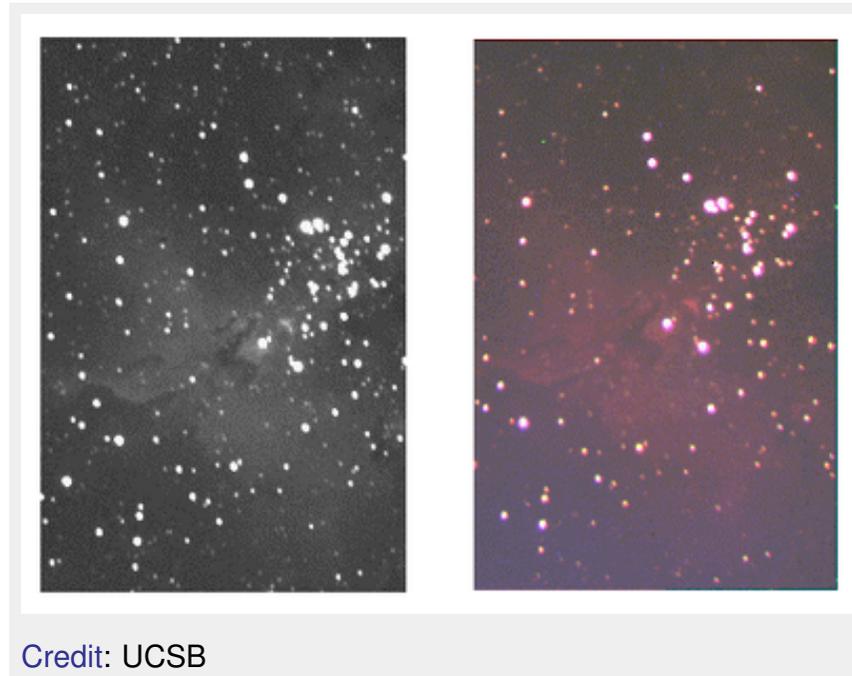


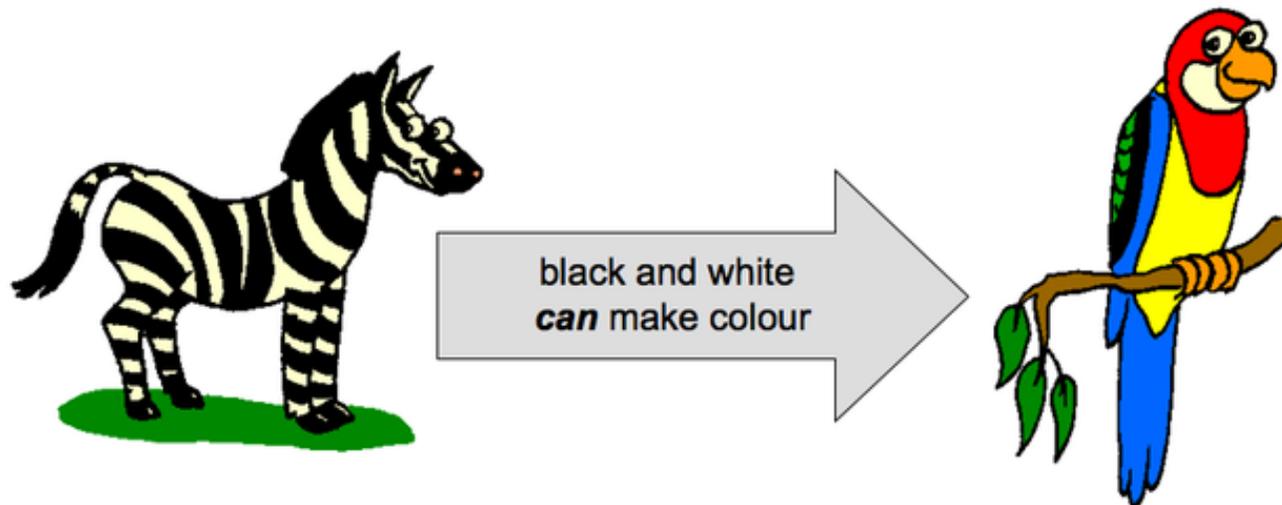
The Importance of Colour: Making a Colour Image



Summary

In this Activity, we will examine:

- colour mixing with **light** (not paint!); and
- adding images taken with different colour filters to get a true colour image of an **astronomical** object.

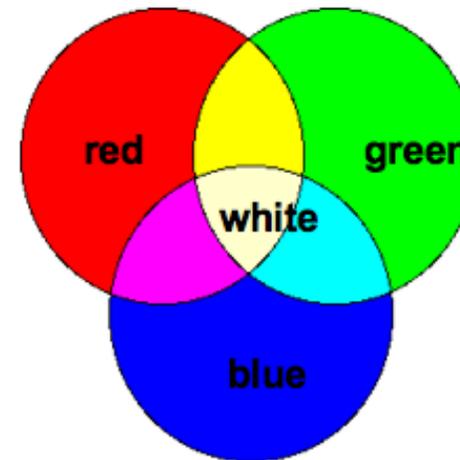
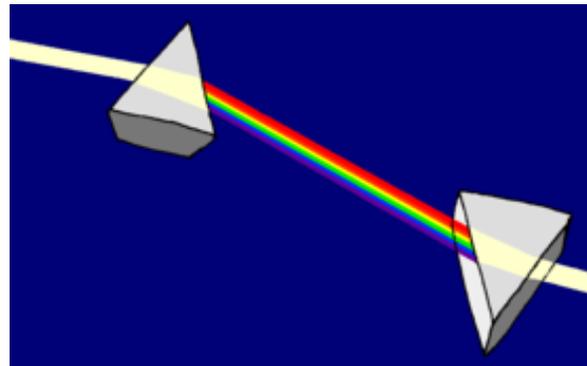


Red + Green + Blue = White!

The pretty colour images you see in books were all made by long-exposure photographs and very sensitive films. Today the same images are made with relatively short exposures, using overlays of digital images.

Here's how it works: Way back in the 1600s, Sir Isaac Newton showed that white light can be split by a prism into a rainbow, and that the rainbow can be recombined into white light.

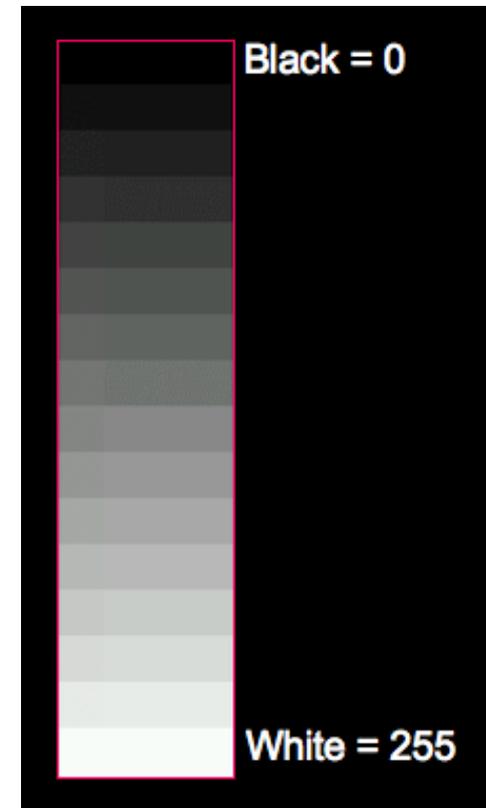
Soon after, folks discovered that the *PRIMARY* colours of light are *RED*, *GREEN*, and *BLUE*, and that combining just these three colours of light, in the correct proportions, gives white light.



r Red + g Green + b Blue = well, it depends!

Recall that a digital image is a 2-dimensional array of numbers. You can add images by adding the intensity values at the same (x,y) location on each image. This z value gives you a new intensity, so you have (x,y,z).

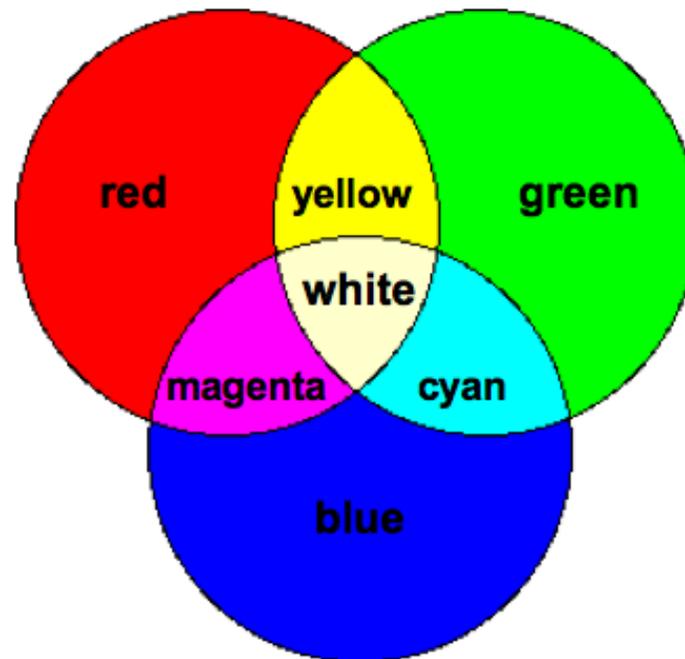
If you define the intensities on an absolute scale from, say, 0 to 255 where 0 = BLACK and 255 = WHITE, then the z value gives you the gray level assigned to that pixel. You then have a grayscale image.



Assigning colours

If you have three different grayscale images you can assign a colour to each of them (using computer manipulation software). That is, you can insert one grayscale image into the red (*r*) channel, another into the green (*g*) channel and the last into the blue (*b*) channel.

If you add red, green, and blue channels together in the correct proportions you get white, but if the proportions are different, then you get some colour in between... like *CYAN*, *MAGENTA*, or *YELLOW*...

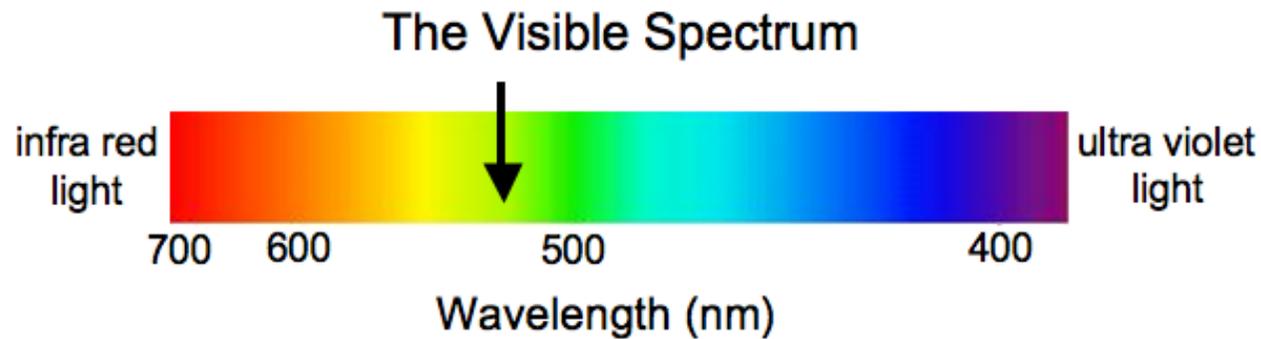


You start with 3 filters: B, V, and R



*Wait a minute: I thought you said red,
blue, and GREEN.
What is V??? Violet???*

No, no, no... sorry. *V* stands for *VISUAL*, and is actually a green-yellow band pass filter, centered on the middle of the visual spectrum, which is actually the PEAK of the response curve of our human eyes (where the arrow is drawn below)!

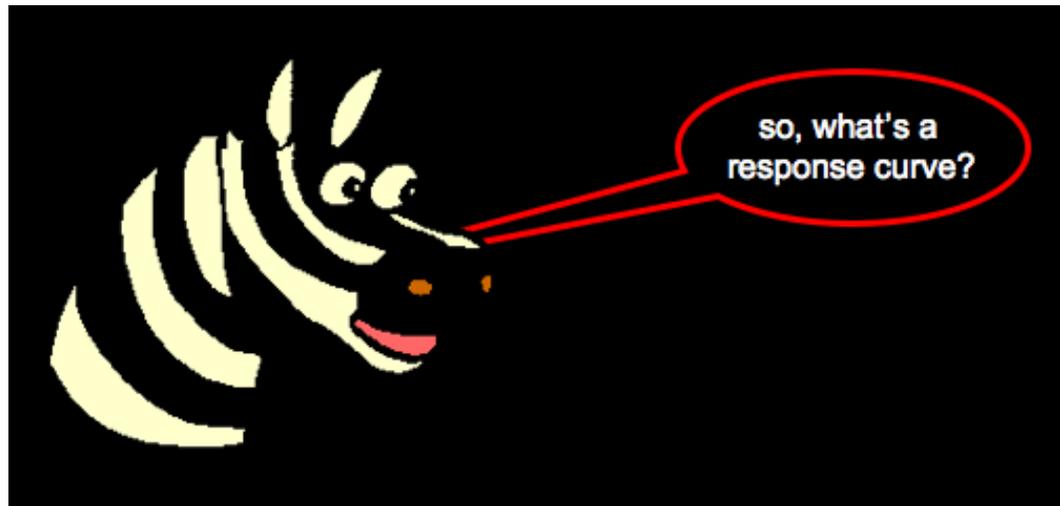


Once again...

1. You start with 3 filters: B, V, and R
2. You take three exposures of the same target, one with each filter.
3. You correct each one for the dark current and flat field it, as we described in a previous module.
4. You make sure they line up properly.
5. You assign:
 - the R filter to the red channel;
 - V to the green channel; and
 - B to the blue channel.
6. *At last you digitally sum them, and — VOILA! —*
you have your three colour (tricolour) image!

Response curves

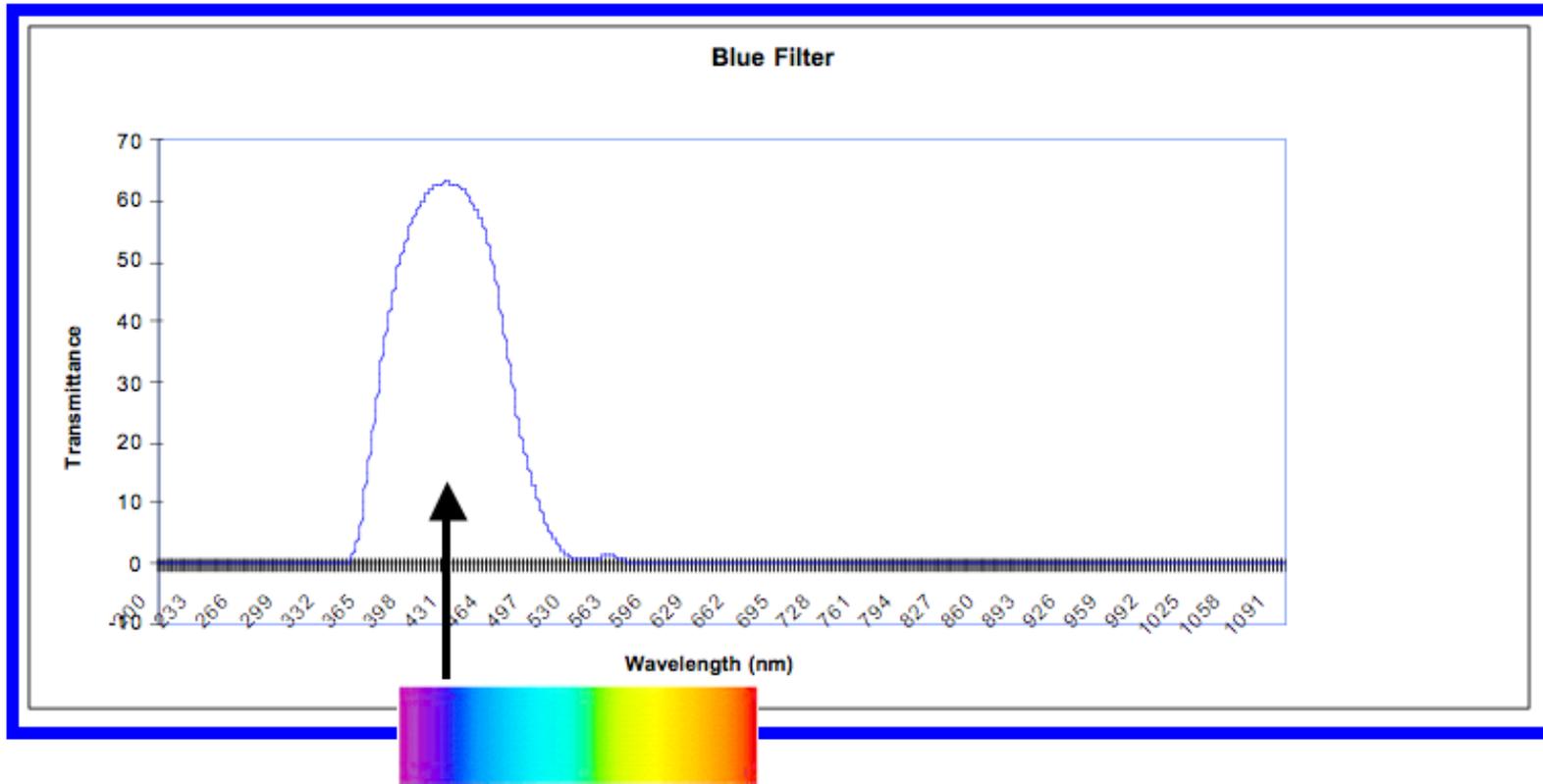
Before we take the images, let's have a look at the RESPONSE curves of some typical B, V, and R band filters.



Every filter allows only CERTAIN **wavelengths** to pass through it. The mathematical function that describes the amount of light that the filter allows through for each **wavelength** is what we call the response curve.

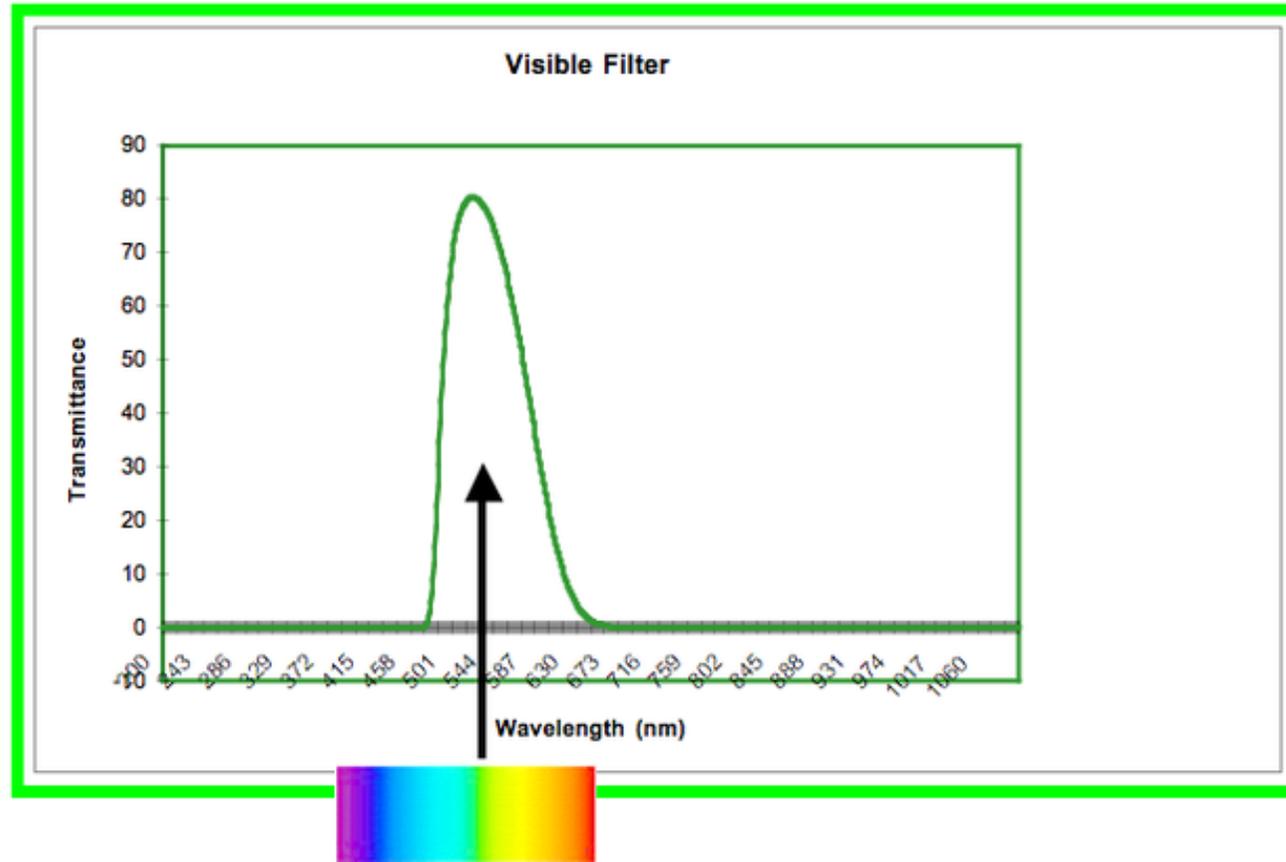
Blue filter

Response curve of the Blue filter on the RAAP telescope at UCSB



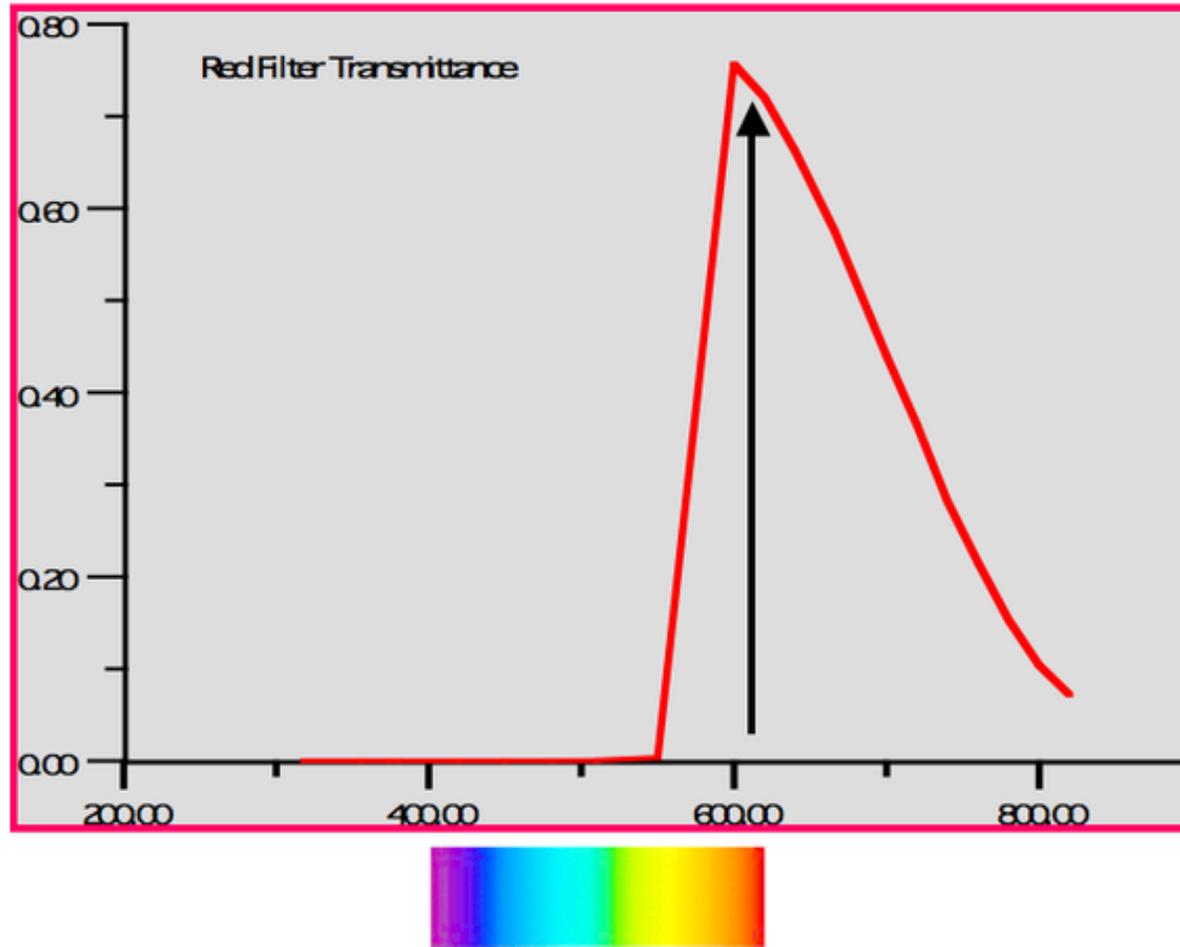
V-band filter

Response curve of the V-band filter on the RAAP telescope at UCSB



Red filter

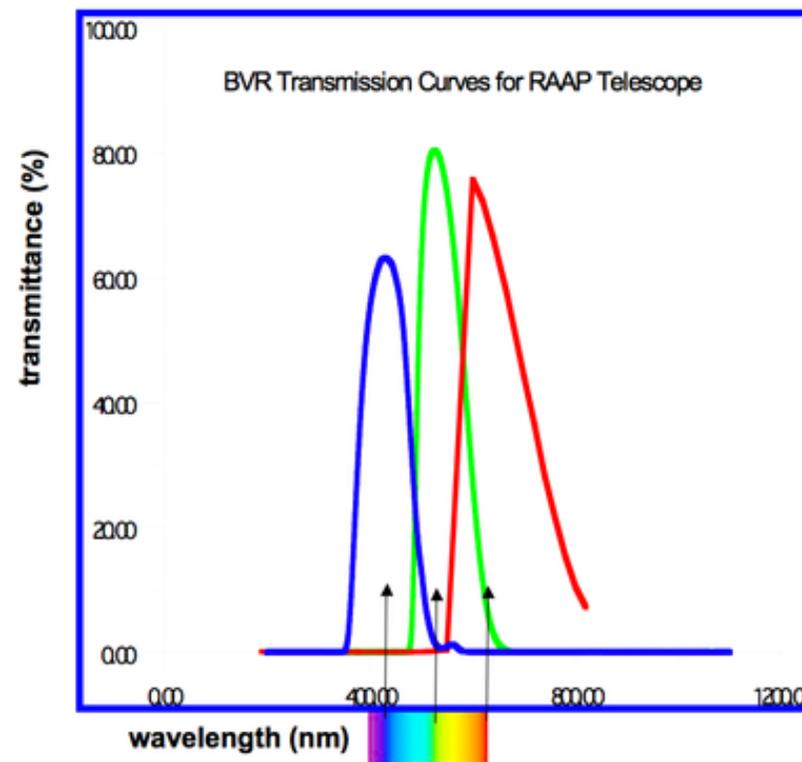
Response of the Red filter on the RAAP telescope at UCSB



All together now...

Here are the curves for all three filters, all graphed at the same scale.

You can see that the V-band filter lets in the most light, the R-band next, and the B-band lets in the least....



Arrows indicate wavelengths that correspond to maximum response of each filter. Does that present a problem?

Scaling properly

Well, it need not be a problem in making a tricolour image, as long as you know the transmission properties of your filters, and CORRECT for them.

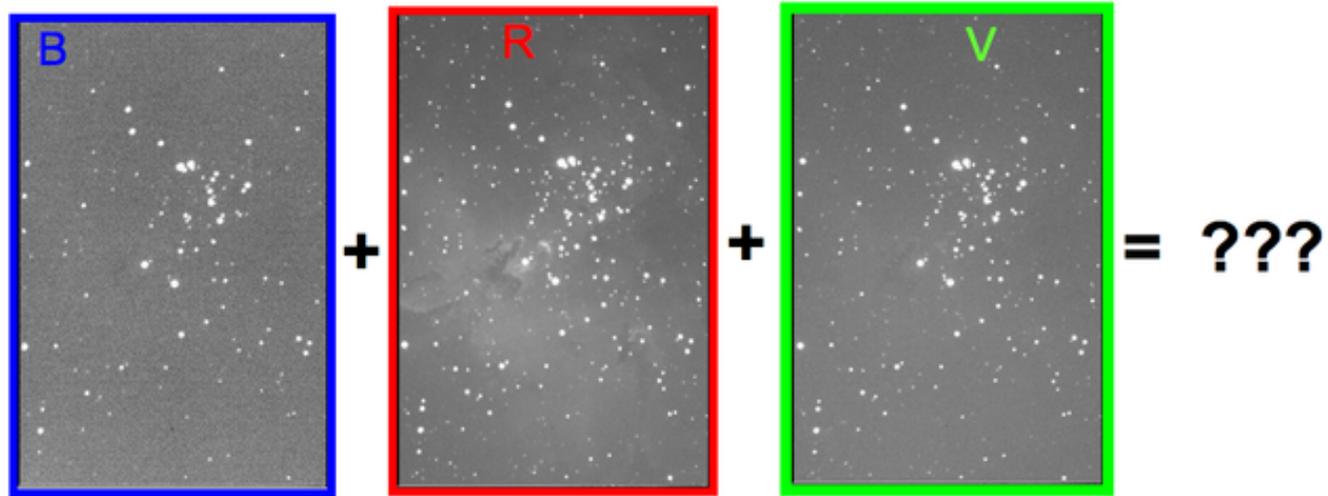
This means that if one filter lets in more or less light than the others, you have to account for that before you add the images, by multiplying each image by the appropriate scale factor. Otherwise you will get colour distortion.

Composing your image

So, let us say that you have done the following:

- taken three raw images of the same target, each with a different colour filter: B (blue), V (greenish), and R (red);
- corrected each raw image for dark current, and flat-fielded it;
- accounted for the difference in transmittance of each of your filters.

You are now ready to make your true colour image! Here goes...



WAIT A MINUTE! These images are not in colour, they are in black and white!

FITS

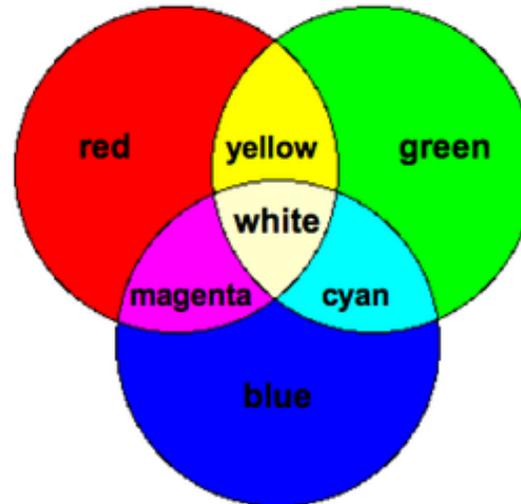
That's right. Each filter lets only certain wavelengths through. The "FITS" (Flexible Image Transport System) image that comes from your CCD to your computer screen maps each pixel location to an intensity from 0 to 255.

You need to assign one of the **RGB** display colours to each image. After colouring all three images you add them together. Each pixel again maps to a range from 0 to 255 BUT now your software will ALSO assign not only an intensity value but your selected RGB value. The RGB value maps 0 to black, 255 to pure colour, with shades of colour in between instead of only shades of gray.

RGB values

Adding the 3 colour-assigned images together means that the 3 RGB values are added together at each pixel. Different values for each R, G and B produces different colours.

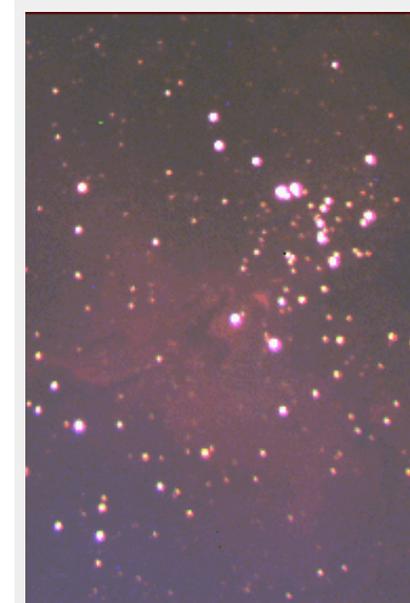
For example, adding $R=255$, $G=255$ and $B=255$ produces white, and a pixel with $R=255$, $G=0$ and $B=255$ produces the colour magenta. So, the result is...



Natural rendition

A natural colour rendition of what this [nebula](#) would look like to your eyes, if they could gather as much light as a telescope.

Do you recognise it? This is M16, the Eagle Nebula in Serpens. Notice the colour of the nebulosity...

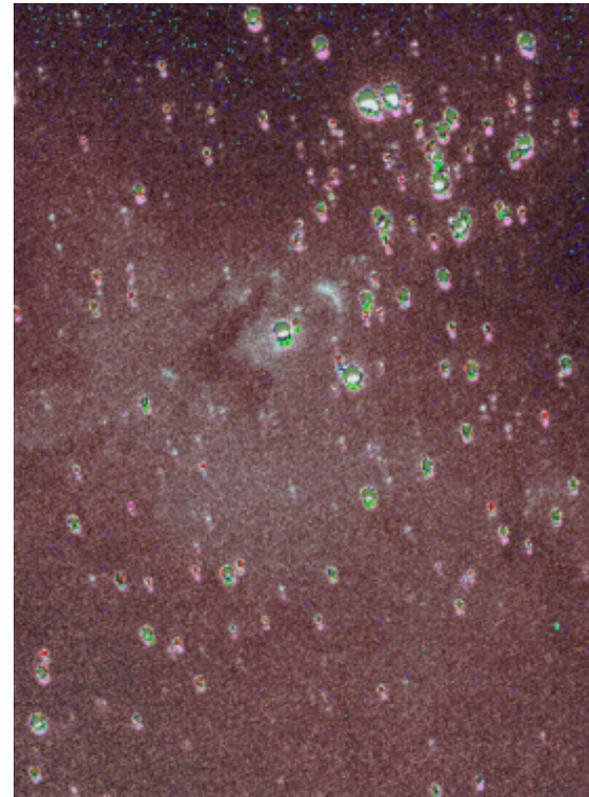


Credit: UCSB

Aligning images

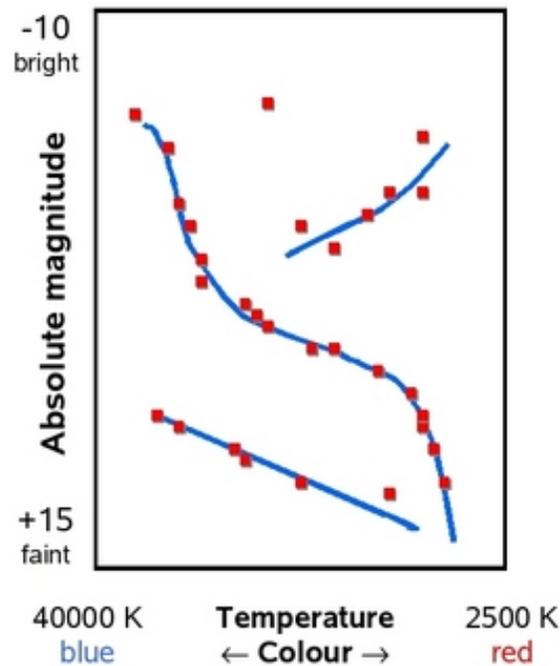
Sounds easy, but there are some potential pitfalls...

1. Be sure to align your images correctly, otherwise instead of **stars** you will get blobs, as in this rendition of M16, in which the same BVR images were added using the commercial software “Paintshop Pro”, and proper alignment was not first performed!



Temperature indication

2. Be sure you have corrected your raw images and accounted for your transmission curves if you want natural colour which gives you an indication of TEMPERATURE.



A star's colour is an indication of its temperature. If you know a star's temperature and **luminosity** you can tell what type of **star** it is!

Summary

In this Activity we have discussed:

- The theory behind colour mixing;
- The practice of adding images and assigning colour values in a digital image, including:
 - The proper preparation of your images;
 - The properties of the BVR filters;
 - The proper way to add images - always align them!
 - The importance of colour and temperature

Happy Image Processing!

