Mildly Mixed Coupled cosmological models

(Higher neutrino mass allowed if CDM & DE are coupled)

*La Vacca, Kristiansen, Mainini,B., Colombo, arXiv:0902.2711 & JCAP  
(Do WMAP data favor neutrino mass and a coupling between CDM and DE?)

*Kristiansen, La Vacca, Colombo,Mainini,B., arXiv:0902.2737 & NewA.  
(Coupling between CDM and DE from neutrino mass experiments)

*La Vacca, B., Mainini (in preparation)  
(Mildly mixed coupled models and WMAP7 data)

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MMC cosmologies

OPPOSITE EFFECTS ON TRANSFER FUNCTION from CDM-DE COUPLING AND NEUTRINO MASS

Opposite effects on $C_l$ data WMAP5

New: Taking into account WMAP7, SDSS, new H, & further recent data

$M(\nu) - \beta$ degeneracy
Dark components dynamically isolated:

\[ T^{\mu}_{(c)\nu;\mu} + T^{\mu}_{(d)\nu;\mu} = 0 \]

\[ \text{CDM} \quad \text{DE} \]

\[ T^{\mu}_{(c)\nu;\mu} = + Q_\nu \quad T^{\mu}_{(d)\nu;\mu} = - Q_\nu \]

(only) 2 options: \( Q_\nu = Q u^{(c)}_\nu / a \quad Q_\nu = Q u^{(d)}_\nu / a \)

both yield: \( \dot{\rho}_c + 3H\rho_c = Q \quad \dot{\rho}_d + 3H(\rho_d + P_d) = -Q \)

(different fluctuation evolution)

further options: \( Q = \rho_c \times a^2 C \quad Q = \rho_d \times a^2 C \)

former option allows CDM \& DE to evolve in parallel

 easing coincidence paradox

option considered first by: Damour, Gibbons, Gundlach, PRL64 (1990)

For further details on the generic approach, see, e.g., L. Lopez Honorez,
B.A. Reid, O. Mena, L. Verde, R. Jimenez, arXiv:1006.08
Dynamical DE: a self-interacting scalar field

$$
\dot{\rho}_e + 3H\rho_e = C\rho_e\dot{\phi} \quad \dot{\rho}_d + 3H(\rho_d + P_d) = -C\rho_e\dot{\phi}
$$

$$
\ddot{\phi} + 2H\dot{\phi} + a^2V' = -C\rho_e a^2
$$

**energy density**

**pressure**

same form of coupling \( \gamma(\phi) \) from Jordan to Einstein

*Implies* \( V(\phi) = A \exp(\mu\phi/m_P) \) (expon. potential)

*Here we shall use*

\( V(\phi) = (\Lambda^{\alpha+4}/\phi^\alpha) \) \( RP \)

\( V(\phi) = (\Lambda^{\alpha+4}/\phi^\alpha) \exp(4\pi\phi^2/m_P^2) \) \( SUGRA \)

potentials admitting tracker solutions
**LCDM problems**

Scale dependence of different cosmic components in a LCDM model

- Coincidence paradox: why now? if earlier... no structure would form
- Vacuum fine tuning paradox 1:10^56 at EW transition Let alone Planck time....

\[ \rho = \rho_{\text{kin}} + V, \quad p = \rho_{\text{kin}} - V, \quad \text{with} \quad \rho_{\text{kin}} = \dot{a}^2 / 2a^2 \]

\[ V(\phi) = \Lambda^{\alpha+4} / \phi^\alpha \quad \text{RP} \]

\[ V(\phi) = (\Lambda^{\alpha+4} / \phi^\alpha) \exp[4\pi(\phi / m_p)^2] \]

SUGRA

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Energy flow from CDMS \( \rightarrow C = 1 / m_p \)

High: \( \dot{\rho}_c = 0.15 \rightarrow C = 0.654 / m_p \)

DE density is purely kinetic dilutes rapidly, but it cannot be fed

Low: DE field attains values making the potential term dominant:

Then it overcomes matter density and causes cosmic acceleration

\[ \rho + \dot{\phi}^2 + a^2 V = + C a^2 \rho_c \]

\[ \dot{\rho}_c + 3 \dot{a} / a \rho_c = - C \dot{\rho} \phi \]

Wetterich C. 1995, Amendola L., 2000, etc.

Different approaches:


* Coupling with Tijd. Gavela M.B. et al, arxiv:0901.1611
Laboratory outputs concerning $\nu$-mass

Tritium $\beta$-decay:
MAINZ & TROISZK (1997 - 2005)
\[ m(\nu_e) < 2 - 3 \text{ eV} \]
\[ \Delta m_1 = 0.05 \text{ eV} \]
\[ \Delta m_2 = 0.009 \text{ eV} \]
KATRIN (taking data from 2011) errors down to systematics level 0.15 - 0.2 eV

Solar $\tau$ atmospheric neutrino experiments

Double $\beta$-decay experiments
Heidelberg - Moskow
Cuoricino / Cuore

Assume that neutrino is Majorana spinor

NEMO

GERDA

To repeat Heidelberg - Moskow experiment

\[ ^{76}\text{Te} \rightarrow ^{76}\text{Se} \]
\[ ^{130}\text{Te} \rightarrow ^{130}\text{Xe} \]
\[ ^{82}\text{Se} \rightarrow ^{82}\text{Mo} \]
\[ m(\nu_e) = 0.2 - 0.6 \text{ eV} \]
WMAP7 (and related data) correct predictions on DE state eqn.

\[ w(z) = w_0 + w_a(1-a) \]

Shift of likelihood ellipses on \( w_0-w_a \) plane

passing from WMAP5+ to WMAP7+

mistreatment corrected
neutrino mass vs. DE state parameter $w$

$\sum \nu$-mass limits (95% c.l.)

.93 eV

WMAP5 (Komatsu et al)

.82 eV

WMAP7 (our test)

with the same MMC of WMAP team

$\Sigma m_\nu [eV]$ vs $\Sigma \nu$ [eV]

$w$ < -1

no longer related to neutrino mass

$M\nu - \beta$ degeneracy in jeopardy?
Large Scale Structure from new SDSS data

Apparently critical in modifying likelihood distribution
The power spectrum of the galaxy distribution has been determined from the survey using a direct FFT-based tech. (Percival et al. 2001) over the range in wavenumber $0.02 < k < 0.15$ h Mpc$^{-1}$,
2.3 Calculating power spectra, window functions and covariances

In this paper we focus on using the angle-averaged power spectrum to derive constraints on the underlying linear theory power spectrum. On linear scales the redshift space power spectrum is proportional to the real space power spectrum (Kaiser 1987; Hamilton 1998). Our halo density field reconstruction mitigates the effects of FOGs from objects occupying the same halo. Though we do not explore it here, we expect that our halo density field reconstruction will be useful to an analysis of redshift-space anisotropies (e.g., Hatton & Cole 1999).

The methodology for calculating the power spectrum of the reconstructed halo density field, \( \tilde{P}_{\text{halo}}(k) \), is based on the Fourier method of Feldman et al. (1994). The halo density is calculated by throwing away all but the brightest galaxy where we have located a set of galaxies within a single halo. This field is converted to an over-density field by placing the haloes on a grid and subtracting an unclustered “random catalogue”, which matches the halo selection. To calculate this random catalogue, we fit the redshift distributions of the halo sample with a spline model (Press et al., 1992) (shown in Fig. 1), and the angular mask was determined using a routine based on a HEALPIX (Górski et al. 2005) equal-area pixelization of the sphere as in (Percival et al. 2007). This procedure allows for the variation in radial selection seen at \( z > 0.38 \), which is caused by the spectroscopic features of the LRGs moving across the wavebands used in the target selection. The haloes and randoms are weighted using a luminosity-dependent bias model that normalizes the fluctuations to the amplitude of \( L_\ast \) galaxies (Percival et al. 2004). To do this we assume that each galaxy used to locate a halo is biased with a linear deterministic bias model, and that this bias depends on \( M_{0.1} \), according to Tegmark et al. (2004a) and Zehavi et al. (2005), where \( M_{0.1} \) is the Galactic extinction and K-corrected \( r \)-band absolute galaxy magnitude. This procedure is similar to that adopted by P09.

The power spectrum was calculated using a 1024\(^3\) grid in a series of cubic boxes. A box of length 4000 \( h^{-1} \) Mpc was used initially, but we then sequentially divide the box length in half and apply periodic boundary conditions to map galaxies that lie outside the box. For each box and power spectrum calculation, we include modes that lie between \( 1/4 \) and \( 1/2 \) the Nyquist frequency (similar to the method described by Cole et al. 2005), and correct for the smoothing effect of the cloud-in-cell assignment used...
What is HALOFIT?

Expression of non-linear spectrum
Obtained from linear 2-p function $\xi(r)$

linear $\xi(r) \rightarrow$ non linear $\xi[f(r)]$

$f(r)$ tested in simulations of LCDM
HALOFIT vs N-BODY SIMULATION
For non-LCDM models

\[ w = -0.95 \]
\[ \Omega_m = 0.274 \]
\[ H = 70 \text{ km/s/Mpc} \]
\[ \sigma_8 = 0.81 \]

program pkdgrav

\[ L = 256 \text{ h}^{-1} \text{ Mpc} \]
\[ N(\text{part}) = 256^3 \]
\[ m(\text{part}) = 7.61 \times 10^{10} \text{ M(\text{sun})} \text{h}^{-1} \]
\[ \epsilon = 25 \text{ h}^{-1} \text{kpc} \]
\[ z(\text{in}) = 24 \]

Simulation run for work in progress by Casarini, La Vacca, Amendola, Maccio'
(The impact of non-linear corrections on Weak lensing forecasts)
Discrepancies between parameter recovery using Halofit or true n-body simulations

Plot for hypothetical tomographic WL exp.

$\sim 200$ non-linearity begins at $\sim 1000$, 50% errors

From Casarini, LaVacca, Amendola, Maccio', 2010 (in preparation)
1D likelihood distributions

Top likelihood not at zero!

Notice also higher limits on Λ scale (however highly undetermined)
KATRIN prior for neutrinos with mass 0.3 eV falls in the top likelihood area.
HM-like $\nu$-mass prior does not yield strong likelihood decrease

would imply CDM-DE coupling "detection"
Conclusions

• Updated CMB data analysis: no degeneration decrease
• Constraints from SDSS survey hard to use
• Procedure to work out spectra from SDSS involves
  Halo model and HALOFIT expressions
  (a bias in favor of LCDM?)
• Results almost independent from potential shape
• [SUGRA & RP describe rapidly & slowly varying \( w(z) \)]
• Constraints on scale \( \Lambda \) eased

MMC models however ease fine-tuning & coincidence

Coupling interpretations
• Single substance?
• Inverse process of inflationary reheating?
Abstract

• Energy exchanges CDM-DE soften limits on neutrino mass

• … but not so much, factor 2-3

• Neutrino mass above standard cosmological limits → new physics between CDM & DE

• KK claim or KATRIN detection also critical for the nature of dark cosmic components