银河系的动力学模型

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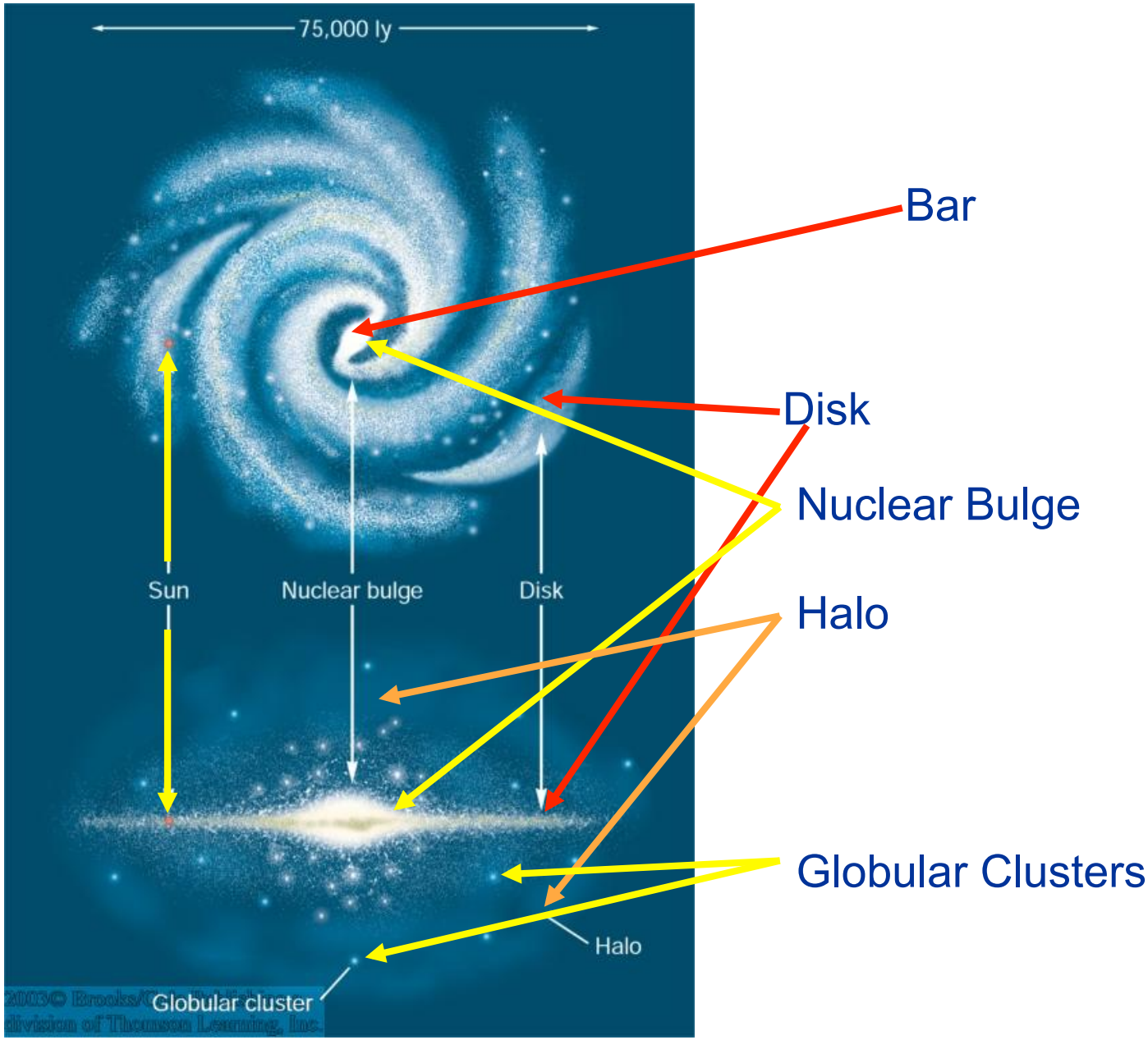
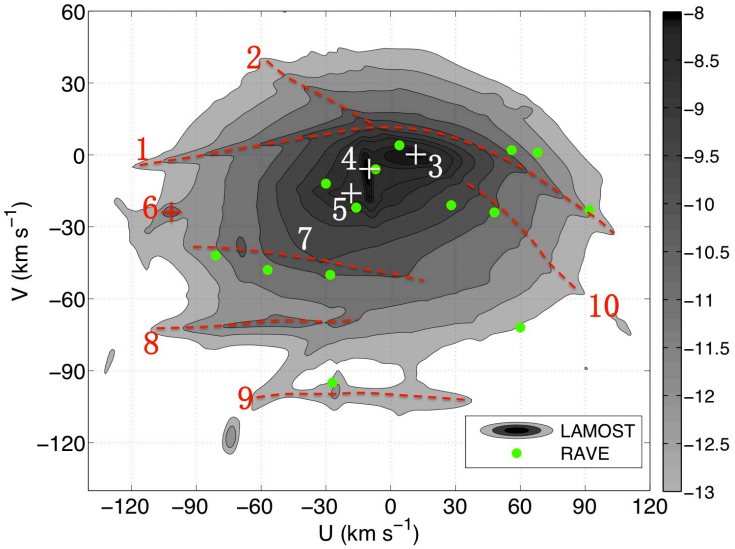
科学目的

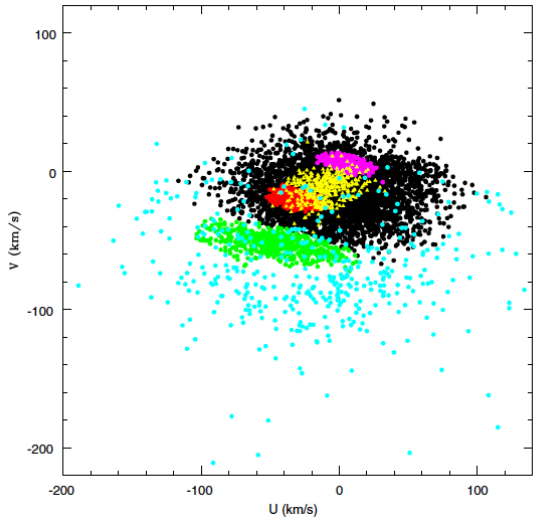
- 测量银河系的基本参数(质量、角动量）
- 刻画银河系的形成演化历史
- 解释星流、超高速星等的起源
- 解决冷暗物质模型下的“too big too fail”以及“Vast Polar Structure”的问题

Milk Way Galaxy-A typical barred spiral galaxy

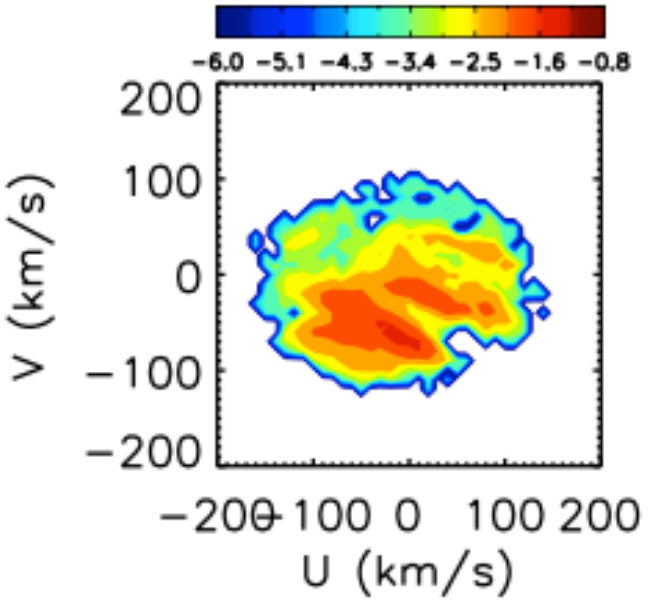


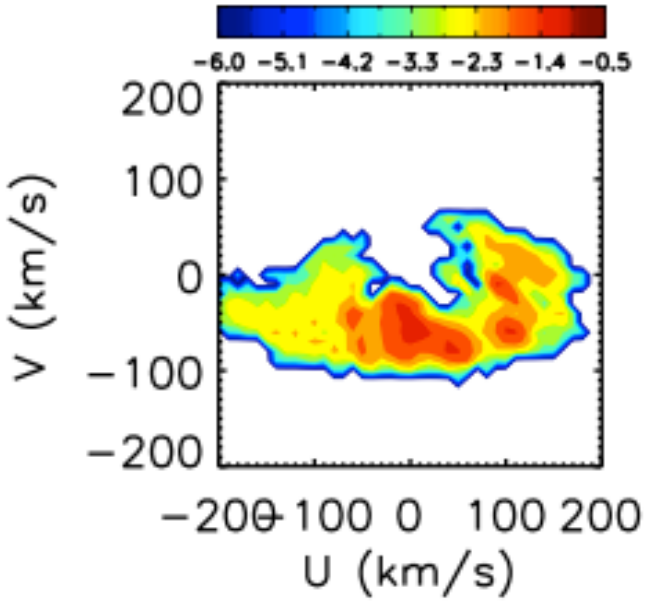


Xia Q., Liu C., Mao S et al. 2014
15000 F/G dwarf from LAMOST

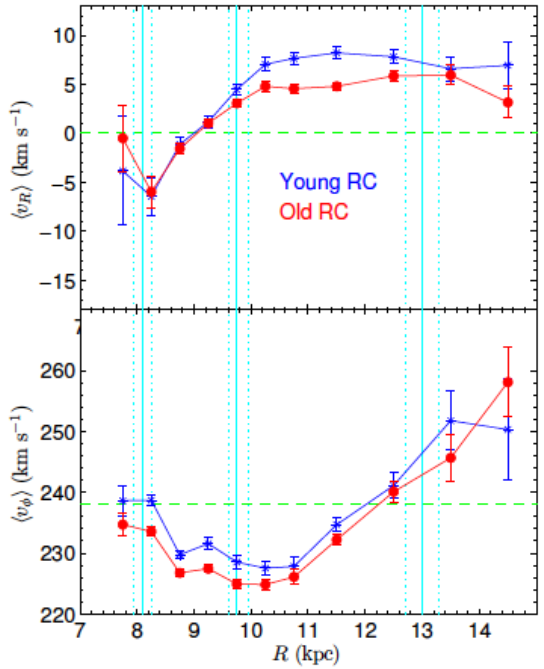


Famaey et al. 2005/
Hipparcos/ K Gaints

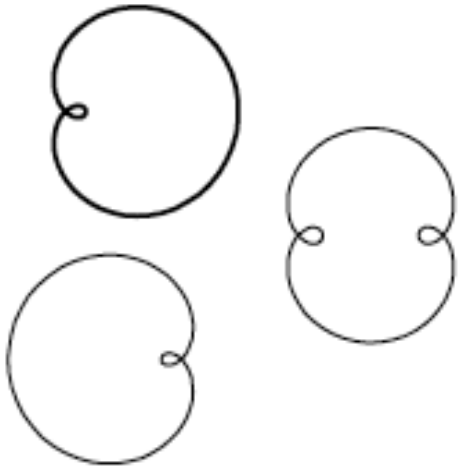


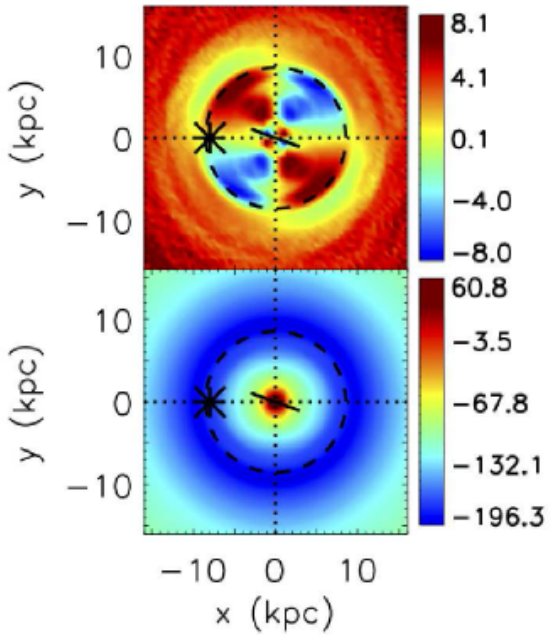


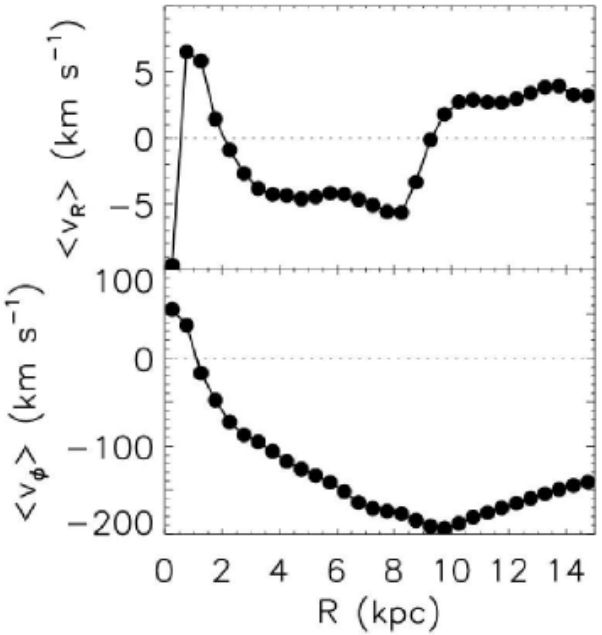
Bar Model from Wang et al. 2012.Left: omp=-40; Right:omp=-60



Tian et al. 2016







Five modeling methods

- Jeans equation
- Schwarzschild method: Orbit based method
- Made-to-Measure (M2M): Particle based method
- Torus Method
- N-body

MW Torus model

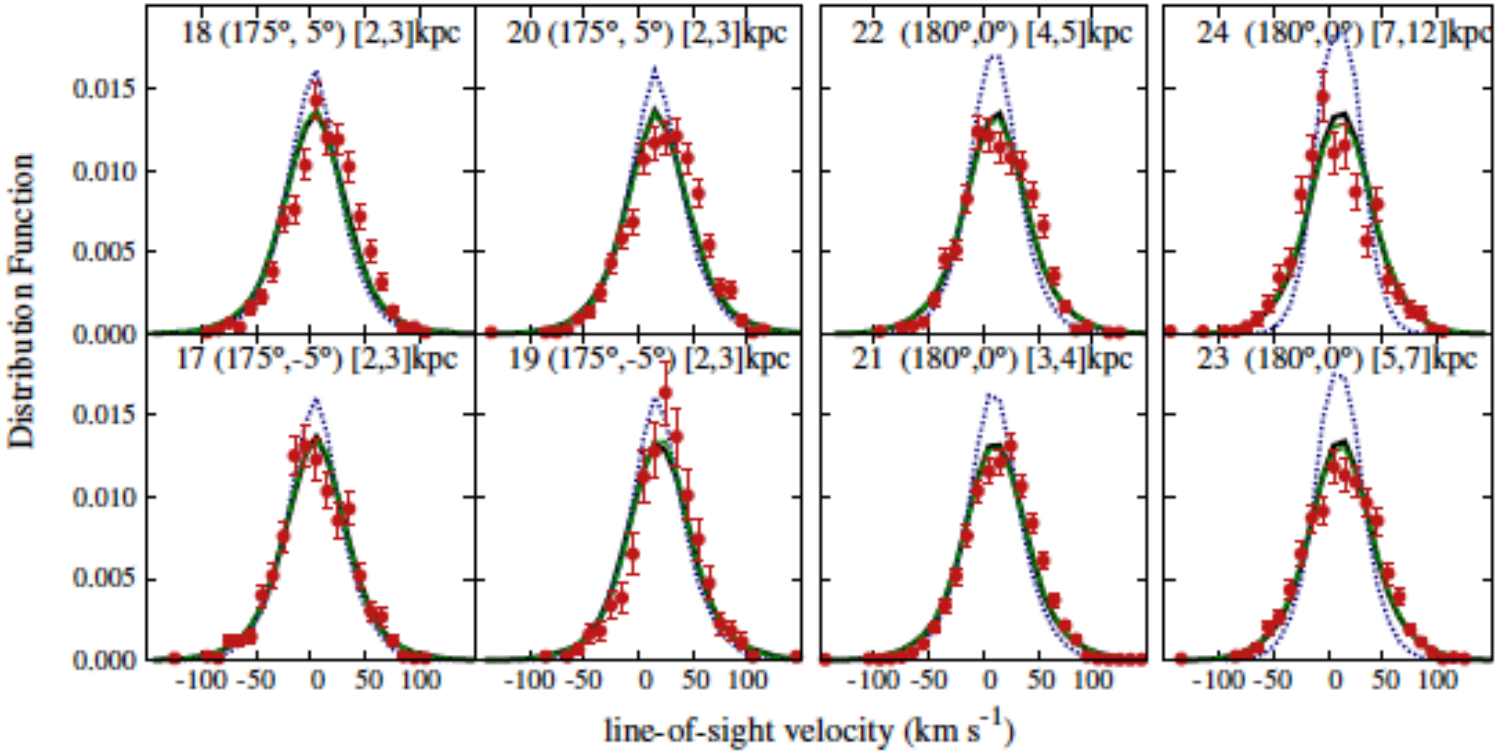
- Three disks: thin, thick, gas $\rho_{\rm d}(R,z)=\frac{\Sigma_{\rm d}}{2z_{\rm d}}\exp\left(-\frac{R_{\rm m}}{R_{\rm d}}-\frac{R}{R_{\rm d}}-\frac{|z|}{z_{\rm d}}\right),$
- Bulge and halo:

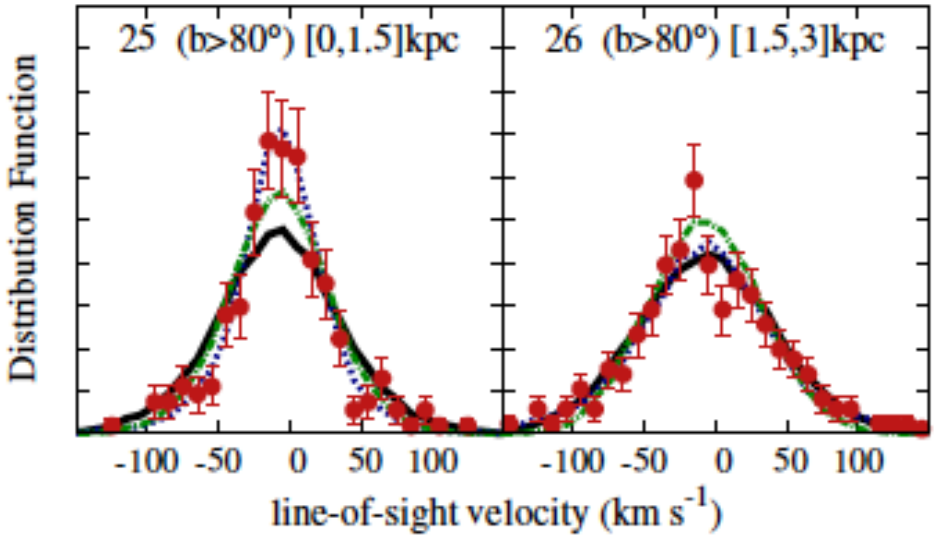
$$\rho(R,z)=\frac{\rho_0}{m^\gamma(1+m)^{\beta-\gamma}}\exp\left[-(mr_0/r_{\rm cut})^2\right],$$

$$m(R,z)\equiv\sqrt{(R/r_0)^2+(z/qr_0)^2}.$$

$$f(J_R,J_z,L_z)=\frac{\Omega\Sigma\nu}{2\pi^2\sigma_r^2\sigma_z^2\kappa}\exp\left(-\frac{\kappa J_R}{\sigma_r^2}-\frac{\nu J_z}{\sigma_z^2}\right)T\left[\frac{L_z}{L_0}\right],$$

$$\sigma_r=\sigma_{r0}\exp\left(\frac{R_0-R_c}{R_\sigma}\right),\sigma_z=\sigma_{z0}\exp\left(\frac{R_0-R_c}{R_\sigma}\right)$$





Black:Wang et al.
Green: 2b
Blue: Binney 2012

MW Sch model (I)

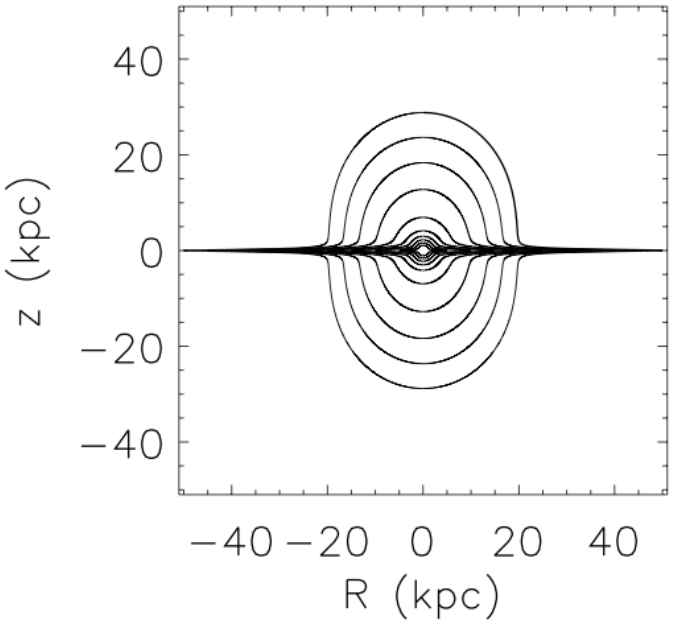
- Bar

$$\Phi_{bar}(r) = -\frac{GM_{bar}}{r+c}$$

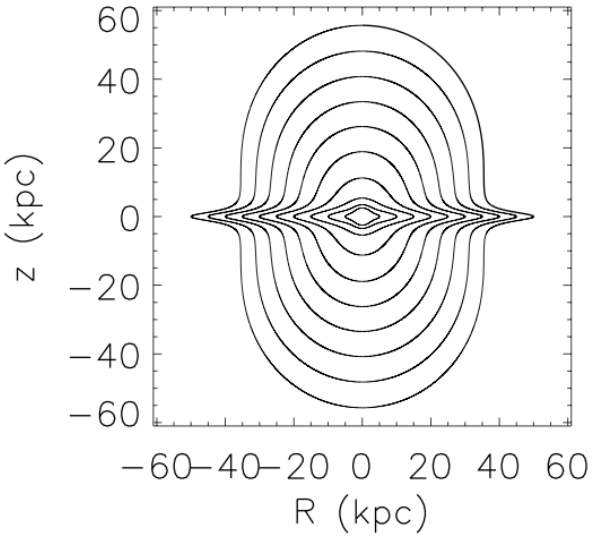
- Disk $\Phi_d(x,y,z) = -\frac{GM_d}{r_3},$

$$r_3 = \left\{ x^2 + y^2 + \left[a_{\rm MN} + (z^2 + b_{\rm MN}^2)^{1/2} \right]^2 \right\}^{1/2},$$

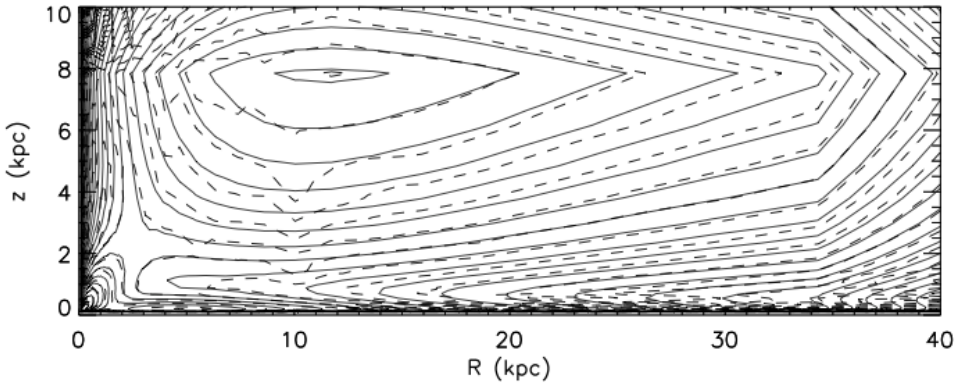
- Halo $\Phi_{halo} = \frac{v_0^2}{2} \ln(1 + r^2/r_c^2)$



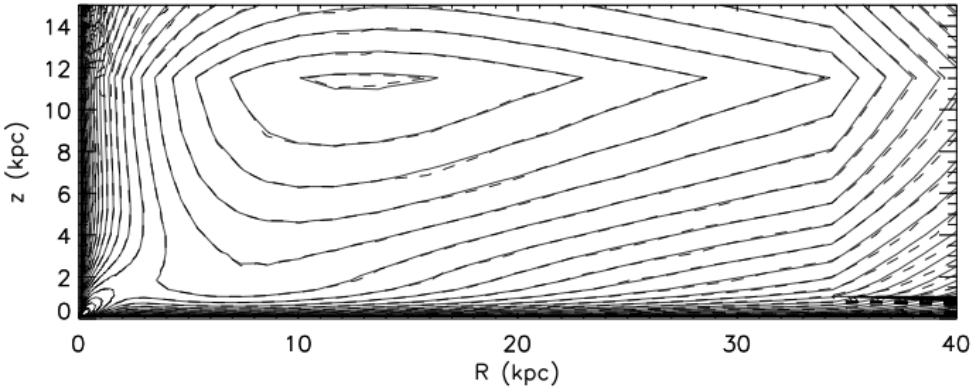
a_{MN}=6.5
b_{MN}=0.26
MN1



a_{MN}=9
b_{MN}=1.8
MN2

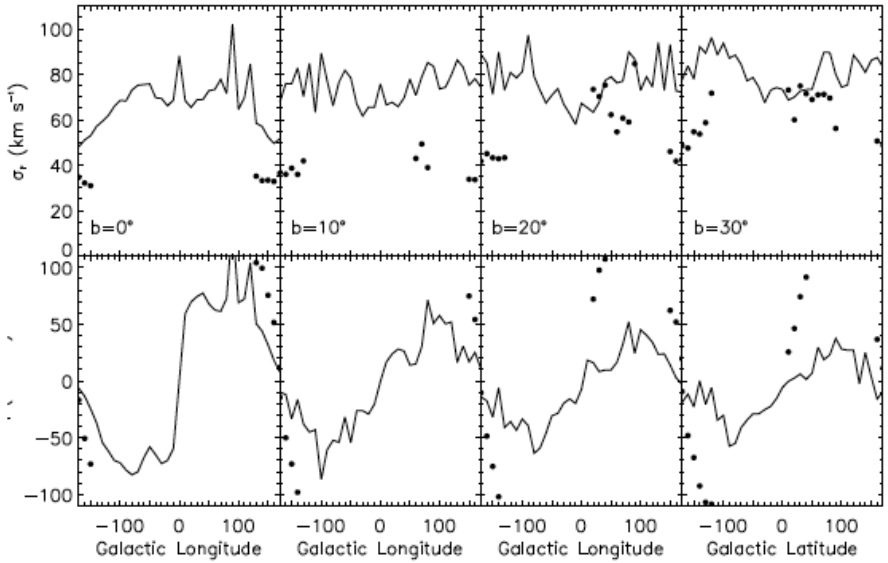


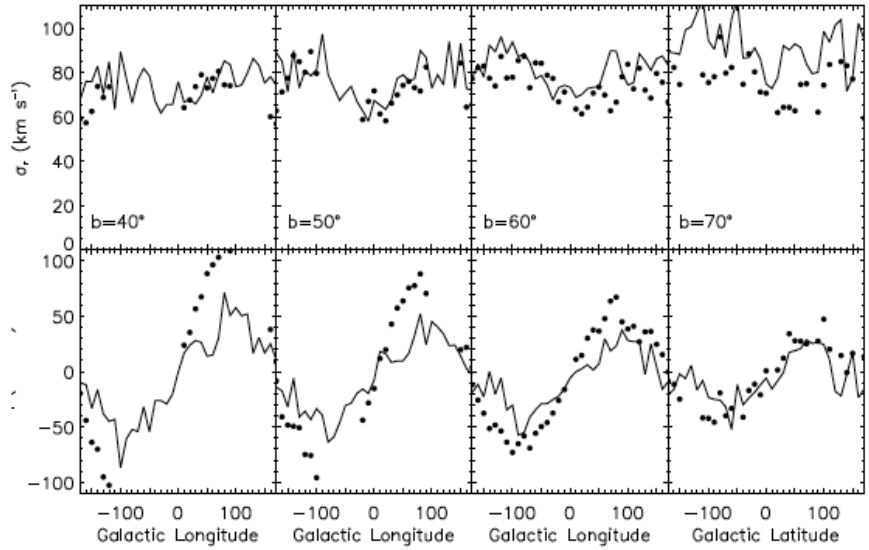
Density reconstruction for MN1



Density reconstruction for MN2

Velocity and velocity dispersion in MN2





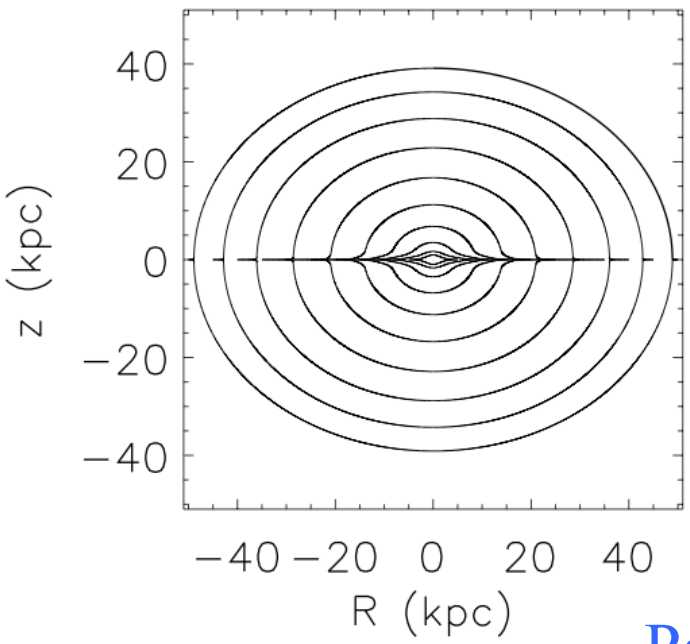
MW Sch model (II)

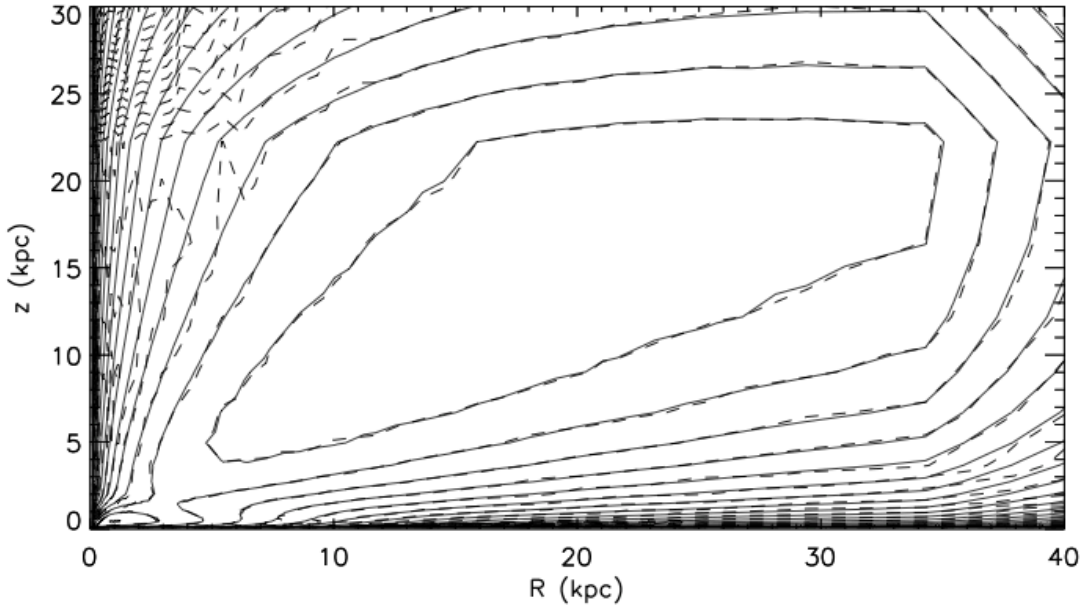
- Three disks: thin, thick, gas $\rho_{\rm d}(R,z) = \frac{\Sigma_{\rm d}}{2z_{\rm d}} \exp\left(-\frac{R_{\rm m}}{R_{\rm d}} - \frac{R}{R_{\rm d}} - \frac{|z|}{z_{\rm d}}\right),$
- Bulge and halo: $\rho(R,z) = \frac{\rho_0}{m^\gamma (1+m)^{\beta-\gamma}} \exp\left[-(m r_0/r_{\rm cut})^2\right],$

$$m(R,z) \equiv \sqrt{(R/r_0)^2 + (z/q r_0)^2}.$$

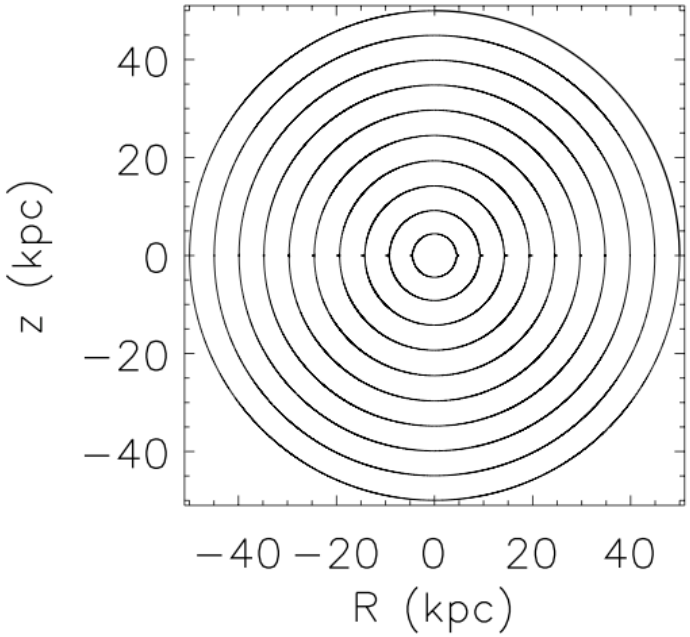
	Potential I			Potential II		
Disc	Thin	Thick	Gas	Thin	Thick	Gas
$\Sigma_0[{\rm M}_\odot\,{\rm kpc}^{-2}]$	1.02e9	1.14e6	7.30e7	7.68e8	2.01e8	1.16e8
$R_{\rm d}$[kpc]	2.4	2.4	4.8	2.64	2.97	5.28
$z_{\rm d}$[kpc]	0.36	1	0.04	0.3	0.9	0.04
$R_{\rm h}$[kpc]	0	0	4.0	0	0	4
Spheroid	Dark	Stellar		Dark	Stellar	
$\rho_0[{\rm M}_\odot\,{\rm kpc}^{-3}]$	1.26e9	7.56e8		1.32e7	9.49e10	
q	0.8	0.6		1	0.5	
γ	-2	1.8		1	0	
β	2.21	1.8		3	1.8	
r_0[kpc]	1.09	1		16.47	0.075	
$r_{\rm cut}$[kpc]	1000	1.9		100000	2.1	

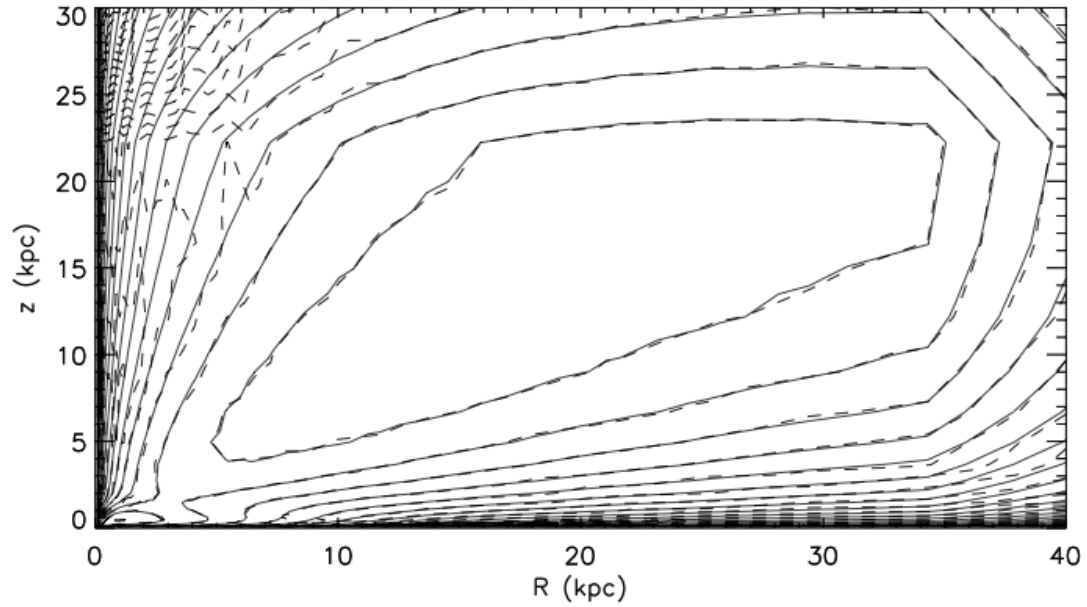
Potential I



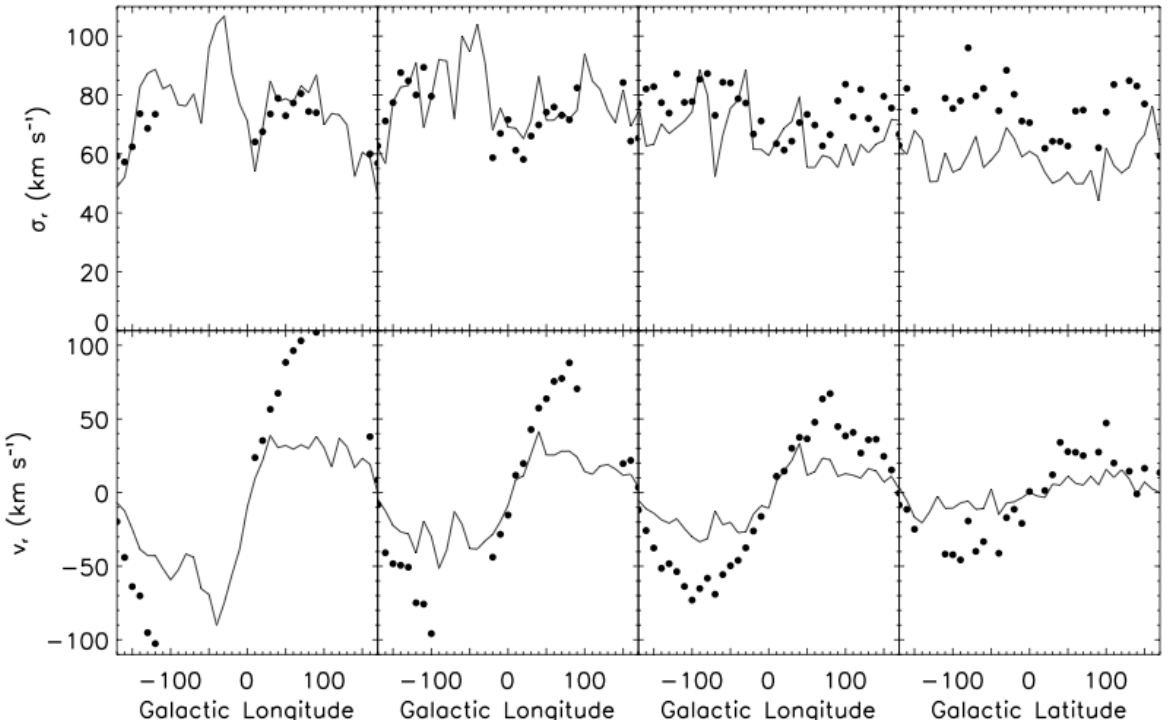


Potential II

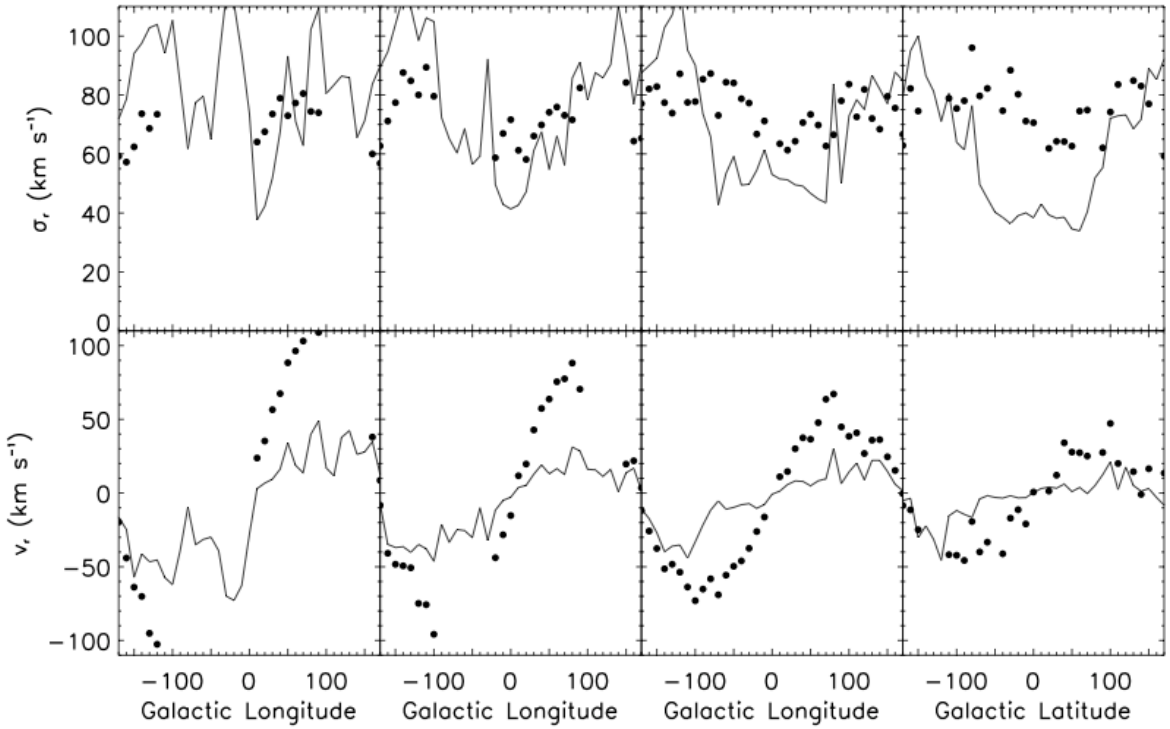




Potential I



Potential II



下一步计划

- Add the age in the distribution function in the torus method

- Constructing the Schwarzschild model

Density

Poisson Equation

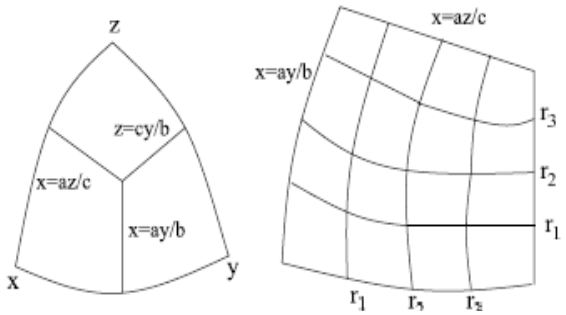
Potential

Initial Conditions for orbit library

Orbit library

Least Square Method, adding the data constraints

Weights



$$\chi^2 = \frac{1}{N_c} \sum_{j=1}^{N_c} \left(C_i - \sum_{i=1}^{N_o} w_j O_{ij} \right)^2 .$$

Initial Conditions for N-body

NBODY code

End State

Analysis (anisotropy, energy distribution, triaxiality, etc.)