Script: A Message about Survey Science with Rubin Observatory for the Incoming Grad Student Cohort of 2022

TITLE

My name is Melissa Graham and I'm research staff at the University of Washington where I work for the Rubin Observatory as a Data Management Science Analyst and as the Lead Community Scientist. Today I'm going to tell you, the incoming cohort of graduate students in 2022, a bit about the scientific motivation for the Rubin Observatory, which is currently under construction and is scheduled to begin its all-sky survey and make its first data releases over the next few years, during your time as graduate students.

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Surveying the universe is by no means a new endeavor. We have always been looking to the night sky and contemplating our cosmic origins. At optical wavelengths, we have looked with our eyes, our cameras, and more recently, our telescopes, as in the three images here of humans under a night sky. What is new is the technology that allows us to survey wider regions of sky, faster, and to greater depths. Technology such as the charge-coupled device or CCD, the automation of telescopes, and the hardware and software that enables us to obtain, process, store, and share data of ever greater volume and complexity. The image at right is a photograph of the Sloan Digital Sky Survey, the SDSS, 2.5m telescope at Apache Point Observatory in New Mexico. The SDSS began in the year 2000.

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A single image of the SDSS covers a huge area about eight times that of the moon. This survey created by far the most detailed wide-area map of the universe in optical colors, and was absolutely revolutionary – not just because of the major scientific discoveries that were made, which would take many more colloquia to cover – but also who made them. The SDSS collaboration enabled many, many astronomers and students from around the world to use the data by making it both publicly available and accessible at skyserver.sdss.org.

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It is now twenty-two years on from the start of the SDSS, and astronomers have more open astrophysical questions about the universe than ever, and so we look to the next generation of sky surveys. The core scientific goals of the Rubin Observatory are:

- One, cosmology, improving our understanding of dark energy, dark matter, and the origin and fate of the universe;
- Two, transient phenomena, understanding the evolutionary processes of stars and other compact objects like black holes by monitoring their changing brightness as evidence of how they interact, merge, and explode;

- Three, the Milky Way, understanding the structure and evolution of our Galaxy's components, satellites, and tidal streams by mapping its stars, and;
- Four, the Solar System, understanding its formation and evolution, and in particular the risk posed to Earth by asteroids, by making a full inventory down to objects as small as 100 meters.

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Major scientific advances in all four of these areas can be accomplished with the Rubin Observatory because of how it was designed and built, and how it will be used. The Rubin Observatory is currently under construction in Chile, in South America, and the main photo at left is from last year. The telescope's primary mirror is large, at 8.4 meters in diameter, but its overall design is very compact, as you can see in the inset at upper left. Its camera has a wide field of view of 9.6 square degrees, which is many times the size of the moon, as you can see in the inset image at lower right.

The big camera providing a large field of view, the big mirror providing sensitivity, and the compact design allowing for quick movement, together allows the Rubin Observatory to survey wider, deeper, and faster than any previous sky survey, by a very wide margin. A map of its main survey of the southern sky, called the Legacy Survey of Space and Time or LSST, is shown at right. Starting in 2024, over 10 years the LSST will revisit patches of the sky between 100 and 1000 times, as illustrated with the purple to yellow scale bar.

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The Rubin Observatory and its Legacy Survey of Space and Time will produce data sets containing billions of stars and galaxies, and millions of supernovae and solar system objects. This will be a data set of unprecedented volume and complexity, serving thousands of astronomers around the world, and providing groundbreaking advances in our understanding of the universe. A considerable amount of innovation is required to meet the challenges of processing and analyzing the LSST data, and astronomers from around the world are working to advance the cutting edge and progress data processing and analysis algorithms to a point where they can handle it.

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I want to tell you a bit about how astronomers and students are preparing now, so that they are ready to do science with the LSST data as soon as it arrives. The data will be freely accessible to everyone working at institutes in the US and Chile, and to members of international partnership teams. However, the LSST marks such an advance in data volume and complexity that many of our past methods and tools for analysis simply will not scale up. So, as a community, people interested in learning about and preparing for science with the LSST have self-organized into 8 LSST Science Collaborations. Together, they are doing things like testing

new algorithmic methods on current data, or simulating LSST-like data to practice their future analyses. These collaborations are all open to, and supportive of, students who are learning.

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Over the next few years, the learning opportunities will continue to expand. In 2021 the Rubin Observatory began a series of Data Previews, which have the goal of giving astronomers and students experience in using LSST-like data, in a supportive software environment that is similar to what we will all be using in the future. Data Preview 0 is based on simulated data, but by the end of your first year of graduate school there should be small amounts of real data generated by the commissioning activities at Rubin Observatory, and plenty of opportunities for students to participate. The LSST is currently scheduled to begin in 2024, which means it is likely that the first real data release will be out by the time you start your fourth year of graduate school. From there, potentially you would be graduating and going on to postdoctoral positions that coincide with the mid- to later-years of the LSST, where you would be achieving the science goals that motivated the original design, and perhaps starting to plan the next generation of sky surveys.

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The Rubin Observatory and the LSST represent a huge investment of money, time, and resources, and it is truly meant to serve the entire astronomical community. It is also very well understood that simply making this massive, complicated dataset publicly available is not the same as making it equitably accessible to the entire astronomical community. Rubin Observatory is committed to research inclusion, and this slide presents a few examples.

Participation in Data Preview 0 is prioritized for individuals from small or underserved institutes, and those who identify with groups that are under-represented in astronomy, for example on the basis of gender, race, or disability. By 2025 there will be thousands of astronomers using LSST data and services which were created by no more than 100 staff members, and knowledge bottlenecks are a real risk to science. Rubin Observatory is prioritizing the maintenance of openly accessible documentation and tutorials, and of a supportive virtual community of scientists who will help each other. A plan to equitably distribute what might be limited computational resources is in the works, Rubin regularly incorporates DEI training and Code of Conduct enforcement into its workshops and its work culture, and just hired a postdoc who will be paid to do both research and DEI work.

That last point is particularly relevant to you as incoming graduate students, because it is becoming more frequent that postdoctoral employers include DEI work as job criteria, research grants expect a component on broader impacts, and opportunities for cross-disciplinary research positions such as the combination of social science and data science become more common. You will find support for research inclusion work at the University of Washington and within the Rubin community.

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To conclude my part on a personal research note, I cannot wait to find all the supernovae, because explosions of carbon-oxygen white dwarf stars as Type Ia supernovae are literally what keep me up at night. Thanks for listening!