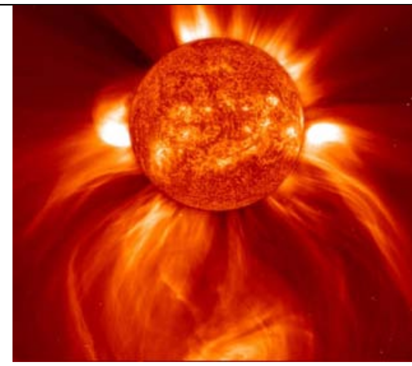
How Big, How Far, How Hot, How Old?

Deborah Scherrer, Stanford Solar Center

Participants arrange imagery of Earth and space objects in order of their size, their distance from Earth, their temperature, and/or their age. By manipulating these images, students and adults represent and confront their own mental models of space and time.

Target Audiences: • Public education events; other informal science locations & activities • Youth groups • Astronomy clubs • Can also be incorporated into public lectures on solar astronomy (or other topics) • Could be incorporated into classrooms	**Activity Time**: 10-30 minutes **Age Group:** Grade 5 - adult	 Image courtesy of ESA/NASA SOHO and Steele Hill

Materials Needed:

- Choose 1 or more of the "What are your ideas?" survey sheets for your group. Make a copy of each for your participants. If you are doing this in a public talk, you can project the survey questions onto a screen. If you are doing this at a table or booth or in a classroom, you can print the imagery onto cardstock, then laminate and cut them out for manipulation by participants.
- A pair of scissors for each participant, if you wish them to cut out the images. (*optional*)

Introduction

Many people, adults and students alike, are familiar with the names of objects in space, but have an incomplete mental model of where those objects are in space, their relative size and scale, and how they fit into the cosmic scheme of things. Understanding the sizes and distances of celestial objects can be tricky. For instance, in our everyday experience the Moon and Sun appear as the same size, but they are drastically different in sizes because of their distances from Earth.

In this activity, questionnaires launch participants into discussions about where objects in space are located, how large and hot they are, and how old they might be. By manipulating images of objects on Earth and in space, students and adults represent their own mental models of space and time.

When you lead discussions with your participants, keep in mind that ideas and insights about the three-dimensional organization of the solar system develop gradually. Getting the "right answer" is not as important as the critical thinking skills that people develop as they confront the questions that arise as they struggle with their mental models.

These particular surveys were developed as part of NASA's Heliophysics Division, and hence are targeted towards the Sun and solar science. Other groups could certainly adjust their surveys accordingly. The activity process works with imagery you might choose to match your objectives – moon phases, photos of stellar evolution, the EM spectrum, whatever. Hence this activity is more of a model, a suggestion on an interesting way to challenge your participants to think, as well as an opportunity for you to gather information on your participants's misconceptions and depth of understanding of a particular topic.

Teachers: The surveys can serve as a pre-unit assessment activity for you to find out how your students think about the Earth, Sun, and solar system. You can use them to design follow-up activities that help students improve their understanding.

Process:

Part 1: What are your ideas?

1. Hand out copies of your chosen survey data sheets (participants may cut out the pictures if they wish), or project them on a screen, or allow participants to "play" with your laminated copies of each image. Start by asking them to work individually to answer the survey questions.

2. Organize the participants into discussion groups of three to five. If you are in a lecture room situation, ask people to turn to their neighbor[1]. Explain that their group/pair is to discuss their survey answers and come to an agreement, if possible, on the best order of images. Encourage participants to discuss any disagreements fully and to write down questions and/or arguments in support of their answers.

Part 2: Discussion

1. Lead the group in a discussion about the different proposed orderings. Play the role of moderator, requiring each group to explain why they chose that order. Ensure that participants are comfortable saying, "We really didn't know about these objects…"

2. After discussing each question, poll the groups on the alternative orders of images suggested. Accept all answers, perhaps writing them on a flip chart or white board.

3. Attached are explanations of possible correct answers vs. frequent ideas and misconceptions. Compare these with your various group's orderings. Note that sometimes there is not an absolute, correct order.

4. If working with students, you can try this activity again with your students as a post-unit assessment, to see if their ideas have changed after the activity.

Thanks to Cherilynn Morrow for introducing this activity to me. This version was developed by Deborah Scherrer, Stanford Solar Center

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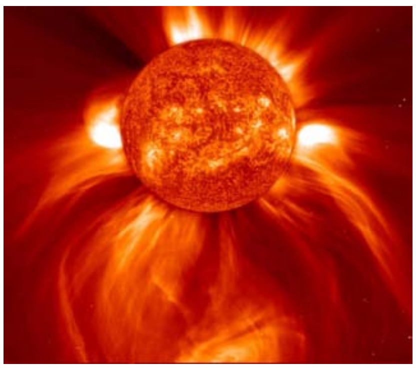
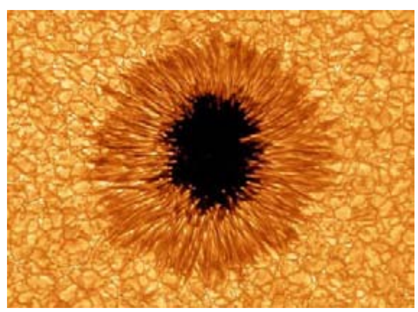
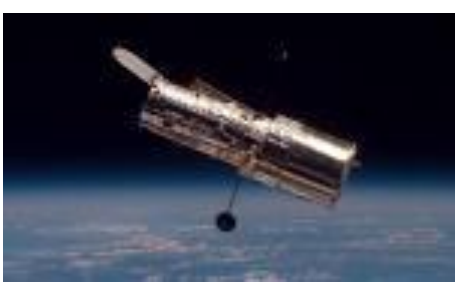
[1] Think-Pair-Share technique -- http://olc.spsd.sk.ca/DE/PD/instr/strats/think/

How Big?

What Are Your Ideas?

Below are images of nine objects associated with the Earth and Sun. Arrange the pictures **in order of actual size (diameter unless otherwise noted) from smallest to largest.** Write down and keep track of questions that arise as you order the images.

 The Sun	 Mt. Everest (height)	 The Moon
 Meteor	 Sunspots	 Asteroid
 Hubble Space Telescope	 Comet (*nucleus*)	 Solar Prominence

Discussion Notes for Solar Survey "How Big?"

Frequent ideas compared with astronomers' measurements

One order for the images, from smallest to largest, is:

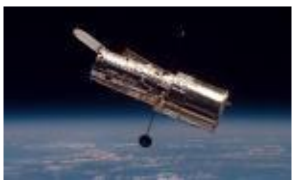
1

Meteor

Wiki Commons image

People may not be aware that most meteors are about the size of grains of sand, left as debris from passing comets and heated to very high temperatures as they enter the Earth's atmosphere. Occasionally large meteors can reach the Earth's surface, potentially impacting it, and becoming meteorites. Students understanding this may rank meteors as larger.

2



Hubble Space Telescope

NASA image

Length: 13.3 m, diameter: 4.2 m.

3

Mt. Everest

Wiki Commons image

8,848 meters in elevation (29,029 feet)

4

Comet *(nucleus)*

NASA image

Participants may also have trouble understanding the size/mass of a comet, which is little more than a mountain. (Thus Mt Everest and Comet could be in either order.) An average comet nucleus is ~10 kilometers in diameter (~6 miles), but some may be larger or smaller. Although a comet's tail may span millions of kilometers, it is so rarified that all its material could all be packed into a suitcase!

5

Asteroid

NASA image

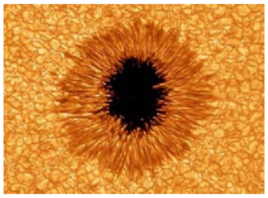
Asteroids vary greatly in size, from almost 1,000 km in diameter for the largest down to rocks just tens of meters across. The dwarf planet Ceres is by far the largest asteroid, with a diameter of 975 km (610 mi).

6

Moon

Image by Anthony Lopez

3,500 kilometers diameter (~2,000 miles)

7 

Sunspots

New Jersey Institute of Technology's New Solar Telescope

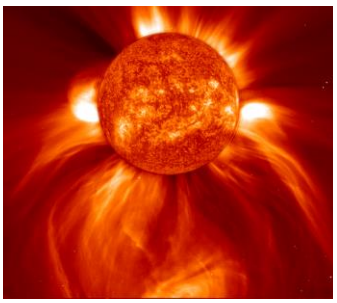
~1 to >5 Earth diameters
Sunspots, though appearing small when seen on the disc of the Sun, may be many times the Earth's diameter.

8 

Solar prominence

NASA SDO/AIA

Up to dozens of Earth diameters

9 

Sun

ESA/NASA SOHO Spacecraft

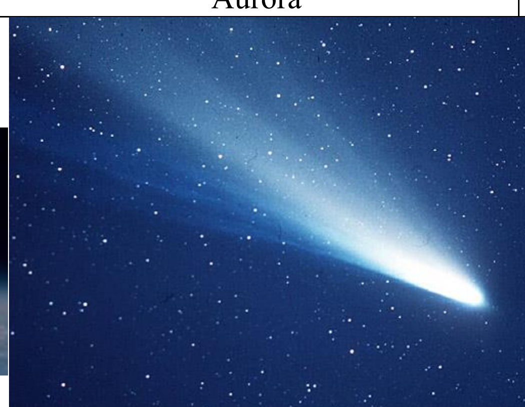
~1,400,000 km diameter (875,000 miles) or
109 Earth-diameters across
Participants answering this survey may have trouble understanding the scale of solar phenomena, almost all of which are much larger than the Earth. The Sun, which contains 99.8% of the mass in the solar system, would be much larger than the Earth, Moon, and other planets combined. It would take 109 Earths to span the Sun's diameter and a million Earths would fit inside it!

Note that it is hard to tell the size of objects from many of the images we see since they could look about the same size in pictures.

How Far?

What are your ideas?

Below are images of nine objects associated with the Earth and Sun. Arrange the pictures **in order of distance from the surface of the Earth, from closest to most distant.** Write down and keep track of questions that arise as you order the images.

 The Sun	 Top of Mt. Everest	 The Moon
 Meteor	 Aurora	 Clouds
 Hubble Space Telescope	 Comet	 Lightning (Top)

Discussion Notes for Solar Survey "How Far?"

One order for the images, from nearest to the Earth's surface to farthest, is:

1

Clouds

http://ed101.bu.edu/StudentDoc/Archives/ED101fa10/jenmks/cumulus.html

Usually <1 to 6 kilometers (up to 4 miles, though some are higher. See http://nenes.eas.gatech.edu/Cloud/Clouds.pdf

2

Mt. Everest
(top)

Wiki Commons image

8.8 kilometers in elevation (29,035 feet, ~5.4 miles)

3

Lightning
(top)

C. Clark, NOAA Photo Library

Up to 20 kilometers (12 miles)

4

Meteor

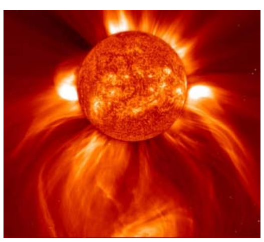
Wiki Commons image

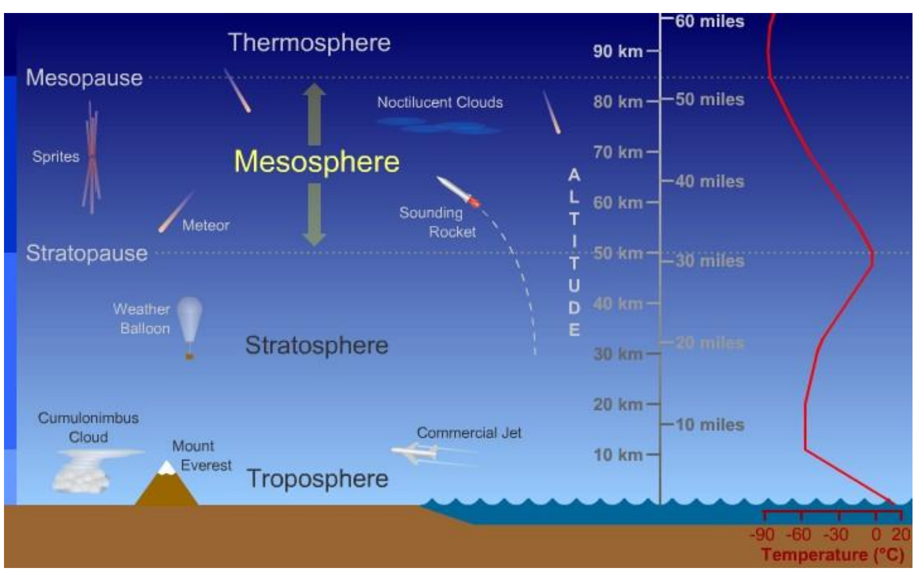
Approximately 100 kilometers up (60 miles). Although meteors are sometimes called, erroneously, "Shooting Stars," most are actually grains of dust, left over from passing comets. They begin to glow when they fall towards the Earth and enter its atmosphere. Most burn up long before they reach the ground. A few do strike the Earth, as meteorites, and some participants will be aware of this and hence place meteors close to the surface.

5

Aurora

100 to 500 kilometers (60-300 miles)

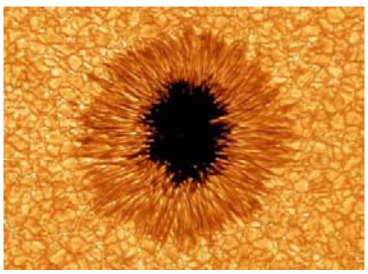
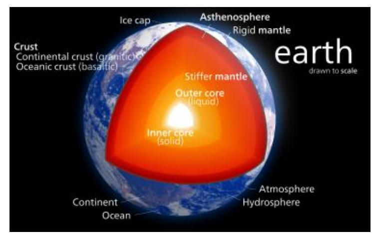
6		**Hubble Space Telescope** NASA	About 560 kilometers (~350 miles) People often struggle with the distance of HST, which many people believe is beyond the orbit of the Moon. It's actually only 350 miles high, low enough to have been serviced by astronauts aboard the space shuttle.
7		**Moon** Image by Anthony Lopez	385,000 kilometers (240,000 miles)
8		**Comet** NASA image	Not usually closer than 700,000 kilometers (about 4 times the distance to the Moon) Although comets appear deceptively close to the Earth, most are usually many times farther away than the Moon. Comets can, of course, come close enough to impact upon the Earth, but this is rare. However, this knowledge might lead some participants to place comets, like meteors, near the top of the list. Many coments have large elliptical orbits that take them beyond the orbit of Neptune. Students aware of that may order comets farther than the Sun.
9		**Sun** ESA/NASA SOHO Spacecraft & Steele Hill	~150 million kilometers (93 million miles)

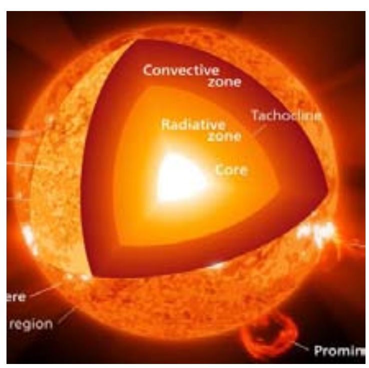


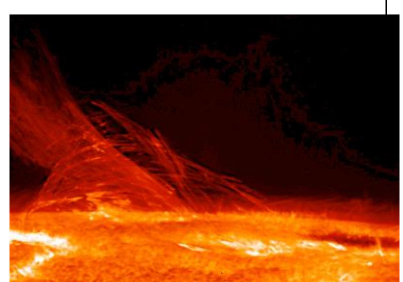
How Hot?

What are your ideas?

Below are images of nine objects. Arrange the pictures **in order of how hot they are, from coolest to hottest.** Write down and keep track of questions that arise as you order the images.

<table>
<tr>
<td>
Sunspot</td>
<td>
The Sun’s Corona
(“atmosphere”)</td>
<td>

Earth’s Core</td>
</tr>
<tr>
<td>
Meteor</td>
<td>

The Sun’s Core</td>
<td>
Surface of the Sun</td>
</tr>
<tr>
<td>
Volcanic lava</td>
<td>
Comet</td>
<td>
Lightning</td>
</tr>
</table>

Discussion Notes for Solar Survey "How Hot?"

One order for the images, from coolest to hottest, is:

1

Comet

NASA image

Comets glow from reflected light from the Sun, so the temperature on a comet will vary by its position in its orbit. When at its farthest from the Sun, its temperature falls to as low as -269°C (- 450° F or 4 K), the effective temperature of outer space. When closer, the part exposed to direct sunlight can easily reach 100°C (212° F) or higher when close to the Sun. Many participants may have trouble with the temperatures of meteors and comets.

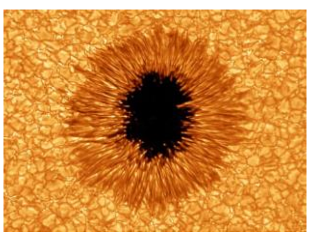
2

Volcanic Lava

Wiki

800-1100 C (1450° to 2000° F), depending upon its chemical composition

3



Sunspots

New Jersey Institute of Technology's New Solar Telescope

3500° C (6300° F or 3700 K)
People usually know that sunspots are "cooler" than the Sun's surface, but they are still very, very hot!

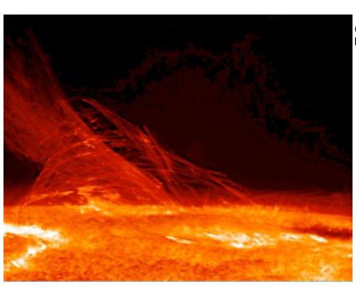
4

Meteor

Wiki Commons image

These objects vaporize and ionize at thousands of degrees Kelvin, roughly the surface temperature of the Sun.

5

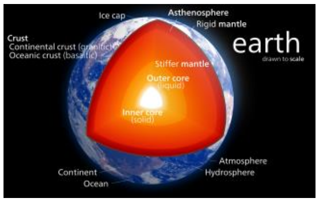


Sun's surface

Hinode's Solar Optical Telescope

5500° C (10,000° F or 5800 K)

6



Earth's Core

Wiki - Kelvinsong

6000° C (10,800° F or 6275 K). The Earth's core is a tad hotter than the Sun's surface.
http://www.sci-news.com/physics/article01040.html

7

Lightning bolt

C. Clark, NOAA Photo Library

30,000° C (54,000° F or 30,000 K)
The air around a lightning bolt can reach as high as 30,000° C. That's about five times hotter than the surface of the Sun. When the air gets that hot, it expands faster than the speed of sound, and the compressed air around it sends out a quick shock wave -- producing thunder!

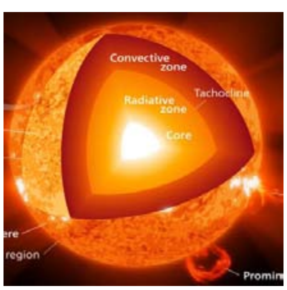
8

Sun's corona

Luc Viatour www.Lucnix.be

5 million degrees C (9 million degrees F or 5 million K)
Participants should have no trouble guessing that the Sun's core is the hottest, but they could be surprised to learn that the Sun's corona is much, much hotter than its surface. The increase in temperature in the corona has been a mystery for years, and may be a result of energy released from magnetic reconnection and a carpet of mini-flares happening at the surface and in the transition region above the surface into extending into the corona.

9



Sun's core

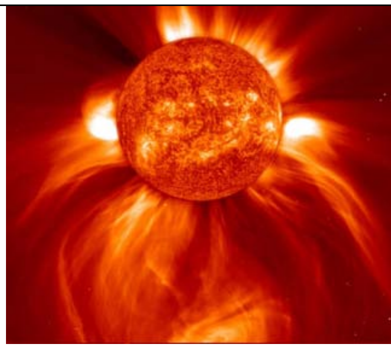
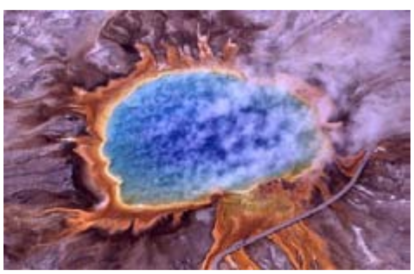
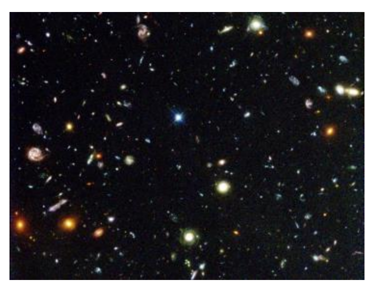
Wiki - Kelvinsong

5 million degrees C (27 million degrees F or 15 million K)

How Old?

What are your ideas?

Below are images of nine objects. Arrange the pictures **in order of age, from the youngest to the oldest.** Write down and keep track of questions that arise as you order the images.

 The Sun	 Rocks	 The Earth
 Life on Earth	 Our Milky Way Galaxy	 The Moon
 NASA's Solar Dynamics Observatory (SDO)	 Comet	 The Universe

Discussion Notes for Solar Survey "How Old?"

One order for the images, from youngest to oldest is:

1

SDO spacecraft

NASA/artist's conception

The Solar Dynamics Observatory was launched 11 February 2010.

3

Life on Earth

Wiki

~3.5 billion years

2

Rocks

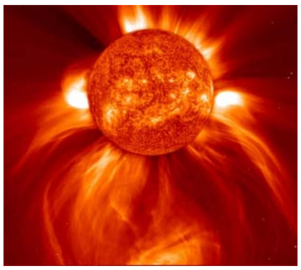
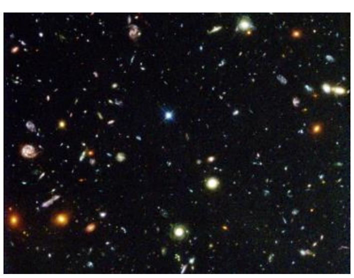
It is a common misconception that rocks originated with the Earth. Participants may be surprised to learn that rocks are younger than the Earth, not being aware that rocks are even currently being formed from continental drift, sedimentation, and volcanic activity.

Amongst the oldest rocks on Earth are the Acasta Gneisses (in what is now northwest Canada), pictured on the left. These rocks are about 4.03 billion years old. However, since rocks are constantly being formed, life on Earth precedes some rocks and some rocks precede life on Earth.

4

Moon

Our Moon is younger than the Earth, since the Moon is believed to be the result of a cataclysmic collision between the young Earth and a planet-sized asteroid. Participants may have trouble with the order of the Sun, Moon, Earth, and especially comets.

5		**Earth** NASA	Earth and the other planets are about 4.5 billion years old.
6		**Sun** ESA/NASA SOHO Spacecraft	About 4.6 billion years, slightly older than the planets, which probably formed from planetesimals (asteroid and comet-like pieces) after the star. The young Sun probably began its fusion process as the planets were forming. The Sun itself is a second-generation star, whose formation included heavy metals generated during the explosion of earlier, first-generation stars.
7		**Comets** NASA	As old as, or older than, the Sun. A cloud of interstellar gas, dust, and ices collapsed to form the nebula from which grew the Sun and the rest of our solar system. Comets that originated within the Kuiper belt and Oort cloud may be early remnants of this proto-planetary disk.
8		**Milky Way** NASA (image is actually Whirlpool galaxy, not our own)	13.2 billion years
9		**Universe** NASA/Hubble Space telescope	About 13.8 billion years (although the galaxies pictured in the image are only a few billion years old). The image used for the Universe is actually a Hubble Space Telescope deep field of galaxies, which themselves are young! Because light takes time to travel, telescope images of far-away objects let us look back in time. The image shows these galaxies as they were when they formed only a few billion years after the Big Bang.

Going Further

If you enjoyed these activities, perhaps you would like to explore more!

NASA Solar Missions

SDO: http://sdo.gsfc.nasa.gov/
SOHO: http://www.nasa.gov/mission_pages/soho/index.html
Hinode: http://www.nasa.gov/mission_pages/hinode/index.html
IRIS: http://science.nasa.gov/missions/iris/
MMS: http://mms.gsfc.nasa.gov/
RHESSI: http://science.nasa.gov/missions/rhessi/

NASA Earth Missions

http://www.nasa.gov/topics/earth/index.html

NASA Moon Missions

Lunar Reconnaissance Orbiter: http://lunar.gsfc.nasa.gov/
LCROSS: http://www.nasa.gov/mission_pages/LCROSS/main/index.html
LADEE: http://www.nasa.gov/mission_pages/ladee/main/#.VW5Q5qZX8lE

Comets

https://solarsystem.nasa.gov/planets/profile.cfm?Object=Comets
Deep Impact: http://www.nasa.gov/mission_pages/deepimpact/main/#.VW5MtqZX8lE
Rosetta: http://rosetta.jpl.nasa.gov/
Stardust: http://stardust.jpl.nasa.gov/home/index.html

Asteroids

https://solarsystem.nasa.gov/planets/profile.cfm?Object=Asteroids
Asteroid Redirect: http://www.nasa.gov/content/what-is-nasa-s-asteroid-redirect-mission

Meteors

https://www.facebook.com/NasaMeteorWatch

NASA Missions to Explore the Age of the Universe

WMAP: http://map.gsfc.nasa.gov/
Planck: https://www.nasa.gov/mission_pages/planck/news/planck20130321.html#.VW5L4qZX8l