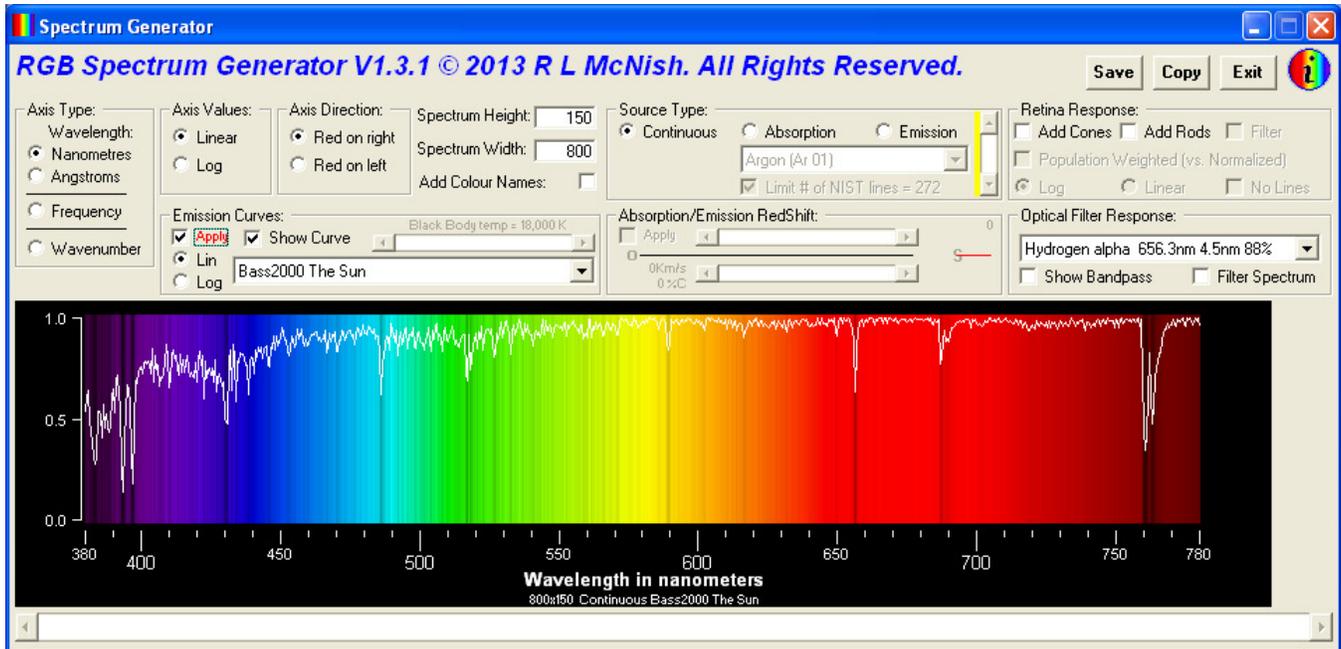


RGB Spectrum Generator V1.3

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****NEW VERSION**** - July 15, 2013



While researching images of spectra on the Internet for another project, I found no consistency in their visual presentation.

There were:

- different sized images
- different axis types and ranges
- unlabelled axes
- long to short wavelengths or the reverse
- low to high frequencies or the reverse
- wave numbers instead of wavelengths or frequencies
- coloured backgrounds that did not represent the correct visual interpretation of colour
- and a number of other inconsistencies based on the personal preferences of the originators

This made it difficult to compare spectra and properly show how a spectrograph or human might perceive the results.

If you work with spectra or are just interested in them, then this program and its many options will assist you in generating a consistent set of standardized images.

This program is copyrighted, but is provided free of charge for non-commercial use. This is the first public release. No registration is required. All options are fully functional. Support is limited to things I have time to fix or add (see the documentation).

The User Interface

The simplest way to see what all the controls on the User Interface do is to try them all.

In the row of "frames" across the application window below the title are the main controls for generating some simple spectra.

Hovering your mouse over these items brings up a short description of what they do.

Axis Type - allows your personal preference for the (labeled) X-axis which covers the theoretical range of human vision. The program does not produce spectra into the ultraviolet or infrared wavelengths. (The selections do not change the spectrum, they just provide a consistent axis which is correctly positioned and labeled.) The choice made here is shown in the legend below the X-axis.

Axis Values - allows your personal preference as to a linear or logarithmic X-axis. When changed, the spectrum is recomputed and redisplayed to match the correctly positioned and labeled X-axis). The choice made here is shown in the legend below the X-axis.

Axis Direction - allows your personal preference as to the direction of the X-axis values. Rather than say "wavelengths low to high", "frequencies high to low" etc., etc. the shorthand choices of "Red on right" or "Red on Left" basically says it all, and the spectra and X-axis are recomputed and redisplayed accordingly.

Spectrum Height - Since a spectrum is actually a plot of Intensity values versus wavelength, a "real" spectrum is just a graph of a line above an X-axis and does not, by itself, imply colour. As I say in other articles, there are no "red" photons, "green" photons, "blue" photons, "blonde" photons or any other colour. They are all just photons with different energies. **But** - comparing a bunch of line graphs is difficult, especially if they have different X-axis types, ranges, and / or directions. Plotting the graph against a coloured background provides immediate visual cues as to the orientation of the data as well as a personal connection as to how we would see that particular point of data. A single pixel line showing how the spectra at that point "looks" would suffice, but it would be hard to see. By duplicating that line vertically, a better visual impression results, and it also gives me room to have a Y-axis labeling the intensity values. You may choose a height to suit your needs, but there will be no differences between any of the value lines that make up the spectra.

Spectrum Width - This program defaults to generating an image 800 pixels wide. You may change this from 300 to 5000 pixels. The spectrum and X-axis are recomputed and positioned properly for the width. A scroll bar is provided below the spectrum image for examining very wide spectra.

Add Colour Names - probably useful only for black and white printed versions of the spectra and appear only if the spectrum is high enough.

Source Type - The default "source of light" for the spectrum program is a theoretical source that emits photons with equivalent energies across the entire visual spectrum. This is called the "**Continuous**" spectral source. Since we evolved on a planet orbiting our Sun, our visual

system perceives the rainbow of colours it generates within our vision limits. However, many sources of light are not as "perfect" as this and typically generate light with "missing colours".

When sunlight (or any other source of light) passes through a gas, the gas attenuates certain wavelengths based on the atomic or molecular structure of the gas. In effect, the gas "steals" some wavelengths and some wavelengths are attenuated more than others. The resulting light coming through the gas displays darkened "absorption lines" accordingly. This is called an "**Absorption**" spectral source. Selecting this enables a drop-down list of sources that the program includes.

When light is emitted by a gas whose atoms or molecules are in an excited state (such as a mercury vapor lamp) the light is not a continuous set of wavelengths. In fact it is the inverse of the absorption spectra for the gas. The result is a set of lines with gaps between them. This is called an "**Emission**" spectral source. Selecting this enables a drop-down list of sources that the program includes.

For the Absorption and Emission line data for the common gasses supplied, I turned to:

Atomic Spectroscopy Group NIST Atomic Spectra Database

National Institute of Standards and Technology of the U.S. Department of Commerce

http://physics.nist.gov/PhysRefData/ASD/lines_form.html

Limit # of NIST lines - this checkbox and the vertical scroll bar to its right work together. The absorption and emission data from the NIST Atomic Spectra Database typically has thousands of intensity-versus-wavelength data points for each gas (many of which are zero). This can produce absorption or emission spectra with hundreds of lines. To limit the effect of minor changes on the generated spectrum, the program can ignore spectral effects that are lower than a percentage of the greatest effect.

Clicking this checkbox on (checked) ignores all data that does not contribute more than 1% of the largest effect the gas has. To eliminate even more lines, use the vertical scrollbar to increase this lower limit up to 100%.

DISPLAYING COLOUR

A coloured background is great, but the colours should accurately represent some standard. Arbitrarily choosing where red turns to orange or blue to green is erroneous. So I researched how wavelengths of light are perceived by humans and if there was a standard way of converting a particular wavelength to a colour that would be properly displayed on a computer monitor so that our visual system would perceive the "correct" colour.

There are two main effects that need to be handled.

1. displaying the spectrum on a computer monitor accurately, and
2. displaying how our visual system perceives that wavelength of light as a colour.

Conversion of the wavelength of light to an "RGB" value for display on a computer monitor is complicated by the fact that there are only 256 levels of red, green, and blue for monitors. Although this allows 16,777,216 different colours to be specified, the phosphors, LEDs, LCDs etc in monitors may not react to these level intensities as we do, and the human vision system can actually perceive many more colours than can be displayed. (We are analog, not digital.)

For an algorithm to convert a wavelength of light into a set of RGB values that take into account the RGB limitations of monitors as well as the perceived colour, I turned to

"Approximate RGB values for Visible Wavelengths" by Dr. Dan Bruton, Professor,
Department of Physics and Astronomy, Stephen F. Austin State University, Texas

<http://www.physics.sfasu.edu/astro/color/spectra.html>

His algorithm has been incorporated into the program and is used for all spectra generation. (Note - this program does not guarantee that your printer will show the same colours!)

PERCEIVING COLOUR

The theoretical limits for human vision are usually specified as 380 to 780 nanometers. But most humans do not perceive this entire range. So, although this program can generate spectra over this range, it is probably NOT exactly what you would see visually.

Our "color vision" is the net effect on our visual cortex that originates with three different color receptors in the retina - the **cones**. Each of the three types of cones responds to a range of wavelengths and energies (brightness) and these ranges overlap producing a "net effect". Although the cones have long been classified as "L cones" (responding to longer wavelengths), the "M cones" (responding to medium wavelengths) and the "S cones" (responding to shorter wavelengths), the net effect depends upon the entire visual system. Since the advent of computer monitors these cones have become known as the "Red cones", "Green cones", and "Blue cones" respectively, but this is a great oversimplification of the actual visual system.

There is also a fourth type of retinal sensor - the **rods**. It has been proven through studies that the colour receptors (the cones) only operate if the light falling on them is sufficiently bright. In effect, they have been "tuned" by evolution to work well under extremely bright sunlight.

However, in low light conditions they are just not sensitive enough. In effect, as light intensity falls, we get progressively more "colourblind".

But evolution had a solution. The rods in the retina do NOT respond to colour, but ARE activated by low light conditions. These broad-spectrum biological sensors provide our "night vision" which is poor at determining colour, but at least lets us see under minimal light conditions. Therefore the rods are much more sensitive to light than the cones, but basically shut down and do nothing in bright sunlight.

To determine how the "average" human (i.e. without color blindness) perceives color from a source (i.e. the monitor mentioned in the section above), I turned to:

"*Cone Fundamentals and Luminous Efficiency functions*" by the
Colour & Vision Research Laboratory, Institute of Ophthalmology, University College London
<http://cvrl.ucl.ac.uk/>

This is a huge amount of work carried on over the last few decades analyzing how the optical system works, and verifying it through volunteers that are categorized as "normal colour vision" individuals.

Retinal Response

Here is where the program can be changed from generating a "theoretical spectrum" one that can be verified by using a very good spectrograph, to one that closely resembles what an individual would "see" if the light enters the eye.

Add Cones - Add the cones (R,G,B) retinal response curves (white = net effect)

Add Rods - Add the rods retinal response curve (gray)

Population Weighted (vs. Normalized) - For the cones - show the population weighted or normalized curves (see the reference in the previous section).

Filter - Filter the spectra by the response curve(s) i.e. apply how we see colour to the theoretical spectrum.

Log - Apply the curves logarithmically (as does the human vision system.) If the spectrum image is tall enough a left-hand Y-axis appears and is a logarithmic axis.

Linear - Apply the curves linearly. If the spectrum image is tall enough a left-hand Y-axis appears and is a linear axis.

No Lines - Process the retinal response effects but removes the curves and the Y-axis from the picture.

Other Spectrum Controls

The second group of "frames" below the first allows even more effects to be applied to the generated spectrum.

Emission Curves - these act like the Emission Source mentioned above but are related more to other light sources including some commercial lighting products rather than pure gasses.

You should usually select a Continuous source (not Absorption or Emission) when choosing one of these Emission Curves.

Apply - applies the emission source (see below) to the spectrum

Show Curve - shows the spectrographic intensity data for the source (the values that modify the continuous spectrum when the Apply box is checked).

Lin - The source curve will be shown plotted against a linear Y-axis.

Log - The source curve will be shown plotted against a logarithmic Y-axis.

Note that when Apply is checked, the curve values (0 to 1) are applied against the continuous spectrum without regards to a linear or logarithmic conversion. It is your visual system that perceives the brightness falling off rapidly.

Sources - This drop-down box allows choosing which Emission Curve you want to display. It includes:

Bass2000 - The Sun - The actual Solar Emission spectrum has been analyzed and includes thousands of absorption lines. The dataset for this display consists of 4000 data points across the visible spectrum. This data is from:

BAse de données Solaire Sol BASS2000 Solar Survey
Archive, l'Observatoire de Paris, High Resolution Solar Spectrum
http://bass2000.obspm.fr/solar_spect.php

KittPeak - The Sun - NOAO (the U.S. National Optical Astronomy Observatory) produced a high resolution coloured image of the Sun's spectrum (but only from 400 to 700 nm) that can be found at: http://www.noao.edu/image_gallery/html/im0600.html "*from a digital atlas observed with the Fourier Transform Spectrometer at the McMath-Pierce Solar Facility at the National Solar Observatory on Kitt Peak, near Tucson, Arizona ('Solar Flux Atlas from 296 to 1300 nm' by Robert L. Kurucz, Ingemar Furenlid, James Brault, and Larry Testerman: National Solar Observatory Atlas No. 1, June 1984.)*". The spectrum used by this RGB Spectrum program is also based on the Kitt Peak study, updated to 2005 by N.A.Sharp, NOAO/NSO/Kitt Peak FTS/AURA/NSF and the information can be found at <http://kurucz.harvard.edu/sun/fluxatlas2005/>.

Black Body Emission at temperature K - Together with the horizontal scroll bar above the source selection, the program generates a theoretical "Black Body Radiation" light source (emission curve) based on the temperature (in Kelvin). Note that for some temperatures most of the curve may be outside the visual wavelength range (i.e. the standard X-axis).

NOAA analyzed commercial lights from:

National Oceanic and Atmospheric Administration of the U.S. Department of Commerce, Earth Observation Group (EOG), Defense Meteorological Satellite Program (DMSP) Data Archive.

<http://www.ngdc.noaa.gov/dmsp/spectra.html>

Absorption/Emission RedShift: - This section allows showing the effect of a stellar redshift (or blueshift).

1. Choose a Source Type of "Emission" and select one of the gases available
2. Use the top horizontal scrollbar in this section to choose a direction of motion angle relative to the Sun ("O") from directly away (redshift) through directly towards (blueshift). The short coloured line protruding from the Source ("S") will rotate according to the direction of motion angle which is also shown in degrees.
3. Choose a velocity of the Source ("S") relative to the Sun ("O") from 0km/sec (0% of the speed of light C) to 299,790 km/sec (99.995% of the speed of light)
4. Click the Apply checkbox to apply the values to the source's emission spectra. You can leave this option on as you change the other control values to dramatically show how the emission lines change position and colour to the right or left.

Optical Filter Response

Astronomers and astrophysicists use optical filters when they want to eliminate portions of the spectrum of light being captured by a camera, spectrograph or even visually.

To show the "bandpass characteristics" of various common filters:

1. Choose a Source Type of "Continuous"
2. Choose a filter type (there are some other things in the list of interest as well)
3. Check Show Bandpass to add the curve to the continuous spectrum
4. Check Filter Spectrum to apply the curve to the spectrum.

Final Notes

Copy - copies the spectrum image to the Windows Clipboard. Even a simple program like Windows Paint can be used (via Paste) to save the image. NOTE - The program does NOT allow saving the images as JPEG files as this compression technique loses some information and often "remaps" colours into one another. I suggest images created by this program are saved as PNG files which is a compression algorithm that reduces file sizes but does not lose any colour information.

Save - allows you to save the spectrum image as a PNG file in the directory of your choice.

Annotation - Almost every option adds information to the legend for the spectrum under the X-axis. If you copy the resulting image to the clipboard and save the file, you can recreate it by applying options until the legend is identical.

Information - The coloured Info image in the top right will bring up a window that shows the scientific source for many of the algorithms and the data in this program. Clicking on one of these items will take you to the relevant website.

Other Combinations of Options - In a few cases where things would not make sense I have disabled one option when another is chosen. But there are still many combinations that, although they work, may not produce a useable result, or may confuse the user. Use combinations of options at your own risk.

Future Enhancements

I wrote this Visual Basic 6 program a couple of years ago and used it to create some spectra for other projects. Currently I have no plans to enhance it further. But - it is possible to add more spectral data (emission curves and optical filter curves) to the program as long as the data can be located and verified. (I cannot just take a graph from some printed material or internet site; I need the data behind the graph at high resolution.) If there is a demonstrated need for a particular item and the data points are readily available I could entertain adding it to the program.

Version 1.2 - original public release

Version 1.3.1 - July 15, 2013 - added "Save" and "Kitt Peak" solar data emission spectrum (with corresponding data file)