UCL

Transient Spiral Arms and Chemo-Dynamics of the Galactic Disk

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MSSL Gaia activities



- CCD and electronics
- Radial Velocity Spectrometer (RVS)
- Gaia DPAC: CU6
  Spectroscopy data processing
  Mark Cropper, Steve Baker and team.
- Research Group → GCDS
  Mark Cropper, Kinwah Wu, Ignacio Ferreras, Steve Boudreault, Curtis Saxton, George Seabroke, Dave Vande Putte (PhD), Awat Rahimi (PhD), Rob Grand (PhD) and Daisuke Kawata

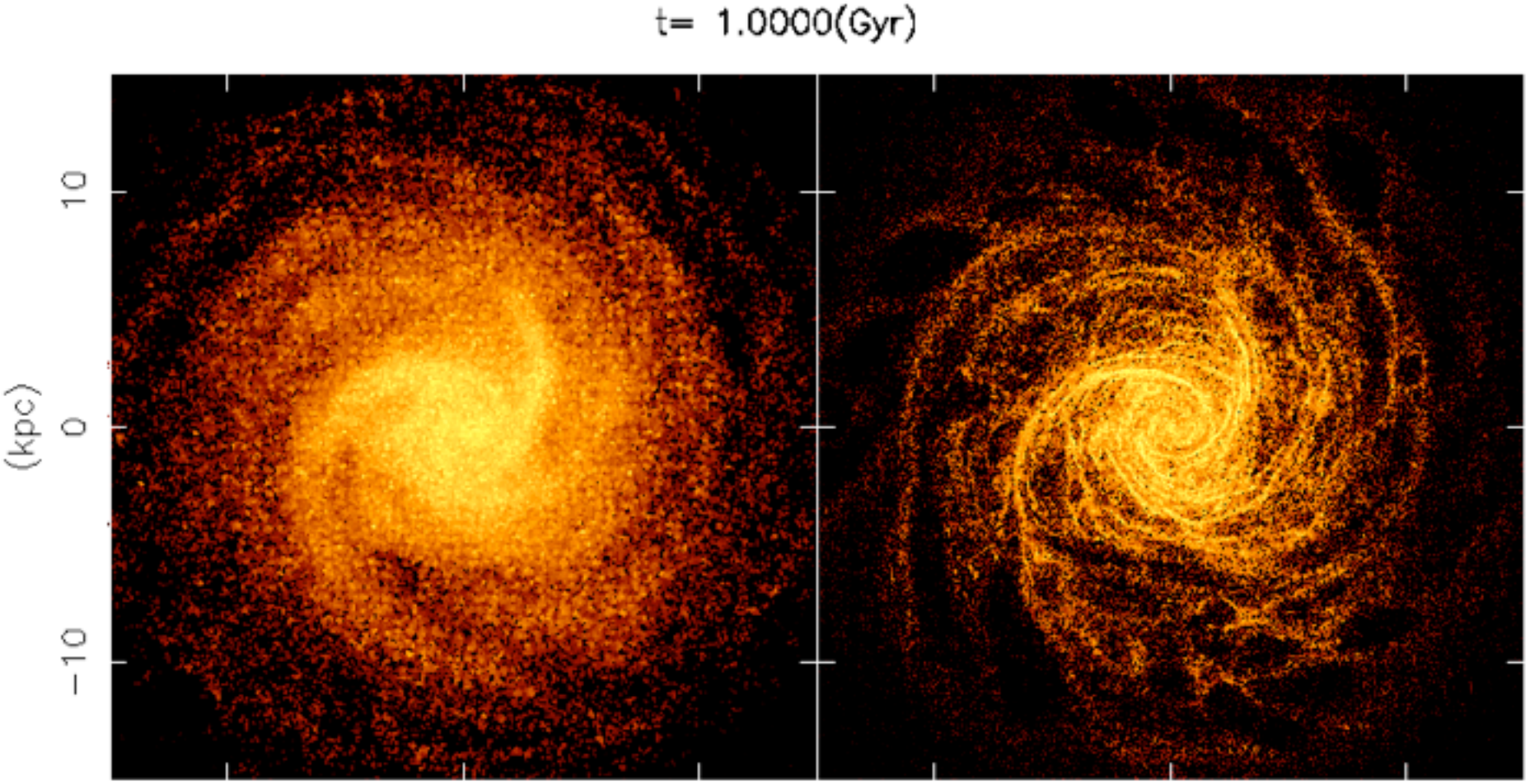
Today's topic:
effects of spiral arms

- Spiral arms are transient features
- Stellar migration due to transient spiral arms
- Metallicity distribution due to migration

Galactic Chemo-Dynamical evolution code, GCD+
(DK 1999, DK & Gibson 2003)

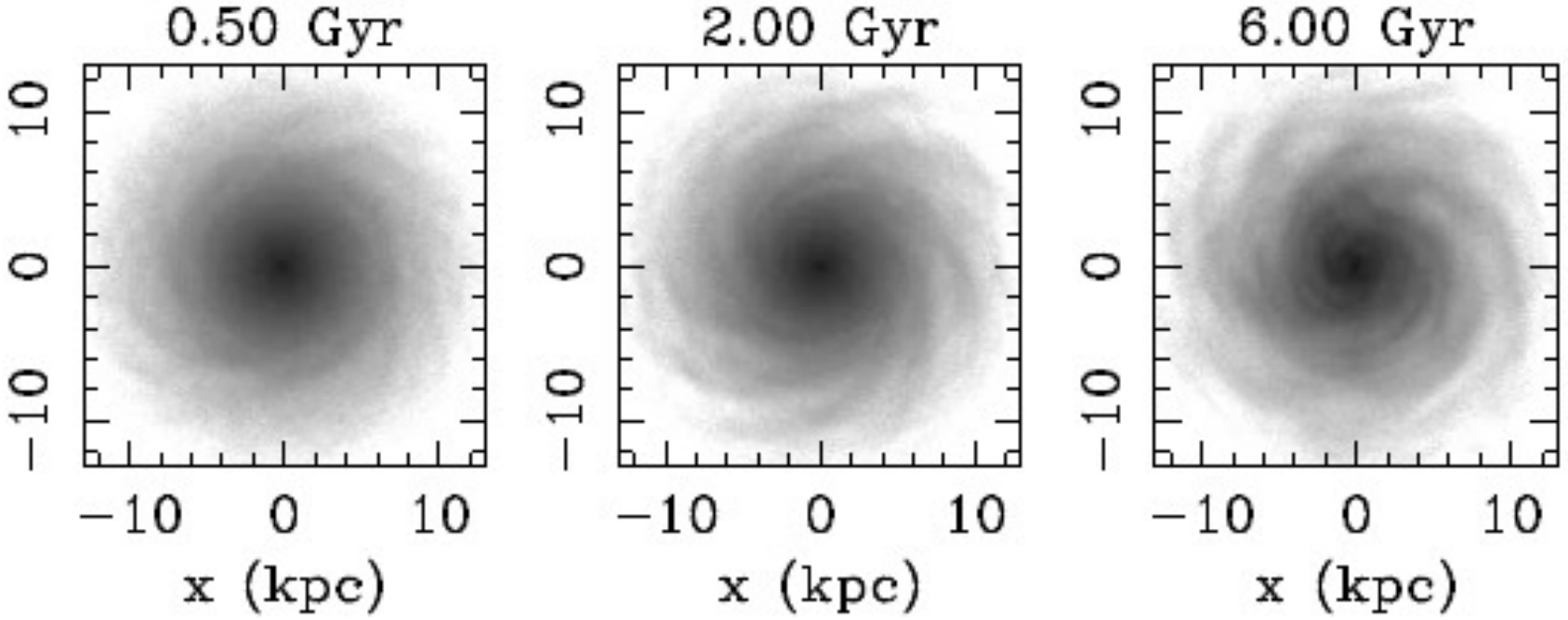
- original 3D parallel N-body/SPH code
- DM and stars: Tree N-body
- Gas: Smoothed Particle Hydrodynamics
  Radiative Cooling
  Star Formation
  SNe feedback
  Metal Enrichment
    from SNe II and I, mass loss from intermediate mass stars ($m<8M_{\odot}$)
  Metal mixing

- bulge ... Rahimi et al. (2010)
- disk ... Richard et al. (2010), Mouhcine et al. (2008), Brook et al. (2007a), Brook et al. (2006), Brook et al. (2005), Bailin et al. (2005), Brook et al. (2004)
- stellar halo ... Renda et al. (2005), Salvadori et al. (2010), Brook et al. (2007b), Scannapieco et al. (2006), Knebe et al. (2005), Brook et al. (2003a,b)
- HVC ... Connors et al. (2006), Kawata et al. (2005)
- dwarfs ... Connors et al. (2006), Kawata et al. (2006)



N~3x10^5 disk gas and star particles, m_p=10^5 $M_\odot$ with a fixed NFW DM potential. After 1 Gyr (to relax), 2 Gyr evolution. Recurrent and transient spiral arms.

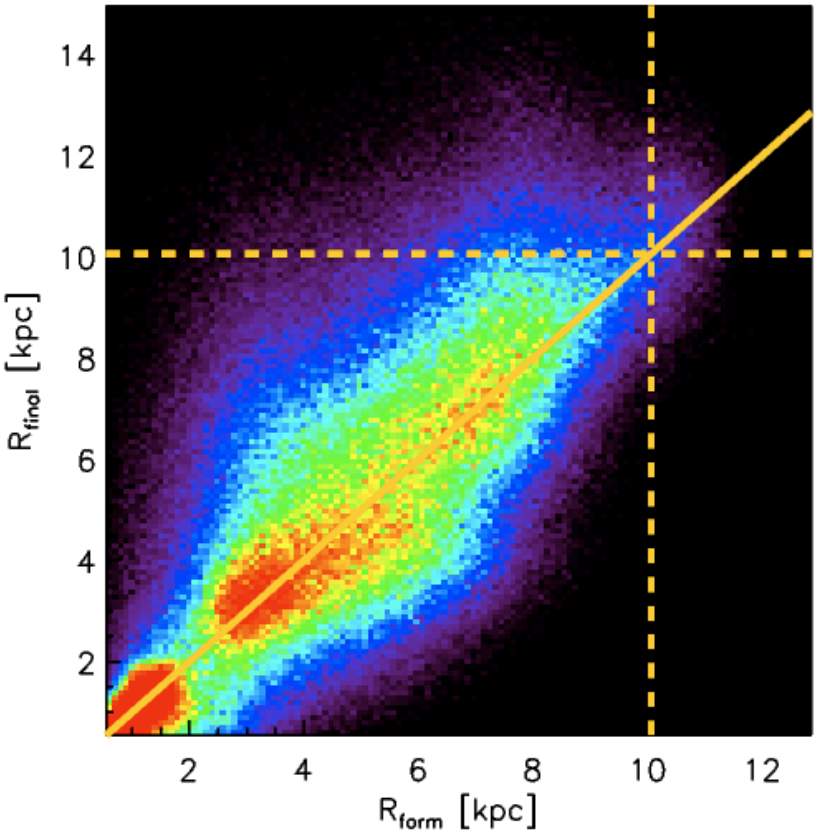
Tough to make long-lived spiral arms...
Spirals are recurrent and transient.
(e.g. Sellwood 2010, Fujii et al. 2010, Quillen et al. 2010)

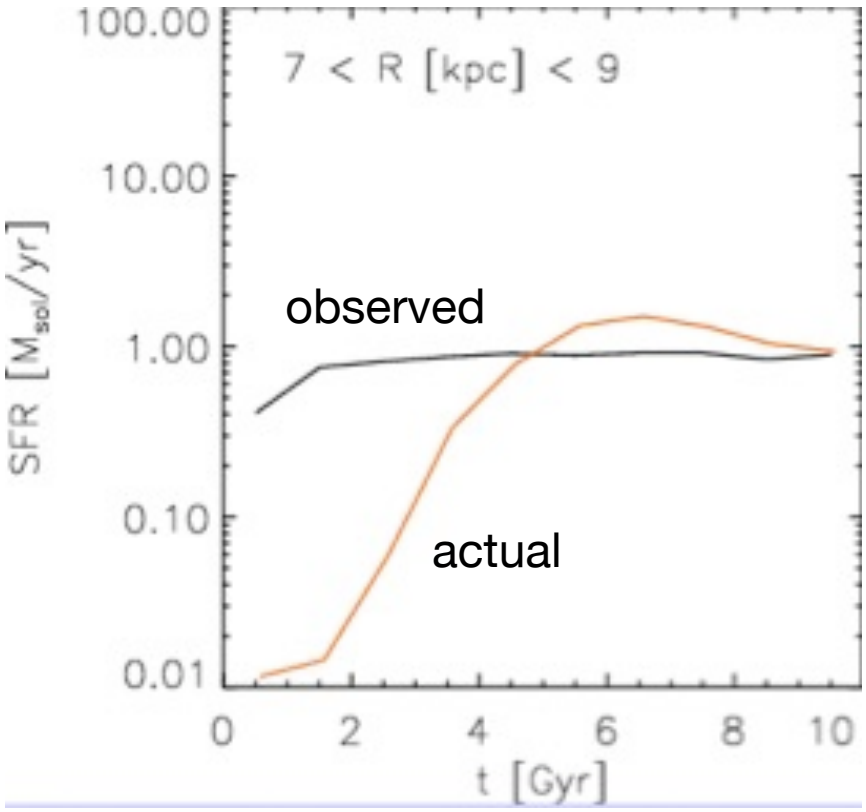


9M N-body simulations (Fujii et al. 2010)

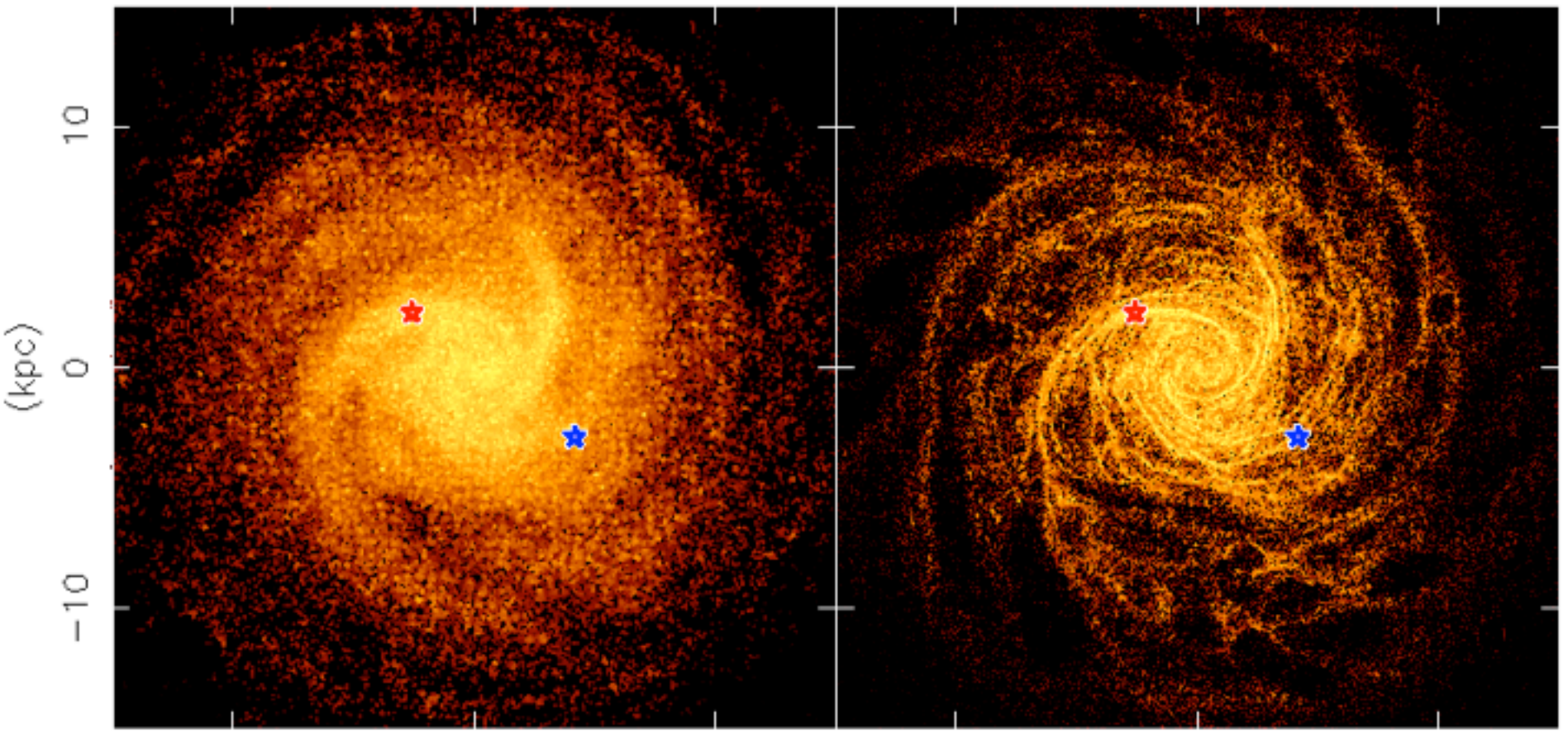
Radial migration (churning) due to transient spiral arms

(e.g. Sellwood & Binney 2002; Roškar et al. 2008a,b; Sánchez-Blázquez et al. 2009; Minchev et al. 2010)

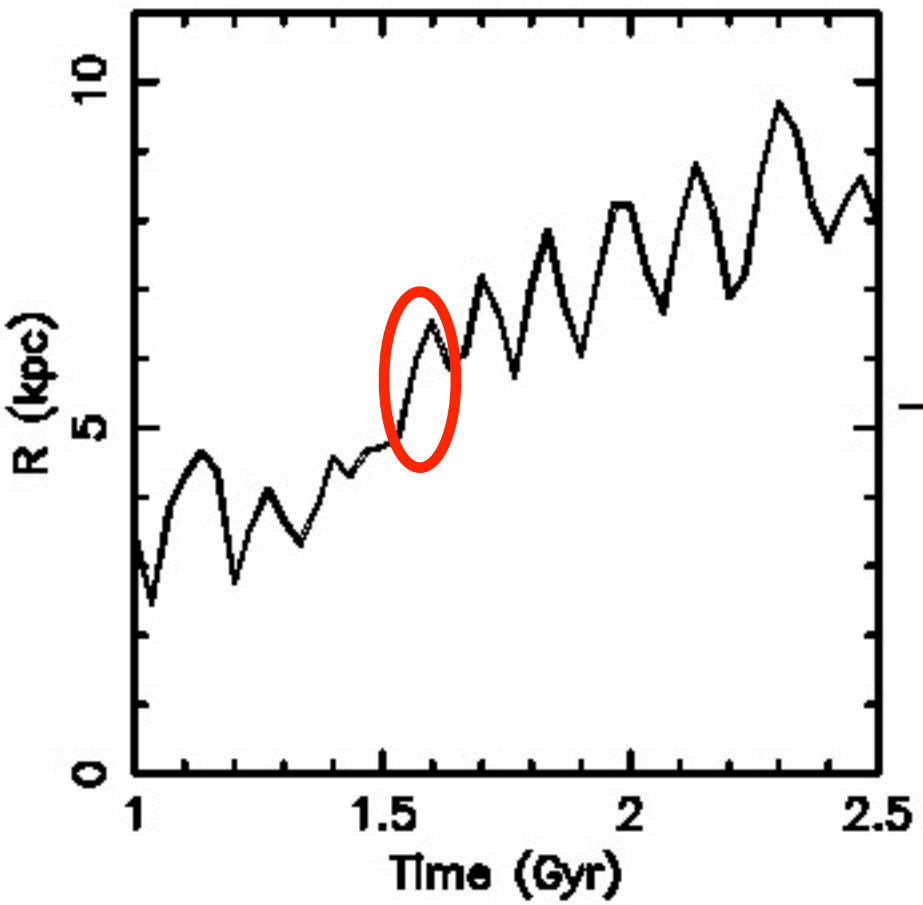


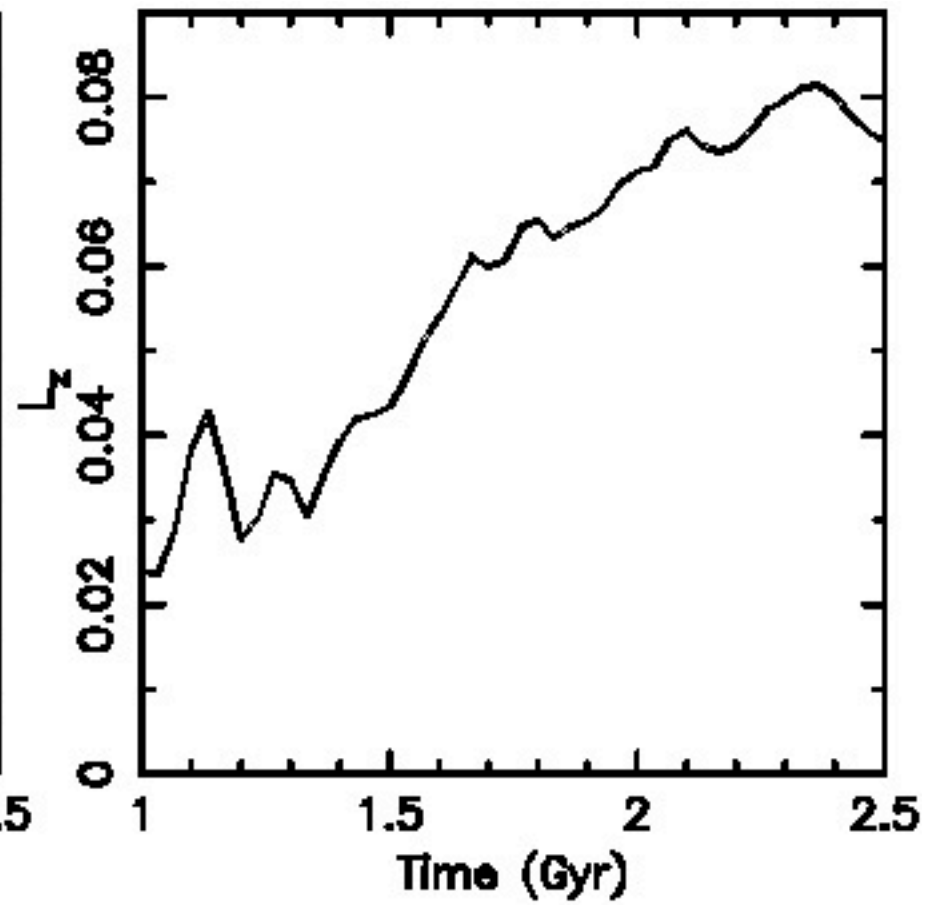


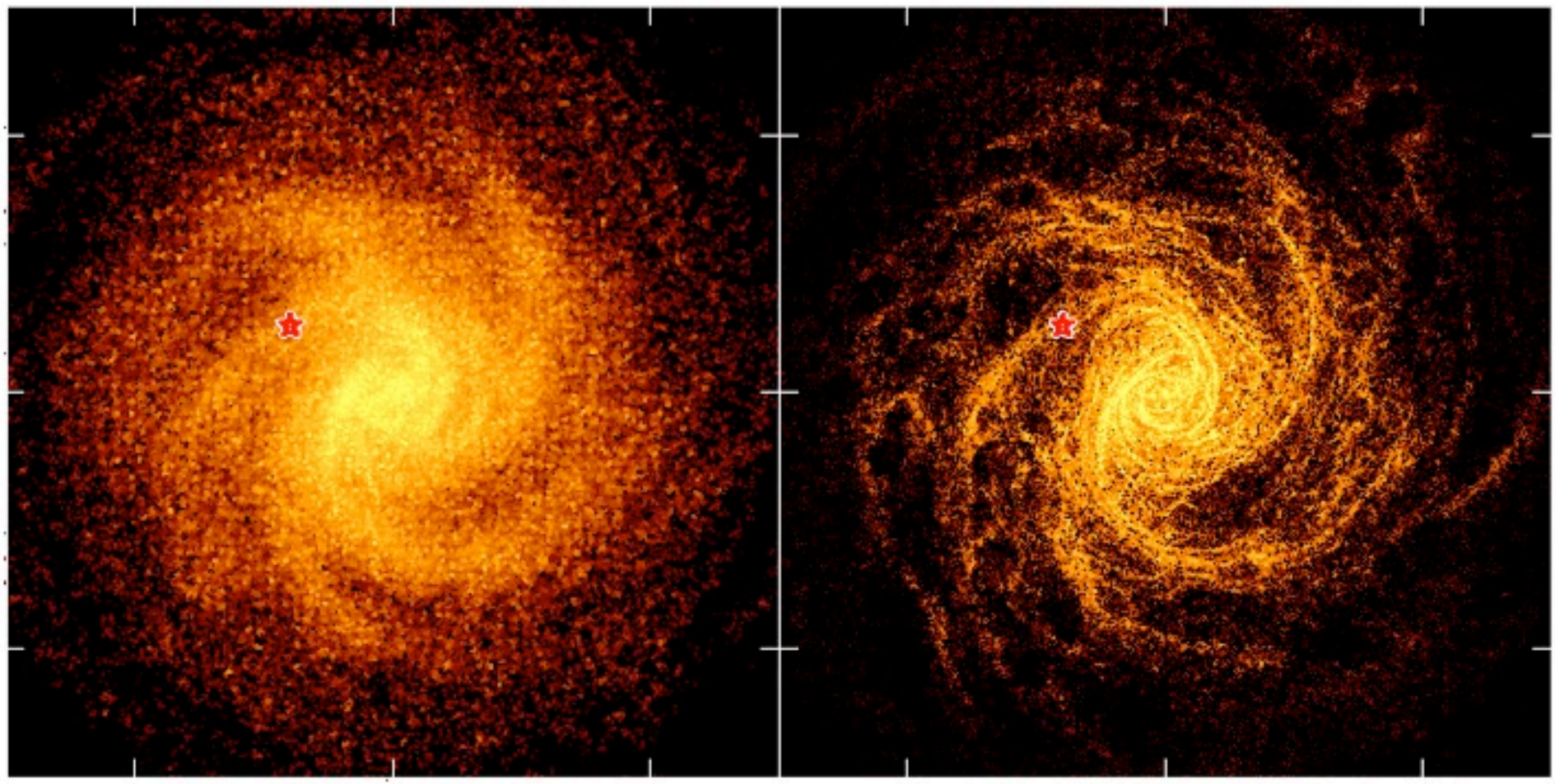
Rošker et al. (2008a,b)

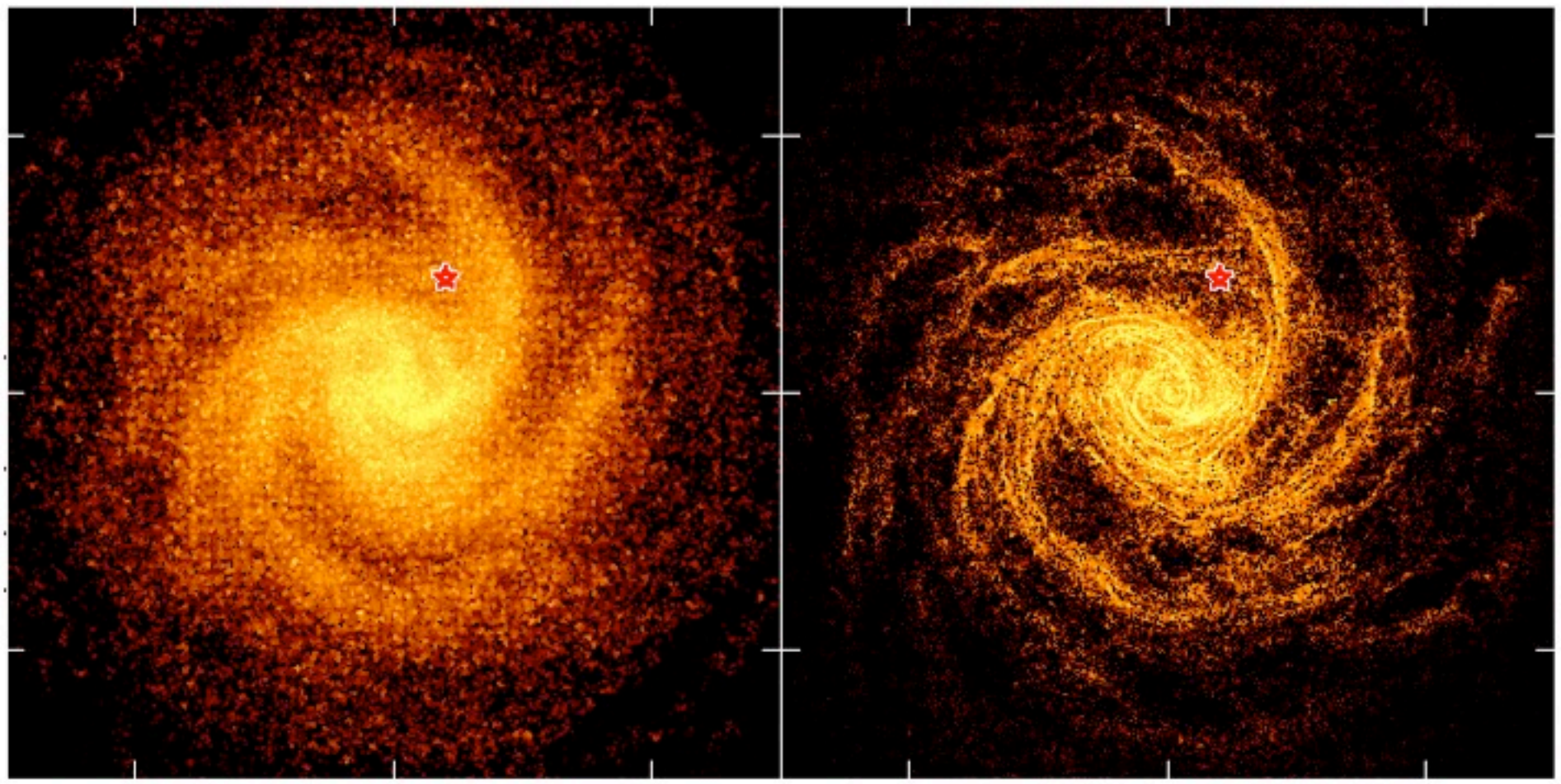

t= 1.0000(Gyr)
10
0
−10
(kpc)

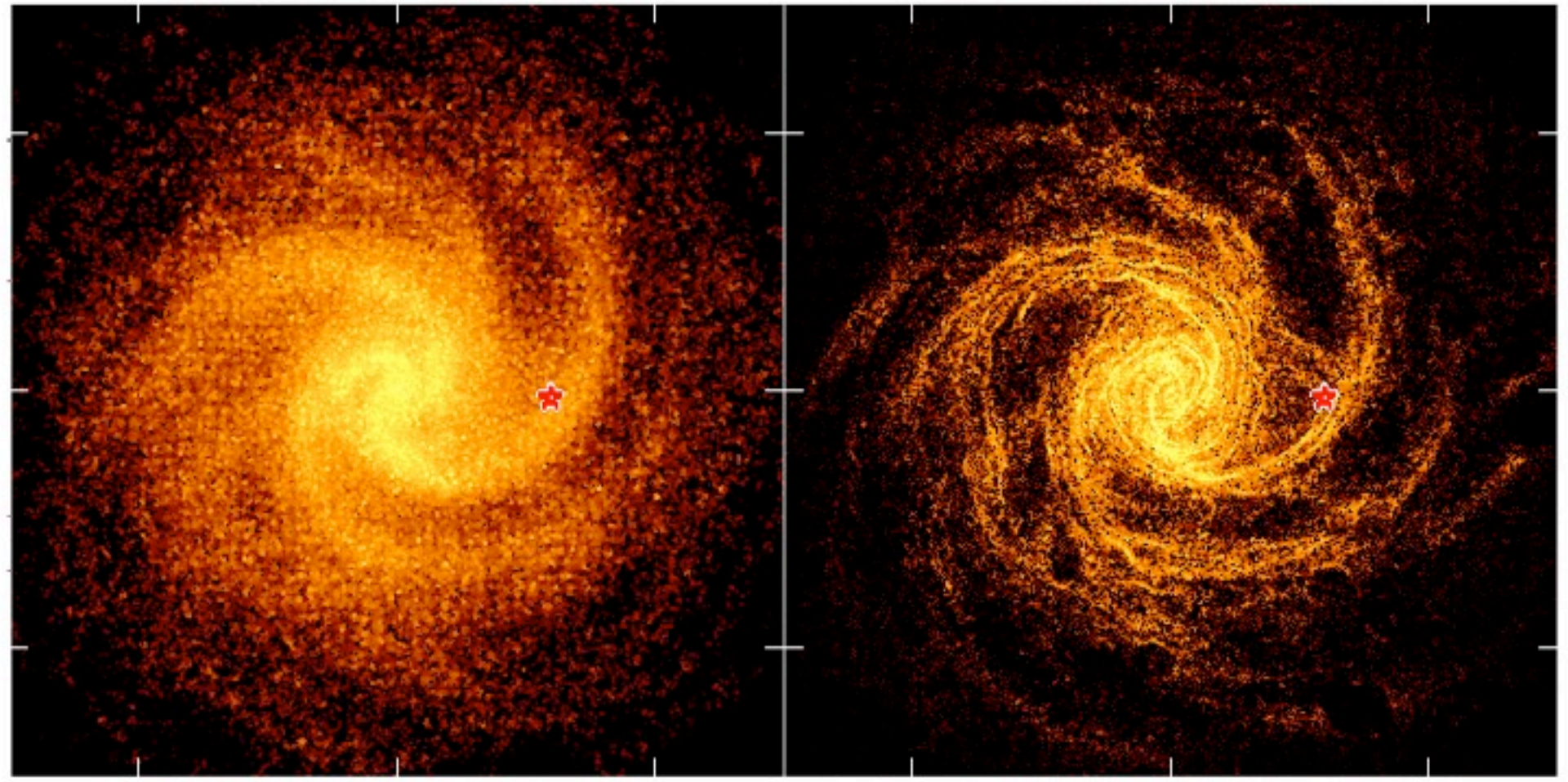
~1 Gyr is enough to travel from
R=3 kpc to 8 kpc!



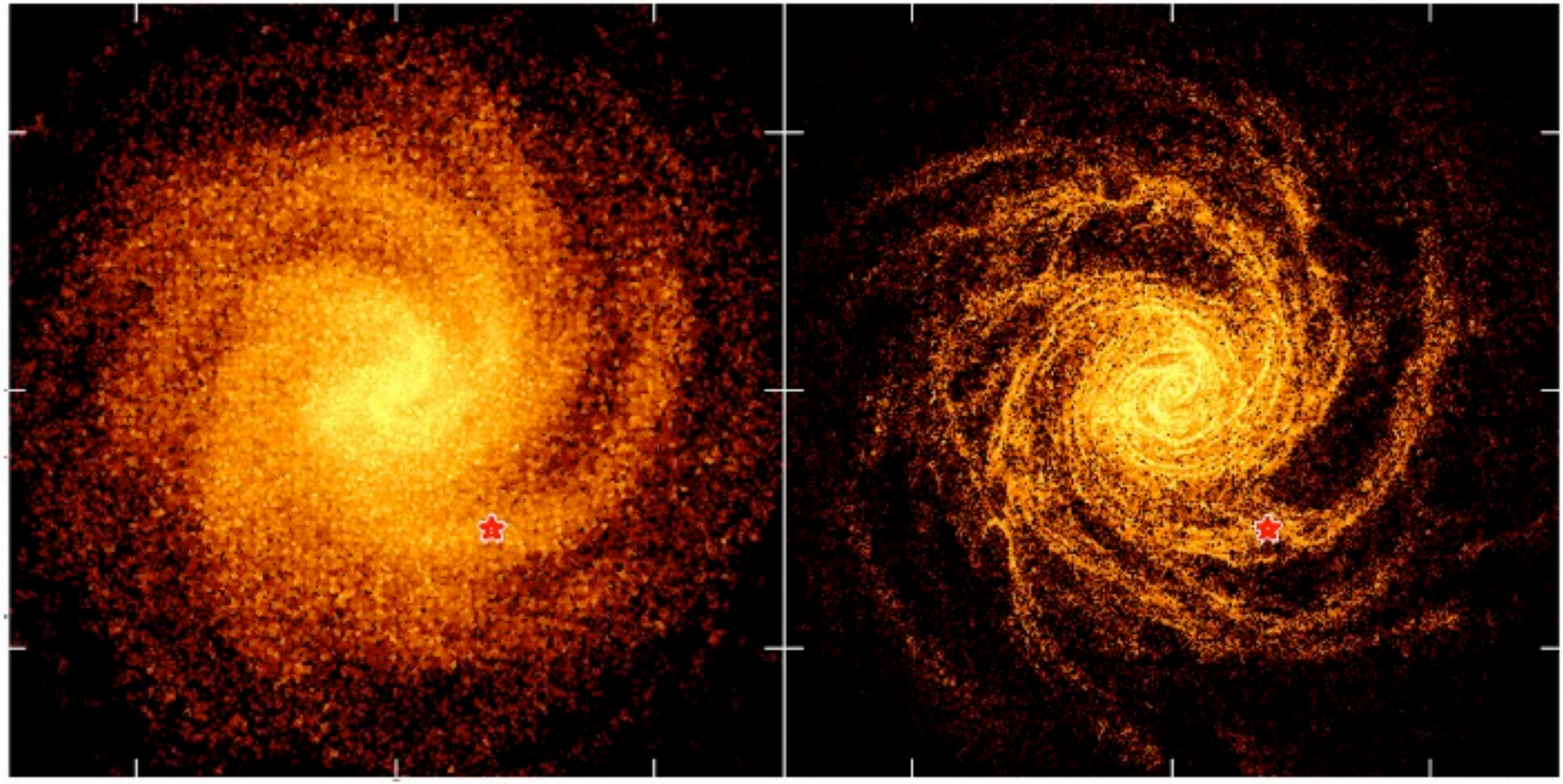



t= 1.5000(Gyr)


t= 1.5333(Gyr)


t= 1.5667(Gyr)

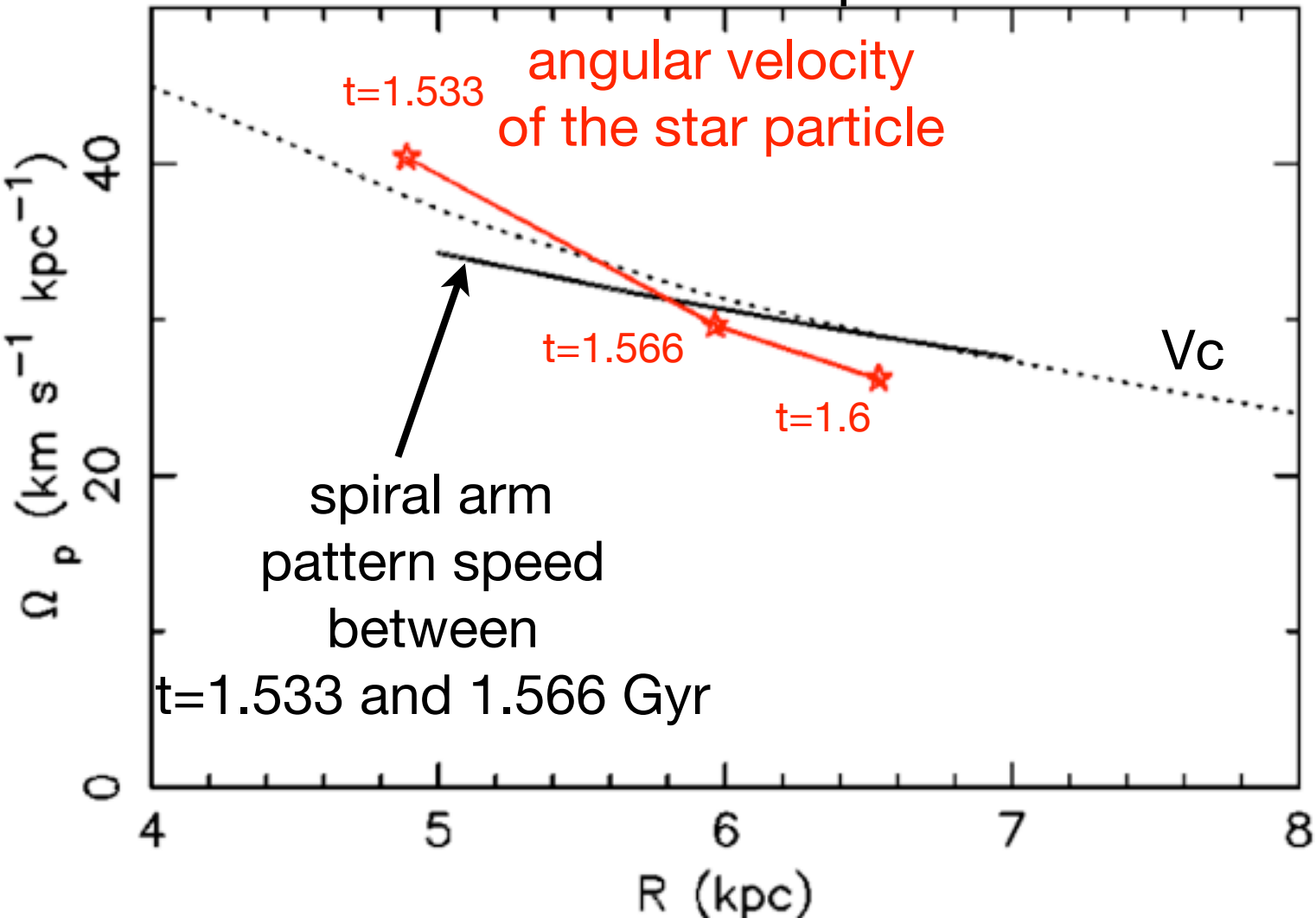
t= 1.6000(Gyr)



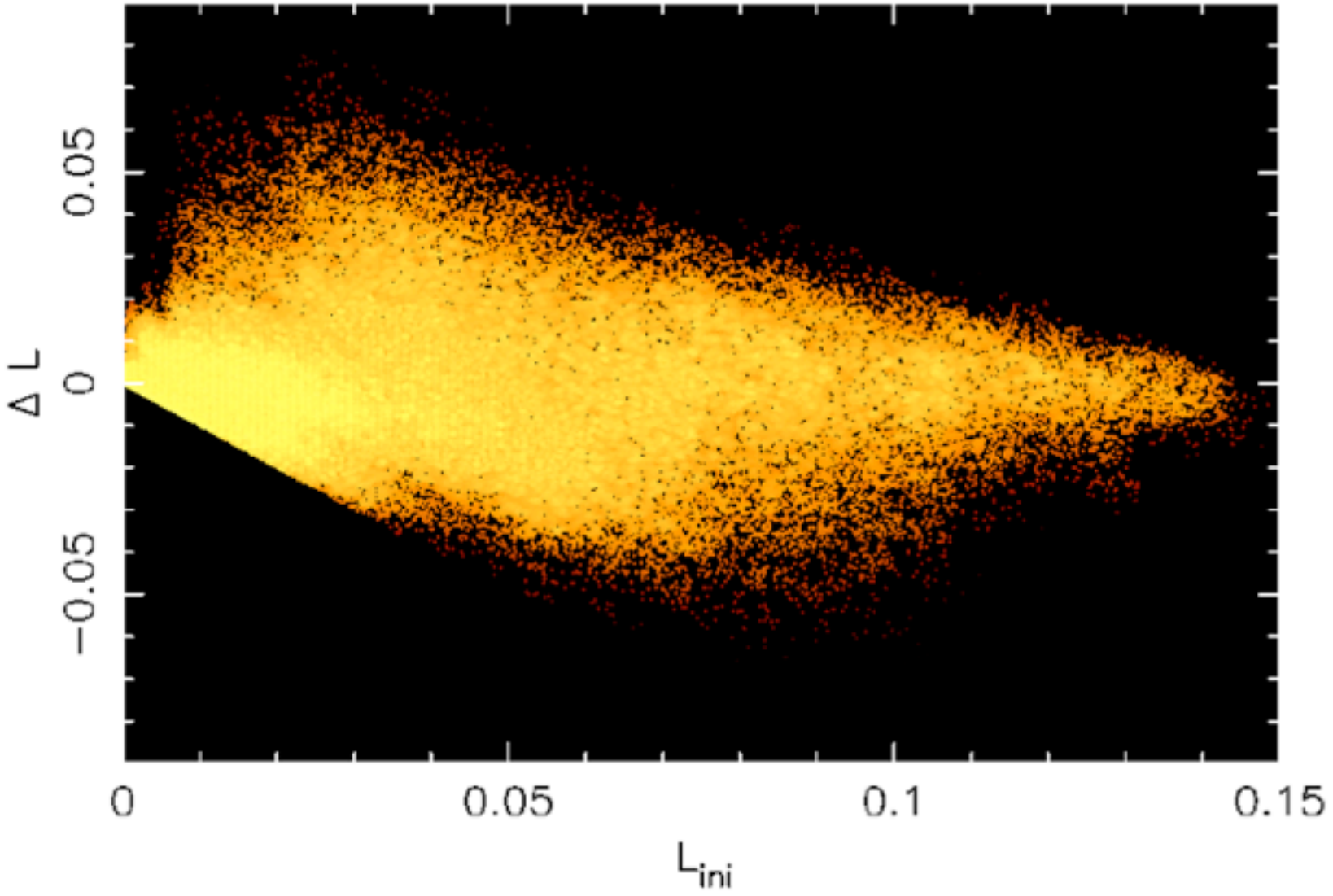
Spiral pattern speed decreases with radius

= spirals are winding up → transient arms

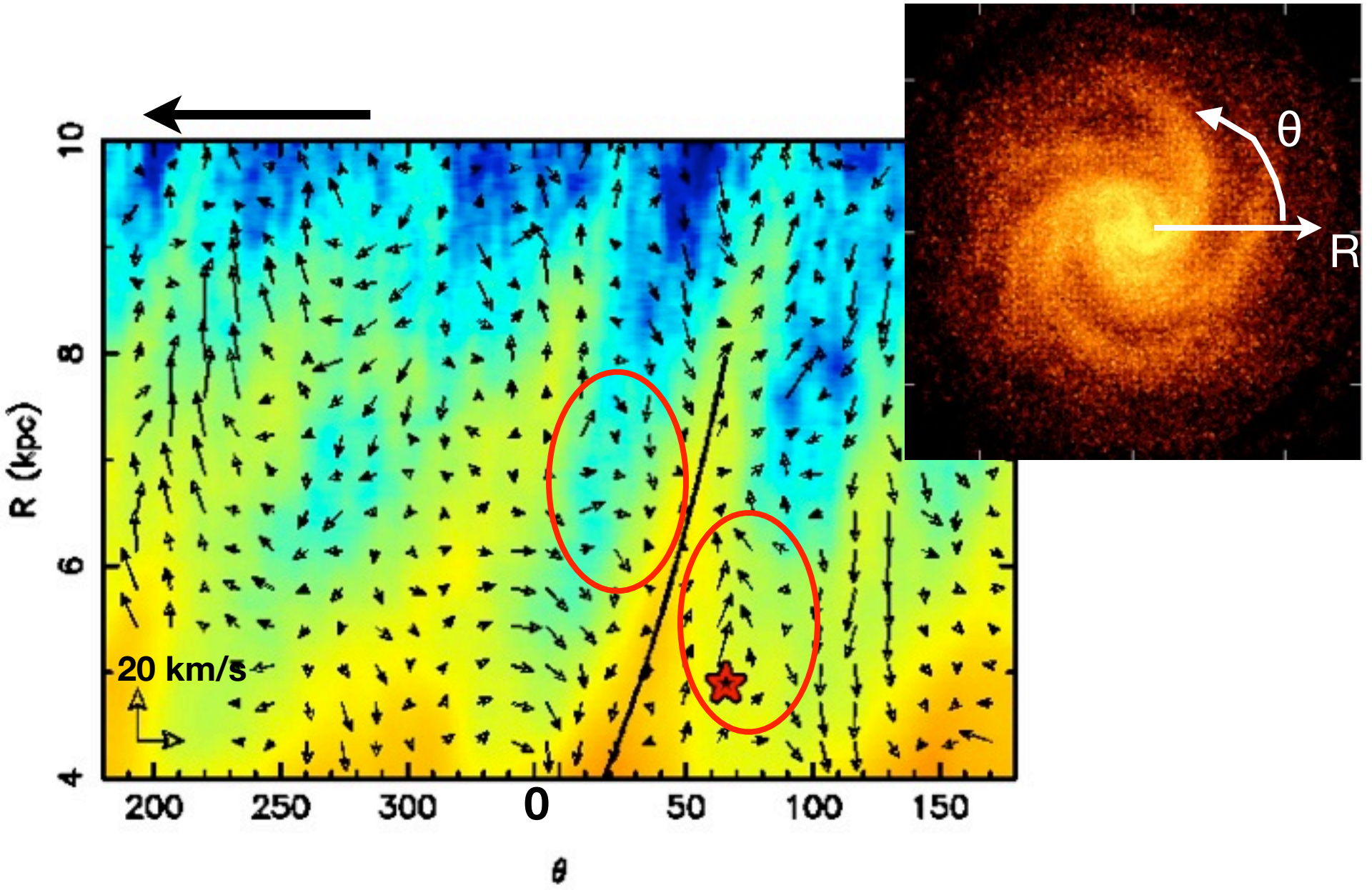
particles accelerated by a spiral stay longer close to a corotation phase



Many different spiral arms contribute to the migration angular momentum gain and loss after 2 Gyr

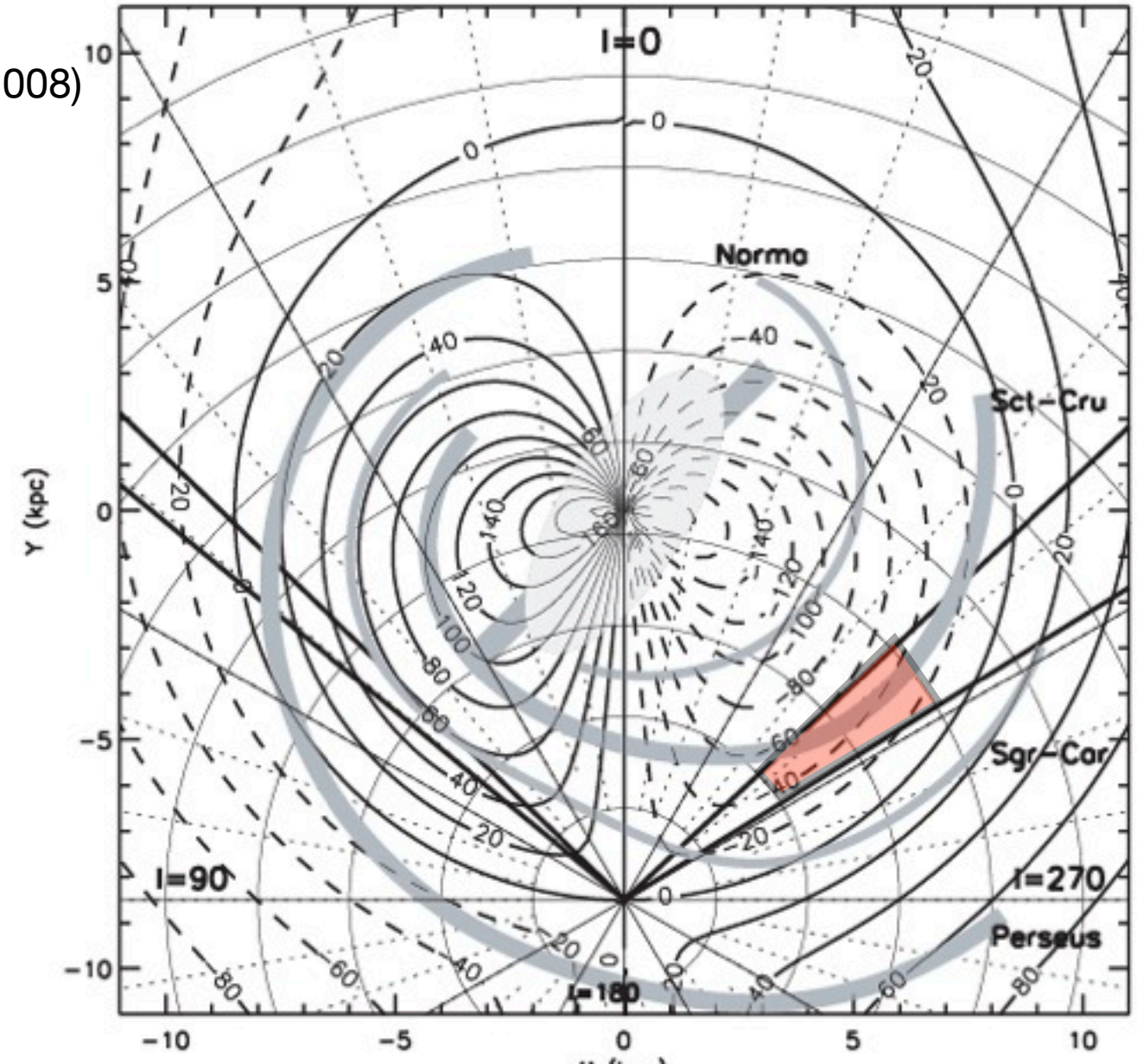


Stellar streaming motion (~10 km/s) due to spirals?

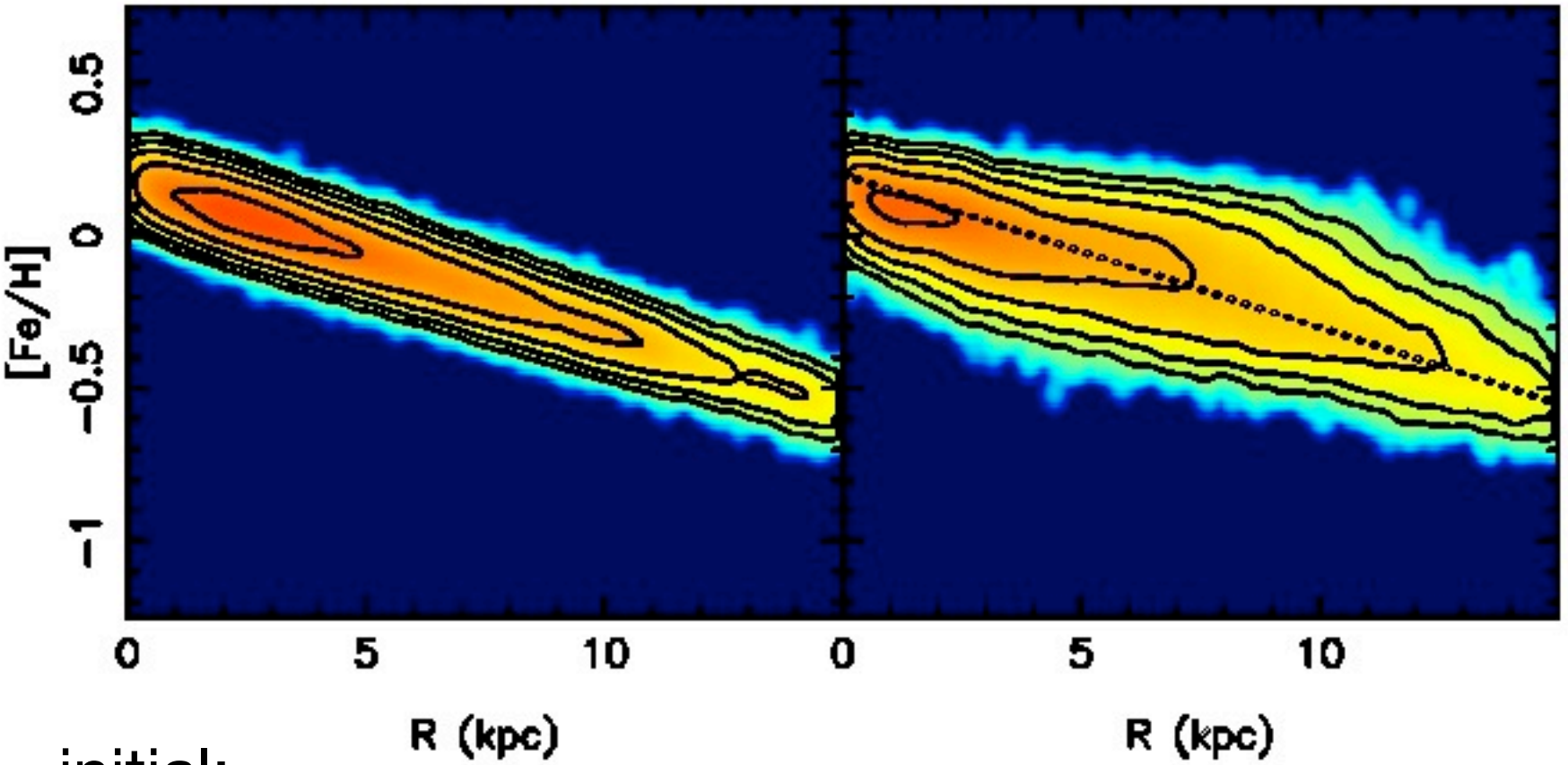


Centaurus Arm is a good target?
tough for RVS?, need radial velocity follow up.

Benjamin (2008)



Metallicity gradient in the thin disk (|z|<200 pc) is smeared out by radial migration?

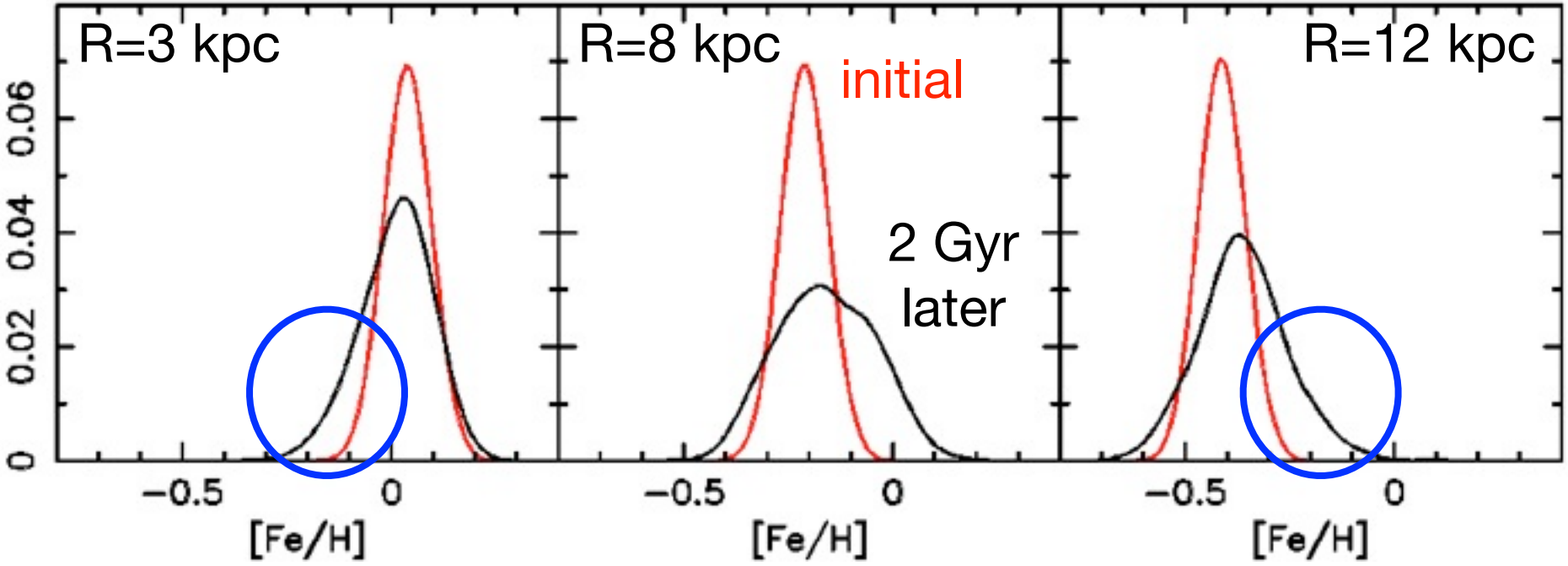


initial:
d [Fe/H]/dR = 0.05 dex/kpc
0.05 dex [Fe/H] dispersion

after 2Gyr:
similar slope with
more dispersion

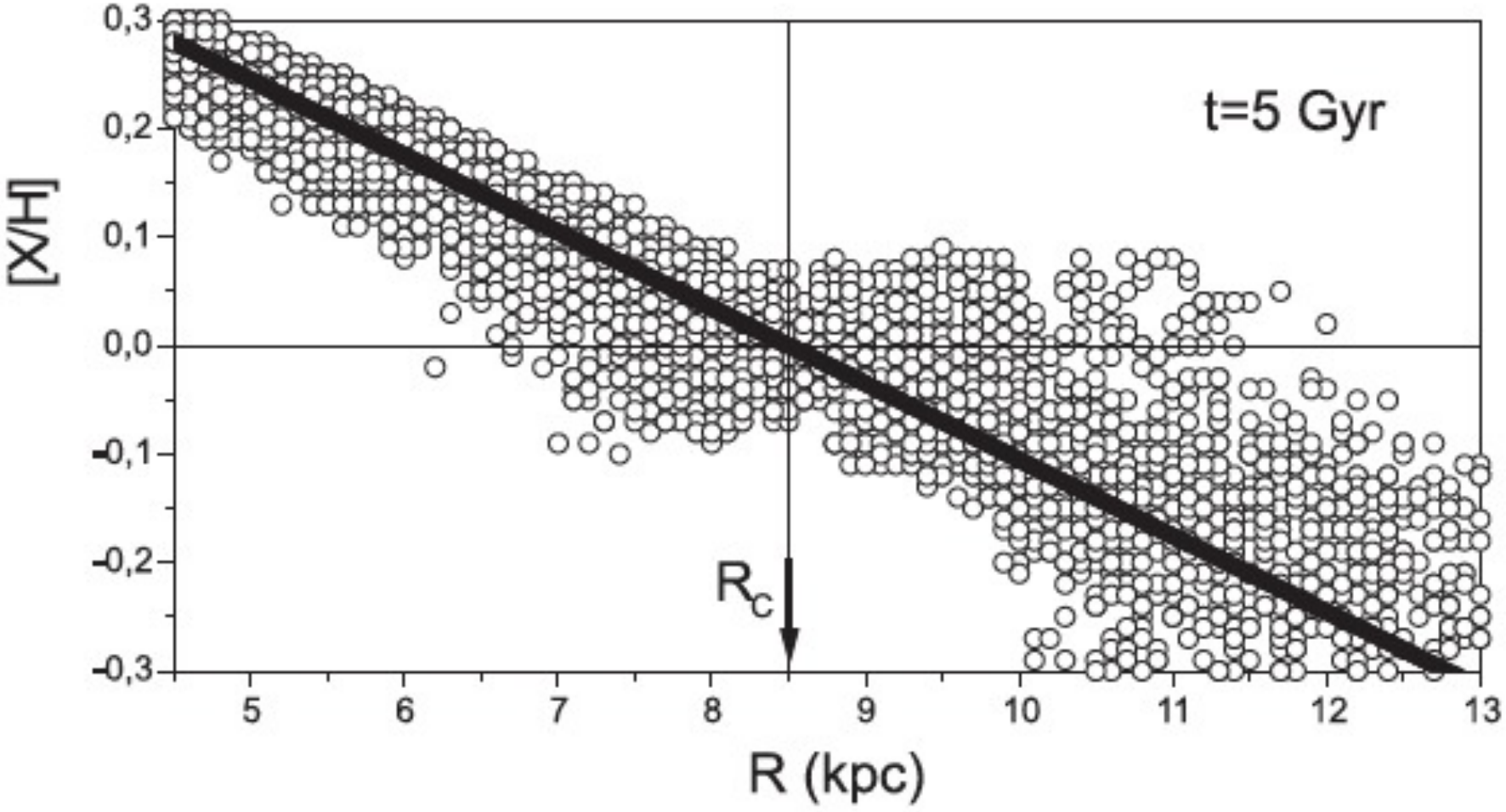
(accurate) MDF for young and old stars at different radii → a critical test for radial migration.

(see also Schönrich & Binney 2009)

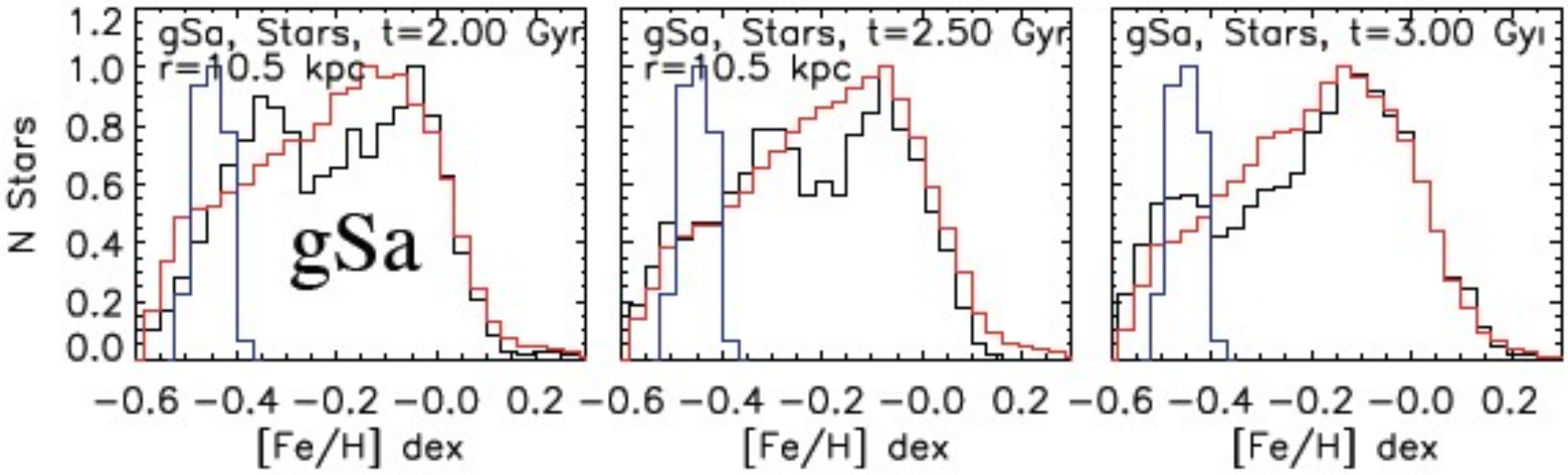


How to compare metallicity between young and old stars *accurately*?

Long-lived solid rotation spiral arm
→ a small effects around co-rotation.
(Lépine et al. 2003)



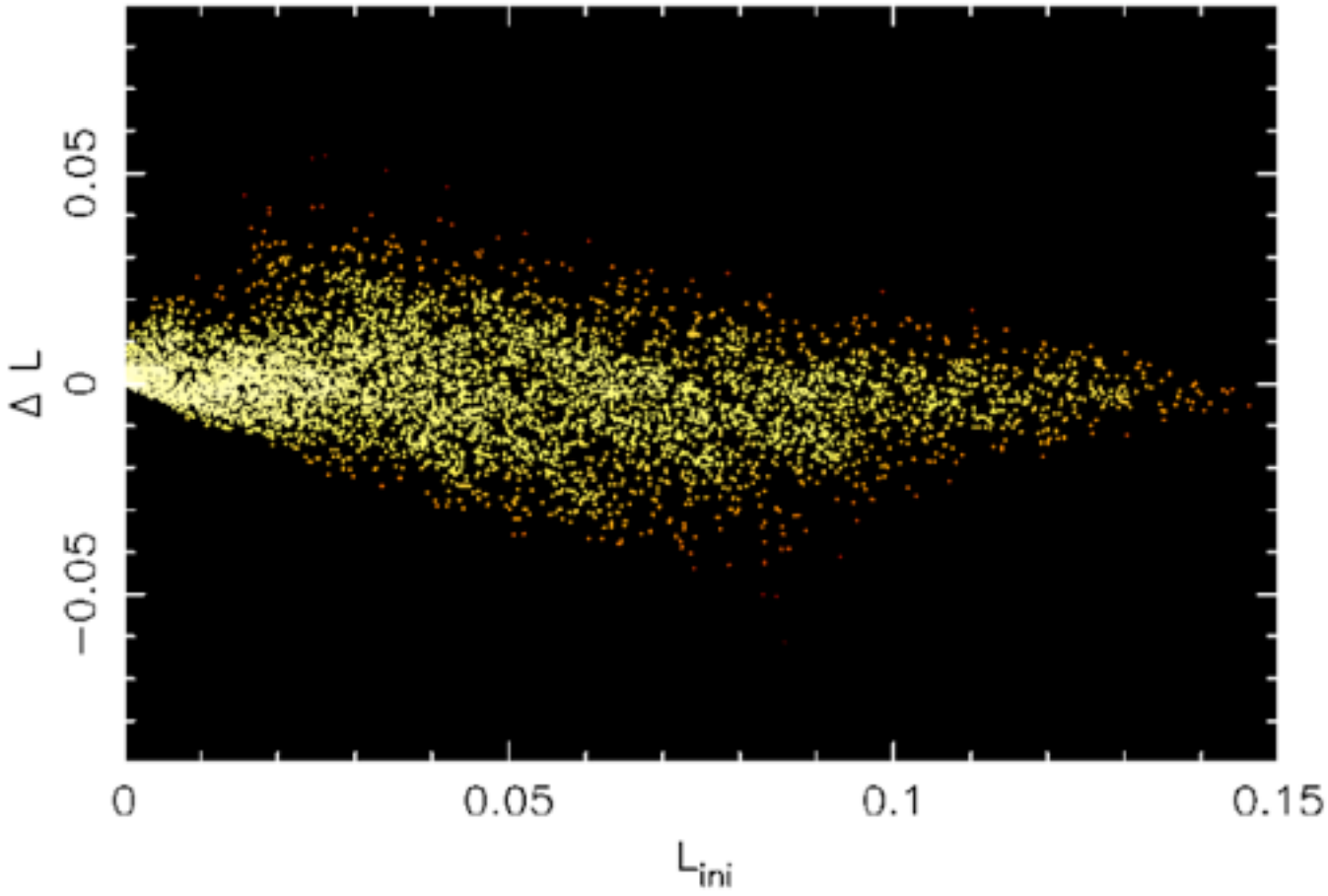
Metallicity distribution function at different radii
for stars with different ages.
Bar + Spiral (Minchev et al.)



initial, cold orbit, hot orbit

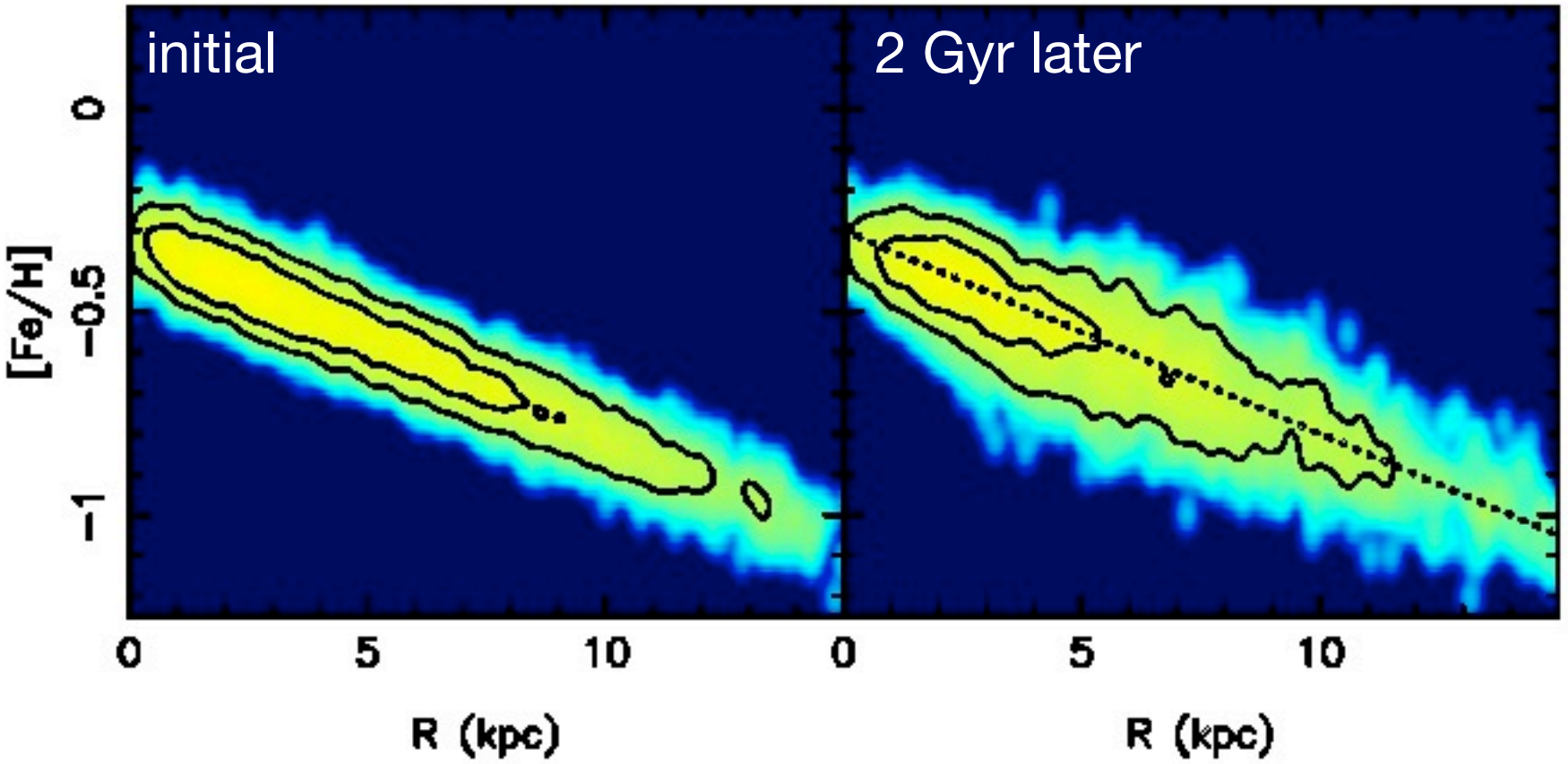
Minchev's talk at
LAMOST meeting 2010

Thick disk (|z|>700 pc) is affected by radial migration?



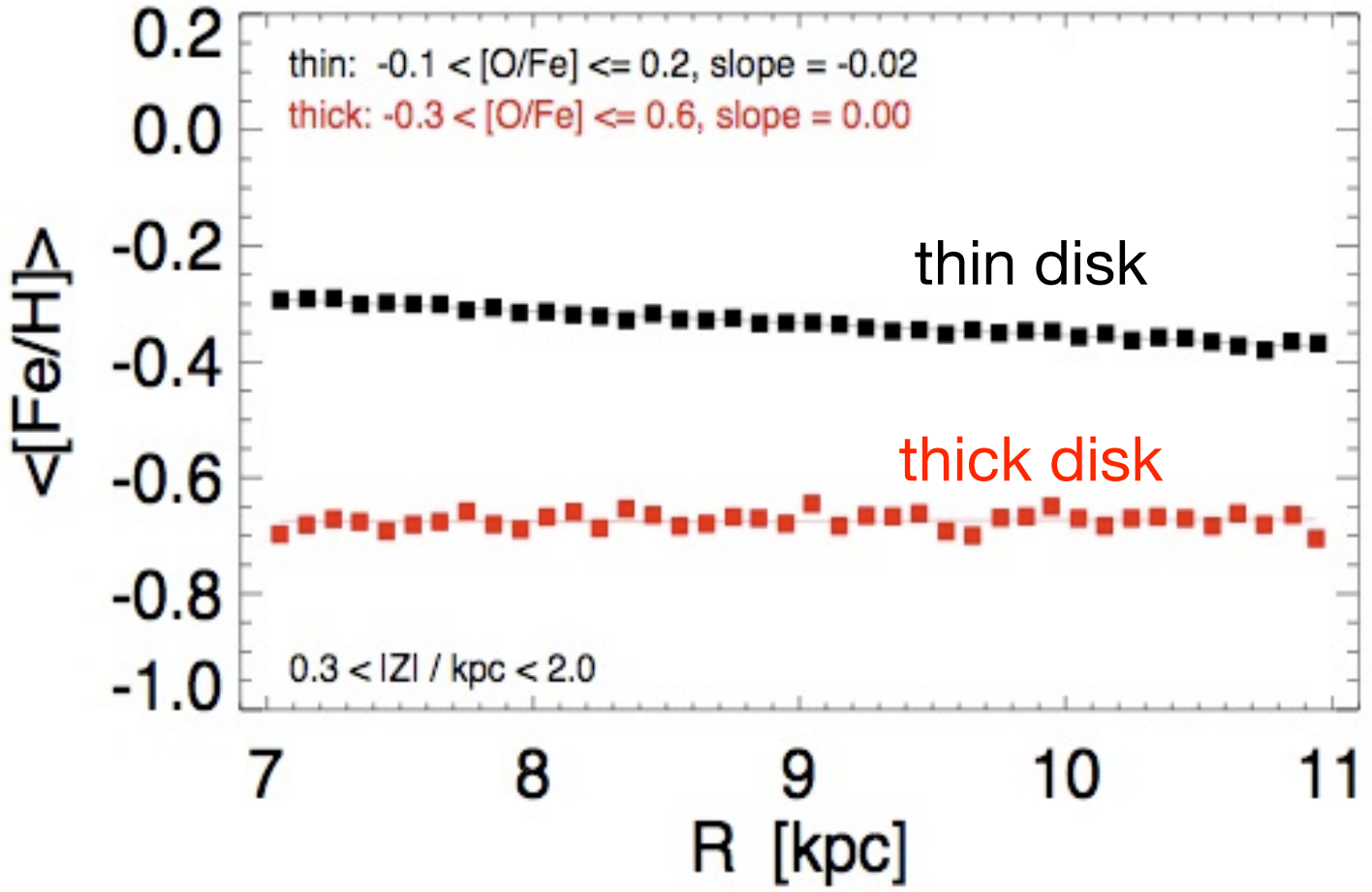
some, but not so significant

Metallicity gradient in the *thick disk* (|z|>700 pc) is smeared out by radial migration?



less significant, but some effect.
a long time evolution (~10 Gyr) will mix more.

Metallicity gradient could be a key? The migration origin thick disk predicts a flat metallicity distribution



Loebman, Rošker, Debattista et al. (2010)

Summary: wish list

- spiral arm patter speed as a function of radius
  young stars, open clusters, gas (HI, CO)?
- stellar stream motion along arms
- MDF for young and old thin disk stars at different radii
- MDF for thick disk stars at different radii
- [α/Fe] vs. [Fe/H] at different radii
  → more constraints on SF history