Machine Learning and the Large Synoptic Survey Telescope

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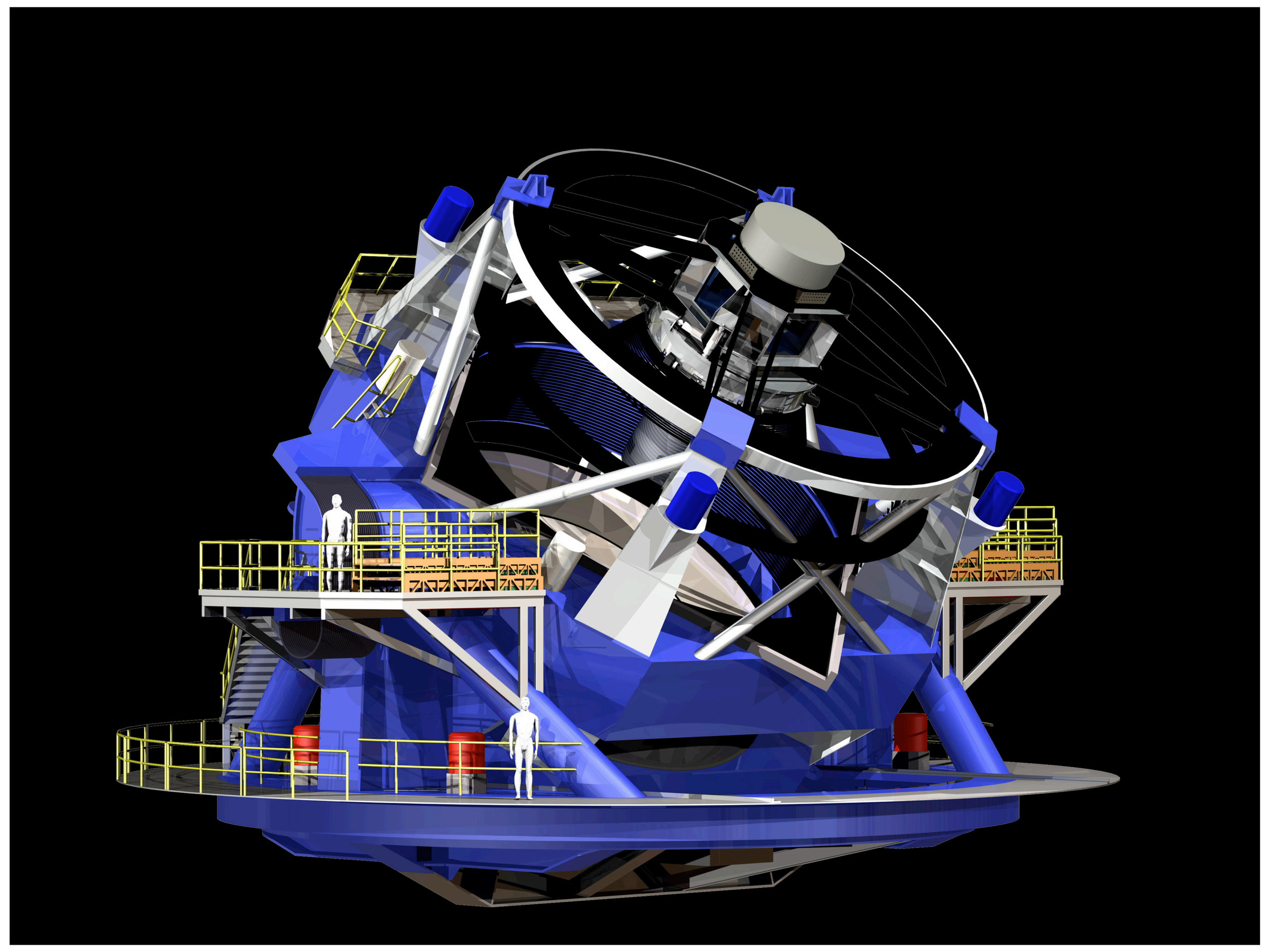
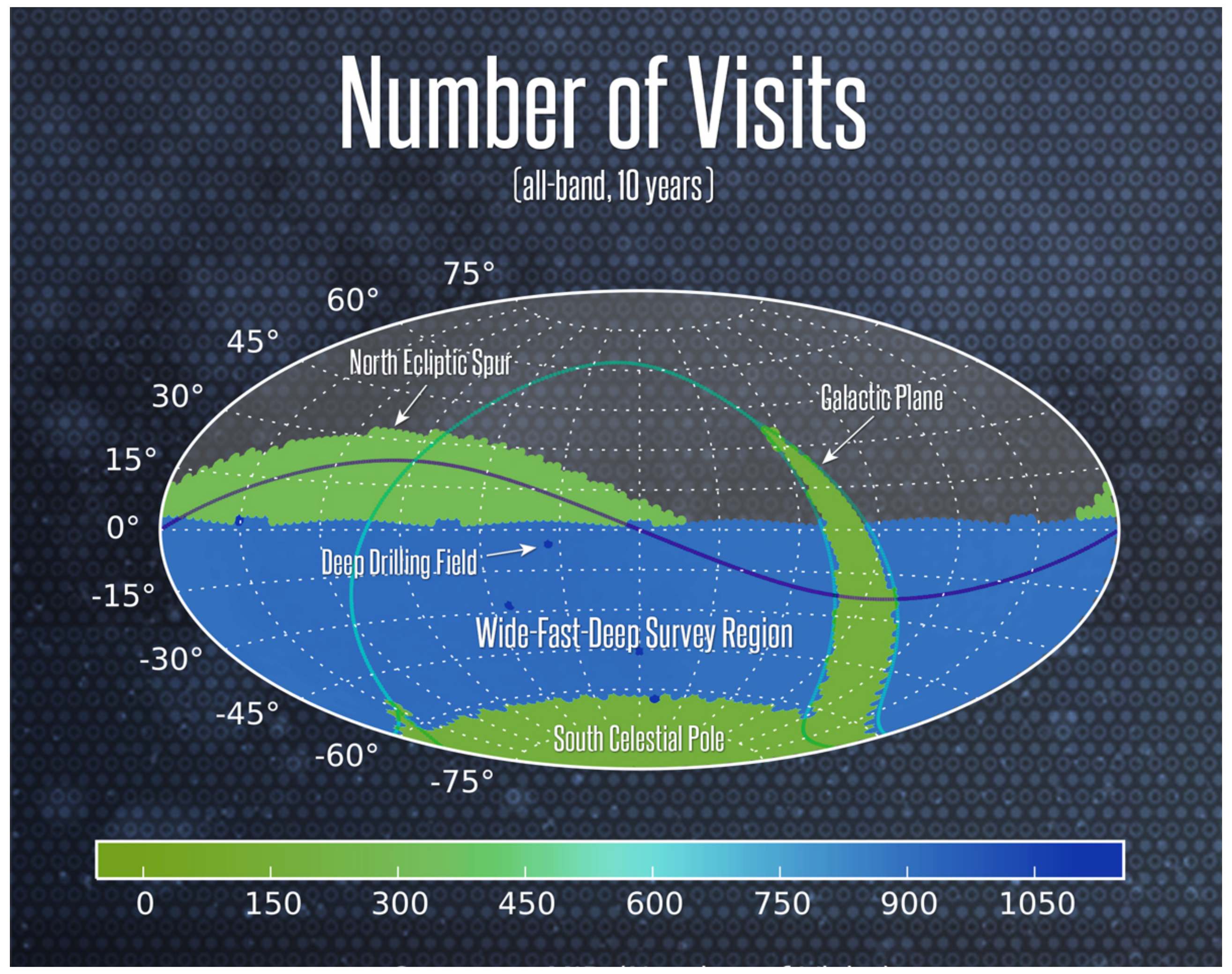
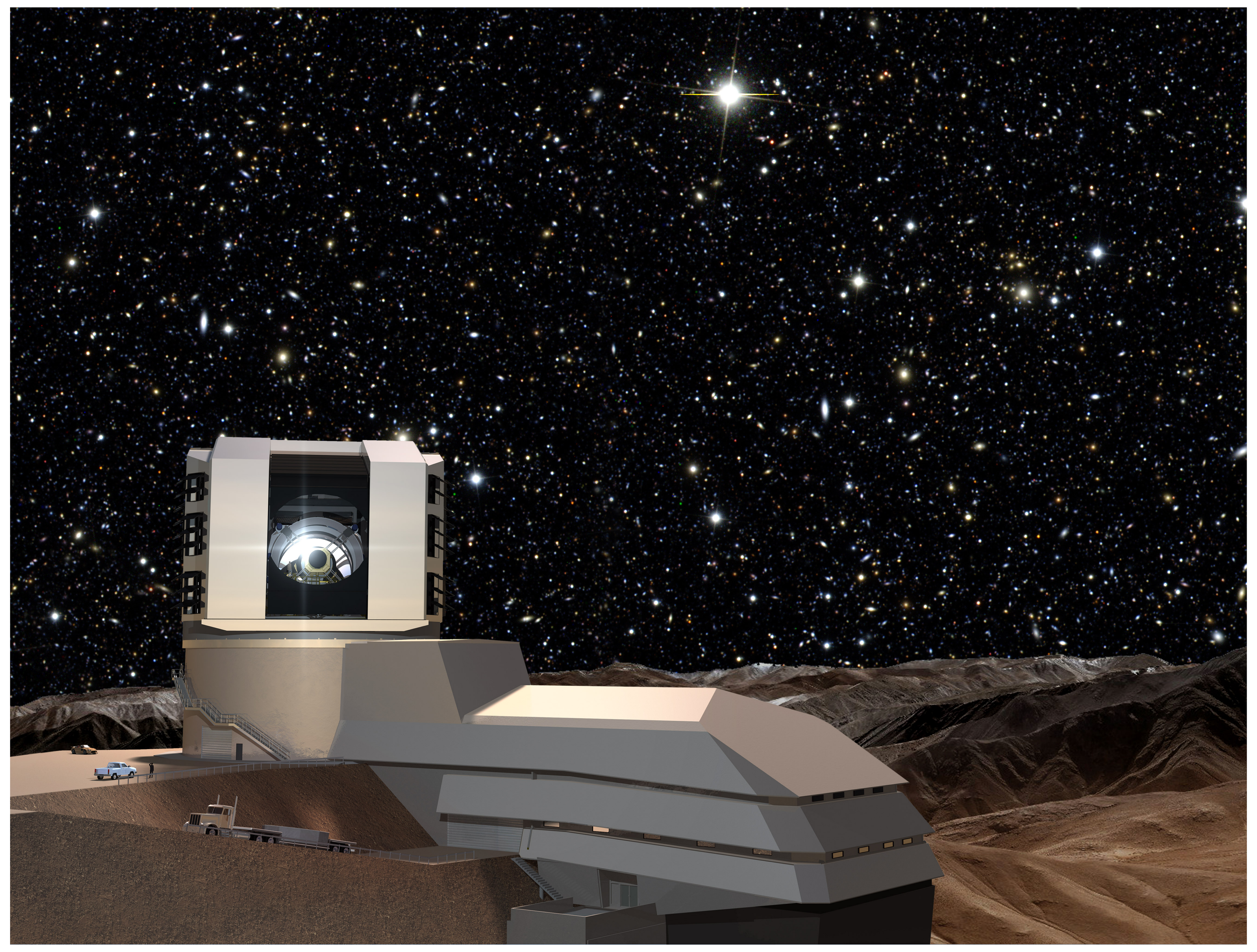
Abstract: The Large Synoptic Survey Telescope (LSST) is a new observatory under construction on Cerro Pachón in Chile. It was the #1 ranked ground-based astronomy project in the 2010 astronomical "decadal survey" conducted by the US National Research Council. LSST will identify over 40 billion sources on the sky. My interest is in identifying the ~100 million quasars and active galactic nuclei (AGN) among those 40 billion sources; however, LSST lacks the spectroscopic capabilities needed to provide positive identifications for these sources. As a result, LSST will rely on machine learning algorithms to provide classifications (based on smaller training sets). Repeat observations will be obtained for all sources nearly every 3 days, allowing construction of time-dependent "light curves" of each source. Signal processing algorithms will be applied to these light curves both in order to improve classification probabilities and also to reveal intrinsic physics. Modern astronomical surveys like the LSST provide for rich interdisciplinary opportunities between astronomers, computer scientists, and statisticians.



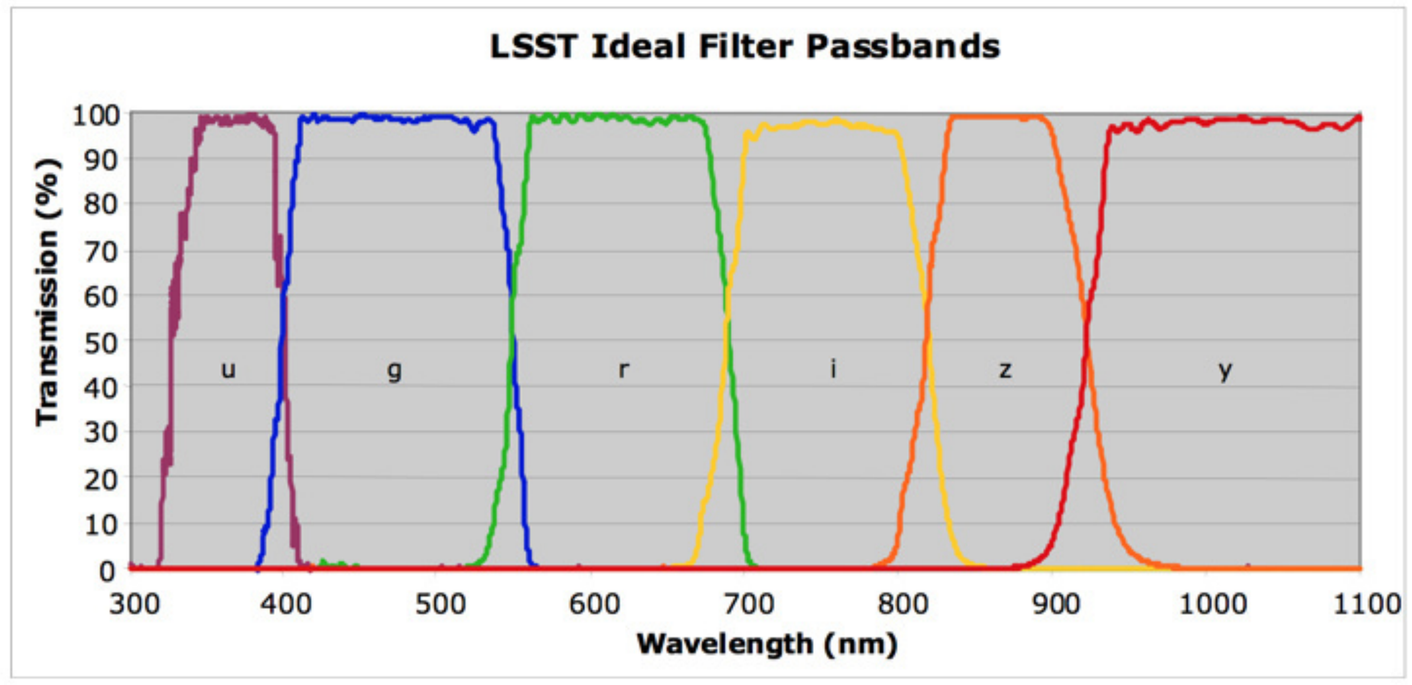


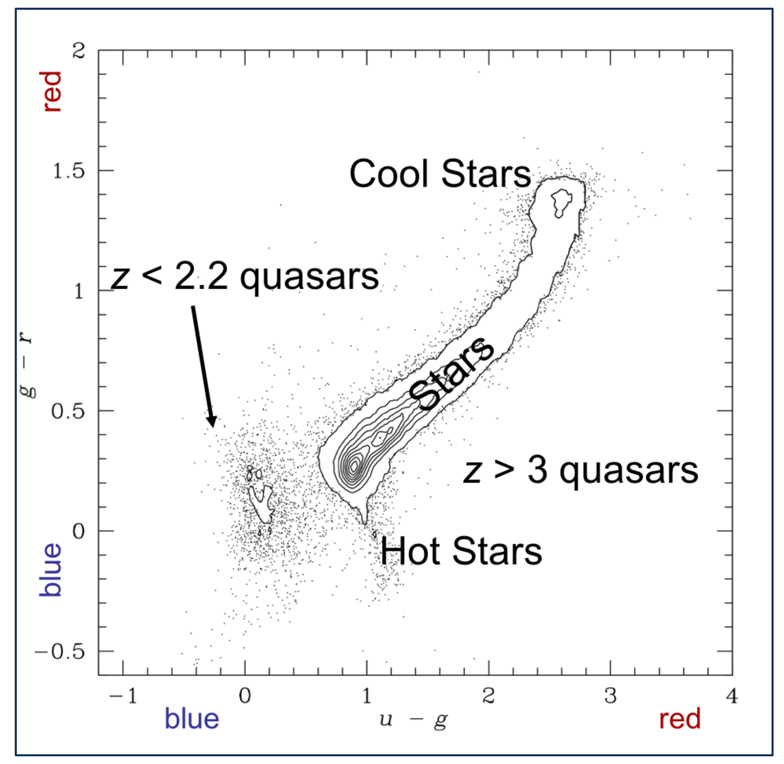
LSST has a compact design (**above**) with a very wide field of view, allowing it to scan the observable sky from Chile in just 3 days (**top right**), whereas its predecessor (the Sloan Digital Sky Survey [SDSS]) took 8 years to cover a similar area of sky. Repeat sky scans over the course of a decade will enable LSST scientists to make a dynamic **movie** of the sky rather than a static map (**bottom right**)

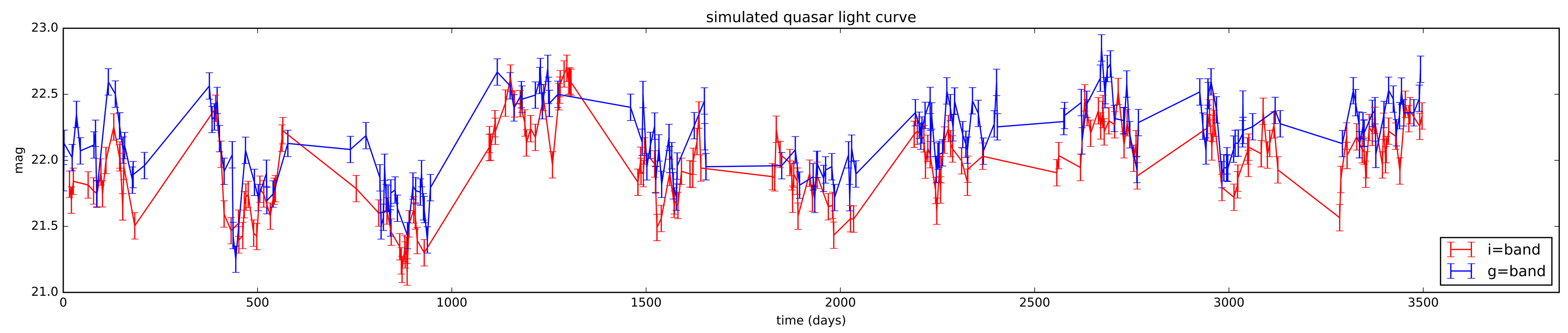


LSST is a highly international project with contributors from 24 countries. German institutions involved in LSST include, Astronomisches Rechen-Institut, Zentrum für Astronomie de Universität Heidelberg (ARI/ZAH), Deutsches Elektronen-Synchrotron (DESY), Leibniz-Institut für Astrophysik Potsdam (AIP), Ludwig-Maximilians-Universität (LMU), Max Planck Institute for Astrophysics (MPA), Max Planck Institute for Extraterrestrial Physics (MPE), and my Humboldt host institution, the Max Planck Institute for Astronomy (MPIA).

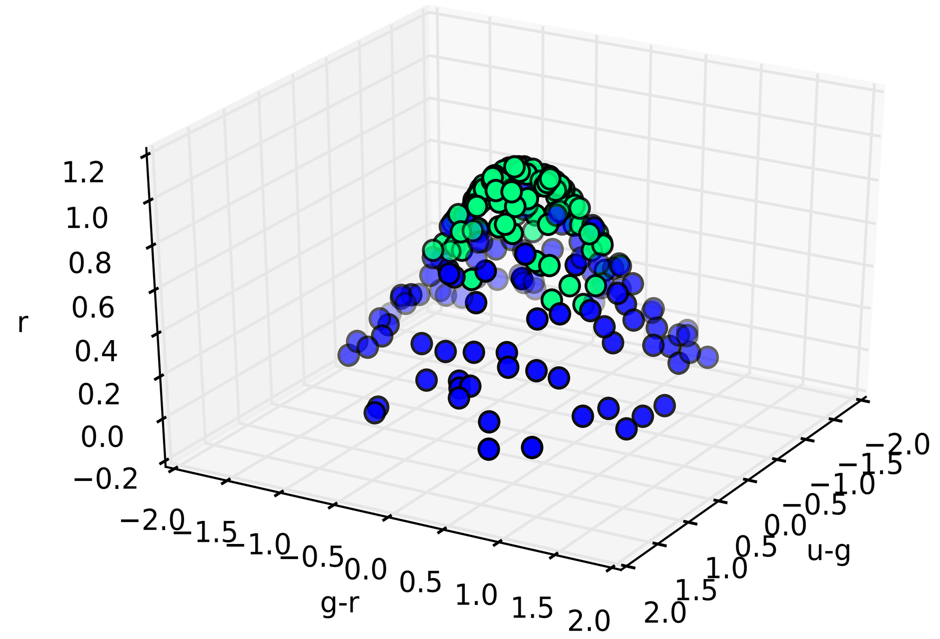
In a typical astronomical experiment color-color diagrams such as shown in the **bottom-right panel** below would be used to identify the best candidates for follow-up spectroscopy in order to positively confirm the type of object and the cosmological redshift (distance). LSST's lack of a spectrograph means that LSST science must be conducted only using the pictures taken by the camera (e.g., **bottom right of the facing panel**). However, the imaging camera is multi-colored, taking pictures in 6 bandpasses spanning ~300nm to 1100nm (**below**). This multi-color photometry enables low-resolution object classification and distance estimates.







Modern machine learning algorithms will take the place of spectroscopy for LSST and will be tasked with identifying the type of each of the 40 billion sources the observatory will detect and estimating their redshifts (distances). Attributes that we can use for classification include fluxes (in 6 bands), variability (**above**), motion on the sky, morphology, and sky position (with respect to the Galactic plane). The classification problem for quasars is inherently non-linear as they are in regions of parameter space that are not necessarily unique in any 2-D projection (e.g., while many of the objects in the bottom-left corner of the **above-right panel** are quasars, there is considerable contamination from white dwarf stars). We show (**right**) an example using a Support Vector Machine (SVM) with a radial basis function to separate two partially intermingled source types.



Conclusion: LSST will be a powerful tool for astronomy in the decade to come. However without modern machine learning tools it would struggle to realize the difficult science goals that we hope to achieve.

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