Solar System Science and LSST

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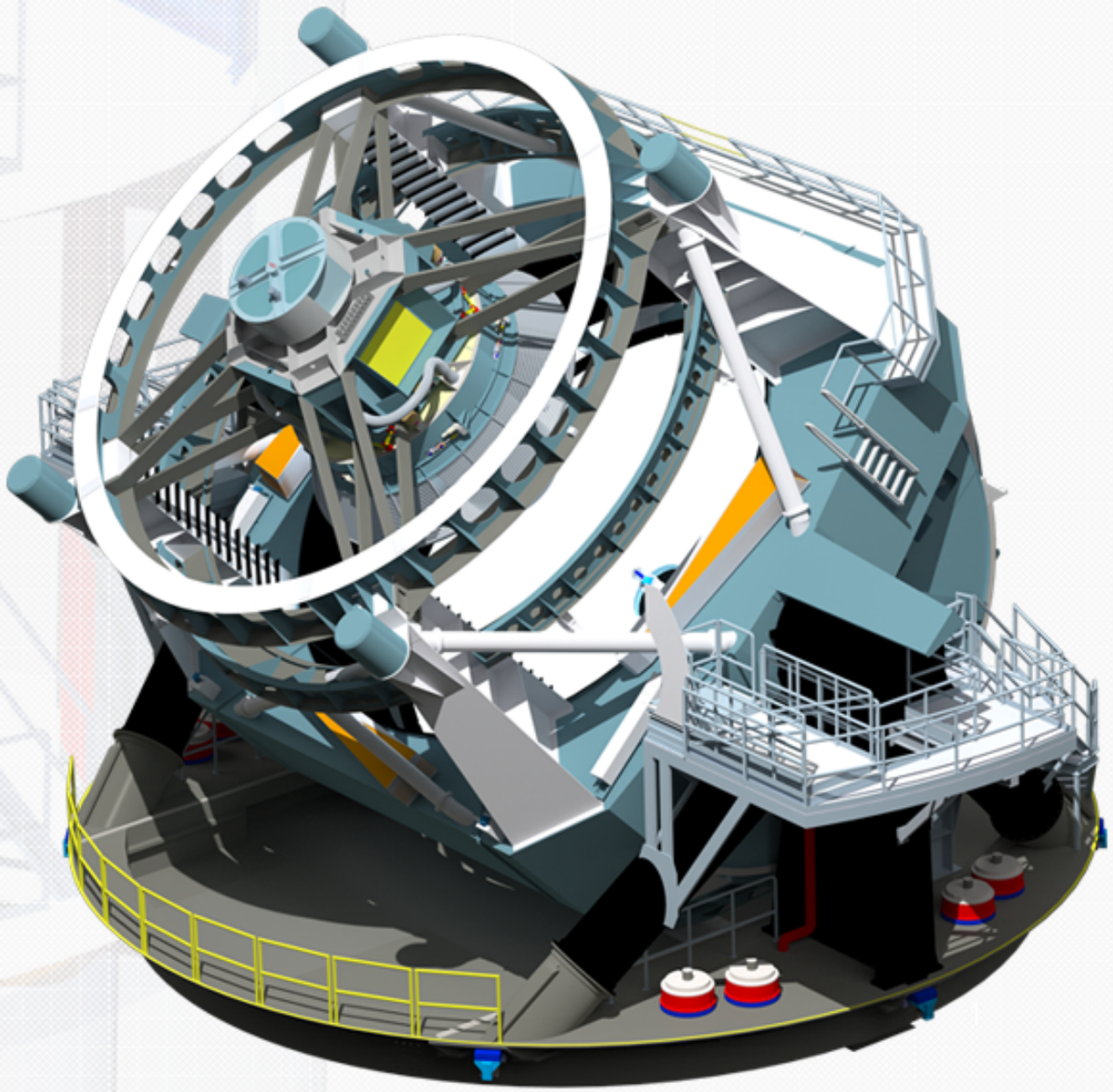
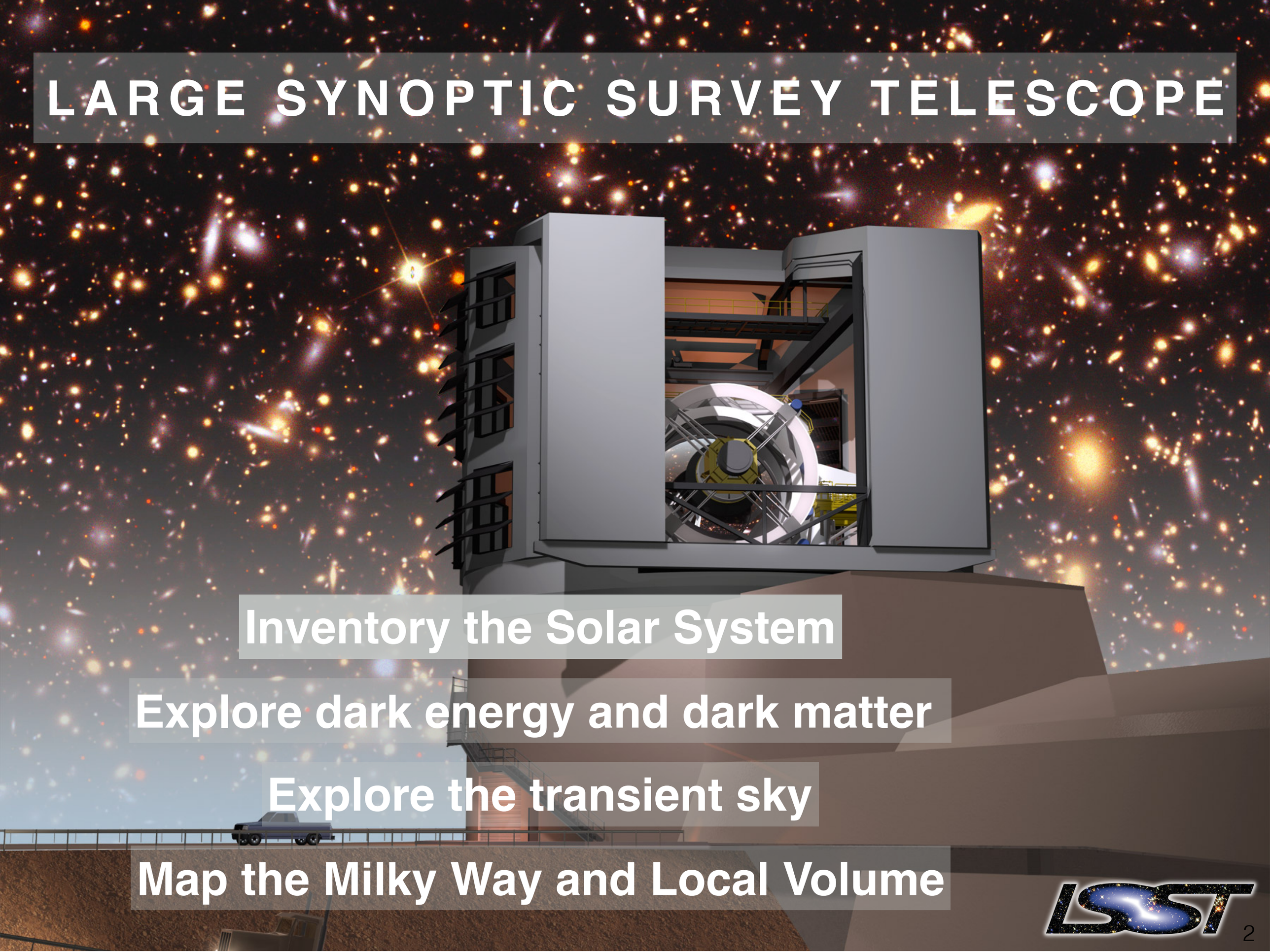
The LSST Simulations Team
The LSST Solar System Science Collaboration



LARGE SYNOPTIC SURVEY TELESCOPE



Inventory the Solar System

Explore dark energy and dark matter

Explore the transient sky

Map the Milky Way and Local Volume

Understanding The Solar System with LSST

10-100x increase in sample size for every small body population in the Solar System

	Currently Known*	LSST Discoveries**	Median number of observations+	Observational arc length+
Near Earth Objects (NEOs)	14,500	100,000	(D>250m) 60	6.0 years
Main Belt Asteroids (MBAs)	650,000	5,500,000	(D>500m) 200	8.5 years
Jupiter Trojans	6000	280,000	(D>2km) 300	8.7 years
TransNeptunian Objects (TNOs) + Scattered Disk Objects (SDOS)	2000	40,000	(D>200km) 450	8.5 years

* As reported by the MPC ** Expected by end of survey +For the brightest objects (near 100% completeness)

Open Data, Open Source: A Community Resource

- LSST data, including images and catalogs, will be available with **no proprietary period** to the astronomical community of the **United States, Chile, and International Partners**

- Alerts to variable and moving sources (explosive transients, variables, asteroids, etc.) will be **available world-wide**, using community-adopted protocols

- LSST **data processing stack will be free software** (licensed under the GPL, v3-or-later)

- **LSST is a public facility: all science will be done by the community (not the Project!), using LSST's data products.**

Level 1

- A stream of ~10 million time-domain events per night, detected and transmitted to event distribution networks within 60 seconds of observation.
- A catalog of orbits for ~6 million bodies in the Solar System.

Level 2

- A catalog of ~37 billion objects (20B galaxies, 17B stars), ~7 trillion single-epoch detections ("sources"), and ~30 trillion forced sources, produced annually, accessible through online databases.
- Deep co-added images.

Level 3

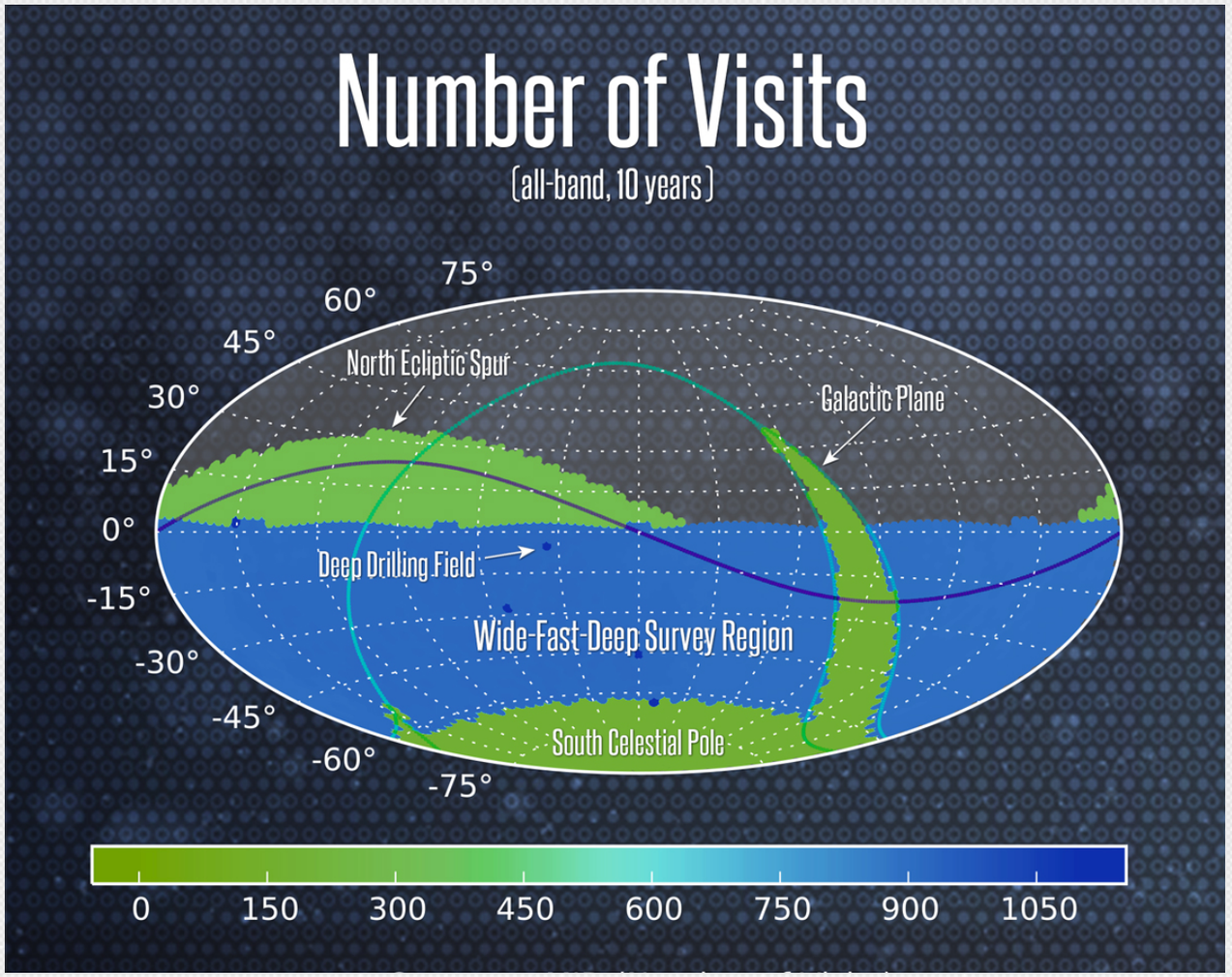
- Services and computing resources at the Data Access Centers to enable user-specified custom processing and analysis.
- Software and APIs enabling development of analysis codes.

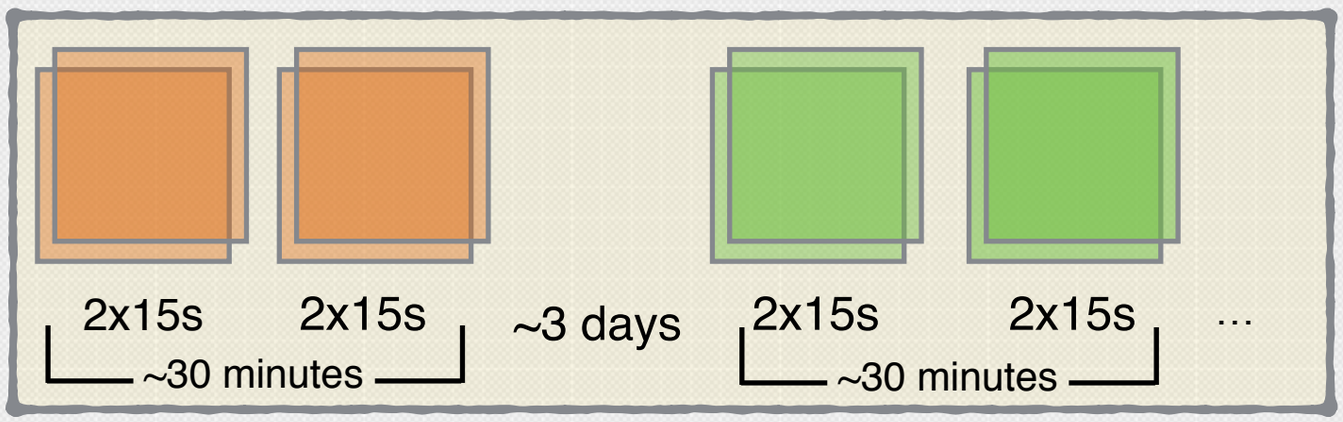
Simulations of LSST survey

Operations Simulator (OpSim)
10 year pointing-by-pointing simulation

Realistic weather
- Sky brightness model
- Seeing history
- Cloud/weather history

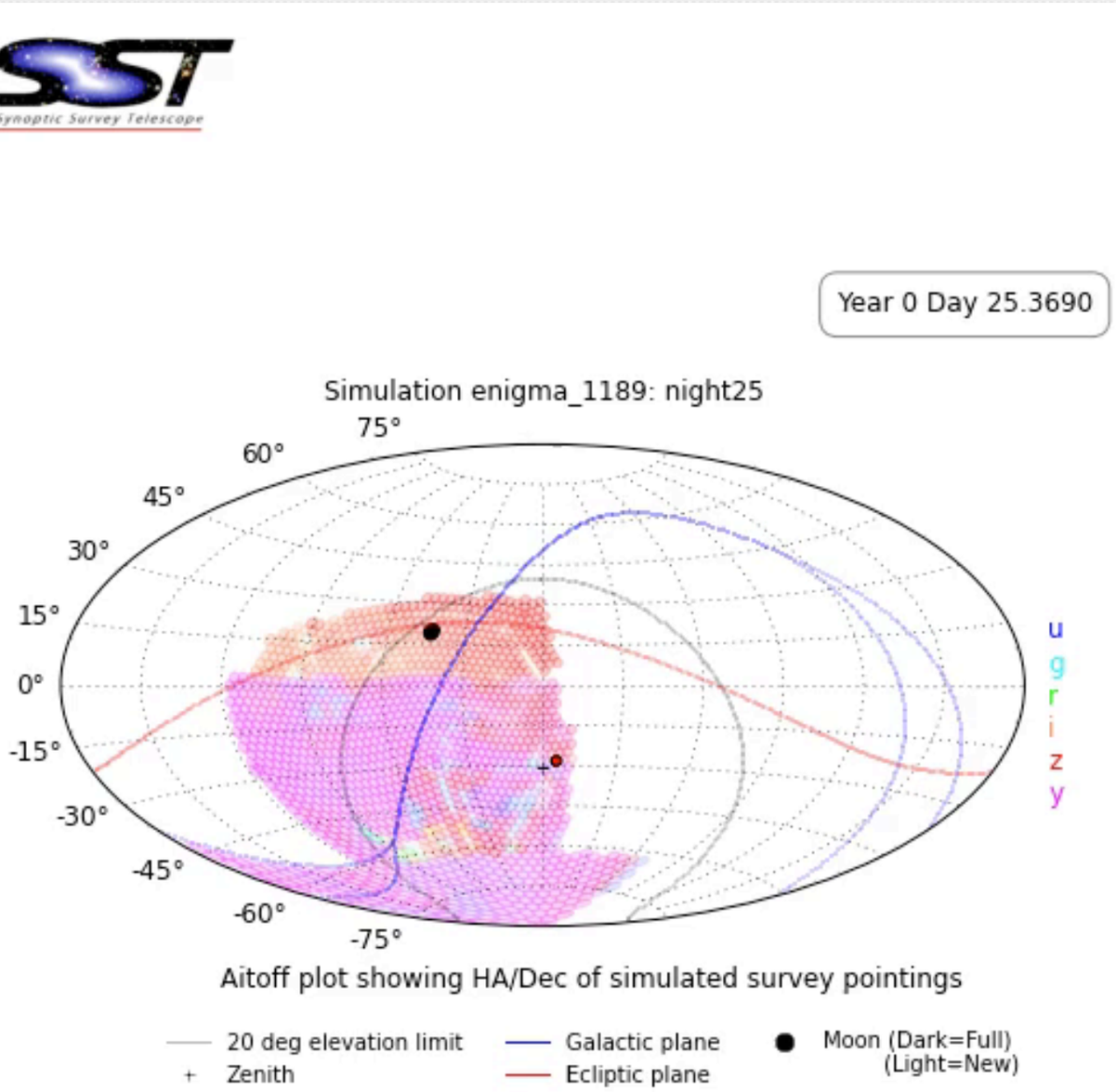
High fidelity telescope model
Observation scheduler

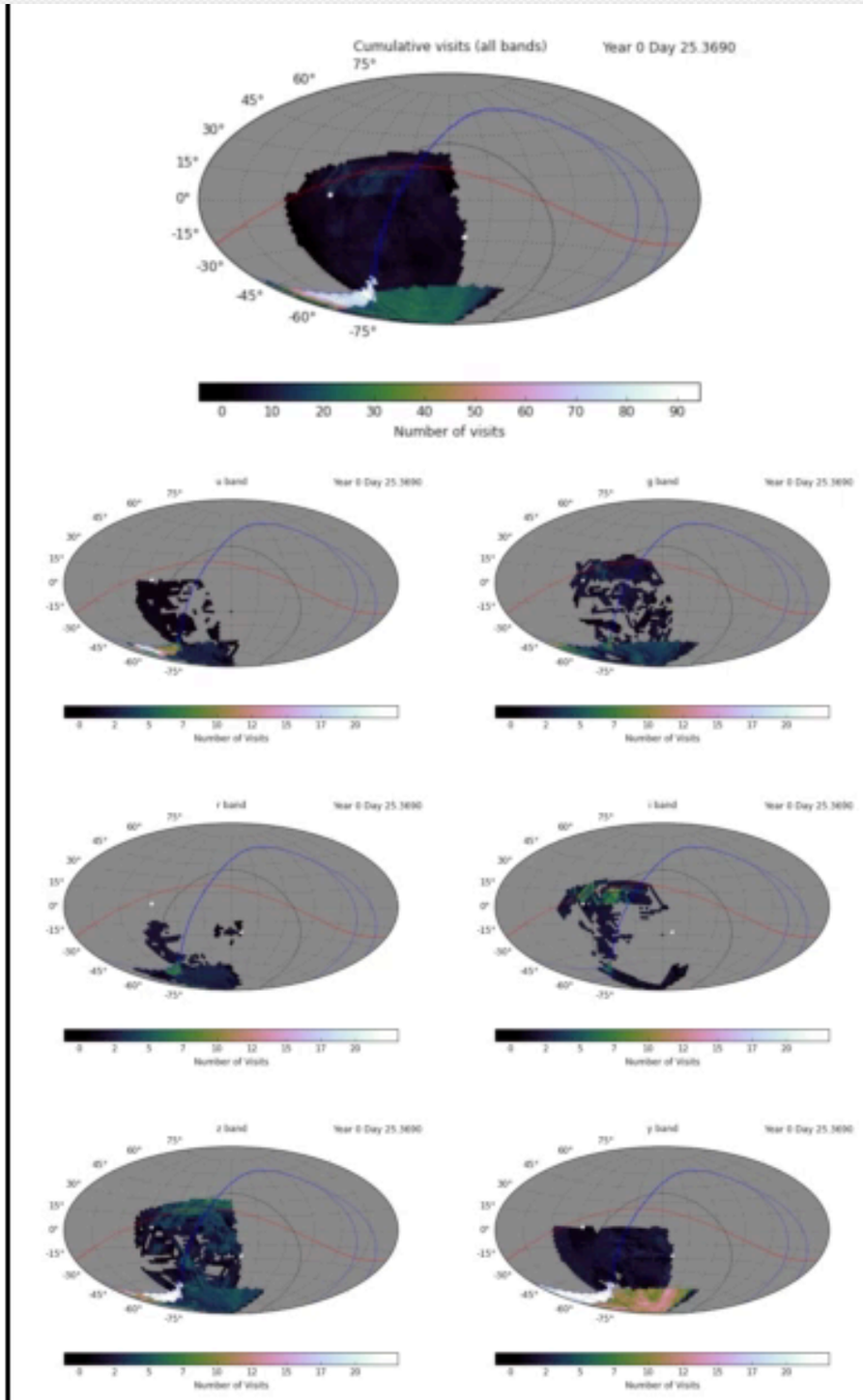




	u	*g*	*r*	*i*	*z*	*y*
# visits	***70***	***100***	***230***	***230***	***200***	***200***
m5 depth	***23.6***	***24.8***	***24.4***	***24.0***	***23.3***	***22.4***

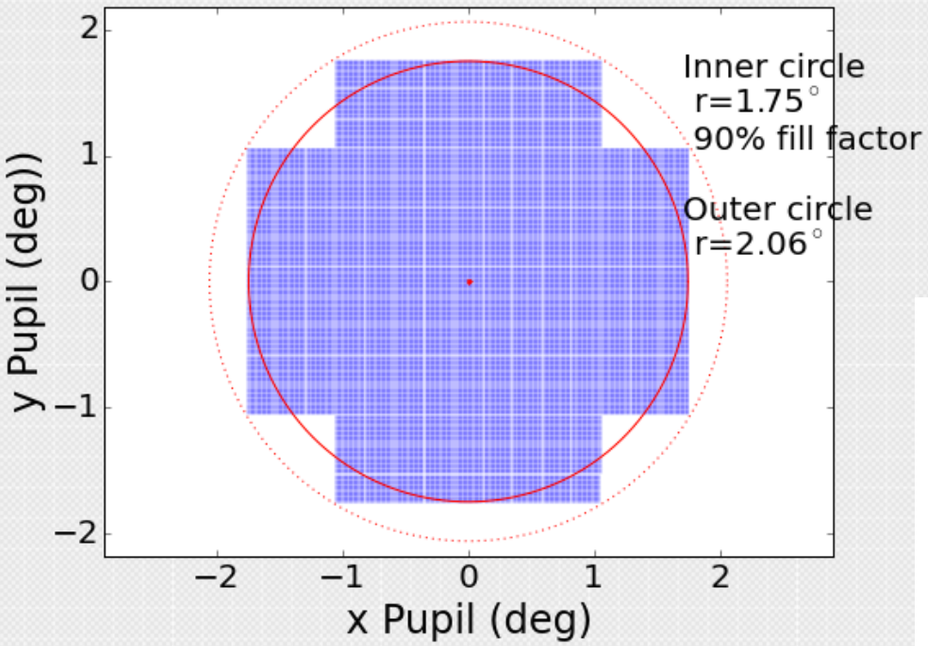
Operations Simulator (OpSim)



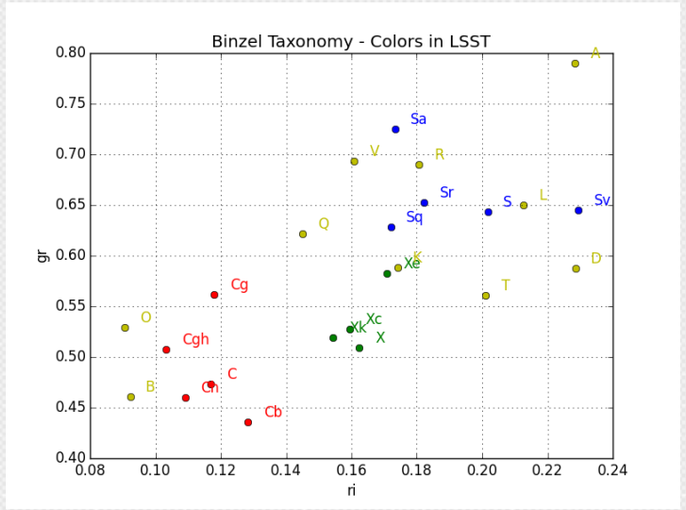


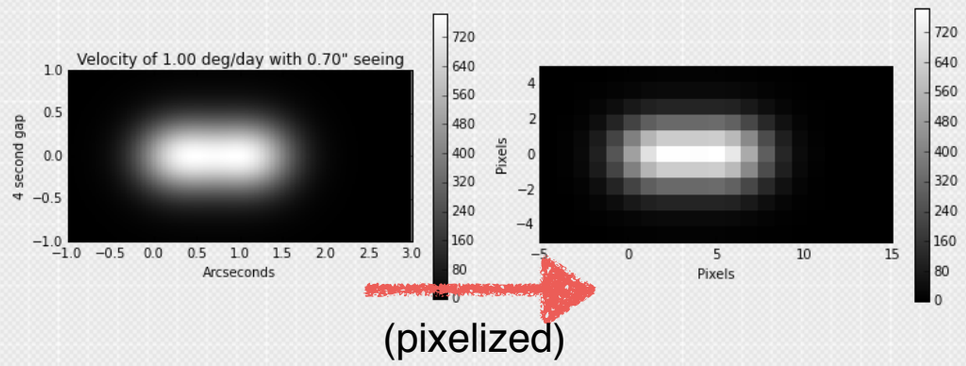
Simulations of small body detections include:

- Orbit propagated over 10 years of LSST survey
- Camera footprint (includes gaps / fill factor)
- Magnitude in filter of observation (account for colors/SED of objects)
- Trailing losses
- SNR of object in observation / Probability of detection



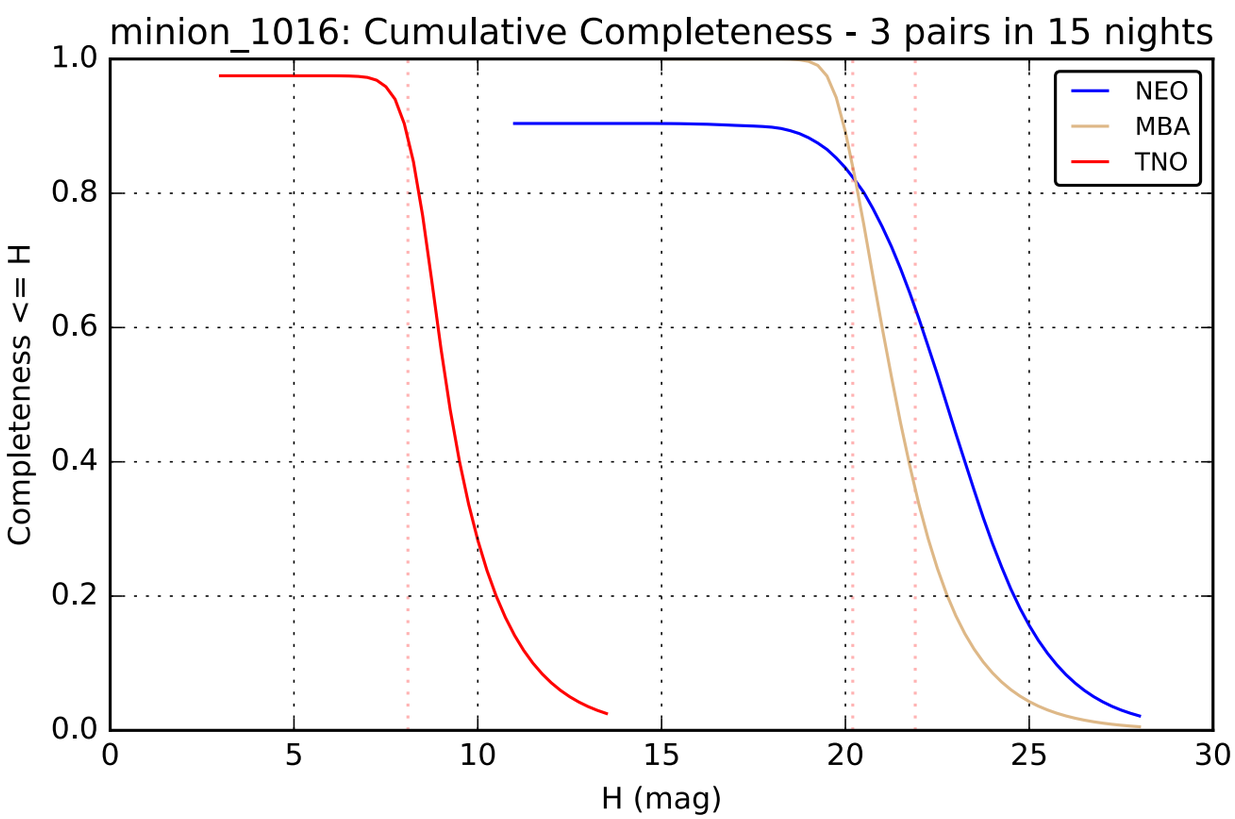
Filter	S complex colors	C complex colors
V-u	-1.82	-1.53
V-g	-0.37	-0.28
V-r	0.26	0.18
V-i	-0.46	0.29
V-z	0.40	0.30
V-y	0.41	0.30



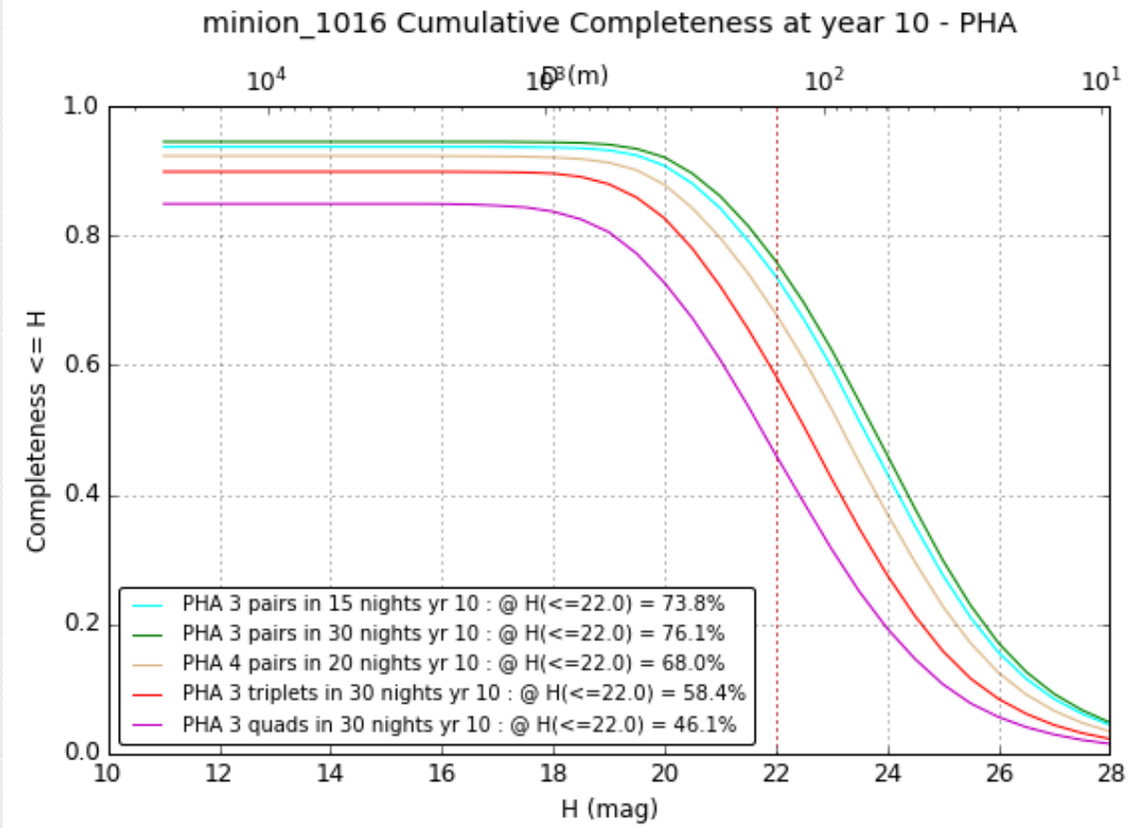


Discovery / Population completeness

Require 3 nights within 15 days, each with a pair of visits



Varying the discovery criteria

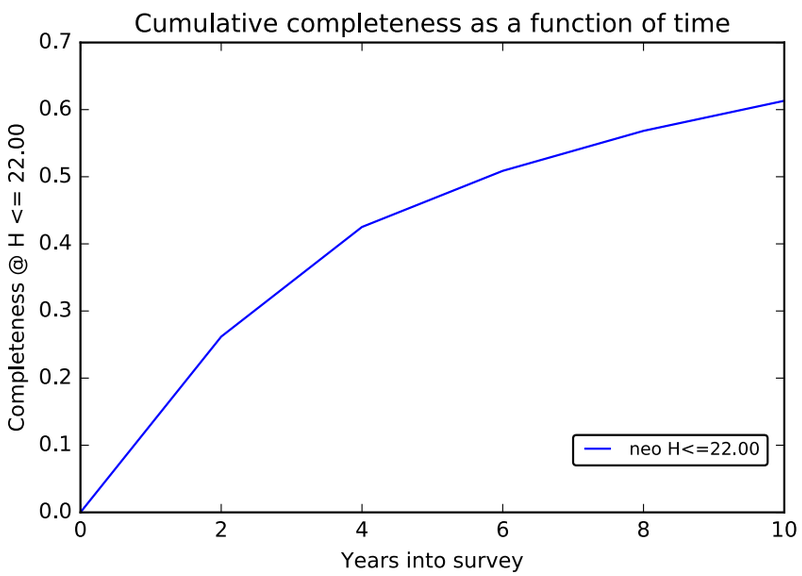


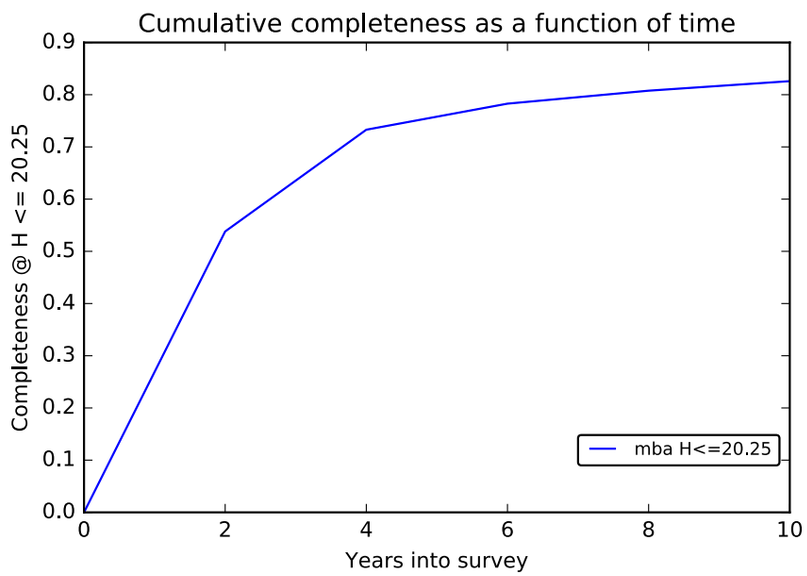
All populations have very high completeness for large objects!

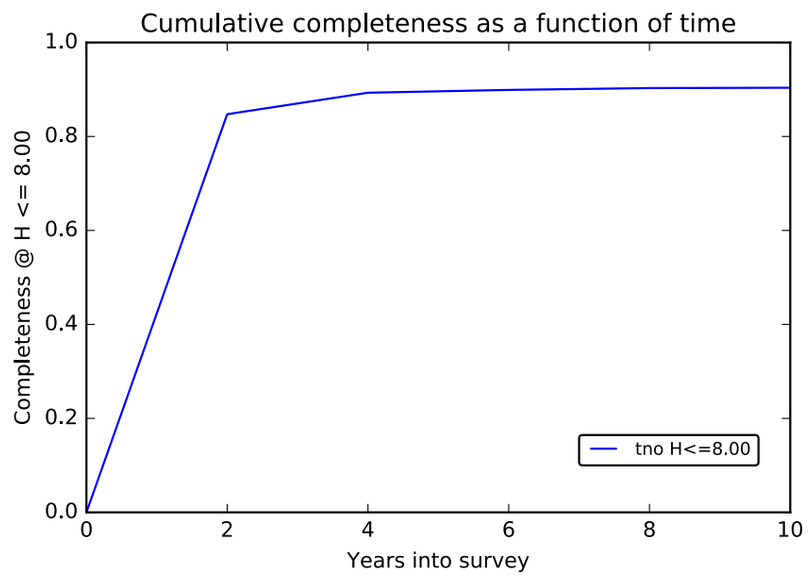
MOPS tests show that linking (3 nights of pairs in 15 night window) is feasible with LSST expected false detection rates

Discovery / Population completeness

Discover many objects early in survey, but discovery still goes on throughout



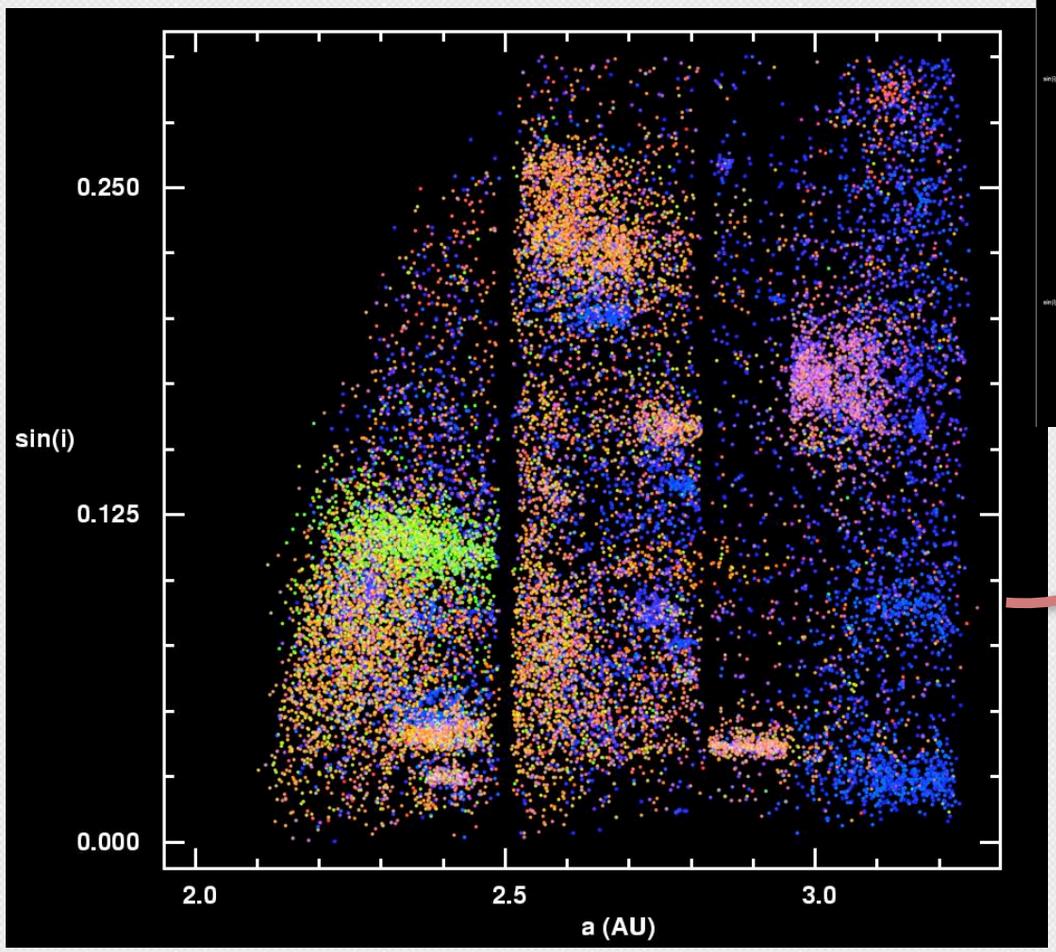




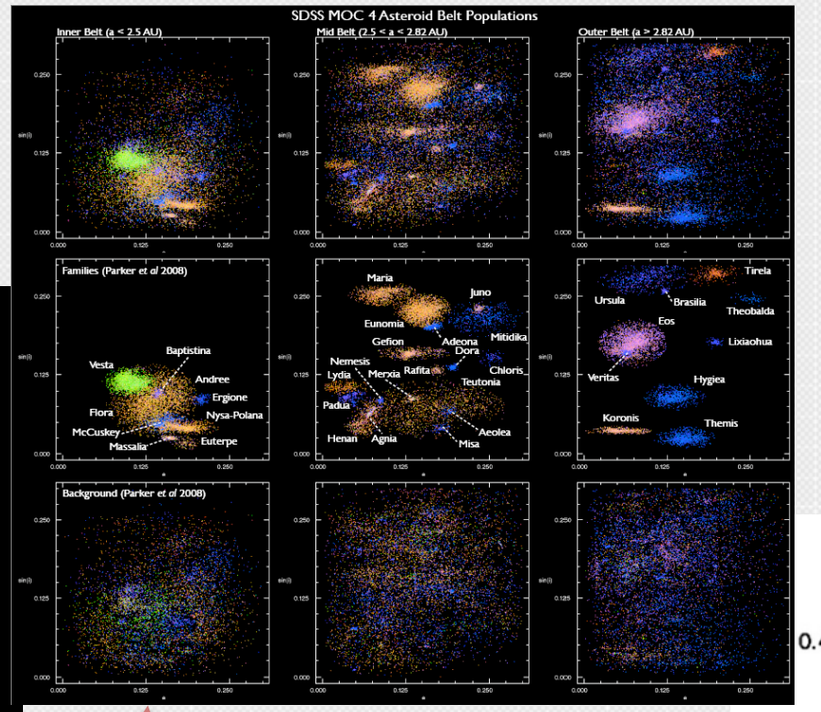
(cumulative completeness at an H value near 50% limit)

LSST observations: *ugrizy*

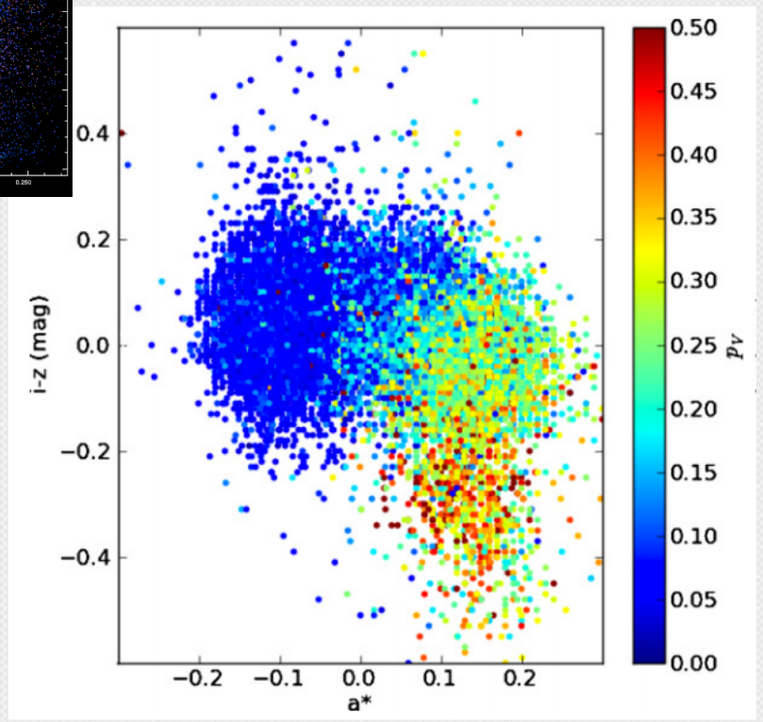
Colors correlate with physical properties (composition, albedo) and help identify families.



MBAs color-coded by SDSS colors
(Parker et al 2008)



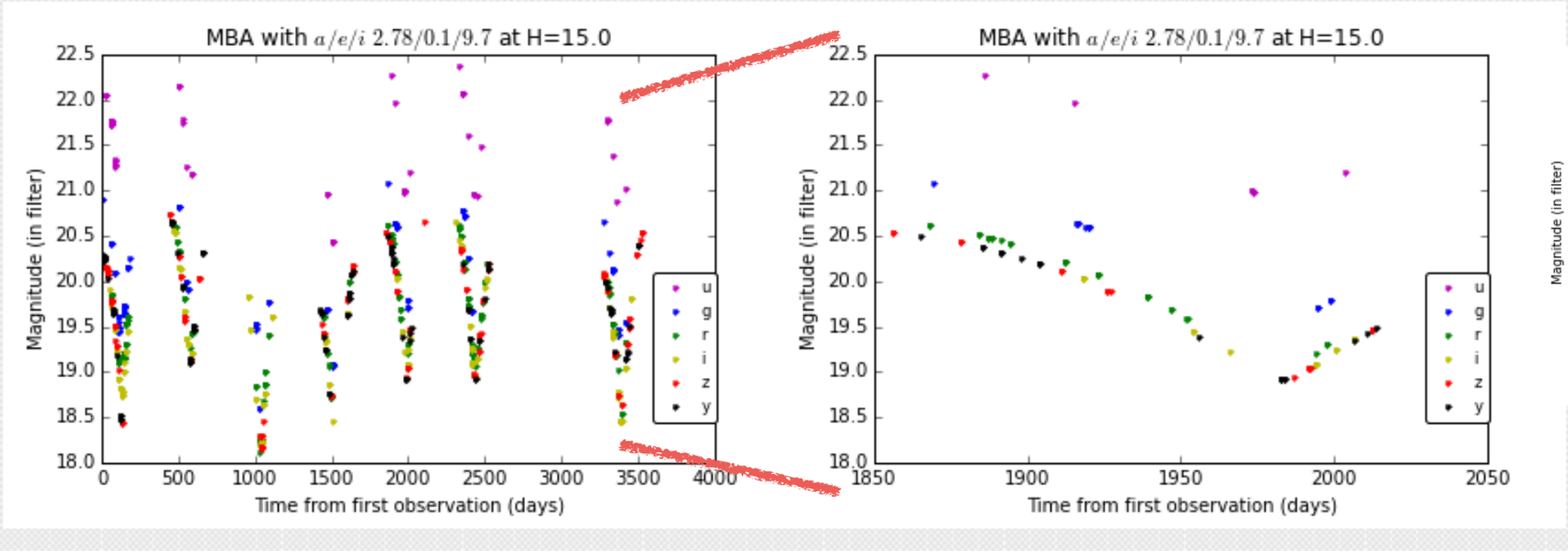
Points color-coded by 'a' (g,r,i combo) & 'i-z'*

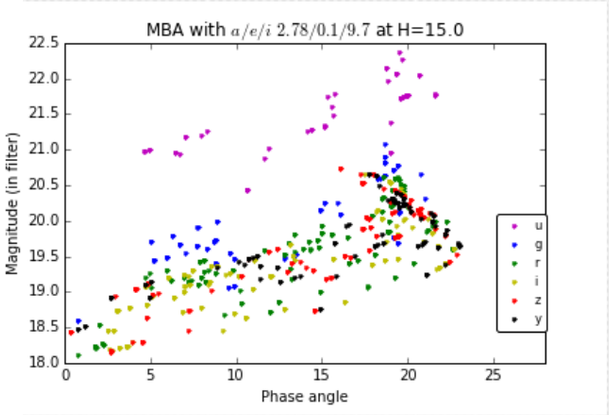


NEO color / albedo
(Mainzer et al 2012)

Color determination

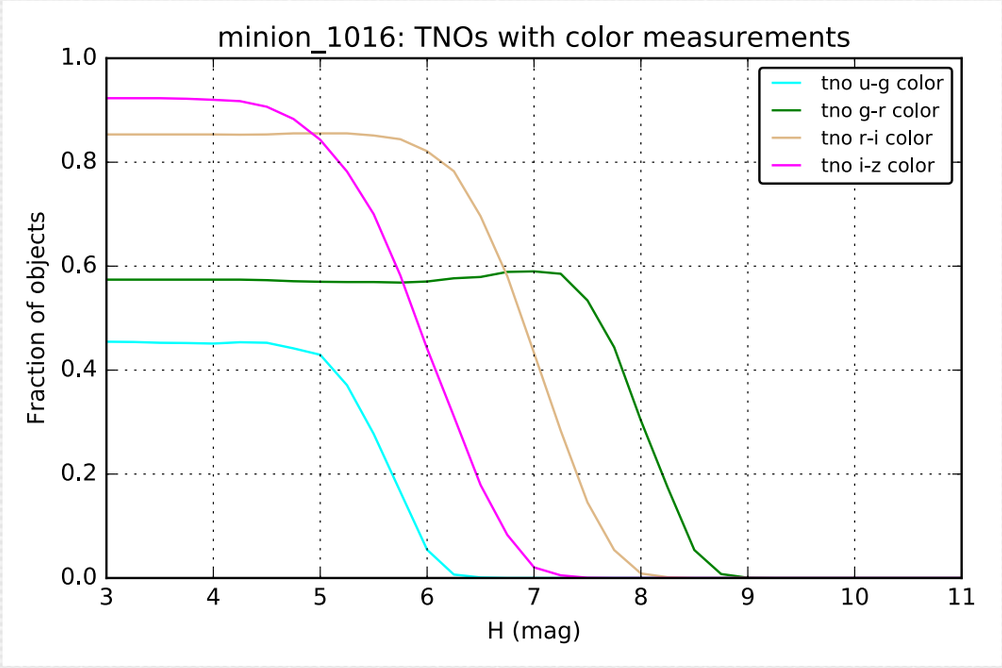
Translating non-simultaneous multi band observations into colors

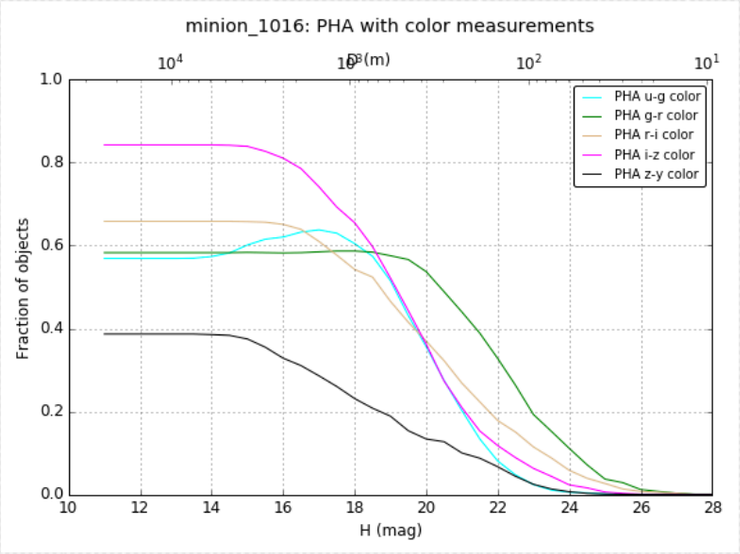




Individual photometric measurements (for bright objects) will be accurate to 10mmag.

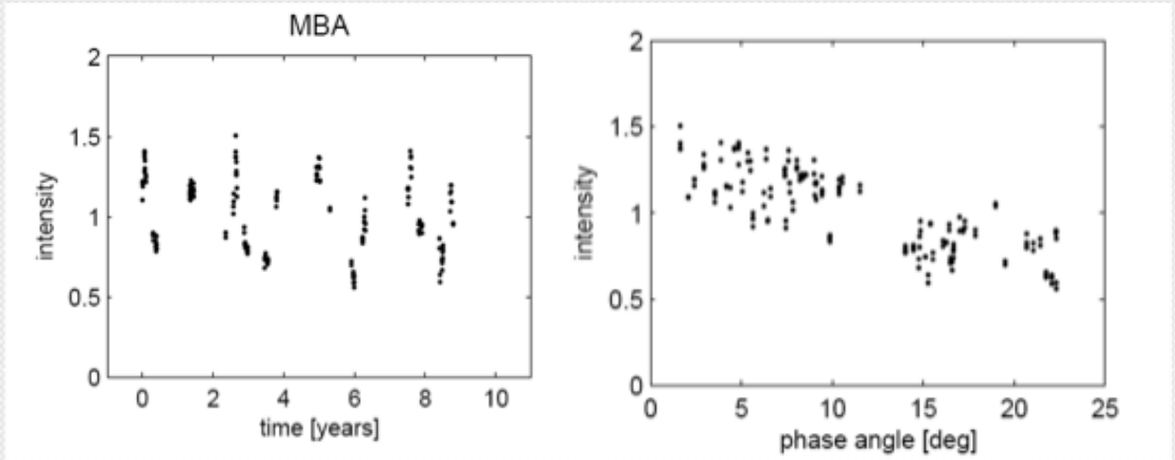
TNO colors: 2+ obs with SNR>10 within 2 hours (Peixinho et al 2015)

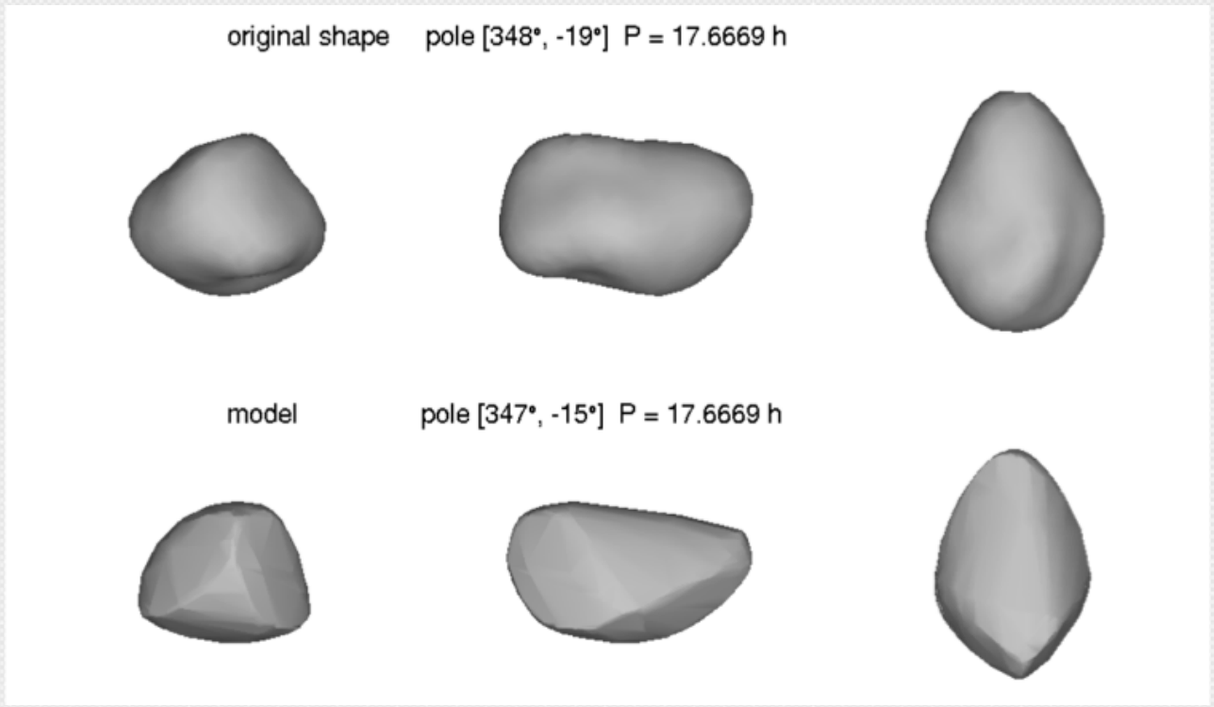




Lightcurve Inversion

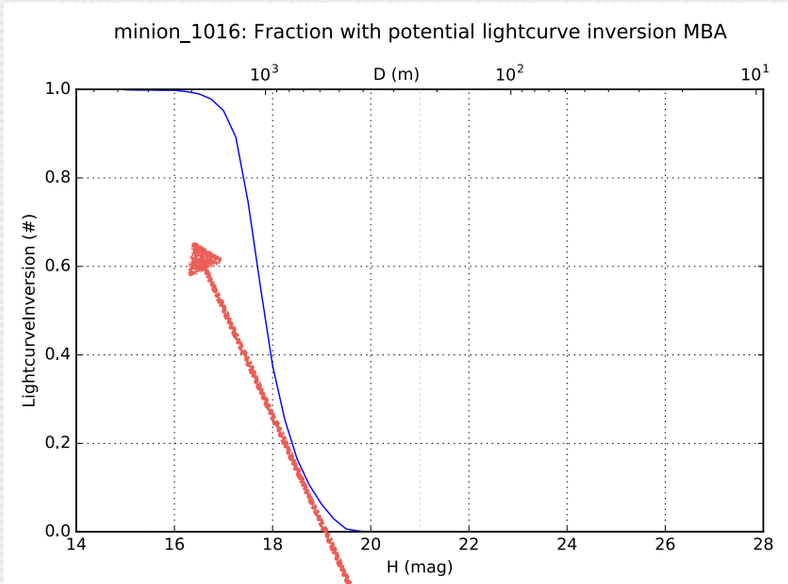
Sparse lightcurve inversion can provide shapes for 10,000-100,000 NEOs and MBAs

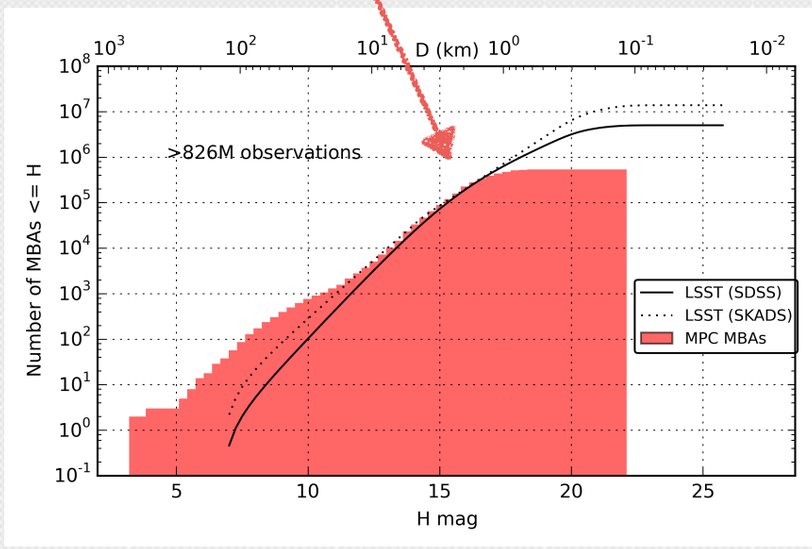




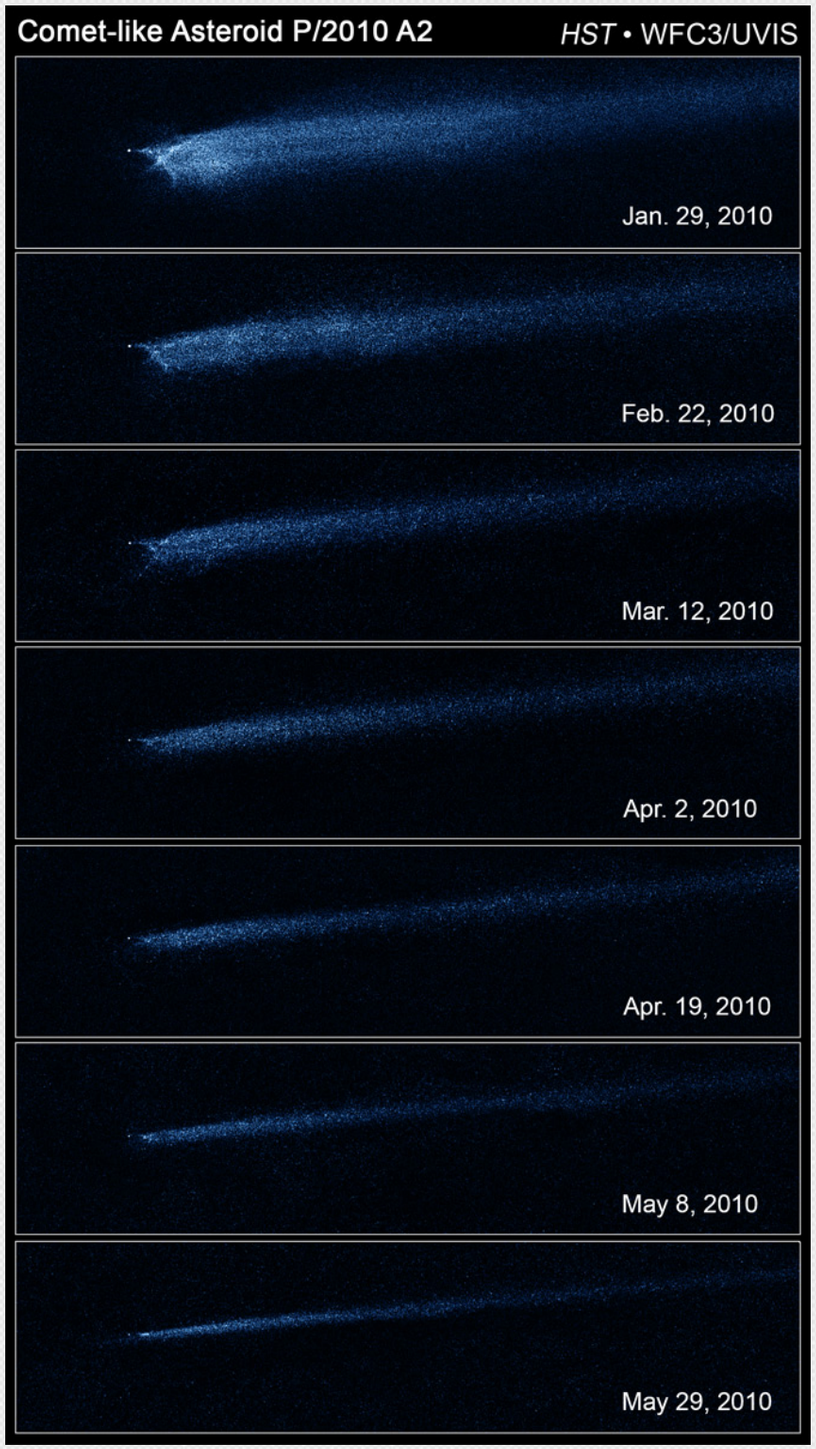
(Durech et al. 2007)

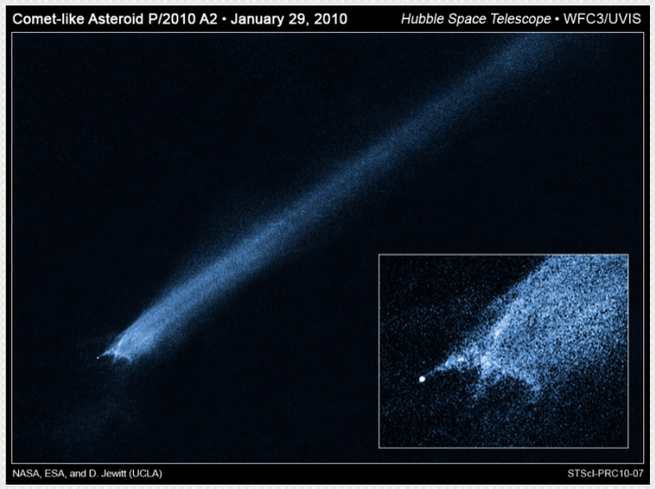
100+ observations with SNR>20

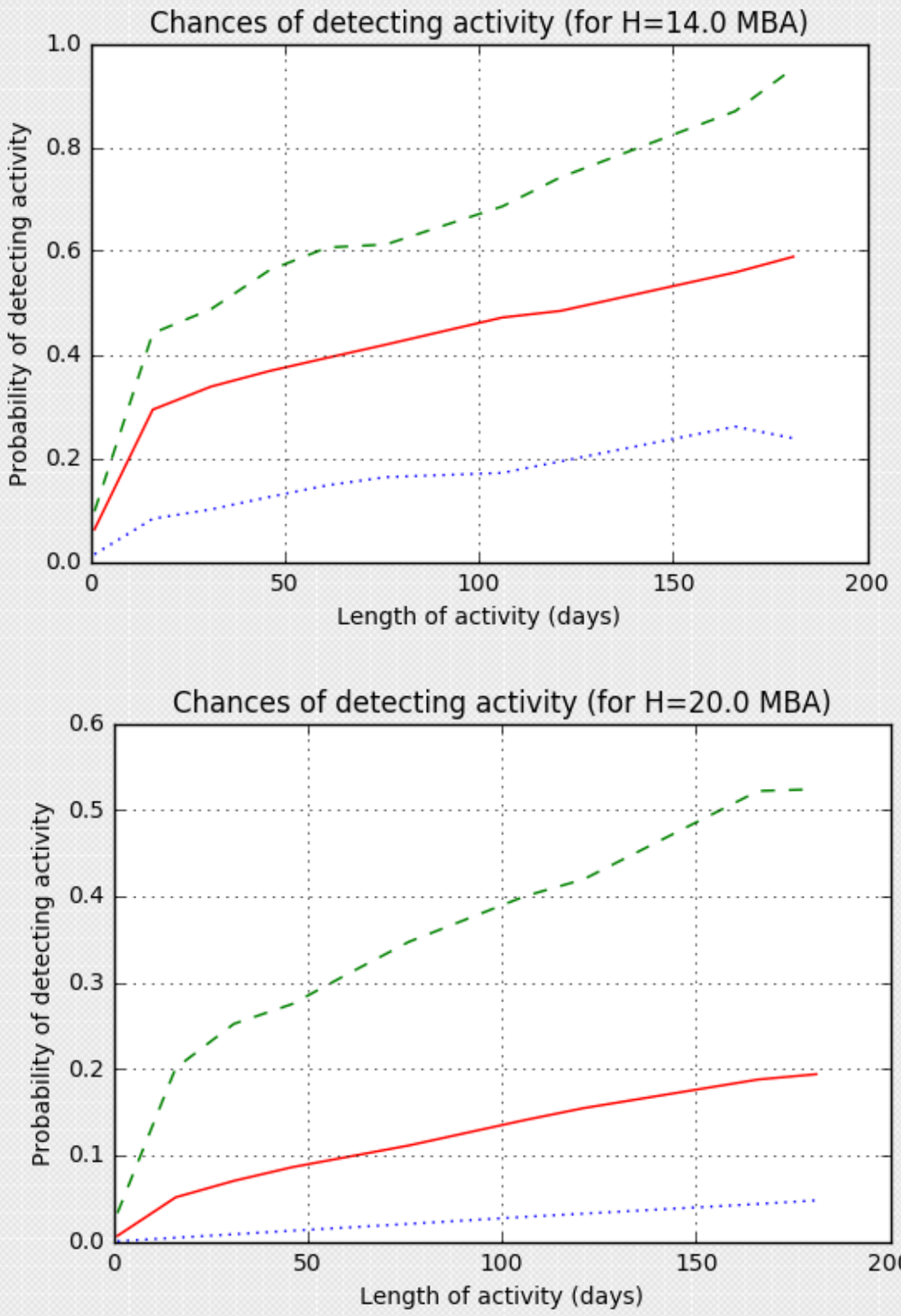




Detecting activity





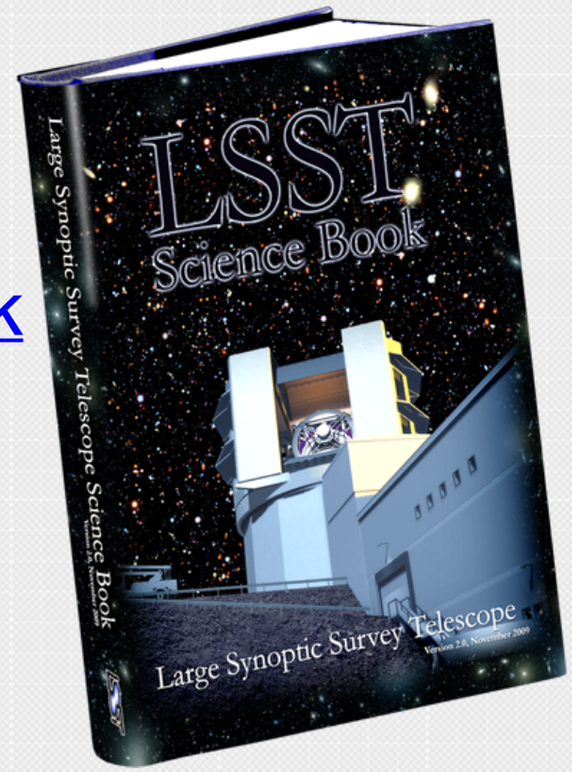


Jewitt et al 2010

More science

- Masses for ~100 MBAs
- Occultation opportunities
- Binaries!
- Shift & Stack - special mini-survey to r=27
- Links between populations

Science book:
http://lsst.org/scientists/scibook



Observing Strategy Whitepaper
https://github.com/LSSTScienceCollaborations/ObservingStrategy

Understanding The Solar System with LSST

10-100x increase in sample size for every small body population in the Solar System

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with multi-band photometry and many observations enabling characterization of each population