THIS IS FOR THE WINTER SKY:

The All-Season Version is Here:

https://docs.google.com/document/d/1JzvE5X1waiDOc3lTgjwbiYsS3NB1eaeXWizzwxsuNhA/edit

The Sky Tonight Show Outline

This and all outlines are meant to be suggestions for what to talk about. Pick and choose whichever facts you'd like, and don't try to fit in everything listed here--the show would be 3 h ours long!

Intro

-Starting on the Oval, can point out Thompson Library to the west

- -Point out directional labels, we're facing north
- -Since the Sun is toward the west, we're a few hours before sunset
- -Everything we're about to see in the sky is exactly what you'd be able to see TONIGHT, if it's clear enough

Cue: Fast forward time to have the sun set

- -The sky is not all that dark
- -We can't see very many stars, only the brightest
- -The glow to the NW is sky glow from the stadium on campus
- -The bigger glow to the south (behind audience) is sky glow from downtown Columbus
- -Light pollution is caused by any lights left on after dark: street lights, car headlights, house lights
- -This is horrible! We can't see anything! Let's go somewhere far away from light pollution…

Cue: Teleport far enough outside the city to get rid of light pollution (turn light pollution off)

- -Can see a lot more stars
- -Point out the Milky Way
- -Milky Way is made of a few hundred billion stars, lots of them just like our Sun
- -We live within the disk of the MW, so it appears as a line across the sky even though it's flat and circular, kinda like looking at a frisbee from the side
- -Milky Way disk is 100 thousand ly across
- -Every star that we see as a pinpoint of light is relatively close to us
- -Most of the stars in the MW are too far for us to see as individual stars, so they make up a diffuse glow in the band of the MW
- -The dark parts in the band of the MW are places where dust clouds block out that distant glow

Constellations and Stars

Note: Not all constellations in this section may be in the show, since the show is set for the current time of year when only certain things are visible. Be sure to run through the show in the planetarium to see which constellations will actually come up!

-The constellations we have today mostly came from the ancient Greeks, although all civilizations had their own constellations and stories behind them

Cue: Turn on Big Dipper lines and label

-Very bright, stars are easy to see, quite large in sky

-Use stars on the end of the “bucket” part of the dipper as “pointer stars”: they point right toward the North Star, Polaris

Cue: Turn on Polaris label

-North star is always in the North whereas all other stars move across the sky over the night and year

-It’s actually part of a constellation too!

Cue: Turn on Little Dipper lines and label

-Most stars in Little Dipper too faint to see from Columbus, except the North Star

-Much easier to try to find the Big Dipper first and use the pointer stars if you’re trying to find the North Star

-Actually, Big and Little Dippers are asterisms (made-up constellations), not official constellations, but they’re part of official constellations

Cue: Turn on Ursa Major and Ursa Minor

-Big bear and little bear

-Greek myth behind Ursa Major and Ursa Minor (warning: includes infidelity, may not be appropriate for children): Ursa Major is actually the beautiful goddess Callisto. Zeus fell in love with Callisto because of her beauty which made Zeus’s wife, Hera, angry, so she turned Callisto into a bear. Callisto’s son, Arcas, was sent to hunt the bear without knowing it was his own mother he was hunting. Zeus saved Callisto at the last minute and put both her and Arcas in the sky as bears for safe-keeping, so Ursa Minor is Arcas.

Cue: Return to Big and Little Dipper lines and labels, then turn on Draco lines and label (all one cue)

-Draco snakes through between the bears

-In Greek mythology, Hercules fought Draco to obtain a golden apple from a tree the dragon was guarding, and killed it

-In Roman mythology, Draco warred with the Olympians (the gods) and was killed in battle and thrown up into the sky. He’s all bunched up instead of straight in the sky because he froze in place so close to the north pole star before he could straighten himself out

Cue: Turn on pics for Draco

Cue: Turn on Cepheus (winter), Cassiopeia (summer and winter), Andromeda (winter), Perseus (winter), and Pegasus (winter)

-Cassiopeia was the queen of Ethiopia in Greek mythology, but she was very vain and obsessed with beauty so she hangs upside down from her throne in the sky (upside down only in summer)

-Cepheus was the king of Ethopia, Cassiopeia’s husband

-Their daughter, the princess, was Andromeda

-Andromeda was supposed to be incredibly beautiful, so beautiful that her mother, Cassiopeia, was jealous of her beauty

-Cassiopeia chained Andromeda to a rock and left her to be eaten by a sea monster
-Perseus the Hero was traveling along the shore and saw Andromeda, fell in love with her beauty, and saved her before she was eaten
-They flew away together on Perseus' winged horse, Pegasus

Cue: Turn on all pics

Cue: Turn everything off

-Point out Andromeda Galaxy (winter)
-Andromeda is bigger than the Milky Way (~1 trillion stars)
-It is 2.5 million lightyears away
-The smudge we see in the sky is actually just the brightest part in the center
-If we could see all of it, it would be about the size of the full moon on the sky

Cue: Turn around to face south

-Warn audience that this makes some people dizzy and to close their eyes if they are
-Tell them to open eyes again when done spinning
-Point out S in front indicating we're facing south, but still same place on Earth (near Columbus) and same time of night, we've just turned around to face the other way

Cue: Turn on Orion

-Here is one of the most famous and fantastic constellations in the night sky
- Lots of bright stars
- Great hunter of Greek myth whom Zeus placed in the heavens

Cue: turn on Betelgeuse, Rigel, Bellatrix, Saiph

-Four of the brightest stars in the constellation
-Arabic names, because the Arabs created extensive naked-eye catalogs of stars in the pre-telescope ear
- Your eyes are not deceiving you, these stars do have different colors! Betelgeuse is a red supergiant, while Rigel, Bellatrix and Saiph are blue supergiants.

Cue: Aldebaran comes up

- We can use the stars in Orion to find other important stars. First, following the stars in Orion's belt up and to the right, we find Aldebaran in the constellation of Taurus the Bull.

Cue: Sirius is labeled

If instead, we follow the stars of Orion's belt down and to the left, we reach the brightest star in the night sky -- Sirius in the constellation of Canis Majoris, or the Big Dog

- Sirius is super-bright because it is both close and putting out a lot of light

Cue: Turn on the labels for Canis Minoris and Lepus

Cue: Turn on the pictures for the hunting group

Cue: Turn on labels for Castor and Pollux and lines and label for Gemini, then pic for Gemini

-Gemini is "the twins" because the two stars Castor and Pollux look exactly the same
-In actuality, these stars are quite different!
-Castor is a system of SIX stars, they're all so close together that their light combines and we see it as just one, and they're all very hot, blue stars, about 51 ly from Earth
-Pollux is a single, orange giant star 34 ly from Earth

Cue: Turn on lines and labels for all zodiac constellations

-The line these constellations make across the sky just mark the path the Sun takes over the course of a full year
-Horoscope signs are supposed to line up with whichever constellation the Sun was “in” during the month of birth
-In actuality, it doesn’t line up properly anymore because the precession of the Earth’s orbit means these constellations aren’t the exact Sun’s path anymore
-(Feel free to get as preachy or not as you want with the difference between astrology and astronomy, some people genuinely don’t know the difference and might ask questions)

Cue: Turn on pics for zodiac constellations

- Say how unimpressive Aries is

Cue: Turn off zodiac, then turn on lines, labels, then pics of ALL constellations

-There are 88 official constellations
-Most come from ancient Greeks, since their society became most pervasive in modern western culture
-”Constellation” doesn’t actually refer to lines connecting points--it’s technically the region of the sky that constellation occupies
-Astronomers use them as a “road map” to help other astronomers find whatever discoveries they’re talking about
-Bright stars in the constellations are named after them, in order of decreasing brightness
-(Feel free to point out whatever interesting constellations you want, I like the giraffe and the unicorn)

Cue: Fast forward time

-Different constellations are up at different times of the night, you have to stay up pretty late to see certain stuff this time of year

Cue: Stop time, turn off constellations, move on

But stars aren’t the only things we see in night sky

Planets

Cue: Turn on planet labels

- Right now we are pretty bleak for naked eye planets in the evening

Cue: Run time forward to see other planets rise

-Venus, Jupiter, Saturn and Mars,
-Saturn is also big like Jupiter, but further away so fainter
-Mars is the red planet and it actually looks slightly red with the naked eye
-Uranus is too far and faint to see with the naked eye, need a small telescope or binoculars
-The only planets we can see with the naked eye from Earth are planets in our own Solar System, all discovered exoplanets require large, modern telescopes
-Neptune and Pluto are not visible without big telescopes

We've been watching sky twirl above us, but why does this happen? Why do we see this?

Daily Motion

Note: We are facing north again, there was no spinning, just teleported around

Cue: Start time running, see sky spins overhead

-Most things rise in east and set in west

-Some stars don't rise or set at all, just circle around the sky in the north, these are called circumpolar stars because they circle around the pole star, Polaris

Cue: Turn on Polaris label

-The north star doesn't appear to move in the sky while everything else circles around it, why is that?

Cue: See spinning Earth from space

-None of the stars are moving at all, it's just the Earth's rotation that makes them appear to move, same phenomenon causes sunrise and sunset

Cue: Hover above one point on Earth and spin with it

-If we spin with the Earth, just like we do on its surface, then the stars look like they're spinning!

Cue: Take different point of view so we can see North Star

-Earth is at bottom of screen, red line is equator, blue line at top is North Pole

-If you draw a line between North and South Poles and follow it up, you get to the North Star

-So the North Star doesn't move because it happens to be right above the North Pole of the Earth, lined up with Earth's axis of rotation

Cue: Back to watching sky spin in Columbus

-So from the Earth, it looks like the North Star doesn't move but everything else does

Cue: Stop time, move on to sky from different places on Earth

Polaris is right there day and night, all year long. But polaris isn't in that same spot in the sky from every place on Earth.

Sky from Different Places

Cue: Turn on meridian and Polaris

-The meridian is an imaginary line that runs North to South, passing directly overhead

-0 degrees is at horizon, 90 degrees directly overhead

-The height of the North Star above the horizon tells you your latitude on Earth

-Columbus is ~40 degrees latitude, so North Star is at 40 degrees above horizon

Cue: Turn on Big Dipper lines and label for reference

Cue: Travel to 60 degrees latitude up in Canada

-Since we're further north, the North Star is higher in the sky

-At 60 degrees latitude, Polaris is at 60 degrees above horizon

Cue: Travel to North Pole

-North Pole is 90 degrees latitude, so North Star is 90 degrees above horizon, directly overhead

-We saw earlier that the North Star is directly over the North Pole

-Note that every direction is south--it's impossible to go any way but south from the North Pole!

Cue: Start time running

-Nothing rises or sets, every star is circumpolar

-This time of year, the Sun is circumpolar too! (Little yellow dot on screen, but we have daylight turned off so we can see the stars even though it's day time)

-North Pole has eternal daytime in the summer, eternal night time in the winter

-The tilt of the Earth's axis causes these seasonal changes, but the stars are always the same at the North Pole because they truly never rise or set

Cue: Stop time

We've talked a lot about the sky from different places in the N hemisphere, but let's check out the sky as seen from the other half of the Earth.

Cue: Blast off from Earth and fly down to Santiago, Chile, in the Southern Hemisphere

-We landed facing north, but we can't see the North Star anymore, it's below the horizon

Cue: Turn around to face south (warn people about dizziness again, remember to tell them when to open eyes when done spinning)

-You might expect to see a South Star in the southern hemisphere, a star just below the south pole, an analog to the North Star

-But it's actually not there! We just got lucky in the northern hemisphere to have one

-We can see other cool stuff though, the Large and Small Magellanic Clouds

-These are dwarf galaxies, 1/100 the mass of the Milky Way, both 150,000-200,000 ly away

-They orbit the MW the same way the Earth orbits the Sun, attracted to the MW's gravitational pull

-We think the MW was built up from dwarf galaxies like these, that fell in and combined to make the MW bigger

Cue: Turn on all constellations

-We can see some new constellations here that were below the horizon in the northern hemisphere

-These have more Latin-sounding names instead of Greek because they were named much later, the ancient Greeks never saw them

-They're also named after South American things, like snakes and toucans, and ocean-navigational things, like a boat and a compass/sextant

Cue: Turn off constellations and run time forward

-Most things still rise in the east and set in the west, and there are still circumpolar stars (including the Magellanic Clouds), but there's no fixed star like the North Star

-Since the North Star's height above horizon can tell you latitude, not having a South Star makes navigation harder in the southern hemisphere

-Navigators have come up with complicated ways of locating the South Celestial Pole without a South Star, using other stars and asterisms like the Southern Cross to point in the right direction

Cue: Stop time and move on to seasons, starting by looking at inner Solar System

Now that we know more about how the sky changes night by night, let's talk about how things change throughout the year, and learn about the reasons for the seasons!

Seasons

We're looking at the inner four planets of the Solar System

Cue: Remove all but the Earth

-The time it takes for the Earth to complete one orbit around the Sun is one year, 365.25 days

Cue: Take a different point of view, look from the side

-Earth's orbit is actually a flat almost-circle, but putting it on the curved dome distorts it a bit from this point of view

Cue: Blow up the image of the Earth so it's easier to see

-This is NOT TO SCALE, the Sun is way, way bigger than the Earth! We just want to be able to see it easier

Cue: Run time forward, the Earth orbits the Sun a few times then stops on northern hemisphere's winter solstice

-The seasons are caused by the tilt of the Earth relative to its orbit

-They are NOT caused by the fact that the northern hemisphere is a bit further away from the Sun in the winter and closer in the summer--while true, this isn't enough to make a difference

-Seasons are actually caused by the angle of sunlight hitting different parts of the Earth over the year

-When sunlight comes from a low angle, you don't get as much of it in each square mile as you do when it's directly overhead

-Less sunlight = shorter days = colder temperatures

-The northern winter solstice is when the north half of the Earth is tilted furthest away from the Sun

-The winter solstice is the shortest day of the year before Earth's orbit starts moving the tilt back toward the Sun

Cue: Run time, Earth stops on north summer solstice

-Exactly halfway across Earth's orbit, the opposite season occurs, summer

-There's more direct sunlight = longer days = hotter temperatures

-Summer solstice is longest day of the year before Earth's orbit starts moving the tilt back away from the Sun

-The Earth's tilt is always the same even as it moves throughout its orbit

-Note that summer in the northern hemisphere means winter for the southern hemisphere

-The two halves of the earth always have opposite seasons

-However, on the spring and fall equinoxes, the entire planet has exactly 12 hours of daylight and 12 hours of nighttime

Cue: Return to Columbus just before sunrise

Solar Annual Motion

Cue: Run time to let sun rise on June 21st, summer solstice

-Longest day of the year

-Sun rises north of east

-Sun gets very high in the sky, but never directly overhead--Columbus is too far north for the Sun to ever be directly overhead at any time of the year

-The furthest north location that has the sun reach directly overhead is the Tropic of Cancer, which runs through Mexico and the Caribbean, and the sun is only directly overhead there on one day a year, the northern summer solstice

-Likewise, the furthest south location where the sun goes directly overhead is the Tropic of Capricorn, which runs through South America and northern Australia, and the Sun is only directly overhead there on one day a year, the southern summer solstice

-The sun sets north of west

-So the sun doesn't always rise and set exactly in the east and west

Cue: Run time to let sun rise on September 21st, autumn equinox

-Sun rises exactly in the east

-Equal amounts of daytime and nighttime on this day, everywhere on earth

-Sun doesn't get nearly as high in the sky as it did on the summer solstice

-Sun sets exactly in the west

Cue: Run time to let sun rise on December 21st, winter solstice

-Shortest day of the year, when sun is directly over the Tropic of Capricorn in the southern hemisphere

-Sun rises south of east

-Sun doesn't get very high in the sky at all

-Sun sets south of west

Cue: Stop time running

Cue: Set up analemma scene

-Let's pretend we take a picture of the sun at noon on every day of the year, and no other time

-Then stitch all these pictures together to make a movie

-We can watch where the sun is at noon every day all year

Cue: Run time, watch sun make a figure-8

-This is called an analemma, it shows only the sun's location at noon throughout the year

-The highest point is the summer solstice, the lowest point is the winter solstice

-The figure-8 pattern is due to the ellipticity of Earth's orbit--it's not a perfect circle so the sun's yearly path is not a straight vertical line

-Every latitude on Earth has an analemma of a different height above the horizon--at the North pole, it would be centered on the horizon so you would only see half of it, at the equator, it would be centered directly overhead

Cue: Stop time

Cue: Move on to Solar System

Solar System

We're looking at the inner four planets

-Each of the four inner planets is small, no bigger than the Earth

-They're all terrestrial planets, meaning they have a rocky surface you could stand on, like the Earth

Cue: Change point of view to look from the side, the ecliptic

-All the planets' orbits lie in the same flat plane, like a disk

-This tells us that they were all likely formed out of the same disk of debris surrounding the Sun when the Solar System was first forming

Cue: Zoom out to see the outer four planets

-Look how far we have to zoom out!

-The outer four planets are all gas giants, much bigger than the Earth, giant balls of gas with no surface to stand on (but maybe a solid rocky core)

Cue: Change point of view to top-down

-All the planets' orbits are roughly circular and orderly, but none of them are perfect circles

Cue: Run time forward, watch planets orbit

-We're fast-forwarding really fast here, looks like 3 Earth years per second

-The inner planets zip around the Sun very fast while the outer planets trudge along slowly

-This is because the Sun's gravitational pull gets weaker the further you get from it

-All orbits are simply falling toward the Sun, but going so fast that they continue to miss, therefore forming an ellipse

-This is why astronauts in orbit around the Earth appear to be in 0g, there is actually still gravity there, but they're constantly free-falling so they don't feel it

-Since the outer planets feel a weaker gravitational pull, they don't have to move as fast to "miss" the sun, so their orbits are slower

-Slower orbits combined with a much further distance to travel around the Sun means their years (time it takes to get back to same point in orbit) are much, much longer than the Earth's

-Neptune takes 165 Earth years to go around the Sun once

Cue: Stop time, turn on Pluto's orbit

-Pluto's orbit is more eccentric, or oval-shaped, than the rest

-Right away this tells us that Pluto is a bit different than the other planets, maybe it had a different formation

Cue: Change point of view to ecliptic, look from side

-Pluto's orbit is also highly inclined, it doesn't sit in the same flat plane the rest of the planets' orbits do

Cue: Turn on Eris's orbit

-Part of the reason why Pluto is no longer a planet is because discussions about what makes a planet were sparked when Eris, another dwarf planet out past Pluto, was discovered

-Eris is actually a bit more massive than Pluto, so it wouldn't really make sense to call it a "dwarf planet" and continue to keep Pluto as a planet

-Official rules were decided upon to call something a "planet," and Pluto did not fit those rules (neither did Eris), so it was demoted

-(The rules are: 1. Must be orbiting Sun primarily 2. Must be spherical (just a statement about mass) 3. Must have cleared its orbit--nothing else too close to its orbit, Pluto fails this because of the other dwarf planets, this is also really just a statement about mass)

-We've actually discovered a few more dwarf planets since then, further solidifying the reason why Pluto should not be a major planet anymore

-The other dwarf planets near Pluto's orbit are Eris, Makemake, and Haumea (last two named after Hawaiian gods)

Cue: Turn on all minor bodies in the solar system: comets (blue lines), dwarf planets (magenta lines), asteroids (everything else)

-Minor bodies aren't as orderly as the 8 major planets

Cue: Zoom into asteroid belt

-Asteroid belt sits between Mars and Jupiter, mostly

-Made up of 100s of thousands of asteroids (that we know about so far)

-There's even a dwarf planet that orbits within the asteroid belt, called Ceres

-Asteroids are hectic, their orbits are all eccentric and inclined, not nice and orderly at all

Cue: Turn off asteroids, turn on inner planet orbits (Earth is green)

-The highly elongated blue orbit is Halley's comet

-It comes by Earth twice every 76 years or so

-It takes so long to come back because it takes a long time for it to go all the way out and come all the way back in

-We see it bright in the sky with a long tail when it gets close enough to the Sun for the ices on its surface to evaporate off and be pushed away by the light from the Sun

-The tail always points away from the Sun, it doesn't stream behind the comet's motion

-Last time it came through was in 1986, it will come back in 2061

Cue: Look at 8 major planets again

-So nice and orderly when we ignore all the minor bodies

Cue: Teleport back to Columbus for sunrise

Sunrise

Cue: Start time running, sun slowly comes up to help everyone's eyes readjust

-Can slowly turn cove lights back up when it's almost done, make sure they're red to avoid hurting anyone's eyes