The LSST Operations Simulator

K.H. Cook (LLNL/NOAO), A. Saha, R. Allsman, F. Pierfederici, F. Delgado, (NOAO), P. Pinto (UA)

With its unprecedented combination of collecting area and field of view, the LSST will image large areas of the sky frequently and to great depth. The cadence of these observations, the order in which different fields of view are observed in each color and the frequency with which they are revisited, will determine just how much sky will be covered, to what depth, and with what temporal sampling. This in turn will determine how useful LSST data will be to different investigations. The development of observing cadences is thus an important part of the LSST design process. A great many scientific programs require multiple, short exposures. As a result, detailed simulations of a decade of LSST operation demonstrate cadences which will satisfy a wide variety of scientific requirements simultaneously. They also demonstrate that there is surprisingly little conflict among the cadence demands of projects as diverse as whole-sky weak lens surveys, near-Earth asteroid, outer solar system, and supernova searches, and catching transients and characterizing variability on a wide variety of timescales. This shows that the LSST need not be "over-engineered" for any given project to be useful for doing many at the same time.

The simulator must answer the question whether proposed sites and telescope designs can meet the science requirements.

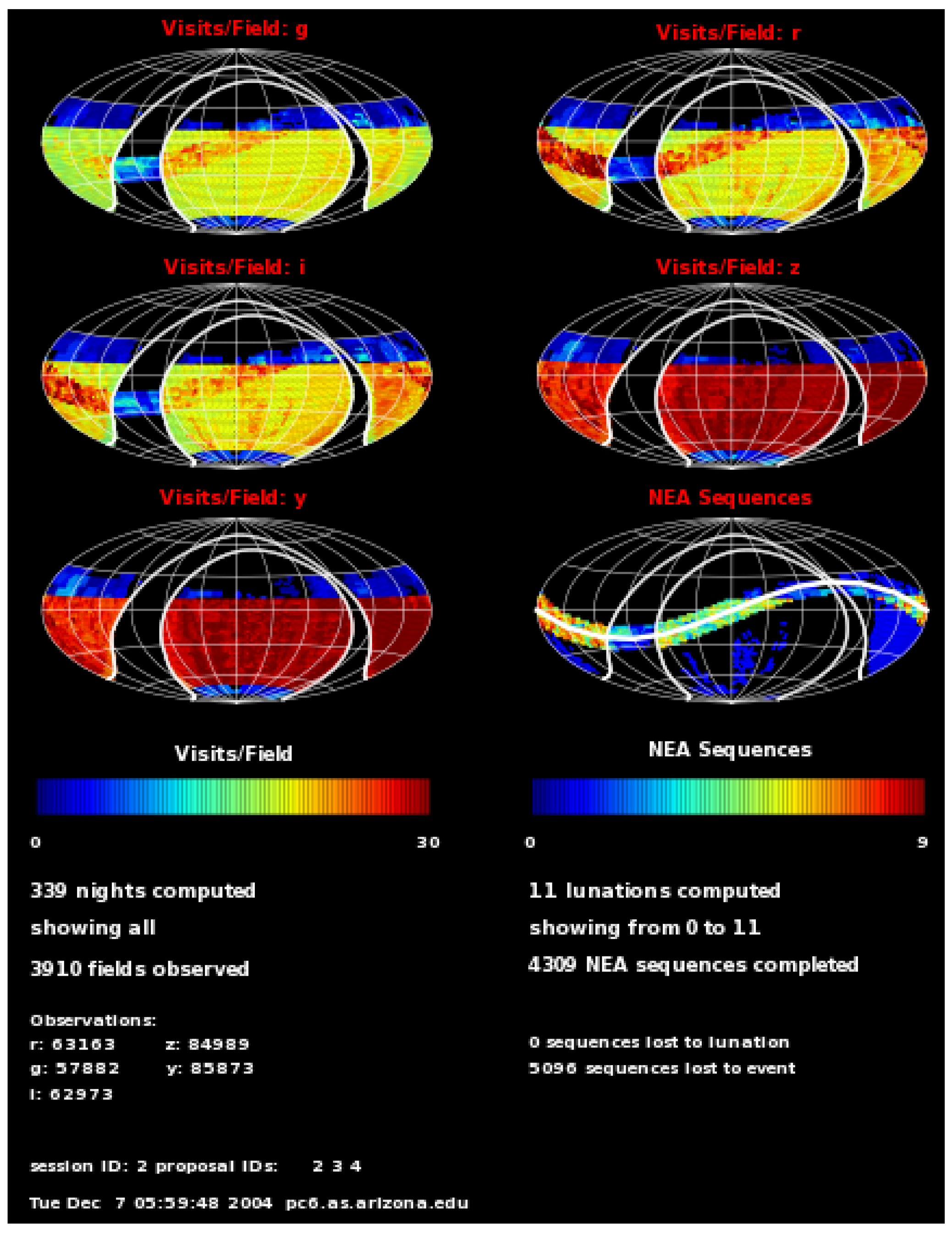
- **There are distinct science goals for the LSST**
  - –Weak lensing
  - –Potentially hazardous asteroids
  - –Supernovae for cosmology
  - –The transient universe
  - –Astrometry for proper motions and parallaxes
- **The operations simulator is a tool to investigate telescope and camera design, observing cadences and strategies**
  - –Will one, or a few cadences suffice?
  - –Will the proposed etendue deliver the science?
  - –Will a particular site allow needed coverage?
  - –Will the proposed telescope design carry out the science programs?

The Simulator Design:

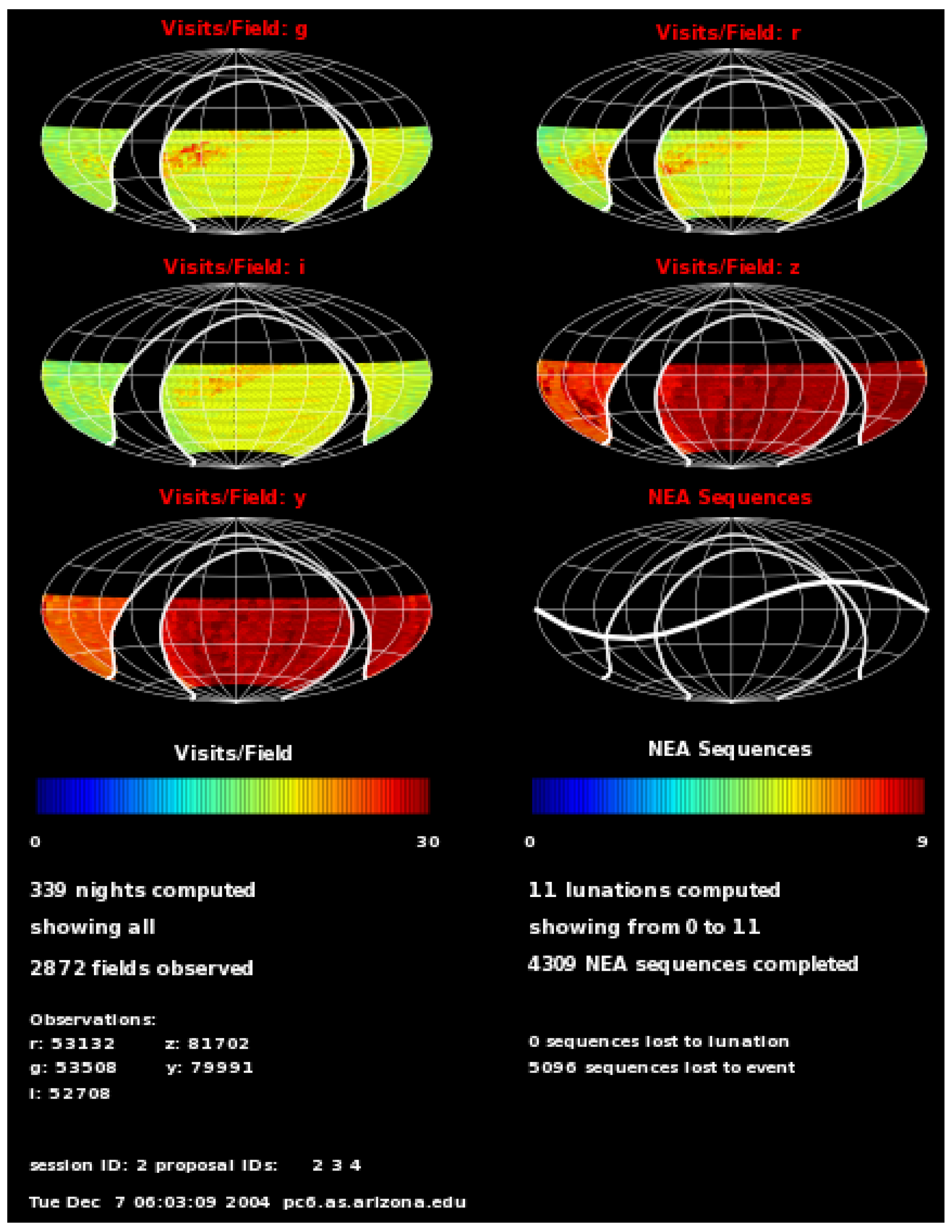
- **Open source based simulation language:**
  - **SimPy (=** ***Simulation in Python*****)** is an object-oriented, process-based discrete-event simulation language based on standard Python.
- **Modular design**
- **All parameters easily set in configuration files**
- **Site and weather configurable**
- **Science program design configurable**
  - –Will accept multiple, distinct, programs
  - –Can model different sites, weather, altitude, latitude…
- **Sophisticated sky model**
  - –Sky brightness from Krisciunas and Schaeffer (1991)
  - –Astronomical objects
- **Sophisticated telescope model**
  - –All motions parametrized

The Simulator Operations:

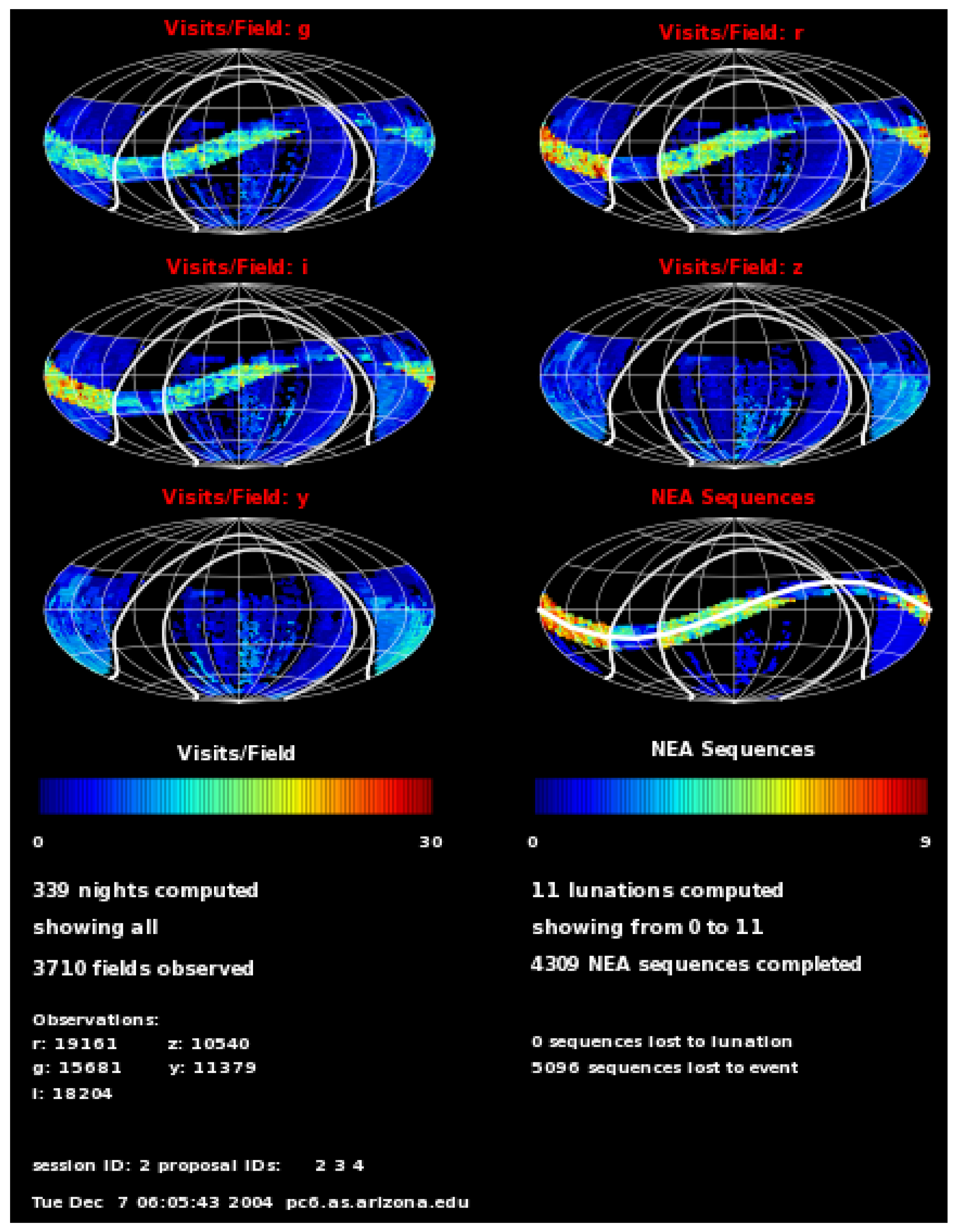
- **Three science programs implemented, more can be added**
  - –Weak Lensing
    - •total visits per field/filter combination is goal
    - •Can set each filter requirements for visits and seeing
  - –NEA
    - •Flexible cadence, currently a strict Harris cadence: (3 x 2 visits) per lunation
    - •NEA sequence can cross lunation, current simulations do not
  - –Supernovae
    - •Flexible transient cadence (~every 3 days for 60 days required in multiple filters)
- **Ranking of fields within a program based upon settable parameters**
- **Ranking of fields between programs equal, can be changed**
- **Speed: 1-2 minutes/day depending on # of proposals being evaluated**
- **Weather: currently 339 days of *real* CTIO seeing and transparency data multiple years for four sites being implemented**
- **Exposures can fulfill multiple science goals**
- **Mysql database stores results**
- **Visualization tools available (see figures below)**



Three programs coverage of the sky from Cerro Pachon using real CTIO seeing corrected to Cerro Pachon

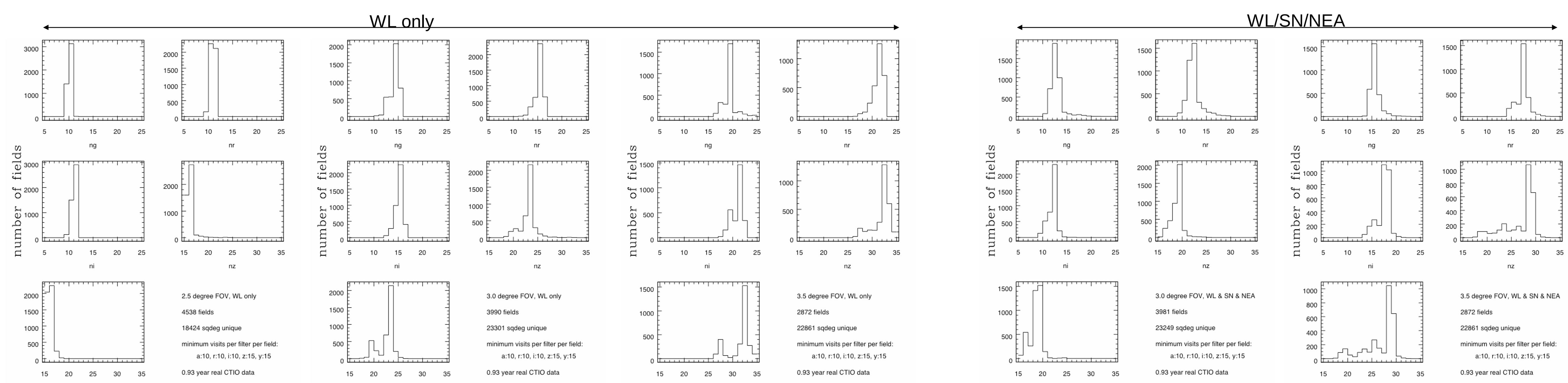


Weak lensing appropriate sky coverage for 339 days of CTIO weather from Cerro Pacho with SN/NEA programs running too.



Transient fields with completed sequences observed (NEA and SN programs) for 339 days CTIO weather from Cerro Pachon with WL/SN/NEA programs running.

Sky coverage for a *single* simulation where three science goals are being sought: 1) Weak lensing (WL) with a minimum of 15, 15, 15,25, 25 visits per field in g, r, i, z, and y, 2) Near Earth Asteroid survey where this survey is limited to +/- 10 degrees of the ecliptic and a complete search sequence has 3 sets of 2 visits per night in a lunation, and the nightly visits are separated by 30 minutes and the 3 sets are separated by 5 nights each, and 3) Super Nova survey where a super nova sequence requires a visit roughly every 3 days for 60 days and sampling in all filters. The left panel shows total visits per field, the middle panel shows visits which could be used for the WL survey, and the right panel shows fields which had completed super nova or NEA sequences.



Results from simulations for 2.5, 3.0 and 3.5 degree FOV focal planes performing just a Weak Lensing survey (WL), *or* performing simultaneous weak lensing (WL), supernova (SN) and near earth asteroid (NEA) surveys using minute-by-minute, CTIO seeing and cloud data. The plots are histograms of the number of visits per field in each filter where that field has a minimum of the required visits in each filter. The visit set of 10, 10, 10, 15, 15 per year in g, r, i, z, y, is the minimum needed for the WL science. *The 2.5 degree FOV achieves 4,500 square degrees less for a pure WL survey and does not achieve the needed sampling for any field for multiple science goals with the current weighting criteria.*

Conclusions:

•Multiple science programs can be successfully carried out over 23,000 square degrees with current LSST point design (3.5 degree FOV)

•For multiple science programs, the 3.0 FOV barely meets (does not completely cover the accessible area) the WL visit requirement, while the 3.5 degree FOV covers the available area with visits to spare.

•LSST science goals can be carried out with the current design under real weather and seeing conditions.