Post-2024 Science Opportunities with DESI

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DESI

- DESI will be a 5000-fiber, 8 deg^2 spectrograph on the Kitt Peak Mayall Telescope.
- 5-year survey planned for 2019-2024:
  - Up to 14,000 deg^2
  - 24M LRG, ELG, Quasars + 10M Bright Galaxies
  - I'll call this DESI-1.
- This presentation are based on only limited discussion; take it as my views, not those of the DESI collaboration.

Post-2024 DESI

- I expect that DESI will remain a world-leading instrument in the second half of the next decade.
- It should be possible to do a cutting-edge cosmology survey.
- Continued operations for an extended mission would leverage a major past investment in the hardware, software, operations models, *and* collaboration science/governance.
  - I'll denote this DESI-2.

Post-2024 DESI Science

- Even though it would be possible to expand the DESI-1 footprint by O(50%), we expect that the better science return will come from new targeting opportunities.
- It is likely that the best science opportunities will not be clearly visible until after a couple years of DESI-1 data.
  - It has been the repeated experience in SDSS that we've learned about the observational capabilities as we've pursued science with the system.
  - The scientific landscape may change, either due to observations (DES, HSC, eBOSS, HETDEX, early DESI/LSST, CMB, etc…) or theory (e.g., improvements in tests or modeling beyond the linear regime).
- We should avoid getting too fixated on a particular science case now, a decade in advance and before we've seen any DESI-1 data!

DESI-2 Science at $z>1$

- DESI-1 will not approach the cosmic variance limit at z > ~1.5.
- Improvements in sampling would improve linear regime measurements for BAO, RSD, and primordial non-Gaussianity.
  - More speculatively: if there were anomalies in the CMB power spectra, then this is another set of modes to compare to.
- Would boost overlap with CMB lensing: measure matter clustering amplitude (neutrino masses), probe properties of high-redshift tracers.
- Boost correlations with deep imaging samples.

Increasing Targets at z>1.5?

- Quasar targeting would be greatly improved with LSST (u-band, variability), Euclid (NIR, morphology), eROSITA (X-ray), Radio.
  - In addition to direct use as tracers, these could boost the Lyman α forest sampling.
- DESI-2 could fish for strong Lyα emission line galaxies at z>2, like HETDEX, but restricting to broadband candidates from LSST.
- DESI-2 could target low-S/N hints from Euclid slitless spectroscopy to increase sampling at 1.2<z<1.6.
- DESI's ability to quickly reconfigure makes it possible to accept relatively low success rates to find strong line emitters.

DESI-2 Science at z<1

- DESI-1 will gather most of the information at $k<0.2$ h/Mpc at $z<1$, but denser samples would map the density field at higher contrast.
- More work needed on the cosmological opportunities of denser maps at z<1.
  - Multi-tracer RSD; modified gravity tests in and around clusters; cosmology with galaxy groups and poor clusters.
  - Combine with weak lensing from LSST, Euclid, and/or CMB to measure amplitude of structure.
- Primary driver of low-redshift mapping is dark energy: chance to measure impact on structure formation in the one volume where dark energy dominates.
- DESI-1 Bright Galaxy Survey is an important test bed for this at z~0.2, but there's a lot more volume available with easily measured galaxies.

Targets at z<1

- Target selection at z<1 is easy. Lots of galaxies available (10^4 per deg^2 to $r \sim 22$).
- DESI-2 should be able to gather redshifts quickly, particularly if aided by precise broad-band colors.
- Exact observational reach will need more data simulation and eventually testing with on-sky DESI data and pipelines. Could imagine surveys exceeding 10^8 galaxies.

DESI-2 and LSST

- DESI is not particularly well-tuned to the task of direct measurement of i=25 galaxy redshifts.
  - It could provide efficient support at brighter magnitudes.
- DESI could be exceptionally good at supplying spectroscopic maps for redshift estimation from clustering.
- LSST supernovae hosts wouldn't fill the DESI fibers, but DESI spectroscopy could be an efficient way to get lots of live SNe & host redshifts while also pursuing another program. Ditto for lens candidates.
- DESI-2 spectroscopy could be an important extra dimension of LSST cluster work.

DESI & LSST footprints

- There is a lot of equatorial sky that is accessible to both DESI and LSST. While DESI-2 would benefit from LSST imaging, it is possible that the most compelling science could be done with denser coverage of 5K-7K deg^2 of equatorial sky.
  - Moving DESI south would incur substantial costs, both in money and opportunity. Let's not leap to judgment.
- DESI is far from the only Northern facility! I would encourage LSST to consider a footprint that is more tuned toward –30°<dec<+20° if it wants to maximize follow-up (and maximize its weak lensing footprint).

Spectroscopy in the South

- Europeans will probably build 4MOST, which is about half the capability of DESI. While this will be an open-use competed facility, it is likely that it will do substantial extragalactic work.
- Euclid will map in both hemispheres.
- Could build a fiber spectrograph for the Blanco/DECam corrector, e.g., re-using DESI technology to supply 1500 fibers or using the Subaru/PFS spectrograph designs to reach the J band.
  - If DESI-2 works down to about –20° dec, the balance of the split of the full-sky footprint isn't too bad.

Augmenting DESI-1 Science?

- What small near-term items would improve DESI-1?
  - Recommend that a few % of DESI fibers be reserved for exploratory use (DESI-2 planning) and for additional small cosmological science cases (like SNe host galaxies).
  - More target imaging always helps.
  - More scientist effort always helps.
  - Coordinating cosmological simulations with LSST, Euclid, and perhaps WFIRST or others could save much effort and improve the product.

Beyond DESI

- There are undoubtedly cosmological opportunities with much large spectroscopic samples….
- ….but I don't think we know today what will be the best technical approach or best survey strategy.
- Need substantial study in the coming years! Results from DES, HSC, HETDEX, eBOSS, Stage 3 CMB, and the early results from DESI should help a lot.
- Note that it may be more cost-effective to invest in larger fiber multiplex rather than bigger primary mirrors. Each DESI field has 1M+ LSST WL galaxies.

Conclusions

- The opportunities for post-2024 DESI science are large, indeed probably larger than are yet realized!
  - Could make better maps on linear scales at $z>1.5$.
  - Could push to large samples at $z<1$.
  - Interesting synergies with several other types of data.
- Lots of room for study and brainstorming in both theory and observations.