

## Project 6: Introduction to X-ray spectroscopy

---

### Summary

---

By measuring the x-ray fluorescence spectra of two metal samples with known K-shell energy transitions, an x-ray detector and multi-channel analyzer can be calibrated. The calibrated system is used to determine the composition of several other metals and a rock sample.

---

### Web Resources

---

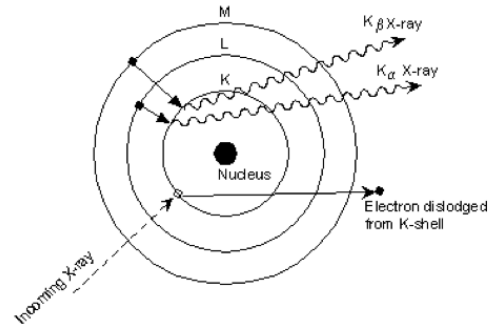
- Professor Kaaret's introductory lecture on x-ray astronomy (on Prof. Kaaret's website: <http://astro.physics.uiowa.edu/~kaaret> )
  - K and L x-ray line emission lookup chart ([http://www.amptek.com/xray\\_chart.html](http://www.amptek.com/xray_chart.html) )
  - Amptek home page: (<http://www.amptek.com/index.html> )
- 

### Background

---

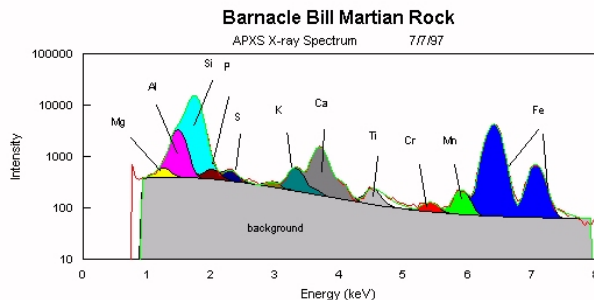
X-rays are photons with energies between a few hundred eV and about 30 keV. Astrophysical sources of continuum x-rays consist of thermal sources, such as accretion disks around stars and black holes. Non-thermal sources include beamed jets from AGN and other relativistic sources.

In addition, x-ray *emission lines* are detected in a number of sources with tenuous hot gas, such as the coronae of active stars. These lines can also be produced by *fluorescence*, i.e., secondary radiation of x-ray emission lines from solids which are excited by continuum x-rays. This process can be used to study the composition of solids, such as Martian rocks. The atomic energy level diagram is shown at right. Electrons are dislodged by continuum x-rays from the lowest (K) shell, followed by electron transitions from higher energy levels (e.g. L shell), resulting in the emission of a photon whose energy is just the energy difference between the two shells.



## Astronomical Laboratory 29:137 Fall 2007

The same model x-ray system you will be using in this lab has been flown on the Mars Pathfinder mission in 1997 [and is still on the surface!]. The purpose was to study the composition of Martian rocks by irradiating them with x-rays and analyzing the resulting fluorescence lines. An example spectrum is shown at right.



Fluorescence x-ray spectroscopy is also used in many non-astrophysical environments. An interesting example is analysis of the composition of the bronze-age gold ibex from Akrotiri in Greece. X-ray analysis showed that the 'gold' statue contains 15% silver, and several percent copper near a weld at the tail. More details can be found in a [research paper](#) by Pantazis et al.



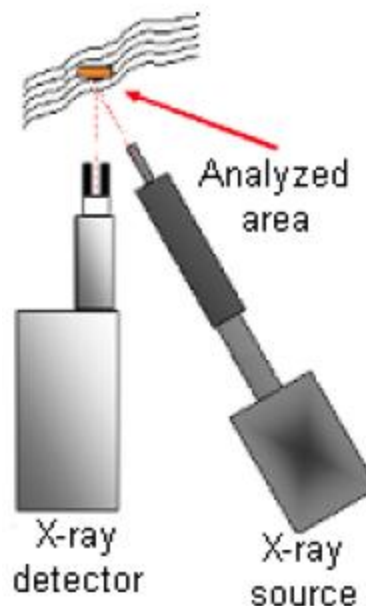
The object of this lab is to use an x-ray fluorescence system (which is essentially identical to the one flown on the Martian Pathfinder mission) to study the composition of several metallic alloys and a terrestrial rock.

## Procedure

---

### Setup

1. Since there is only one (very expensive) x-ray generator/detector system, each team will use the system in 15 minute periods.
2. *The beryllium window in the detector is extremely fragile. Do not touch the detector.*
3. *There are dangerous x-rays in the box. Do not put your hand in front of the x-ray source.*



## Astronomical Laboratory 29:137 Fall 2007

4. The instructor or TA will power everything up. Wait for approval before using the equipment.
5. Your first goal is to calibrate the spectrum, i.e. determine the relationship between channel number and energy. To do this, use two metal samples, titanium and copper.
  - a. For each sample, take a spectrum, and save it as a column-based data file.
  - b. Use Logger pro to fit a Gaussian to the dominant peak.
  - c. Look up the K-alpha line energies of titanium and copper online (see table reference in the introduction (note: You will see both the K-alpha and beta lines, but the alpha line will be dominant)).
  - d. Assume that the channel-count to energy relationship is linear (but with a non-zero offset) solve for the relationship between energy and channel number.
6. Now measure the x-ray spectra of the 'unknown' samples and the rock.
  - a. The metal samples are all alloys, so there will be more than one element in the spectrum.
  - b. Fit Gaussians to all the stronger lines to determine the center channel, and hence peak energy.
  - c. Consult the online table to determine elemental abundances, and hence what metallic alloy the sample is.
  - d. Although the line strengths are all different, unless a careful calibration of amplitudes is done, you will be able to determine fractional composition, only the presence or absence of an element.
  - e. There is one line that may show up on all spectra near 3 keV. See if you can figure out where that line arises.

