Mildly Mixed Coupled cosmological models

*La Vacca, B., Colombo, arXiv:0810.0127 & NewA.
(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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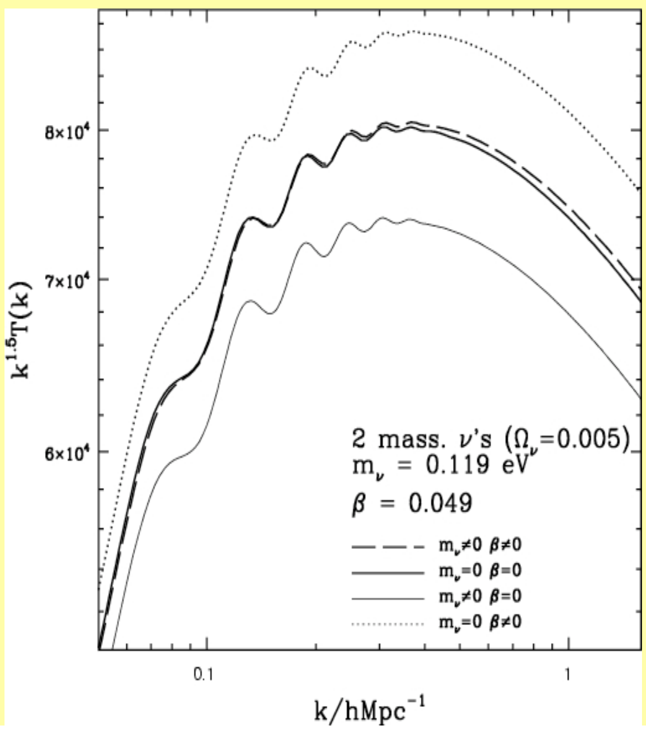
MMC cosmologies

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

ANTISYMMETRIC EFFECTS OF NEUTRINO MASS & CDM -DE COUPLING

MMC models

(mildly mixed coupled models)



Opposite effects on C_l

data WMAP5

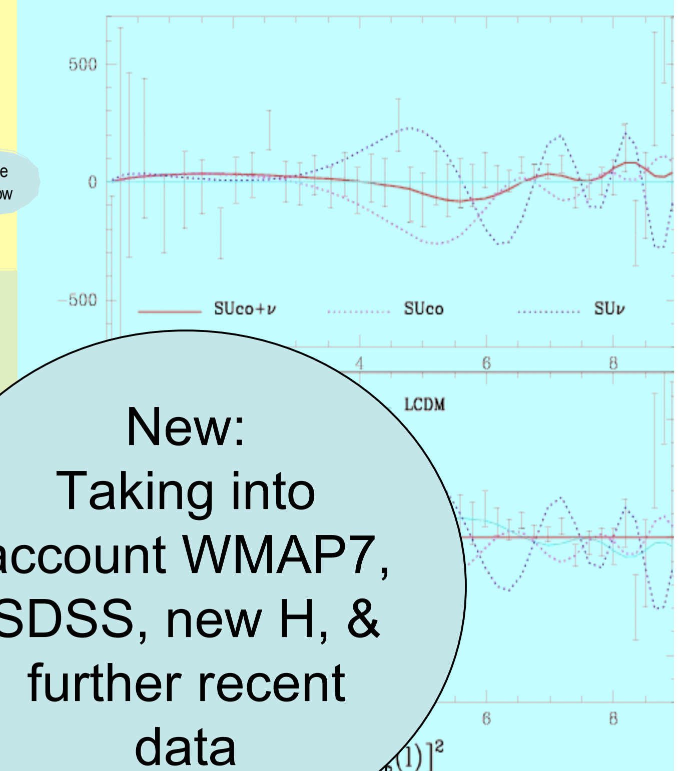
BEST FIT LCDM

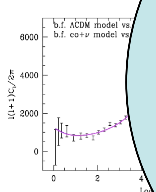
& (nearly) BEST FIT MILDLY-MIXED COUPLED SUGRA

see below

3 ν's yielding M_ν=0.9 eV

β = 0.15





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

$M(\nu)-\beta$ degeneracy

Dark components dynamically isolated:

$$T_{(c)}{}^{\mu}_{\nu;\mu} \quad + \quad T_{(d)}{}^{\mu}_{\nu;\mu} \quad = \quad 0$$

CDM *DE*

$$T_{(c)}{}^{\mu}_{\nu;\mu} = +\,Q_\nu \qquad T_{(d)}{}^{\mu}_{\nu;\mu} = -\,Q_\nu$$

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

FRW frame:

both yield : $\dot\rho_c + 3\mathcal{H}\rho_c = Q\ , \qquad \dot\rho_d + 3\mathcal{H}(\rho_d + P_d) = -Q$

(different fluctuation evolution)

further options : $Q = \rho_c \times a^2 C\ , \qquad Q = \rho_d \times a^2 C$

former option allows CDM & DE to evolve in parallel
easing coincidence paradox

option considered first by: Damour, Gibbons, Gundlach, PRL64 (1990)
detailed analysis: Wetterich, AA301 (1995), Amendola, PRD62 (2000) ......

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

$$\dot{\rho}_c + 3\mathcal{H}\rho_c = C\rho_c\dot{\phi} \qquad \dot{\rho}_d + 3\mathcal{H}(\rho_d + P_d) = -C\rho_c\dot{\phi}$$

Dynamical DE : a self-interacting scalar field

$'(\phi)\ ]$

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

energy density **pressure**

same form of coupling ... ansformation
from Jordan to Einstei...

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

Here we shall use

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

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

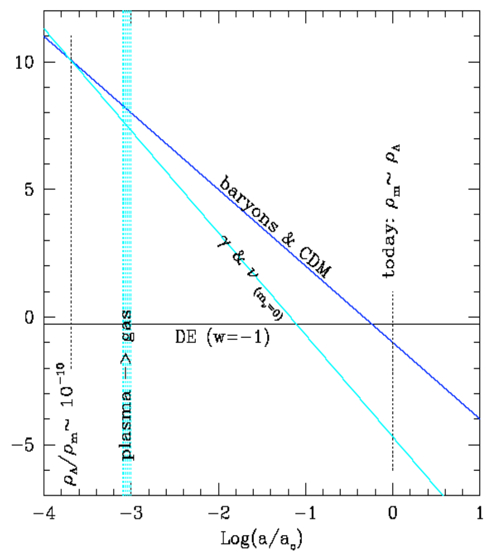
potentials admitting tracker solutions

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….

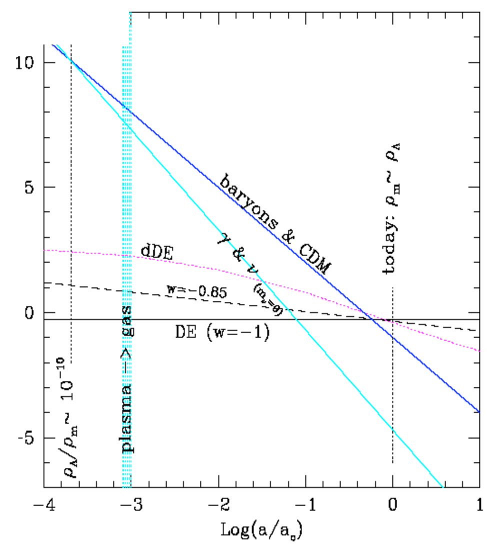


$\rho = \rho_k + V(\phi)\,, \quad p = \rho_k - V(\phi)\,,$ with $\rho_k = \dot\phi^2/2a^2$

DE as a self-interacting scalar field (Wetterich 1988, Ratra & Peebles 1988)

Fine tuning eased (may be..)
Coincidence still a problem

$$\rho = \rho_{kin} + V$$
$$p = \rho_{kin} - V$$
$$\rho_{kin} = \phi^2/2$$



$$\ddot\phi + 2\frac{\dot a}{a}\dot\phi + a^2 V'_\phi = + C a^2 \rho_c$$
$$\dot\rho_c + 3\frac{\dot a}{a}\rho_c = - C \rho_c \dot\phi$$

Coincidence eased as well

Energy flow from CDM to DE: $\beta = 0.25 \rightarrow C \approx 1/m_p$

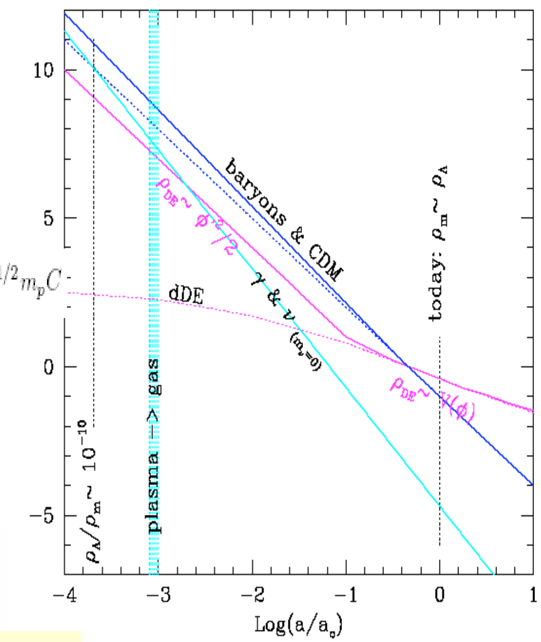
High z: $\beta = 0.15 \rightarrow C = 0.614/m_p$

DE density is purely kineti[c], dilutes rapidly, but it cont[inues] to be fed

$\beta = (3/16\pi)^{1/2} m_p C$

Low z:
DE field attains values making the potential term dominant :
Then it overcomes matter density and causes cosmic acceleration

$$T^{(de)}\,{}^{\mu}_{\nu;\mu} = + C T^{(c)} \phi_{,\nu}$$
$$T^{(c)}\,{}^{\mu}_{\nu;\mu} = - C T^{(c)} \phi_{,\nu}\,,$$



$$\ddot\phi + 2\frac{\dot a}{a}\dot\phi + a^2 V'_\phi = + C a^2 \rho_c$$
$$\dot\rho_c + 3\frac{\dot a}{a}\rho_c = - C \rho_c \dot\phi$$

Wetterich C. 1995, Amendola L., 2000, etc.
Different approaches :
* Neutrino DE (Wood -Vasey et al arxiv :0701040, Hung P.Q. arxiv :0010126, Blatt J.R. et al:0812.1895v1, etc. But see: Bjaelde & Hannestad , arxiv:0812.1895v1)
* Coupling with T(d): Gavela M.B. et al, arxiv :0901.1611

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

Laboratory outputs concerning ν-mass

Tritium β-decay:

MAINZ & TROISZK (1997 - 2005) m(ν_e) < 2-3 eV

KATRIN (takng data from 2011) errors down to systematics level 0.15-0.2 eV

$$\frac{1}{\tau} = G(Q,Z)\left|M_{nucl}\right|^2 m_\nu^2$$

Solar + atmospheric neutrino experiments Δm_1 = 0.05 eV, Δm_2 = 0.009 eV

Neutrino mass eingenstates different from flavor eigenstates

		τ /y >	Klapdor et al. τ /y =
Double β-decay experiments	Heidelberg-Moskow	1.9e25	0.69 - 4.18e25
	Cuoricino / Cuore	2.9e24	
	NEMO		
	GERDA		

Assume that neutrino is Majorana spinor

To repeat Heidelberg-Moskow experiment

$^{76}Te \rightarrow Se$

$^{130}Te \rightarrow {}^{130}Xe$

$^{82}Se \rightarrow {}^{82}Mo$

m(ν_e) = 0.2 -0.6 eV

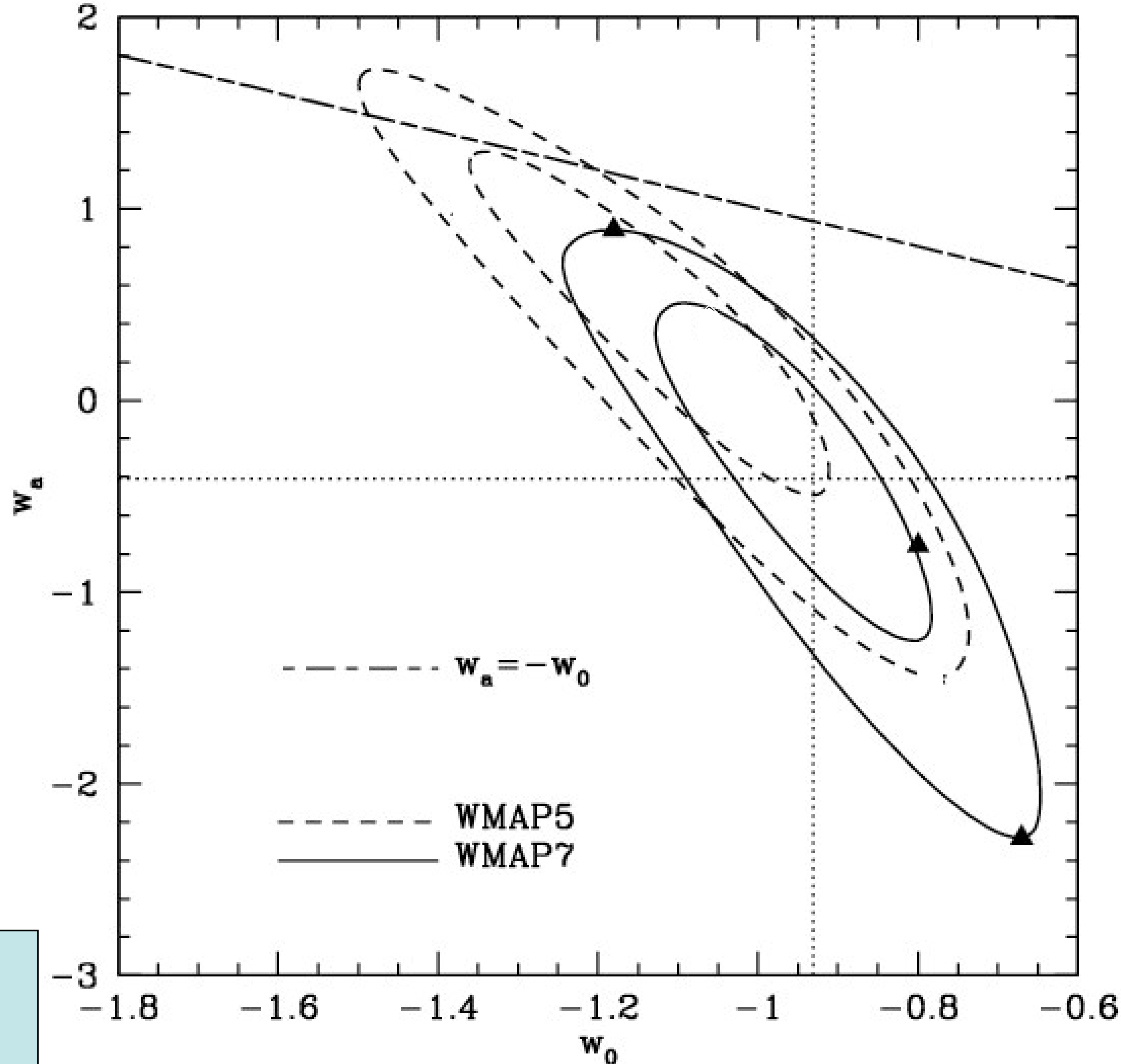
WMAP7
(and related data)
correct predictions
on DE state eqn.

$w(z)=w_o+w_a(1-a)$

Shift of likelihood
ellipses on
w_o-w_a plane

passing from
WMAP5+ to
WMAP7+

mistreatment
corrected



neutrino mass vs. DE state parameter w

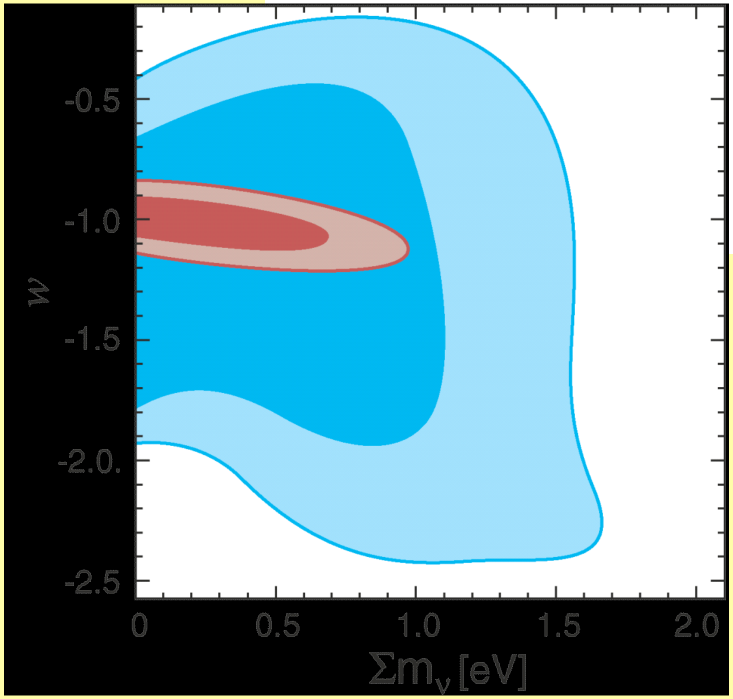
$\Sigma\ \nu$-mass limits (95% c.l.)

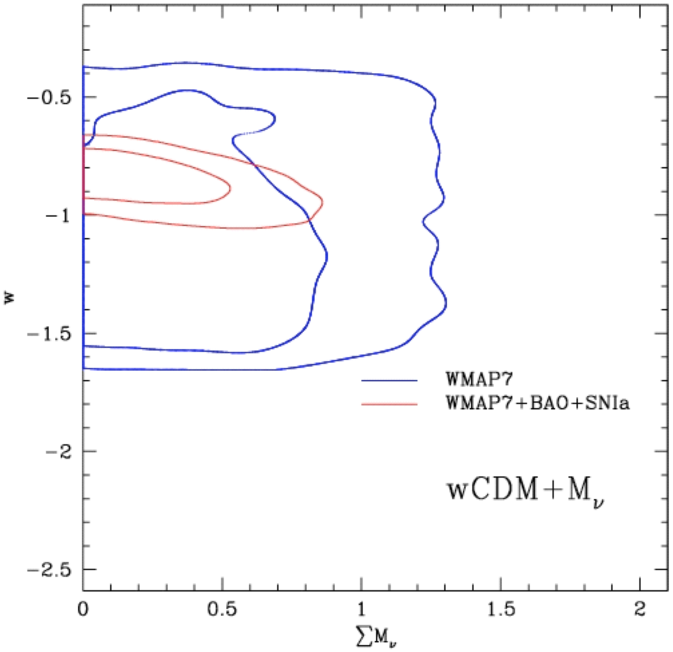
.93 eV — WMAP5 (Komatsu et al)

.82 eV — WMAP7 (our test)

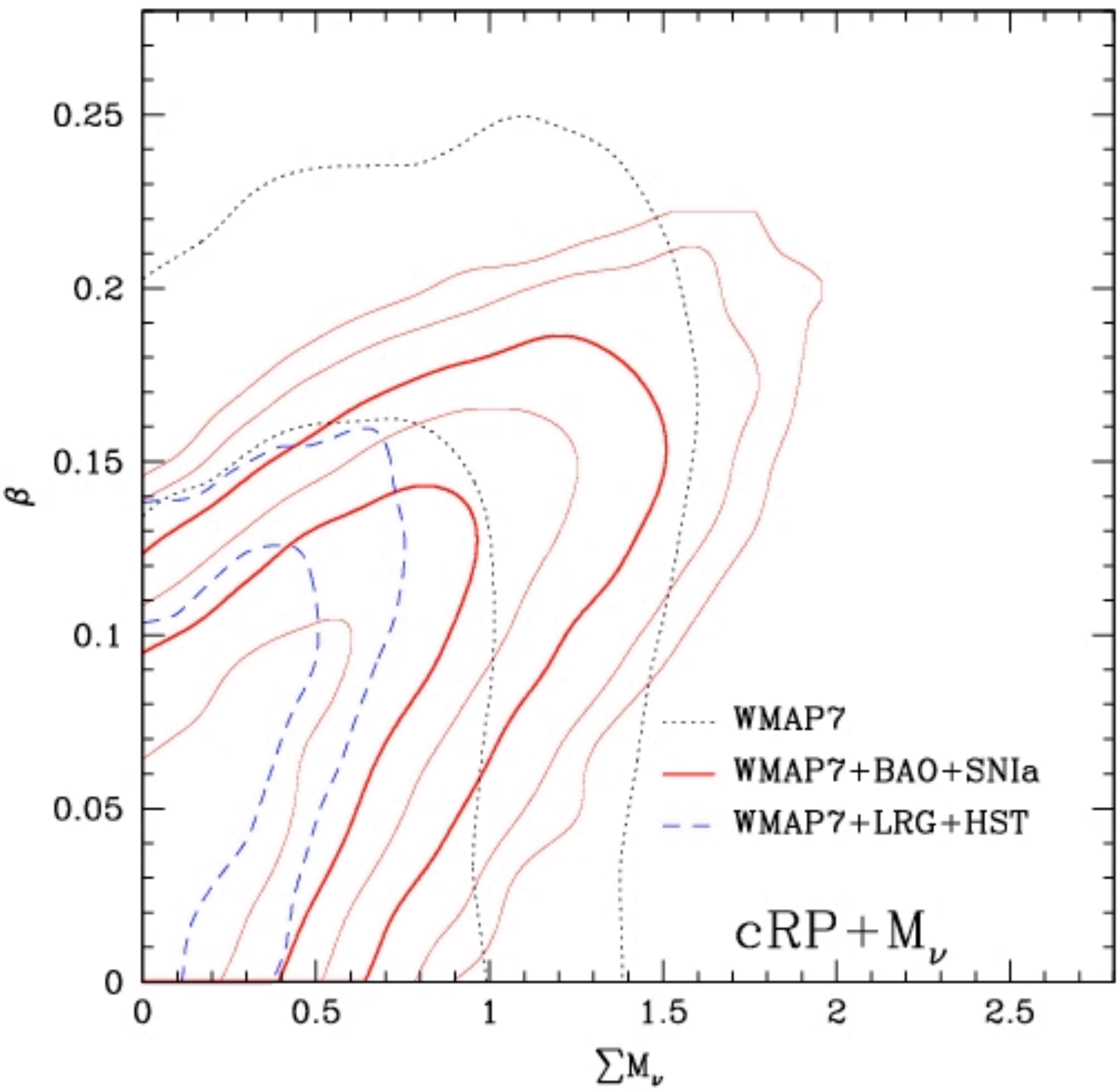
with the same MMC of WMAP team

3 ± .014





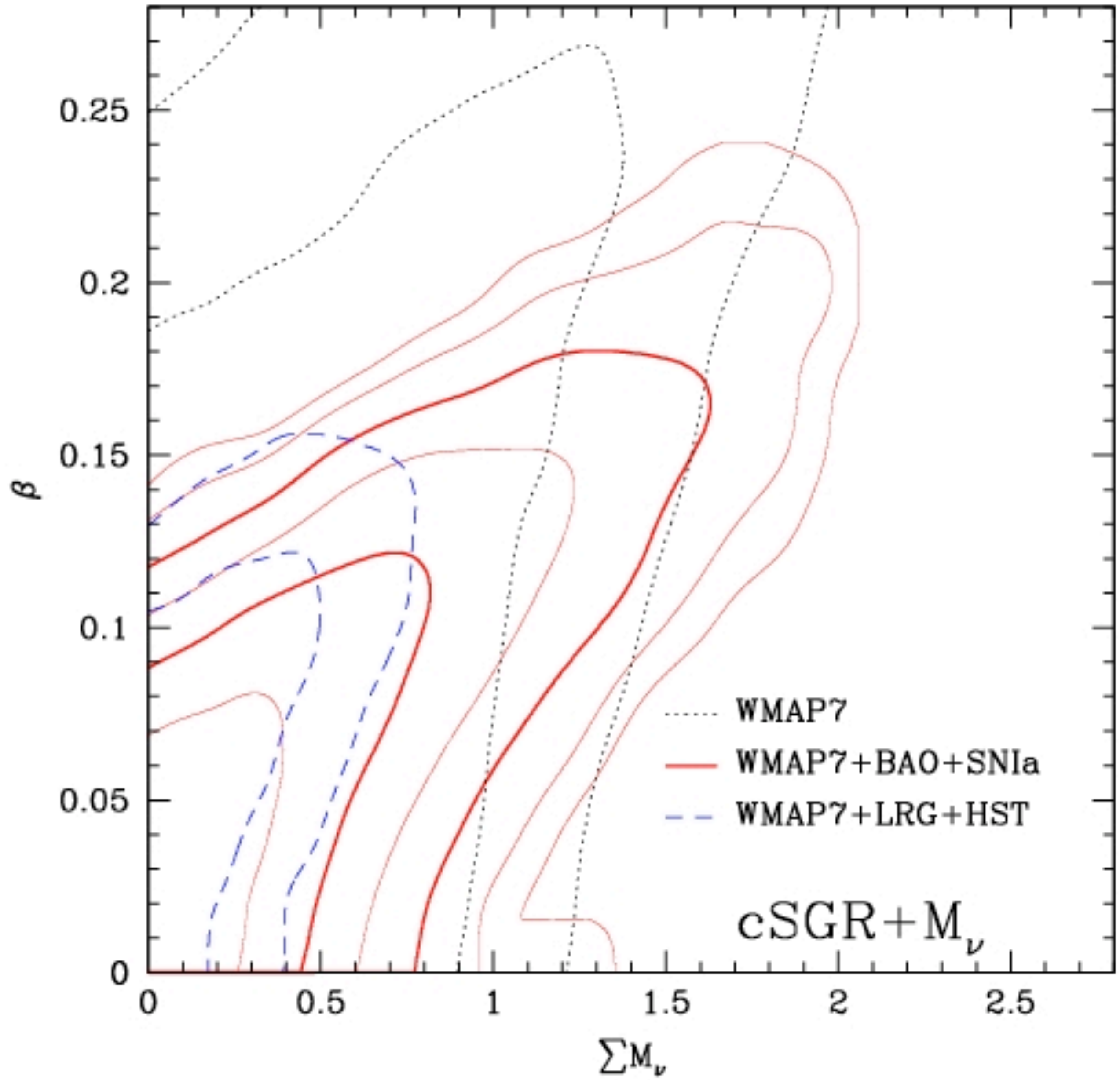
w<-1
no longer related to neutrino mass
$M\nu-\beta$ degeneracy in jeopardy ?



LRG

Large Scale Structure from new SDSS data

Apparently critical in modifying likelihood distribution

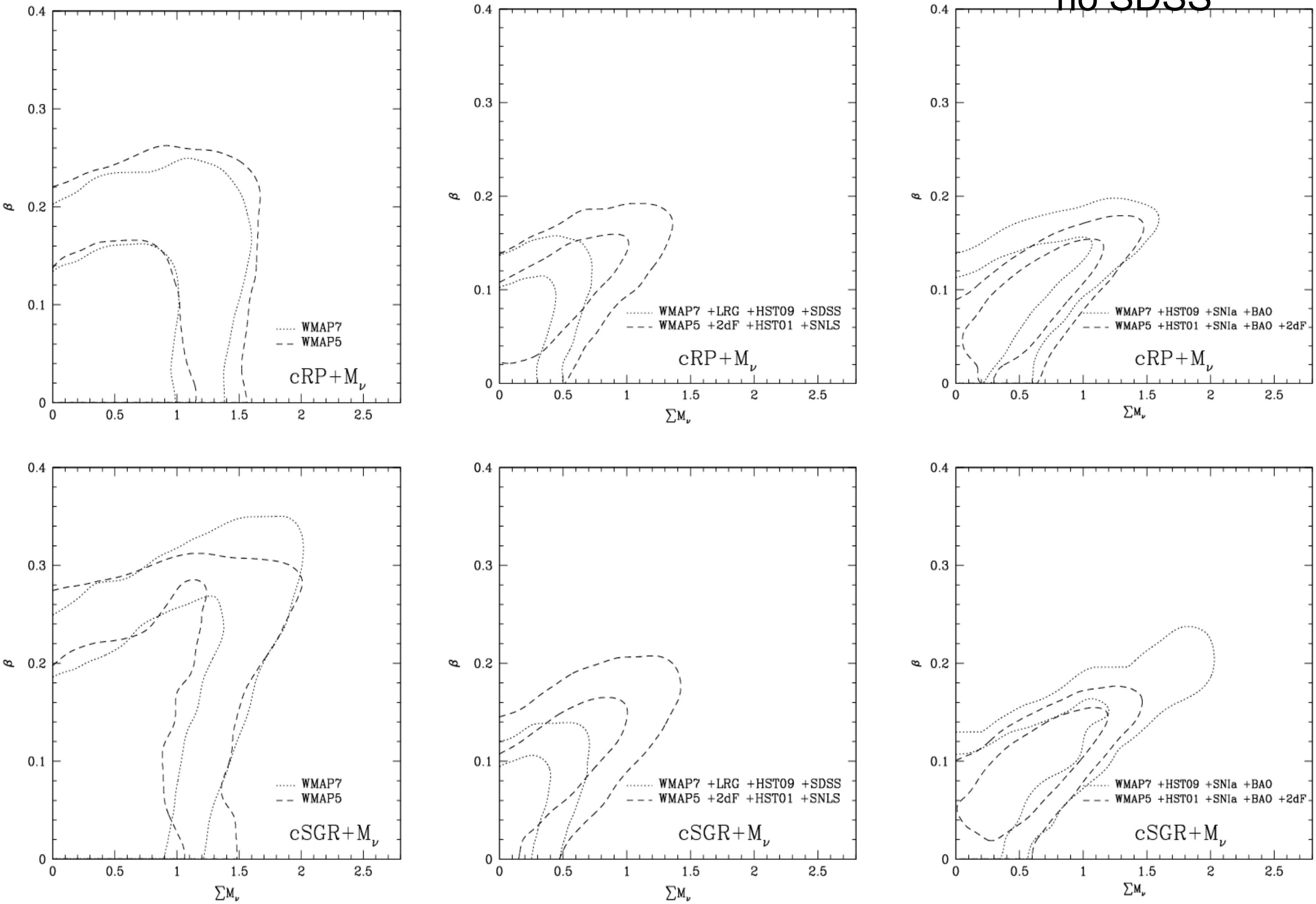


0.25
0.2
0.15
0.1
0.05
0
β
0
0.5
1
1.5
2
2.5
∑M_ν
WMAP7
WMAP7+BAO+SNIa
WMAP7+LRG+HST
cSGR+M_ν

CMB data only

effects of SDSS

whole data sets
no SDSS



2df

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},

Cosmological Constraints from the Clustering of the Sloan Digital Sky Survey DR7 Luminous Red Galaxies

Beth A. Reid[1,2*], Will J. Percival[3], Daniel J. Eisenstein[4], Licia Verde[1,5], David N. Spergel[2,6], Ramin A. Skibba[7], Neta A. Bahcall[2], Tamas Budavari[8], Masataka Fukugita[9], J. Richard Gott[2], James E. Gunn[2], Željko Ivezić[10], Gillian R. Knapp[2], Richard G. Kron[11,12], Robert H. Lupton[2], Timothy A. McKay[13], Avery Meiksin[14], Robert C. Nichol[3], Adrian C. Pope[15], David J. Schlegel[16], Donald P. Schneider[17], Michael A. Strauss[2], Chris Stoughton[18], Alexander S. Szalay[8], Max Tegmark[19], David H. Weinberg[20], Donald G. York[11,21], Idit Zehavi[22]

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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, $\hat{P}_{halo}(k)$, 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_* 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 $M_{0.1r}$ according to Tegmark et al. (2004a) and Zehavi et al. (2005), where $M_{0.1r}$ 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

3.2 Non-linear structure growth

As the small perturbations in the early universe evolve, gravitational instability drives the density field non-linear, and power on small scales is enhanced as structures form. HALOFIT (Smith et al. 2003) provides an analytic formalism to estimate the real space non-linear matter power as a function of the underlying linear matter power spectrum. While Eqn. 10 accounts for the effects of non-linear growth of structure on the BAO features in $P_{halo}(k, \mathbf{p})$, HALOFIT provides a more accurate fit to the smooth component of the non-linear growth in the quasi-linear regime ($k \lesssim 0.2$) when evaluated with an input spectrum $P_{nw}(k, \mathbf{p})$ rather than the linear matter power spectrum containing BAO wiggles:

$$r_{halofit}(k, \mathbf{p}) = \frac{P_{halofit,nw}(k, \mathbf{p})}{P_{nw}(k, \mathbf{p})} \quad (11)$$

$$P_{DM,halofit}(k, \mathbf{p}) = P_{damp}(k, \mathbf{p}, \sigma_m) r_{halofit}(k, \mathbf{p}). \quad (12)$$

Eqn. 12 is our modified HALOFIT model real space power spectrum, using Eqn. 10 to account for BAO damping and HALOFIT for the smooth component. The bottom left panel of Fig. 3 shows that $P_{DM}(k)/P_{damp}(k, \sigma_m)$ and $r_{halofit}$ agree at the $\sim 1.5\%$ level for $k \lesssim 0.2$ in our fiducial cosmology. Since we normalize the final model $P_{halo}(k, \mathbf{p})$ using our mock catalogues at the fiducial cosmology $\mathbf{p}_{fid}$, in practice HALOFIT only provides the cosmological dependence of the non-linear correction to the matter power spectrum:

$$r_{DM,damp}(k, \mathbf{p}) = \frac{r_{halofit}(k, \mathbf{p})}{r_{halofit}(k, \mathbf{p}_{fid})} \frac{P_{DM}(k, \mathbf{p}_{fid})}{P_{damp}(k, \mathbf{p}_{fid}, \sigma_{DM})}. \quad (13)$$

$r_{DM,damp}(k, \mathbf{p})$ is our model for the ratio of the non-linear matter power spectrum to the damped linear power spectrum. The normalization of $r_{DM,damp}$ accounts for the small offset between the N-body and HALOFIT results in Fig. 3 at the fiducial cosmology. In the space of cosmologies consistent with the data, the small cosmology-dependence of this correction is primarily through σ_8. In Section 5.2 we find that the LRG-only likelihood surface is independent of the assumed value of σ_8 over the range 0.7 to 0.9.

3.3 Halo bias

In our likelihood calculation we marginalize over the overall amplitude of $\hat{P}_{halo}(k)$, so in this Section we are concerned only with the scale dependence of the relation between the reconstructed halo and matter power spectra. Smith et al. (2007) show that the scale dependence of halo bias in real space is large for the most massive haloes, but should be rather weak for the halo mass range which host the majority of the LRGs; Matsubara (2008) demonstrates this analytically in redshift space in the quasi-linear regime. Indeed, Reid et al. (2008) find that the power spectrum of the (redshift space) reconstructed halo density field is nearly linearly biased

What is HALOFIT ?

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

linear $\xi(r)$ ⟹ non linear $\xi[f(r)]$
f(r) tested in simulations of LCDM

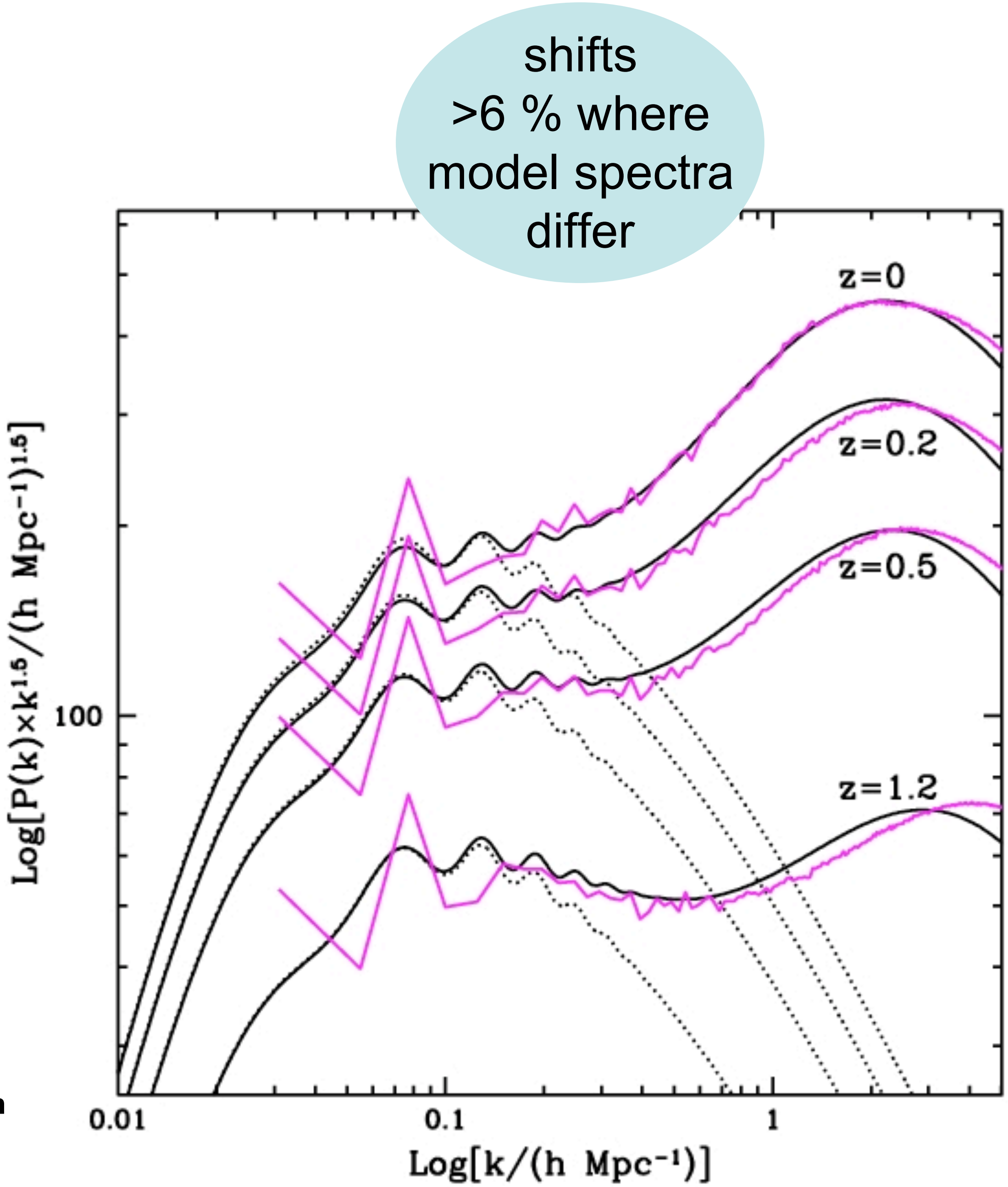
HALOFIT vs N-BODY SIMULATION
For non-LCDM models

w = -0.95
Ω_m = 0.274
H = 70 km/s/Mpc
σ_8 = 0.81

program **pkdgrav**

L = 256 h-1 Mpc
N(part) = 256^3
m(part) = 7.61e10 M(sun)h^-1
ε = 25 h^-1 kpc
z(in) = 24

Simulation run for work in progress by Casarini, La Vacca, Amendola, Maccio' (The impact of non-linear corrections on Weak lensing forecasts)

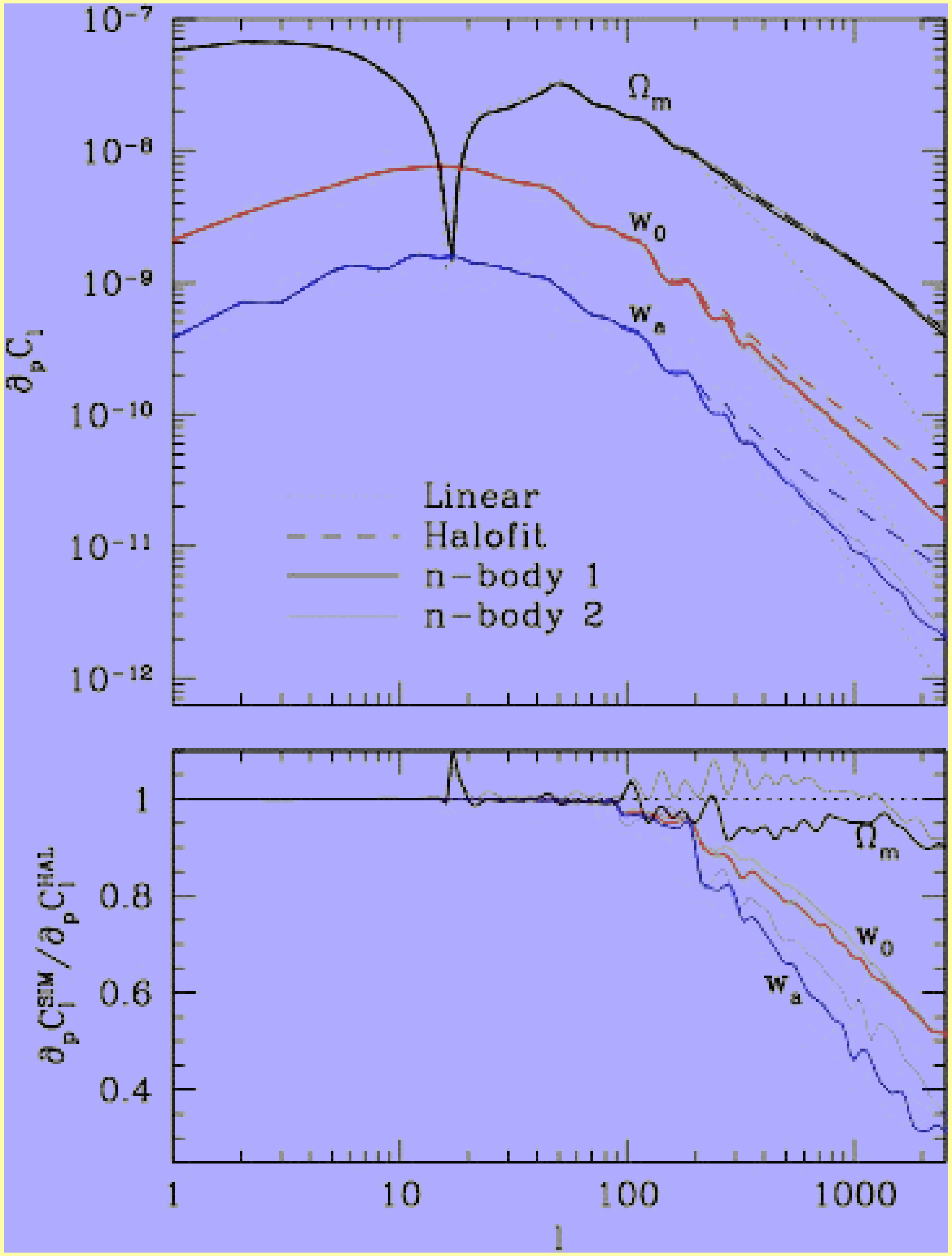


Discrepances between parameter recovery using Halofit or true n-body simulations

Plot for hypothetical tomographic WL exp.

l ~200 non-linearity begins at ~1000, 50% errors

From
Casarini, LaVacca, Amendola, Maccio', 2010 (in preparation)



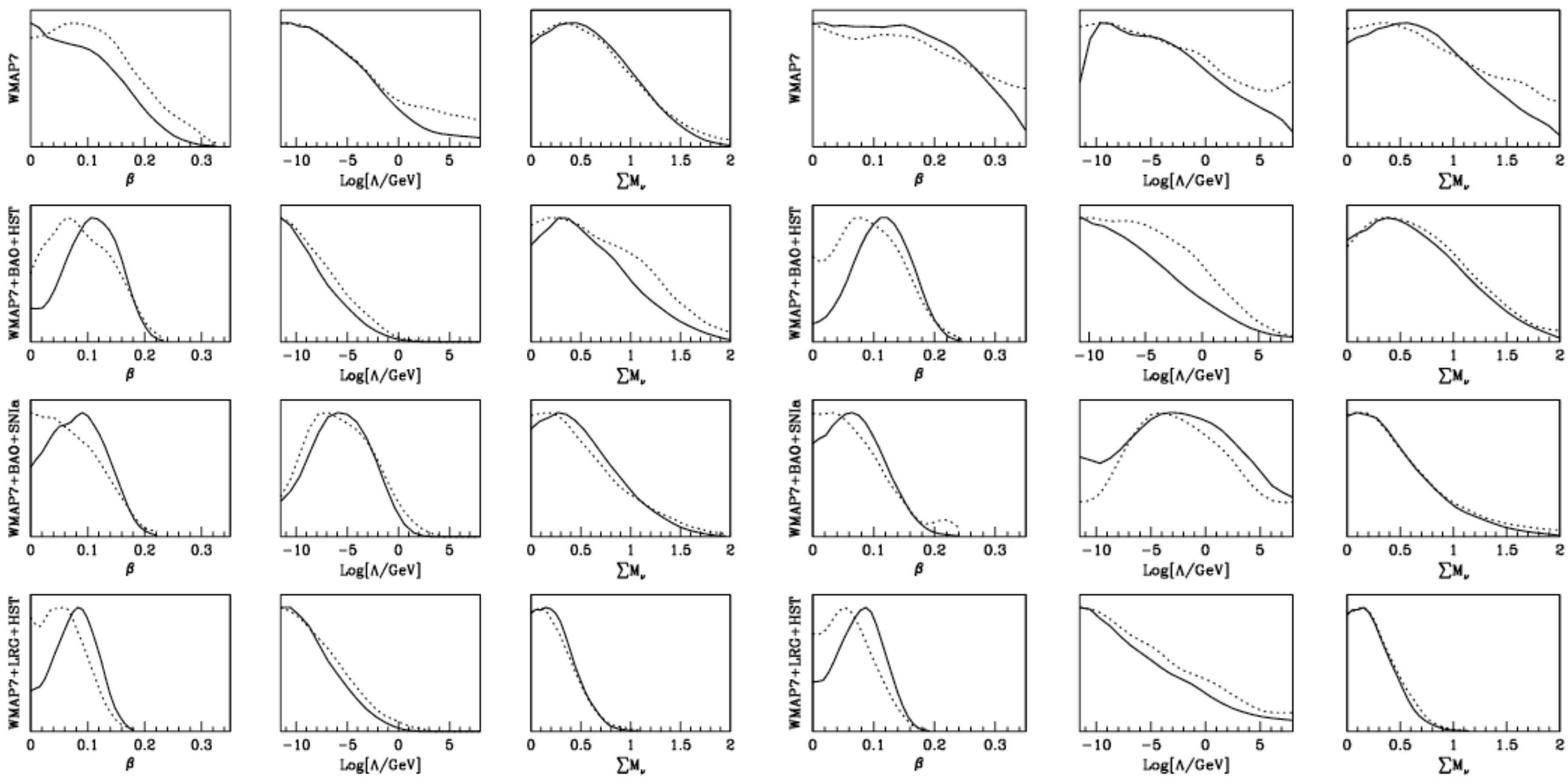
1D likelihood distributions

Notice also higher limits on Λ scale (however highly undetermined)

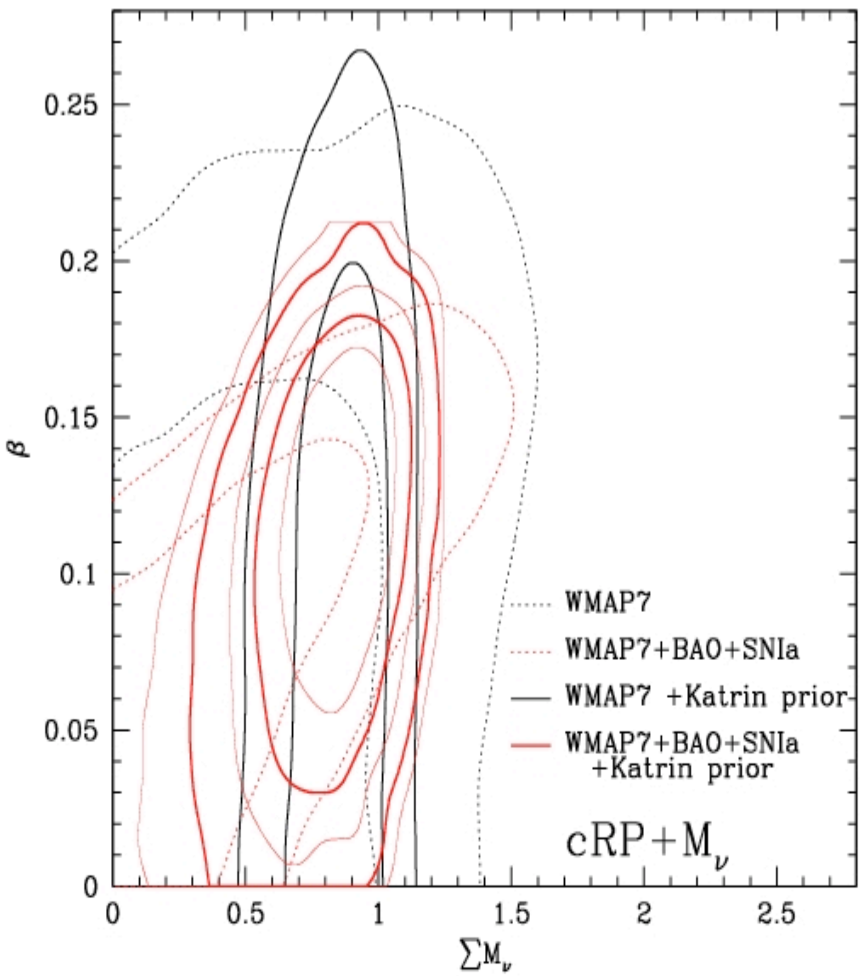
Top likelihood not at zero !

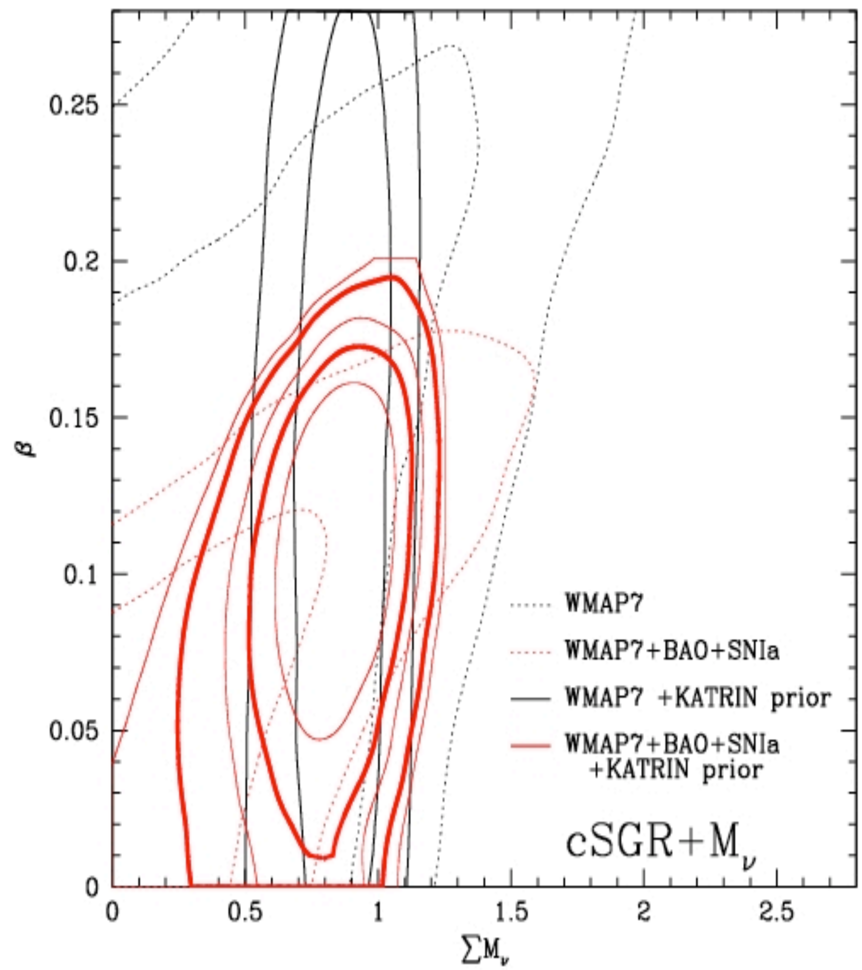
RP

SUGRA



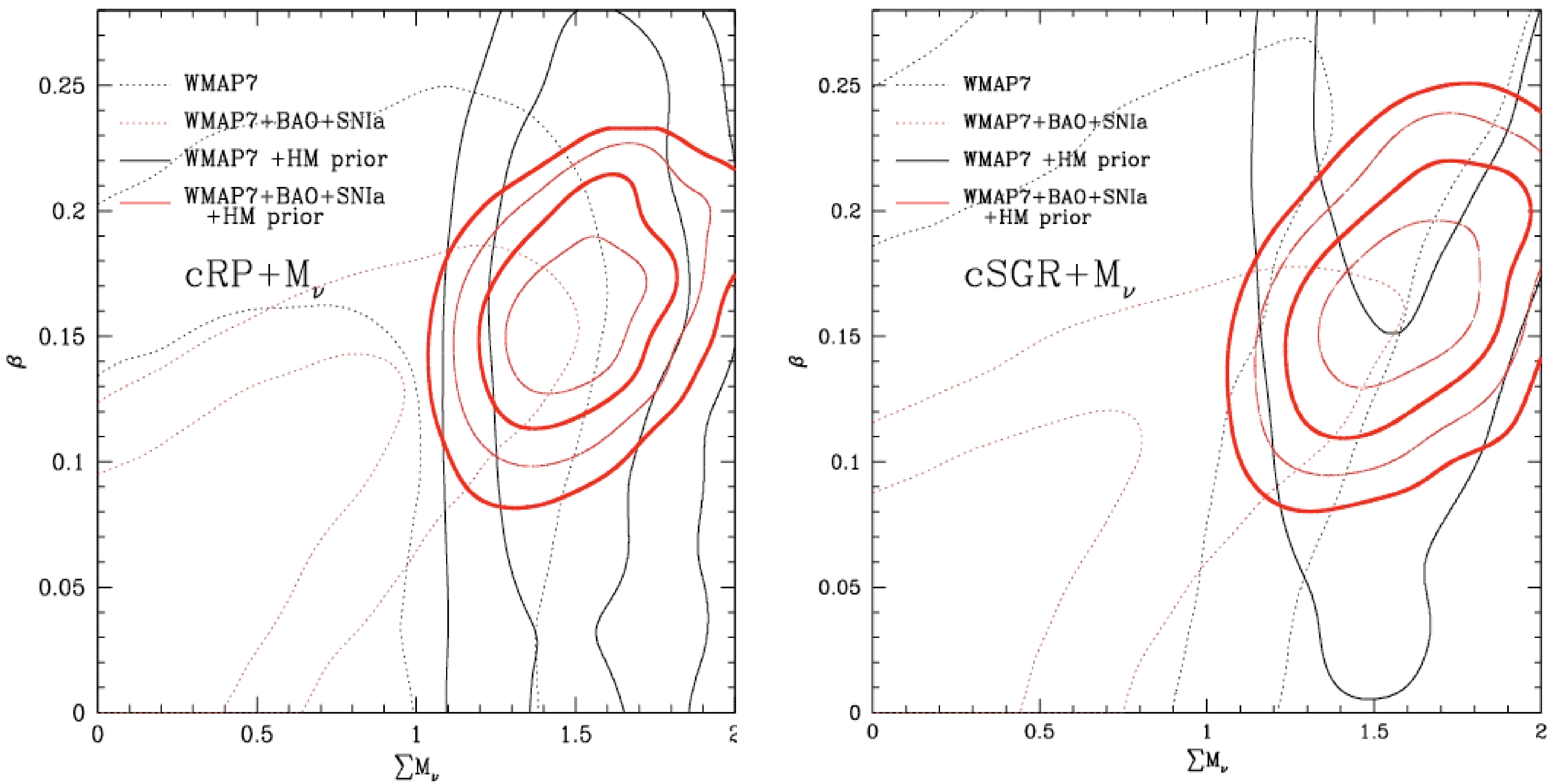
KATRIN prior for neutrinos with mass 0.3 eV falls in the top likelihood area





HM-like ν-mass prior does not yield strong likelihood decrease

would imply CDM-DE coupling "detection"



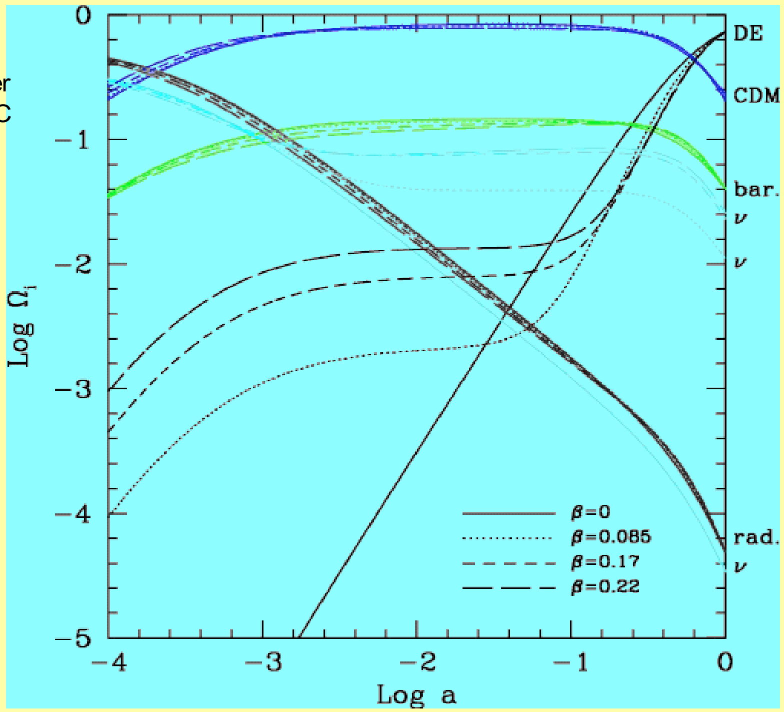
Conclusions

- 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 Λ eased

MMC models however
ease fine-tuning & coincidence

Coupling interpretations
- Single substance ?
- Inverse process of inflationary
  reheating ?

Density parameter evolution in MMC SUGRA models



Abstract

- Energy exhanges 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