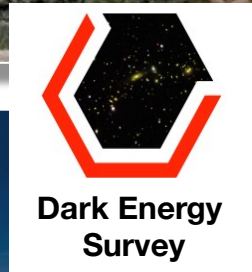
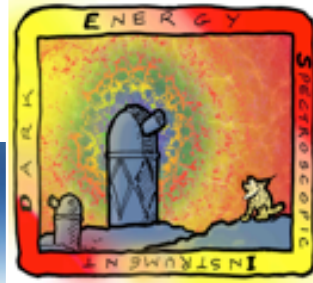
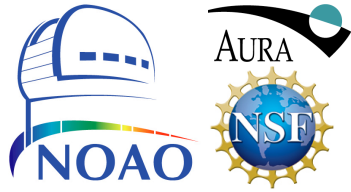




NOAO Transformed

David Silva, NOAO Director





NOAO Transformed: **Drivers**

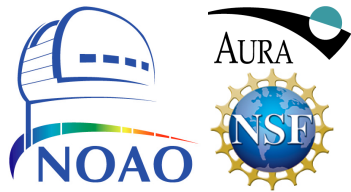
A Mission Unchanged → Enable Discovery

Advancing Astronomy
in the Coming Decade:
Opportunities and Challenges

Report of the National Science Foundation
Division of Astronomical Sciences
Portfolio Review Committee

August 14, 2012

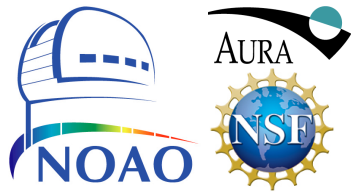
- You, the Community
 - NSF AST Portfolio Review (2012)
 - Evolving research topic priorities
 - Evolving research support needs (especially related to Big Data)
- Countdown to LSST era
- NSF programmatic & financial guidance



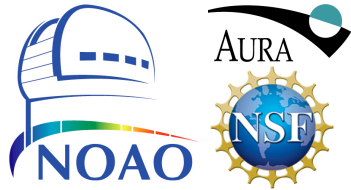
NOAO Transformed: **Outcomes**

A Mission Unchanged → Enable Discovery

- Base funding reduced → NOAO more lean
- New, deeper partnerships with DOE and NASA
- Open access, PI-class research retained (albeit reduced)
- Increased emphasis on public data from wide-field surveys
- Increased emphasis on data science services
- Path to LSST operations era
- **Resultant program is exciting and world-class**



NOAO Now



Open access to telescopes

New instruments on all platforms

- Gemini North 8.2-m
- Gemini South 8.2-m
- SOAR 4.2-m
- Blanco 4-m
- Mayall 4-m (until Aug 2017)
- WIYN 3.5-m
- SMARTS 1.5-m, 1.3-m, 0.9-m
- WIYN 0.9-m





Gemini 8.2-m telescopes

Under-used opportunity for USA

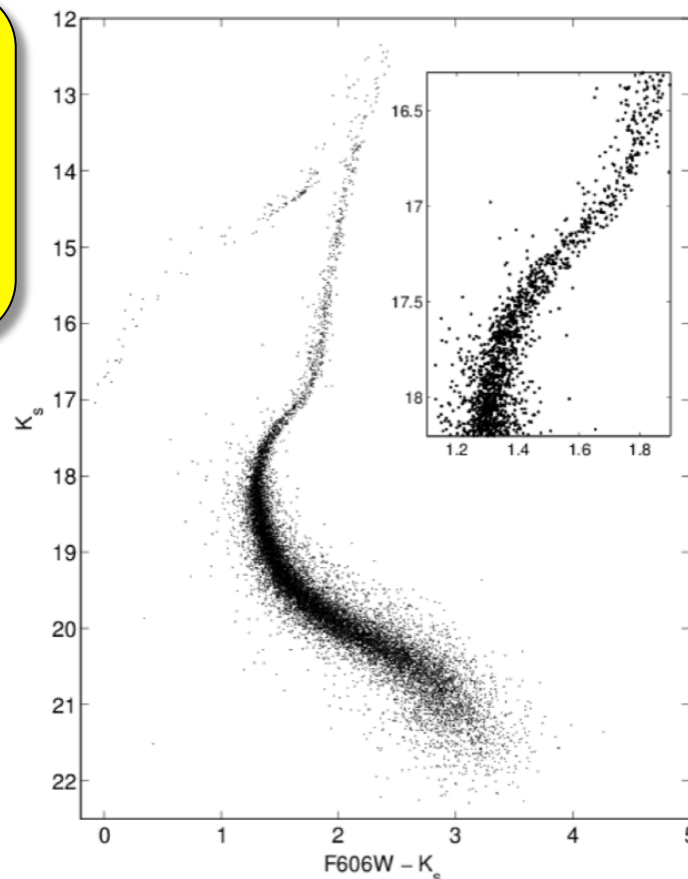
USA | 65% of time, **over-subscription** ~ 2
Excellent image quality
Queue and classical observing
As Mayall access declines, consider Gem-N

Available capabilities

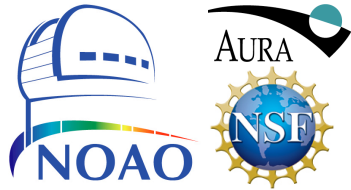
MCAO NIR imager (world-best) (S) →
ExAO NIR coronagraphic (world-best) (S)
→ Imaging and spectroscopy

Optical, multi-mode instruments (N/S)
→ Imaging, long-slit, MOS

NIR spectroscopy (medium & echelle) (N/S)
NIR imager (N)
NIR IFU spectroscopy (N)



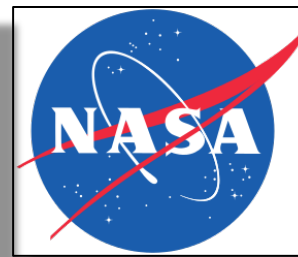
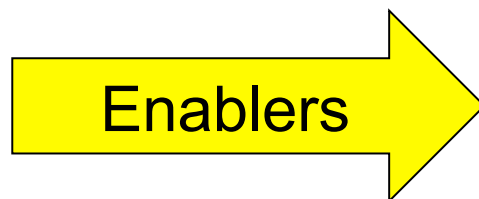
NGC 1851, Turri et al. 2016
Arxiv 1509.01764
0.09" PSF K-band



NOAO 4-m Class Telescopes

World-class scientific leadership continues

- Wide-field surveys (small, medium, large)
 - DECam @ Blanco, Mosaic-3 @ Mayall, pODI @ WIYN
 - DESI @ Mayall ([coming...](#))
- Exoplanet mass determination
 - Extreme Precision Doppler Spectrometer (EPDS) ([coming...](#))
- Exoplanet host stellar system characterization
 - General purpose spectrographs @ all 4-m telescopes
 - GLAO imaging @ SOAR
- Time-domain exploration and survey follow up
 - General purpose imagers & spectrographs @ all 4-m telescopes

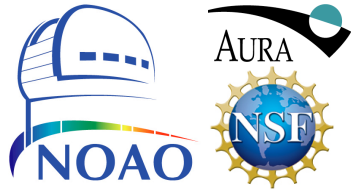




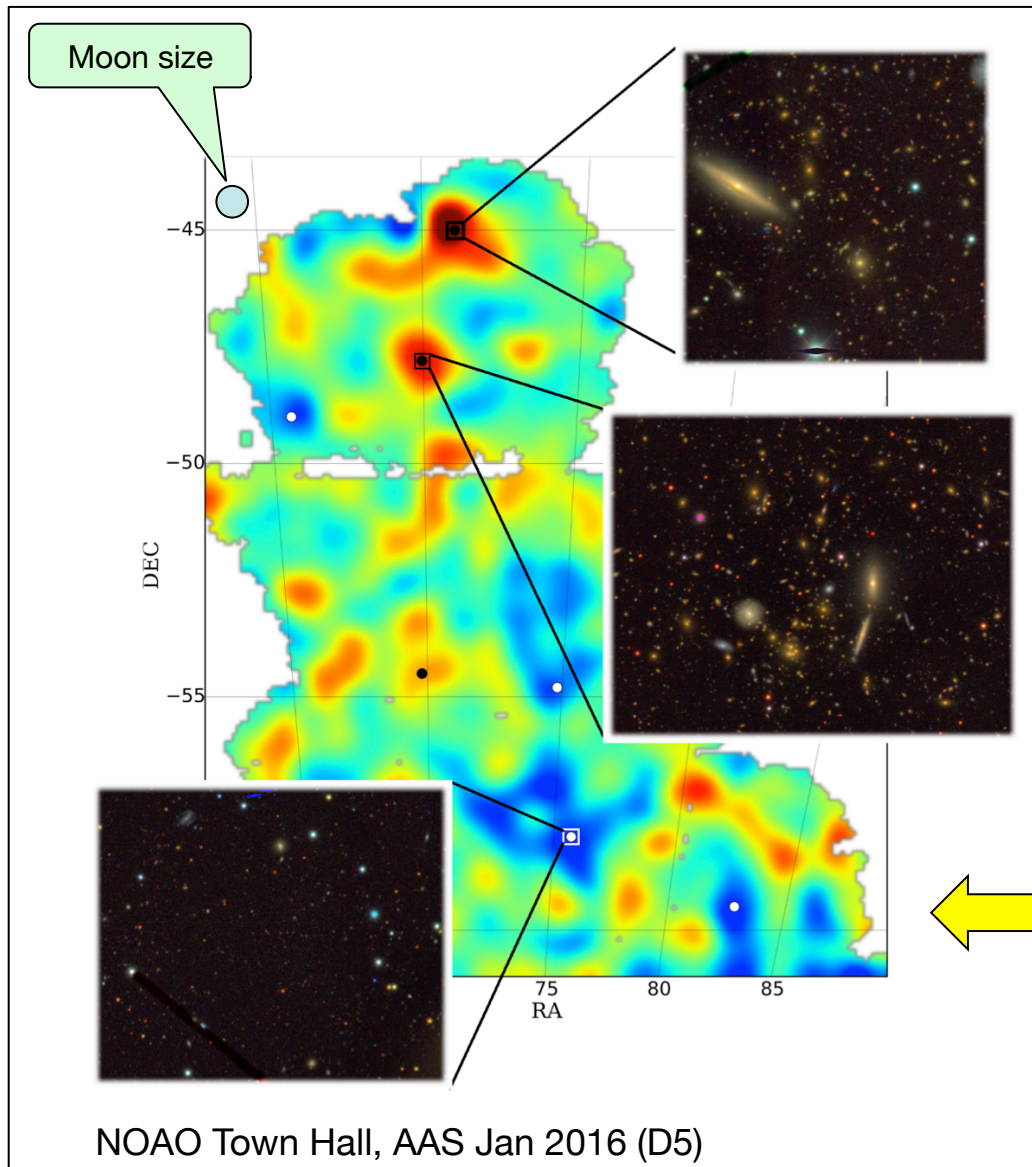
DECam @ CTIO Blanco 4-m Dark Energy Camera

3 sq. deg FOV, 520 Mpix
Lifetime (minimum) = 2013 – 2022





Wide-Field Lensing Mass Maps from DES Science Verification Data



Projected mass distribution
Weak lensing (“shear”)
Mass peaks → red
Mass voids → blue
Circles = observed clusters

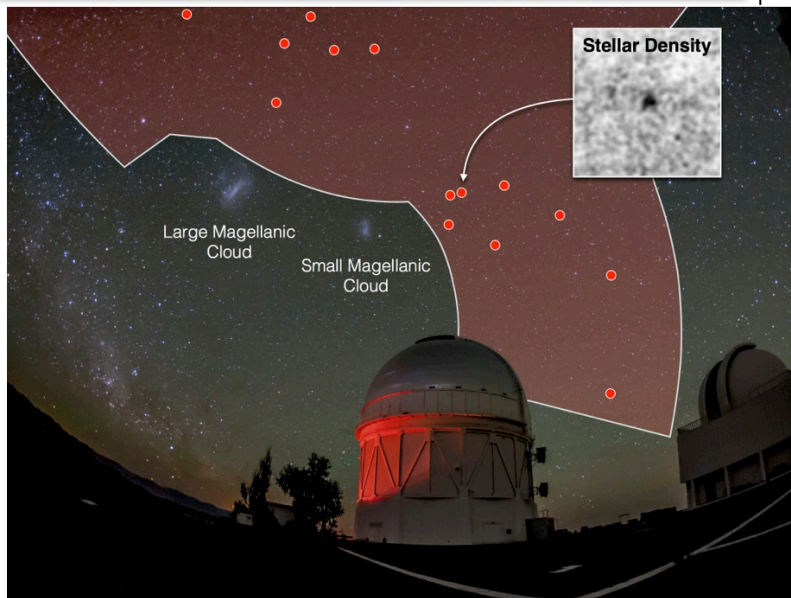
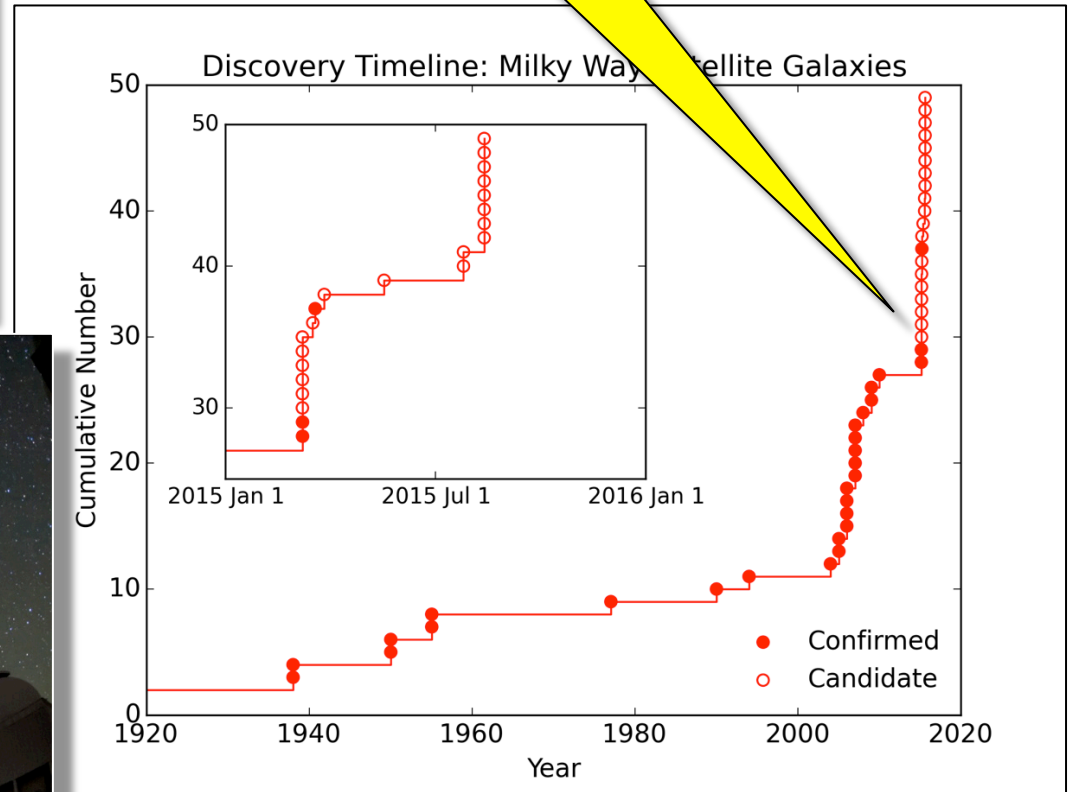
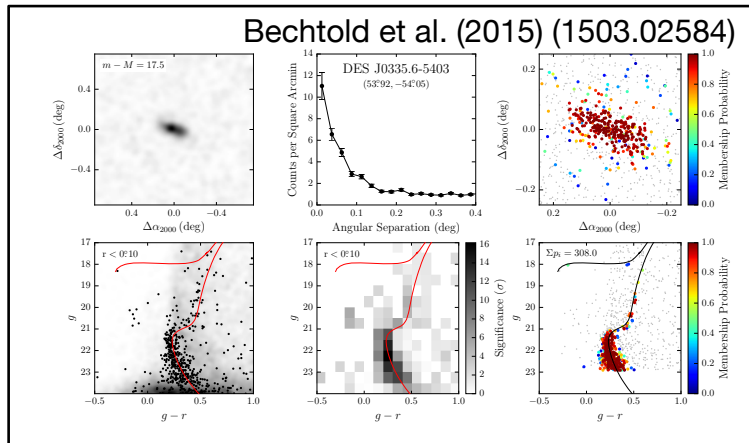
Only 3% of total DES area

Vikram et al. 2015
arXiv:1504.03002

Major technical triumph:
Image size and stability

New dwarf galaxies near Milky Way

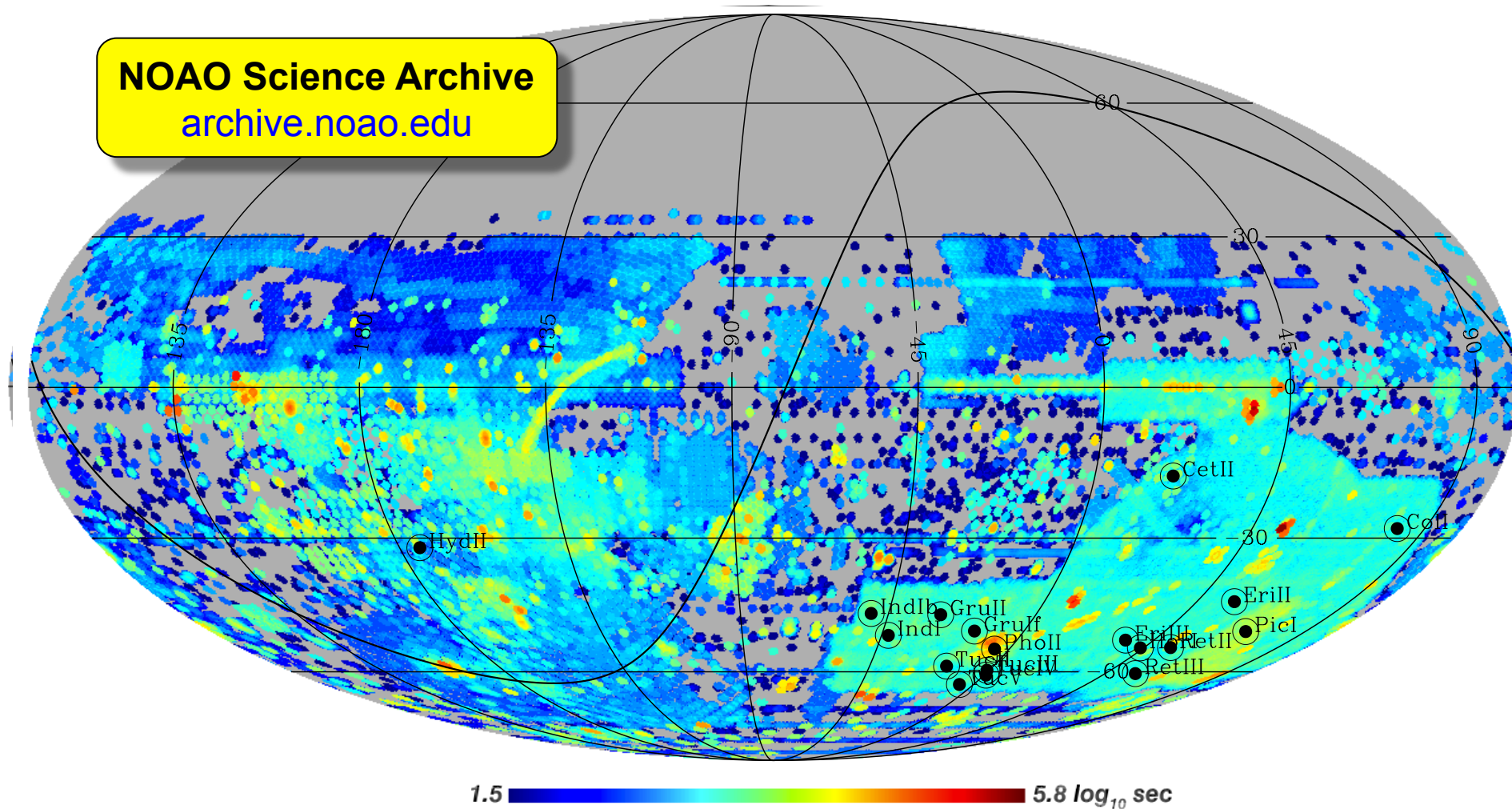
DECam era

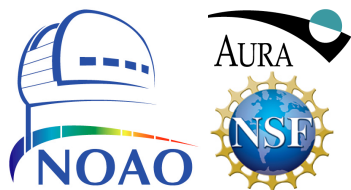


DECam images, 2015 June

Available to you!

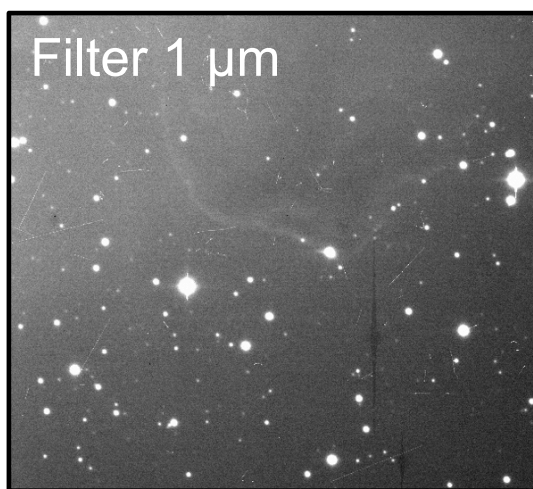
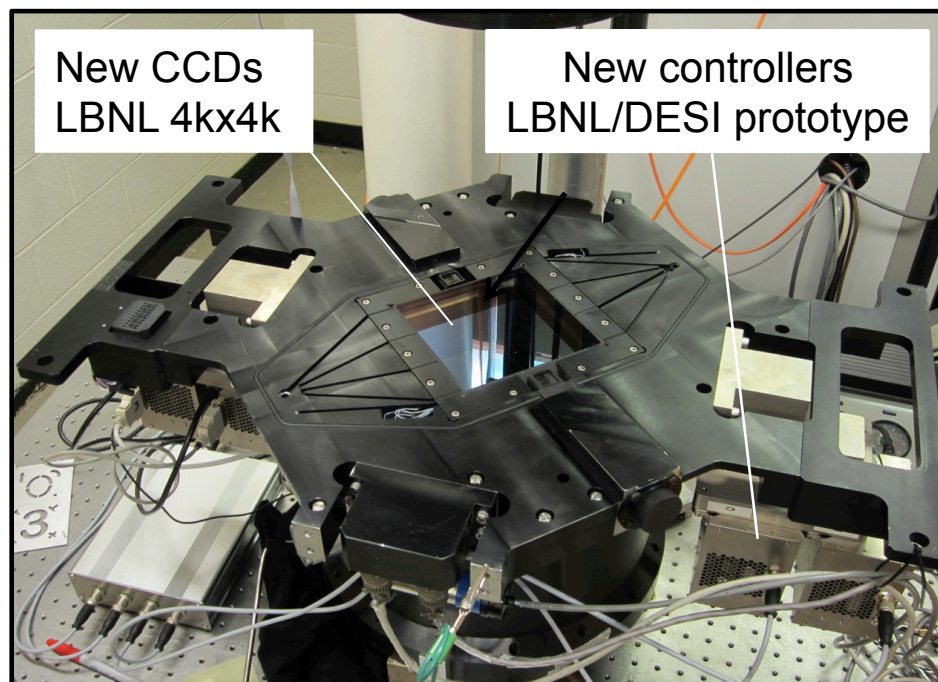
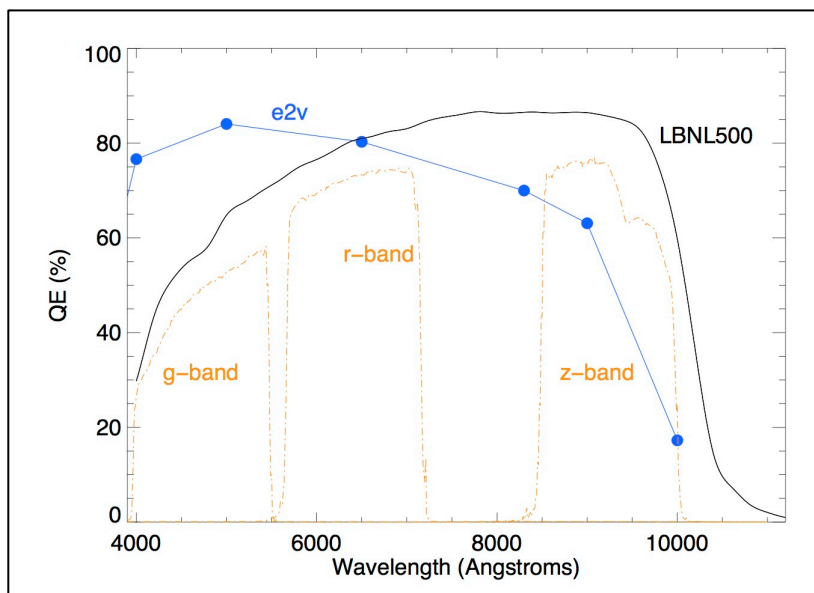
NOAO Science Archive
archive.noao.edu





Mosaic-3 @ KPNO Mayall 4-m DESI, Yale, NOAO collaboration

8K x 8K (64 Mpix) \rightarrow 36 x 36 arcmin
500 μ m thick LBNL deep-depletion CCDs



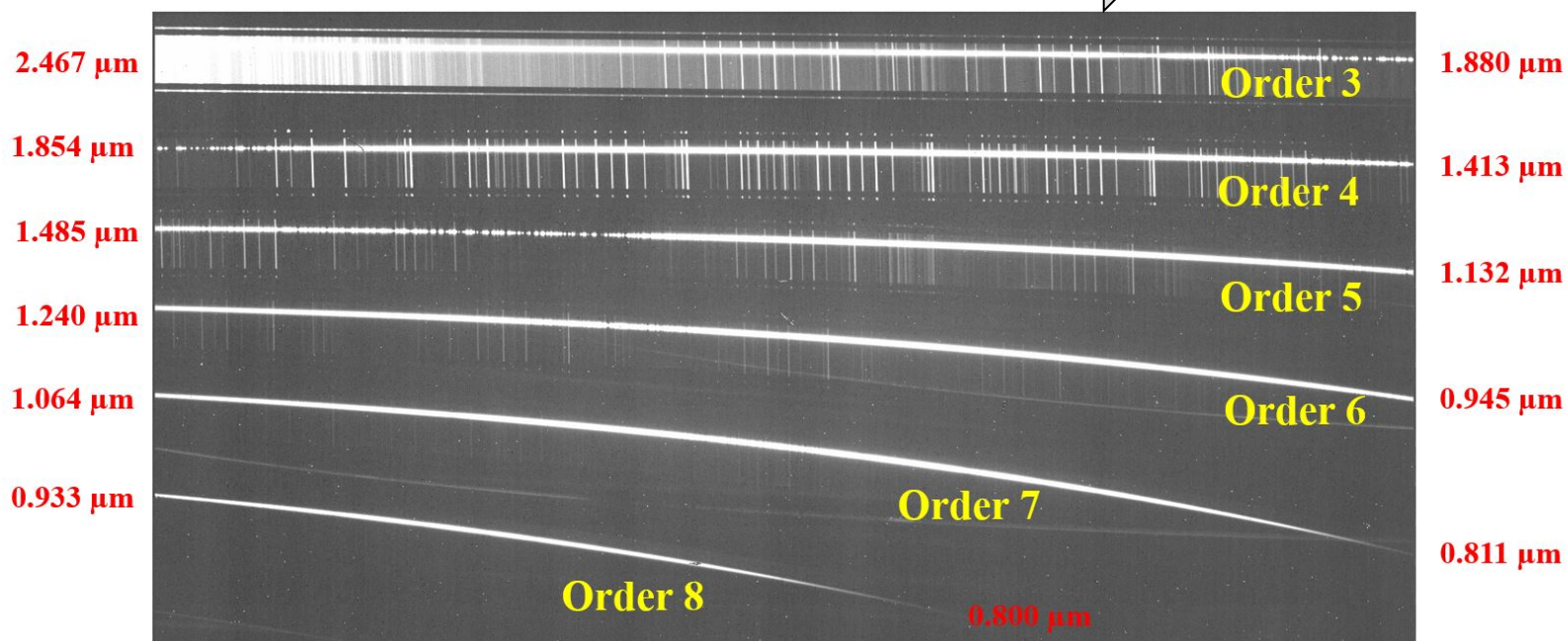


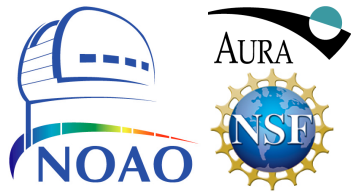
ARCoIRIS @ Blanco 4-m AKA TripleSpec-4

Long-slit NIR spectrometer
Cross-dispersed (0.8 – 2.5 μm)
Fixed slit format, $R \sim 3500$
Built by Cornell, funded by NSF



Image via S. Shields (Cornell) Twitter feed





ODI @ WIYN 3.5-m

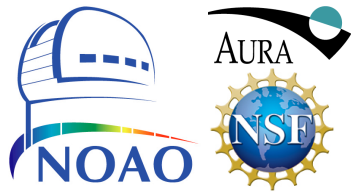
Upgraded → 48 x 40 arcmin

Available filters: u' , g' , r' , i' , z'

Median image quality: r' ~ 0.7 arcsec

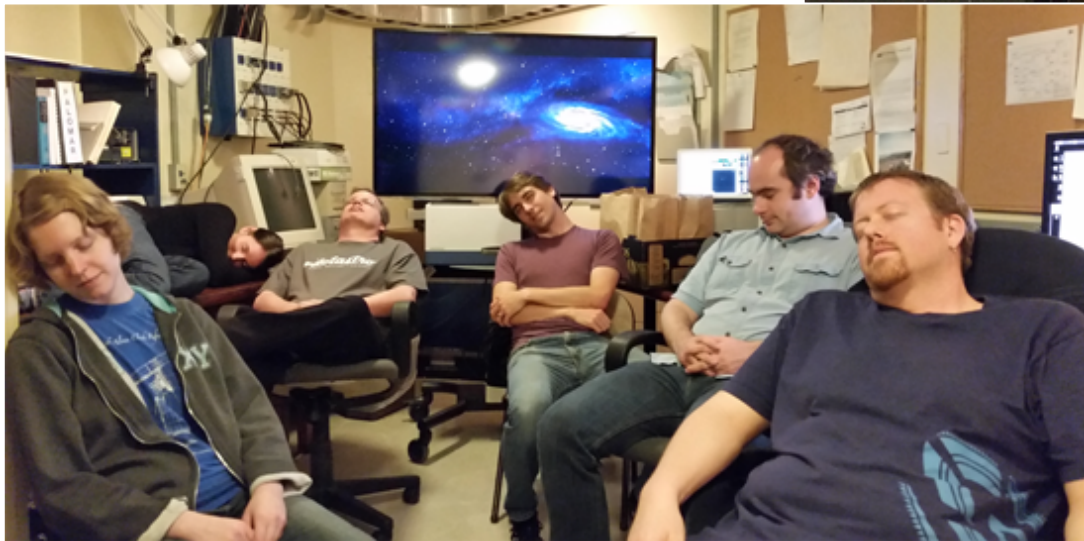
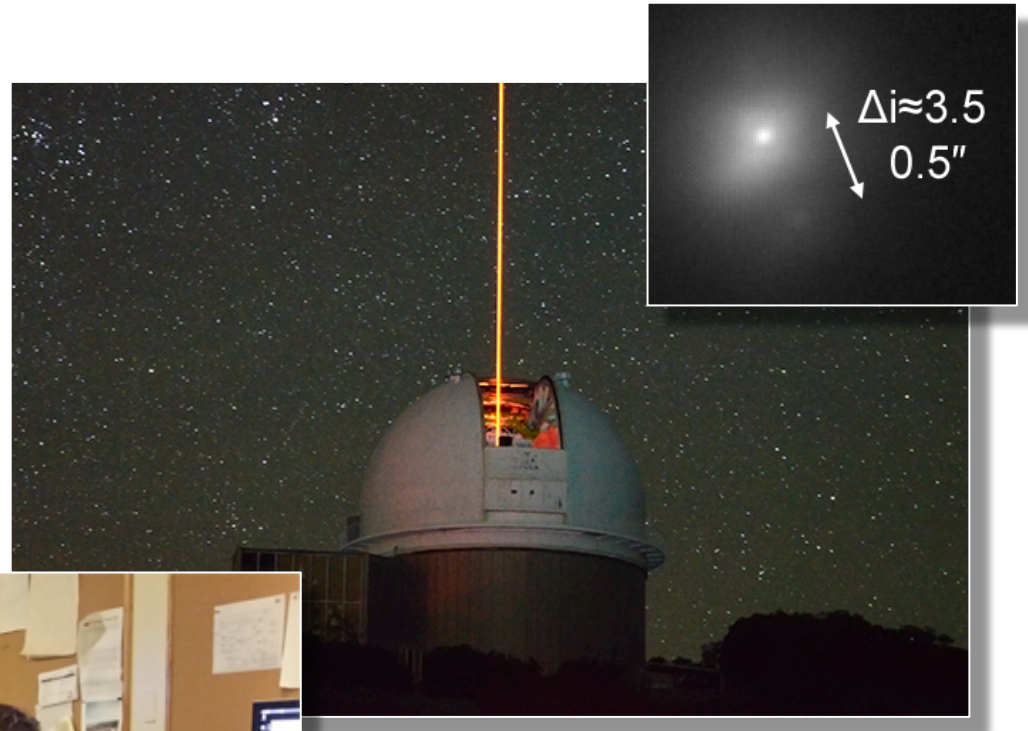
On-line pipeline available





Robo-AO @ KPNO 2.1-m

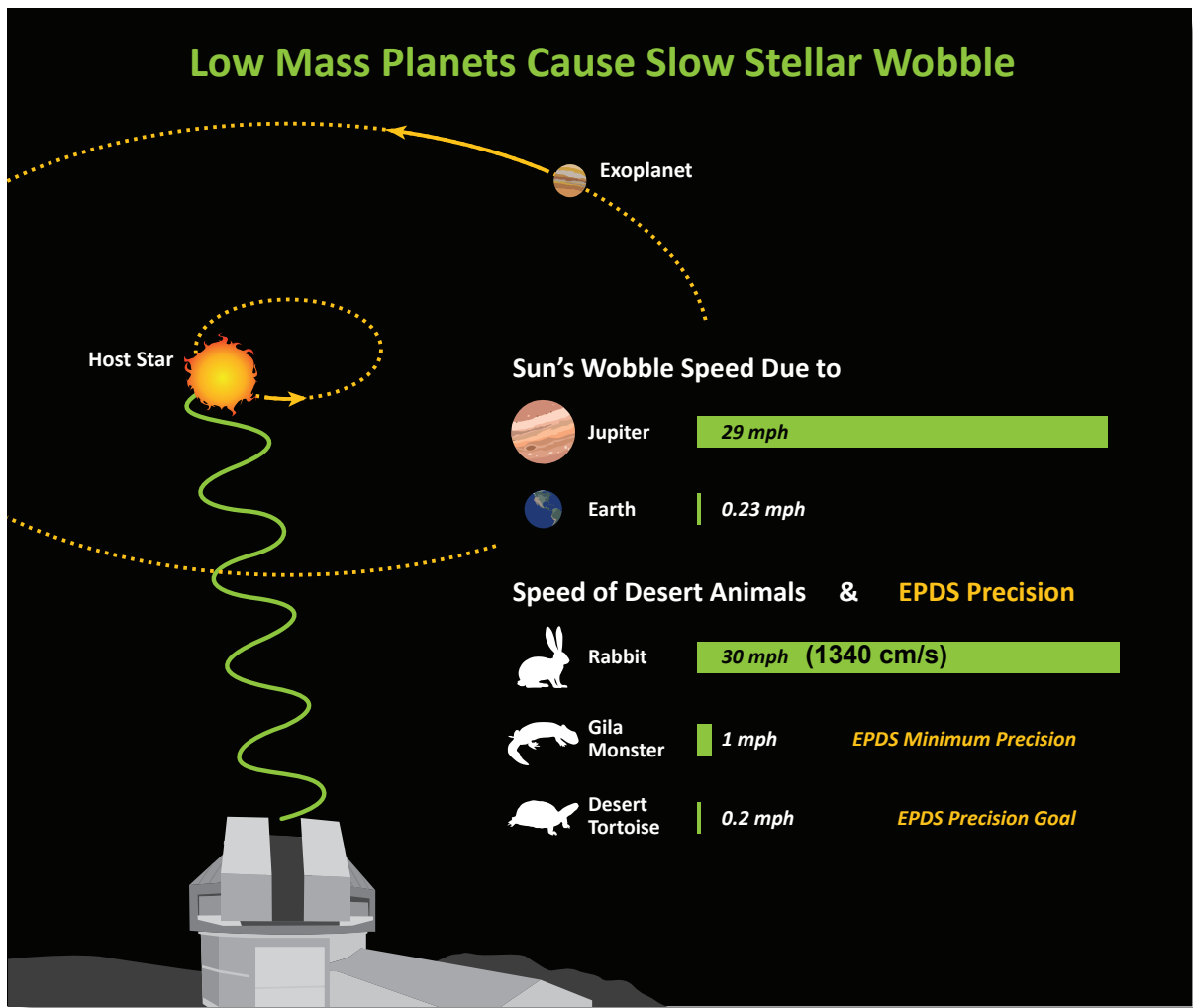
Robotic laser SCAO system
Many objects per night!
FWHM, $r \sim 0.1$ arcsec
NIR camera coming...
Caltech/Hawaii team
[Public access](#)



NOAO Town Hall, AAS Jan 2016 (D5)



EPDS @ KPNO WIYN 3.5-m Extreme Precision Doppler Spectrometer



Mission
Determine masses of Earth-like planets found with (e.g.), K2 and TESS

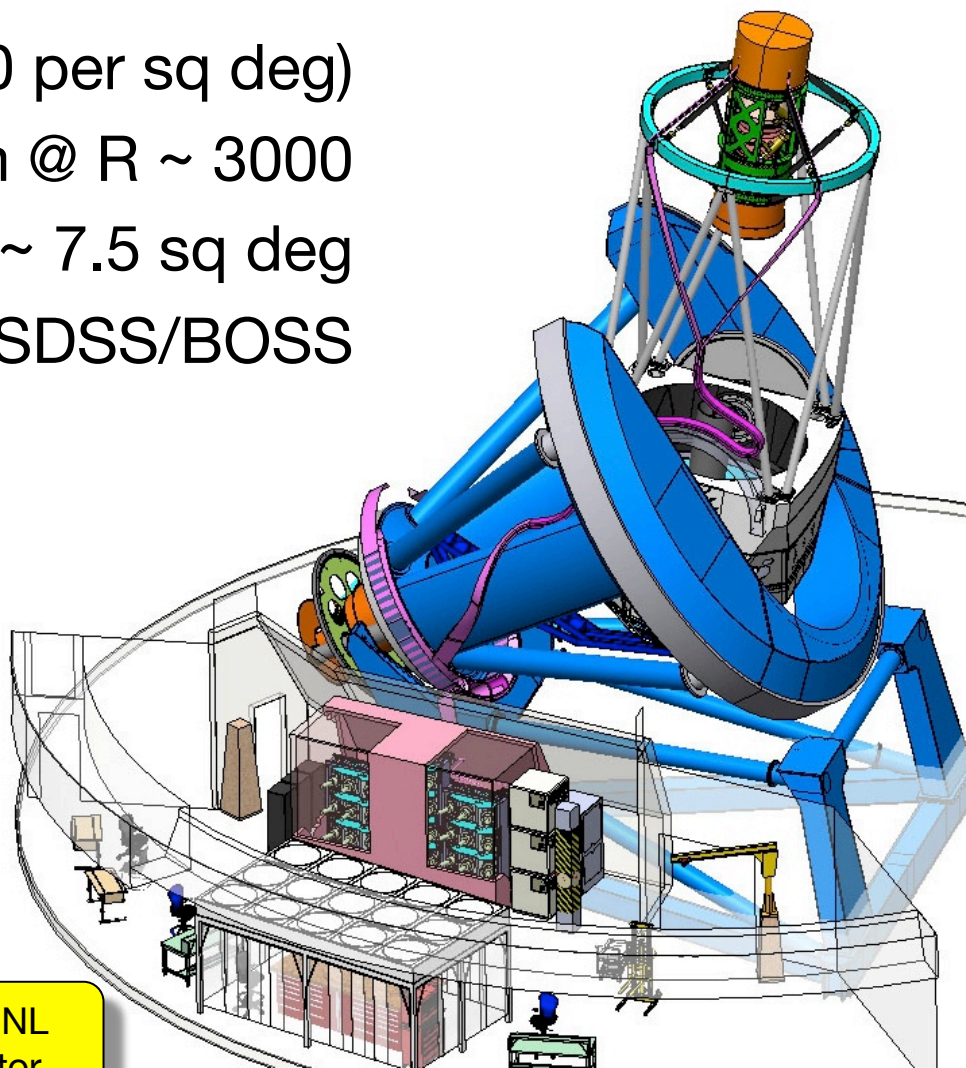
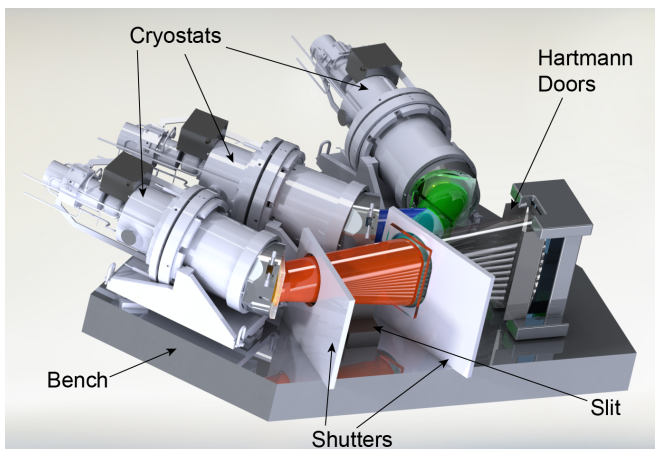
Requirement: < 50 cm/s
Goal: ~ 10 cm/s

NN-EXPLORE Program
NASA NSF Exoplanet Observational Research



DESI @ Mayall 4-m Dark Energy Spectroscopic Instrument

5000 fibers (~ 700 per sq deg)
0.36 – 0.98 μm @ $R \sim 3000$
Field-of-view ~ 7.5 sq deg
Much inherited from SDSS/BOSS



Images: M. Levi, LBNL
DESI Project Director



DESI Key Experiment Dark Energy Characterization

Five target classes spanning redshifts $z=0 \rightarrow 3.5$.
~34 million redshifts over 14,000 sq. degrees (baseline survey).

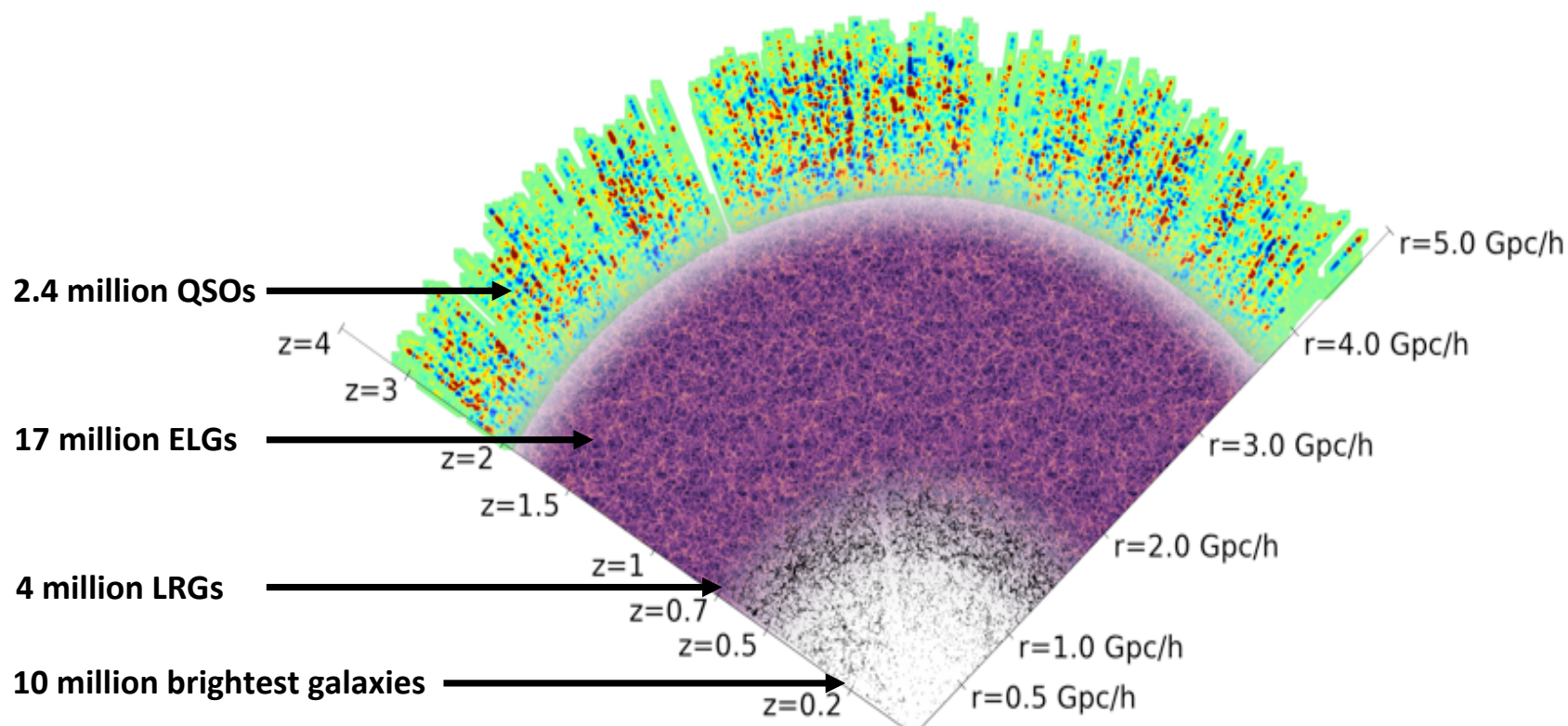
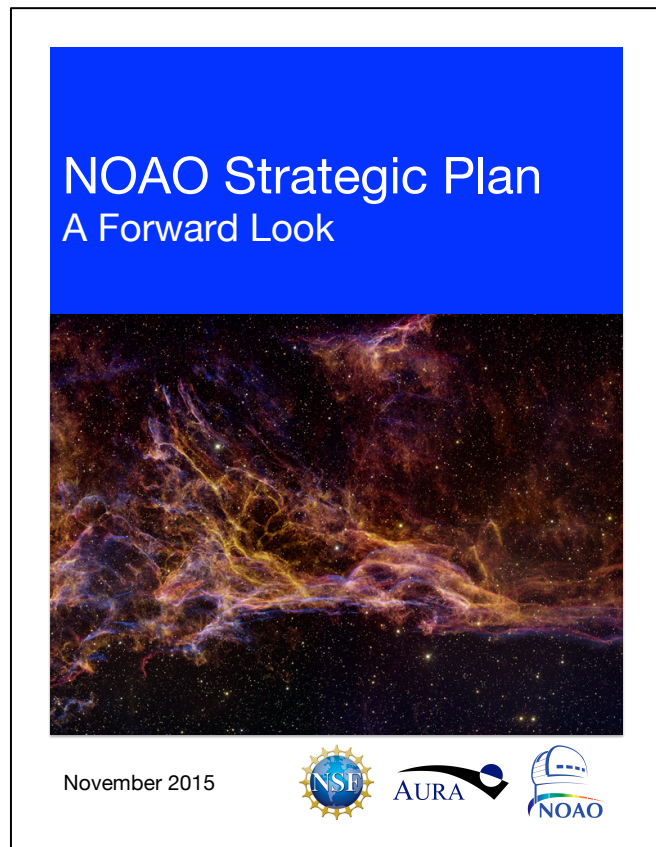
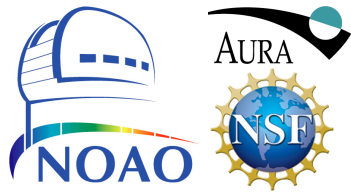


Image credit: A. Slosar & D. Schlegel, via R. Wechsler



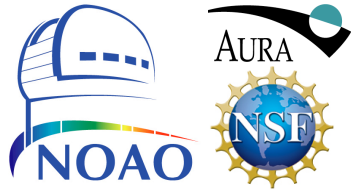
DESI, beyond cosmology

- All data products will be public
 - Targeting survey: images and catalogs
 - Spectra: 33M galaxies + 10M stars
- Public bright time program (2019 – 2023)
 - 500 bright-time hours available for community access
 - Program details under development
 - Watch for Announcement of Opportunity
- Community spectroscopic surveys (2024++)
 - DESI @ Mayall availability not yet guaranteed
 - May require significant non-Federal funding support
 - Decision deferred for several years



Strategic Initiatives Towards 2020 and beyond

Coming soon...

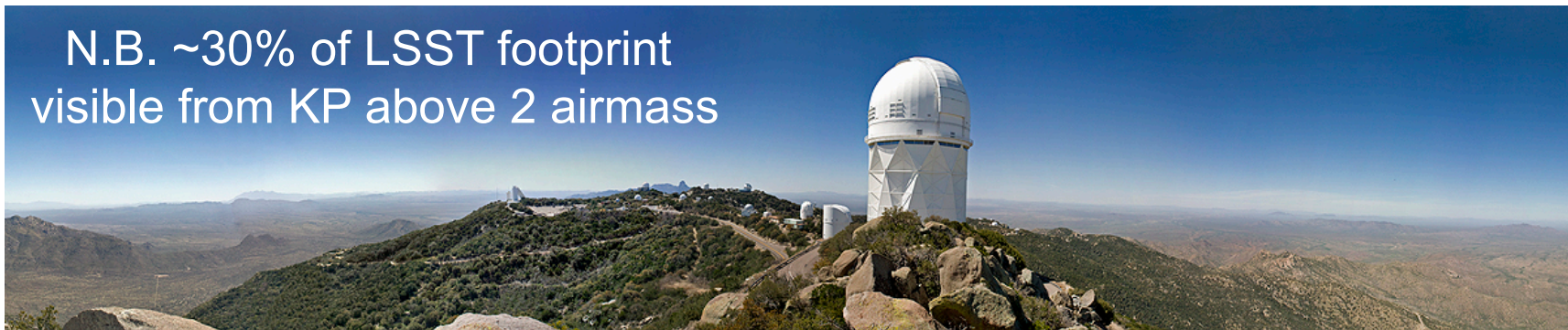


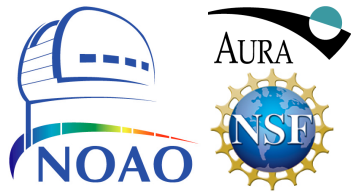
Observational research infrastructure: To 2030 and beyond

- Cerro Tololo, Cerro Pachón, Kitt Peak
- Viable for **decades** into the future for Federal & non-Federal facilities
- Objectives
 - Continuous maintenance & modernization
 - Continuous adaptation to new scientific missions (e.g., **LSST research support & follow up**)



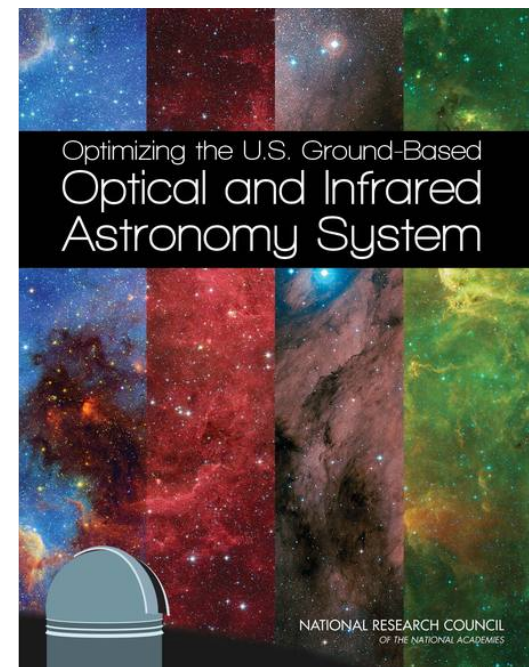
N.B. ~30% of LSST footprint visible from KP above 2 airmass

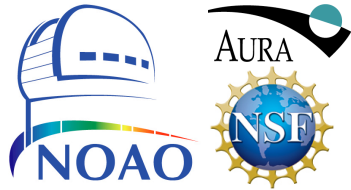




OIR System Optimization

- 2015 NRC Report recommendations for NOAO
 - Develop / administer new processes for telescope time exchanges
 - Enable community-wide System capability planning
 - *Other recommendations also impact NOAO directly and indirectly (e.g., LSST research support services)*
- First concrete step
 - **Community study** on maximizing LSST science return (**next slide**)
- Next steps
 - Depends on NSF funding, directives



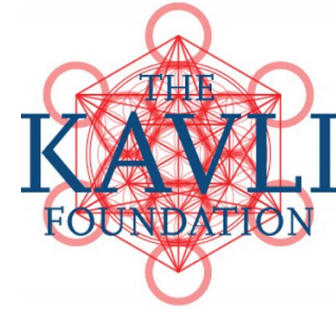


Maximizing Science in the Era of LSST

A Community-based Study

<http://www.noao.edu/meetings/lsst-oir-study>

- **Goal**
 - Quantify & prioritize supporting capabilities needed by you for your LSST research (instruments, modes, data tools, etc.)
- **Why**
 - Influence funding prioritization (public & private)
 - Influence observatory planning (federal and non-federal)
- **How You Can Participate (Deadline: 15 Jan 2016)**
 1. Describe your LSST-enabled science goals and supporting capabilities you require to achieve those goals
 2. If interested in deeper involvement, volunteer for study group
- Co-sponsored by LSSTPO and NOAO
- Endorsed by NSF, funded by the Kavli Foundation





Premier survey data products

Current projects

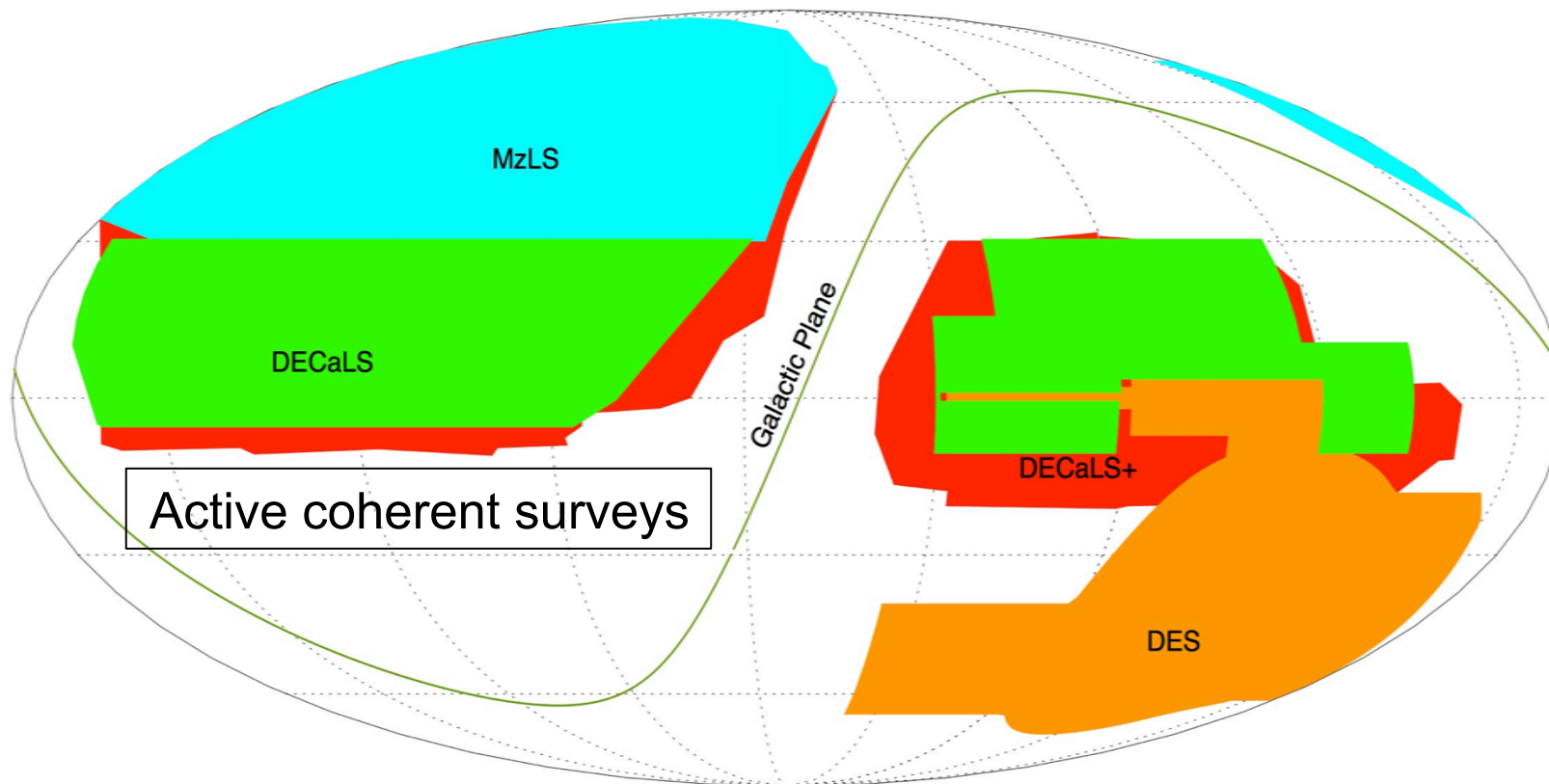
- Dark Energy Survey (DES)
 - DECam @ Blanco, 2012 - 2017
 - 5000 sq deg, *grizY*, $r \sim 26$
 - Deep fields, $r \sim 28$
 - Overlaps many VISTA NIR surveys
- DECam Legacy Survey (DECaLS)
 - DECam @ Blanco, 2014 - 2018
 - 9000 sq deg, *grz*, $r \sim 24$
 - SDSS/Pan-STARRS overlap, **much deeper**
- Mayall z-band Legacy Survey (MzLS)
 - Mosaic-3 @ Mayall, 2016 - 2017
 - 5000 sq deg, *z*, $z \sim 23$
 - SDSS/Pan-STARRS overlap, **much deeper**



Data science tools and services

Challenge: mega-object catalogs

- 100s of millions of astronomical objects
- 10s of billions of measurements
- **Needed: catalog research support services**



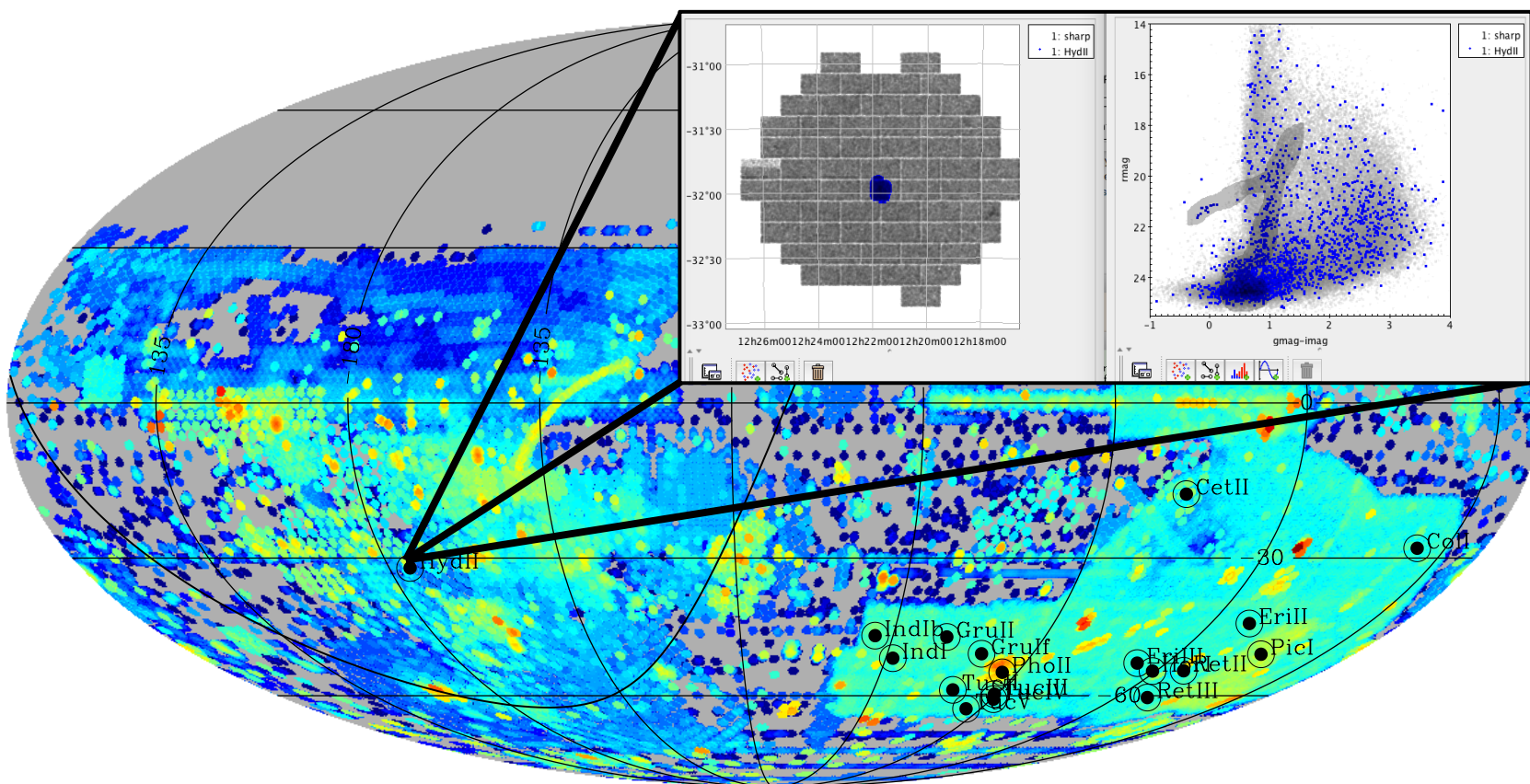


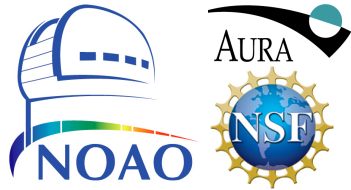
Data science tools and services

Solution: NOAO Data Lab

Enable exploration, visualization and analysis
Enable processing at image cutout level
Provide collaborative workspaces

Under development
2016 Jun: AAS demo
2017 Aug: Public release



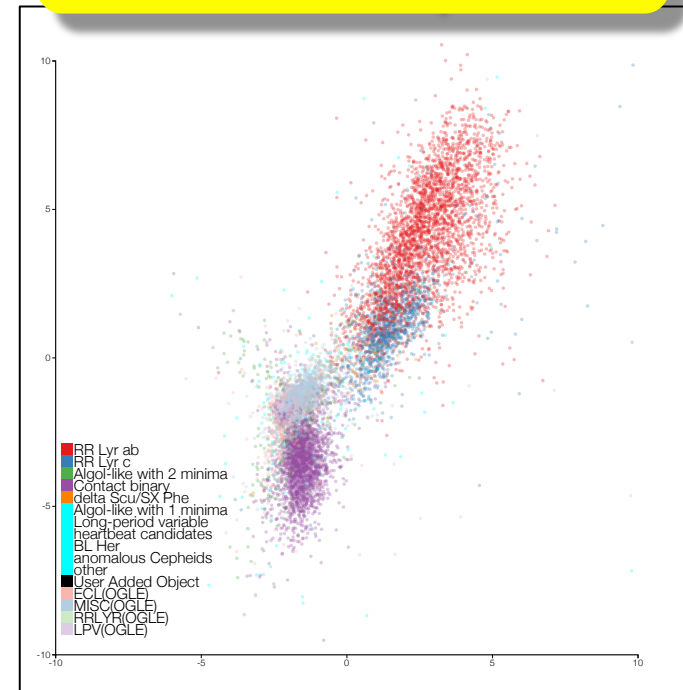


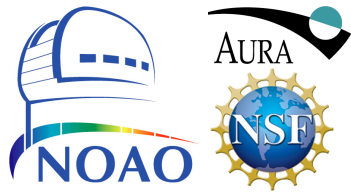
Data science tools and services

Challenge: time-domain alert flood

- Examples
 - ZTF (2018) $\rightarrow 10^5$ events per night
 - LSST (2023) $\rightarrow 10^7$ events per night
- Solution \rightarrow **ANTARES**
 - Arizona-NOAO Temporal Analysis and Response to Event System
 - National service with user plugins in era of LSST
 - Parse events into increasingly narrow bins, concluding with “rarest of rare”
 - Broadcast classifications (“add value”)
 - First public release: 2018

Time-domain feature space
PCA-based separation



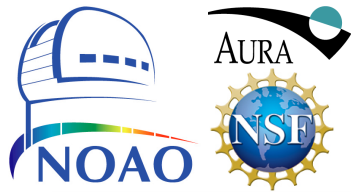


LSST operations and community research support



Strategic objectives

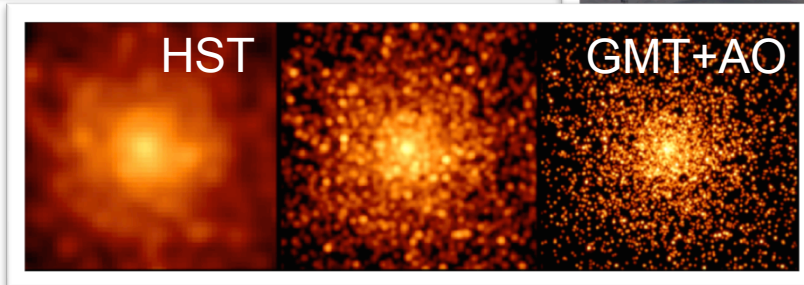
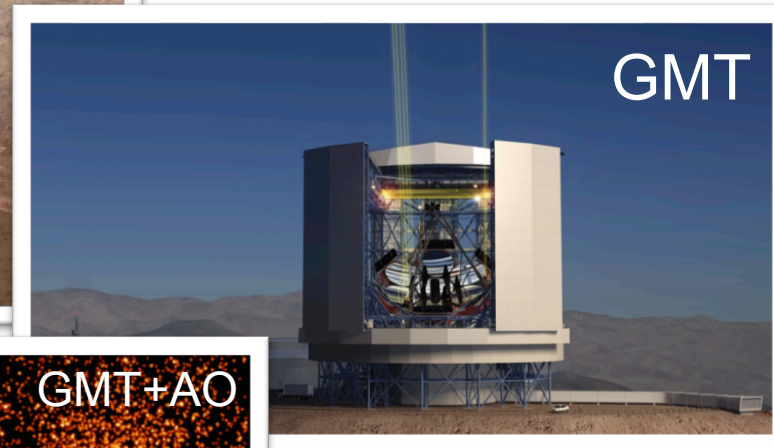
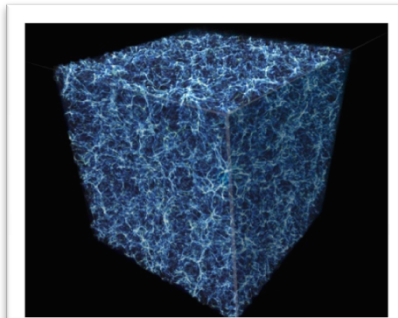
- Major partner within end-to-end LSST system operations
- Center for community research support
 - SLAC = dark energy, **NOAO = other**
 - Follow up observations → NOAO facilities (North and South)
 - Data science services (Data Lab, ANTARES, etc.)
 - Gateway to Gemini, US federal & non-federal observatories

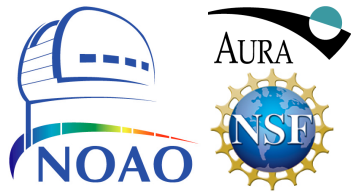


GSMT operations and community research support

Strategic objectives

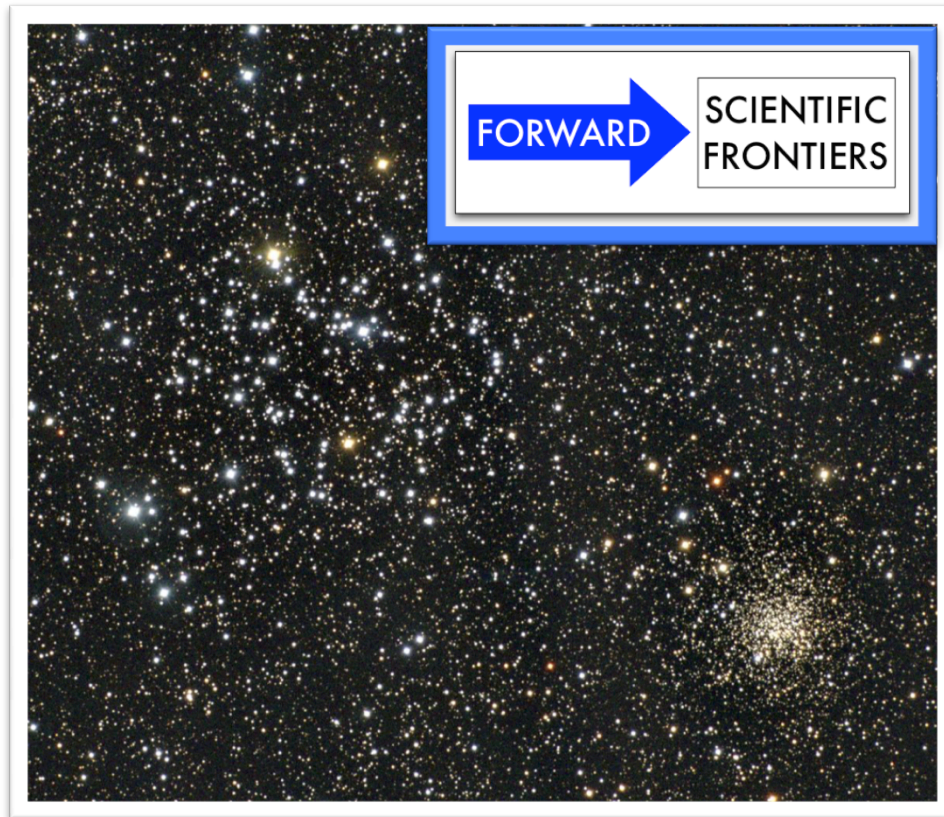
- Federal interface = NOAO
- Data operations support
- Community research support
- Instrument consortia participant
- Engage public





Beyond LSST and GSMT

Community discussion facilitator

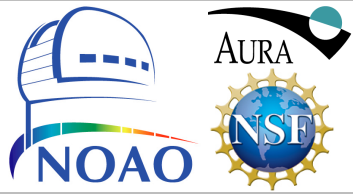


NOAO incubated Gemini, LSST, and GSMT (and played major roles in DES/DECam and DESI).

So...

What are the Next Big Questions?
What are the Next Big Projects?
Is there a Next Big Machine?

NOAO looks toward facilitating a community-based discussion



NOAO

Enabling discovery today
Working to enable discovery tomorrow

