Isolated halos as cosmological probes for Dark Energy

Paul de Fromont

supervised by *Jean-Michel Alimi*

July 2, 2014

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Laboratoire Univers et Théories

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Introduction
Dark energy problem

Today's Universe composition

- Baryonic matter : $\sim 5\%$
- Dark Matter (CDM) : $\sim 25\%$
- Dark Energy : $\sim 70\% \Rightarrow$ accelerated expansion of the Universe

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Dark energy nature ?

- equation of state : $p_{DE} = \omega \rho_{DE}$
- acceleration $\Rightarrow \omega < -1/3$
- in GR, $\omega \in [-1, -1/3]$
- 3 cases :
  1. $-1 < \omega \leq -1/3$, *quintessence*
  2. $\omega = -1$: cosmological constant $\rho_{DE} = cste$
  3. $\omega < -1$: extension of GR, *modified gravity*

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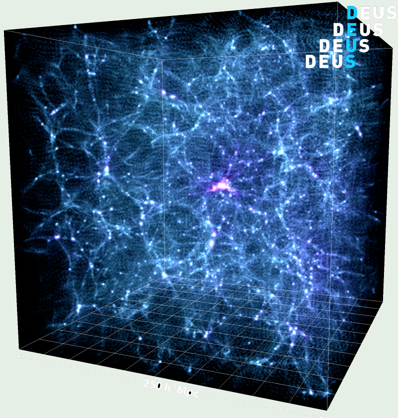
cosmic structures as probes for dark energy

DEUS simulation

N-body simulations

- ΛCDM with $\omega = -1$
- $RPCDM$ quintessence model with $\omega \sim -0.87$
- $SUCDM$ idem with $\omega \sim -0.94$

box of 250 Mpc/h



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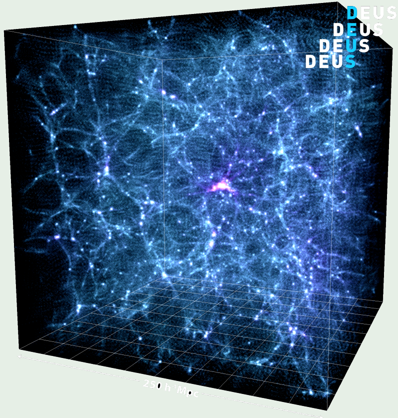

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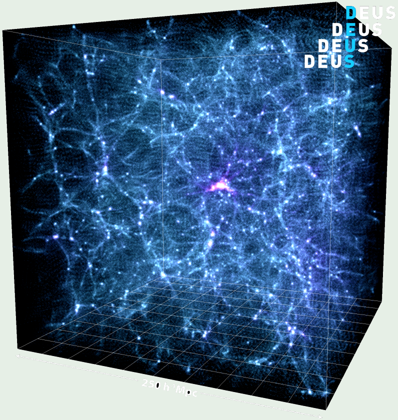

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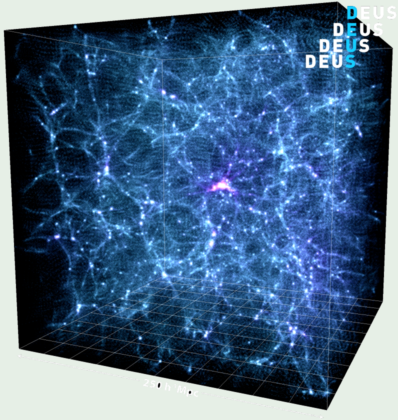

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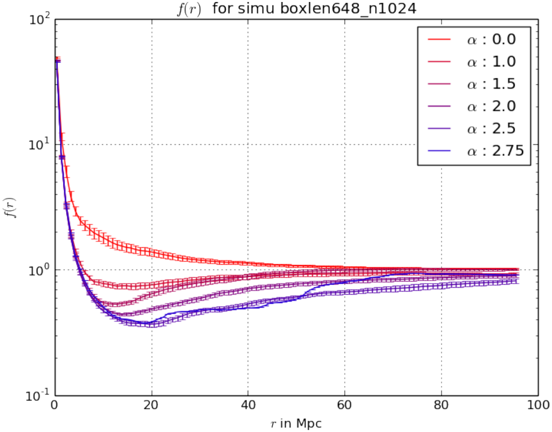
density and mass profile



mass profile

$$f(r) = \frac{M(r)}{4/3\pi\bar{\rho}r^3}$$

for halos of mass $M_h \sim 5.1\ 10^{12}\ M_o$

and $d_i \geq \alpha(R_i + R_0)$

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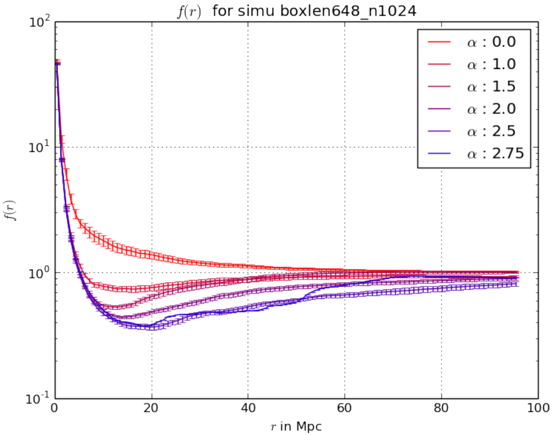

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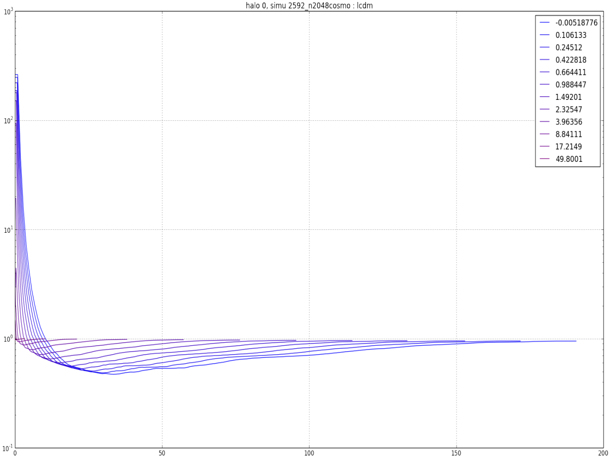
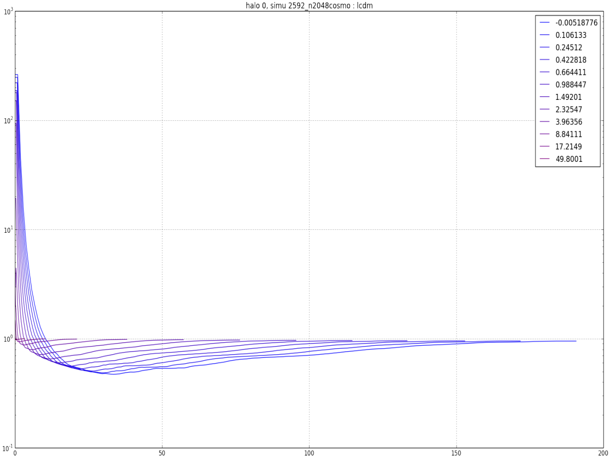
profile evolution



shape evolution

evolution of an initial profile

profile evolution



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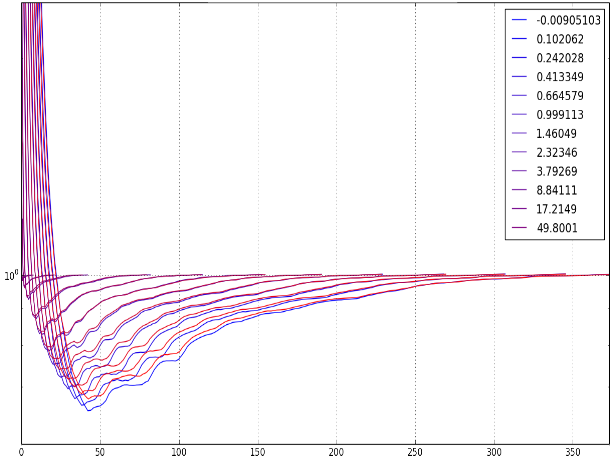
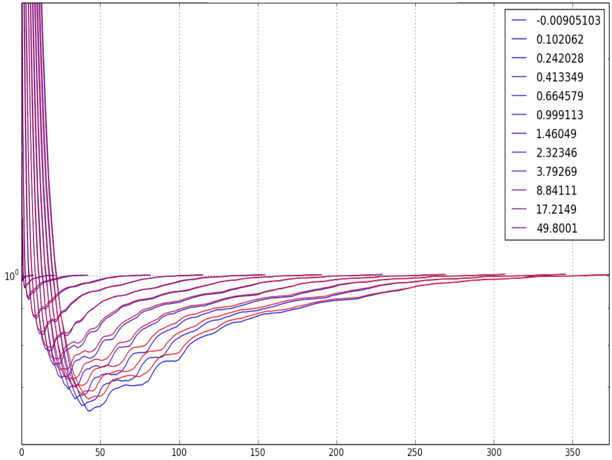
difference between cosmologies



cosmology comparison

shape sensitive to cosmology

difference between cosmologies



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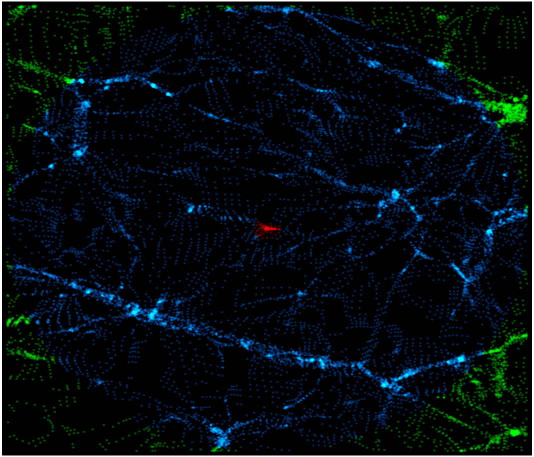
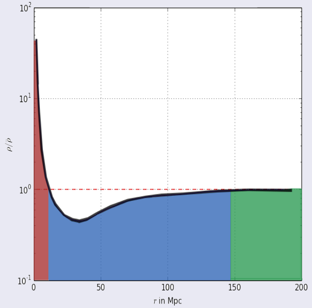


color convention



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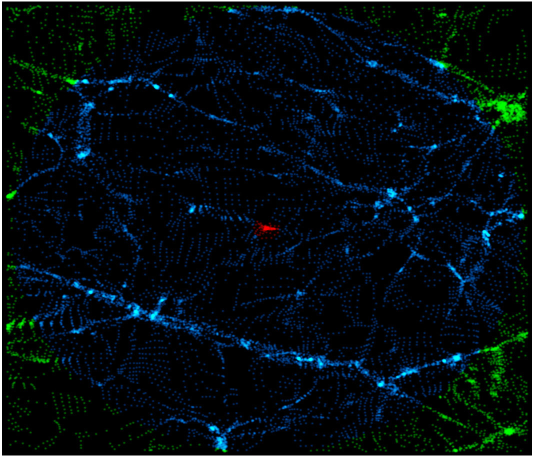

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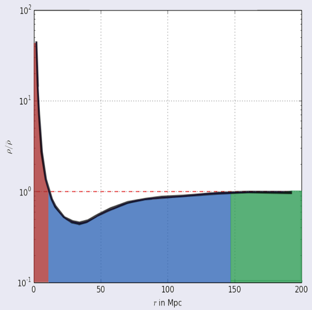

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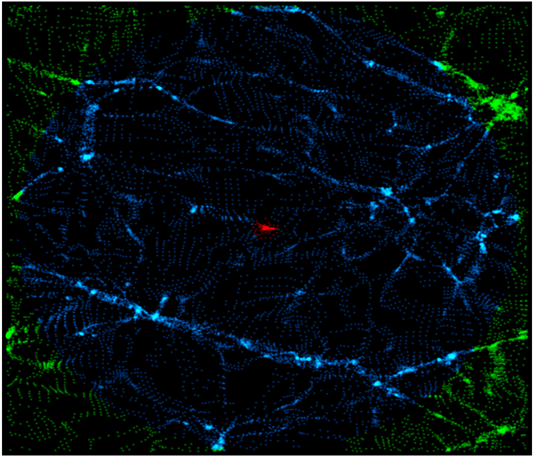

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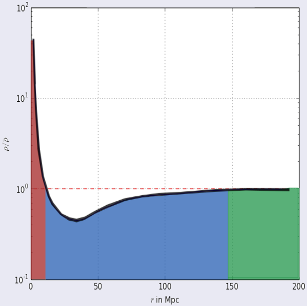

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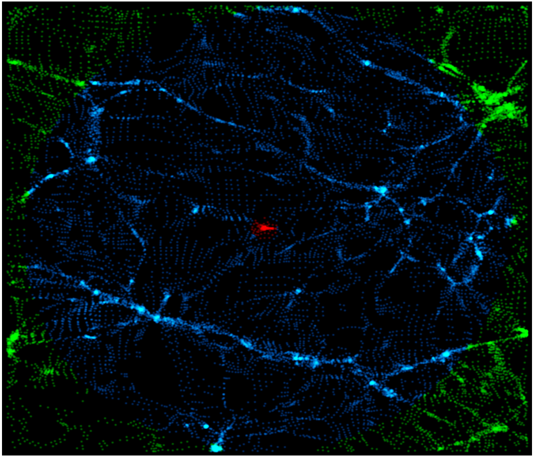

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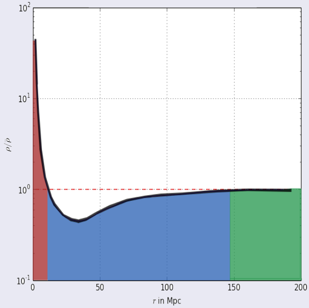

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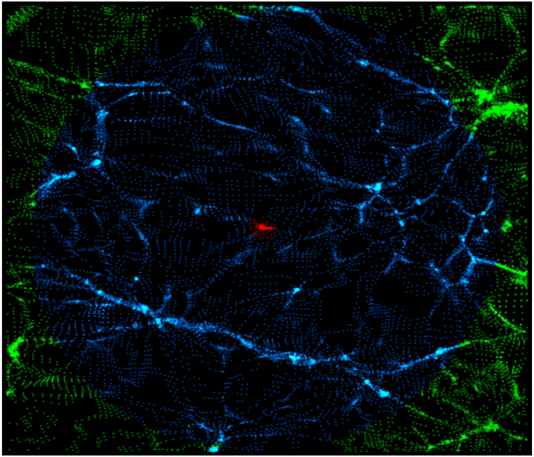

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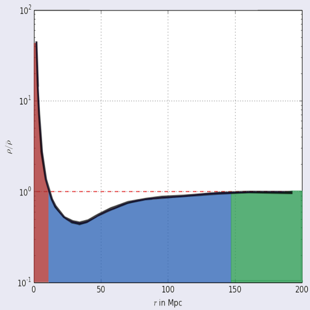

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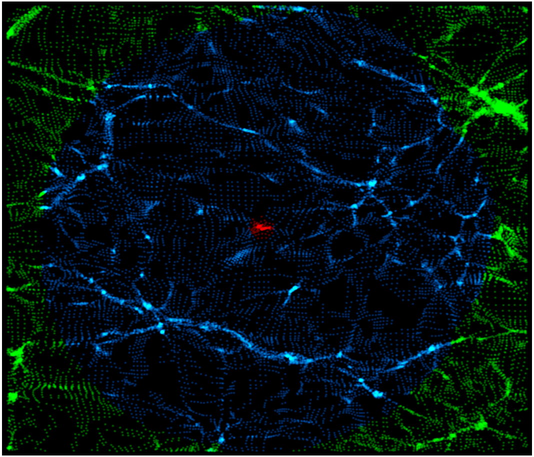

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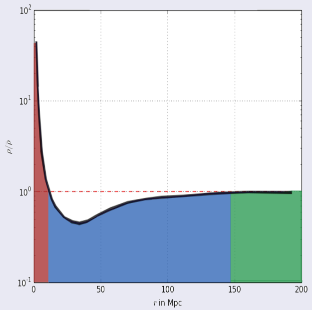

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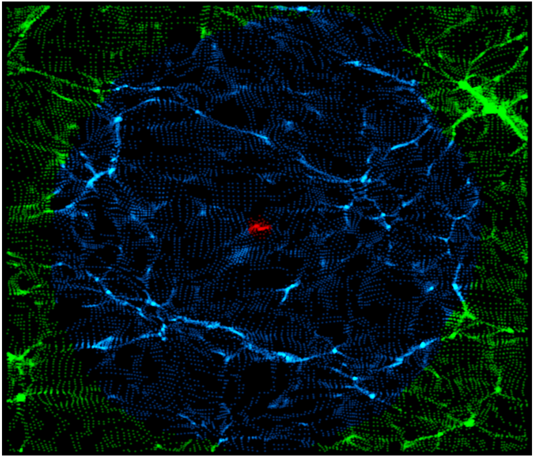

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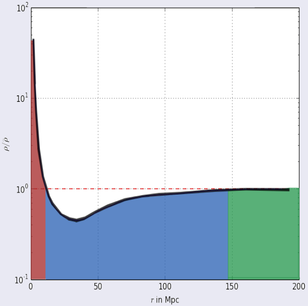

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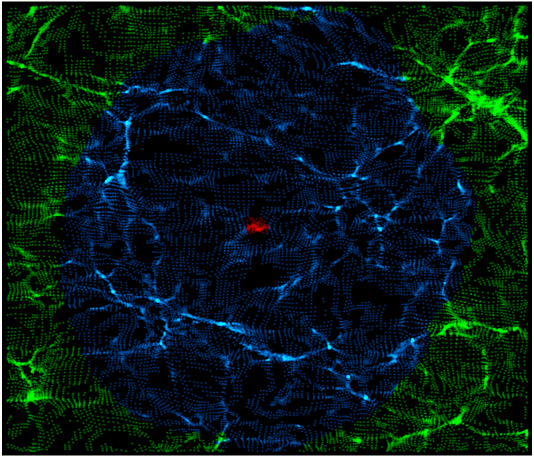

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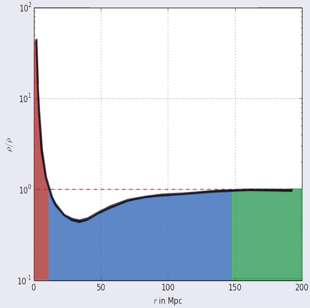

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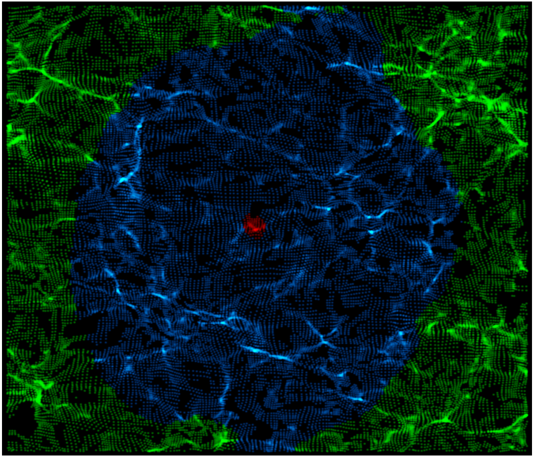

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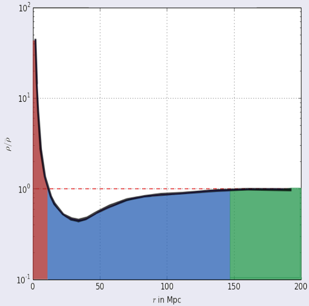

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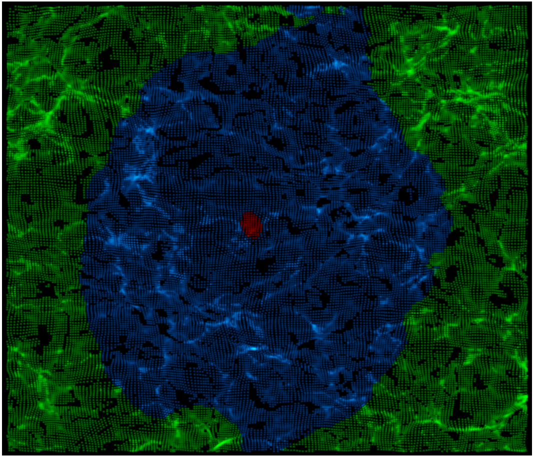

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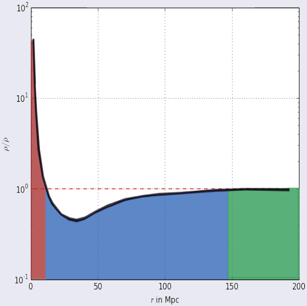

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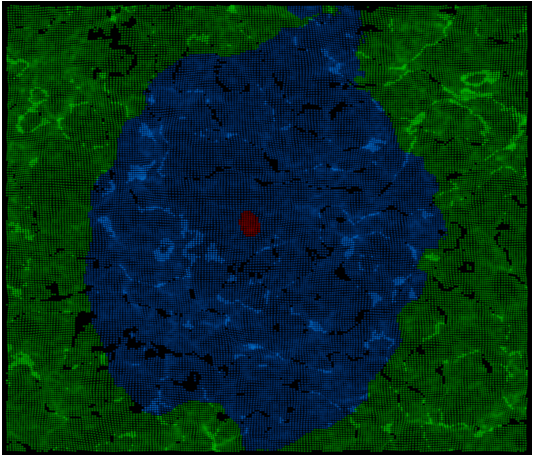

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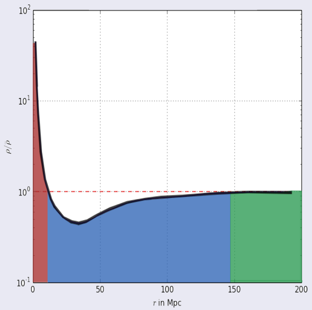

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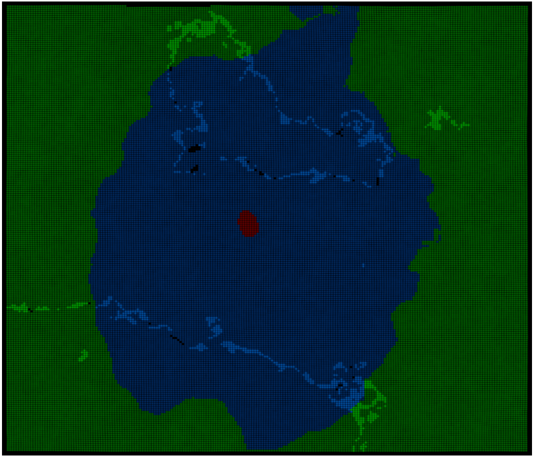

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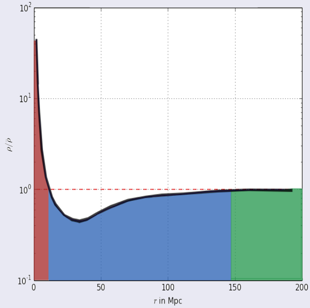

dynamical evolution

dynamical properties

- no *shell-crossing* !
- "self similar" evolution for $f_0(r) \to f(r,t)$
- r_1 such as $f(r_1,t) = 1 \Rightarrow r_1(t) \propto a(t)$
- $f_{min}(t)$ such as $\partial_r f(r,t) = 0$

$$f_{min}(t) = \frac{f_{min}(0)}{x(t, f_{min}(0))^3}$$

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dynamical evolution

Evolution equations

introducing $x(t, r_0) = r(t, r_0)/a(t)$

$$\frac{\partial^2 x}{\partial \tau^2} + \frac{1}{\sqrt{2\Omega_m(\tau)}} \frac{\partial x}{\partial \tau} = x - \frac{f_0(r_0)}{x^2}$$

with

$$\tau = \frac{\sqrt{2}}{3\omega} \sinh^{-1}\left[\sqrt{\frac{\Omega_m^0}{1-\Omega_m^0}} \left(\frac{a(t)}{a(0)}\right)^{3\omega/2}\right]$$

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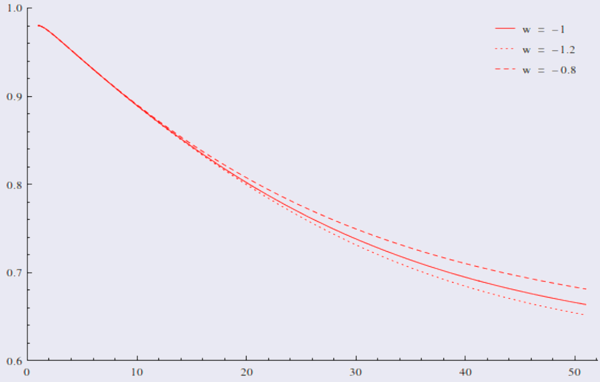
dynamical evolution

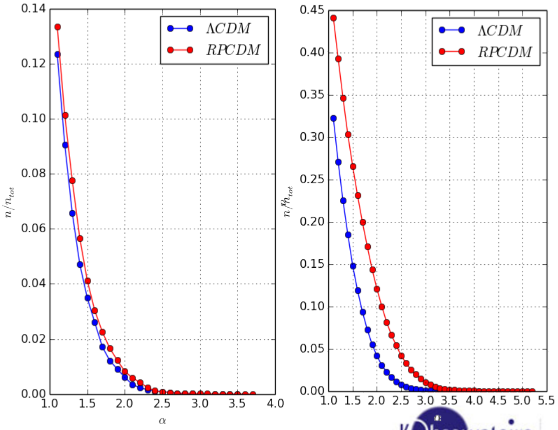
cosmological dependence of $f_{min}(a)$



Isolated halos

number of isolated halos

for halos of mass :
$M_h \sim 5.2\ 10^{12}\ M_o$ (left)
$M_h \sim 3.2\ 10^{15}\ M_o$ (right)



Isolated halos

why useful ?

- known dynamics
- access to $f_0(r)$ (*Gaussian Random Field* and $P(k)$)
- gives $f_{min}(t)$, $r_{min}(t)$ ...
- probability to be isolated $p(\alpha, M_h)$
- depends on the cosmology !

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Conclusion

Isolated halos

shape and population leads to the cosmology !

work still in progress

finish the job ... include *modified gravity*

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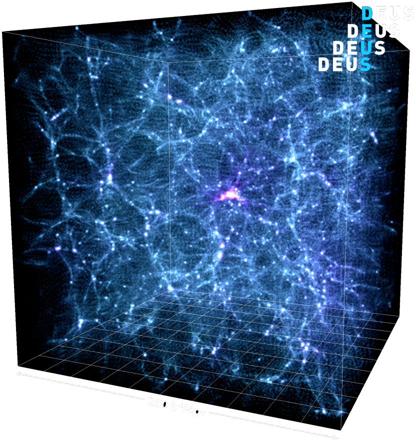
Thank you for your attention !



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Isolated halos

what is an isolated halo ?

No neighbour around ...

$$\forall i,\ \|\vec{x}_0 - \vec{x}_i\| \geq \alpha(R_i + R_0)$$

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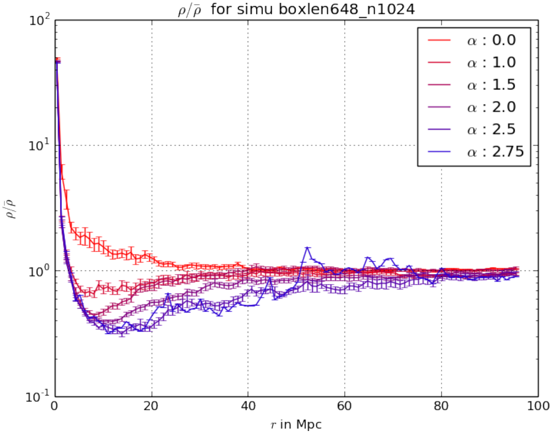
density and mass profile



density profile

$$\delta(r) = \frac{\rho(r)}{\bar{\rho}}$$

for halos of mass $M_h \sim 5.1\ 10^{12}\ M_o$