Structure formation in fast transition UDM models

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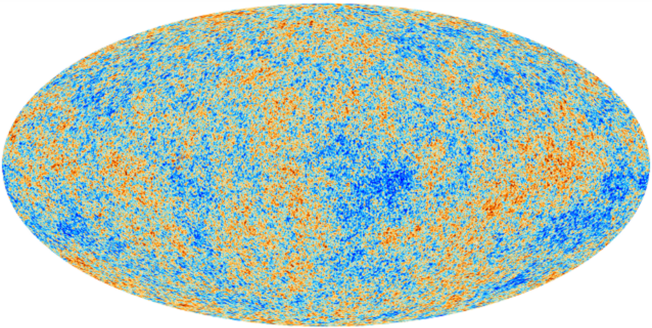
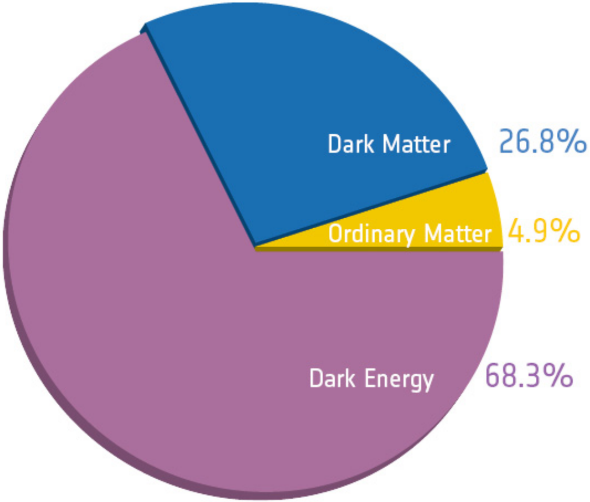
Outline

1. Observational evidence
2. Theoretical motivations
3. UDM models
4. Structure formation
5. Conclusions



Planck Collaboration, 2013


Dark Matter
26.8%
Ordinary Matter
4.9%
Dark Energy
68.3%

Theoretical motivations

- Two unknown components appear in the Standard Cosmological Model
- Dark Matter and Dark Energy could be two aspects of a single underlying component (Quartessence/ Unified Dark matter (UDM))
- It might explain the ”why now?” problem

UDM models

- Fluid triggering the late time accelerated expansion is also the one clustering
- The energy budget of the universe is dominated by a single fluid ✓
- Strong dependence on the effective sound speed $c_{\rm s}^2$ ✗
- We need $c_{\rm s}^2 \ll 1$, but it requires fine tuning
- $\rho = \rho_\Lambda + \rho_{\rm m}$

Classes of UDM models

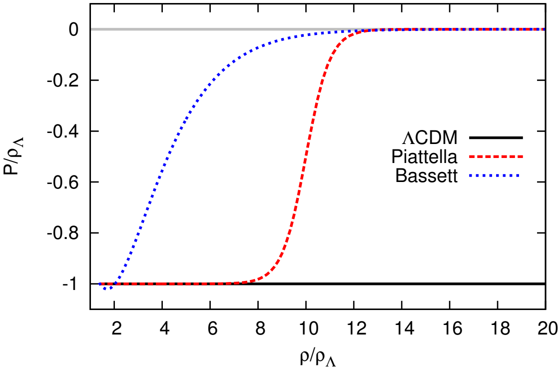
1. Adiabatic UDM: $P = f(\rho)$ with $c_{\rm s}^2 = c_{\rm ad}^2 = dP/d\rho (= s)$

   (Balbi et al. 2007, Quercellini et al. 2007, Piattella et al. 2010)

2. Non-adiabatic UDM: $P \neq f(\rho)$, but for example $P = f(\rho, S)$, where S is the entropy

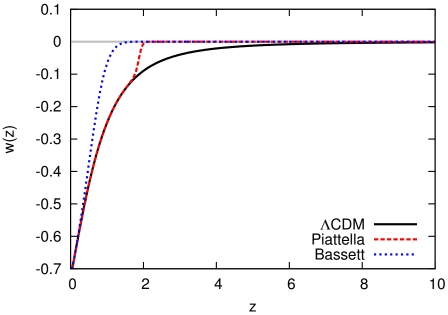
   (Bertacca et al. 2008, Bertacca et al. 2011, Bruni et al. 2013)

Background



Pace, Bertacca & Battye, in preparation

Background



Pace, Bertacca & Battye, in preparation

Evolution of perturbations

Continuity equation

$$\delta_j' + \frac{3}{a}(s_j - \bar{w}_j)\delta_j + [1 + \bar{w}_j + (1 + s_j)\delta_j]\,\frac{\tilde{\theta}_j}{a} = 0$$

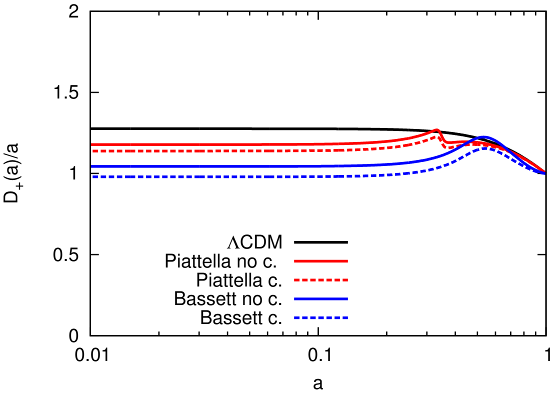
Euler equation

$$\tilde{\theta}_j' + \left(\frac{2}{a} + \frac{H'}{H}\right)\tilde{\theta}_j + \frac{\tilde{\theta}_j^2}{3a} + \frac{\tilde{\sigma}_j^2 - \tilde{\omega}_j^2}{a} + \frac{1}{a^3 H^2}\nabla^2\Phi + \frac{\tilde{\theta}_j P_j'}{\rho_j c^2 + P_j} = 0$$

Poisson equation

$$\frac{\nabla^2\Phi}{a^3 H^2} - \frac{3}{2a}\sum_k \Omega_k (1 + 3s_k)\delta_k = 0$$

Growth factor (adiabatic models)



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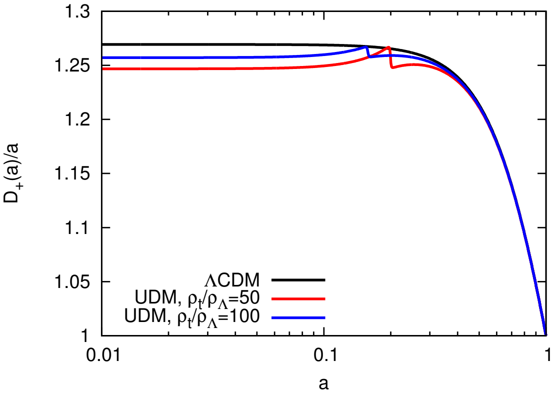
Growth factor (non-adiabatic models)



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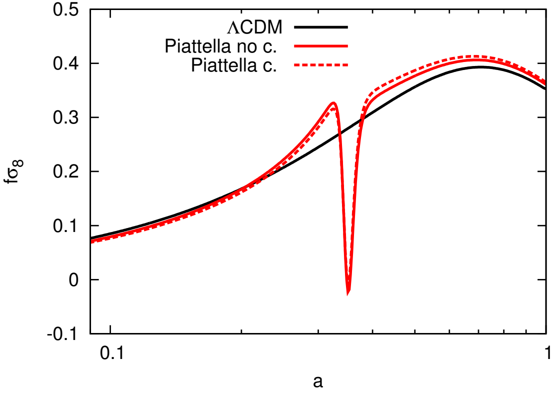
A more observational quantity: fσ_8



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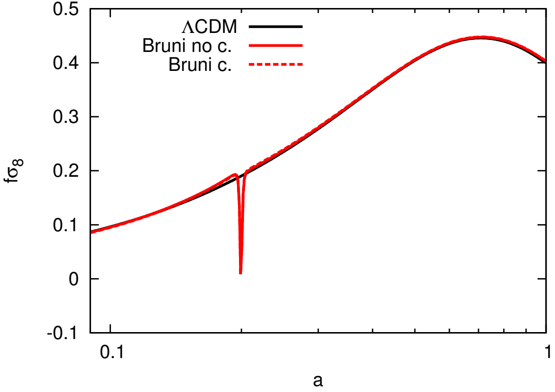

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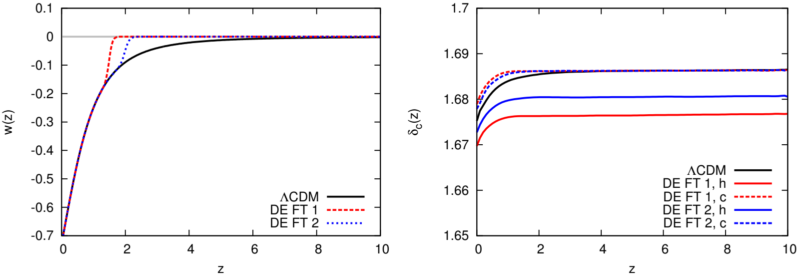
Fast transition DE models



Pace, Bertacca & Battye, in preparation

Conclusions

- UDM models are an alternative to understand the nature of DM and DE
- Fast transition avoids the fine tuning for $c_{\rm s}^2 \ll 1$
- Features in the growth factor where the fast transition takes place
- What happens at the non-linear level (see DE fast transition models)?
- Study limited to barotropic fluids, but it can be extended to non-adiabatic models: how to treat $\delta P/\delta\rho$?