The Large Synoptic Survey Telescope Status Update

LSST:UK Consortium

Armagh Observatory
University of Birmingham
University of Bristol
University of Cambridge
Cardiff University Prifysgol Caerdydd
Durham University
The University of Edinburgh
University of Exeter
University of Glasgow
University of Hertfordshire UH
University of Hull
Imperial College London
Keele University
University of Kent
University of Leicester
Liverpool John Moores University
Manchester 1824 The University of Manchester
UCL MSSL
The University of Nottingham
The Open University
University of Oxford
University of Portsmouth
Queen Mary University of London
Queen's University Belfast
The University Of Sheffield.
University of Southampton
University of St Andrews
University of Surrey
University of Sussex
UCL
uclan
UK Astronomy Technology Centre
The University of Warwick

Ian Shipsey

LSST in a nutshell

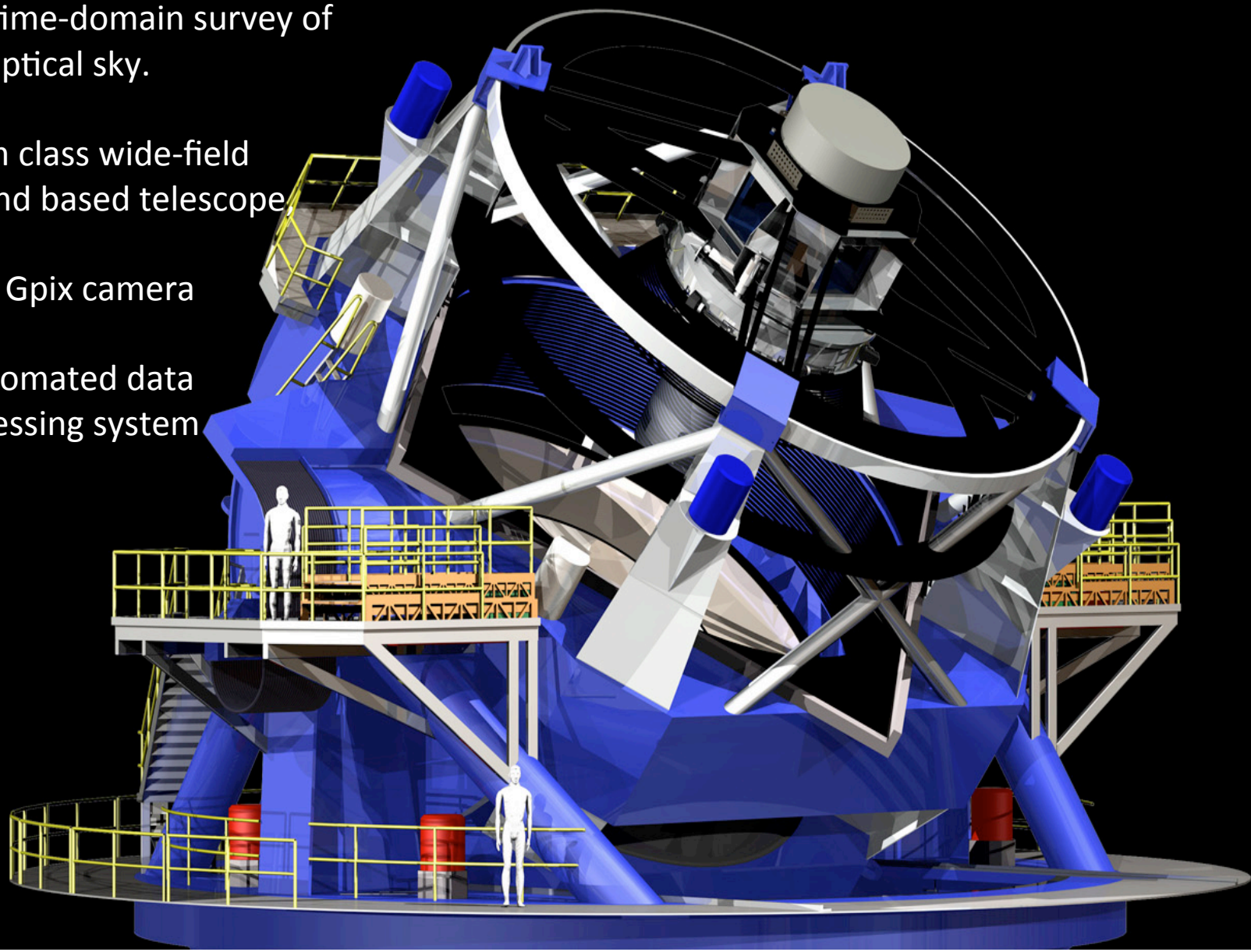
Synoptic = Big Picture

LSST : an integrated survey system designed to conduct a decade-long*, deep, wide, fast* time-domain survey of the optical sky.

* 8-m class wide-field ground based telescope

* 3.2 Gpix camera

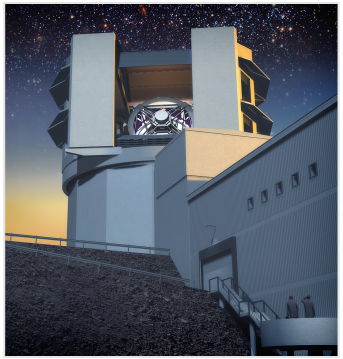
* automated data processing system



Wide

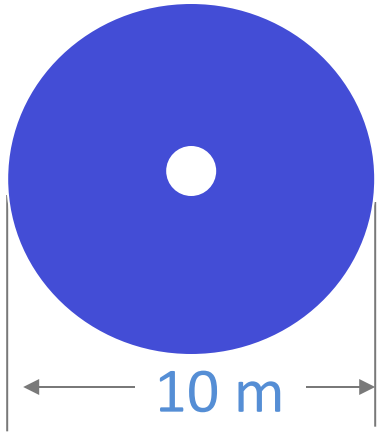
Why is the LSST unique?

KECK TELESCOPE



LSST

Primary Mirror Diameter

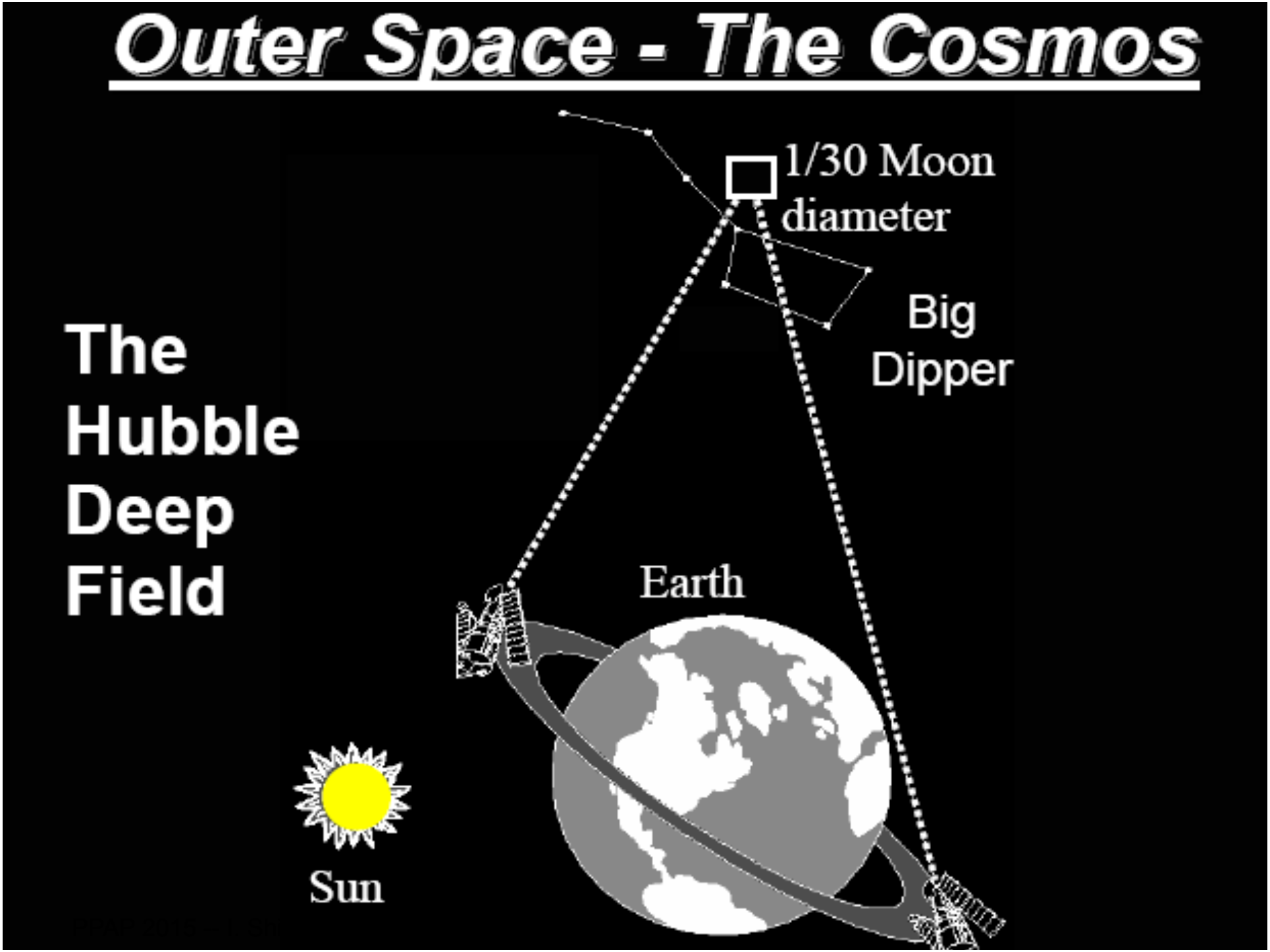


Field of View

(full moon is 0.5 degrees)

0.2 degrees

Outer Space - The Cosmos

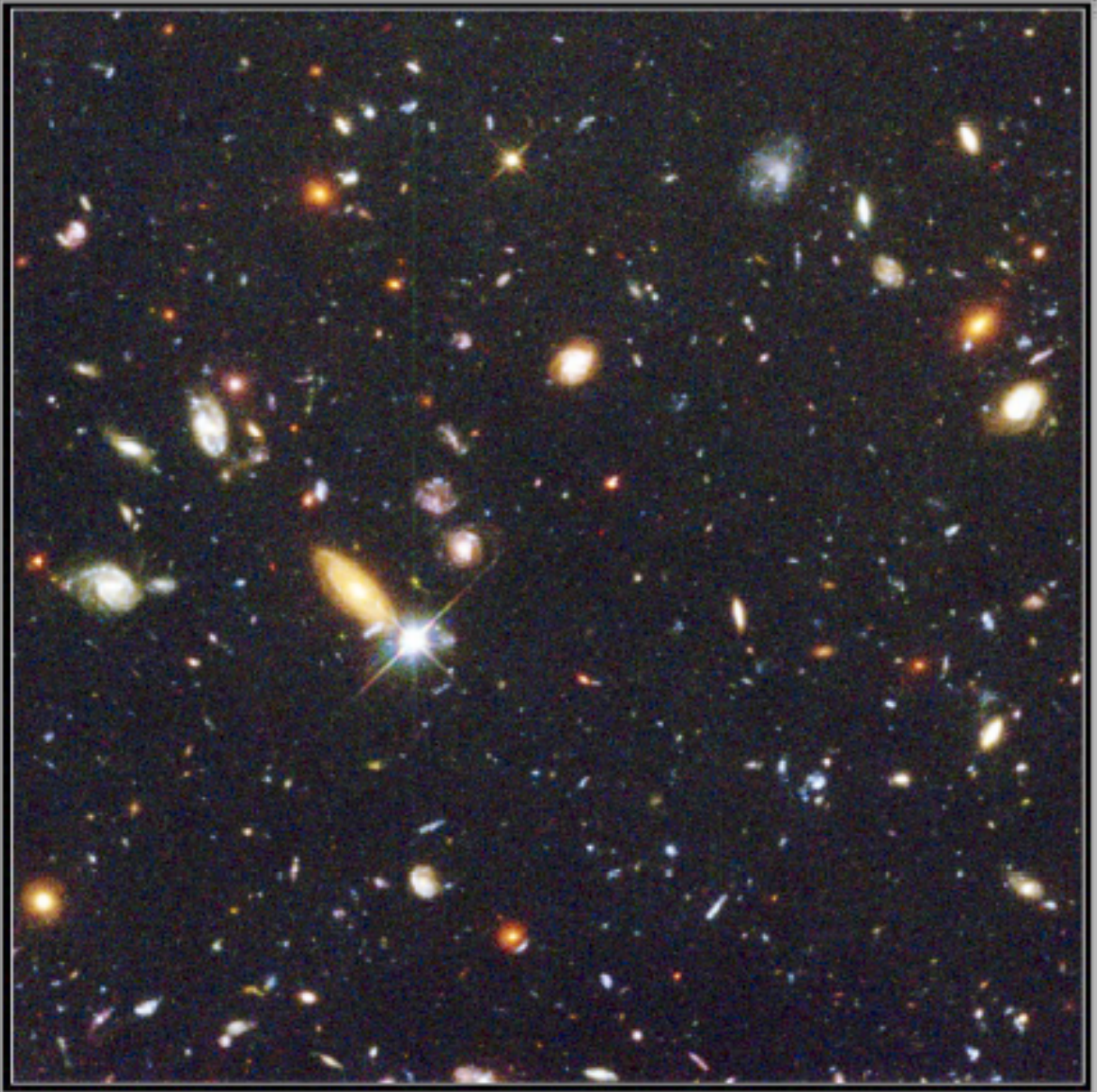


Hubble deep field

UNIVERSE OF GALAXIES

3000 here →

100 billion over entire sky

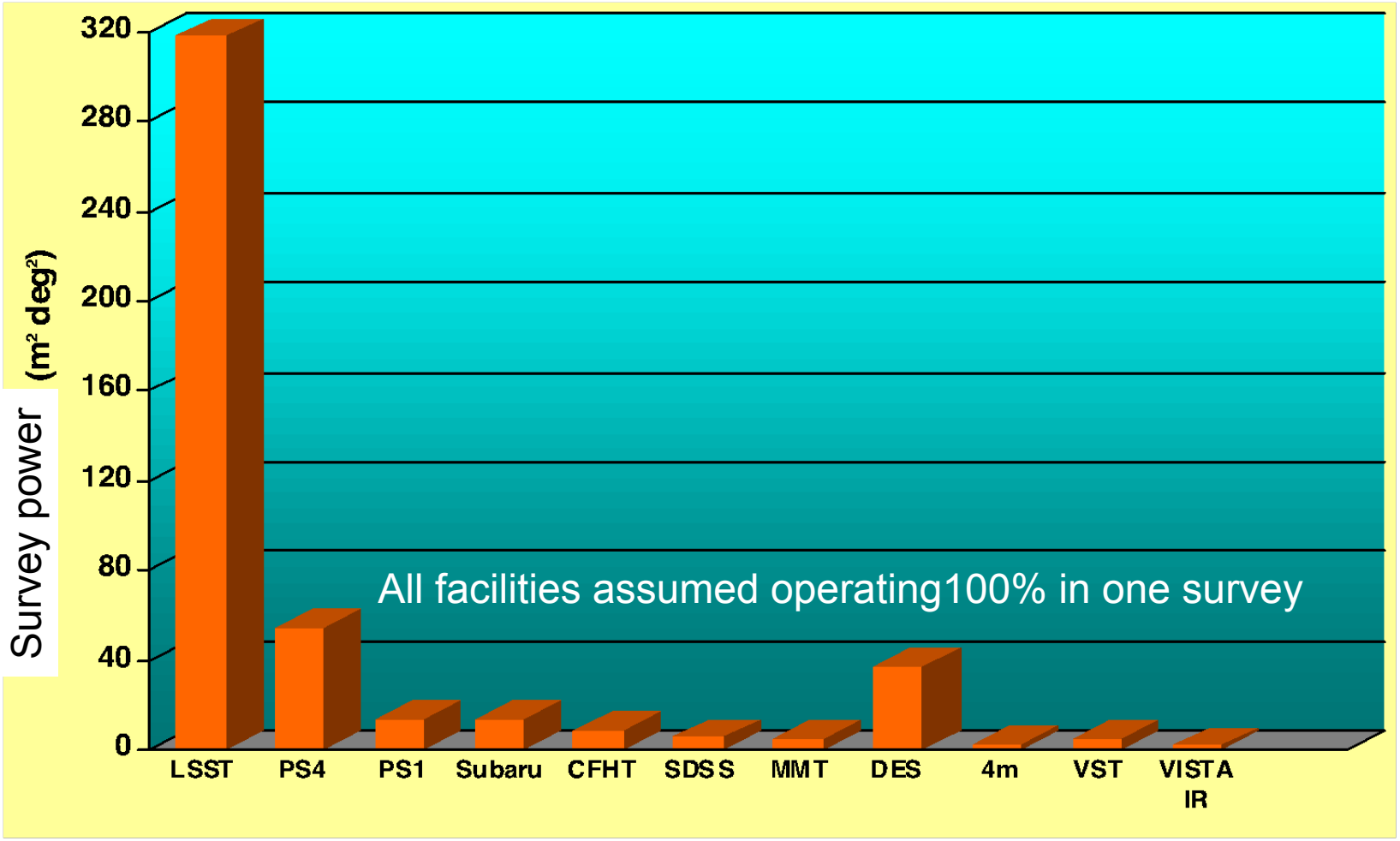


Wide
Image sizes LSST, Moon, HST

Wide

Wide

Survey Power = aperture x field of view



Wide

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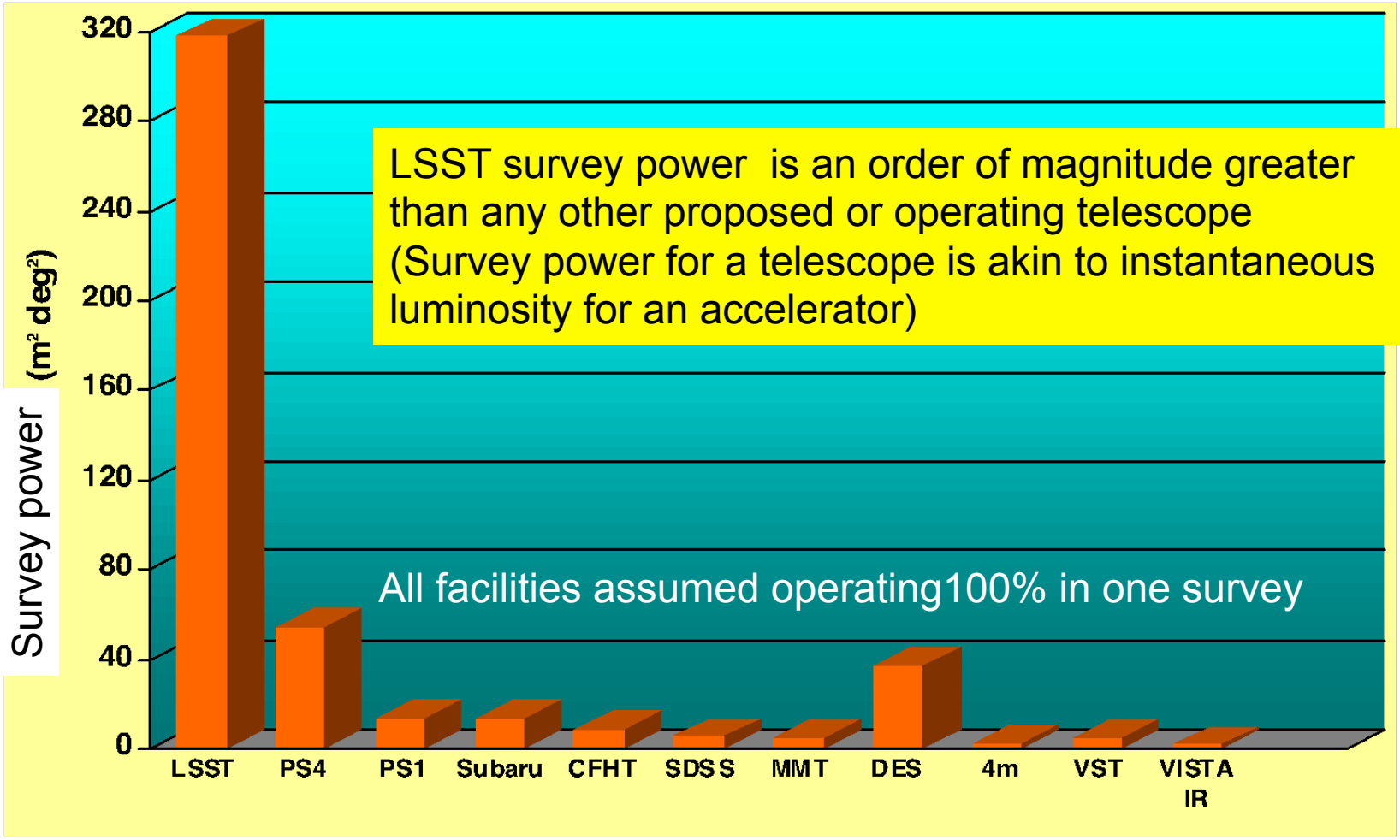
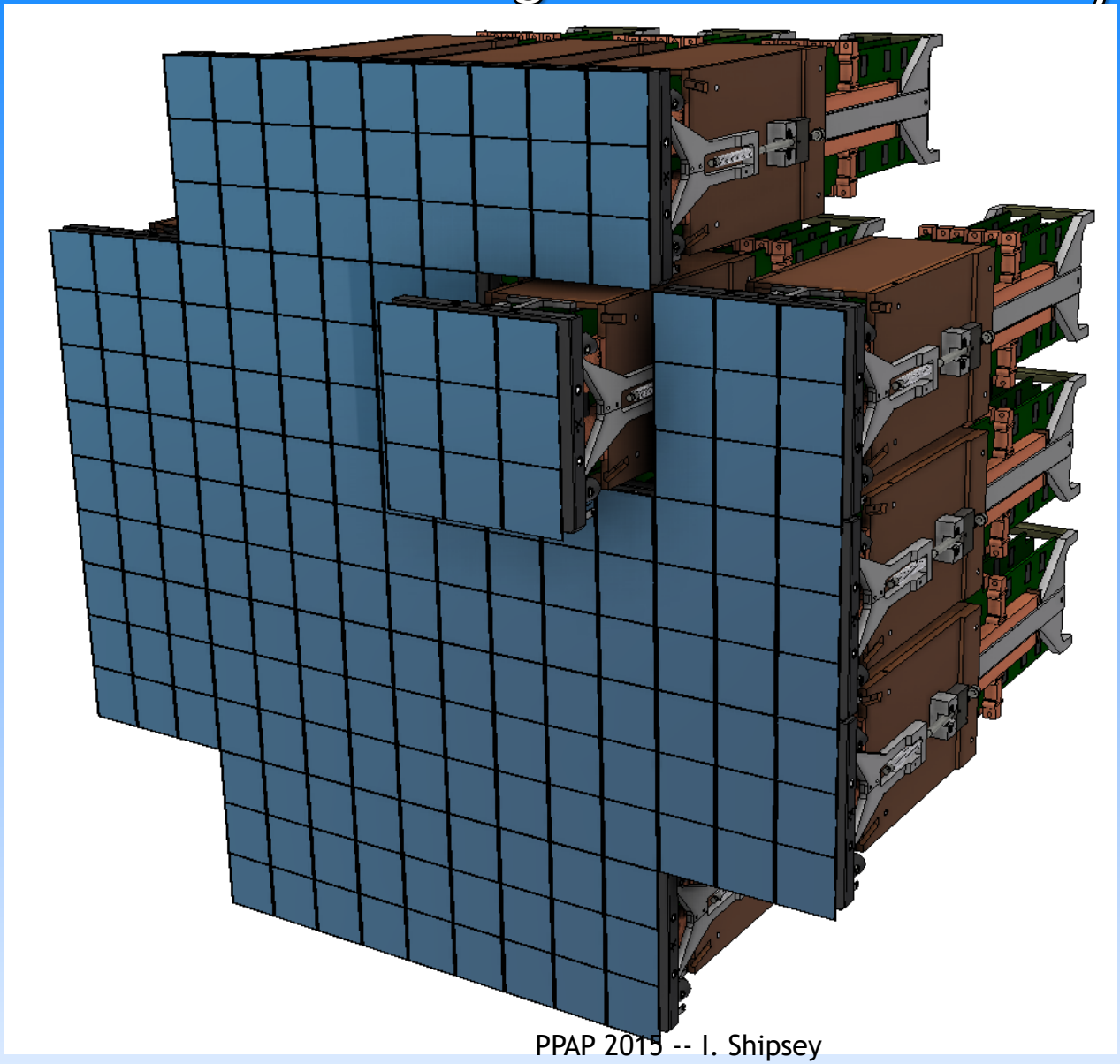


Fast

189 4K x 4K CCDs Largest & fast astronomy CCD camera



3 Gpix multiport CCDs

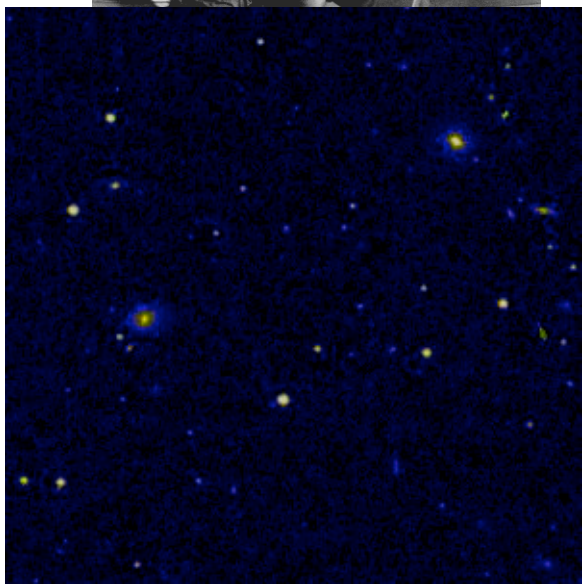
Record image in 15 seconds

Readout image In 2 seconds

LSST is the next great advance in optical surveys of the cosmos

DEEP

ca. 1950 POSS (Photographic)



LSST probes <u>100x</u> fainter & enables the exploration of the time domain.

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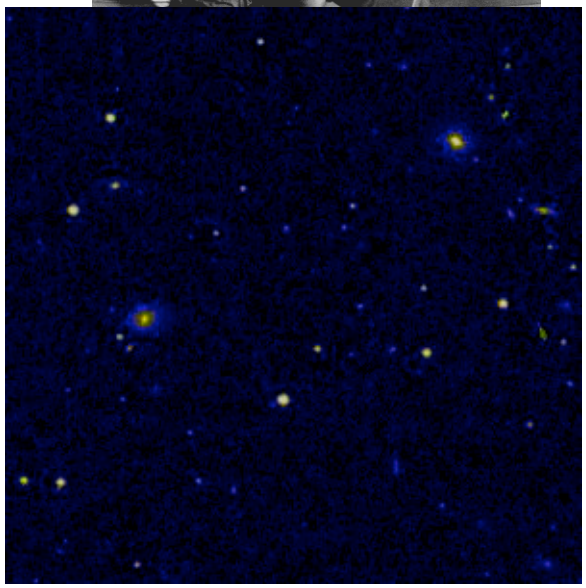
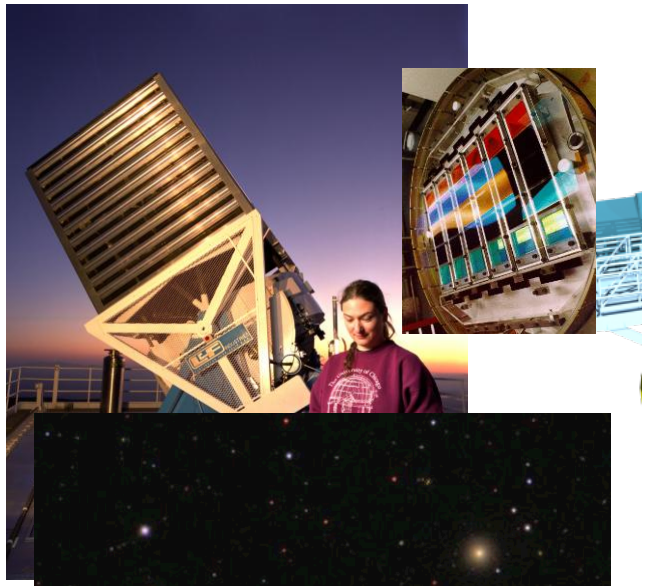
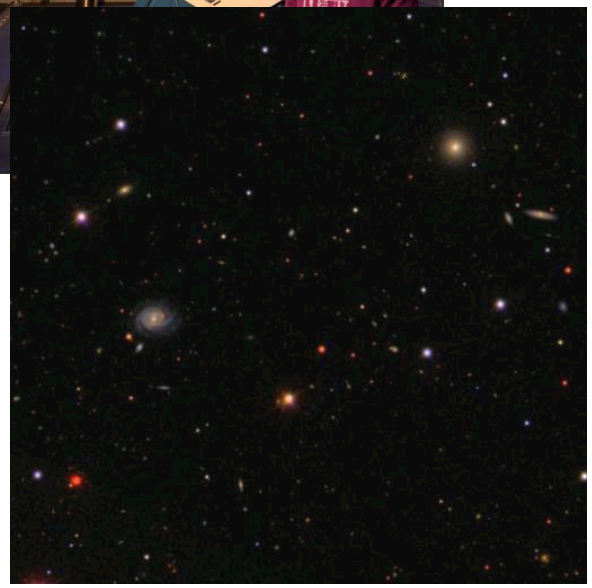


ca. 2000 SDSS (Digital)





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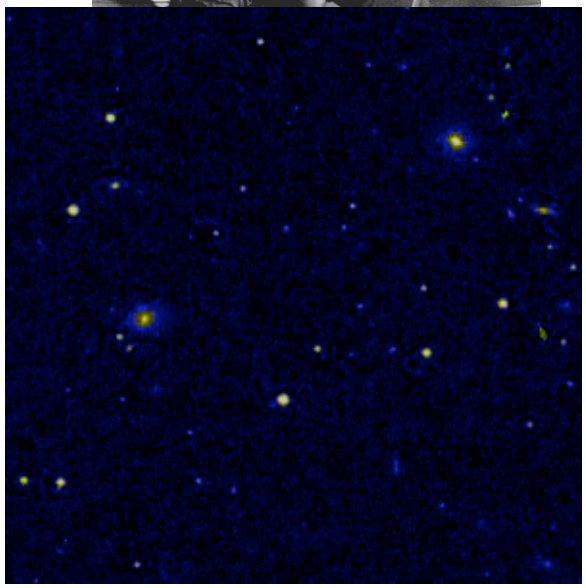

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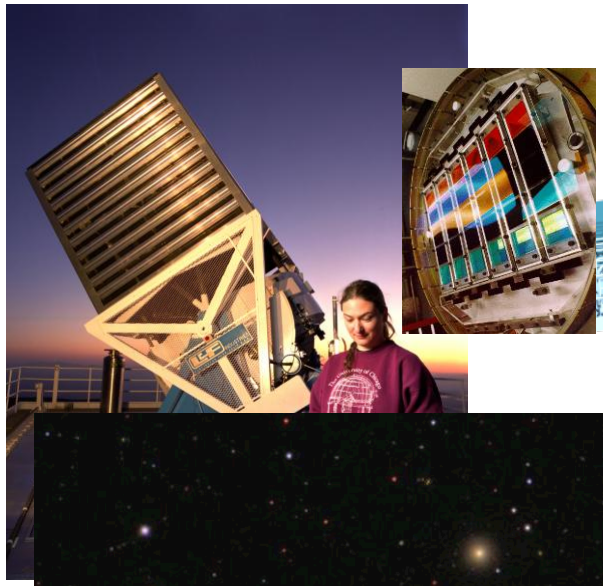
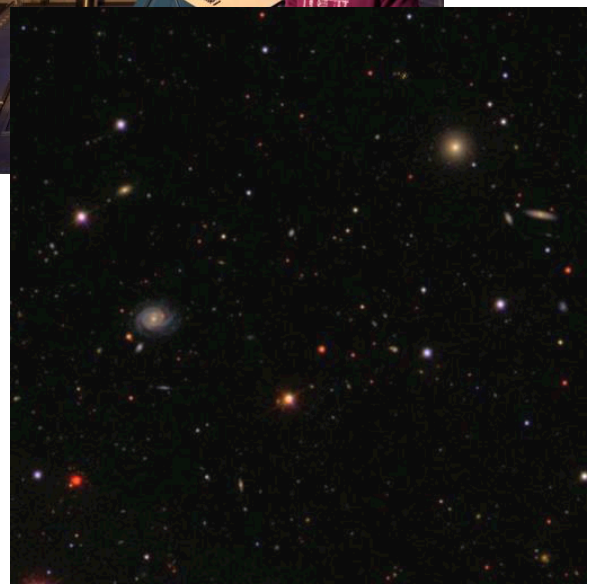
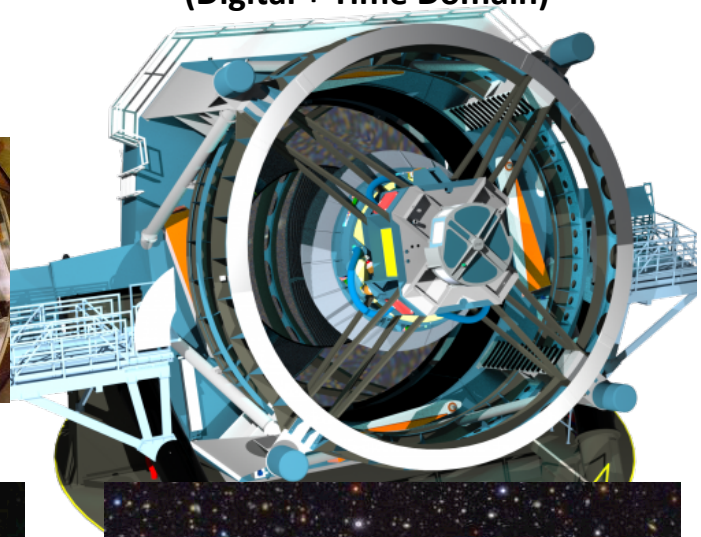
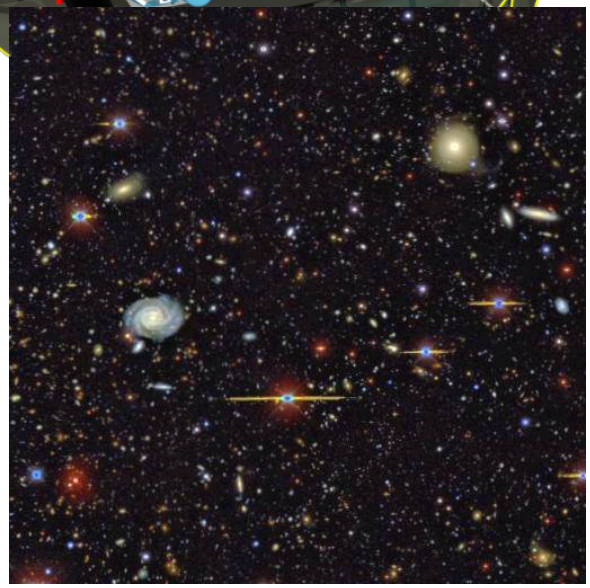




ca. 2023 LSST
(Digital + Time Domain)





LSST probes <u>100x</u> fainter & enables the exploration of the time domain.

LSST will make the first movie of the universe

- ~800 images of every field will open up the time domain for large-scale study for the first time: a movie of the universe

Google Earth | Google Sky | Google Universe

A survey of 40 billion objects in space and time

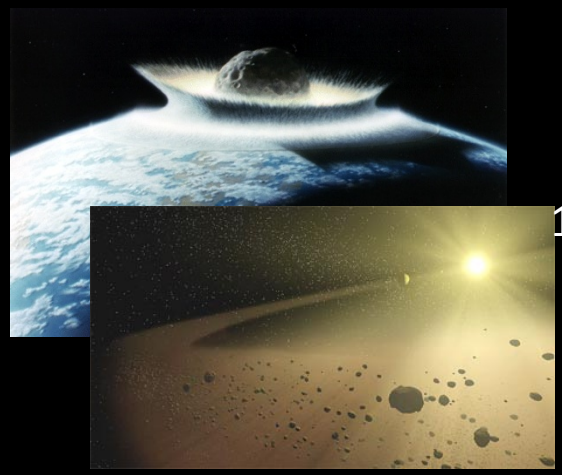
32 trillion measurements

LSST 4 Science Missions

Dark Energy-Dark Matter

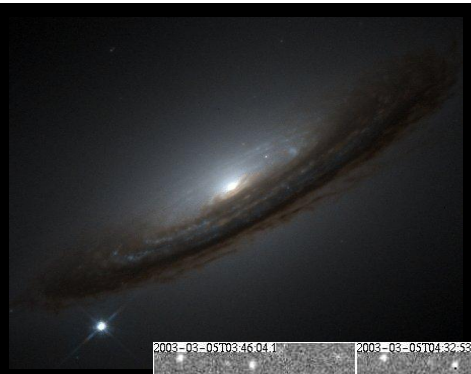
Multiple investigations into the nature of the dominant components of the universe

Inventory of the Solar System

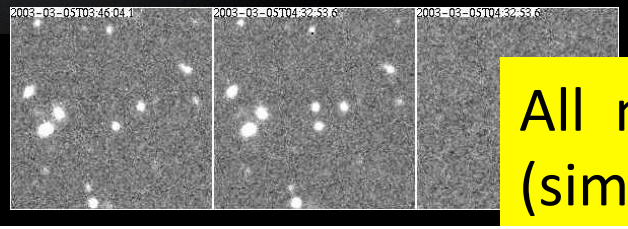


Find 82% of hazardous NEOs down to 140 m over 10 yrs & test theories of solar system formation

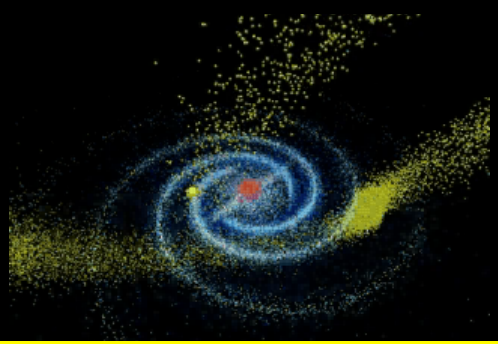
"Movie" of the Universe: time domain



Discovering the transient & unknown on time scales days to years



Mapping the Milky Way



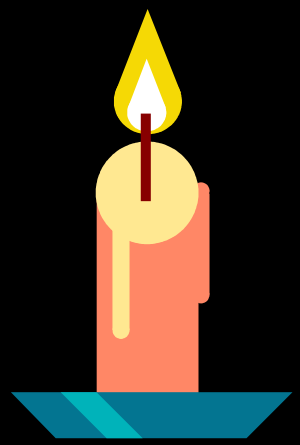
Map the rich and complex structure of the galaxy in unprecedented detail and extent

All missions conducted in parallel
(similar to a general purpose expt @ LHC)

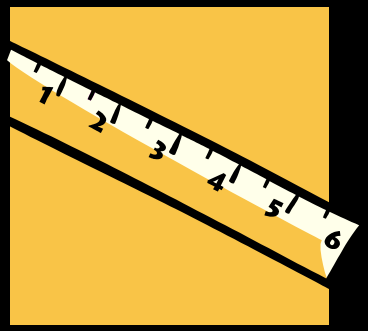
Probing Dark Energy

Measure the expansion history of the universe

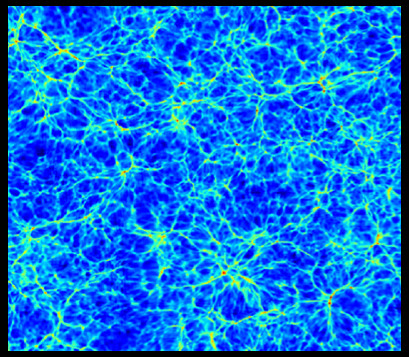
luminosity distances of standard candles (Type 1a SNe)

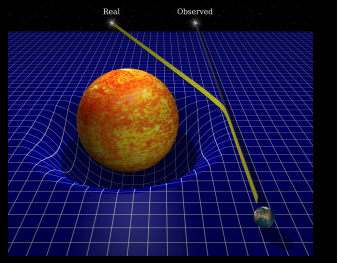


angular diameter distances of standard rulers baryon acoustic oscillations (BAO)

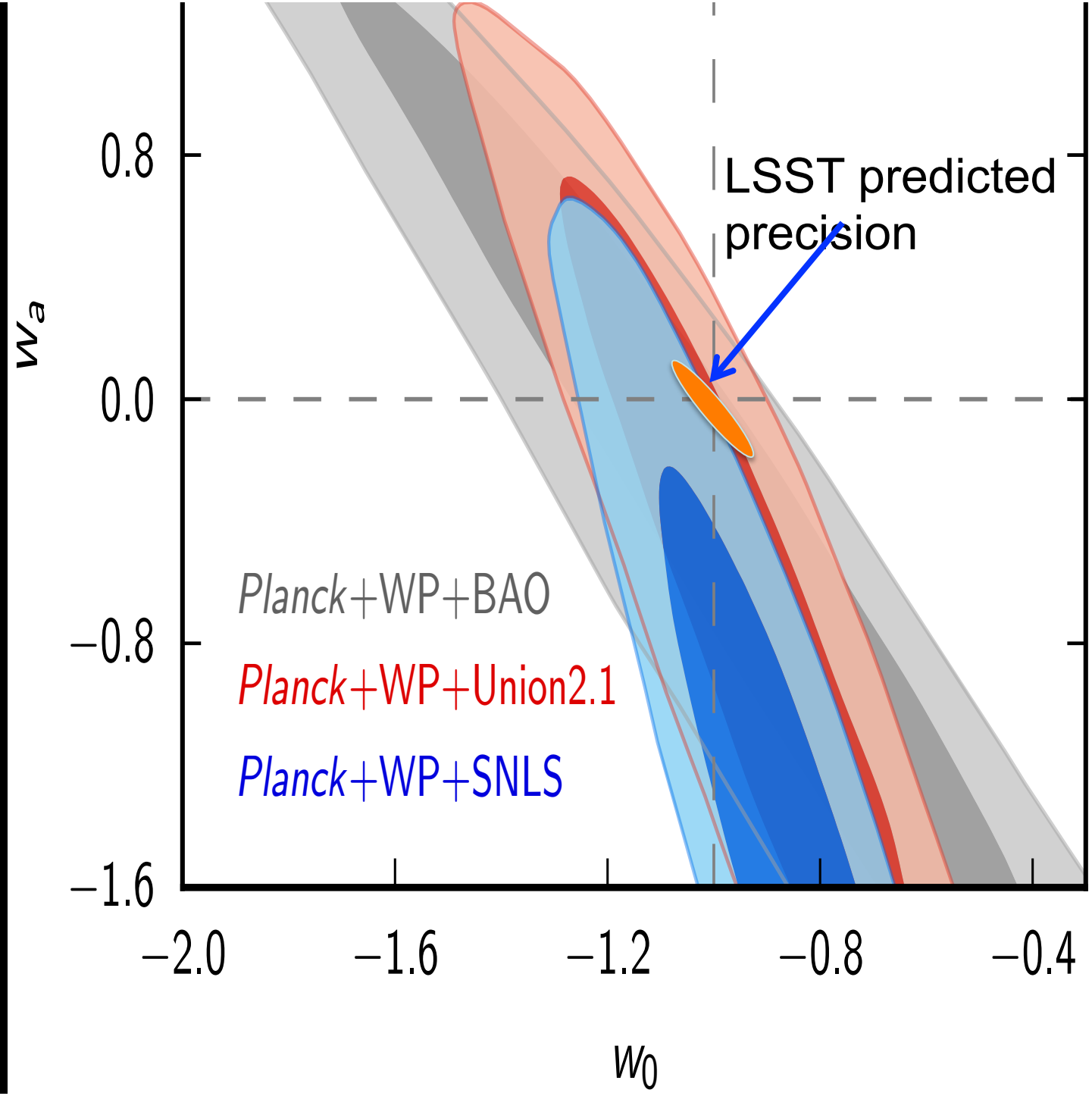


- **measure growth of structure as function of redshift**
- **Galaxy Cluster surveys & Weak Lensing (WL) Surveys**





Present state of knowledge



Good Timing: The Green light

There are two US funding agencies supporting LSST the Astronomy Division of NSF and the Particle Physics Office of the DOE

NSF authorised project construction Aug. 1 2014 ($473M)

DOE authorised project construction July, 2015 ($168M)

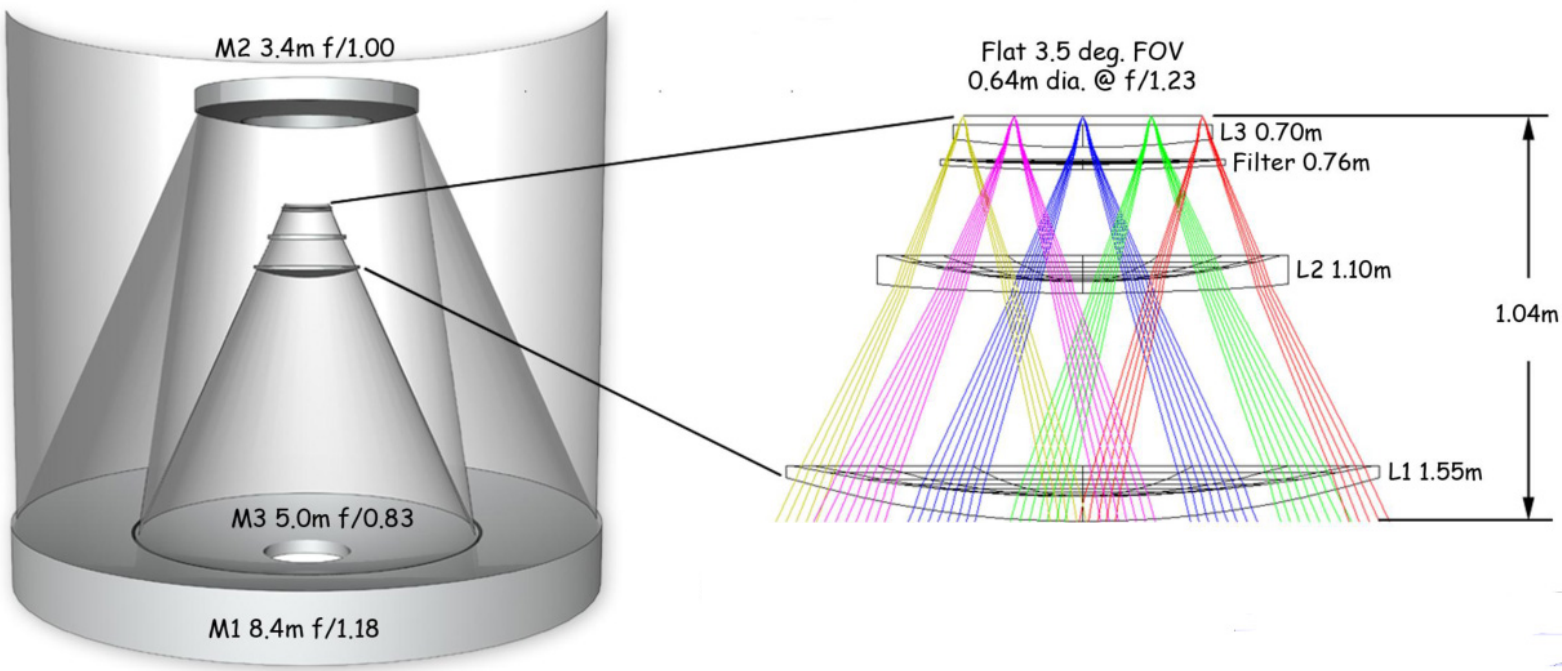
Commissioning start 2020

Science October, 2022

Ten year survey
US will provide 270M$ for operations
non-US partners provide 100M$ in return for data rights

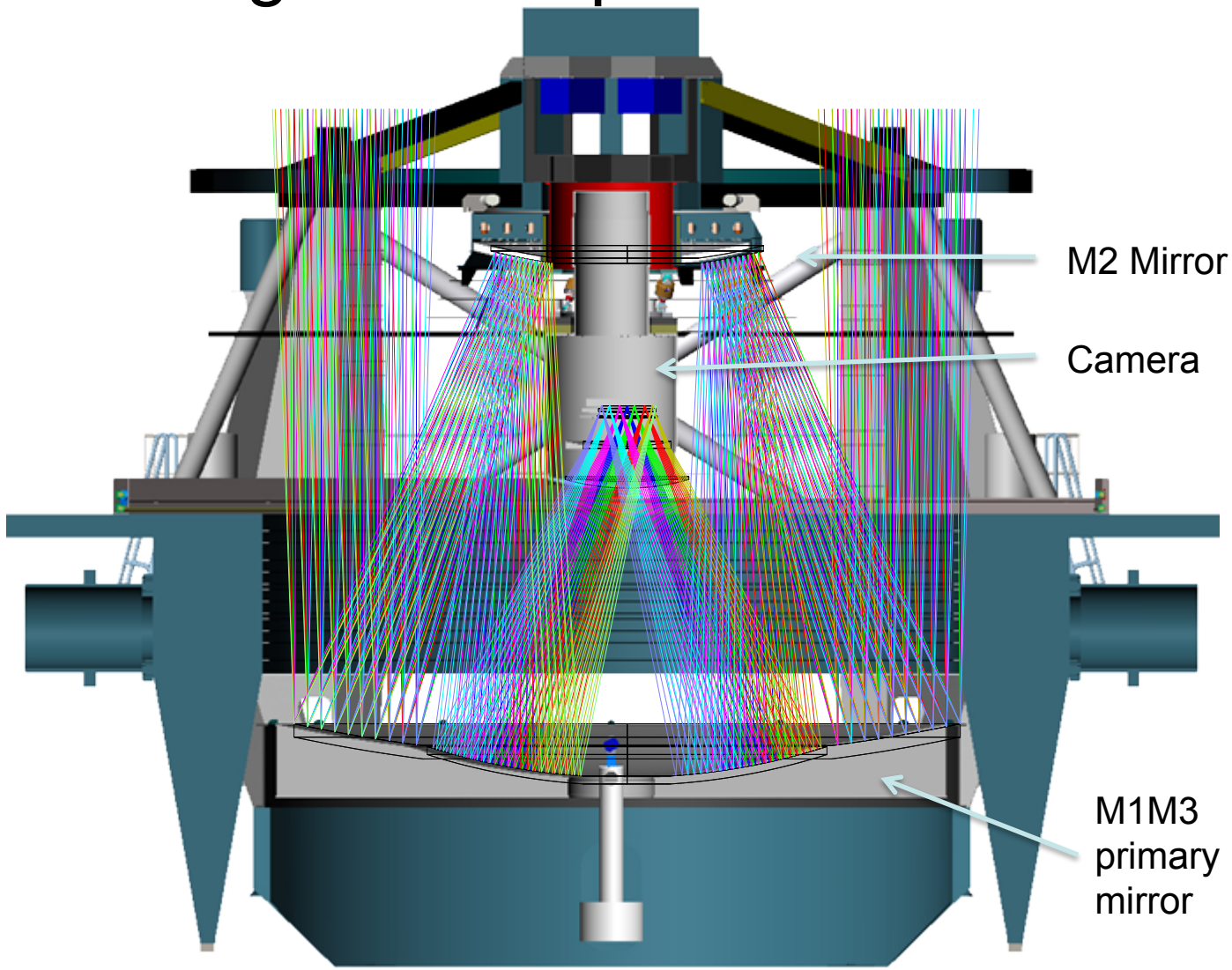
LSST Optical Design

- *f/1.23* Very short focal length gives wide field of view for given image size
- 3.5 ° FOV over a 64 cm focal plane, Etendue = 319 $m^2 deg^2$
- < 0.20 arcsec FWHM images in six filter bands: 0.3 – 1 μm



I. Shipsey

Cross section through telescope and camera



I. Shipsey

Unique Monolithic M1 / M3 mirror polishing complete

Secondary Mirror Substrate ready for optical polishing

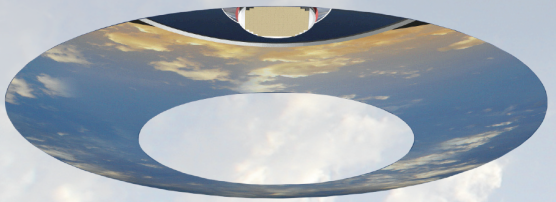
Sept 2008

Private donors have joined with more than thirty universities, research institutions, and corporations to construct the Large Synoptic Survey Telescope (LSST), a survey telescope capable of producing a high-definition digital movie of the entire sky and forever changing the way we view the Universe. The LSST Corporation invites you and a guest to share with us in the completion milestone of this unique telescope mirror, spun cast from molten glass in 2008 and meticulously polished to perfection for more than 6 years.

Save the Date

M1/M3 Completion

Saturday, January 10, 2015



Please join us on January 10th, 20

primary (M1) and tertiary (M3) mi

Steward Observatory Mirror Lab

A formal invitation with details re

follow. For now, just save the date

Questions can be directed to:

Pat Eliason, peliason@lsst.org

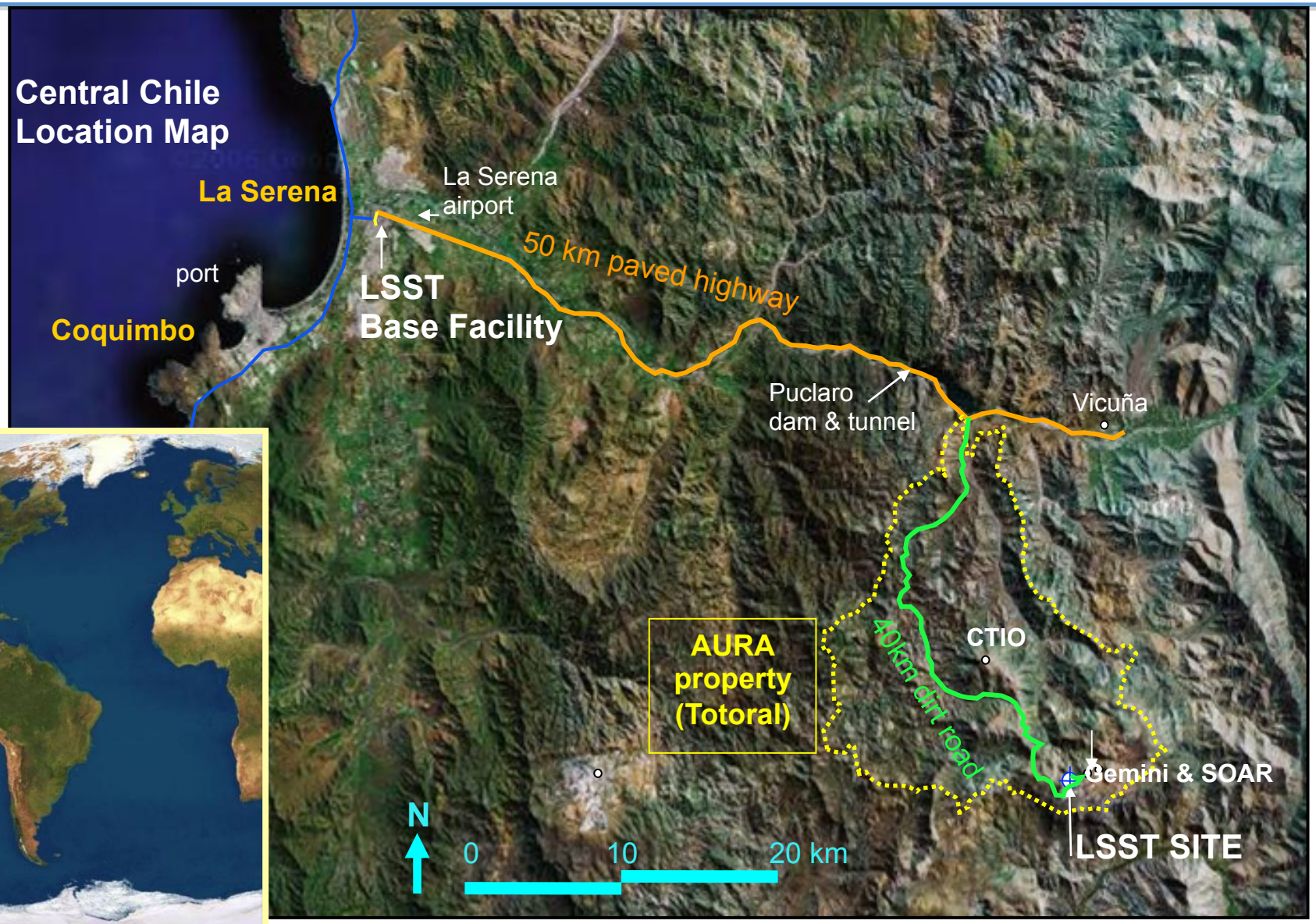
More information about the Larg

can be found at http://www.lsst.o

LSST CORPORATION

I. Ships

LSST Will be Sited in Central Chile



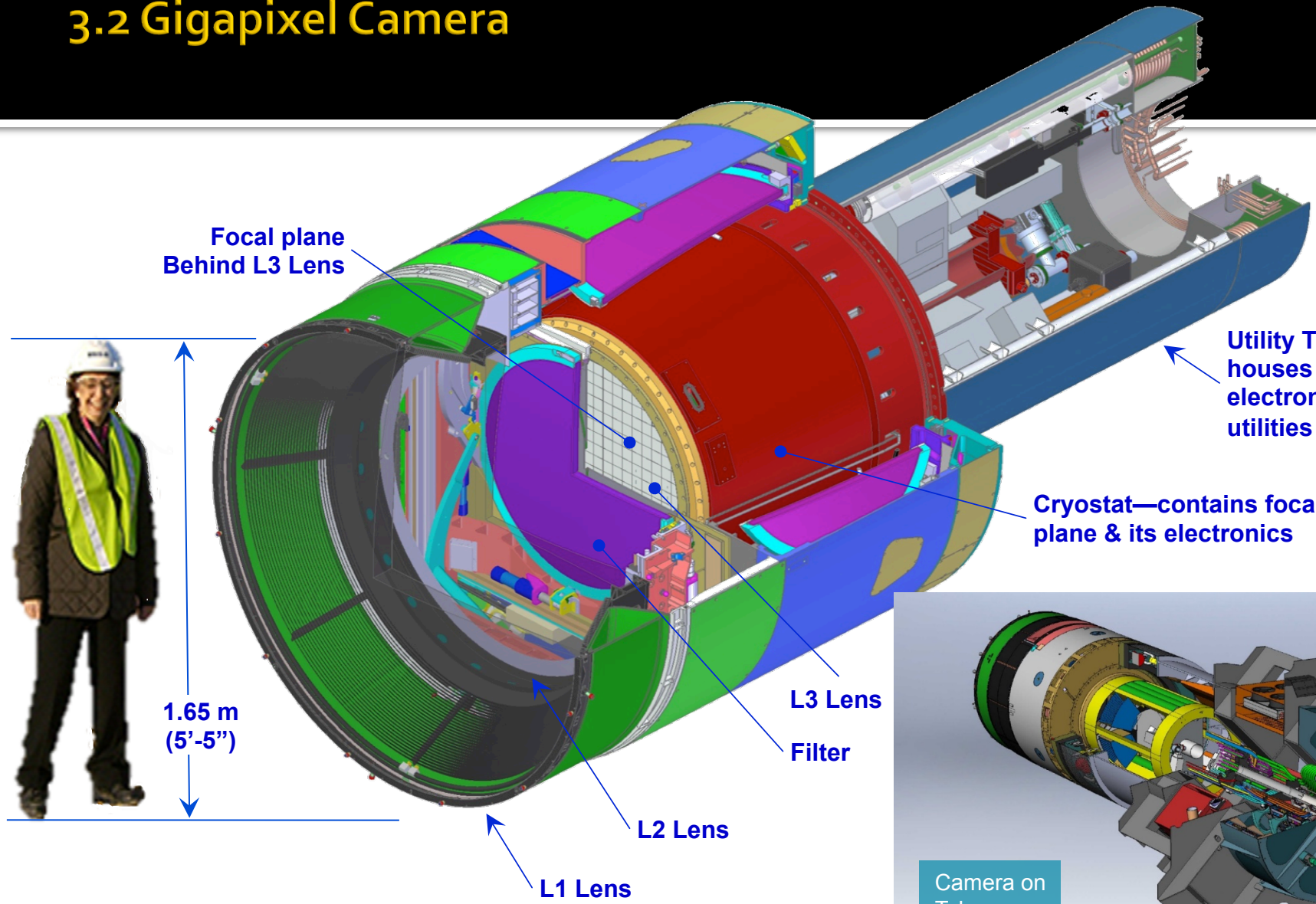
Site and observatory: construction has begun

facility designed to minimalize atmospheric turbulence in the vicinity of the dome
Formal "laying of the 1st stone" for the observatory April 14, 2015

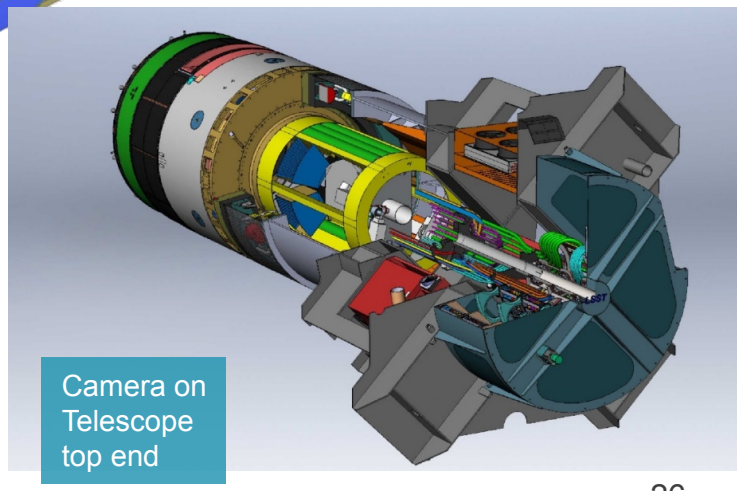
LSST Laying of First Stone – 14 April 2015

3.2 Gigapixel Camera

UK: Oxford (sensors and mechanics)



Camera ¾ Section



Sensors meet Requirements, Procurement is Under Way

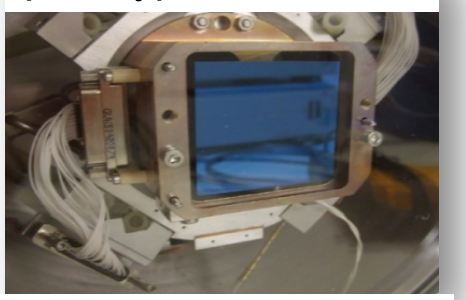
LSST prototype sensors meet project requirements.

1st article sensor procurement is now under way with two vendors e2v (UK) & ITL (US)

Sensor delivery rate is the critical path pacing item for the LSST camera.

Oxford: UK liaison between LSST and e2v (weekly meetings in Chelmsford)

prototype, vendor 1



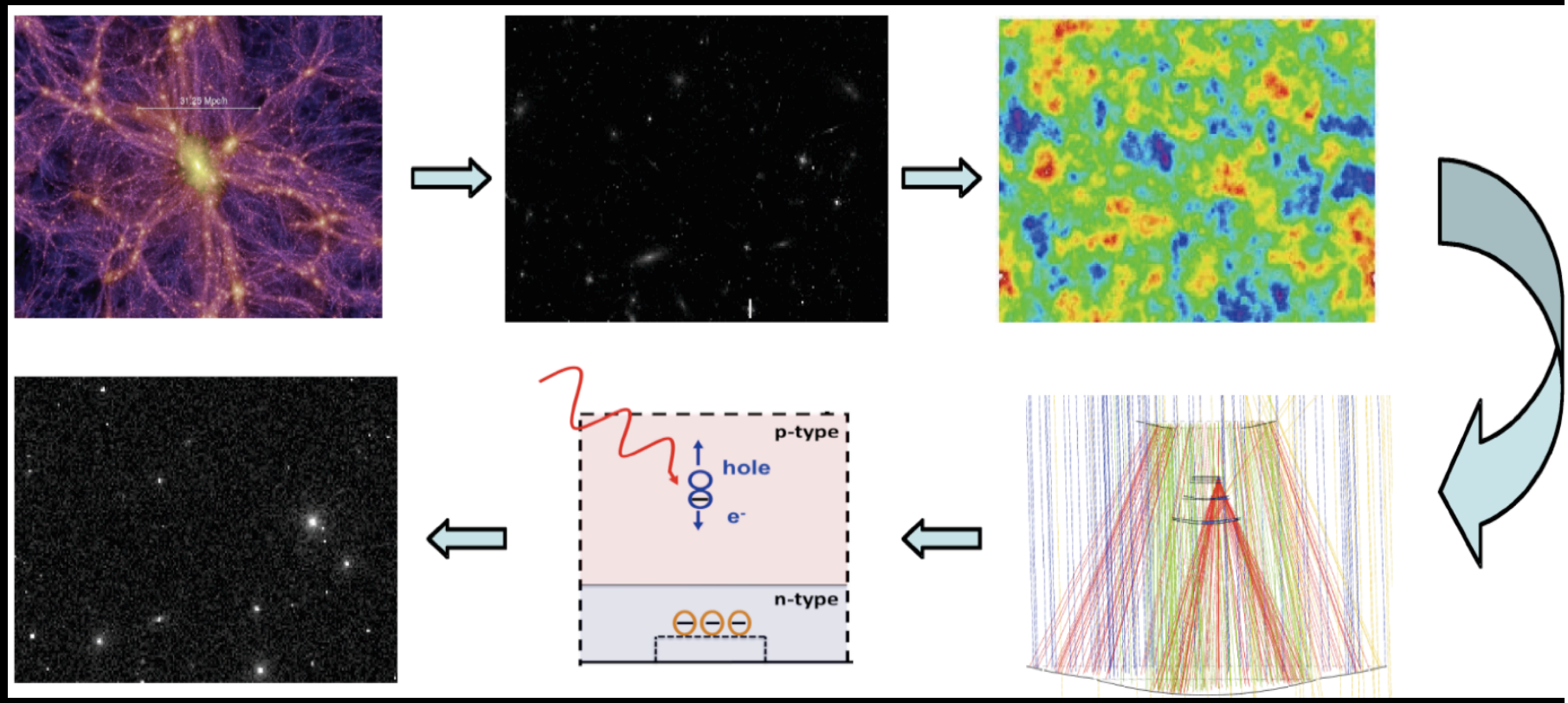
prototype, vendor 2

compliance matrix

	Number	Specification	Value	Unit	No. Tested/Passe	Result
ARCHITECTURE	CCD-001	Format	Design Consideration		ALL	-
	CCD-002	Pixel size	Design Consideration		ALL	-
	CCD-003	Segmentation	Design Consideration		ALL	-
	CCD-004	Contiguity	Design Consideration		ALL	-
ELECTRICAL	CCD-006	Read time	2	sec	9/9	tested at 545kpix/s
	CCD-007	Read noise	8	e- rms	6/0	7.8 ±1
					3/3	5.01 ±0.97
	CCD-008	Bloomed full well	175000	e- max	4/4	145000 ±17000
	CCD-009	Nonlinearity	±2	%	2/2	1.00 ±0.3

- Every 15 sec exposure, 2 sec readout, repeat
- 5 second slew to new sky location
- Nightly data generation rate: 15 Tbytes
- SDSS Data Release 7 was 16TB

Image Simulation: Implementing a simulated sky



+ operations simulator

LSST in UK

Very broad interest in all four science themes

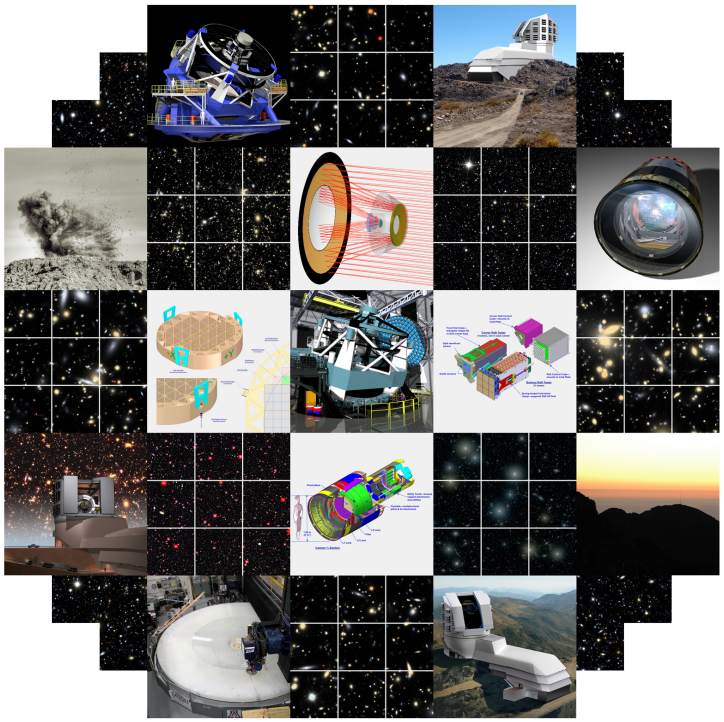
Formed LSST:UK
Autumn 2013

Proposal to PPRP July, 2014

35/36 UK Astronomy Institutes
184 astro PIs

PP involvement:
Clarke (computing)
Shipsey (camera/dark energy)

UK Involvement in the Large Synoptic Survey Telescope



The LSST : UK Consortium

Presentation to PPRP October, 2015, followed by site visit Jan, 2015

UK involvement in the Large Synoptic Survey Telescope

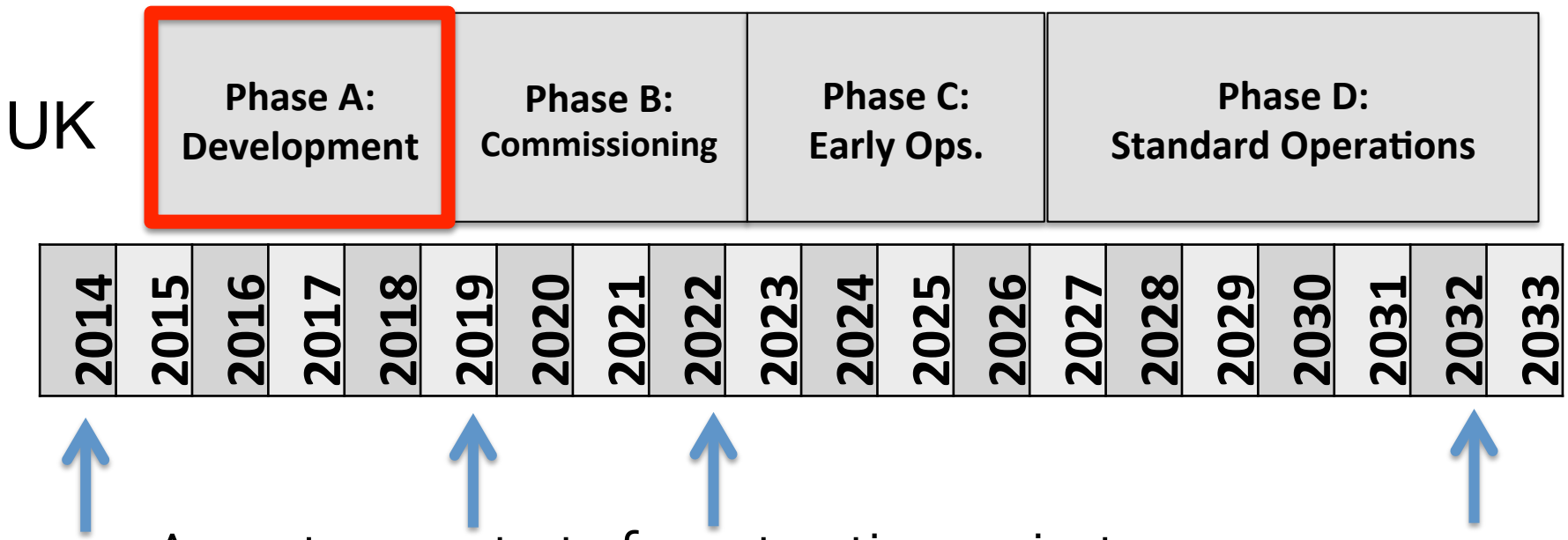
Bob Mann
University of Edinburgh
LSST:UK Project Leader

Sarah Bridle
University of Manchester
LSST:UK Project Scientist

Ian Shipsey
University of Oxford
LSSTC Board Member
LSST Project Member

on behalf of the LSST:UK Consortium

Timeline for LSST
Support for Phase A



- 1 August 2014: start of construction project
- October 2019: telescope First Light
- October 2022: start of main survey operations
- September 2032: end of main survey

From an email on March 26 2015:

We have been waiting to get formal feedback on our PPRP proposal

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- which is, apparently, STFCs communication channel of choice for major announcements.

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We still don't have formal confirmation of the proposal outcome, but now that the news has been tweeted, we should not have much longer to wait.

Phase A funding from PPRP

- £15M set aside for 10 years operations contribution
- £2.7M for Phase A programme (4 years):
- Coordinate activities through a distributed entity – the LSST:UK Science Centre (LUSC). Four strands:
  - Data Access Center: 6 staff-years
    - Data Challenges, supporting LUSC-DEV (Edin)
  - Preparing for data (analysis tools & hardware): 16 staff-years
    - Weak lensing: sims., PSF, deblending, Euclid synergy (Man/Oxf/UCL)
    - Milky Way: star/galaxy separation, tidal stream detection (Cam)
    - Transients: alert handling, classification, cadence optimisation (QUB)
    - Solar System: postage stamps, lightcurves (QUB)
    - Sensor characterisation: image analysis systematics (Oxf)
  - EPO: Citizen Science and outreach (start in phase B)
  - Training: computing/stats (seek funding from EC)

PP in LSST

Liverpool Camera/DAQ/Dark Energy
Oxford Camera/Database/ Dark Energy
UCL DAQ/Dark Energy

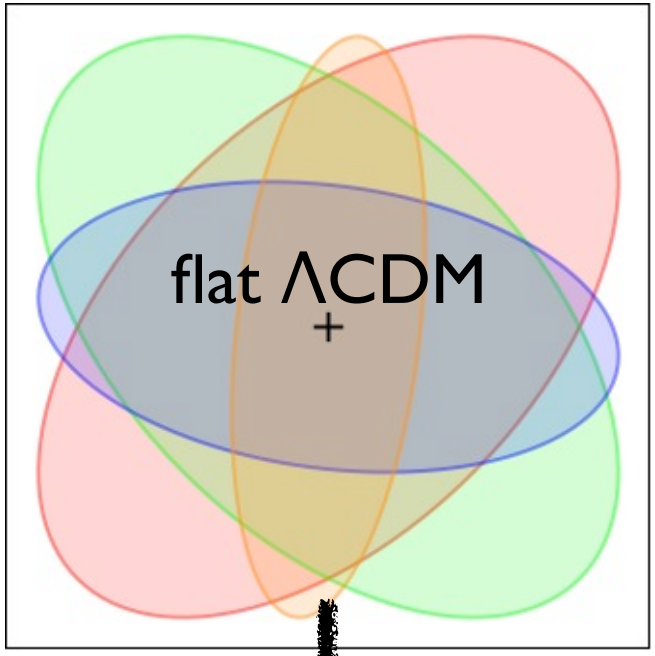
requested small fractions (typically 0.2) academic time of 6 academics in PPCG2015 this was awarded

Edinburgh & Manchester GridPP staff to support LSST data analysis as part of the 10% budget pledged by GridPP for use by non-LHC experiments

GridPP
UK Computing for Particle Physics

Already started pre-LSST pilot activity using DES cosmic shear analysis at Manchester (see Peter Clarke's talk)

Circa 2019



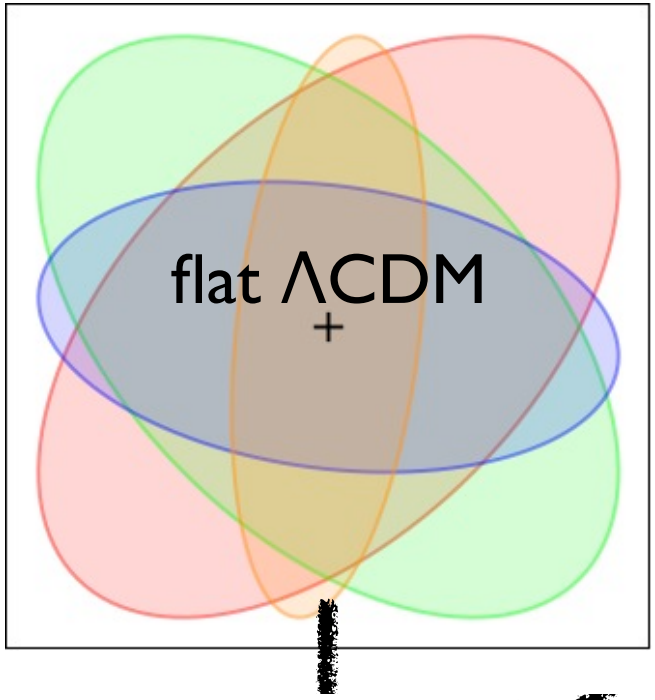
Measurements of dark energy with several techniques with Stage III experiments.
Precision is limited.

Stage III

Circa 2026

LSST
& other stage IV experiments

Circa 2019



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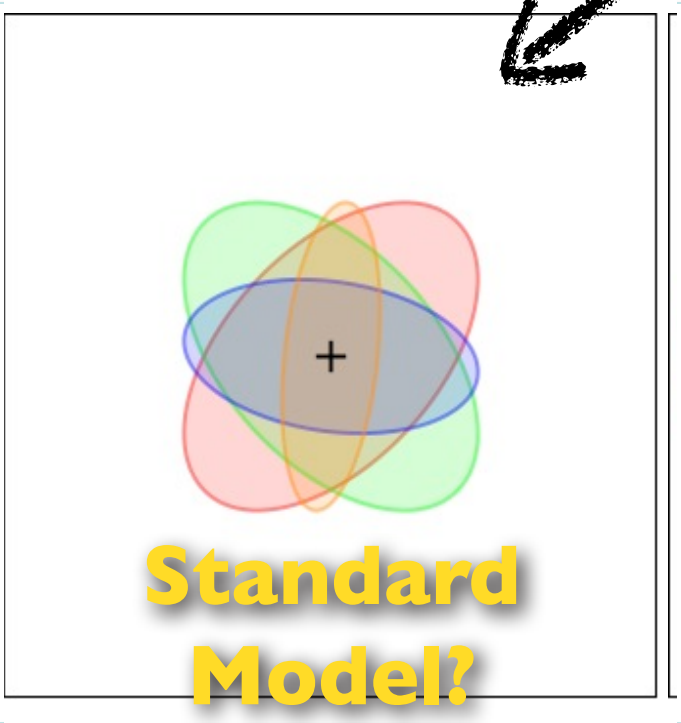
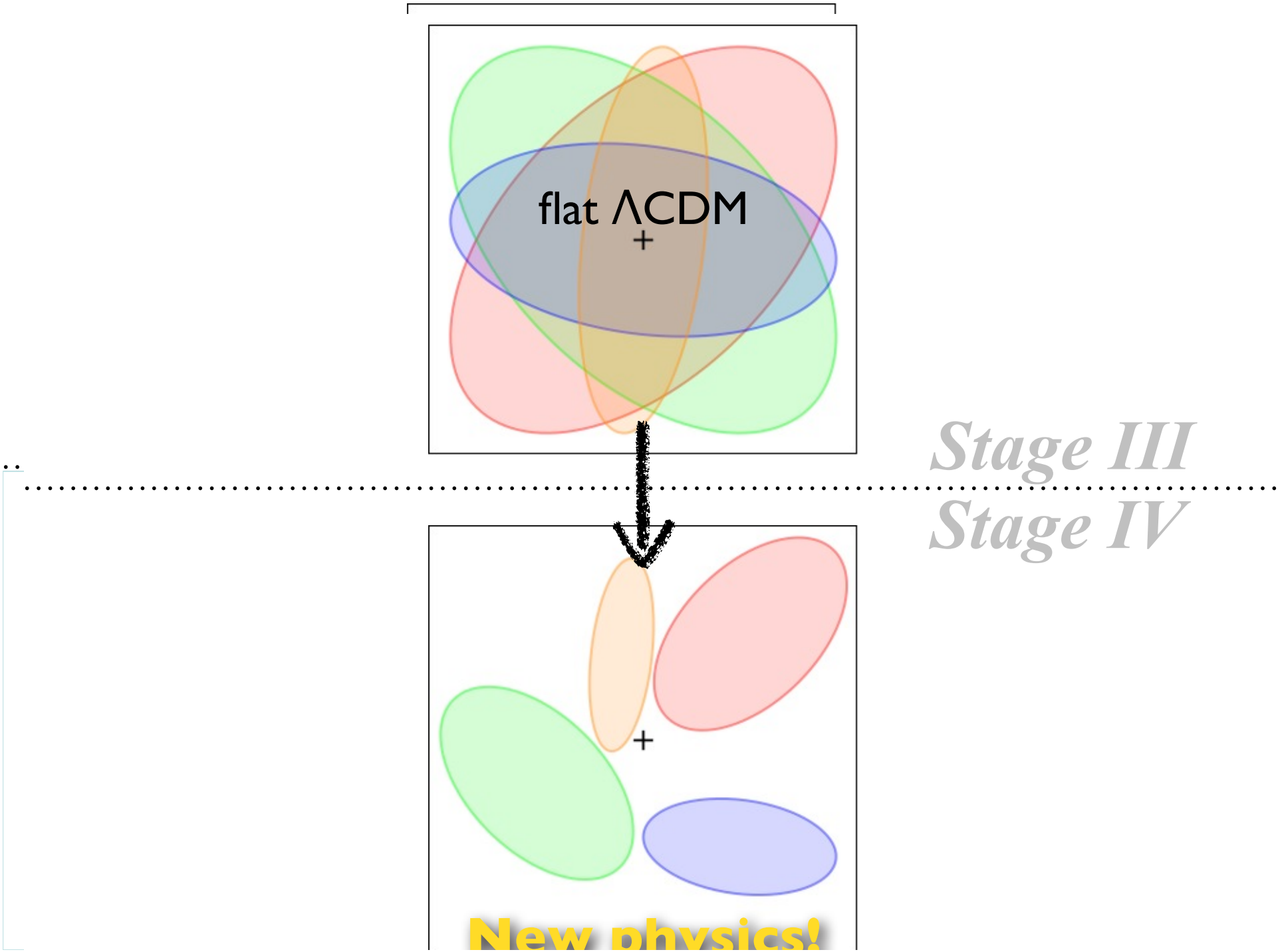


LSST
& other stage IV experiments


flat ΛCDM
+
Stage III
Stage IV
+
New physics!

LSST Outreach Data will be used in classrooms, science museums, and online

Classroom Emphasis on:

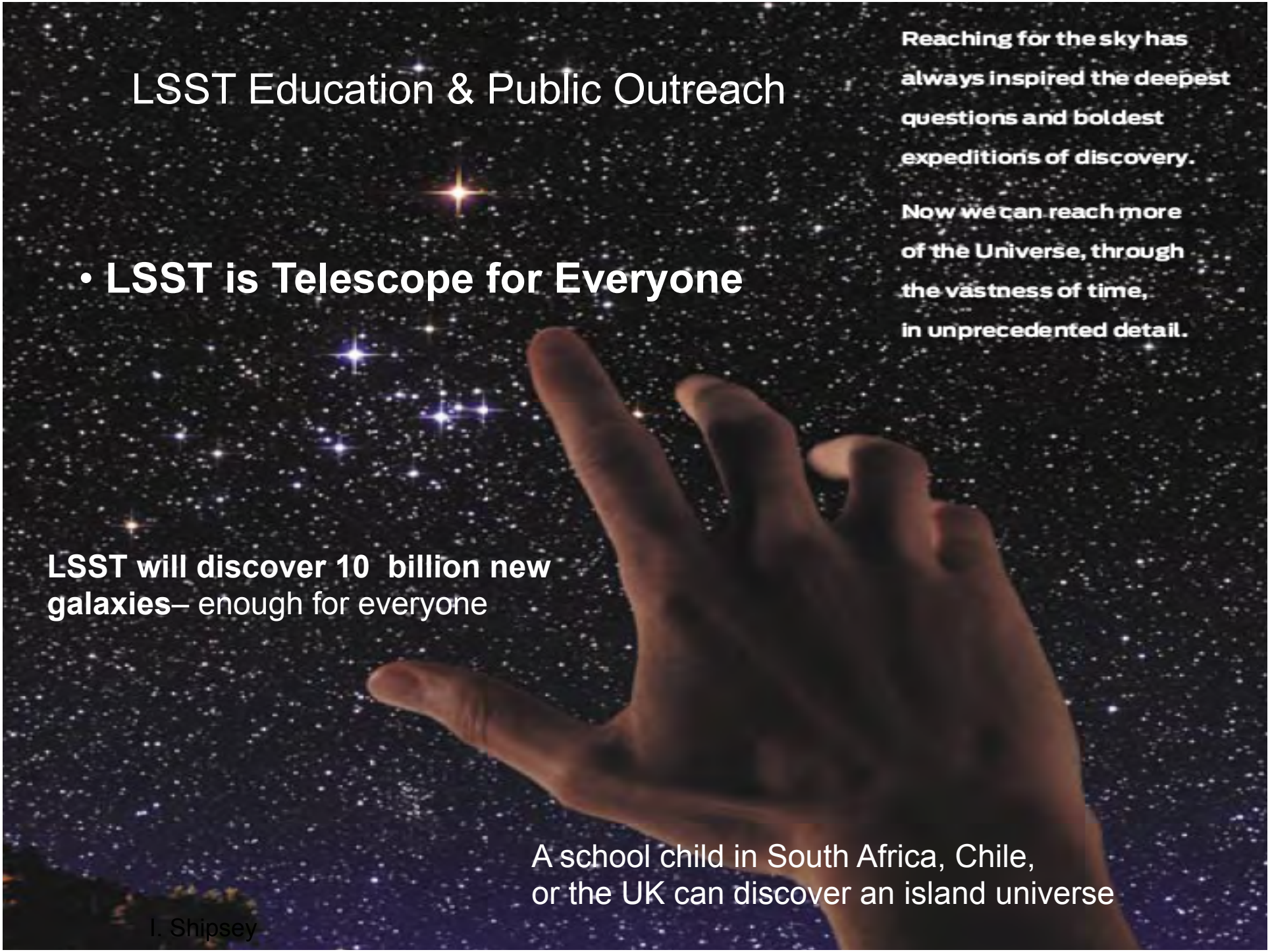
- Data-enabled research experiences
- Citizen Science
- College classes
- Collaboration through Social Networking

ZOONIVERSE
REAL SCIENCE ONLINE

LSST Education & Public Outreach

- **LSST is Telescope for Everyone**

LSST will discover 10 billion new galaxies– enough for everyone



A school child in South Africa, Chile, or the UK can discover an island universe

I. Shipsey

LSST IS HIRING

Large Synoptic Survey Telescope
LSST.ORG

WE'RE SEEKING TOP TALENT TO WORK IN A TEAM ENVIRONMENT THAT INSPIRES EXCELLENCE.

LSST HEADQUARTERS
TUCSON, AZ

SLAC/STANFORD
MENLO PARK, CA

PRINCETON UNIVERSITY
PRINCETON, NJ

NCSA / UIUC
URBANA-CHAMPAIGN, IL

UNIVERSITY OF WASHINGTON
SEATTLE, WA

LSST OBSERVATORY SITE
CERRO PACHÓN, CHILE

ABOUT US

LSST IS A PUBLIC-PRIVATE PARTNERSHIP AND THE TOP-RANKED LARGE-SCALE GROUND-BASED PROJECT FOR THE NEXT DECADE AS RECOMMENDED BY THE NRC'S ASTRO2010 DECADAL SURVEY. LSST WILL SCAN THE SKY FOR 10 YEARS, PRODUCING A PETABYTE-SCALE, NON-PROPRIETARY DATABASE DESIGNED TO ADDRESS THE MOST PRESSING QUESTIONS IN ASTRONOMY AND PHYSICS, WHILE DRIVING ADVANCES IN BIG-DATA SCIENCE AND COMPUTING.

CAREERS

LSST IS A NEW PARADIGM FOR LARGE SCIENTIFIC FACILITIES: OPEN SOURCE, OPEN DATA, AND AN OPEN, FLEXIBLE WORK ENVIRONMENT. ALL LSST WORK SITES OFFER EXCEPTIONAL BENEFITS PACKAGES AND ROOM FOR PROFESSIONAL GROWTH.

OUR TEAM

PROJECT OFFICE

DATA MANAGEMENT

TELESCOPE & SITE

CAMERA

EDUCATION & PUBLIC OUTREACH

SYSTEM ENGINEERING

@LSST @mjuric

LSST.ORG/HIRING

NSF

U.S. DEPARTMENT OF ENERGY | Office of Science

CHARLES AND LISA SIMONYI FUND
FOR ARTS AND SCIENCES

Part of the LSST Collaboration

A partnership of particle physicists, astrophysicists & computer scientists

I. Shipsey

Summary of the LSST Project

- The Project Team began construction in August 2014. We are building the system to survey, store, process and serve the data starting in 2022.

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- The analyses will be complex and will require significant attention to detailed systematics uncertainties. *The UK has recognized the opportunities for UK astronomers, particle physicists and computer scientists to become involved now to optimize the anticipated science that will come from this marvelous facility.*