How do you prepare to discover the unknown?

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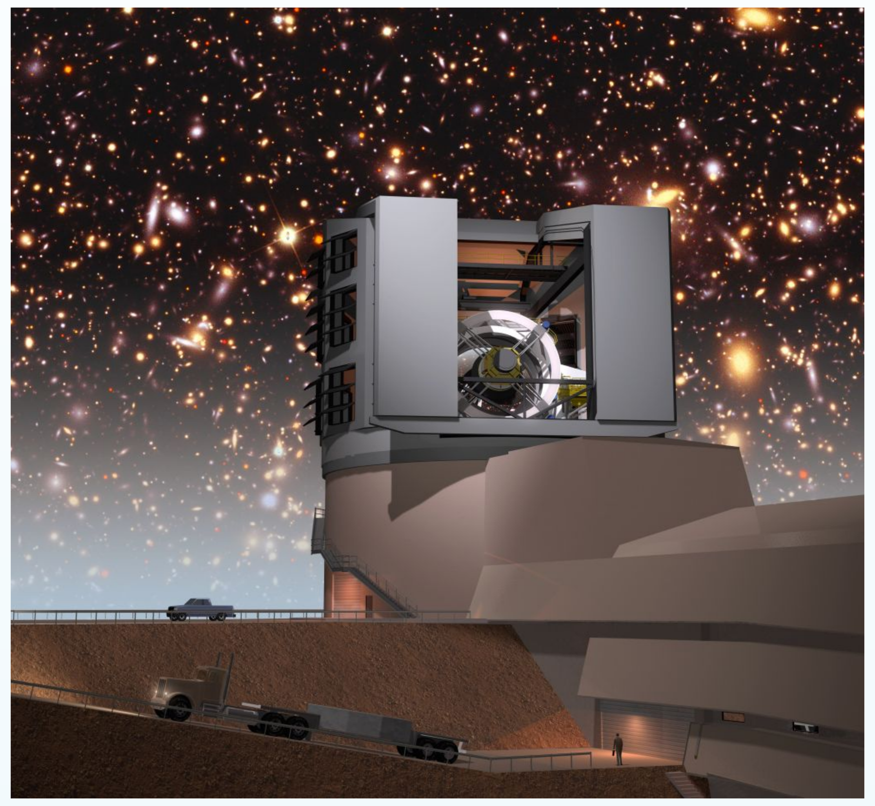


A rendition of the LSST as it will look after completion.

The Large Synoptic Survey Telescope (LSST) is the **next big thing** in astronomy!

Based in Chile and expected to start in 2022, with a sensitivity and resolution similar to those of the Hubble Space Telescope, the LSST will take pictures of the whole southern hemisphere sky in 6 different colors repeating observations of each sky position every few days: an unprecedented survey delivering 20Tb of information-rich data every night for 10 years. LSST is certain to revolutionize our understanding of the Universe from Solar System asteroids to the shape and evolution of the Universe itself. But most importantly LSST will have the potential to make ***unexpected discoveries***. But how can we assure that the choices we are making in designing the LSST observing strategy will not prevent us from discovering of the unknown?

The operations of LSST are evaluated by metrics under the Metric Analysis Framework (MAF) API. Although many metrics have been designed to assess how well a proposed strategy would discover planets, or exploding stars, and allow us to extract their physical properties, given a set of observational choices (points, alternation of filters, cadence of observations), designing a metric to evaluate LSST's ability to discover unknown phenomena is a conceptually and practically challenging task that no one had yet attempted.

We present such a metric by mapping LSST planned observations to a phase space defined by the brightness, color and the change of those features. Based on the distribution in phase space we will be able to tell which regions support detection and which do not. Our results allow us to design a survey that maximizes our chances to discover unknown unknowns.

The current status of the LSST Telescope in the mountains of Chile.

LSST by numbers

Telescope:

- **Field of View = 9.6 square degrees**
- **Mirror diameter = 8.4 m**
- **Resolution = 0.2 arcsec/pixel**

Camera:

- **Pixel count = 3.2 Gpixels**
- **Full bandpass range = 320-1050 nm**
- **Total number of filters = 6**

Observation:

- **Visits per night = about a 1000**
- **Objects = 37 billion**
- **Sources = 7 trillion**

Data:

- **Data collected per 24 hr = 20 TB**
- **Final volume of raw image = 60 PB**
- **Final disk storage = 0.4 Exabytes**

LSST will

detect and study 20B galaxies, 17B stars characterized in shape, color, and variability;

detect and track 6 million objects in the Solar System;

detect 1-10 million changes in the night sky,;

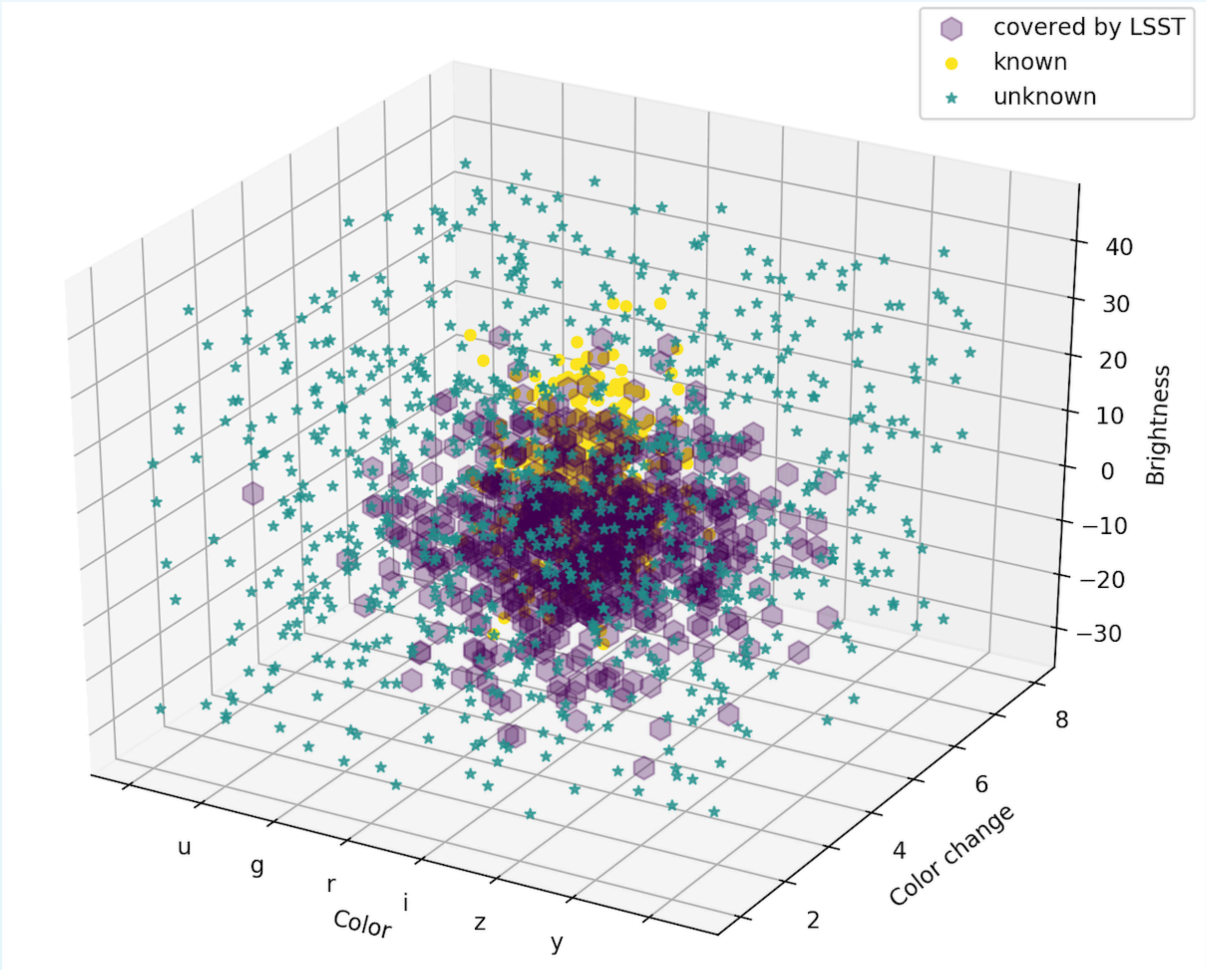
detect and share with the world within 60 seconds of observation including 10000 exploding stars every night;

probe the nature of dark matter and dark energy using several billion galaxies;

revolutionize the study of astronomical objects.

Characterizing known and unknonwn phenomena

Astronomical objects are characterized by color, brightness, position, shape, and the rate and direction of change in any of those features. This leads to a multidimensional ***phase space*** to be explorable. Different categories of phenomena lie in different regions of the phase space.



This 3D cube, defined by the color, the change of color and the brightness, shows an example of a phase space. Scattering points in three different colors demonstrate respectively the known phenomena, which have been properly observed by current telescopes, the region that will be covered by LSST, and some unexpected phenomena that no one has seen or predicted.

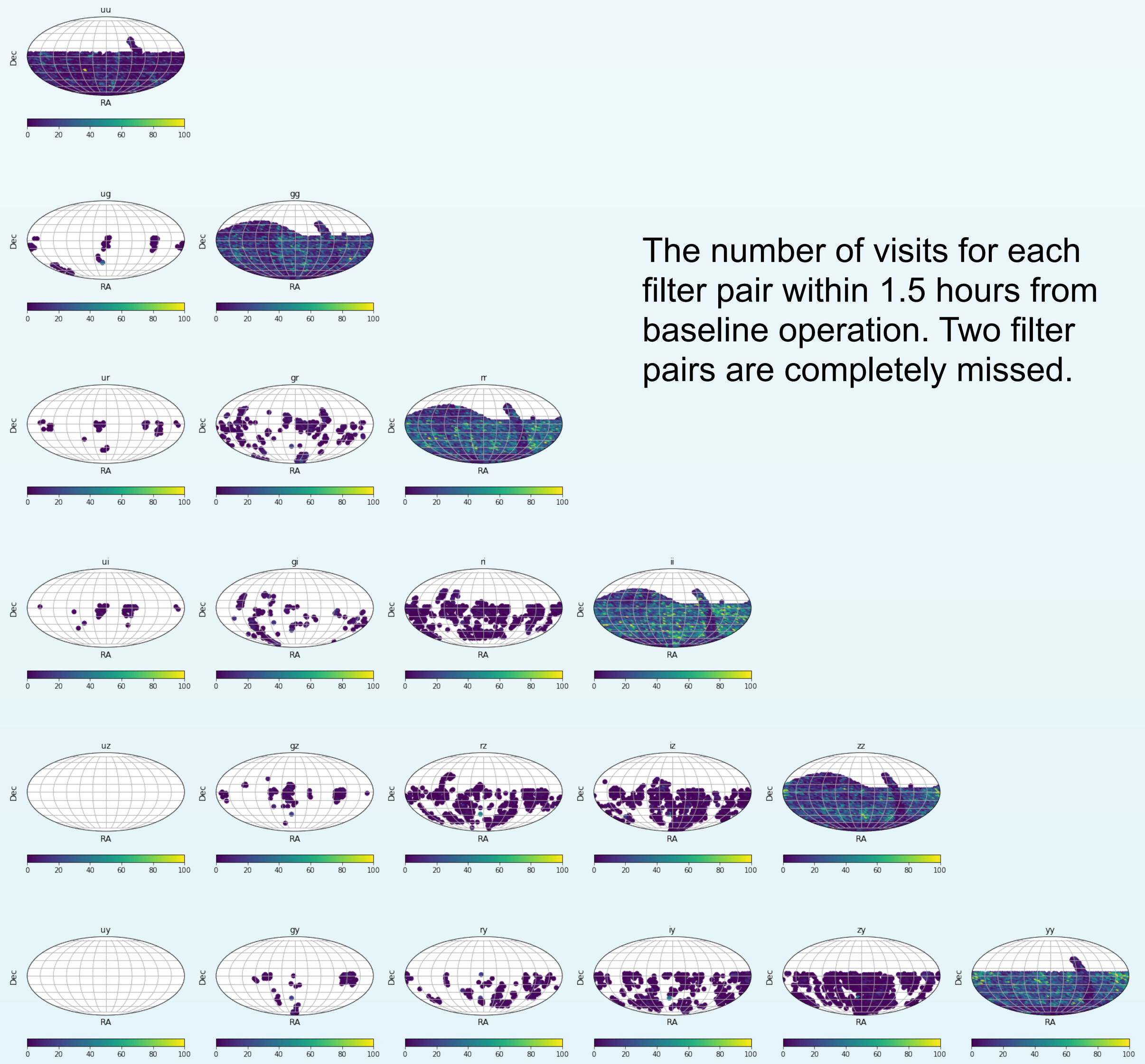
Thousands of observing strategies can be designed. But how can we assure that the LSST's observing strategy do not prevent the discovery of the unknown?

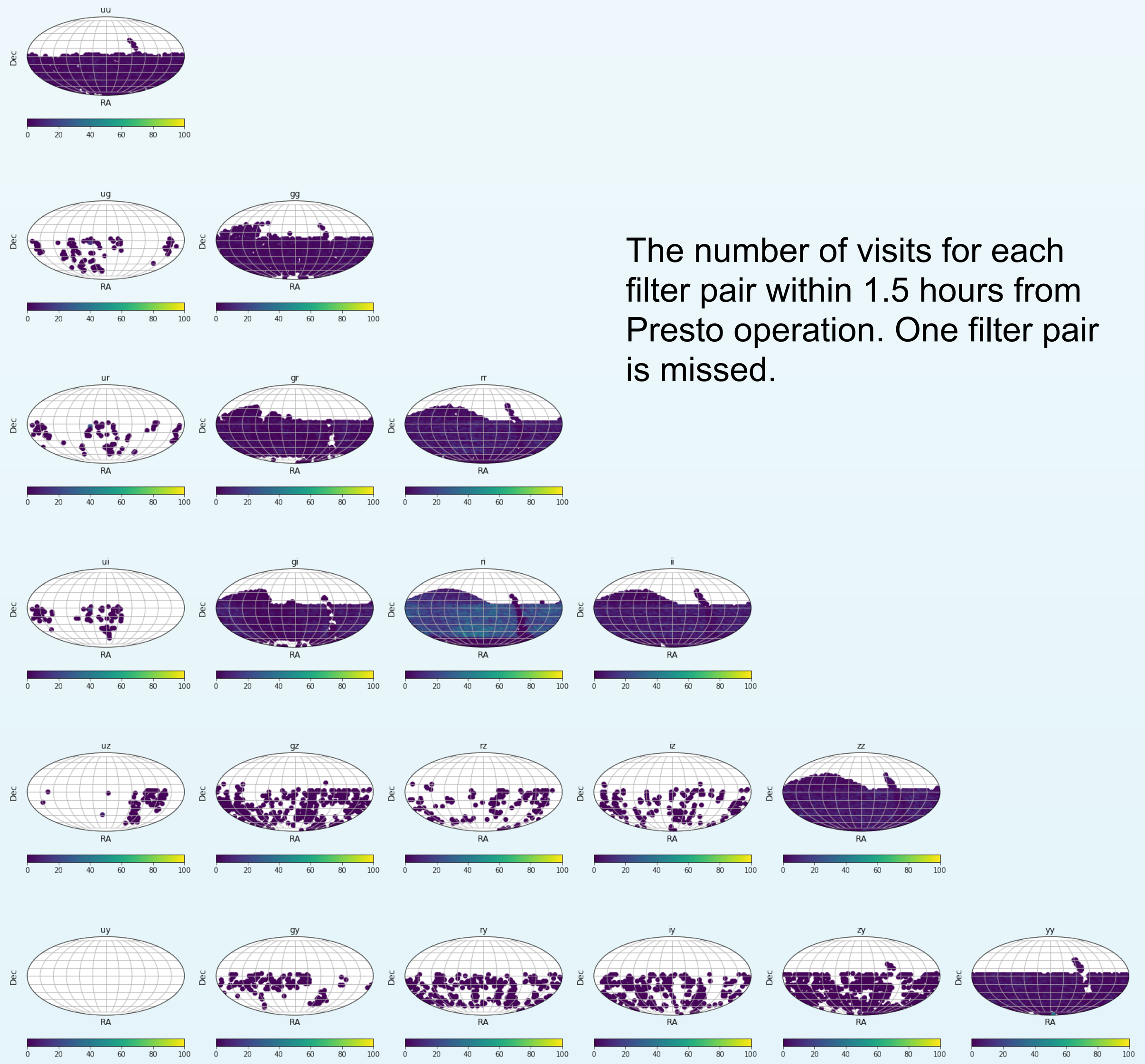
The operation of the LSST is simulated by OpSim module, whose outputs are databases containing features of the LSST images. Once we understand which features can be extracted, we can explore the phase space of these features and identify gaps induced by observational choices . We completed a metric to do that and it can run on all observing strategies.

Will LSST's observations lead to any gaps in this phase space? We want to make sure that it will not!

Results

We considered two different observation strategies. One is the latest Baseline operation, which serve as a benchmark for others, and the Presto-Color, which is designed specifically to identify color evolution. We compared their abilities to capture information about color evolution by counting the number of visits within 1.5 hours for each filter pair at each sky position. We present here the results as an array of skymaps.





The left figure shows the number of visits for each filter pair within 1.5 hours from Baseline operation. The right one is the same plot but from Presto-Color operation.

The diagonal skymaps indicate that the southern hemisphere are well covered for both operations by visits in same filter. In comparing with the off-diagonal skymaps, we find that Baseline has more visits of same filter, while Presto-Color has more visits in mixed filter pairs, especially in g-r, g-i, and r-i. Baseline has no visits in two filter pairs, u-z and u-y. Presto-Color has no visits in u-y.

Overall, Presto-Color operation is a better strategy to get enough information about color evolution. But both operations have large gaps that are not covered in phase space. This means a large part of astronomical phenomena will be missed by these operations. Better observing strategies are necessary to be designed. We presents here only two operations. In the near future, we are going to explore all of the strategies and identify the best one.

References

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