Pushing the Limits of Dark Energy Experiments

October 6, 2016

Background

Introduce the research topic. Place the project in academic or professional context by referring to major works by others on the subject.

Understanding the accelerated expansion of the Universe is one of the most important unsolved problems in fundamental physics. This was recognized by the 2011 Nobel Prize on Physics to three astronomers who lead research teams that found observational evidence for this phenomenon. A complete understanding of the accelerated expansion lies either on a new kind of negative pressure energy component (dubbed under the generic name of Dark Energy) or in the modification of Einstein's General Relativity.

The Dark Energy Spectroscopic Instrument (DESI) is a world-class experiment that is designed to bring the most significant experimental advance on this front. DESI will take the spectra of 35 million galaxies to make the most accurate measurement of the expansion history of the Universe on the timescale 2019-2024 using the Baryon Acoustic Oscillation technique.

One of the significant milestones to prepare DESI operations is a full simulation of its expected five years of operations. This simulation will allow to stress-test all the software that will be used on the real data and also identify in advance strategies to maximize DESI's scientific return. The results will be useful for the broad scientific community expecting to use DESI data products.

The work to simulate such a complex experiment integrates the knowledge of different groups of experts [1]. From the engineers designing the instrument, to the astronomers processing the data, including the expert simulators of universes and galaxies. This is a process I have been involved with during the last two years by writing software and curating input data. After the simulation is completed by mid 2017, I will join the effort to analyze the resulting data.

This work will allows us to understand how close we are to answering one of the most fundamentals questions about Science and Nature. What will be the power of DESI to decide whether Einstein's General Relativity is correct? Perhaps more exciting is that this would be our first step into the unknown with DESI. What do we need to do to take the experiment beyond its original design limits? Where are exactly DESI's power and limits for discovery?

References

[1] B. Nord, A. Amara, A. Réfrégier, L. Gamper, L. Gamper, B. Hambrecht, C. Chang, J. E. Forero-Romero, S. Serrano, C. Cunha, O. Coles, A. Nicola, M. Busha, A. Bauer, W. Saunders, S. Jouvel, D. Kirk, and R. Wechsler. SPOKES: An end-to-end simulation facility for spectroscopic cosmological surveys. *Astronomy and Computing*, 15:1–15, April 2016.

Objectives

Clearly define the aims of the project.

The main objective is to analyze the data resulting from a simulation of five years of DESI operations.

This will allow us to reach three goals:

- Forecast with great detail the accuracy at which the Dark Energy Spectroscopic Instrument will be able to constraint the expansion history of the Universe.
- Quantify the degree to which different instrumental systematic errors can degrade the experiment's performance.
- Test strategies to mitigate systematic effects and maximize DESI's scientific return.

Methodology

Methodology: Describe the project. Explain the approach, methods and plan you will use (for example, interviews, library or archival research, or laboratory experiments). Indicate whether the proposed research is quantitative or qualitative.

Significance

Significance: Explain the importance of the project for the field, your home country and your own professional development. Indicate what effect you expect the opportunity to have on your teaching or professional work in your home country. (For example: new approaches to curriculum planning, student advising or pedagogy; expanding knowledge in the field through collaboration with U.S. colleagues). Describe briefly the expected impact of your participation on your home institution, community or professional field.

DESI is a world-class experiment in the area of observational cosmology. This imposes a high threshold on the require quality for the simulation and data products available to the collaboration.

This collaboration can also enrich the colombian scientific community.

I also act as a coordinator in the Astronomy for Development (AfD) initiative. The AfD was started by the International Astronomical Union as a result of the international year for astronomy in 2009. The high level goal is to use astronomy to create a better world. This is achieved by implementing projects that use the cultural, technical and scientific aspects of astronomy to engage with local communities and impact their development status.

I will also use my time at LBL to create new partnerships to achieve the AfD golas. In particular I will contacti LBL scientists interested in teaching in summer schools for students in the Anean Region. I will also engage with scientists and professionals working in the science museum to contact them with people working in local musesms to exchange ideas about best practices. We in the Andean Region are also developing work to make outreach material useful for people with disabilities.

Evaluation and Dissemination

Evaluation and Dissemination: Describe plans for assessment and distribution of research results in your home country and elsewhere.

DESI has a formal project management structure. This specifies milestones and deadlines for the different tasks defined in the current proposal. The internal assesment process by the managers in the collaboration provides a natural strategy to asses the project progress.

The software contributions done in this project will be publicly available through the public DESI repository.

Publications by the collaboration.

The project results will also be presented in scientific meetings. Thr first natural venues is the internal collaboration meetings. Also to enahce the impact in the colombian astronomical community, I will also present the results in the Colombian Congress of Astrophysics to take place in 2018.

Justification

Justification for Residence in the United States for the Proposed Project: Indicate why it is necessary to conduct the research on site in the United States.

DESI is coordinated by the Lawrence Berkeley National Laboratory. The collaboration includes close to 300 scientists in 40 institutions around the world. Most of the simulation work is done in different locations (including Bogota) and it is coordinated via virtual meetings. However, to consolidate progress (i.e. by releasing software or data to the collaboration) it is crucial to spend a minimal amount of time in face-to-face meetings.

Since 2014 I have used funding from my University and the DESI collaborationn to spend at least one week per semester at Berkeley Lab writing and integrating sofware for the data simulation pipeline. As DESI gets closer to starting operations in January 2019, the experiment has reached a point where the end-to-end simulation effort has matured and gained relevance to the operational aspects of the project.

A significant and timely contribution to DESI needs the focused effort on site at Berkeley Lab that a Fulbright fellowship can best provide.

Duration

Duration: Explain how the project can be completed within the time period proposed.

I expect to spend a total of 16 weeks working on site at Berkeley Lab starting mid August 2017 through December 2017.

Currently we are working on the preparation of the full simulation (August-December 2016) and the associated analysis tools. We will perform the simulation next year (January-July 2017) and complete the analysis in the period August-December 2017.

The analysis stage will be the focus of my visit to Berkeley Lab. We foresee four stages, each one fitting into a 4-week period.

1. Measure the accuracy at which the simulated data constrains the expansion history of the Universe.
2. Quantify different instrumental systematic errors can degrade the experiment's performance. The focus will be on the effect of fiber assignment and success of the spectroscopic pipeline.
3. Run simplified simulations to test strategies that mitigate systematic effects and maximize DESI's scientific return.
4. Consolidate a detailed report on the results from the end-to-end simulation challenge. The full report is aimed at the DESI collaboration. A condensed version will be published for the broader scientific community interested in understanding the kind of data that the DESI collaboration will produce.

This tasks depend on software that we are constrained to develop in the period August 2016 - July 2017. As the simulation runs we will analyze small chunks of data to fine tune the required tools.

The experience we gain in this one-year preparation period ensures that focused work during 16 weeks, using mostly existing tools, is the only critical step to succeed in the global analysis task.