Constraints on Large Scale Voids From WMAP-5 and SDSS

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24th September 2008

Why are $\mathcal{O}(100)$ Mpc voids interesting?

A local void would act as dark energy:

- Younger SNe 1a inside the void recede more rapidly than older SNe 1a outside $\Rightarrow$ *mimics cosmic acceleration*.
- Scenario requires $\frac{\delta H}{H} \gtrsim 0.2$ for $R \gtrsim 200\, h^{-1}\,\mathrm{Mpc}$ Alnes *et.al.* 2006, Alexander *et.al.* 2007, Garcia-Bellido and Haugbølle 2008.

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A void could explain the WMAP cold spot:

- A $R \simeq 200\, h^{-1}\,\mathrm{Mpc}$ void at $z \sim 1$ would produce the cold spot due to the late ISW effect Inoue and Silk 2006.
- Consistent with observed decrement in the NVSS radio survey McEwen *et. al.* 2007, Rudnick *et. al.* 2007 (but disputed by Smith and Huterer 2008).

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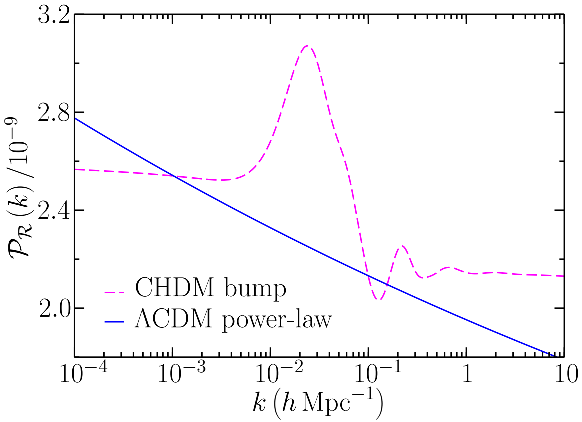
Granett *et. al.* 2008 identified 50 voids in the SDSS LRG survey then looked for their ISW signal:

- The voids have $30 < R < 140\, h^{-1}\,\mathrm{Mpc}$ with $\frac{\delta\rho}{\rho} \gtrsim -0.2$ and lie at $z \sim 0.5$.
- However the voids seem to be too small to account for the observed ISW signal - perhaps they are larger/more underdense than reported?

A 'bump' in $\mathcal{P}_{\mathcal{R}}(k)$ allows an EdeS model $(\Omega_{\rm m} = 1, \Omega_{\Lambda} = 0, h = 0.44)$ to fit WMAP data.



WMAP without dark energy Hunt and Sarkar 2007

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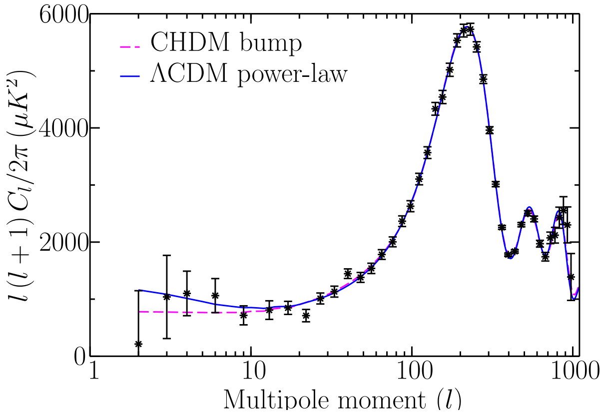

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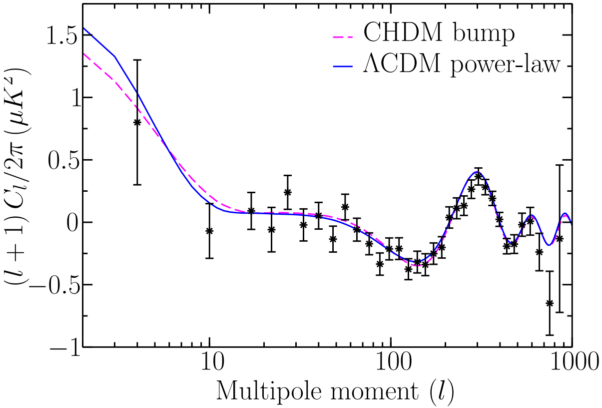

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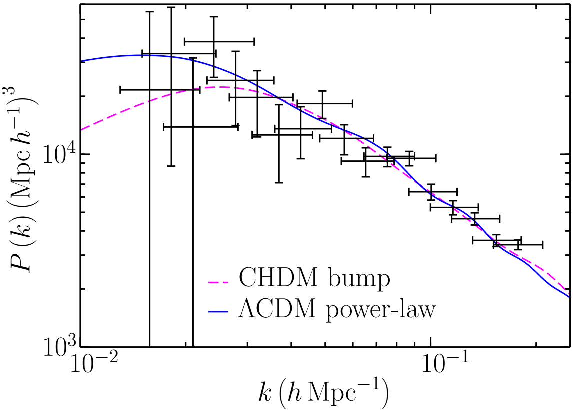

Add 3 ν of mass 0.5 eV ($\Rightarrow \Omega_\nu \simeq 0.1$) to suppress small-scale power.

The WMAP and SDSS results constrain $\mathcal{P}_{\rm m}(k) \Rightarrow$ use this to estimate $\delta \equiv \delta\rho/\rho$, $\delta_H \equiv \delta H/H$, $\delta_\Omega \equiv \delta\Omega_{\rm m}/\Omega_{\rm m}$ and v.

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For example, the variance of δ_H on the scale R is Wang *et al.* 1997

$$\left\langle \delta_H^2 \right\rangle_R = \frac{\Omega_m^{1.2}}{2\pi^2 R^2} \int \mathrm{d}k\, \mathcal{P}_{\mathrm{m}}(k) \left[\frac{3}{k^2 R^2} \left(\sin kR - \int_0^{kR} \mathrm{d}x \frac{\sin x}{x} \right) \right]^2 .$$

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Use MCMC to draw n samples $\boldsymbol{\theta}_i$ from $P(\boldsymbol{\theta}|\,\mathrm{data})$. Then estimate of distribution is

$$P(\boldsymbol{\theta}|\,\mathrm{data}) \simeq \frac{1}{n} \sum_{i=1}^{n} \delta_D (\boldsymbol{\theta} - \boldsymbol{\theta}_i) .$$

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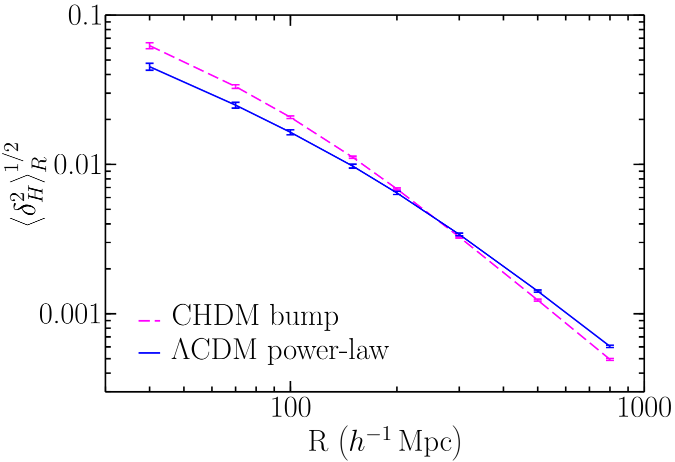
Hence

$$P(\delta_H|\,\mathrm{data}) = \int P(\delta_H|\,\boldsymbol{\theta})_R P(\boldsymbol{\theta}|\,\mathrm{data})\,\mathrm{d}\boldsymbol{\theta} \simeq \frac{1}{n} \sum_{i=1}^{n} P(\delta_H|\,\boldsymbol{\theta}_i)_R ,$$

where

$$P(\delta_H|\,\boldsymbol{\theta})_R = \frac{1}{\sqrt{2\pi \left\langle \delta_H^2 \right\rangle_R}} \exp\left(-\frac{\delta_H^2}{2 \left\langle \delta_H^2 \right\rangle_R} \right) .$$

Results



Thus to determine H to 1% requires measurements out to 150 $h^{-1}\,\mathrm{Mpc}$.

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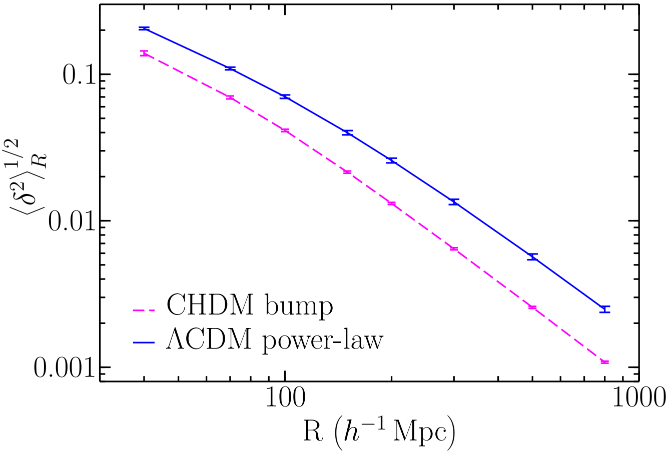
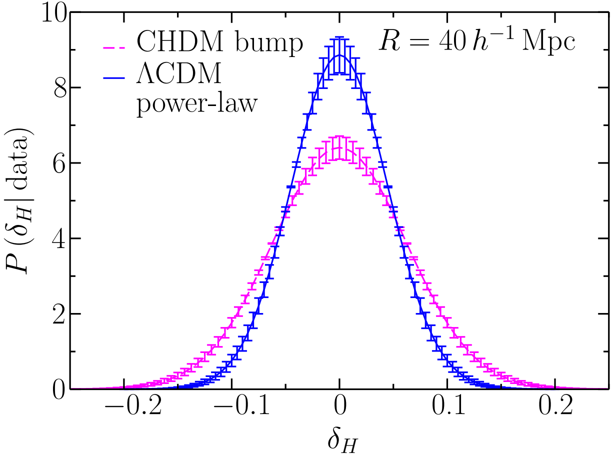


0.1
0.01
0.001
$\langle \delta^2 \rangle_R^{1/2}$
100
1000
R (h^{-1} Mpc)
CHDM bump
ΛCDM power-law

$P\left(\delta_H \middle| \text{data}\right)$



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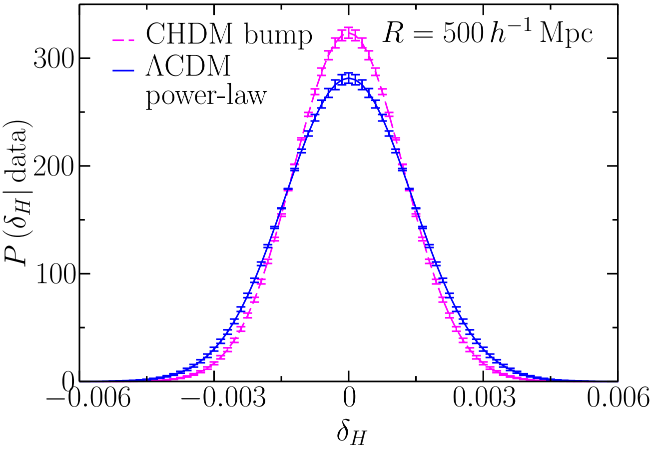
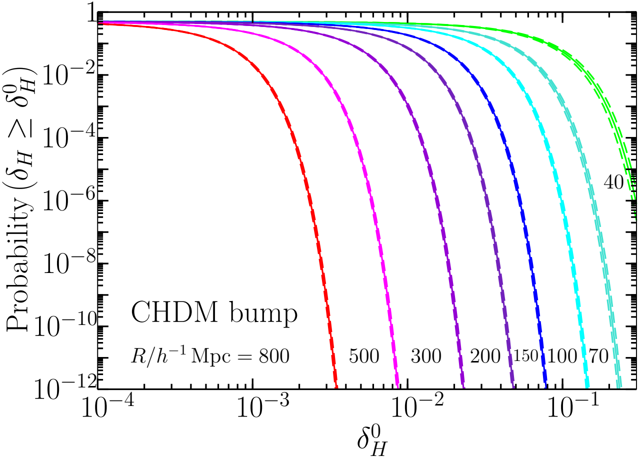


Void probabilities



...c.f $\delta_H \simeq 0.2 - 0.3$ for $R = \mathcal{O}\left(10^2 - 10^3\right)\ h^{-1}\,\mathrm{Mpc}$ required by void scenario.

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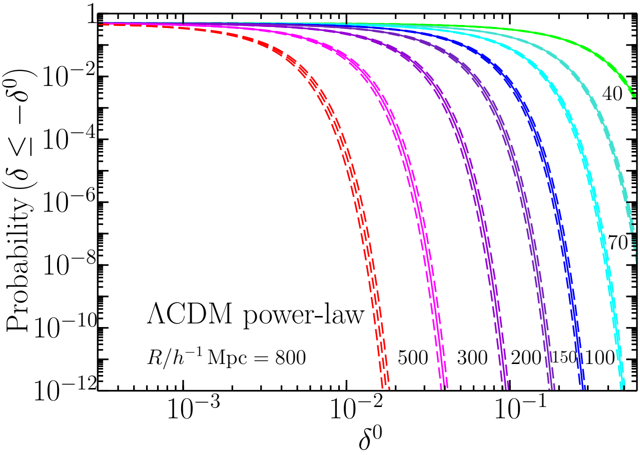

...c.f $\delta \lesssim -0.3$ for $R \simeq 200\,h^{-1}\,\mathrm{Mpc}$ required by WMAP cold spot.

Conclusions

We used WMAP and SDSS data to determine the probability of fluctuations in H, ρ, $\Omega_{\rm m}$ and v on various scales.

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If this is true it would conflict with the standard model of structure formation.