LSST/Euclid future surveys

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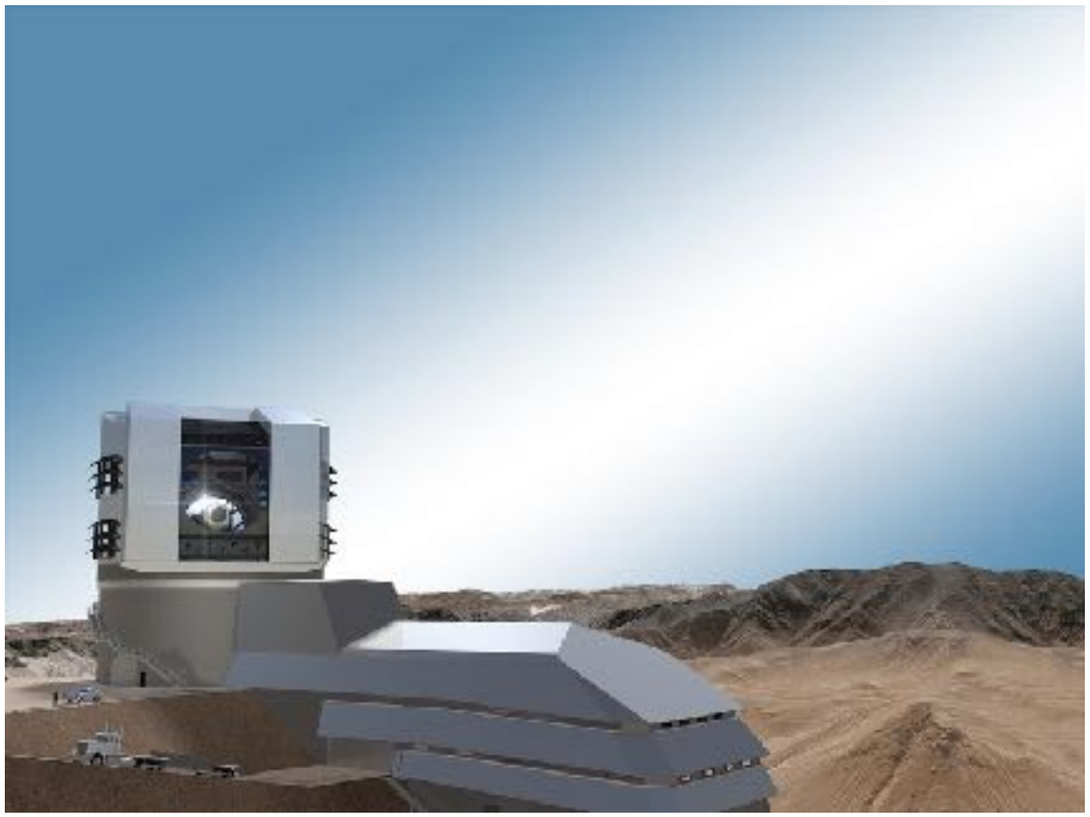
- LSST and Euclid are large sky surveys that will occur after 2020, with cosmology as a main science driver.

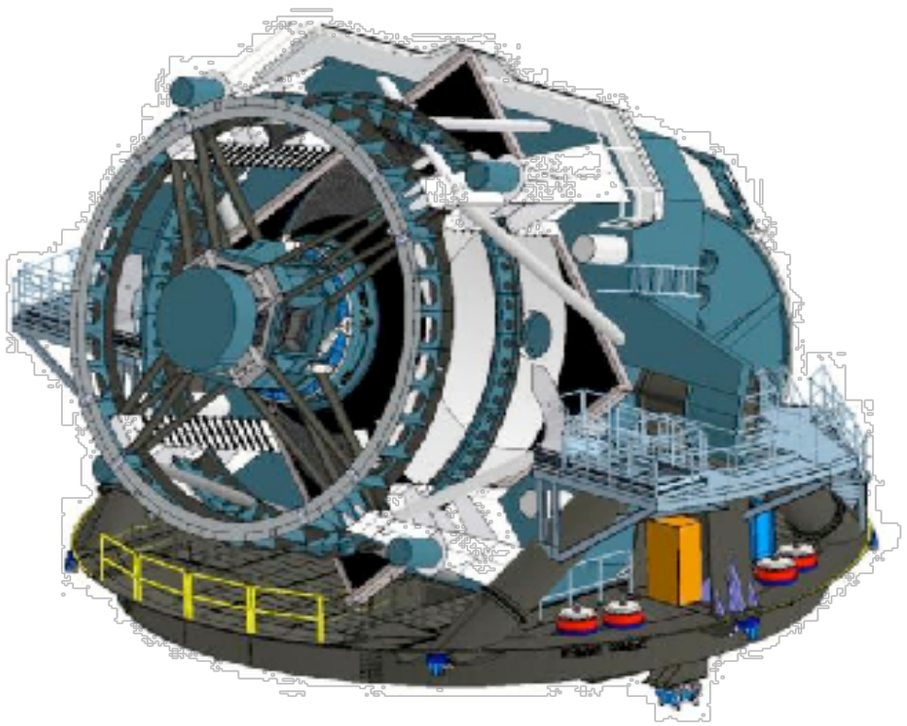
- LSST : a ground-based 8.4 m imaging telescope

- Euclid : a visible + infrared, imaging + spectroscopy, space mission

- LSST and Euclid will survey similar sky areas, will be largely contemporary, and are complementary.

The large synoptic survey telescope



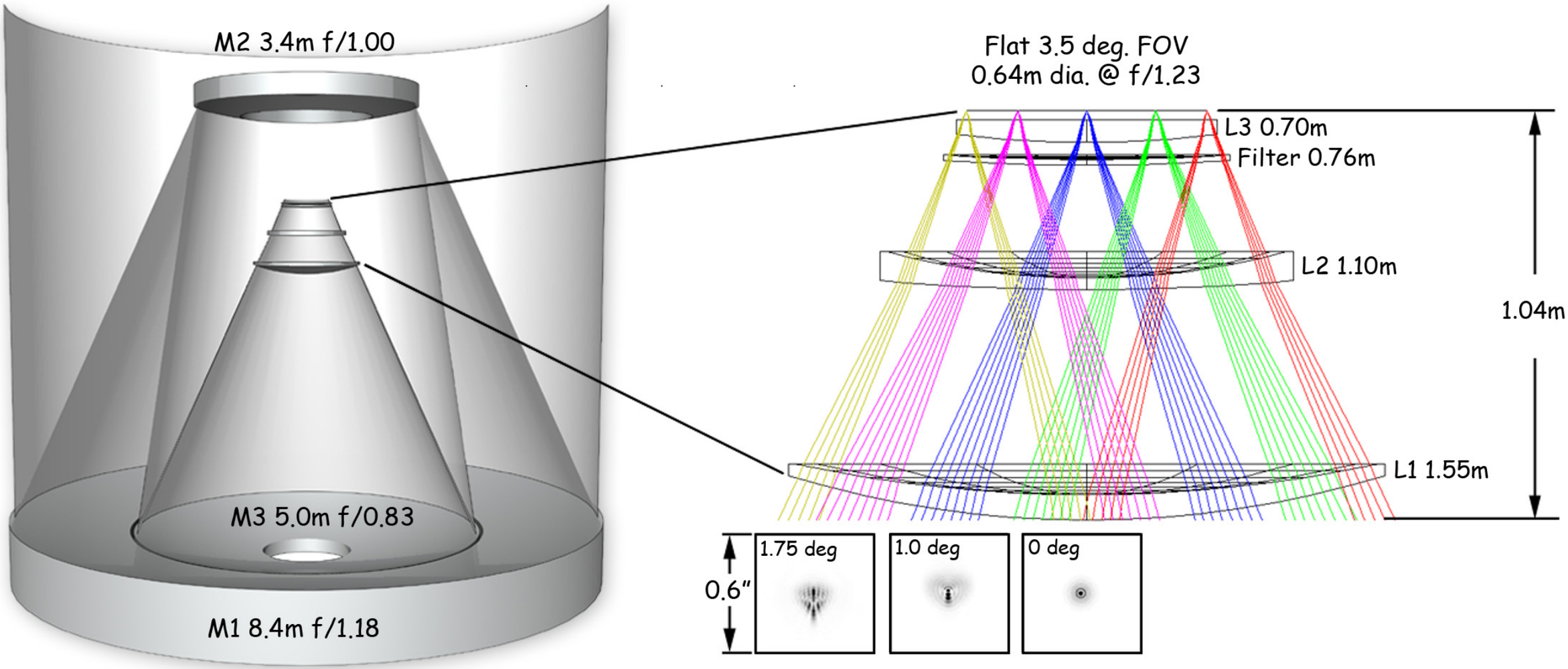


- 8.4-m (6.5 eff.) dedicated telescope, wide field (10 sq. deg.), in Chile.

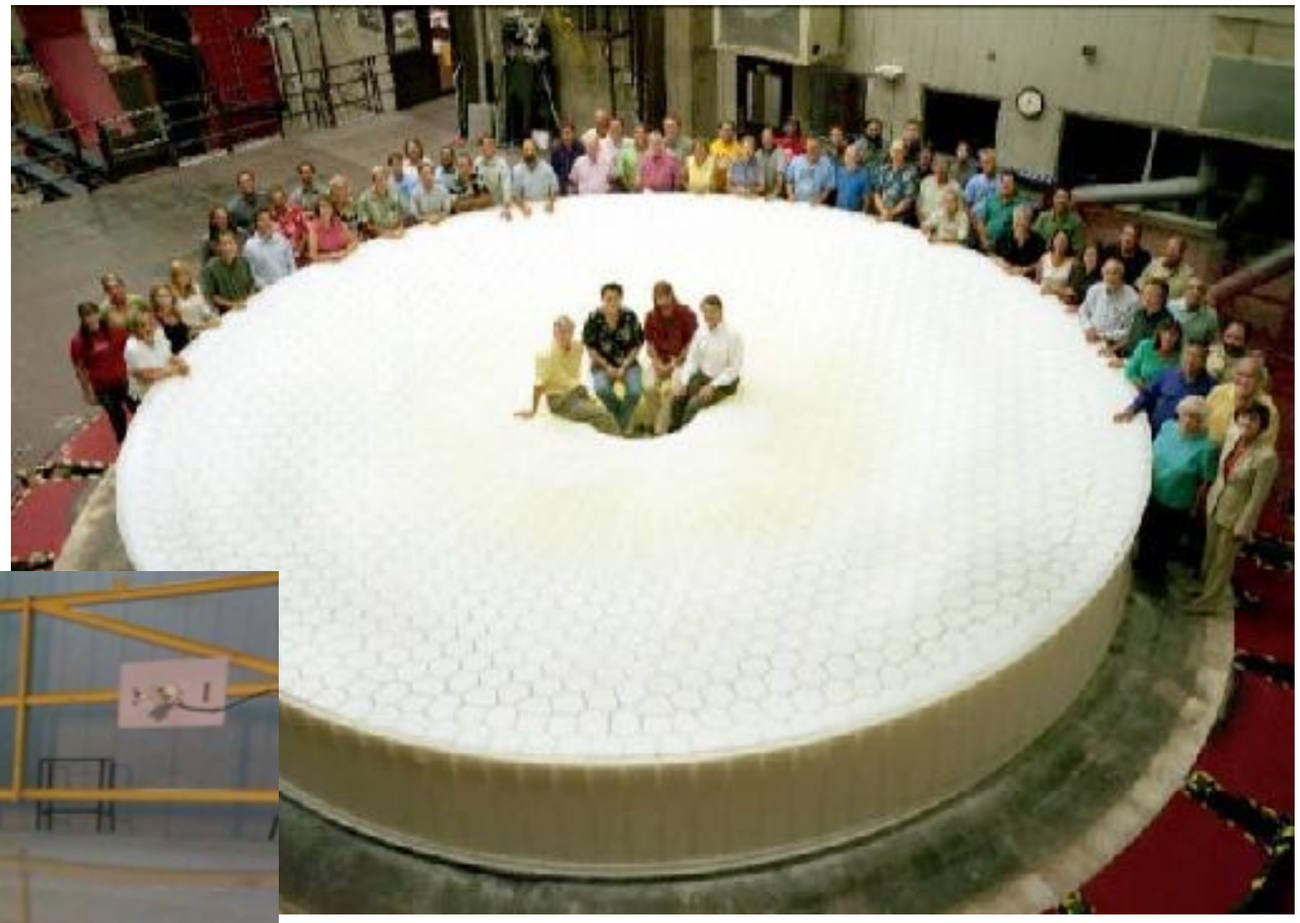
- 3.2 GPixels (10μm = 0.2”), 6 bands (ugrizy).

- Pairs of 15 seconds exposures (2 s. readout), on 20,000 sq. deg., full coverage every ~3 nights, during 10 years (science survey starting **2022**).

LSST optical design



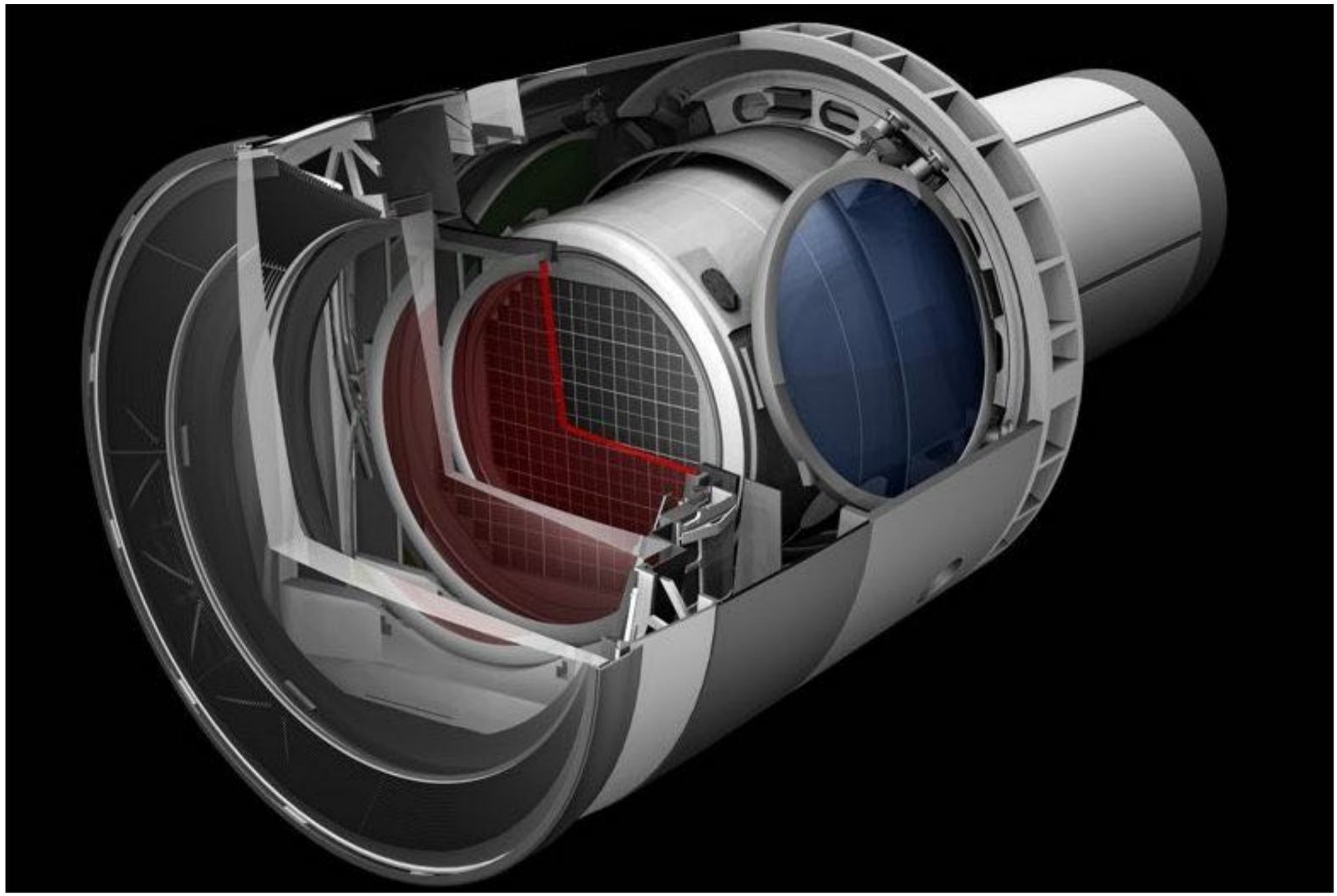
LSST mirrors



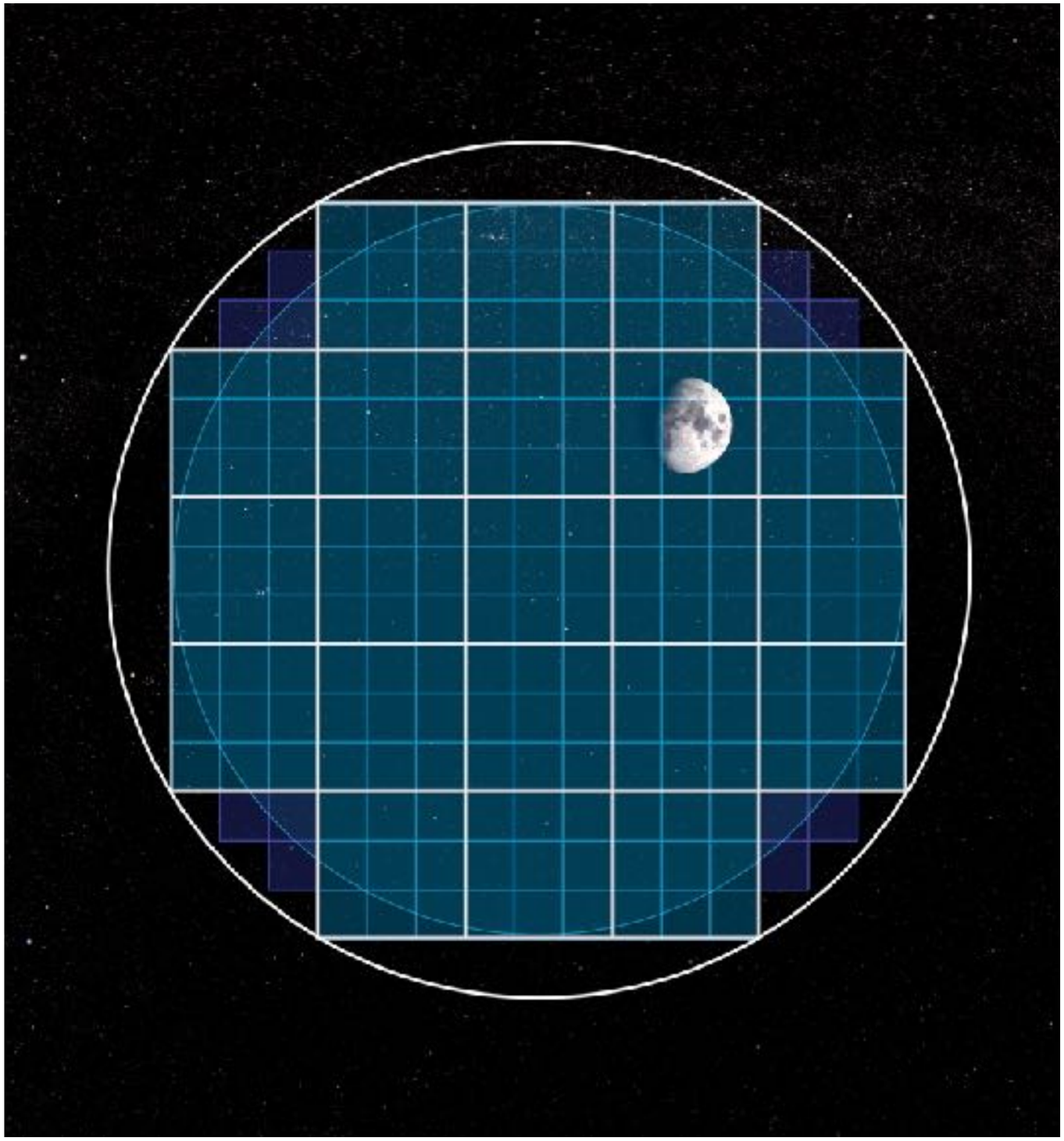
LSST mirrors

LSST Camera

~1,6m



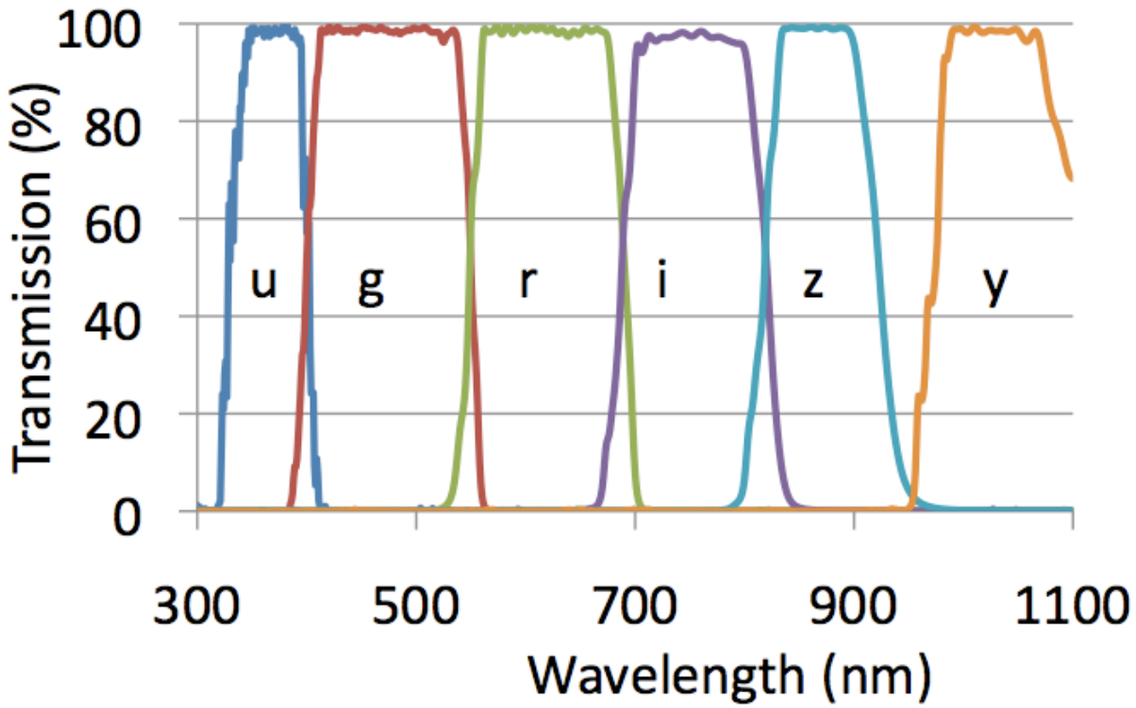
Focal plane

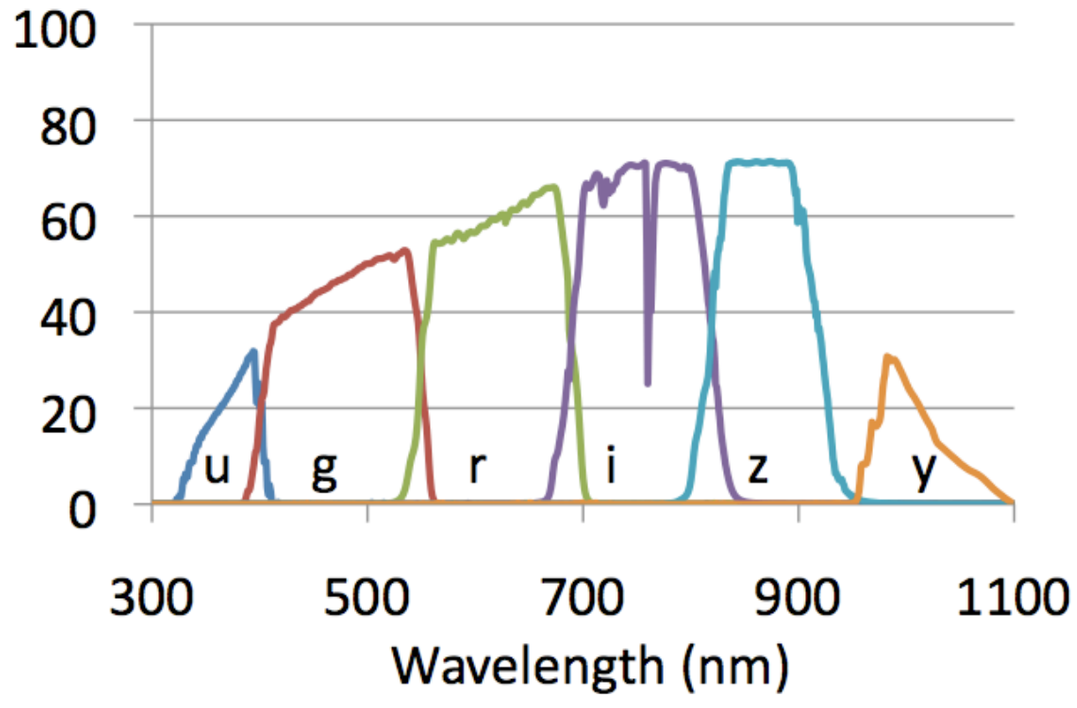


3.2 billion pixels
189 4k x 4k science CCDs,
organized in 3x3 “rafts”.
10 square degrees FoV

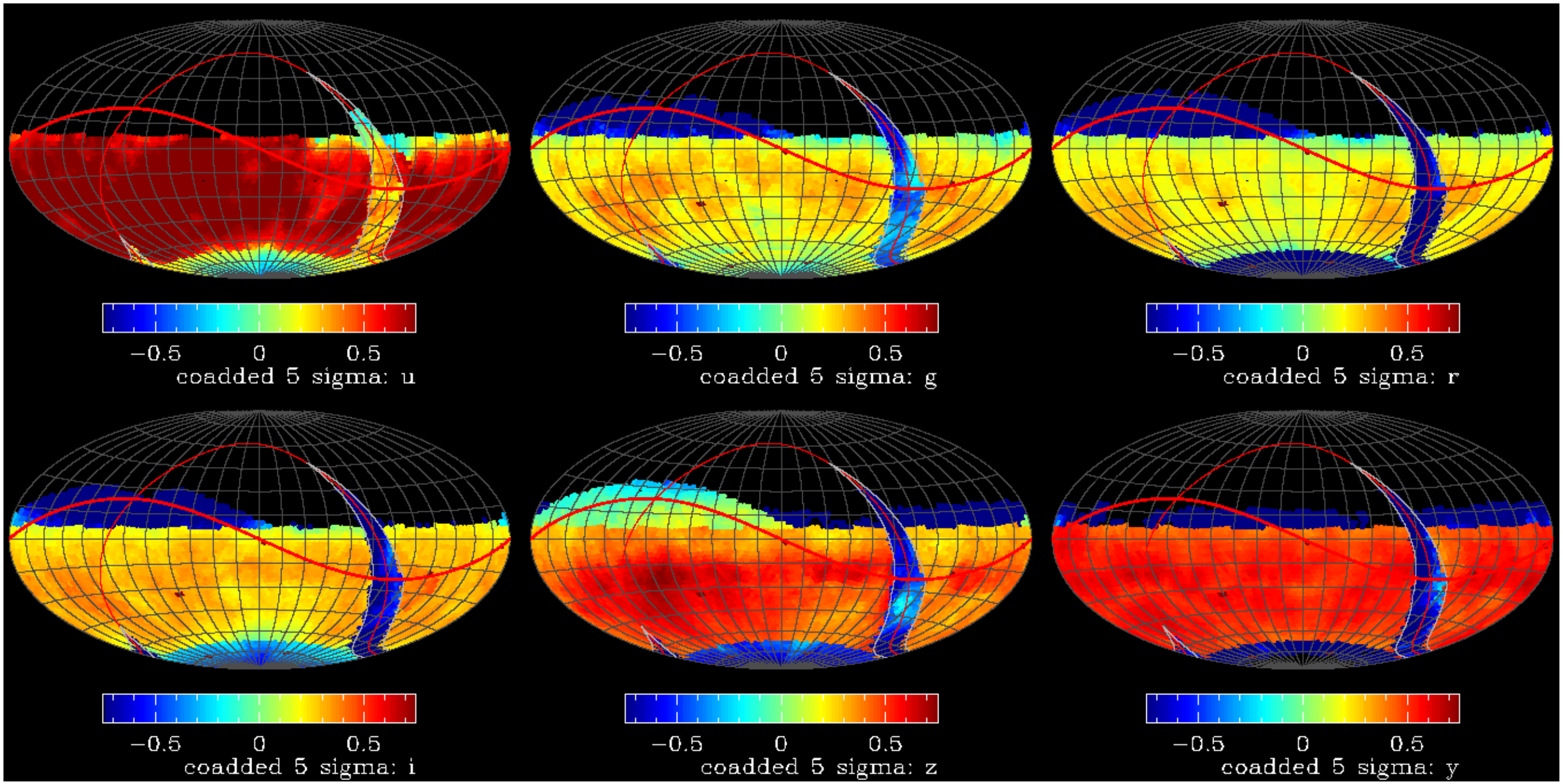
In the corners, guiding and wavefront sensing CCDs

LSST filters





LSST sky coverage



Main survey

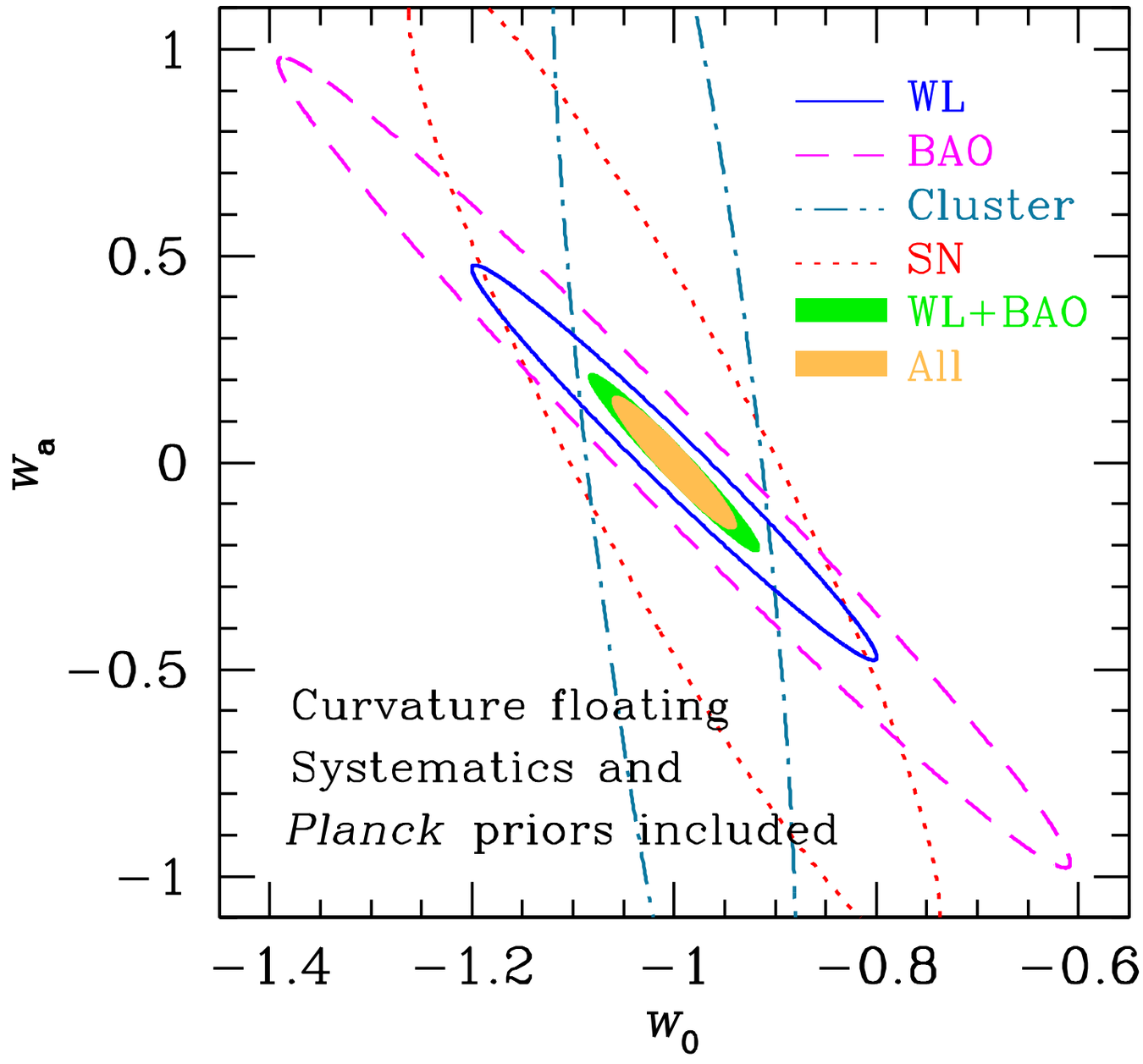
LSST science objectives

- LSST has four major science drivers, that guided the requirements and the design
  - The Nature of Dark Matter and Understanding Dark Energy
  - Cataloging the Solar System
  - Exploring the Changing Sky
  - Milky Way Structure & Formation

LSST science objectives

- Dark matter/dark energy via weak lensing
- Dark matter/dark energy via baryon acoustic oscillations
- Dark energy via supernovae
- Dark energy via counts of clusters of galaxies
- Galactic Structure encompassing local group
- Dense astrometry over 20000 sq.deg: rare moving objects
- Gamma Ray Bursts and transients to high redshift
- Gravitational micro-lensing
- Strong galaxy & cluster lensing: physics of dark matter
- Multi-image lensed SN time delays: separate test of cosmology
- Variable stars/galaxies: black hole accretion
- QSO time delays vs z: independent test of dark energy
- Optical bursters to 25 mag: the unknown
- 5-band 27 mag photometric survey: unprecedented volume
- Solar System Probes: Earth-crossing asteroids, Comets, trans-Neptunian objects

A stage-IV multiprobes DE survey



DESC white paper 1211.0310

Data products

- 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.
- 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 (r ~ 27.5 AB).
- 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.

Data products

- Data right holders have full immediate access:
  - All US and Chilean professional astronomers
  - Members of international collaborators
- Full data will become world public after two years
- The Dark Energy Science Collaboration (DESC) produces specific tools and data.

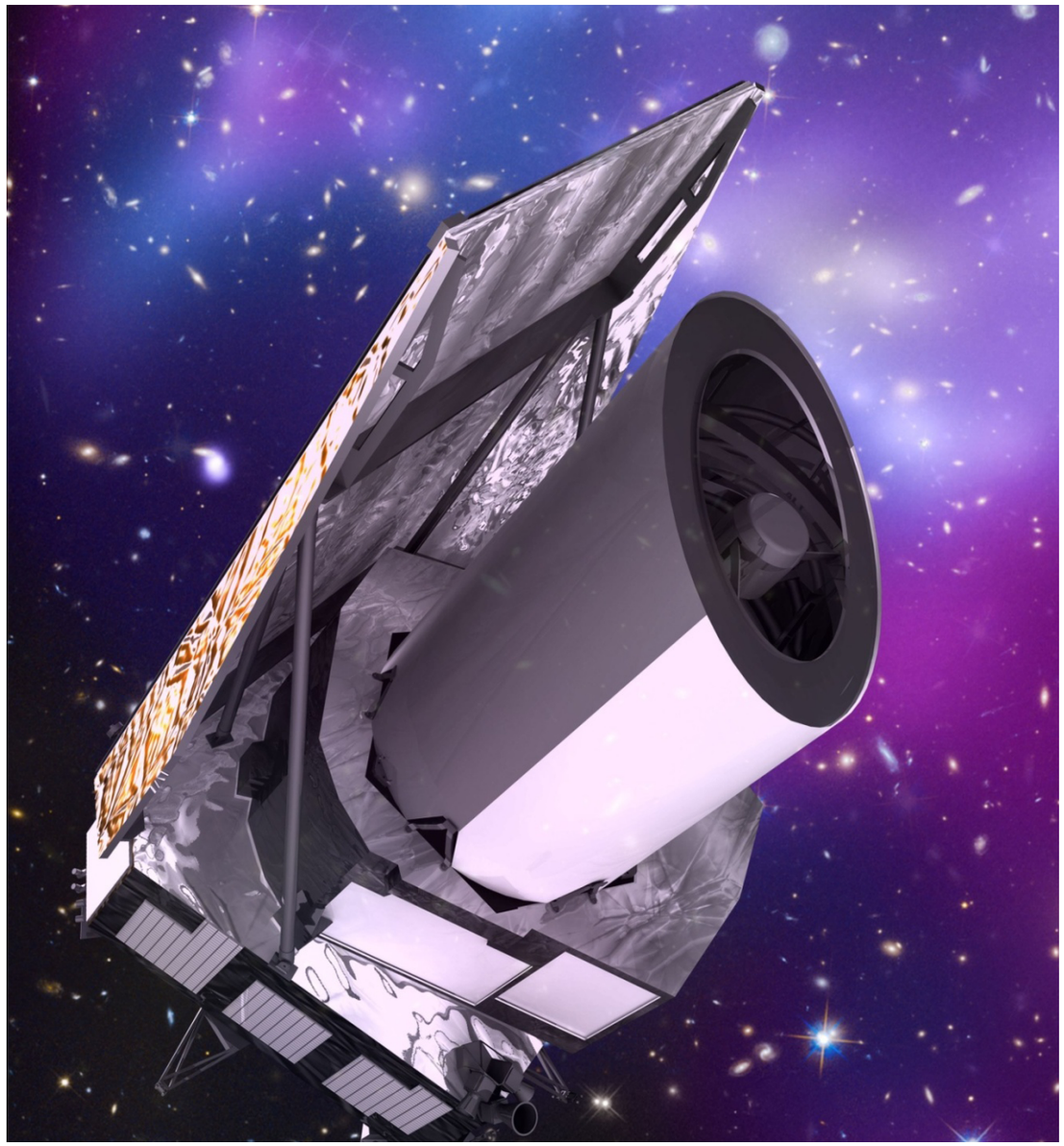
Euclid

- A dark energy space mission with a 1.2-m diameter telescope.

- 6-year mission at L2.
  ~contemporary with LSST survey.

- Imaging survey in visible wide band and photo-z: 15,000 square degrees, 12 billion sources, 1.5 billion galaxies for weak lensing (30 gal/ arcmin^2).

- Redshift survey : 35 million spectroscopic redshifts of emission line galaxies $0.7 < z < 1.85$.

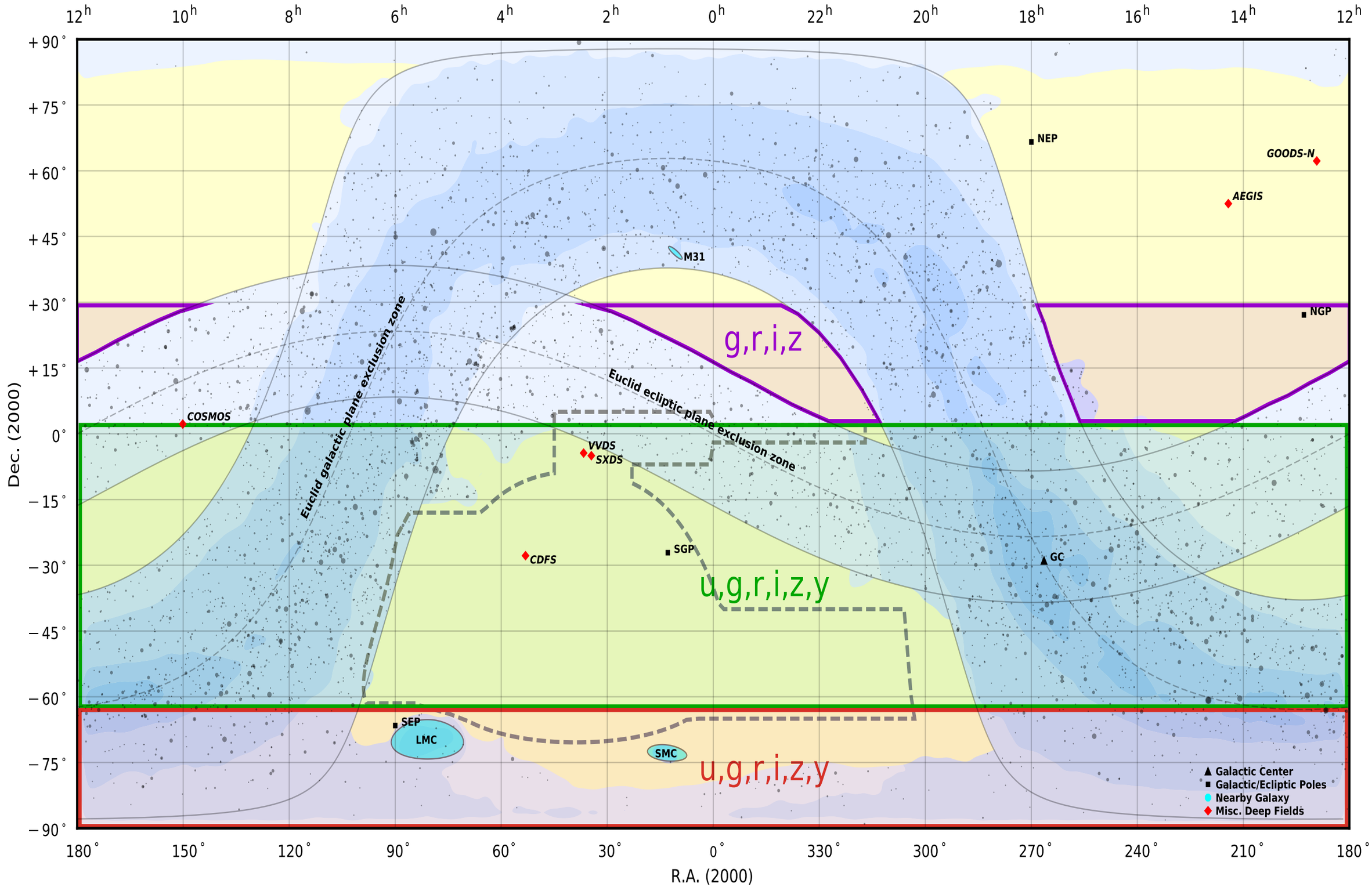


Euclid needs for photo-z

- Euclid's VIS band is wide, targeting weak lensing. Not useable for photo-z.

- Euclid has 3 NIR imaging band. ***Combined with ground-based*** multi-color visible imaging, it provides the photo-z needed by the weak-lensing measurement. (*Do not do from space what can be done from the ground*).

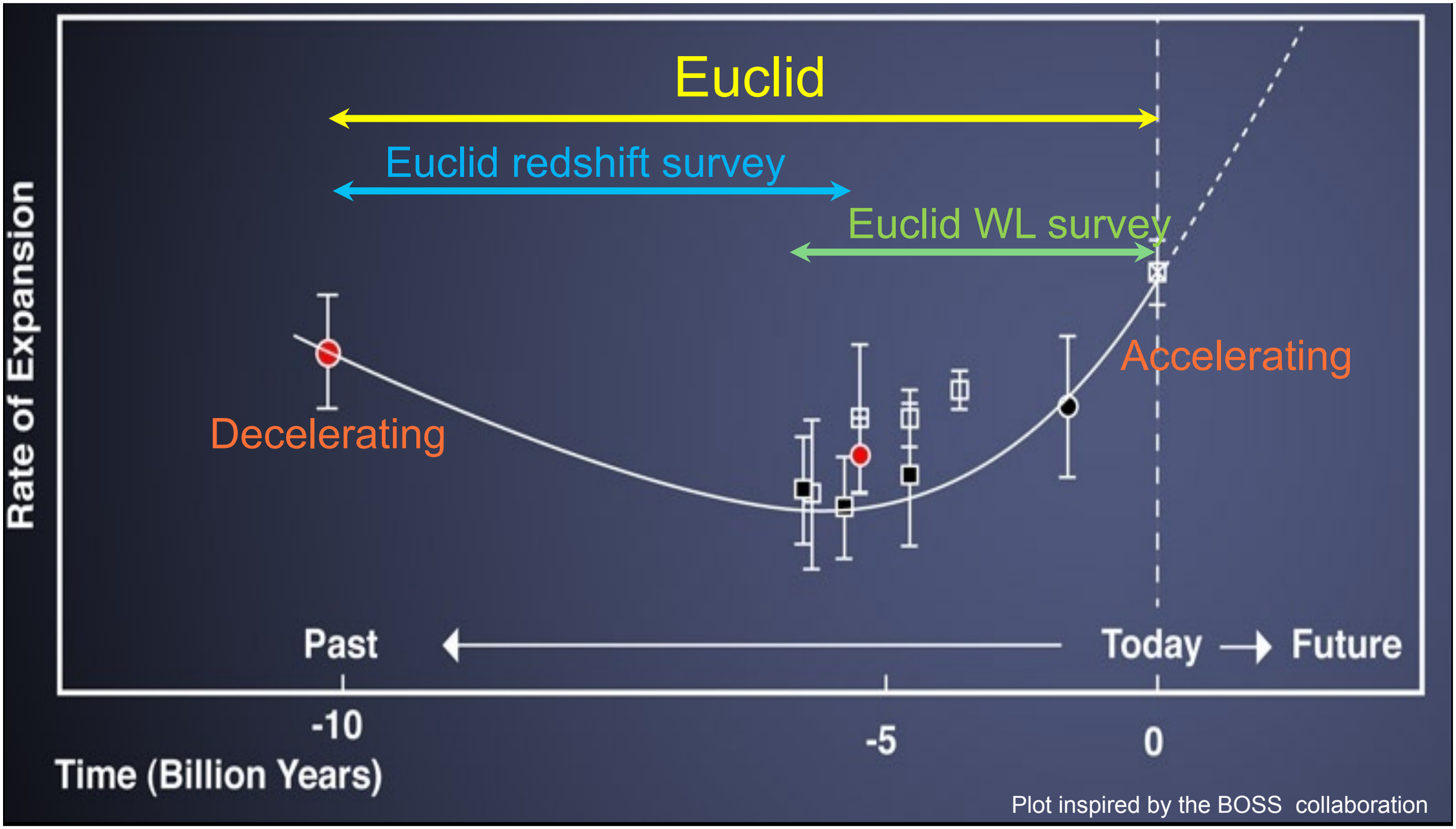
    - DES, LSST, Pan-STARRS, CFIS/CFHT, JST



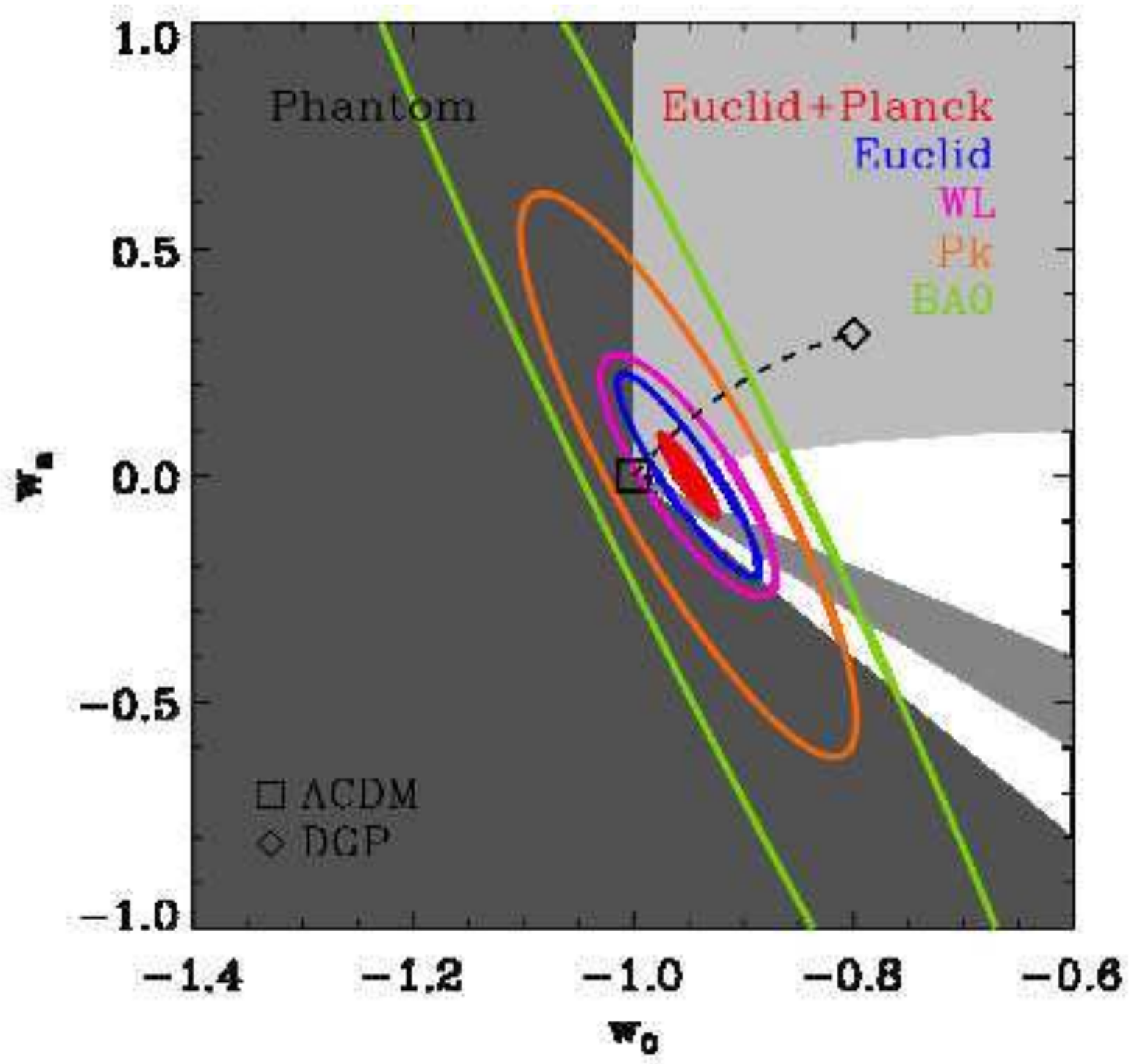
LSST main survey and extensions : complementarity with the Euclid Wide Survey

- Euclid exclusion zone : 26,000 deg.^{2} [galactic+ecliptic planes]
- Euclid Wide Survey : 15,000 deg.^{2} [with E(B−V)<0.08]
- DES : 4,500 deg.^{2} Euclid overlap in g,r,i,z
- LSST main survey : 7,000 deg.^{2} Euclid overlap in u,g,r,i,z,y
- LSST south extension : 1,000 deg.^{2} Euclid overlap in u,g,r,i,z,y
- LSST Euclid extension : 3,000 deg.^{2} in g,r,i,z specific to Euclid (depths/coverage)

Exploring the DM-DE transition



Euclid: WL+P(k)+BAO



Cimatti & Scaramella 2012

Euclid data

- > 1500 researchers in the Euclid consortium

- Data will become public ~ 2 years after acquisition (DR1 will contain 1 year of data, public at T0+26 months)

Main dark energy probes

	LSST	Euclid
Weak lensing	50 gal/arcmin2 20,000 sq deg median PSF 0.7 arcsec	30 gal/arcmin2 15,000 sq deg PSF 0.2 arcsec
BAO	photo-z (2D), 0.9 < z < 3) 10 billion galaxies (BAO with SN, z<0.8?)	spectro (3D), 0.7 < z < 1.8 35 million galaxies
Clusters	> 300,000 clusters 0.1 < z < 1.4	~200,000 clusters 0.2<z<2 ~40,000 at z>1 at 5σ
SN	10 milions SN several 100,000 well sampled SNIa	1000-2000 SNela to z < 0.7 1000-2000 to z < 1 (from deep fields) + serendipitous spectro & NIR LSST overlaps

The whole is better than the sum of its parts

- Euclid and LSST have a large overlap (7,000 sq deg at least)
- They have different systematics (different PSF, ground vs space...), and different bands (6 visible bands, vs one high-resolution wide visible band and 3 NIR bands)
- Joint pixel-level analysis should be superior to a-posteriori result combination, with better constraints on dark energy models, modified gravity models, etc.
- Examples : photo-z, deblending, shear measurement...
- Cf Rhodes et al. 2017 for a detailed review.

LSST depth

LSST 1-2 years is a good match to Euclid.

Full LSST is a good match to WFIRST

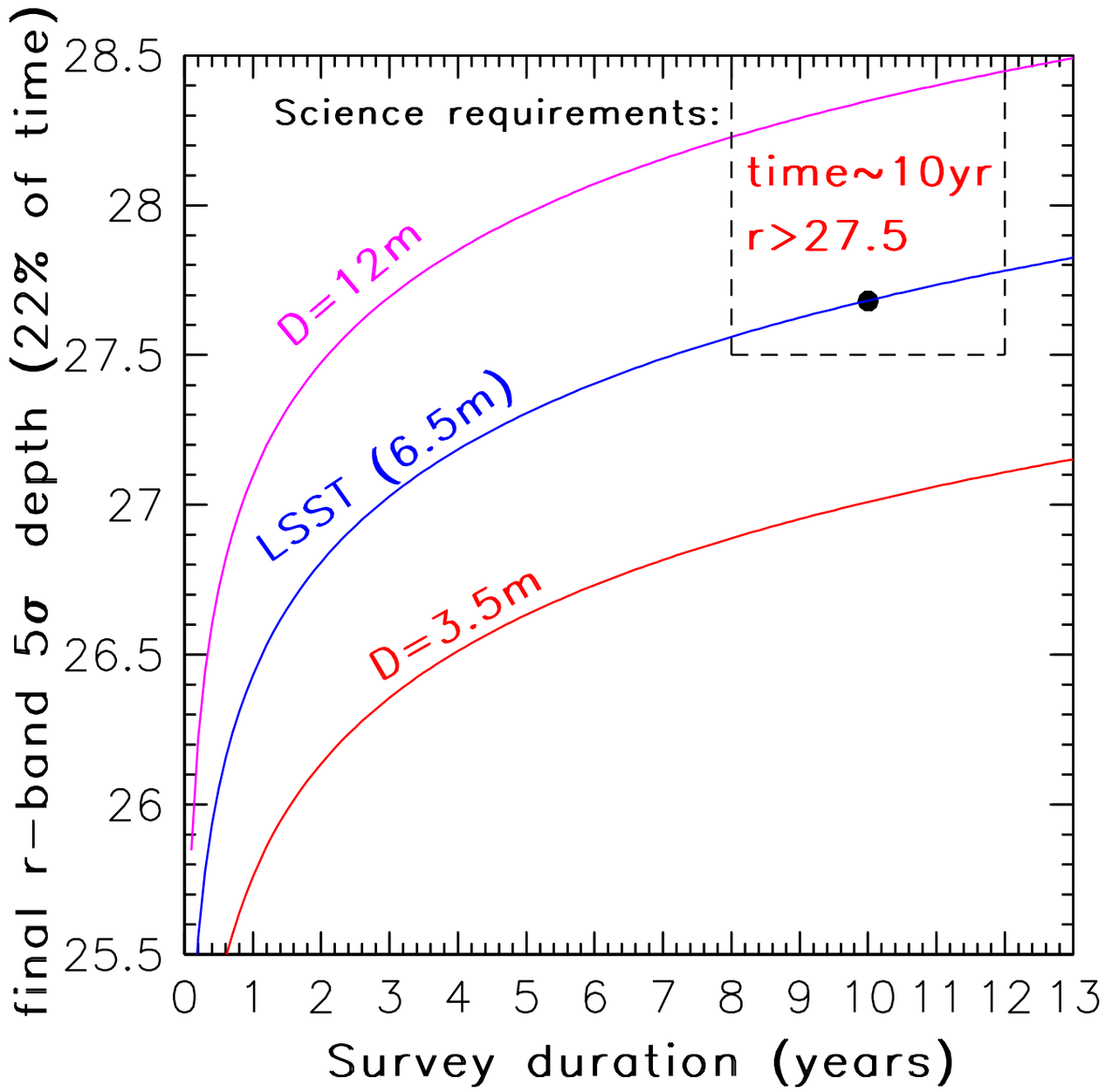
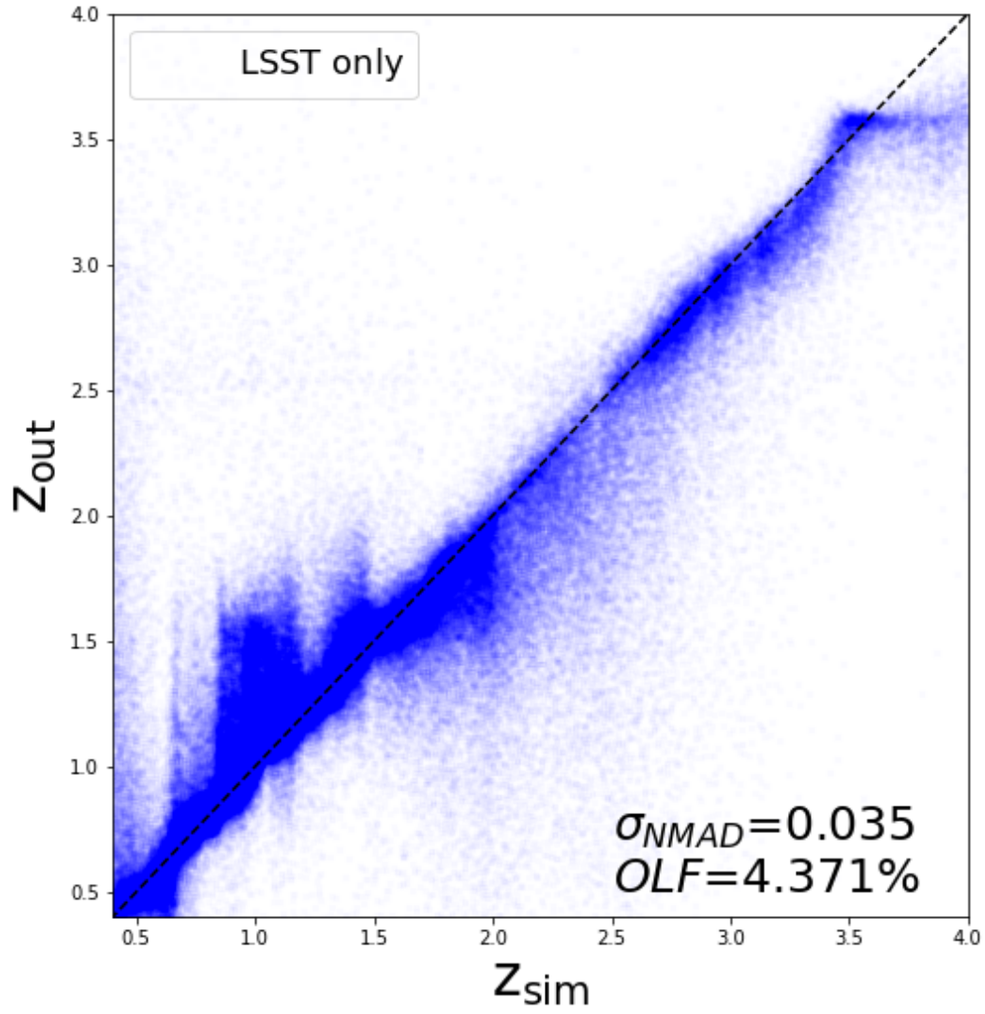
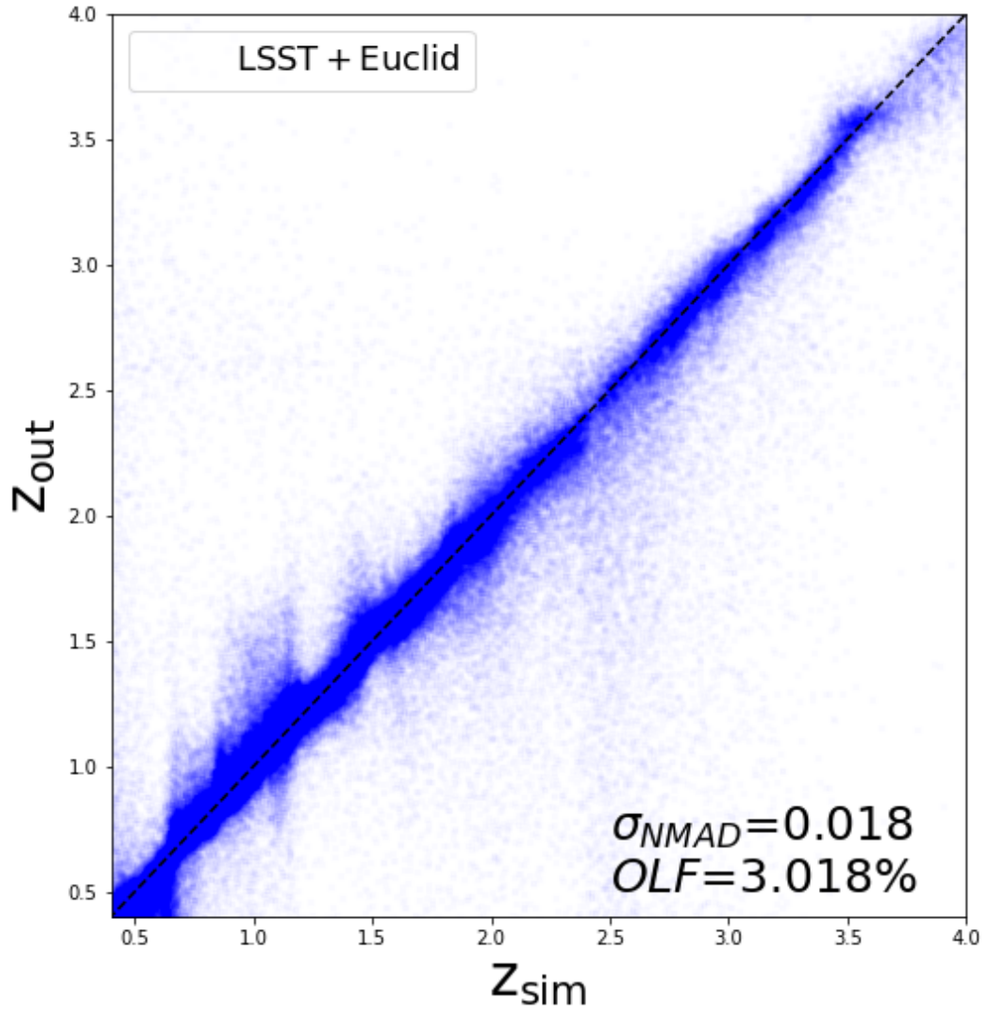
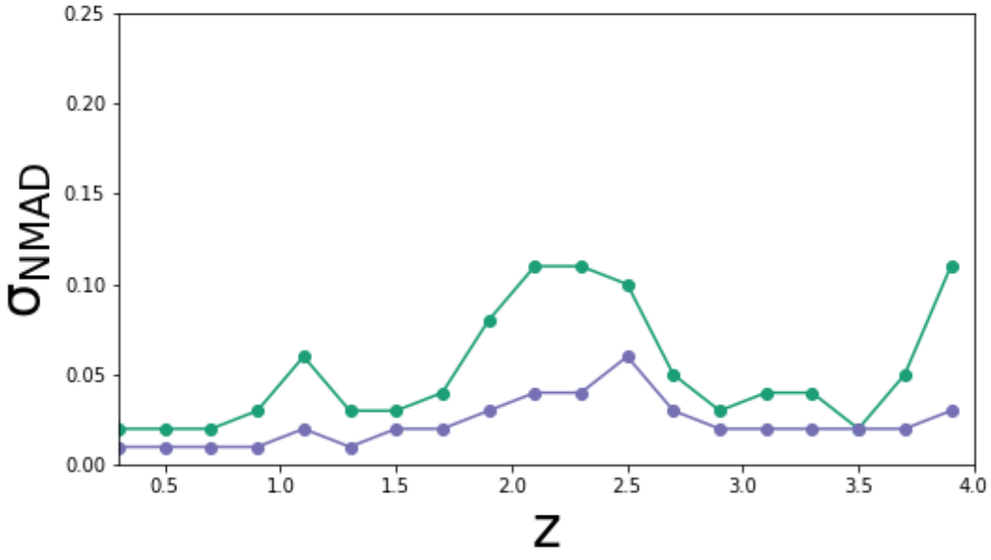
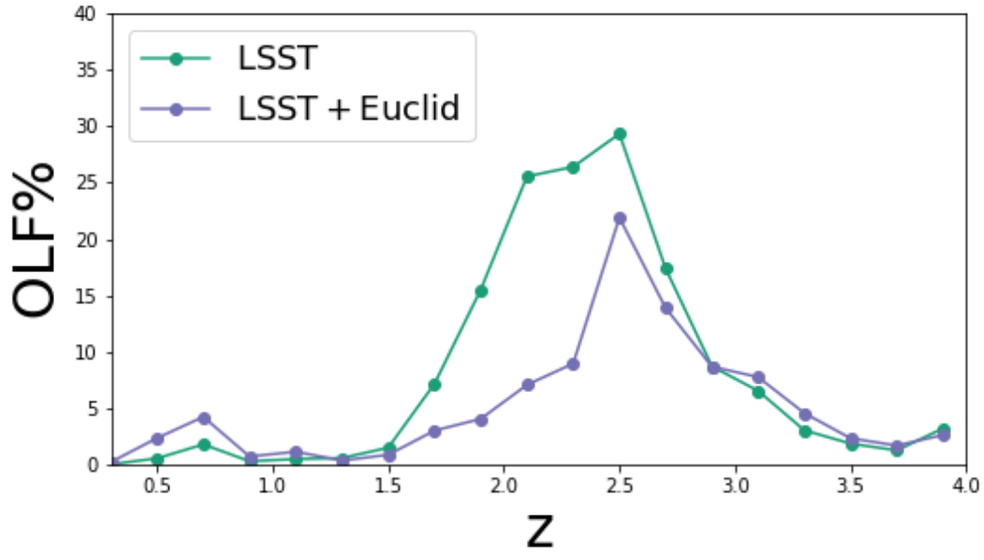


Photo-z


LSST only
z_{out}
z_{sim}
σ_{NMAD}=0.035
OLF=4.371%


LSST + Euclid
z_{out}
z_{sim}
σ_{NMAD}=0.018
OLF=3.018%


σ_{NMAD}
z


LSST
LSST + Euclid
OLF%
z

Weak lensing with LSST and Euclid

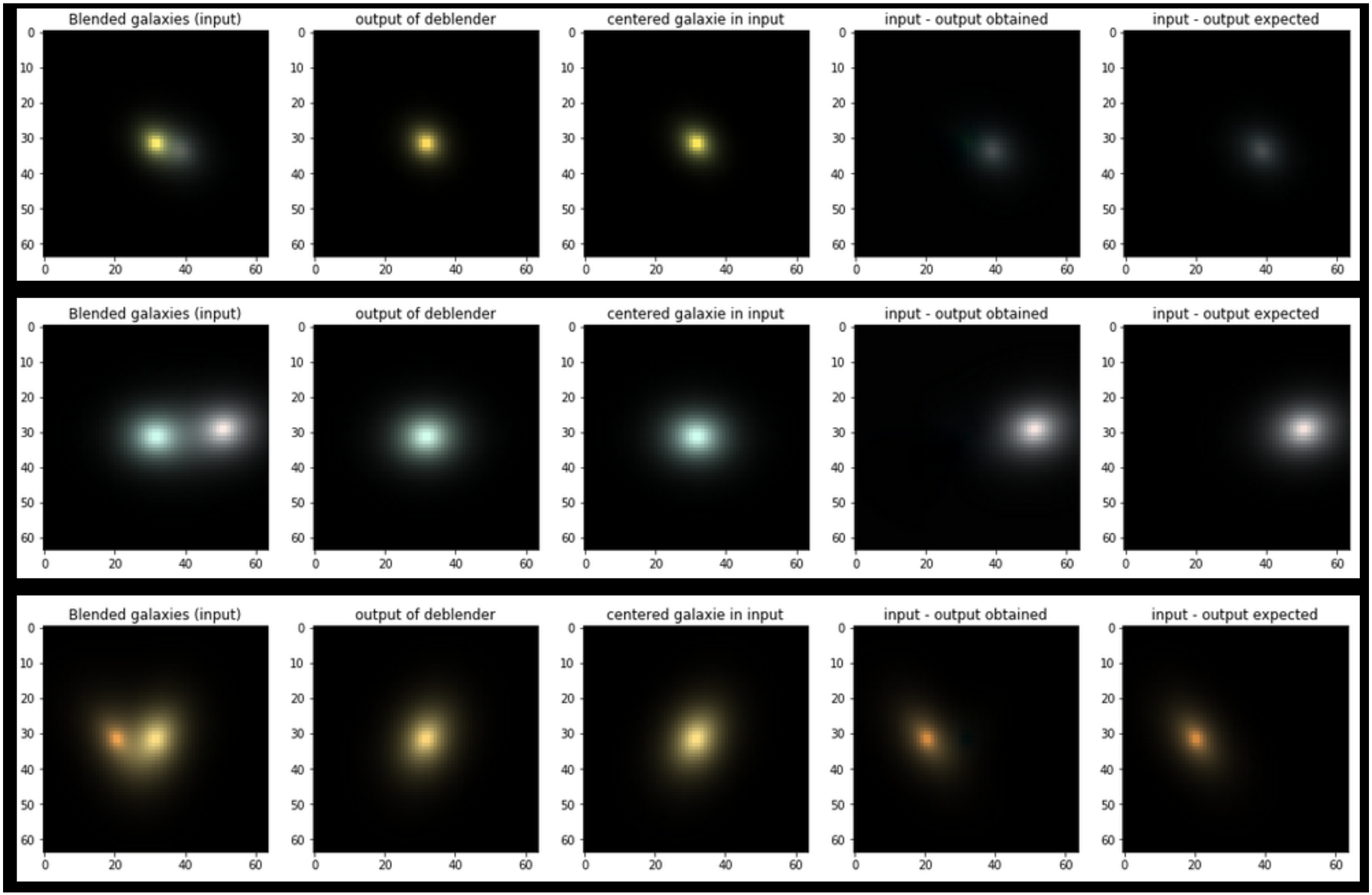
- More than 50% of LSST galaxies useable for lensing are blended (overlapping another galaxy).

- Deblend, or deal with blending in the analysis?

- Multi-color, multi-resolution imaging helps deblending (Scarlett, Melchior et al., neural networks Arcelin/Doux et al in prep.)

- Shape measurement can also use multi-resolution to fight systematics (core of galaxies with Euclid, outskirts with LSST, multi-color with VIS+IR)...

Multi-color deblending (preliminary)



- LSST and Euclid will survey similar areas of the sky, in the same timeframe (2022+).

- They will provide unprecedented constraints on dark energy/ modified gravity, through several probes (geometry/expansion, structure growth...)

- They will have different systematic errors.

  - Comparing analyses will help understand biases.

  - Joint pixel analysis should improve the constraints and help control systematics.