What's the "Habitable Zone"?

Why is there life on Earth and not on Venus or Mars?
What about planets around other stars?

About the Activity

Model the habitable zone around stars and how an atmosphere influences the habitability of a planet.

Materials Needed

- 1 – Red Candle (representing a small, red star)
- 1 – sheet of yellow cellophane (for the campfire representing a sun-like star)
- 3 – sheets of blue cellophane (for the bonfire representing a hot, blue star)
- *(Optional)* Small bead or ball representing the Earth

Topics Covered

- How a planet's atmosphere and the distance from its sun affect conditions.
- What kind of planet has liquid water?

Participants

Use this activity with families, the general public, and school or youth groups ages 8 and up. It is best with a group of at least 10 people.

Location and Timing

This activity is great for classrooms, star parties, and other interactive settings. It can be held during the day or at night. It takes about 15 minutes to complete.

Included in This Activity

Detailed Activity Description
Background Information

This activity was developed from an idea in NASA's "Astro-Venture" guide:
http://astroventure.arc.nasa.gov/

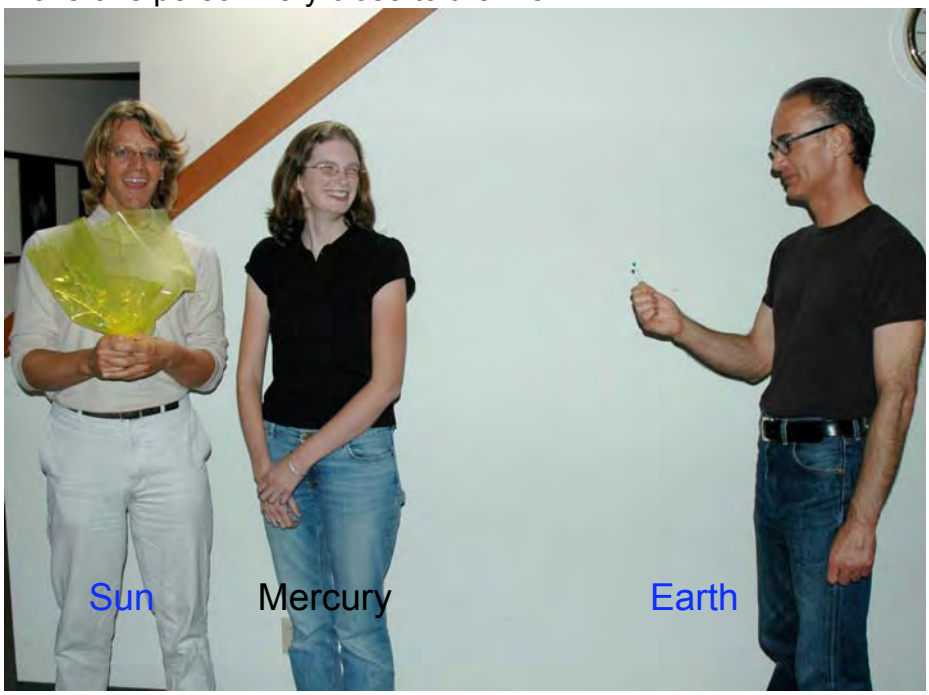
Additional astronomy activities can be found here: http://nightsky.jpl.nasa.gov
Astronomical Society of the Pacific www.astrosociety.org

Detailed Activity Description

What's the "Habitable Zone"? Why is there abundant life on Earth and not on Venus or Mars?

Leader's Role	Participants' Role (Anticipated)
To Say: Look up – what do you mostly see in the sky at night?	Stars!
Can we see any stars in the daytime?	Yes, one – our Sun
Does our star have planets orbiting it?	Yes.
Do you suppose some of the stars we see at night also have planets orbiting them?	Maybe.
Yes. Scientists have already found many that do, but only planets that are very large, close to the size of Jupiter and bigger.	Don't know.
Do you suppose some of those planets might be able to support life?	Maybe.
NASA's *Kepler Mission*, within about five to eight years, will determine if small Earth-size planets exist around other Sun-like stars. It is looking for planets in the habitable zone of stars.	
But what is a "habitable zone"? Why do you suppose there is so much life on Earth and no apparent life on Venus or Mars?	Variety of answers.
Earth is in the "habitable zone" of our star, the Sun. Let's see what it means.	

Leader's Role	Participants' Role (Anticipated)
PART I: Habitable Zone of a Sun-Like Star **This section addresses the topic of "habitable zone" and how atmosphere affects the habitability of a planet.** *To Do:*   Grab the sheet of yellow cellophane in the center and flare it into a bouquet shape. *To Say:* Pretend we are outside on a cold night and all we have is this campfire. *To do:* Give the campfire prop (one sheet of yellow cellophane) to one person. *To say:* Imagine this fire is as big as [his/her] upper body. *(Point to someone in the crowd)* Where would you have to stand to be comfortable? The campfire represents the Sun and you represent the position of Earth. Does Earth have liquid water? What about the people in the back – would you be comfortable? Would you be too warm?	Person adjusts their position. Yes. Lots. No. No! Too cold.

Leader's Role	**Participants' Role (Anticipated)**
To do: Move one person very close to the fire.  *To say:* I need you to take off your jacket. Would you be comfortable here?	No, I'd be too hot.
To say: *(Indicating person next to fire)* This person is like Mercury – too close to the Sun. Mercury has a daytime high temperature of 800° F (430° C). Can liquid water exist on its surface? *To do:* Pick another person and place him/her far from the campfire *To say:* I'm going to ask you to take off your jacket too. This person is like Mars – too far from the Sun and too cold. The temperature at the planet's surface varies widely during the course of a Martian day, from about -125° F (-87° C) just before dawn and warms up to about -4° F (-20° C) in the afternoon. Can it have liquid water? *(Indicating the person in the middle)* This person is like Earth – just right. Earth is in the habitable zone around our star, the Sun.	No – that's way too hot. Removes jacket. No– it would all be frozen.

Leader's Role	**Participants' Role (Anticipated)**
To say: The "habitable zone" around a star is where liquid water could exist on the planet's surface year-round. What's the most common substance in most living things?	Water?
Yes, Water! And not just any water, but liquid water. Most living things we know of require liquid water to live. So one thing that determines habitability is a planet being at the right distance from its star so the planet might have liquid water.	
To Say: Now let's look at something else that determines habitability: an atmosphere! Let's use a jacket to represent a planet's atmosphere. Why do you suppose I had Mars and Mercury take their jackets off? Mars and Mercury have little or no atmosphere. Wearing a jacket is like a planet having an atmosphere. Earth has just the right amount of atmosphere to insulate it and maintain a comfortable temperature.	No atmosphere?
The Moon is essentially the same distance form the Sun as Earth – but has no life and no liquid water - what's different? Right – no atmosphere – daytime temp on Moon:273° F (134° C) Nighttime temp on Moon: -274° F (-170° C)	No atmosphere!
But we have a planet missing. Which planet is between Mercury and the Earth? *(Select another person from the audience)* Would you stand here and be Venus? Venus has a very dense atmosphere. I'm going to have you keep your jacket on and imagine that I'm putting another other big down jacket on you too. Imagine I'm also wrapping a blanket around you. Would you be comfortable here?	Venus! OK. No – I'd get way too hot.
Right – Venus has too dense an atmosphere too close to the Sun. The temperature of Venus is always about 880° F (470° C). Can it have liquid water?	No.
So an atmosphere can make a big difference too in whether a planet might be habitable. Would it be easy for us to live on any of these planets, other than Earth?	No!

Leader's Role	Participants' Role (Anticipated)
PART II: Habitable Zone of Other Kinds of Stars **This section introduces the concept of different masses of stars along with the topic of "habitable zone".** *To Say:* But not all stars are like our Sun. Stars come in many different sizes. When a cloud of gas and dust collapses to form a group of stars, the stars are not all the same size, or mass. *To do:* Pick a person from the audience and give the candle to that person. Give the campfire prop (one sheet of yellow cellophane) to a second person. Pick 2 people to hold bonfire prop (2 sheets of blue cellophane). *To say:* These represent 3 different kinds of stars. *(Pointing to person with candle)* This candle represents a small cool red star. *(Pointing to person with campfire)* This campfire represents a yellow-white star like our Sun. Remember to think of the fire as being the size of his/her upper body. *(Pointing to people with bonfire)* Imagine this bonfire is as big as both of these people together. And what kind of star does this bonfire represent? Right, a hot massive bluish star.  	Holds props. A big, hot star.

Leader's Role	**Participants' Role (Anticipated)**
To Do: Line the "stars" up at least 5 feet (about 2 meters) apart from each other. You need 10 – 20 feet (or 3-6 meters) of clear space in front of them. *To Do:* Hand an Earth bead to one person from the audience. *To say:* *(To person with Earth bead)* Where would you place your planet in front of the candle so it would stay warm, but not too hot? *To Do:* Choose two other people. *To say:* Each of you stand at a distance from your fire where you can be comfortable. These represent stars with three different amounts of mass. You are each in the habitable zone of that star. Are each of the habitable zones the same distance from the star?	 Visitor holds bead close to candle. Visitors position themselves. No!
To say: *(Standing by the campfire)* As we mentioned, this campfire represents a star like our Sun. That's what we mean by "habitable zone around Sun-like stars". The stars like our Sun with planets in this vicinity *(indicating the position of the person standing in front of the star)* are what the *Kepler Mission* is hoping to detect. The mission will also collect information on other planets orbiting the stars and the variety of planetary systems in our neighborhood of the Galaxy.	
OPTIONAL Continuation of the activity: Have one person orbit the campfire in a highly elliptical orbit. *To Say:* If this fire represented another Sun-like star, and it had one planet with an orbit that brought it really close, then really far away (a highly elliptical orbit) – could you ever be comfortable on it? When it is close to the star, what would happen? How about when it is far away? Could that planet have liquid water on its surface year-round?	 You'd get too hot You'd get too cold. Not likely.

Background Information

More info on Mercury:
Virtually no atmosphere and very close to the Sun. Like being in the desert in a swimsuit. Daytime temp of Mercury is 660 F (250 C) and night side is about –300 F (–180 C).
(Mercury's "day" is about 58 Earth days long and its "year" is about 88 Earth days – it rotates very slowly)
More info on Venus:
Venus's "day" is about 243 Earth days long and its "year" is about 225 Earth days – it rotates very slowly.
Venus has a pressure at the surface about 90 times that of Earth - a pressure equivalent to a depth of 1 kilometer under the ocean – lie down and imagine the weight of one dictionary sitting on your chest. Now imagine 90 dictionaries.
More info on Mars:
Very little atmosphere – like wearing a t-shirt in the Arctic.
Mars pressure is like Earth at 20 miles up – 0.7% of the surface pressure on Earth.

Stellar Classification

Here is how we have classified the stars in this activity to take a more simplified approach to main sequence stars of various spectral types:
"Cool, red stars": Main Sequence stars of spectral type K, M, and cooler (lowest mass)
"Yellow/white stars": Main Sequence stars of spectral type G and F (mid-mass)
"Hot, bluish stars": Main Sequence stars of spectral type O, B, and A (higher mass)

All main sequence stars are classified as "dwarf" stars.
"White dwarf" is the hot core of a star that has lost its outer layers – a star that has "died".
"Red dwarf" is a cool, red main sequence star.

Giant stars (of various sizes) are stars that are “in retirement”, no longer burning primarily hydrogen. These are stars no longer on the main sequence. They still are given one of the above spectral types, but they are in a different “luminosity class”. Main sequence stars have a luminosity class of “V”. Here are the others:

Ia	Most luminous supergiants
Ib	Less luminous supergiants
II	Luminous giants
III	Normal giants
IV	Subgiants
V	Main sequence stars (dwarfs)

For more information on spectral types of stars:
http://antwrp.gsfc.nasa.gov/apod/ap040418.html (basic discussion - follow the links)
http://cas.sdss.org/dr4/en/proj/advanced/spectraltypes/ (tutorial)