Measuring the Copernican Principle

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at Benasque Cosmology, 2012
15 August 2012

Lemaître-Tolman-Bondi

$$ds^2 = -dt^2 + S^2(r, t)dr^2 + R^2(r, t)(d\theta^2 + \sin^2\theta\, d\phi^2)$$

$$S(r, t) \equiv \frac{R'(r, t)}{\sqrt{1 + 2r^2 k(r)}}$$

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cosmological
constant

$$\left(\frac{\dot{R}}{R}\right)^2 = \left(\frac{\dot{a}}{a}\right)^2 = H^2(r,t) = \frac{8\pi\tilde{M}^2}{3}\left[\frac{1}{a^3(r,t)} + \frac{3k(r)}{4\pi a^2(r,t)} + \frac{\Lambda}{8\pi\tilde{M}^2}\right],$$
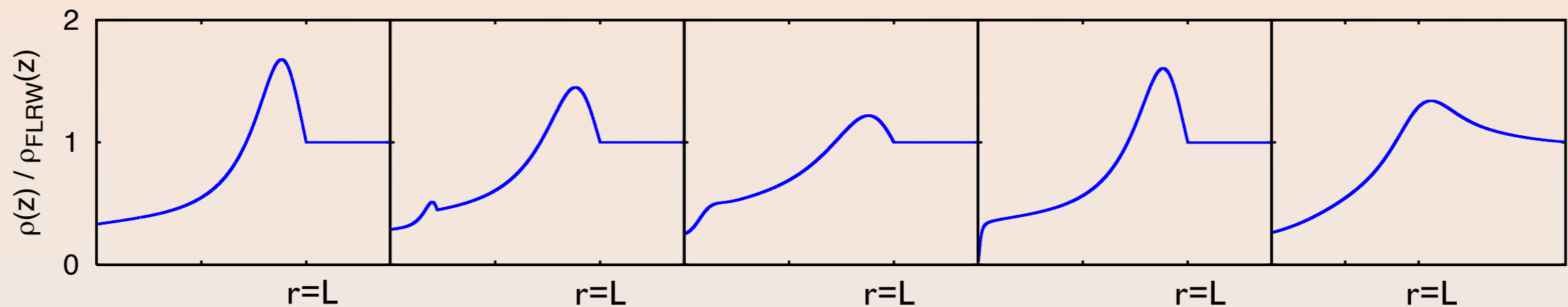
$$R(r,t) \equiv r\,a(r,t)$$

matter density

Radially dependent
curvature

Once upon a time: no Λ
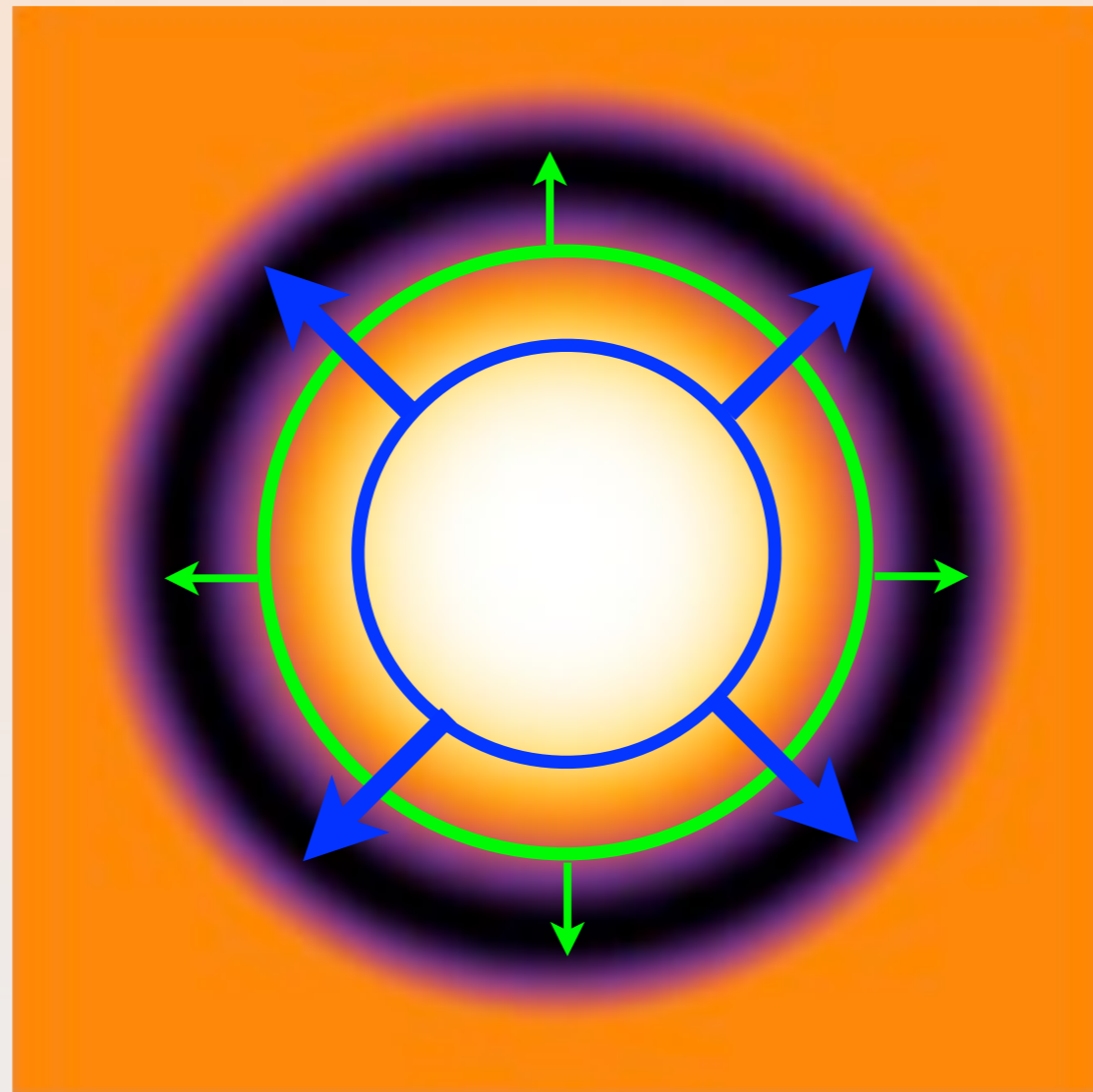

L ~ 1 - 2 Gpc

Less matter ➜ more curvature ➜ slower decrease of H in time ➜ larger H at same time ➜ H in lightcone looks like accelerated expansion

Kinematic Sunyaev-Zeldovich effect
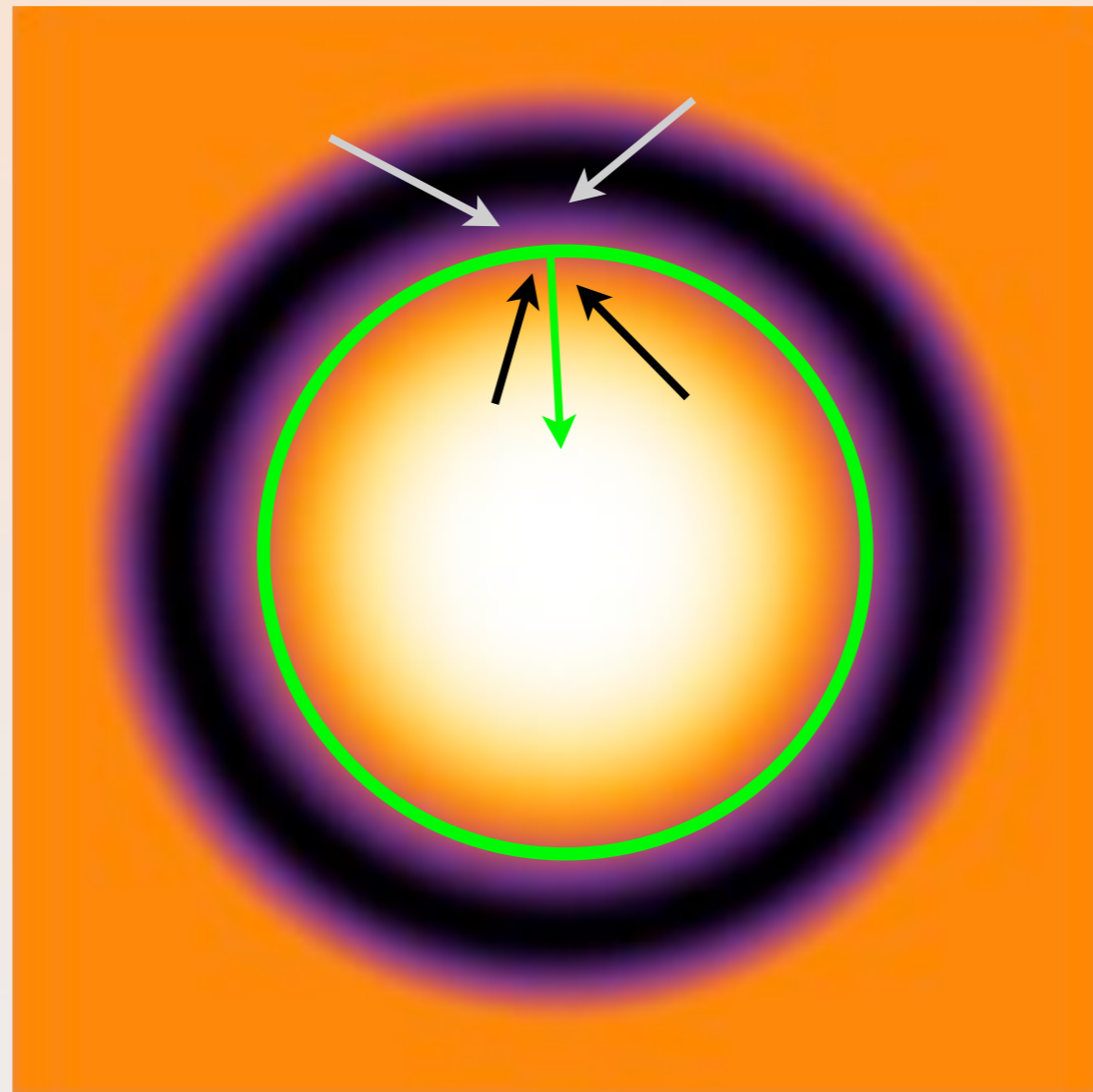
Kinematic Sunyaev-Zeldovich effect

- Correlated outward velocity

- Transfer of energy from outward moving electron gas to CMB photons

- Strong imprint on CMB temperature map

- Rules out Gpc-scale Λ-less voids

[Garcia-Bellido, Haugbølle, 2008]
[Stebbins, Zhang, 2010]
[Zibin, Moss, 2011]

Compton-Y distortion

Black body spectrum to not entirely black body spectrum

Observational constraints on large perturbations around us

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- CMB: corrected d_A to last scattering

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[Stebbins, Caldwell, 2007]

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- kSZ: up scatter CMB photons and induce secondary anisotropies
  [Garcia-Bellido, Haugbølle, 2008]

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- H(z): radial expansion rate at different redshifts

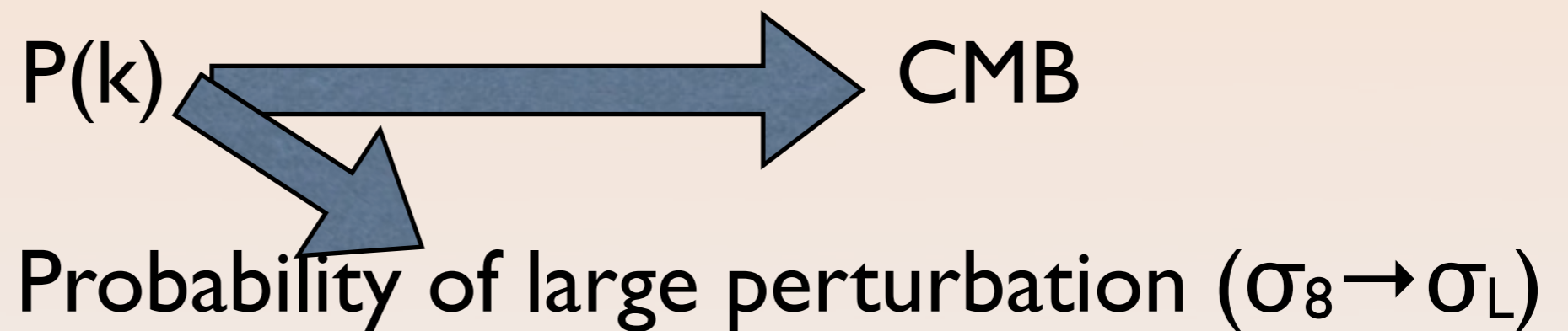# Observational constraints on large perturbations around us

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- SN: geometrical distance measure

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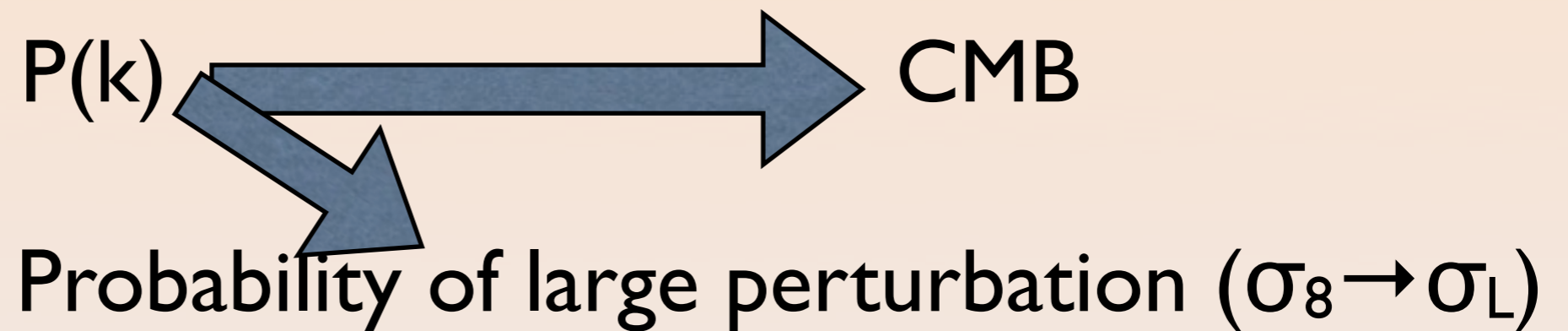- SN: geometrical distance measure

- BAO: geometrical distance measure

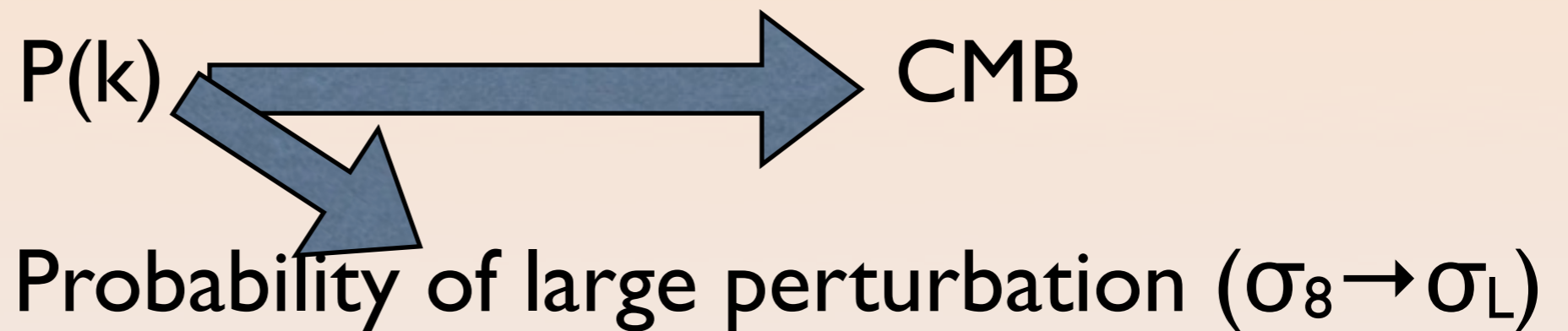# How copernican is the universe?

How copernican is the universe?

P(k) $\longrightarrow$ CMB

Probability of large perturbation ($\sigma_8 \to \sigma_L$)

Homogeneity Prior

P(k) $\longrightarrow$ CMB

Probability of large perturbation ($\sigma_8 \rightarrow \sigma_L$)

How copernican is the universe?

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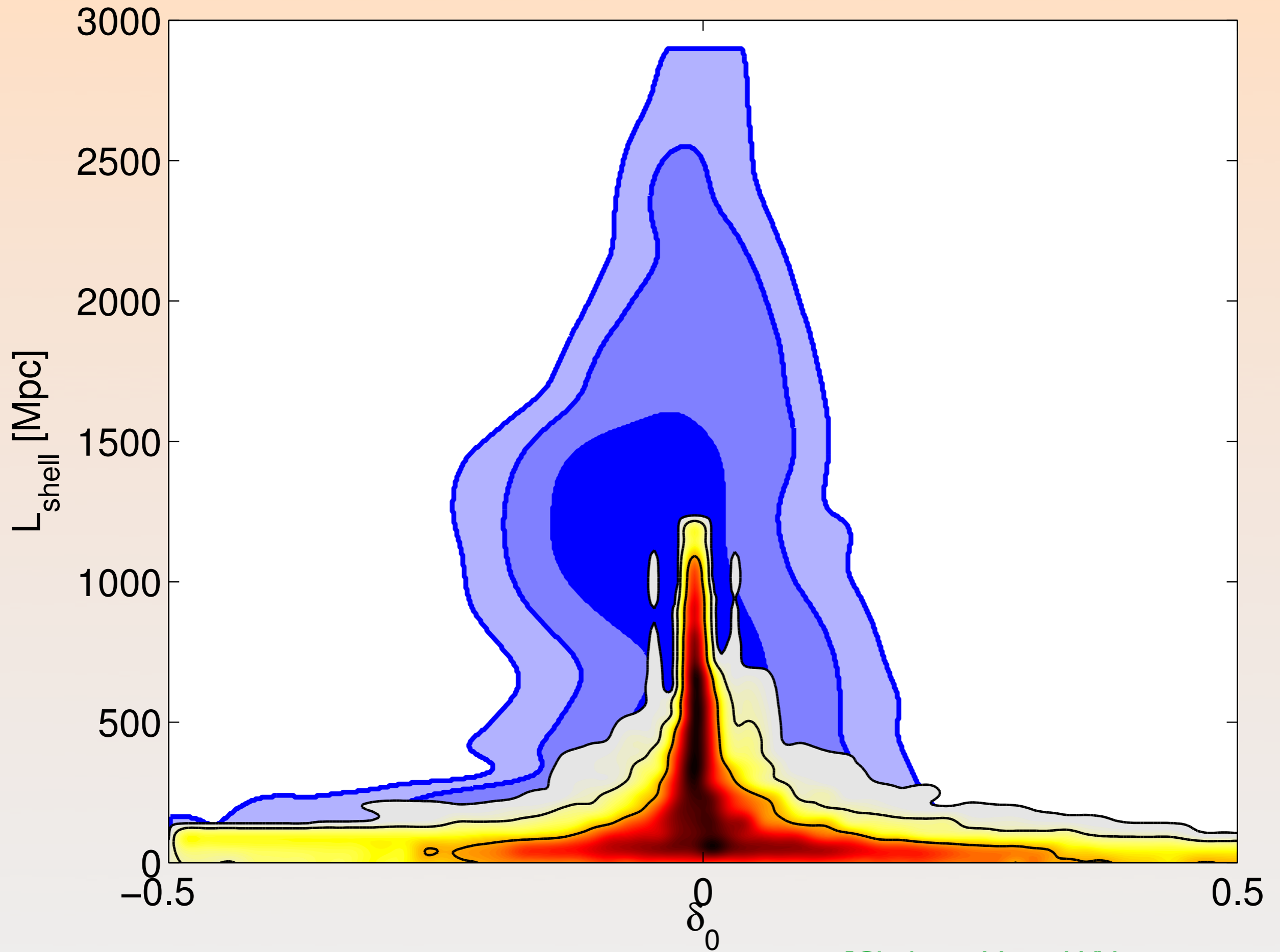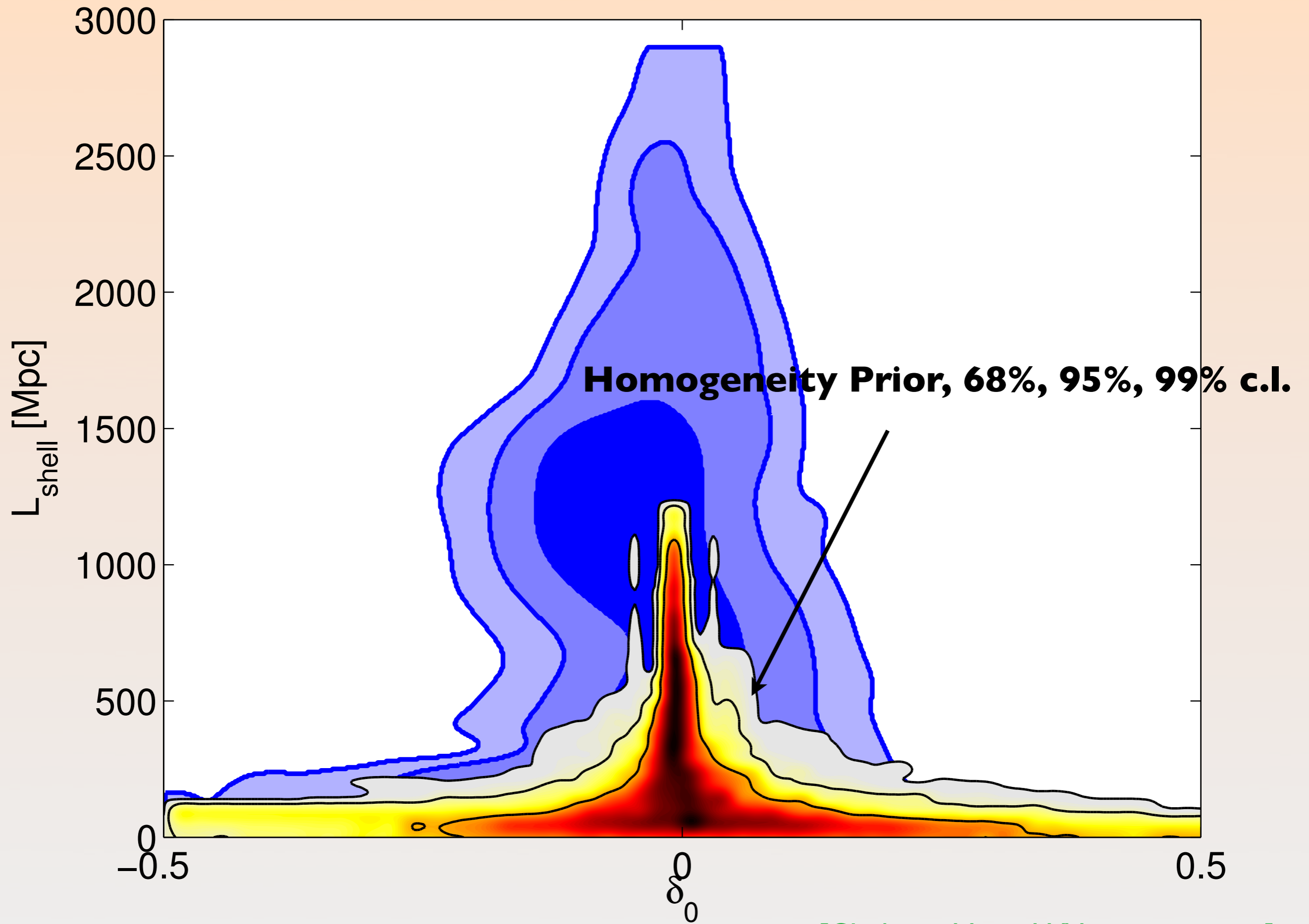Probability of large perturbation ($\sigma_8 \rightarrow \sigma_L$)

Observational constraints

H0, SN, BAO, CMB, kSZ, Compton-y, H(z)
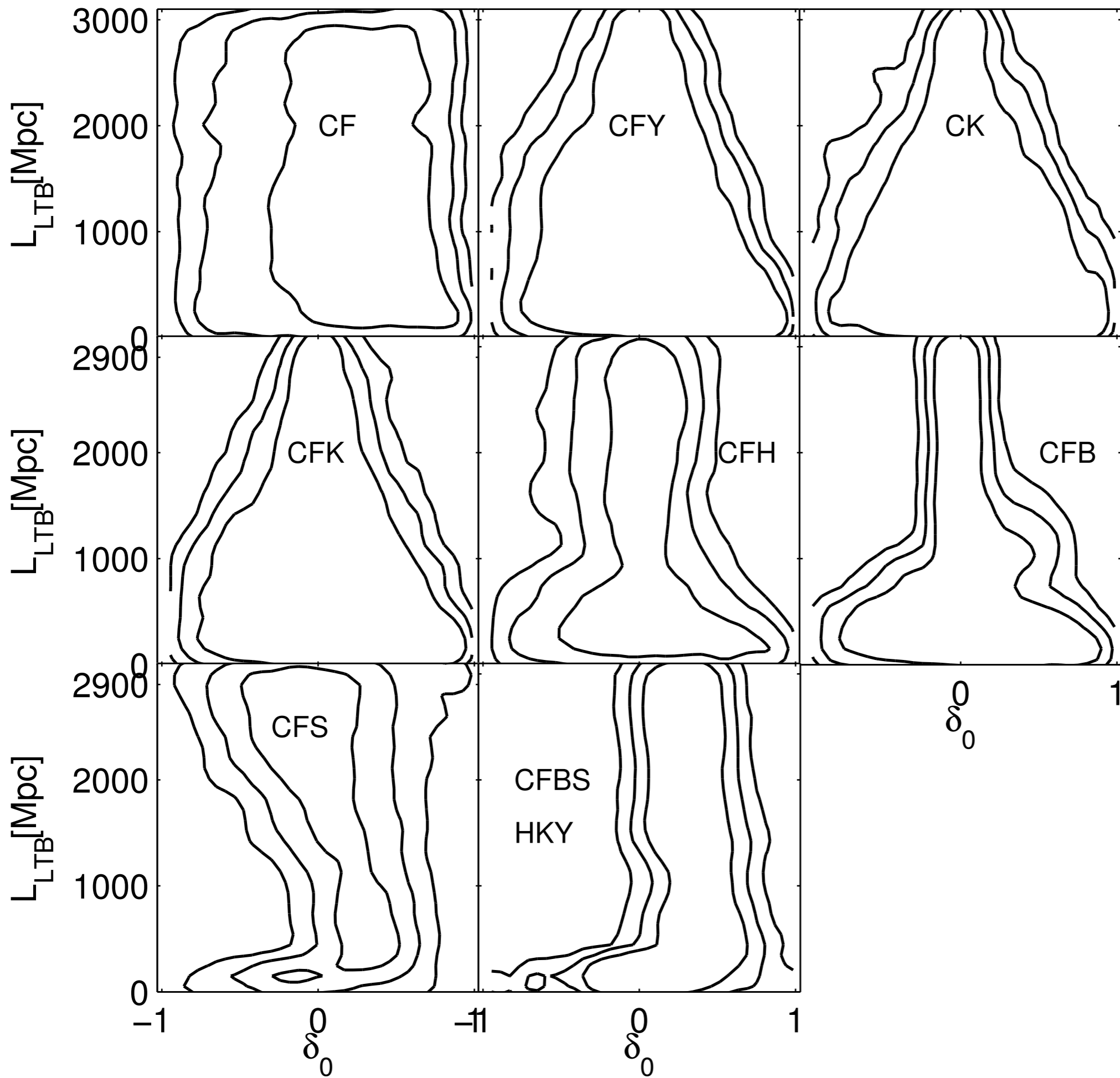
C=CMB
F=H_0
Y=Compton-Y
K=kSZ
H=H(z)
B=BAO
S=SN

[Clarkson, Marra, WV, in preparation]

Homogeneity Prior, 68%, 95%, 99% c.l.

[Clarkson, Marra, WV, in preparation]

Wednesday, 15 August 12

Observational constraints, 68%, 95%, 99% c.l.

Homogeneity Prior, 68%, 95%, 99% c.l.

L_{shell} [Mpc]

δ_0
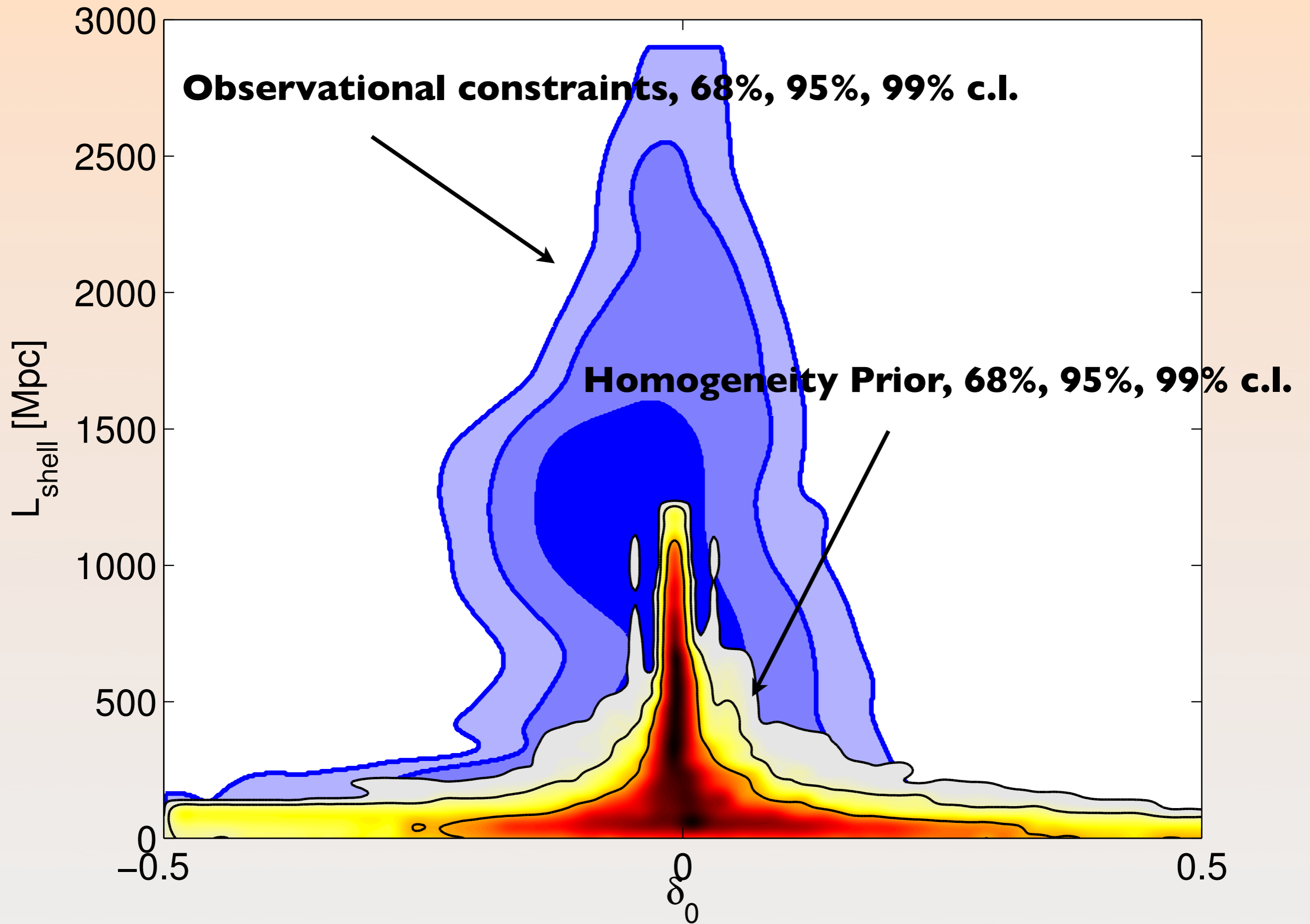
[Clarkson, Marra, WV, in preparation]

Summary

- Now we can promote the Copernican Principle from fantasy to reality.

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Almost....