# Celebrating International Year of Astronomy 2009 in your Classroom

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**Abstract.** In this presentation, I describe International Year of Astronomy (IYA) 2009 globally, and in Canada, and the resources that are being developed for educators. I suggest how these can be used to engage and inspire Ontario students. Specific connections to the revised secondary school science curriculum – especially the Grade Nine Astronomy/Space Units – are given. The emphasis is on Galileo's revolutionary contributions to astronomy and physics (including optics), and to the development of the scientific method and to scientific communication, as promoted by the curriculum.

## 1. International Year of Astronomy

International Year of Astronomy (IYA) 2009 is a world-wide (129 countries and counting), year-long celebration of the 400th anniversary of Galileo's development and first use of the astronomical telescope – developments that revolutionized our exploration and understanding of the universe, and our place in it. IYA is organized by the International Astronomical Union, and supported by UNESCO and endorsed by the UN General Assembly. One of the dozen global "cornerstone projects" is the *Galileo Teacher Training Program* – you are now part of it! The global IYA website is:

http://www.astronomy2009.org

It's interesting to reflect on some of the global objectives and projects. Unlike the school science curriculum, they tend to emphasize some of the "deeper" facets of astronomy: Illustrating the remarkable cultural influence of astronomy over time, and its connections with culture today; demonstrating the inspirational nature of astronomy, especially for young people; reminding humanity that we are responsible for the long-term future of our planet; showing astronomers as a global family of peaceful, international collaborators; encouraging scientific and critical thinking in society. Most of these considerations do not appear in the curriculum – but should be touched upon in teaching and learning.

How does this presentation relate to the STSE theme of this STAO 2008 conference? Galileo's *science* revolutionized our understanding of the universe. His telescope has been the enabling *technology* by which we achieve most of that understanding. His results profoundly impacted *society* – religion, culture, and philosophy. Some of the IYA global cornerstone projects relate directly to celebrating and preserving the *environment*, and our planet.

## 2. International Year of Astronomy in Canada

IYA is led, in Canada, by a broad-based IYA Canada Committee, with enthusiastic, experienced representatives of professional and amateur astronomy, education, government and academia, business and the media, and Canada's Aboriginal communities. I am a member of that committee. Our vision is "to offer an engaging astronomical experience to every Canadian, and to cultivate partnerships that sustain public interest in astronomy". One such partnership is with Canada's school science teachers, and with the Science Teachers Association of Ontario (STAO). One way of expressing our vision is in terms of offering "Galileo moments". This could be your students' first look through a telescope, their inspiration by an astronomical image or work of art or piece of music, or their wonder in contemplating planetary exploration, black holes, extraterrestrial life, or the birth of the universe. Our bilingual website is:

http://www.astronomy2009.ca

## 3. Who Was Galileo?

Galileo Galilei (1564-1642) was born 15 February 1564, in Pisa, Italy. His father Vincenzo was a lutenist and composer who made significant contributions to understanding the physics of vibrating strings, specifically the relationship between their length, tension, and pitch. Galileo first studied medicine, but transferred to math. He was a math professor at Pisa, then at Padua. In later life, he was a scientist and philosopher to the court of the Medici family. Perhaps due to his father's influence and example, his approach to nature became an observational and experimental one. He is considered the *founder of modern observational astronomy*, and is one of the greatest scientists of all time. A good summary of Galileo's life and work can be found in *Wikipedia*; a comprehensive website about Galileo and his work can be found at:

http://galileo.rice.edu

Though a devout Catholic, Galileo fathered three children out of wedlock; one is the subject of Dava Sobel's award-winning book *Galileo's Daughter*.

*Project: Compare the life of a present-day astronomer with that of Galileo.*

*Project: Find out about the Galileo spacecraft that explored Jupiter and its moons, and that was named after Galileo.*

## 4. Galileo's Telescope: A Revolution in Technology

There's a misconception that a telescope's power is in its magnification. Actually, a telescope provides two more important powers: (i) *light-gathering power* – the power to capture much more light (or other radiation) and to therefore see much fainter objects, and (ii) *resolving power* – the ability to see detail which the unaided eye cannot see. The things that Galileo saw and studied through his telescope are bright enough to be seen with the unaided eye, but the resolving power of the eye is not sufficient to see them. Why not? By the way: an excellent practical example of resolving power is the eye chart in opticians' offices. Download one from the Internet, and use it to investigate the concept of resolving power.

Your students can assemble a simple telescope, and learn about optics, and use it, and learn about astronomy. One global IYA project is to develop the *GalileoScope* – an inexpensive but effective replica of Galileo's telescope. Inexpensive classroom telescope kits are also available from Learning Technologies Inc. (www.starlab.com).

Galileo's telescope used a lens to gather and focus light. Isaac Newton discovered that a concave mirror could be used for the same purpose. But the principles are the same. Nowadays, astronomers use mirror telescopes almost exclusively.

*Project: Research important Canadian telescopes, past and present. Why are most Canadian telescopes now located outside of Canada?*

## 5. Galileo's Discoveries: A Revolution in Science

Galileo's discoveries were part of a golden age of astronomy. Along with Nicolaus Copernicus (1473-1543), Tycho Brahe (1546-1601), Johannes Kepler (1571-1630), and Isaac Newton (1643-1727), he revolutionized scientific method and understanding. And his discoveries are not esoteric. Students with a simple telescope can rediscover them, then model them. The connections between these simple observations, and our model of the universe, fit perfectly with the expectations of the school science curriculum (see Section 11).

### 5.1. The Moons of Jupiter

According to Aristotle, and the geocentric model of the solar system, all objects revolve around the earth. Galileo discovered four moons of Jupiter (now called the Galilean moons) that clearly revolved around that planet, on timescales of days and weeks. They were *satellites* of Jupiter. This was fundamental evidence against a basic assumption of Aristotle's model. It also addressed the question: if the earth is one of six planets orbiting the sun, why would it be the only one with a satellite?

Newton's Law of Universal Gravitation, and his laws of motion, explain the observed motions, and enable astronomers to "weigh" Jupiter. They also enable astronomers to discover and weigh "invisible" objects such as black holes and planets around other stars, by observing those objects' effect on the motion of other objects that move in their vicinity.

*Project: Research the nature of each of the four Galilean satellites of Jupiter. In what ways are they similar? Different? Why do you think they are different?*

*Question: Could the Galilean satellites be considered "a miniature solar system"? Why or why not?*

### 5.2. The Phases of Venus

The phases of Venus are due to the relative position of the sun, earth, and Venus, just as the phases of the moon are due to the relative positions of the sun, earth, and moon (grade six astronomy). The sun is a source of light. Venus, and the moon are spheres that shine by reflected light only. Galileo observed phases of

Venus that were inconsistent with the geocentric model of the solar system, but consistent with the heliocentric model.

*Activity: model the phases of Venus by using a light bulb for the sun, and a Styrofoam ball for Venus, and noting the illuminated appearance of the Styrofoam ball as it moves around the light bulb. Write a short report on how to make this demonstration as effective as possible.*

### 5.3. The Mountains on the Moon

Even to the unaided eye, the moon can be seen to have "features", that make up such patterns as "the man in the moon". But look at the moon with a *GalileoScope* or binoculars, and you will see many more features such as craters and mountains. For an interesting activity on how craters are formed, see:

http://mars.jpl.nasa.gov/classroom/pdfs/creatingcraters.pdf

*Activity: How could Galileo (and you) tell that there were mountains and valleys on the moon, not just bright and dark regions on a perfectly flat surface?*

### 5.4. The Spots on the Sun

Galileo didn't "discover" sunspots; they had been observed before by scientists in both Europe and Asia, but his telescope enabled them to be studied in detail, and his systematic observations showed that the sun was not an unchanging, perfect body, as Aristotle's philosophy implied. Sunspots appear. They come and go. Their apparent motion shows that the sun is rotating on an axis.

*Activity: Project an image of the sun on a white sheet of cardboard or paper, using a small telescope or binoculars. Do this every day or two, and record the changes that you see from day to day. Instructions can be found here:*

http://www.astrosociety.org/education/publications/tnl/05/stars2.html

**Safety Warning:** Do not look directly at the sun, especially with a telescope, unless you are absolutely sure that you have adequate eye protection.

You can supplement your observations of the sun with images from the Internet; you can find current images of the sun here:

http://umbra.nascom.nasa.gov/images/latest_mdi_igram.gif

*Project: On the Internet, find data on "sunspot numbers" – the number of sunspots visible in different years during the last century or two. Either graph the data, or locate graphs of these sunspot numbers. Describe the relation between sunspot number, and time.*

### 5.5. The Milky Way of Stars

Galileo observed, with his telescope, that the Milky Way – a hazy, nebulous band across the sky – was actually made up of vast numbers of faint stars, too faint to be seen individually with the unaided eye. The Milky Way is beautiful to behold – if you can see it from your light-polluted skies.

In any astronomy course/unit, students should look at awesome images – not just Hubble images of things that their eyes could never see, but phenomena like the Milky Way that they could, in principle, see from the schoolyard at night. A good source of images is (look at #351, for instance):

http://www.skynewsmagazine.com/pages/pow_archive.html

*Question: If the earth revolves around the sun, why don't the nearer stars appear to move, relative to the more distant stars – an effect called parallax?*

### 5.6. The "Ears" of Saturn

The low resolution of Galileo's telescope prevented him from seeing that Saturn had rings. They looked like "ears" to him. Furthermore, the ears disappeared! This was because the rings are thin; as their orientation changed, they were seen almost edge-on, and were no longer visible. We now know that the rings consist of an infinity of small chunks of icy material, orbiting in a flat plane above the planet's equator.

*Activity: Your students can duplicate this phenomenon with a "grapefruit" model of Saturn; see:*

http://www.astrosociety.org/education/publications/tnl/40/saturn.html

Galileo actually recorded the planet Neptune in one of his sketches, but did not observe it long enough to realize that it was moving, and therefore not a star but a planet!

## 6. Duplicating Galileo's Observations

Students can learn to plan an observing session, using on-line sources, or software such as *Starry Night*, or sky charts from a book or magazine. A good source of star charts, with information about what's visible, is:

http://www.skymaps.com

**Safety Warning:** Be sure to do your sky observing from a safe, secure location, preferably in the company of your family or friends, or with a visiting astronomer.

*Project: Use published star charts, or a planisphere, or computer software such as Starry Night, to determine when you could observe the moon, Venus, Jupiter, Saturn, or the Milky Way tonight.*

## 7. Galileo and Physics

It's not widely known that Galileo laid the groundwork for Newton's three laws of motion. This understanding was necessary; according to Aristotle's model, everything on earth would fly off into space if the earth was rotating, and revolving around the sun. Galileo showed that, under uniform acceleration, the trajectory of a moving object would be a parabola – a result with obvious military applications.

One of his supposed experiments was to show that two objects, dropped from the same height, hit the ground at the same time, irrespective of their masses or densities. It's said that he did this from the top of the Leaning Tower of Pisa, but that's not certain, nor is it clear whether the experiment was done at all.

*Activity: Plan a re-creation of this famous experiment. Identify possible sources of error, and suggest ways to reduce them. Ask the audience to predict the results of the experiment.*

Galileo is also credited with another famous experiment, in 1638, to measure the speed of light. This is described, in creative fashion, by Toronto story-tellers and educators Lorne Brown and Mindy Kalchman, at:

http://www.astrosociety.org/education/publications/tnl/42/42.html

*Activity: Devise an experiment to measure the speed of sound by the same method. How can you identify and reduce the experimental errors?*

In this experiment, you will encounter the concept of *reaction time*. It's said that astronomers were the first to measure reaction time [they measured time by noting exactly when stars crossed the north-south line in their telescope, so they had to account for reaction time]; in this sense, they were the founders of experimental psychology!

Galileo also made contributions to other areas of science (such as sound and vibration) and technology (such as the compass) and to mathematics. Perhaps his greatest contribution to math was to show that it could be used to *describe* phenomena in nature. A few of his interpretations (such as of tides) turned out to be incorrect, but "nothing ventured, nothing gained".

## 8. Galileo's Record-Keeping and Communication

Record-keeping and communication are two important scientific skills that are part of the curriculum, and that students should learn. You can access some of Galileo's sketches and notebooks on-line – his drawings of the moon, and the satellites of Jupiter, and the stars of the Milky Way, for instance. The galileo.rice.edu website, mentioned earlier, is an excellent resource. How were these records an important part of Galileo's scientific work?

How were his results published or disseminated? His short book *Sidereus Nuncius* (Starry Message, or Messenger) was a presentation of his observations and interpretations, exemplary in its clarity, and a model for lab reports. His longer book *Dialogue Concerning the Two Chief World Systems* was a unique and creative approach to science communication. How are scientific results published and disseminated today, to different audiences? Obviously in much different ways than in Galileo's time.

*Activity: Inspect copies of Galileo's original sketches of the moons of Jupiter, and of the surface features on the moon. Comment on whether they were an effective way to record and communicate the observations.*

## 9. The Implications: A Revolution in Religion and Philosophy

Galileo is most widely known to the public because of his conflict with the Catholic Church. He was forced to recant his heliocentric views, and lived out his last few years under house arrest. He was not formally vindicated by the Catholic Church until 1992, though it should be pointed out that the Vatican has, for many years, operated a modern astronomical research observatory, whose staff members are simultaneously PhD astronomers and Jesuit priests.

Actually, his conflict was equally with other philosophers of the time. Aristotle, in Classical Greek times, had proposed a model that the universe was made of five elements – earth, water, air, and fire (in order outward), and a fifth "quintessence" which made up the heavens, and which was perfect and unchanging. You and your students should understand how Galileo's observations did not support this model, but instead supported a model in which the sun was at the centre of the then-known universe. And, according to Galileo's observations, the objects in the heavens were certainly not perfect and unchanging!

*Question: Does the fact that Galileo's results showed that Aristotle was wrong mean that people were smarter in Galileo's time than in Aristotle's time?*

Fittingly, 2009 marks the 200th anniversary of the birth of Charles Darwin, and the 150th anniversary of the publication of his book *On the Origin of Species*. Darwin, too, was in conflict with the church, and fundamentalist churches still do not accept that life on earth (and the universe itself) has evolved over billions of years. But we should emphasize that most mainstream religions find no conflict between science and religion.

*Project: What is philosophy, and how is it different from science? Write an article, or give a presentation on the philosophical importance of Galileo's work.*

## 10. Subsequent Developments

Of course, things didn't stop with Galileo. Within a year of Galileo's death, Isaac Newton was born. He is arguably even more important than Galileo. He developed the reflecting (mirror) telescope that astronomers use today. He showed that white light could be broken up into a rainbow of colours – a spectrum. Spectroscopy, along with imaging, is the primary methodology of observational astronomy. He co-developed calculus, extended Galileo's studies of motion, and formulated his three Laws of Motion. He hypothesized that there was a universal force of gravity; he expressed it as a formula, and used it to explain, successfully, all celestial motion. Newton's Laws of Motion, and of Gravity, are still sufficient, in most cases, to explain the structure and motions of stars, galaxies, and the universe. He wrote this up in his book, colloquially known as *Principia*, one of the most important science books of all time.

William Herschel built ever-bigger telescopes, and used them to study stars, star clusters, and nebulae. Harlow Shapley showed that we live on the outskirts of a galaxy of hundreds of billions of stars – the Milky Way. Edwin Hubble showed that there were other galaxies than our own (now known to be tens of billions), and the universe of galaxies was expanding. Finally, there was Albert Einstein, arguably the greatest scientist of all time; his General Theory of Relativity explained that matter *and* space were together expanding from their birth, now known to have occurred 13.7 billion years ago.

## 11. Curriculum Links

In many ways, Galileo developed what we now call *scientific investigation skills*, as listed in the introduction to the SNC1D/P courses (revised for 2009). He advanced the concept of testing theories through experiments or observations. He recognized the existence and significance of experimental error. So his impact on science is very broad. Ideally, students can follow in Galileo's footsteps as they *investigate the characteristics and properties of a variety of celestial objects*, either with a *GalileoScope*, or with an amateur astronomer's telescope at a star party at the school or in a public location, or even on the Internet.

In the sections above, we have emphasized the processes of performing and recording, analyzing and interpreting, and communicating the results of scientific investigations. We touch on almost every expectation of the curriculum, for both the Academic and Applied courses.

The primary curriculum links are with the Grade Nine Science Course, both Academic (SNC1D) and Applied (SNC1P), in the Earth and Space Systems units. Galileo's revolution relates, in a fundamental way, to the central "big idea" in SNC1D: *people use observational evidence of the properties of the solar system and the universe to develop theories to explain their formation and evolution.* And the telescope is the tool by which astronomers determine most of the properties of celestial objects. There are strong links to the Grade Ten Science Courses (SNC2D and SNC2P), in the Optics unit; in fact, the majority of expectations, in that unit, can be related to either Galileo's lens telescope, or Newton's mirror telescope. There are also obvious links to the Grade Twelve Earth and Space Science Course (SES4U), and even to the Grade Six Science Course, astronomy/space unit. In fact, astronomy is so interdisciplinary that there are many other possible links, to Physics, Mathematics, Philosophy, and even the arts.

Applied units are often problematic. The telescope, and its connections to technology, to the direct observation of the sky, and to the kinds of observations that can be made, would be especially suitable for the applied courses. In the language of SNC1P-D2.4: the telescope overcame a technological challenge – the faint, fuzzy image provided by the unaided eye. I like to think that the activities that amateur astronomers carry out, with a high degree of skill and excellence, and with modest but modern technology, are a good model for students in these applied courses.

*Activity: Find out what amateur astronomers are, and what they do. Discuss whether they "do science".*

An excellent general resource for astronomy teaching in Canada is:

http://www.cascaeducation.ca

## 12. Celebrating IYA in your Classroom

In addition to the suggestions above, which connect IYA to the curriculum, we encourage you to come up with creative, interdisciplinary ways to incorporate IYA into both the science program at your school, to school life in general, and to your community. Here are some suggestions; I am sure you can think of more:

- Encourage your school orchestra to play a movement from Holst's *The Planets*, or Williams's score for *Star Wars*, or encourage your drama club to perform Brecht's *Galileo*.
- For MultiCultural Day in your school, learn and communicate something about astronomy in many cultures, including Canadian Aboriginal culture, and how indigenous peoples used astronomy to navigate, and keep track of the seasons for agriculture, hunting, and ceremony.
- Investigate sky stories, including constellation stories, from many cultures.
- Create a mural, illustrating the many facets of astronomy, or a display of astronomical images or art.
- Organize an Astronomy Day program for the public, or for the students in the school.
- Invite an astronomer to your school, and/or have an evening "star party".
- Encourage the Environment Club to take up the issue of "light pollution".