

Spherical ST galaxy model

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scalar-tensor theories

$$\mathcal{L} = \frac{\sqrt{-g}}{16\pi} \left[-\phi R + \frac{\omega(\phi)}{\phi} (\partial\phi)^2 - V(\phi) \right] + L_M(g_{\mu\nu})$$

Ecuaciones de gravedad:

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R = \frac{1}{\phi} \left[8\pi T_{\mu\nu} + \frac{1}{2} V g_{\mu\nu} + \frac{\omega}{\phi} \partial_\mu \phi \partial_\nu \phi - \frac{1}{2} \frac{\omega}{\phi} (\partial\phi)^2 g_{\mu\nu} + \phi_{;\mu\nu} - g_{\mu\nu} \square\phi \right]$$

Ecuación del campo escalar:

$$\square\phi + \frac{\phi V' - 2V}{3+2\omega} = \frac{1}{3+2\omega} [8\pi T - \omega' (\partial\phi)^2]$$

Weak field limit

$$\mathbf{g}_{\mu\nu} = \eta_{\mu\nu} + \epsilon \mathbf{h}_{\mu\nu} \rightarrow$$
$$\phi = <\phi> + \bar{\phi}$$
$$\frac{1}{2} \nabla^2 h_{00} = \frac{1}{\langle \phi \rangle} \left[4\pi \rho - \frac{1}{2} \nabla^2 \bar{\phi} \right] , \quad \Phi_N \equiv \frac{1}{2} h_{00}$$
$$\nabla^2 \bar{\phi} - \left(\frac{mc}{h} \right)^2 \bar{\phi} = -8\pi \alpha \rho ,$$

where:

$$\frac{\phi V' - 2V}{3 + 2\omega} = m^2 \bar{\phi} - m^2 k \bar{\phi}^2 + \dots$$

$$\alpha \equiv 1/(3+2\omega)$$

Choosing the parameters

$$\langle \phi \rangle = 1/G_N$$

→

$$G_{\text{eff}} = G (1 + \alpha e^{-r/\lambda})$$

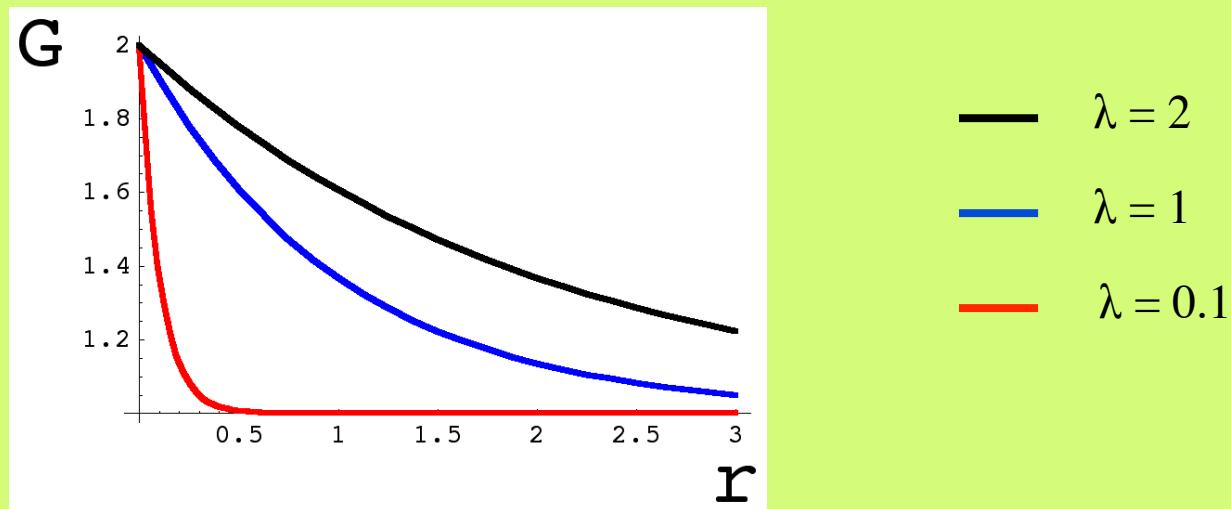
$$\text{deviations of } G \text{ for } r < \lambda \quad \rightarrow \quad \alpha \sim 10^{-10}$$

$$\langle \phi \rangle = (1 + \alpha)/G_N \rightarrow$$

$$G_{\text{eff}} = \frac{G}{(1 + \alpha)} (1 + \alpha e^{-r/\lambda})$$

$$\text{deviations of } G \text{ for } r > \lambda \quad \rightarrow \quad \alpha \sim 1$$

$$\alpha > 0$$



General solution

Defining

$$\psi \equiv (\mathbf{1}/2)(\mathbf{h}_{00} + \bar{\phi}/\langle \phi \rangle)$$

$$\nabla^2 \psi = \frac{1}{\langle \phi \rangle} 4\pi\rho \quad \rightarrow$$

$$\nabla^2 \bar{\phi} - m^2 \bar{\phi} = -8\pi\alpha\rho$$

$$\begin{aligned} \Phi_N &= \psi - \frac{1}{2}\bar{\phi} \\ &= - \int d\mathbf{r}_s \frac{\rho(\mathbf{r}_s)}{|\mathbf{r} - \mathbf{r}_s|} \\ &\quad - \alpha \int d\mathbf{r}_s \frac{\rho(\mathbf{r}_s) e^{-|\mathbf{r} - \mathbf{r}_s|/\lambda}}{|\mathbf{r} - \mathbf{r}_s|} + \text{B.C.} \end{aligned} \quad \rightarrow$$

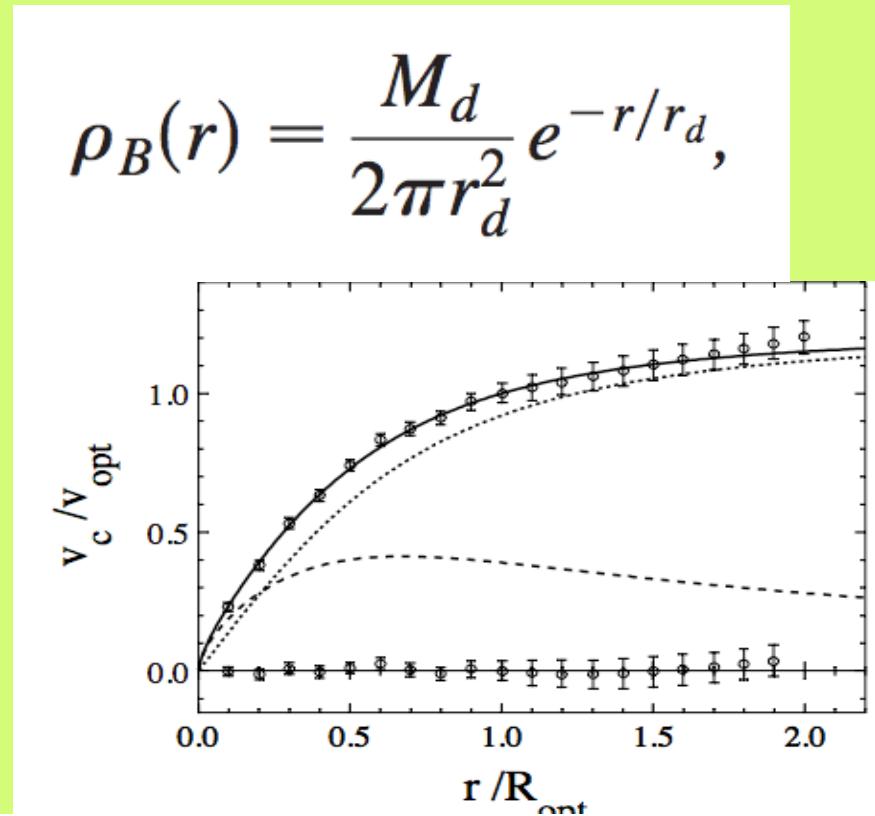
$$\Phi_N = -\frac{G_N}{1 + \alpha} \frac{m}{r} (1 + \alpha e^{-r/\lambda}) \quad \text{Point particles}$$

Galactic model

Freeman Disc:

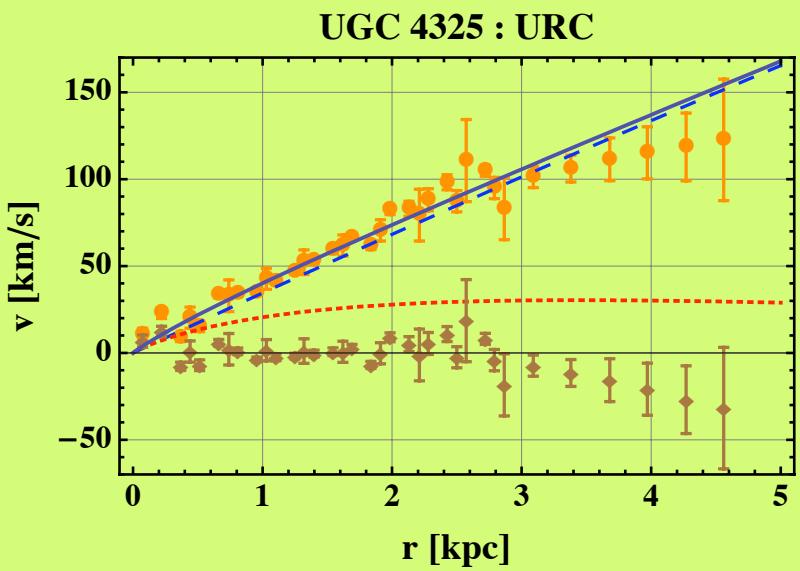
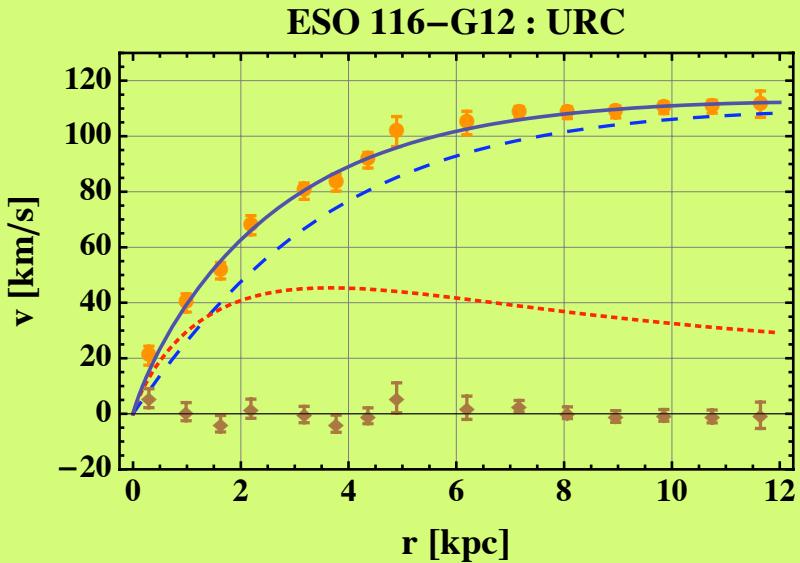
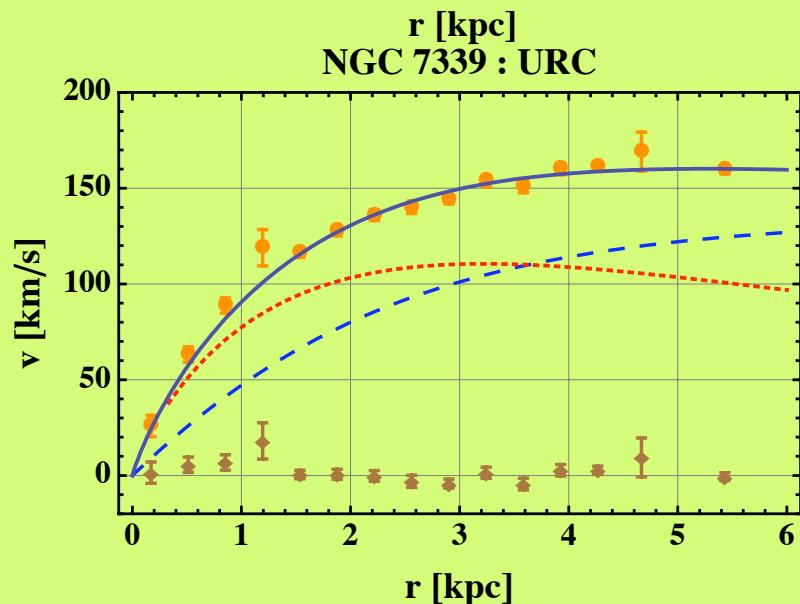
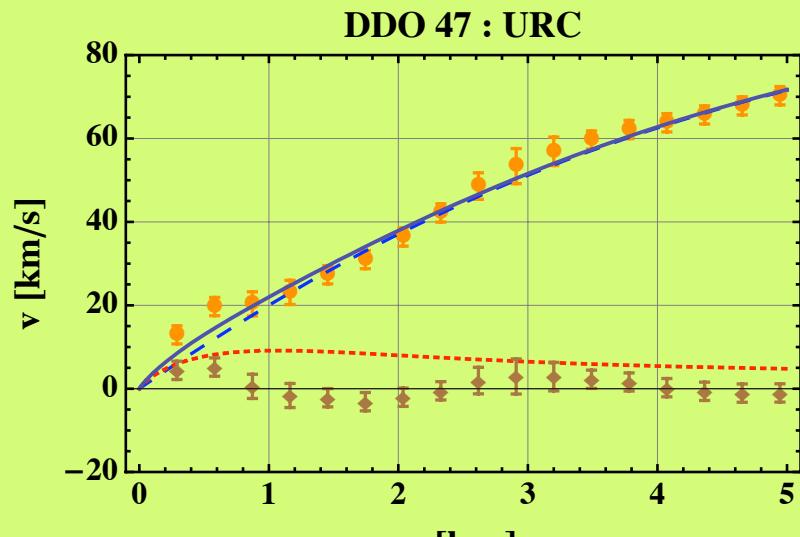
Halo: ?

$$\Phi_N$$



$$\begin{aligned}
 v_{URC}^2 &= v_{URCD}^2 + v_{URCH}^2 \\
 &= \frac{GM_d}{2r_d} \left(\frac{r}{r_d} \right)^2 \left[I_0 \left(\frac{r}{2r_d} \right) K_0 \left(\frac{r}{2r_d} \right) - I_1 \left(\frac{r}{2r_d} \right) K_1 \left(\frac{r}{2r_d} \right) \right] \\
 &\quad + \frac{2\pi G \rho_0 r_0^3}{r} \left\{ \ln \left(1 + \frac{r}{r_0} \right) + \frac{1}{2} \ln \left[1 + \left(\frac{r}{r_0} \right)^2 \right] - \arctan \left(\frac{r}{r_0} \right) \right\} = r \frac{d\Phi_N}{dr},
 \end{aligned}$$

Más ajustes



Galactic parameters

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TABLE I. Properties and best fitting parameters of the galaxies used.

Galaxy	Type	r_d [kpc]	M_d [M_\odot]	r_0 [kpc]	ρ_0 [M_\odot/kpc^3]	χ^2_{red}
DDO 47	IB	0.5	$3.60 \pm 0.62 \times 10^7$	5.43 ± 0.09	$2.67 \pm 0.03 \times 10^7$	1.74
ESO 116 – G12	SBcd	1.7	$2.09 \pm 0.08 \times 10^9$	4.77 ± 0.03	$4.44 \pm 0.04 \times 10^7$	0.99
NGC 7339	SABd	1.5	$1.10 \pm 0.01 \times 10^{10}$	3.03 ± 0.03	$1.60 \pm 0.02 \times 10^8$	1.69
UGC 4325	SA	1.6	$8.42 \pm 0.47 \times 10^8$	40.54 ± 10.16	$6.59 \pm 0.08 \times 10^7$	3.56

The system to solve:

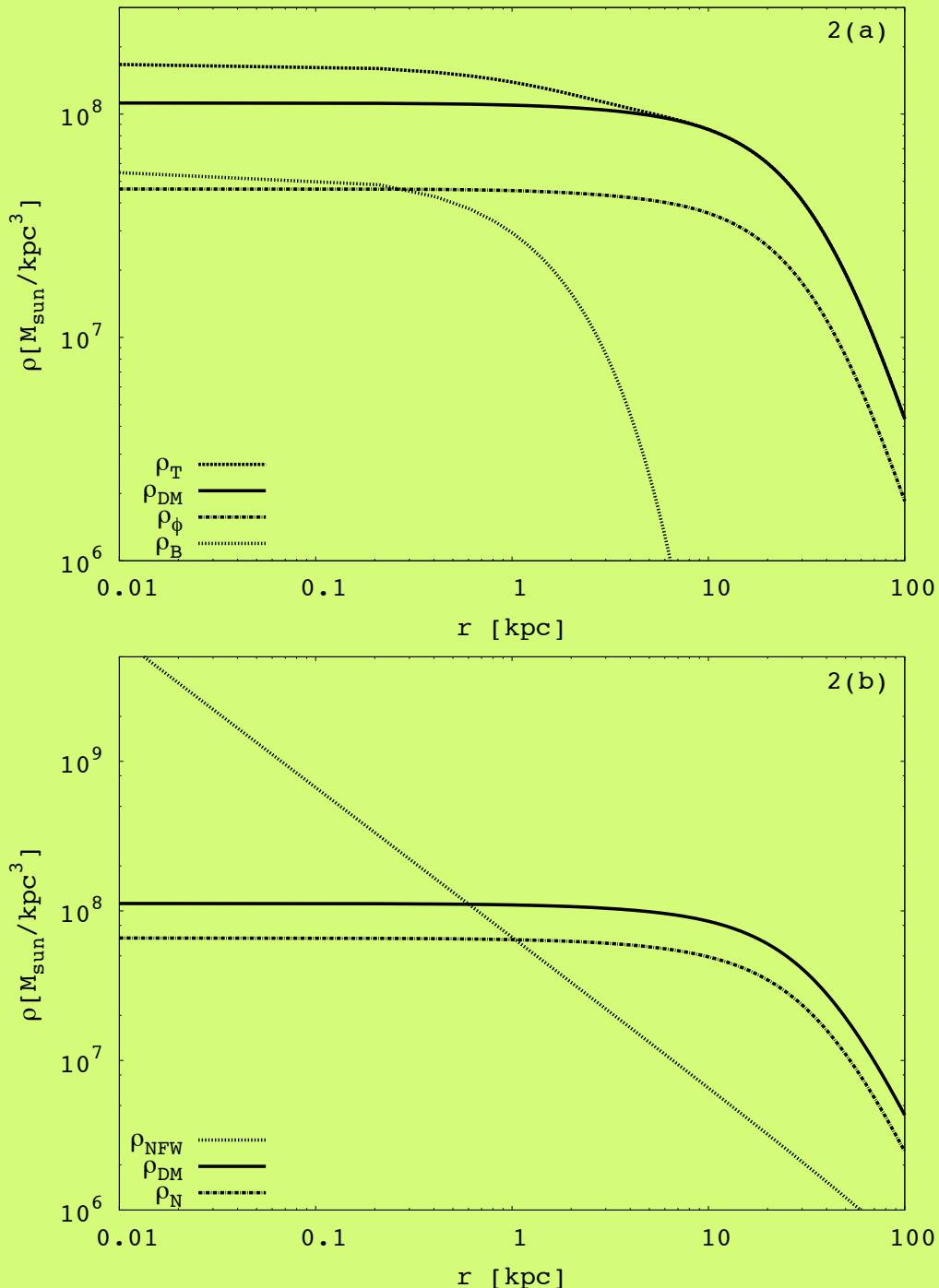
$$\nabla^2 \bar{\phi} - \frac{m^2}{(1 + \alpha)} \bar{\phi} = -\frac{2\alpha}{G_N} \nabla^2 \Phi_N ,$$

$$\rho_{DM} = -\rho_B + \frac{1}{4\pi G_N} \nabla^2 \Phi_N + \frac{1}{8\pi(1 + \alpha)} \left(\frac{mc}{h}\right)^2 \bar{\phi}$$

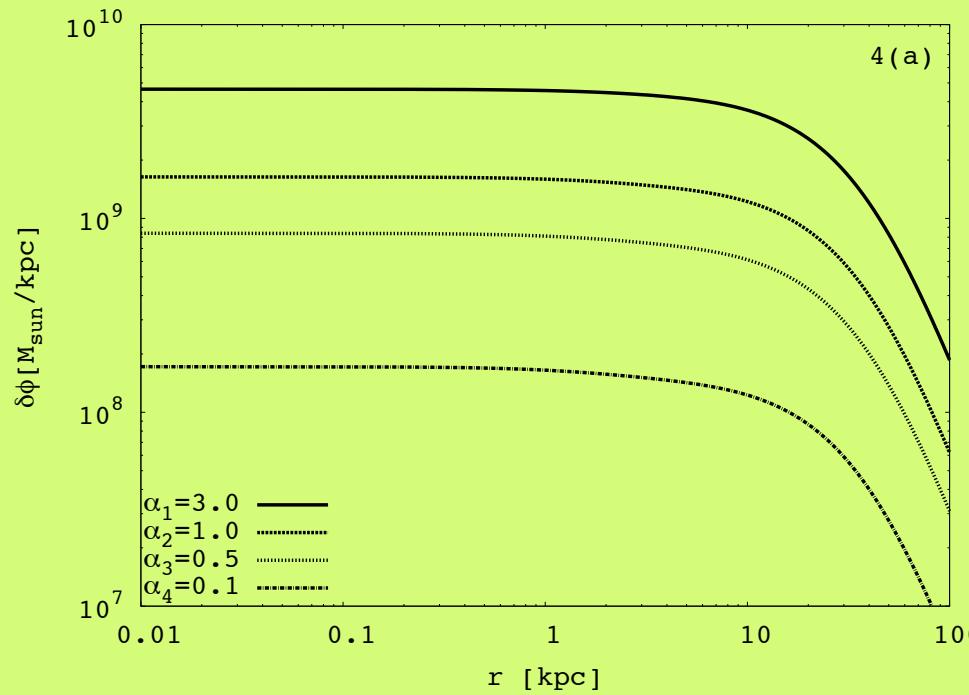
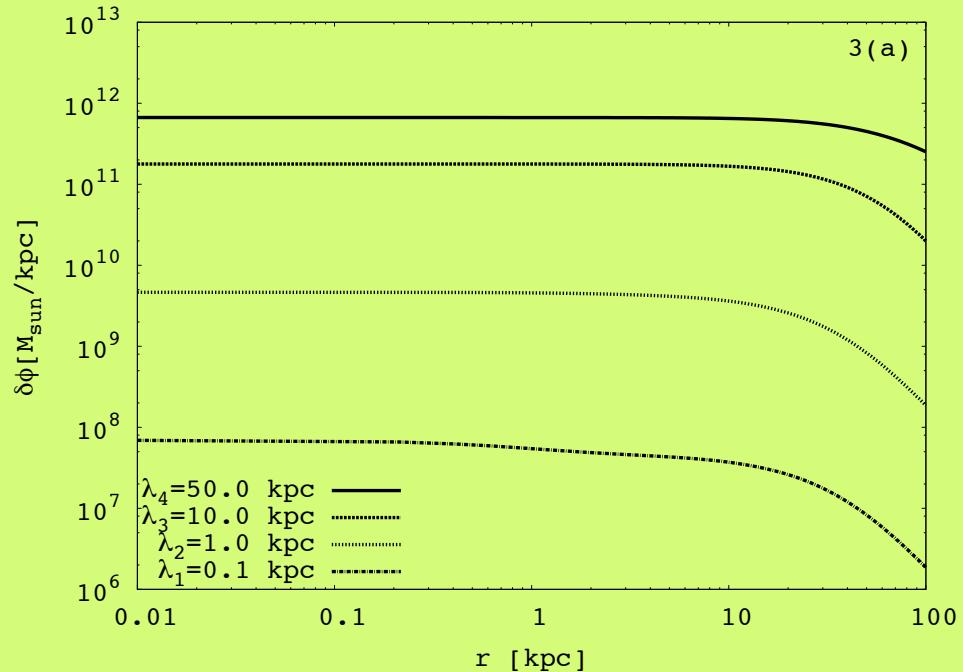
With:

$$\begin{aligned} \Phi_N &= \Phi_{ND} + \Phi_{NH} \\ &= -\frac{1}{2} \frac{GM_d}{r_d} \frac{r}{r_d} \left[I_0\left(\frac{r}{2r_d}\right) K_1\left(\frac{r}{2r_d}\right) - I_1\left(\frac{r}{2r_d}\right) K_0\left(\frac{r}{2r_d}\right) \right] \\ &\quad + \frac{2\pi G \rho_0 r_0^3}{r} \left\{ \left(1 + \frac{r}{r_0}\right) \left[\arctan\left(\frac{r}{r_0}\right) - \ln\left(1 + \frac{r}{r_0}\right) \right] + \frac{1}{2} \left(-1 + \frac{r}{r_0}\right) \ln\left(1 + \frac{r^2}{r_0^2}\right) \right\}, \end{aligned}$$

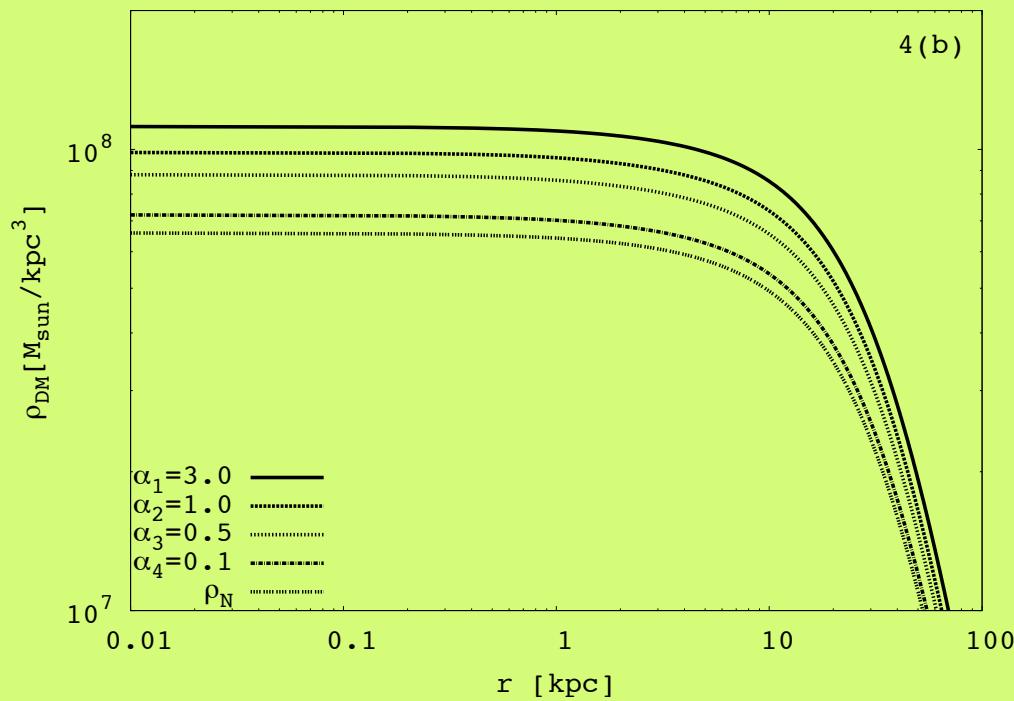
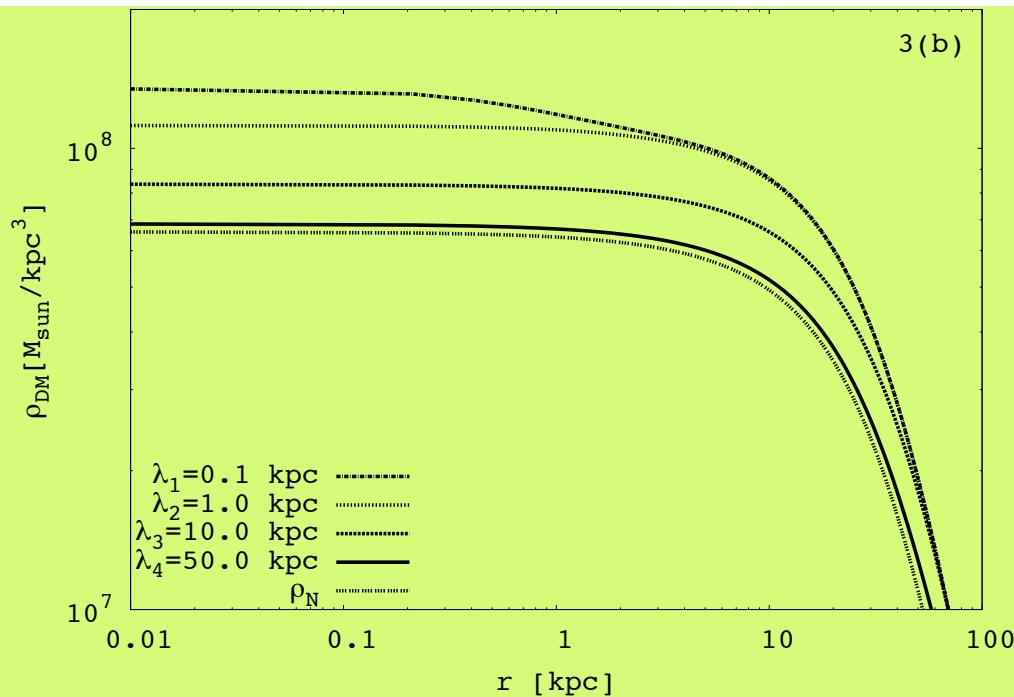
Results-1, $\alpha=-0.1$, $\lambda=1$ pc



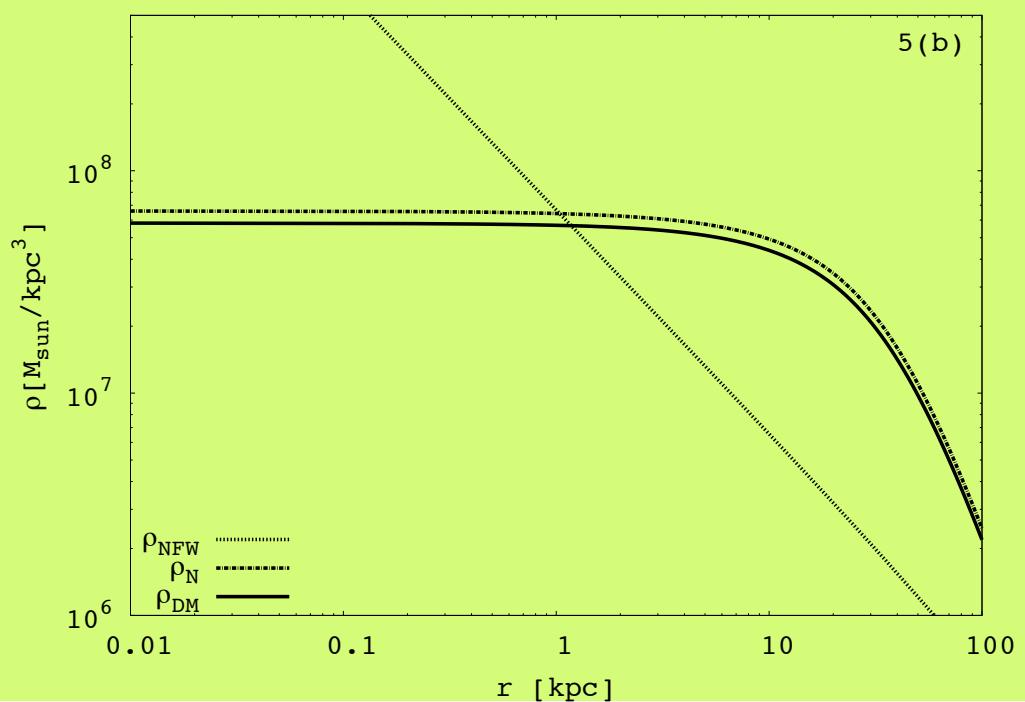
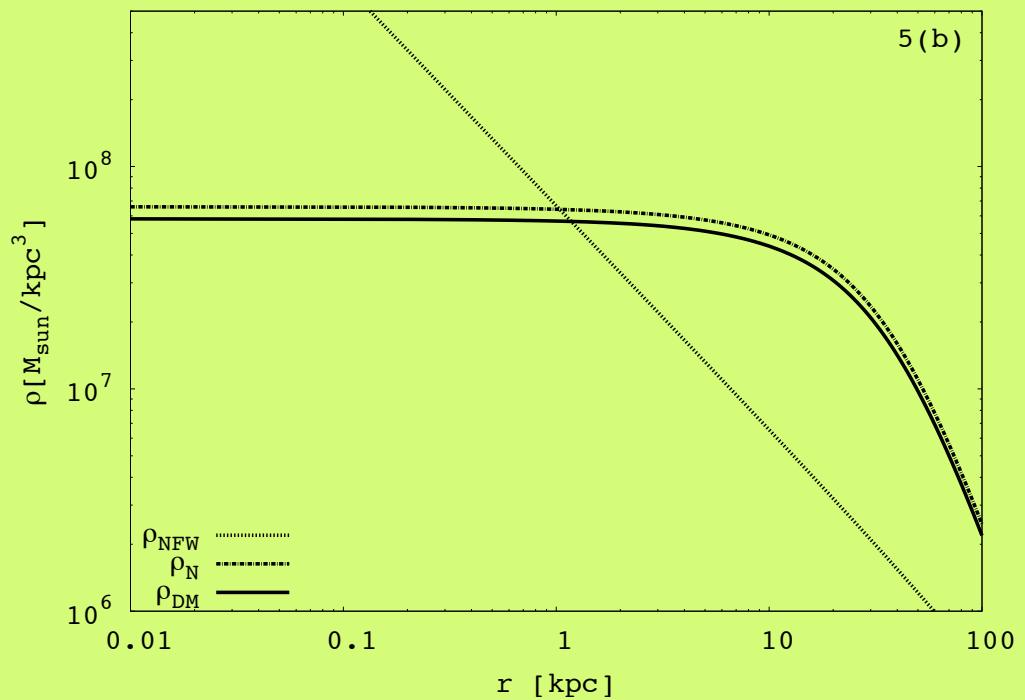
Results-2



Results-3



Results-4, $\alpha=-0.1$, $\lambda=1$ pc



Conclusions

We have presented a galactic model built from a general static STT. We investigated the effects of the two parameters of the theory (α , λ) on the dark matter halo, when we force the solution to obey a typical observed rotation velocity profile.

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