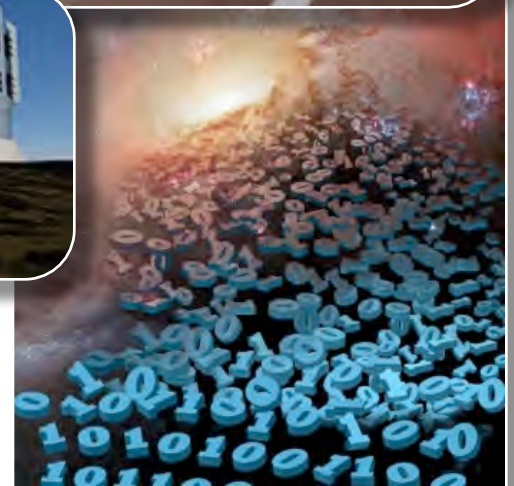




NOAO Forward

Robert Blum, NOAO Deputy Director





NOAO Forward, Program Status

A Mission Unchanged → Enable Discovery

- Ongoing, deeper partnerships with DOE and NASA



- Open access, PI-class research on world best facilities
- Increasing emphasis on public data sets from wide-field surveys
- Active emphasis on data science services
- Emerging, more defined path to LSST operations era
- **Current program is exciting and world-class**



NOAO Current Program

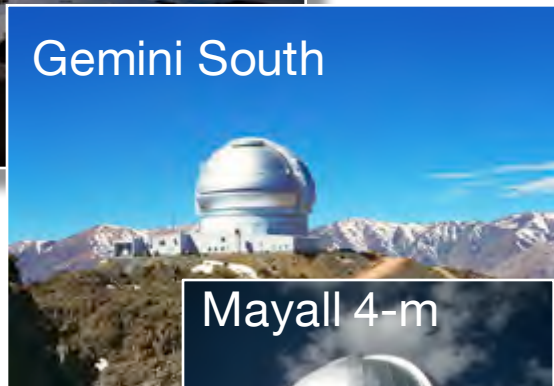
Three Mountains

- Tololo
 - Mix of survey and PI science
 - Open access platforms
- Kitt Peak
 - Collaborations to drive new science opportunities
 - New communities
- Third Mountain Top
 - Data sets
 - Data tools and access
 - Community development
 - Coordination and access across OIR system



Open access to telescopes 350+ nights on all platforms for 2017B

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

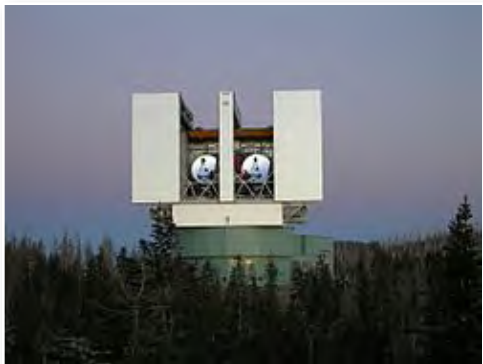




Open access to telescopes

Community access nights

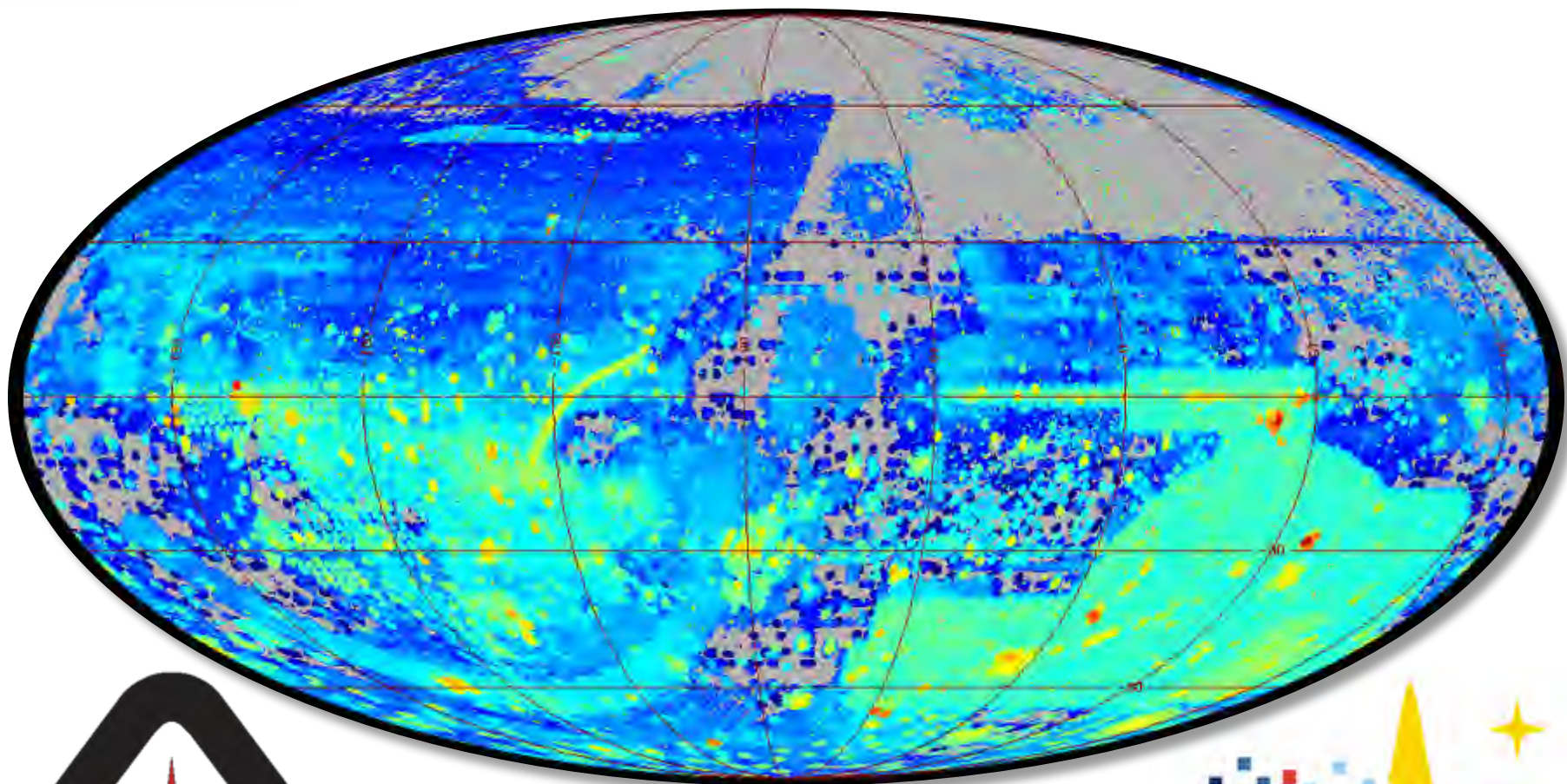
- TSIP/MSIP Programs (see Smith talk)
 - LBT (2017B+, 30 nights total)
 - Las Cumbres (100's hours per semester, 7 semesters)
 - Chara Array (50 nights/yr through 2020)



- Continuing access on time trades
 - Subaru 3 nights
 - AAT 5 nights



Open access to data
New data sets and tools



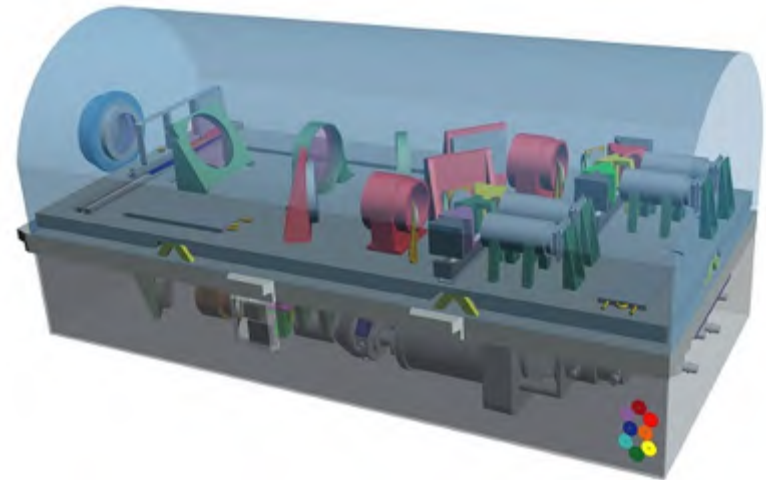
- DESI construction
- Mayall takedown in November
- NEID Construction
- SOAR STELES Delivered





Gemini 8.2-m telescopes Advances

- “PI” oversubscription ok, but can handle more demand (Long Large Program strong demand)
- Long Large Program well subscribed
- Visitor instruments welcome
- New Instruments
 - GHOST 2018
 - GPI to GN in 2018
 - OCTOCAM 2021





Program Highlight

NOAO Science

Cerro Tololo (see Heathcote talk)

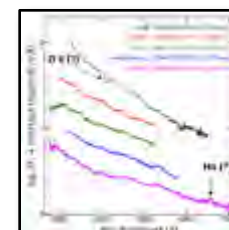
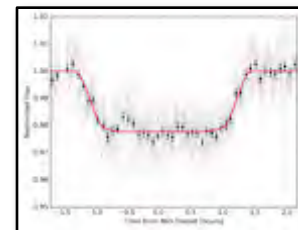
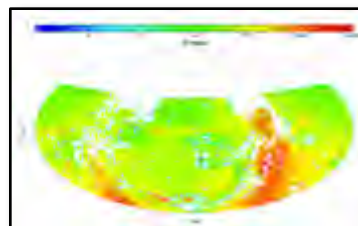
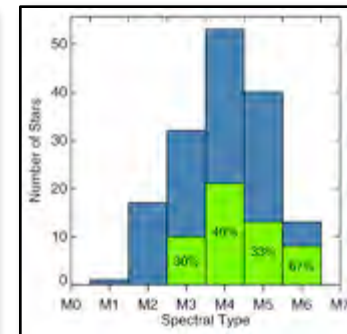
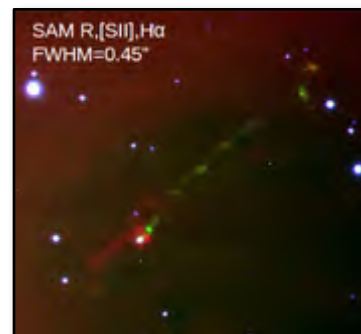
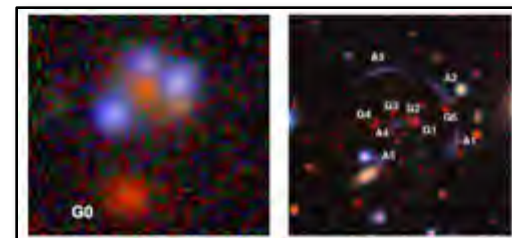
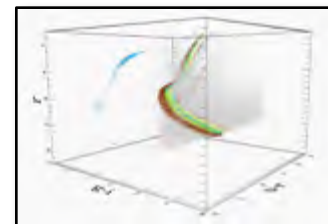
- DES: super luminous SNe, strong lensing, **first major cosmology papers coming soon**, TNO's, Omega Cen
- SOAR, transient follow up: ASASSN/Sne, first pc scale jet from brown dwarf

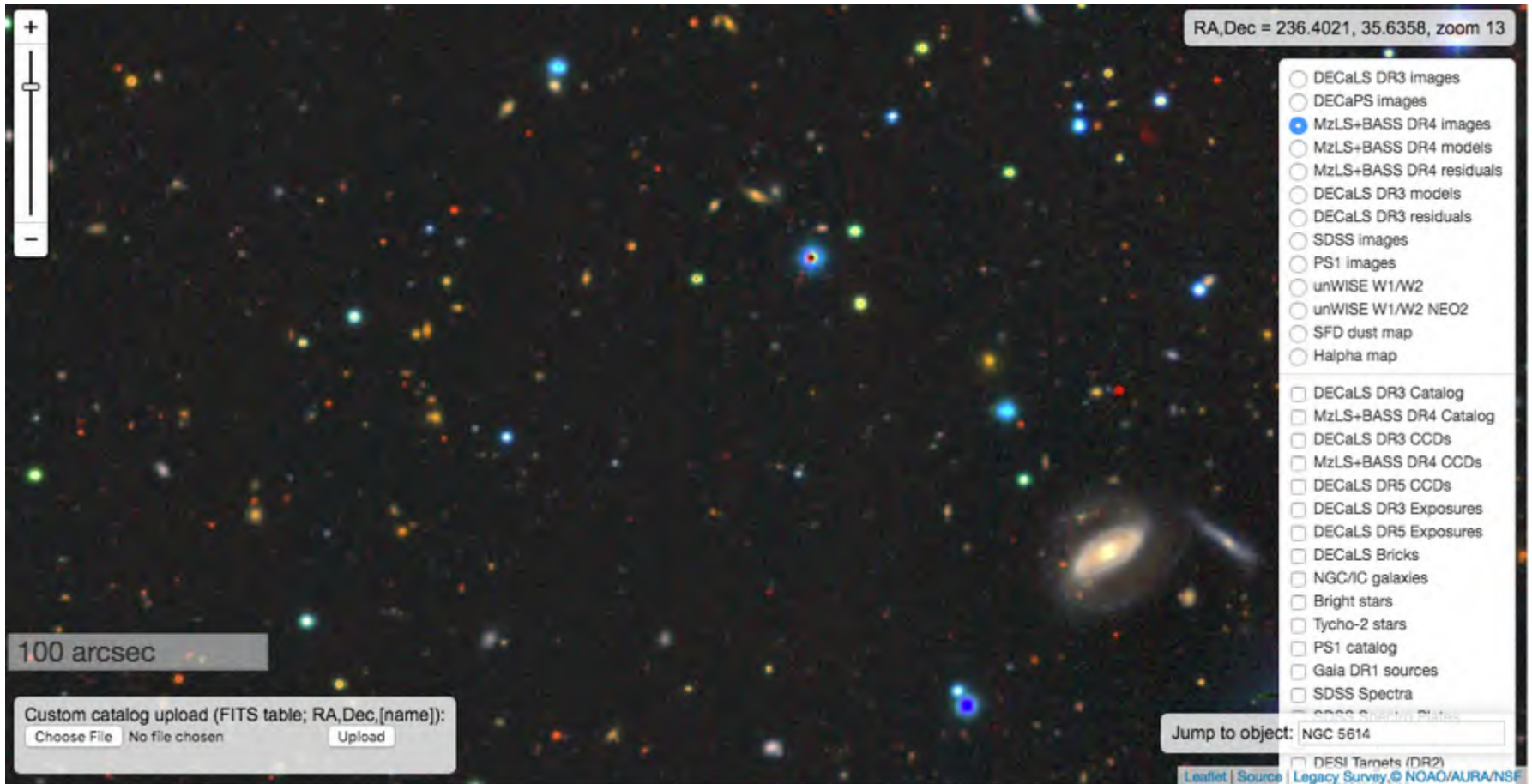
Kitt Peak (see Allen talk)

- Mayall -- The DAWN Survey, Rhoads+ (1.07 um NB survey, reionization, $z=7.7$)
- MzLS (public data with Bok 90 Prime)
- WIYN – NNEXPLORE M dwarfs in Kepler field, chromospheric activity (Hydra), Planet transits (WHIRC)

“Third Mountain Top” (see Norman talk)

- SMASH data release January 2017
- Data lab all sky catalog





Data release 4 imminent, first MzLS+BASS catalogs



Program Highlight

Premier surveys current status

Science Archive
archive.noao.edu

- Dark Energy Survey (DES)
 - DECam @ Blanco, Y4 complete, Y5.5 under discussion with DOE
 - 5000 sq deg, *grizY*, $r \sim 26$
- DECam Legacy Survey (DECaLS)
 - DECam @ Blanco, 50% complete, nights for 2017B – 2018B assigned
 - 9000 sq deg, *grz*, $r \sim 24$
- Mayall z-band Legacy Survey (MzLS)
 - Mosaic-3 @ Mayall, 75% complete
 - 5000 sq deg, *z*, $z \sim 23$
 - Combines w/BASS



OIR System Optimization & community development

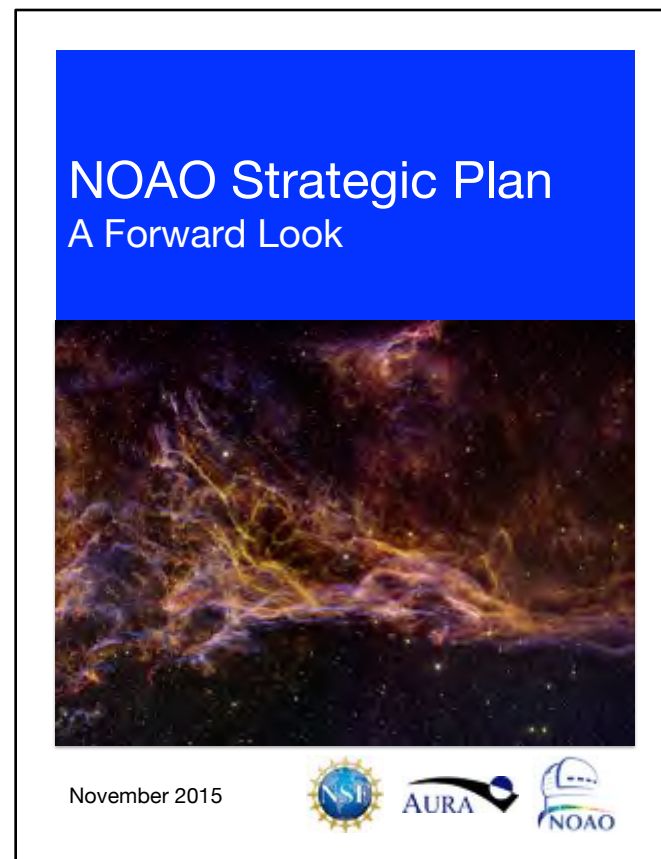
- 2015 NRC Report recommendations for NOAO
 - Develop / administer new processes for telescope time exchanges
 - Enable community-wide System capability planning
 - LSST research support services and activities
- Current activity
 - Community study on maximizing LSST science return (Najita/Willman Kavli report: <https://www.noao.edu/meetings/lsst-oir-study/>)
 - Time Domain Infrastructure workshop May 2017 (<https://www.noao.edu/meetings/lsst-tds/>)
 - LSST Community Science Center development (see Norman talk)
- Near term activity
 - Supplemental Funding Request submitted April 2017
 - Initiating collaboration with AURA facilities and Las Cumbres (see Blum talk)
- TMT Engagement on hold (report submitted to NSF, waiting on site selection)



Strategic Initiatives

Towards 2020 and beyond

- Wide field imaging
- Wide field spectroscopy
- LSST follow up
- LSST Data science services





DECam @ CTIO Blanco 4-m Dark Energy Camera

- LSST follow up
 - Cadence
 - Different Filters
- LIGO follow up
- New Surveys



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



DESI @ KPNO Mayall 4-m Dark Energy Characterization

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

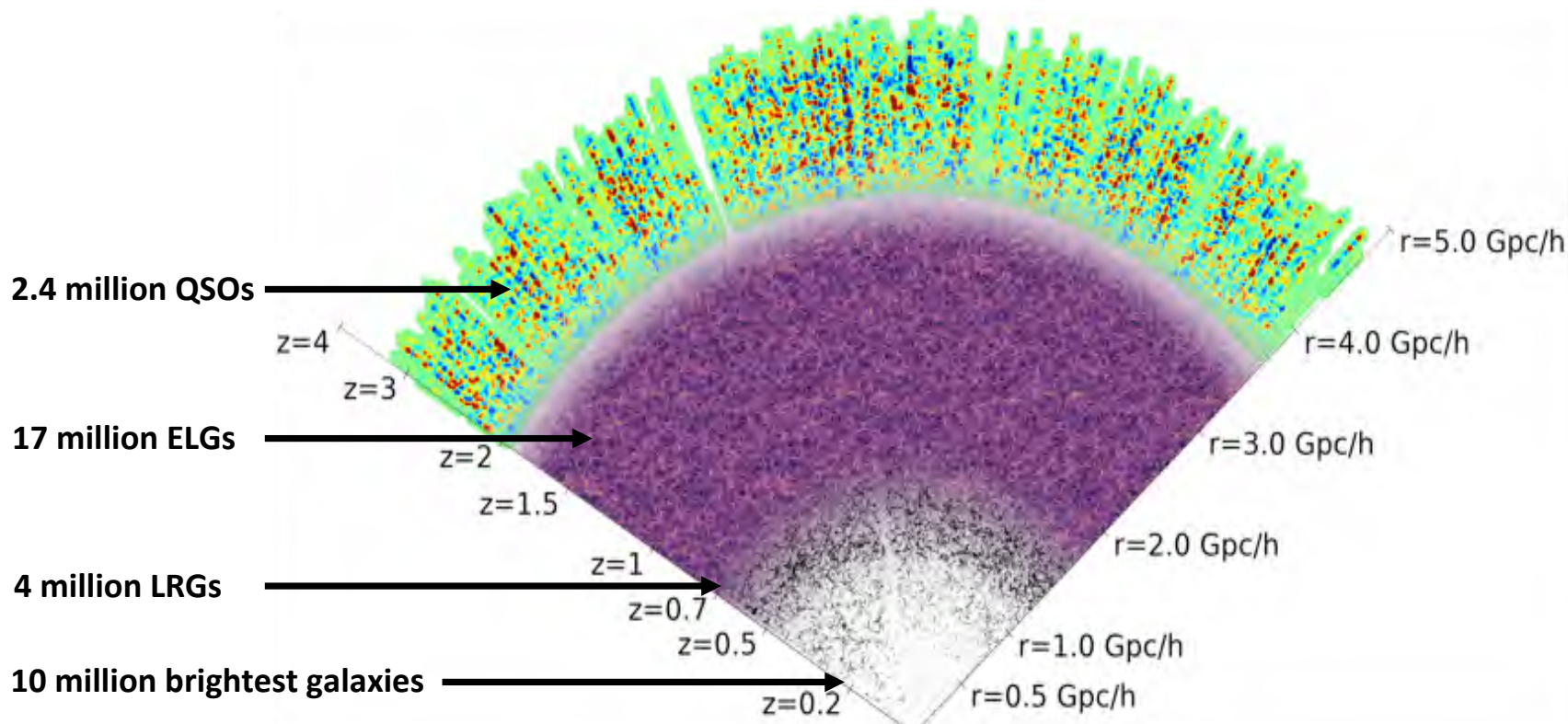


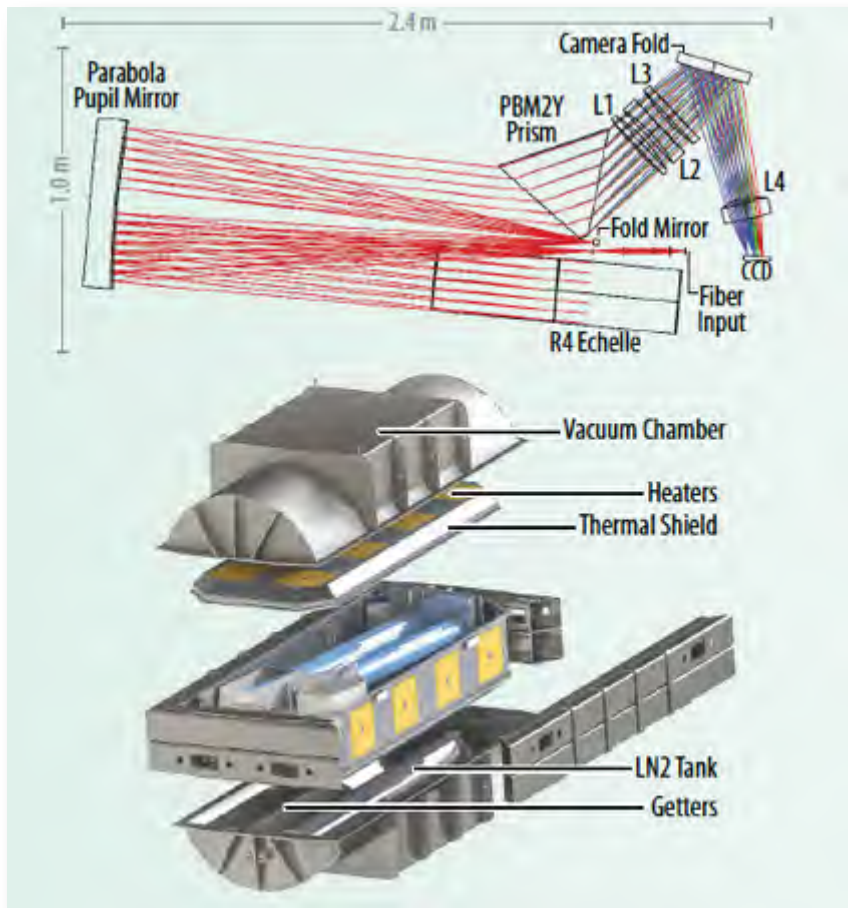
Image credit: A. Slosar & D. Schlegel, via R. Wechsler



DESI, beyond cosmology

- All data products will be public
 - Targeting survey: images and catalogs
 - Spectra: 33M galaxies + 10M stars
- Community spectroscopic surveys (2024++)
 - DESI @ Mayall availability not yet guaranteed
 - May require significant non-Federal funding support
 - Decision deferred for several years
- NOAO Decadal Workshop (Najita) good opportunity to advocate for astronomy program

NEID @ KPNO WIYN 3.5-m



PI: S. Mahadevan (PSU)

Derived from Tohono O'odham word "to see"
 Derived from Tohono O'odham word "to see"



Extreme Precision Doppler Spectrometer

Motivation: TESS, K2, etc.

Mission: determine masses of Earth-like planets

Requirement: < 50 cm/s

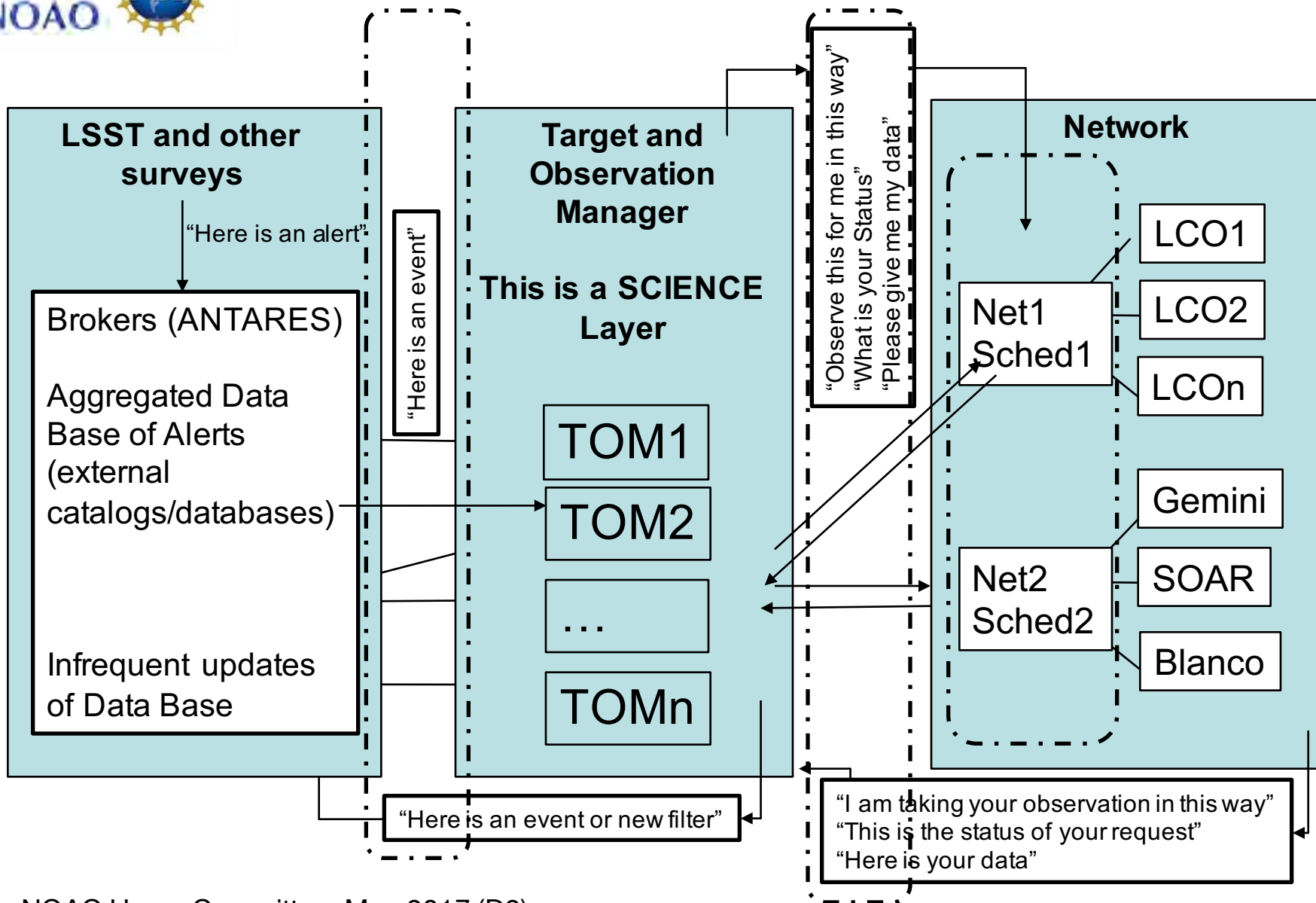
Goal: ~ 10 cm/s

Instrument for the community

Operations start 2019 Q2

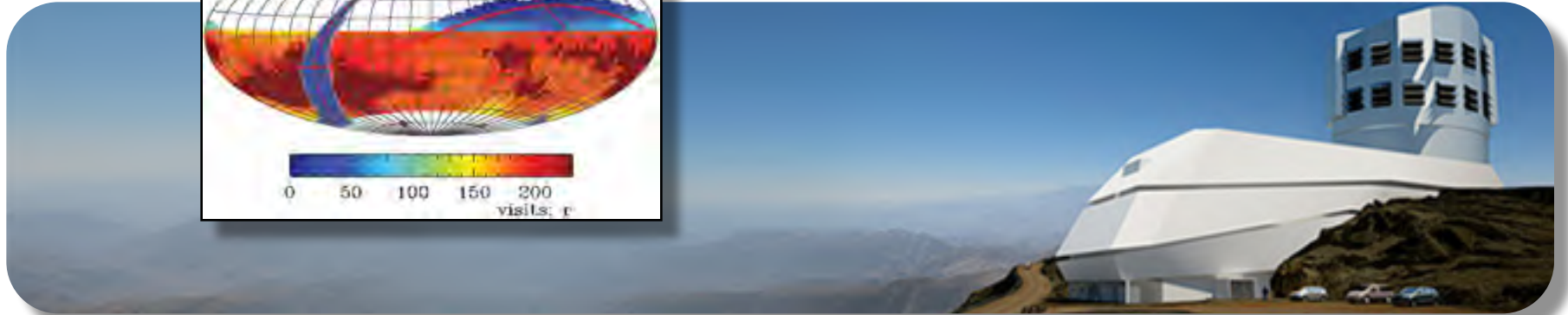
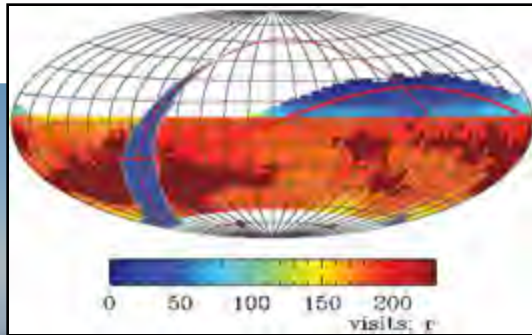


Follow up @ SOAR, Blanco, Gemini





LSST operations and community science support



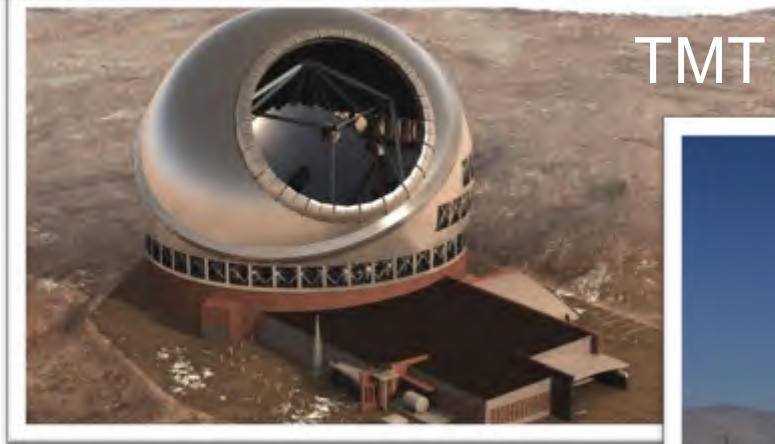
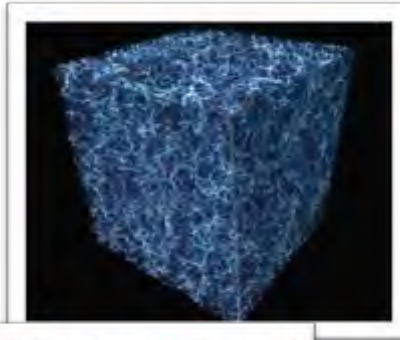
- Center for community research support
 - Survey begins 2023
 - SLAC = dark energy, **NOAO = astronomy “data products to science”**
 - Follow up observations → NOAO facilities (**NOAO working towards strong role for SOAR**)
 - Data science services (Data Lab, ANTARES, etc.)



GSMT operations and community research support

Strategic objectives

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





Beyond LSST Community leader



Currents

2020 Decadal Survey Community Input Invited

In preparation for the upcoming Decadal Survey, NOAO invites community input regarding scientific opportunities in areas in which NOAO can provide critical resources and/or areas that will strengthen the US ground-based OIR system. A ["Dear Colleague" letter](#) requests community input and describes our planning process.

In this Issue

[Dear Colleague Letter](#)
[Contact Us](#)

Dear Colleague,

In preparation for the 2020 Decadal Survey of Astronomy and Astrophysics, NOAO invites community input regarding scientific opportunities for the coming decade in areas in which NOAO can play a role in providing critical resources and/or areas that offer opportunities to strengthen the US ground-based OIR system.

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

Call for white papers, 2018 workshop



End of Presentation





Presentation (January 2017)
NOAO Town Hall
AAS Winter Meeting, Grapevine/TX



Vera Rubin (1928 – 2016)



KPNO 2.1-m, 1970
Image credit: Carnegie DTM



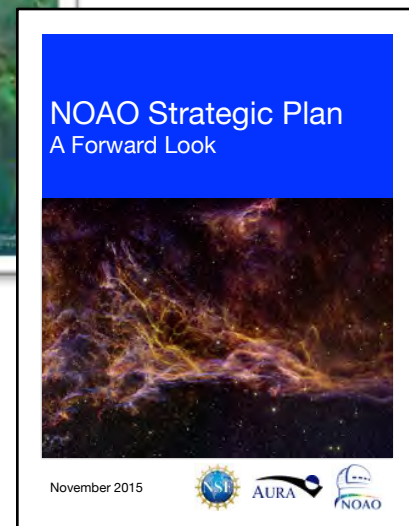
Image credit: AIP Emilio Segre Visual Archives



NOAO: a multi-mission national center

Community research excellence in astronomy Enabled by robust, broad capabilities

- Open access to telescopes
- Open access to data products, data services
- Ultra-wide-field imaging & spectroscopy surveys
- LSST community science support



Google for
"NOAO Strategic Plan"

 AURA development

NOAO is an FFRDC operated by AURA under a Cooperative Agreement with NSF

- Education, public outreach



Open access to telescopes

Broad capabilities = broad opportunities

Telescope	Diameter (m)	Nights Per Year
Subaru	8.2	10
Gemini North	8.1	110
Gemini South	8.1	110
CTIO SOAR	4.1	70
CTIO Blanco	3.9	200
AAT	3.9	10
KPNO Mayall	3.8	100
KPNO WIYN	3.5	125
KPNO 2.1m	2.1	60
CTIO 1.3m	1.3	30
CTIO 0.9m	0.9	30
KPNO 0.9m	0.9	30

Full aperture range
 Full instrument range
 Full user support
 Over-subscription ~ 2.5
 Semi-annual proposal cycle

**KPNO Mayall, open access,
 Last semester, 2017B
 → DESI install starts**

Other available capabilities
 LCO time-domain network
 CHARA optical interferometer
 Large Binocular Telescope



Spectroscopic capabilities

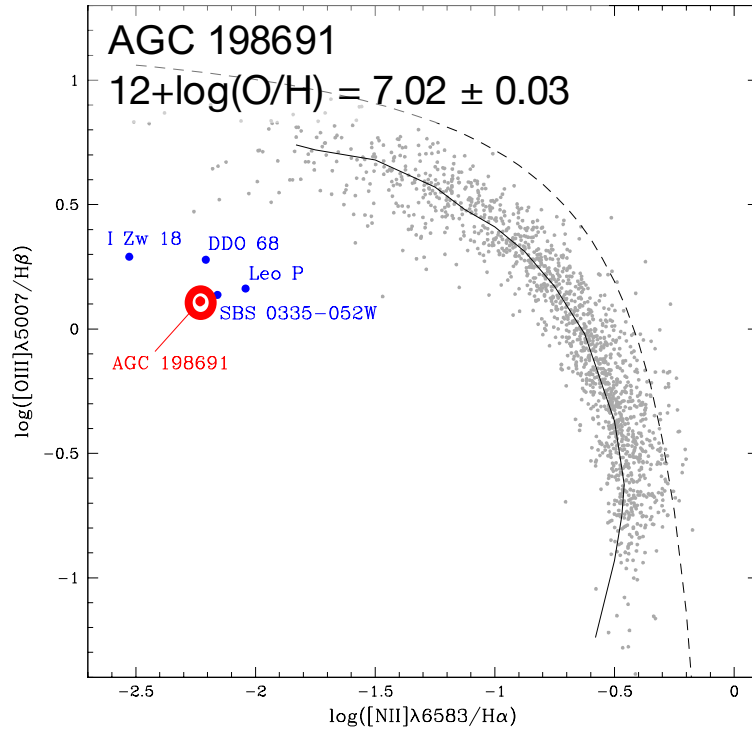
Available now or soon

	Optical					Near-IR		
	Medium Resolution				Echelle	Medium		
	Single	Multi Slit	IFU	Fiber	Single	Single	Multi-slit	IFU
Gemini North 8.1	●	●	●		●	●		●
Mayall 3.8	●	●		2019				
WIYN 3.5			●	●	2019			
Gemini South 8.1	●	●	●		2018	●	●	
SOAR 4.1	●	●			2017			
Blanco 3.9	●	●				●		

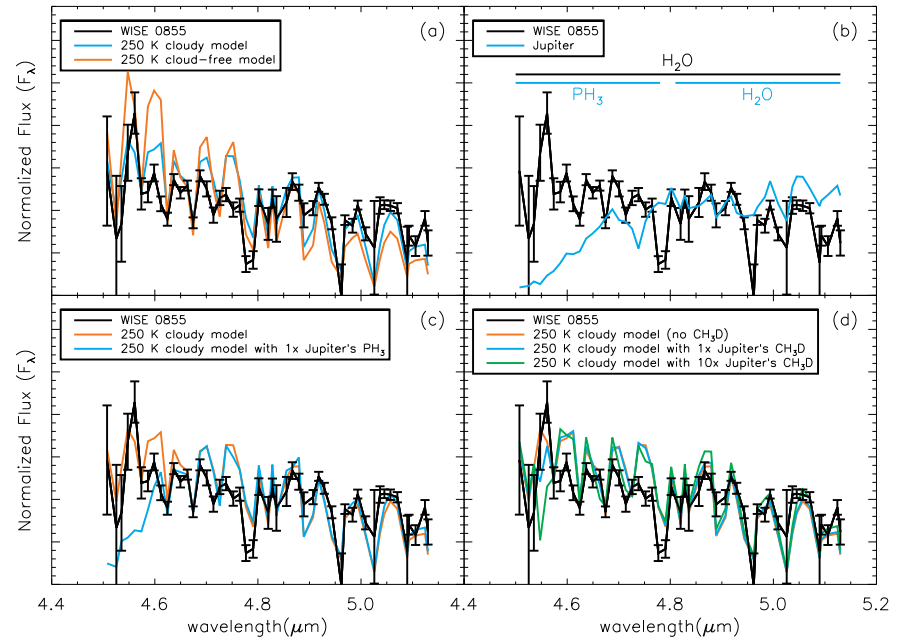
NEW → optical echelle spectroscopy at Gemini N, Gemini S, SOAR, WIYN
 Mid-IR echelle spectroscopy (Gemini North, TEXES)
 Near-IR echelle spectroscopy (Gemini South, Phoenix)

Spectroscopic capabilities

Recent science highlights



Most metal-poor, gas-rich galaxy
 Hirschauer et al. 2016 (KPNO
 Mayall/KOSMOS)



Water vapor clouds on coldest brown dwarf
 Skemer et al. 2016 (Gemini/GNIRS)

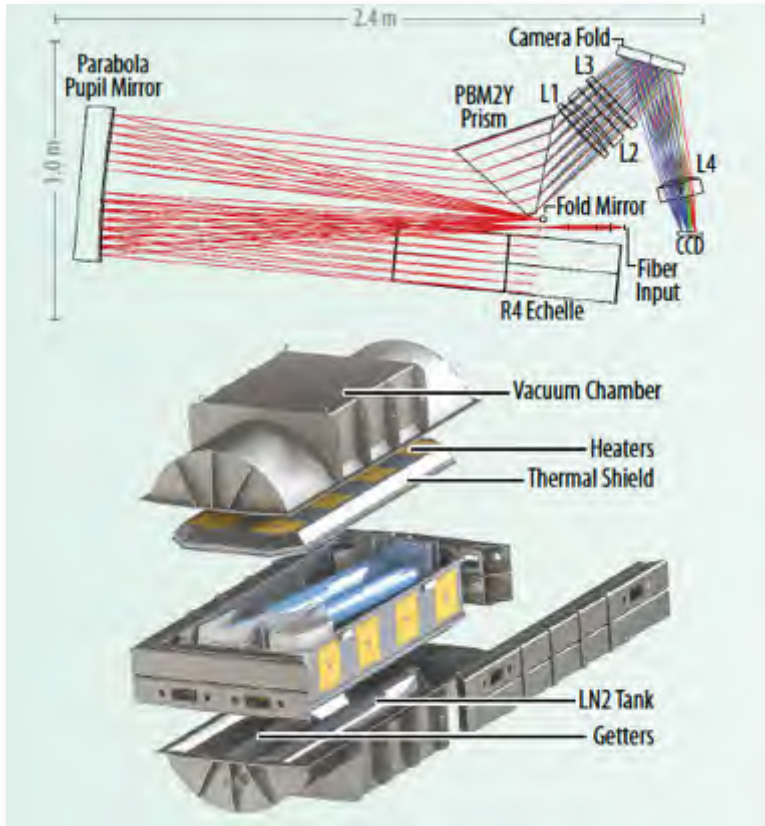


PennState

Spectroscopic capabilities

Coming 2019 → **NEID @ KPNO WIYN 3.5-m**

Derived from Tohono O'odham word "to see"



Extreme Precision Doppler Spectrometer

Motivation: TESS, K2, etc.

Mission: determine masses of Earth-like planets

Requirement: < 50 cm/s

Goal: ~ 10 cm/s

Instrument for the community

Operations start 2019 Q2
PI: S. Mahadevan (PSU)



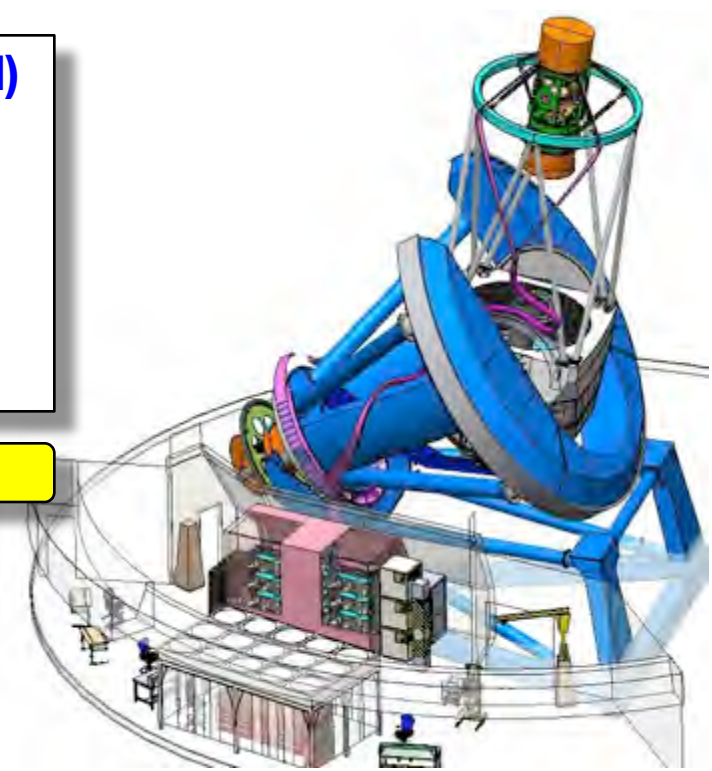
Spectroscopic capabilities

Coming 2019 → [DESI @ KPNO Mayall 4-m](#)

Dark Energy Spectroscopic Instrument (DESI)
5000-fiber spectrometer

5000 fiber positioner robots @ prime focus
New prime focus corrector (creating an 8 sq deg FOV)
New top ring and cage, barrel and hexapod assembly
Ten 3-arm spectrographs (cf., BOSS spectrographs)

Images: M. Levi, DESI Project Director





DESI hardware!



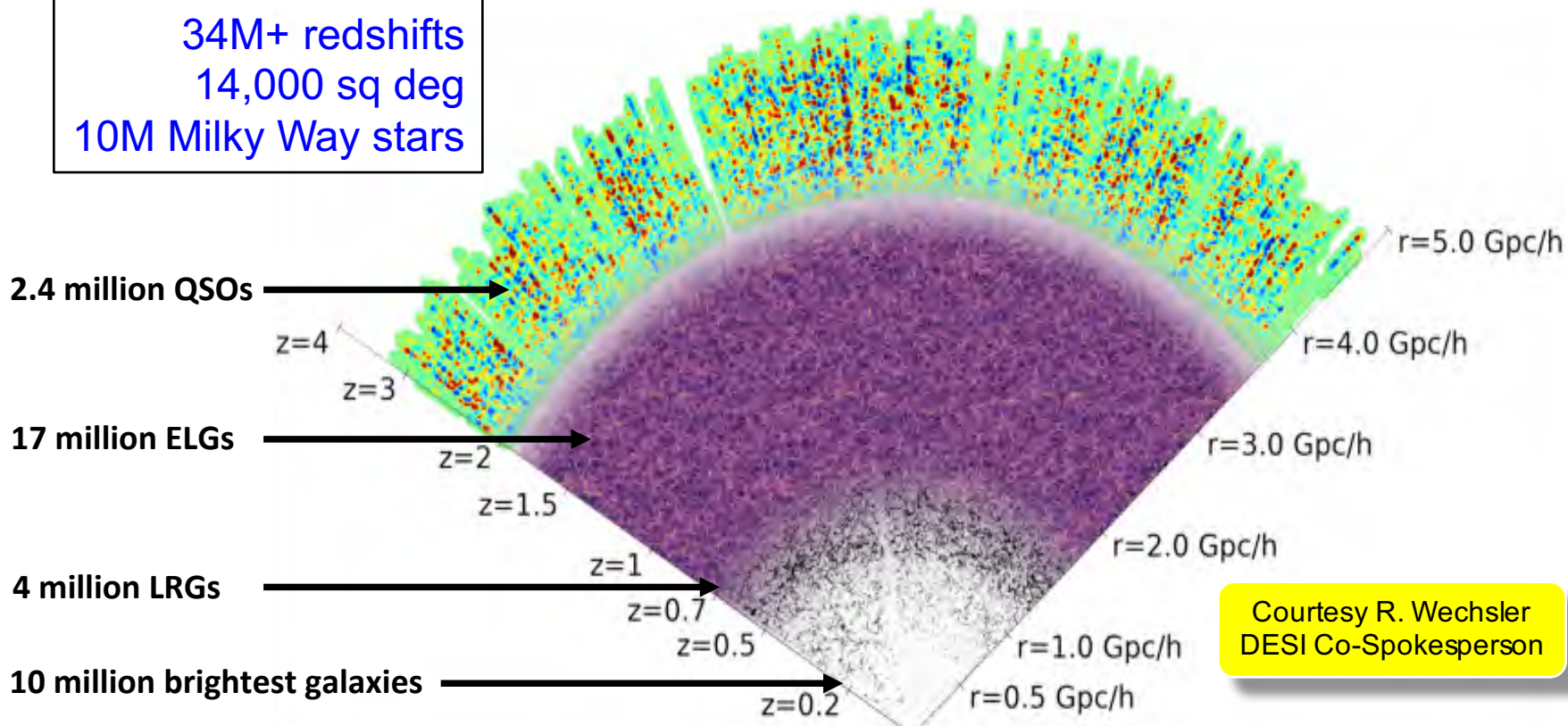
Images: M. Levi, DESI Project Director



DESI Key Experiment

Ultra-wide, deep spectroscopic survey

34M+ redshifts
14,000 sq deg
10M Milky Way stars

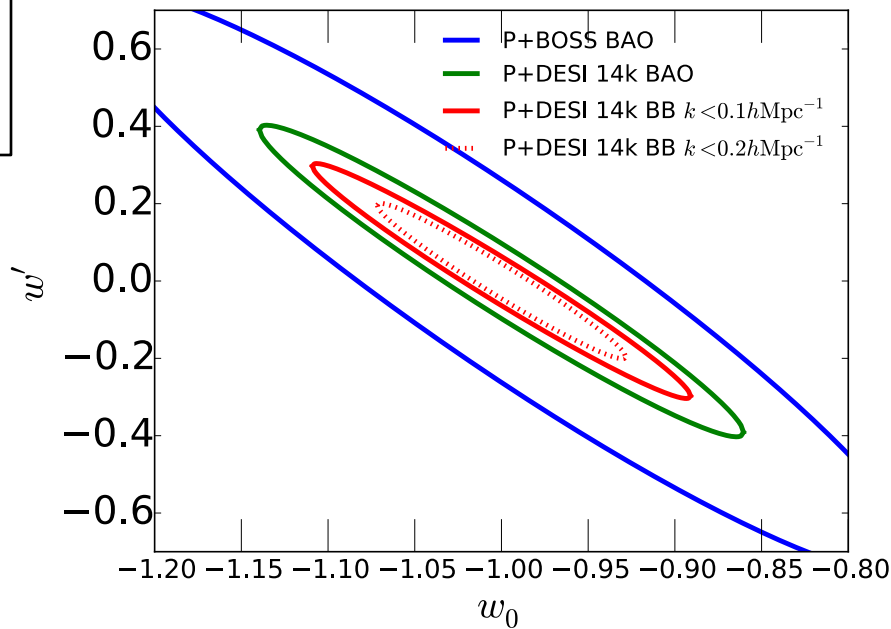
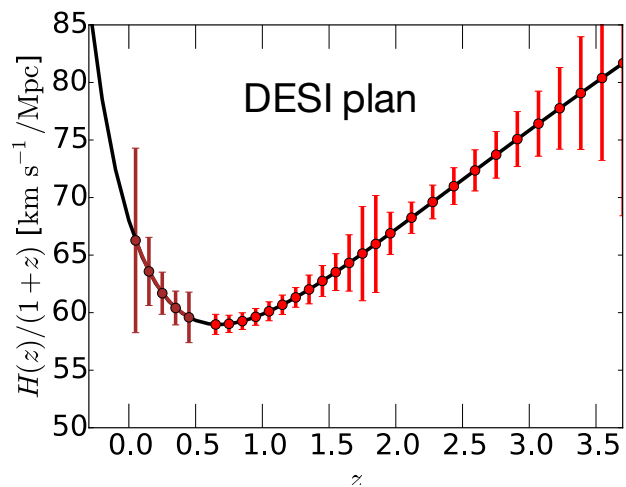
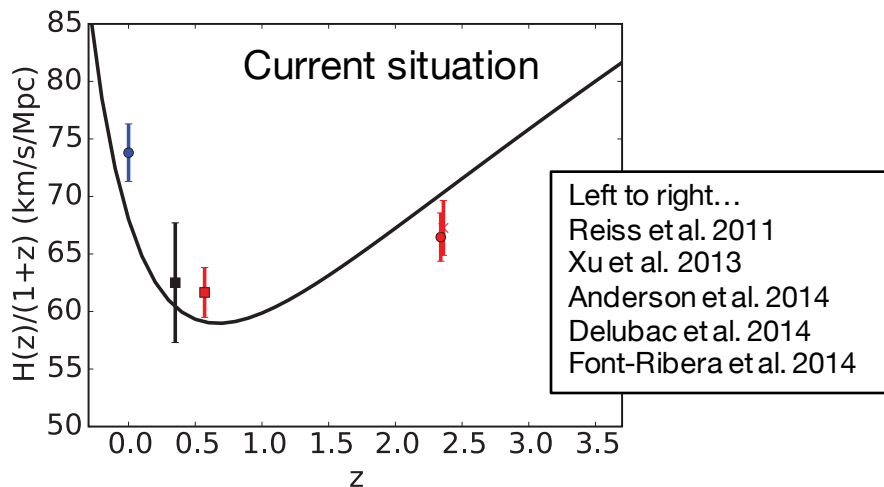


Courtesy R. Wechsler
DESI Co-Spokesperson



DESI Key Experiment

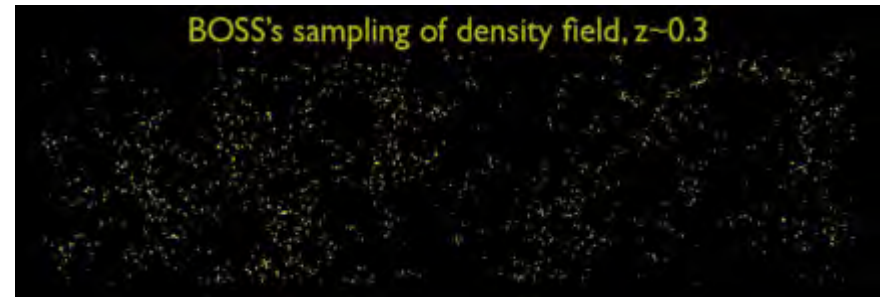
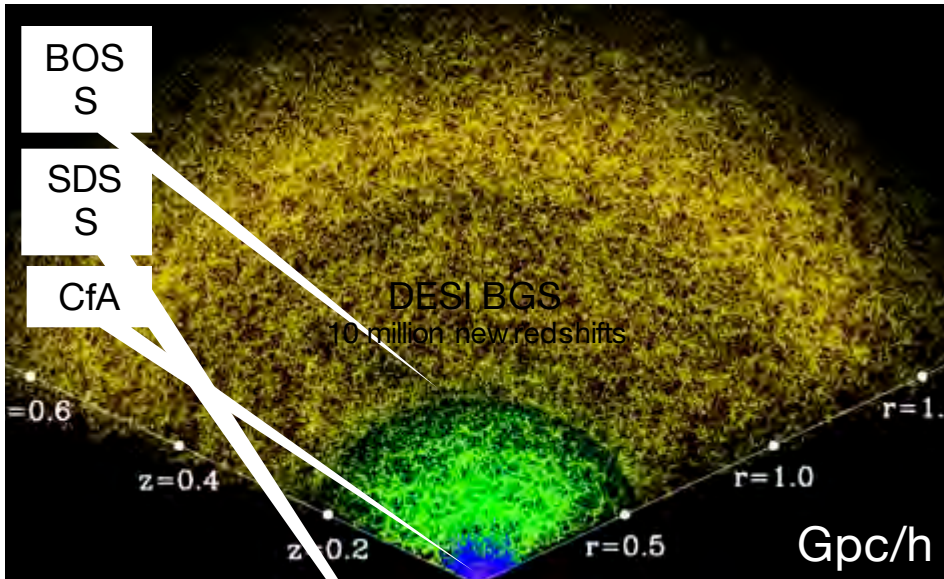
Cosmic Acceleration over Time



Credit: DESI FDR Report, Part 1, DESI Collaboration



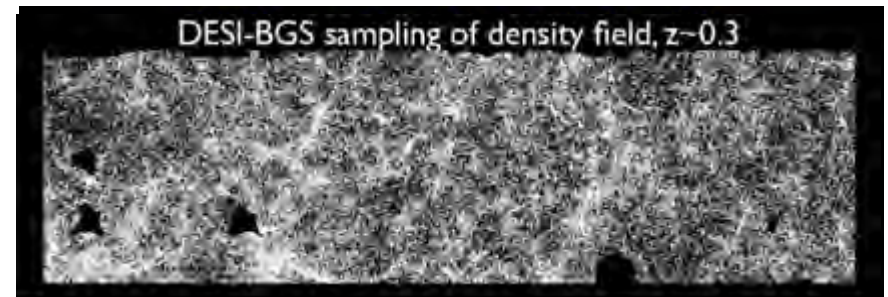
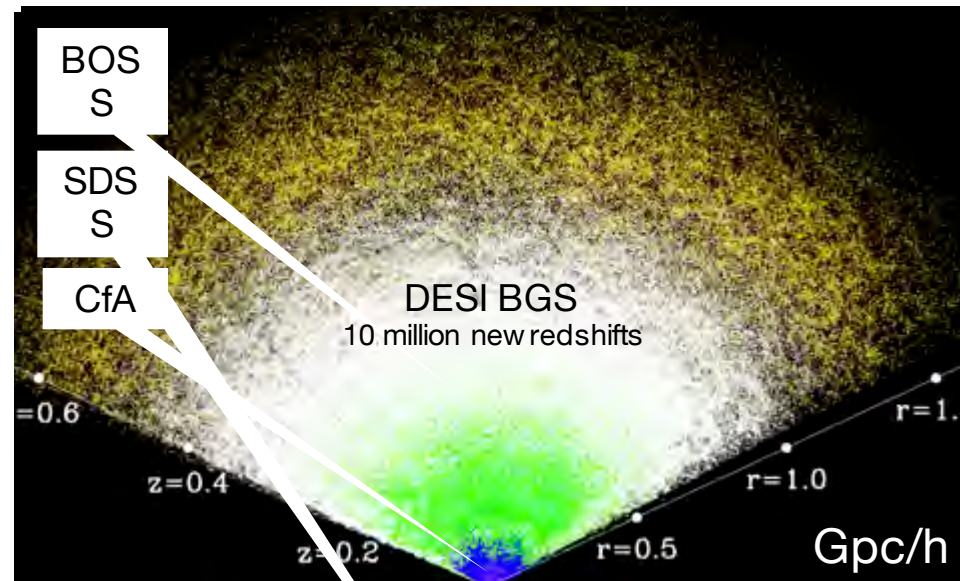
DESI Bright Galaxy Survey



Credit: D. Weinberg



DESI Bright Galaxy Survey



Credit: D. Weinberg



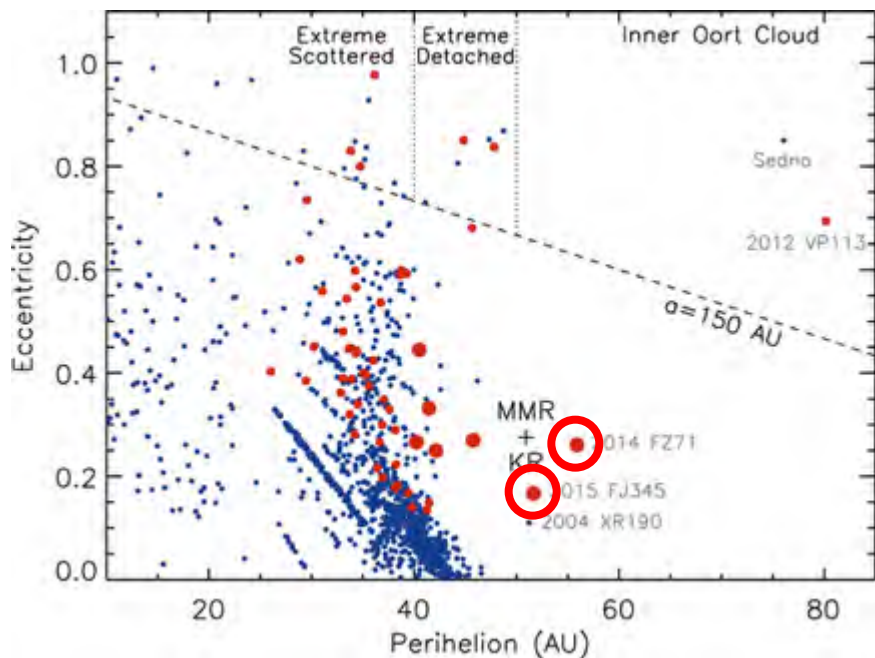
Imaging capabilities

Available now

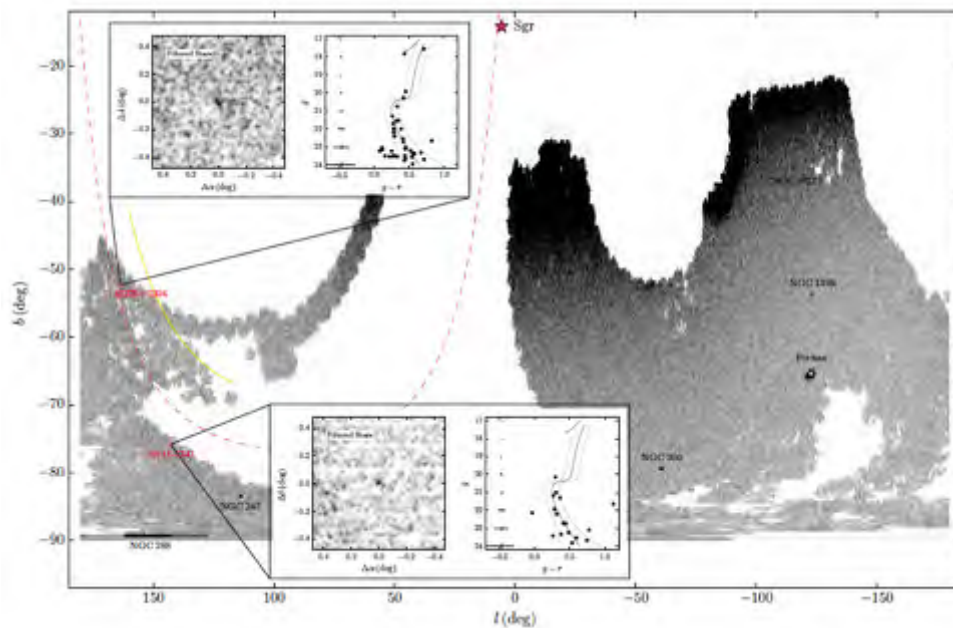
	Optical				Near-IR	
	Natural			AO	Natural	AO
	Small Field	Medium Field	Wide Field		Small Field	
Gemini North 8.2	●				●	Laser SCAO
Mayall 3.8		●			●	
WIYN 3.5		●		Speckle		NGS Tip-Tilt
KPNO 2.1				Laser SCAO		Laser SCAO
Gemini South 8.2	●				●	Laser MCAO
SOAR 4.2	●			GLAO	●	
Blanco 3.9			●			

Imaging capabilities

Recent DECam community science highlights



Discovery of two new TNOs beyond the Kuiper belt edge
 Sheppard et al 2016 ApJ 825 L13



Discovery of two faint stellar systems associated with the Sgr stream
 Luque et al ArXiv 1608.04033



Ultra-wide-field imaging surveys

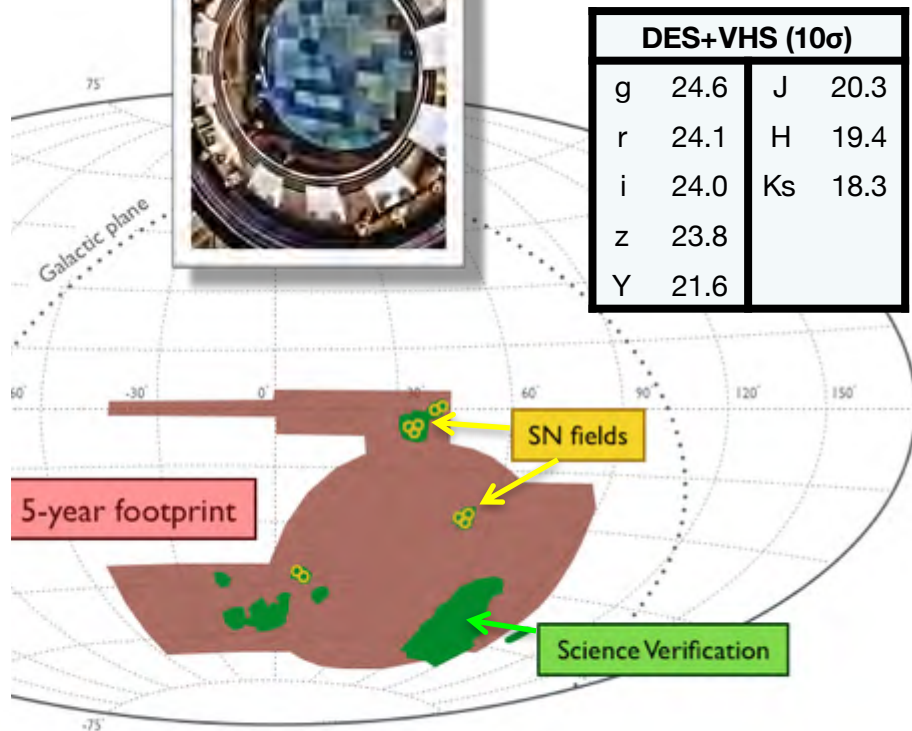
Dark Energy Survey



DECam focal plane

DES+VHS (10σ)			
g	24.6	J	20.3
r	24.1	H	19.4
i	24.0	Ks	18.3
z	23.8		
Y	21.6		

5000 sq deg with Blanco/DECam
 300 million objects, 5-band (g,r,i,z,Y)
 JHK from VISTA surveys
 Year 4 of 5 completed



All data products will be public

Raw data (after 12 mons)
 Processed images (Y1, SV)

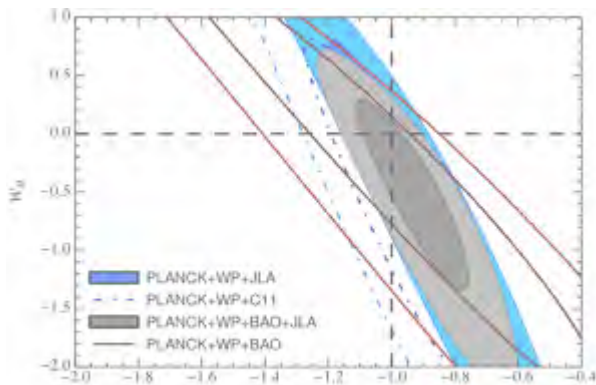
Dec 2017 → Public DR1
 Coadded Y1 – 3 (images, catalogs)





Ultra-wide-field imaging surveys

Dark Energy Survey



Betoule et al. 2014

Key Experiment

Constrain nature of dark energy

Probes

- Clusters
- Weak Lensing
- Large-scale Structure (BAO)
- Supernovae

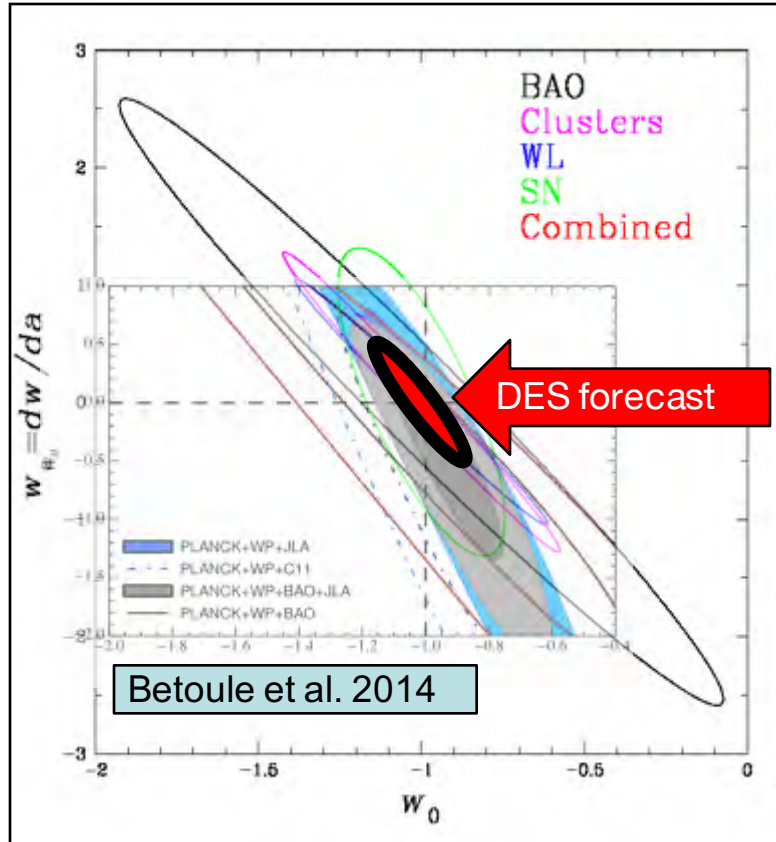
DES Collaboration

- Almost 90 papers submitted to date



Ultra-wide-field imaging surveys

Dark Energy Survey



Key Experiment

Constrain nature of dark energy

Probes

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DES Collaboration

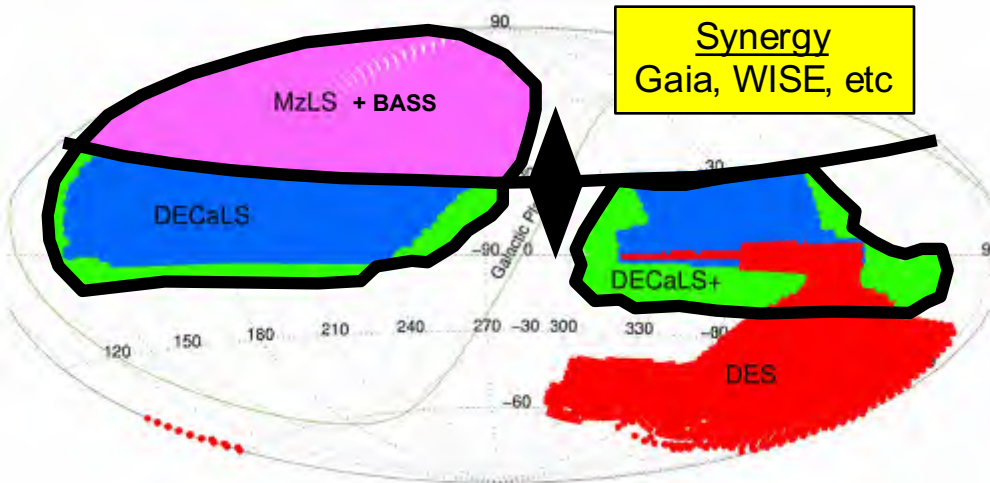
- Almost 90 papers submitted to date



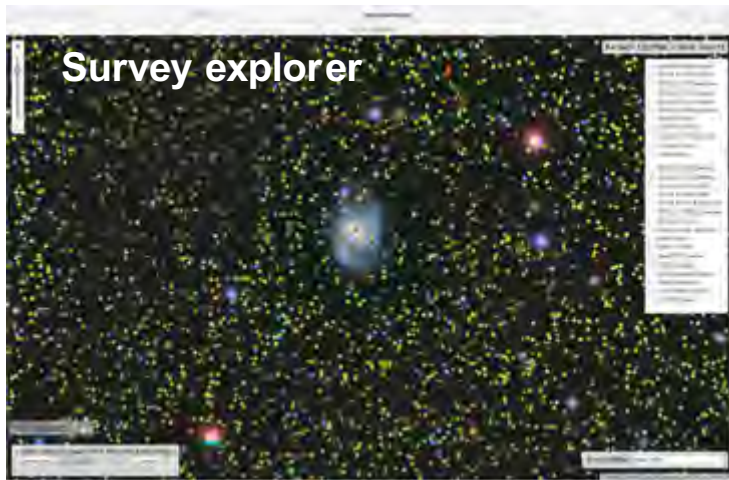


Ultra-wide-field imaging surveys

Legacy Survey



Imaging Survey Status, DESI Collab Meeting, OSU, 2016-12-06



Motivation: DESI targets
 Mayall/Mosaic-3 (MzLS)
 Blanco/DECam (DECaLS)
 Bok/90-Prime Mosaic (BASS)

14,000 sq deg
 1200 million unique objects
 $(g,r,z) = 24.7, 23.9, 23$ (5-sigma)
 SDSS overlap
 DESI fields

DR3 available now

4300 sq deg

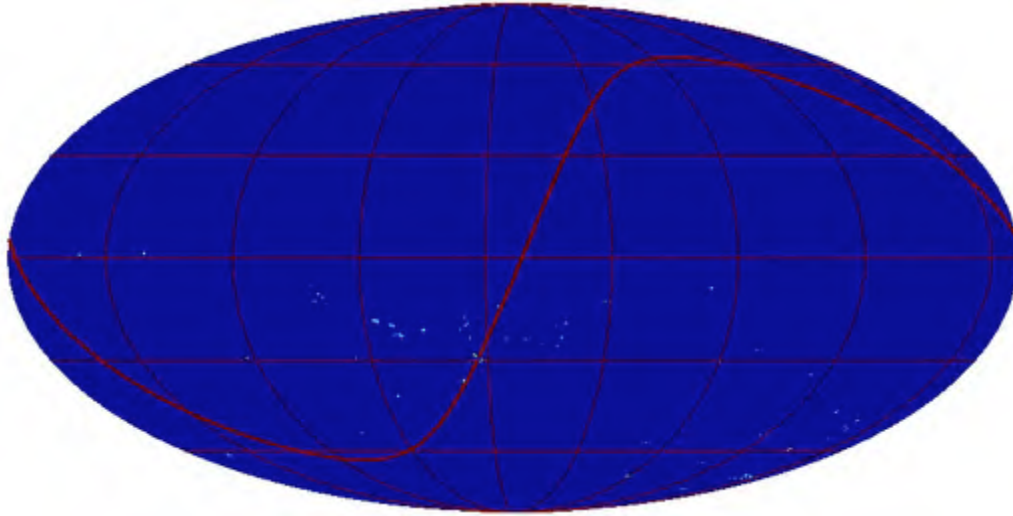
→ legacysurvey.org

Also: NOAO Data Lab



High-value data products @ NOAO

archive.noao.edu



Mosaic, DECam exposure map (May 2016)
Raw, processed images
Catalogs for coherent surveys

N.B. This is movie, will not run in PDF version

- DES Science Verification DR
- DES SN fields
- DES Public DR1 (Jan 2018)

- SMASH survey fields (Nidever et al.)
- DECam Legacy Survey DR3+
- Mayall z-band Legacy Survey DR3+
- MW dwarfs (Mighell, internal)
- MW Bulge survey fields (Saha et al.)

Coming Soon (with spectra)

- SDSS DR7 – 13 (Mar 2017)
- SDSS DR14 (Jan 2018)



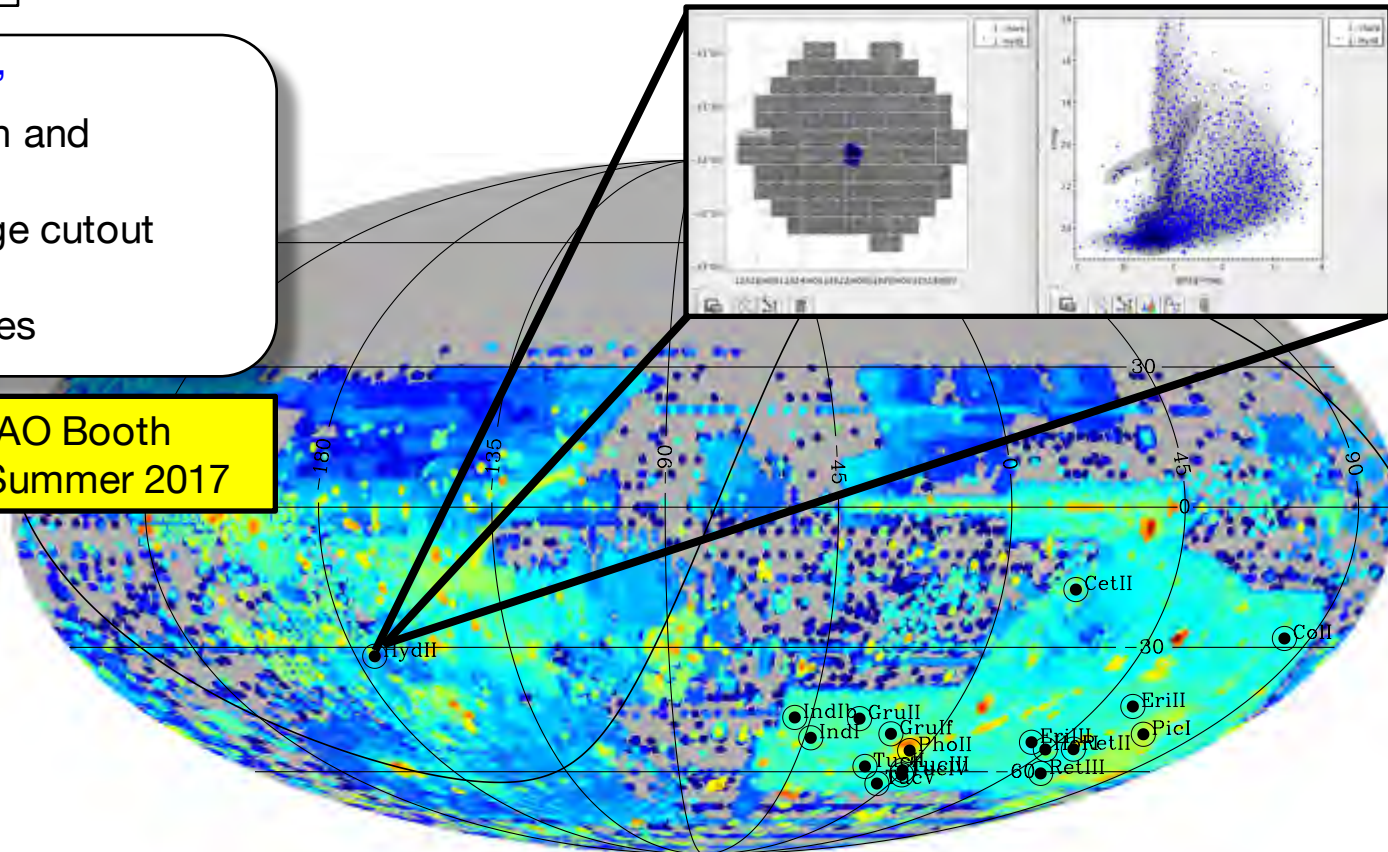
Data services for TB-scale catalogs

NOAO Data Lab

“Computing at the data”

- Exploration, visualization and analysis
- Pixel processing at image cutout level
- Collaborative workspaces
- Built in analysis tools

Latest Demo @ NOAO Booth
Public release → AAS Summer 2017

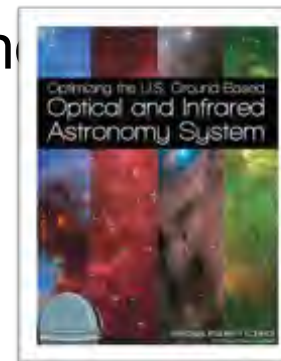




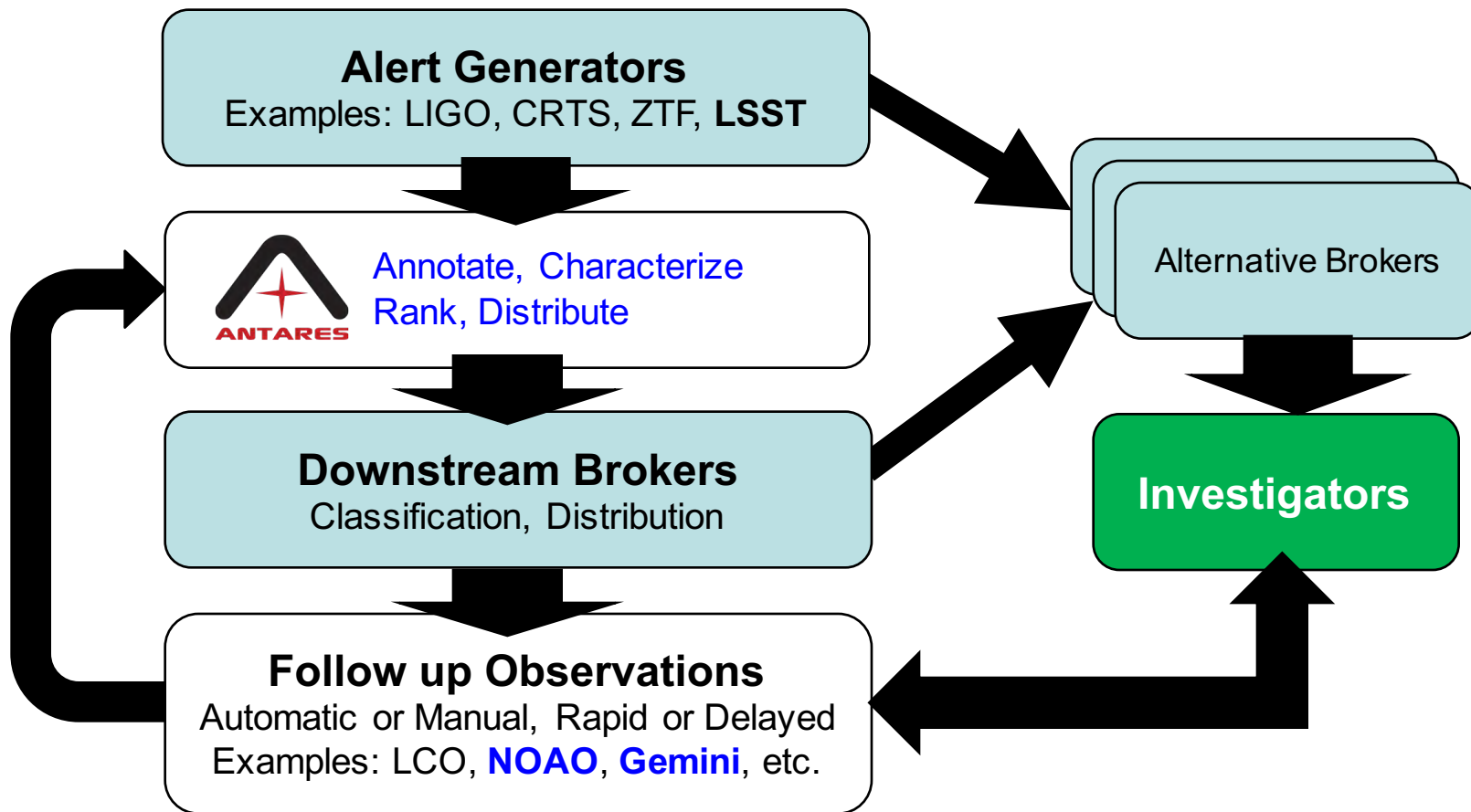
On the road to LSST

Focus areas


- Time-domain science analysis and follow-up
- Static-sky science analysis and follow-up
- Custom data-intensive analysis applications
- Community-based planning of new observatories
- Workshops, conferences, schools, and outreach



Time-Domain Ecosystem





-  **NOAO Temporal Analysis & Response to Events System**
 - Collaboration: NOAO, U. Arizona Dept. of Computer Science
- **Goal: deploy national broker service at LSST scale**
- Alert processing functionality
 - **Annotate** with external information and past history
 - **Characterize** by features in time-domain
 - **Rank** → identify “rarest of the rare”
 - **Distribute** value-added information
- Flexible, modular architecture
 - Open source, can be run by anyone
- API for user-specific feature filtering





Time-Domain Science Infrastructure

Community Workshop, 22 – 25 May 2017

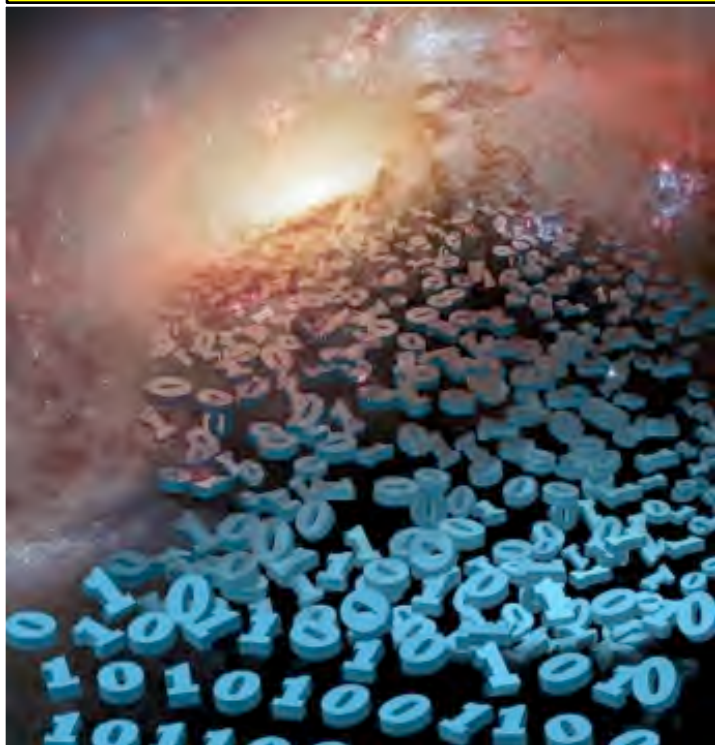




La Serena School for Data Science:

Applied Tools for Astronomy

Application deadline: 15 April



- 21 – 29 August 2017, La Serena, Chile
- Advanced undergrads, early grads
- International, interdisciplinary lecturers
- Team-based, project-based
- Topics include:
 - Astronomical data acquisition
 - Processing pipelines
 - Astronomical databases
 - Virtual Observatory



Forward NCOA From NSF Town Hall



National Center for Night-time OIR Astronomy

- Numerous recommendations regarding enhanced coordination among NSF OIR observatories.
- September 2016: After many discussions with AURA management and Observatory leadership, NSF provided guidance to AURA on planning a National Center.
 - Purpose, mission and scope of a single administrative organization to coordinate resources among LSST operations, Gemini Observatory, and continuing NOAO programs.
 - AURA is to deliver to NSF a proposed plan for this National Center, with a targeted delivery date of mid-2017.
 - Separately, the potential National Center is being discussed with Gemini, LSST, and NOAO partners.
- The overall benefit envisioned is the provision of enhanced science return through coordination of capabilities as LSST moves toward operations.

1/04/2017

NSF-AAS Town Hall

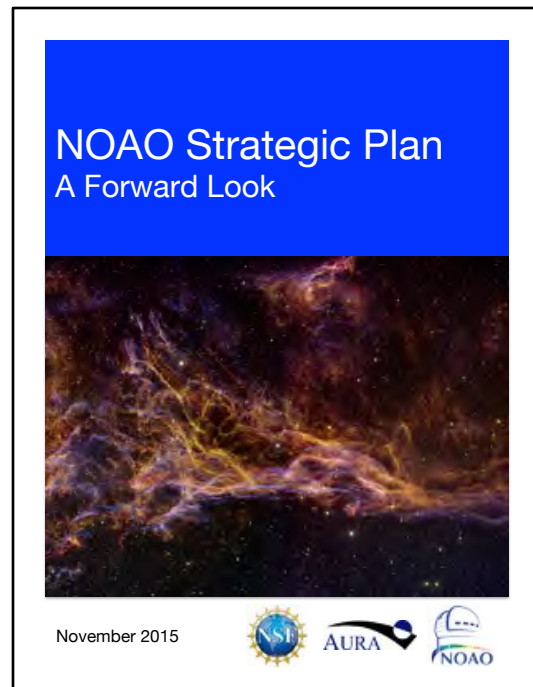
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NOAO: a multi-mission national center

Community research excellence in astronomy Enabled by robust, broad capabilities

- Open access to telescopes
- Open access to data products, data services
- Ultra-wide-field imaging & spectroscopy surveys
- LSST community science support
- Time-domain research infrastructure development
- Education, public outreach



Google for
“NOAO Strategic Plan”



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