Diffusion in barred spiral galaxies

Maura Brunetti

in collaboration with

C. Chiappini and D. Pfenniger

UNIVERSITÉ DE GENÈVE

Geneva Observatory

University of Geneva

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Plan of the talk

- Motivations
- Description of N-body models
- Results
- Conclusions & future work

Motivations

Diffusion in the disk

Wielen 77
Pfenniger 86

- Interesting dynamical problems: chaotic regions, resonances, interaction between stars and spiral waves, ...

Sellwood & Binney 02
Minchev & Famaey 09

- Radial migration affects predictions of traditional chemical evolution models

Haywood 08
Roškar et al. 08
Schönrich & Binney 09

Open problems

- Time and length scales of diffusion
- Link to dynamics of bar / spiral arms, to resonances in the disk

N-body simulations

MODEL A Bulge+Disk

Miyamoto-Nagai ('76): $\rho_B + \rho_D$

$$\Phi(R,z) = \frac{-GM}{\sqrt{R^2 + (A + \sqrt{B^2 + z^2})^2}}$$

Pattern speed	Ωp = 35 km/s/kpc
Corotation radius	Rc = 4 kpc
Disk scale-length	R* = 5.3 kpc
Toomre parameter	Q(R = 8 kpc) = 2.5

MODEL B Bulge+Disk+Halo

$\rho_B + \rho_D + \rho_H$, with :

$$\rho_H = \frac{\rho_0}{1 + R^2/R_0^2 + z^2/z_0^2}$$

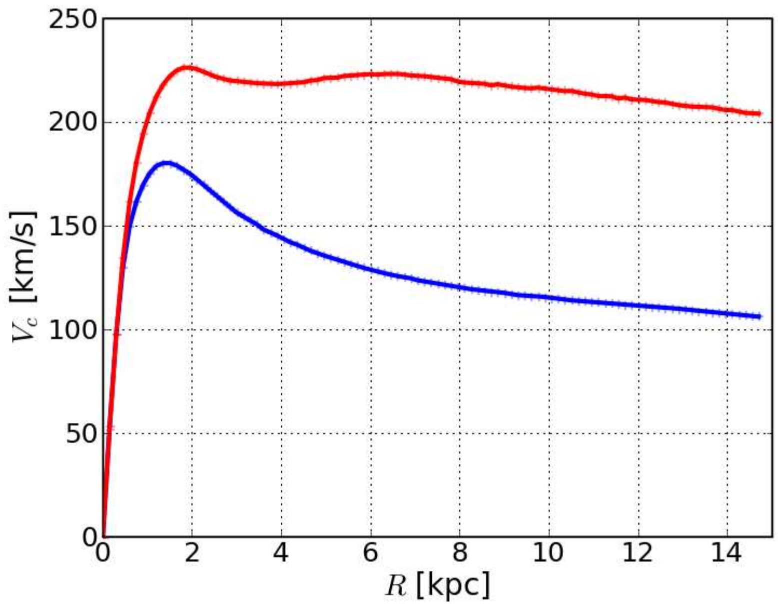
Ωp = 40 km/s/kpc

Rc = 2 kpc

R* = 3.2 kpc

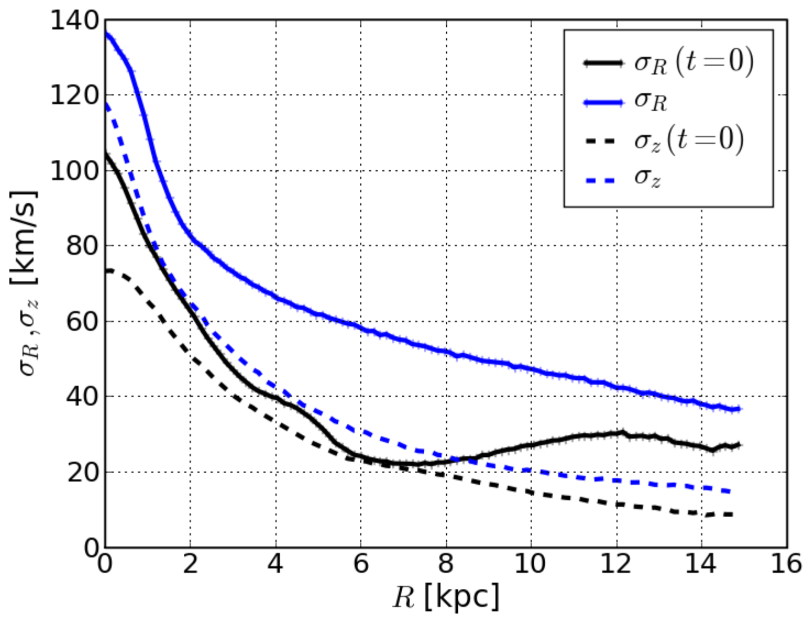
Q(R = 8 kpc) = 20

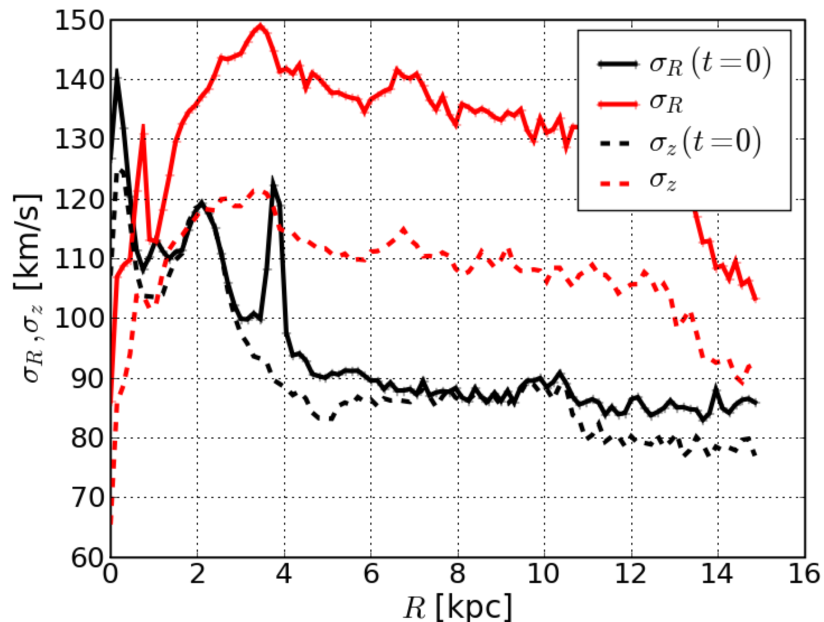
Rotation curve:



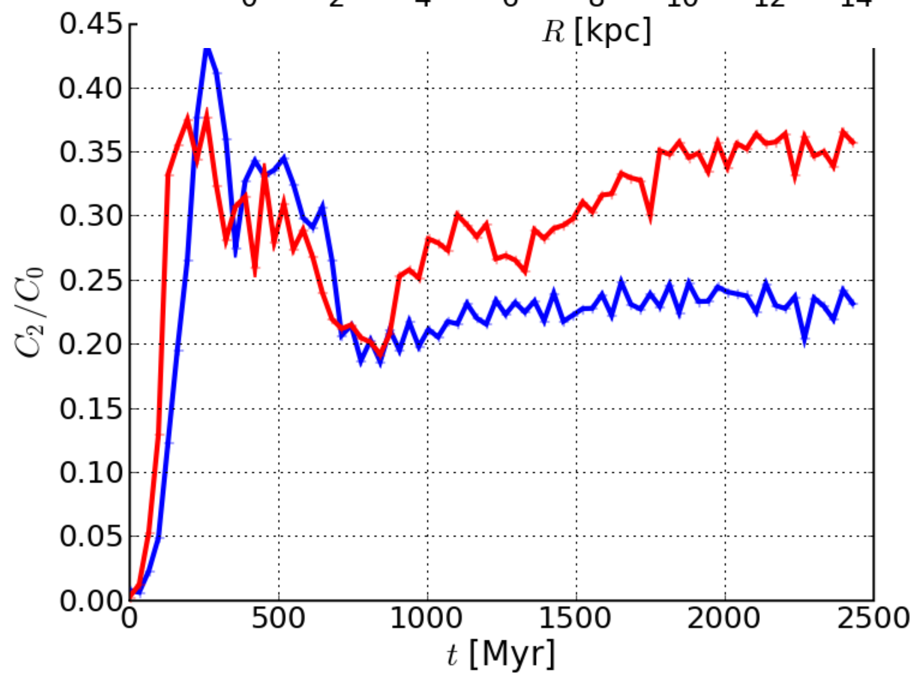
Velocity dispersions

MODEL A: Bulge+Disk **MODEL B**: Bulge+Disk+Halo





High diffusion also in z when the bar is strong

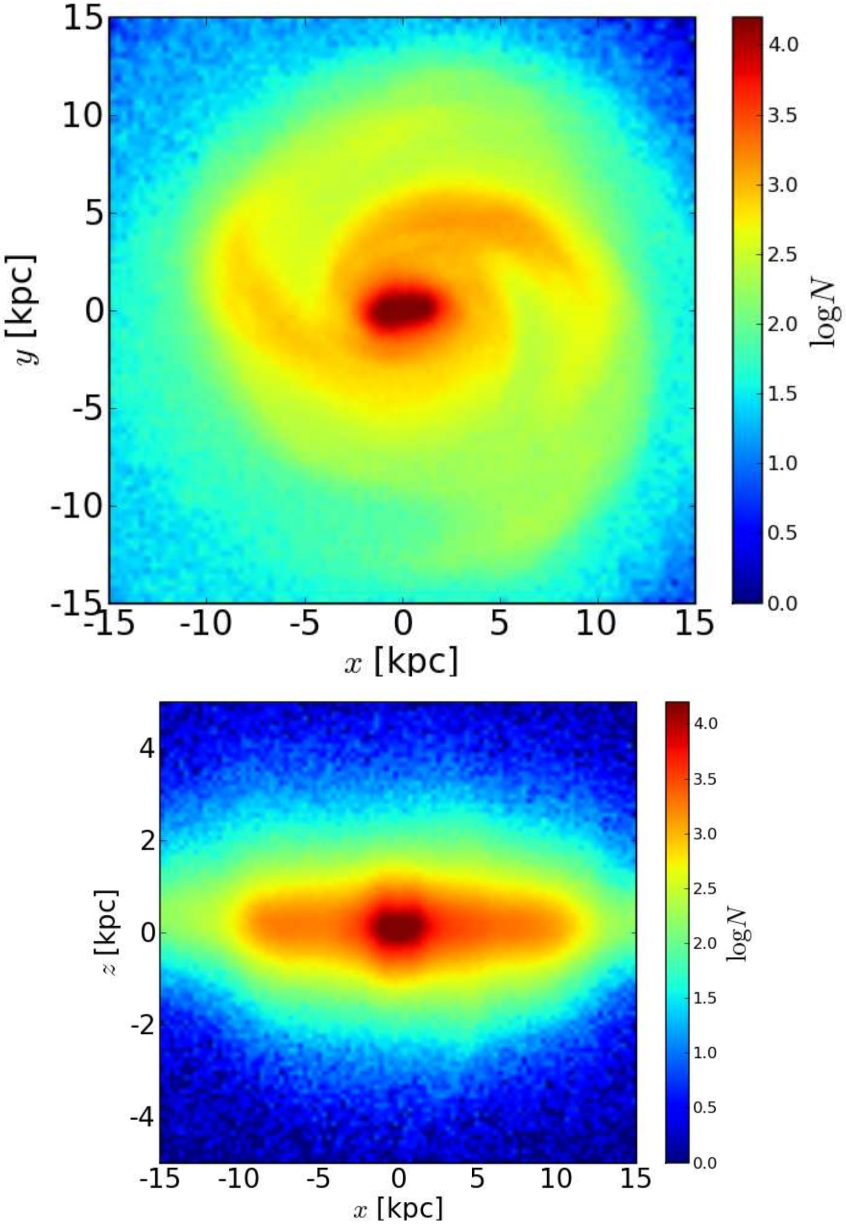


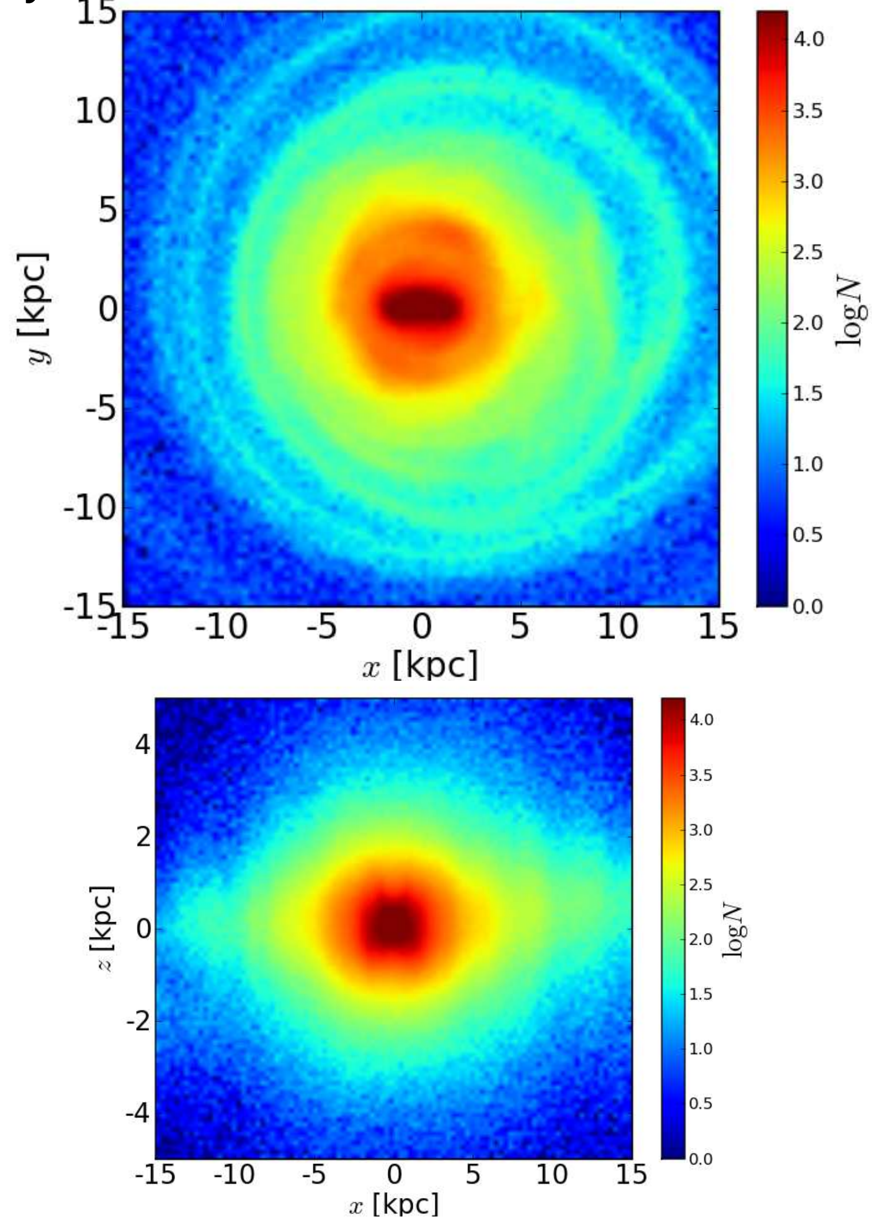
Bar's strength:

$$C_2 = \sum_j \exp(2i\theta_j)$$

MODEL A: without Halo **MODEL B**: with (hot) Halo

t = 570 Myr





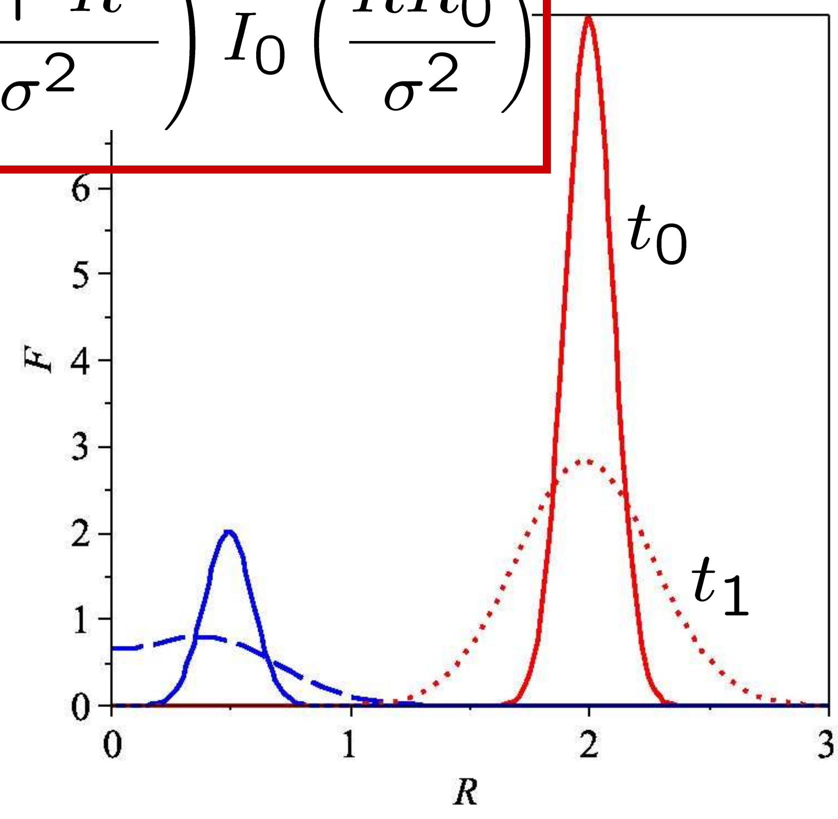
Diffusion coefficient in axisymmetric system

Diffusion equation: $$\partial_t F = \frac{\kappa}{R}\partial_R(R\,\partial_R F)$$

$$F(R,t) = \frac{R_0^2 F_0}{\sigma^2}\exp\left(-\frac{R_0^2+R^2}{2\sigma^2}\right) I_0\left(\frac{RR_0}{\sigma^2}\right)$$

with: $\sigma = \sqrt{2\ \kappa\, T_D}$

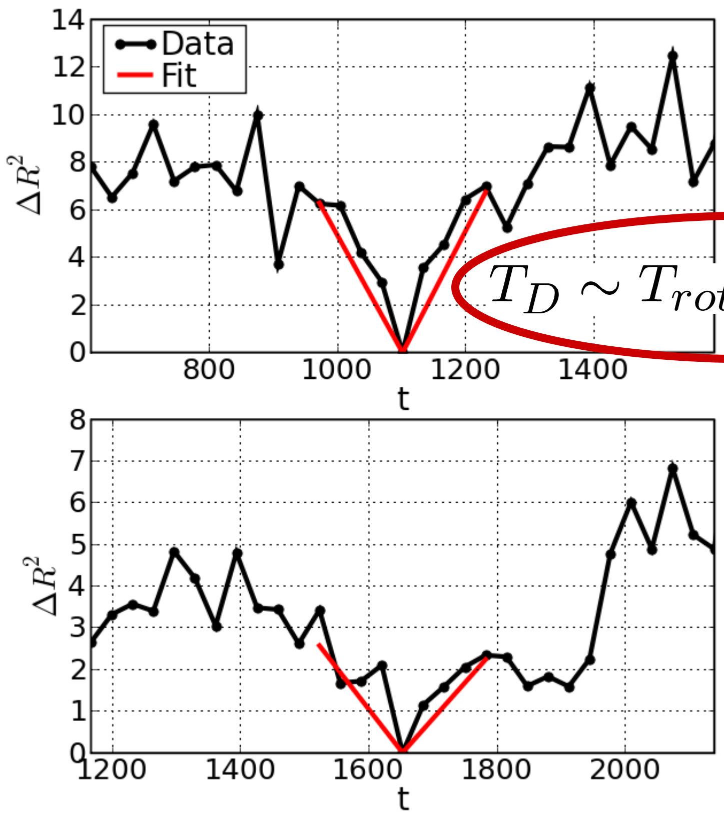
$$T_D = t_1 - t_0$$



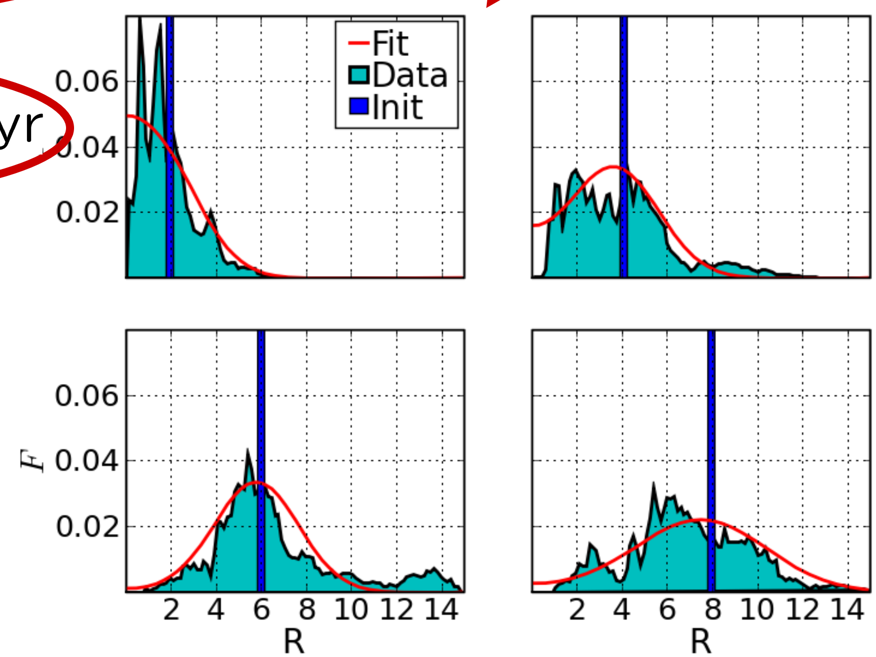
Calculation of the diffusion coefficient

$$F(R,t) = \frac{R_0^2 F_0}{\sigma^2} \exp\left(-\frac{R_0^2 + R^2}{2\sigma^2}\right) I_0\left(\frac{R R_0}{\sigma^2}\right)$$

with: $\sigma = \sqrt{2\,\kappa\, T_D}$

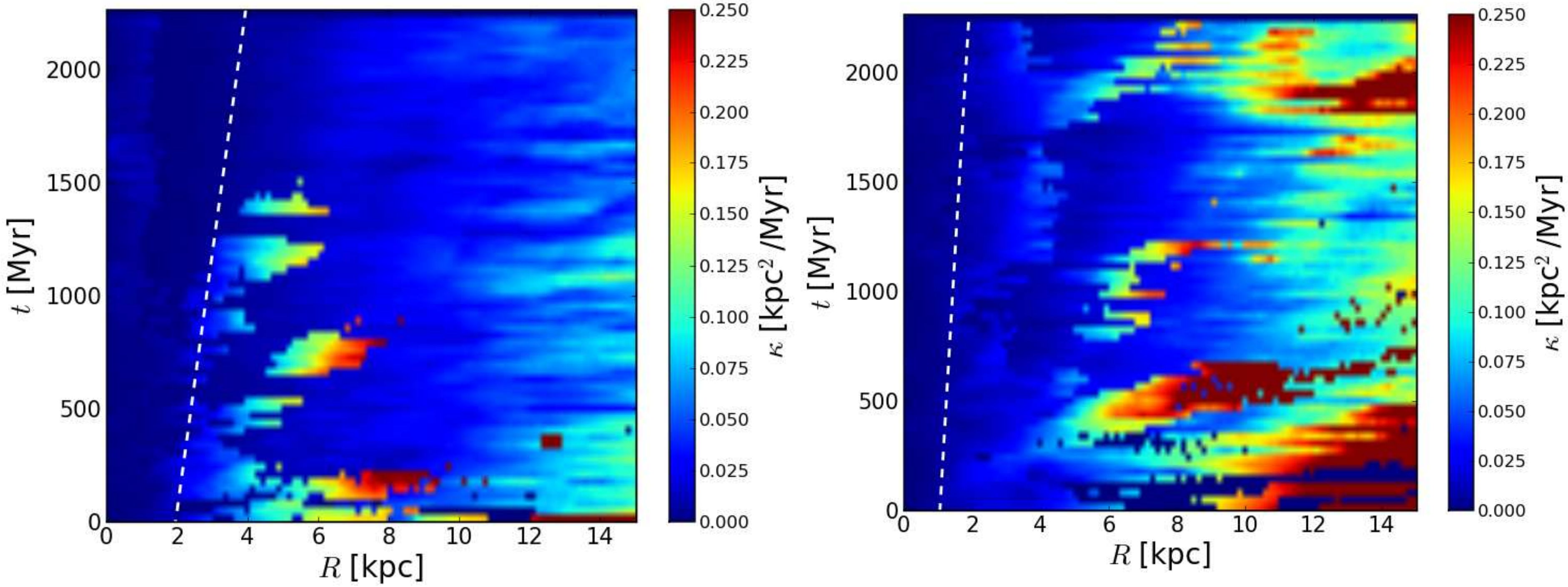


$T_D \sim T_{rot} \sim$ 150 Myr



DIFFUSION COEFFICIENT $\kappa(R,t)$

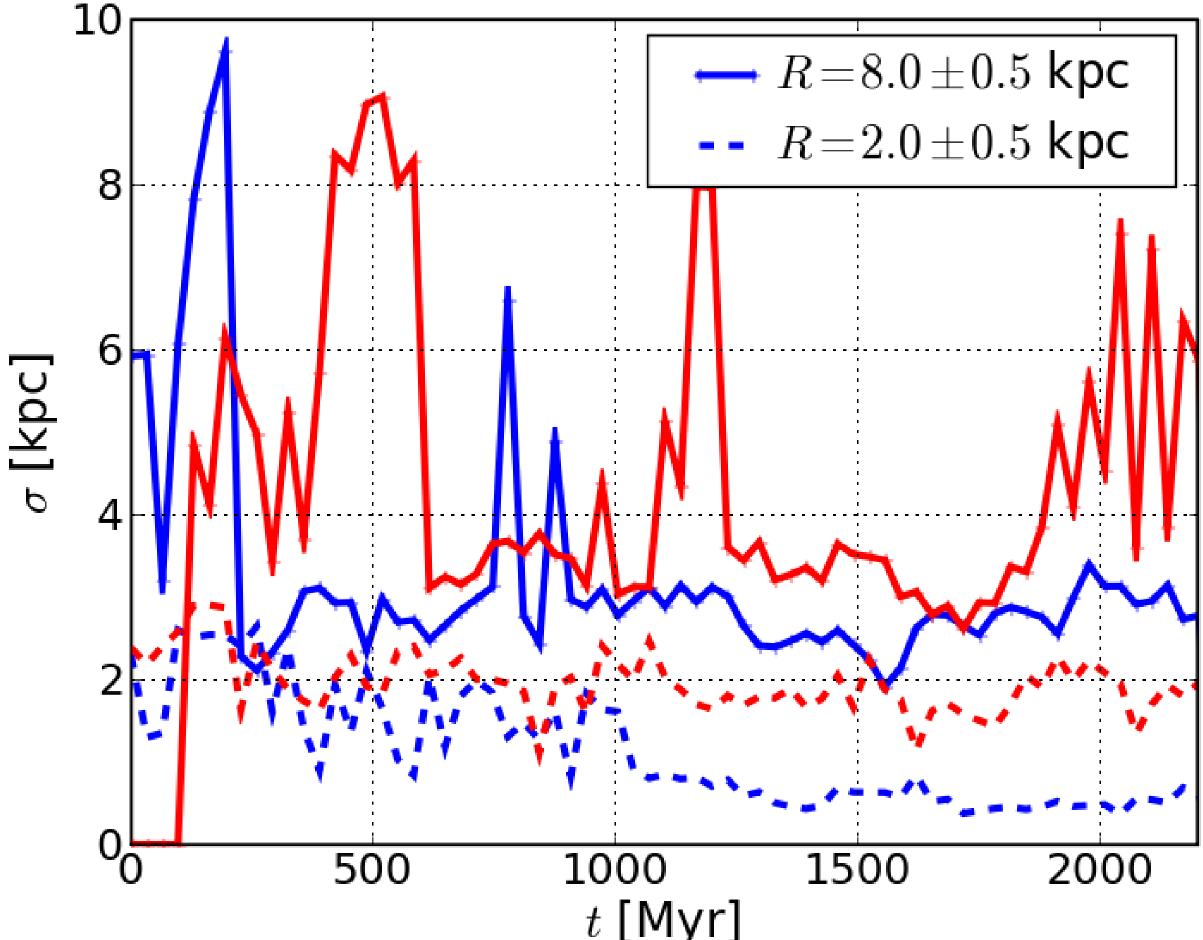
MODEL A: without Halo **MODEL B**: with (hot) Halo



The diffusion coefficient is not constant at all
and it depends on bar's strength

RADIAL DISPERSION

MODEL A: without Halo **MODEL B**: with (hot) Halo



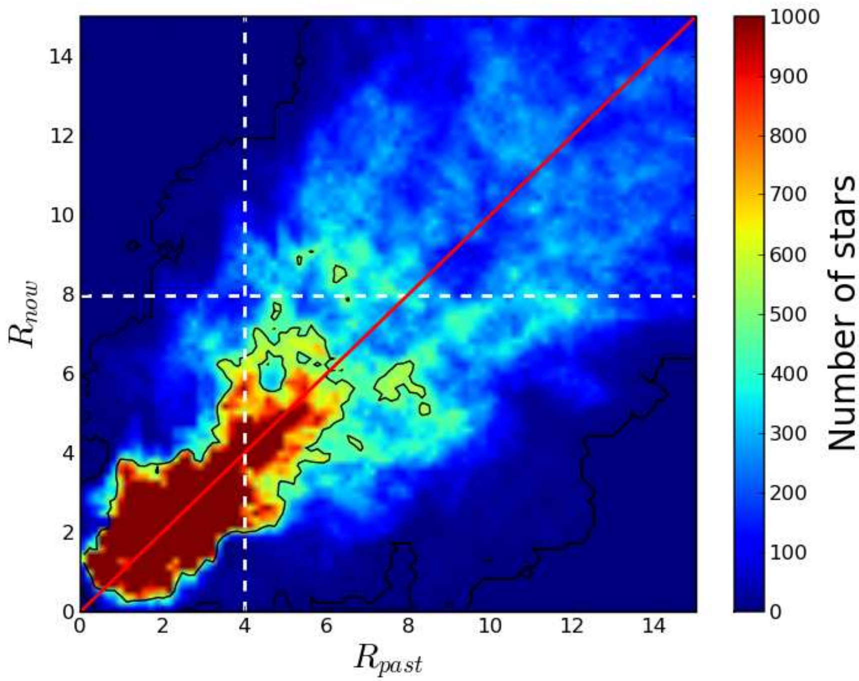
$$\sigma = \sqrt{2\kappa T_D}$$ with: $T_D \sim T_{rot}$

PRESENT STARS and THEIR RADIAL DISTRIBUTION IN THE PAST

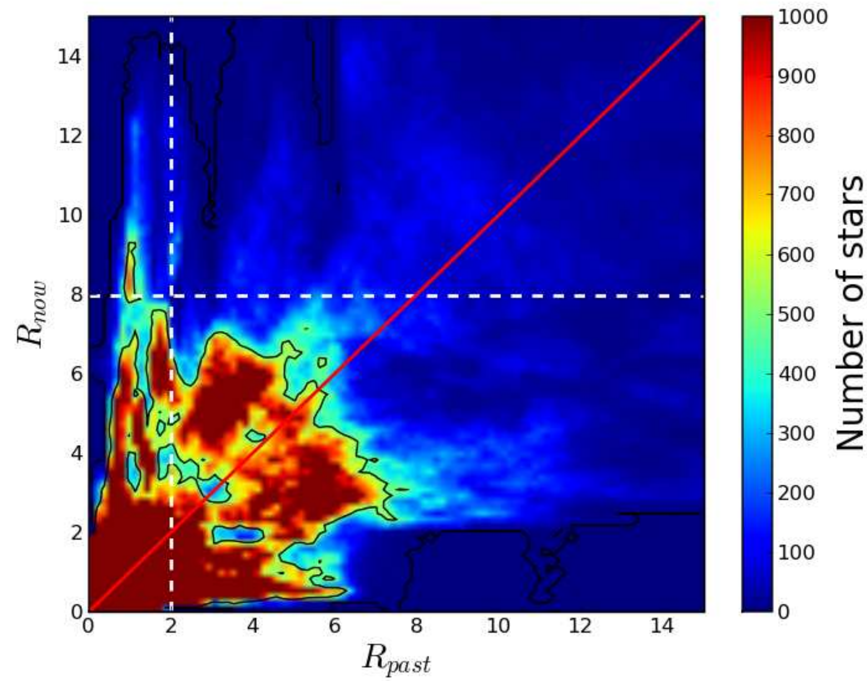
$R_{now} =$ distribution of stars at the end of the simulation t_{end}

$R_{past} =$ distribution of stars at $t_{end} - T_{rot}$

MODEL A : without Halo



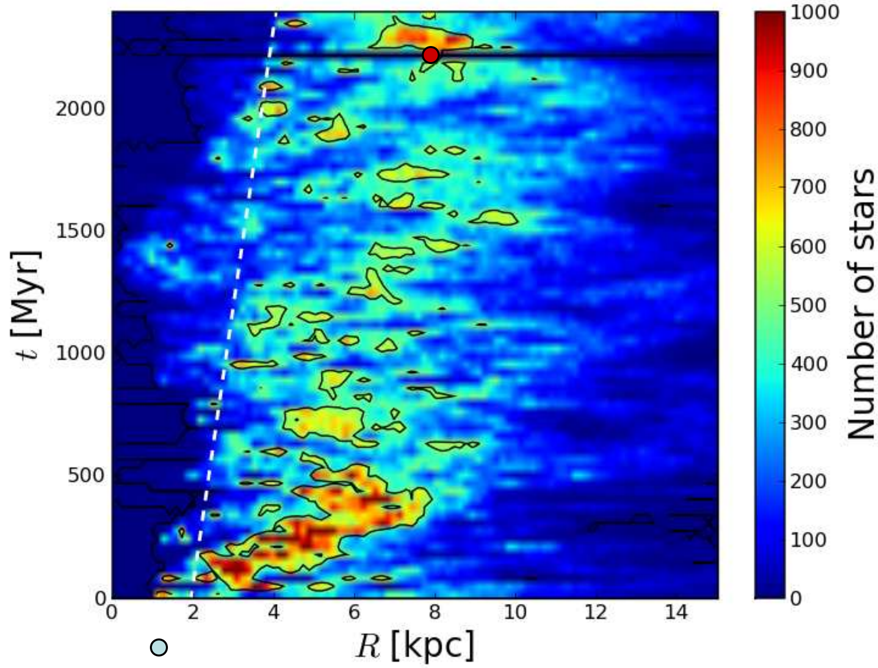
MODEL B: with (hot) Halo



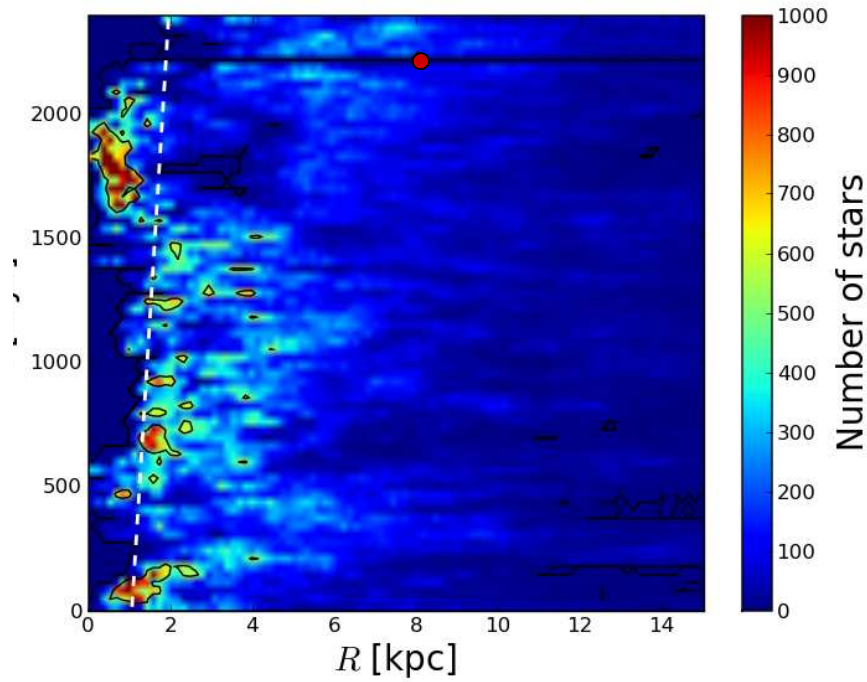
Migration of stars in the radial direction is greatly modified by a strong bar

Stars in R = (8.0 ± 0.1) kpc at t = 2200 Myr:
evolution of their radial distribution

MODEL A: without Halo



MODEL B: with (hot) Halo



Diffusion is dominant near corotation
when the bar is strong

Conclusions & future work

- The diffusion coefficient
  - is not constant in time
  - depends on bar's strength and history
- Strong bar → strong migration from corotation region, with recurrent radial dispersion of the order of ~ 8 kpc

- Explore different configurations (ex. strong bar + spiral arms, Milky Way...)
- Relate diffusion to resonances in the disk
- Implications for chemical evolution models