Grade 9 Astronomy Unit

Introduction:

The grade 9 astronomy unit is a content-heavy unit. It is usually taught near the end of the term, when time is limited; sometimes by teachers who are not expert in this field. For the majority of the students, this will be their last astronomy course. It is the hope of the authors that the students take away from this course some of the most important concepts about the nature of the universe and some of its constituents. We believe that at this level, simple and descriptive understanding of the material is sufficient. Details and technical explanations are therefore not necessary.

The first part of this document outlines what we feel are the overarching goals of the unit. The sections following it are arranged by topics (Part I: Galaxies and the Universe, Part II: The Solar System, Part III: Stars, Part IV: The Night Sky, and Part V: Astronomy and Us). For each part, we start by listing what we feel are the important concepts for the topic, *in order of priority*, followed by some notes to the teachers. Finally, we suggest some activities the teachers could use.

Throughout the document, corresponding Ontario Ministry Expectations are given in codes within brackets. These codes are those found in the Ministry's Curriculum Planner and are explained in Appendix A.

Our View of the Overall Goals of the Grade 9 Astronomy Unit:

The purpose of this unit is to provide students with opportunities to appreciate the wonders of the universe through the study of astronomy. By the end of this unit, students are expected

- To be able to describe the significant constituents of the universe;
- To have a sense of the scale of objects in the universe;
- To be able to describe the generally accepted theory of the origin and evolution of the universe;
- To be able to describe the most significant characteristics of the solar system;
- To be able to describe the generally accepted theory of the formation of the solar system;
- To appreciate that stars evolve over time, and to be able to describe their origin, evolution, and death;
- To gain a familiarity with the night sky and how its appearance changes with time, date, and latitude of the observer;
- To understand how the Sun affects the Earth;
- To be aware of how Canadians contribute to the field of astronomy and space science.

PART I: The Origin and Evolution of the Universe (Addresses Basic Concepts ES1.01, ES1.02 and many skills and communication expectations)

By the end of this section, the students should be able to

- Describe the significant constituents of the universe;
- Have a sense of the scale of objects in the universe;
- Know that the universe is expanding;
- Describe the currently accepted theory of the origin of the universe (The Big Bang theory).

Background

- The significant constituents of the universe, in increasing size scale, include planets, stars, planetary systems, galaxies, clusters of galaxies, and the universe itself.
- Galaxies are made up of billions of stars, planetary systems, gas and dust, held together by gravity.
- The galaxy that our solar system is located is called the Milky Way Galaxy. If you could travel at the speed of light, you could travel from one side of the Milky Way Galaxy to the other side in 100,000 years.
- Clusters of galaxies consist of tens to thousands of galaxies, held together by gravity.
- Observations of galaxies by Hubble and other astronomers in the 1920s show that the distant galaxies are all moving away from us at high speeds proportional to their distances. According to the Doppler Effect, this means that the universe is expanding. To be precise, it is space that is expanding, and carrying the galaxies along as it expands. Therefore, the galaxies appear to be moving away from each other. The galaxies themselves are not moving through space. [The balloon analogy given in the strategy section below illustrates this concept effectively.]
- If space is expanding, then it is larger now than it was. This argument will lead to the conclusion that some time in the distant past, the universe was so small that it was just a point. This is the beginning of the universe, termed the “Big Bang”.
- Observations are accumulating to show that the Big Bang happened about 13 billion year ago, therefore, this is also the age of the universe as we know it.
- The Big Bang theory is the best theory of the origin of the universe because several observations, including the following, support this theory in detail. First, if this theory were true, we would expect that in the distant past the universe, being small and dense, would be very hot. As the universe (i.e., space itself) expands, it will cool. The signature of this cooling has been observed in detail by the COBE satellite in the early 1990s.
- Second, astronomers know that the element Helium makes up about one quarter of the matter in the universe. Indeed, the Big Bang theory predicts that Helium is produced during the Big Bang, by exactly the right amount.

<u>*Strategies*</u>

Lesson One (addresses expectations ES1.01, ES2.04, ES2.05, ES2.07)

- In the spirit of co-investigation, you may book a period at the library and have the students work in groups of threes to research the five most significant constituents of the universe. They will come across many objects, and all of them will appear important. For any object they pick, have them ask themselves what would be the consequence if the universe did not have such an object (so based on this criteria, clusters of galaxies may not be picked, which would be fine). For each object, find out what the average size and separation are.
- After the groups have picked their four or five objects, have them make a concept map, starting with "The Universe" at the top and fill in the rest underneath it according to decreasing sizes.
- Have a few groups present their list, describe each object and explain why they chose these objects.
- Side notes
    - Throughout this section, the concept of gravity keeps returning. It is important to stress that gravity is an attractive force that pulls things together. The reason why people on the other side of the earth do not fall into space is that they are attracted towards the centre of the earth by gravity. The same concept applies to the solar system, galaxies and clusters of galaxies. This is an example of the universality of physical laws.
    - In order to avoid having the students present a bunch of number facts about each object, ask them to describe the physical differences of each object and how they are related to each other (particularly the differences).

Lesson Two (addresses expectations ES2.02, ES2.08)

- Comparing the sizes of these objects is important to give physical meaning to the scales of things in the universe but difficult to accomplish because of the wide range. A video called "Powers of Ten" (The films of Charles & Ray Eames, vol.1. Pyramid Film & Video, duration: 10 min) achieves this objective quite nicely.
- After the video, you could have the students make their own scale model of these objects. For example, if the Earth is the size of a grain of salt (0.5 mm), how big would the Sun, the solar system, and the Milky Way Galaxy be? They will find that for the galaxy, they need to use scientific notation, which they have learned in Grade 8 Math, to represent the number. Combining the numbers they have obtained with the images they have seen in the video would help to visualize the scale of the universe. Have the students discuss what would be a useful scale.
- Another activity the students could do is form teams to calculate, assuming a constant speed, how long it would take to travel around Earth's equator, around the Sun's equator, from the Sun to Pluto, from the Sun to the centre of the Milky Way, and so forth. They could then increase the speed to the speed of light and repeat the calculations. By incorporating math into the science curriculum, the

students would have a feel for the distances between objects and the meaning of the term "light year".

Lesson Three (addresses expectations ES1.02, ES2.06)

- Another opportunity for co-investigation here. Book a computer lab and have students form groups and search the internet for information regarding the Big Bang Theory.
- Ask students if observations show the galaxies are moving away from us, does that mean we are at the centre of the universe.
- The concept that space is expanding and that galaxies are not moving through space can be illustrated using a balloon and a marker. Have students draw dots on the surface of the balloon and measure the separation of the dots before blowing it up. As they blow up the balloon, they will see that the dots move apart because the balloon (space) expanded, and not because the dots themselves move along the surface of the balloon. It should be emphasized that the two dimensional *surface* of the balloon is being used as an analogy for the three dimensional *volume* of space. While the analogy is not ideal, it is the best we can do to help visualize the situation.
- The same activity can be used to demonstrate that there is no centre and no edge to the universe, as an ant living on the surface of the balloon would attest to.
- If you would like to teach the concept of redshift, you could have the students draw a wavy line on the surface of the balloon and watch the wavelength lengthen as the balloon expands.
- Ask students what did the universe looks like when it was half its current age. Ask them what they expect the universe to look like if they keep going back in time. The concept that the universe was very small would come naturally, though they may not know that the temperature and density would have been very large.

Lesson Four (addresses expectations ES1.02, ES2.09)

- To show that the universe does evolve, show the students the Hubble Deep Field image. (Nelson Science 9, Section 15.6 has the image. Otherwise, it can easily to downloaded from the "Astronomy Picture of the Day" website (http://antwrp.gsfc.nasa.gov/apod/ap020901.html)
    - Discuss "look back time", which the students would readily understand if they have done the calculation activity above.
    - Together with the students, identify different kinds of galaxies on the image (elliptical galaxies, spiral galaxies and irregular galaxies). Point out the richness of the universe. Keep in mind that the galaxies are at different distances, so the apparent size of the galaxy does not necessarily reflect its true size.
    - A variation of the above activity is to have the students devise their own classification system. This will show them that classification schemes do not necessarily lead to physical explanations of why the galaxies look different.

    - Point out that there are many more irregular galaxies when the universe was younger, and it suggests that galaxies collide with each other more frequently in the past. Presumably, this is due to galaxies being closer to each other when the universe was younger and smaller, as predicted by the Big Bang theory. (This is not a mainstream part of the unit, but it demonstrates how astronomers can learn about the evolution of galaxies and the universe.)
- Finally, as an aside, you might want to point out to the students that the Big Bang theory is currently the most accepted theory of the origin of the universe. However, 50 years ago, another rivalling theory, which suggested that the universe does not evolve, existed. This theory could explain only one aspect of the nature of the universe, i.e., the expansion of the universe, but only if intergalactic matter could be created. It has since been discarded in favour of the Big Bang theory, which can explain many more observations more successfully.

PART II: The Solar System

The Most Significant Characteristics of the Solar System (Expectations addressed: ES1.01, ES1.03, ES2.01, ES2.02, ES2.04, ES2.06, ES2.07, ES2.08)

By the end of this section, the students should be able to

- Describe the major constituents of the solar system;
- Identify the most significant characteristics of the solar system;

Background

- The sun comprises 99.8% of the total mass of the solar system. All other components, including the planets and their moons, asteroids, and comets make up only 0.2% of the mass. (precise numbers are not important)
- In ascending order of the average distance from the sun, the planets are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune and Pluto. (Mnemonic: "My Very Educated Mother Just Showed Us Nine Planets")
- Planets, with their moons in tow, revolve around the sun in *nearly* circular orbits. The largest deviations from circular orbits are the orbits of Mercury and Pluto.
- Planets orbit the sun on nearly the same plane. That is, if one were to look at the solar system on the side, it will look like a very flat disk.
- Planets revolve around the Sun in the same direction (counter-clockwise when viewed from the top, or north, of the solar system).
- The planets (except Pluto, which could be considered too small to be called a planet) may be classified into two groups with very different properties. The inner planets, up to and including Mars, are called Terrestrial Planets. The outer planets, from Jupiter to Neptune, are called Gas Giants.
- The terrestrial planets are mainly made of rock and metal; the gas giants are mainly made of gases.
- An asteroid belt resides roughly between Mars and Jupiter. Asteroids are large chunks of irregularly shaped rock, left over from the formation of the solar system.

Strategies

Lesson One

- Have a class discussion on what the students already know about the solar system. Most students would know the basic information as they have encountered them in Grade 6. Some students may be able to recite number facts, but not appreciate "the big picture".
- Discuss what are the most important characteristics of the solar system. Ask them whether the number of moons a planet has is significant. Ask them what is more important to know: that the gas giants and the terrestrial planets are made of different material or that Jupiter has 27 moons.
- Have students identify an area of interest for further investigation. They could choose to work in groups of up to 3.

- Book the library or computer lab for half a period for students to do some research. Teach them to ask themselves whether a piece of information they come across is significant or not: What does this information tell us about how the solar system form or how the object changes over time? Does it matter if the number is different? Have them justify their choice of important information.
- Have each group make a list of significant characteristics.

Lesson Two

- Have the groups discuss and complete their list. For the rest of the class, have each group take turn reading out one characteristic in their list and justify why they chose it. Make a class list of all characteristics chosen and post them for reference, especially for the next topic.

Theory of the Formation of the Solar System (Expectations addressed: ES1.05, ES1.07, ES2.02, ES2.06, ES3.03)
By the end of this section, students should be able to

- Describe the currently accepted theory of solar system formation

Background

- The study of the formation of the solar system is an interesting example of how science progresses, because it is in its early development, and many details are still not understood.
- From the previous section, the students should be able to describe the major characteristics of the solar system. These characteristics must be explained by the theory of solar system formation.
- Currently accepted theory of the solar system (Evolution Theory or the Nebula Theory): This theory suggests that the solar system formed from the contraction of an interstellar dust cloud. If the cloud has any slight rotation, the contraction will cause the rotation to increase. An analogous situation is the speeding up of the spin of a figure skater when he pulls in his arms. The material in the centre becomes the sun. The rotation motion of the cloud causes the matter surrounding the newly forming sun to flatten into a disk.
- As the gases in the disk cool, they begin to condense into solids (ices and dust grains). The dust grains collide with and stick to each other and form progressively larger chunks. Over a few hundred thousand years, a few of these larger chunks grew still larger into the planets. Around them, similar process formed their moons.
- Closer to the sun, temperature is very high, therefore the ices evaporated, leaving the inner planets the rocky worlds that they are today. Further out from the sun, temperature is cooler, the gravity of the planets there are able to incorporate ices to become the planets' atmosphere. These are the gaseous planets.
- Another theory of the formation of the solar system, now discredited, is called the Catastrophe Theory. It proposed that they solar system was formed in an unusual event such as the collision of the Sun with another star.

- This type of theories would predict that solar systems are rare, since they are produced by unusual events. However, astronomers have now discovered over one hundred such systems. Moreover, the material pulled from the sun would be too hot to condense into planets. Therefore, this type of theories has now fallen out of favour by astronomers since the 1930s.

Strategy

Lesson One

- Using a physical activity to teach this difficult concept to an applied class. An activity, as well as a slightly more detailed description of the formation process, can be found in the CASCA website http://www.ioncmaste.ca/homepage/resources/web_resources/CSA_Astro9/files/html/module4/lessons/lesson3/solar_nebula.html

PART III: The Life of a Star (Expectations addressed: ES1.07, ES2.02, ES2.03, ES2.04, ES2.05, ES2.07)

By the end of this section, the students should be able to

- Describe the gaseous nature of a star and how it produces energy
- Explain the major difference between a star and a planet
- Understand that the Sun is an ordinary star and the Earth is one of the planets
- Understand why a star does not collapse under its own weight
- Describe, in very general terms, the evolution of a star like the sun

Background

- A star is a spherical ball of gas. It is made up of mostly hydrogen (75% by mass) and Helium (23% by mass), with a trace amount of elements heavier than helium (total of 2% by mass).
- The structure of a star is such that the pressure (and density and temperature) increases inward because of the weight of the overlying layers.
- The part of the star that we see (which we usually call the "surface" of a star, even though it is a misnomer) is called the *photosphere*. For the Sun, the photosphere appears to be yellow in colour because the Sun emits most of its energy in the yellow-green part of the light spectrum.
- The distinction between a star and a planet is that a star produces energy in its centre. Heat and light are then transferred to the surface where we see it glow. A planet is a spherical body that evolves around a star, and it does not produce enough energy to glow. We see planets in the Solar System because they reflect sunlight.
- Observations suggest that stars are born out of gas clouds (the solar nebula theory). The contraction of a cloud causes it to spin faster (all clouds has a small spin initially, the odds of anything having absolutely no rotation at all is tiny). The centre accumulates mass and becomes denser and hotter (a protostar). Eventually, it gets hot and dense enough to combine 4 hydrogen nuclei (which are protons) into a helium nucleus. This process is called *nuclear fusion*, and it releases a large amount of energy (like a hydrogen-bomb!). This energy makes its way to the surface and a star is born!
- It is important that the students understand that only the inner few % of the radius of a star is hot and dense enough to be involved in producing energy. The rest of the star does not engage in nuclear fusion.
- Since a star is mostly made of hydrogen, there is a lot of "fuel" to produce energy for a long time (for a star like the sun, this lasts about 10 billion years).
- Stars are massive (the sun's mass is 2×10^{30} kg, and it is a low-mass star), so why do they not collapse under their own weights? The answer to this question is that he tendency for a star to implode due to its mass is offset by the outward force (from the centre of the star to the surface) due to the pressure of the hot gas (kinetic theory of matter).
- All stars evolve. A star like the Sun will eventually use up the hydrogen fuel in the core and stops producing energy.

- In its final stages, the Sun will expand so much that its atmosphere will envelope the Earth. This expanded atmosphere will eventually escape the Sun into the space between the stars. What will be left of the Sun is the dense and hot core (the innermost part of the original Sun), called a White Dwarf.
- Rare, massive stars end their lives as neutron stars or black holes.

Strategy

This is another opportunity for co-investigation. There are several key questions: 1) How does a star produce heat and light? 2) Why do stars not collapse under their own weight? 3) How do stars change over time?

Lesson One

- Book a period at the library and/or computer lab. Split the class into three sections, each to tackle one of the questions above. Within each section, students should group into groups of no more than threes, so there may be three groups of threes investigating the same question.
- The groups should be able to find answers to their questions easily in the library. They have to make sure they understand enough to teach it to the rest of the class.
- Your role would be to circulate amongst the groups and listen to their conversations as they try to understand what they found. At the same time, you could learn from the same sources.
- In the last 20 min of the class, regroup so that each student has different partners who also investigated the same questions. Have the new groups discuss their findings and consolidate information.

Lesson Two

- During this period, you may randomly pick a couple of students from each section to teach the class what they have learned the previous class. Each presentation could be 20 min in length, leaving 15 min at the end for you to consolidate the learning.

PART IV : The Night Sky (expectations addressed: ES1.01, ES1.03 ES1.06, ES2.01, ES2.03, ES2.05, ES2.06, ES2.09)
By the end of this section, the students should be able to describe and explain the following

- The celestial objects visible in the sky
- The motions of the Sun, Moon, planets and stars throughout the course of a day

Background:

- Objects visible in the day sky include the Sun and the Moon
- Objects usually visible in the night sky, without technology, include the Moon, one or more of the five naked-eye planets (Mercury, Venus, Mars, Jupiter and Saturn), stars of various colours and brightnesses, and constellations. On dark site away from the city light, the Milky Way, the Orion nebula, and the nearest other galaxy (the Andromeda Galaxy) is also visible
- Occasionally, other objects or phenomena such as aurora, meteors, comets, eclipses could be visible
- The Sun, Moon, planets rise somewhere in the East and set somewhere in the West. Each object takes 24 hours from one rising to the next. This motion is due to the Earth's rotation around its own axis.
- Stars, in general, also rise in the East and set in the West in a 24-hour period. However, some stars are always above the horizon. These are called *circumpolar stars*. Which stars and constellations are circumpolar depends on the latitude you are observing from. For example, as viewed from Toronto, the stars in the constellation Ursa Major (the Big Dipper) never dips below the horizon. On the other hand, as viewed from Mexico City, the stars in the Ursa Major constellation will rise and set.

Strategy

Lesson One (Review)

- Use this as a review for the class. Have the students work in groups to brainstorm all the objects they think are visible in the sky (day and night)
- Make a list of vocabulary from this activity to be posted in the classroom for reference.
- Have students describe these objects in their journal. As the class learns more about each object, tell the students to go back to the journal to modify their descriptions as necessary. This will ensure the students monitor their own learning and learn how they learn.

Lesson Two (Expectations addressed: ES1.01, ES1.03, ES2.01, ES2.03, ES2.05, ES2.09)

- Use slides of the night sky to show students what they can see, and encourage them to make observations. (See also Appendix B for other options)
    - Show how to use a simple star chart (you may learn about it in http://www.utm.utoronto.ca/%7Eastro/grade9/node4.html)

- Show how to measure angles in the sky. Nelson Science 9 section 13.5 has a nice activity to teach this, and section 13.4 has an activity on Recognizing Constellations
- Some winter constellations are relatively easy to identify: Orion (the hunter), Canis Major (the Great Dog, the brightest star Sirius is in this constellation), Canis Minor (the Little Dog), Auriga (the Charioteer), Taurus (the Bull)
- In the spring, Orion and Canis Major are low in the sky, but Leo (the Lion) and Gemini (the Twin) are well placed for observation.
- Have students observe and sketch a few bright constellations such as Orion, Taurus, Auriga, Gemini, Canis Major and Canis Minor, or have them sketch the Moon and the bright planets
- The website (http://www.utm.utoronto.ca/%7Eastro/grade9/node4.html) has more information on observing the night sky and the sketching activity.

PART V: Astronomy and Us

The Effect of the Sun on Earth (Addresses Basic Concepts ES1.06 and many skills and communication expectations)
By the end of this section, the students should be able to

- Explain that the major source of heat on Earth comes from the Sun;
- Describe other influences the Sun has on the Earth (e.g., Solar wind and the auroras);
- Describe the greenhouse effect and list the greenhouse gases

Background

- The Sun affects the Earth in many different ways, both good and bad for the inhabitants on Earth. Heating is one of the most obvious. The website (http://library.thinkquest.org/15215/index_2.html?tqskip1=1) keeps a list of these (click on Man's Friend and Man's Foe on the website's left panel).
- The Sun radiates energy in the form of light (or electromagnetic radiation). Much of the Sun's energy is concentrated in the visible part (mostly in the yellow-green part) of the electromagnetic radiation.
- The Earth absorbs some of this radiation and its surface is warmed. It then re-emits the energy in the infrared (another form of the electromagnetic radiation). This balance determines the Earth's temperature.
- Water vapour, carbon dioxide and methane are gases in the Earth's atmosphere. These gases block the re-emitted infrared light from escaping back into space. Therefore, the Earth would be much colder without the atmosphere. These gases are called greenhouse gases, and the process of blocking infrared light is called the "greenhouse effect".
- Sunspots are cooler regions on the surface of the Sun. Their appearance is related to the magnetic activities on the Sun; therefore, the number of sunspots varies over a period of days. The change in position of any particular sunspot reflects the rotation of the Sun around its axis, once every 28 days.
- Another influence of the Sun on Earth is the solar wind. Solar wind refers to particles such as protons, which emanate from the Sun.
- When solar wind particles arrive at Earth, they are captured by the Earth's magnetic field and interact with the molecules in the upper atmosphere (e.g., nitrogen, oxygen) of the Earth. During the interactions, light is emitted. This is called Aurora Borealis, or commonly known as the Northern Light. (In the southern hemisphere, it is called Aurora Australis.)

Strategy

Lesson One (addresses expectations ES1.06, ES2.02, ES2.04, ES2.06, ES2.07, ES3.01)

- Students have probably heard about the greenhouse effect and its negative impact on Earth. It is important to point out that the greenhouse effect is a natural consequence of the atmosphere and is important for keeping the Earth warm. It is

only harmful if the greenhouse effect becomes out of control (e.g., human activities introduce too much greenhouse gases into the atmosphere).
- The greenhouse effect can be explained most easily by asking students to recall in a hot summer day, it is much warmer in an enclosed car than outside. This is because glass traps heat in the same way the greenhouse gases do. (If you have time, you might want to conduct an investigation to show this, see McGraw Hill SciencePower 9 Investigation 16-A).
- This is a good lesson for a debate on Global Warming. Divide the class into two halves. Have each half present one side of the argument: global warming is a natural trend or global warming is caused by human activities. Give the class one lesson to do their research and plan their strategy in the library or the computer lab and have the debate during the first half of the next lesson.

Lesson Two (Expectations addressed: ES1.01, ES1.06, ES2.01, ES2.03, ES2.05, ES2.06)
- Making observations of the sun using one of the following methods and have students sketch what they see.
  - View the surface of the sun on an internet site (http://umbra.nascom.nasa.gov/images/latest_mdi_igram.gif)
  - Have students collect daily images from the same internet site to describe the change (e.g., the number of sunspots, the positions of sunspots)
  - Ask students why they think the sunspots appear to move across the disk of the Sun. Ask students why the sunspots appear and disappear and the number changes. Have them devise hypotheses to explain these.
  - Have students estimate the rotation period of the Sun. The internet site (http://solar-center.stanford.edu/spin-sun/spin-sun.html) has an excellent activity which you could use without having to collect data for an extended period of time.
  - *Impress upon the students the importance of viewing the Sun safely in case they want to do some observations of the Sun.*

Lesson Three (Expectations addressed: ES1.06)
- Show students images of aurora from the "astronomy picture of the day" website (http://antwrp.gsfc.nasa.gov/apod/astropix.html) (do a search on "aurora"). You will also find the explanation for the different colours of the aurora.
- Have students keep a list of their favourite pictures from this website.
- Point out that the effect of the solar wind is more than just beautiful aurora. Heightened amount of solar wind particles may also cause power outages or damage to satellites and interrupts telecommunication on Earth. Make it a homework assignment for the students to find out when in North America history did this occurred.

Canadian Contribution to Astronomy and Space Science (Addresses Basic Concepts ES3.02, ES3.03, ES30.4 and many skills and communication expectations)
By the end of this section, the students should
- know that Canada has made important contributions in the fields of astronomy and space science;

- be able to describe some of these contributions;
- have an idea the possible careers they could have in these fields and the educational requirements.

Background

- Canada has always participated in national and international projects in astronomy and space science
- Some examples are:
  - The Dominion Astrophysical Observatory (DAO) in Victoria, B. C. and the Dominion Radio Astrophysical Observatory (DRAO) in Penticton, B. C. are two important national telescope facilities, where many astronomical studies are being carried out.
  - Internationally, Canada collaborates with other countries to build world-class facilities such as the James Clerk Maxwell Telescope (JCMT), the Canada-France-Hawaii-Telescope (CFHT), and the Gemini Telescopes. Many important scientific results came from these facilities.
  - In terms of space science, Canada's participation included the astronauts program; the development of the Canadarm, the International Space Station (ISS), the satellites RADARSAT and MOST. Canada also aims to be involved in the scientific mission to Mars in the near future (by the end of this decade).
  - For more information on this topic, see the webpage: http://www.ioncmaste.ca/homepage/resources/web_resources/CSA_Astro9/files/html/module7/lessons/lesson2/canadaSpaceScience.html
  - The David Dunlap Observatory (DDO) in Richmond Hill and the DAO in Victoria were once the second and third largest telescopes in the world!

Strategies:

Lesson One (addresses expectations ES2.04, ES2.05, ES3.01, ES3.02, ES3.03, ES3.04)

- This is an excellent unit for co-investigation. Book a period at the library or computer lab or both. Have the students work in groups of fours. Each group will identify an area they would like to research (see a list of possible topics on the website above.)
- Have the groups identified what jobs allow people to make these contributions and find out what education is required.
- Mention that there is a range of careers in astronomy. Some interesting examples are: Terence Dickinson, one of the world's foremost astronomy writers; Helen Sawyer Hogg, recently inducted into Canadian Science and Engineering Hall of Fame, was a researcher, teacher, and writer. (See www.cascaeducation.ca for more information.)

Lesson Two/Three (as above)

- Have the groups present their findings in this period. 10 minutes per group.
- Alternatively, this could be a poster project, though you may need an extra day for the groups to make the posters. Have the posters session on the third day. To

ensure accountability, each student will have to write a short journal entry to report what they have learned from the other groups after the poster session.

Appendix A: Ministry Expectations
Grade 9 Academic (SNC 1D)
Earth and Space Science: The Study of the Universe

Overall Expectations:

ESV.01: demonstrate an understanding of how scientific evidence and technological advances support the development of theories about the formation, evolution, structure, and nature of our solar system and the universe

ESV.02: investigate and predict the appearance and motion of visible celestial objects

ESV.03: evaluate how human endeavours and interest in space have contributed to our understanding of outer space, the Earth, and living things, and describe Canadian contributions to space exploration

Understanding Basic Concepts:

ES1.01: describe and compare the major components of the universe, using appropriate scientific terminology and units (e.g., record the location and movement of planets and satellites, and of stars, galaxies, and clusters of galaxies, using Astronomical Units and light years)

ES1.02: describe the generally accepted theory of the origin and evolution of the universe (i.e., the "big bang" theory) and the observational evidence that supports it

ES1.03: describe and compare the general properties and motions of the components of the solar system (e.g., the composition and the physical properties – such as size and state, rotation, size and period of orbit – of the Sun, planets, moons, asteroids, comets)

ES1.04: describe and explain the effects of the space environment on organisms and materials (e.g., the effects of microgravity on organisms in a spacecraft)

ES1.05: outline the generally accepted theory of the formation of the solar system (i.e., that it was formed from a contracting, spinning disc of dust and gas)

ES1.06: describe the Sun and its effects on the Earth and its atmosphere (e.g., explain the importance of the Sun as an energy source and the types of radiation emitted; describe the aurora borealis)

ES1.07: outline models and theories for describing the nature of the Sun and stars and their origin, evolution, and fate

Developing Skills of Inquiry and Communication:

ES2.01: through investigations and applications of basic concepts formulate scientific questions about the motion of visible celestial objects

ES2.02: through investigations and applications of basic concepts plan ways to model and/or simulate an answer to the questions chosen (e.g., determine, using scale models, and describe, using appropriate astronomical units, how astronomers are able to understand and compare the sizes and distances of objects in the solar system, and in the universe beyond)

ES2.03: through investigations and applications of basic concepts demonstrate the skills required to plan and conduct an inquiry into the motion and characteristics of visible celestial objects, using instruments, tools, and apparatus safely, accurately, and effectively

ES2.04: through investigations and applications of basic concepts select and integrate information from various sources, including electronic and print resources, community resources, and personally collected data, to answer the questions chosen (e.g., analyse and predict the time required for a spacecraft to travel to the Moon, or to another planet or moon in the solar system, and investigate the factors which limit the feasibility of the voyage – such as fuel, costs, time, comfort, safety, speed of travel, and human requirements)

ES2.05: through investigations and applications of basic concepts gather, organize, and record information using a format that is appropriate to the investigation (e.g., maintain a log of observations of changes in the night sky; prepare a comparative data table on various stars)

ES2.06: through investigations and applications of basic concepts analyse qualitative and quantitative data, and explain how evidence gathered supports or refutes an initial hypothesis (e.g., determine the actual size of a celestial object from its distance and its apparent size)

ES2.07: through investigations and applications of basic concepts communicate scientific ideas, procedures, results, and conclusions using appropriate SI units, language, and formats

ES2.08: calculate and compare the sizes of, and the distances to, objects in the solar system and in the universe beyond, using appropriate SI units

ES2.09: predict the qualitative and quantitative characteristics of visible celestial objects (e.g., determine the temperature of a star by observing its colour; predict the next appearance of a comet from the time of its last appearance and the period of its orbit)

Relating Science to Technology, Society, and the Environment:

ES3.01: describe, evaluate, and communicate the impact of research and other accomplishments in space technology on our understanding of scientific theories and principles and on other fields of endeavour (e.g., advances in fluid physics, crystal growth, and material science, and in technologies associated with robotics, agriculture, and telecommunications)

ES3.02: investigate the ways in which Canada participates in space research and international space programs (e.g., the International Space Station, telecommunications, satellite technology)

ES3.03: describe and explain how data provided by ground-based astronomy, satellite-based astronomy, and satellite exploration of the Sun, planets, moons, and other solar system objects contribute to our knowledge of the solar system

ES3.04: explore science and technology careers that are related to the exploration of space, and identify their educational requirements

Appendix B

For Observing the Night Sky:

- Universities hold public observation nights (e.g., at York University http://aries.phys.yorku.ca/~delaney/public.html and at University of Toronto http://www.astro.utoronto.ca/lectures.html)
- The Ontario Science Centre has a planetarium and presenter, who can show the students the motions of celestial objects.
- Play movies made with the software, Starry Night, to show the daily and yearly motions of celestial objects in the sky.
- The Royal Ontario Museum Mobile planetarium.
- Sky information may be obtained from www.astronomy-watch.com/home.htm

Other Astronomy Resources:

- The Royal Astronomical Society of Canada (RASC) is the largest organization of amateur astronomers in Canada. A local member may be interested in giving your class a presentation. www.rasc.ca
- Terry Dickenson writes a weekly column in the Toronto Star every Sunday.
- See list at http://www.astro.princeton.edu/%7Eclark/teachersguide.html
- See list at http://www.cascaeducation.ca/files/planet_scicenter_obs.html