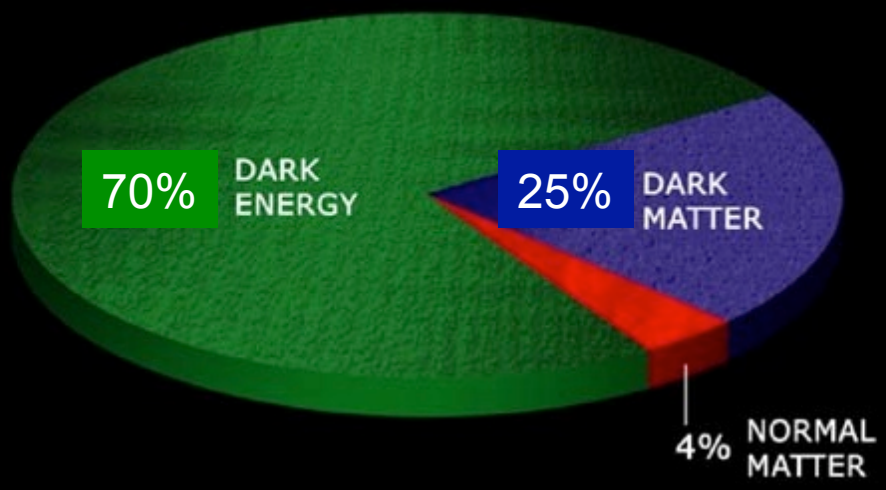
Dark Energy Survey Update

Josh Frieman
Fermilab and the University of Chicago
Dark Energy Survey Director

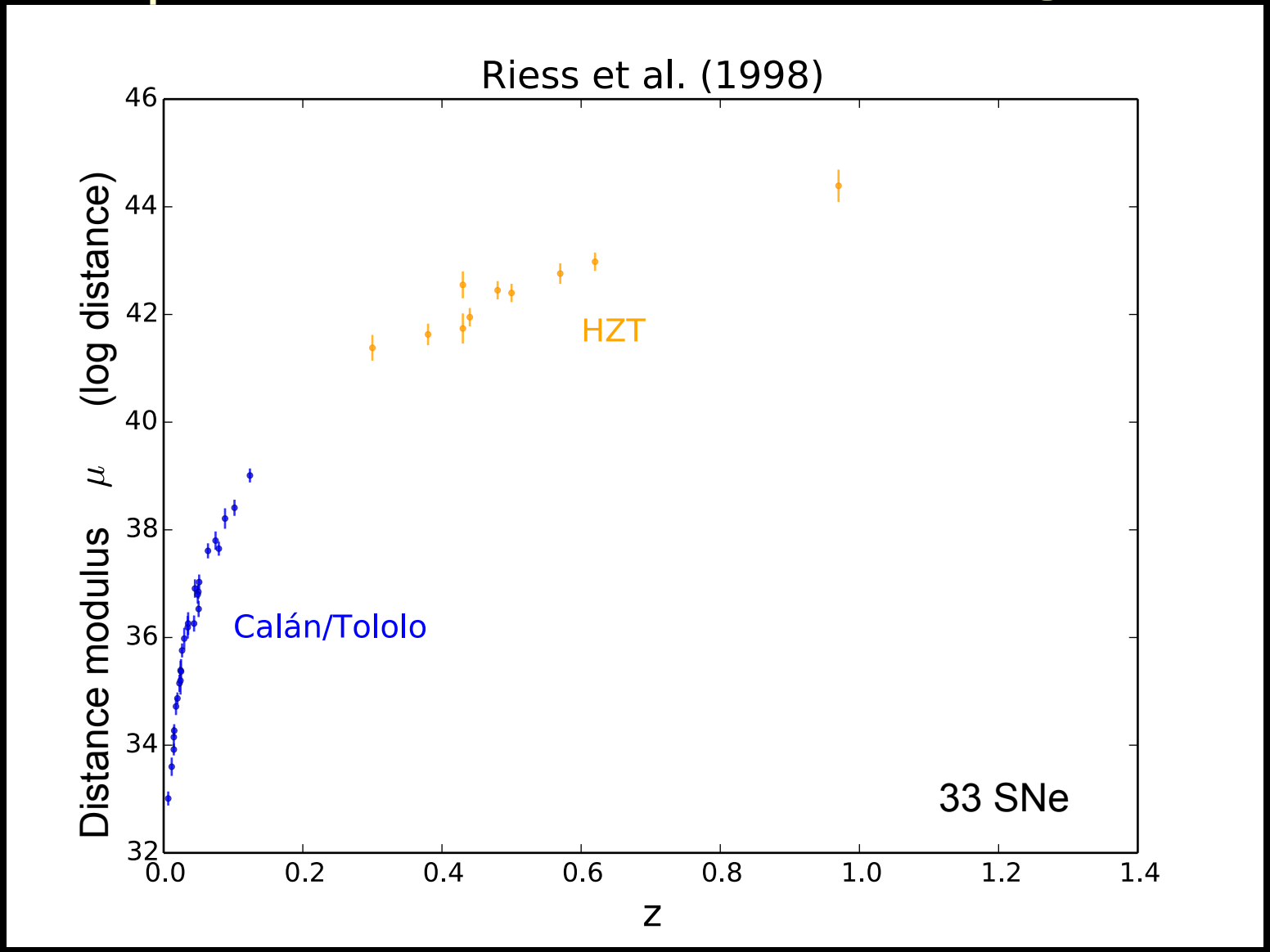
Fermilab PAC Meeting
January 23, 2014

From Discovery to Physics

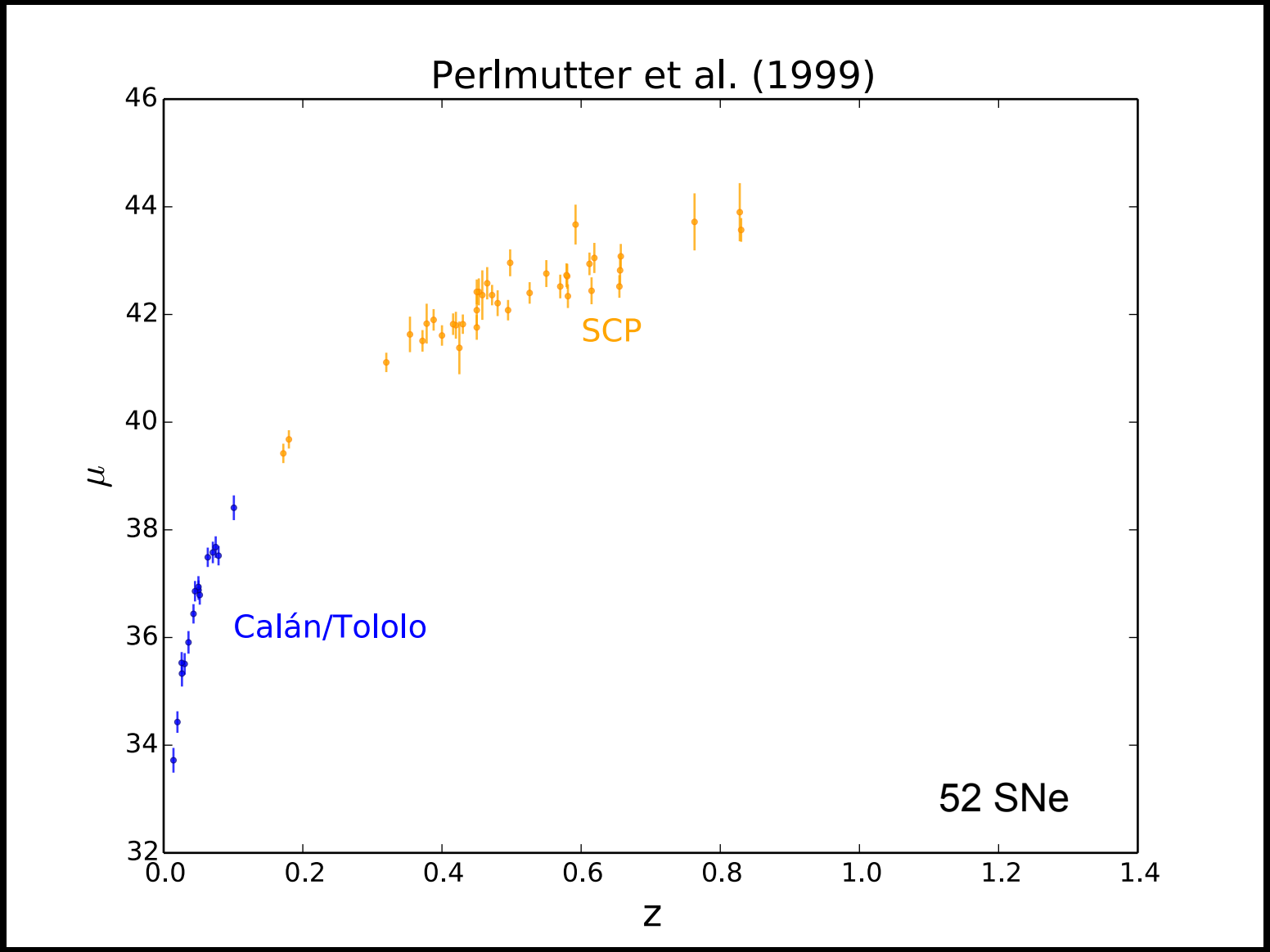
- What is the physical cause of cosmic acceleration?
  - Dark Energy or modification of General Relativity?
    - If Dark Energy, is it Λ (the vacuum) or something else?
      - What is the DE equation of state parameter *w* and (how) does it evolve?

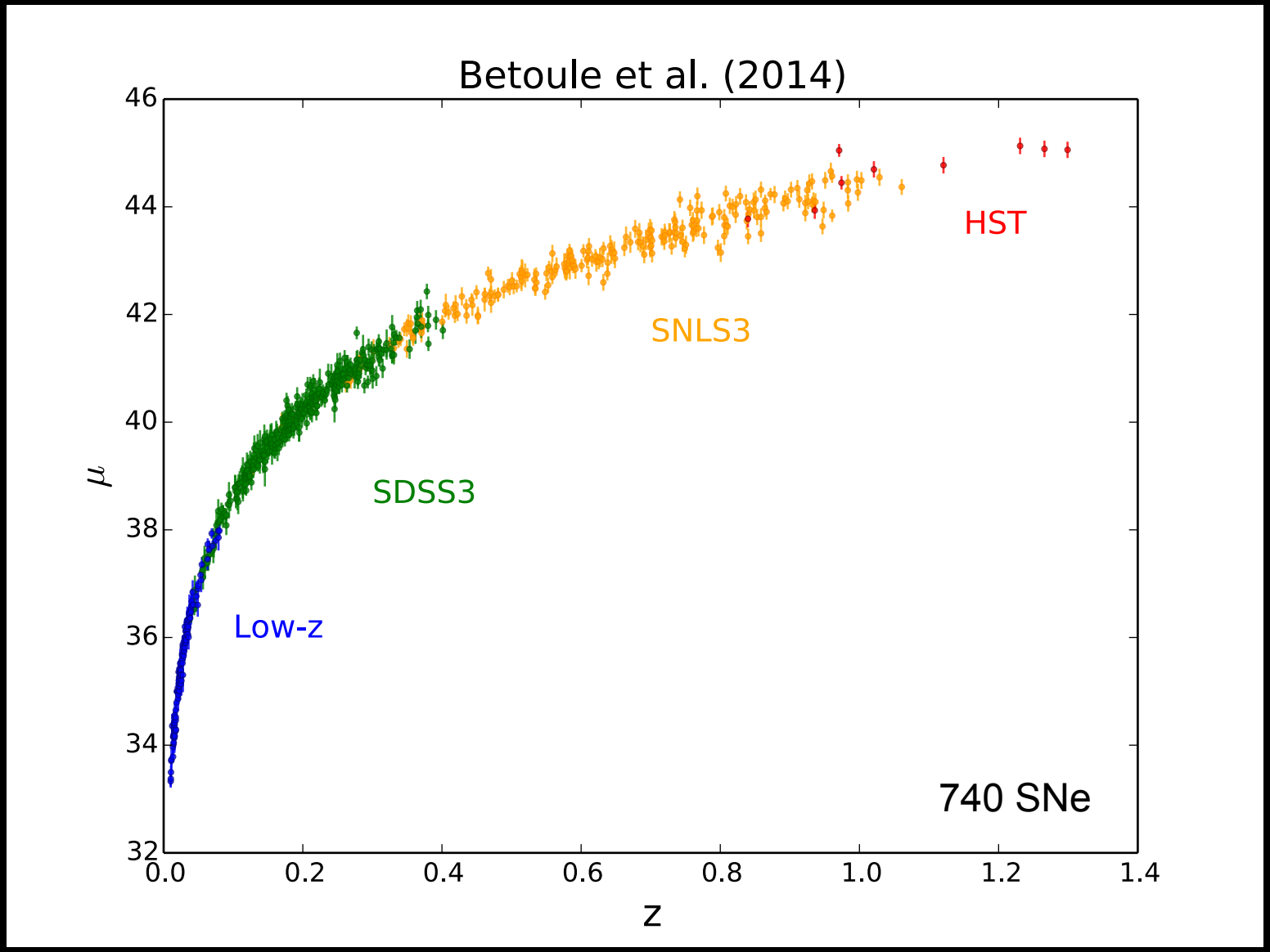


Supernova Ia Hubble Diagram

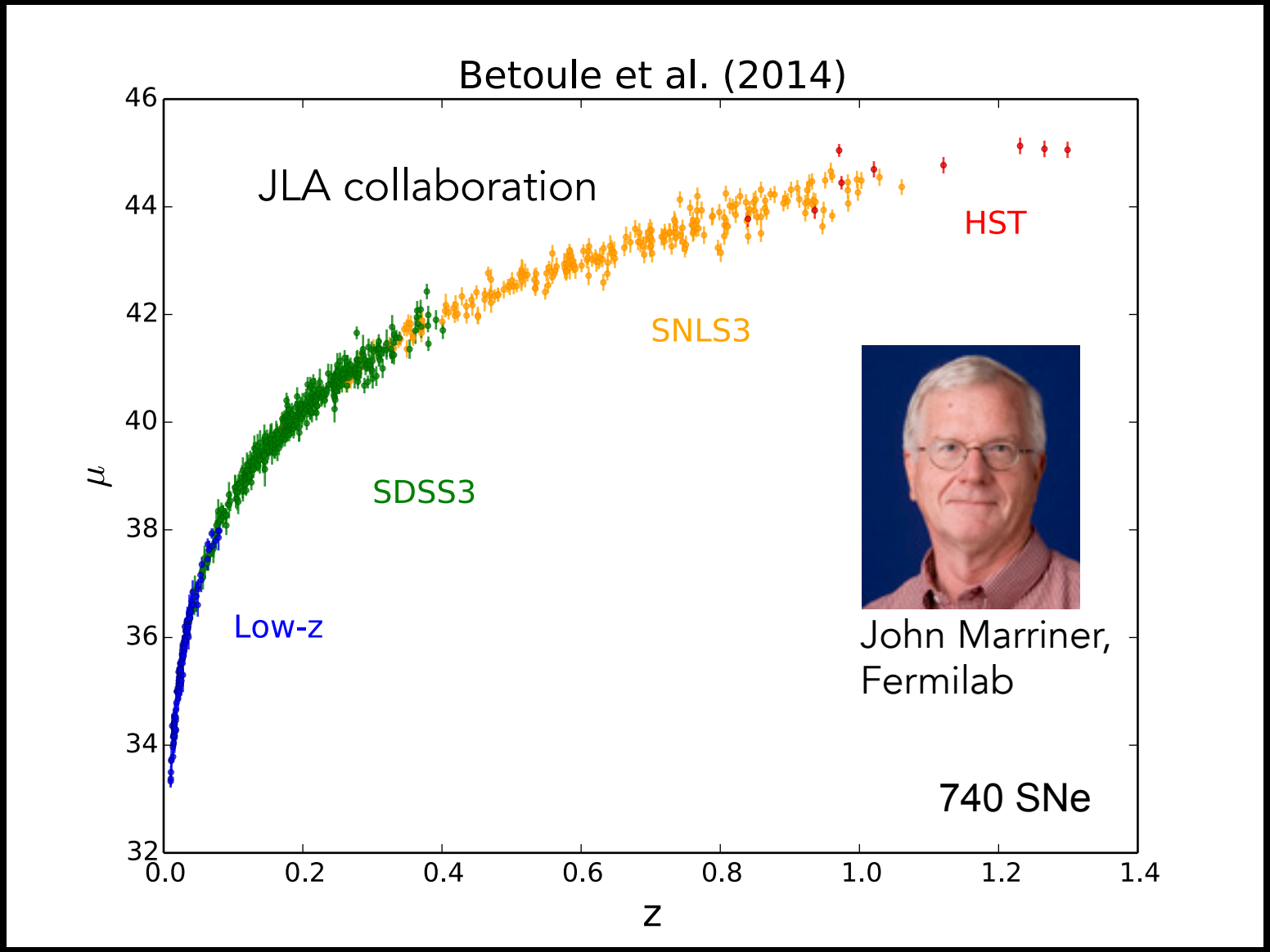


SN figures by A. Conley


Perlmutter et al. (1999)
46
44
42
40
38
36
34
32
μ
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
z
SCP
Calán/Tololo
52 SNe



arXiv:1401.4064



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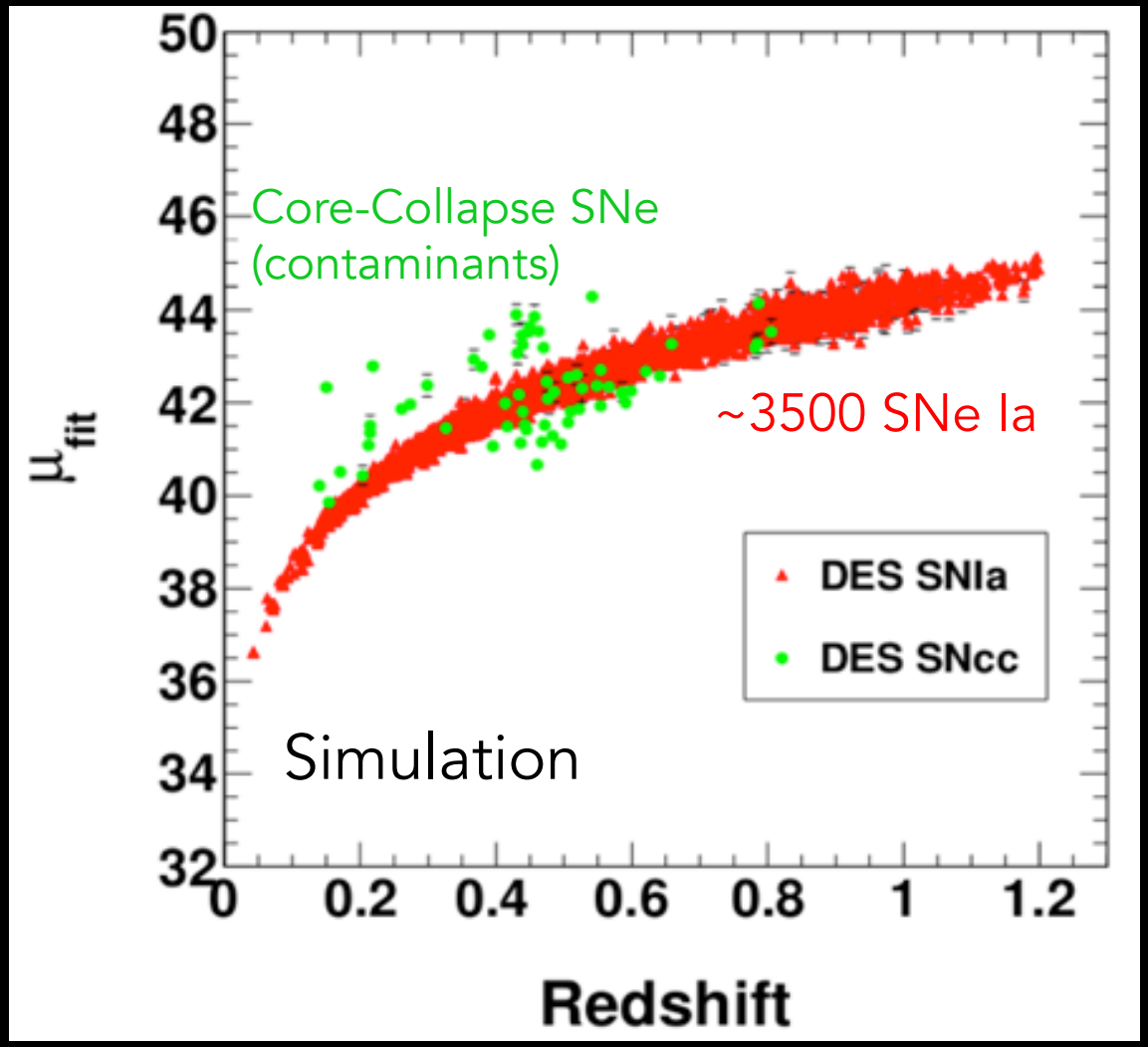
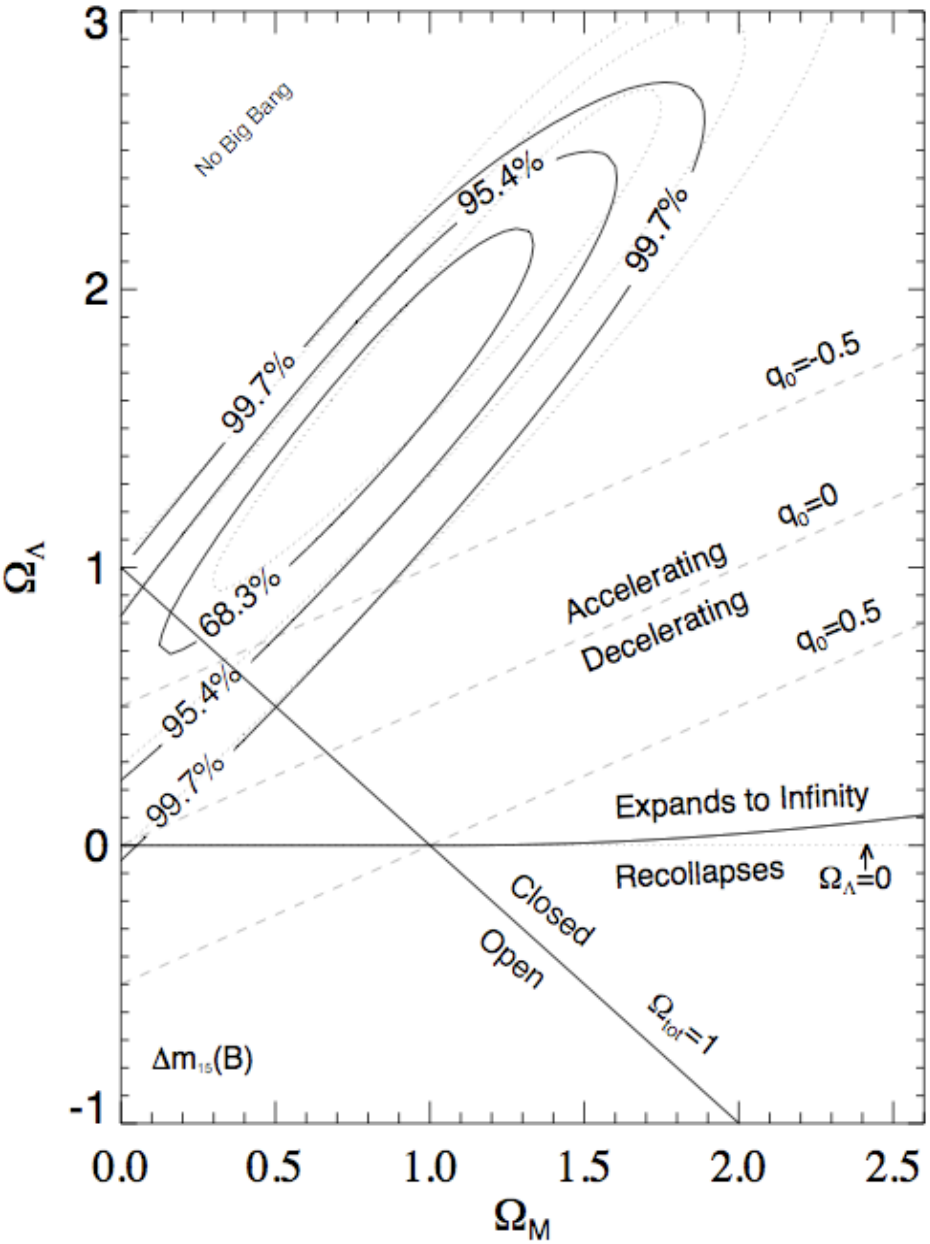
DES SN Hubble Diagram ~2018



Bernstein, etal 2012

Riess et al. (1998, AJ)



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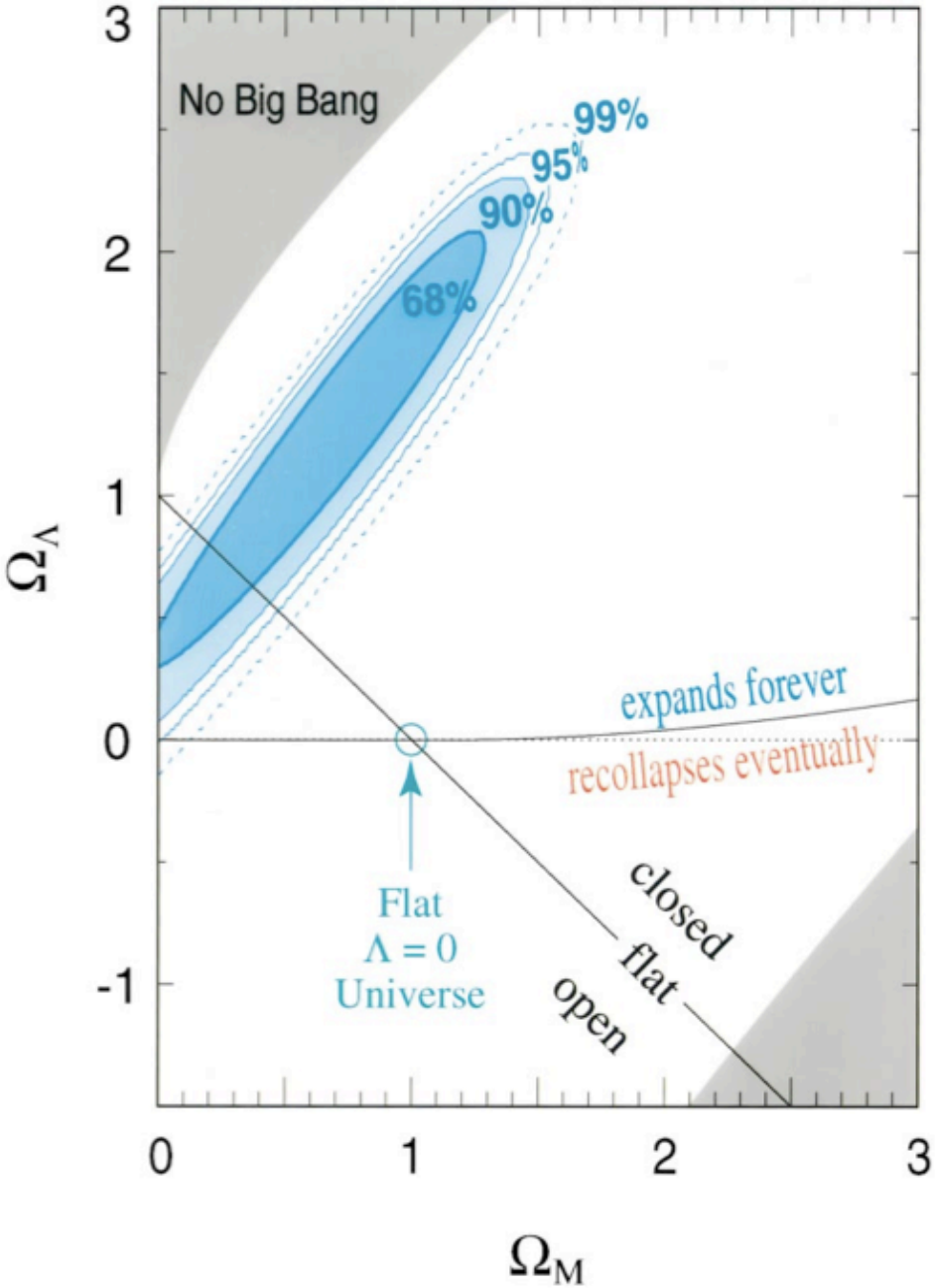
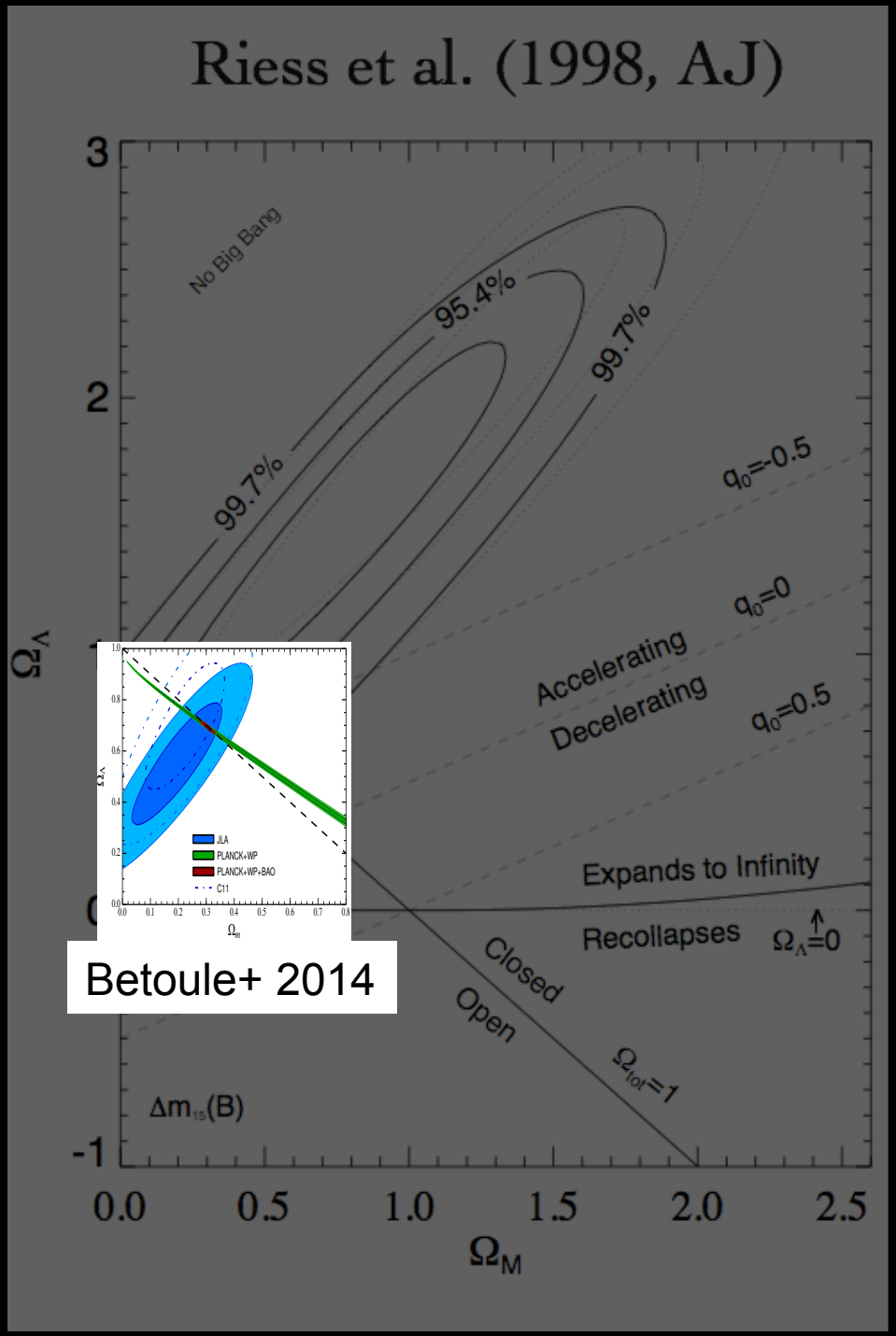


Progress over the last 15 years



Supernovae

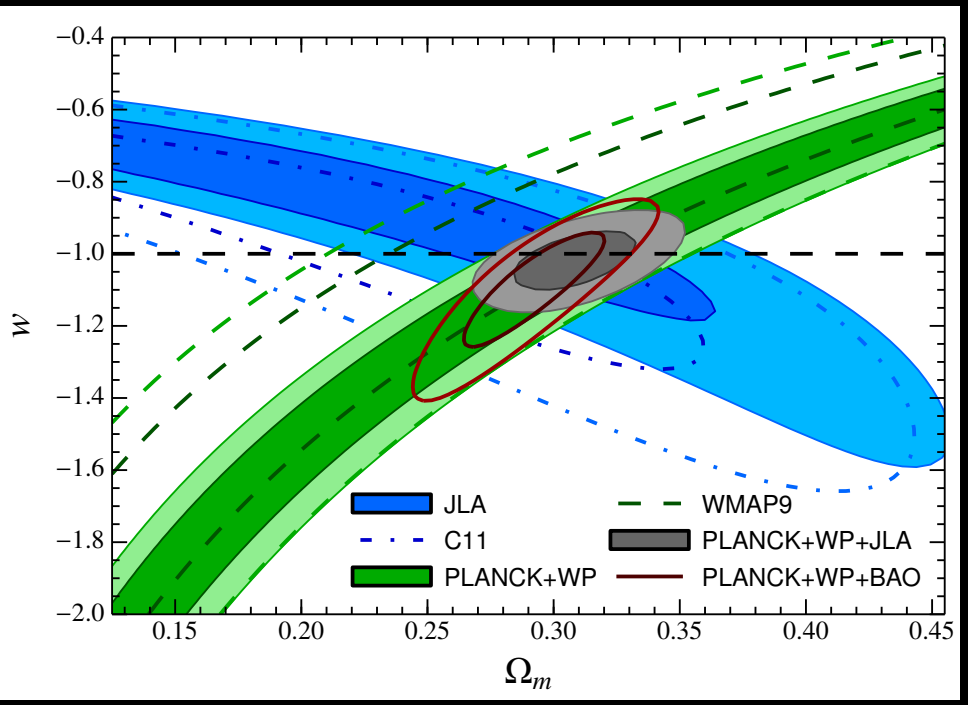
Cosmic Microwave Background (Planck, WMAP)

CMB+BAO

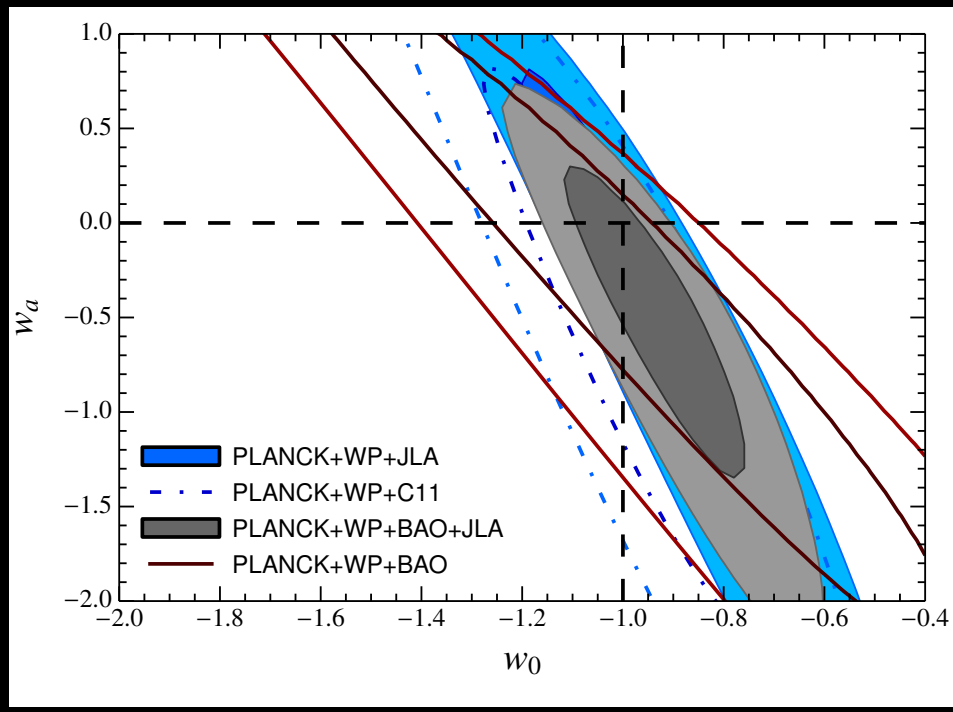
Here assuming $w=-1$

Current Dark Energy Constraints from Supernovae, CMB, and Large-scale Structure

Assuming constant w



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

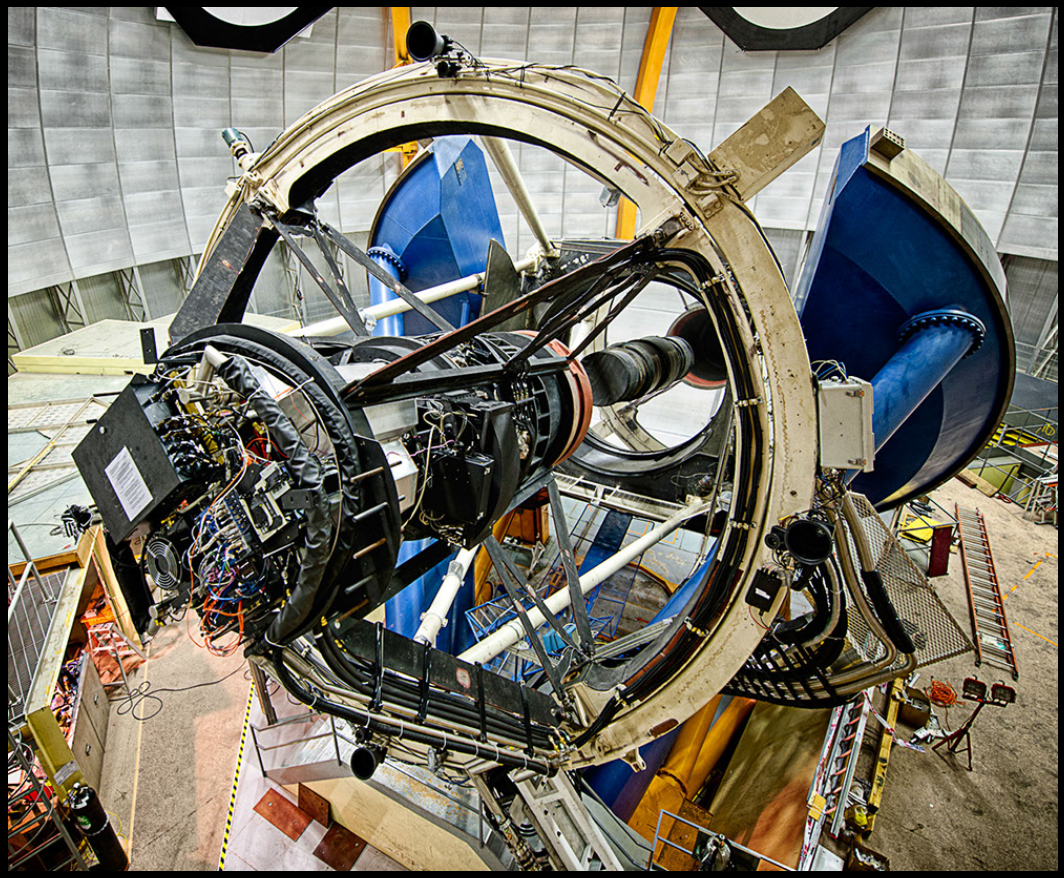


Betoule etal 2014

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

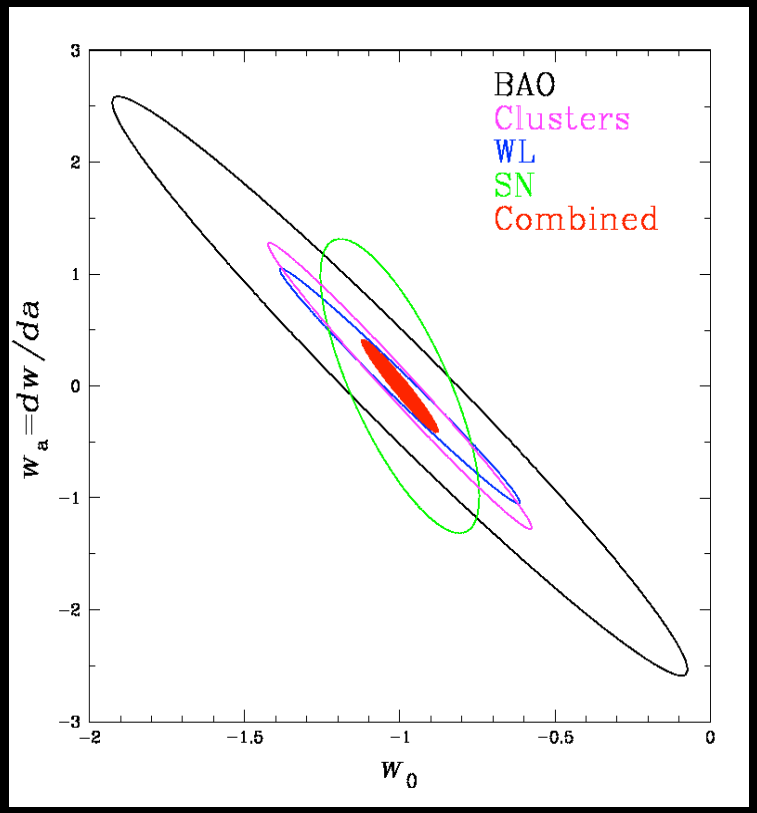
DES Science Summary

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

$$w(a) = w_0 + w_a(1 - a(t)/a_0)$$



DES forecast

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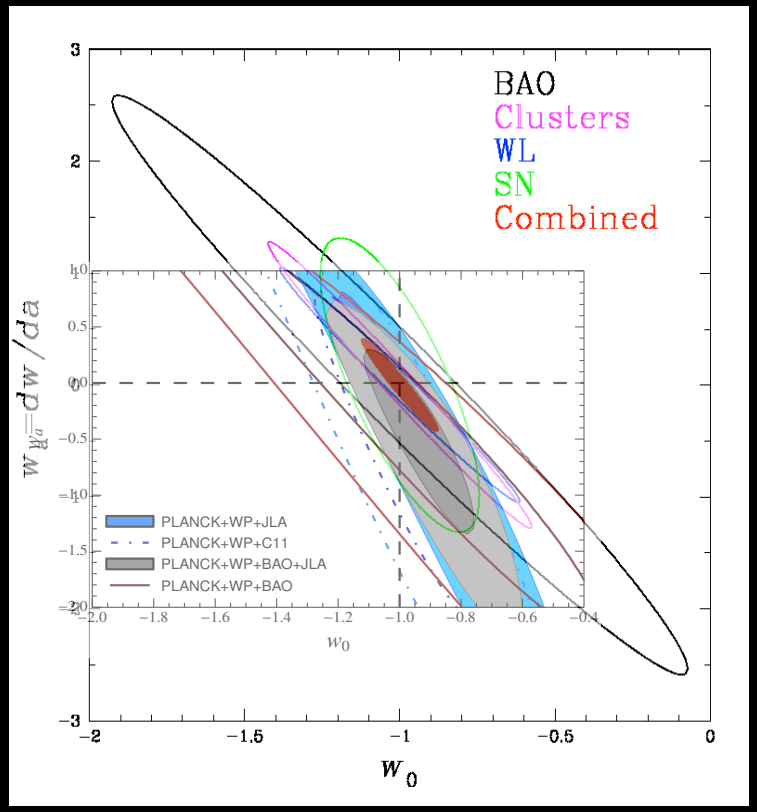
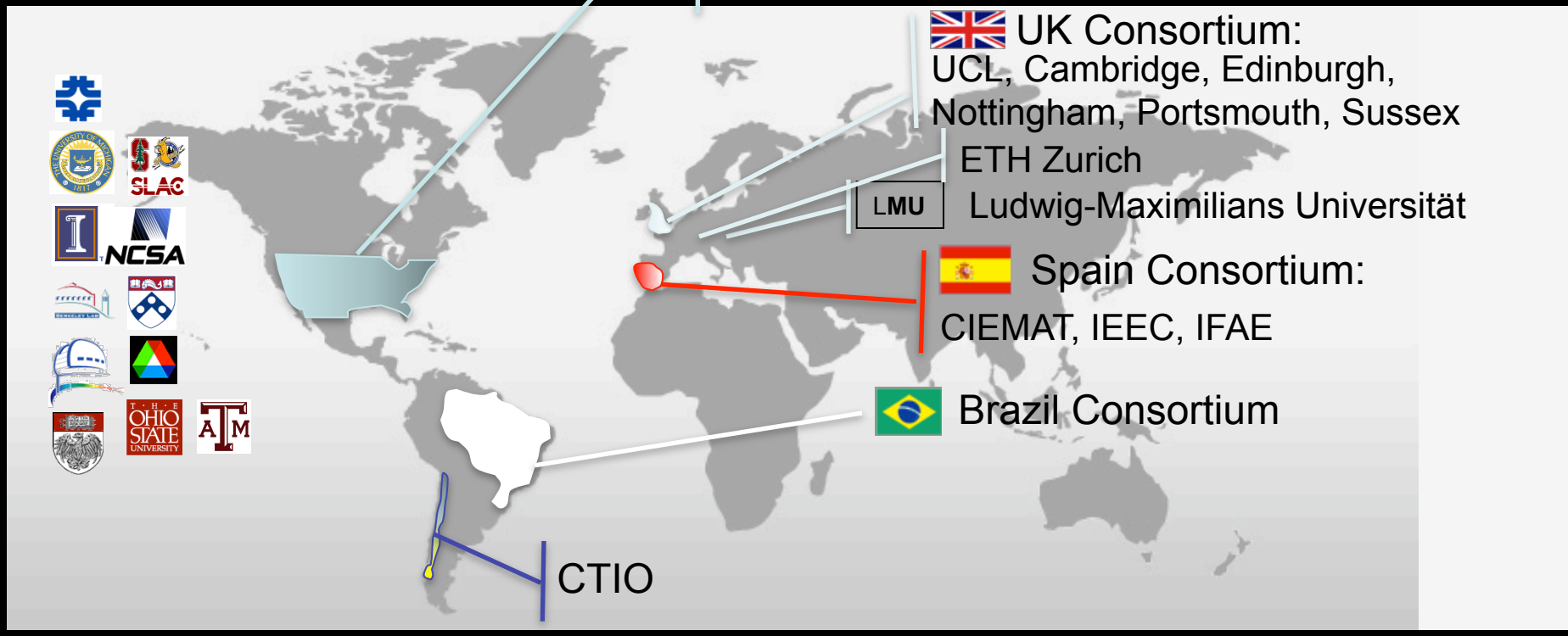


DES forecast

Dark Energy Survey Collaboration

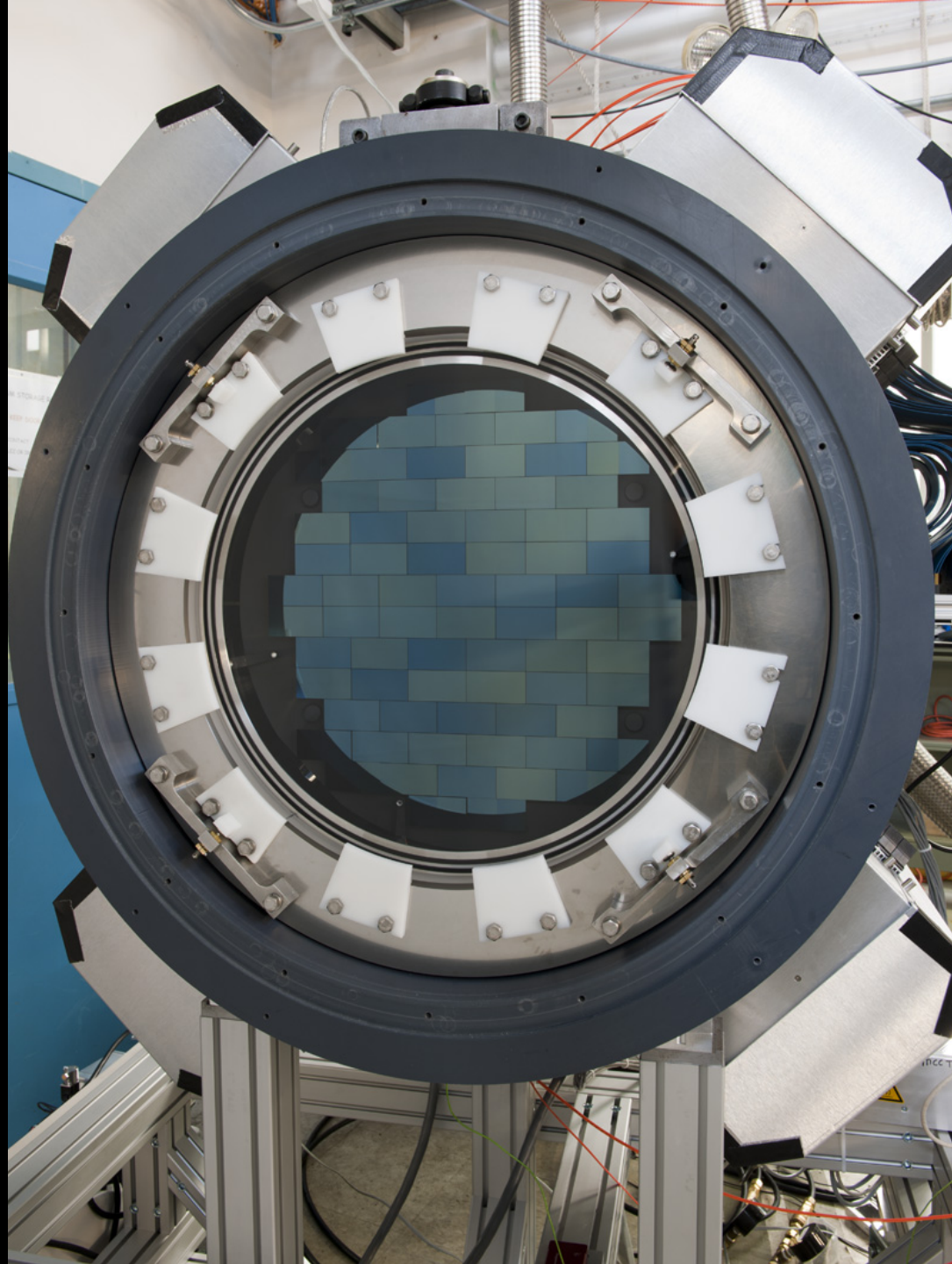
~300 scientists from around the world

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



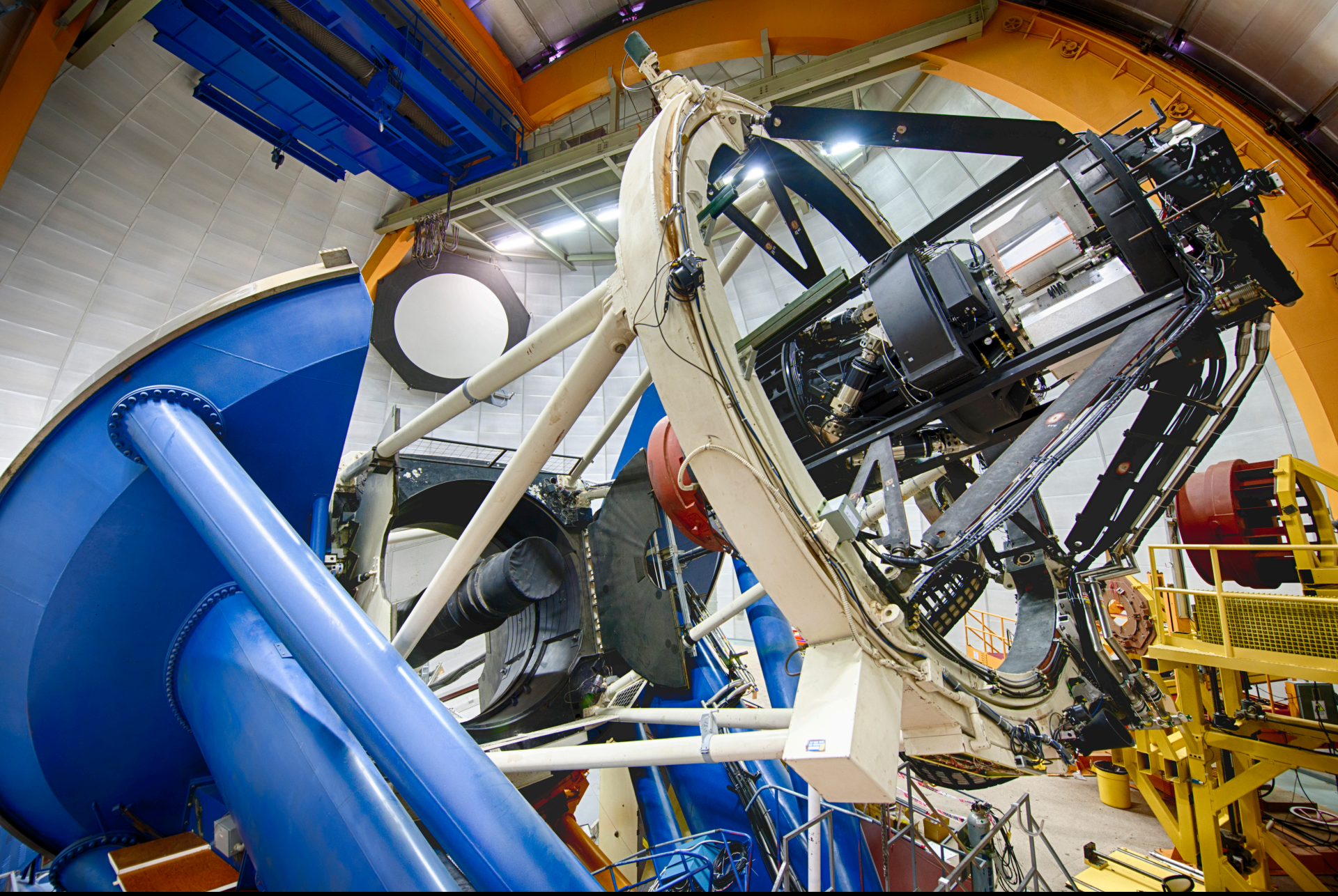
570-Million pixel
Dark Energy Camera

installed on the
Blanco Sept. 2012



DARK ENERGY SURVEY

Biggest Lens
(out of 5 lenses)



Dark Energy Camera on the Blanco Telescope

Early Image taken with the Dark Energy Camera

Image: E. Sheldon

DES Timeline

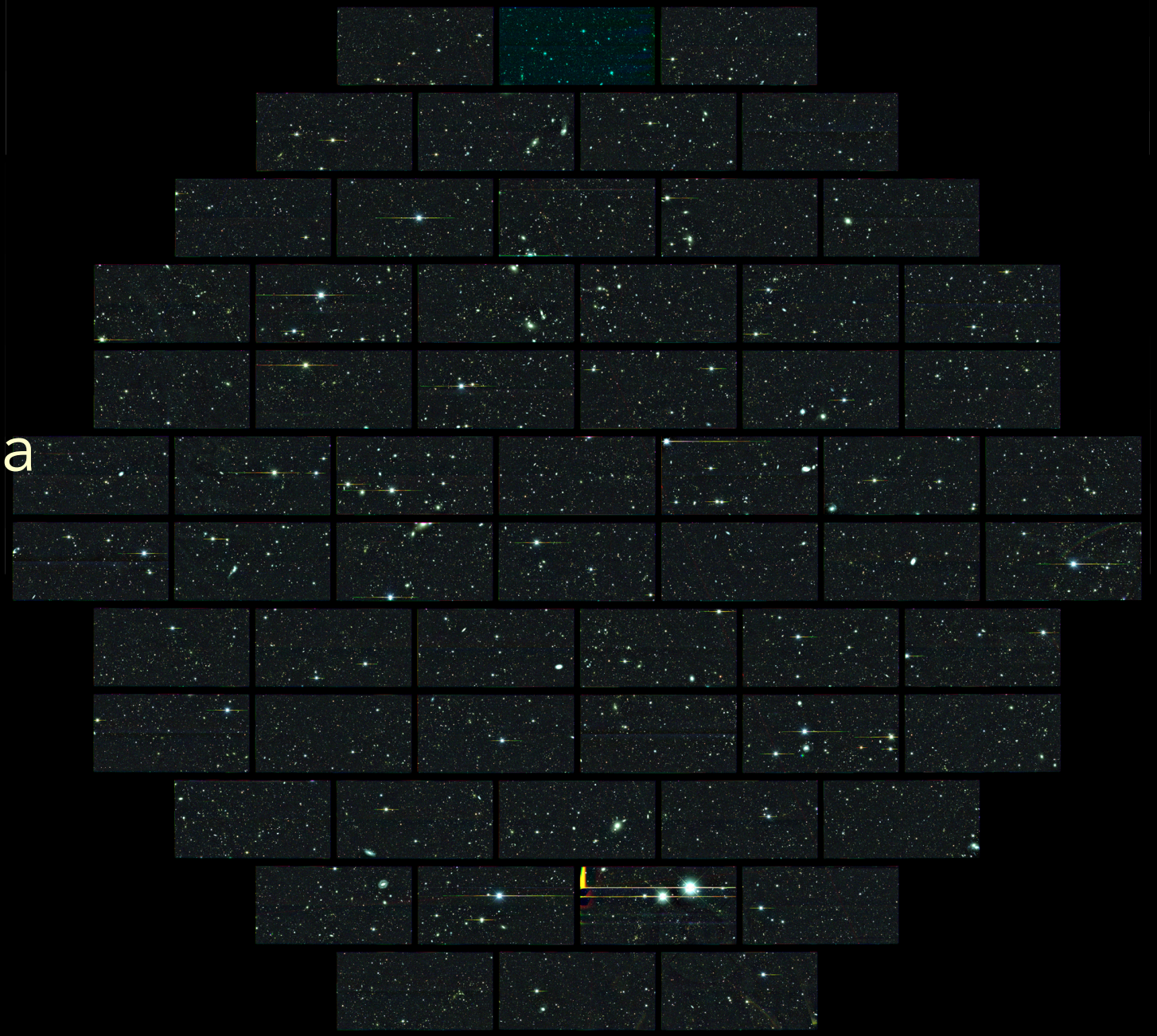
- Project start 2003
- R&D 2004-8
- DECam Construction 2008-11, led by FNAL
- Installation 2012
- First Light Sept. 2012
- Commissioning Sept-Oct. 2012
- Science Verification (SV) Sept. 2012-Feb. 2013
- First Season (Year 1) Aug. 31, ’13-Feb. 9, ’14
- Planning on 5 105-night seasons

Recent Progress (2013-14)

- April: DOE-NSF pre-Operations Review
  - "The DECam is working well and almost all performance goals and specifications were met during commissioning."
  - "DES team has a viable plan for beginning the survey in September 2013"
- June: DES awarded 100.5 nights by NOAO in 2013B (4.5 for 2014A)
- August: Data Management $835K NSF supplement funded to NCSA
- August: Acceptance of DECam System by NOAO Director
  - Condition for award of 525 nights for DES
- Aug. 31: Start of DES Survey Operations (Year 1)
- Sept.: DESDM Release of SV-A1 Data Products to collaboration
  - ~300 sq. deg., 40 million catalog objects, 1-3% photometry, basis for early science papers
- Early Oct.: DES collaboration meeting near Barcelona
- Jan: release of value-added SV-A1 Gold catalog to collaboration
- Jan: DES Special Session at AAS
- Feb: planned release of preliminary partial Year 1 data products by DESDM
- Mar: DES-LSST Workshop at Fermilab

DARK ENERGY SURVEY

DES SV image of a deep SN field



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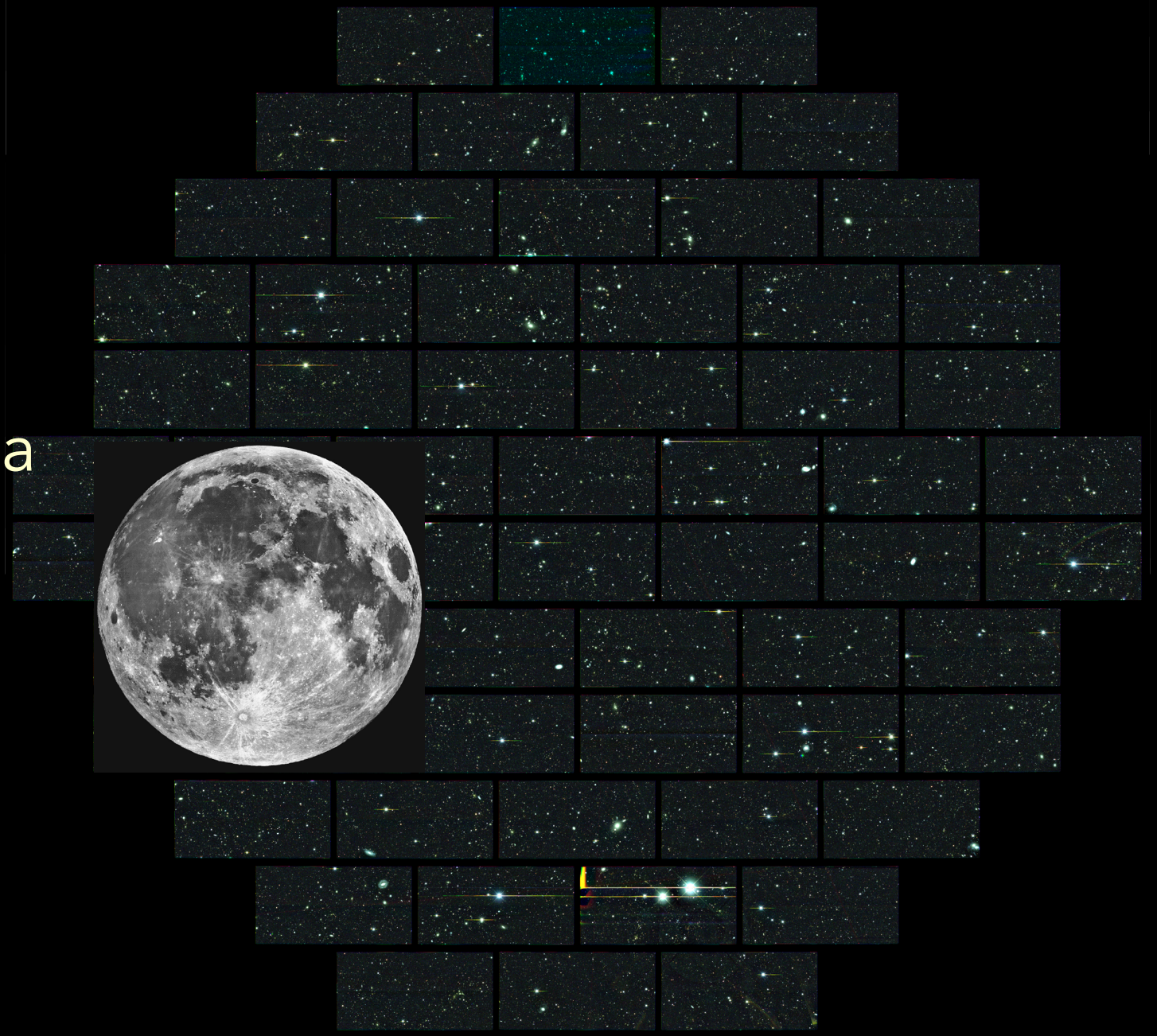
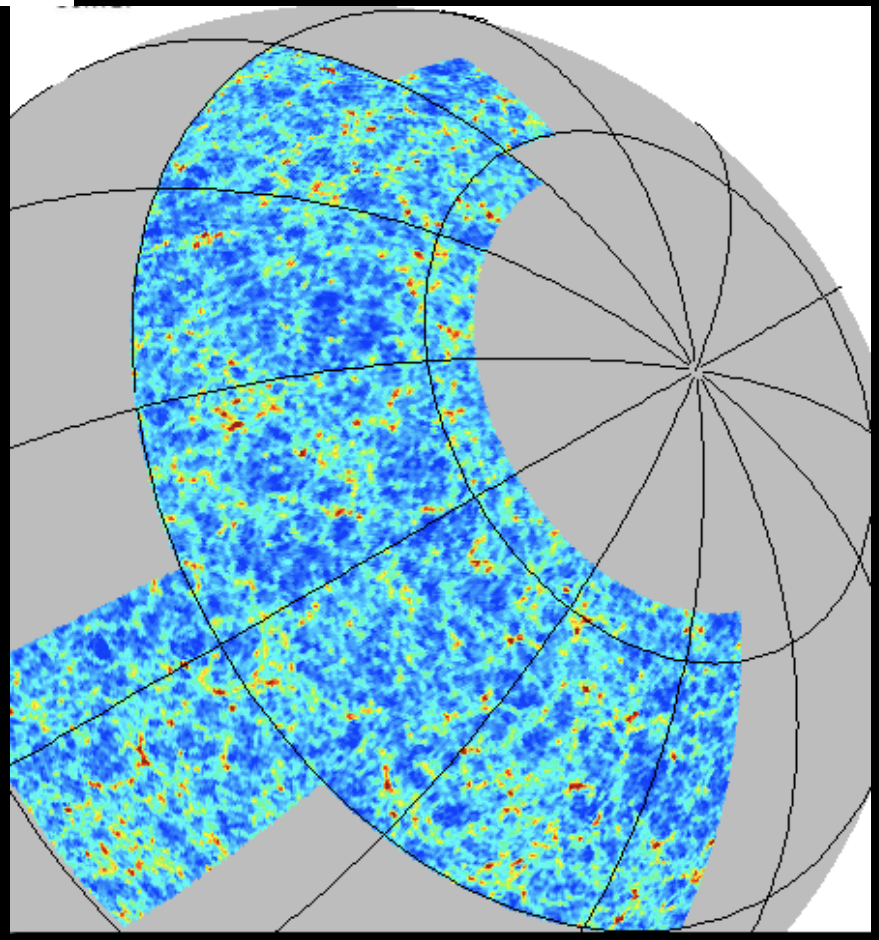


Synergy with South Pole Telescope

DES footprint: 5000 sq deg



DES survey area encompasses SPT Sunyaev-Zel'dovich Cluster Survey

Synergy with South Pole Telescope

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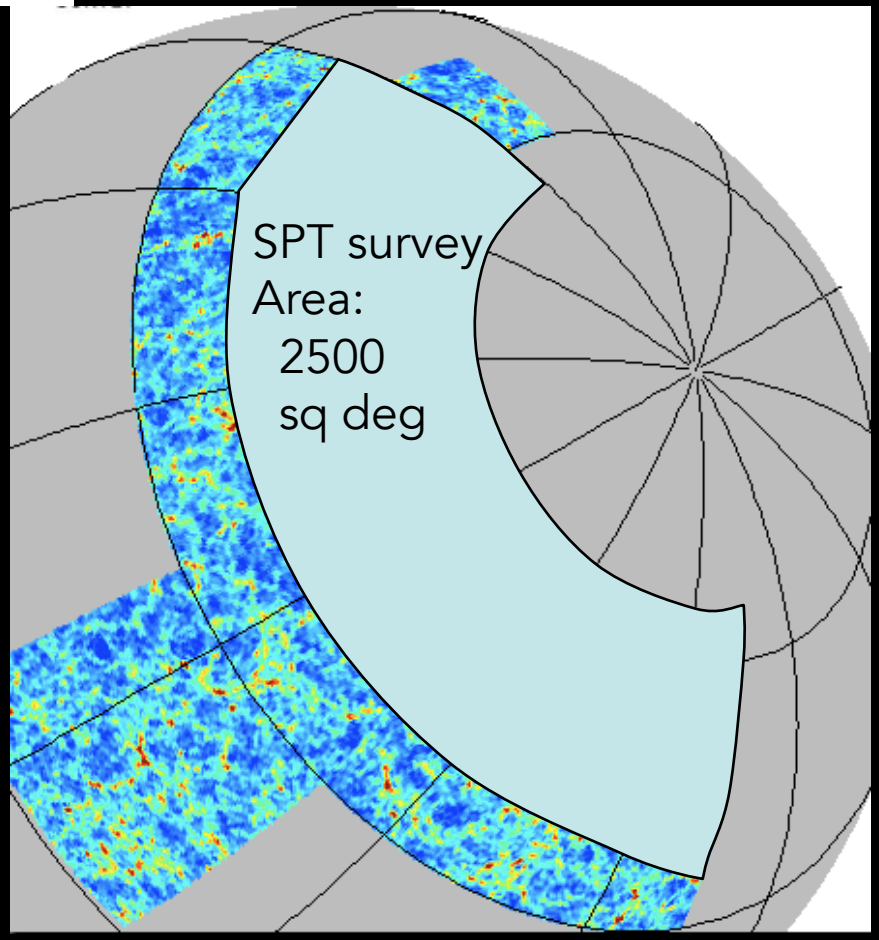
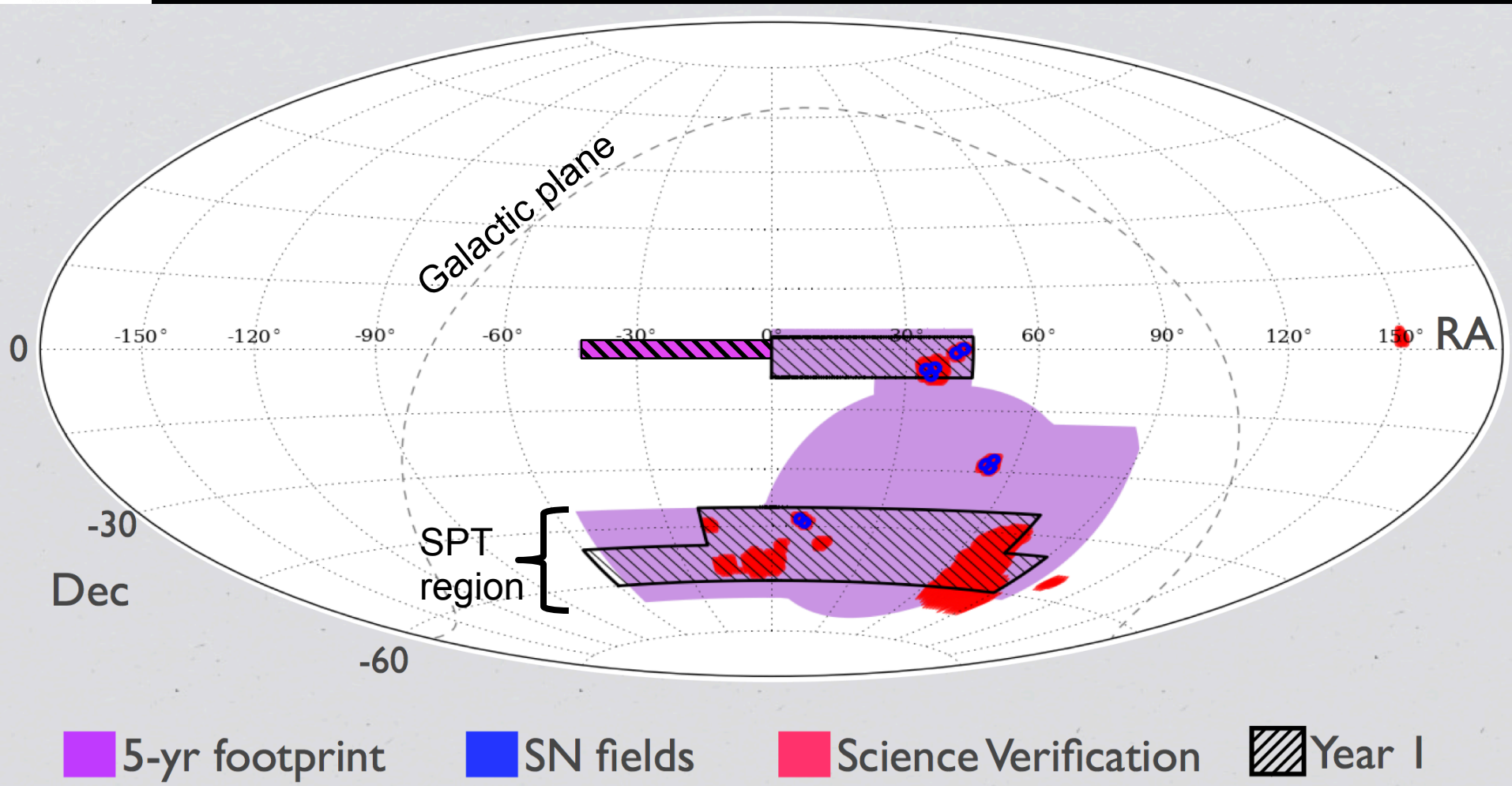


DES survey area encompasses SPT Sunyaev-Zel'dovich Cluster Survey
SZ flux correlates with cluster halo mass with ~10% scatter

DES Survey Footprint



- Total area: 5000 sq. deg. Year 1: ~2000 sq. deg.
- 10 Supernova fields (2 deep, 8 shallow)
- Footprint is overhead at night from Sept.-Feb.

Sampling of Early Papers in Preparation

- Supernova candidate detection & selection & spectroscopic follow-up
- Supernova Rates
- Weak Lensing Mass Calibration of SPT Clusters in SV
- Weak-Lensing Study of Five Massive Galaxy Clusters Using DES-SV Data
- DES SV Voronoi Tesselation Clusters: Catalog, X-ray properties, Mass-Richness Relation
- DES Confirmation and Redshift Estimation of XCS Selected Clusters
- The Richness-Mass relation of DES SV redMaPPer Clusters
- Chandra/X-ray Properties of DES SV redMaPPer Clusters
- Dark Energy Survey Weak Lensing Shear Catalog from SV Data
- Galaxy-Shear Cross-Correlations from DES SV
- Photometric Redshifts from the DES Science Verification Data
- DES+VISTA Cross Identifications using the DES Science Verification Data

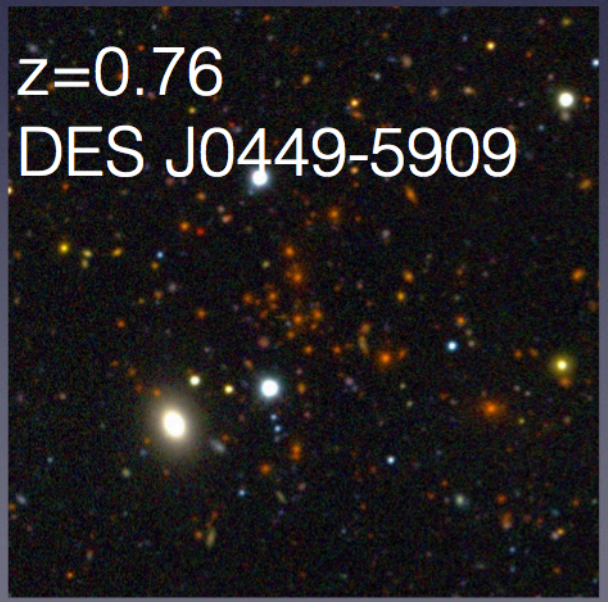
DARK ENERGY SURVEY

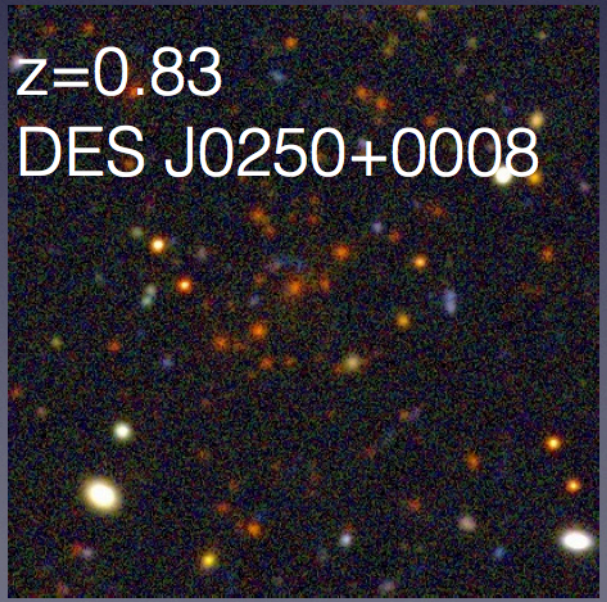
All DES results in this talk are

PRELIMINARY

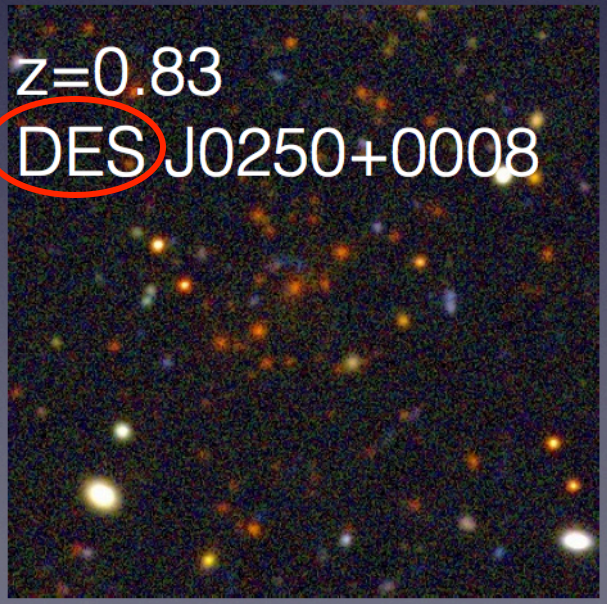
Galaxy Clusters in SV

Slide from E. Rykoff

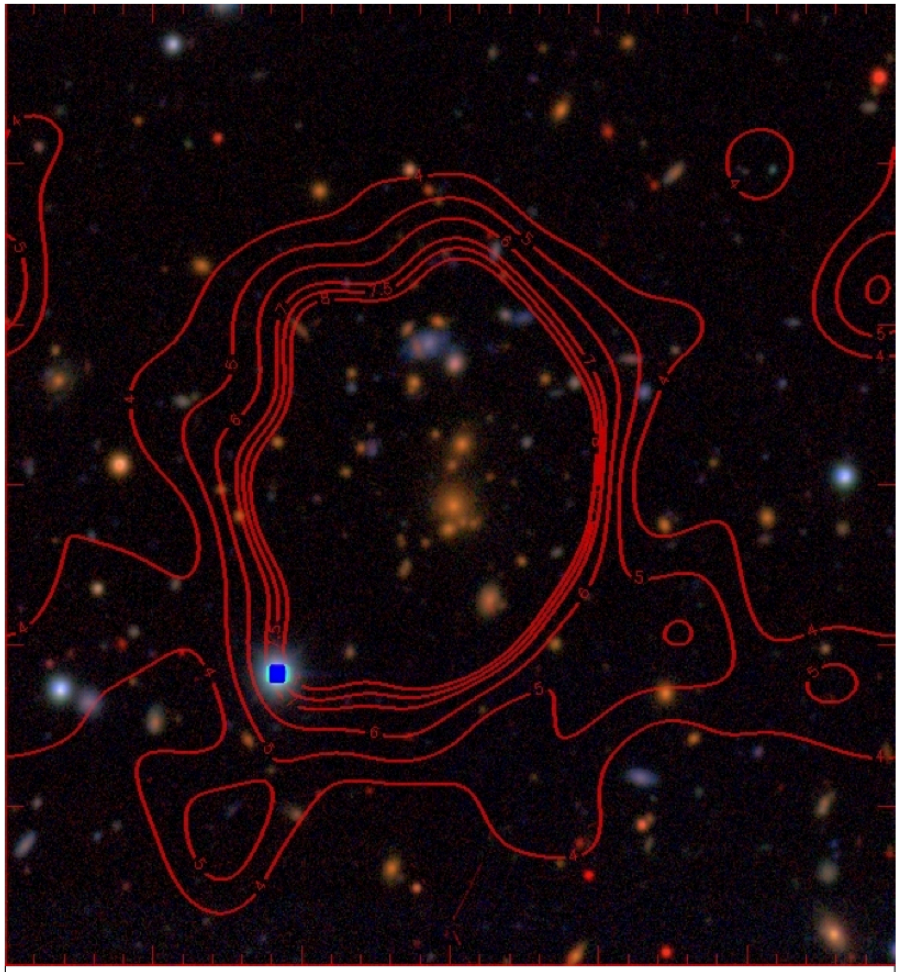




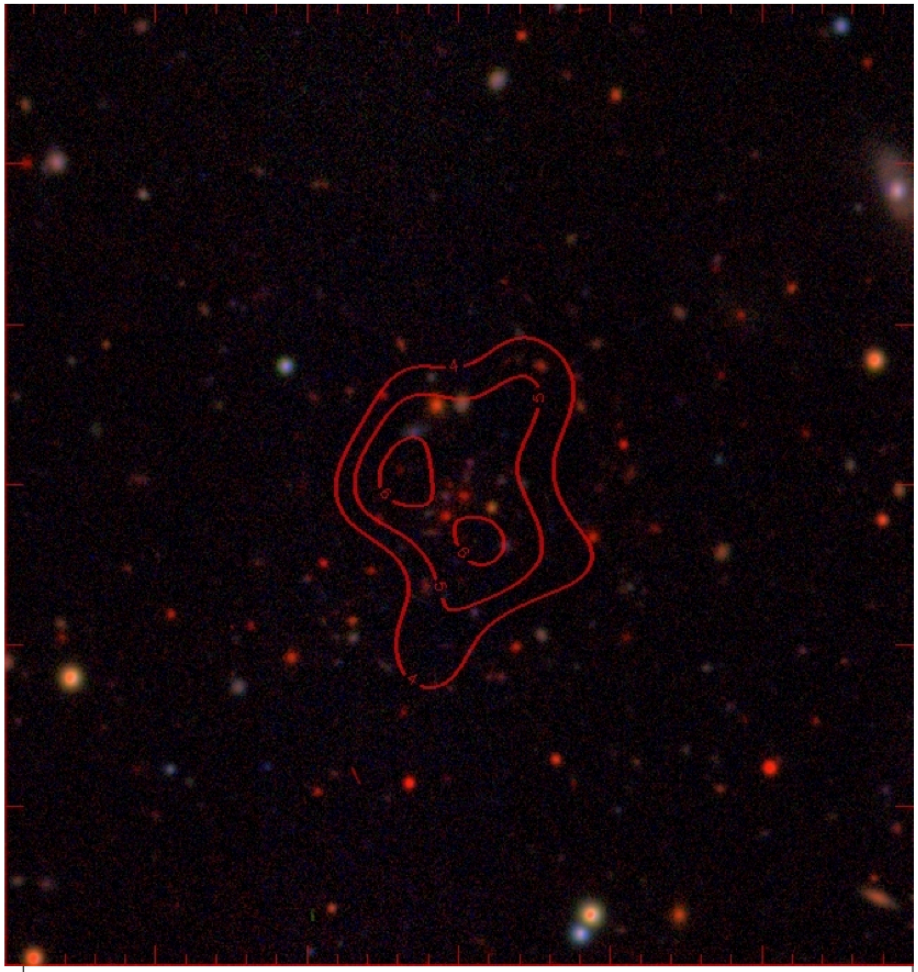
Galaxy Clusters in SV



New X-ray Clusters in SV



XMMXCSJ234231.5-562106.8



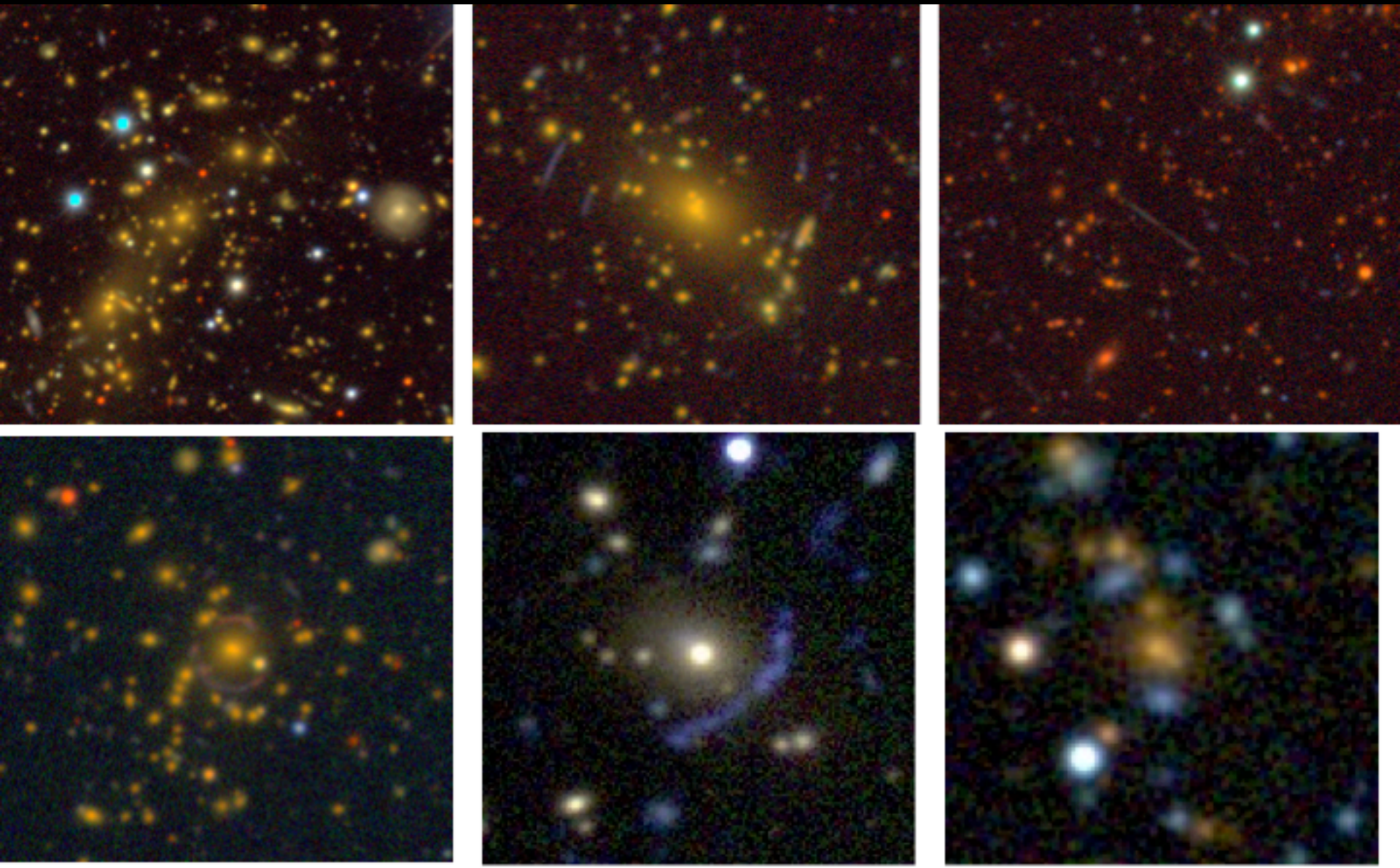
XMMXCSJ234155.3-550745.5

DECam Imaging with X-ray contours overlayed.

Slide from P. Rooney

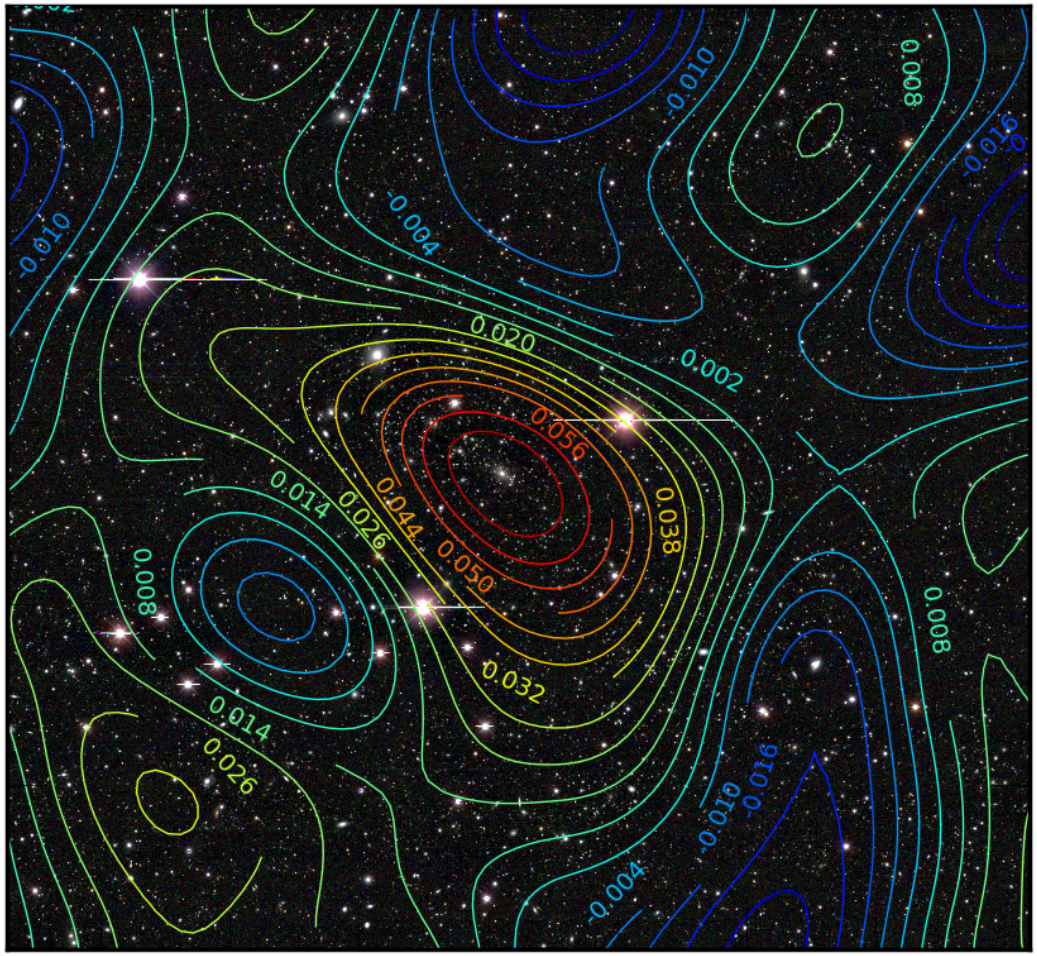
Strong Gravitational Lensing

foreground mass bends light from distant galaxies (SV images)



Cluster Weak Lensing: `Seeing' Dark Matter

- Image: light from a cluster of galaxies
- Contours: inferred projected dark matter distribution in the cluster from weak gravitational lensing
- DES SV data



Clusters in Science Verification

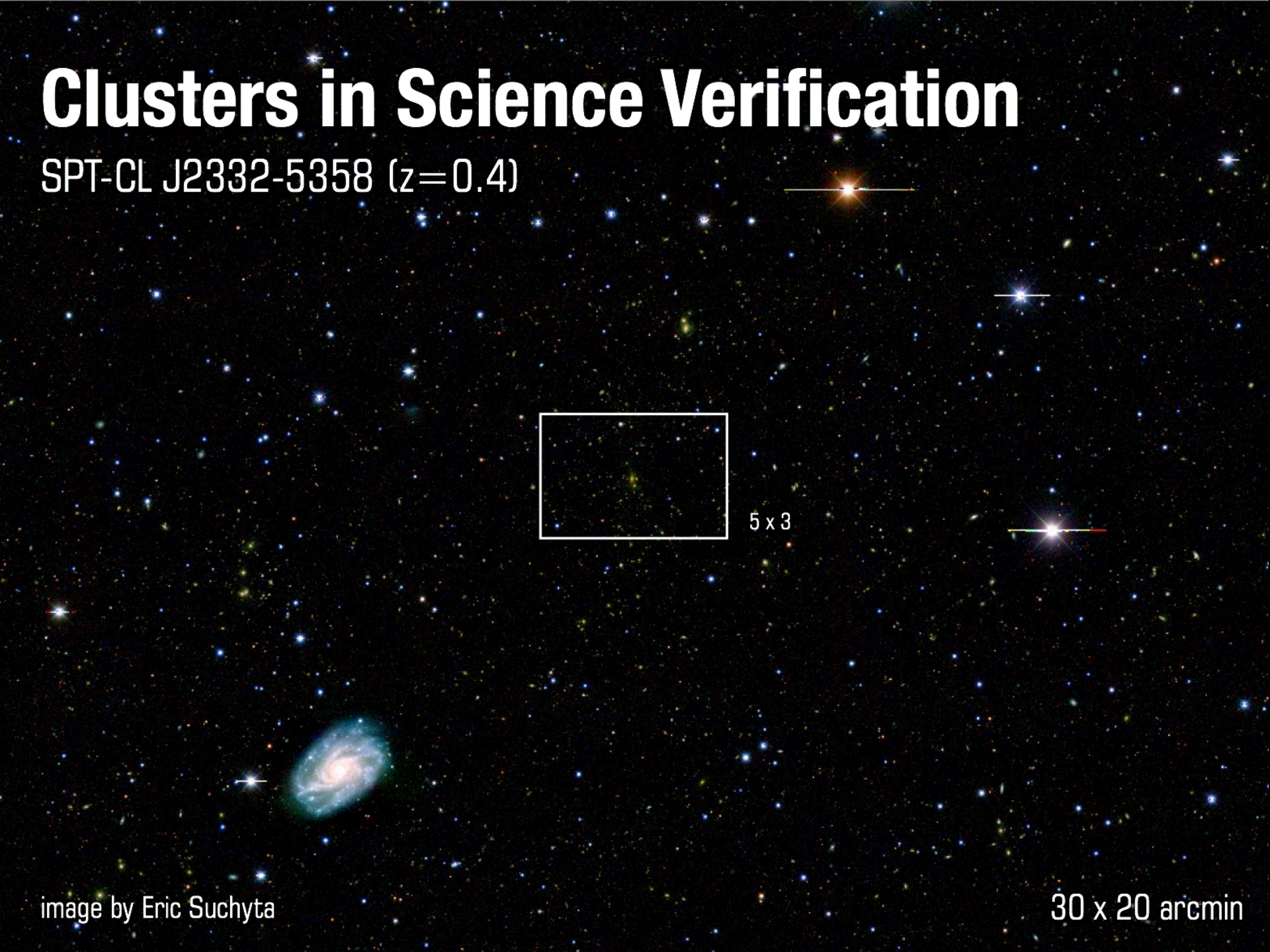
SPT-CL J2332-5358 (z=0.4)

image by Eric Suchyta

5 x 3 arcmin

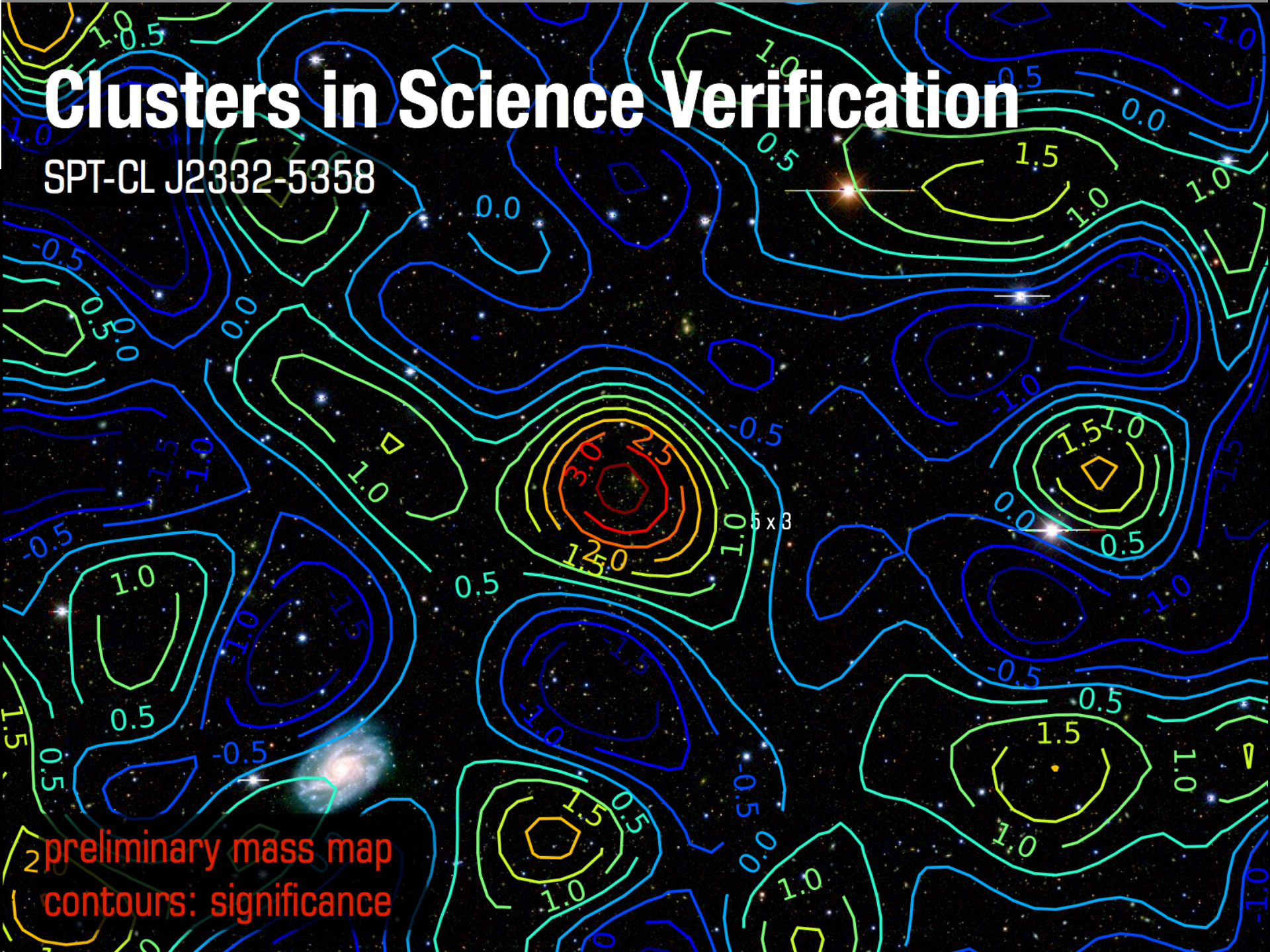
Clusters in Science Verification

SPT-CL J2332-5358 (z=0.4)



Clusters in Science Verification

SPT-CL J2332-5358

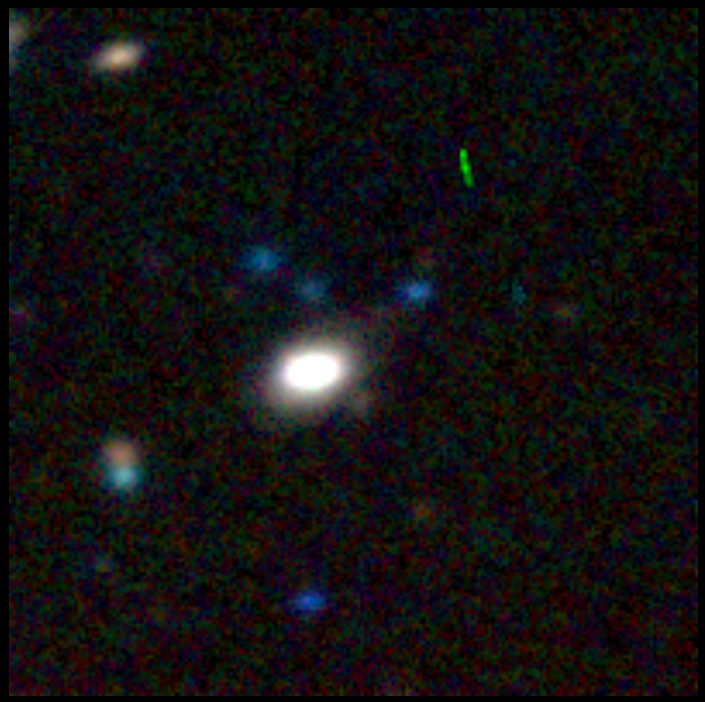


DARK ENERGY SURVEY

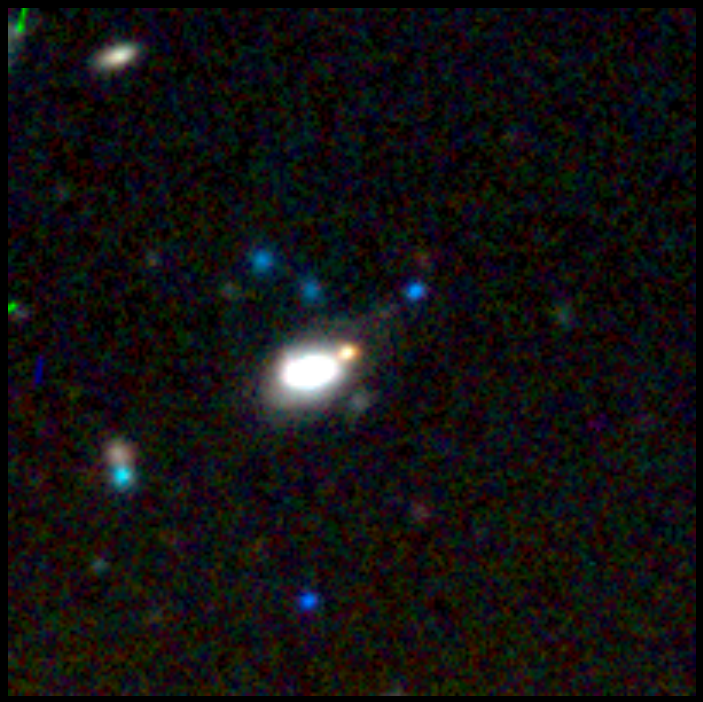
1x1 deg Image

~1/3 of DECam field of view

Discovering Supernovae



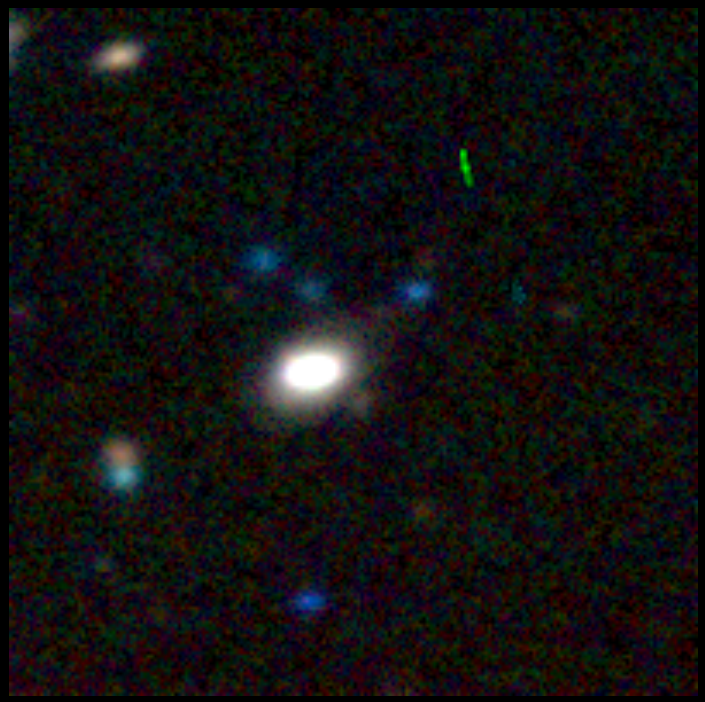
Nov. 7, 2012



Dec. 15, 2012

SN Ia at z=0.2 confirmed at AAO (OzDES: 100 spectroscopy nights over next several years)

Discovering Supernovae



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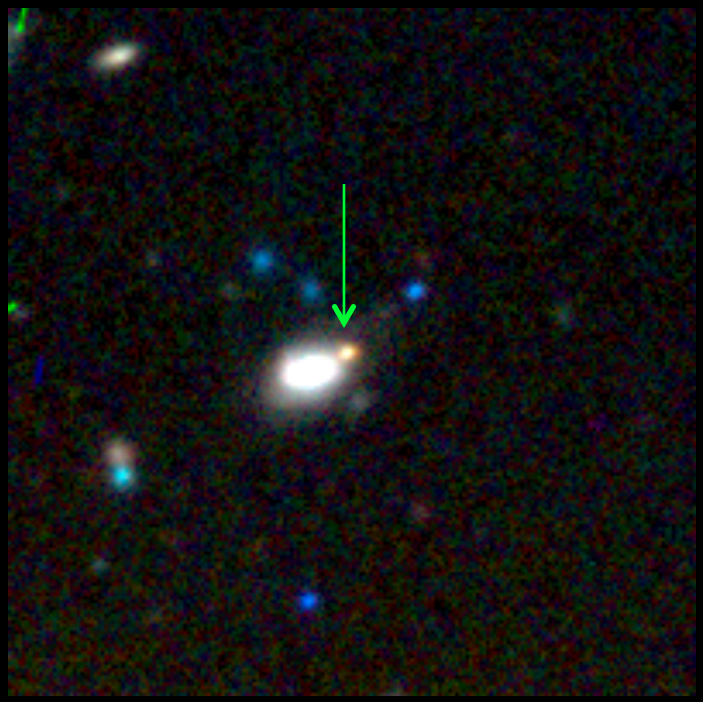

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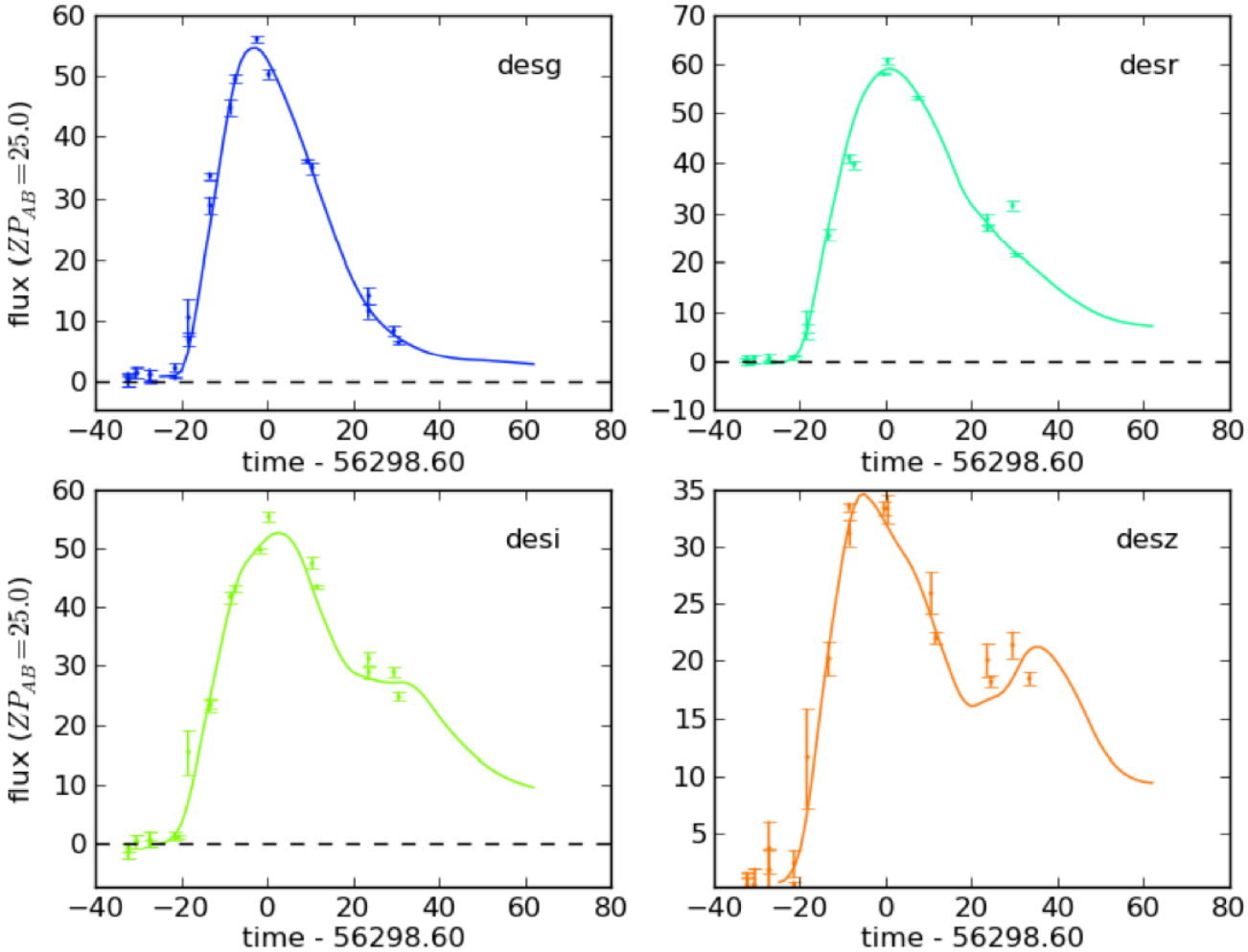
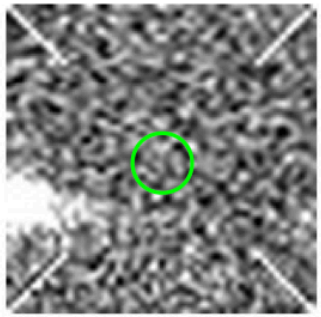


$z = 0.241$

DES12C3a

(642239)



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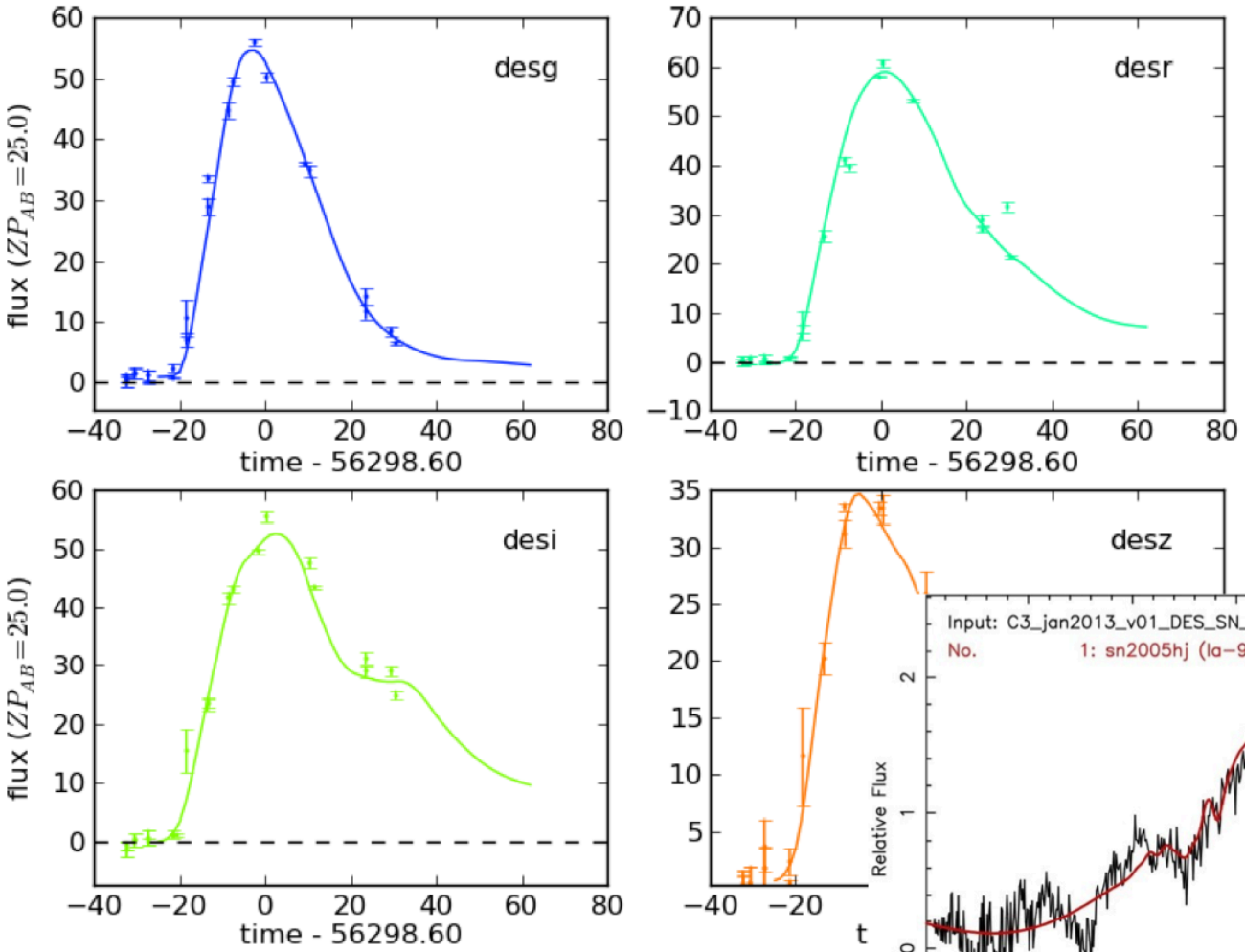

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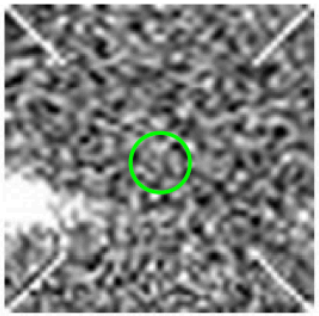
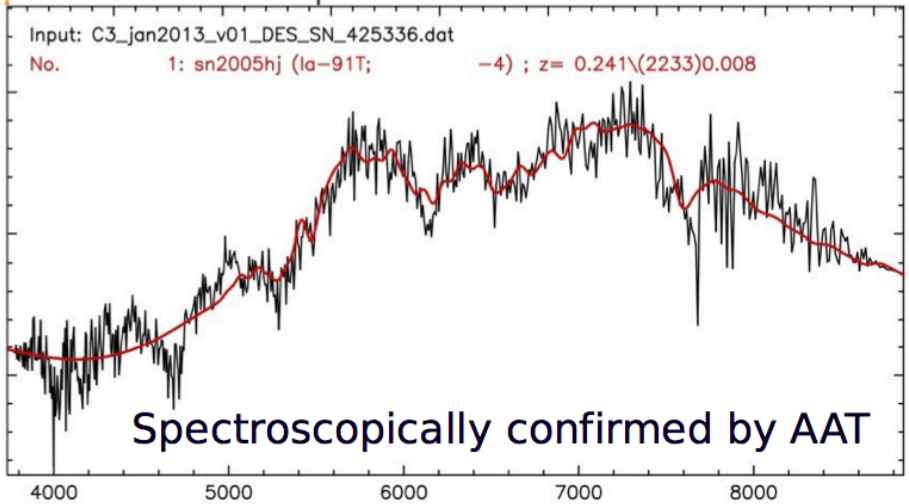
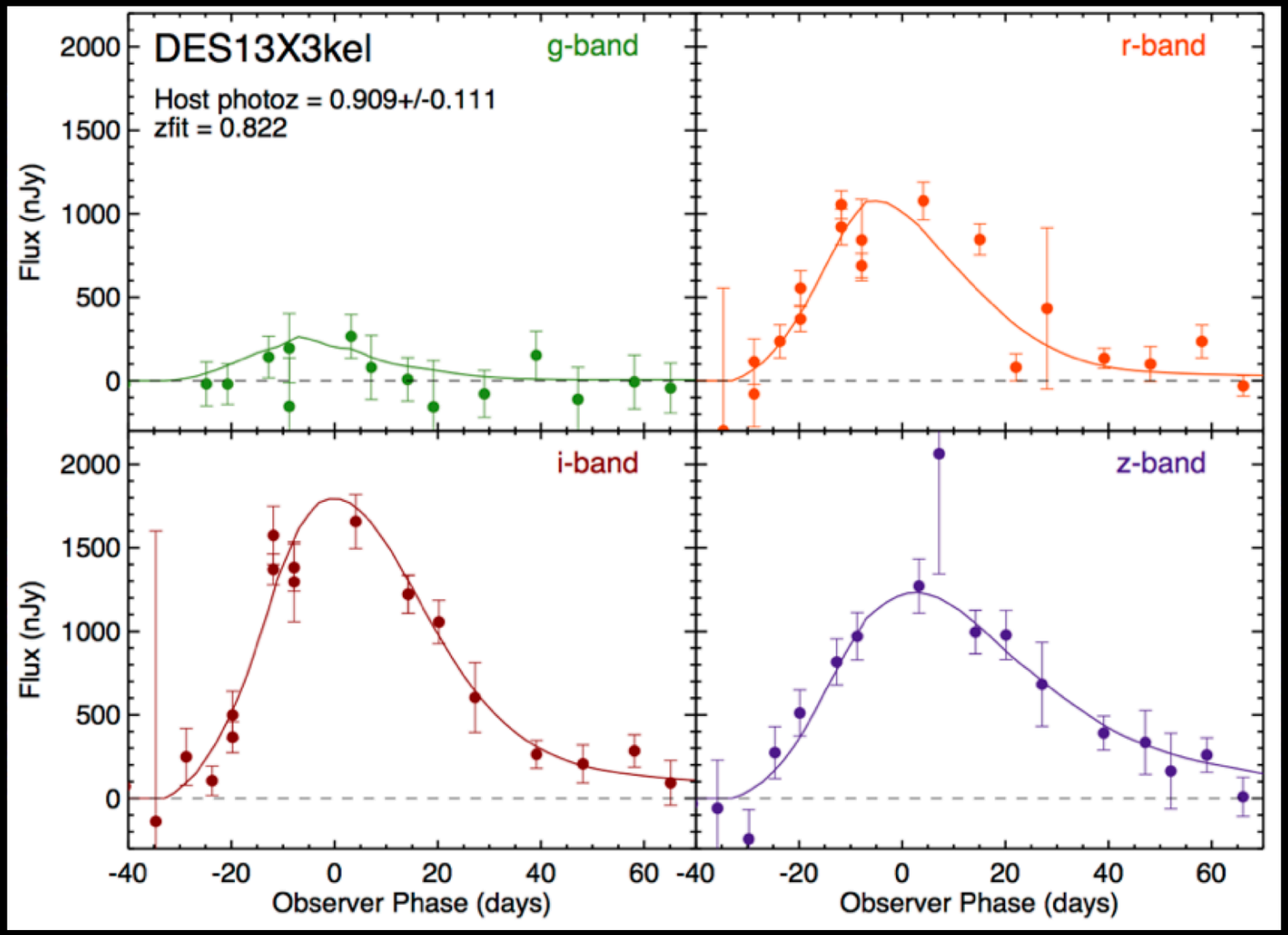


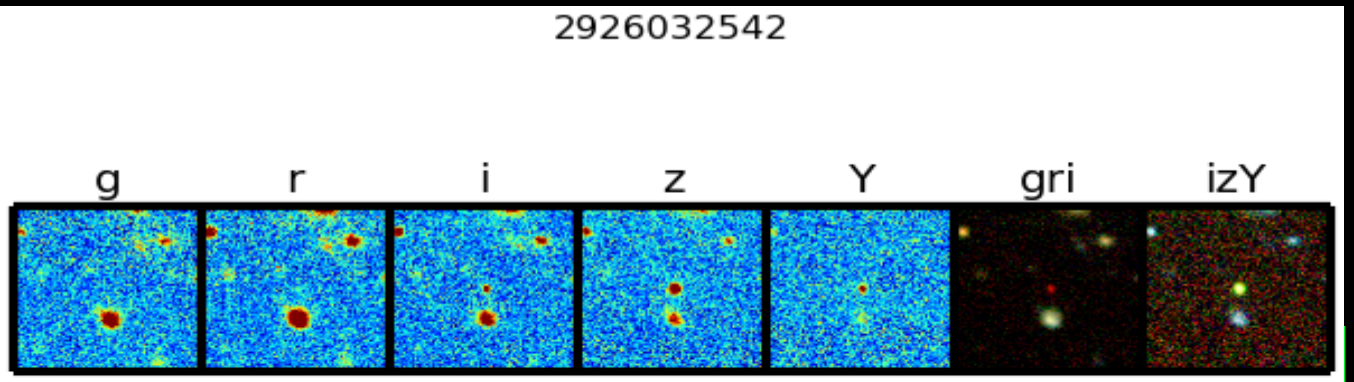


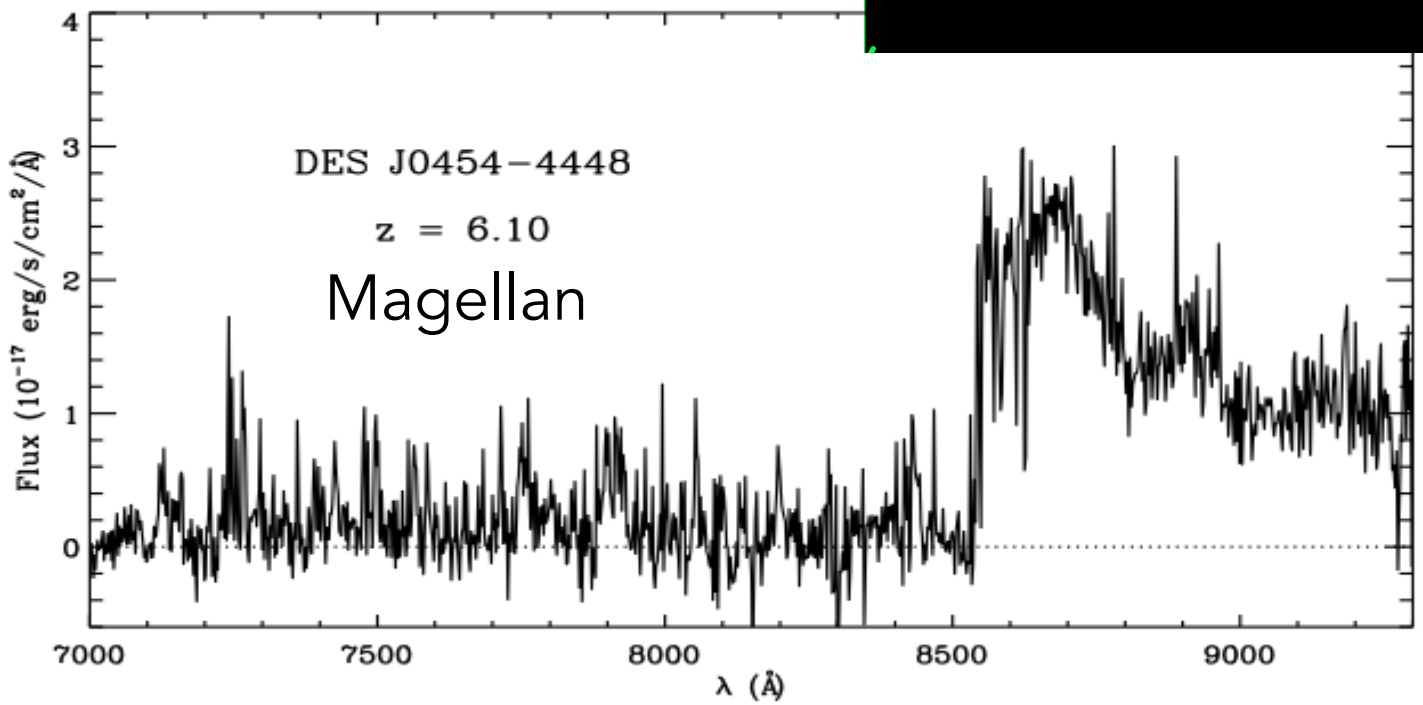
High-Redshift Supernovae



Slide from C. D'Andrea

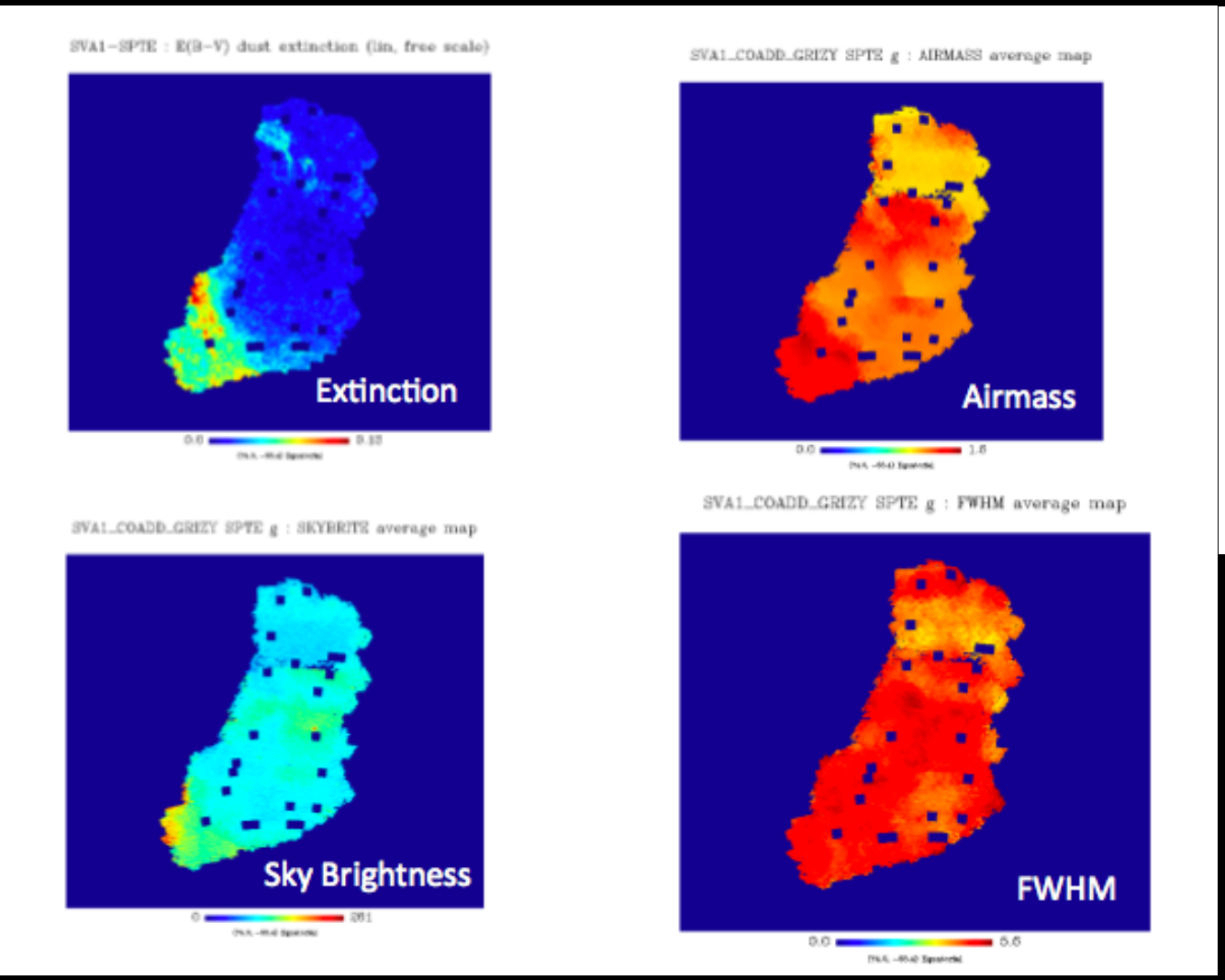
Discovering High-redshift Quasars

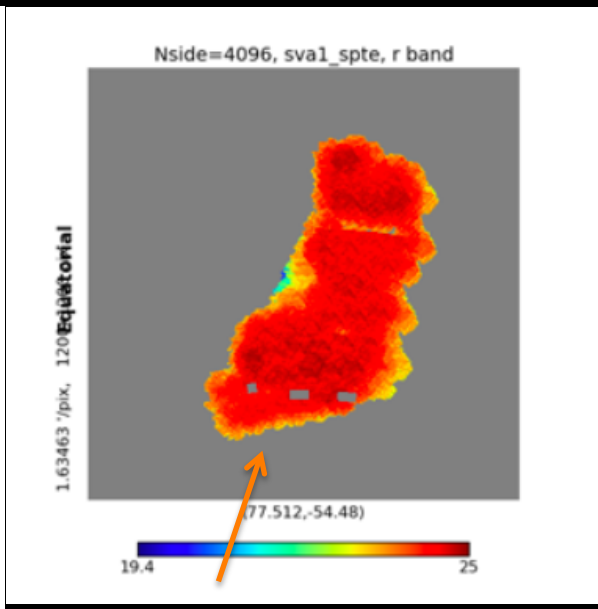




Becker, McMahon, Banerji, Reed, Ostrovski

Systematics Checks for the SV Maps





Benoit-Levy, Swanson, Daues
Mangle masks

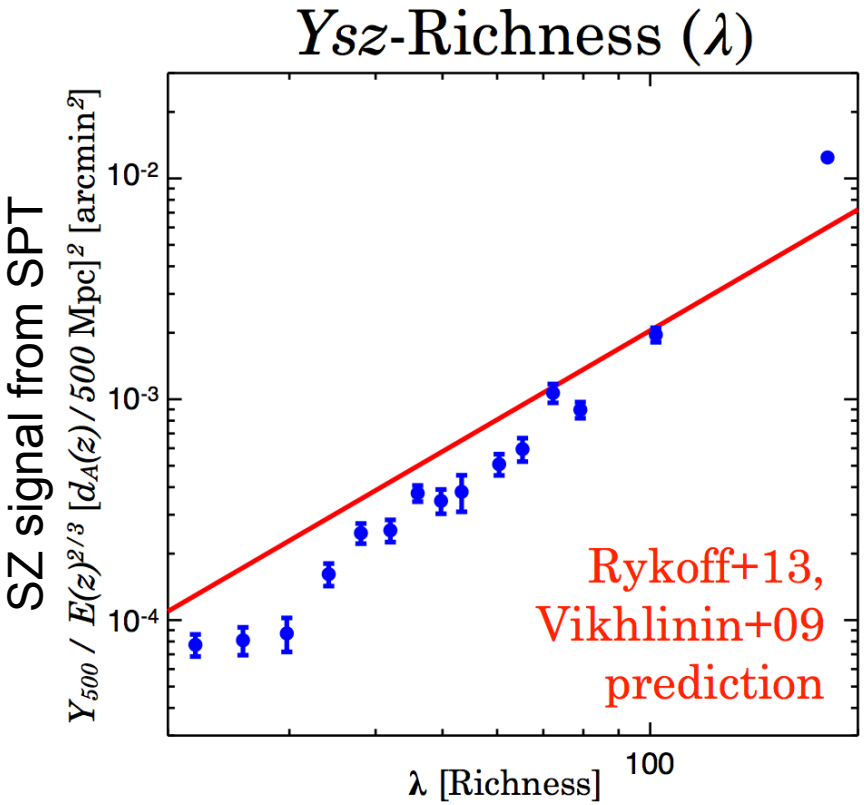
B.Leistedt, H.Peiris et al.
Systematics maps

Slide from I. Sevilla

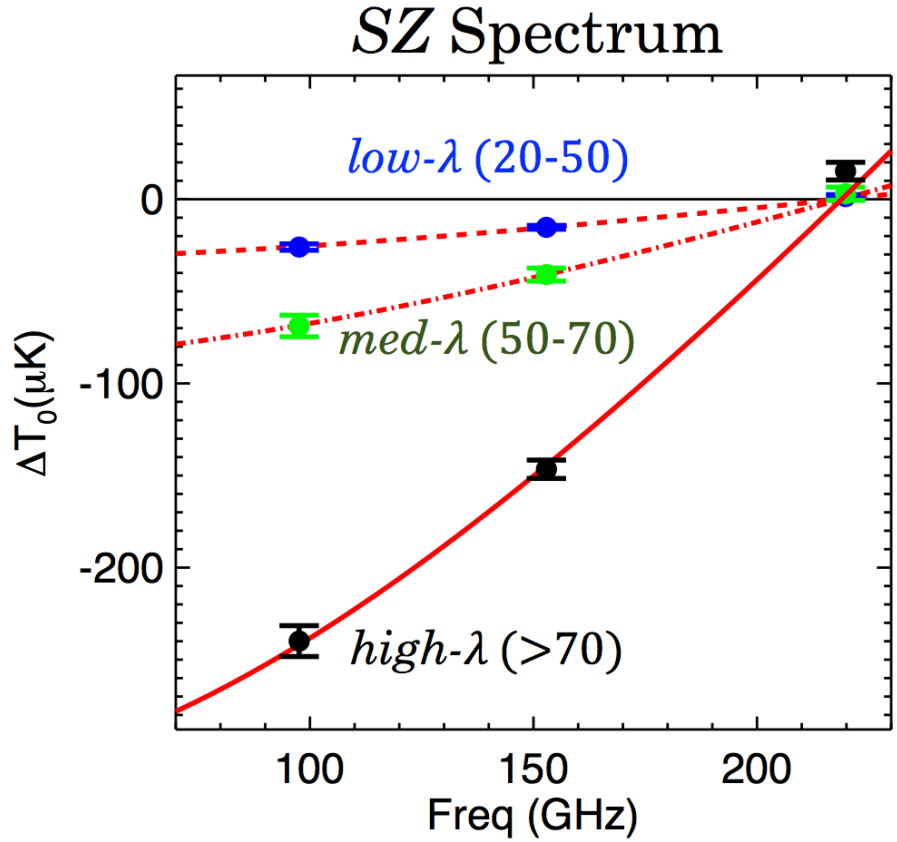
Dark Energy Survey (DES) and SPT

Using 150 deg^2, stack SPT-SZ data on 602 DES-selected clusters:

- ***High S/N detection of Ysz-Optical Richness relation***
- ***220 GHz flux implies dusty sources are <3% of SZ signal at 150 GHz for λ > 20 (cluster mass > ~1e14 Msun)***

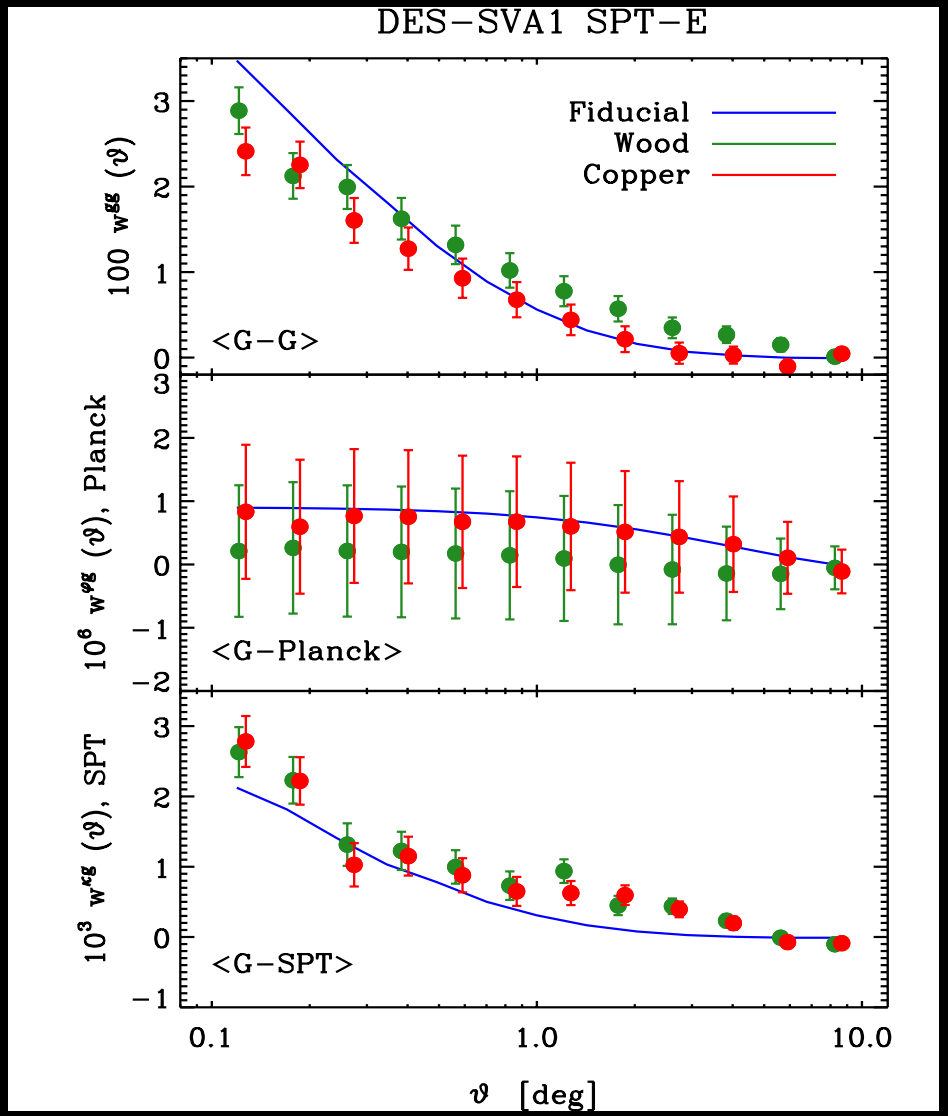


Optical richness from DES

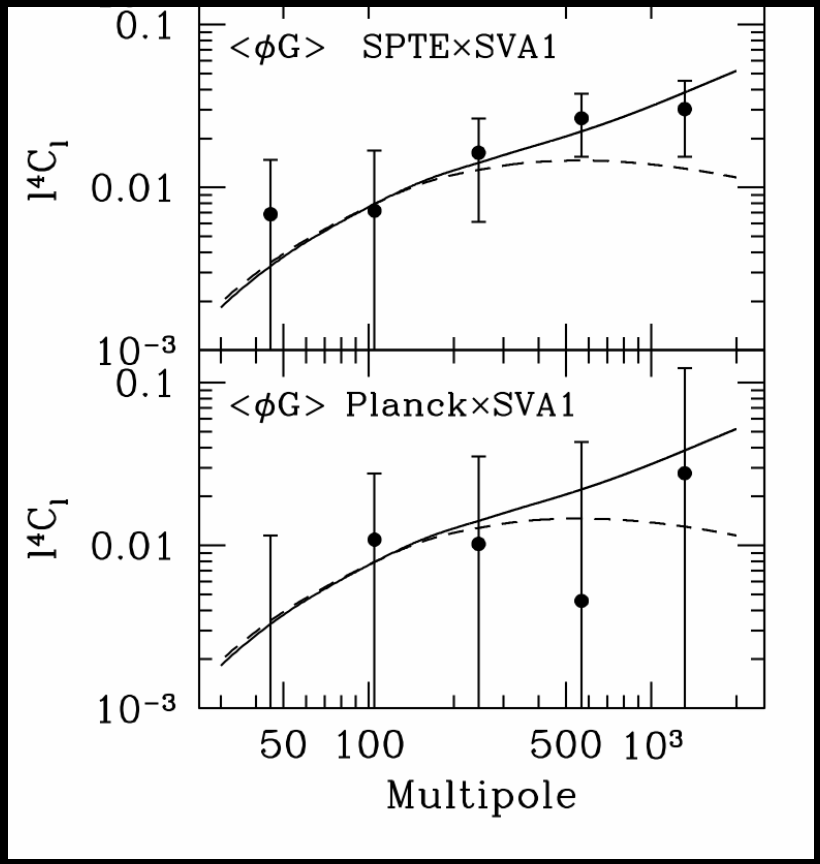


slide from B. Benson

Cross-correlate DES Galaxies with CMB Lensing



DES Galaxies responsible for (some of) the gravitational potential mapped by CMB



Giannantonio, Fosalba, Dodelson +

DES started Aug. 31, 2013

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NATURE NEWS BLOG

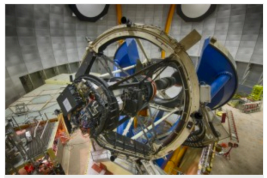
Dark energy survey launches

03 Sep 2013 | 19:25 BST | Posted by Alexandra Witze | Category: Space and astronomy

High in the Chilean Andes, a massive project to probe the nature of dark energy has begun.

The Dark Energy Survey (DES) launched on 31 August at the 4-metre Blanco telescope at the Cerro Tololo Inter-American Observatory. It is one of several new pushes to explore the physical properties of dark energy, the mysterious force that is driving the Universe to expand at an ever faster rate.

Over the course of 5 years, the DES will map 300 million galaxies over one-eighth of the night sky. Its backbone is a 570-megapixel digital camera (pictured).



The Dark Energy Camera photographs galaxies from its perch on the Blanco telescope in Chile.

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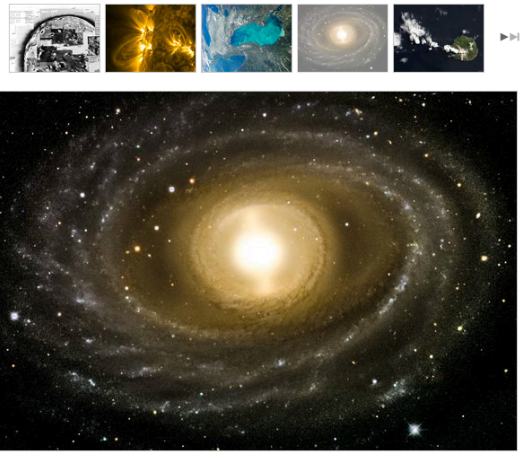
Space Pictures This Week: Solar Storm, Spiral Galaxy



Majestic Spiral

Image courtesy Dark Energy Survey Collaboration

Like a ghostly pinwheel, a majestic spiral galaxy known as NGC 1398 shines in the Fornax constellation some 65 million light-years from Earth in a picture released September 3.

Stretching some 135,000 light-years across, the galaxy is just slightly bigger than our own Milky Way galaxy, but contains less than a tenth the amount of stars.

This deep-sky image is part of the Dark Energy Survey being conducted by the 4-meter Victor M. Blanco Telescope at the National Science Foundation's Cerro Tololo Inter-American Observatory in Chile.

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Trending News

Rare White Giraffe Spotted in Africa
Stunning white animal is not a true albino but is merely a lighter color than the average giraffe.

Poachers Kill Hundreds of Vultures
Why are elephant poachers killing vultures? Because vultures circling in the sky alert wildlife authorities to the location of poachers' activities.

Indelible 9/11 Pictures
See iconic images of the tragedy, as chosen by National Geographic photo editors. *Warning: graphic content.*

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VIDEO | The ultimate dating experience

Giant digital camera probes cosmic 'dark energy,' the universe's deepest mystery

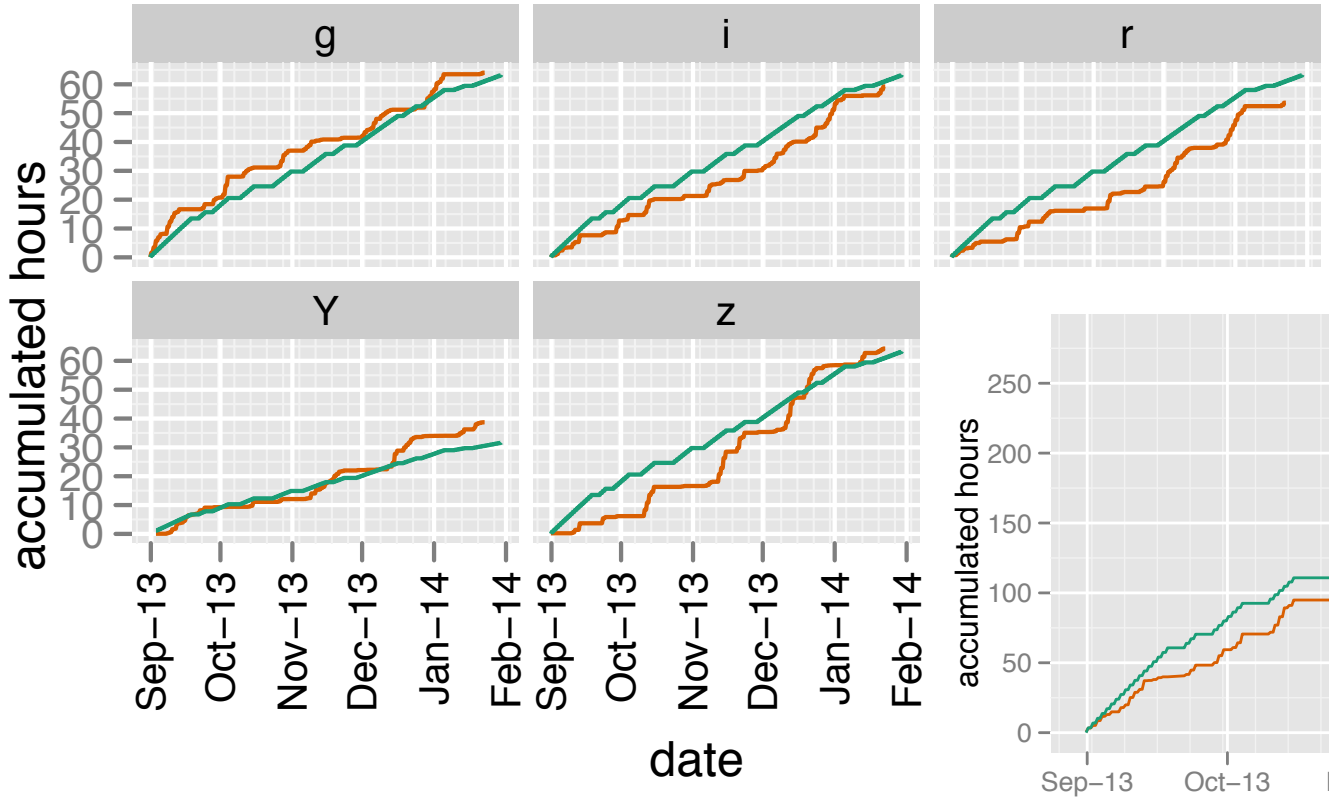
DES First Season (Y1)

- Weather and atmospheric conditions exceptionally poor & variable Sept-Oct. (they generally improve in Chilean Spring), much better since mid-Nov.
  - 60% images were survey-quality in Sept., 92% in Nov., Dec.
  - 12 (5.5)% of observing time has been lost to weather (hardware)
- Improvements in telescope environment by CTIO:
  - dome floor & primary mirror cooling (early Nov)
  - dome position encoders (Dec)
  - hydraulic oil cooling (Jan)
  - Daytime dome cooling, cage covers, primary mirror active control (coming 2014)
- Survey strategy refinements to improve efficiency and survey completeness/homogeneity have been on-going
- Real-time data processing and data-quality evaluation by DESDM team at NCSA

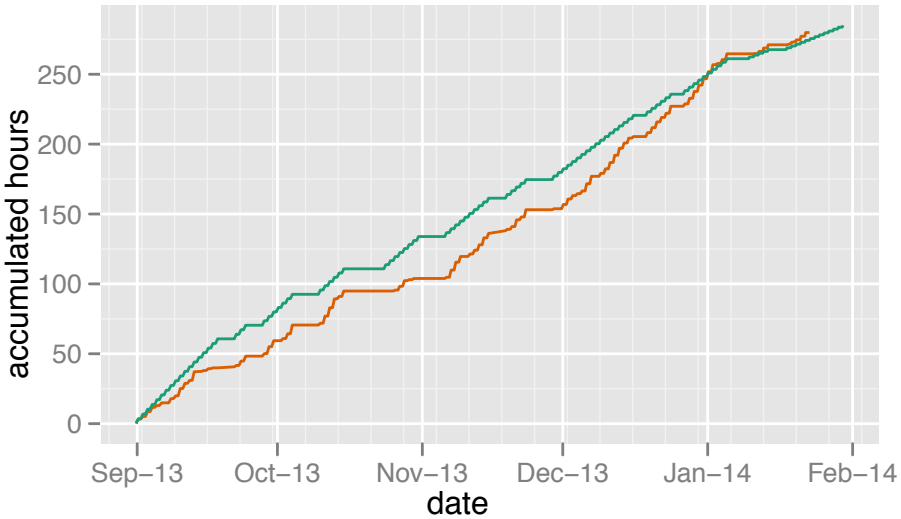
T. Diehl, A. Walker, D. Petravick

WF Survey Progress in Year 1

14,787 wide-field images taken through Dec. 31



All filters combined



Green: target to complete survey, assuming constant efficiency
Red: actual so far

E. Neilsen

Survey Progress

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

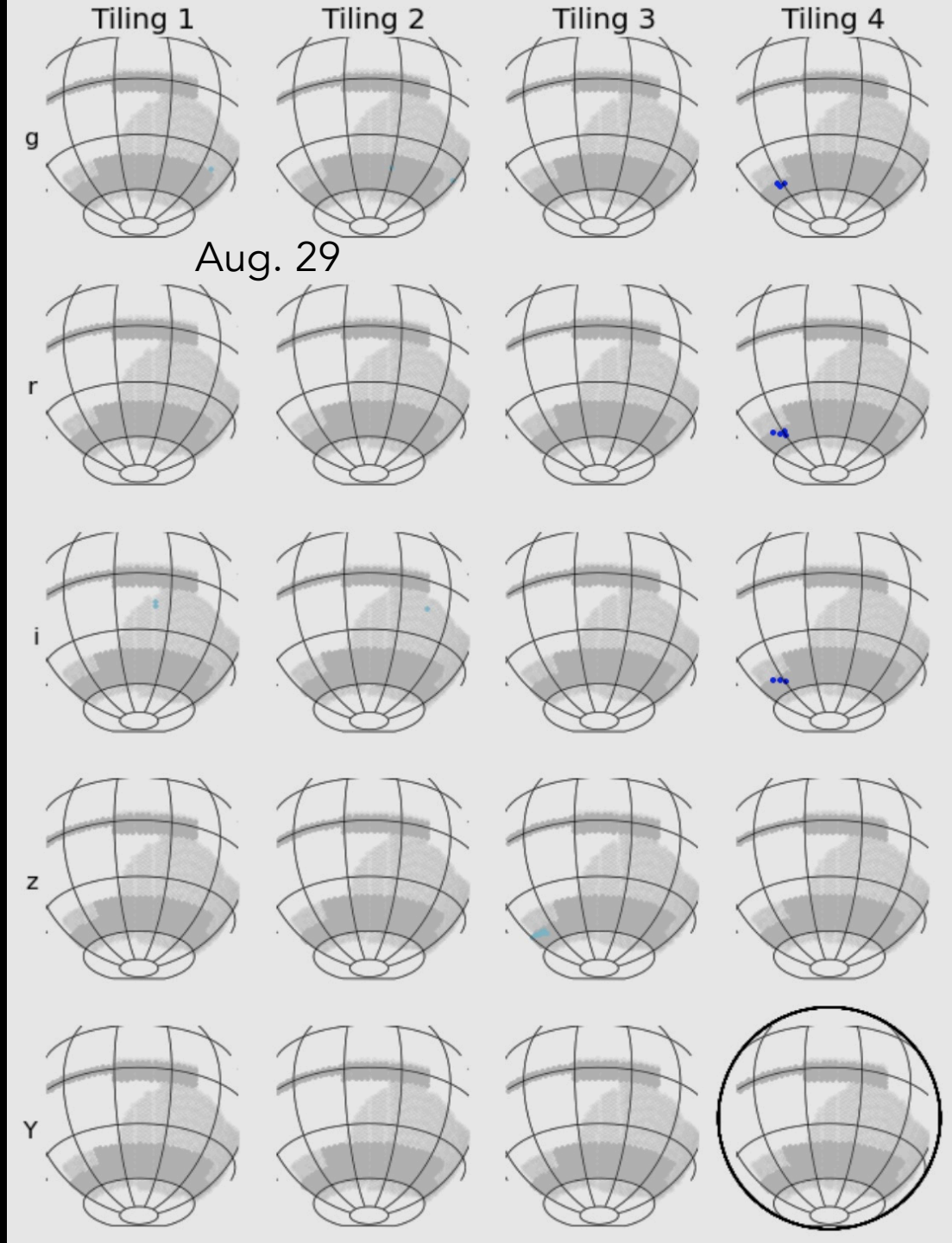
Year 2: fill in middle (grey) region

Use only best conditions (image quality) for riz: Weak Lensing

In poor conditions do g (if dark) or Y (if moon)

Do SN in intermediate conditions or if not recently observed

Repeat exposures if they don't meet science requirements



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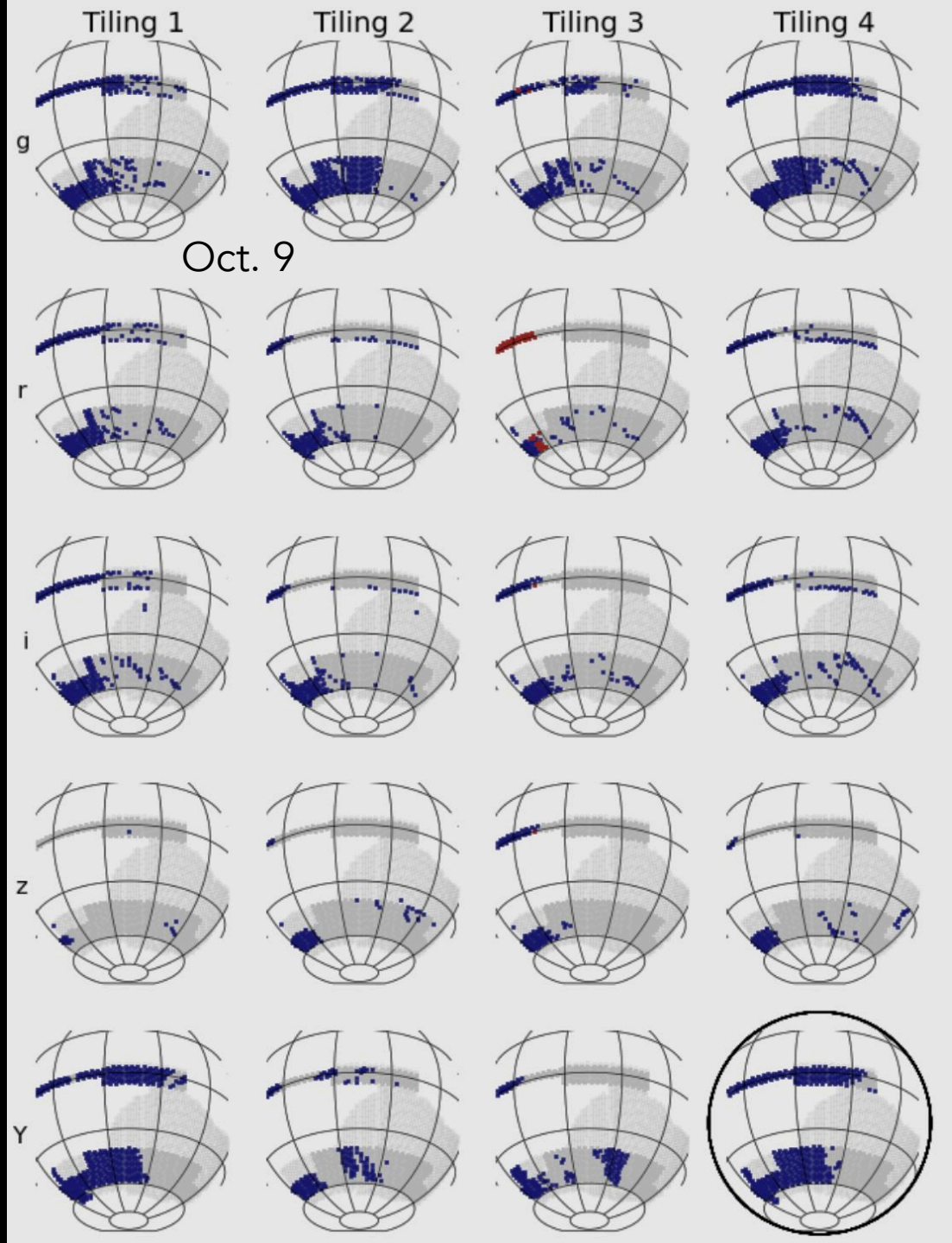

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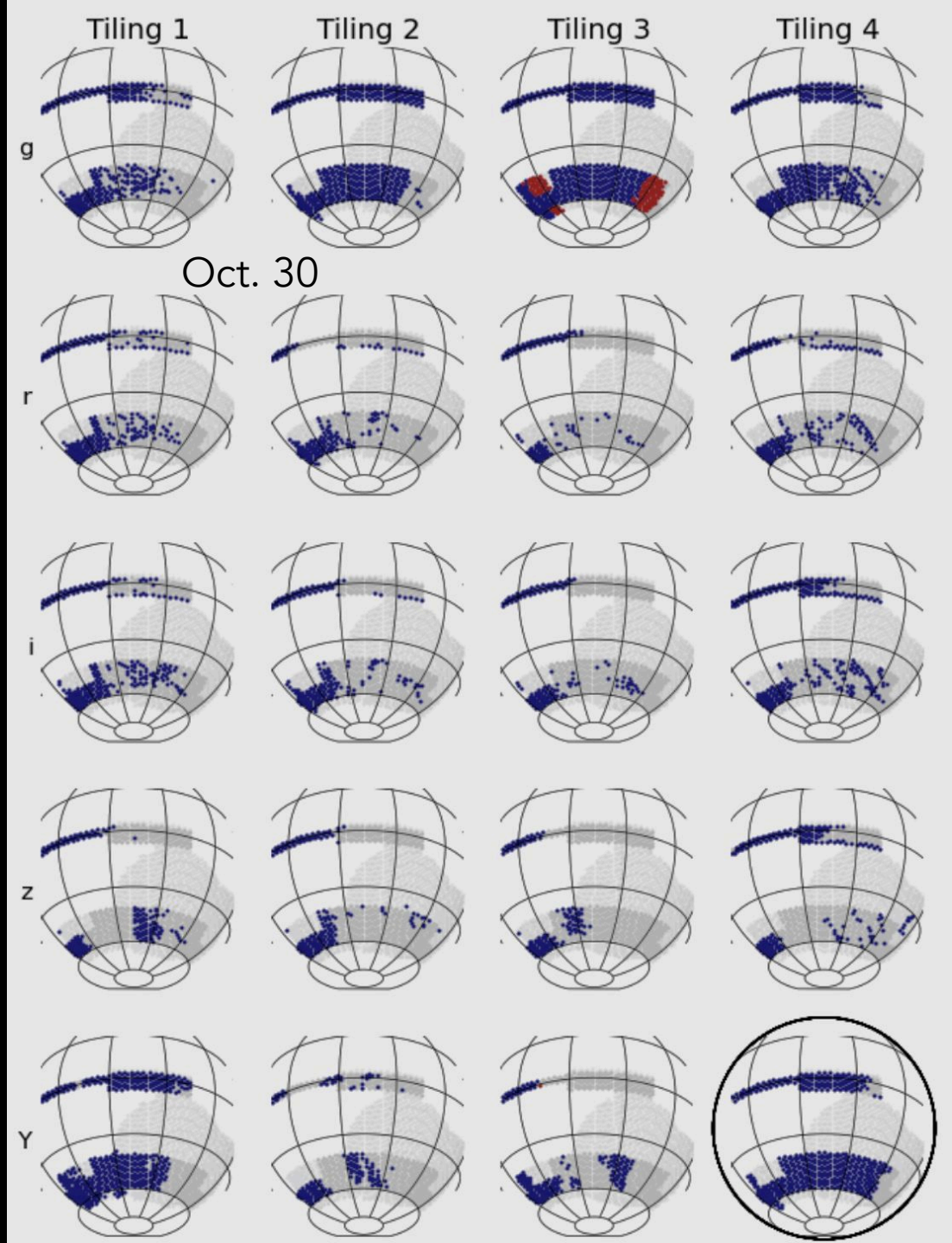

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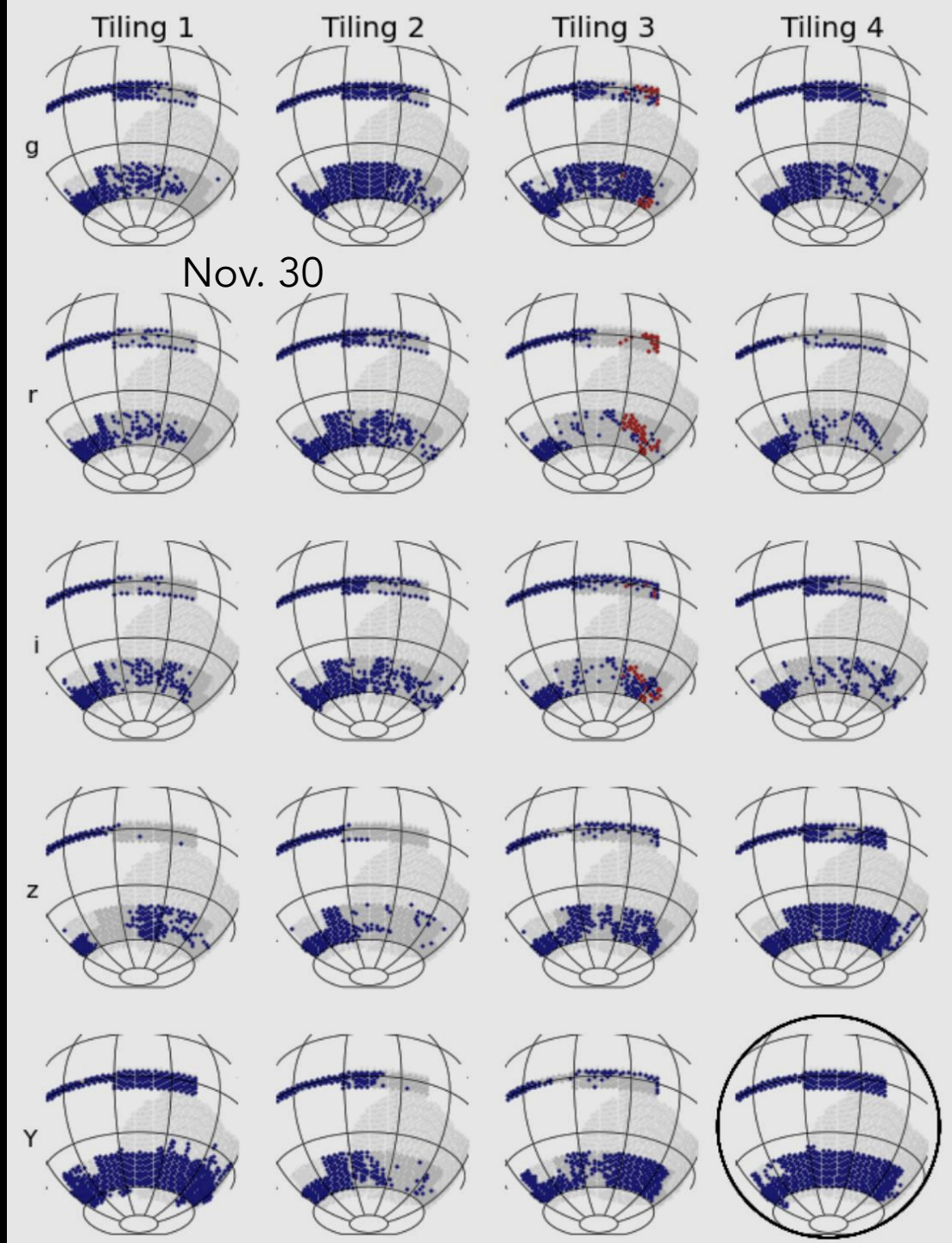

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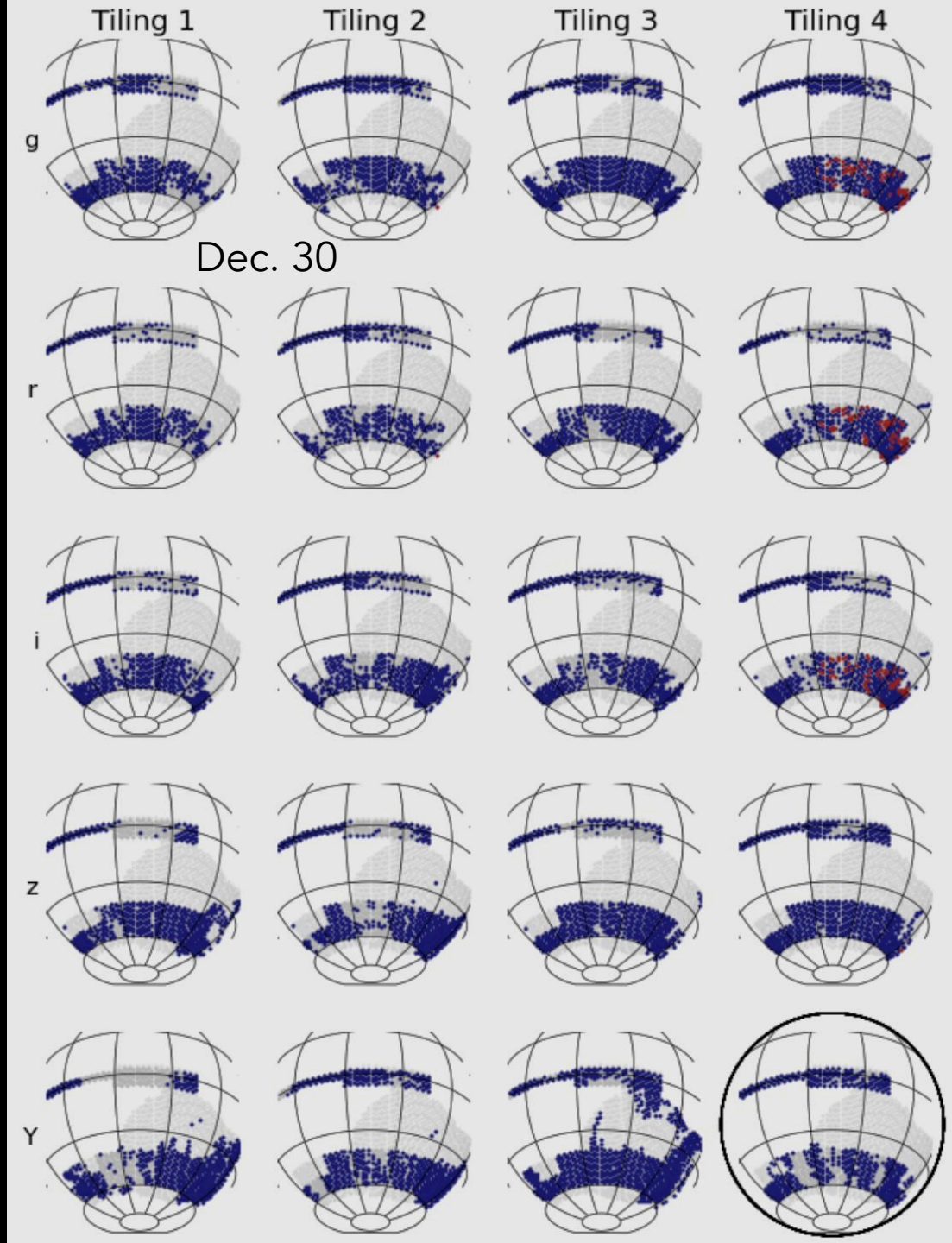


Survey Progress

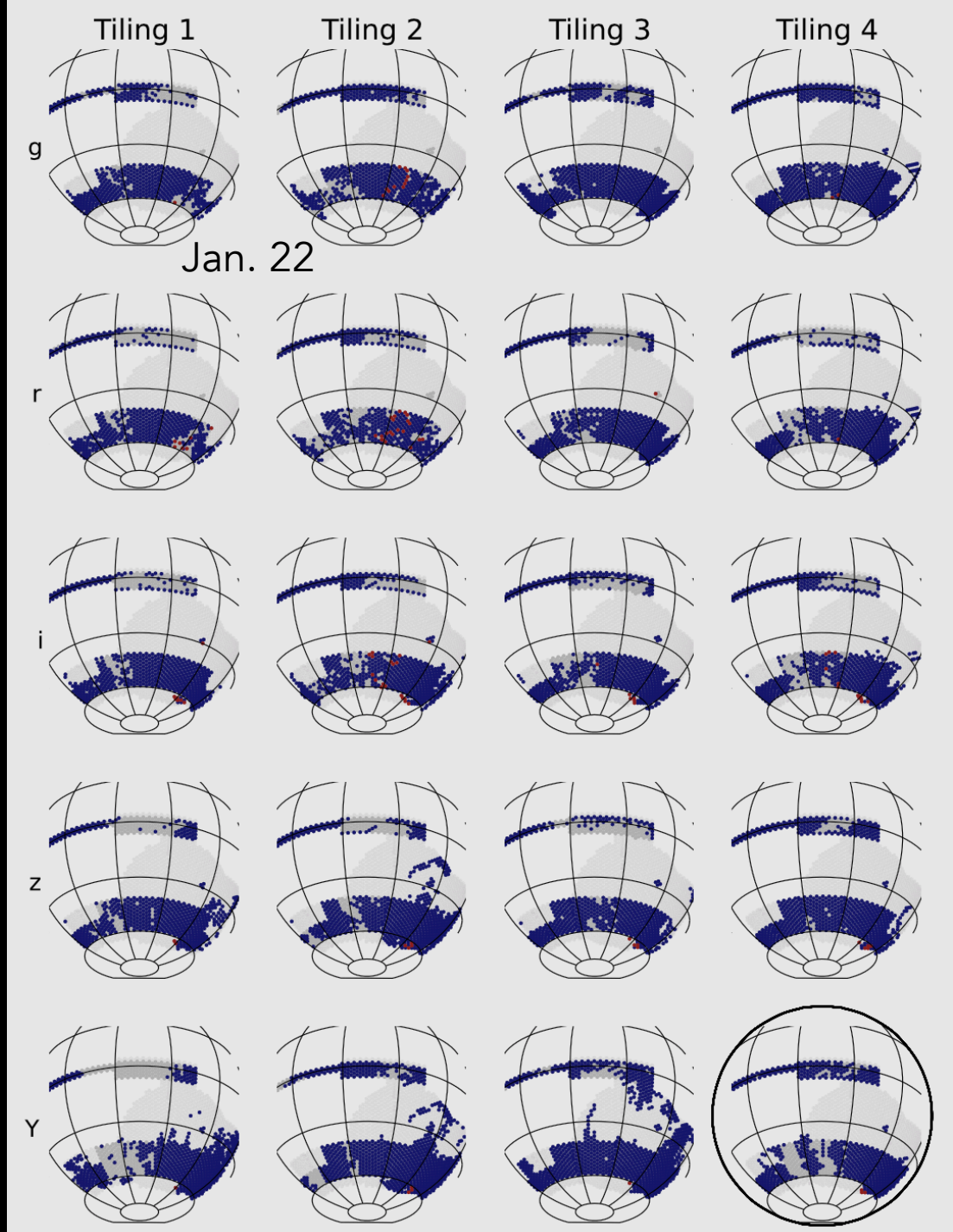
Goal for Year 1: cover northern (SDSS stripe 82) and southern (SPT) regions 4 times in each filter (grizY): 2000 sq deg. Expect to complete ~80-85% of Y1 exposures by Feb. 9

Use only best conditions (image quality) for riz: Weak Lensing

In poor conditions do g (if dark) or Y (if moon)

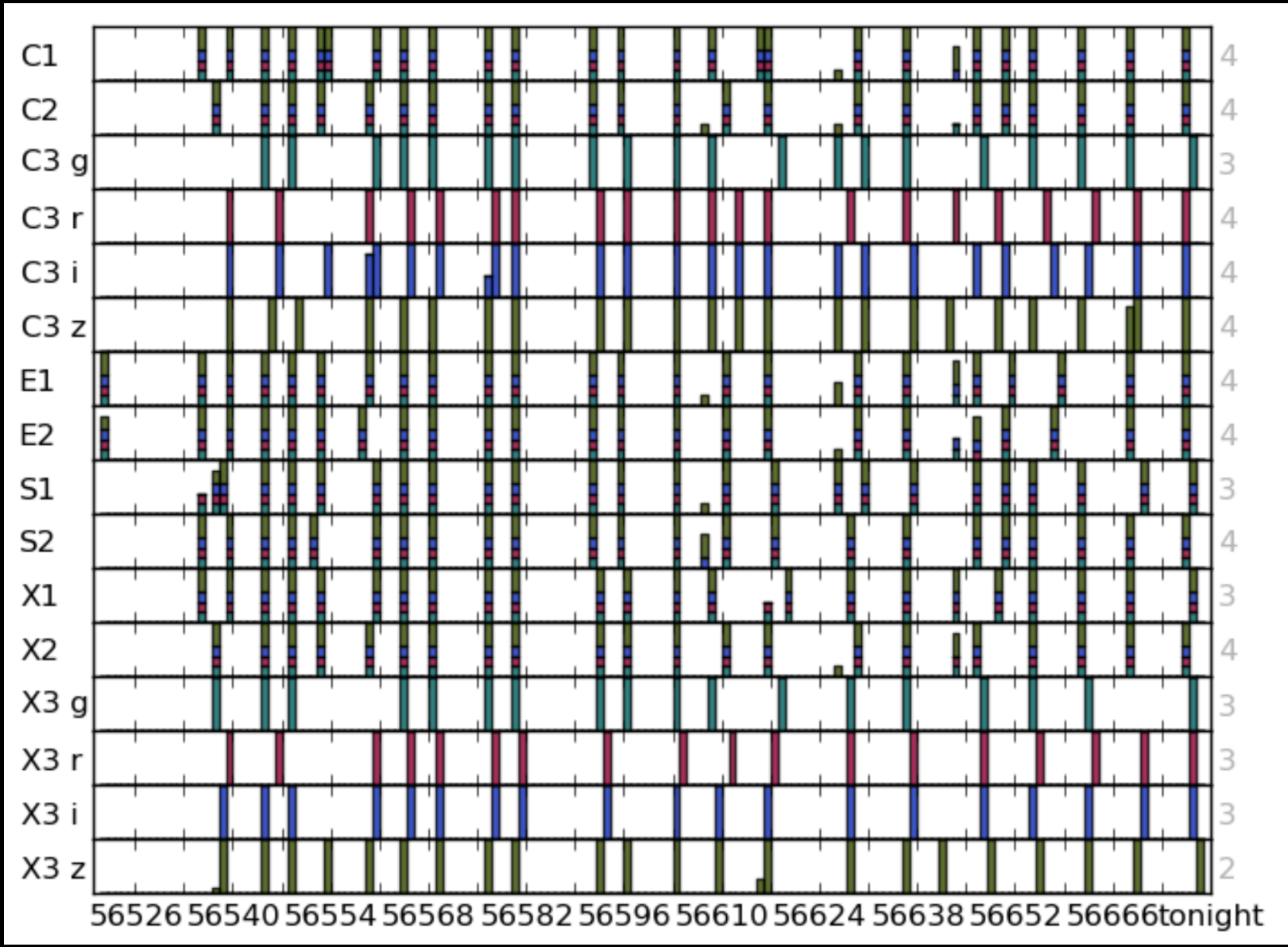
Do SN in intermediate conditions or if not recently observed

Repeat exposures if they don't meet science requirements

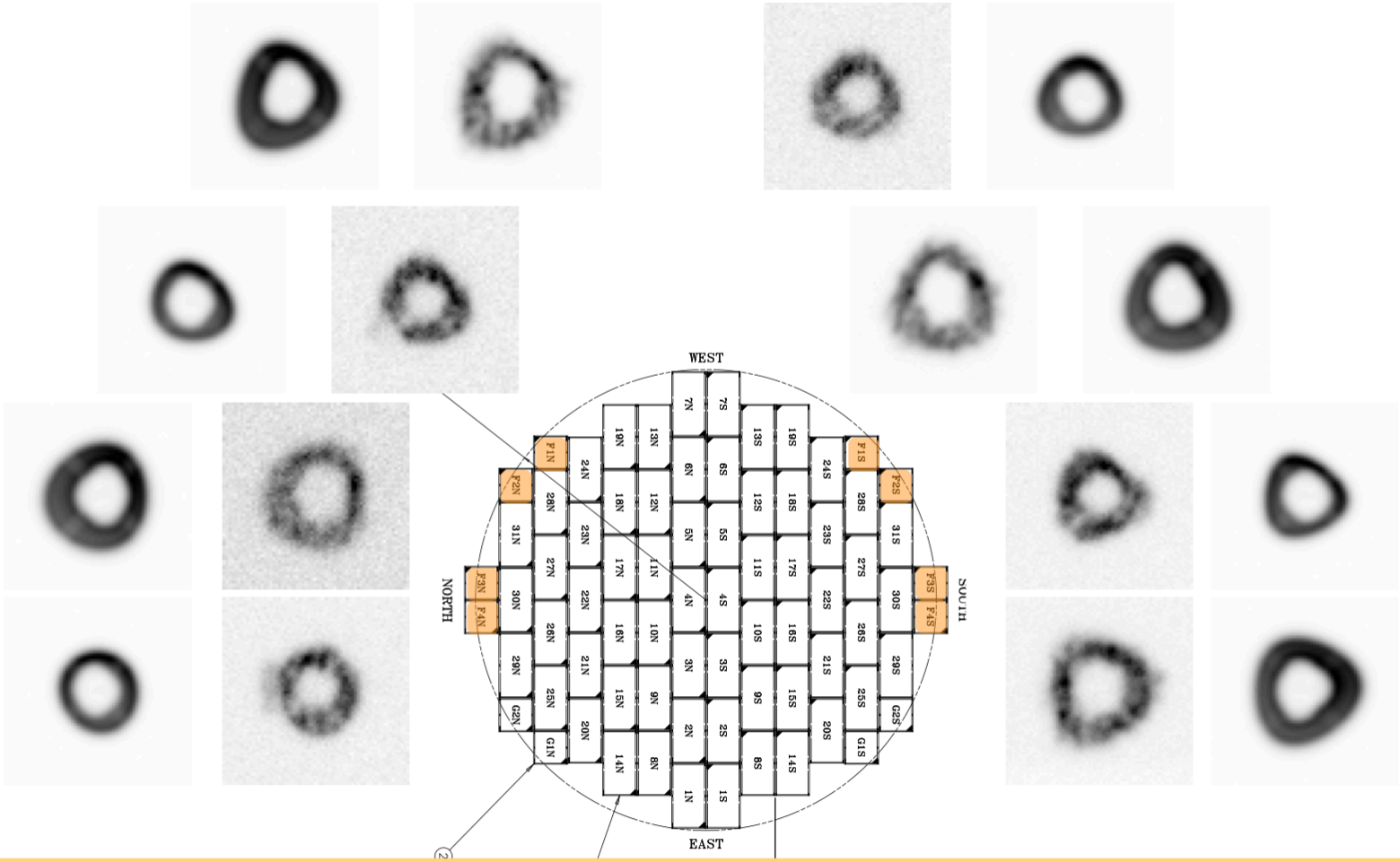


Supernova Survey Cadence

Mean gap 6.3 days per field



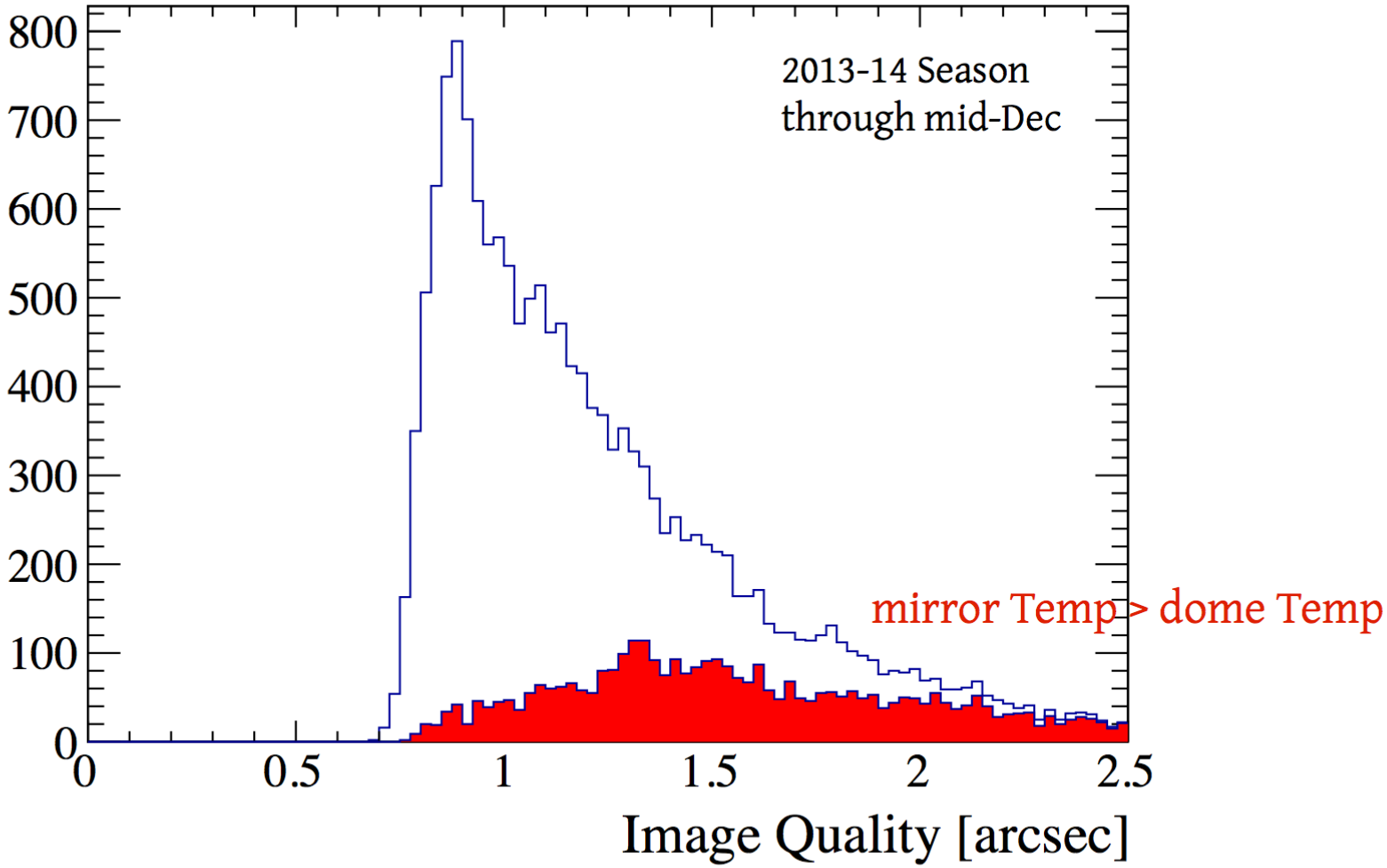
Dark Energy Camera: Active Optics System



- 8 CCDs placed ±1.5mm out-of-focus
- out-of-focus stars forward fit to 9-term Zernike polynomial pupil-plane wavefront

DES Delivered Image Quality

PSF FWHM for all DES images



+ Blanco Telescope improvements to control mirror temperature

DES Delivered Image Quality

PSF FWHM for r,i,z band wide field images

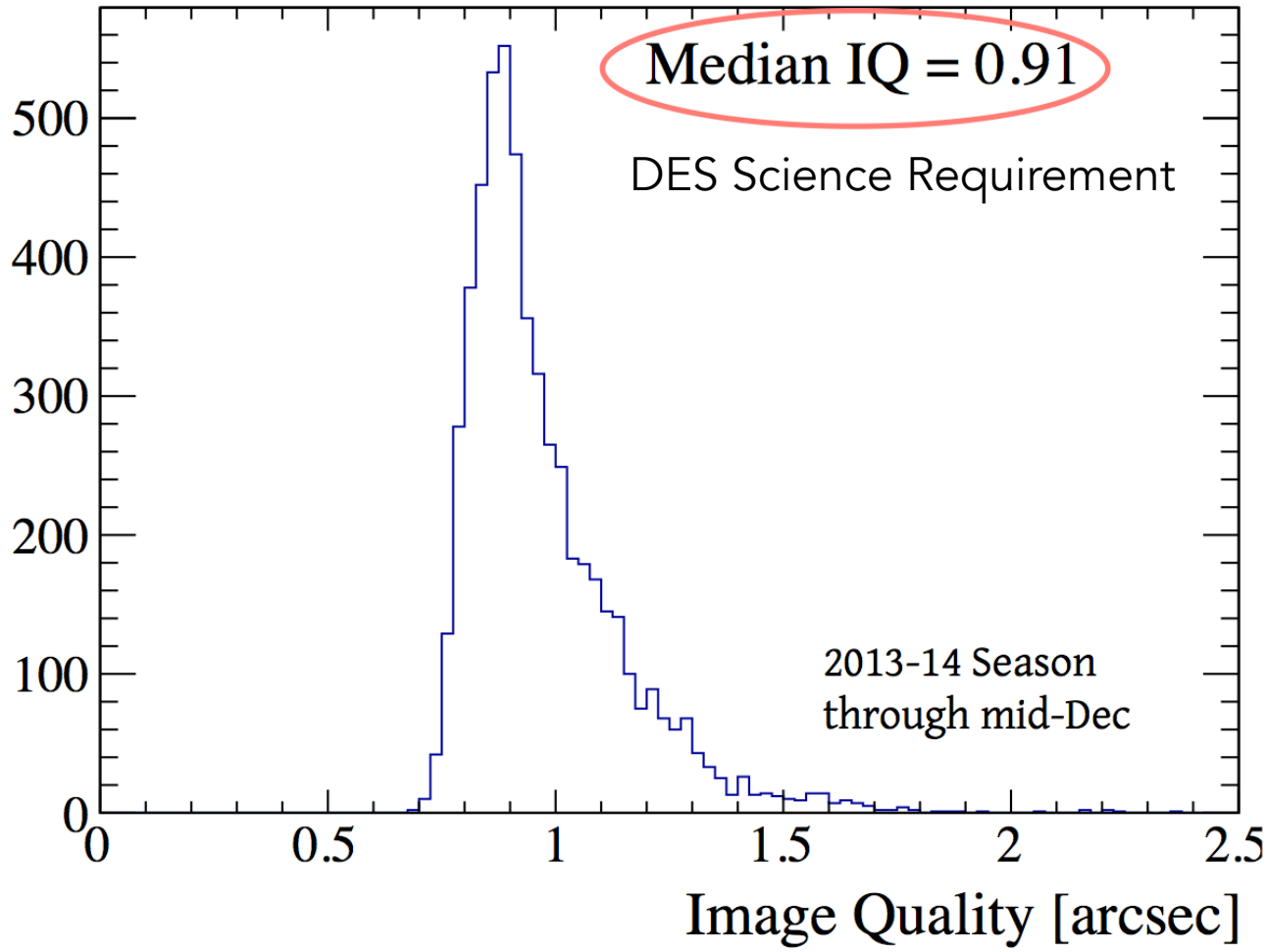
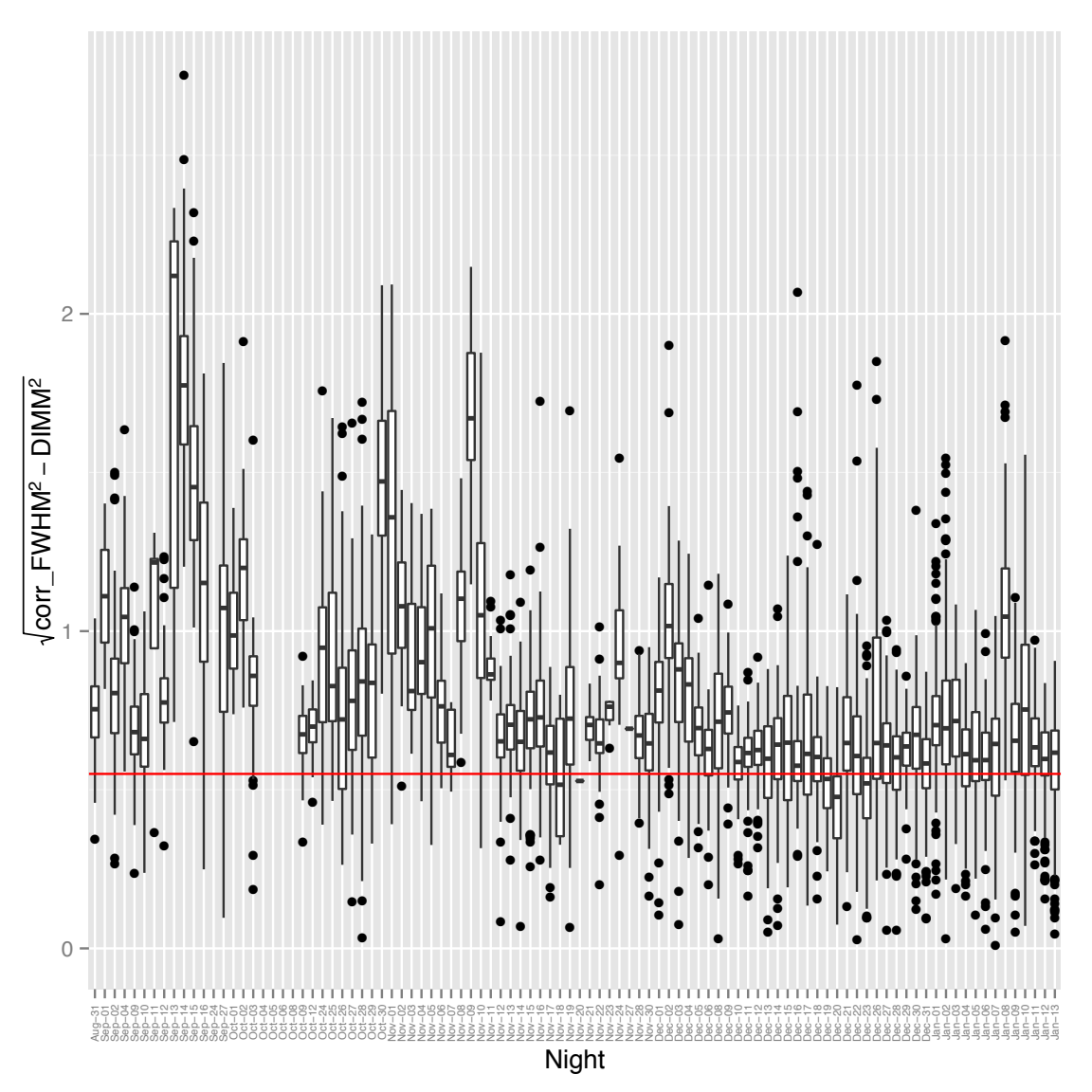


Image Quality

Non-atmospheric contribution (e.g., dome seeing, CCD diffusion, optics) to PSF FWHM

Compare DECam to site-seeing monitor (DIMM)

Better, more stable since mid-Nov.



E. Neilsen

- DES started survey operations Aug. 31!
- Science analysis of DES Science Verification data underway, first papers expected in coming months
- First Season (Year 1) now winding down
  - Operational system (camera, observers, Data Management) working well
  - Planned improvements in telescope & efficiency tweaks for Year 2
- First Dark Energy results expected from first 2 seasons of data