

Centaur's with the Large Synoptic Survey Telescope

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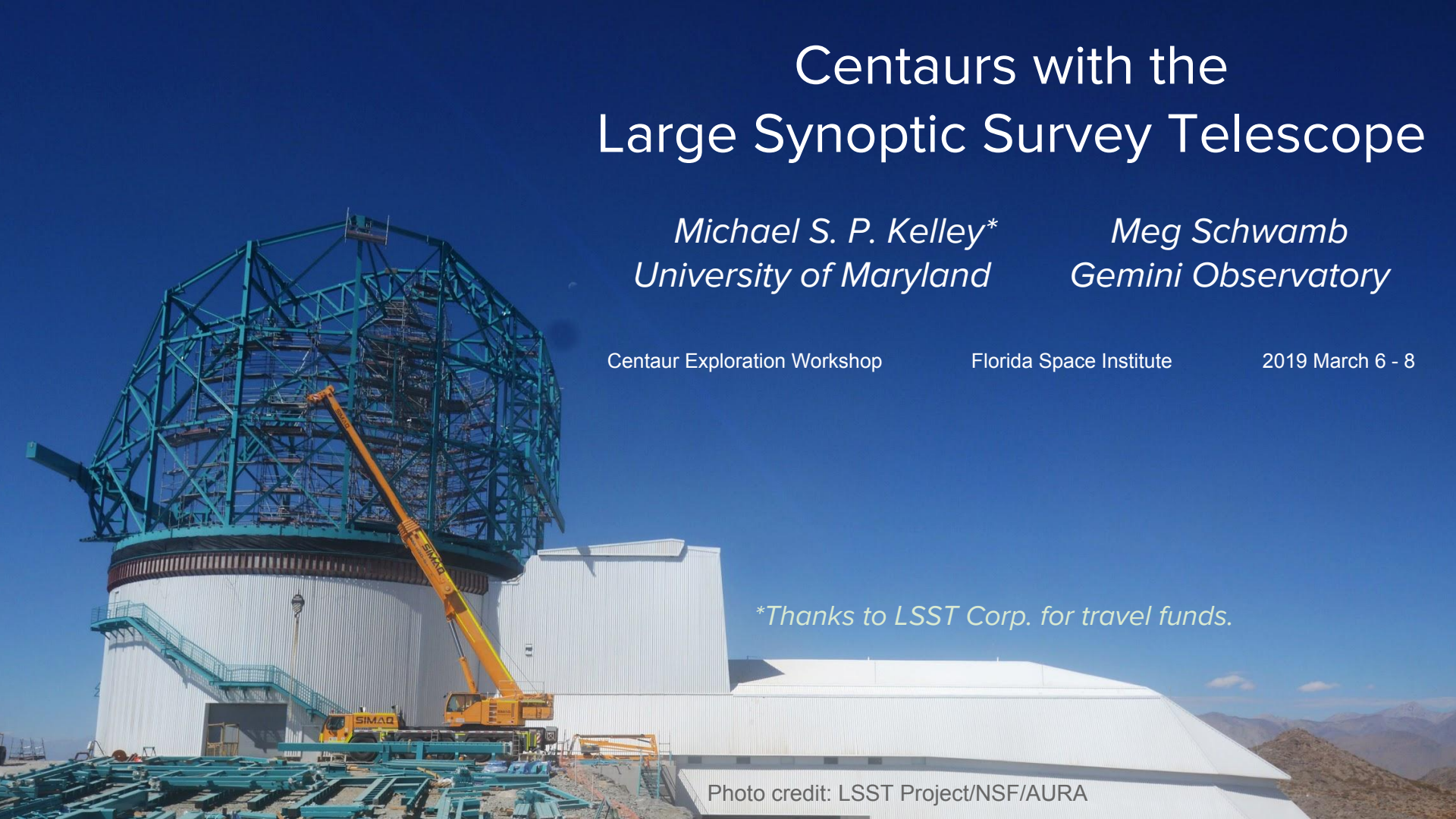
Centaur Exploration Workshop

Florida Space Institute

2019 March 6 - 8

**Thanks to LSST Corp. for travel funds.*

Photo credit: LSST Project/NSF/AURA



LSST Solar System Science Collaboration (SSSC)



David Trilling & Meg Schwamb
SSSC Co-Chairs



Active objects Working Group (Lead: Mike Kelley): broadly consisting of all categories of activity in the minor planet populations: short period comets, long period comets, main belt comets, impact- or rotationally-generated active asteroids, etc



Community software/infrastructure development Working Group (Lead: Henry Hsieh): broadly consisting of people interested in helping build databases, software packages, etc to be used by the Solar System community on LSST data



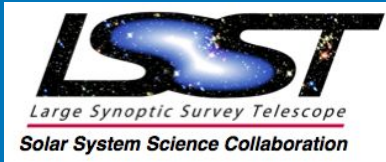
Inner Solar System Working Group (Lead: Cristina Thomas): broadly consisting of the main belt, Mars/Jupiter Trojans, and Jupiter irregular satellites



NEOs (Near Earth Objects) and Interstellar Objects Working Group (Lead: Steve Chesley): broadly consisting of objects on orbits inward of or diffusing inward from the main belt as well as interstellar objects temporarily residing in the Solar System



Outer Solar System Working Group (Lead: Darin Ragozzine and Matt Holman): broadly consisting of KBOs, Centaurs, Oort cloud, Saturn/Neptune/Uranus Trojans, and Saturn/Neptune/Uranus irregular satellites



www.lsstsssc.org



Wes Fraser
LSST: UK Solar System POC

LSST

Large Synoptic Survey Telescope

An optical, time-domain survey telescope.

At Cerro Pachón, Chile.

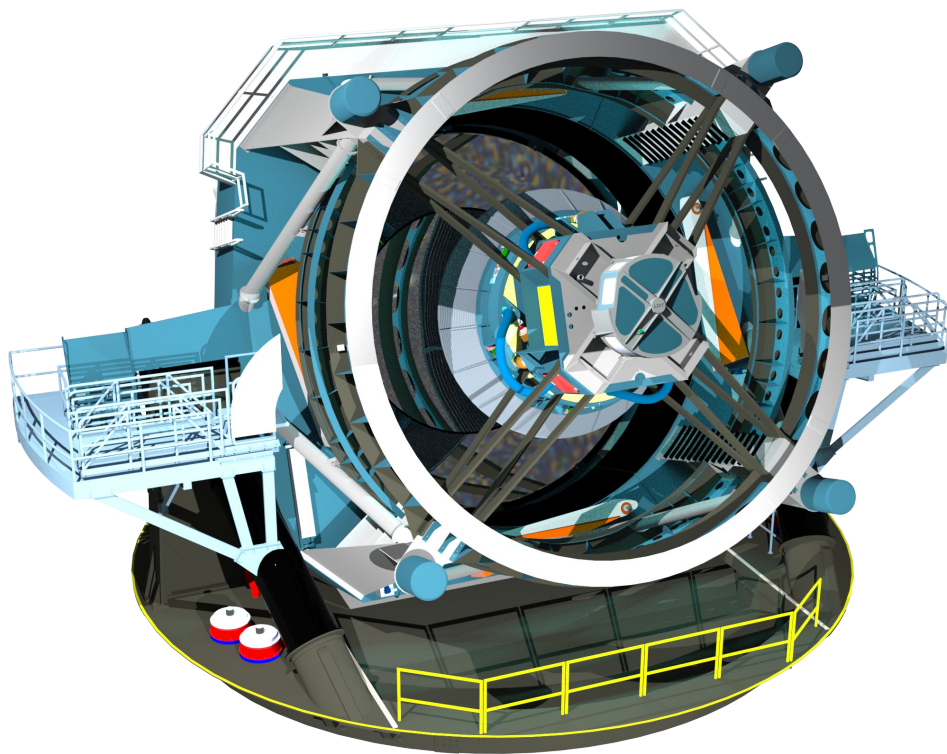
8.4-m primary mirror and 3.2 gigapixel camera.

189 $4k \times 4k$ CCDs, 0.2" per pixel, >90% fill factor.

9.6 square degrees FOV.

30-s exposure 5σ depth 22 to 25 mag.

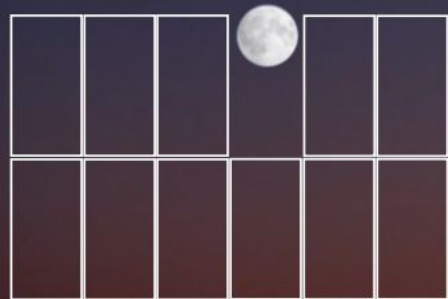
About 2.6 million sky images over 10 years.



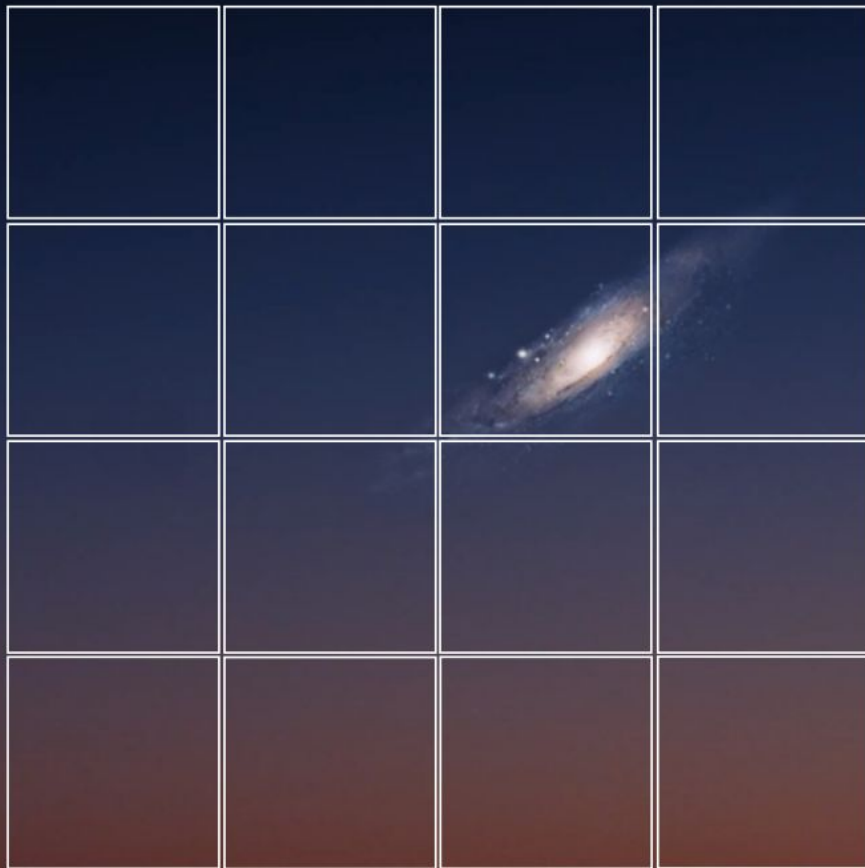
HSC,
1.7 deg²



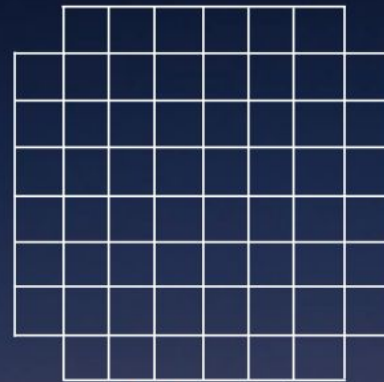
DES,
2.5 deg²



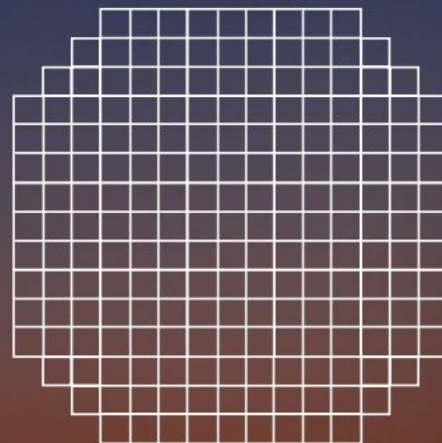
PTF/iPTF, 7.3 deg²



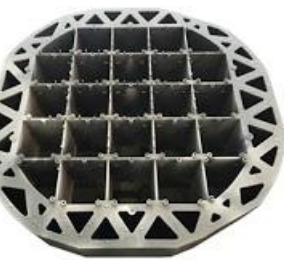
ZTF, 47 deg²



PS1, 7 deg²



LSST, 9.6 deg²



Plane received
Light up LSST network

50% Sensor Production Complete
Summit substantial completion

Auxiliary Telescope data processing system available
Camera L1-L2 assembly complete

Telescope & Site substantial completion, System integration & test start
System First Light

Data Access Services available at US DAC

Full science operations Survey Begins

2018

2019

2020

2021

2022

2023

First Prototype Science Platform

Commissioning Camera ready for testing

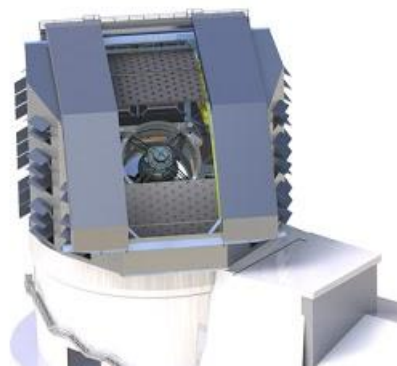
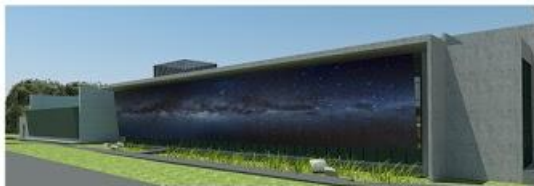
Engineering first light

Science verification complete

First production science raft complete

Base facility complete

Camera ready at SLAC



2nd LSST Solar System Readiness Sprint

June 4-6, 2019
Chicago, IL

<https://goo.gl/forms/xXadBR9iqqRatmbV2>

ADLER

PLANETARIUM



Image credit: - Chris Smith -
flickr



We are expecting 1000s of Centaurs will be observed and characterized with LSST (LSST Science Book)

But what does that exactly mean?

→ With LSST operations simulations and a catalog of Centaur orbits, we can determine what kind of data to expect, and consider what results can be made from those data.

Processing ([Info](#))

List Of Centaurs and Scattered-Disk Objects

Information on [converting absolute magnitudes to diameters](#) is available, as is an [explanation of the quantities given](#).

This list is updated daily and is also updated as and when new objects are discovered.

Designation (and name)	Prov. Des.	q	Q	H	Epoch	M	Peri.	Node	Incl.	e	a	Opp
2019 CY4		10.090	84.798	11.2	20190427	359.9	87.3	61.5	19.6	0.787	47.444	(
2019 CR		5.871	23.153	13.4	20190427	351.8	332.4	23.1	160.3	0.595	14.512	
2019 AB7		20.332	33.302	9.5	20190427	15.4	36.4	64.6	12.1	0.242	26.817	
2018 V035		33.448	222	6.6	20181208	342.8	307.5	235.9	18.6	0.738	128	(
2018 VM35		45.289	436	7.6	20181208	356.2	302.0	192.5	8.5	0.812	241	(
2018 VG18		21.739	169	3.6	20181118	73.8	32.9	247.4	31.7	0.772	95.234	(

MPC list with:

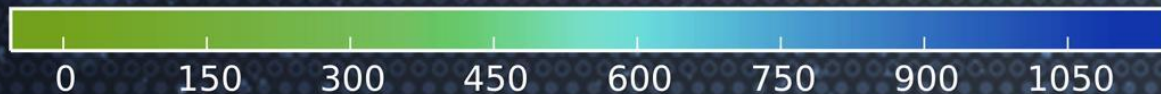
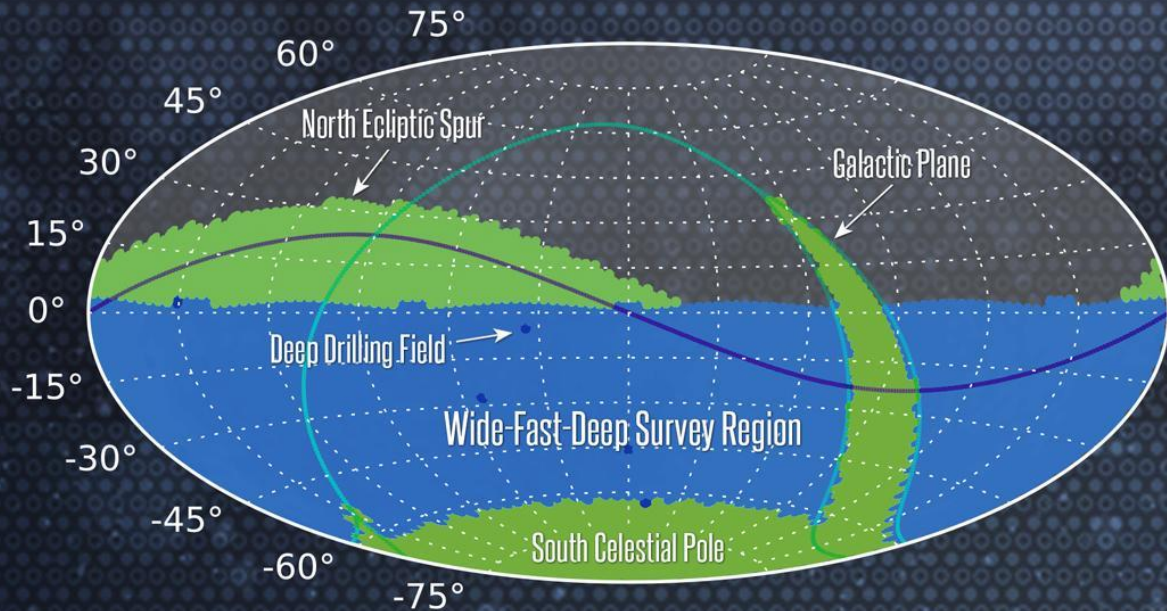
- $a_J < q < a_N$
- at least 1 opposition of astrometry

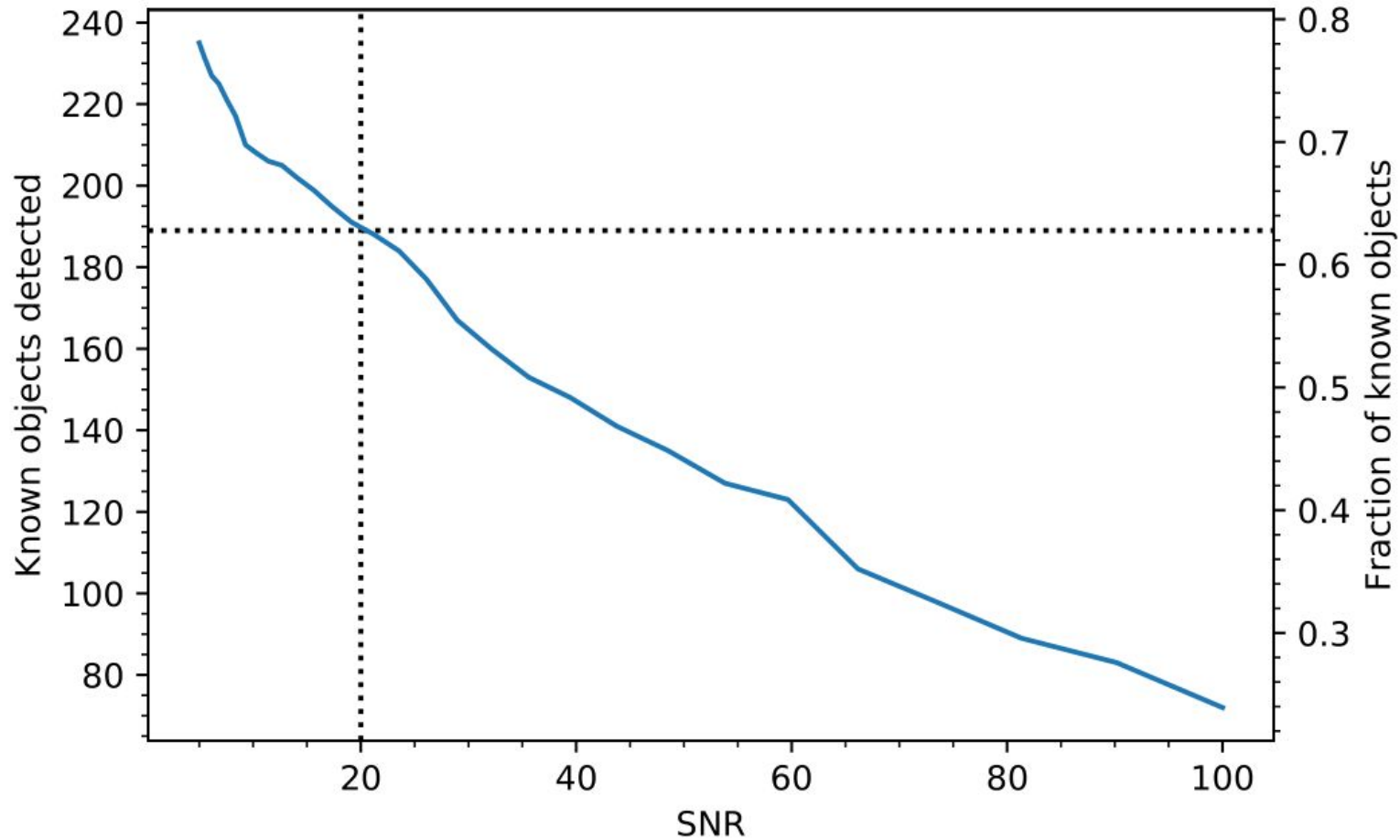
→ 302 objects

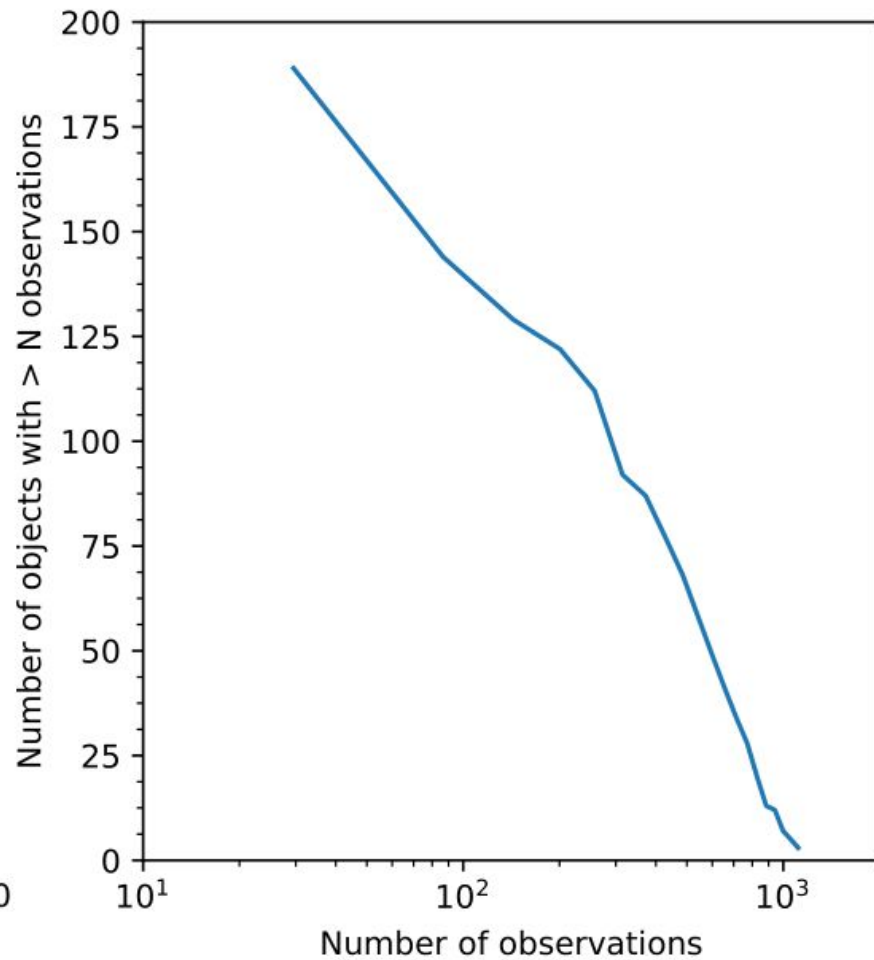
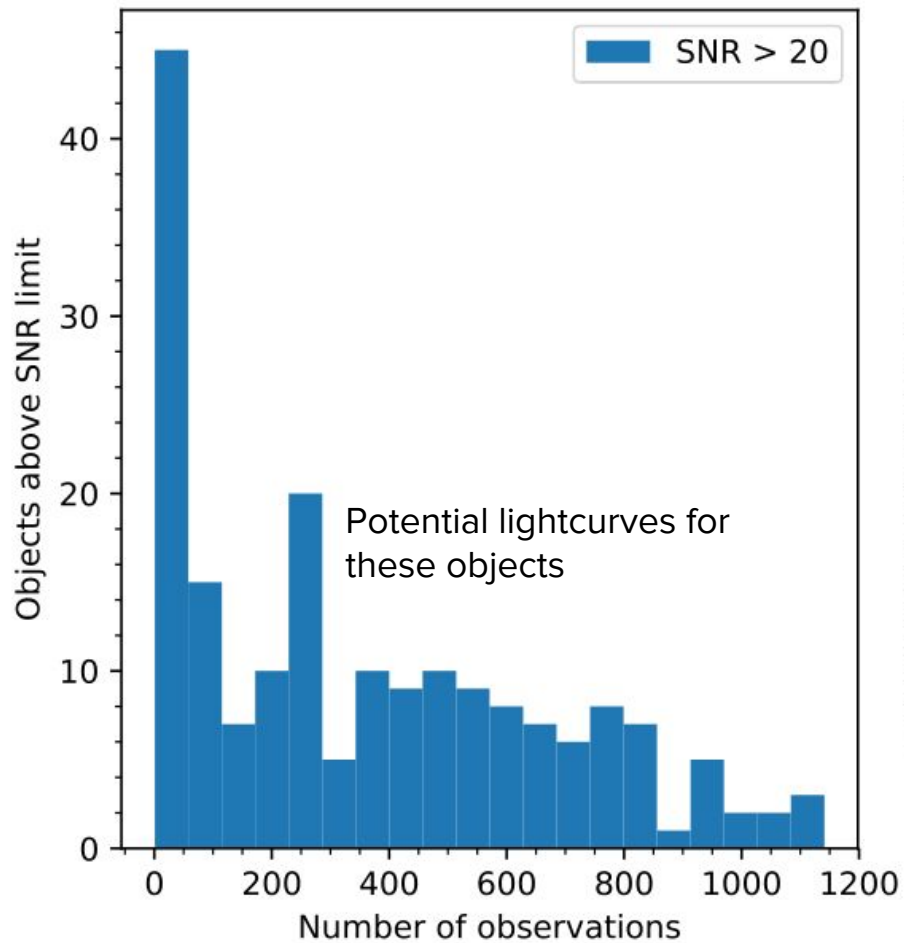


Number of Visits

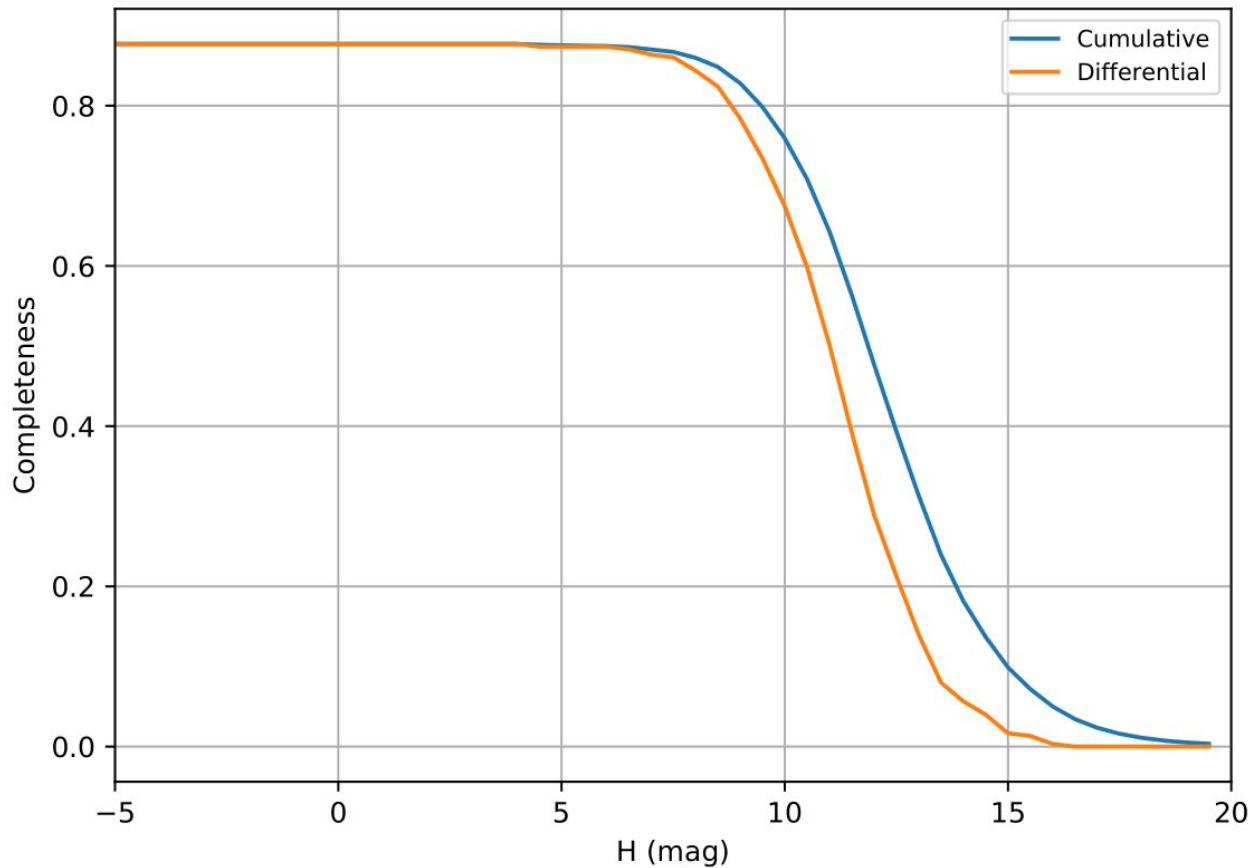
(all-band, 10 years)







Biased example



A notional plot of what could be done.

Assumes $dn/dH = H^{0.33}$

These differential and cumulative completeness curves are based on a list of **known objects**, which is a **biased sample** of the Centaur population.

What to expect from today's known population?

- Lightcurve inversion
- Colors, and distribution with H
- Activity distribution
 - vs. true anomaly for closer objects
 - vs. heliocentric distance for the population
- LSST + Gaia catalog = occultations: diameters and rings
- LSST + JWST = surface composition
- LSST + ALMA = ????
- LSST + your telescope here =

How do we effectively study LSST's Centaur discoveries?

Centaur science has key time-domain aspects: not just new objects, but also events like outbursts, and new activity.

- Follow-up resources are limited, especially those that are queue scheduled, due to demand from all time-domain disciplines.
- How can we enable communication between the collaboration?
- Would Centaur and other Solar System astronomers want a new iteration of the observing campaign site? or an evolution of it?

General Solar System Data Products

Prompt Products

Nightly or shorter timescale.

- Alerts associated with all identified solar system objects, including metadata.
- Moving object tracks (to MPC).
- Orbit catalog for LSST discovered objects.
- Calibrated images.

Data Release Products

Annual release schedule.

- Object catalog with precise photometry.
- Re-calibrated images.

A lot of the tools to efficiently digest these products are up to the community to develop.

Centaur's observed via the Baseline 2018a simulation.

Note the final survey parameters have not been defined, so any results are notional.

