5000 Eyes

Mapping the Universe with DESI

#	Time	Visual	English Narration
-0.1	00:21	Title sequence	
0.0	00:37		Space seems to be very dark and very still,
	00:41		but our universe is constantly in motion.
	00:47	all-sky cosmo simulation (CLUES)	As you sit comfortably in your seat, all around you galaxies are changing, colliding, and falling together to form massive structures. They dance around a colossal web of dark matter, which is invisible to us. Meanwhile, the universe rapidly expands, repelled by the mysterious force known as dark energy.
	01:24		We don’t see this in the night sky.
	01:27		Our neighbor galaxies are very far away and their movements happen over billions of years. A human lifespan amounts to merely a snapshot of the cosmic story.
	01:40	Kitt Peak all-sky timelapse starts	It seems we are left with only a picture of what our universe looks like today, and must use simulations like this one to piece together the evolution happening around us.
	01:54		...unless you could peer back in time.
0.1	02:00	KP all-sky timelapse continues through 0.3	…this is exactly what a large group of scientists are doing now - thanks to the properties of light, global collaboration, and a lot of tiny robots!
0.2	02:19		We’re sitting atop Kitt Peak, a mountain in Arizona on the Tohono O'odham* Nation. It is home to deer, coyotes, cactus, and 22 telescopes. They observe everything from distant planets to our own Sun. The largest one is scanning the

			sky and capturing pieces of the universe from the depths of time …
0.3	02:49		"*We want to know more about how the structure of the universe changes, and why. So DESI is measuring the positions of MANY galaxies with a telescope modified to observe many galaxies at once.* *…It is a little wild when you think about it. Here we are, on top of a mountain in the middle of the desert, using 5000 robots to map out the Universe. But of course, there's a lot more to the story…"*
		----- 1 -------	—---BACKGROUND SCIENCE ----------
1.0	03:29	Leave Earth	The key to looking into the past is that light takes time to travel.
	03:37		Light travels very fast, so fast it's hard to notice on Earth. Over short distances it seems instantaneous…
	03:53	See Sun	However, the Sun is much further away. Sunlight hitting your skin left the Sun about 8 minutes ago!
	04:3	See stars	When you look up at the night sky, you're seeing star light that traveled through space for years, sometimes thousands of years, before ending its journey at your eyes.
	05:04	Fly through stars	The further away a star or galaxy is from us, the older its light will be by the time it arrives at Earth. In one year, light can travel about 6 trillion miles, a distance known as a "light-year.".
	05:24		If there are intelligent beings on a planet 100 light years away, they will just now be able to receive the first human television signals sent out in the 1920's.
	05:40	See MW	The Milky Way, our home galaxy, is 100,000 light years across. Intelligent beings living on the other side, looking at Earth today, would see humans just starting to migrate out of Africa! In a way, history is preserved as our light traverses space.
	06:06	Fly away from MW, see other galaxies	The history of the Universe is preserved in the same way. Astronomers can see what the cosmos looked like millions of years ago, just by looking at light from galaxies that are millions of light years away!
1.1	06:36	See other	But how do we know the distances to galaxies?

		galaxies	
	06:55		We can figure this out thanks to another handy fact: the universe is expanding.
	07: 03		Not everything in the universe is getting bigger, - just the space between galaxies.
	07:11	Basic animation of expanding galaxies	The further away a galaxy is, the more space there is between us to expand.
	07:17		This means that nearby galaxies are moving away slowly, and distant ones are moving faster.
1.2	07:27		By measuring how fast a galaxy is traveling away from us, we can figure out its distance.
	07:32		We can break apart the light of a galaxy using an instrument known as a “spectrograph” to see all the colors in its “spectrum.”
	07:42	Basic animation displays color, spectra	As objects move away from us, the light we see from them is stretched and appears redder. The faster a galaxy is moving, the redder it appears.
	07:55	Animation fades, see galaxies again	The most important thing to remember is that the color of a galaxy can tell us how far away it is. If we want to see what the universe looked like in the past, we can make a 3-dimensional map of the matter around us by measuring the spectra of many galaxies.
1.3	08:21		This has been done before.
	08:25		We’re flying through data taken by the Sloan Digital Sky Survey, a collaboration which measured over a million galaxies.
	08:55	Fly out to see SDSS map	With this information, we can map out the galaxies around us. Each dot you see here is an entire galaxy, containing hundreds of billions of stars and hundreds of billions of planets.

	09:17		With so much data, you can start to see... patterns.
	09:24		Galaxies aren't randomly scattered about. On very large scales they are organized in a sort of sponge-like structure. There are clumps, sheets, and strands of galaxies, all surrounding cosmic voids: large regions with very little matter.
	09:50		This structure is constantly in motion, ever evolving. To see how it's changed, we can peer back in time.
1.4	10:09	Basic animation comparing slices of the structure to a simulation	Light from nearby galaxies is relatively young, so the structure we see close to Earth is of a more evolved Universe.
	10:21		Light from more distant galaxies is older by the time it arrives.
	10:26		It carries information of a younger universe, when structure was less evolved.
	10:33		By mapping out this structure at different distances, we can see what the universe was like in different moments of time.
	10:43		When you put each snapshot together, you can see the story of how the universe evolved.
1.5	10:52		It's maps like this one, which extend through space and time, that reveal how the universe is changing and help us study the ingredients that affect this evolution - such as gravity, dark matter, and dark energy.
	11:09	Travel back to Earth	But just like this structure, our story has some holes. For instance, scientists have determined that dark energy is driving the expansion of the cosmos and that it makes up most of the universe. We see its effects, but we don't really know what it is. We need a more detailed map of time.
		------- 2 -----	----------SURVEY----------

2.0	11:40		To accomplish this, cosmic cartographers from all over the world have come together.
	11:47	Images of collaboration around globe	The Dark Energy Spectroscopic Instrument, or DESI, is creating the most complete map of our nearby universe.
	11:57	Fly into Earth	It's a lot of work. A large survey like this needs hundreds of people working over decades: building the instrument, designing software, generating simulations, planning the survey, observing on the telescope, managing and analyzing data, keeping the observatory running, and much more.
2.1			[Short clips of DESI members talking (not all in English!)]
	12:17	Rectangular video of each person pops up for each clip	[Claire (English)] *My name is Claire Lamman, I'm from the United States, and I'm a graduate student at Harvard.*
	12:23		*When you watch videos about observations in astronomy, like this one, you're often seeing a very neat, distilled version of the process.*
	12:33		*Real data can be messy and there's so many small things to take into account - from the subtle ways that galaxies are oriented to wind at the telescope!*
	12:44		*That's why we need many different people, with many different specialties, to take on a project like this one.*
	12:52		[Siwei (Chinese)] *My name is Siwei, and I work at the Kavli Institute of Astronomy and Astrophysics at Peking University.*
	12:56		*The science goal of our group is to study the formation and evolution of galaxies and their implications on cosmology.*
	13:06		[Andreu (Spanish)]

			My name is Andreu Font Ribera and I'm a cosmologist at IFAE, the high-energy physics institute in Barcelona
	13:11		*One of my roles in DESI is to generate fake universes: simulated versions of the galaxy spectra that DESI observes.*
	13:17		*These simulations showed us what to expect before we had real observations, and now we use them to validate our analysis.*
	13:26		[Khaled (English)] *My name's Khaled. I work as a researcher at the University of Queensland in Australia.*
	13:32		*One thing that many of us here at the University of Queensland are helping with is a process called visual inspection.*
	13:39		*During this process, we actually look at every single spectrum from DESI to ensure the quality of the spectra, classifications, and redshifts.*
2.2	14:00	Visualization of Legacy Imaging Survey on Sky	The galaxies they are measuring are too faint to be seen by eye.
	14:04		This small patch of sky may look dark and empty - but it is brimming with the ancient light of far away galaxies.
	14:15		For observations, these galaxies need to be in the right place in the sky: far enough away from the Milky Way so that the light and dust in our own galaxy doesn't get in the way.
	14:30		Using 3 different telescopes, the DESI team has chosen and imaged the galaxies they will measure: all 40 million of them.
2.3	14:42		Gathering 40 million spectra is no easy task. If you measured each galaxy one at a time, it would take 20 thousand years to finish the survey.
	14:55		This means you need more than a typical telescope.

	15:03		DESI is part of the Mayall telescope on Kitt Peak
2.4	15:08	Fly around 3D model of Mayall	To complete the survey in just 5 years, DESI is built to observe 5000 objects at once.
	15:17		Each observation starts with the Mayall pointing at a region of sky
	15:23		All the light from this patch travels into the telescope, where it hits a massive mirror. The light then reflects up, where it passes through a series of lenses before it's focused in a beam onto the "focal plane".
	15:41		At this point, the beam contains the light of 5000 galaxies…but it also contains the light from everything else in that patch of the sky.
	15:54		The focal plane is where the light of each galaxy is separated from everything around it.
2.5		Fly-through of DESI's 5000 robots	
	16:04	Kevin's rectangular interview plays over top	[Kevin (English)] *My name is Kevin Fanning, I am a graduate student at the Ohio State University located in the US,*
	16:11		*and I have worked on the DESI focal plane for the better part of six years.*
	16:14		*Behind me is the Mayall 4-meter telescope on Kitt Peak. Mounted at the top of the telescope is the DESI instrument.*
	16:22		*Inside of the instrument is the focal plane, which has five thousand pencil-shaped robots to position fibers onto galaxies.*
	16:30		*These robots can position themselves to an accuracy of about five microns. A human hair is only about eighty microns thick, which means we're literally splitting hairs with these robots.*

	16:47		The light from each robot passes down fiber optic cables to a separate room containing 10 spectrographs. These spectrographs measure the color of each galaxy, and in mere minutes you have the redshifts, and therefore distances, to thousands of galaxies!
2.6	17:12	Footage of the Mayall in motion	But these robots can't do it alone…
	17:29	Satya's rectangular interview plays over top	[Satya (French)] *My name is Satya Gontcho A Gontcho. I am a French cosmologist and I work at Lawrence Berkeley National Laboratory.*
	17:37		*I am one of the DESI lead observing scientists.*
	17:42		*I'm standing here in the historical control room of the Mayall Telescope.*
	17:47		*I am fortunate to come regularly to the mountain top in order to conduct nights of observing.*
	17:53		*We want real, in-person people doing the observing because we need them to exercise their judgment to handle any situation that may arise.*
	18:03		*Be it the weather, technical challenges, you name it, we handle it.*
		--------3----------	-----CONCLUSION ----------
3.0	18:13	A second KP timelapse / continue of telescope time lapse from above	DESI is always going. Observing a new patch of galaxies every 10 minutes, every clear hour, every clear night for 5 years.
	18:29		The terabytes of data coming in will help solve many mysteries - from constraining the mass of subatomic particles to exploring our own galaxy!
	18:40		With so much new information, who knows what secrets will be revealed over the

			next few years…
	18:50	Fly-through of DESI Y1 data	Let's look at what DESI's 5000 eyes saw in the first year of the survey… over *10 million galaxies*
	19:05		…galaxies which cluster together and trace out the largest structures in the Universe. DESI's data reveals massive strands, sheets, and voids of matter as never seen before.
	19:29		A long time ago, light left these galaxies. As the universe expanded, the light was stretched and reddened until, hundreds of millions of years later, it found itself reflecting off a massive mirror towards a multitude of small robots.
	19:51		Humans studied the color of that light, figured out just how far it traveled, and added it to our ever-growing map of galaxies. ...a map that not only extends back through space, but back in time.
	20:11		To explore this mysterious frontier is to read the story of the cosmos... and probe the big questions about our home:
	20:20		What does the universe look like? What is it made of? How is it changing? ...all to be illuminated with a map of ancient light
3.1		Fly through continues, on top: credits, sponsors, websites, social media, etc.	

* for a correct pronunciation, see the "common pronunciation" in this video: https://www.facebook.com/watch/?v=351006023032520