Exploring fundamental physics with multiple cosmological observables and data sets

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Program: Topic Area

Motivation:

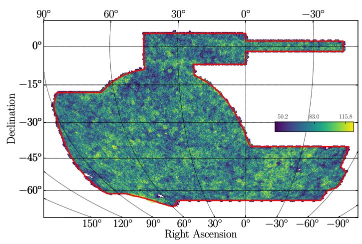
Our current understanding of the history of the Universe holds that it starts out from a singularity, undergoes an early phase of rapid expansion (inflation), after which expansion continued, decelerating during the so-called matter dominated phase. Then, five billion years ago, the expansion of the universe started *accelerating*. This acceleration continues, and the energy density associated with it is now the dominant component of the universe today.

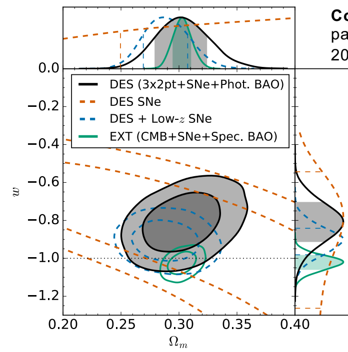
While there are many proposed physical models that attempt to explain the acceleration of the universe, all of them would represent a major departure from our current understanding of fundamental physics. A better understanding of cosmic acceleration is thus a major scientific priority, and so a broad range of future missions (including WFIRST and Euclid) and new ground-based facilities will investigate cosmic acceleration over the next decade.

Several large precursor programs are already under way. Here we describe our contributions under this award to the current state of the art.

The Dark Energy Survey (DES)

Map of galaxy positions, shapes for 200 million galaxies





Final Cosmological Parameter Constraints from headline results paper (Abbot et al., published May 2019)

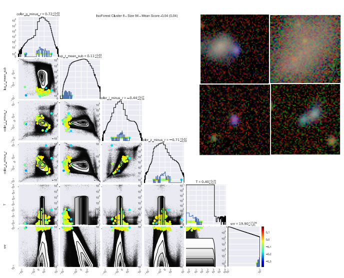
DES is an ongoing survey that will has covered 5000 square degrees of the southern sky in five photometric bands using a purpose-built wide-field camera. Analysis of the first three of its five years of data will provided the strongest constraints on the nature of dark energy to date.

Work done under award was instrumental in making **DES** work. ***Precision Lensing Measurements*** rely heavily on calibration algorithms developed by **Huff** (*MetaCalibration*).

Machine Learning in Big Astronomical Data Sets

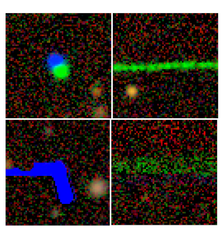
Precision cosmology with **DES** and its successors requires high-quality science measurements. With individual measurements for over 300 million galaxies, validation of the galaxy catalogs is a major challenge.

Wagstaff and **Rebbapragada** have used two machine learning algorithms (DEMUD, isolation forest) to comb through the DES science catalogs in search of anomalies.



We identified clusters of sources with unusual colors, suggesting good potential for machine-assisted discovery on large, feature-rich data sets of this kind.

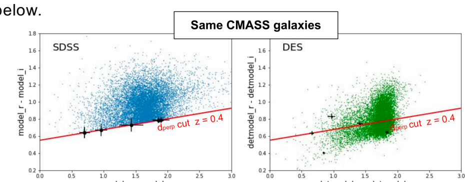
We also established that 1-2% of the **official, vetted Year 3 science catalogs** were contaminated with non-astrophysical sources, despite years of validation. Our anomaly algorithms were efficient at finding such sources.



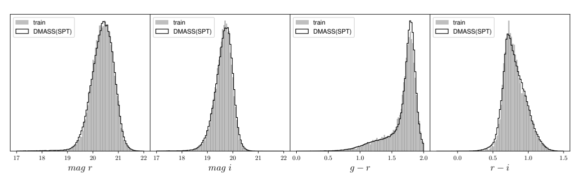
Cosmology from the combination of heterogeneous surveys

The best constraints on dark energy and modified gravity will come from the combination of spectroscopic (such as the Sloan Digital Sky Survey, SDSS) and imaging surveys (such as DES). The former constrain how galaxies move under gravity, and the latter (using gravitational lensing) map the distribution of matter. However, current and future surveys of these types do not overlap, and a combined analysis using all of the data is not previously possible.

The difficulty of creating a statistically common sample from different surveys is shown in the plots of the colors of common galaxies (from a sample termed 'CMASS') shown below.



Under this award, we devised and implemented a common sample selection between DES and SDSS, solving the problem of selecting the same samples of galaxies from different surveys. The results are published in [A]. A demonstration of the equivalency is shown below.



The sample we defined here will be used to produce unprecedented constraints on the nature of gravity and cosmic acceleration.

Benefits to NASA and JPL:

- High visibility of JPL cosmology group through leading roles in **DES** papers
- Innovative new algorithms and tools, applicable to current and future data
- Ideal preparation for Euclid, WFIRST, LSST

Selected Publications:

A. Lee, S., Huff, E.M., and 59 colleagues 2019. Producing a BOSS CMASS sample with DES imaging. Monthly Notices of the Royal Astronomical Society 489, 2887.
B. Zuntz, J., and 107 colleagues (incl. E.M.Huff) 2018. Dark Energy Survey Year 1 results: weak lensing shape catalogues. Monthly Notices of the Royal Astronomical Society 481, 1149.
C. Troxel, M.A., and 135 colleagues (incl. E.M. Huff) 2018. Dark Energy Survey Year 1 results: Cosmological constraints from cosmic shear. Physical Review D 98, 043528.

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