# SCIENCE TOPICS FOR CLASS DISCUSSION

Throughout *Alien Rescue* you should have an opportunity to tie your students' comments to key scientific concepts. For your convenience, some information is provided here on several topics that might come up during class discussions. Use this information to enrich class discussions, but resist the temptation to lecture students or overwhelm them with more information than they can handle.

## GALILEO AND MOONS OF JUPITER

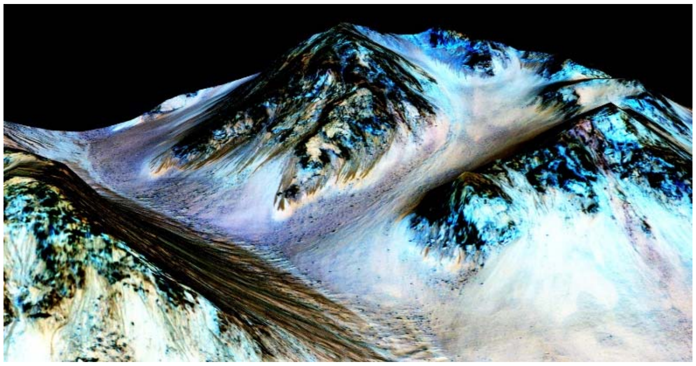
Galileo (1564-1642), one of the most famous scientists who ever lived, was a brilliant student whose acerbic tongue frequently got him into trouble with his teachers. In fact, when finishing his education, he was unable to find a suitable job for a couple years and had to move home. As a mathematician at University of Pisa, and later at Padua, he was constantly doing little physics experiments and trying to find ways to make them pay off.

When Galileo made his first telescope about June 1609 after hearing of its invention, his first thoughts were of how to sell the usefulness of the idea to rulers who might value it as an instrument that would help trade and defense. With the telescope, one could report the approach of ships (either merchant ships or vessels of war) earlier than previously possible. Galileo's scientific discoveries, however, came when he began to observe the sky with his telescope. (Others had earlier telescopes -- but they either didn't look at the night sky or, if they did, they didn't rush into publishing their observations.)

Most people of the time believed the sun, moon, planets, and stars revolved around a stationary Earth and that the heavenly bodies were perfect. Galileo discovered sunspots, craters and mountains on the moon, phases of Venus (which indicates that it revolves around the sun as the moon does about the Earth), and the moons of Jupiter. The four largest moons of Jupiter were a surprise to Galileo himself. As a systematic observer, his notebook at first shows views of Jupiter with the background stars. The drawings are scattered throughout the other observations and notes. However, after several days, he realized that some of the fainter "stars" appeared to be always close to Jupiter as it moved with respect to the background stars. His notes became more organized as he aligned his observations on the pages and kept careful track of their relative spacings. Using these observations, taken between January and March 1610, he asserted that these were moons revolving around Jupiter, just as our moon revolves about Earth. In a push for political recognition, he named them the *Medicean stars* in his book "Sidereus Nuncius" which was published in March 1610. Just as scientists do today, rushing into print with theories and observations provide priority in acknowledging a discovery. He resigned his job in June of that year and was hired by the Grand Duke Cosimo de Medici in Florence as Chief Mathematician and Philosopher in September. Although we don't call them after the Grand Duke anymore, Io, Europa, Callisto, and Ganymede were the key to Galileo's success. And while these moons are named after characters from Roman mythology, together, they are referred to as the Galilean moons.

For those interested in how this discovery and his future writings eventually got him into trouble, see **Galileo's Daughter** by Dava Sobel.

## WATER ON MARS?



The American astronomer Percival Lowell (1855-1916) founded Lowell Observatory in 1894. His studies of Mars led him to believe that the linear markings (first noted by Schiaparelli) on the surface were "canals" and therefore that the planet was inhabited by intelligent beings.

The first spacecraft to probe Mars ended up shattering ages of myths and delusions. Unlike Earth, Mars had no lakes, rivers, nor vegetation as some astronomers had imagined after seeing elusive dark patches and white ice caps that seemed to change with the seasons. Instead, Mariner 4, which flew past Mars 35 years ago, found a wasteland of dust and craters, although later observaitons have shown that the white polar regions contain both dry ice (carbon dioxide) and water ice. The Viking fly-bys and landings of 1976 showed some features like dry riverbeds but no life. Mars' atmosphere is so thin that any liquid water would quickly vaporize. But, with some surprise, the Mars Global Surveyor in summer 2000 photographed regions that look like gullies and valleys cut in modern times by running water. (Recall, that for things billions of years old, "modern" times could mean hundreds, thousands, or even millions of years.) Scientists now think the Martian crust harbors up to three times as much water as previously thought. One explanation may come from observations of evidence of recent volcanism. If the interior of Mars is warmer than previously thought, perhaps deep water ice could melt and produce surface flows.

Scientists are interested in water since they believe it is one of the building blocks of life as we know it. Perhaps the only way to find water will be to send a lander that can dig deeply into the Martian soil. Martian meteorites (that have been found on Earth) show bacteria-like fossils that lead to speculation about life developing on Mars. No one has seen an alien walk past one of NASA's expensive cameras on Mars, but when future missions bring samples back from Mars they will be treated as potentially dangerous to Earth and special procedures will be followed to keep them from contaminating our planet.

## GEOLOGICAL ACTIVITY: ACTIVE AND DEAD WORLDS

We who live on Earth easily identify it as an "active" planet -- and this doesn't mean that lots of people are doing exciting things on a weekend. It means that it is geologically active, that is, there are movements in the crust of the Earth, resulting in earthquakes and volcanoes.

Not all worlds are geologically active. Many worlds in our solar system are considered dead, meaning that there is no longer any geological activity on them.

Why are some worlds active while others are dead? The difference lies far beneath the surface, at the core of a world. Those worlds with hot cores are more likely to be active. The heat in the core of the world builds up to a point where it must find release. As this heat pushes its way toward the surface, it creates convection currents (the same thing that makes warm air rise and cold air sink) beneath the plates in the crust, moving them in different directions. This causes earthquakes. This heat can also force melted rock up to the surface, exploding in a volcano.

In contrast, worlds that are geologically dead tend to have cooler cores. These cores may have once been hot, but they have cooled off over time. Generally, small worlds are more likely to have cooled off and become geologically dead. A notable exception is Io. Io is so close to Jupiter that Jupiter and the other moons pull on Io, keeping its core liquid and hot. As a result, volcanoes explode on Io all the time, and though we have no proof, we would expect to find quakes there as well.

A hot core may have an important benefit for a world. Liquid metal that spins creates a magnetic field. If the core of a world is both hot and made of metal, then the rotation of the world creates a magnetic field around it. This magnetic field helps to catch the particles blown out of the sun by the solar wind, thus protecting the world from its damaging effects.

## RADIO WAVES


You probably have a radio in your house, in your car, or as part of your Walkman. So, your perception of "radio" is something to "listen" to. But, scientists know that radio waves are part of the spectrum of electromagnetic radiation that includes many types of radiation. In order of wavelength (short to long), they are x-ray, gamma-rays, ultraviolet, visible, infrared, and radio. They all travel at the same speed - the speed of light.

If radio waves are part of the same spectrum of electromagnetic radiation as visible light, why are we able to "see" some waves but not others? That has to do with the ways our eyes have evolved. Our eyes are sensitive to some wavelengths but not others. Therefore, we can see blue and red, but not radio.

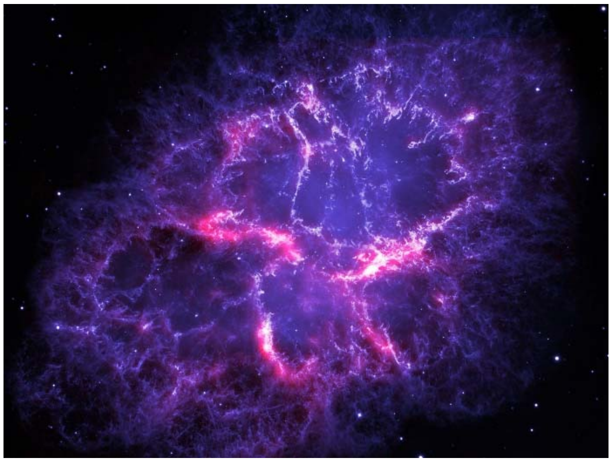
The ability of radio waves to carry signals was discovered over a century ago. In Italy in 1895, Guglielmo Marconi performed simple experiments that showed it was possible to send signals by using electromagnetic waves to connect a transmitting and a receiving antenna. The transmitting antenna converts sound into a signal, then the receiving antenna translates these waves into sound. By 1901, Marconi sent a wireless signal across the Atlantic.

Radio waves have a big advantage over sound waves as a means of sending sound long distances. Sound waves travel very slowly and need a medium (e.g. air or water) in which to travel. Radio waves travel at the speed of light and do not need a medium. The confusing thing is that although you "listen" to a radio, you don't hear the radio waves -- you hear what they've been transformed into.

While radio waves are longer than other types of waves, there are still ranges of radio wavelengths. When you tune your radio to a different wavelength, you pick up AM or FM signals. For example, KMFA broadcasts at 89.5 megahertz. The transmitter at the radio station oscillates at a frequency of 89,500,000 cycles per second. (Wavelength is the speed of light divided by the frequency and refers to the physical length of the wave.) Television broadcasts also use radio waves, though in a different part of this radio spectrum than radio broadcasts.

One of the advantages of radio waves is that they can travel through most things. To them, people, trees, and wooden buildings are smaller than their wavelength and they pass right through them. Radio waves can also travel through a vacuum. This means that our radio signals travel off the earth, and keep going out in to space. So, those signals sent by Marconi over a century ago have traveled over a hundred light years from our world. Technological civilizations within a distance equivalent to that time (e.g. about 100 light years) could possibly detect our radiation and interpret it as signals of our methods of communication. Although at the beginning there were few signals, and all were very faint, we have come to dominate much of the radio spectrum with messages. If there is an advanced civilization out there looking for signals from other worlds, they could come to know us through our broadcasts.

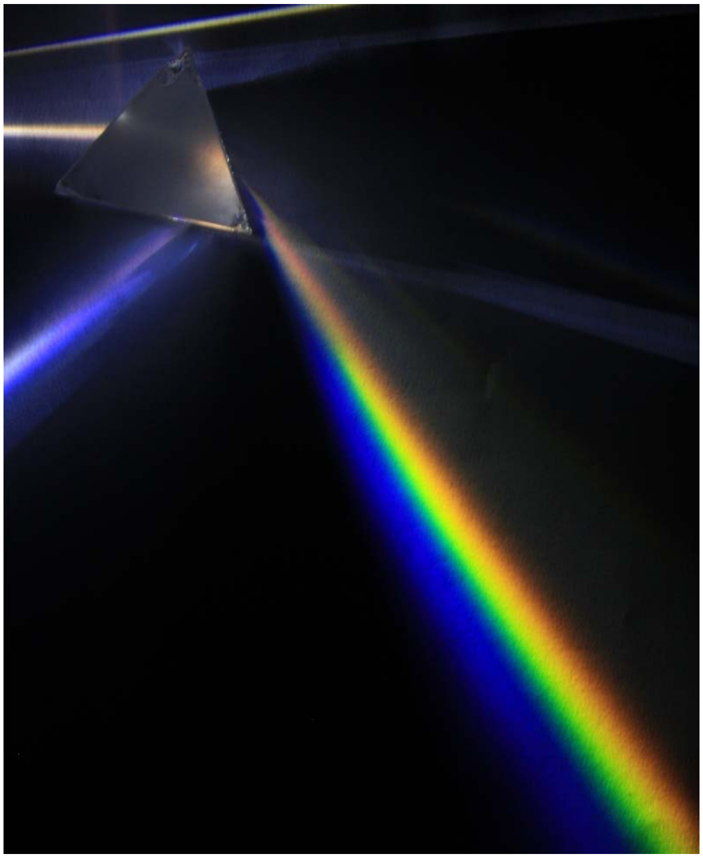
## SUPERNOVA



It should be no surprise that if astronomers have theories of star-birth, they have theories of star-death. The sudden appearance of a supernova is a dramatic observational event. Historically, "nova" refers to "new" and supernova refers to a super new "star" appearing in the sky. Ancient observers recorded seeing a supernova about once every three hundred years. Some were so bright that they could be seen in the daytime sky. The last one seen in our galaxy was Kepler's star in 1604. Eventually, the light faded and only the ancient reports remained. In the modern era, astronomers came to understand that these fairly rare events are the energetic explosion of a very massive star.

Most stars are quite a bit smaller in mass than our sun; they end their lives as we expect our sun will - throwing off its outer atmosphere, leaving behind a small hot remnant that slowly cools to become a white dwarf. The massive star that ends its life in an explosion also lives a much shorter time than sun-like stars. Observations of supernovae in other galaxies help astronomers estimate distances to those galaxies and help them put limits on their theories of how stars are born and die. During the supernova explosion the particles travel with such large energy that they slam into each other and create elements heavier than lead (e.g. gold, silver, platinum) thereby enriching the nearby gas and dust. There is no other natural source for these elements. The explosion itself may provide a shock wave that allows star formation to begin in nearby clouds of gas and dust. The clouds of gas and dust are enriched with new elements. In a way, we can say "the universe recycles." The high-energy radiation from the explosion is intense and life, if it existed nearby, would not survive.

## SPECTROSCOPY



A star keeps few secrets. It reveals its temperature, its chemical composition, and its motion through space. It tells the universe whether it has any companions, and if so, how well they get along. With this information, astronomers can piece together the star's life history - and even its future.

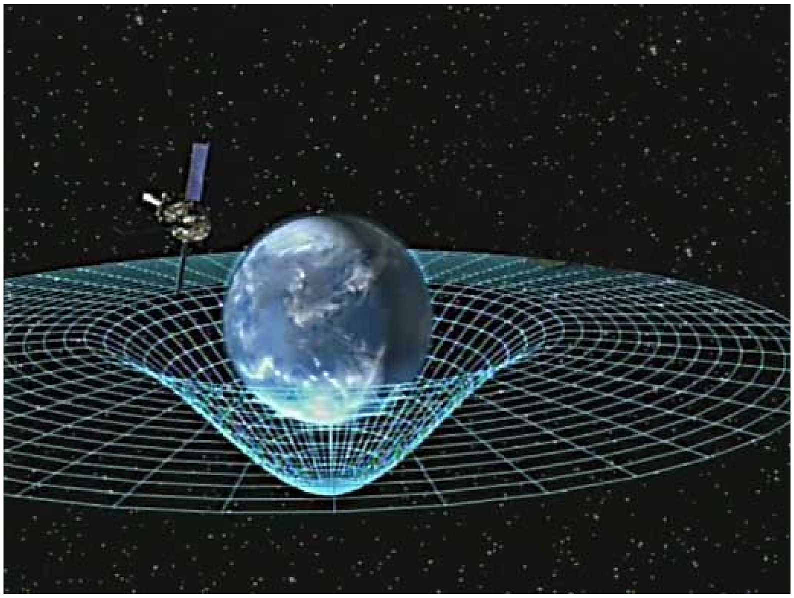
All of this information is embedded in starlight.

The light that we see with our eyes is really a combination of many wavelengths of light. By using a technique called spectroscopy, astronomers split starlight into individual wavelengths. How strongly or weakly the star shines at each wavelength tells a bit about the star.

For example, each chemical element impresses its own "fingerprint" on the star's light. By measuring these fingerprints, astronomers found that "normal" stars like our Sun consist mainly of hydrogen. But stars also contain traces of other elements, such as carbon and oxygen. Exactly how much of these elements a star contains reveals something about when and where it was born, and how it's changed over the eons.

Sometimes, the fingerprints shift a bit - they look "redder" or "bluer" than normal - indicating that the star is moving. The size and direction of the shift tell astronomers how fast the star is moving, and whether it's moving toward or away from us. If the shift goes back and forth, it means the star has one or more companions. Astronomers can even tell if one star is stealing gas from the other.

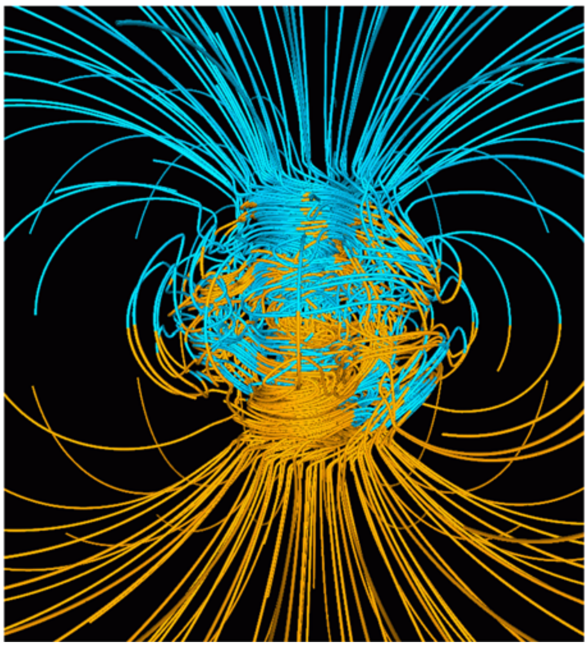
## GRAVITY



Gravity is a force of attraction between all matter. It is the weakest known force in nature, but it still manages to hold galaxies and solar systems together. Ancient peoples considered gravity as a downward force since it was easy to observe that when anything was released, it went down. Several scientists of the late Middle Ages and early renaissance tried to understand gravity, including Galileo’s student Vincenzo Viviani. Many consider him the founder of experimental physics since he rolled balls down inclined planes and may have dropped balls of different masses off the Tower of Pisa. He discovered that balls of different weight would land at the same time. (If the size is different, you might get a different result because of air resistance.)

Although Galileo also observed many things with his telescope, he wasn't too interested in the mathematical calculations needed to show the exact shapes of the orbits of planets around the sun. Johannes Kepler (1571-1630) was the expert of that era. He used years of precise data and many difficult calculations (in a time with no adding machines or calculators) to show that planets travel in elliptical orbits. Jumping ahead in history, we find Isaac Newton (1642-1727) who supposedly sat under an apple tree and wondered why an apple hit him on the head. His ideas about gravity combined Galileo's experiments, Kepler's calculations, the invention of calculus, and his own genius. He defined gravity as the force between any two masses in the universe. This force is proportional to the product of the masses of the bodies and inversely proportional to the square of the distance between them. Everything that has mass has gravity and attracts everything else in the universe. What this means is that when you stand on the Earth, you are attracted to the Earth with a force proportional to your mass times the mass of the Earth (a very large number) divided by the square of the Earth's radius (another rather large number) -and the Earth is attracted to you by the same force. When you stand next to someone, you have a gravitational attraction to him or her, but it is rather small compared to the one between you and the Earth so you are not likely to be thrown off balance. If you learn to use your muscles on Earth, and then go someplace (like the moon) which has lower gravity, you will find it easier to jump, lift, move - because your muscles are capable of much more effort. But imagine a future child born on the moon - growing up in a place of lower gravity, this child's muscles would feel very weak and not able to withstand greater gravitational forces if she moved to a place with more gravity.

## MAGNETIC FIELDS



When you use a compass you demonstrate that Earth has a magnetic field. It acts like a large electromagnet with its north magnetic pole not too distant from its rotation axis. The current theory is that self-excited dynamos maintain electric fields within planets. There are two necessary conditions: a rotating body and a hot, fluid, electrically conducting interior within which convective motion occurs.

Measuring the rotation of celestial bodies is fairly easy. Understanding how they could have a hot, fluid, electrically conducting interior is not. We know it has something to do with size and whether the interior is "active." For example, the moon has no general magnetic field and therefore must lack an internal dynamo. It is too cold to have a hot core (and it rotates very slowly). It does have some magnetic patches that are unexplained.

One way to notice the presence of a magnetic field is to see how it influences charged particles. The sun is constantly releasing charged particles into space. This phenomenon is known as the "solar wind," and it streams throughout the solar system, well beyond the orbit of Pluto. The number of particles released by the sun changes over time depending upon how active the sun is. Some of these events come during solar storms and the particles can damage satellites near Earth causing disruption to communication. (Cell-phone users should beware of this danger near the time of solar maximum every eleven years. The latest peak was expected in 2013, but these solar storms were some of the weakest seen in 100 years!)

Celestial bodies with magnetic fields can divert the stream of the solar wind, pushing the particles around the magnetic field and protecting the surface from them. The region of space in which a world's magnetic field dominates that of the solar wind is called the magnetosphere. Celestial bodies without magnetic fields lack a magnetosphere, and therefore don't have the ability to interact with the solar wind, so the particles hit them over their entire surface.

Though most of the particles the solar wind sends our way are pushed around the Earth, some do make it to the surface, providing us with a spectacular phenomenon. As the magnetic field comes close to the north and south poles, particles stream through the atmosphere creating auroras.