Synergies between DECam/DES and DESI

Paul Martini, The Ohio State University On behalf of the DESI Collaboration

DECAM at 10 years - Looking back, looking forward September 12-14, 2022 Tucson, AZ

synergy: the interaction or cooperation of two or more organizations, substances, or other agents to produce a combined effect greater than the sum of their separate effects



DARK ENERGY SPECTROSCOPIC INSTRUMENT A Tale of Two Telescopes

U.S. Department of Energy Office of Science



Many upgrades including computers, encoders, servo motors, and pointing software

Image Credits: NOIRLab



DARK ENERGY SPECTROSCOPIC INSTRUMENT A Tale of Two Instruments

U.S. Department of Energy Office of Science

Outline:

- 1. Instrumentation synergies
- 2. Status of DESI
- 3. Concept of successive instrument development



c Instrumentation Synergies

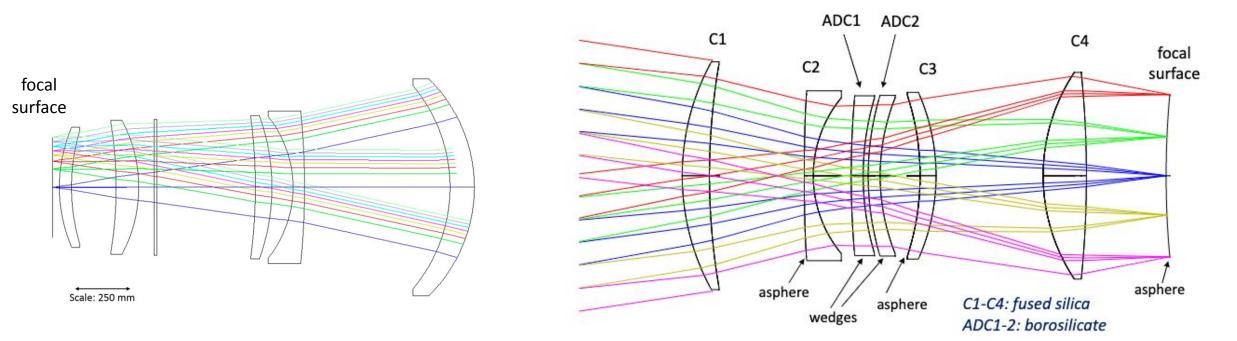
U.S. Department of Energy Office of Science

- Corrector Barrel
- Cage, Vanes, Hexapod
- Lens Mounts
- CCDs
- Active Optics System
- Instrument Software
- Telemetry Database
- Installation
- Management structure and personnel

So many!



U.S. Department of Energy Office of Science



All DECam lenses are fused silica

Same relative scale

Flaugher, Diehl, Honscheid et al. (2015)

Miller, Besuner, Levi, et al. (2018)

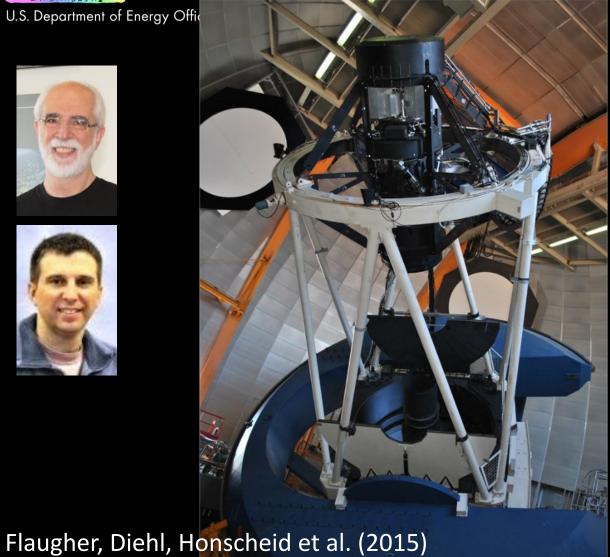


DARK ENERGY Corrector Barrel, Vanes, Cage SPECTROSCOPIC INSTRUMENT

U.S. Department of Energy Offic











U.S. Department of Energy Office of Science

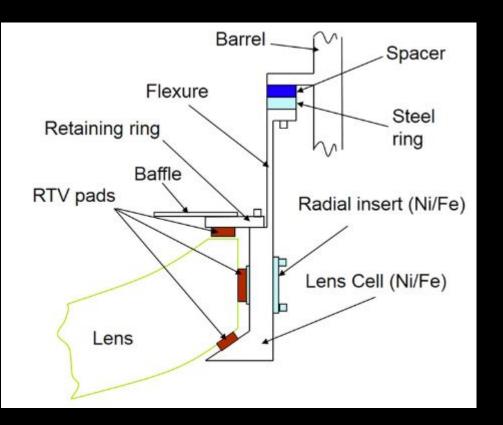


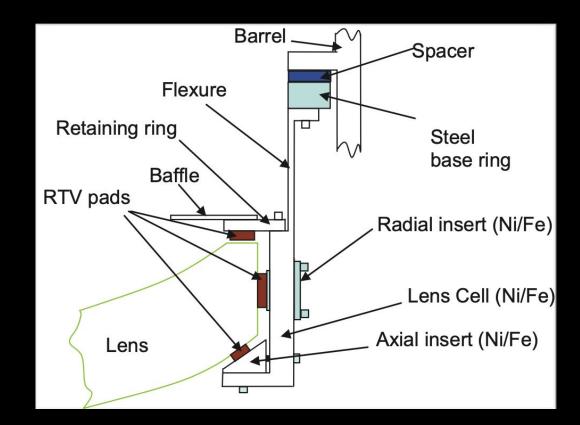
Image Credits: Fermilab



Lens Mounts

U.S. Department of Energy Office of Science



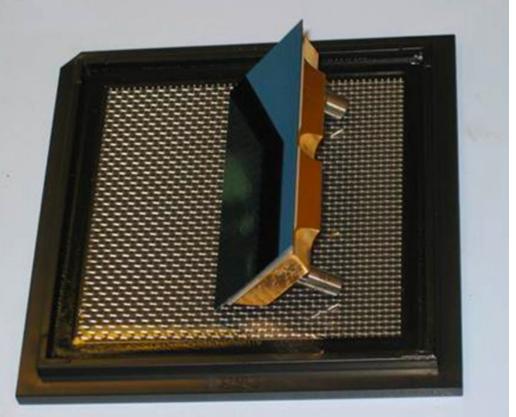


Flaugher, Diehl, Honscheid et al. (2015)

Doel et al. (2016)



U.S. Department of Energy Office of Science

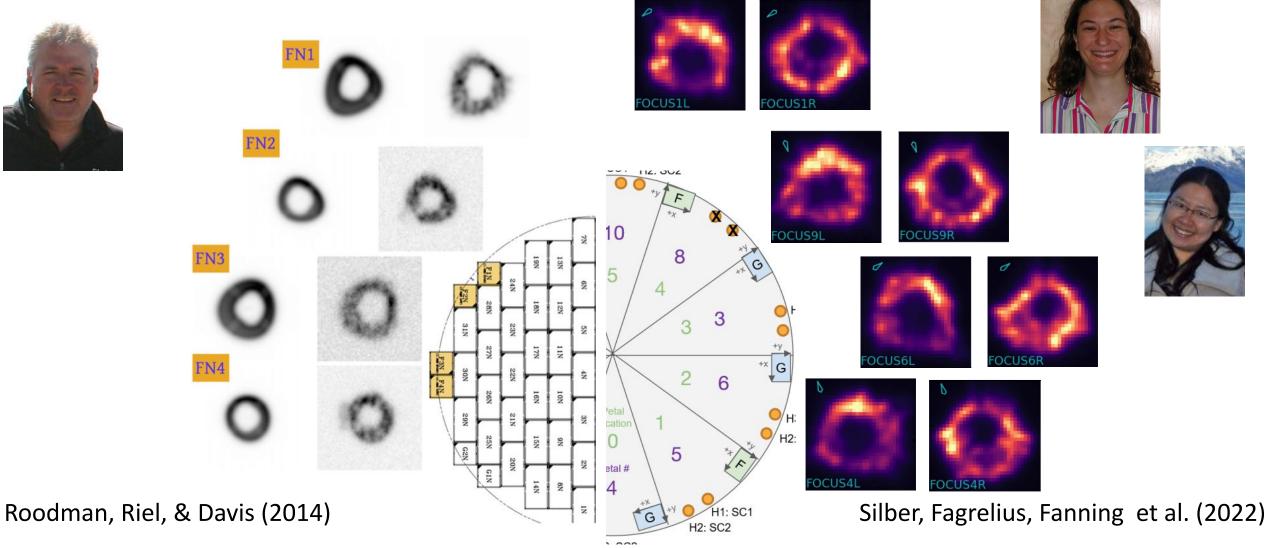




Both use thick, red sensitive, deep depletion devices designed by LBL and packaged by FNAL



U.S. Department of Energy Office of Science







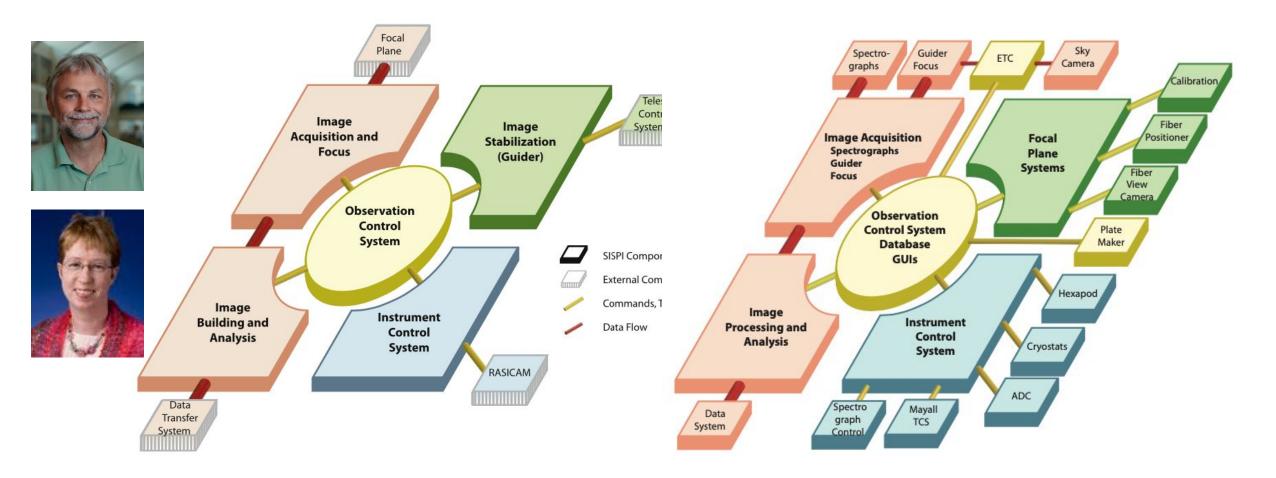
Flaugher, Diehl, Honscheid et al. (2015)

Miller, Doel, Gutierrez et al. (2022)



DARK ENERGY SPECTROSCOPIC Instrument Software + Database

U.S. Department of Energy Office of Science



Honscheid et al. (2012)

Honscheid et al. (2016)



DARK ENERGY SPECTROSCOPIC Instrument Software

U.S. Department of Energy Office of Science

INSTRUMENT

		O Observer Console DESI: Ready Session: klaus_2	🗼 Alarm 🔮 🧟 Logout 🛛 🙍
	Observer Console	ICS Status System Control Request Control Setup: Monitor: Interlock: Setup ICS Petals Bias Voltages Observing	Exposure NFS Emergency
Observer Console	approblement Console/ C Console/ C Console/ C C Console/	OCS: (READY) Walting: Observers Current Constants: DESI:CURRENT DESIObserver Configure Initialized Focus Con Dusk 19:33:15	81903 Survey
Exercise Service Marxisor LEDix (M. Sanuel C. B. Sanuel C. C. B. Sanuel C. Sanuel C. B. Sanuel C. C. B. Sanuel C. Sanuel C. Sanuel C. B. Sanuel C. C. B. Sanuel C. Sanuel Sanuel Sanuel C. Sanuel Sanuel C. Sanuel Sanuel Sanuel C. Sanuel Sanuel Sanuel C. Sanuel Sanuel Sanuel C. Sanuel	Type: Twee: Other: Control: Control: Control: Exp. Ope: Control: Image: Image: <td>Instrument Status Purpose Reset Standby Oulder Om Hold Cause Cryostats: FXC: Devices: PC: Pos Power Om Hold Cause Petalboxes: PC: Pos Power Comstants Pos Comercing Constants Pos Comercing Pos Comercing Constants Pos Comercing Pos Comercing Comercing Pos Comercing Constants Pos Comercing Pos Come</td> <td>Split Starting Starting Storp All Storp All Manual Storp All Storp All Accumulated Effective Exposure Tim 10 9 min 0.282 10 16.7 5 4.4 3.0 6 6 4.3 10 Exposure 60861, Exp. Time: 692.04, PA.250.0000, doc:23.1000, skyra: 80961, Exp. Time: 692.07, PA.250.0000, doc:23.1000, skyra:</td>	Instrument Status Purpose Reset Standby Oulder Om Hold Cause Cryostats: FXC: Devices: PC: Pos Power Om Hold Cause Petalboxes: PC: Pos Power Comstants Pos Comercing Constants Pos Comercing Pos Comercing Constants Pos Comercing Pos Comercing Comercing Pos Comercing Constants Pos Comercing Pos Come	Split Starting Starting Storp All Storp All Manual Storp All Storp All Accumulated Effective Exposure Tim 10 9 min 0.282 10 16.7 5 4.4 3.0 6 6 4.3 10 Exposure 60861, Exp. Time: 692.04, PA.250.0000, doc:23.1000, skyra: 80961, Exp. Time: 692.07, PA.250.0000, doc:23.1000, skyra:
	11 Jun 14, 2010750.000 C File: popelinid3.cbs.nosa.mbi.rbstas.bicelihinages/015202126-0995002136.cbstas.to 321751 zero C File: block, Tel/14, 75, 1844, 3502126-0995002136.cbstas.to 321756 zero C File: block, Tel/14, 74, 251.04, 18602.cs, 20.4198, 5eq, 3 exponsives (3 of 3), PropIC 20126-09903 321759 zero C File: block, Tel/14, 74, 251.04, 1860.cs, 20.4198, 5eq, 3 exponsives (2 of 3), PropIC 20126-09903 321769 zero C File: block, Tel/14, 74, 251.04, 1860.cs, 20.4198, 5eq, 3 exponsives (2 of 3), PropIC 20126-09903 321769 zero C File: block, Tel/14, 74, 2168, 1860.cs, 20.4184, 5eq, 3 exponsives (2 of 3), PropIC 20126-09903 321769 zero C File: block, Tel/14, 74, 2168, 1860.cs, 20.4184, 5eq, 3 exponsives (2 of 3), PropIC 20128-09903 321769 zero C File: block, Tel/14, 74, 2168, 1860.cs, 20.4184, 5eq, 3 exponsives (2 of 3), PropIC 20128-09903 321769 zero C File: block, Tel/14, 74, 2168, 1860.cs, 20.4184, 5eq, 3 exponsives (2 of 3), PropIC 20128-09903 321769 zero C File: block, Tel/14, 74, 2168, 1860.cs, 20.4184, 5eq, 3 exponsives (2 of 3), PropIC 20128-09903 321769 zero C File: block, Tel/14, 74, 2168, 1860.cs, 20.4184, 5eq, 3 exponsives (2 of 3), PropIC 20128-09903	2021-03-25 11:48:52 0 0 0 0 0 0 18:00:10 81896 DESI, science 0 0 0 0 0 TielD: 1 2021-03-25 11:29:18	80734, Exp. Time: 922.03, RA.229.6400, dec:2.5800, skyra: 80734, Exp. Time: 922.06, RA.229.6400, dec:2.5800, skyra:
some Bat, 10a, Y, 20,05, 6, previdyt (15 of 160) some Bat, 10a, Y, 20,05, 5, previdyt (15 of 160) some Bat, 10a, Y, 20,05, 5, previdyt (17 of 05) some Bat, 10a, Y, 10,05, 5, previdyt (18 of 163) some Bat, 10a, Y, 10,05, 5, previdyt (21 of 163) some Bat, 10a, Y, 20,05, 5, previdyt (21 of 160) some Bat, 10a, Y, 50,05, 5, previdyt (22 of 160) some Bat, 10a, Y, 50,05, 5, previdyt (22 of 160) some Bat, 10a, Y, 50,05, 5, previdyt (22 of 160) some Bat, 10a, Y, 50,05, 5, previdyt (22 of 160) some Bat, 10a, Y, 50,05, 5, previdyt (22 of 160) Some Bat, 10a, Y, 50,05, 5, previdyt (24 of 160) Confuspte	381746 two O O Time: 0.000, Priar: Mook, Tim7A, 45.4628, TacCles: 33.4045, Seg 3 responses (1 of 3), Physic D 20128-0993 381747 two O Priar: 0.000, Priar: Mook, Tim7A, 45.45285, TacCles: 33.4045, Seg 3 responses (1 of 3), Physic D 20128-0993 381747 two O Priar: 0.000, Priar: Mook, Tim7A, 45.34671, Seg 3 responses (1 of 3), Physic D 20128-0993 381746 tem O Priar: 0.000, Priar: Mook, Tim7A, 45.34671, Seg 3 responses (1 of 3), Physic D 20128-0993 381746 tem O Priar: 0.000, Priar: Mook, Tim7A, 45.34671, Seg 3 responses (1 of 3), Physic D 20128-0993 381746 tem O Priar: 0.000, Priar: Mook, Tim7A, 45.34671, Seg 3 responses (1 of 3), Physic D 20128-0993 381746 tem O Priar: 0.000, Priar: Mook, Tim7A, 45.34671, Seg 2 responses (1 of 3), Physic D 20128-0993 381746 tem O Priar: 0.000, Priar: Mook, Tim7A, 45.4621, Seg 2 responses (1 of 3), Physic D 20128-0993 381746 tem O Priar: 0.000, Priar: Mook, Tim7A, 45.4621, Seg 2 responses (1 of 3), Physic D 20128-0993 381743 tem 0.000, Priar: Mook, Tim7A, 37.400, Chec: 33.3763, Seg 2 responses (2 of 3), Physic D 20128-0993 Time: 0.000, Priar: Mook, Tim7A, 37.400, Chec: 33.3763, Seg 2 responses (2 of 3), PhysicD 20128-0993 Tim	OCS 10:30:10: DESI: Sequence (#1902) complete PML 10:30:21: SU0CESS Sky Level Seeing OCS 10:30:21: Stop request loop requested. Current 10.0 3.00 arcsec PML 10:30:00: SUCCESS 7.5 2.50 arcsec 2.00 arcsec PML 10:30:00: SUCCESS 5.0 5.0 1.00 arcsec 1.00 arcsec PML 10:30:00: SUCCESS 5.0 5.0 5.0 1.00 arcsec 1.00 arcsec PML 10:30:01: SUCCESS 5.0 </td <td>Transparency 100 ••••• 101 ••••• 102 ••••• 103 ••••• 104 ••••• 105 ••••• 106 ••••• 107 15 108 10 109 •••• 100 •••• 101 •••• 102 •••• 103 •••• 104 •••• 105 •••• 106 •••• 107 10 108 10 109 10 100 10 100 10 100 10 100 10 100 10 100 10 100 10 100 10 100 10 100 10 100 10 100 10 100</td>	Transparency 100 ••••• 101 ••••• 102 ••••• 103 ••••• 104 ••••• 105 ••••• 106 ••••• 107 15 108 10 109 •••• 100 •••• 101 •••• 102 •••• 103 •••• 104 •••• 105 •••• 106 •••• 107 10 108 10 109 10 100 10 100 10 100 10 100 10 100 10 100 10 100 10 100 10 100 10 100 10 100 10 100 10 100
Blance TCS READY READY DEC: 20:31:00.055 BC: 20:31:00.055	HEADY HIM HIM HIM RAMA HEADY HIM HIM RAMA HIM HIM RAMA H	TCS ADC Hexapod Guider Focus READY READY Represented (Augusta) In Position In Position In Position In Position In Active X 11400 Guider Position In Position In Active X 11400 Guider Position In Position In Position In Position In Position Position Position In Position In Position In Position In Position Position Position In Position In Position In Position In Position Position In Position In Position In Position Position In Position In Position In Position Position In Position In Position In Position Position In Position In Position In Position Position In Position In Position In Position Position In Position In Position	PETALS CALIBPROC PRE-LO PETALS CALIBPROC Remaining PETALS N°SPROC Acc. Time PETAL9 GRAPROC SRITTER PETAL9 CRAPROC SRITTER PETAL9 CRAPROC Res. Let TE READY POSPROC Acc. Time

Honscheid et al. (2012)

DESI Collaboration (2022)



Telescope Installation

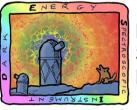
U.S. Department of Energy Office of Science





Flaugher, Diehl, Honscheid et al. (2015)

DESI Collaboration (2022)



DARK ENERGY SPECTROSCOPIC Management, Planning, People

U.S. Department of Energy Office of Science

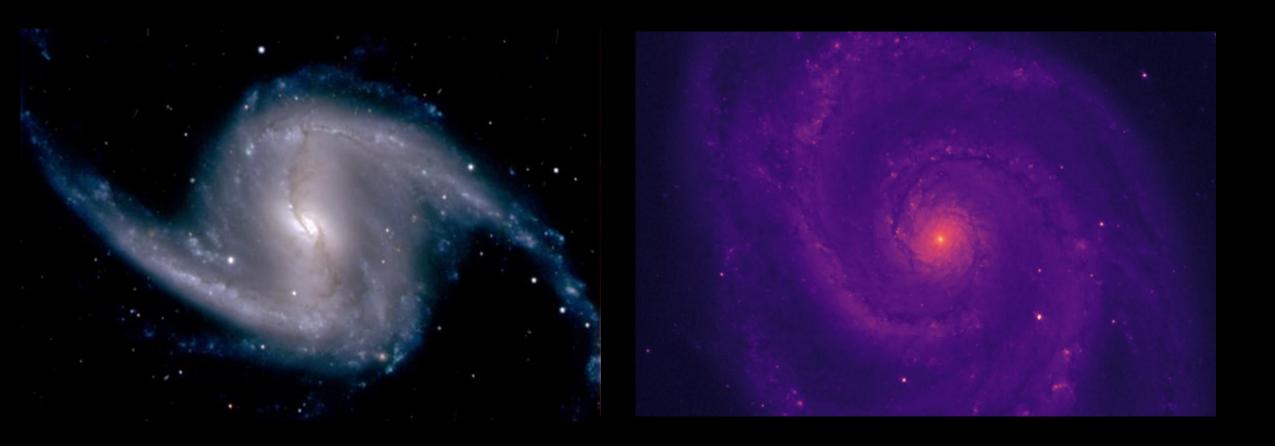
- DOE project management
- Experience in astronomy community with DOE project management
- Leadership
- Commissioning Planning
- Science Verification / Survey Validation

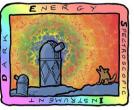




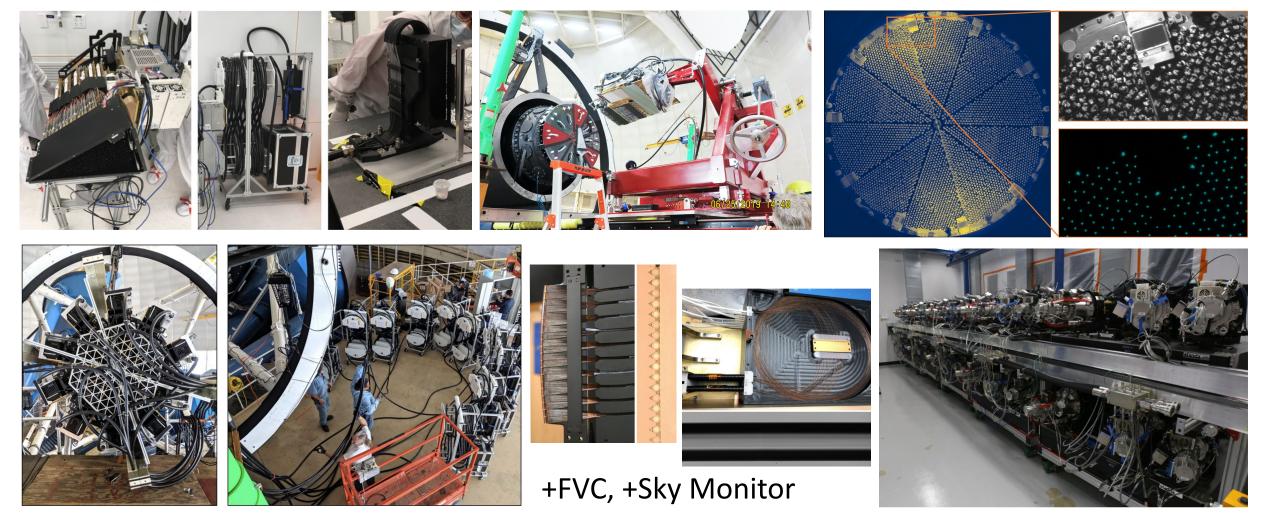


U.S. Department of Energy Office of Science





U.S. Department of Energy Office of Science

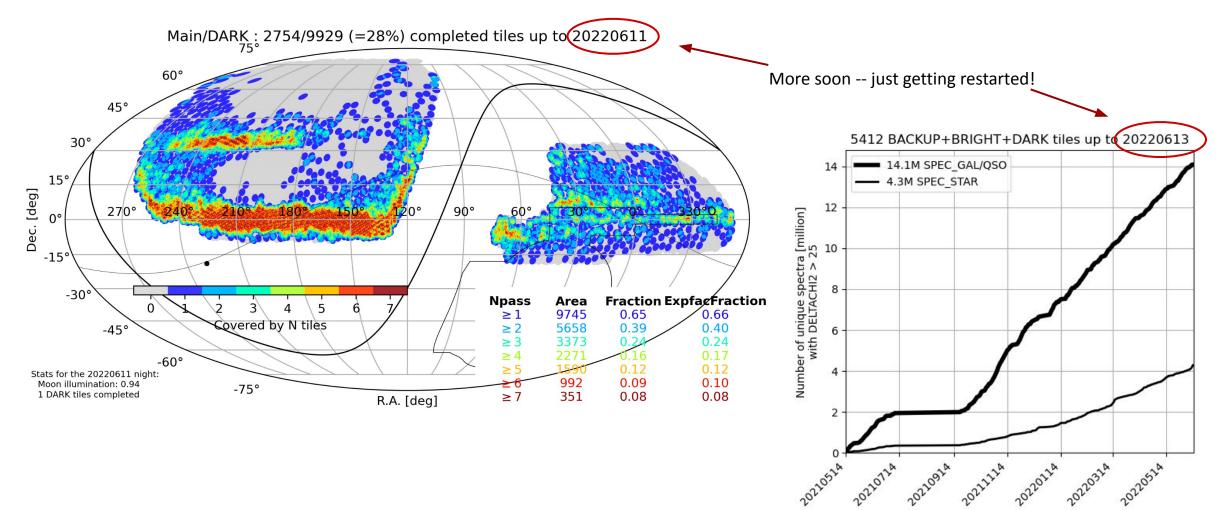


See DESI Collaboration (2022) arxiv:2205.10939 and Silber, Fagrelius, Fanning et al. (2022) arxiv:2205.09014



U.S. Department of Energy Office of Science

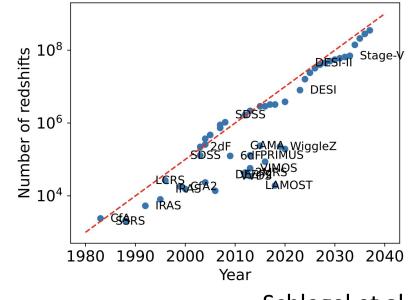
We have already observed 14.1M Galaxies and Quasars + 4.3M stars!

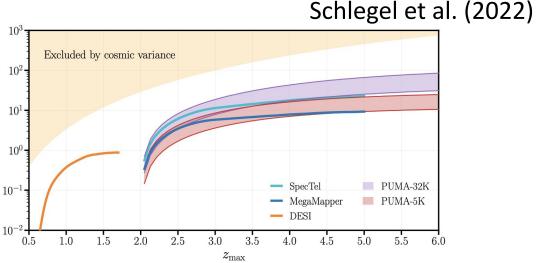




U.S. Department of Energy Office of Science

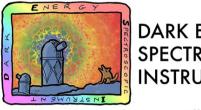
- Lots of cost savings from lessons learned, use of proven solutions
- Extend the investment in instrument R&D across more projects
- Maintain groups of experts, which is especially difficult in university groups
- University groups are important to train the next generation of instrument builders
- Science case for more observations remains compelling (e.g. primordial inflation)





Ferraro et al. (2022) arxiv:2203.07506

Primordial FoM





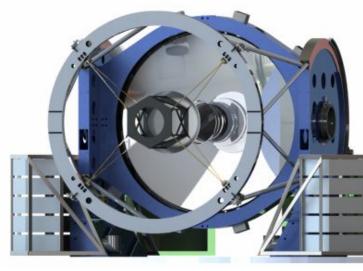
SDSS

ca. 2000

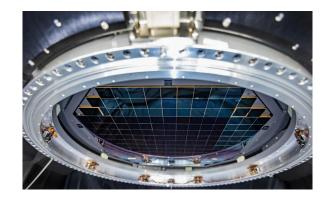
U.S. Department of Energy Office of Science

. . .

MegaMapper, MSE, SpecTel

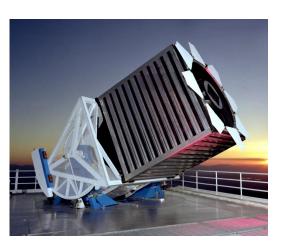


Rubin Observatory



Astrolabe ca. 200 BCE

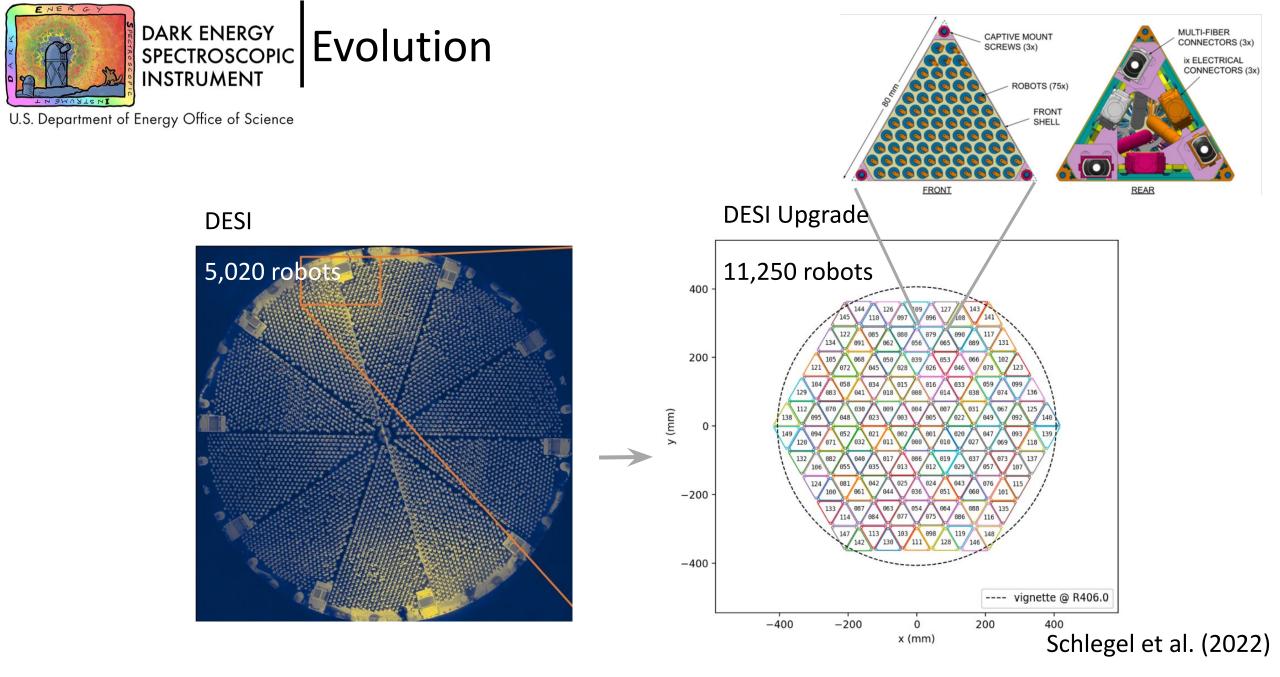




DECam ca. 2010 **DESI** ca. 2020



Not to scale!





K ENERGY CTROSCOPIC RUMENT

U.S. Department of Energy Office of Science

- Lots of cost savings from lessons learned, use of proven solutions
- Extend the benefits of instrument R&D across more projects
- Maintain groups of experts, which is especially difficult in university groups
- University groups important to train the next generation of instrument builders
- Science case for more observations is very compelling!



	-		
	Experi- ment type	Concept	Redshift Range
DESI	spectro	5000 robotic fiber fed spectrograph on 4m Mayall telescope	0.1 < z < 2.0
Rubin LSST	photo	<i>ugrizy</i> wide FoV imaging on a 6.5m effective diameter dedicated telescope	0 < z < 3
SPHEREx	narrow- band	Variable Linear Filter imaging on 0.25m aperture from space	0 < z < 4
$MSE+^{\dagger}$	spectro	up to 16,000 robotic fiber fed spectrograph on 11.25 m telescope	$\begin{array}{c} 1.6 < z < 4 \\ (\text{ELG+LBG} \\ \text{samples}) \end{array}$
MegaMapper	spectro	20,000 robotic fiber fed spectrograph on 6m Magellan clone	2 < z < 5
$\mathrm{SpecTel}^\dagger$	spectro	20,000-60,000 robotic fiber fed spectrograph on a dedicated 10m+ class telescope	1 < z < 6
PUMA	21 cm	5000-32000 dish array focused on intensity 21 cm intensity mapping	0.3 < z < 6
mm-wave LIM concept	mi- crowave LIM	$\begin{array}{c} 500\text{-}30000 \text{ on-chip} \\ \text{spectrometers on} \\ \text{existing 5-10m} \\ \text{telescopes,} \\ 80\text{-}300 \text{ GHz with} \\ \text{R}{\sim}300\text{-}1000 \end{array}$	0 < z < 10

Snowmass 2021 Topical Group Report, Dark Energy and Cosmic Acceleration in the Modern Universe

https://snowmass21.org/cosmic/start

NAS Decadal Report: Pathways to Discovery in Astronomy & Astrophysics for the 2020s

https://www.nationalacademies.org/our-work/decadal-survey-on-astronomy-and-astrophysics-2020-astro2020



U.S. Department of Energy Office of Science



Thanks to our sponsors and 69 Participating Institutions!