

“The Stars Tonight”

LIVE Planetarium Show

Theme: The Stars Tonight Program is built around a realistic simulation of the night sky, something fewer and fewer visitors get to experience firsthand

The educational value of NASM Theater programming is that the stunning visual images displayed **engage** the interest and desire to learn in students of all ages. The programs do not substitute for an in-depth learning experience, but they do facilitate learning and provide a framework for additional study elaborations, both as part of the Museum visit and afterward. See the “Alignment with Standards” table for details regarding how *The Stars Tonight* and its associated classroom extensions meet specific national standards of learning (SoL’s).

The Stars Tonight takes its audience on a tour of the night sky, free from cloudy skies and city lights. Many NASM visitors have never had the chance to see a dark sky, with the stars on display as Nature intended; the novelty of the experience is the engaging “hook” for learning.

NASM’s Einstein Planetarium is particularly well-suited to host *The Stars Tonight*. Its large dome and Zeiss Mark 6A projector allow the accurate simulation of the sky as seen from any place on Earth at any (reasonable) point in history.

Because *The Stars Tonight* (TST) is a live show, hosted by different NASM staff members, with programmatic ties to the season of the year and other “current” events, the topics covered will vary somewhat. The Stars Tonight will obviously align with SoL’s relating to objects in the sky and their motion, but, depending on the speaker’s “spin,” TST might also align with other SoL’s.

Learning Elaboration While Visiting the National Air and Space Museum

The Explore the Universe Gallery is devoted to Astronomy, including galactic distance determination, collisions, and dark matter. Of particular interest are the tools used centuries ago to measure the position of objects in the sky, how the distance to the galaxies is calculated, and dark matter, but the entire gallery is filled with astronomical learning opportunities.

The Einstein Planetarium at NASM shows two other programs on astronomical topics:

- *Infinity Express*
- *Cosmic Collisions*

Thousands of books and articles have been written about observational astronomy, but two good starting points are the many books and related materials available at the **Museum Store** in each NASM building, and the list of research and publications of NASM’s expert curators:

- Aeronautics: <http://www.nasm.si.edu/research/aero/research.cfm>
- *Center for Earth and Planetary Studies*: <http://www.nasm.si.edu/research/ceps/research/research.cfm>
- *Space History*: <http://www.nasm.si.edu/research/dsh/research.cfm>

Post-Visit Discussion Points to Align Program Material with National SoLs

High School

see High School Alignment Table

“Strong alignment” is shown in red on the Table and in bold-faced text below

S A2: Understanding Science Inquiry

The host/teacher may choose to emphasize some of the components of this particular element, perhaps including: the use of technology to enhance gathering and manipulation of data, the accuracy/precision of data gathering as a function of technology, and/or the role of mathematics in all aspects of scientific inquiry. See also: S E2.

S B4: Motions and Forces

A subset of this standard deals with gravitational force. Movements of visible planets and the control of those movements by gravity can be showcased in a given TST show. TST gives good examples of how humans can be confused by the apparent movement of celestial objects; the sky wasn't turning around us, rather the Earth is turning on its axis.

S B5: Conservation of Energy; Entropy

Alignment with this standard applies only if the host/teacher discusses the overall energy budget of the Universe over time. “The total energy of the Universe is constant” is in the language of the Standards, but mass and energy can be interchanged ($E = mc^2$), and every “transaction” has an energy-loss “tax.”

S B6: Interactions of Energy and Matter

Alignment with this standard applies only if the host/teacher discusses how atoms absorb/release discrete quantities of energy, equivalent to very specific wavelengths of radiated energy. Cool gases absorb radiated energy with those precise wavelengths and then re-radiate it in random directions; light coming through such a gas loses only those key wavelengths. Hot gases emit those wavelengths only, instead of all wavelengths. In either case, each chemical element has a distinctive and unique set of wavelengths it can absorb, sort of a chemical “fingerprint.” This is how we know what stars are made of and how the element helium (from the Greek *helios*, meaning Sun). See also the spectrum exhibit in the Explore the Universe Gallery.

S C1: The Cell

Alignment with this standard applies only if host discusses the rod and cone-shaped cells of the eye and their role in night vision. Fainter stars are particularly good for helping visitors discover their powers of (averted) vision; using averted vision can help the visitor see the Andromeda Galaxy (both the real one and in the TST simulation).

S D 4: Origin and Evolution of the Universe

Three areas are cited under the HS level of this standard, and all three can be addressed by the TST host:

- The “Big Bang” Theory of the origin of the Universe
- A brief outline of the post-Bang formation of stars and galaxies
- Stellar fusion and supernovae: Formation of all the elements

S E2: Understanding Science & Technology

The TST host may opt to describe the observations made by Galileo, using one of the first astronomical telescopes that showed the Earth-centered model of the Solar System to be incorrect:

- The Sun and Moon have “blemishes” and are, therefore, not “perfect” as prevailing dogma held for any object in the sky, whose celestial location implied divine status, which in turn required “perfection.”
- Galileo discovered the four large moons of Jupiter today known collectively as the “Galilean Satellites.” Prevailing dogma required the Earth to be the center of ALL celestial motion, but Galileo disproved that notion with this discovery.
- The proof of heliocentricism: Galileo discovered that Venus showed a full range of phases, like the Moon does, as predicted under the Heliocentric Solar System. Under a Geocentric System, Venus can only show a crescent phase, if it is visible at all.

Another example of the link between newly-developed technology and new scientific discoveries is *spectroscopy* (see also S B6 above). Being able to observe solar and stellar spectra, and discovering what the detail of each spectra meant, was key to a much deeper understanding of the structure and history of the Universe.

Having actual samples of the Moon for analysis led to a deeper understanding of the Moon’s origin and evolution, something not possible until Apollo technology.

S G1: Science as a Human Endeavor

S G2: Nature of Scientific Knowledge

S G3: Historical Perspectives

The TST program lends itself to engaging the audience using any and all of the three History and Nature of Science standards. The host/teacher can opt to describe observational astronomy from its pre-historical beginnings through its mythological, then ancient Greek, then Middle Age Arabic, and finally Renaissance portions of its development. Along the way, focus on both some of the key persons involved (e.g. Galileo, da Vinci, Ptolemy) and on just what it was they were observing and how they drew conclusions.

Life Skills: Thinking and Reasoning 5: Level IV: 9. Problem Solving: Historical Examples

The TST host may opt to frame their talk in the context of archeo-astronomy, particularly the role of observations in establishing and maintaining an accurate calendar and/or other uses. A number of ancient civilizations needed to have extremely well-developed astronomical abilities in order to satisfy religious or other objectives:

- Calendar for agriculture: Farmers need to time planting and harvests around seasonal changes in weather. Having an accurate calendar is essential, and using the stars is the key to making one.
- Calendar for religious purposes: Examples abound from many cultures; one such is Easter, set as the first Sunday after the first Full Moon after the Vernal Equinox (although the use of this definition over time is more complicated than first glance!). Planning for such events requires accurate astronomical predictions.
- Navigation: The ancestral Polynesians used the night skies to assist their long-distance oceanic navigation. Similarly, centuries ago, Middle Easterners could travel long distances in featureless desert regions, using only the stars as their guide.

Post-Visit Discussion Points to Align Program Material with National SoLs

Middle School

see Middle School Alignment Table

“Strong alignment” is shown in red on the Table and in bold-faced text below

S A2: Understanding Science Inquiry

During the TST program, middle school students can be exposed to examples of the use of the scientific method in the recognition, refinement, and answering of questions. One example is Galileo’s observations that proved Copernicus correct (see separate standard regarding the Trial of Galileo below). Several ancient civilizations had developed their observational astronomy capabilities to a high level. They had accurate calendars, and could predict a variety of astronomical phenomena, such as solar and lunar eclipses. The teacher using the TST materials for their classes may opt to point out the difference between being able to utilize and observation, as the ancients certainly could do; and having a full understanding of the situation leading to their observations, which ancient peoples certainly did not have. (Ancients could predict when and where an object would appear in the sky, some could even predict phenomena like eclipses, but none had any idea of the actual structure of the Solar System that led to their prediction being true).

S B3: Transfer of Energy

Alignment with this standard applies if the host/teacher discusses how light interacts with the eye during vision and/or how a very small percentage of the Sun’s total emission of large amounts of energy as heat and light – a variety of wavelengths of radiated energy – interacts with the Earth.

S C1: Structure/Function of Living Systems

Alignment with this standard (“Specialized cells perform specialized functions in multicellular organisms”) applies only if host discusses the rod and cone-shaped cells of the eye and their role in night vision. Fainter stars are particularly good for helping visitors discover their powers of (averted) vision; using averted vision can help the visitor see the Andromeda Galaxy (both the real one and in the TST simulation).

S D2: Earth’s History

The TST aligns with this standard/level if the host/teacher discusses comet/meteor impacts and their effect on the Earth system.

S D3: Earth in the Solar System

TST can be used to engage middle school students with a visualization of the following points explicitly listed under this standard (see also the “Fallacy Alert” section):

- “The Earth is the third planet from the Sun in a system that includes the Moon, the sun, eight other planets and their moons, and smaller objects, such as asteroids and comets. The Sun, an average star, is the central and largest body in the Solar System.”
- “Most objects in the Solar System are in regular and predictable motion ... explain(ing) such phenomena as the day, the year, phases of the Moon, and eclipses.”
- “Gravity is the force that keeps planets in orbit around the sun and governs the rest of the motion in the Solar System.”

S E2: Understanding Science & Technology

TST can be used by the host/teacher to help address the “reciprocal” relationship between science and technology.



- One example is the aforementioned telescope of Galileo (see also separate standard on Galileo’s trial below). Optical aid was essential in being able to see the extraordinary evidence needed to overcome the prevailing view of the Earth being the center of motion of “perfect” celestial objects.
- Comparative planetology provides another example. “Comparisons” are simply not possible without the technological ability to study geology on other planets “up close” enough to be able to see diagnostic details. Once robotic explorers could orbit, land on, and rove the surfaces of other bodies in the Solar System did comparative planetology become feasible as a scientific discipline.

S G1: Science as a Human Endeavor (see the section about Galileo’s trial below)

S G2: Nature of Science

S G3: History of Science

The TST program lends itself to engaging the audience using any and all of the three History and Nature of Science standards. The TST host can opt to describe observational astronomy from its pre-historical beginnings through its mythological, then ancient Greek, then Middle Age Arabic, and finally Renaissance portions of its development. Along the way, focus on both some of the key persons involved (e.g. Galileo, da Vinci, Ptolemy) and on just what it was they were observing and how they drew conclusions.

H World History: Science, Technology, and Society, Standard 27, Benchmark 4, Statement 3, Copernicus to Newton

This particular standard is addressed if the host/teacher discusses the geocentric model of the Solar System of Ptolemy, how it was perceived to have problems from the beginning, how prevailing dogma prevented open inquiry, and how the evidence gathering made possible by new technologies led to the extraordinary evidence needed support the Copernican view.

- Johannes Kepler determined the geometric characteristics of planetary orbits.
- Isaac Newton determined the mathematics underlying Kepler’s geometry
 - In the process, he developed the mathematical formulation for gravitation
 - In the process, he developed the branch of math called *calculus*

H World History: Science, Technology, and Society, Standard 27, Benchmark 5, Statement 6, Trial of Galileo

The trial of Galileo resulted because he supported a viewpoint the Catholic Church considered heretical. He used his telescope to first cast doubts on the prevailing dogma of an Earth-centered Universe, then to prove conclusively that the Sun was the center of the Solar System. He was tried, convicted, and forced to publicly recant his position. It was centuries before he was finally exonerated. The extraordinary evidence he found to support what was then an extraordinary claim included the following:

- Prevailing dogma held that any object in the sky must be “perfect,” by definition. Galileo saw spots on the Sun and blemishes on the Moon, so he knew that part of the “conventional wisdom” was flat-out wrong.
- Prevailing dogma held that the Earth was the Center of All Things in the Universe, including motion. Galileo discovered that Jupiter has four large moons orbiting it (to this day they are collectively known as the Galilean Satellites!), thereby disproving another part of the “conventional wisdom.”
- Decisive: Galileo could make a prediction of how Venus should appear over time, based on whether the Earth or the Sun was the center of motion. In the Earth-centered system,

Venus, if it could be seen from the Earth at all, would appear as a thin crescent only; never half, gibbous, or full phases. In a Sun-centered system, Venus could have any phase the Earth's Moon shows. Galileo saw a full range of phases, knowing right then and there that Copernicus was right!

T Technology: Science, Technology, and Society, III, Benchmark 3: Technology influences History

This standard is concerned specifically with the ways in which technology has influenced the course of history. One example previously mentioned is the role of Galileo's telescope in upsetting the prevailing dogma of his times that the Earth was the Center of the Universe.

Post-Visit Discussion Points to Align Program Material with National SoLs

Elementary School

see Elementary School Alignment Table

“Strong alignment” is shown in red on the Table and in bold-faced text below

S A2: Understanding Science Inquiry

Alignment with this particular standard is based on the host/teacher emphasizing the process of science in the context of the program (observe, hypothesize, test, refine), on the role of evidence in any explanation, and the role technology plays in allowing humans to make better observation than possible without such aids.

S B2: Position and Motion of Objects

The demonstration of apparent circular movement of celestial objects around the celestial pole is a staple of TST shows. Observing the position of a star or planet relative to a foreground object (tree, house, etc.) at one time of the evening, then going out hours later allows one to assess the movement relative to the landmark, whether in real life, or in the planetarium’s sky simulation. The TST host may demonstrate how planets move over a period of weeks and months, with the motion being readily visible against the stationary background stars. See also the “Fallacy Alert” section following this one.

S B3: Light, Heat, Electricity & Magnetism

The standard is “Light travels in a straight line until it strikes an object (at which time it is) reflected by a mirror, refracted by a lens, or absorbed.” The straight-line nature of light is well-demonstrated during TST, and reflection and/or refraction are the basis for how telescopes work (mentioned in TST; see also the telescope exhibit in the Explore the Universe Gallery).

S D2: Objects in the Sky

The TST program addresses the following portion of this standard completely: “The Sun, Moon, stars, clouds, birds, and airplanes all have properties, locations, and movements that can be observed and described.”

S D3: Changes in the Earth and Sky

The TST program addresses the following portion of this standard completely: “Objects in the sky have patterns of movement. The sun, for example, appears to move across the sky in the same way every day, but its path changes slowly over the seasons. The moon moves across the sky on a daily basis much like the sun. The observable shape of the moon changes from day to day in a cycle that lasts about a month.”

SG1: Science as a Human Endeavor

The TST host can opt to describe observational astronomy from its pre-historical beginnings through its mythological, then ancient Greek, then Middle Age Arabic, and finally Renaissance portions of its development. Along the way, focus on both some of the key persons involved (e.g. Galileo, da Vinci, Ptolemy) and on just what it was they were observing and how they drew conclusions.

Life Skills: Thinking and Reasoning 4. Level II: Observation versus Inferences

TST provides several good starting points for a discussion of the differences between observation and interpretation: Sky appears to go around us; really it's the Earth's rotation; "milky" band of light is combined light of unresolved stars, not milk spilt from the tables of the Gods at Mt. Olympus, etc.

Fallacy Alert!

Many students wrongly think that the orbits of Solar System planets are highly elliptical, rather than being almost circular. The primary reason for the confusion is the way in which orbits are depicted on a flat surface, like the page of a book. Rather than being shown from directly above, artists often portray the orbit from an oblique perspective. Try it for yourself! Take a circular object, like a CD, and look at it from directly above. It looks like a circle. Now tip the back edge of the CD away from you so that you are looking at the CD from an oblique angle (not quite directly edge-on). Does the CD edge still look circular? NO, it looks like an eccentric ellipse! For more on the shape of orbits, see UCAR's "Windows on the Universe" website's Orbits page at:

http://www.windows.ucar.edu/tour/link=/physical_science/physics/mechanics/orbit/ellipse.html&edu=elem

Another common fallacy is that summer is caused by the Earth being closer to the Sun than it is in winter. Not true! If it were, the Northern and Southern hemispheres of the Earth would have the same seasons at the same time, instead of the seasons being "opposite" (Southern Hemisphere winter is in June, July, and August). Further, the Earth is closest to the Sun on or about January 4th, exactly the opposite one would expect if the eccentricity of the Earth's orbit around the Sun were responsible. Lastly, the Earth's orbit is almost circular; there is little difference in the intensity of sunlight at the Earth due to orbit parameters. For more on the "reason for the seasons," see: <http://www.astronomy.org/programs/seasons/index.html>

For more on fallacies associated with Astronomy, see Phil Plait's famous "Bad Astronomy" website: <http://www.badastronomy.com/bad/index.html>



Resources for Learning Elaboration after the Visit to NASM

Thousands of books and articles have been written about observational astronomy, but two good starting points are the many books and related materials available at the **Museum Store** in each NASM building, and the list of research and publications of NASM's expert curators:

- Aeronautics: <http://www.nasm.si.edu/research/aero/research.cfm>
- *Center for Earth and Planetary Studies*: <http://www.nasm.si.edu/research/ceps/research/research.cfm>
- *Space History*: <http://www.nasm.si.edu/research/dsh/research.cfm>

Explore the Universe Gallery on-line at: <http://www.nasm.si.edu/exhibitions/gal111/universe/index.htm>

“First Light” section of the EtU Gallery: <http://www.nasm.si.edu/exhibitions/gal111/universe/firstlight/index.htm>

NASA's “Stargazers” website: <http://stargazers.gsfc.nasa.gov> (Lots of useful info and links!)

Numerous books have been written about observational astronomy. See, among many others:

- Observers Handbook 20XX, published annually by the Royal Astronomical Society of Canada
- *Astronomy* magazine: <http://www.astronomy.com>
- *Sky and Telescope* magazine; <http://www.skytonight.com>
- SEDS maintains an extensive bibliographic meta-page: <http://seds.org/links.php>

Spectroscopy, Chemical “Fingerprints,” and the Discovery of Helium

NASA's “Imagine the Universe”: Helium: http://imagine.gsfc.nasa.gov/docs/science/how_11/spectral_what.html

Applet showing spectral lines associated with each element: <http://jersey.uoregon.edu/vlab/elements/Elements.html>

Vision: Rods and Cones; “Averted” Vision

The University of Utah maintains a high-level website about vision: <http://webvision.med.utah.edu>

National Optical Astronomy Observatory site: <http://www.noao.edu/outreach/nop/nophigh/eye.html>

Aristotle knew about it (!): http://articles.adsabs.harvard.edu/cgi-bin/nph-iarticle_query?1977JRASC..71..327B

Astronomy in Ancient Cultures

Northern Arizona University's LUHNA webpage: http://www.cpluhna.nau.edu/People/sw_archaeoastronomy.htm

The Center for Archaeoastronomy at University of Maryland: <http://www.wam.umd.edu/~tlaloc/archastro>

“Traditions of the Sun,” a NASA Sun-Earth Connection partnership: <http://www.traditionsofthesun.org/index.html>

Journal of Archaeoastronomy: <http://www.utexas.edu/utpress/journals/jarch.html>

Galileo's Key Observation of Venus and Trial; Kepler and Newton

P. Palmieri, 2001, Galileo and the discovery of the phases of Venus, *Journal for the History of Astronomy*, v. 32, p. 109-129 (available free from NASA's ADS at <http://adsabs.harvard.edu/abs/2001JHA....32..109P>)

Galileo Project: <http://galileo.rice.edu>; http://galileo.rice.edu/lib/student_work/astronomy96/tdunn/venus.html (see the first figure in the second-listed page for a good explanatory diagram)

PBS Nova show, “Galileo's Battle for the Heavens,” http://www.pbs.org/wgbh/nova/transcripts/2912_galileo.html

Example of Catholic Church's perspective: <http://www.catholiceducation.org/articles/history/world/wh0005.html>

Kepler: <http://kepler.nasa.gov/johannes> (NASA), <http://galileo.rice.edu/sci/kepler.html> (Galileo Project),

<http://www-groups.dcs.st-and.ac.uk/~history/Mathematicians/Kepler.html> (St. Andrews)

Newton: <http://spaceplace.nasa.gov/en/kids/orbits1.shtm> (Newton's Cannon); <http://www-groups.dcs.st-and.ac.uk/~history/Mathematicians/Newton.html> (St. Andrews);

http://www.pbs.org/wnet/hawking/cosmostar/html/cstars_newt.html (PBS)

Navigation

“Wayfarers: A Pacific Odyssey,” see: <http://www.neh.gov/news/humanities/1999-05/wayfinders.html>

NOVA's “Lost at Sea: The Search for Longitude,” <http://www.pbs.org/wgbh/nova/longitude>

U.S. Navy's Astronomical Applications Department: <http://aa.usno.navy.mil>

“John Harrison and the Longitude Problem,” <http://www.nmm.ac.uk/server/show/ConWebDoc.355>

Smithsonian NMAH sextants: <http://americanhistory.si.edu/collections/navigation/type.cfm?typeid=6>

