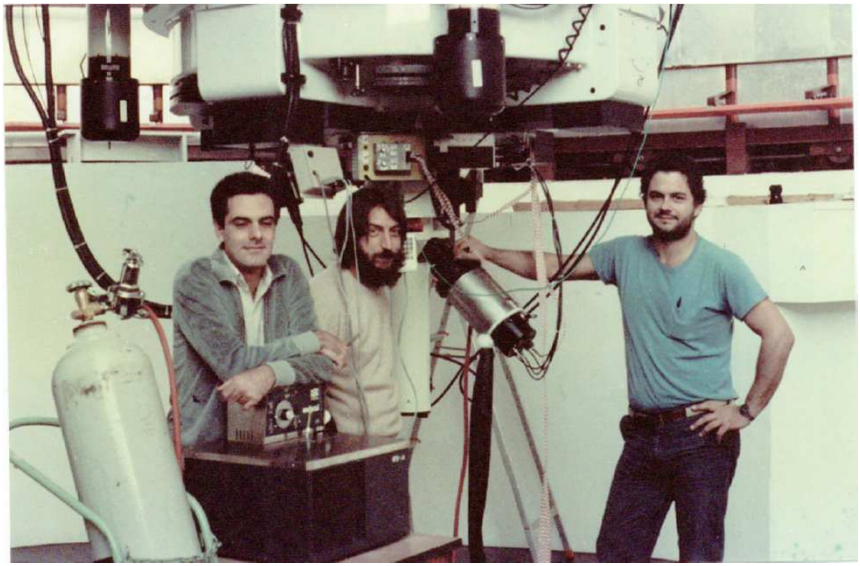
Dark Energy Survey: Status Report

Luiz Nicolaci da Costa
LIneA & ON

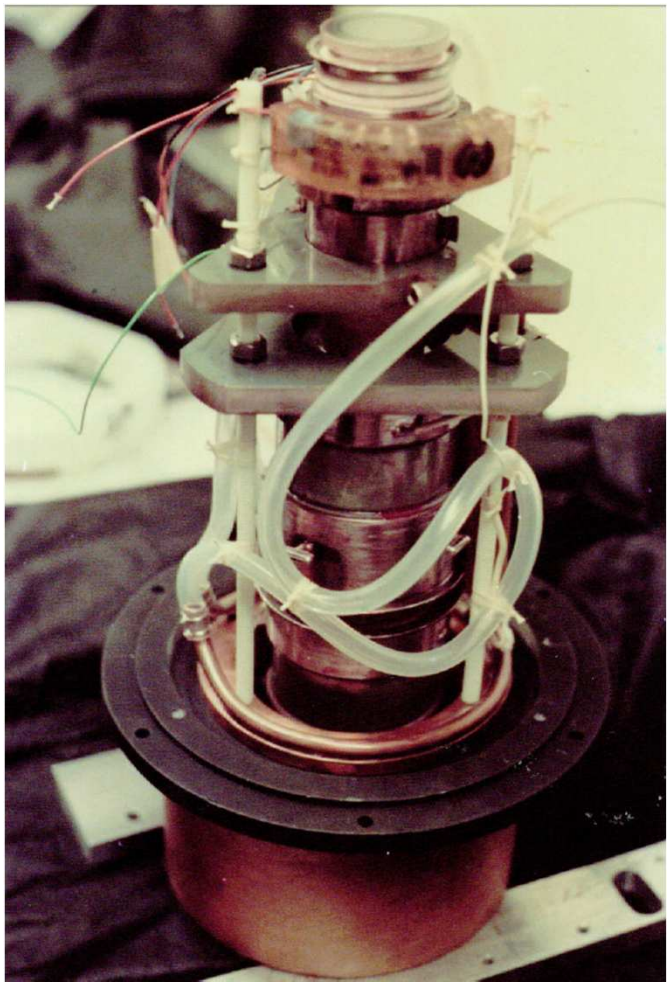

DARK MATTER
DARK ENERGY
INFLATION
Rests upon three mysterious pillars
All implicate new physics!

Background



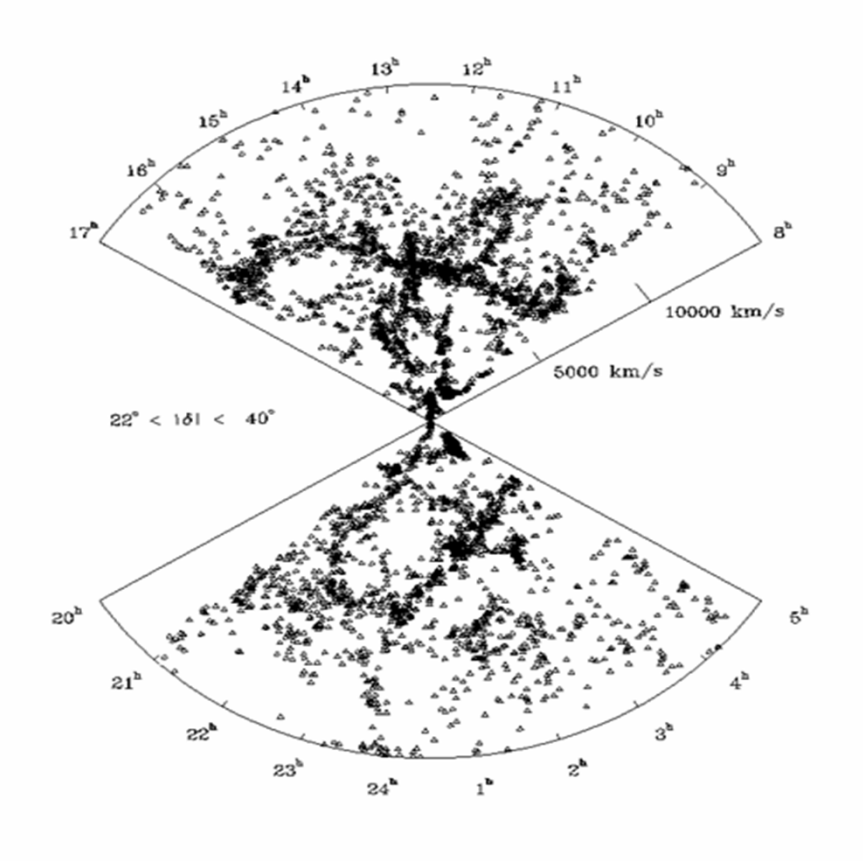
(1982)

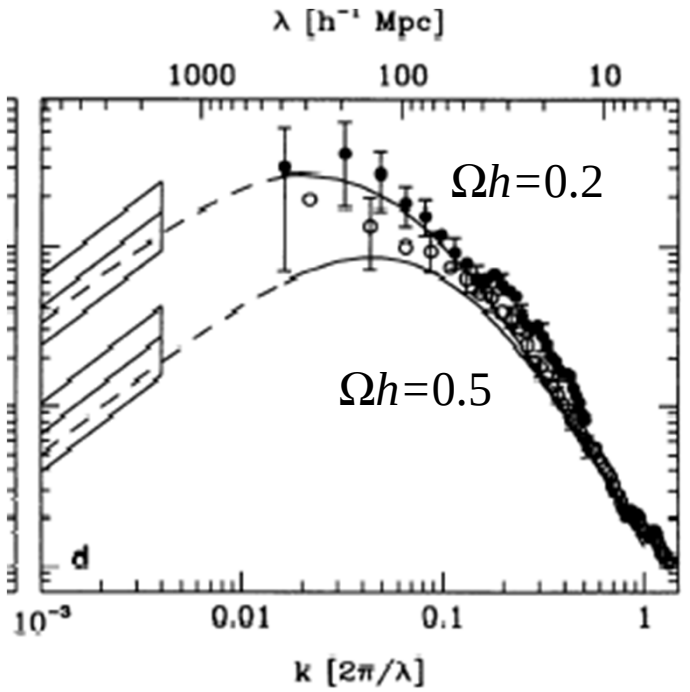
ON-CfA Collaboration



Z-machine

LSS (1979-1994)

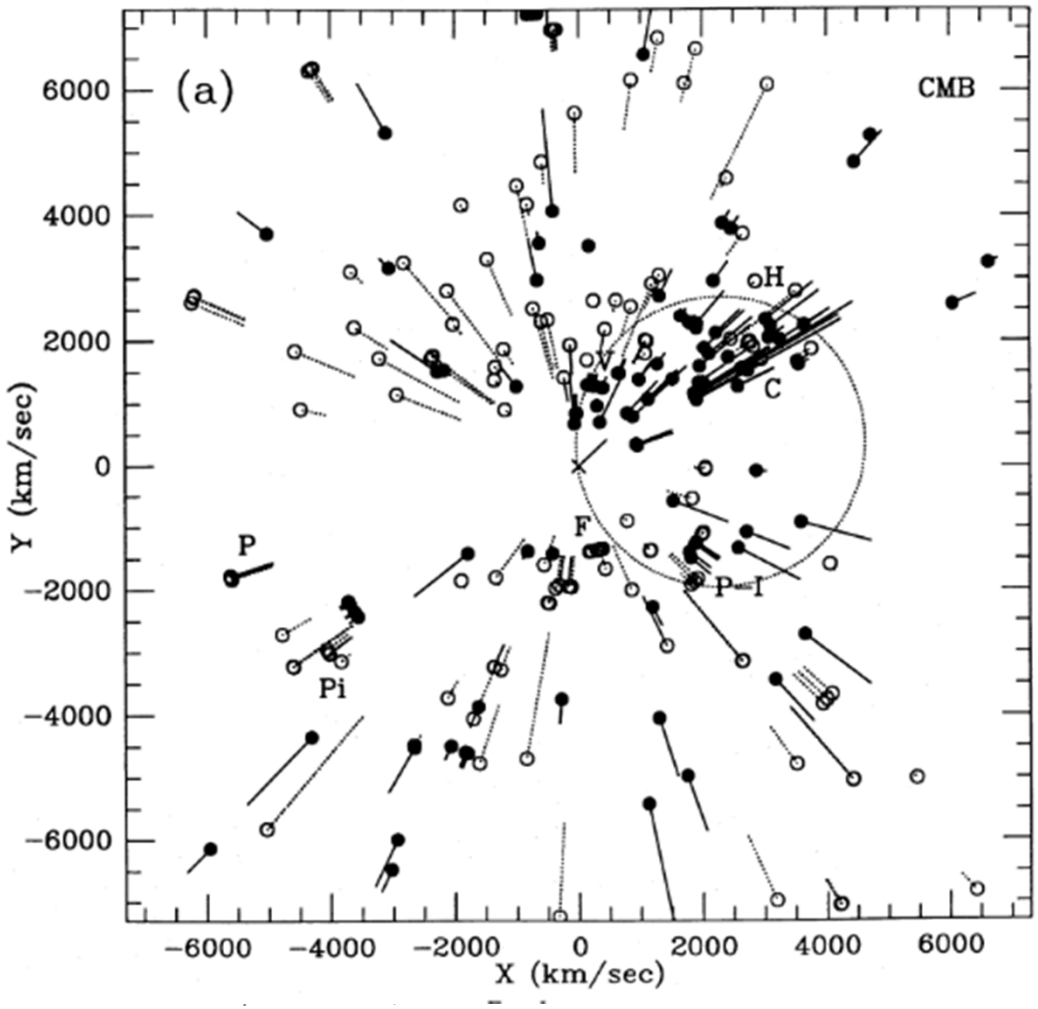




Best-fit ΛCDM with $b \sim 1$; $\Omega_m = 0.3$

Great Attractor

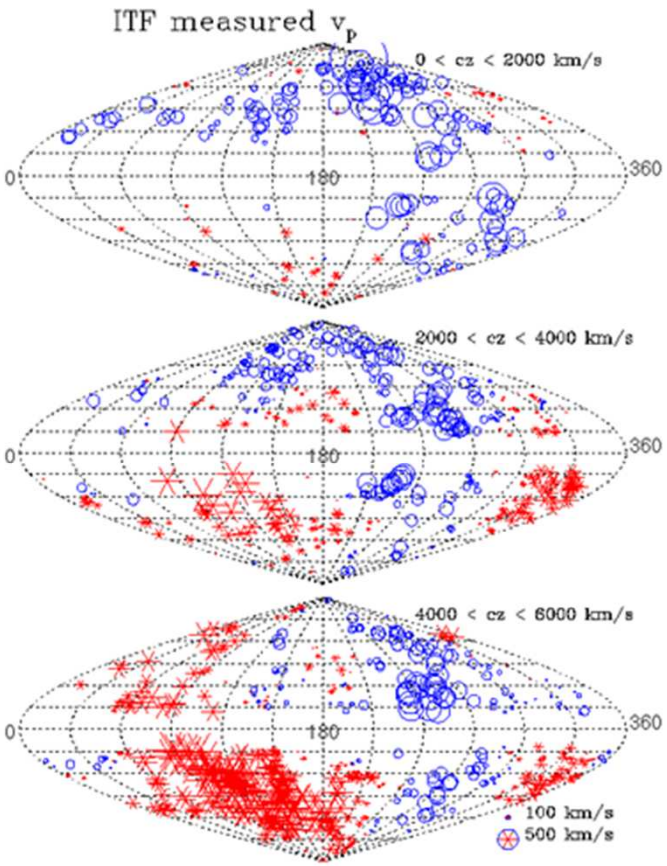
7 Samurai
(1988)



Ω = 1
Inconsistent with LSS

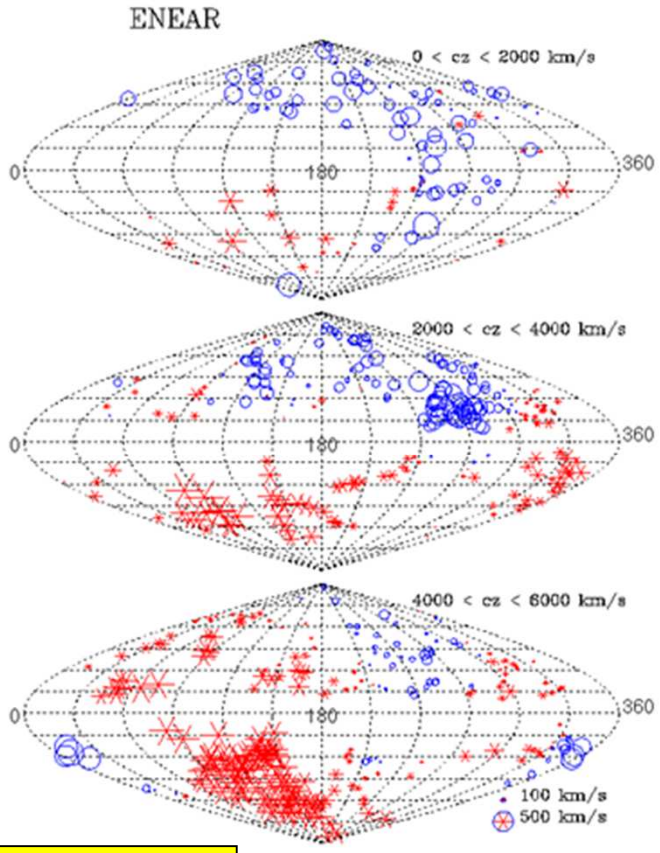
Peculiar velocity field (1988-2003)

Tully-Fisher relation



Spirals

Dn-σ relation



Early-types

$b \sim 1;\ \Omega_m = 0.3$

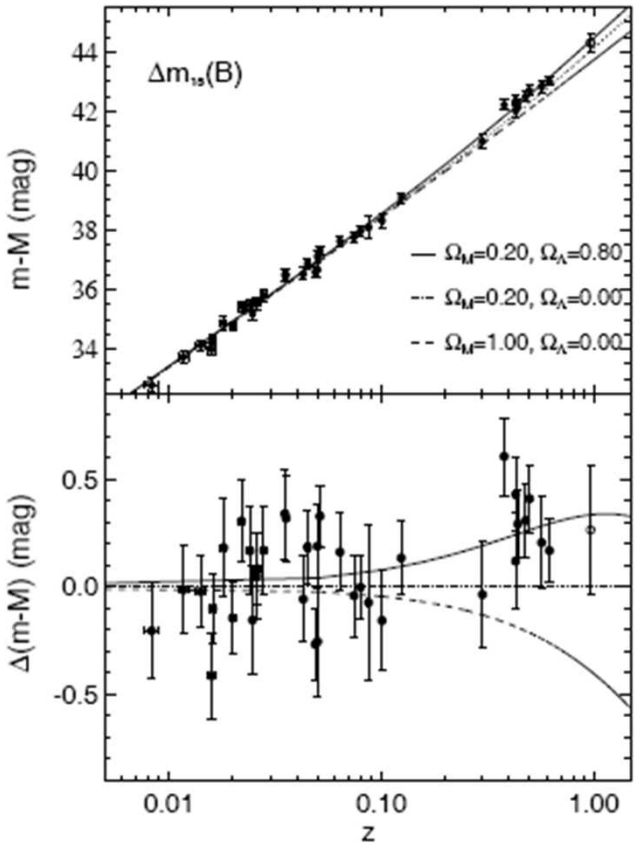
First Evidences LCDM/DE

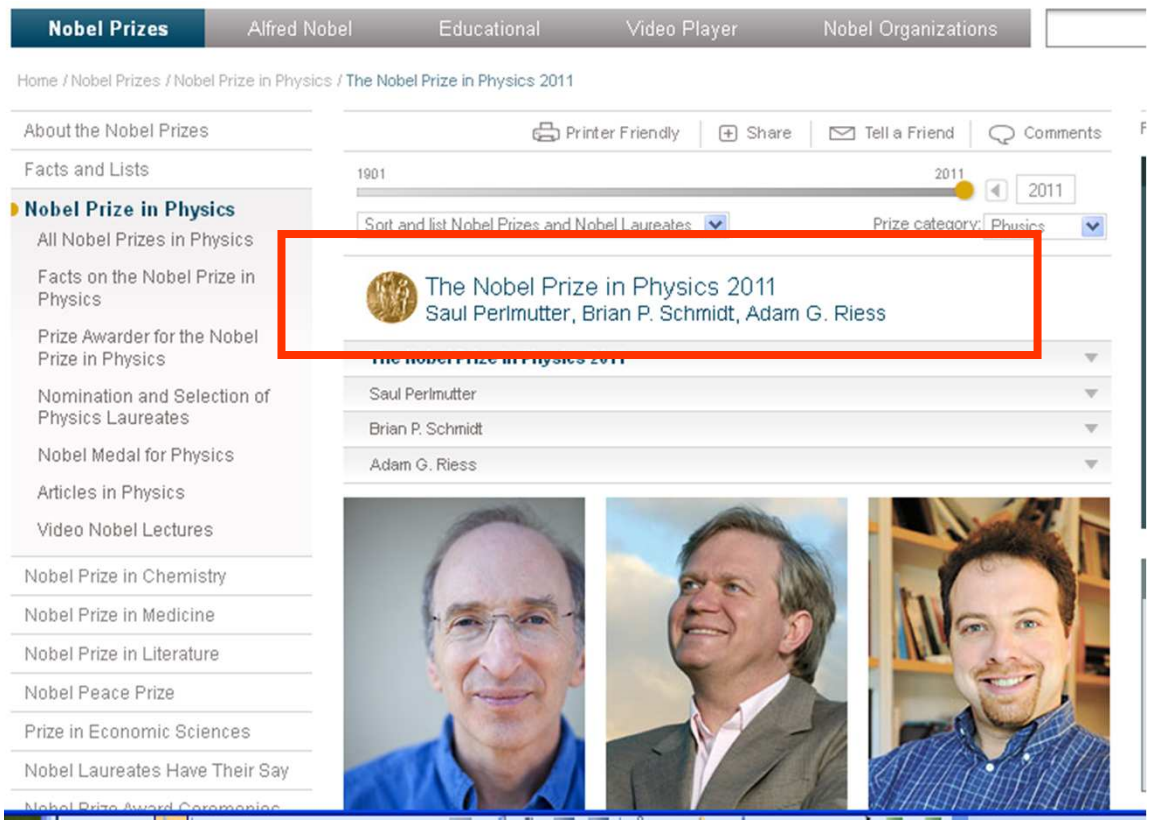
After long debate concordance among different estimates such as:

1) LSS
2) Peculiar motions on small and large scales
3) Other measurements (e.g. cluster abundances)

$$b_O \sim 1 \Rightarrow \Omega_m \sim 0.3$$

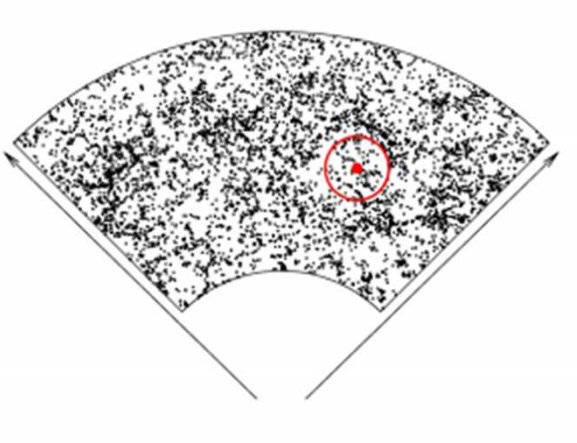
Direct confirmation (1998)

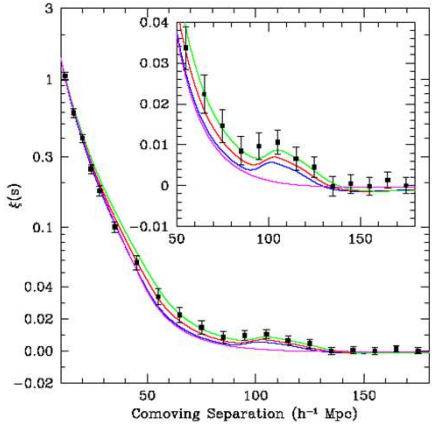


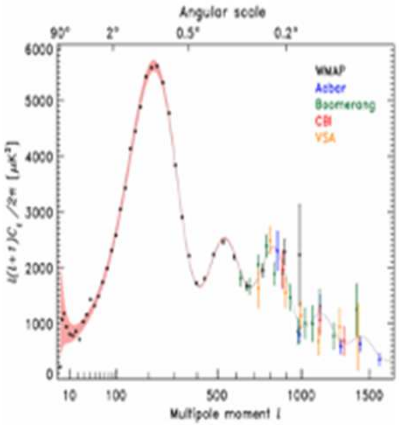


Evidence for Dark Energy

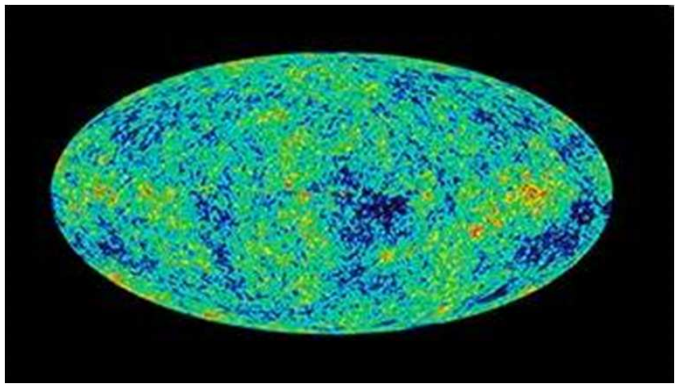
LSS



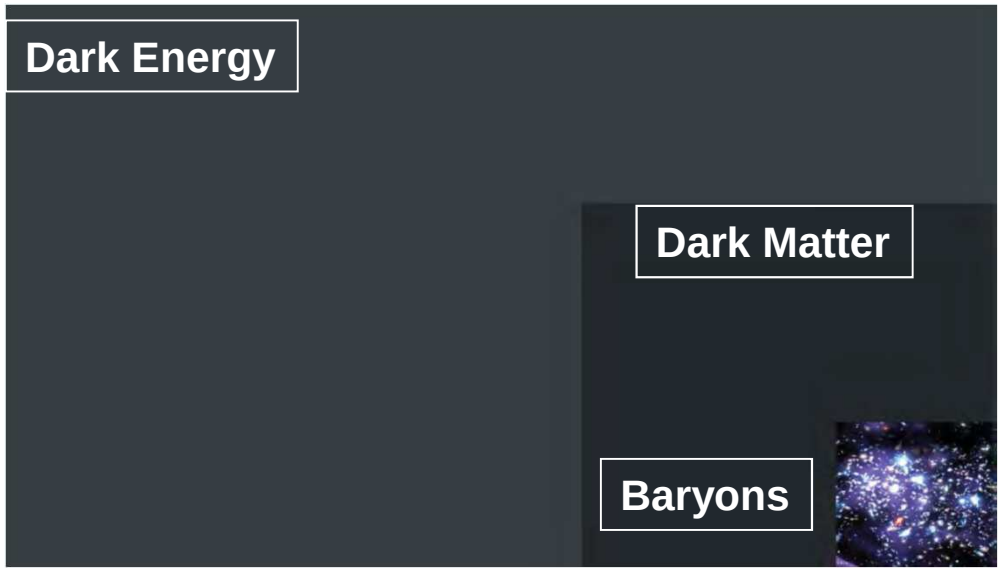


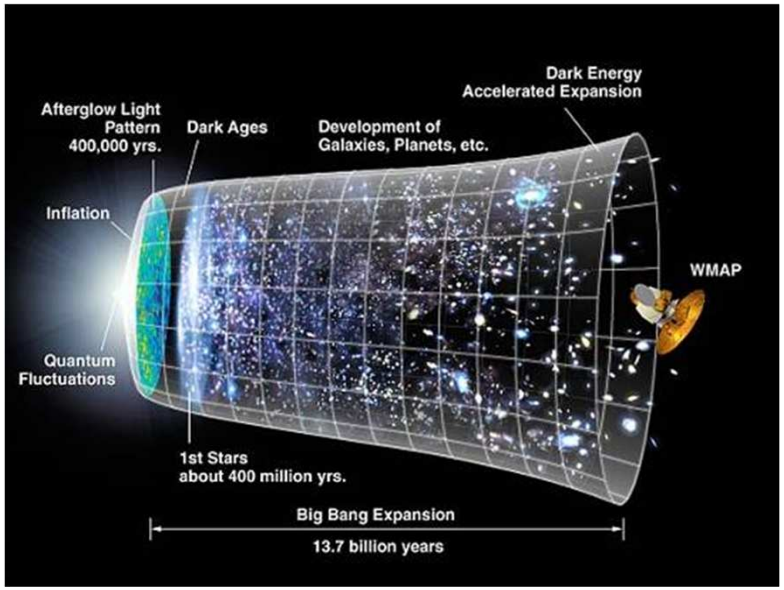


CMB



Contents of the Universe





September 2006

REPORT OF THE

DARK ENERGY TASK FORCE

Andreas Albrecht, University of California, Davis
Gary Bernstein, University of Pennsylvania
Robert Cahn, Lawrence Berkeley National Laboratory
Wendy L. Freedman, Carnegie Observatories
Jacqueline Hewitt, Massachusetts Institute of Technology
Wayne Hu, University of Chicago
John Huth, Harvard University
Marc Kamionkowski, California Institute of Technology
Edward W. Kolb, Fermi National Accelerator Laboratory and The University of Chicago
Lloyd Knox, University of California, Davis
John C. Mather, Goddard Space Flight Center
Suzanne Staggs, Princeton University
Nicholas B. Suntzeff, Texas A&M University

Dark energy appears to be the dominant component of the physical Universe, yet there is no persuasive theoretical explanation for its existence or magnitude. The acceleration of the Universe is, along with dark matter, the observed phenomenon that most directly demonstrates that our theories of fundamental particles and gravity are either incorrect or incomplete. Most experts believe that nothing short of a revolution in our understanding of fundamental physics will be required to achieve a full understanding of the cosmic acceleration. For these reasons, the nature of dark energy ranks among the very most compelling of all outstanding problems in physical science. These circumstances demand an ambitious observational program to determine the dark energy properties as well as possible.

The Dark Energy Task Force (DETF) was established by the Astronomy and Astrophysics Advisory Committee (AAAC) and the High Energy Physics Advisory Panel (HEPAP) as a joint sub-committee to advise the Department of Energy, the National Aeronautics and Space Administration, and the National Science Foundation on future dark energy research.

Dark Energy Task Force

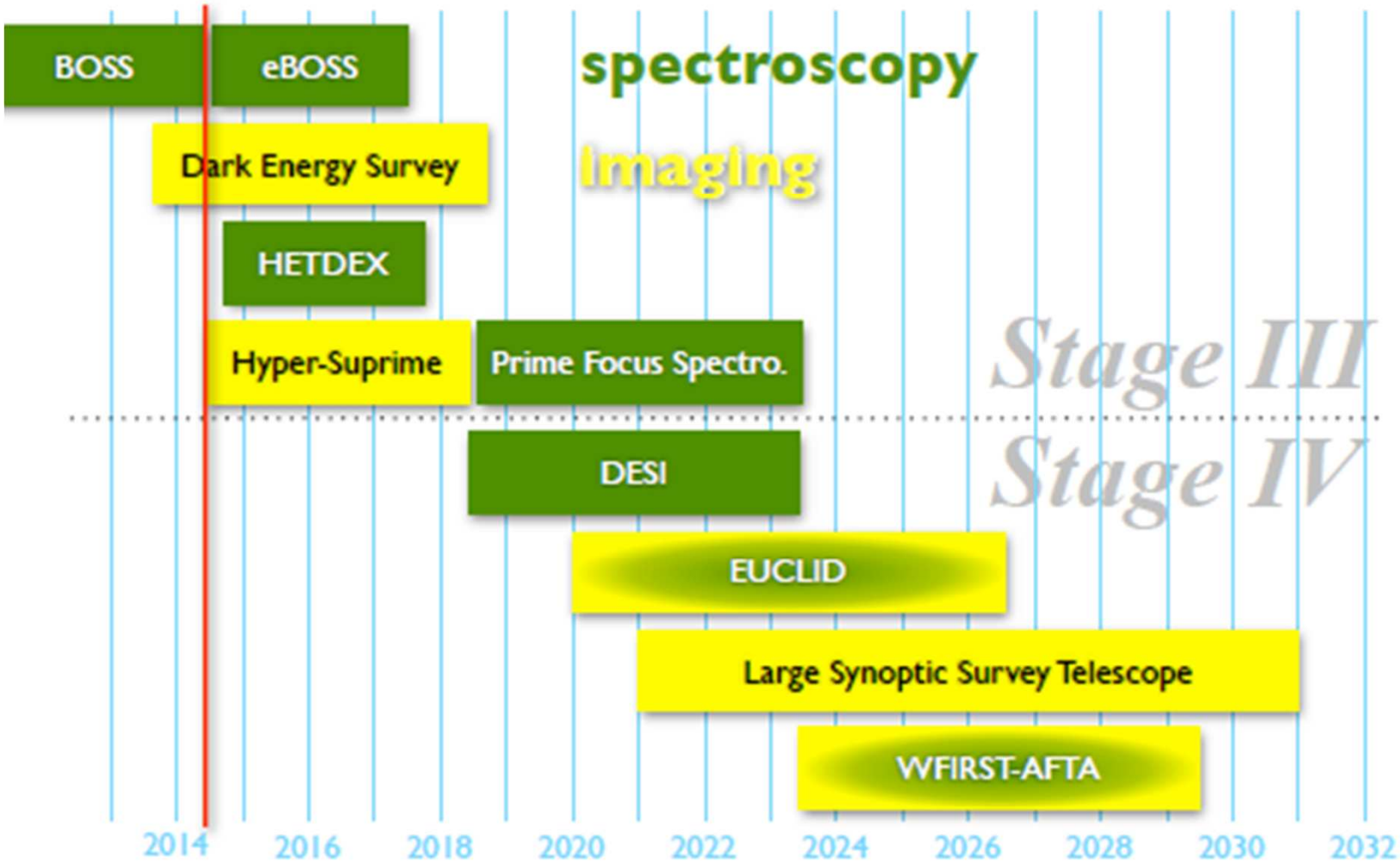
Recommended techniques for probing dark energy

geometry

1. Supernovae
2. Baryon Acoustic Oscillations
3. Galaxy Cluster Counting
4. Weak Gravitational Lensing

growth of structures

The dark energy facilities roadmap




New Worlds,
New Horizons

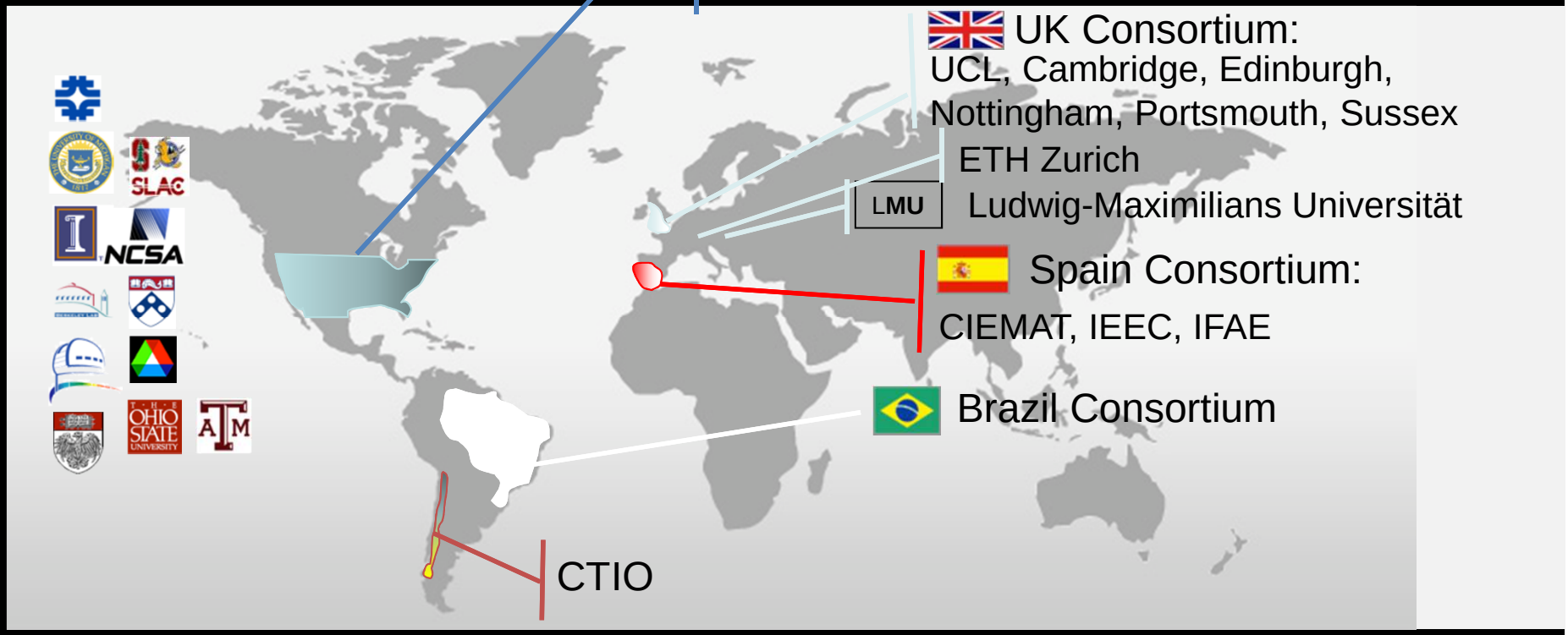

Building for Discovery
Strategic Plan for U.S. Particle Physics in the Global Context
DRAFT FOR APPROVAL
Report of the Particle Physics Project Prioritization Panel
May 2014

Dark Energy Survey (DES)

Dark Energy Survey Collaboration

~300 scientists
US support from DOE+NSF

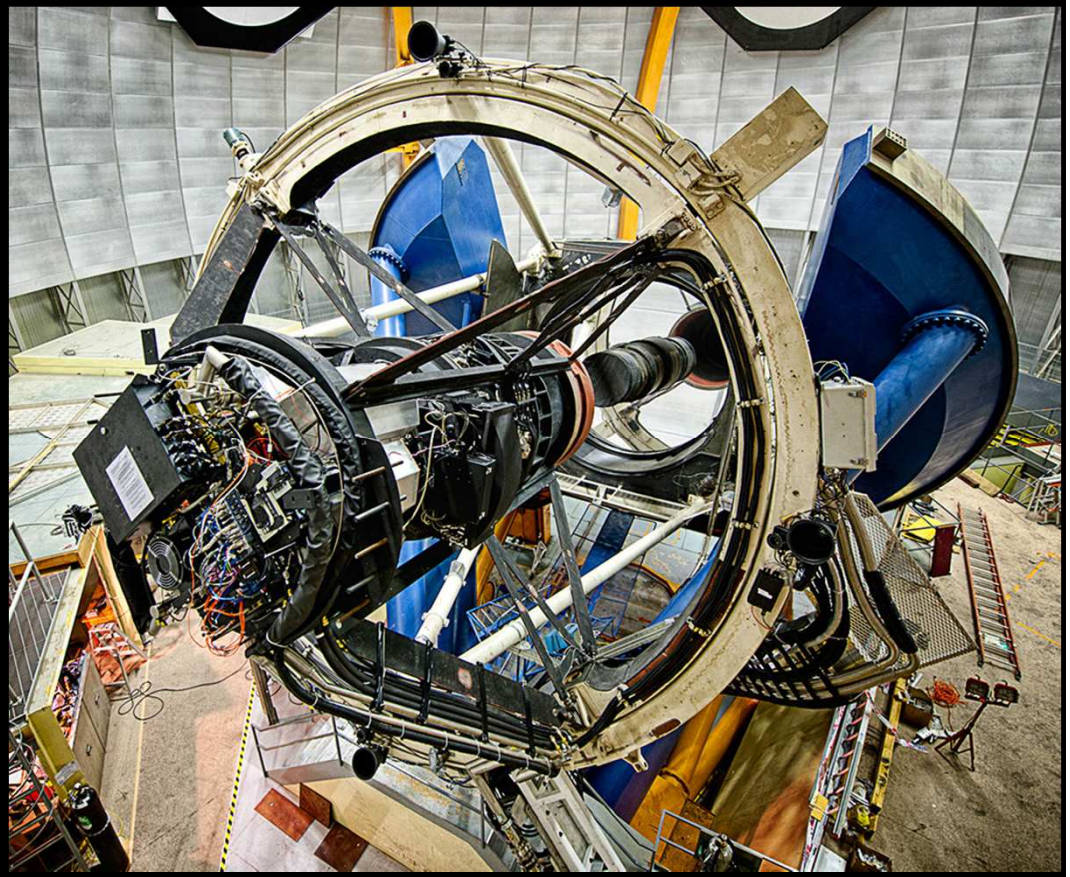
Fermilab, UIUC/NCSA, University of Chicago, LBNL, NOAO, University of Michigan, University of Pennsylvania, Argonne National Lab, Ohio State University, Santa-Cruz/SLAC/Stanford, Texas A&M



The Dark Energy Survey

- Probe Dark Energy and the origin of Cosmic Acceleration:
  - Distance vs. redshift
  - Growth of Structure
- Two multicolor surveys:
  - 300 M galaxies over 1/8 sky
  - 3500 supernovae (30 sq deg)
- Built new camera for CTIO Blanco telescope
  - Facility instrument
- Five-year Survey started Aug. 31, 2013
  - 525 nights (Sept.-Feb.)

DECam on the Blanco 4m



www.darkenergysurvey.org
www.darkenergydetectives.org

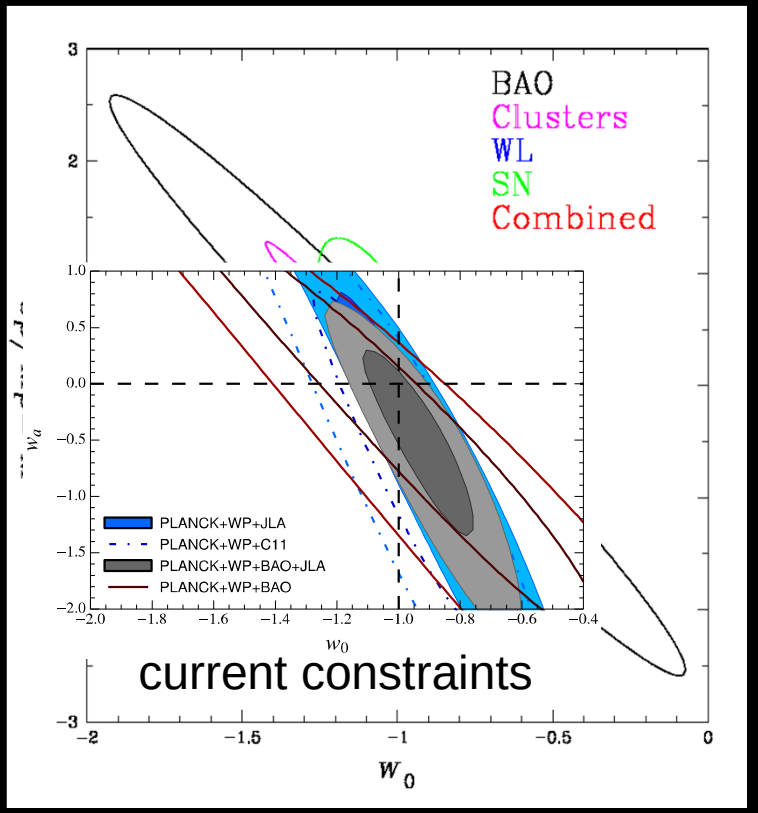
DES Science Summary

Four Probes of Dark Energy

- Galaxy Clusters
  - Tens of thousands of clusters to z~1
  - Synergy with SPT, VHS
- Weak Lensing
  - Shape and magnification measurements of 200 million galaxies
- Baryon Acoustic Oscillations
  - 300 million galaxies to z = 1 and beyond
- Supernovae
  - 30 sq deg time-domain survey
  - 3500 well-sampled SNe Ia to z ~1

Forecast Constraints on DE Equation of State

$$w(a) = w_0 + w_a(1 - a(t))$$



DES forecast

The Dark Energy Survey Camera

DECam:

Replace this PF cage with a new 2.2 FOV, 570Mega pixel red sensitive CCD camera and optics

Time scale:

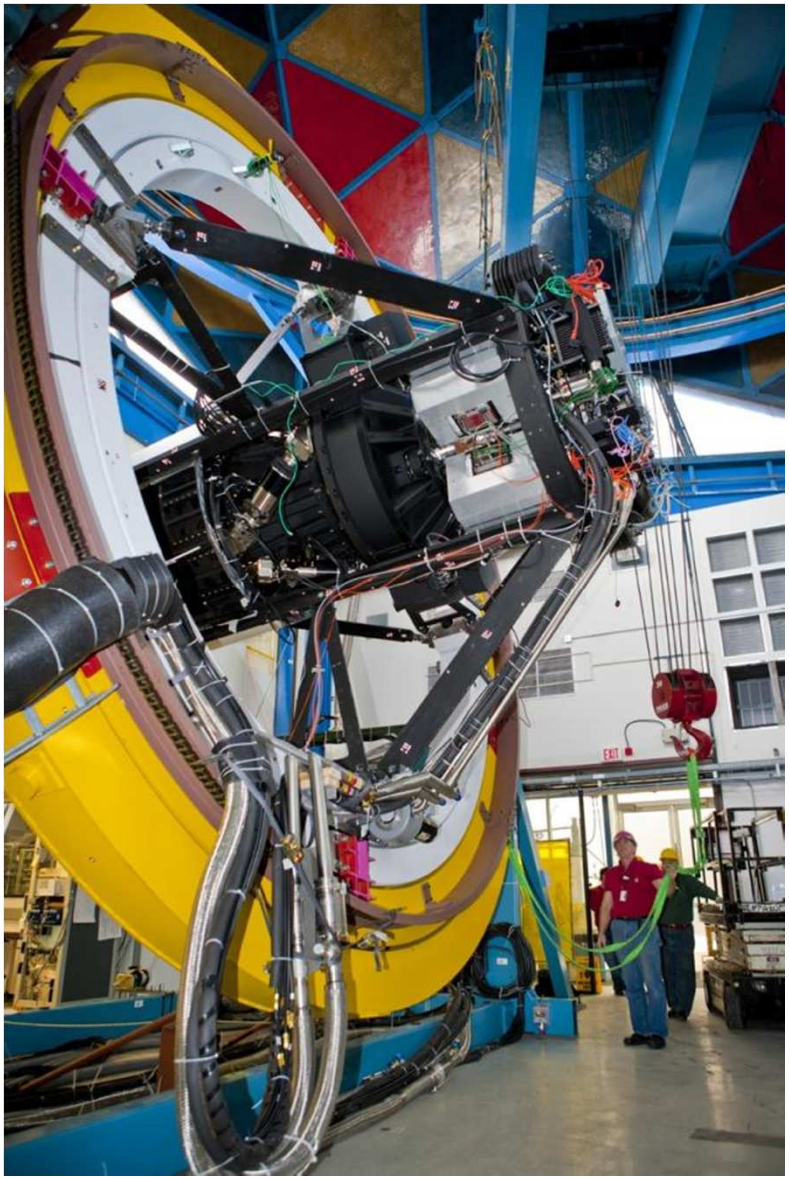
- **R&D and Reviews 2003-2008**
- **Instrument Construction 2008-2011**
- **Delivery to CTIO 2011-2012**
- **Installation Jan.'11-Aug.'12**

First Light: **Sept. 2012**

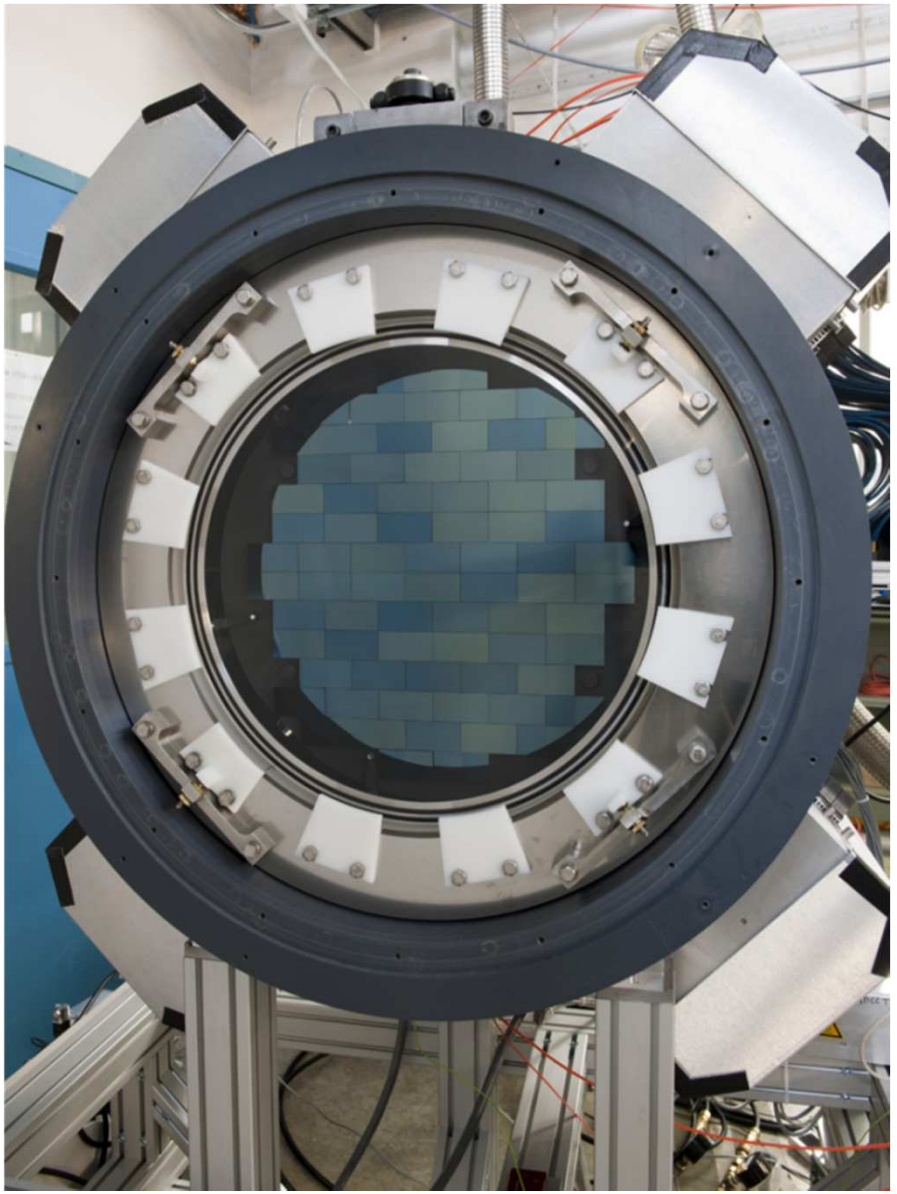
Beginning of Survey: **Aug 2013**

Use the Blanco 4M Telescope at the Cerro-Tololo Inter-American Observatory (CTIO)

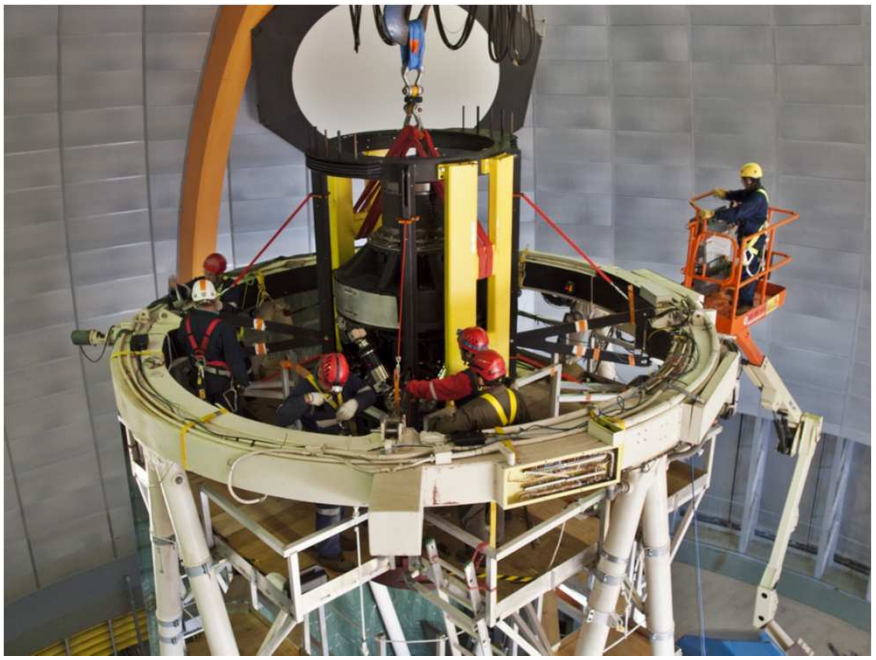
Telescope Simulator



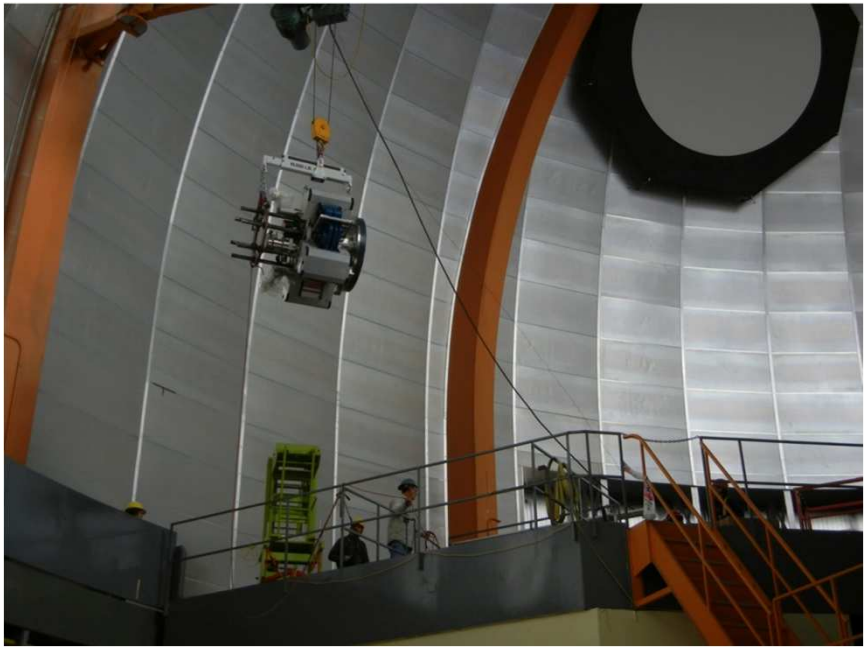
570-Million pixel DECam



Installation at CTIO



New cage – May 2012



Imager – August 2012

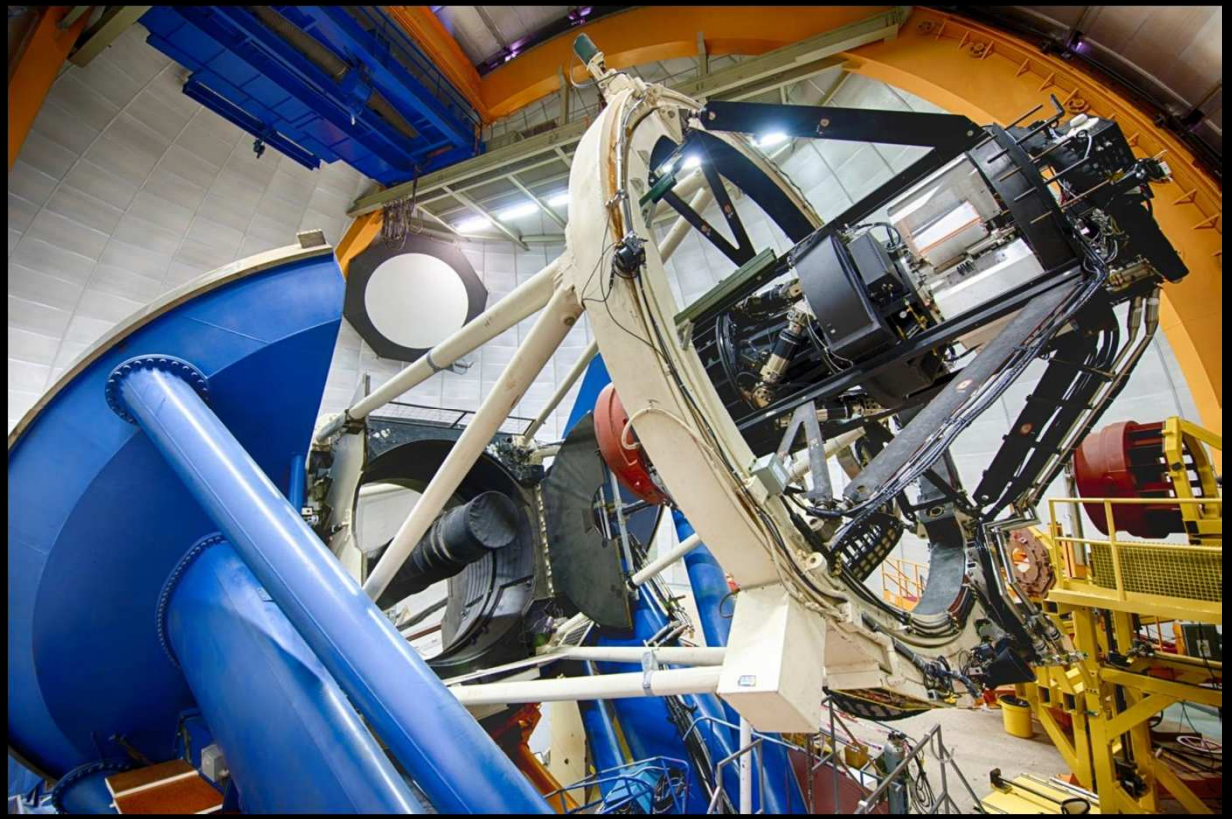
First Light Sept 2012

First light: Sep 2012

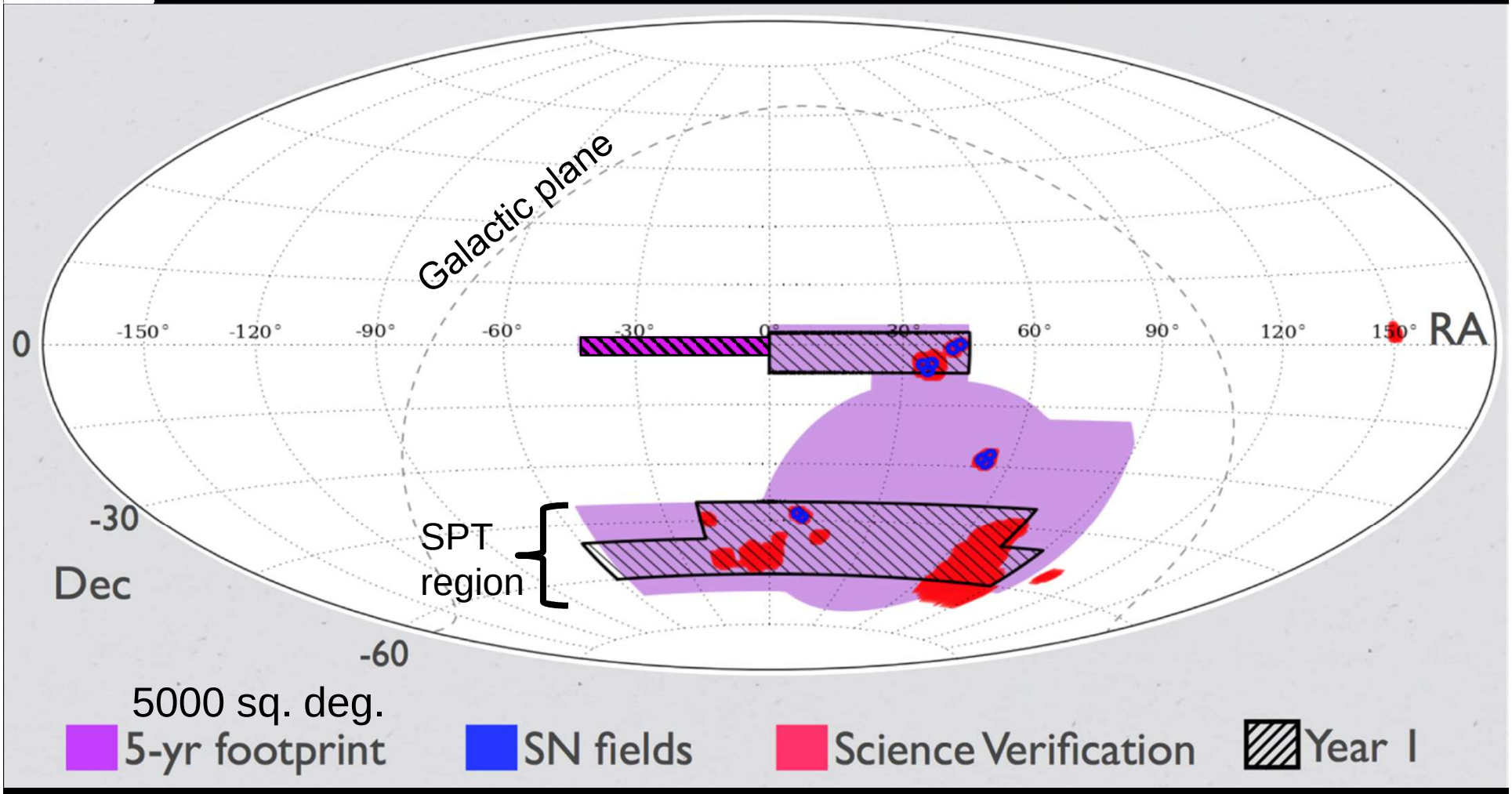
SV: Oct 2012/Feb 2013

Hand over to CTIO

Survey: Aug 2013



DES Survey Footprint



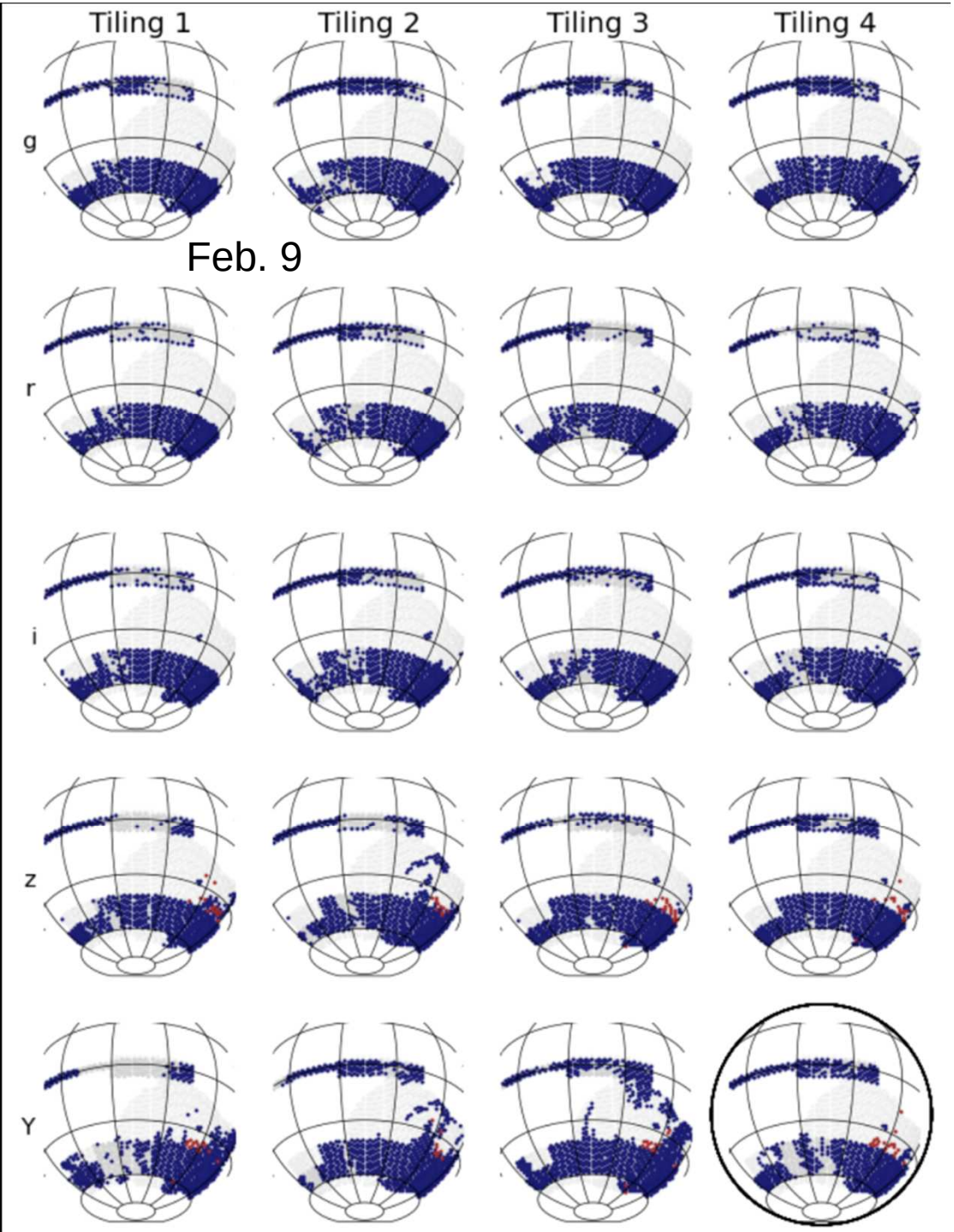
- Science Verification: ~250 sq. deg. to ~full depth; 45 M objects
- Year 1: ~2000 sq. deg. overlap SPT, SDSS: 4/10 tilings; 140 M objects

Survey Progress

Goal for Year 1: cover northern (SDSS stripe 82) and southern (SPT) regions 4 times in each filter (grizY): ~2000 sq deg.

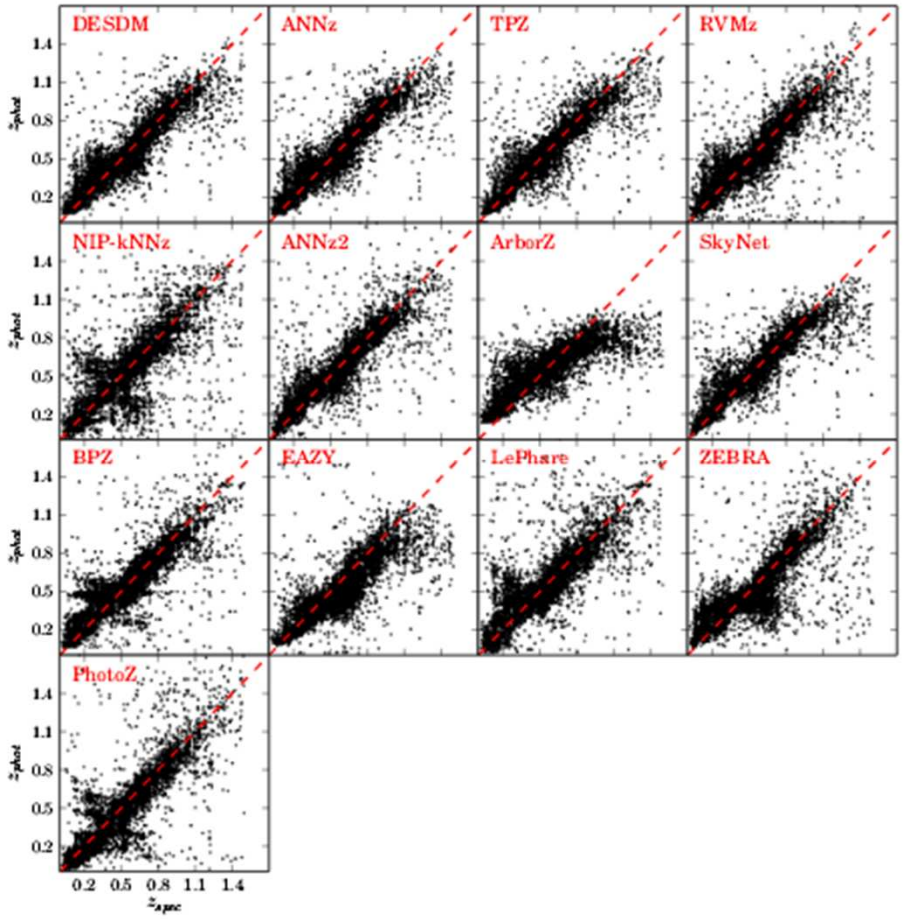
Completed 82% of survey-quality Y1 exposures (11,215/13,691) and 17% of Y2 exposures

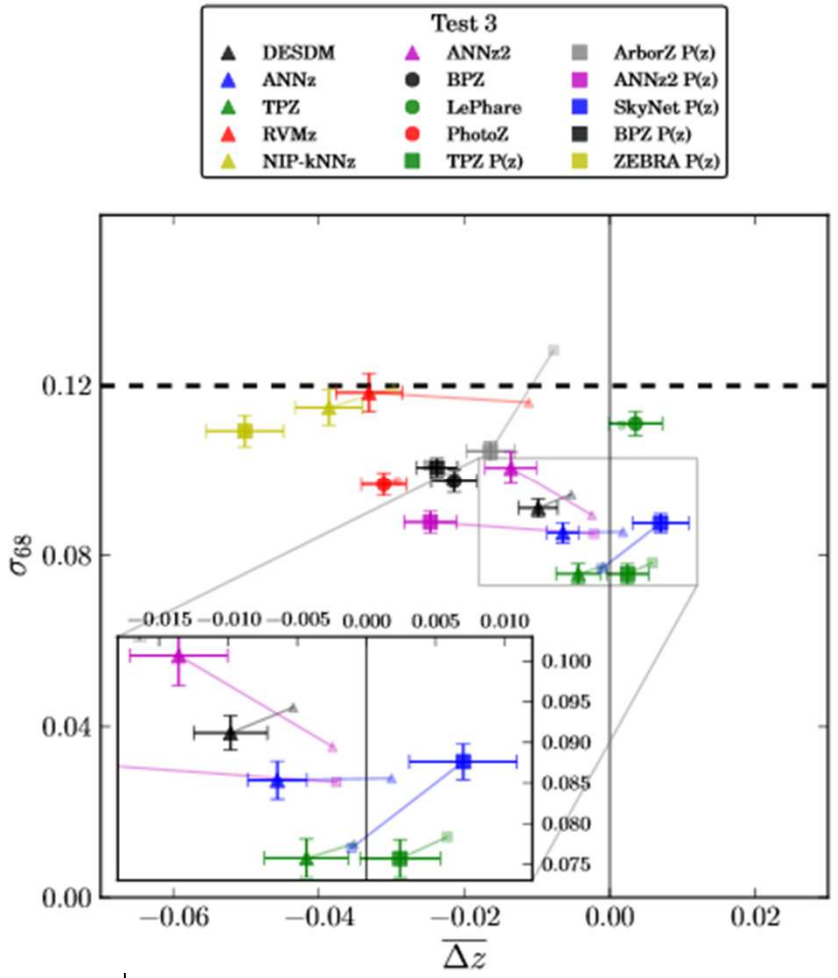
From Nov. onward, >92% of exposures were survey-quality (not returned to queue for re-observing). For season, ~16% of time lost to weather+HW failures



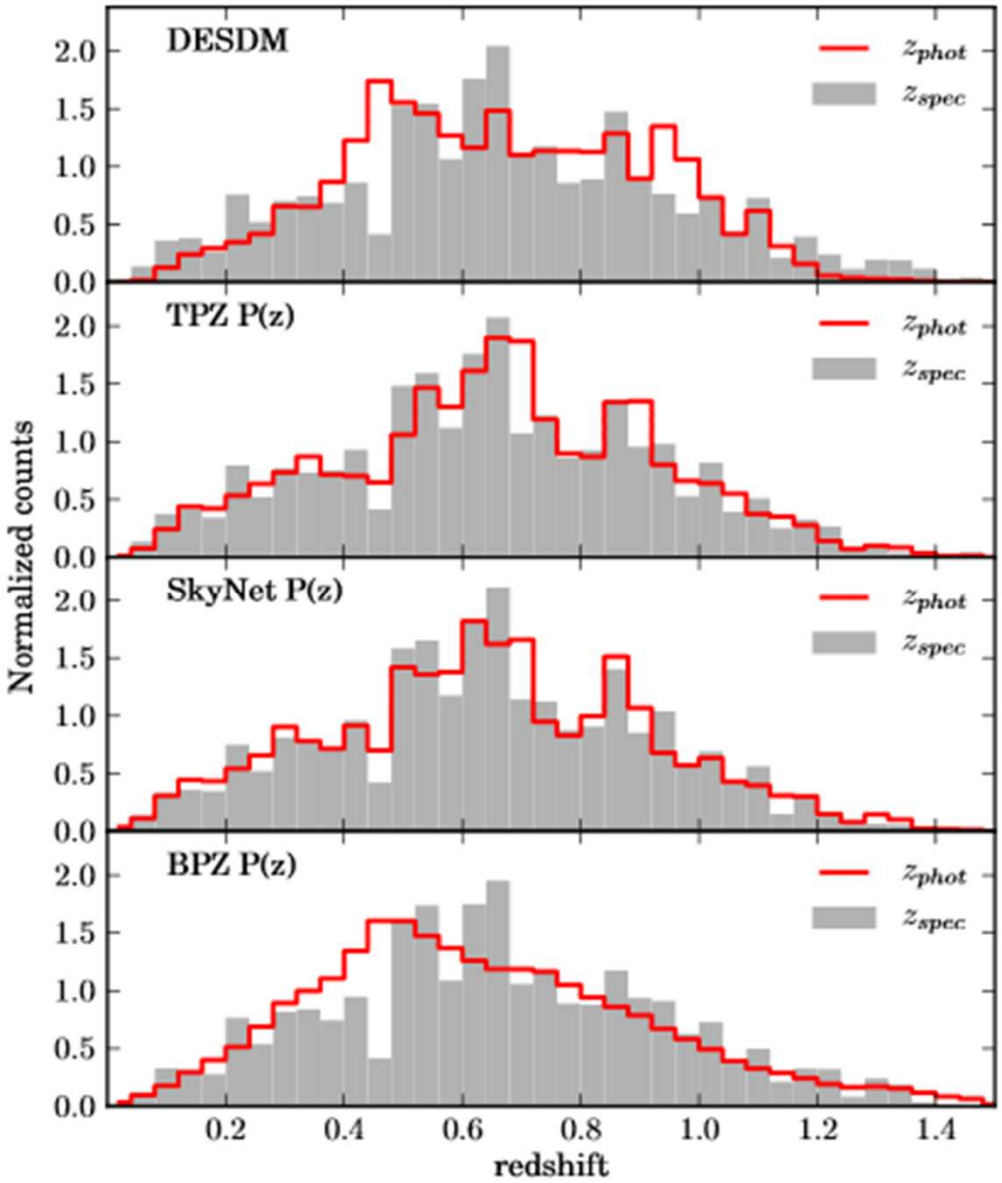
First Results

Photo-z

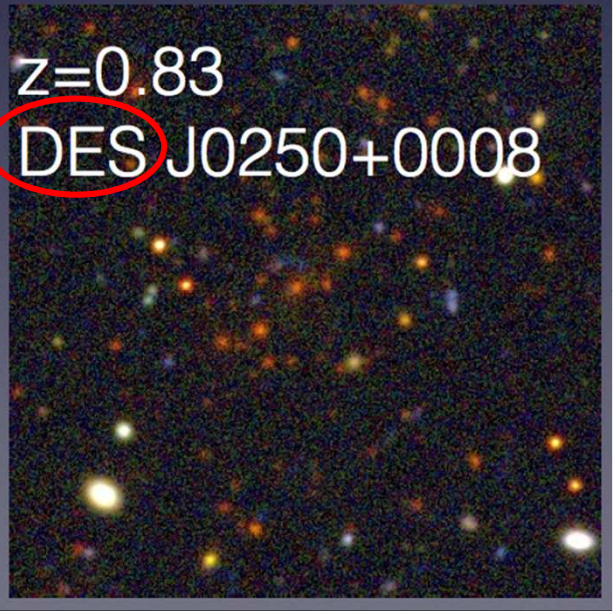


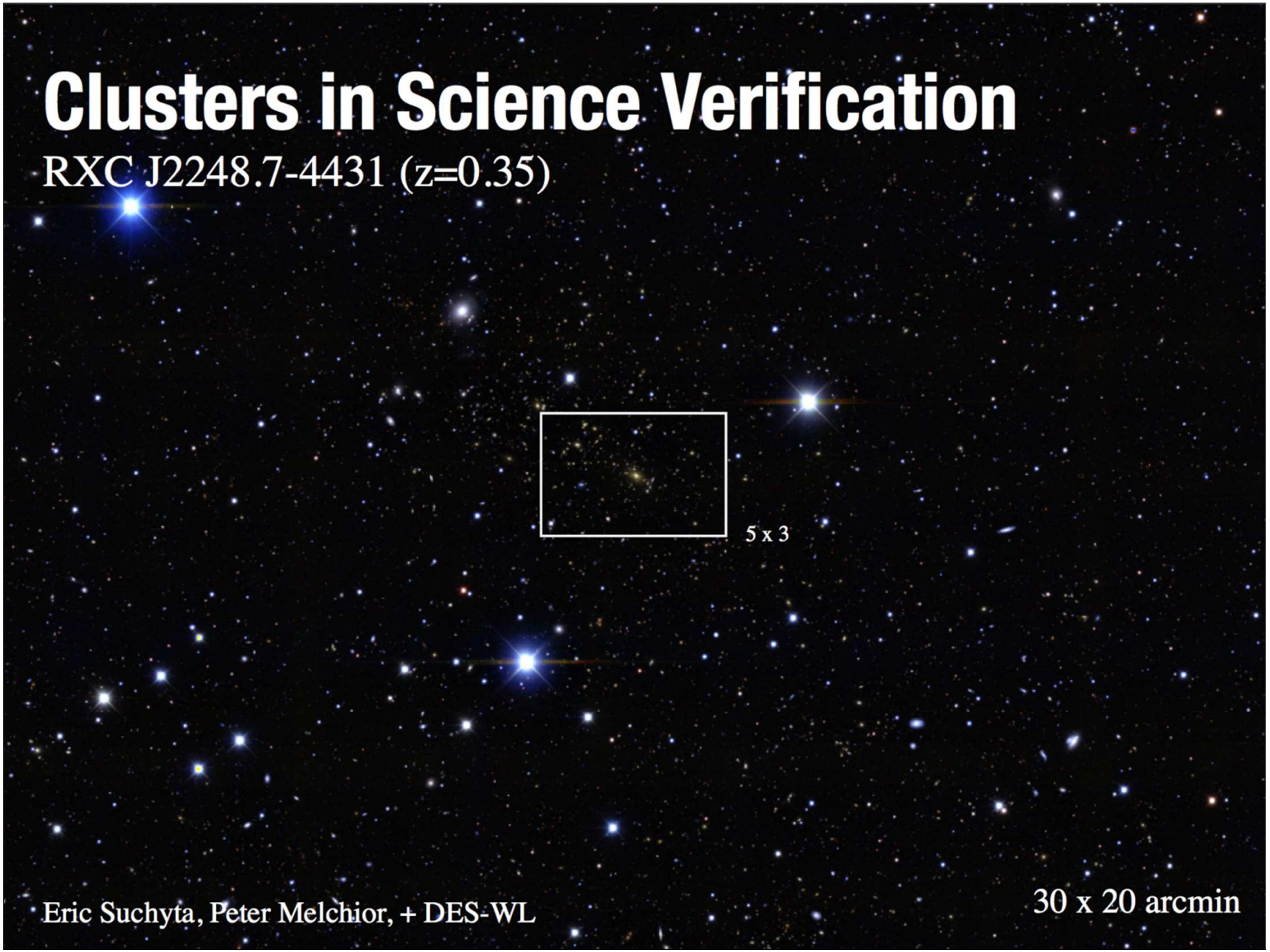


Sanches et al

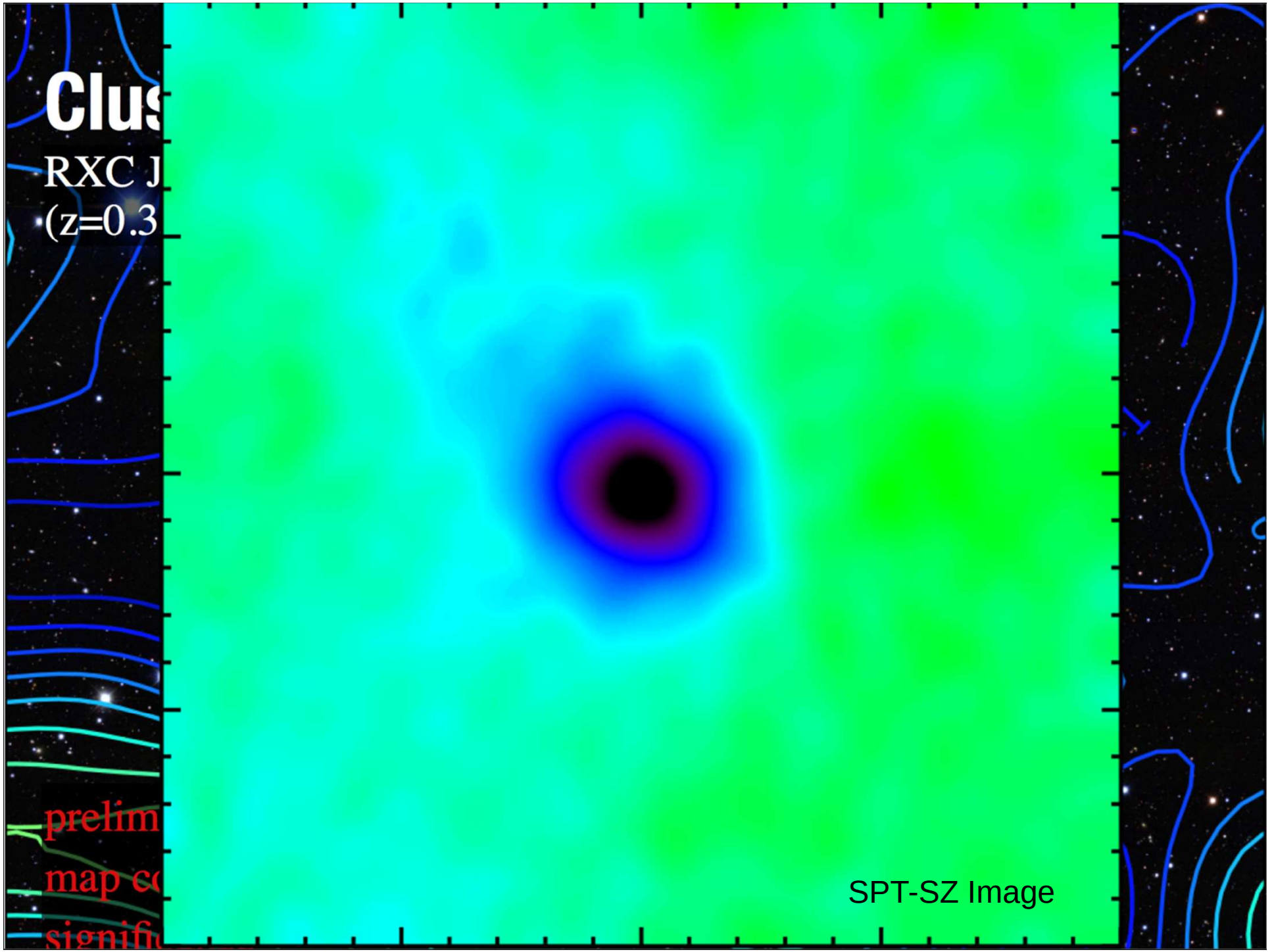

DESDM
TPZ P(z)
SkyNet P(z)
BPZ P(z)
z_{phot}
z_{spec}
Normalized counts
redshift
0.0
0.5
1.0
1.5
2.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4

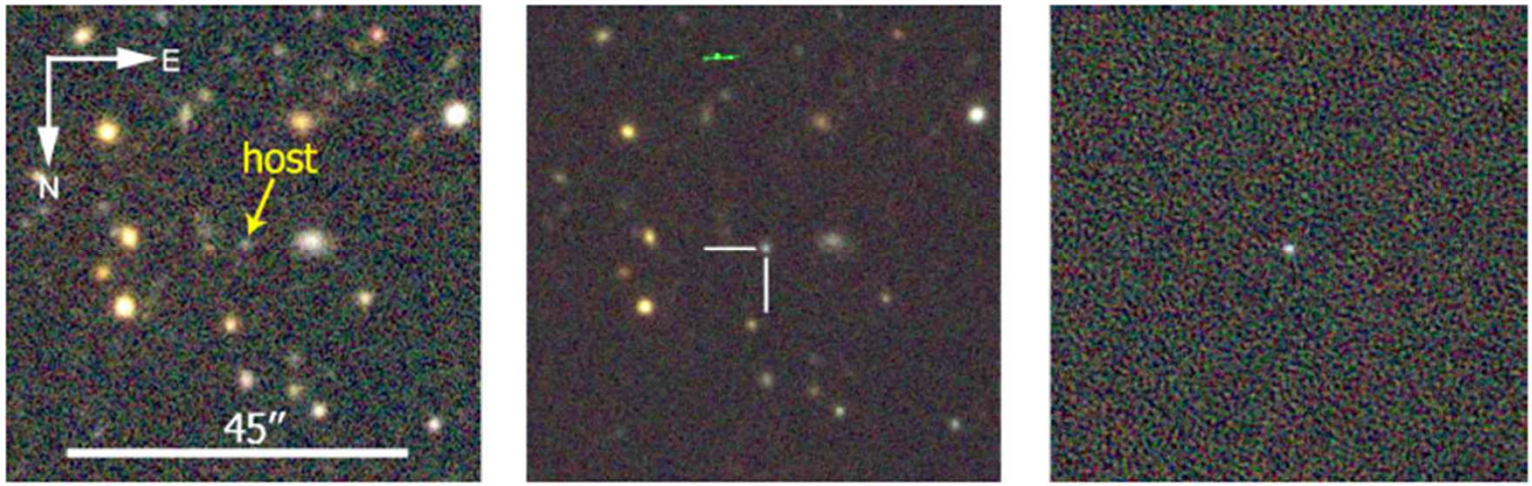
Galaxy Clusters in SV




Clusters in Science Verification
RXC J2248.7-4431 (z=0.35)
5 x 3
Eric Suchyta, Peter Melchior, + DES-WL
30 x 20 arcmin

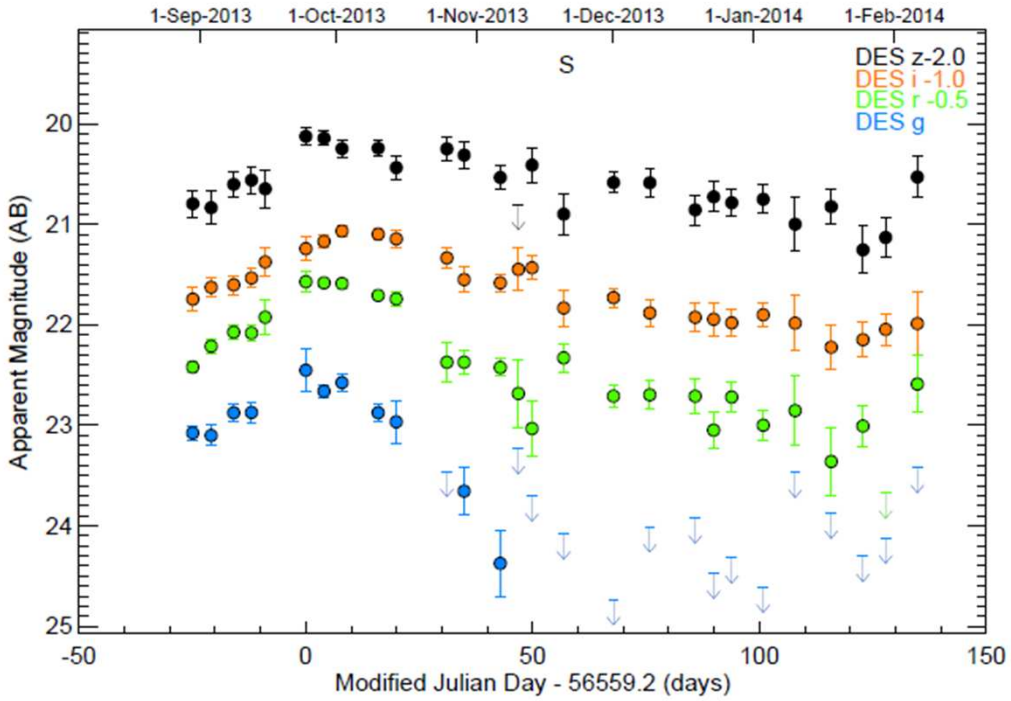

Clusters in Science Verification
RXC J2248.7-4431
(z=0.35)
3
4
5
-1
1
2
preliminary mass
map contours:
significance


Clus
RXC J
(z=0.3
prelim
map c
signifi
SPT-SZ Image

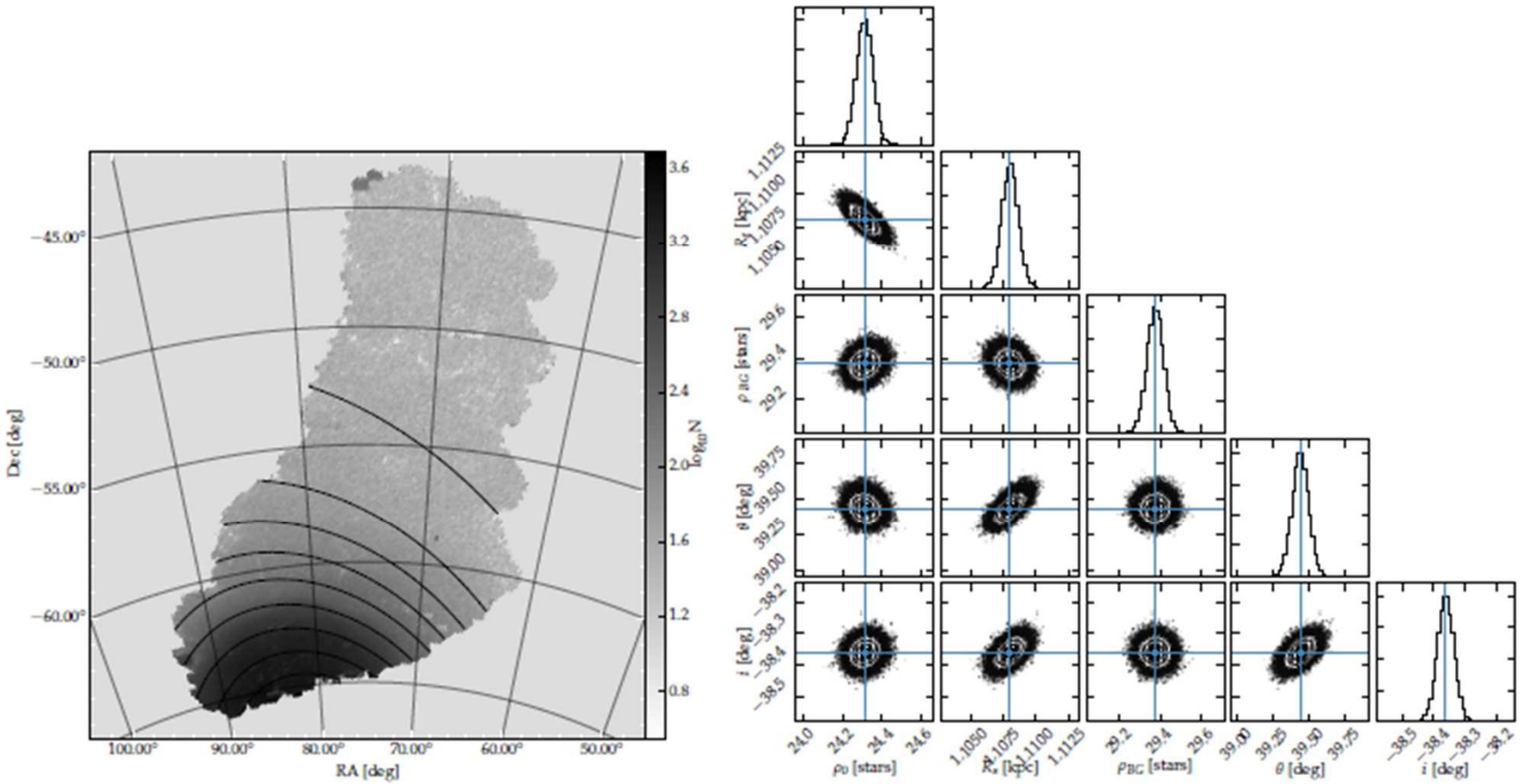


z=0.66

Papadoupolos et al.

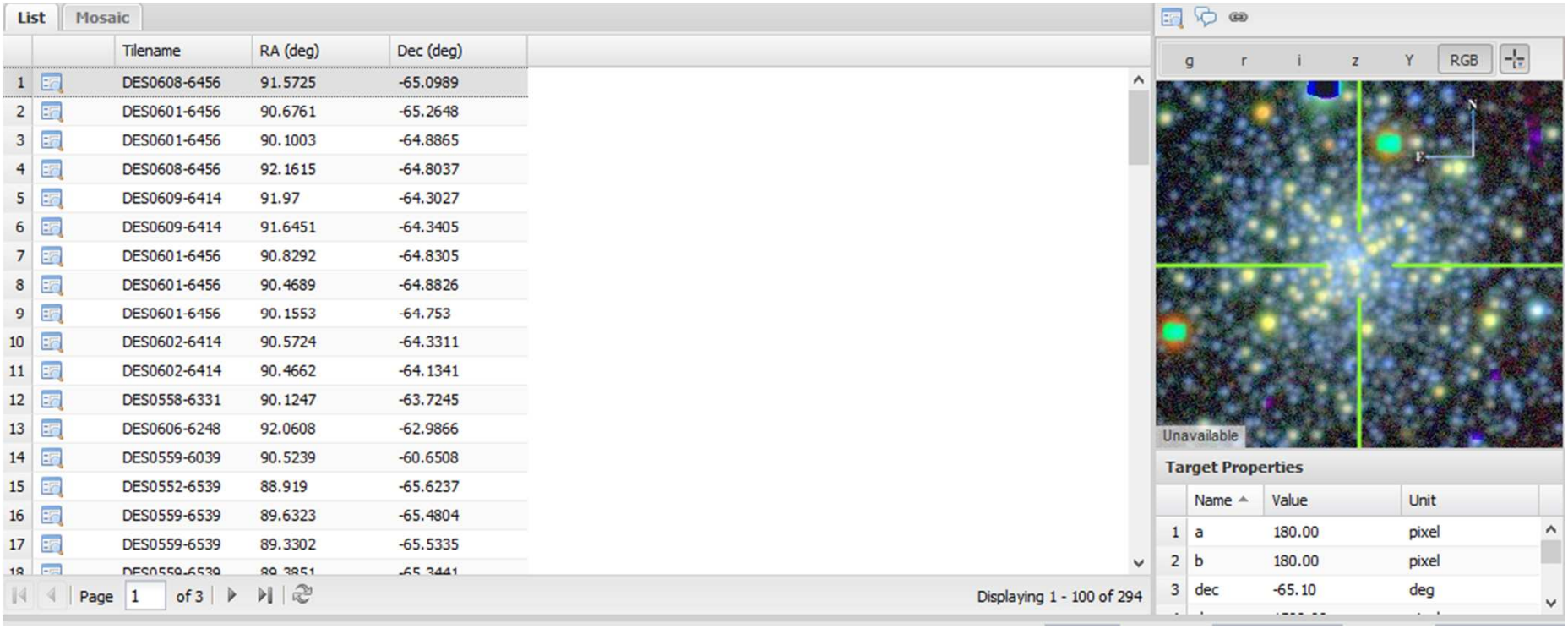


LMC Geometry



Balbinot et al

Star Cluster Catalog



A “modest” data challenge

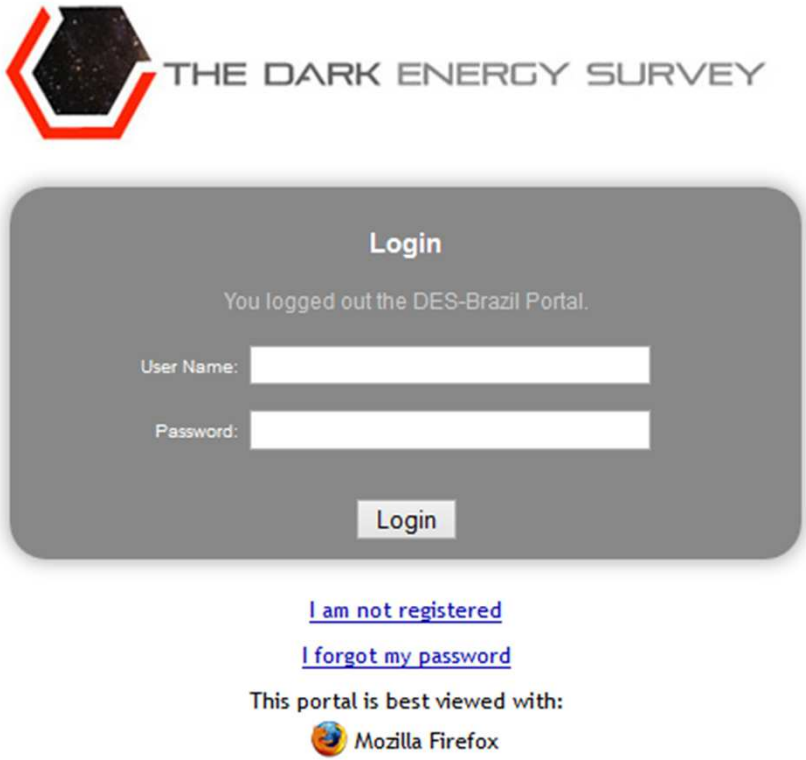
- Each image 1GB; 300–700 GB of raw data/night
  - Data must be moved from Chile to NCSA before next night begins (<18 hours), preferably in real time
  - YEAR 1: Each image transferred in <120 sec!
  - Data must be processed within <24 hours to inform next night’s observing: using NCSA resources
- TOTAL Dataset will be ~5 PB
- Considered by DOE a precursor of LSST

DES Science Portal

(1996-2005)

People ....

- get tired
- get sick
- change jobs
- make mistakes
- get bored
- .....

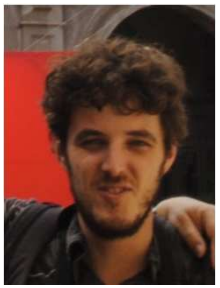


Need to have an integrated system with streamlined procedures running unsupervised

Start 2006
480 FTE-months

IT Team













Cost: US$ 800k/year

http://www.linea.gov.br/

DOU Novembro de 2010

MCTI Ministério da Ciência, Tecnologia e Inovação

Laboratório Nacional de Computação Científica

Observatório Nacional

RNP Rede Nacional de Ensino e Pesquisa
Promovendo o uso inovador de redes avançadas no Brasil

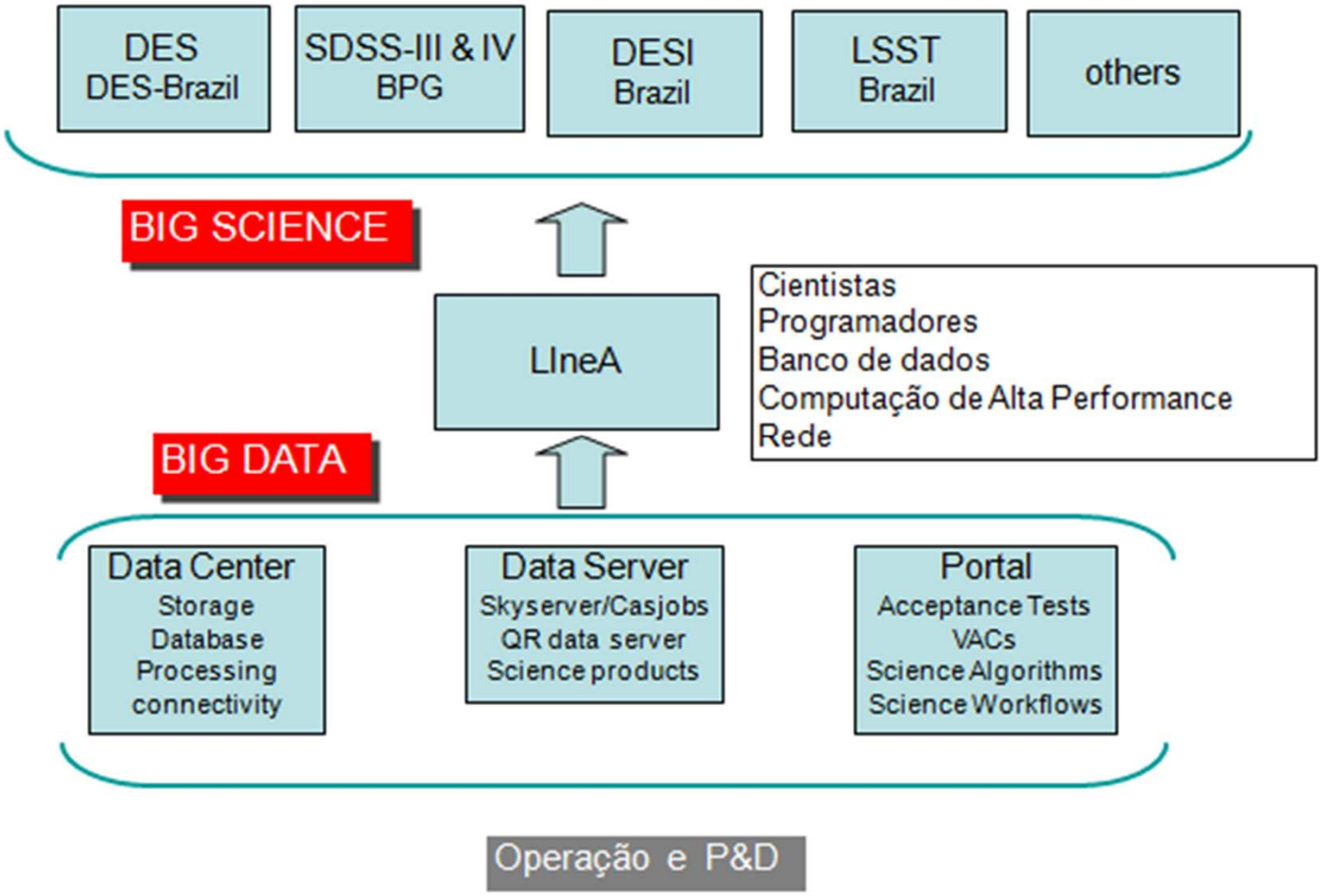
Convidado

LNA LABORATÓRIO NACIONAL DE ASTROFÍSICA

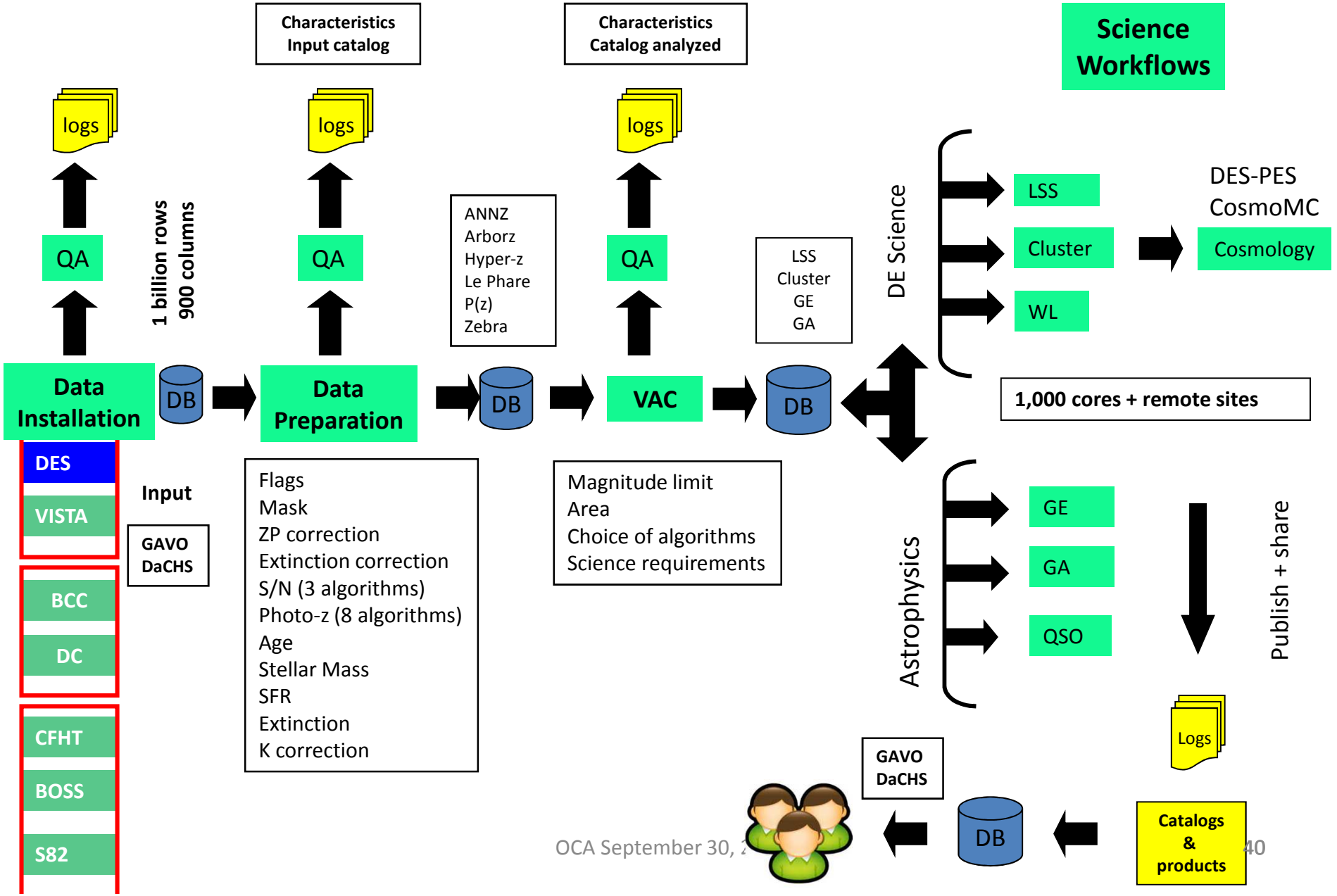
FINEP

CNPq Conselho Nacional de Desenvolvimento Científico e Tecnológico

FAPERJ


DES
DES-Brazil
SDSS-III & IV
BPG
DESI
Brazil
LSST
Brazil
others
BIG SCIENCE
LIneA
Cientistas
Programadores
Banco de dados
Computação de Alta Performance
Rede
BIG DATA
Data Center
Storage
Database
Processing
connectivity
Data Server
Skyserver/Casjobs
QR data server
Science products
Portal
Acceptance Tests
VACs
Science Algorithms
Science Workflows
Operação e P&D

Science Portal Grand View

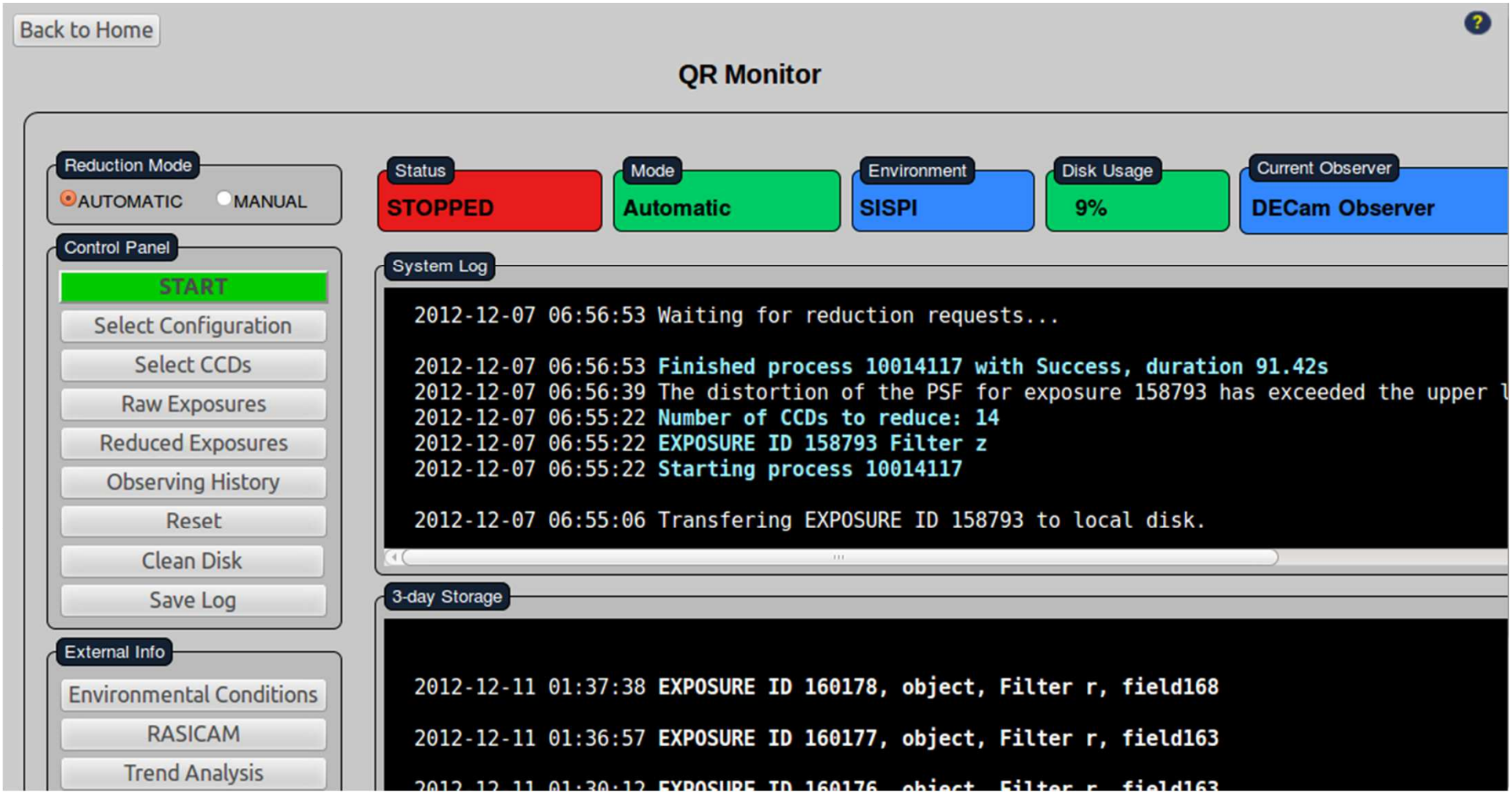


Portal Instances & operation model

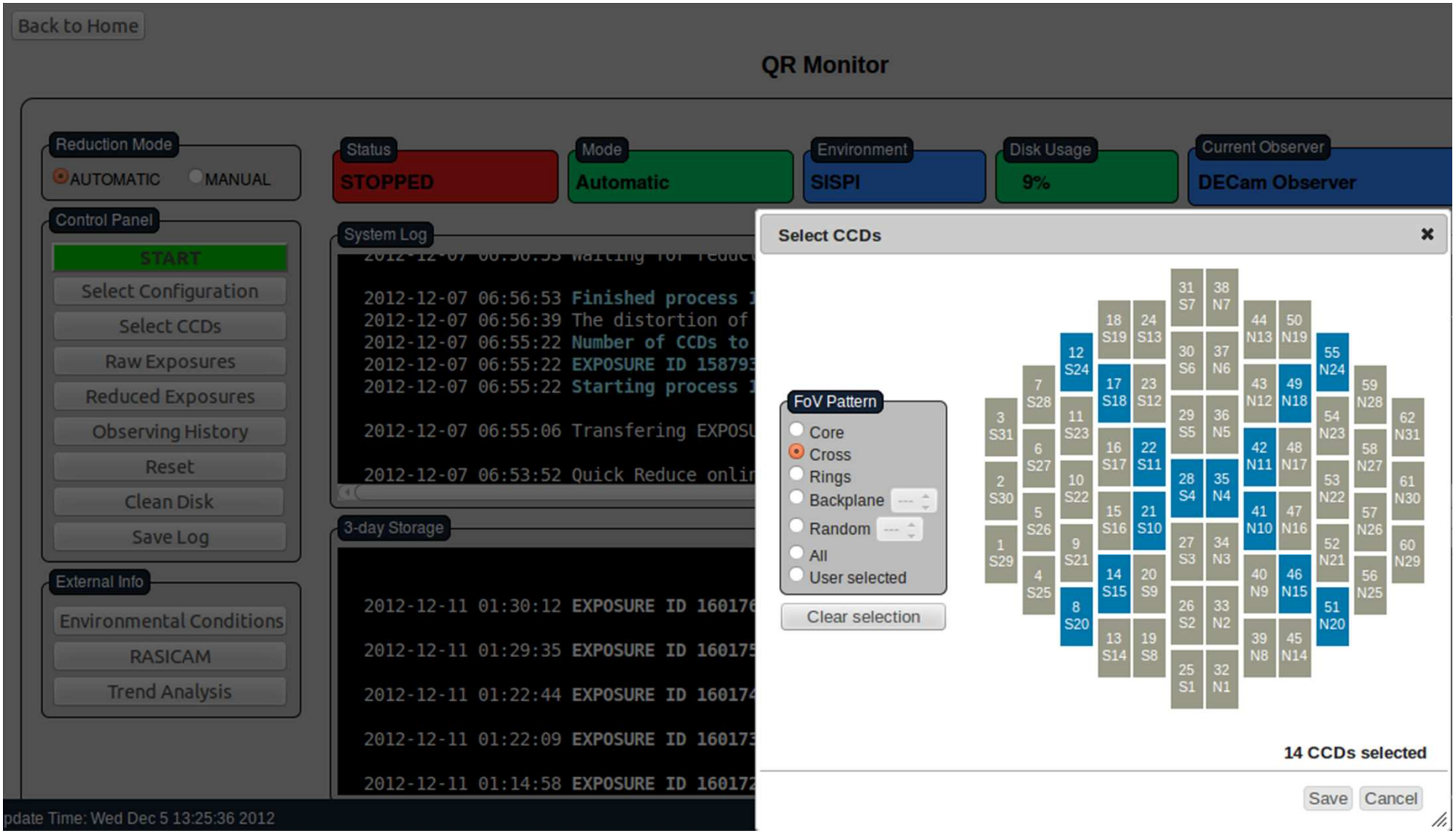
- CTIO Portal
  - Quick reduce
- DES Science Portal (LIneA, restricted access)
  - Data installation
  - Data preparation
  - Value-added catalogs
  - Science workflows
  - Other ancillary pipelines (e.g. training set maker, random catalogs)
  - Administration
- DES Data server (Fermilab)
  - Reductions (QR server, Final cut)
  - Monitoring survey progress
  - Coadds (product log, footprint, tile viewer, object viewer)
  - User queries
  - Catalog server (value-added catalogs, favorites, targets)
  - Science Workflow products

CTIO Portal: all DECam users

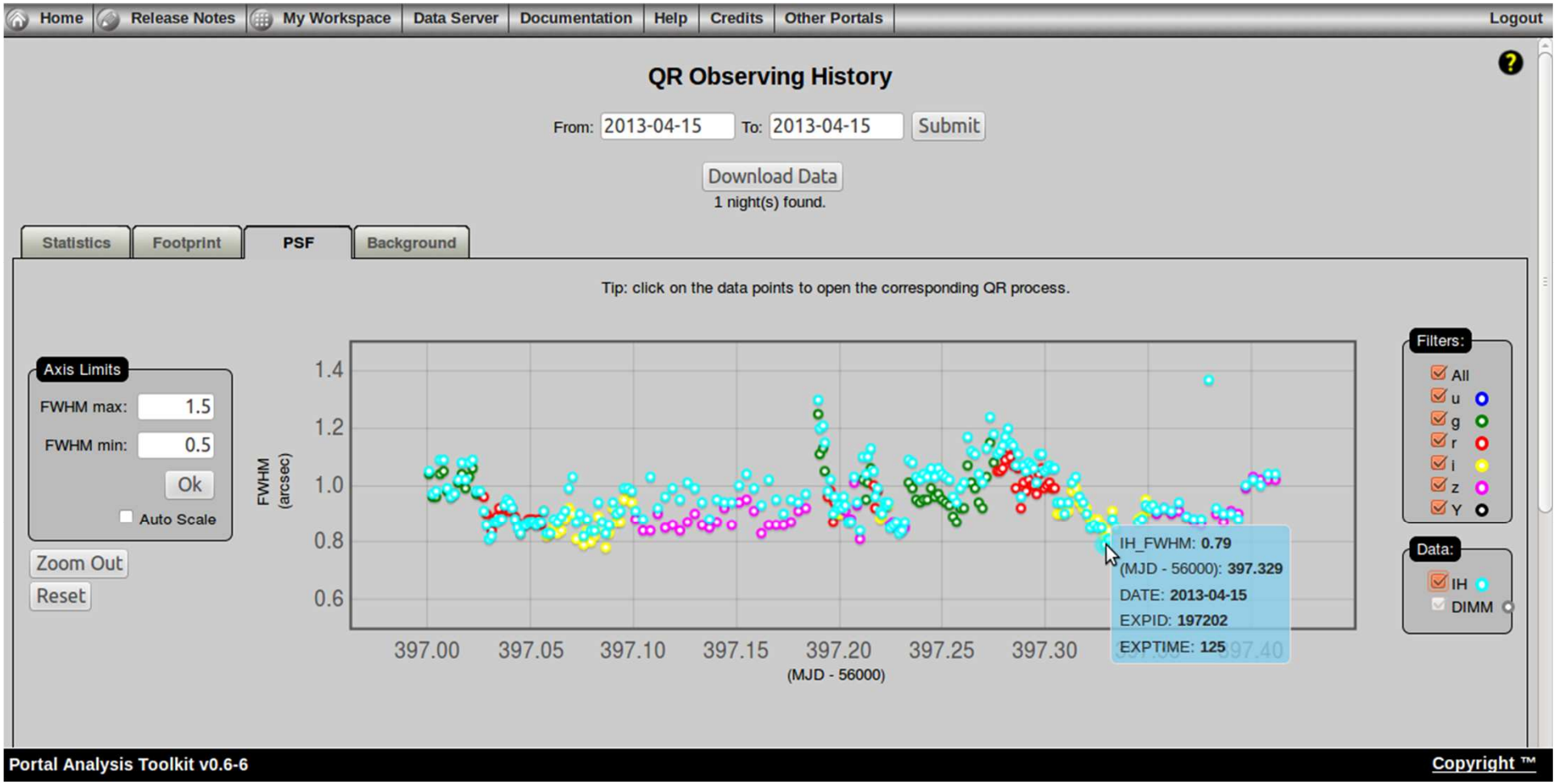
Quick Reduce



Quick Reduce

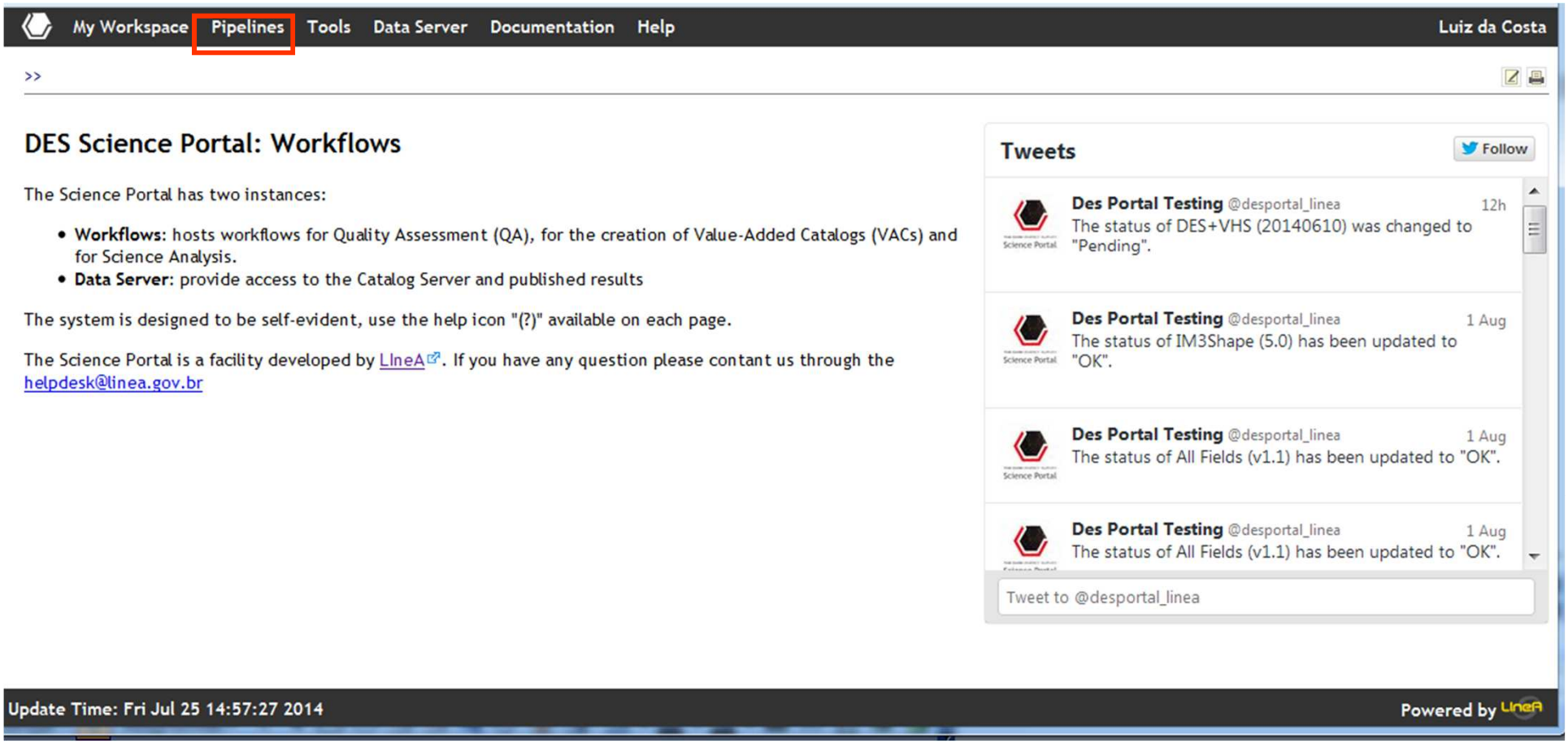


Seeing monitor

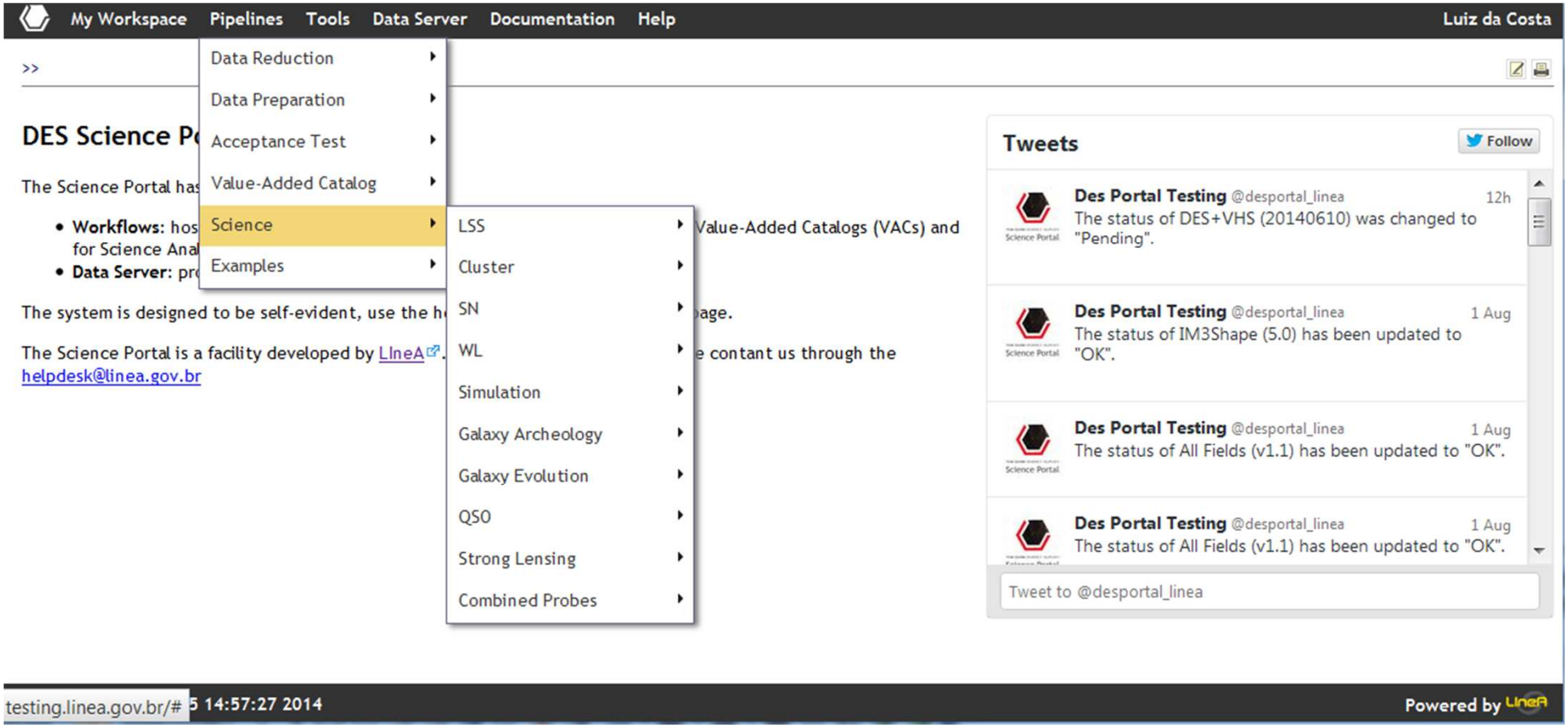


Sala de controle do Blanco

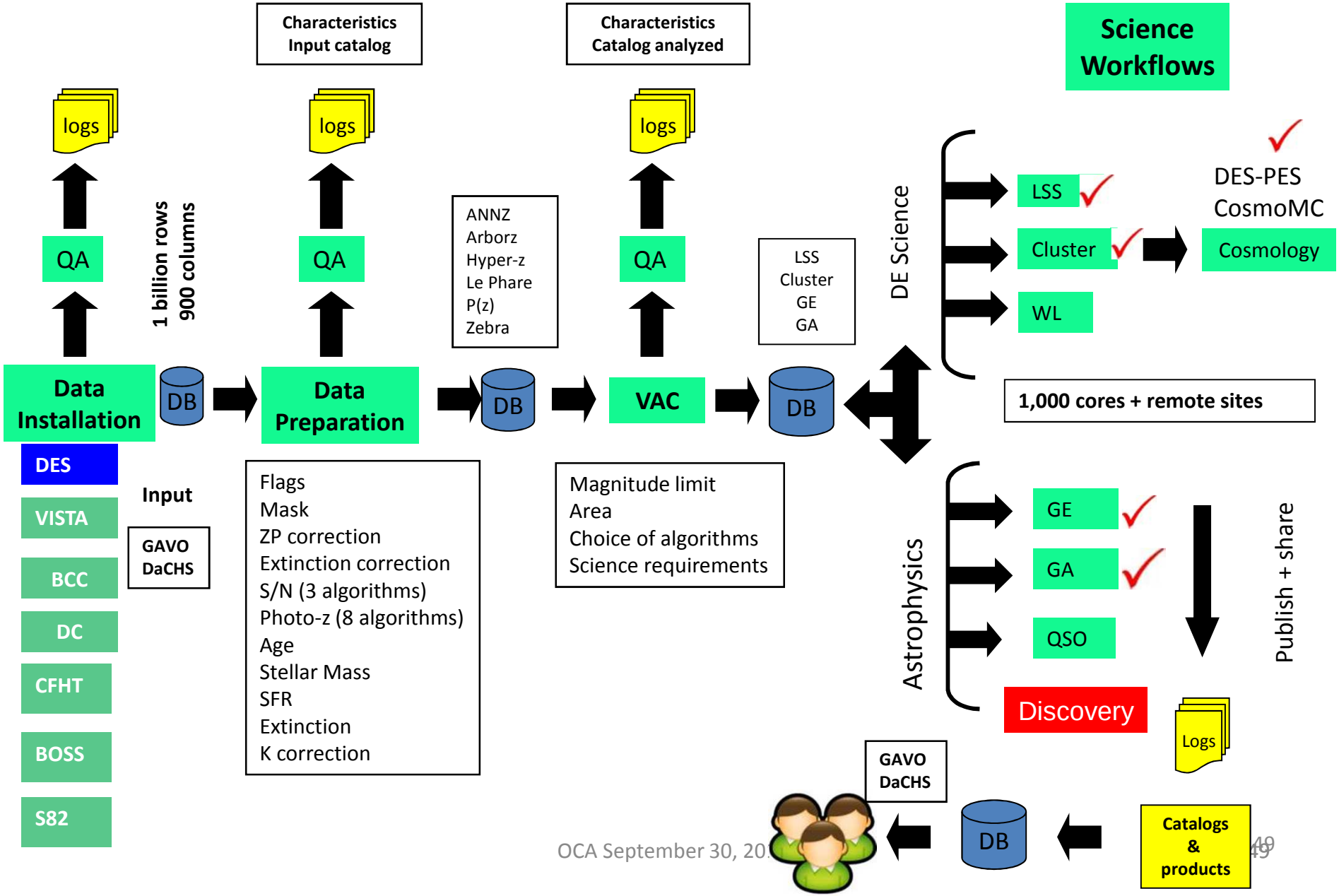
Science Portal: restricted Access



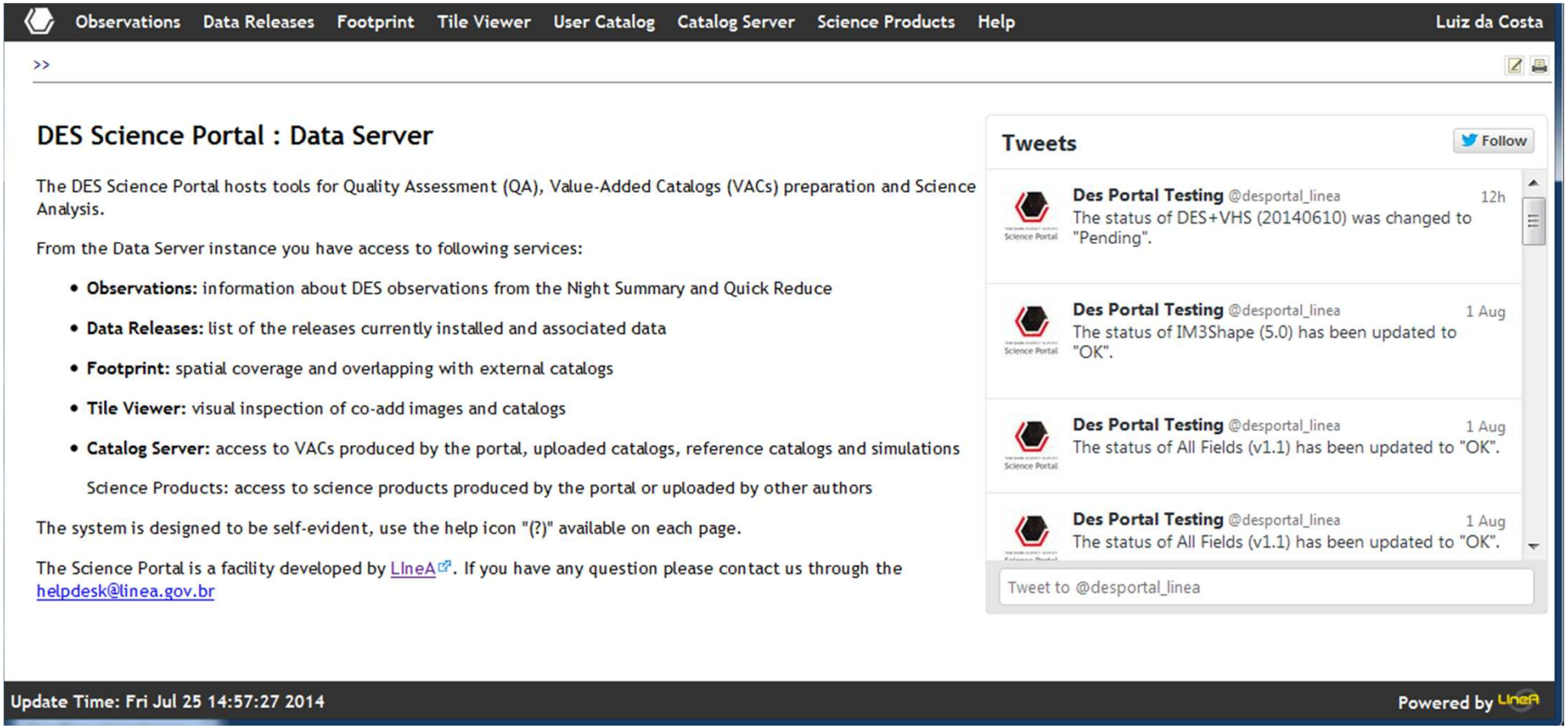
Workflows for SWG



Portal End-to-End Data Flow



Data Server: open access to the collaboration



Portal Reviews

2010 - “The system is actually much more than a Science Portal, it is a comprehensive, web-based eScience Analysis Center for the Dark Energy Survey Collaboration. It is designed to be very general, and allow the sharing of code, data, and results of analysis world-wide, in a virtual environment. We don't know that anything quite like it exists yet - it is forward-looking and ambitious.”

2011 - “The Brazil Portal concept includes a place where large-collaboration astrophysics analysis can be directed: a central place for checking in codes; compiling, linking, and running those codes; making plots and sharing them, all in a repeatable, archived fashion; and the ability to run things in parallel in larger volume. The vision of the Brazil portal is commendable and should go forward. The portfolio of tasks is large, yet the resources to undertake the work are limited.”

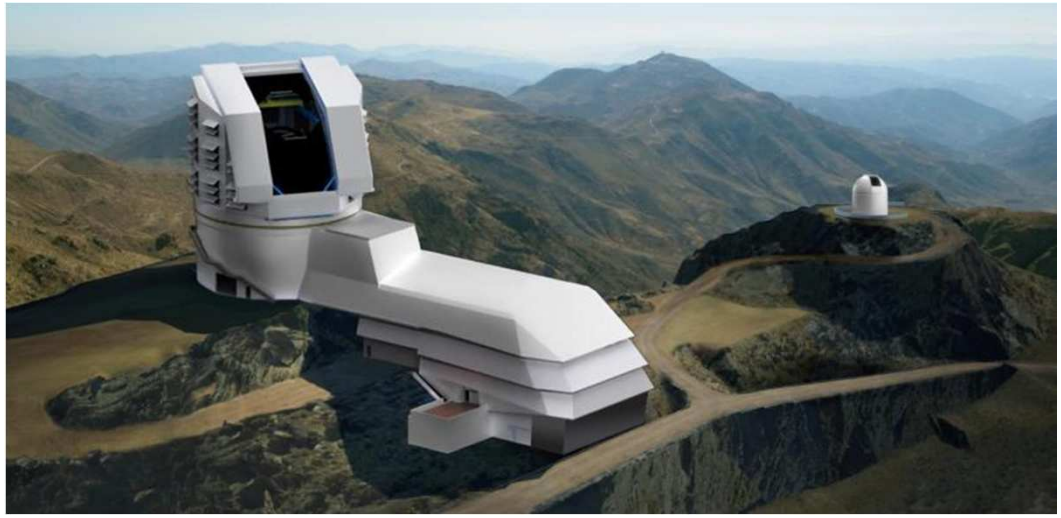
2012 – QR

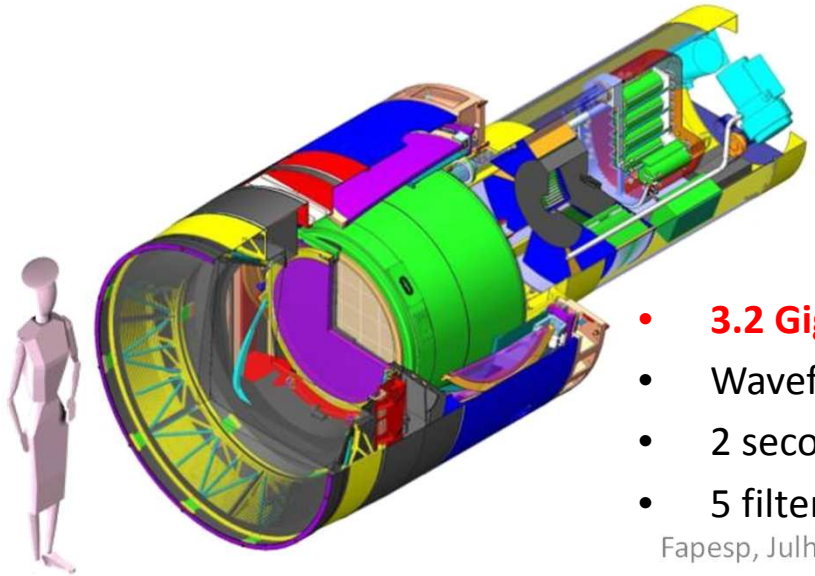
2013 – July and November

2014- Scheduled

NCSA
NOAO
NERSC
LSST
LSST@Home

LSST





1.65 m
(5'-5")

- **3.2 Gigapixel science array – 10 square degree FOV!**
- Wavefront and guide sensors
- 2 second readout
- 5 filters in camera

The LSST Science Book

- Contents:
  - Introduction
  - LSST System Design
  - System Performance
  - Education and Public Outreach
  - The Solar System
  - Stellar Populations
  - Milky Way and Local Volume Structure
  - The Transient and Variable Universe
  - Galaxies
  - Active Galactic Nuclei
  - Supernovae
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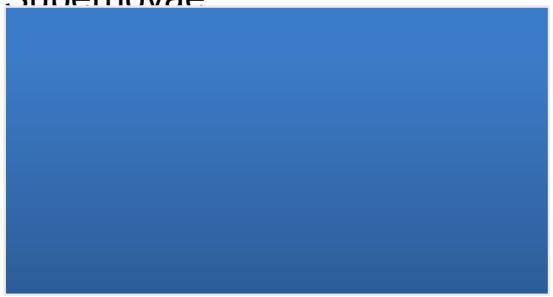

Dark Energy

Project & Science Collaboration

Summary of High Level Requirements

Survey Property	Performance
Main Survey Area	18000 sq. deg.
Total visits per sky patch	825
Filter set	6 filters (ugrizy) from 320 to 1050nm
Single visit	2 x 15 second exposures
Single Visit Limiting Magnitude	u = 23.5; g = 24.8; r = 24.4; I = 23.9; z = 23.3; y = 22.1
Photometric calibration	2% absolute, 0.5% repeatability & colors
Median delivered image quality	~ 0.7 arcsec. FWHM
Transient processing latency	60 sec after last visit exposure
Data release	Full reprocessing of survey data annually

Petascale Data Management

- Each image roughly 6.5GB
- Cadence: ~1 image every 15s
- 15 to 18 TB per night, 30TB “reduced”!
  - ALL must be transferred to NCSA archive center
    - within image timescale (17s), >>10 Gbps
- REAL TIME reduction, analysis, & alerts
  - Send out alerts of transient sources within 60s
    - ~2 million events per night every night for 10 years
  - Provide automatic data quality evaluation, alert to problems
  - Change survey observing strategy on the fly based on conditions, last field visited, etc.

LSST:
"Data Science" in real time

TRANSIENT SCIENCE (Data Stream)

- >3 Terabytes per hour (reduced) that must be mined in real time for alerts.
- 20 billion objects will be monitored for important variations in real time.
- ~2 million events per night every night for 10 years

New approaches must be developed for knowledge extraction in real time

NON-TRANSIENT SCIENCE

- $>10^{10}$ objects in a 20 PB final database catalog, backed by a 100 PB final image archive

New approaches to data mining needed to sift through data to identify samples, or individual objects, of interest

Summary

- DES has just started Y2
- Data meeting requirements
- Science already being produced with SV data
- Portal useful tool to explore the large volume of data in a reproducible way and capture and retain the know-how for the lifetime of the project
- Agreement with LSST being worked out
- DES path finder to LSST