

Observational Probes of Cosmic Acceleration

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Summary of Changes in Revised Version

In response to the [arXiv](#) posting of the original draft of this review article, in January 2012, we received an exceptional number of thoughtful and valuable comments. This note summarizes the most significant of the changes we have made in the final version of the article, now accepted for publication in *Physics Reports* and available as [arxiv:1201.2434v2](#). Completing these changes has taken us much longer than we had hoped, in part because of the sheer magnitude of the task, and in part because of the press of other commitments, notable among them the writing of the WFIRST SDT final report (Green et al. 2012), which both informed and was informed by the review article, and publication of the first spectroscopic data from BOSS and the survey's first BAO results from galaxies and the Lyman-alpha forest.

The comments on the [arXiv](#) posting included many good suggestions on additional references, and some of these in turn led to other references. We did not adopt all of the suggested additions because, notwithstanding the length of the article, some of them did not connect sufficiently to the points we are trying to convey about observational probes of cosmic acceleration. However, we did adopt the majority of these suggestions, and the referencing of the article is much improved as a result. Overall, the number of references has grown from 778 to 942.

We have also updated the article to reflect some of the field's major developments of the past year, including new papers on supernovae, BAO, weak lensing, clusters, and redshift-space distortions. The final WFIRST SDT report provides a thorough description of the proposed mission and its capabilities, implemented with a 1.3-m (DRM1) or 1.1-m (DRM2) off-axis telescope. Meanwhile the new possibility has arisen of a WFIRST implementation using one of the 2.4-m telescopes recently transferred to NASA from the National Reconnaissance Office; the white paper by Dressler et al. (2012) provides an initial sketch of such an implementation, which is now the subject of a new SDT study, the report from which is expected in April. Any review of a field is necessarily a snapshot in time, but we have attempted to largely advance that snapshot from January 2012 to February 2013.

Beyond these added references and updates, the two most substantial changes to the article are:

1. We have significantly improved the discussion of redshift-space distortions (RSD) in Section 7.2. In addition to a clearer discussion of the methodology for extracting cosmological constraints from RSD, we have used the public code of White et al. (2009) to forecast RSD constraints for several different scenarios, including one that is matched to our fiducial Stage IV BAO program. The bottom line of this section remains the same as before: RSD has the potential to greatly increase the cosmological return from galaxy redshift surveys, but realizing this potential will require major advances in theoretical modeling to reduce systematic uncertainties associated with non-linear gravitational evolution and galaxy bias.
2. In the forecast chapter, we have added a new subsection, 8.6, focused on the concept of aggregate precision as an alternative, nearly model-independent way of characterizing the power of a set of cosmological measurements. While this concept is simple to the point of obvious, we find it a valuable way of thinking about planned dark energy experiments and the level of systematics control required to fully exploit them. This section also incorporates more detailed comparison between our fiducial Stage IV cosmic acceleration program and the specific expectations for Euclid, WFIRST, and other experiments.

For someone who has already read the whole review article, the revised section 7.2 and the new section 8.6 are the two items that merit a new read, along with any of the items below that are of particular interest.

We now summarize other high-level changes in order of appearance:

3. Chapter 1 (Introduction) includes updated discussion of WFIRST and Euclid, as described above, and a brief discussion of inhomogeneities as a suggested explanation of cosmic acceleration (an explanation that we consider non-viable but do not examine in detail).
4. Chapter 2 (Observables, Parameterizations, and Methods) includes several clarifications and a few references to alternative fitting approaches that focus on reconstructing a scalar field potential $V(\phi)$. We find the “CMB-normalized” models employed in this section a valuable source of intuition for understanding the impact of distance or structure growth measurements in a (realistic) situation where CMB anisotropies impose tight parameter constraints. We have added a paragraph at the end of section 2.4 that provides guidance for creating such families of models.
5. In addition to updated references, Chapter 3 (supernovae) includes a paragraph on the philosophy of current light-curve fitting methods and a paragraph summarizing recent studies of spectroscopic luminosity indicators. In this section and, primarily, at the end of section 8.3.1, we have added nuance to our earlier discussion of the maximum redshift of a SN program. We emphasize that the value of high redshift ($z \gtrsim 1$) measurements depends critically on whether their systematic uncertainties are uncorrelated with those of lower redshift measurements. If so, then the high redshift measurements add new information once the low redshift measurements have started to hit a systematics floor; if not, then high- z data are likely to be less valuable than more or better low- z data.
6. Chapter 4 (Baryon Acoustic Oscillations) has been updated in light of recently published results from a reconstruction analysis of the SDSS-II LRG sample and the first BAO measurements from SDSS-III BOSS. It also incorporates an updated discussion of Euclid and WFIRST capabilities.
7. Chapter 5 (Weak Lensing) incorporates numerous small clarifications and additional references throughout, including slightly longer discussions of cross-correlation calibration of photometric redshifts and the importance of baryonic physics effects on model predictions, and an updated comparison of LSST, Euclid, and WFIRST capabilities. We have added a new figure (Fig. 19, in section 5.9) that compares the statistical errors of our fiducial Stage IV WL program to potential systematic errors. The new aggregate precision section (8.6) compares these projected statistical errors to the effects of cosmological parameter changes.
8. Chapter 6 (Clusters of Galaxies) incorporates a number of new references, including several recent papers related to Planck SZ results at the end of section 6.2. Section 6.3.3, on calibrating the observable-mass relation, includes a paragraph on statistical calibration from cluster correlations (which, we argue, can help constrain the observable-mass scatter but cannot usefully constrain the mean relation on their own) and a paragraph on cluster-galaxy velocity distributions (which are probably a less precise mass calibrator than stacked weak lensing but exploit different data and allow novel tests of modified gravity models).
9. Chapter 7 (Alternative Methods) incorporates numerous changes in addition to the revised RSD subsection mentioned above. The H_0 subsection (7.1) has been updated in light of recent papers, and the standard sirens subsection (7.5) includes more discussion (based on Cutler & Holz 2009) of the potential of future space-based gravity wave missions such as Big Bang Observer and Decigo. Strong gravitational lensing, galaxy ages, and redshift drift, previously combined into one “Other Alternatives” subsection, have been broken out into individual subsections, with more extensive discussion and referencing for the first two of these. We remain skeptical that these methods can

achieve the percent-level control of systematics that will be required to make a valuable contribution in the Stage III and Stage IV era, but the wording of our original section may have been unduly pessimistic on this point. Finally, we have added a summary subsection (7.13) to highlight the takeaway points from our discussion of alternative methods.

10. The most important changes to Chapter 8 (A Balanced Program on Cosmic Acceleration) have been mentioned already: the addition of the aggregate precision subsection (8.6) and the more detailed discussion (in 8.3.1) of the SN maximum redshift and its interplay with systematic error correlations. We also place more emphasis on the fact that the DETF FoM generally scales as an inverse variance and therefore tends to increase linearly with data volume, and we have added comments on the scaling of PC-based FoMs in this context. Finally, we have significantly revised the summary subsection 8.7 (Prospects with Many Probes), incorporating our new RSD forecasts and showing several variants on our fiducial Stage IV program to illustrate the dependence on SN, WL, BAO, and RSD errors.

11. The conclusions section includes a new paragraph summarizing our findings on aggregate precision. Other changes to this section are minor.