Science at Work

As a leading Canadian astrophysicist, Roberto Abraham is helping to unlock mysteries about how the universe was formed.

Canadians in Science

Roberto Abraham first began to explore astronomy at the age of 12 with a small backyard telescope. Today, Roberto is an astrophysicist and professor based at the University of Toronto. He has access to modern telescopes in places such as Hawaii and Chile, and he is a world leader in astronomy. Roberto is making important contributions to science through his research. For example, he worked on an international study of distant regions of the universe. This study helped advance theories about how galaxies formed and evolved. Here are some of Roberto's thoughts about Canada's participation in space research.

In Roberto Abraham's Words

Canada has emerged as a leader in astronomy and space research and will continue to stay at the forefront. The Canadian Space Agency is one of the main partners developing the James Webb Space Telescope. It is a next-generation successor to the Hubble telescope and will be launched in 2013. From its position about 1.5 million kilometres from Earth, the Webb telescope will significantly expand what we can see in the universe.

Telescopes are as close as we can get to a time machine. It is endlessly fascinating to me to explore our past through images that have taken billions of years to reach Earth. Everything in our vast and complex universe developed from the simplest of elements: hydrogen and helium. There is so much to learn about the processes that brought us from there to here, and that will carry us into the future.

This is the golden age of astronomy and cosmology. Improved technology is helping us to peer deeper into space, to go back in time farther than ever in the quest to solve mysteries about how the universe developed. The more we explore, the more we must revise our notions about the universe and how it formed. And with every discovery we are reminded that there is much more to discover. For students interested in careers in astronomy and cosmology, this is an exciting time to get involved.

Roberto Abraham and a colleague are shown here at the Mont-Mégantic Observatory in Québec. This observatory is the largest of its kind in eastern North America.

Space Science at Work

The study of space science contributes to these careers, as well as many more!

Display Designer

Display designers at planetariums, science centres, and museums create exhibits that explain the universe in non-technical terms. These exhibits often include a variety of techniques to engage viewers, such as three-dimensional models, graphics, scale models, photographs, games, and videos. Designers usually have technical skills and a degree or diploma in art and graphic design.

Project Manager

Project managers in the Canadian Space Program coordinate the work of individuals and teams on projects related to space technology and innovation, including space missions. Project managers organize schedules, monitor work performance, and manage costs. They also oversee processes to analyze and solve any problems that arise. They usually have technical expertise in a related field such as civil, computer, or mechanical engineering.

Aerospace Engineer

Aerospace engineers contribute to the design, construction, testing, and operation of spacecraft. They specialize in areas such as aerodynamics and propulsion. Aerospace engineers often work in teams to develop highly complex spacecraft for space exploration.

Go to **scienceontario** to find out more

Over To You

1. Why does Roberto Abraham say that telescopes are as close as we can get to a time machine?
2. Roberto Abraham says that Canada has emerged as a leader in the study of space. Conduct research to find one example of a recent discovery in space science by Canadian scientists, and explain why you think this discovery is important.
3. Imagine that you are a reporter for a popular television science show for children. What questions would you ask Roberto Abraham if you were interviewing him for the show?
4. Choose a space-science career that interests you. If you wish, you may choose a career from the list above. Research the career, including how you would prepare for it. **What essential skills would you need for this career?**

Work Learning Life

Unit 3 Projects

Inquiry Investigation

Simulating a Cosmic Event

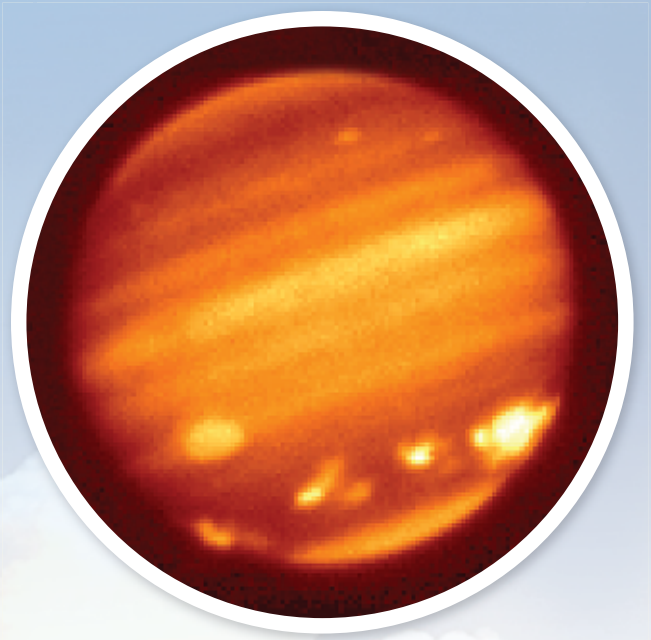
In July 1994, astronomers from all over the world watched in awe as Comet Shoemaker-Levy 9 (SL9) slammed into the southern hemisphere of Jupiter. Comet SL9 had originally orbited the Sun. It came close enough to Jupiter, however, to be captured by Jupiter's gravitational pull and it had begun to orbit Jupiter instead. The collision allowed scientists to make observations about Jupiter, especially about the chemical composition of its atmosphere. Many of these observations had never been possible before.

Inquiry Question

How could you simulate a cosmic event?

Initiate and Plan

1. Make a list of cosmic events that could take place in the outer solar system or in other galaxies.
2. Select and research one cosmic event in your list. Have your teacher approve your choice.
3. Make a hypothesis about what the "Before," "During," "Soon After," and "Long After" observations of this cosmic event might be from Earth and/or space.
4. With your teacher's approval, select the materials you will use to create a simulation of this cosmic event.



Perform and Record

5. Create your simulation in the form of an electronic slideshow, storyboard, poster, dramatic skit, video performance, physical model, or graphic novel.
6. Label or identify the components of your simulation clearly.

Analyze and Interpret

1. Analyze your predicted observations. Use the following guiding question to support your analysis: How might the cosmic event you simulated affect the outer solar system, the night sky, or the solar system near Earth?
2. Evaluate the design of your simulation. Use the following questions to guide your evaluation: Does your design represent the event as it would likely occur? How would you improve your design if you could?

Communicate Your Findings

3. Present your simulation to the class. Include all your observations and analyses.

Assessment Criteria

Once you complete your project, ask yourself these questions. Did you...

- K/U develop an accurate list of cosmic events?
- T/I state a hypothesis related to possible observations of a cosmic event clearly and accurately?
- T/I select an appropriate design and appropriate materials to simulate the cosmic event?
- T/I present a reasonable analysis of the possible observations related to the cosmic event based on reliable research sources?
- T/I include in your analysis a description of how accurately the simulation reflects real cosmic events and possible improvement to the design?
- C organize the information presented in a clear and logical manner?
- C select a format appropriate for your purpose and audience?

An Issue to Analyze

Canadian Space Missions: To Go or Not to Go?

The mandate of the Canadian Space Agency is

To promote the peaceful use and development of space, to advance the knowledge of space through science, and to ensure that space science and technology provide social and economic benefits for Canadians.

Suppose that you work for the Canadian federal government. Your job is to ensure that taxpayers' funds are used as effectively and responsibly as possible for space research.

Issue

Should taxpayers' funds be used for space research and exploration?

Initiate and Plan

1. Research and select three space missions in which Canadians have been involved. For example, Canadian astronaut Dave Williams made a record three space walks during the *Endeavour* space mission in August 2007.

Perform and Record

2. List some hazards, benefits, and costs of each mission, using a risk-benefit-cost analysis chart. Include the following perspectives in your chart: economic, political, scientific, technological, and environmental.

Analyze and Interpret

1. Evaluate each mission based on the following criteria:
   - Did the benefits of the mission outweigh the risks and costs (economic perspective)?
   - Have the mission and the spinoffs from the mission been peaceful (political perspective)?
   - Did the mission help advance knowledge of space and space science (scientific perspective)?
   - Have Canadians benefited from the results of the mission? (technological perspective)
   - Did the mission harm Earth's atmosphere or environment in any way? (environmental perspective)
2. Based on your findings and analysis, decide whether Canada should continue to contribute to space research and technology. Provide supporting evidence from the varying perspectives to support your position on this issue.

Communicate Your Findings

3. Write and deliver a speech to explain your position and recommend a future course of action. Consider your intended audience, for example, members of Parliament.

Assessment Criteria

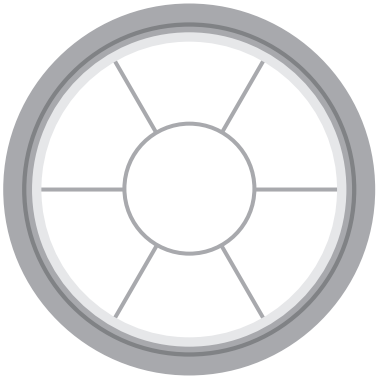
Once you complete your project, ask yourself these questions. Did you...

- A describe the risks, costs, and benefits of each of the three space missions thoroughly from varying perspectives?
- A support your position on the issue of space exploration and space technology with evidence from varying perspectives?
- C use an appropriate graphic organizer to summarize and clarify connections from a variety of perspectives in support of your position?

Unit 3 Review

Connect to the BIG IDEAS

Use this bicycle wheel graphic organizer to connect what you have learned in this unit to the Big Ideas, found on page 265. Draw one bicycle wheel for each Big Idea and write the Big Idea in the centre. Between the spokes of the wheel, briefly describe six examples of that Big Idea.



Knowledge and Understanding K/U

For questions 1 through 5, select the best answer.

1. The model of the solar system that places the Sun at the centre is called the

a. geocentric model

b. solar nebula theory

c. heliocentric model

d. big bang model

2. Which instrument does an astronomer use to analyze the spectrum of a star?

a. a refracting telescope

b. a reflecting telescope

c. a radio telescope

d. a spectroscope

3. If a star is the same mass as the Sun, for how many years can it fuse hydrogen into helium?

a. 5 billion years

b. 10 billion years

c. 15 billion years

d. 20 billion years

4. Which type of galaxy is the largest?

a. elliptical

b. spiral

c. irregular

d. the Milky Way

5. Dark matter and dark energy, respectively, make up which percentages of the universe?

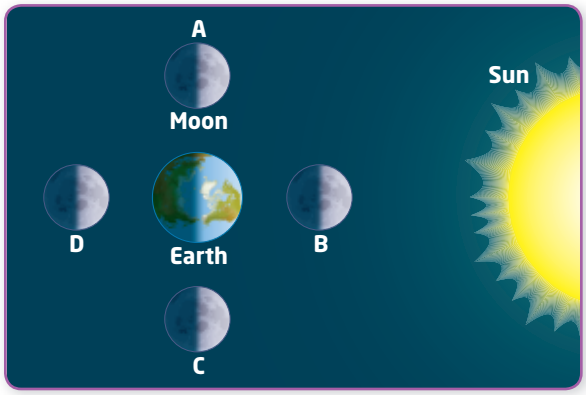
a. 73 percent and 23 percent

b. 23 percent and 73 percent

c. 10 percent and 86 percent

d. 86 percent and 10 percent

6. Use the diagram below to answer the questions that follow.



The Moon is shown in four different positions in its orbit.

a. In which position is the Moon at third quarter?

b. In which position is the Moon at first quarter?

c. For a lunar eclipse to occur, in which position in its orbit must the Moon be?

d. For a solar eclipse to occur, in which position in its orbit must the Moon be?

7. Astronomers have a model for how stars are born.

a. How do stars form? Include a diagram to support your answer.

b. What condition is required within a star to cause the fusion of hydrogen into helium?

8. Draw a concept map to summarize the model that represents how astronomers theorize stars and planetary systems form. Include the name of the model.

9. What are two advantages of using a radio telescope compared with using an optical telescope?

10. Using Internet or print resources, research the information you need to complete the final column in the table below.

Magnitude and Distance of Stars

Star	Apparent Magnitude	Absolute Magnitude	Distance from Earth (light-years)
Star A	−26	4.7	0.000 02
Sirius	−1.5	1.4	
Alpha Centauri	0.01	4.4	
Rigel	0.1	−7.0	
Betelgeuse	0.4	−5.0	
Capella	0.8	−0.8	

a. What is star A in the table?

b. Which star appears brightest in the nighttime sky to an observer on Earth?

c. Which star appears brightest from a distance of 32.6 light-years from Earth?

d. According to the table, are the stars that are closest to Earth always the brightest? Explain your answer.

11. Will the Sun become a black hole in 5 billion years? Explain your answer.

12. What property of a star has the greatest effect on the star's life cycle?

13. Summarize the life cycles of stars in a graphic organizer of your choice.

14. Describe observational and theoretical evidence related to the origin and evolution of the universe.

15. Dark matter and dark energy make up a significant portion of the universe.

a. Why are dark matter and dark energy so mysterious?

b. What are the effects of dark matter and dark energy?

Thinking and Investigation T/I

16. The astronomical unit is the average distance between Earth and the Sun. Why is this measurement not exact?

17. Mercury is heavily cratered, Mars has fewer craters on its surface, and Earth has very few craters. Account for these differences.

18. Why do you think an energy source other than solar energy is necessary to fuel spacecraft that explore the outer reaches of the solar system?

19. What observational clues do astronomers use to determine the spectral type of a star?

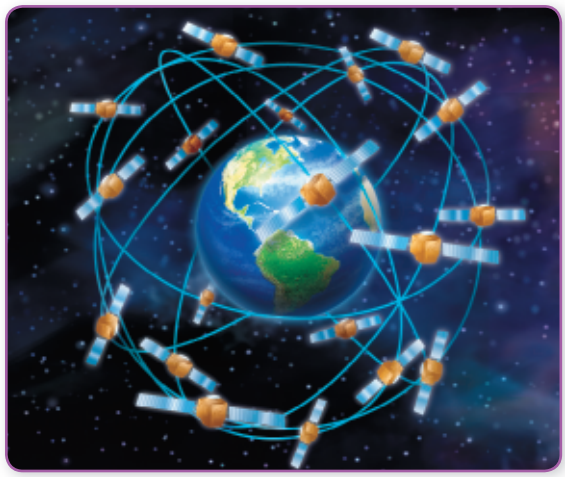
20. The Canadarm and the Canadarm2 cannot support their own weight on Earth, yet they move massive objects in space. Explain why.

21. The cosmic microwave background radiation is very cold, but it has arisen from an unimaginably hot event. Explain why.

22. The GPS system consists of a large fleet of satellites in Earth orbit, as shown in the diagram below.

a. Why are so many satellites needed?

b. There are 32 GPS satellites in orbit, but only 24 are in operation at any one time. Suggest a reason for this.



There are 32 GPS satellites orbiting Earth.

Unit 3 Review

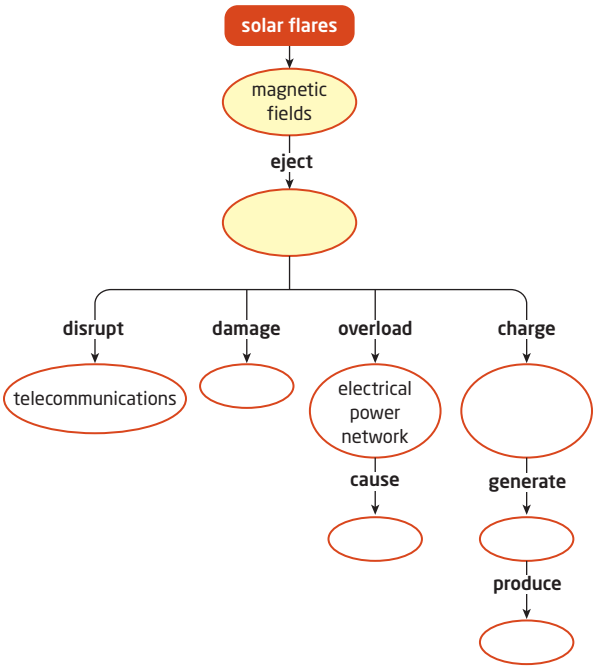
Communication C

23. Building and maintaining the International Space Station is incredibly expensive. Sending a crewed mission to Mars will be even more expensive. Suggest some arguments for and against these projects.

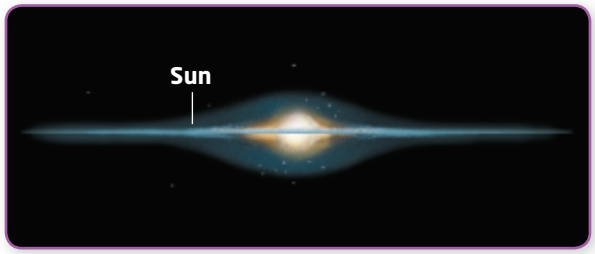
24. Using a diagram, illustrate and explain the Doppler effect.

25. Choose three planets that you would like a spacecraft to explore. Explain what you would have the spacecraft explore on these planets. Give reasons to support your answer.

26. Use the following terms to complete the cause-and-effect graphic organizer below: aurora borealis, electric currents, electronic equipment, electrical power network, gases in Earth's magnetic field, intense stream of charged particles.



27. Refer to the diagram of the Milky Way galaxy below. Explain the reasoning used by Harlow Shapley to determine that the Sun is located at a significant distance from the centre of the Milky Way galaxy.



28. Explain how the rate of expansion between two points is proportional to their distance. Use a diagram or an example of an expandable surface, such as a balloon or a rubber sheet, to illustrate your explanation. Then relate the rate of expansion between two points to Hubble's law.

Application A

29. Can other planets have seasons? Explain your answer.

30. Explain how the positions of the stars and the Sun can be used for navigation.

31. "Calendars are a prerequisite for civilization." Explain why this statement is true.

32. In your opinion, should the Government of Canada continue to spend money on developing and launching satellite technology? Explain your answer.

33. Assess some of the costs, hazards, and benefits of space exploration. Formulate an opinion, and present your opinion in a graphic organizer of your choice.

Literacy Test Prep

Read the selection below and answer the questions that follow it.

Helioseismology

If you tapped a bell and watched the surface of the bell closely, you might be able to see the surface vibrating very quickly. These vibrations cause the sound of the bell. Helioseismology is the study of the vibrations in the Sun. (*Seismo* means vibration, and *helio* means Sun.) Helioseismologists have learned that stars, including the Sun, "ring" like a bell. They study the interior of the Sun because this is where the sounds are produced.

In the interior of the Sun, the process of convection starts the sounds. Convection is a method of transferring energy through the movement of particles. Boiling water in a pot is an example of convection. The water molecules move up from the bottom of the pot to the surface of the water. In the Sun, the flow of energy starts in nuclear reactions in the core. The energy moves out from the core until it reaches the photosphere and escapes. The particles that transfer the energy in the Sun are gas particles. Solar convection produces huge bubbles on the photosphere. The noise from the convection is then trapped and filtered inside the Sun to produce the "ringing."

You cannot hear the ringing of the Sun for two reasons. First, the sound is too low for our ears to detect. Second, sound needs a medium in which to travel. Sound cannot travel through the vacuum of space. So how can helioseismologists detect the sound of the Sun? Vibrations inside the Sun cause parts of the outside of the Sun to move up and down. Astronomers use special cameras to watch this movement.

This image of the Sun shows the parts of the Sun that are vibrating. The blue parts are moving toward the observer, and the red parts are moving away from the observer. **Note:** These colours were added.

Multiple Choice

In your notebook, record the best or most correct answer.

34. Paragraph 1 does *not*

- **a.** introduce the term *helioseismology*
- **b.** state that the Sun makes a sound
- **c.** discuss earthquakes
- **d.** state what helioseismologists study

35. Helioseismology is the study of

- **a.** earthquakes on Earth
- **b.** vibrations in the Sun
- **c.** vibrations in a bell
- **d.** vibrations in Earth

36. Paragraph 2 relates to paragraph 1 because paragraph 2

- **a.** explains why you cannot hear the ringing of the Sun
- **b.** relates the ringing of the Sun to the ringing of a bell
- **c.** describes how helioseismologists know that the Sun produces sound
- **d.** provides a sequence of explanations that clarify the information in paragraph 1

37. The image of the Sun on the left depicts the Doppler effect of the up-and-down motions of the photosphere because

- **a.** blueshifted motion is shown in blue, and redshifted motion is shown in red
- **b.** redshifted motion is shown in blue, and blueshifted motion is shown in red
- **c.** blueshifted motion is shown in blue, and redshifted motion is shown in blue
- **d.** blueshifted motion is shown in red, and redshifted motion is shown in red

Written Answer

38. Summarize this selection. Include the main idea and one relevant point that supports it.