Reply to Referee B

> (a) clear up the presentation of the treatment of the critical point,
> It may be that the authors' analysis is correct, but this is not entirely
> transparent from the manuscript. For clarity, it would be better to
> start with the model where the free functions are taken to be
> polynomials.

Taking E and M as polynomials from the beginning would obscure the main idea of our paper. Our aim is to show what L–T solution is obtained when one imposes no a priori constraints on its arbitrary functions, e.g. gives them no handpicked algebraic form, but adjusts them only to observational data.

The polynomials are not needed for redshifts below the critical value. The polynomials were introduced after obtaining the low-z results, in order to overcome numerical divergences at the apparent horizon, and enable an extension beyond the critical point, while still showing we can get very close to the given data functions at higher z too. The polynomials are designed to smooth out the numerics, but they do not appreciably change the results obtained in the region between the observer and the apparent horizon (see Fig.1).

Had we started with polynomials, the resulting arbitrary functions and density profile may have been the same, but our guiding idea would become invisible. Nevertheless, we modified a bit the comment below eq. (9) which we hope will make the situation clearer.

> The title of the manuscript is somewhat obscure, and I would suggest
> changing it to something more suitable for a general audience.

We have changed the title.

> (b) emphasize that the model is not meant to be taken seriously at large
> redshifts (or discuss briefly how the model might be expected to fare
> with other cosmological data other than the Snae),

We have added two small paragraphs at the end of Sec.1 to stress this.

> (c) remove the third paragraph of the concluding section and (d) mention
> which parameter values they have used for the ΛCDM model,

This has been done.

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Reply to Referee C

> Issues raised by Referee A

- Point 1

We can easily generate a profile $\rho(t = 3 \times 10^5 y, r)/ < \rho(t = 3 \times 10^5 y) >$. However, we would prefer not to follow the referee's suggestion here, since it will just introduce either unwanted confusion or unnecessary information. A large part of the PRL readership consists of physicists who are not so well-versed in cosmology, especially in inhomogeneous models, and who might gain the impression that $t \approx 3 \times 10^5$y is the instant of last scattering for every spatial point in our model. However, in the L–T model, the temperature is a function of both the t and r coordinates (see, e.g., Schneider and Célérier, 1999, Astron. Astroph. 348, 25), thus the last scattering surface occurs at different times t for different radial coordinates r, and therefore a profile $\rho(t = 3 \times 10^5 y, r)/ < \rho(t = 3 \times 10^5 y) >$ will not be a profile of the density distribution at last scattering. If we adopt the usual definition of the last scattering surface as the surface where the temperature is constant and equal to 3000K, and a simple equation of state like $T = T(\rho)$, then the density is also constant, i.e. the density profile $\rho(t_{LS}(r), r)/ < \rho_{LS} >= 1$ by construction. If we were to follow the referee's suggestion, then we would have to explain to our readers that the profile $\rho(t = 3 \times 10^5 y, r)/ < \rho(t = 3 \times 10^5 y) >$ is calculated on a hypersurface that intersects with the last scattering instant only on a single sphere (which lies also in the past null cone of the observer). Thus, to avoid confusion we would prefer not to present such a profile. A rigorous derivation of the last scattering surface in an inhomogeneous model would be an interesting project that is well beyond the scope of the present paper.

- Point 2

This has been done – see the end of Sec. 1

$>$ New criticisms

- Point 1

In the introduction we have added an explanation of how we view the use of L.T models. We do not argue that they imply an actual large-scale spherically symmetric inhomogeneity with an observer located at or very near its center, but rather that they should be considered as a first approximation to the inhomogeneities observed in the Universe, in which the inhomogeneities are smoothed over all angles, and only the radial component remains. Hence, the exact central location of the observer is an artefact of the smoothing that does not contradict any cosmological principle. The next step for inhomogeneous cosmology should be of course to relax this approximation and consider models with less symmetry or no spatial symmetry at all.

- Point 2

The ISW effect applies only to the analysis of the CMB data which we do not consider here. Following the request (b) of Referee B we have added at the end of our introduction:

“Note this model is not designed to reproduce all the available cosmological data nor to be considered as the final model of our Universe. Its purpose is to exemplify the proper use of L.T models and to show what can come out of it. Moreover, it cannot be considered to be accurate beyond redshift ranges where the ΛCDM functions used are robustly established.”

To follow the referee’s suggestion, we would need to analyze the CMB in the background of inhomogeneous models. In the standard FLRW approach, the ISW effect requires a perturbation scheme. While a perturbation scheme for the homogeneous models is well developed and studied, this effort took hundreds of papers. The development of a similar scheme for an inhomogeneous background is still in its early stages (see Zibin, 2008, PRD 78, 043504; Clarkson, Clifton, and February, 2009, JCAP, 06, 025), so its completion and application will involve many researchers and extend to many papers. Consequently, the analysis of the ISW effect has not even been performed within simplified giant void models where $t_B = 0$. Thus, what the referee requires is far beyond of the scope of this paper. However, we acknowledge his/her suggestion, and in Sec. 4 we mention that in the future an analysis of the ISW effect will provide interesting results. In reality, the referee cannot already know that the inhomogeneous ISW calculation would have problems that are probably “more acute for the matter distribution presented in this paper than in large void models”. Whether this is true or not will turn out in the course of further research, and papers should not be rejected on the basis of calculations that have not been done. We aren’t at all sure what problems the referee is expecting, or why. Possibly the referee is concerned about the potential caused by the giant hump. Here we must again emphasise that the hump does not appear on the past null cone, only on the $t =$ now surface. In fact the luminosity distance $D_L(z)$ and redshift space density $\mu_n(z)$ are exactly the same as the ΛCDM functions, by construction. How this affects the ISW is yet to be determined, and should not be surmised. In summary, to satisfy the referee on this point we would have to carry out a large and time-consuming separate project, and then, if we were to report on the results still in this paper, we would have to do it within just a few lines to obey the PRL space limitations. We find this requirement unrealistic and unfair. But we do acknowledge that such a research will have to be done in the future, and we have mentioned this in the amended paper.

- Point 3

See our answer to the request of Referee B in point 2 above. Moreover, we feel the referee should take into account two circumstances:

a. The PRL has a strictly enforced length limit on its papers – 4 printed pages. It is thus unrealistic and unfair to demand too many questions answered within such a short space.

b. We agree more research is required on several problems connected with fitting a general L–T model to the SNIa data more precisely. But this will require time and probably quite a big effort. Thus it is unfair again to demand this to be done already in the first paper that is intended to point the way to the proper use of this model, rather than to provide final solutions to all problems of cosmology.

- Point 4

Understanding the nature of dark energy is currently one of the most important and topical problems in cosmology. It is not only cosmologists' concern, but it is also of interest to a general readership. Among the various hypotheses the inhomogeneous models play an important role as they do not require any new physics or exotic energy component in the Universe.
It seems that the Editorial Board of Physical Review Letters shares this point of view, since within the last 1.5 year 6 letters which explore the L–T models have been published in this journal:
C. Quercellini, M. Quartin, and L. Amendola, Possibility of Detecting Anisotropic Expansion of the Universe by Very Accurate Astrometry Measurements. Phys. Rev. Lett. 102, 151302, 2009
J. P. Zibin, A. Moss, D. Scott, Can we avoid dark energy? Phys. Rev. Lett. 101, 251303, 2008
A. Paranjape, T. P. Singh, Cosmic Inhomogeneities and Averaged Cosmological Dynamics. Phys. Rev. Lett. 101, 181101,2008
T. Clifton, P. G. Ferreira, K. Land, Living in a Void: Testing the Copernican Principle with Distant Supernovae. Phys. Rev. Lett. 101, 131302, 2008
C. Clarkson, B. A. Bassett, T.H.-C. Lu, A general test of the Copernican Principle. Phys. Rev. Lett. 101, 011301, 2008
J.-P. Uzan, C. Clarkson, G.F.R. Ellis, Time drift of cosmological redshifts as a test of the Copernican. principle. Phys. Rev. Lett. 100, 191303, 2008

Referee B points out that "Dark energy is a central topic in cosmology, and it is important to understand possible alternatives. The view that a giant void is required in order to fit the supernova data with a LTB model is widely held, and from the point of view of rigorously testing this alternative to dark energy, it is important to understand the different possibilities in detail." Even Referee C agrees that: "I do sense that some popular astrophysicists have a rather myopic view of the possibilities within the L-T setup". However, it is not true to say that our paper is merely a "correction" to a particular paper published earlier in PRL. We rather wish to correct a general perception that L–T models of SNIa dimming are limited to voids, and we do not wish to hold any one paper responsible. Though we inevitably have to cite some examples, we cannot cite all giant void papers within 4 pages.