TWO SMALL PIECES OF GLASS

The Amazing Telescope

Visual List/Script

Blue = Computer Graphics

Black = HD footage/video

Red = Time Lapse photography

Purple = Planetarium Graphics

Scene I Visual I Audio

Intro and title sequence		
1.	Circle showing a view through a simple refractor as if the audience were looking through it. As it pans around it shows a view of the Moon, Jupiter with its moons, and the Milky Way. Fly through the telescope seeing two pieces of glass coming together in front of a fuzzy title, as they line up the title comes into focus. Fades to current star field.	Dramatic Music...starts slow and builds
2.	Two spot lights representing bicycle lights move across a park entrance sign. A paper sign reads "Star Party Tonight" Lights fall off the sign.	[The clatter of two bikes dropping to the ground is followed by the sound of feet walking on gravel.]
3.	silhouette of a teenage girl appears facing forward against a darken dome	**Youth 1 (The voice of the audience)** Hey, wait up! I can't see.
4.	The silhouette turns around to meet a second silhouette of a teenage boy	**Youth 2** OK. We'll wait for your eyes to get use to the dark.
5.		**Youth 1** Why does it seem so dark here?
6.		**Youth 2**

Scene	Visual	Audio
	Youth 1 stumbles, bumps into tree, startling an owl; The yellow eyes of an owl appear. Glaring at the kids, he slowly blinks and flies off the tree.	Because we rode in from the bright lights of the city into the dark of the park, your pupils in your eyes are slowly opening up right now to let more light in… just wait - you will be able to see well enough soon.
7.	Stars appear on the dome – set for equator. Brighten as eyes adjust.	**Youth 1** Is that why owls have big eyes, so they can see at night?
8.	Human eye with pupil, changing as it adapts to darkness. Shown in south at 45 degrees above horizon Refractor with light path on east side of dome Reflector with light path on west side of dome	**Youth 2** Yeah. The larger the pupil, the more light it lets in and that's why they can hunt at night. The telescopes we're going to look through tonight work the same way. The bigger the mirror or lens, the more light the telescope captures. Last year they had a telescope that was big enough that . I got to see galaxies through it. It was really cool!
9.	Youths move down the path and silhouettes of	**Youth 1** Wow,! I can see the path now. Let's go.

Scene	Visual	Audio
	a group of people appear. 6 to 8 telescopes silhouettes at cove line around dome with people at each one.	[The sounds of footsteps on gravel continue and then go silent as the youths appear to move off the path onto grass. Voices are heard – they become louder. Sounds of laughter, a child can be heard saying, "Wow!"
10.	Silhouettes of a mature female emerges to join the two youths	**Astronomer (Voice of authority)** Hello there! Glad you could come. I've been looking for you.
11.		**Youth 2** Did you bring your big telescope this year?
12.		**Astronomer** Of course, it's over here.
13.	The scene moves to a silhouette of a large Dobsonian telescope and ladder	
14.		**Youth 1** No way. That thing is huge! And it sure doesn't look like the telescope in our science classroom at school. The

Scene	Visual	Audio
		eyepiece is at the back. Where is yours?
15.		**Youth 2** It's at the top, that's why we need the ladder to look though it.
16.	Reflector optical system – fly through showing the inside of telescope and light paths	**Astronomer** That's right. This is a reflecting telescope, which means the light is gathered on a mirror at the back of the telescope and reflected to the front of the telescope, where it hits another mirror and the light is reflected again, into the eyepiece. The telescope your teacher has is called a refractor; that uses lenses instead of mirrors to gather and focus the light.
17.		**Youth 1** Which is better, the reflector or the refractor?
18.		**Astronomer** **I**t depends on what you want to observe with your telescope. But the general rule is, the bigger the mirror or lens, the more light the telescope will gather, and the brighter and more resolved the

Scene	Visual	Audio
		object you are looking at will be.
19.		**Youth 1** Resolved?
20.		**Youth 2** To resolve an object means that you can see detail. When you look through the telescope from our school you can see Jupiter and its four moons. But when you look through this telescope, you can see the bands of clouds on Jupiter, too! So the better the resolving power – or resolution - the better the view. Right?
21.		**Astronomer** Right! You have a great memory.
22.	Image of Saturn as viewed through a moderate size instrument	**Youth 2** How could I forget? I will always remember seeing Saturn's rings for the first time and the spiral arms of that galaxy you showed me last year.
23.		**Youth 1** Can I look through your telescope?
24.		**Astronomer** Sure, the whole reason I brought it here.

Scene	Visual	Audio
25.		**Youth 1** - (?)
26.	One student viewed on ladder at the eyepiece. Jupiter appears in view showing Galilean Moons	[Sounds of climbing a ladder]
27.		**Youth 1** Wow! Is that really Jupiter? What are those stars lined up on either side?
28.		**Astronomer** Those are the four Galilean moons – Io, Callisto, Europa and Ganymede.
29.		**Youth 1** Why are they called Galilean moons?
30.	Footage of Galileo appears off to side of dome Background is CGI to match setting	**Astronomer** An Italian mathematician named Galileo in 1609 was the first man to see them with a telescope. In fact, it's believed that Galileo was the first to use a telescope to view the heavens. He was surely the first to record his observations.
31.		**Youth 1** Galileo invented the telescope?
32.		**Youth 2** Nope. Can you tell the story of that Dutch guy?

Scene	Visual	Audio
33.	Stonehenge All Sky Image (fisheye) Eclipse footage Live sky motion (rendered out for full dome facilities) Ptolemaic model of the solar system. Copernicus footage off to one side of dome Heliocentric model of solar system above	**Astronomer** Sure, but let me tell your **brother**(?) what it was like before there were telescopes. Big events, like lunar eclipses and meteor showers, can be enjoyed without the use of a telescope. All you need to do is look up and view them with your own eyes. Everyone used to believe that the Earth was the center of the Universe and that the Moon, planets, and even the Sun orbits around it. Then a man named Nicholas Copernicus proposed a different model with the Sun, not the Earth, at the center; most people did not take the idea seriously. They felt that Copernicus' model was far fetched.
34.		**Youth 1**
35.		**Astronomer**

Scene	Visual	Audio
36.		
37.	Footage of Lipperhey – CGI in background to match.	**Astronomer** But in 1609, a Dutchman named Lipperhey took two small pieces of glass and fixed them in a tube creating a spyglass. Now, this was probably not the first time that this had been done but the idea for the telescope was published in the newspapers and Galileo read about it.
38.		**Youth 2** …and Galileo did something that no one had done before, he looked at the night sky with his telescope.
39.	Clip of Galileo from documentary shown in laptop... CGI/Images illustrating FOV of the telescope.	**Astronomer** On a clear evening in January 1609, he pointed it toward Jupiter. Let me show you a clip of him on my laptop. The telescope's narrow field of view made it difficult for him to find Jupiter, but when he did,

Scene	Visual	Audio
	Jupiter – fuzzy, with moons Galileo's Journals showing Jupiter and Galilean Moons Copernican Orrey	he saw three stars next to Jupiter - one to the right of Jupiter and two more on the planet's left. He watched these points of light over several nights, noting how they changed their position. He determined that they were moons orbiting Jupiter - not the Earth. This became the first observational evidence that the heavens worked differently than what people had imagined up to then. Copernicus' theory, that we orbited the sun, was eventually proven using Galileo's new window on the universe – the telescope.
40.		
41.		**Astronomer** And His telescope was even smaller than the one in your school!
42.		**Astronomer**

Scene	Visual	Audio
	Footage of Galileo's Telescope Images of the Moon, Venus, the Sun and Milky Way.	The lens was very small and not very clear. It's only due to Galileo's patience and careful observing that he saw what he did. Galileo's telescope had a small lens so the resolution was very poor. The telescope magnified enough for him to recognize that there are mountains on the Moon, spots on the sun, and that Venus goes through phases like our Moon, but he couldn't see much more than that. He did see that the Milky Way was made up of thousands of stars. Now, would you like to look at Saturn?
43.		**Youth 1** Sure.
44.	Silhouette moves up the ladder and moves the telescope.	**Astronomer** Give me a minute. [Sound of the telescope moving, shuffling of feet] Here we go. Take a look.
45.		**Youth 1**

Scene	Visual	Audio
	Image of Saturn.	Wow, that's awesome! IS it real?
46.		**Youth 2** It's real!
47.		**Youth 1** Did Galileo see Saturn in his telescope?
48.	Galileo's drawings of Saturn Footage of Huygens and friend viewing Saturn Huygen's telescope	**Astronomer** Yes, but all he saw an oblong point of light because his telescope lacked the resolving power to see the rings. He described it as a planet with "ears" since his image was distorted. The Dutch astronomer Christiaan Huygens used a 23-foot long refracting telescope, revealing Saturn as a ringed planet and discovering its largest moon Titan.
49.		**Youth 1**
50.		**Astronomer**
51.		**Youth 1**
52.		**Youth 2**

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Scene	Visual	Audio
53.		**Astronomer**
54.		**Youth 1** .
55.		**Youth 2**
56.	Newton at his desk, and at the window w/prism optical aberration through a simple set of lenses Images of Refractor and Reflector light paths with Red and Blue light paths – shows aberration in refractor	**Astronomer** Shortly after Huygens made his long refractors, a man named Sir Isaac Newton did some experiments and figured out that color aberration, a common problem with refracting telescopes that causes an image to have a colored ring around its edge, was produced when light passes through the lenses. So he found a way to use a mirror to focus the light just like a lens, but without the color aberrations. Now do you want to see some real color?
57.		**Youth 1** Sure!
58.	Silhouette of the telescope being moved.	**Astronomer** OK…I'll point the telescope over here to a pretty sight. Alberio A and B. A binary star system, which means these two stars

Scene	Visual	Audio
		appear extremely close; in fact, with your unaided eyes it appears as a single star in the sky.
59.	Image of Alberio A and B	**Youth 1** I see two stars but they're not the same color. One is blue and one is gold.
60.	Footage of a candle's flame; pan from blue to red	**Youth 2** That's because each star is of a different temperature. I learned that last year. When you look at a candle flame you see it go from blue near the wick, to almost red at the top. Each color relates to the temperature of the flame at that point. The top of the flame – the red part is hot. But the blue part is really hot.
61.	Newton at window w/prism and spectra on wall – shown on laptop Visual spectrum with a thermometer showing temperature difference.	**Astronomer** Right again! Newton was involved with figuring that out as well. He passed light through a prism and discovered that colors of the rainbow correspond with different temperatures. The blue portion of the rainbow, or spectrum, is warmer than the red.

Scene	Visual	Audio
	Images of Keck and La Palma	So not only did Newton figure out how to build a telescope using a mirror as a lens to remove color aberrations, he also started the study of light called spectroscopy. These unique discoveries **are** utilized on telescopes all over the world every night, even on the 10-meter mirror telescopes in La Palma and Hawaii.
62.		**Youth 1** 10 meters?
63.		**Youth 2** That's like over 30-feet. What's it like looking through one of them?
64.	Footage of a detector being changed out, astronomers at computer screens – pan to onscreen image. Photo of stars compared to spectrum of stars	**Astronomer** Astronomers don't "look" through telescopes that big. They use devices called "detectors". Detectors take the focused light and either "image" it into a digital photograph or break the light up into a spectrum. Now, a photograph can tell you a lot about an object, but a spectrum can reveal the unseen! When astronomers study the spectrum of a star, they can

Scene	Visual	Audio
		deduce a lot of information about the star. By comparing the observed spectrum to those created in a lab, they can tell how hot the star is. They detect what elements are in the star's upper layers, and they can find its temperature. They can also observe the star's apparent motion by how much the spectrum is "shifted". Have you ever heard a siren from a police car or ambulance change its pitch as it drove by? (Audio of a passing siren)
65.		**Youth 1** Sure.
66.	Compressed and Stretched sound wave Doppler shift of spectrum	**Astronomer** What you heard was something called the Doppler effect – where the sound wave was compressed as it came toward you, and then "stretched" as it went away. This same effect can be seen in spectra of stars that are in motion coming toward or going away from the observer. This effect can also be used to observe motion in galaxies!
67.		**Youth 1**

Scene	Visual	Audio
		Galaxies? Don't we live in a galaxy?
68.	Milky Way as seen from above showing spiral structure	**Astronomer** Yes, it 's called the Milky Way. and… we've only known that for less than a hundred years!
69.		**Youth 2** Why did it take so long for us to figure that out?
70.	Caroline Hershel star disk Image of faint fuzzy. footage of the Hooker Images of Edwin Hubble Telescopic Image of Andromeda Galaxy	**Astronomer** Before the 20th century astronomers thought the universe consisted of a flat disk of stars with the Earth and the solar system residing in the center. An astronomer named Carolyn Herschel even made a map of this disk. Because telescopes of the day didn't have the resolving power to see individual stars in galaxies, they thought the patches of light, which they called spiral nebulae, where part of this immense disk. Astromomers were finally able to see individual stars in the spiral nebulae when the 100 inch telescope was built atop Mt. Wilson.

Scene	Visual	Audio
		An astronomer named Edwin Hubble used this telescope to observe a special type of star called a Cepheid variable and was not only able to determine that spiral nebulae were individual galaxies, but that they were also extremely far away. Look here. This is the closest major galaxy to ours. It's called the Andromeda galaxy.
71.		**Youth 1** Awesome!
72.	Pan across the spiral arm.	**Astronomer**
73.		**Youth 2** Didn't Hubble also determine that the universe was expanding?
74.	Real Time data sets – Tully and or SDSS	**Astronomer** Yes, he did. The expansion that he observed, and later observations of cosmic background radiation in the 1960's, confirmed the model that the Universe was created in a "big bang"
75.		**Youth 1** Is that why they named the Hubble Space Telescope after him?

Scene	Visual	Audio
76.	Images of HST CG of twinkling star.	**Astronomer** That's right. When NASA launched the Hubble Space Telescope, they knew that the telescope would reveal a universe unseen by land-based telescopes of the day. See how the stars twinkle?
77.		**Youth 1** Yeah.
78.	Atmosphere and diffracting starlight – show light coming through and effects of atmosphere 3D flight through Orion Nebula Supernova remnant images collage	**Astronomer** Our atmosphere causes that. And regardless of how big you make a telescope, the –limiting factor in what a telescope can see is the air between it and space. So when they put a telescope in space astronomers knew that they were in for some surprises. The Hubble space telescope revealed the formation of stars and planets. The magnificent remnants of stellar death. It has shown us that the universe

Scene	Visual	Audio
		is dynamic and not stagnant. But what it really showed us is that the early universe was different than the one we live in today.
79.		**Youth 1** What? What do you mean, the early universe? Isn't all the same? How can we see the early universe if we are older?
80.	Circle around Vega Circle around Deneb	**Astronomer** Great question. See that star over there? That's Vega it's about 26 light years away. That means that the light which that star generates takes 26 years to travel to us. So we see it as it was 26 years ago. Now that star over there is called Deneb and it is 3,600 light years away.
81.		**Youth 1** So that is the way it looked 3,600 years ago. Right?
82.		**Astronomer** That's correct.
83.		**Youth 2** And how old is the light from the Andromeda galaxy?

Scene	Visual	Audio
84.	Hubble Ultra Deep Field fly through Colliding galaxies	**Astronomer** Over 2 million years. So telescopes are not only optical instruments, they can be used as time machines. And the Hubble looked back to over 13.5 billion years when it took an image called “Ultra Deep Field”. This image revealed a very different universe than we live in today. It shows small young galaxies colliding and merging to form larger galaxies, which led to galaxies that surround us today.
85.		**Youth 1** So now that we have telescopes in space, astronomers don’t need telescopes on earth anymore, right?
86.	Adaptive Optics system - pre and post star images Footage of observatories/telescopes- Gemini GMT conceptual image	**Astronomer** That might have been true if they hadn’t developed a process called adaptive optics. Astronomers and engineers can now measure the distortions cause by the atmosphere in real-time and subtract them out before the light from an object reaches the focal plane of the telescope. Because of this

Scene	Visual	Audio
		technology, large aperture telescopes that operate around the world can now rival the resolution of the Hubble Space Telescope and even larger telescopes, the size of football fields, are planned to be constructed in the next ten years, and will look even further back into time.
87.		**Youth 1** Wow, what do you think they will see?
88.	Montage of bizarre Hubble images	**Youth 2** I'm not sure, but I want to be the first astronomer to use that telescope!
89.	Real time Data Set of Expansion of the Universe Dark Matter Isospheres Earthlike planets Galileo at the window, sketching the moon	**Astronomer** Good for you! Astronomy is filled with puzzles and unsolved mysteries. The recent discovery that the universe is accelerating in its expansion is one that will need lots of observations to figure out what drives it. Dark matter and the physics that hold galaxies together is another one. But the one that excites me the most is that we are close to having the optical and instrument

Scene	Visual	Audio
	Full Dome fly through of the universe.	power to observe earth-like planets around other stars and should be able detect life on those planets! Who knows, maybe you will be as famous as Galileo is today, because of two small pieces of glass that he turned to the heavens to launch humanity on the ultimate voyage of discovery.
90.	Two pieces of glass coming together, as they line up audience flies through them past a montage of celestial objects – planets, nebula, galaxies. Title appears Credits for production	