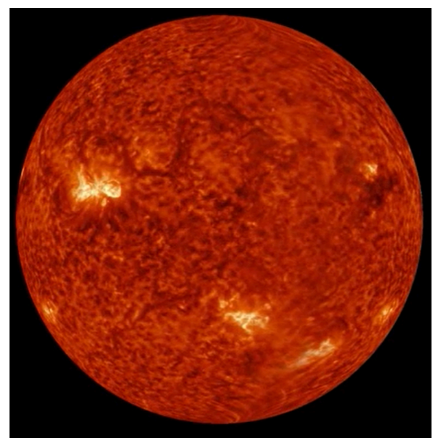
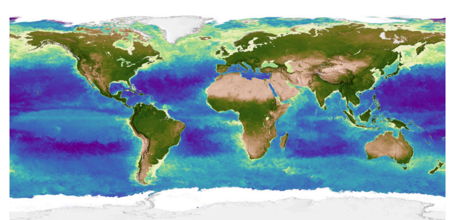
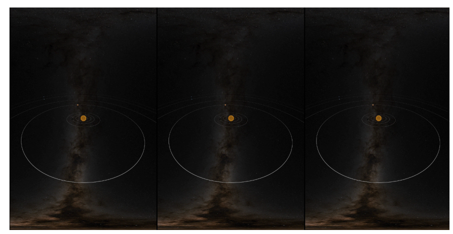
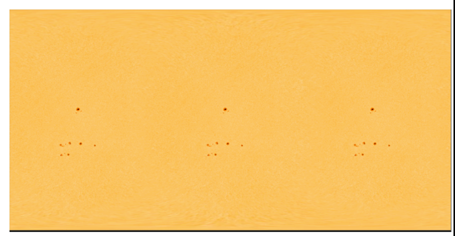
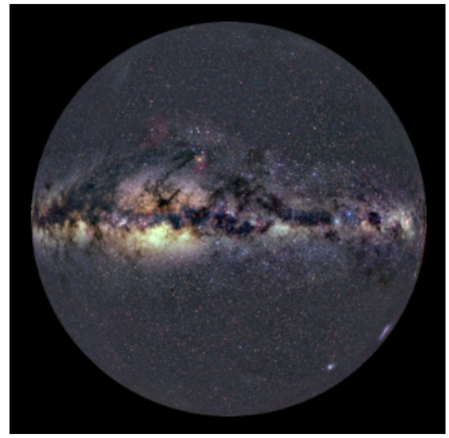
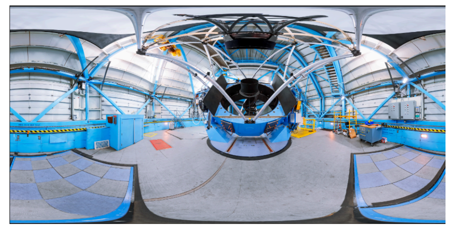
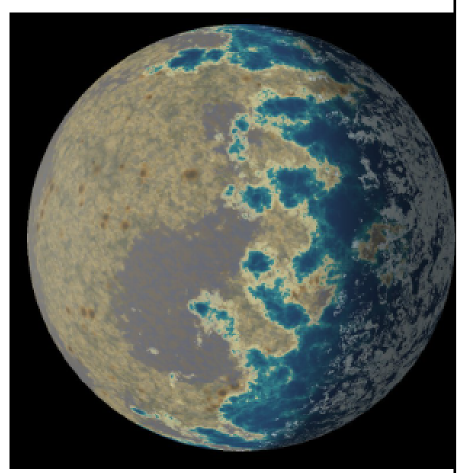
The Sun, Our Living Star

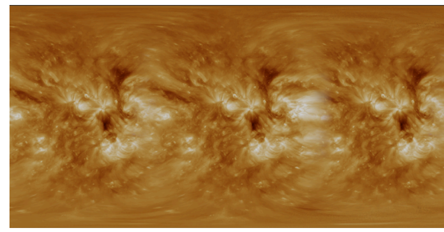
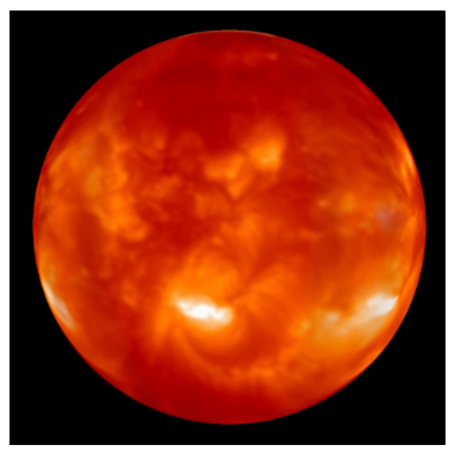
— a Science on a Sphere show produced by NSF's NOIRLab for the Windows on the Universe Center

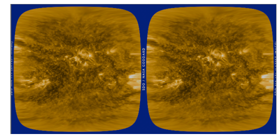
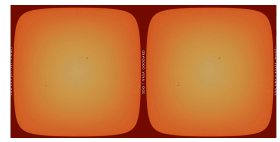
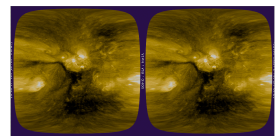
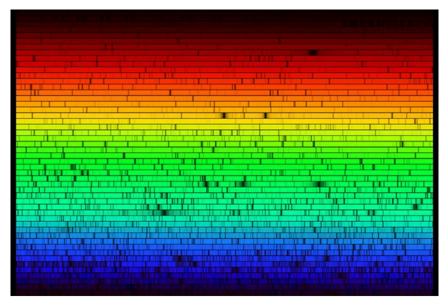
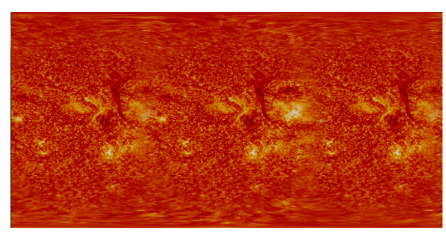
Sun Show Datasets. Duration: ~15 minutes

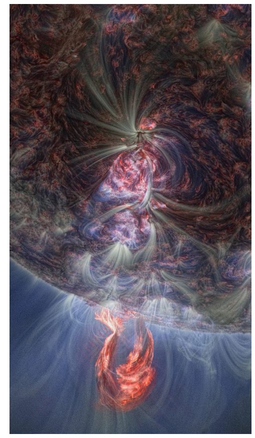
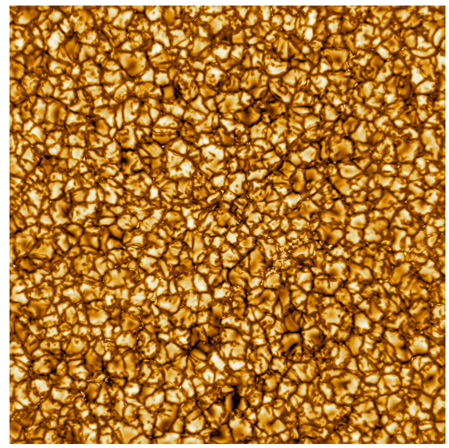
Seq	English	Key Takeaways	Visuals and Music
1	Our home planet is a **blue oasis in a vast cosmic desert**, and the **only place in the entire Universe where life is known to exist**. **The Sun is the lifegiver** that has shone constantly on our world for four and a half billion years. The light from the Sun that warms our skin today has been felt by every person who's ever lived.	The Earth is fragile and unique. Life on Earth could not have started nor have been sustained without the Sun.	 https://sos.noaa.gov/catalog/datasets/blue-marble/ Credit: NASA Goddard Space Flight Center/NOAA Pre-show & section music
2	**The Sun is our planet's powerhouse**, the source of the energy that drives our winds and our weather. It is the primary generator of the extraordinary web of life crawling, swimming, running, and flying all over the world. **All life on Earth depends, in some way or another, on our nearest star … the Sun.**	The Sun is the source of all life on Earth.	 Sun: Helium Wavelength (AIA 304) - Science On a Sphere
3	In oceans and on land, **plants harness energy from sunlight**, converting it into food through **photosynthesis**. This productivity drives many ecosystems on our planet.	Photosynthesis converts energy from sunlight into food for life.	 NASA SVS | Near Real-Time Global Biosphere

4	Did you know that **plants also release precious oxygen into the atmosphere which we breathe?** This allows our cells to unlock energy from the food we eat.	Plants release oxygen which is necessary for life.	 [KPNO Buildings 360 Panorama | NOIRLab]()
5	The passage of its fiery disc across the sky — day by day, month by month — was, for countless past civilizations, the only way to keep track of time. **The Sun's motion formed the basis of many ancient — and indeed modern — calendars**, helping us chart our past and predict our future. **The Sun drives the rhythms of our lives**. The tilt of Earth's axis causes daytime sunlight to change in intensity and duration over the course of a year, and gives rise to the seasons and their cycles of growth and decay.	Humans have used patterns of the Sun's motion to form the basis of past and modern day calendars. The seasons are a result of Earth's tilt and differential intensity of sunlight.	
6	**Some cultures reasonably, but incorrectly, placed the Earth at the center of the cosmos**, with the Sun, planets and stars revolving around our planet. In the 16th century, however, the truth of our place in space began to emerge. European astronomer **Nicolaus Copernicus put forth the heliocentric model** of our Solar System, with the Sun at its center. Our relationship with the Sun was transformed.	The Earth was once thought to be the center of the known Universe.	 Solar system footage.
7	In 1610, Italian astronomer **Galileo Galilei was the first to use an instrument called a telescope to observe the Sun**. Much to his surprise, he discovered **black splotches marring its surface**. We know these splotches as **sunspots**, areas on the Sun where the magnetic field is so strong, it blocks light from the inner layers of the Sun from reaching the surface, therefore **"cooling" the area down and forming a darker spot**. These formations helped inspire the paradigm shift that triggered the scientific revolution. **Gradually, science replaced mythology.** **With the passing centuries, our knowledge of the Sun has evolved as technology has advanced** and more astronomers have turned their gaze towards our star to uncover its secrets.	The Sun is not a blank disc or sphere. Science uncovers the Sun's secrets Scientific expla-nations are subject to revision in light of new evidence. Technology advances have influenced the progress of science.	 Converted from: https://sdo.gsfc.nasa.gov/assets/img/latest/latest_1024_HMIIF.jpg

8	**We have measured the distance to the Sun,** 150 million kilometers from the Earth **(93 million miles)**. We can now estimate that it is just one of **some 200 billion stars in the Milky Way Galaxy**. Just as we orbit around the Sun, so too does the Sun orbit around the center of our galaxy, completing a galactic orbit every 250 million years.	The Sun is just one of many stars that is part of the Milky Way Galaxy.	 [use own 40k all-sky image] Section 6-7 music (maybe longer): [stellardrone-the-belt-of-orion.wav]()
9	Within this grand structure, telescopes in space and on the ground, **such as the WIYN 3.5-meter Telescope here at Kitt Peak, have found more than 5000 exoplanets in orbit around other stars.** And there are probably **billions more to be found.**	There are multitudes of planets orbiting other stars.	 [WIYN 3.5-meter Telescope Interior 360 Panorama | NOIRLab]()
10	**We lack the technology so far to see if these strange, new worlds might support life**. But over the next couple of decades, as our searches and studies continue, we may find we are not alone in the Universe.	Advances in technology will increase their detection and help determine if there may be life on them.	 Artist's concept of an exoplanet: [Exoplanet: TRAPPIST - 1d - Science On a Sphere]()

11	The best places to look for alien life may be on planets orbiting stars much like our own. As a star, our Sun is not exceptional. In fact, one could say that **it is rather average.** **Stars come in many sizes and colors**, from tiny dwarfs to supergiants — like Betelgeuse symbolized by the sphere here — which could hold five billion Suns inside. Don't be fooled by the terminology… As a yellow dwarf, our Sun could still comfortably fit over one million Earths inside it. The Sun's immense proportions dominate our Solar System. This luminous, titanic object is **500 times as massive as all the planets combined**.	The Sun is an average dwarf star Stars come in many sizes and colors	Star size comparison  .
12	Almost **five billion years old**, our star is now well into its adulthood **half-way through its 10 billion year life**. It is an enormous **ball of hot, glowing gas**, composed mainly of hydrogen, and small amounts of heavier elements including carbon, nitrogen, oxygen, and iron. **These elemental ingredients also compose our bodies and all other living things**. The Sun is radically different from our world. Although it has no solid ground on which we could set foot, it does possess a visible surface. This region is known as the photosphere, and **it appears to boil** like a colossal pot of soup. **The temperature of this visible surface is about** 5500 degrees C or **10,000 F** — more than 20 times hotter than the hottest kitchen oven.	The Sun is half-way through its lifespan. We are made of star stuff. The Sun is really hot on the surface…	 From: https://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=11379 Alternatives: https://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=11379 https://svs.gsfc.nasa.gov/12034 https://svs.gsfc.nasa.gov/search/?series=SDO%20-%20Footage
13	But beneath its surface, **temperatures at the Sun's core soar above an incredible** 15 million degrees Celsius or **27 million F**. Almost all of the star's energy is generated in the core. **Extreme heat and pressure force hydrogen atoms together, producing helium and liberating tremendous amounts of energy in a process called nuclear fusion.** Fusion allows the Sun to consume 600 million tons of hydrogen each second, turning it into 596 million tons of helium. **The missing** four million tons of matter — **a bit less than 1% — is converted into a tremendous amount of pure energy** — one million times the amount of energy that the entire world uses in a year. [OPTIONAL, for schools etc: Einstein's most famous equation, $E=mc^2$, tells us how even a little mass can be turned into a lot of energy: Energy equals Mass times the speed of light, c, and times the speed of light again. Since the speed of light is enormous — over one billion kilometers per hour — **the amount of energy in just a gram of matter is almost unfathomable**.]	but much hotter further down! Fusion produces the Sun's energy. 1% of the matter is turned into pure energy. Mass and energy are two sides of the same thing. A small amount of matter equals an unimaginable amount of energy.	 https://sos.noaa.gov/catalog/datasets/sun-x-ray-2003/

14	**Solar observatories** on the ground — like the McMath Pierce Solar Telescope we're standing in — and in space **provide scientists with a continuous view of the roiling Sun**.	Science keeps progressing	 https://noirlab.edu/public/images/archive/category/360pano/?search=math
15	**Here you see the Sun as it looks today.** We are now close to solar [maximum/minimum] which is reflected in the level of activity seen: sunspots, prominences etc.	The Sun changes all the time.	   This is a multi-layer dataset that updates daily with the latest images from SDO and SOHO.
16	**By splitting its light into its various colors or wavelengths using spectroscopy, we can determine the chemical composition of the Sun**. The black lines in the spectrum, called absorption lines, are fingerprints of different elements. **Astronomers using the McMath Pierce Solar Telescope even discovered water vapor on the Sun.** And have made some of the **highest precision spectra of the Sun**.	Spectra unveils chemistry MMP contributed with important discoveries	 MMP spectrum
17	The **Earth's ozone layer was studied for years from here** as well as the Sun's magnetic fields that weave up and down the Sun's surface. And minute movements of the Sun — **solar oscillations — caused by sound waves inside were found.** This is now a prominent field of solar research. Also the **connection between activity on the Sun and violent events here** on Earth was studied.		 Converted from: Filament Eruption Creates 'Canyon of Fire' on the Sun (For more MMP science see notes: Content Collaboration Next Steps.docx)

18	We now know that the **sunspots** discovered by Galileo **can lead to explosive ejections of high-energy particles, called solar flares, which can damage satellites and electrical power grids on Earth**. The high-energy particles it throws into space can bring beauty to Earth. **So-called "space weather" intensifies the ethereal northern and southern lights**. These aurorae arise near Earth's poles, where Sun-blown particles called solar wind — funneled by our protective magnetic field — interact with the atmosphere. On the 1st of Sept 1859 the Sun caused **one of the largest geomagnetic storms ever measured, called the Carrington Event**. Northern and southern lights were seen all over the Earth and **the storm caused fires in telegraph stations**. Imagine that happening today with all the sensitive electronics orbiting the Earth!	The Sun can be violent Space weather is a thing Aurorae are caused by particles from the Sun	 https://supernova.eso.org/static/archives/exhibitionimages/original/0303_A_Untitled_000418.tif Background: Sun: Historical Solar Flare - 2003 - Science On a Sphere
19	**The McMath Pierce is no longer used for research and the National Science Foundation's latest solar telescope was built on Maui**, Hawaii, by the National Solar Observatory and is called the **Daniel K. Inouye Solar Telescope**. With a 4-meter mirror it is now **the world's largest solar telescope** and has cutting-edge technology to provide **views of the explosive photosphere like we've never seen before**. Incredible images and spectra reveal the turbulent "boiling" plasma that covers the entire Sun.	NSF is at the forefront of solar research with the Inouye.	 https://nso.edu/gallery/gallery-images-from-the-inouye

20	The immense, but finite, reserves of fossil fuels — including coal and oil — have enabled the rise of the modern world. Those fuels were formed from plants and sea creatures that also thrived on the Sun's nourishing output millions of years ago. Our continuing need to depend so heavily on burning fossil fuels that lay trapped beneath the ground for millions of years **has changed our atmosphere's chemistry, leading to rising temperatures on the Earth** with serious consequences for life here. This has motivated scientists to discover and develop different, **renewable, and sustainable, energy sources, among them water, wind, and . . . the Sun.** [OPTIONAL, for schools etc: **Some think that a long-term solution lies not with collecting the energy expelled from the Sun, but instead mastering the *fusion* process that takes place in its core.** The fuel needed for fusion is practically unlimited. It only requires hydrogen, the most abundant element in the Universe. On Earth, hydrogen can be readily found in the planet's oceans, unlike the scarce uranium that is currently used in today's nuclear fission power plants. While it is hoped that fusion will sustain humanity by providing an essentially limitless power supply for our needs, the same cannot be said for the Sun.]	Everything here comes from the Sun Manmade global warming is a big peril But the Sun can also continue as life-giver in a different way Harnessing the Sun's fusion here may provide a solution	 Gemini South on Cerro Pachón 360 Panorama | NOIRLab
21	**What lies ahead for our beloved star? Eventually, the Sun's supply of fuel will dwindle and the fusion at its core will cease**, prompting a spectacular, but deadly transformation. **Starved of fuel, the Sun will expand**, and with its dying breaths it will almost certainly **engulf the inner planets and become a planetary nebula. Our star will consume the world it once nurtured!** **Fortunately, this will happen in the far future — in 5 billion years**. Until then life will continue to evolve on this small blue planet, drinking in the life-giving rays of a living star, our Sun.	The Sun will die … …consume the Earth and become a Planetary Nebula	 The Helix Nebula, NGC 7293 | NOIRLab
22	[Prompt audience to leave]		Logo: KPNO Color NOIRLab NSF

NSF NOIRLab / NOAA / KPNO

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Learning Objectives

Through the solar and planetary data visualizations in *Our Sun, the Living Star*, students and other guests will gain insight to the Sun's dynamic nature including its motions, cycles, and influence on space weather and on Earth. Guests will be able to recognize how breakthroughs in technology have significantly progressed our understanding of the Sun and led to the advancement of renewable energy solutions to address climate change.

Correlations to the Next Generation Science Standards

Earth's Place in the Universe

Space Systems

MS-ESS1-1

- Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models (MS-ESS1.A).
- This model of the solar system can explain eclipses of the sun and the moon. Earth's spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year (MS-ESS1.B).

HS-ESS1-1

- The star called the sun is changing and will burn out over a lifespan of approximately 10 billion years (HS-ESS1.A).
- Nuclear Fusion processes in the center of the sun release the energy that ultimately reaches Earth as radiation (HS- PS3.D).

HS-ESS1-3

- The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth (HS-ESS1.A)
- Other than the hydrogen and helium formed at the time of the Big Bang, nuclear fusion within stars produces all atomic nuclei lighter than and including iron, and the process releases electromagnetic energy. Heavier elements are produced when certain massive stars achieve a supernova stage and explode (HS-ESS1.A).

Weather and Climate

MS-ESS3-5

- Human activities, such as the release of greenhouse gases from burning fossil fuels, are major factors in the current rise in Earth's mean surface temperature (global warming). Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities (MS-ESS3.D)

HS-ESS2-4

- The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, and redistribution among the atmosphere, ocean, and land systems, and this energy's re-radiation into space (HW-ESS2.D).

Nature of Science

- Science is a Human Endeavor
- Scientific Knowledge is Open to Revision in Light of New Evidence