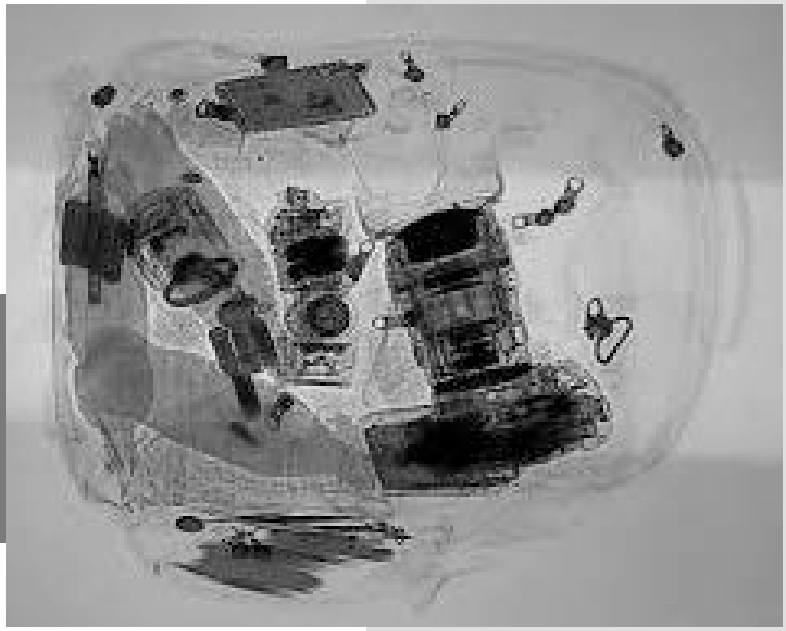
EarthDate

Making the Invisible Visible



Some baggage screening machines use X-ray technology to visualize items being carried into airports, museums, and other places where security is a top concern. This photo shows a scan of a backpack holding a camera, MP3 player, bottles, and more.

Credit: IDuke (CC BY)

In a previous *EarthDate*, we told you about the accidental discovery of X-rays in the late 1800s. Scientists around the world began to experiment with them. Thinking them no more harmful than visible light, they did so without protection… sometimes with disastrous results.

Early researchers would place the emitter in the center of the room, hold up their hands, and—using special lenses to examine their bones—looking directly into the beam.

One of Edison's scientists absorbed enough X-rays to develop severe skin cancer, which killed him.

Non-scientists around the world went to demonstrations and submitted themselves to high doses.

In the 1930's, shoe stores used X-rays to fit their customers' feet, a practice that endured, remarkably, till 1950.

By then, X-rays were more completely understood, both for their incredible potential and their potential danger.

Since then, their medical use has safely expanded to include sophisticated 3D imaging and highly targeted beams to destroy cancer cells.

Beyond airport scanners, X-rays are now used to examine concrete structures for defects, to authenticate rare paintings, and to study the atomic structure of mineral crystals.

NASA used similar technology on its rovers to analyze Martian soil and gathers X-ray data from space using orbiting telescopes.

Revealing the inner secrets of celestial bodies and our own, this accidental discovery continues to make the invisible visible.

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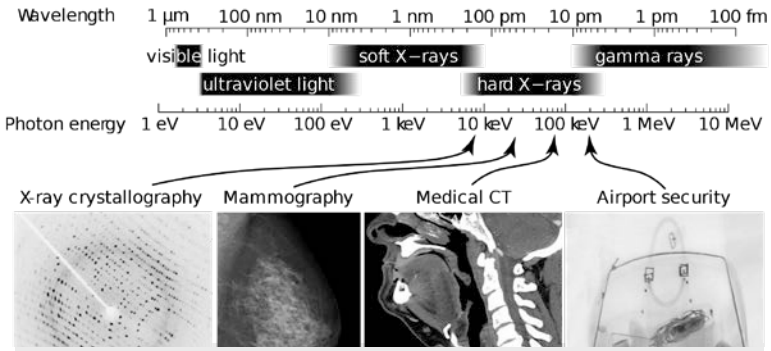
Background: Making the Invisible Visible

Synopsis: X-rays provided a way to view the invisible and became a novelty for people in the early 1900s. While their benefits were visible, their dangers were invisible to those who studied them. Sadly, many scientists learned about the debilitating effects of radiation exposure too late. Technology has since addressed these dangers and enabled beneficial uses from atomic-scale studies to space science research.

- X-rays are produced by accelerating an electron beam onto materials such as copper or gallium so that their own electrons get jostled out of equilibrium. The copper or gallium atoms emit X-rays as they return to their equilibrium state.
  - This radiation must be focused in order to produce a useful bright source of X-rays, so around 1947, scientists developed particle accelerators called *synchrotrons* to control and aim the stream of radiation.
- X-rays are part of the electromagnetic spectrum and are more energetic than radio waves and visible light. Since wavelength is inversely related to frequency, higher-energy radiation is characterized by higher frequencies but shorter wavelengths.
  - Technological advances have led to many different applications that use different parts of the X-ray spectrum.
  - "Soft" X-rays have higher frequencies just above visible and ultraviolet light, with wavelengths about 1000 times shorter than visible light.



X-rays are part of the electromagnetic spectrum. Their wavelengths are shorter than those of visible light.

Credit: Ulflund (CC BY-SA)

  - On the high-frequency end of their range, "hard" X-rays extend into the domain of gamma radiation, which is produced during nuclear reactions within atomic nuclei.
- The benefits of X-rays were exciting, but their harmful effects took a while for scientists to understand.
  - Originally, researchers believed X-rays to be as harmless as visible light, but the death of Thomas Edison's assistant Clarence Dally of skin cancer in 1904 raised awareness of radiation sickness.
  - Radiation from X-rays is energetic enough to strip the electrons from atoms within a cell—this can damage or destroy the cell. If the radiation is focused, it can be used to kill cancer cells, but it can also damage normal cells and cause cancer.
  - In the 1930's, American shoe stores began featuring X-ray fluoroscopes to be used for fitting shoes. This dangerous practice didn't provide any protection from radiation and was finally abolished in the 1950's.
- X-rays have many useful applications.
  - They have revolutionized medical diagnostic imaging—from still images like mammograms or dental X-rays to 3D volumes like CT scans, which use a rotating X-ray apparatus that encircles the body. Sometimes a denser contrasting fluid is injected into the body and used to investigate softer tissues in more detail, with a fluoroscope used to visualize fluid movement. MRIs and ultrasounds do not use X-rays.
  - Medical radiation therapy uses precisely targeted beams to destroy cancerous tumors.
  - Structural imaging uses X-rays to look for weaknesses in solid objects like concrete and metal welds.

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References: Making the Invisible Visible

Röntgen (Roentgen), Wilhelm Conrad | Encyclopedia.com
What Are X-Rays? | LiveScience
How X-Rays Work | HowStuffWorks.com

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Contributors: Juli Hennings, Harry Lynch

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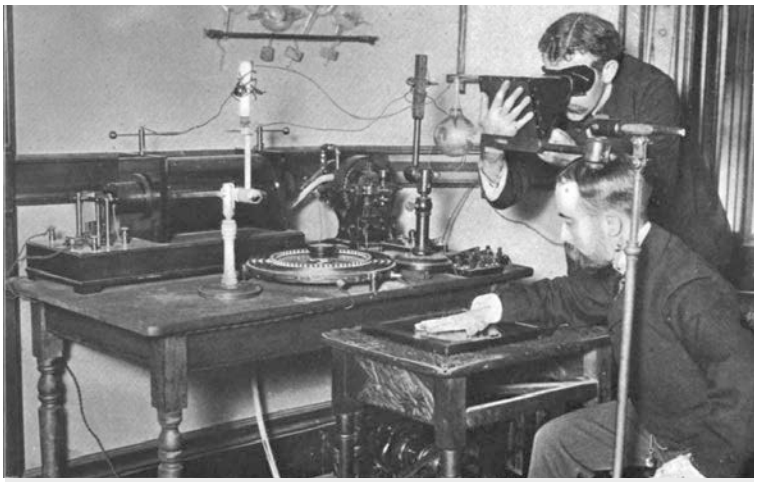
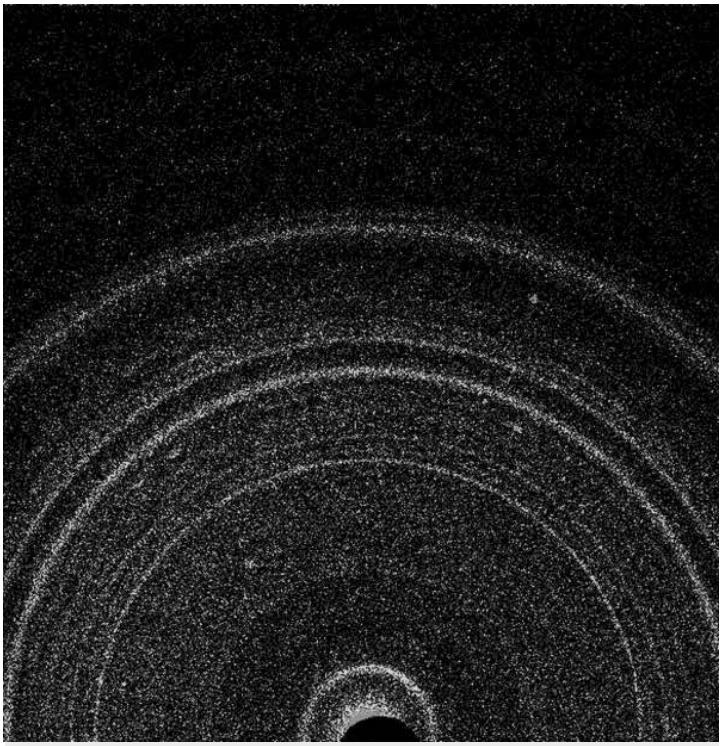
- X-rays have been used to examine paintings for authenticity and degradation of pigments.
- Because X-rays allow operators to view the contents of an object without opening it, these wavelengths have security applications in baggage scanners used by airports and truck scanners used by police and border control agents.
- Some astronomical features emit X-rays that can be detected only by special high-altitude or orbiting telescopes. These telescopes must be located so high above Earth's low-lying surfaces because the planet's atmosphere blocks X-radiation from reaching that far down.
- Because X-rays possess shorter wavelengths than visible light, they can be used to study structures too small for a microscope. Fiber X-ray diffraction was used to discover the double-helix structure of DNA in 1952.
- X-rays are used to determine the positions of atoms in crystals, allowing scientists to identify the minerals in soils and rocks. They diffract through the atomic structure of the mineral crystal to produce unique recognizable patterns caused by constructive interference of the rays. In 2012, this type of analysis was used on NASA's Curiosity rover to determine that the Martian soil it was testing is similar to volcanic soils in Hawaii.



A photo from 1896 of experimenters taking an X-ray with an early Crookes tube. The Crookes X-ray tube, which looks like a lightbulb, is visible suspended near the center of the photo. The standing man is examining the bones of his hand with a fluoroscope screen, while the sitting man is taking a radiograph of his own hand with a photographic plate. Neither of them are taking precautions against radiation exposure; its hazards were not known at the time.

Credit: William J. Morton (Public domain)



This graphic shows results of the first analysis of Martian soil by the Chemistry and Mineralogy (CheMin) experiment on NASA's Curiosity rover in October 2012. Each dot in this diffraction pattern was formed by the constructive interference of scattered X-rays passing through a crystal. This soil sample, taken from a wind-blown deposit within Gale Crater, is similar to volcanic soils in Hawaii.

Credit: NASA/JPL-Caltech/Ames (Public domain)

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