

Seasons Lab 1

Names:

Purpose

In this lab you will examine how different elements emit and absorb different wavelengths of light. Each element's pattern of absorption/emission is like a fingerprint and you will use this fingerprint to identify an unknown sample and then to match the composition and temperature of a simulated astronomical gas cloud. Directions

Lab

You're going to start by observing different elements through diffraction gratings. The diffraction grating breaks up light into its component colors. For each light source, sketch the spectrum (set of colors) that seem to be produced by the source.

Hydrogen



Helium



Neon



What differences do you notice between neon, helium, and hydrogen? Why do you suppose those exist? (There's more than just color that's different!)

Incandescent Bulb

Why is the incandescent bulb spectrum different from the previous two?

Molecular Nitrogen Gas

You should find that nitrogen is different yet again. There's something fundamentally different between nitrogen and the hydrogen and helium we've been looking at. What is it?

Unknown

What do you think is in the unknown sample? Why?

Hydrogen

Wavelength (Angstroms)	Color
6563	Red
4861	Blue-Green
4340	Violet
4101	Deep Violet (dim)

Mercury

Wavelength (Angstroms)	Color
6073	Orange
5780	Yellow
5461	Green
4916	Blue-Green (dim)
4358	Violet
4047	Violet (dim)

Krypton

Wavelength (Angstroms)	Color
6458	Red
5871	Yellow-Orange
5570	Green
4502	Violet (dim)
4459	Violet (dim)
4368	Violet (dim)
4320	Violet (dim)
4274	Violet (dim)

Alright. Talk to an instructor about what you've learned so far. Once we're satisfied that you understand how spectroscopy can be used, it's time to try it out with some more realistic data.

The Software

To do this lab, we're going to use the CLEA package, "Dying Stars and the Birth of Elements". (Called "XMM_Lab.exe" on your computers.) So fire up your computer and start the program.

The first thing you'll have to do is to log in. Go to "File > Log in". Actually, you don't have to enter any names, really. You can just click "OK" and move along. (Ignore it's pop-up warning.) For our purposes, we don't really care.

As before, you'll have to point your telescope and acquire data. This time, it's a space telescope, though. So no having to open a dome! Start by pointing at a supernova remnant. Go to Slew > Hotlists > Objects. An "Observation List" window will pop up with a set of coordinates. Double-click on them. The telescope will move to the position of the supernova remnant. Under the View section (on the right), change the field of view to Chart. The crosshairs will show you where you are pointed (the center of the supernova remnant). Point your crosshairs at the field of view box. Once the telescope is in the field, change your View to Field. This will provide a "close-up" view of the field. Your targets are the four bright clumps of gas, or "knots," near the center of the screen, labeled "1" through "4". Pick any one and point at it. Make sure you're centered on the knot!

Now we can take data. Technically, this isn't quite the same as our diffraction grating since we're using X-rays, but the principles are the same. So click the spectrometer button to open the spectrometer window. Click "Go" to start. You need to acquire enough data to get a signal-to-noise of at least 15, but do not exceed 20. The software breaks at that point, for some reason. Once your spectrum looks good, save it by going to File>Data>Save Spectrum. YOU MUST DO THIS or you will have to take a new one.

Once you've acquired your spectrum, you can close the spectrometer window.

Now that you have a spectrum, you can compare it to a mathematical model that includes how each element produces X-rays. You can change the amounts of several elements and see how the model spectrum changes. You can also change the temperature and a few other parameters. As you adjust the model parameters, the model spectrum will change. The goal is to get the model spectrum to match the observed one. The model of the knot you have created will then closely match the real characteristics of the observed knot. You will have determined the physical nature of the gas in the supernova remnant!

Select Tools > Spectrum Analysis. Load your spectrum from File > Load Spectrum. Once you do this, you'll see your spectrum in the middle of the window. You should now load a model spectrum with Tools > Comparison spectrum. This loads in the top panel. Once you have the model, the bottom panel will show the difference of the two spectra (top minus the middle). This is a good way to gauge how well you're modeling the data and where you need the most work.

Now to play with your model. There are a series of model parameters controlled by sliders. These parameters are

- Temperature (kT): this is the temperature of the gas. You can think of a gas at a temperature of 1 keV being equivalent to about 10 million degrees Celsius — almost as hot as the core of the Sun!
- Absorption (nH): This represents the amount of cool, Galactic hydrogen gas between you and the X-ray emitting gas. The more gas there is, the more X-rays it absorbs out of the spectrum.
- Iron (Fe), Sulfur, Silicon, Calcium, and Magnesium: This is the abundance of the element iron, etc. in the gas, relative to the abundance of iron in the Sun. An abundance of 1.0 in a sample of supernova gas means it has the same ratio of iron in it that the Sun does. 2.0 means twice as much, and so on.

You have two goals (that work together). One, get the difference spectrum as flat as possible. Two, get the "Quality of Fit" statistic as low as possible. It should be down near 1, but get it as low as you can!

Some tips from my best friend:

TIP 1: Every time you adjust a parameter, go back and adjust all the parameters you already adjusted. This way you will converge more rapidly on a good solution. If you simply move down the list of parameters once, you'll never get a good fit.

As you adjust a parameter, note what is changing. You may find that some things change in similar ways when two different parameters are adjusted.

TIP 2: You may appear to be getting close to a solution, and then find that you are suddenly not improving. This is normal. Try moving one of the sliders quite a bit, to break out of that impasse. Try again using very different parameter values to start with, to make sure you don't get locked into those incorrect values again.

Be patient. This takes some getting used to. It may take a few minutes when you first try it.

TIP 3: Watch the "Quality of Fit" number as you move a slider. When it drops to a minimum value, move to another parameter. When it's again at a minimum, go back to the first parameter and adjust it again. This method will let you converge on a solution more rapidly.

Once the "Quality of Fit" value drops below about 1 (the specific value is different for every observation depending on the knot you observe and the signal-to-noise ratio you achieved), you are getting close. Note that the display for it turns green, letting you know your fit is getting good. Keep adjusting the sliders to get this value as low as possible.

When you think you have it, call an instructor over to share your results.

Checkout

We'll do hallway talks for this lab. What I want you to tell me on this stroll is what spectroscopy is, why it's useful, and what its challenges are when working with real data. You don't need to tell us what you did step-by-step, but you can use examples from your lab to illustrate your points. You will have a short time to make your point (down the hall and back), so think about what you want to tell me!