

“Infinity Express”

Planetarium Show

Theme: An Evening Star Party Morphs into a Tour of the Universe

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 *Infinity Express* and its associated classroom extensions, meet specific national standards of learning.

What you will see in the *Infinity Express* program:

- How simple observations of the night sky lead to “cosmic” questions.
- The historical progression of observational astronomy from the basis for ancient calendars to its synergy with the Renaissance to modern ideas.

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.

The Exploring the Planets Gallery is devoted to the study of the planets in our Solar System.

The Looking at Earth Gallery is devoted in part to remote sensing of the Earth from orbiting satellites, producing the “data storm” referred to in *Infinity Express*.

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

- *Cosmic Collisions* – An overview of the Universe from atoms to galaxies, all in the engaging context of objects colliding with one another.
- *The Stars Tonight*, NASM’s thrice-weekly “live” star show.

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 with bold-faced headings below

S A2: Understanding Scientific Inquiry

Discuss how scientists go about formulating the “big questions” in a way in which the scientific method can be employed to ultimately yield correct answers. A good case study for discussion might be the story of Supernova 1987A in the Great Magellanic Cloud. Observations of distant supernovae led to several models of their behavior that were not testable until we were fortunate enough to have a supernova close enough for us to see the details needed to resolve past questions, and generate new ones.

S B2: Structure / Properties of Matter

The concept of “dark matter” is too new to have been incorporated into the national standards of learning, but it is an important topic in modern astrophysics. Its inclusion in *Infinity Express* could be used to spur a classroom discussion of this important “current events” topic. See also the related exhibits in the Explore the Universe Gallery.

S B4: Motions and Forces

Gravitation is a subset of this particular standard; the role gravity plays in the observable Universe is a recurring sub-text throughout *Infinity Express* (IE).

S B5: Conservation of Energy; Entropy

The process of stellar fusion is a good case study of the relationship between matter and energy; and entropy. Hydrogen fusion essentially takes four hydrogen atoms and makes one helium atom out of them. The helium atom is a little less massive than the four hydrogens collectively; the lost mass is converted to a LOT of energy ($E = mc^2$). The energy then dissipates, making it hard (impossible) to reverse the process fully.

SB6: Interactions of Energy and Matter

Some of the observations described in IE deal with electromagnetic radiation of wavelengths other than those our eyes can see directly. The absorption/emission of electromagnetic radiation of specific energies (implies specific wavelengths) by specific atoms is a key to their identification from afar, and a very important astronomical tool. See the Explore the Universe Gallery for more on the science of *spectroscopy*, the analysis of light as a function of its wavelength.

S D3: Origin/Evolution of the Earth System

Scientists study other planets in large part to better understand the Earth. Observing the details of Mars geology via robot surrogates allows scientists to “compare and contrast” how geology works in a similar, but very different, environment.

S D4: Origin/Evolution of the Universe

Infinity Express touches on/visualizes several aspects of the evolution of the Universe:

- The Deep Sky Survey shows numerous galaxies and the overalls structure of the observable Universe.



- The 1987 supernova in the Large Magellanic Cloud (a satellite galaxy of our own Milky Way) helped astronomers understand end-of-life processes for large stars.
- The Milky Way and Andromeda galaxies will eventually “collide.”

S E2: Understanding Science & Technology

The “Data Storm” sequence in *Infinity Express* emphasizes the link between technological advancement, the improvement in our observation ability as a consequence of that advance, and the corresponding refinement in our theories fostered by those better observations. This coincides fully with the following from the national standards: “New technologies often extend the current levels of scientific understanding and introduce new areas of research.” Technology advances allow us to see objects in the Universe from closer/with greater clarity. Other examples from *Infinity Express* include:

- How the invention of the telescope revolutionized Astronomy.
- How observations made by the Mars Global Surveyor and other spacecraft have revolutionized our understanding of Mars.

S G1: Science as a Human Endeavor

S G2: Nature of Scientific Knowledge

S G3: Historical Perspectives

The development of the impact theory of the origin of the Moon can make a good case study of all three standards, including, but not limited to, the following points.

- The theory was the work of several diverse groups of researchers.
- Presentation of results in scientific journals and at scientific conferences was a crucial part in both the development of the theory and in its distribution among scientists.
- The impact theory gained favor only because it is consistent with all the available evidence, particularly the then-new results from analysis of Apollo samples.
- Scientific advancement is usually slow, building upon the existing body of research. In some cases, however, new evidence is so compelling that a more abrupt paradigm shift results. The impact theory is a case in point; others include:
 - Plate tectonics gaining rapid acceptance when new sea-floor maps and detailed earthquake monitoring were developed
 - The recognition that some meteorites here on Earth actually came from Mars. This was a very abrupt shift, caused by the extremely-compelling match of gases in the martian atmosphere with the gases dissolved in bits of glass within those meteorites.
 - Recognition of an impact origin for catastrophic mass extinctions in the geologic record; another abrupt shift triggered by the observations by Alvarez and Alvarez of a “cosmic” abundance of iridium in sediments from the time of mass extinction.
- Investigators from a diversity of backgrounds have made important contributions to astronomy. Examples that relate to the topics covered in IE include:
 - Henrietta Leavitt (Cepheid period-luminosity distance determination technique), and
 - Annie Jump Cannon (classification of stellar spectra).

H World History: Science, Technology, and Society, Standard 44, Benchmark 8: Space-related “spin-offs” have a big effect on society

Technology developed to explore other planets is used for observing Earth from Space is used for weather prediction, environmental monitoring, resource exploration, and land-use planning and management.

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 with bold-faced headings below

S A2: Understanding Scientific Inquiry

Several subsets of this particular standard are addressed explicitly in *Infinity Express*:

- “Technology used to gather data...” The “data storm” sequence in IE is an example.
- Science advances through the systematic asking of questions, evaluating explanations, and the use of mathematical models, sub-themes of this standard; all are represented thoroughly in IE.

S B3: Transfer of Energy

Part of this standard deals with several topics shown in *Infinity Express*, including but not limited to:

- Nuclear fusion within the Sun as the source of most of Earth’s energy.
- Stellar / galactic evolution, and galaxy collisions as part of the evolution of the Universe.

S D2: Earth’s History

IE’s focus on the topic of this particular standard is less from the perspective of Earth’s immediate history, but rather in Earth’s role in the larger scheme of things, in the context of the evolution of the Milky Way galaxy.

S D3: Earth in the Solar System

The effect of gravity acting over interstellar and intergalactic distance scales is an important theme throughout IE, not so much on gravity’s role in the Solar System (the thrust of the standard), but in the larger sense of governing the movements of stars and galaxies.

- The importance of the Sun’s energy output to Earth, the thrust of the standard, is certainly covered in IE, but IE has a wider context, including the energy of supernovae, and how that energy is/has been important to Earth’s history.
- *Infinity Express* explicitly covers recent Mars exploration. A class discussion of “comparative planetology,” the comparison and contrasting of geological features, hence processes, formed in dissimilar environments, can be based on the Mars results in IE.

S E2: Understanding Science and Technology

IE offers several good examples of the “reciprocal nature” of science and technology, part of this particular standard (scientific advances drive technological innovations; in turn, technology advances make possible new scientific observations):

- Without access to a primitive telescope, Galileo could not have made the observations that proved the Copernican model of the Solar System to be correct.
- Astronomical technology is mandatory for the study of galaxies and supernovae.
- Our knowledge of Mars and other planets depends critically on spacecraft technology.
- Understanding galactic motion and the evolution of the Universe requires advanced astronomical instrumentation.

S F3: Natural Hazards



Astronomical hazards, such as asteroid impact as discussed in IE, are explicitly mentioned in this standard. Similarly, a “nearby” supernova explosion could pose a risk to life on Earth, too, a risk we cannot begin to assess and understand without a thorough knowledge of how/why supernovae happen.

S G1: Science as a Human Endeavor

S G2: Nature of Science

S G3: History of Science

Infinity Express has content relating directly to these particular standards, including:

- IE explicitly reviews the development of astronomical knowledge over time
- Modern satellite technology has created a “data storm” from observations of Earth. Those data have allowed scientists to refine mathematical climate models, assess global warming models, etc.; all part of the process of scientific inquiry.
- Investigators from a diversity of backgrounds have made important contributions to astronomy. Examples that relate to the topics covered in IE include:
 - Henrietta Leavitt (Cepheid period-luminosity distance determination technique), and
 - Annie Jump Cannon (classification of stellar spectra).

Life Skills: Thinking and Reasoning 4: Level III: 2. Experimental Verification

The “observe, hypothesize, observe/**experiment to verify**, refine” part of the process of scientific inquiry is illustrated throughout IE, particularly in the segments reviewing the development of astronomy as a scientific discipline, the 1987A supernova, Mars and Solar System exploration, and dark matter.

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

The recapitulation of the early history of Astronomy as a scientific discipline, as related in IE, aligns directly with knowing “the astronomical discoveries from Copernicus to Newton” as required in this particular standard.

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

The recapitulation of the early history of the development of Astronomy as a scientific discipline, as related in IE, can be used as a starting point for a classroom discussion of the trial of Galileo.

- Geocentric and heliocentric models of Solar System can be used to predict the appearance of Venus as seen from Earth over time. The predictions are different, and testable by observation (provided Venus could be seen “better”).
- The development of the telescope allowed Galileo to see Venus “better.”
- He observed Venus show a full range of lunar-like phases, something not possible if the Earth was the center of the Solar System, and shared his results with others.
- The prevailing authority of the time, the Catholic Church, held that the Earth was the Center of the Universe, demanded Galileo recant, then tried and punished him for his refusal to do so. He lost, was forced to recant, and was ultimately exonerated long after his death.

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



Infinity Express offers at least two discussion topics relating to this standard at the MS level:

- Ancient civilizations developed astronomical observation skills and tools in order to prepare calendars used for religious, agricultural, and other purposes.
- The discoveries of Galileo, made possible by the invention of the telescope, were an integral part of the Renaissance, a period of great intellectual growth and societal advancement.

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 with bold-faced headings below

S A2: Understanding Scientific Inquiry

The “asking of questions” part of the process of scientific inquiry is shown several times in *Infinity Express*, most notably the “Big Questions” – “Are We Alone?” etc. mentioned early in the show. *Infinity Express* also showed the role the newly-developed telescope, and the people who used it, played in allowing the advancement of astronomical knowledge.

S B1: Properties of Objects and Materials

The use of tools in the form of ever-more-sophisticated telescopes allows scientists to determine the physical properties of stars and galaxies very far away.

S B2: Position and Motion of Objects

Tracing and measuring the position of planets in the night sky helped scientists understand the structure of the Solar System.

S B3: Light, Heat, Electricity, and Magnetism

A subset of this standard is the understanding that “light travels in a straight line” and that light can undergo reflection, refraction, or absorption when it strikes an object. The depiction of telescopes and related technology in *Infinity Express* shows how light can be manipulated to help scientists understand the objects that emitted that light. There are several exhibits in the Explore the Universe Gallery that will help visitors understand how various telescope designs allow for the manipulation of light.

S C1: Characteristics of Organisms

The posing of the “Are We Alone in the Universe?” question can be used as a springboard for a class discussion of the possibility of extraterrestrial life and what form it might take.

S D2: Objects in the Sky

Infinity Express shows two aspects of this particular standard:

- The Sun, Moon, and planets have locations and movements that can be observed and described, and
- The Sun provides light and heat for the Earth.

S D3: Changes in the Earth and Sky

The apparent movements in the sky of the Sun and Moon, and their true explanation, are parts of this standard illustrated in *Infinity Express*.

S E2: Understanding Science and Technology

A recurring theme throughout *Infinity Express* is a part of this standard, “Tools help scientists make better observations...” Astrolabes, then telescopes of increasing sophistication, and now computers all have proven to be tools that have helped scientists make better observations. For example, Galileo could not have seen the phases of Venus without a telescope, and therefore could not have proved the Heliocentric Solar System was correct.



S G1: Science as a Human Endeavor

The section in *Infinity Express* recounting how astronomical research has changed over the centuries is a good starting point for discussion of the human side of science.

Life Skills: Thinking and Reasoning 4: Level II: Observations and Inferences

Galileo's observations made possible by the newly-invented telescope conclusively demonstrated that the Sun, not the Earth, was the center of the Solar System.

- Everyone thought that if an object was in the sky, it had to be “perfect.” Galileo could see spots on the Sun and blemishes on the Moon, so he knew that “perfection” was not true.
- Everyone thought that the Earth was the center of the motion of all the objects in the sky. Galileo found that Jupiter had four moons that went around it, not the Earth.
- The final proof that the Sun was the center of the Solar System came when Galileo saw that Venus showed the same type of phases that the Moon shows. If the Earth were the center, Venus, if we could see it at all, would have to have a crescent shape. People on Earth could see Venus as “full” or “gibbous” only if both Venus and Earth were going around the Sun.



Resources for Learning Elaboration after the Visit to NASM

Thousands of books and articles have been written about 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>

Overview

Start with NASM's Explore the Universe and Looking at Earth Gallery websites:

<http://www.nasm.si.edu/exhibitions/gal111/universe/index.htm>; http://www.nasm.si.edu/exhibitions/lae/css_gal110.htm

Astronomy textbooks such as Carl Sagan's classic, *Cosmos* (1980 plus later editions/versions); ISBN-10: 0394502949; ISBN-13: 978-0394502946); *Cosmos* also appeared as a PBS mini-series, and was re-mastered and re-released on The Science Channel: <http://science.discovery.com/convergence/cosmos/cosmos.html> Dr. Sagan was a founding member of The Planetary Society: http://www.planetary.org/about/founders/carl_sagan.html

Big Question: Are We Alone in the Universe?

Drake, F.; D. Sobel, 1992, *Is Anyone Out There? The Scientific Search for Extraterrestrial Intelligence*, ISBN 0-385-30532-X.
Rood, R.T.; J.S. Trefil (1981), *Are We Alone? The Possibility of Extraterrestrial Civilizations*. ISBN 0-684-16826-X.

The SETI (Search for Extraterrestrial Intelligence) Institute: <http://www.seti.org/site/pp.asp?c=ktJ2J9MMIsE&b=178025>

The Planetary Society's SETI page: <http://www.planetary.org/explore/topics/seti>

NASA History SETI page: <http://history.nasa.gov/seti.html>

The Drake Equation: <http://www.pbs.org/lifebeyondearth/listening/drake.html>

Scientific "Revolutions"

Plate Tectonics: USGS on-line book, "This Dynamic Earth" <http://pubs.usgs.gov/gip/dynamic/dynamic.html>

Meteorites from Mars: Summary by LPI's Allan Treiman: http://www.agu.org/sci_soc/eistreiman.html

Meteorites from Mars: JPL metapage on Mars Meteorites: <http://www2.jpl.nasa.gov/snc>

Impact event "killed the dinosaurs" (original journal article): Alvarez L.W, Alvarez W, Asaro F, Michel H.V, 1980, Extraterrestrial cause for the Cretaceous-Tertiary extinction. *Science*. v. 208, p. 1095-1108

Impact event "killed the dinosaurs": http://www.lpl.arizona.edu/SIC/impact_cratering/Chicxulub/Chicx_title.html

Mars and Comparative Planetology

For the latest on Mars exploration: <http://mars.jpl.nasa.gov>

"Geomorphology from Space," a NASA Special Publication: <http://disc.sci.gsfc.nasa.gov/geomorphology/index.shtml>

NASA on Solar System science: http://science.hq.nasa.gov/solar_system/index.html

U Wash CP Lab (and others): <http://www.astro.washington.edu/labs/clearinghouse/labs/Complanets/complanets.html>

Large Magellanic Cloud Supernova of 1987

AAVSO webpage on Supernova 1987: <http://www.aavso.org/vstar/vsots/0301.shtml>

NASA GSFC Astronomical Picture of the Day: <http://antwrp.gsfc.nasa.gov/apod/ap970124.html>

HST images of Supernova 1987: <http://www.spacetelescope.org/images/archive/freesearch/SN+1987A/viewall/1>

Dark Matter

NASA GSFC "Imagine the Universe" webpage: http://imagine.gsfc.nasa.gov/docs/science/know_11/dark_matter.html

NASA WMAP page: http://map.gsfc.nasa.gov/m_uni/uni_101matter.html

NASA announcement: http://www.nasa.gov/home/hqnews/2006/aug/HQ_06297_CHANDRA_Dark_Matter.html

Astronomy as a Human Endeavor: Galileo, Henrietta Leavitt, Annie Jump Cannon, and others

Galileo and the phases of Venus: http://galileo.rice.edu/lib/student_work/astronomy96/tdunn/venus.html

Henrietta Leavitt on NASA's Astronomy Picture of the Day: <http://apod.nasa.gov/apod/ap981027.html>

PBS' "A Science Odyssey" People and Discoveries webpage: <http://www.pbs.org/wgbh/aso/databank/entries/baleav.html>

Wellesley College info about AJC: <http://www.wellesley.edu/Anniversary/cannon.html>

The AAS issues the Annie J. Cannon Award in Astronomy each year: <http://www.aas.org/grants/awards.html#cannon>

Women Astronomers (Astronomical Society of the Pacific): http://www.astrosociety.org/education/resources/womenast_bib.html

Infinity Express was produced by Sky Scan, Inc.; see: <http://www.skyskan.com/IE/index.html>

