Dark Energy or a Void: no verdict

Wessel Valkenburg (ITTK, RWTH Aachen)

Outline

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- ΛLTB

Motivation

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- Dark Energy / Λ:
  - FLRW
  - homogeneous cosmology

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- Dark Energy / Λ:
  - FLRW
  - homogeneous cosmology
- What do observations say?
  - how homogeneous must the universe be?
  - how necessary is Λ?

Why a void?

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- Λ: fine tuning in time (why now?)
- Void: fine tuning in space (why here?)

Lemaître-Tolman-Bondi

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

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

$$S(r,t) = f\left(\Omega_M(r), \Omega_k(r), t\right)$$

Each 'isoradial shell' obeys its own FLRW equation.

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$$k(r) \ \ \& \ \ t_{BB}(r)$$

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For all the following we chose $t_{BB}(r) \equiv 0$

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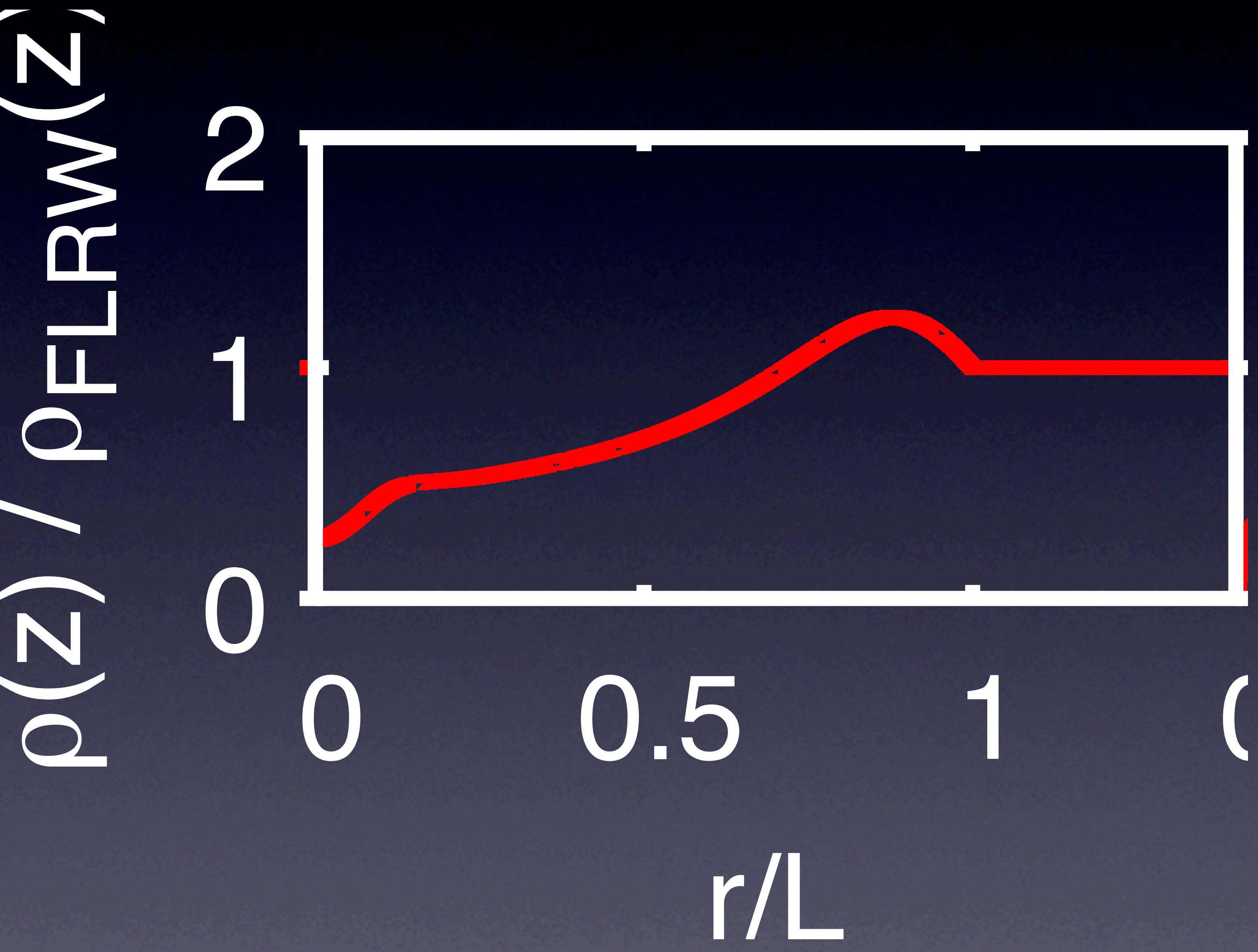
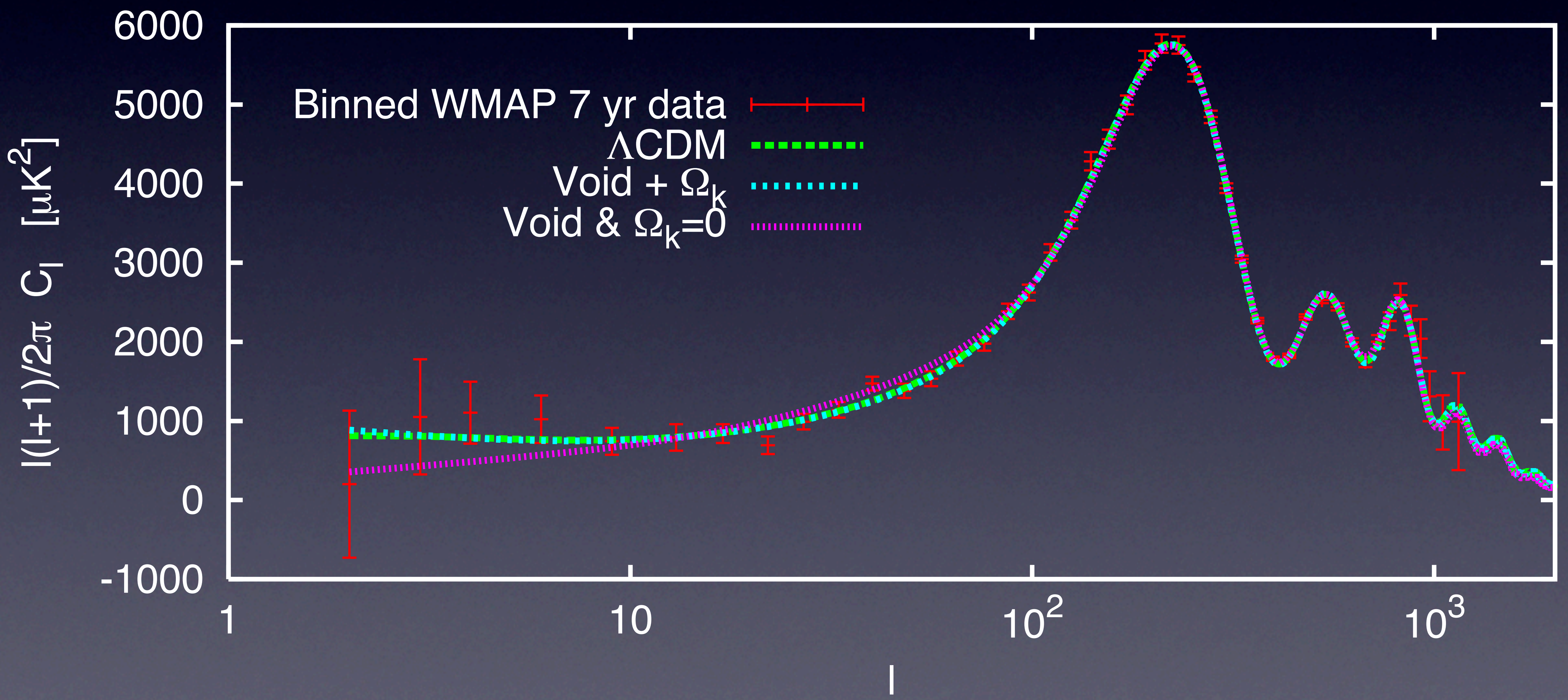
Density profiles



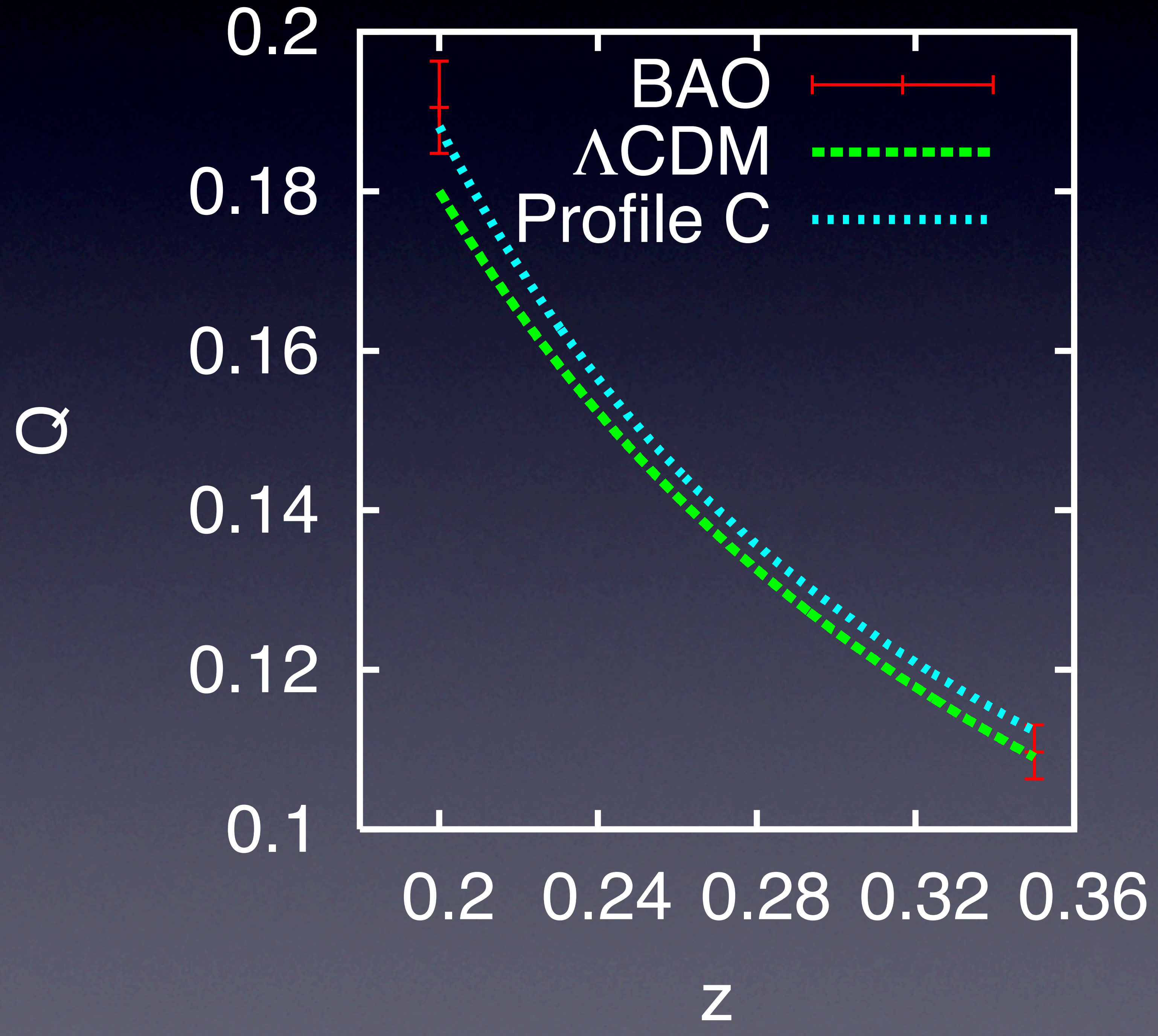
[Biswas, Notari, WV, 2009]

CMB

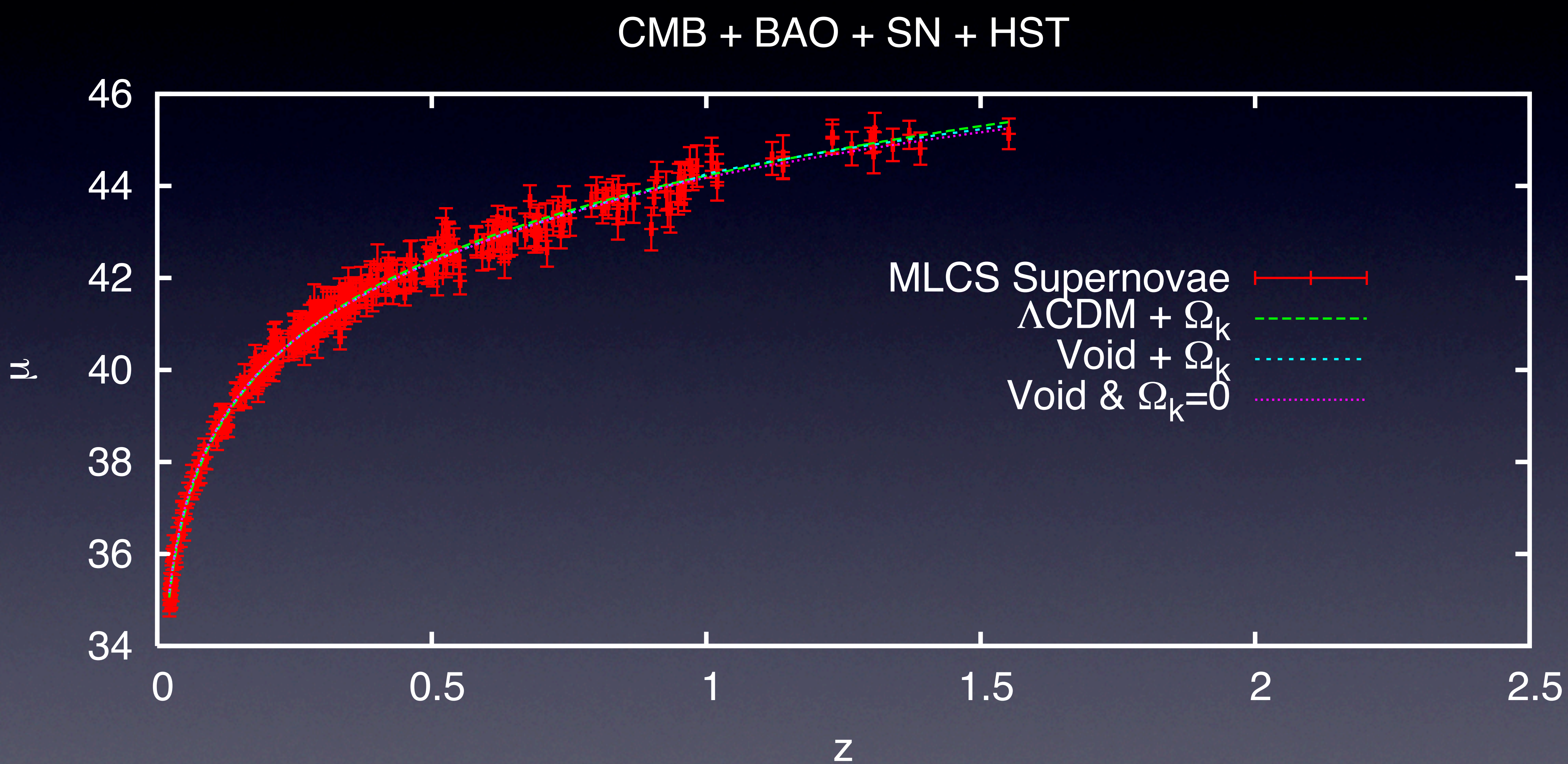


[ignoring ISW]

BAO



Supernovae



LCDM Void in EdS Void in Curved FLRW

How good is it?

Model	CMB	BAO	SN	$HST_{62\pm6}$	total χ^2
ΛCDM	3372.1	3.2	239.3	0.4	**3615.0**
LTB (Profile C)	3376.9	1.0	234.9	3.7	**3616.5**

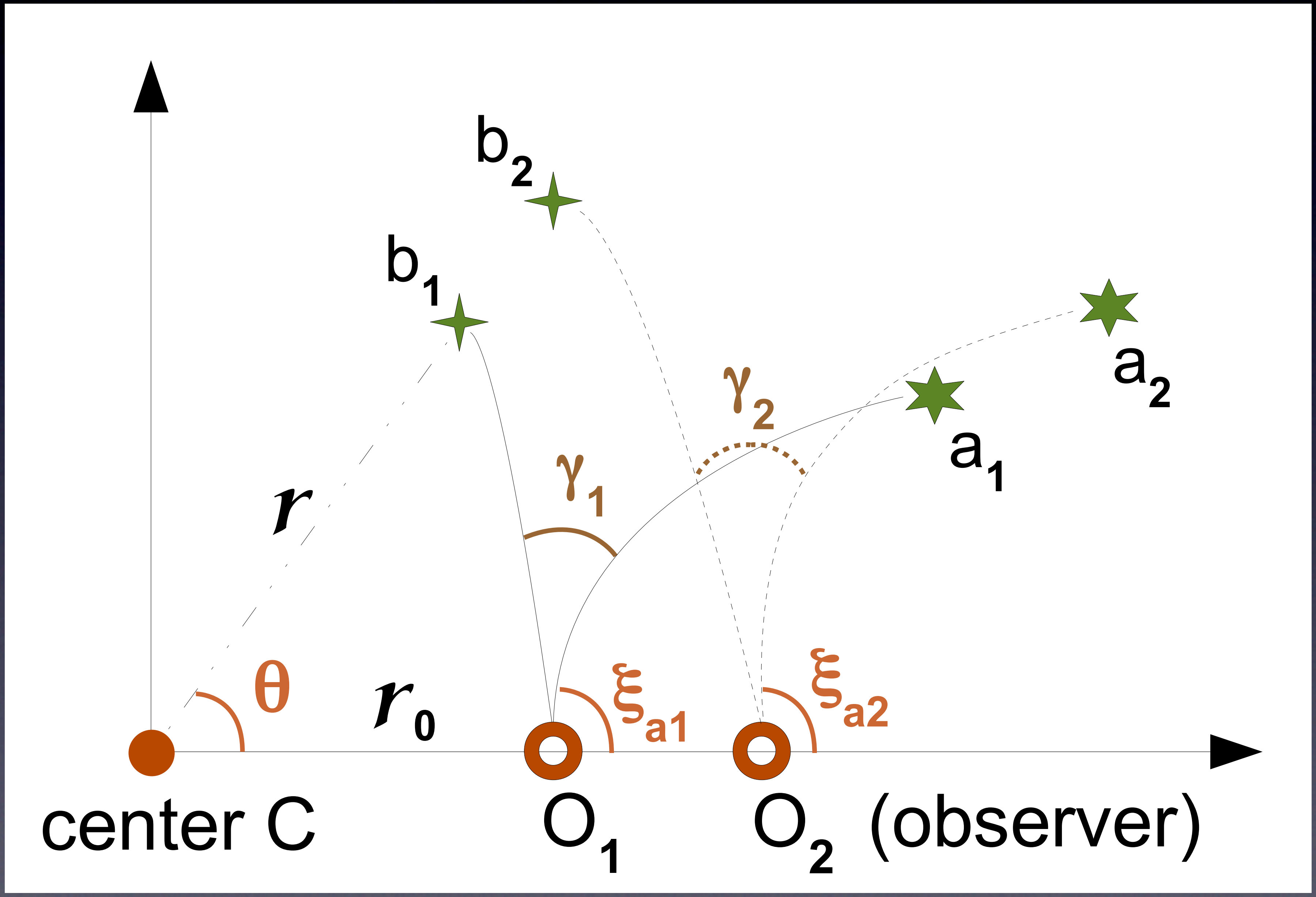
[Biswas, Notari, WV, 2009]

How crazy is it?

Profile	z_B	L [Mpc]	$r_{3.355\text{mK}}$ [Mpc]	r/L
C	2.912	3599.686	12.664	0.00167

[Biswas, Notari, WV, 2009]

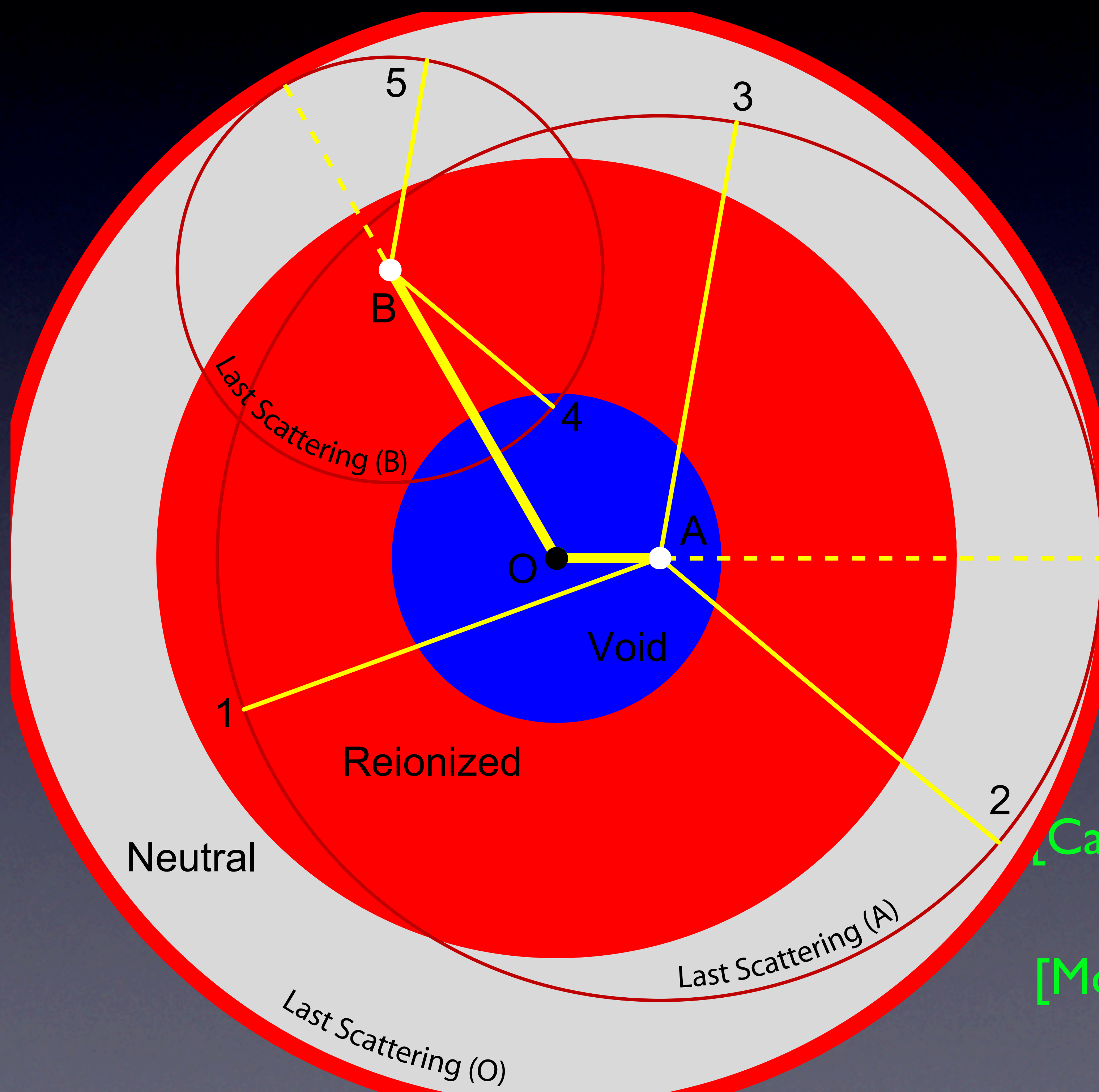
Realtime cosmology



[Quartin, Amendola, 2009]

Compton y distortion

departure from black body

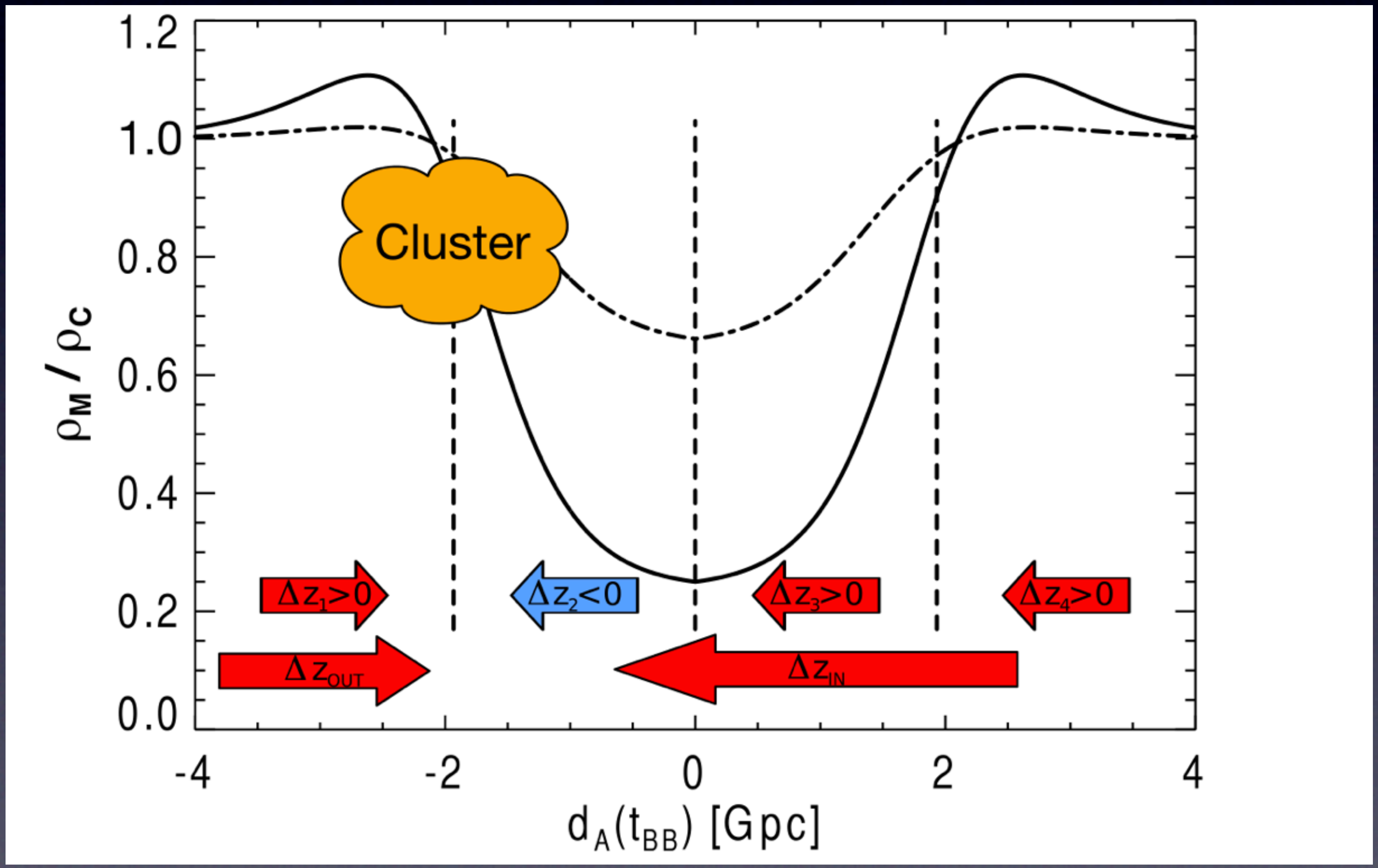


[Caldwell, Stebbins, 2008]

[Moss, Zibin, Scott, 2010]

kinematic SZ

change in temperature



[from García-Bellido & Haugbølle, 2008]

[Zhang & Stebbins, 2010]

Connection to “normal cosmology”

$$H_0\,[t(A) - t_{BB}(r)] = \int_0^A \frac{\sqrt{a}\,da}{\sqrt{\Omega_m(r) + \Omega_k(r)a + \Omega_\Lambda(r)a^3}}$$

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$$= \frac{2}{3\sqrt{\Omega_\Lambda}} \frac{(-1)^{-\frac{9}{2}}}{\sqrt{\prod_{m=1}^{3} y_m}} R_J\left(\frac{1}{A} - \frac{1}{y_1}, \frac{1}{A} - \frac{1}{y_2}, \frac{1}{A} - \frac{1}{y_3}, \frac{1}{A}\right)$$

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- ΛLTB gives the full exact(ly solved!) metric for spherical collapse in ΛCDM

[WV, arXiv:1104.1082]

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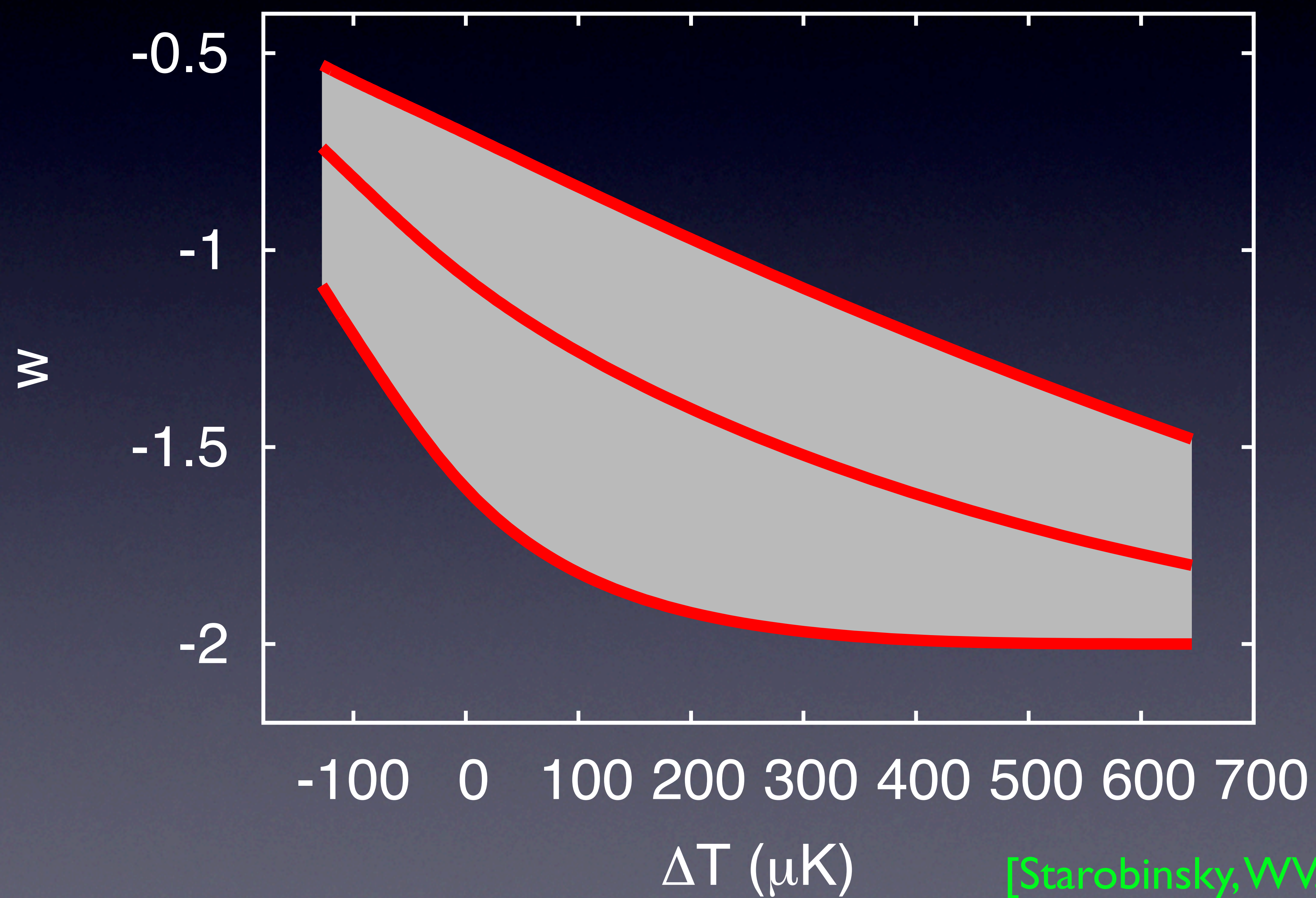
- ΛLTB allows for modelling the CMB cold spot to what it has become today

[Starobinsky, WV, in preparation]

Living in the cold spot



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Conclusion

- ΛCDM is the not only possibility yet.
- Future observations may test the Copernican / cosmological principle.
- Even in ΛCDM, ΛLTB is a useful tool.