PHYSICS AT THE COSMIC FRONTIER WITH THE DARK ENERGY SURVEY AND BEYOND
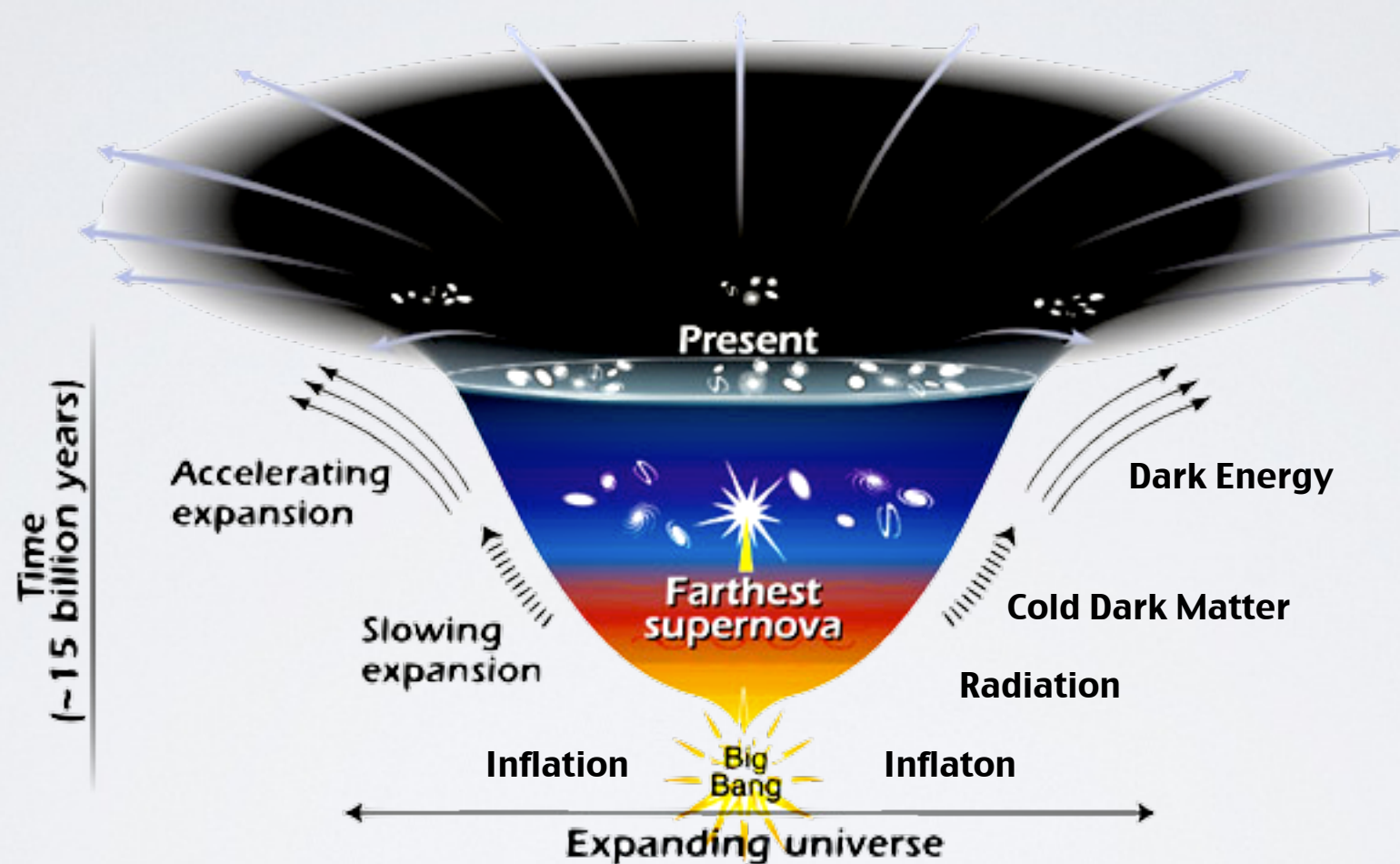
Marcelle Soares-Santos
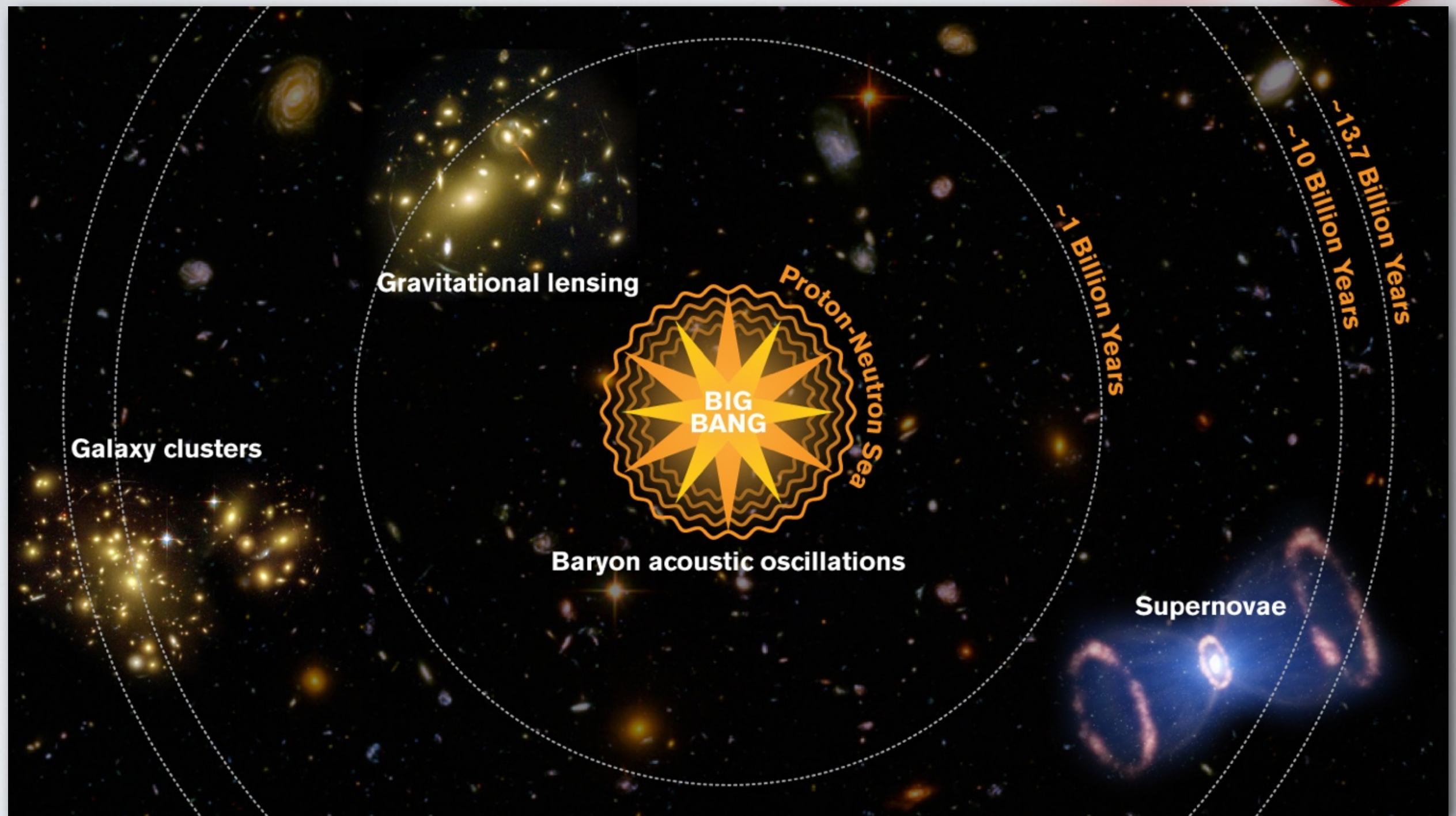
Fermilab

DARK ENERGY & ACCELERATED EXPANSION

COSMIC SURVEYS

Gravitational lensing

Galaxy clusters

Proton-Neutron Sea

BIG BANG

Baryon acoustic oscillations

Supernovae

~1 Billion Years

~10 Billion Years

~13.7 Billion Years

BASIC OBSERVABLES

Positions on the sky (RA, Dec)

correct for distortions

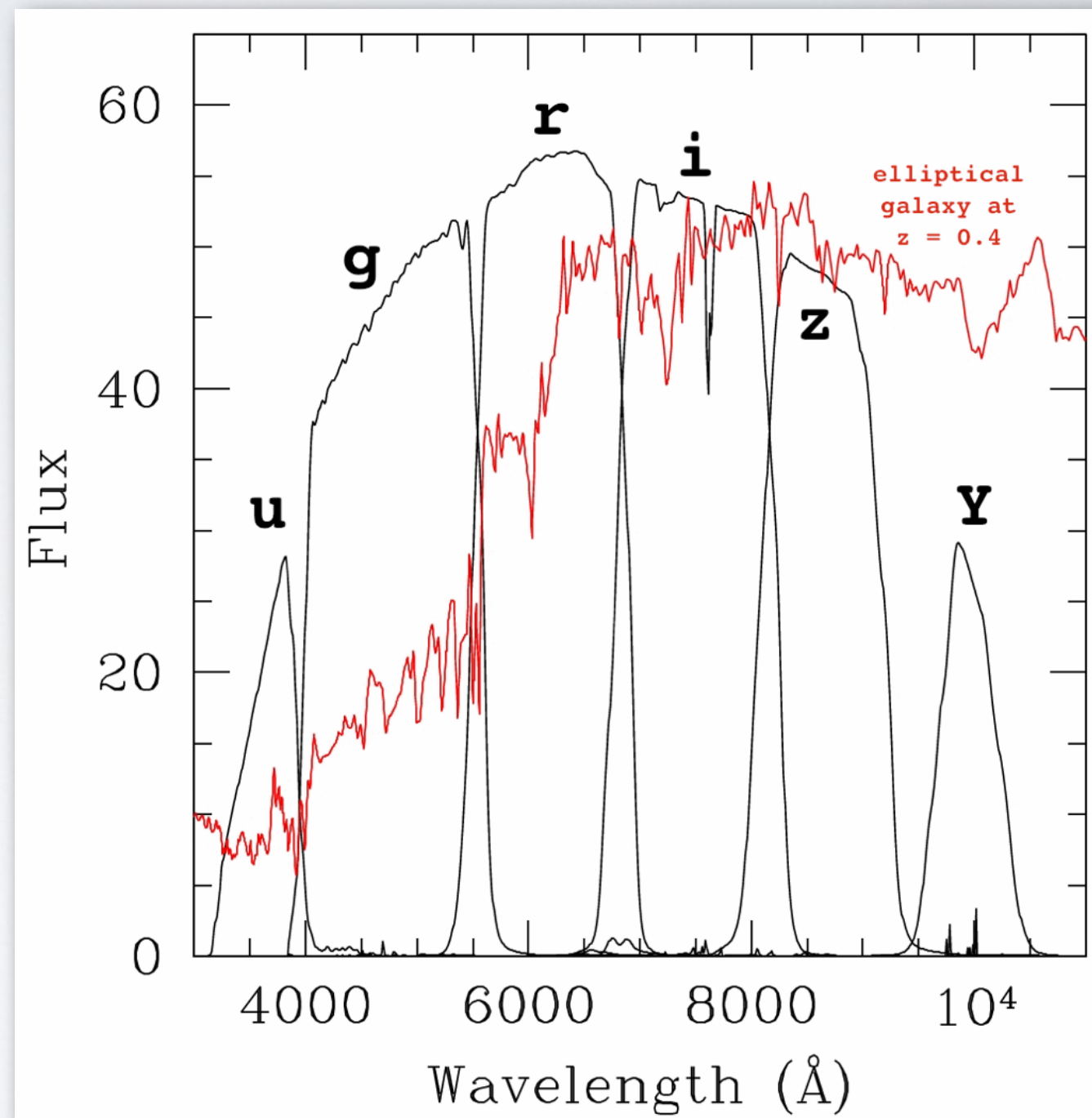## Fluxes (counts/pix/sec)

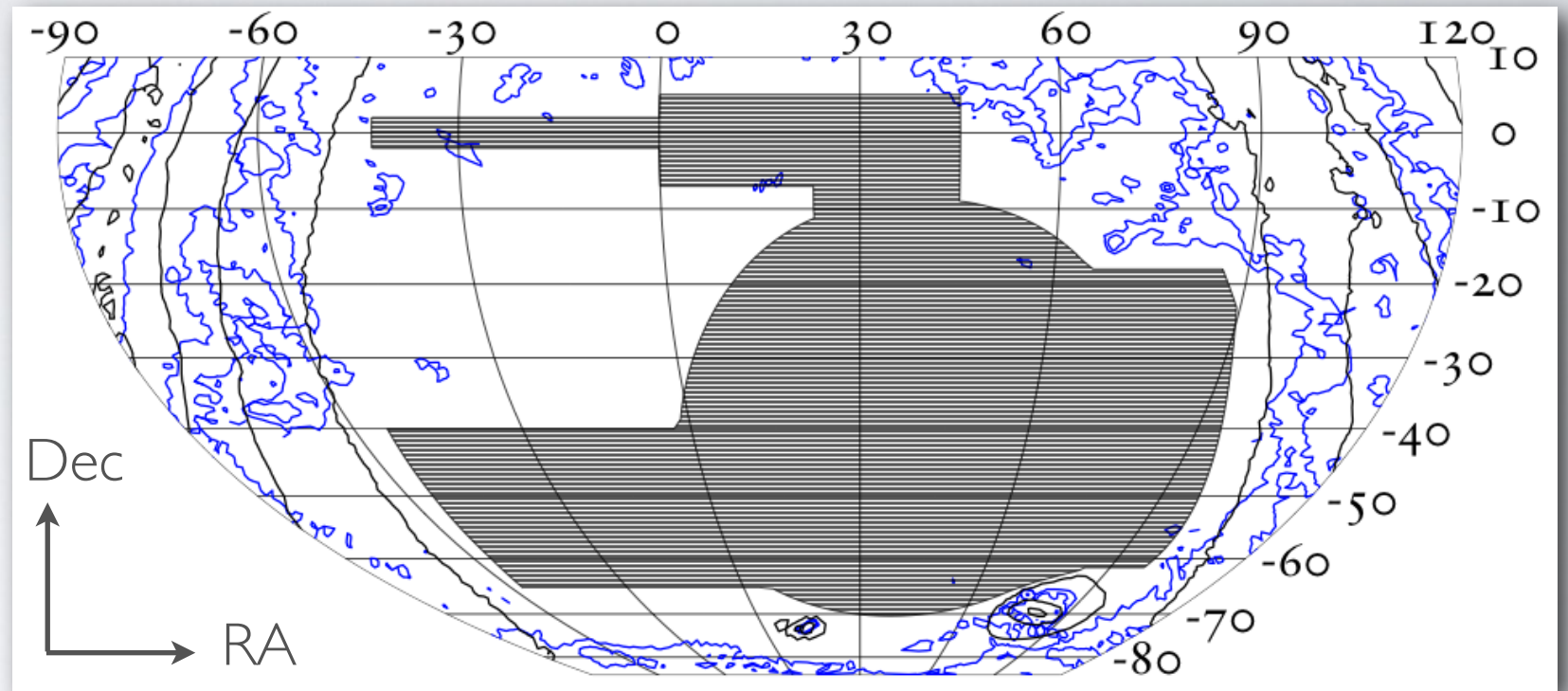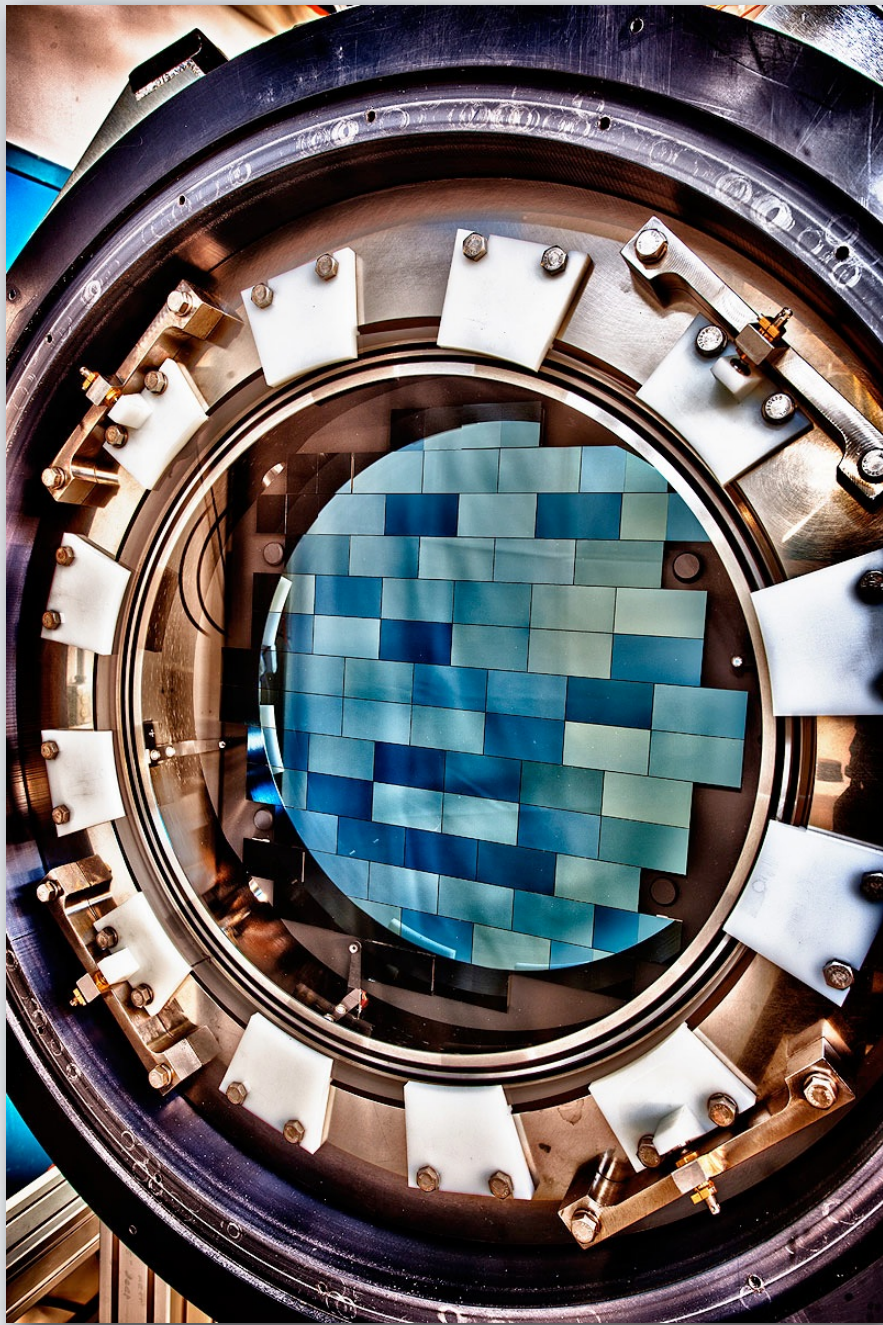calibrate from instrumental units to physical units

get colors from different **filters** and compute photometric redshifts

Shapes (ellipticity, size)

correct for distortions

elliptical galaxy at z = 0.4

DARK ENERGY SURVEY

DECam

3 sq deg FOV, **570 Mpix** optical CCD camera

Facility instrument at **CTIO Blanco 4-m telescope in Chile**

First light: Sep 2012

Survey

5000 sq deg grizY to **24th mag**
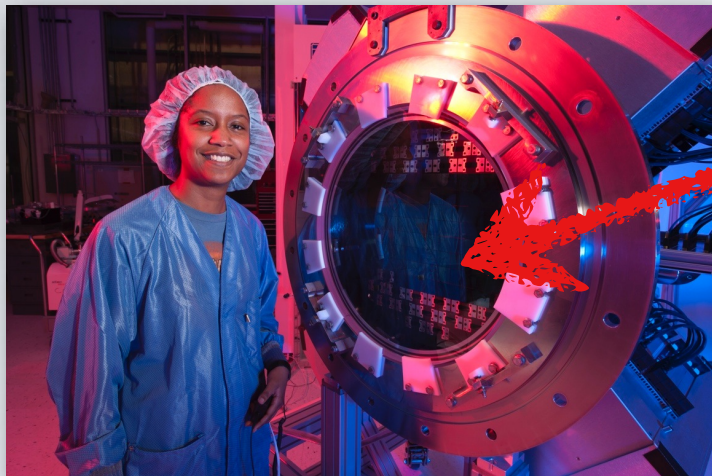**0.9 arcseconds seeing** overlapping with SPT, VISTA

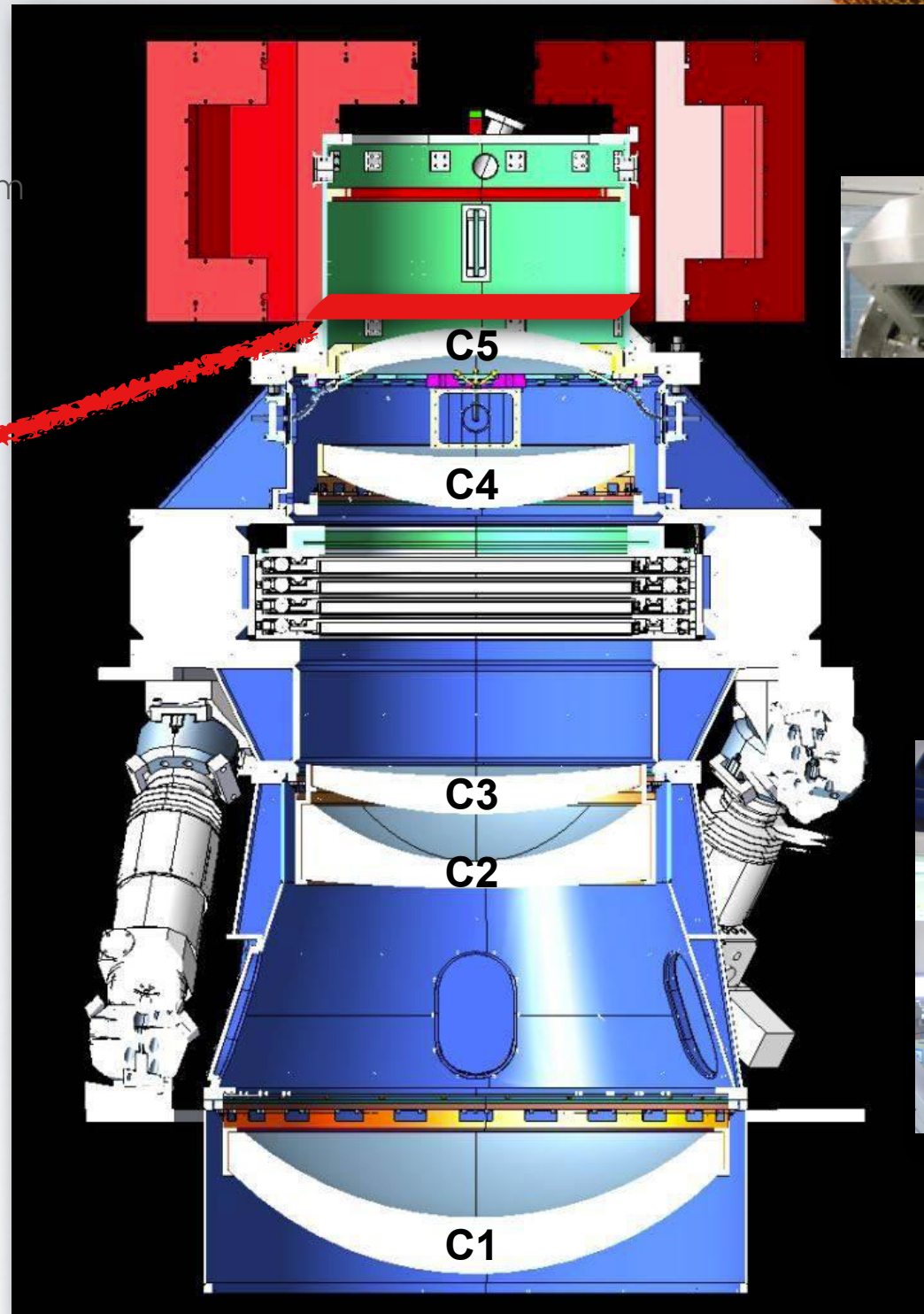**30 sq deg** SNe survey

525 nights: 2013-2018

DECAM

CCD focal plane is housed in a vacuum vessel (**the imager**)

CCD readout electronic crates are actively cooled to eliminate thermal plumes

C5

C4

C3

C2

C1

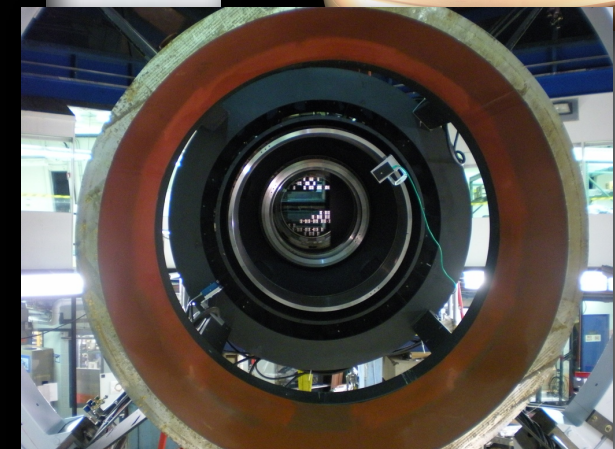**Filter changer** with 8 filter capacity and **shutter** fit between lenses **C3** and **C4**

Hexapod provides focus and lateral alignment capability for the corrector-imager system

Barrel supports the **5 lenses** and imager

LN2 is pumped from the telescope floor to a heat exchanger in the imager: cools the CCDs to -100 C
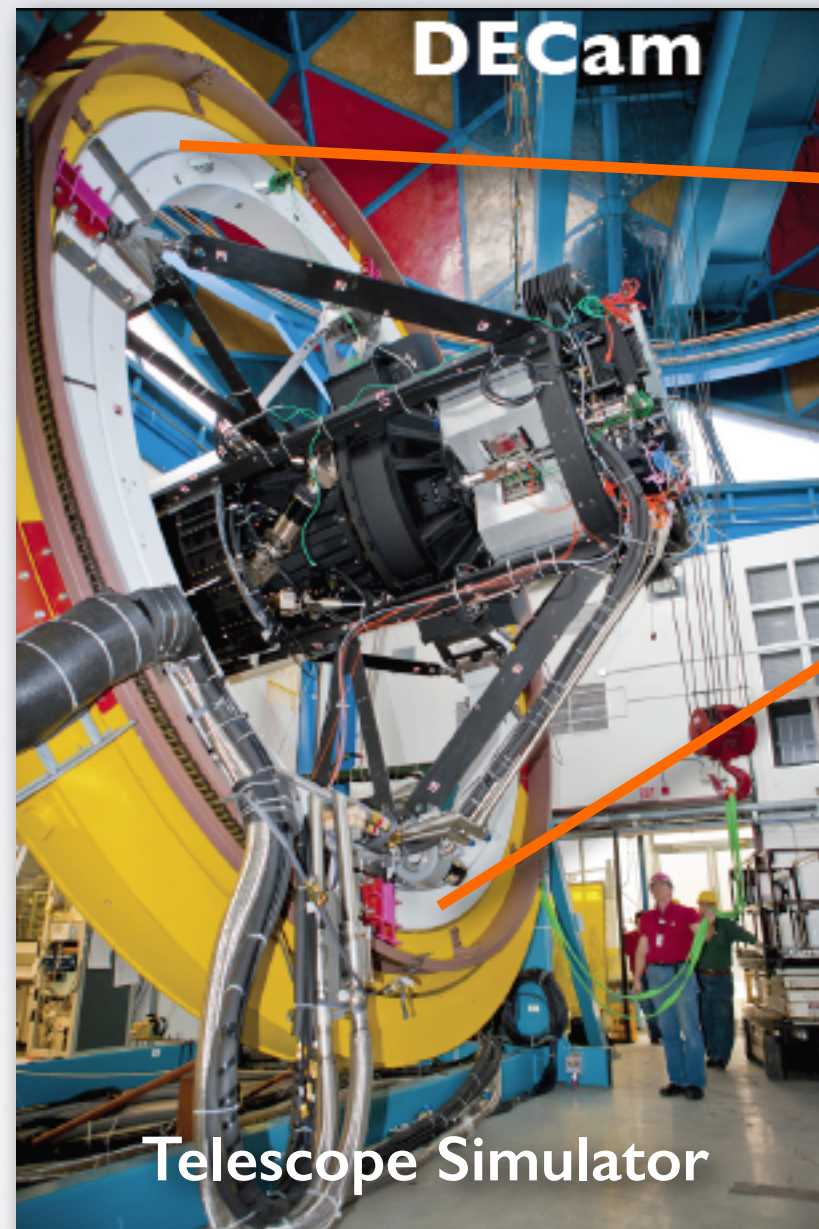
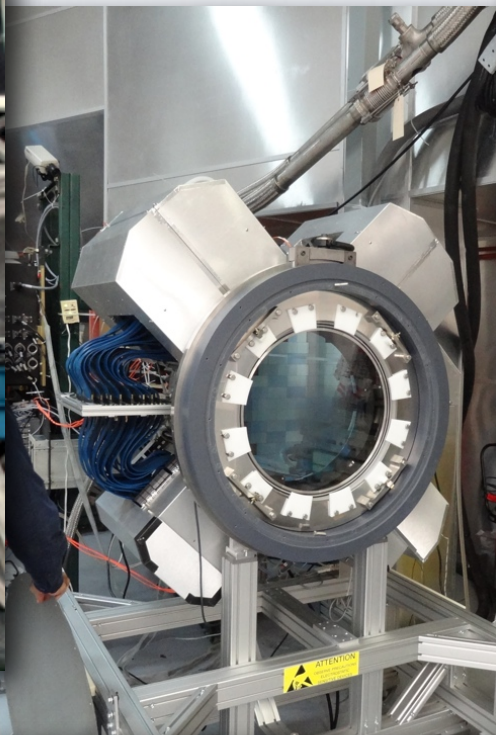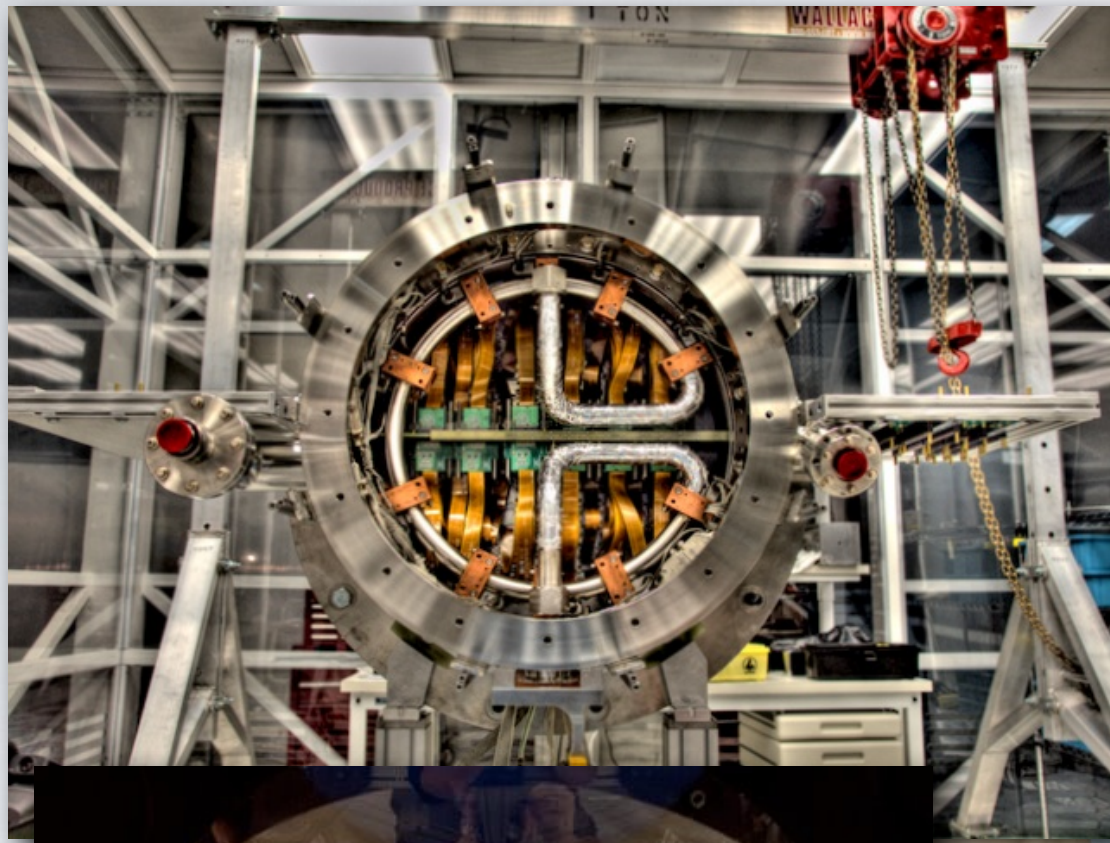# DECAM TELESCOPE SIMULATOR AT FERMILAB

Platform for testing **DECam** operations and installation procedures prior to shipping to Chile.

Full system tests, including a **mock observing run**.

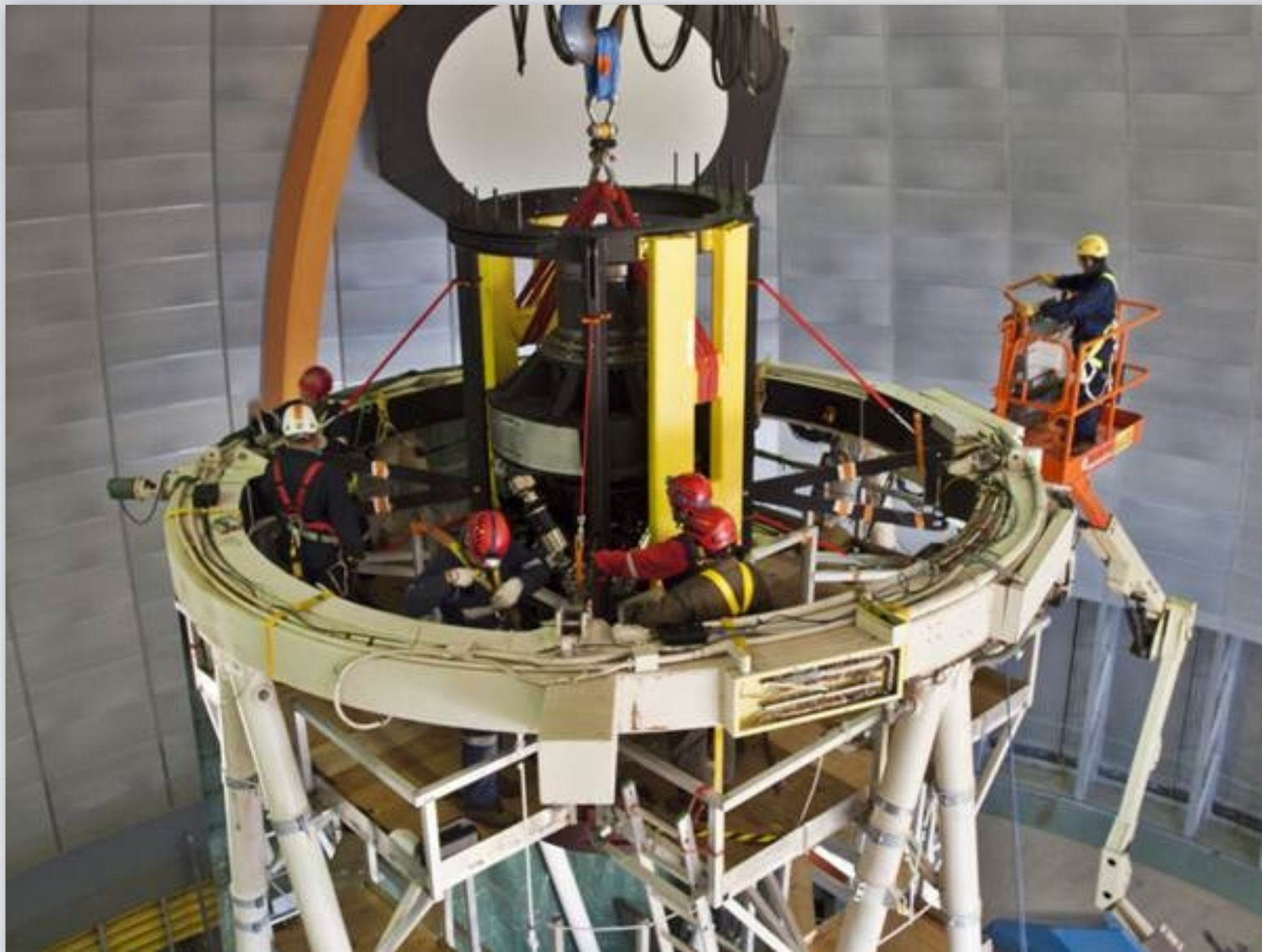Imager with CCDs, filter changer, shutter, hexapod, LN2 cooling, CCD readout crates.

DECam

Telescope Simulator

Mosaic

Blanco 4-m Telescope

DECAM IN CHILE

From
Dec 2011
to
Jan 2012

We checked out the imager at CTIO!

DECAM IN CHILE
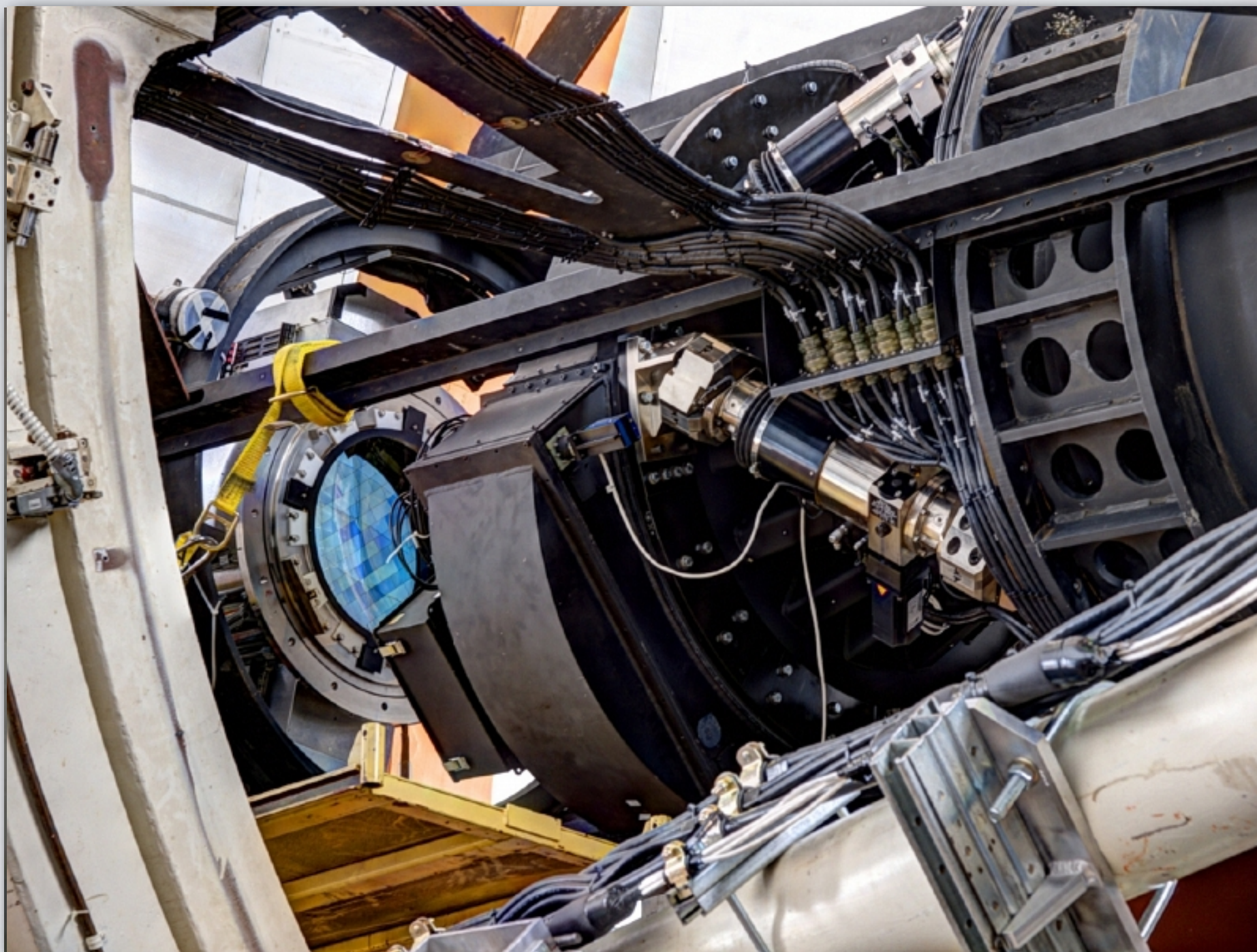
From
February
to
September '12

We installed
DECam on
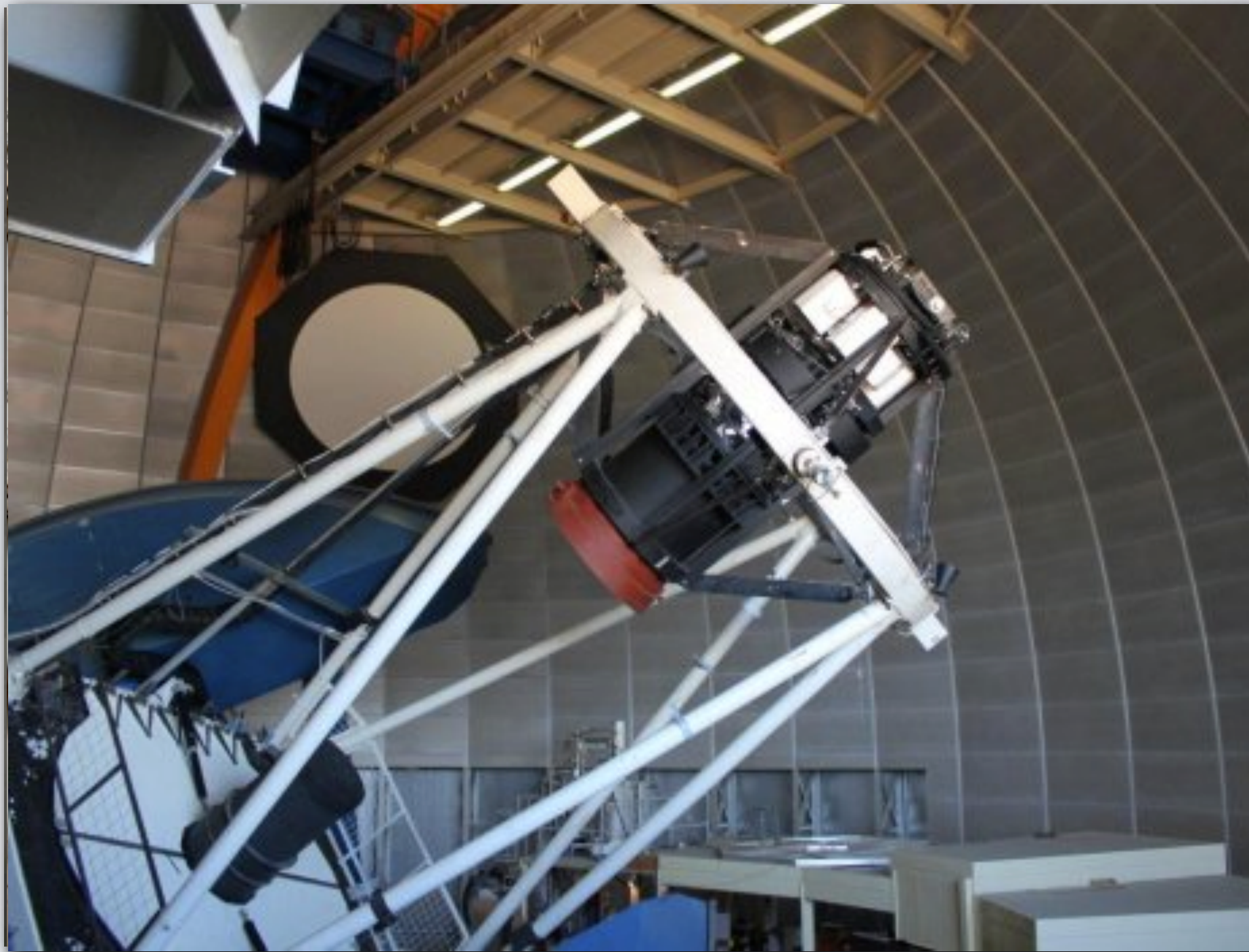the Blanco
Telescope

DECAM IN CHILE

From
February
to
September '12

We installed
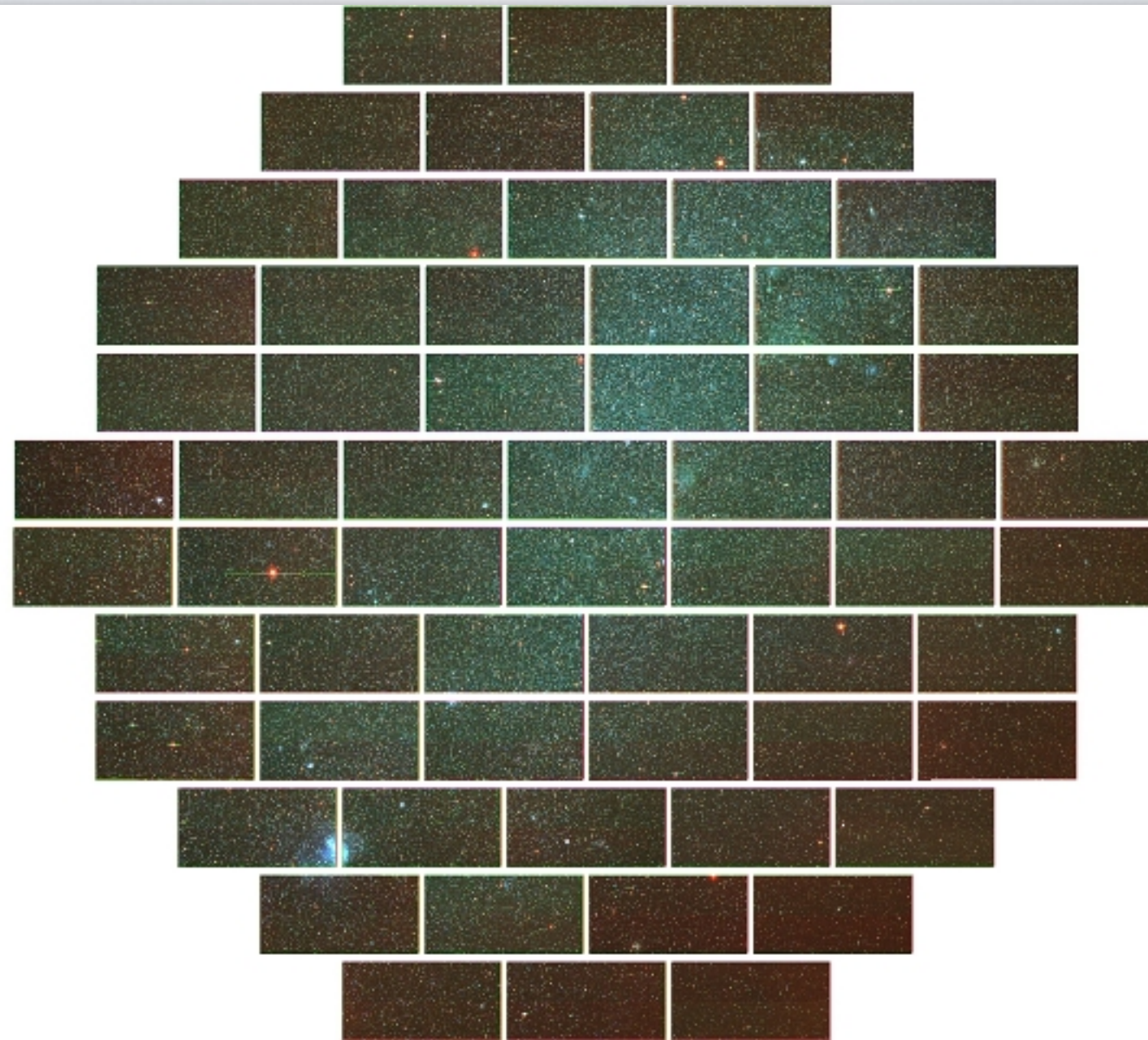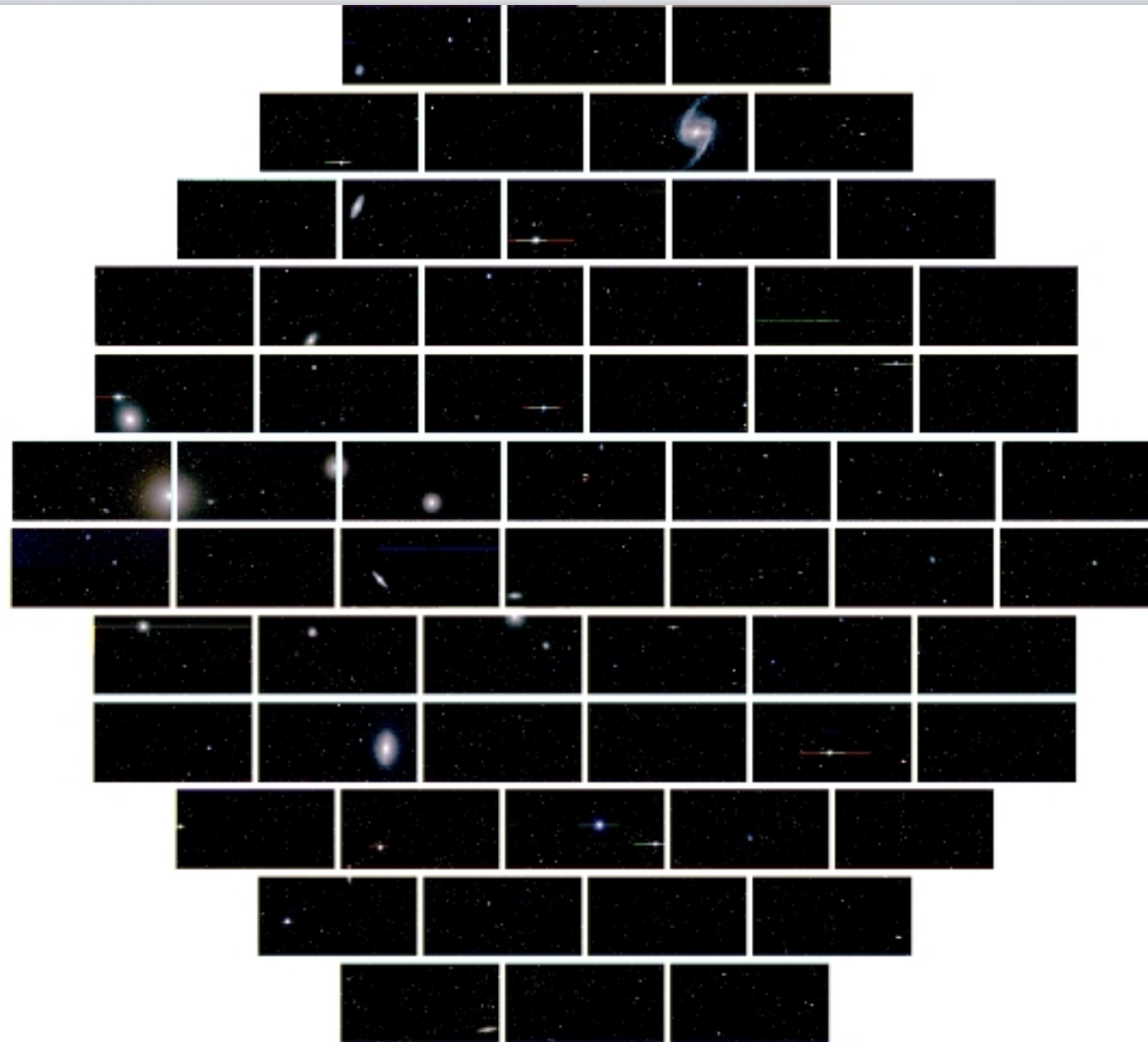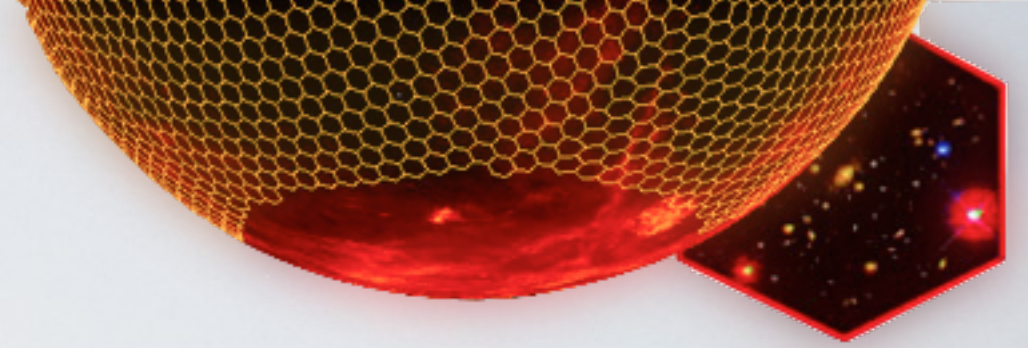DECam on
the Blanco
Telescope

DECAM IN CHILE

From
February
to
September '12

We installed
DECam on
the Blanco
Telescope

FIRST LIGHT IMAGES

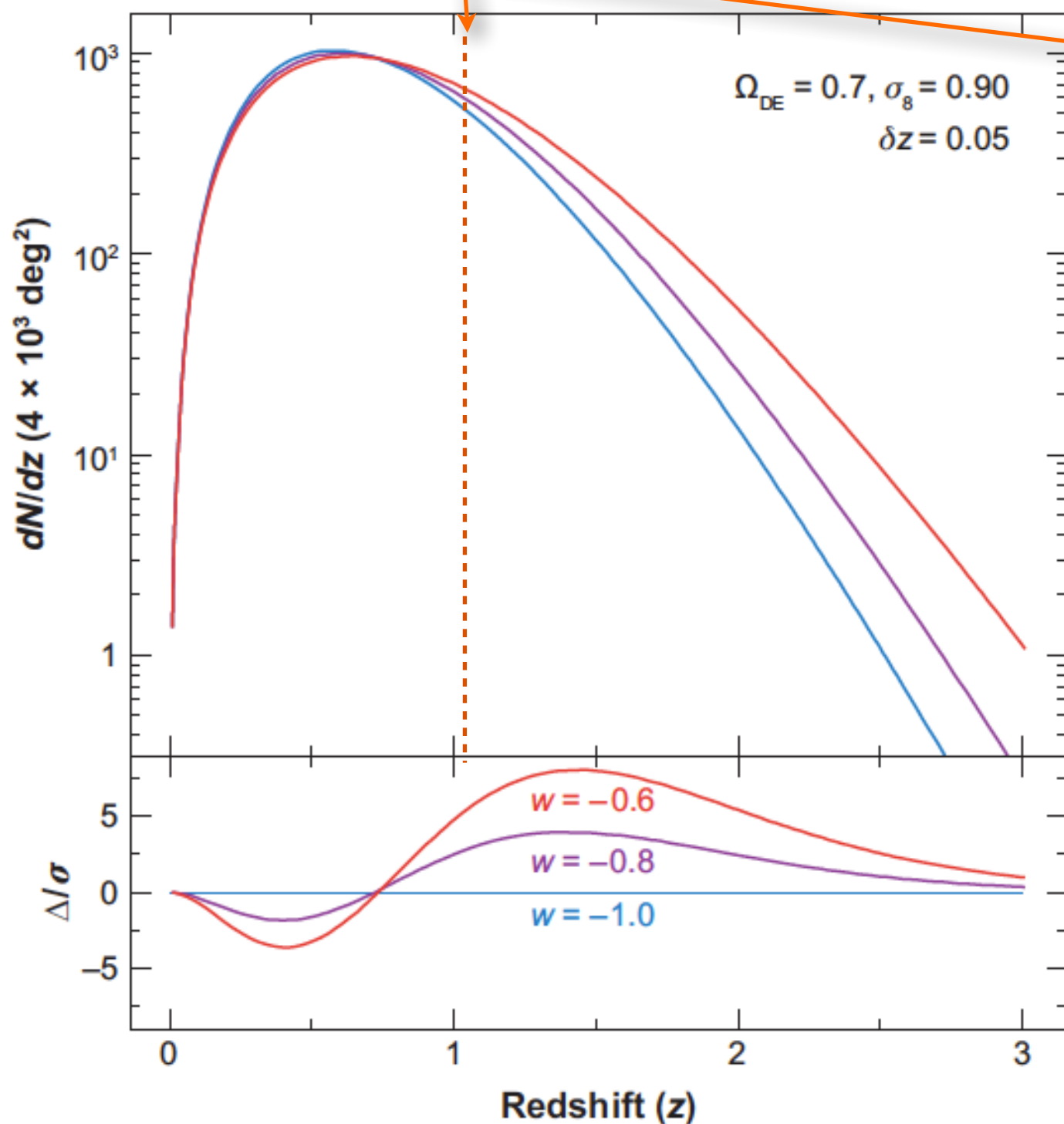

SMC

FIRST LIGHT IMAGES
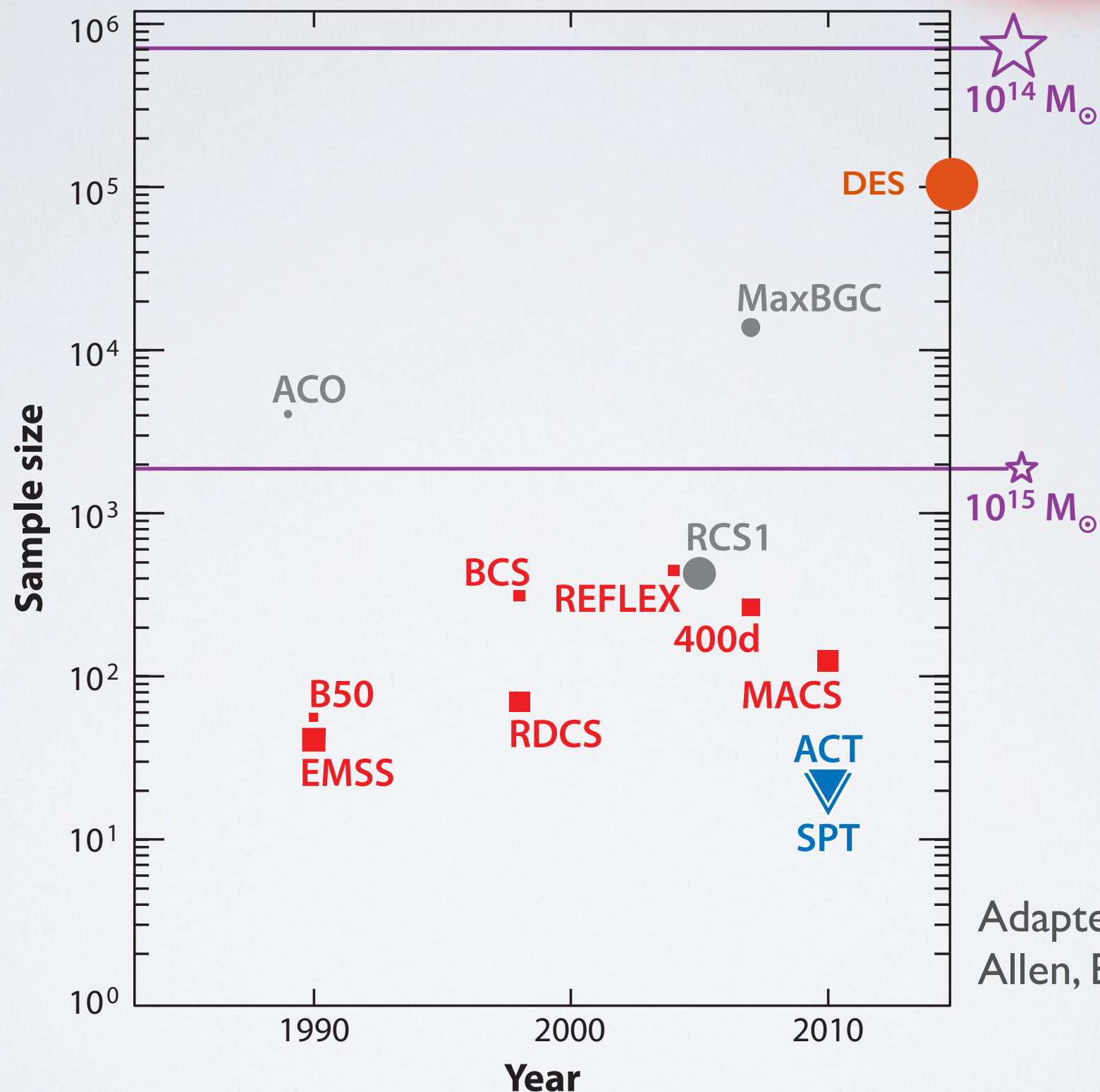

Fornax

FIRST LIGHT IMAGES

NGC 1365

Fornax

DES SCIENCE: CLUSTERS

DES sample:
up to z ~ 1

Number of clusters above $10^{14.5}$ solar masses as a function of z, for a 4000 sq-deg survey in 3 different cosmologies.
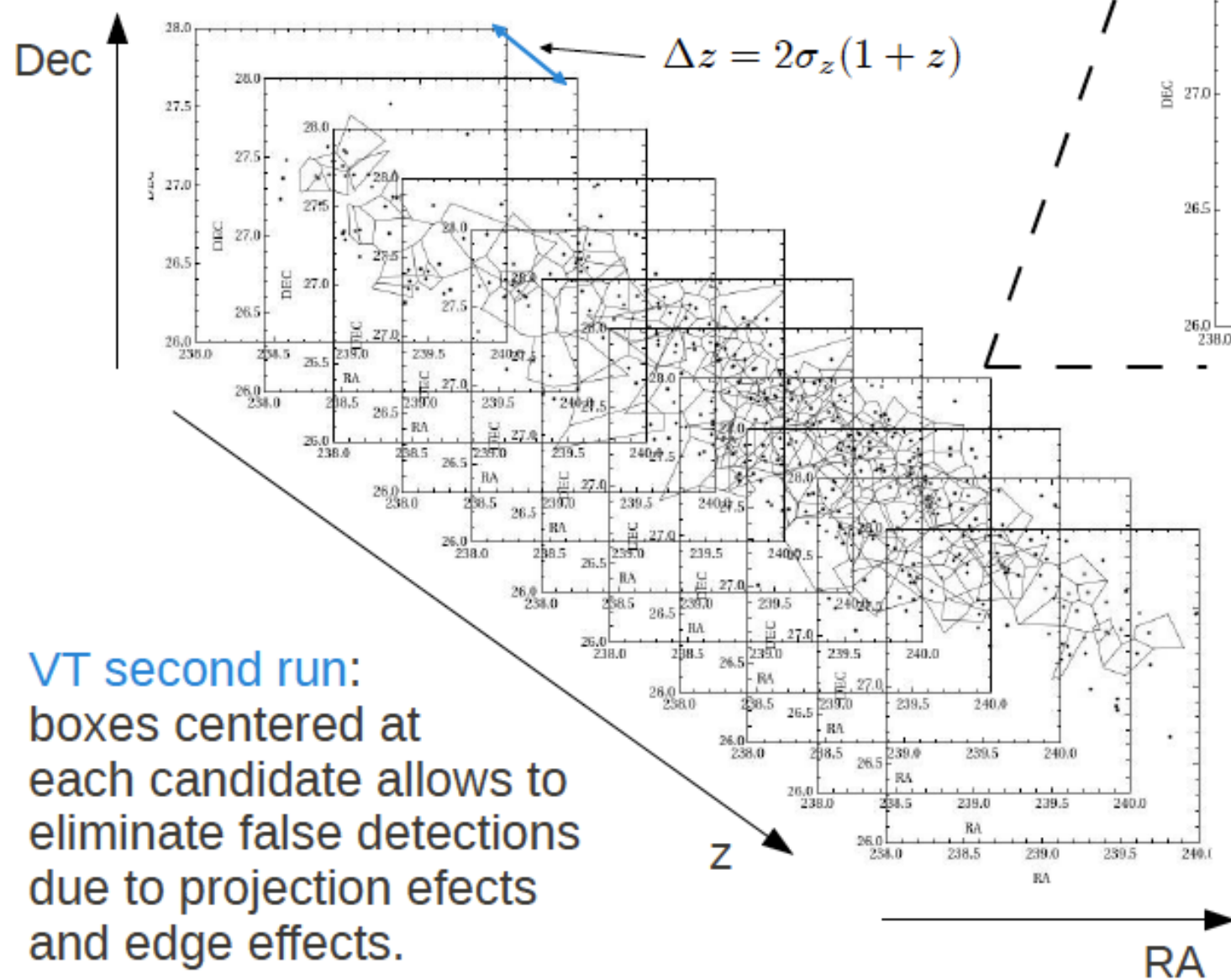
CLUSTER SAMPLES

Stars and horizontal lines: Full sky cluster counts expected above this mass threshold in Lambda-CDM cosmology.

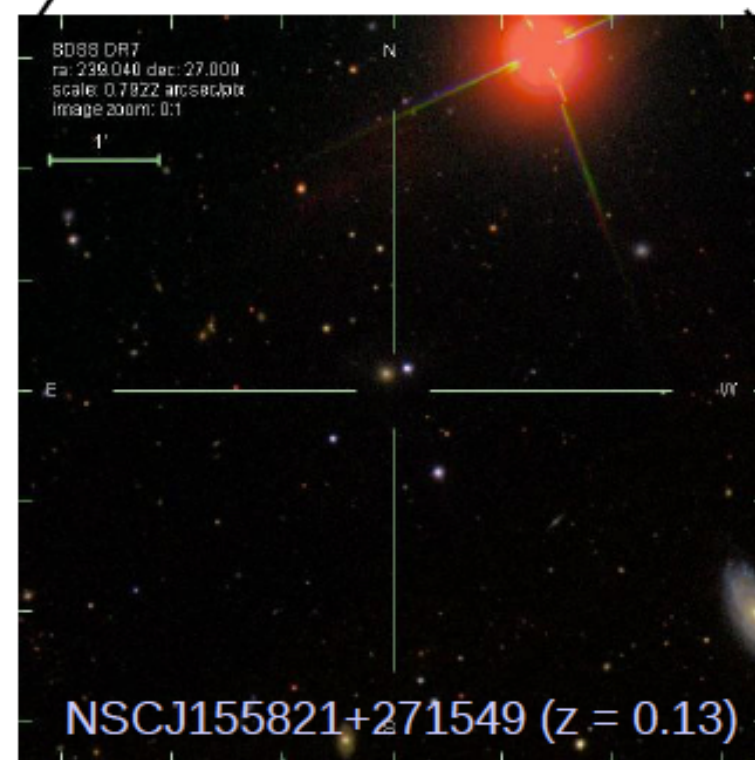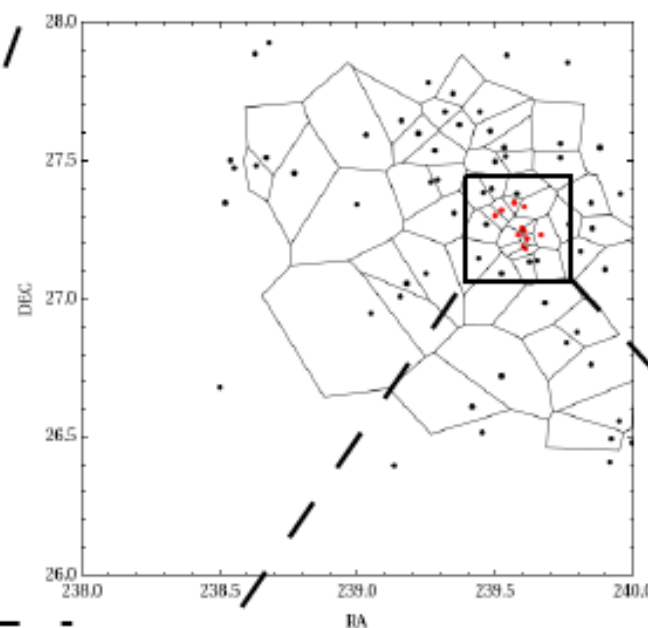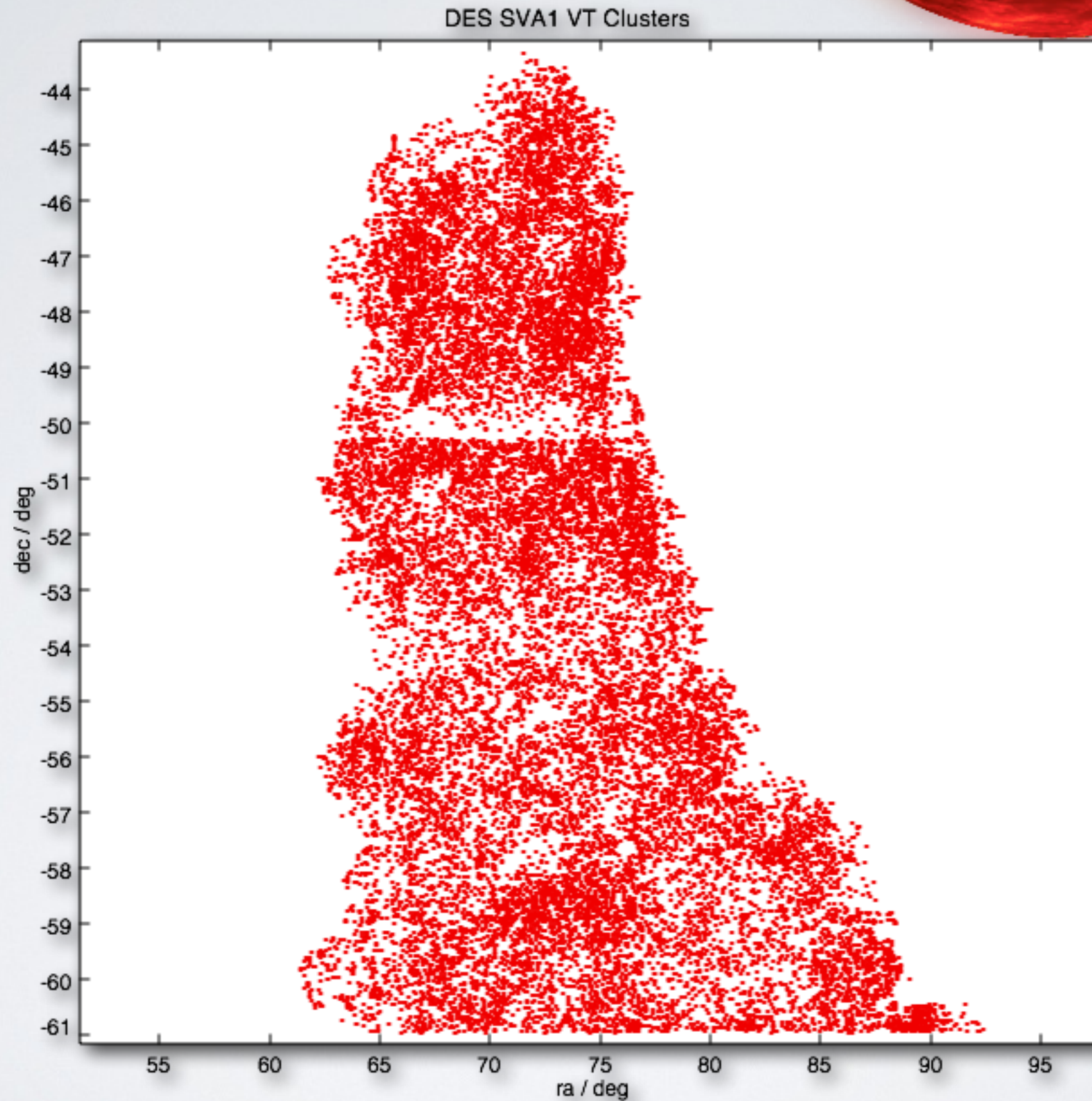Adapted from Allen, Evrard & Mantz 2011

VT cluster finder in 2+1D

VT first run: cluster
candidates detected in photo-z shells

Dec

$$\Delta z = 2\sigma_z(1+z)$$

VT second run:
boxes centered at
each candidate allows to
eliminate false detections
due to projection efects
and edge effects.

z

RA

SDSS DR7
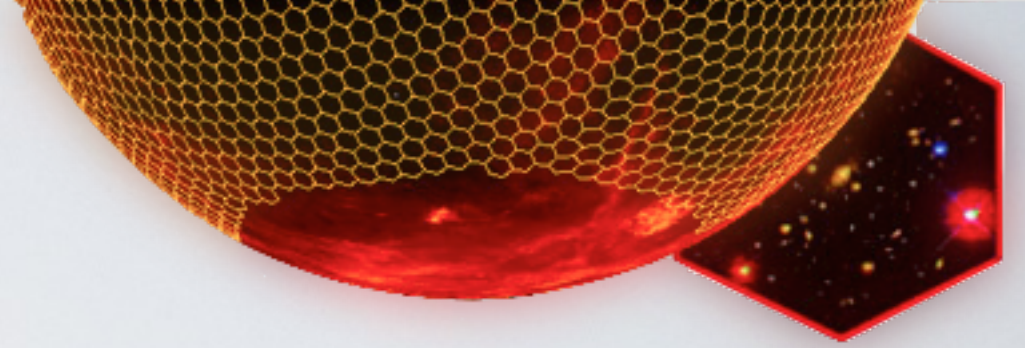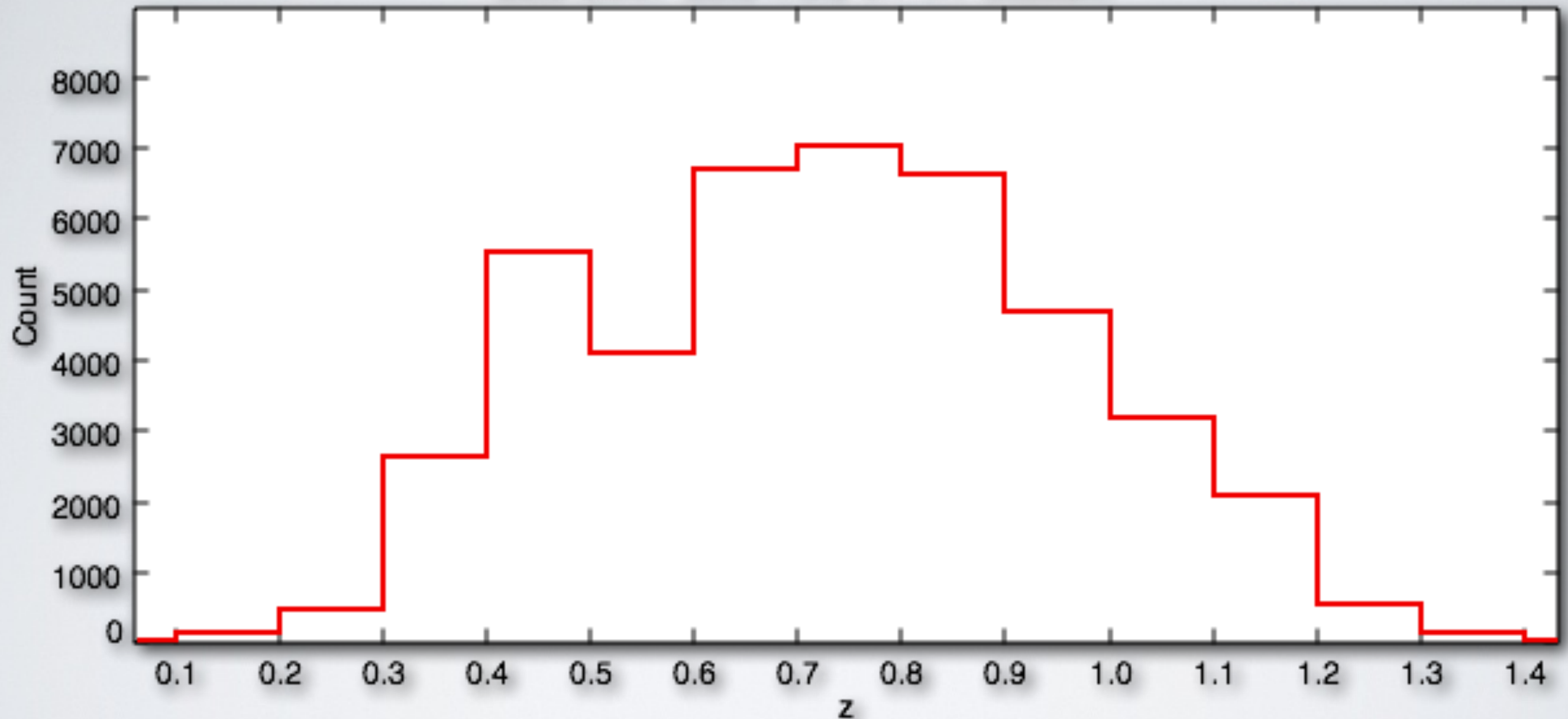ra: 239.040 dec: 27.000
scale: 0.7922 arcsec/pix
image zoom: 0:1

NSCJ155821+271549 (z = 0.13)

VT CLUSTERS

DES SVA1 VT Clusters
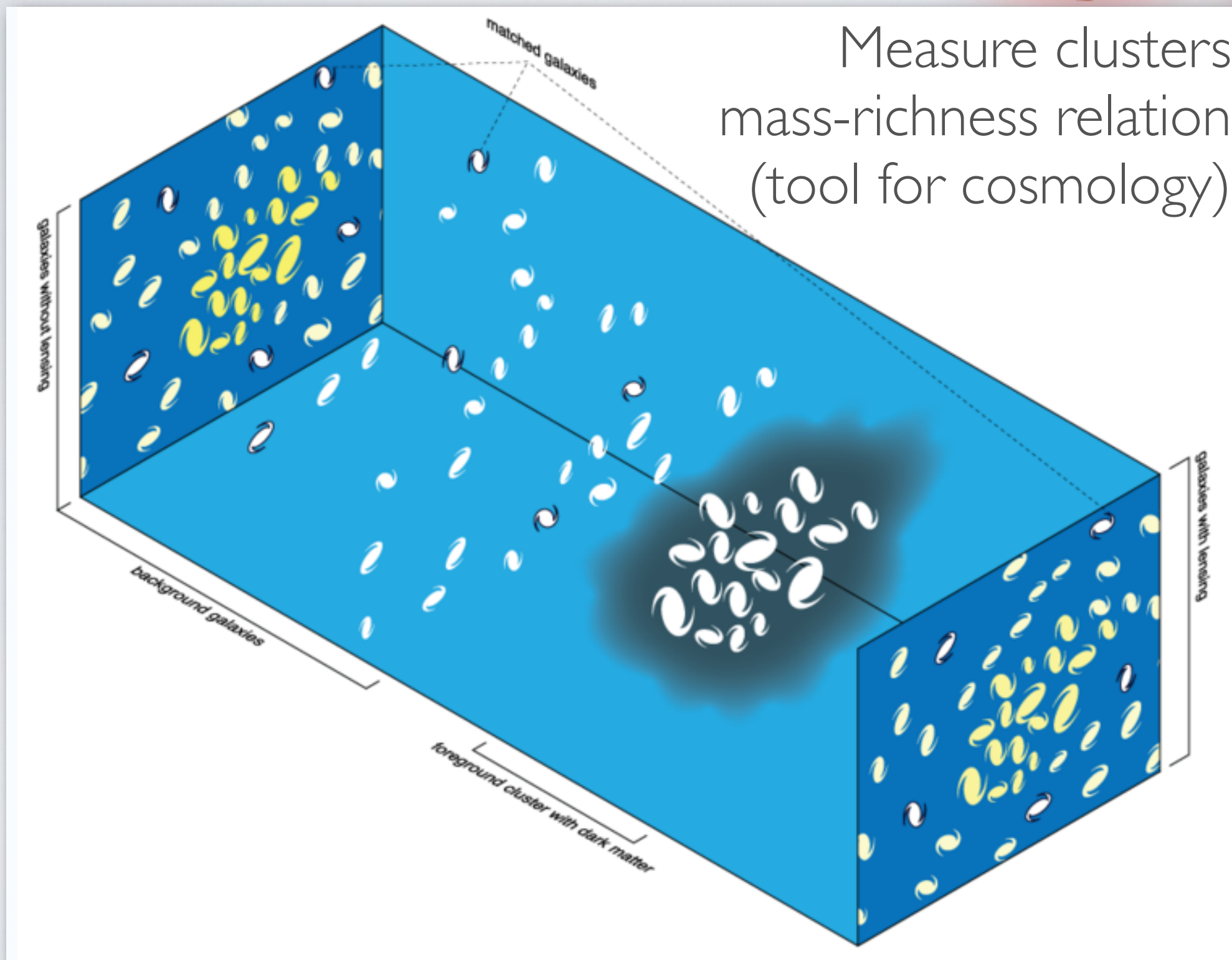
CLUSTER PHOTO-Z

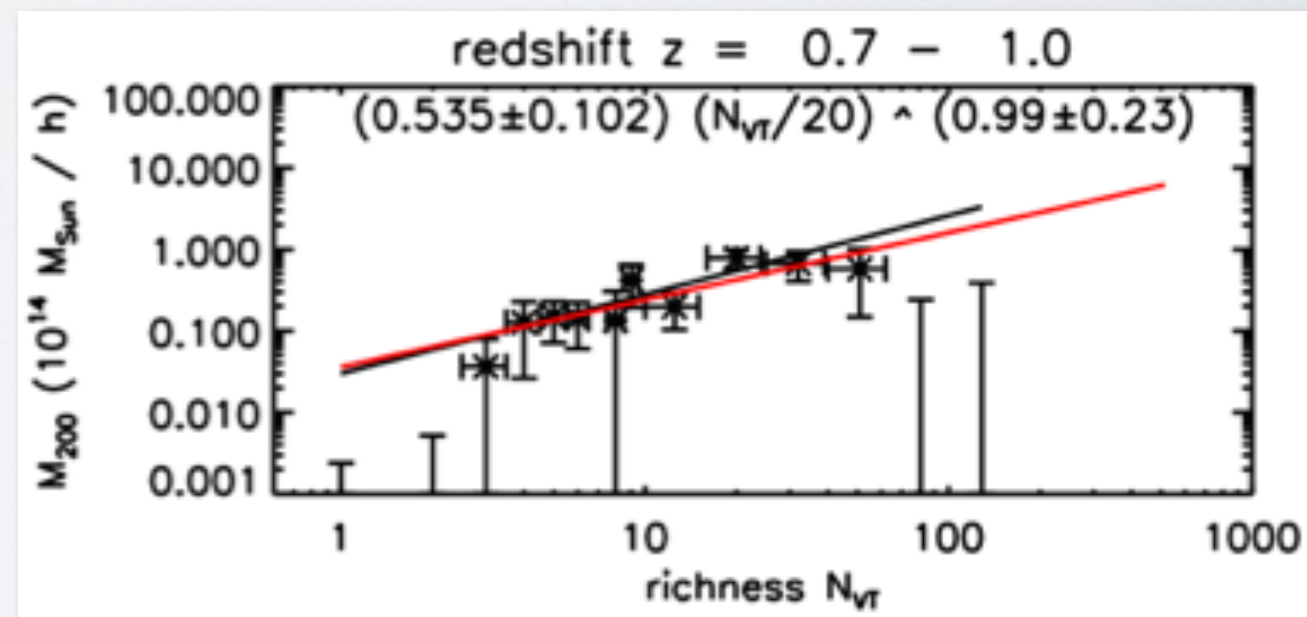

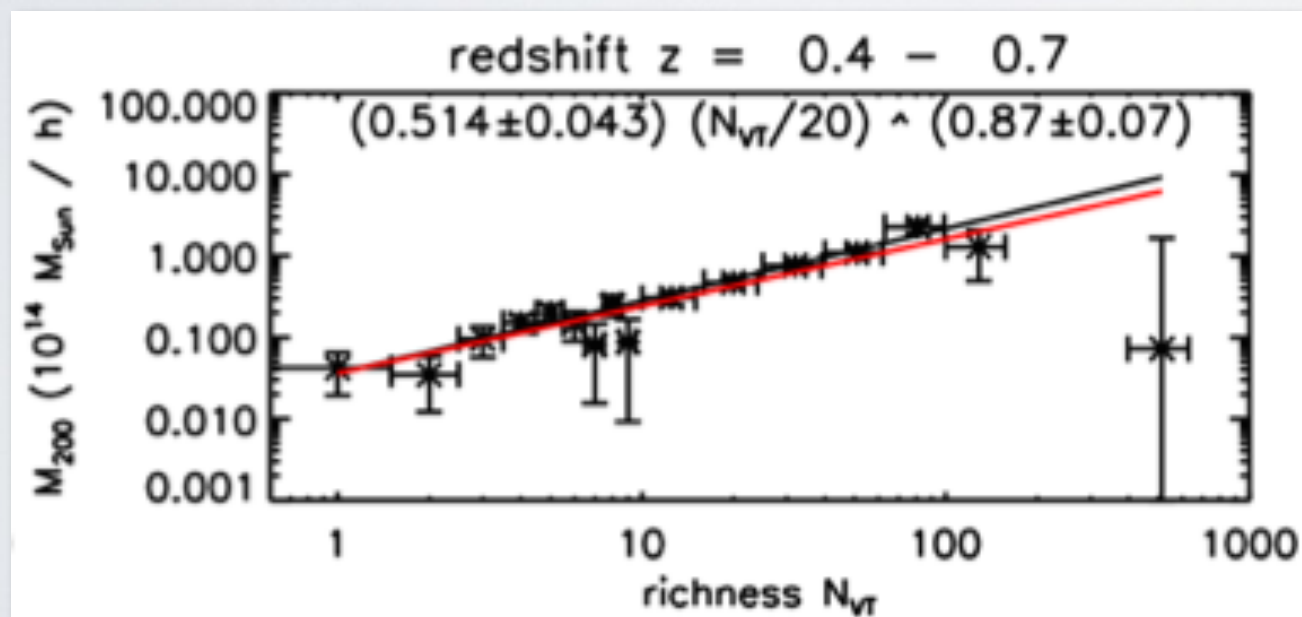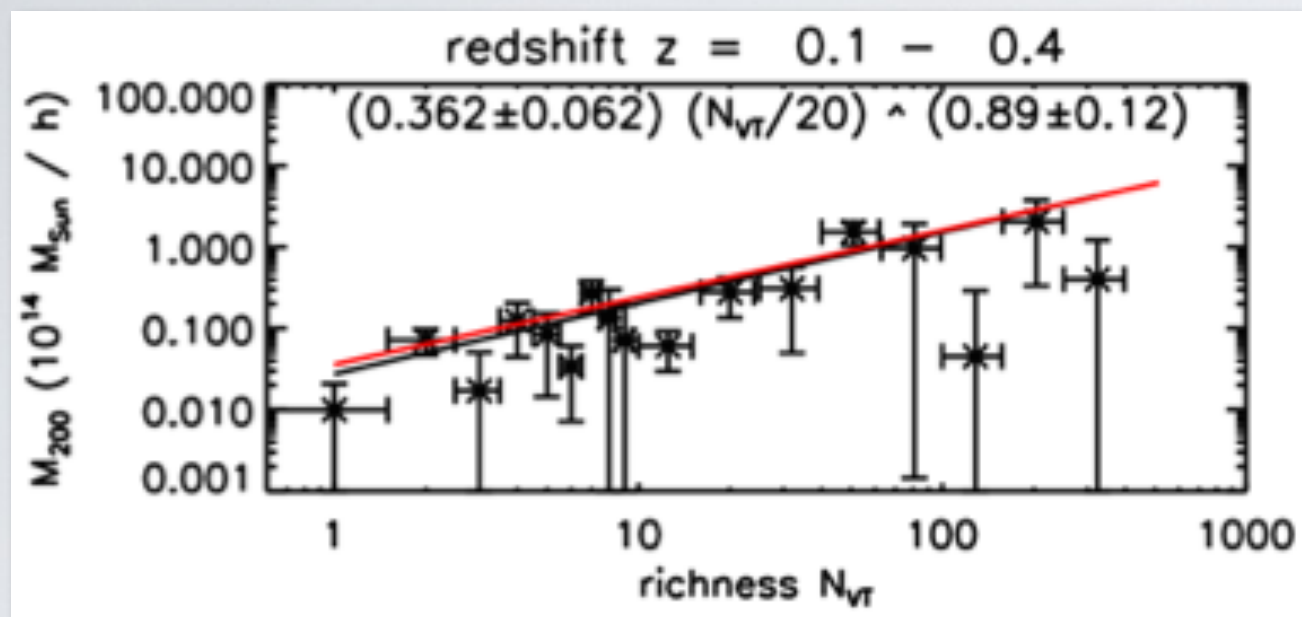DES SVA1 Gold-1.0.2 VT-1.1 Clusters

CLUSTERS LENSING

Measure clusters
mass-richness relation
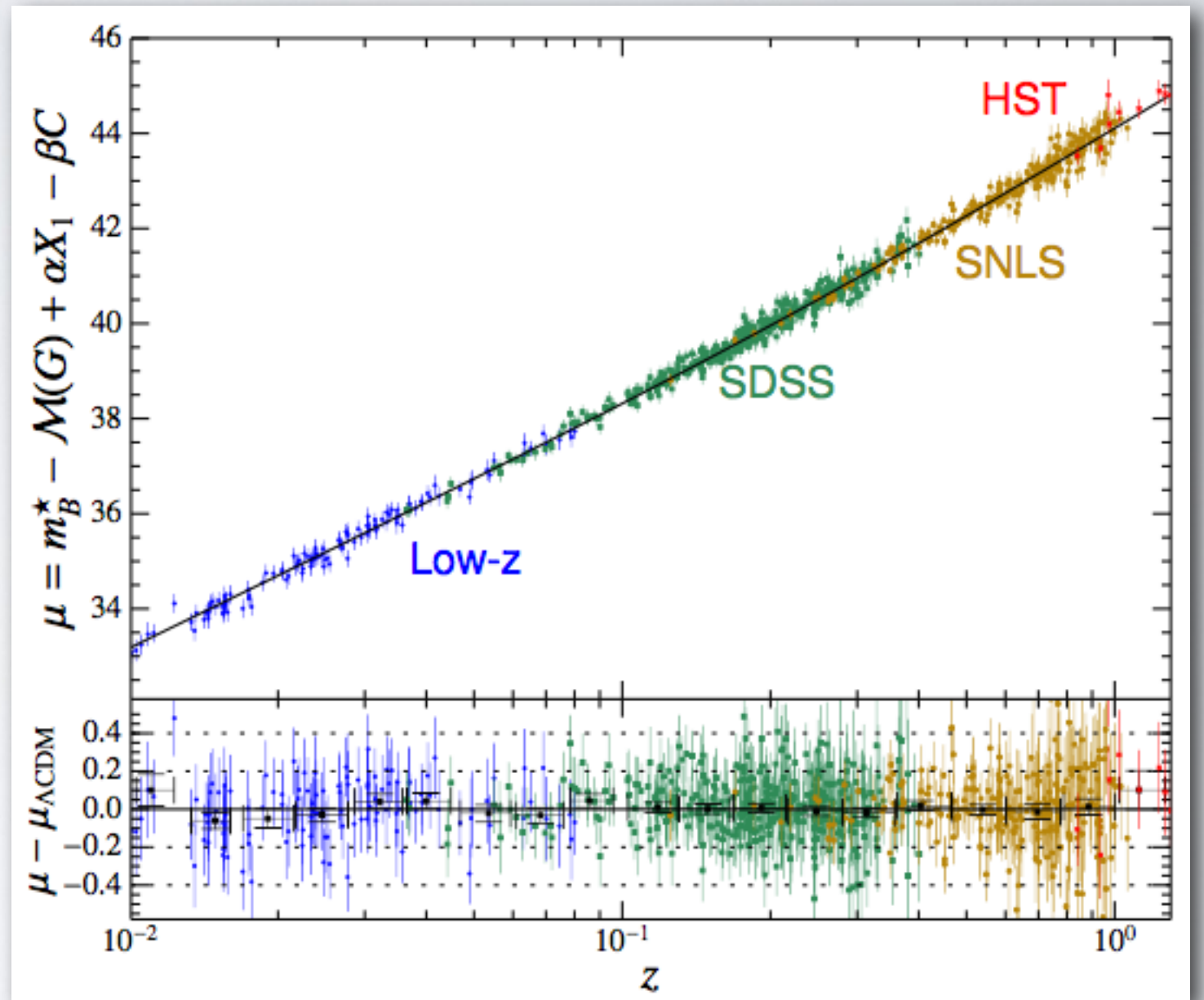(tool for cosmology)

MASS CALIBRATION
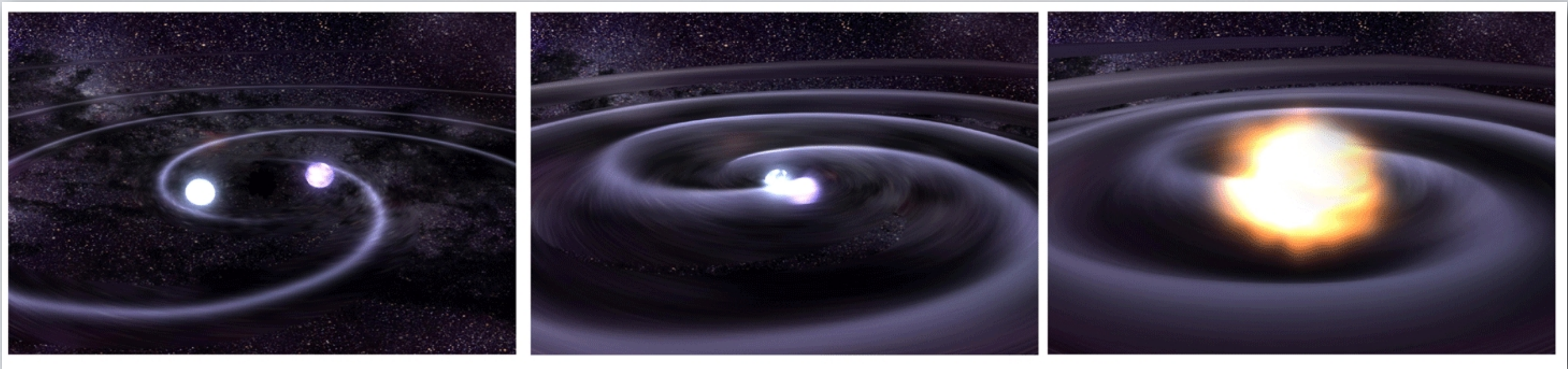
(Very Preliminary)
Mass-Richness calibration

HUBBLE DIAGRAM

We know how to measure Cosmology from a **Hubble diagram** like this using Type Ia Supernovae as standard candles.

Can we do the same with a different "standard" quantity?

NEW INITIATIVE: GRAVITATIONAL WAVES

Coordinated detection of electromagnetic and gravitational radiation from mergers of compact objects (neutron stars, black holes).
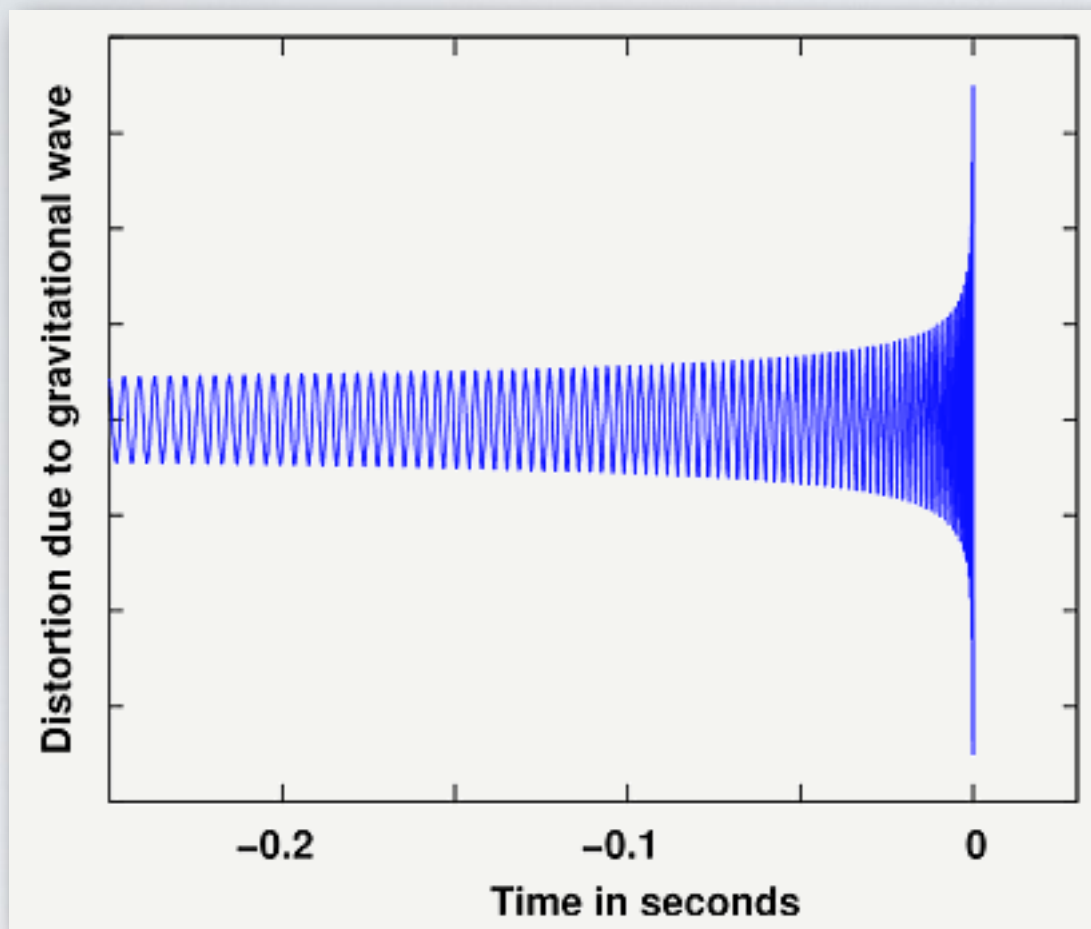
- **Search for optical counterpart of events detected by the advanced LIGO/VIRGO detectors**

Time of flight experiment: Do gravitons travel at the speed of light?
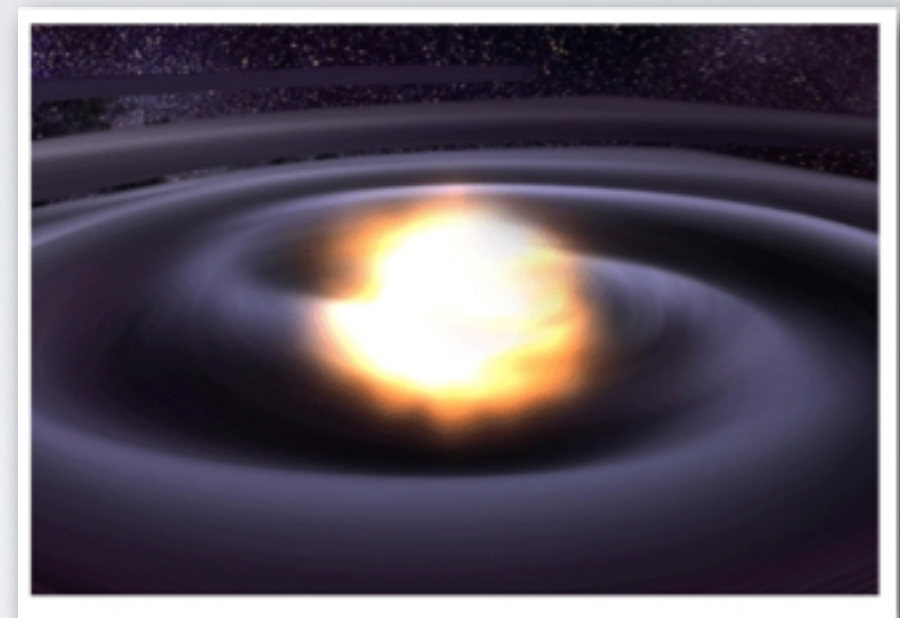**Standard Sirens:** Potentially a new cosmological probe in the future
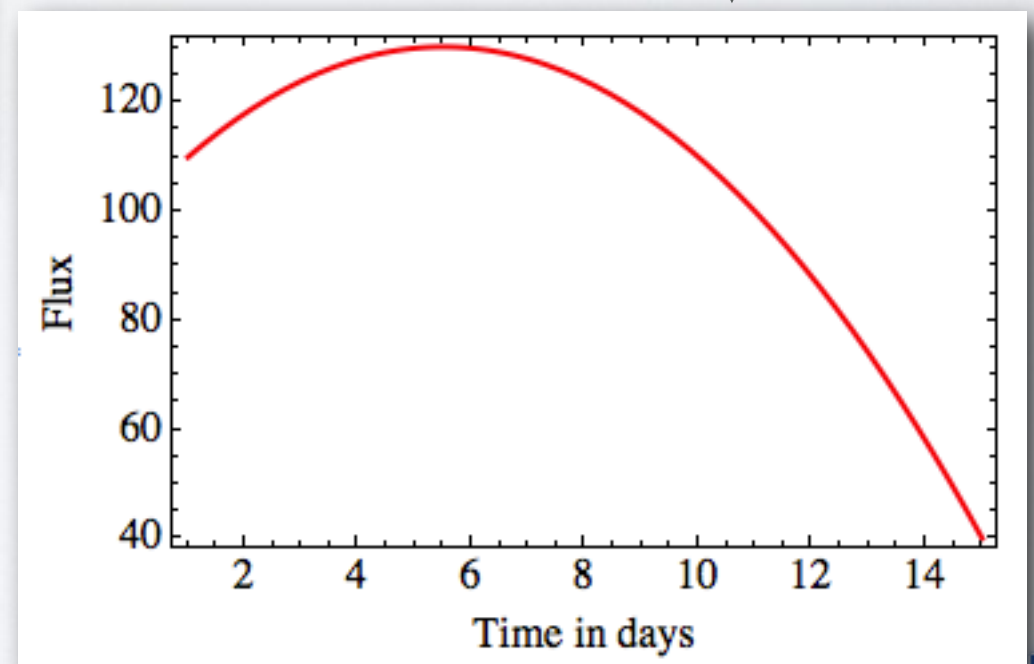
ELECTROMAGNETIC & GRAVITATIONAL RADIATION

GW

EM

ToF experiment
Standard Sirens

THE GW PROGRAM

GW trigger

time stamp
sky region
distance

DES search system

build template image
schedule observations
take new images
perform image subtraction
detect, model counterpart

- <u>Near term goal</u>: background rate studies, preparations for a 'pilot search' in 2016-17 and 2017-18

- <u>Long term goal</u>: a large scale program beyond DES

  - DECam — still available after the DES 5-year run

  - LSST — to start in ~2022, faster than DECam

  - Synergy with future neutrino experiments — ToF experiment including neutrinos?

SUMMARY

It was a pleasure and a privilege to help build the DECam and make DES a success.

DES has completed its 1st season, after a productive science verification phase.

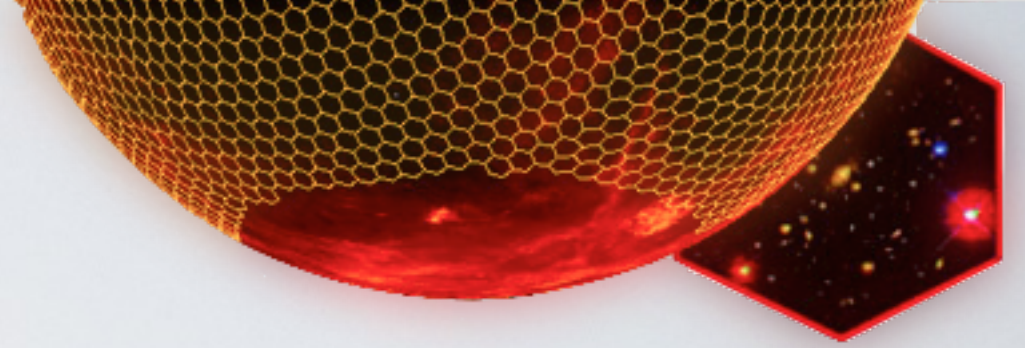In this talk I described two analyses with DES and beyond:

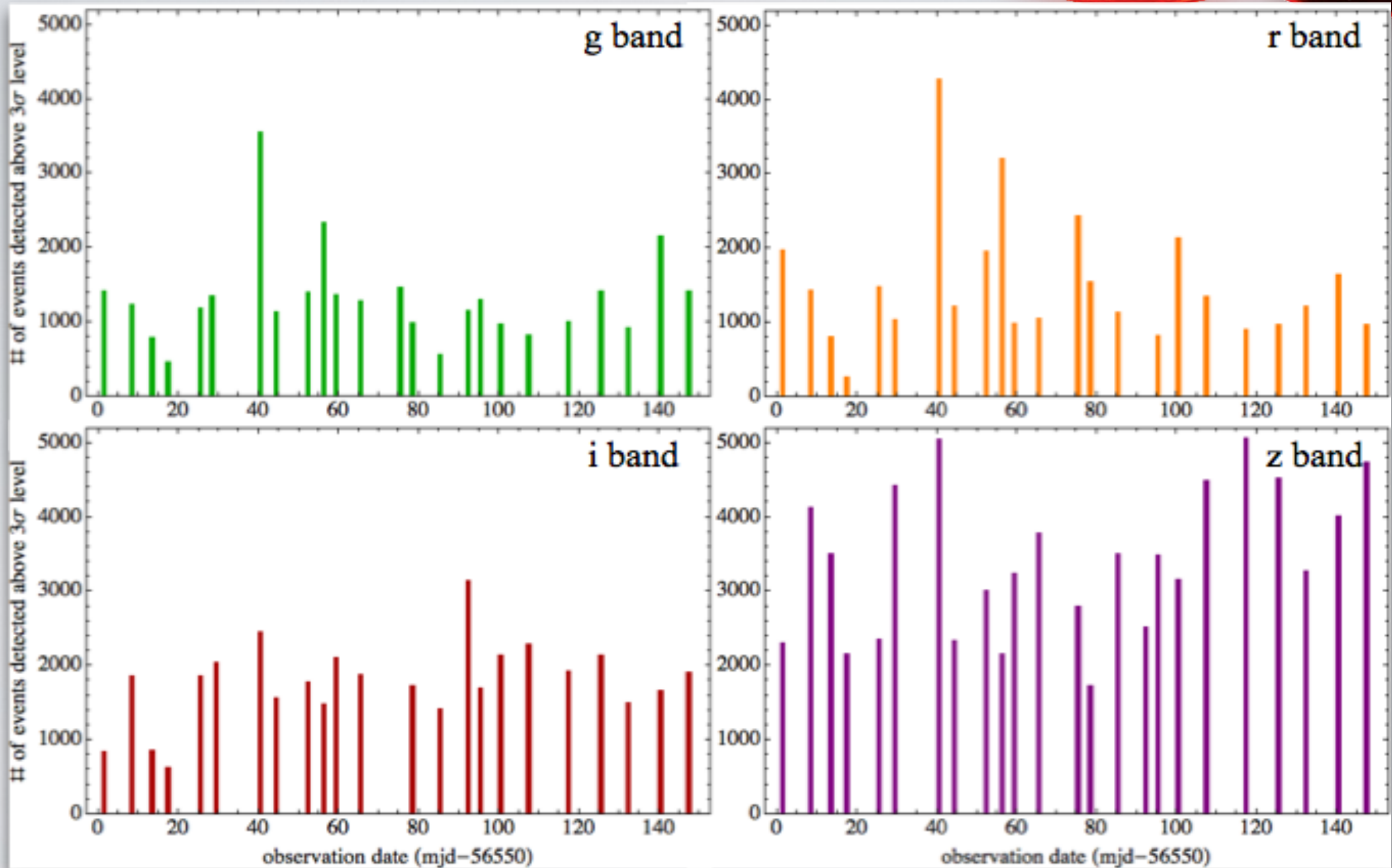—Voronoi Tessellation cluster analysis
— New initiative: GW program
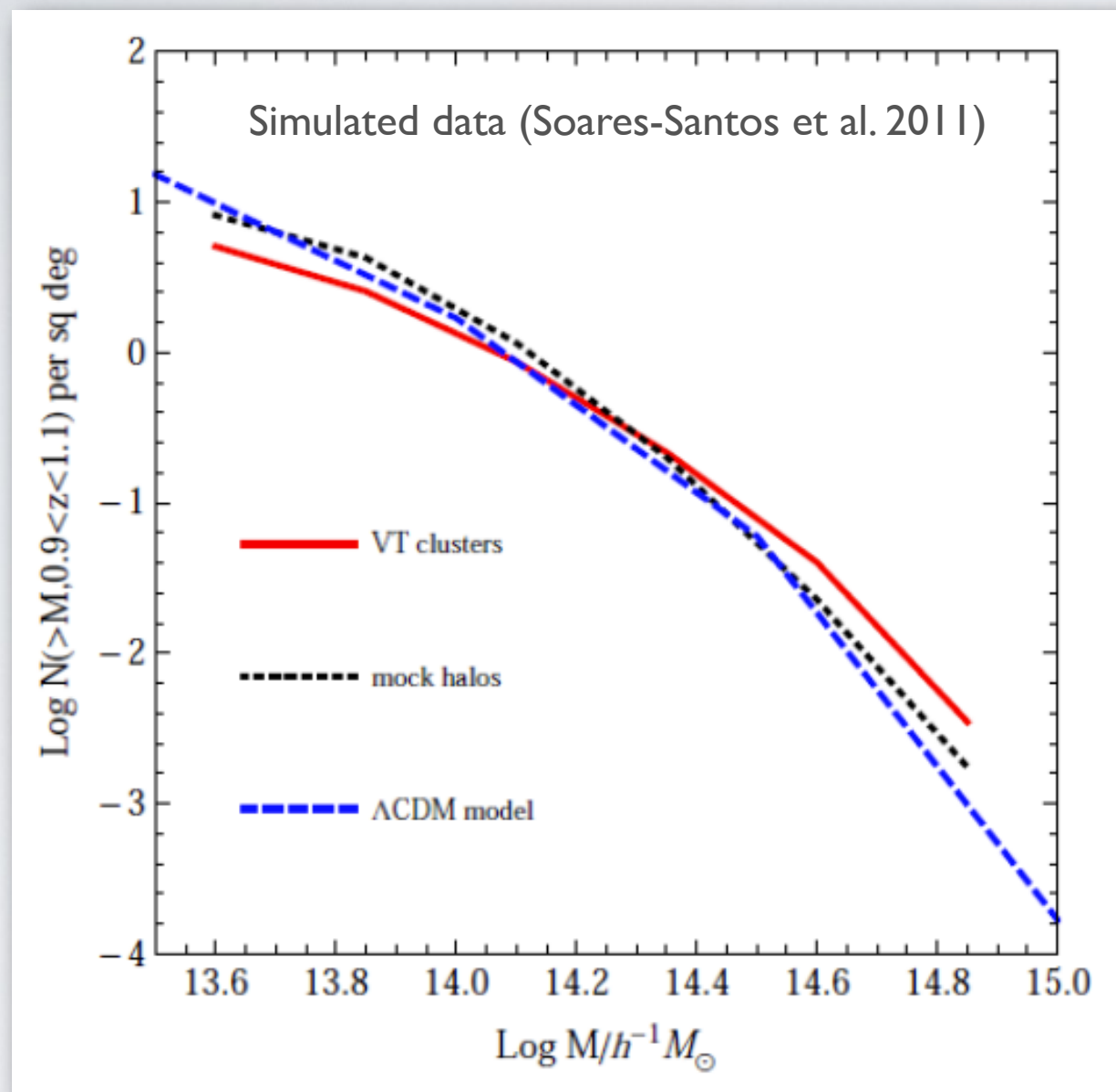

DES image of the Bullet Cluster
arXiv:1405.4285

300 kpc

BACKUP

EVENT RATE

CLUSTER MASS FUNCTION

Simulated data (Soares-Santos et al. 2011)

- VT clusters
- mock halos
- ΛCDM model

By applying the VT cluster finder on mock catalogs, we can measure the selection function for our cluster catalog.

We apply that selection function back to the cluster number counts to obtain the mass function.