Transiting Exoplanets with LSST: The challenge of sparsely-sampled light curves

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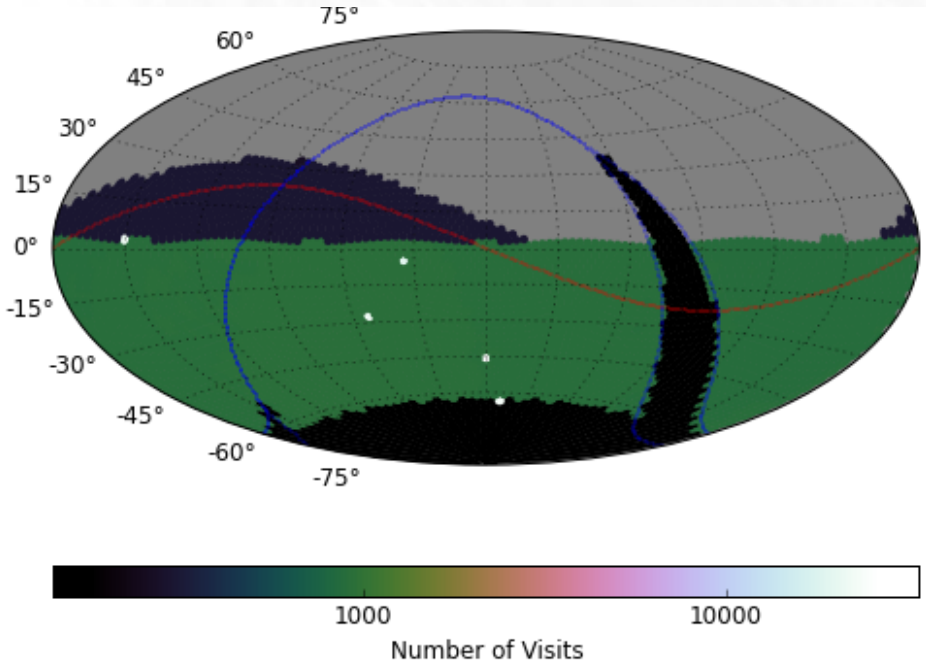
Overview

- Why use LSST for planets?
- High Cadence fields
  - Standard algorithms in planet detection work
- Low Cadence fields
  - New approaches will be needed
  - We need help developing these methods

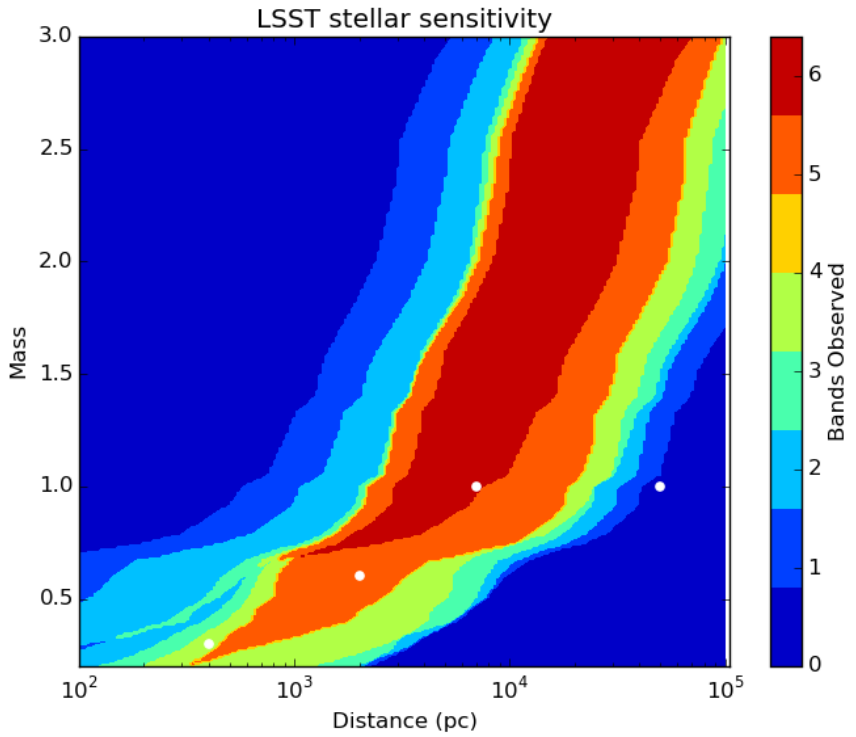
LSST Basics

- Multiband observations
- Deep-drilling fields: ~10,000 observations
- Wide-Fast-Deep fields: ~1,000 observations



Why planets with LSST?

- LSST will produce 1 billion light curves
- Stars will be in regions not normally included in transiting planet searches
  - Red dwarfs
  - cluster stars
  - Galactic Bulge
  - LMC



LSST Limits and Opportunities

- Faint stars mean follow up will be very limited, better to rely only on LSST data
- LSST will provide 6 bands of observation
  - Transits are achromatic, astrophysical false positives like eclipsing binaries are often not
- Possibility to use LSST to compare planet formation rates in different environments

Transiting Exoplanets

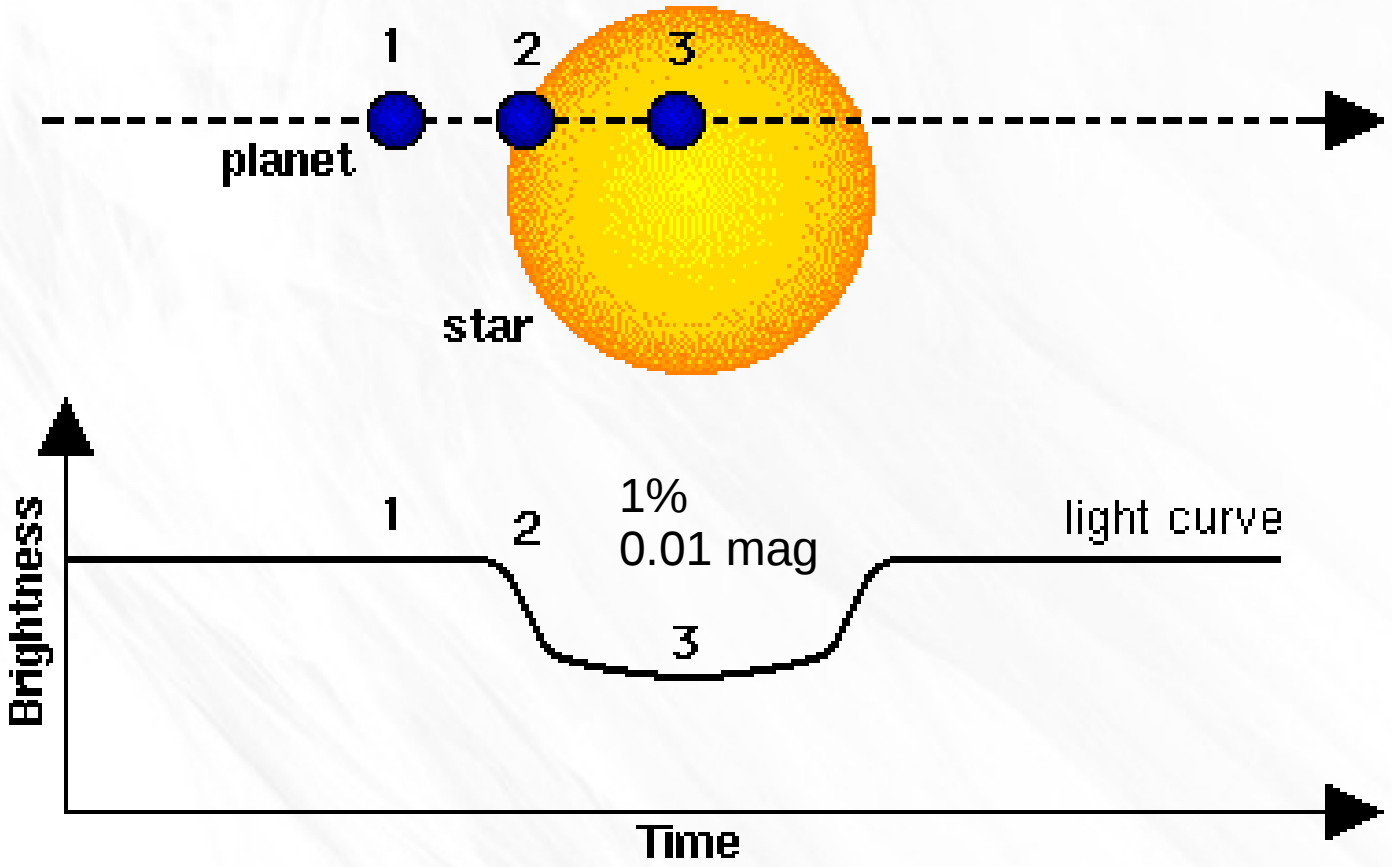
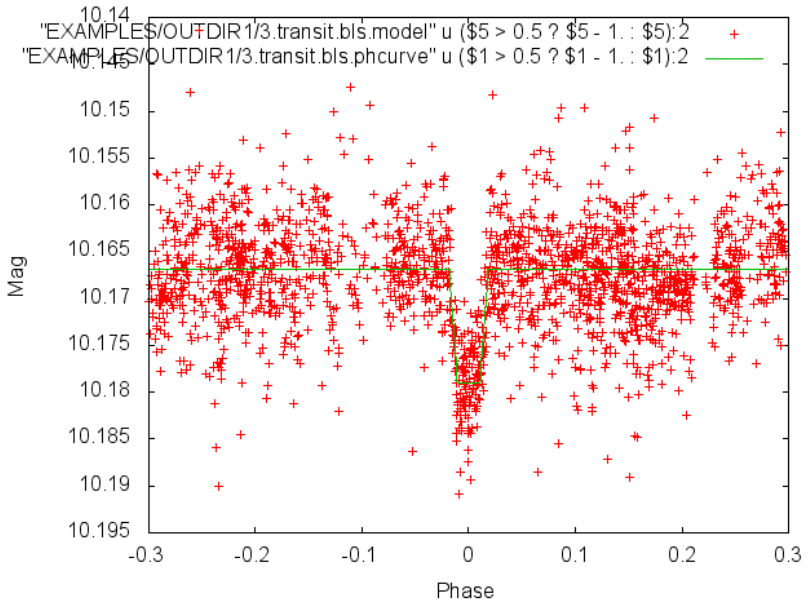
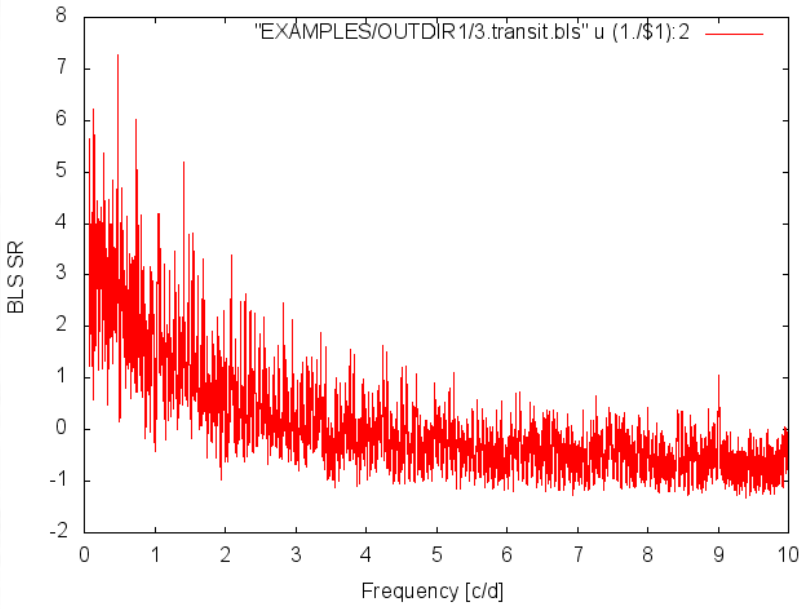


Image from AstronomyOnline.org

Finding Transiting Exoplanets
(normally)

- Box-fitting Least Squares (BLS) algorithm
- Assumes periodic signal with only two values
- Solves for period, time spent in transit, depth of transit, epoch of transit

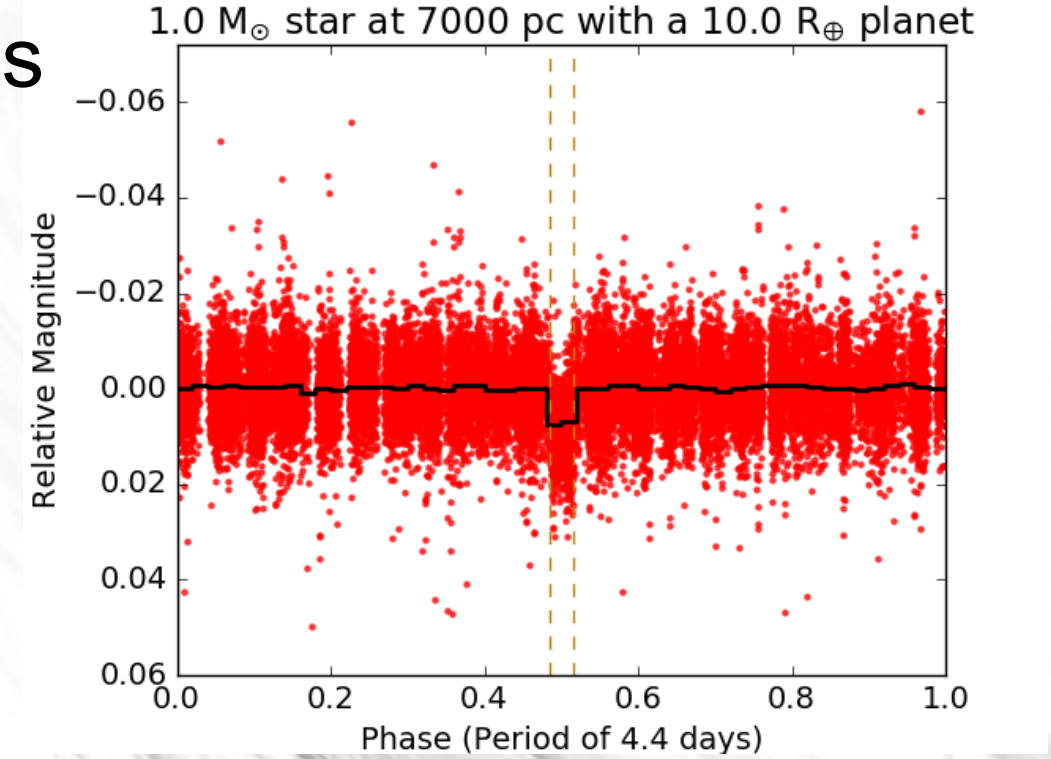




VARTOOLS example code

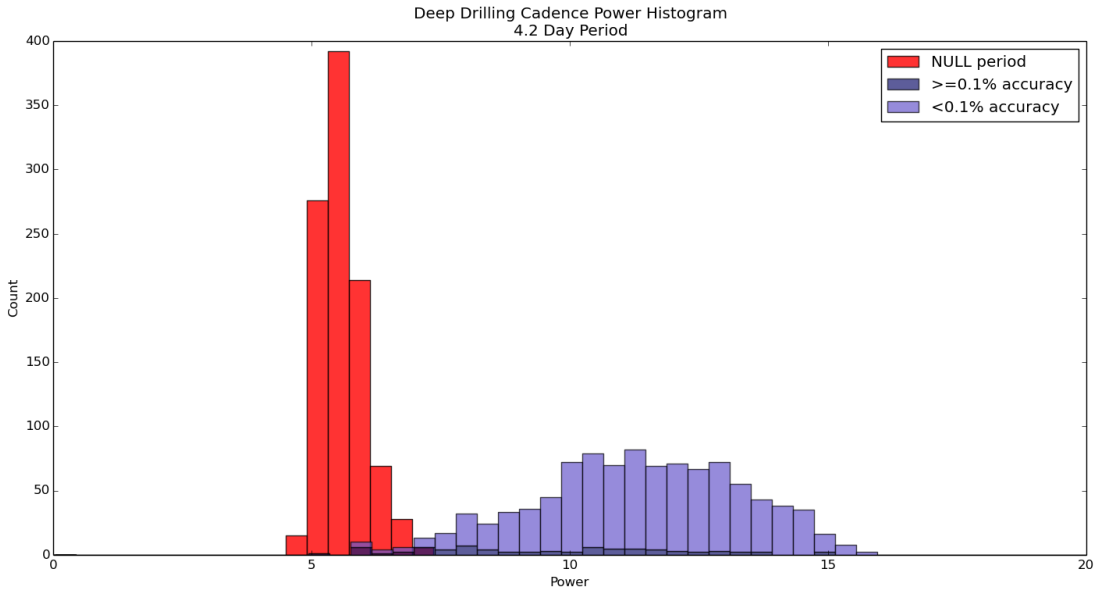
High Cadence Fields

- Comparable # of observations per year to ground-based surveys
- BLS is a useful approach here
- Approx 2 minutes per light curve



High Cadence Fields

- BLS can be used to detect a large number of transiting planets in these fields
  - BLS power from transiting planets is much larger than signals caused by noise



Jacklin et al 2015

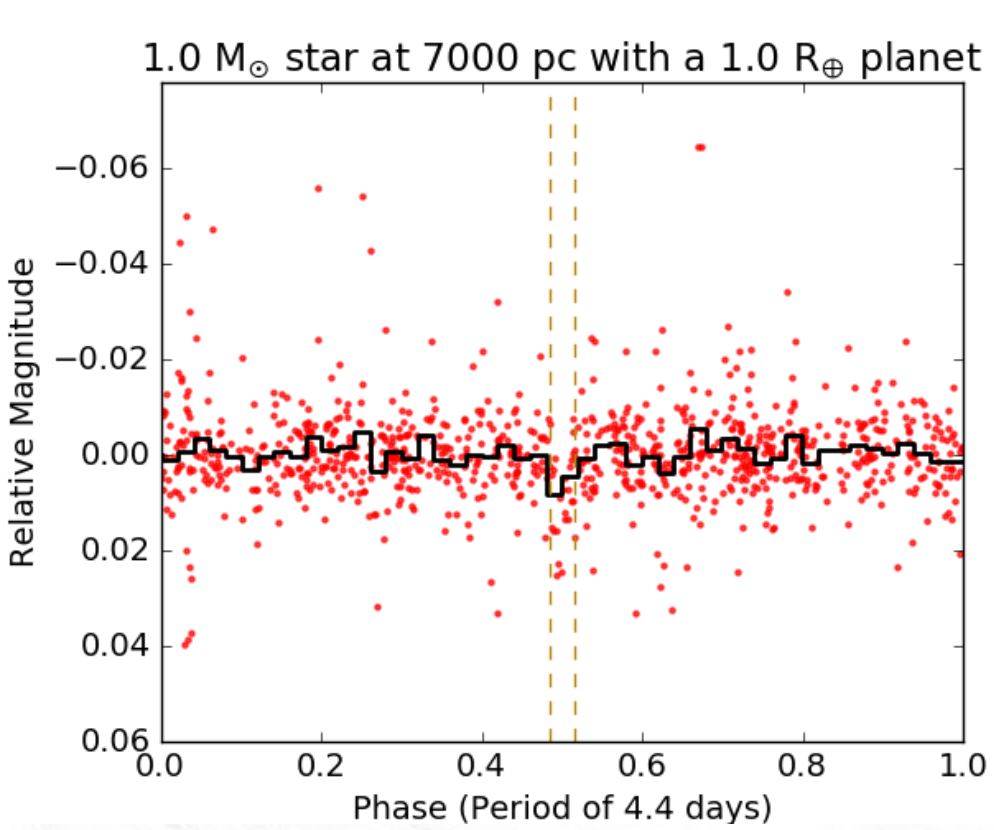
High Cadence Field Summary

- Standard detection methods can be easily applied with promising results
- Also see Lund et al. 2015, Jacklin et al. 2015, more papers in prep

- However, these fields will be < 100° of over 20,000° surveyed

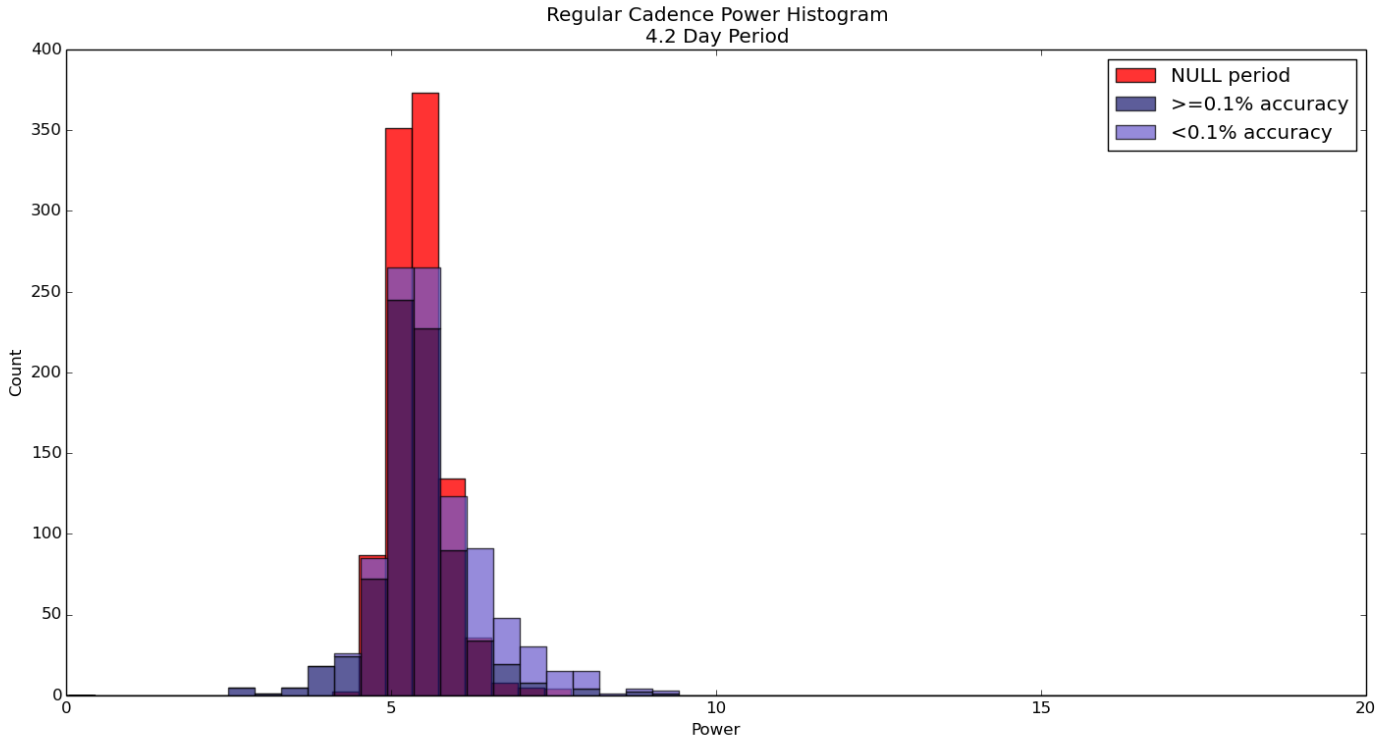
Low Cadence Fields

- Very sparsely sampled light curves
  - ~100 observations per year
- BLS limited to very short periods



Low Cadence Fields

- Even when BLS is accurate, power is not significantly different from signal strength from noise



Low Cadence Summary

- Most stars that LSST will observe will have ~1000 observations or fewer
- We need a computationally quick way to find transiting planet candidates
- We can sacrifice completeness if we can still understand limits of this method

Low Cadence Data Sets

- In the process of creating several large data sets that will be publicly available at astro.phy.vanderbilt.edu/~lundmb/LSST_challenge.html
- Stars without large transits will greatly outnumber host stars
  - false positives could swamp the candidates we care about
  - False negatives just need to be quantified

Future Challenges and Applications

- Once we can detect real signals from the background noise, we will also need to be able to separate transiting planets from other astrophysical signals
  - Stellar variables
  - Eclipsing binaries
- Low cadence light curves are also data products from Hipparcos and Gaia

Summary

- LSST provides a tool for finding planets in many stellar environments
- Most stars will be observed at low cadence
- We need new statistical tools for this domain

- **How do we find a needle in a haystack?**
- **What fraction of needles do we miss?**
- **How many needles are there?**