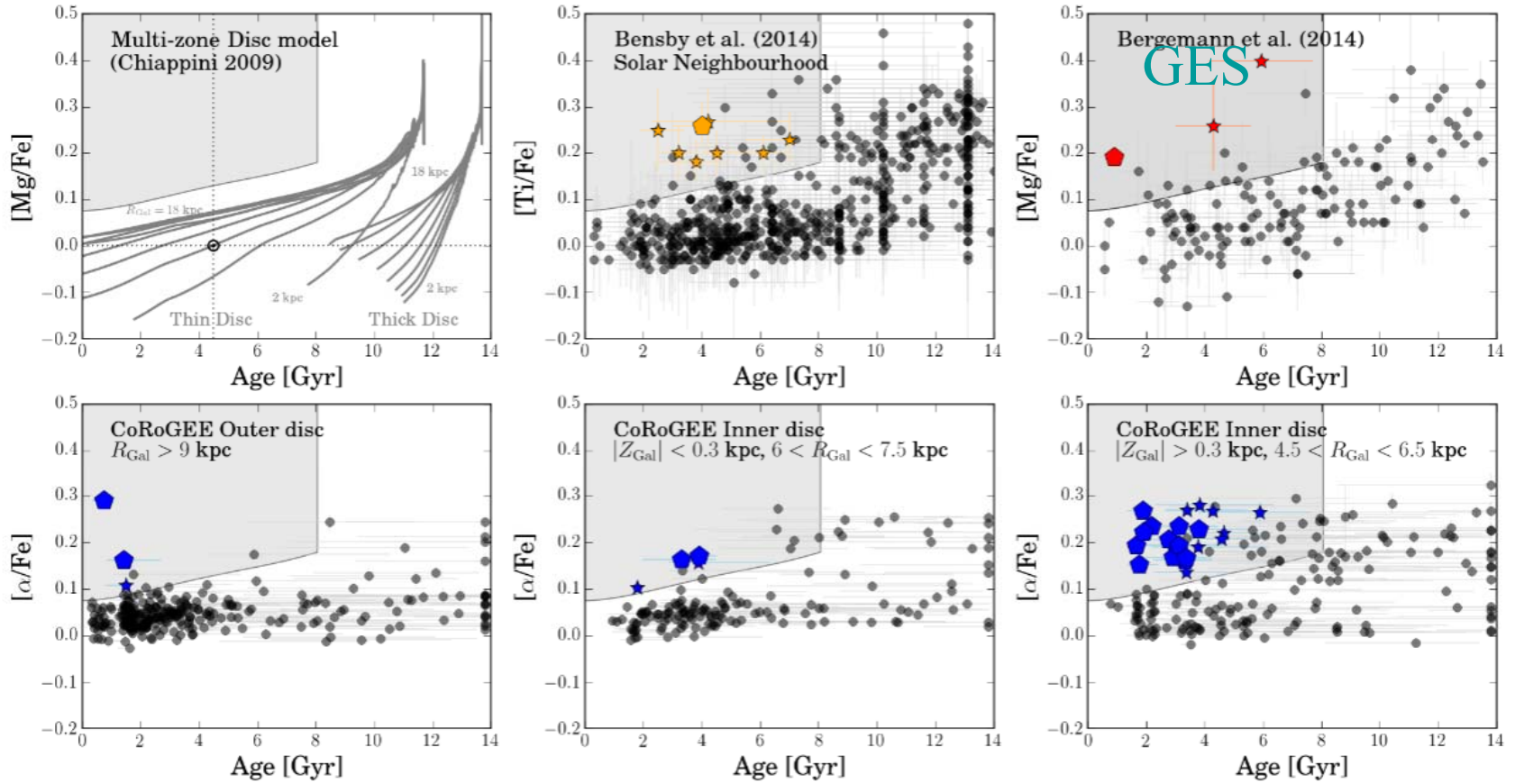
Strong SFR episode, until quenching 8 Gyr ago then restarting a slow SFR

Young α/Fe-rich stars



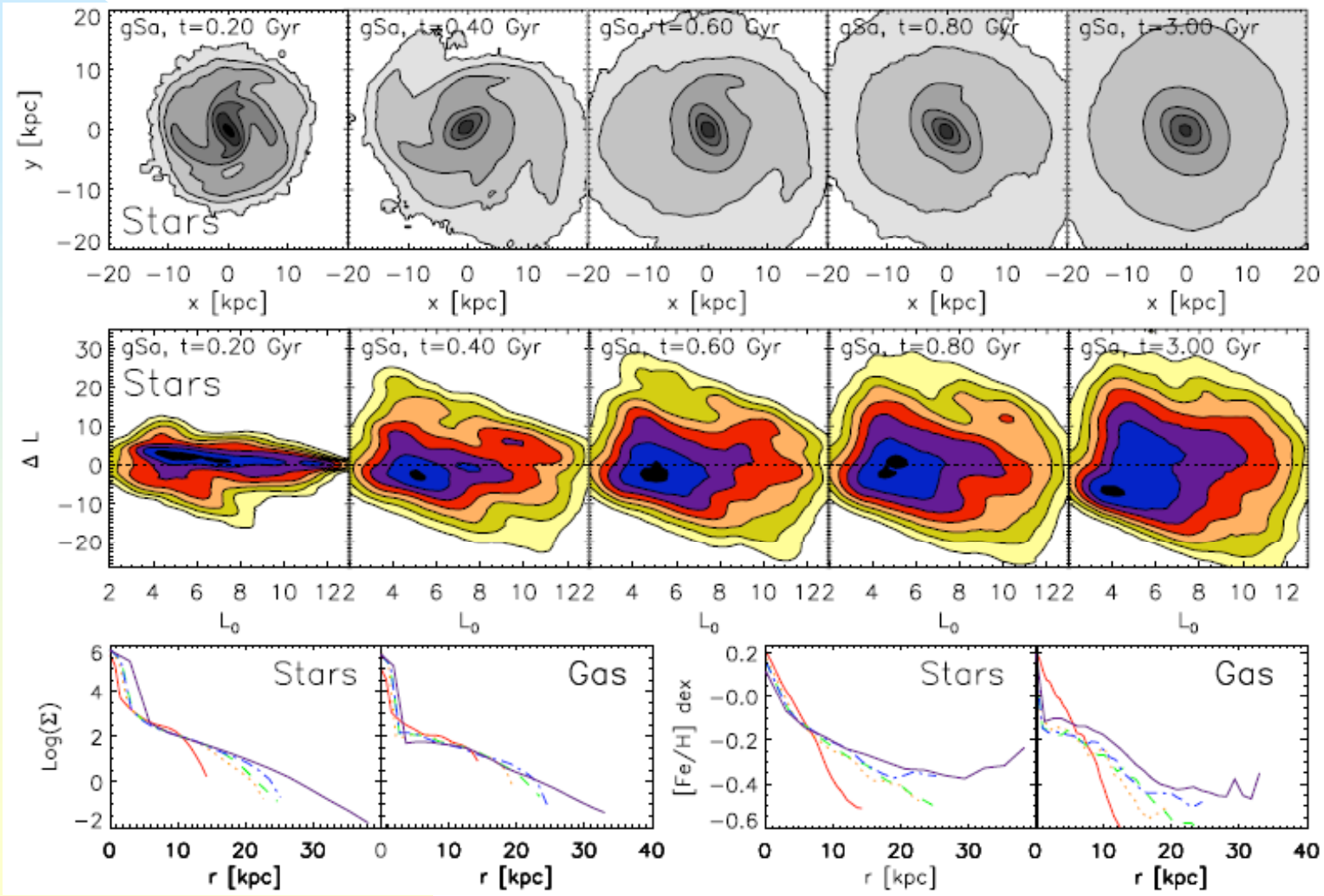
CoRoT-APOGEE stars:*Chiappini et al 2015*

AT R < 6kpc: Gas either is refueled from old stars (with low Fe/H) or accreted from pristine gas



Bar+spiral: radial migrations

Overlap of resonances



Minchev et al 2010

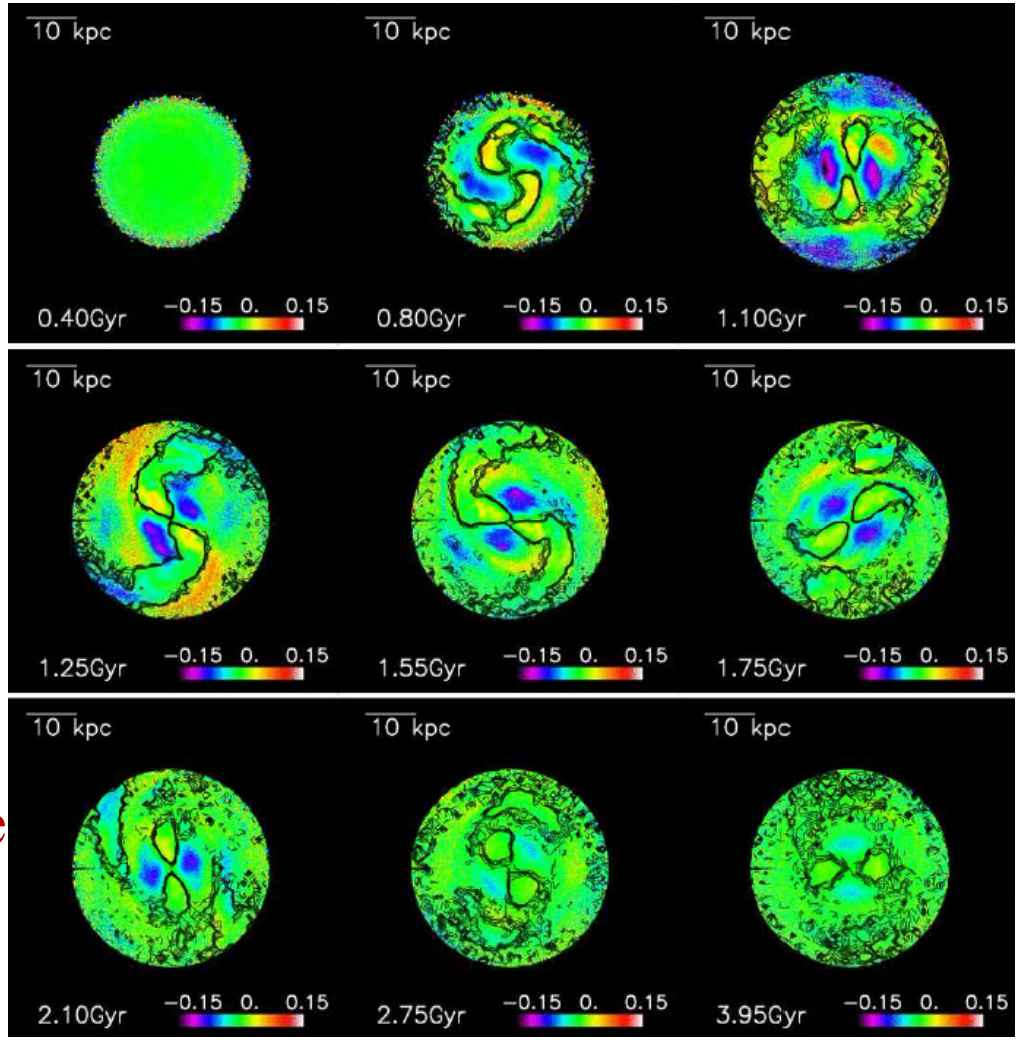
Azimuthal signature of radial migration

The migration is due to exchange of angular momentum through bars and spirals
Azimuthal signatures are seen **during the migration**

GES: Kordopatis et al 2015
6kpc < R < 10kpc
Identificaiton of the thick disk by their high α/Fe, up to Fe/H~0.2 and thin disk down to Fe/H~-0.8

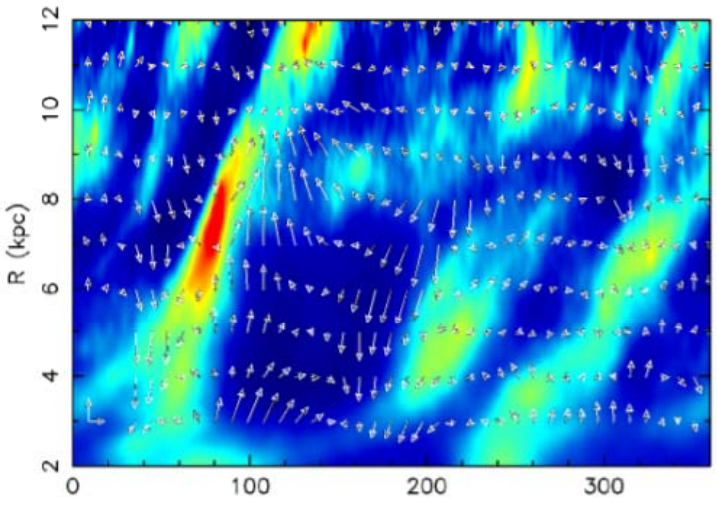
Radial & vertical gradients in α/Fe for thin disk, but not thick
Evidence of radial migration

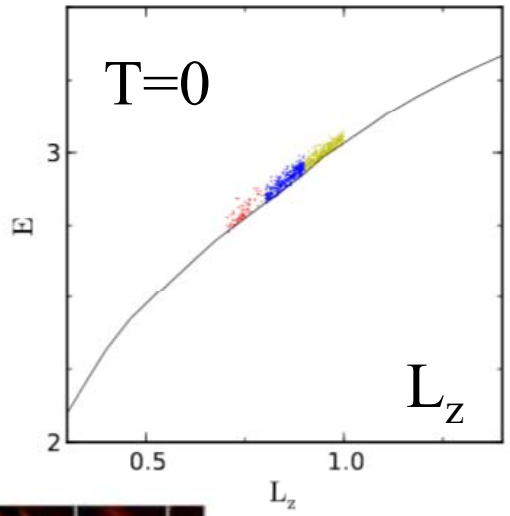
Di Matteo et al 2013
Maps of δ[Fe/H]

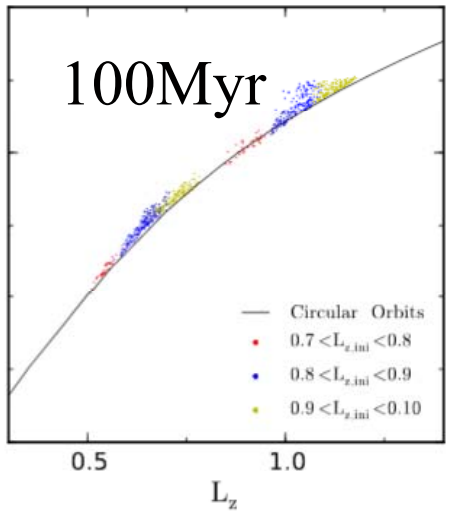


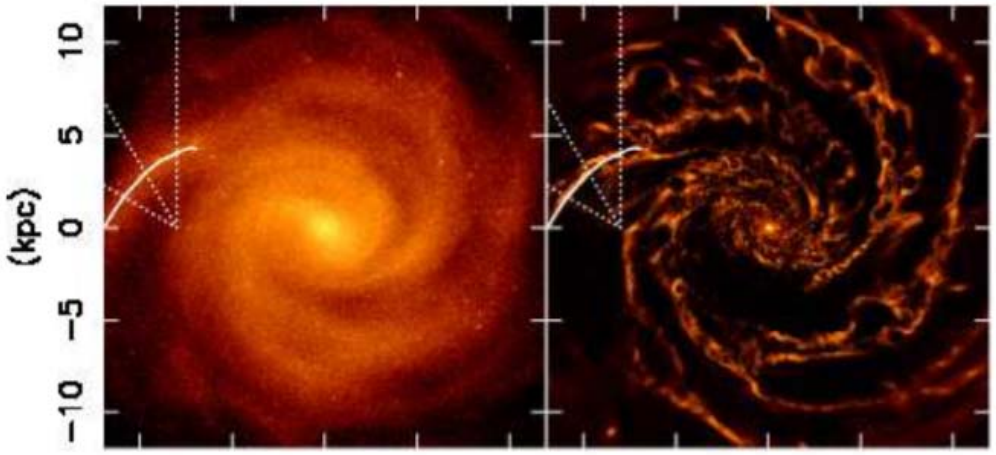
Radial migration: circular orbits

Grand & Kawata 2015









Transient spiral structure ➔
streaming motions
Exchange of angular momentum
➔ radial migration

Simulations: 2.5 10^{12} $M_\odot$ DM-NFW
410^{10} $M_\odot$ stars & 10^{10} $M_\odot$ gas
Kawata et al 2014

Streaming motions compatible with APOGEE red clump
Only broadening, no gradient