# Astrophotography Workshop

USE YOUR TIME CREATIVELY!

Co-funded by the Erasmus+ Programme of the European Union

# Astrophotography workshop

Aims:
- familiarising with the process of preparation astronomical pictures
- increasing curiosity of the participants and their creative thinking
- raising a positive attitude towards science
- expressing the creativity of the participants by preparing an own piece of art - astropicture

Materials:
- tutorial (in English): https://youtu.be/AMohsCOGZ2M
- GIMP software preinstalled: https://www.gimp.org/downloads/
- SAO DS9 software preinstalled: https://sites.google.com/cfa.harvard.edu/saoimageds9
- raw astronomical pictures in 3 Johnson-Cousins filters R,V,B (own or downloaded from http://byk.oa.uj.edu.pl/~elzbieta/m101/)

Instruction of software installation:

GIMP: go to the https://www.gimp.org/downloads/ webpage. If your operating system is Windows simply click the 'Download GIMP 2.10.28 directly' button. If you have another system, choose the correct option from 'Show downloads for' menu and follow the instructions.

SAO DS9: go to the https://sites.google.com/cfa.harvard.edu/saoimageds9 webpage. Click the 'Download' button and choose your operating system. Download the program and install it in the standard way.

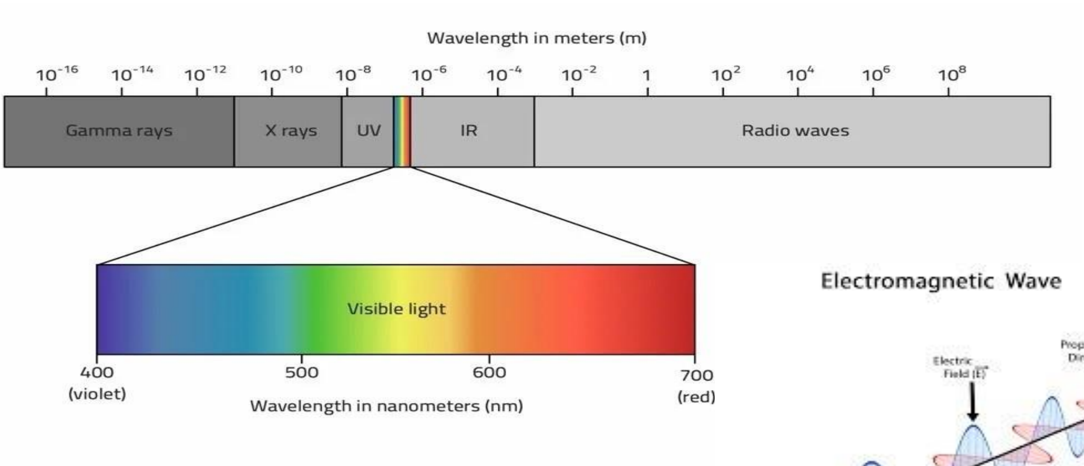
The Lagoon nebula – a coloured astropicture (credit: NASA)

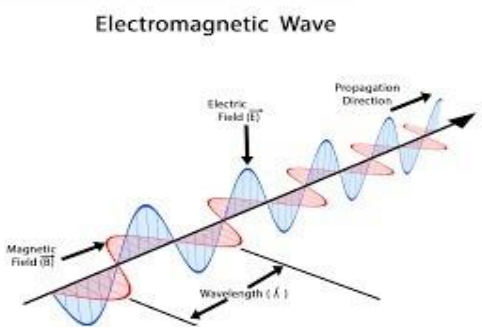
# Introduction

The extended introduction is available in the tutorial:
https://www.youtube.com/watch?v=LlhmzVL5bm8

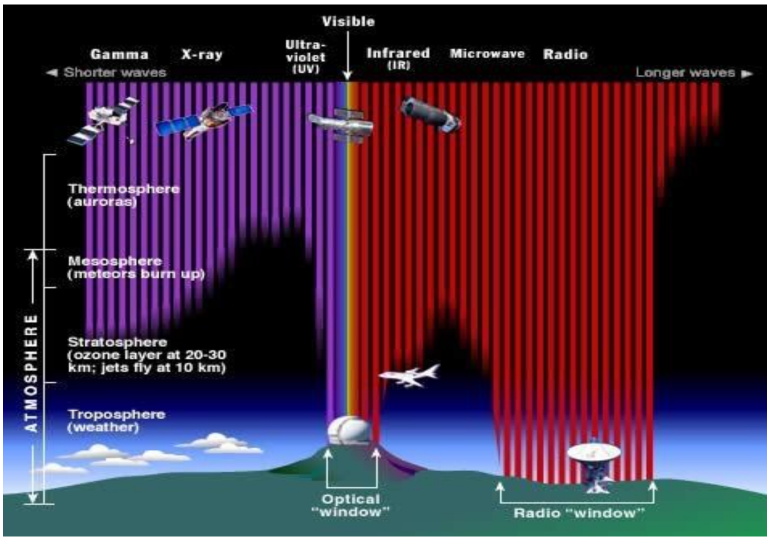
<u>What the light is?</u>

Visible light: wavelength between 700 and 400 nm, the part of electromagnetic spectrum that we can see and which is expressed through rainbow colours.



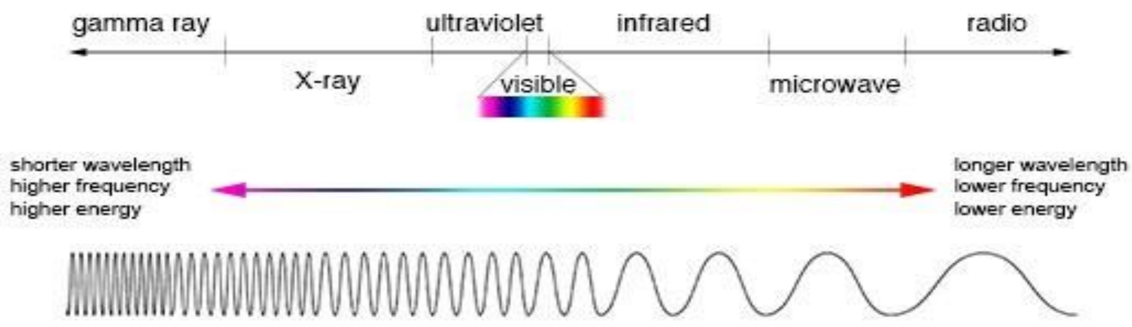




- ✓ atmosphere of our Earth acts as a filter blocking large part of electromagnetic spectrum except the visible and radio one
- ✓ that's why we can use radio telescopes from the ground to study while for other frequencies it is necessary to construct and send special telescopes in space – satellites
- ✓ some animals, such as bees, can see parts of electromagnetic spectrum that we cannot see (such as ultraviolet light or infrared): the world does not appear to them as to us



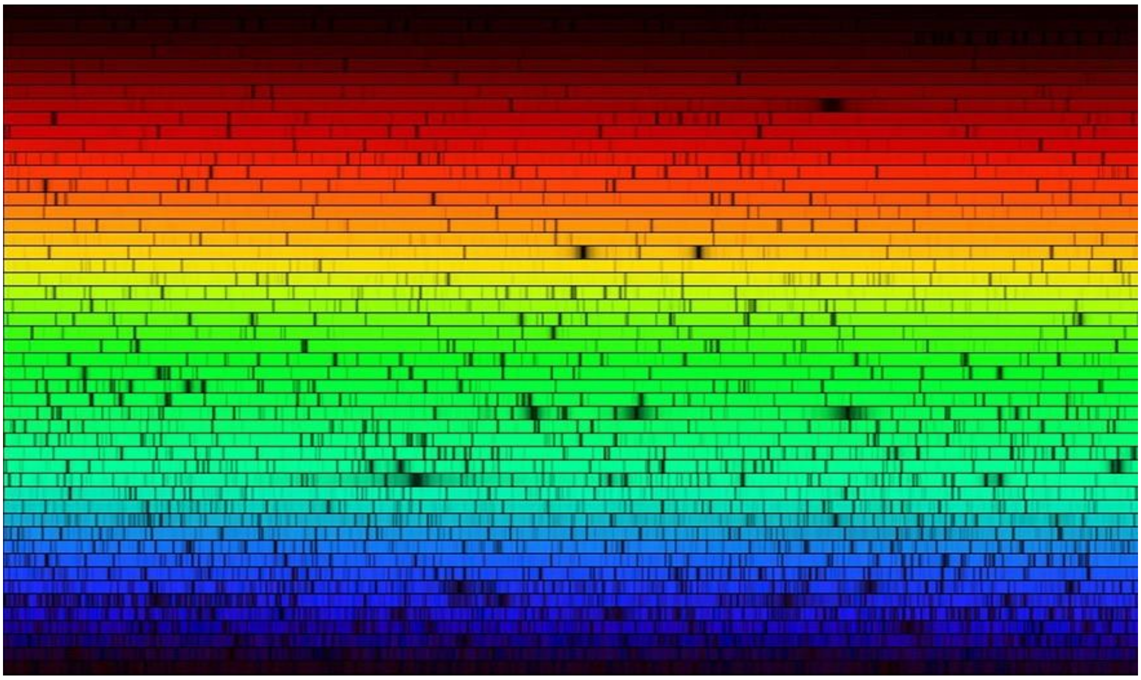
The light which our eyes can detect is part of the visible spectrum:

- there is a lot of radiation around us which is "invisible" to our eyes, but can be detected by other remote sensing instruments
- visible wavelengths cover a range from approximately 0.4 to 0.7 µm the longest visible wavelength is red and the shortest is violet
- this is the only portion of the spectrum we can associate with the concept of colours **(and it's only about 0.0035% of EM spectrum!!!)**




The visible spectrum of  the Sun

It spans the range of visible light colours, including orange and yellow and green, and ends at the bottom with blue and violet colours. The dark lines throughout the spectrum are caused by absorption of light by various elements in  the Sun's atmosphere. This dark-line absorption spectrum  is sort of like a fingerprint of  the Sun; it provides scientists with lots of information about the chemical composition of the Sun and even about the temperature of different regions of the solar  atmosphere.



The visible spectrum of the Sun (credit: N.A.Sharp, NOAO/NSO/Kitt Peak FTS/AURA/NSF)

## So, what is the color of the Sun?

Sun is essentially all colours mixed together which appear to our eyes as white.

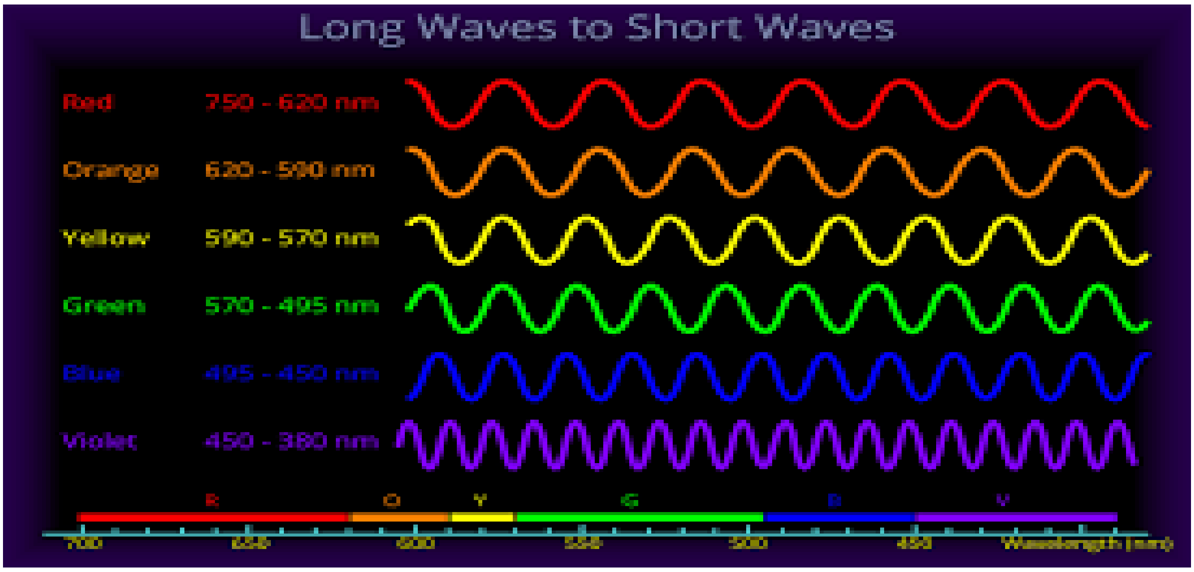
When we see it at sunrise or sunset, when it is low in the sky, it may appear yellow, orange, or red – because its short-wavelength colours (green, blue) are scattered out by the Earth's atmosphere, much like small waves are dispersed by big rocks along the shore. So only the reds, yellows and oranges get through the thick atmosphere to reach our eyes.


The Sun seen from the space (credit: NASA) and from the Earth during a sunset (credit: timeanddate.com)

## And why the sky is (often) blue?

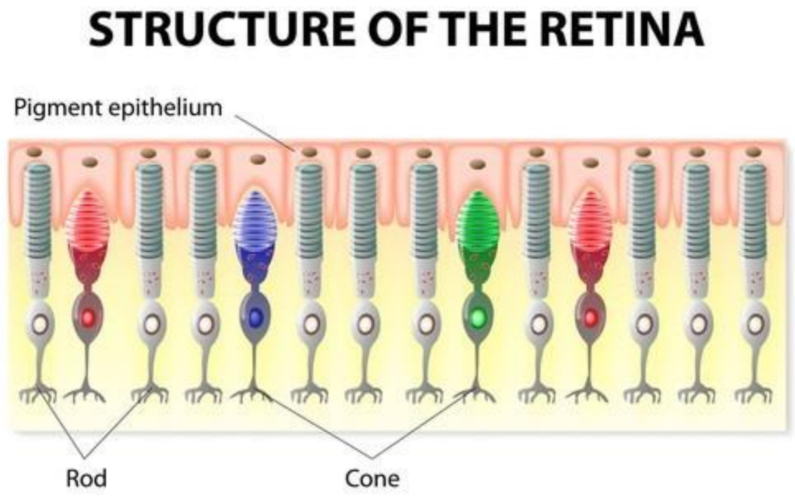
As white light passes through our atmosphere, tiny air molecules cause it to scatter. When the Sun is high in the sky, the shorter waves (blue ones) strike air molecules in the upper atmosphere. Violet and blue light have the shortest wavelengths, so blue light is scattered more than red light and the sky appears blue during the day.

When the Sun is low in the sky during sunrise and sunset, the light has to travel further through the Earth's atmosphere. We don't see the blue light because it gets scattered away, but the red light isn't scattered very much – so the sky appears red.

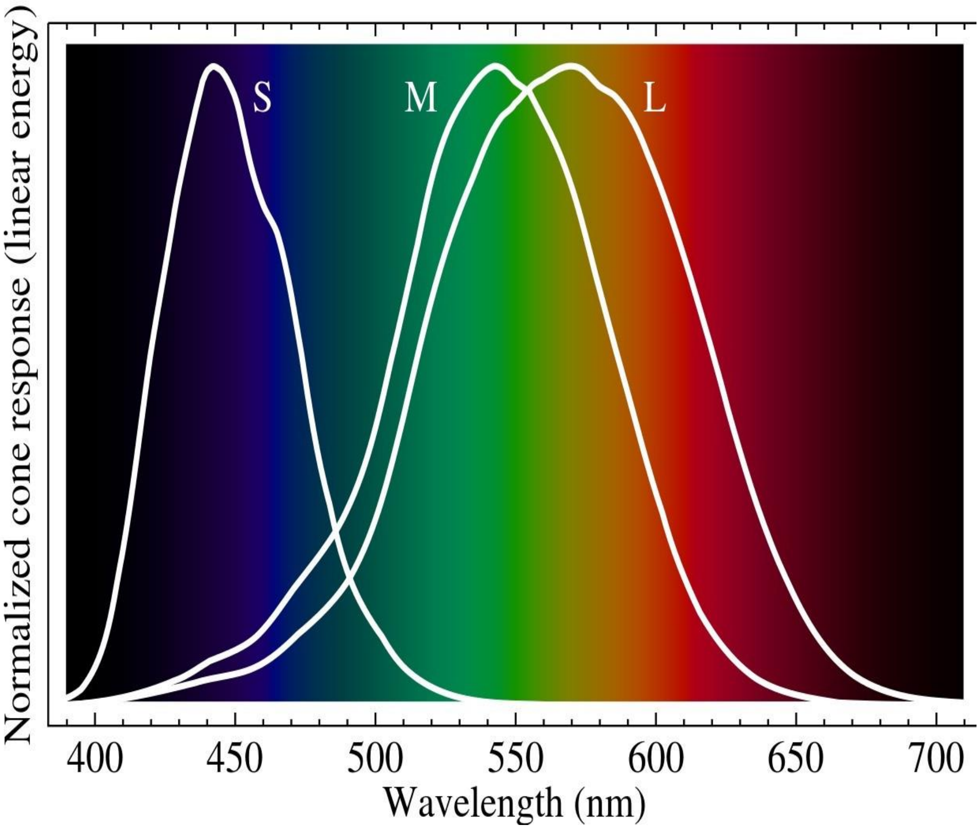


Our perception of colours

- We have specialised retinal cells – cone cells, equate to pixels on an imaging sensor

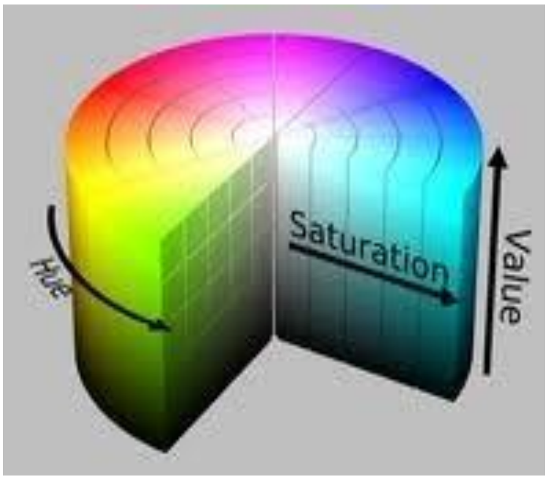



- Cone cells contain different forms of opsin (a pigment protein) that have different spectral sensitivities
- Three cone types result in trichromatic colour vision (like a RGB system)
- The peaks of their spectral sensitivities: short (S), medium (M) long (L) cone types




- Human brain combines the information from each type of receptor to give rise to different perceptions of different wavelengths.

Technical introduction – characteristics of a colour




How a computer 'sees' a colour?

**hue** refers to the wavelength of light, which we commonly just call 'colour = **base pigment**

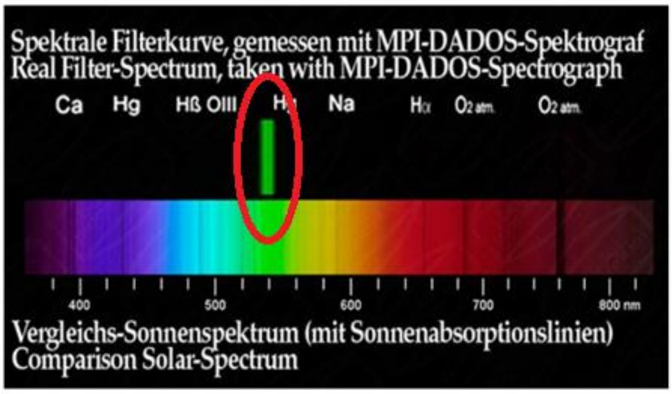
**saturation** refers to how pure the colour is, or how much white is mixed in with it. For example, 'pink' can be considered a less saturated version of 'red' = **more pigment**

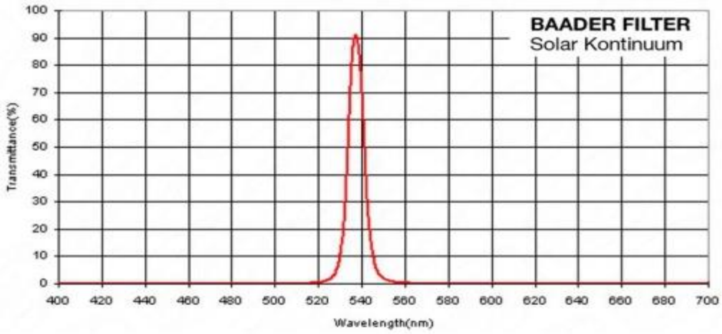
**value** (also: brightness) refers to the relative lightness or darkness of a colour, If you take a colour and remove all hue, you are left with value - basically grey scale = **brighter colour**



Astronomical filters

Small optical elements installed to a telescope. They are made of special glass that blocks most of the wavelengths coming from a celestial object except for a specific range of wavelengths.

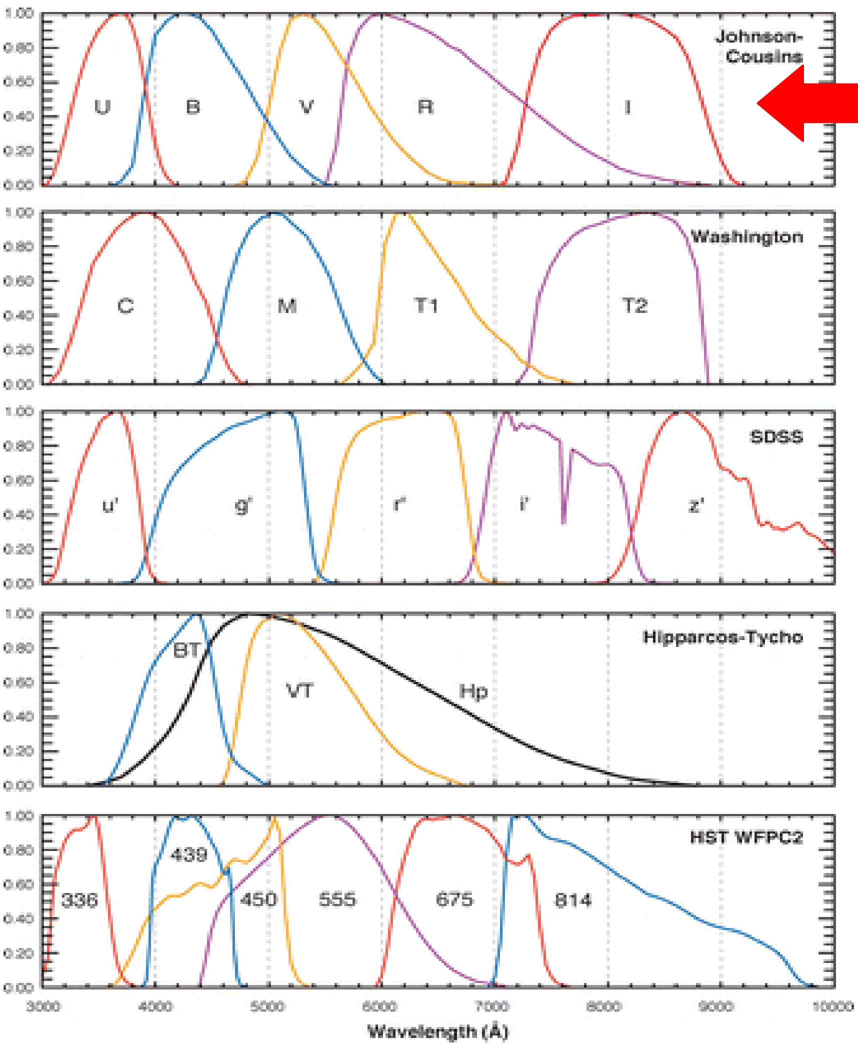



For example this filter blocks the radiation except for a part of green light (the wavelength range is given in the plot).

Popular astronomical filters systems:

UBVRI standard (Johnson-Cousins) – one of the most popular one

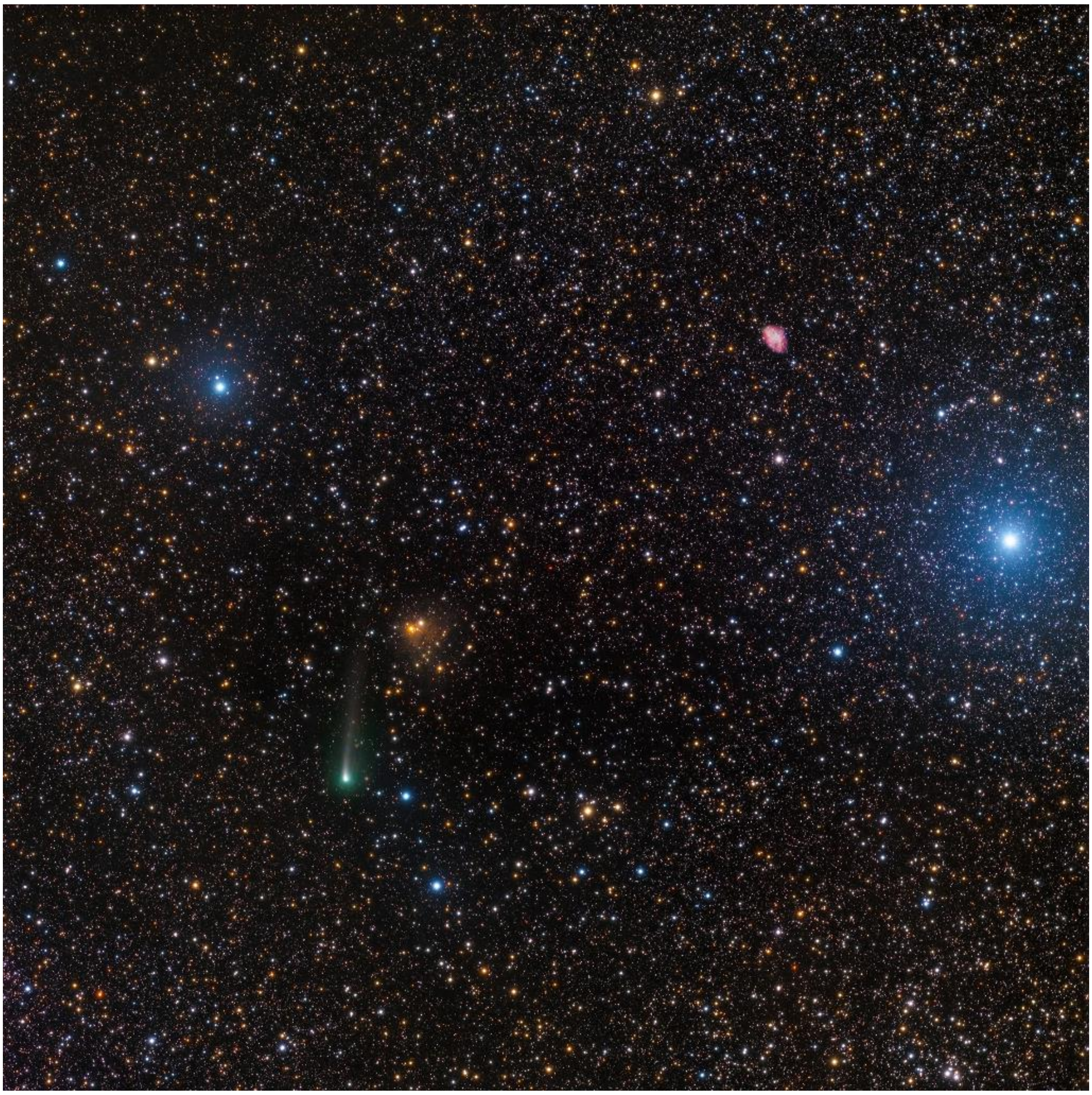



Bessell, MS. 2005
Annu. Rev. Astron. Astrophys. 43: 293–336

**U – ULTRAVIOLET**
**B – BLUE**
**V – VISIBLE**
**R – RED**
**I - INFRARED**

**Ultraviolet and infrared are not visible for human eyes**

An astrophoto



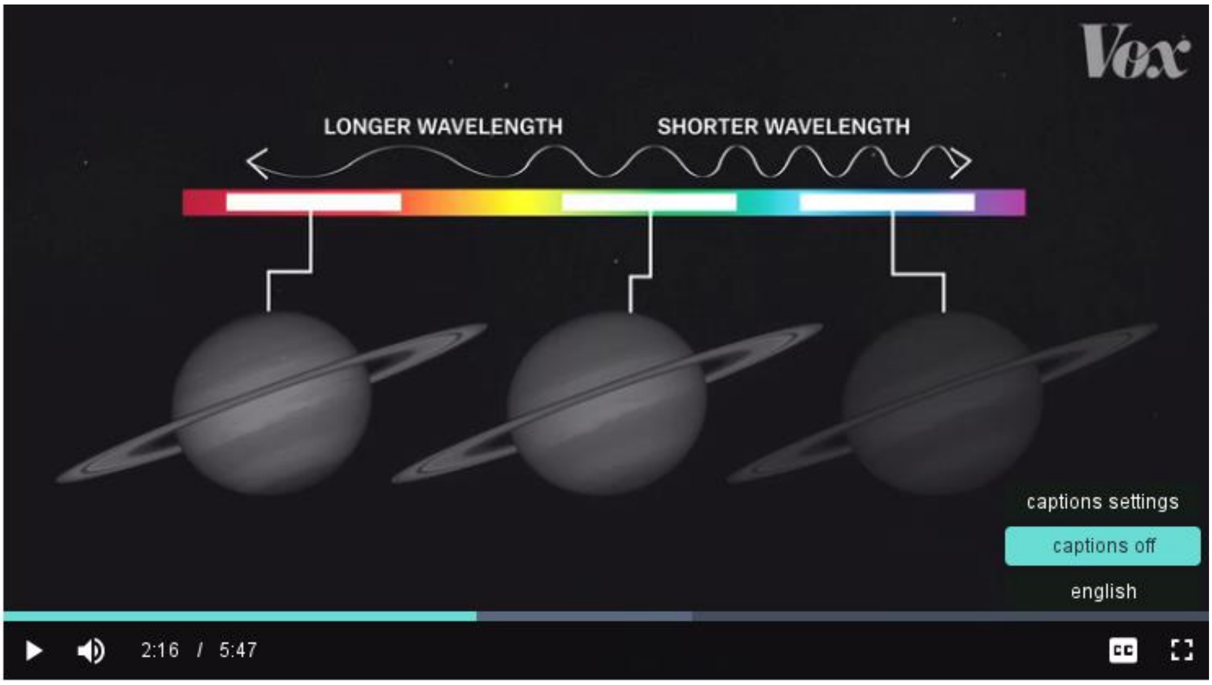
A composition of three different Johnson-Cousins filters (B, V and R):

- R - fuzzy reddish M1 – Crab Nebula
- V - green coma of periodic comet 67P Churyumov-Gerasimenko
- B – young blue stars in our Galaxy
- mix of V and R filer - older yellow or red stars

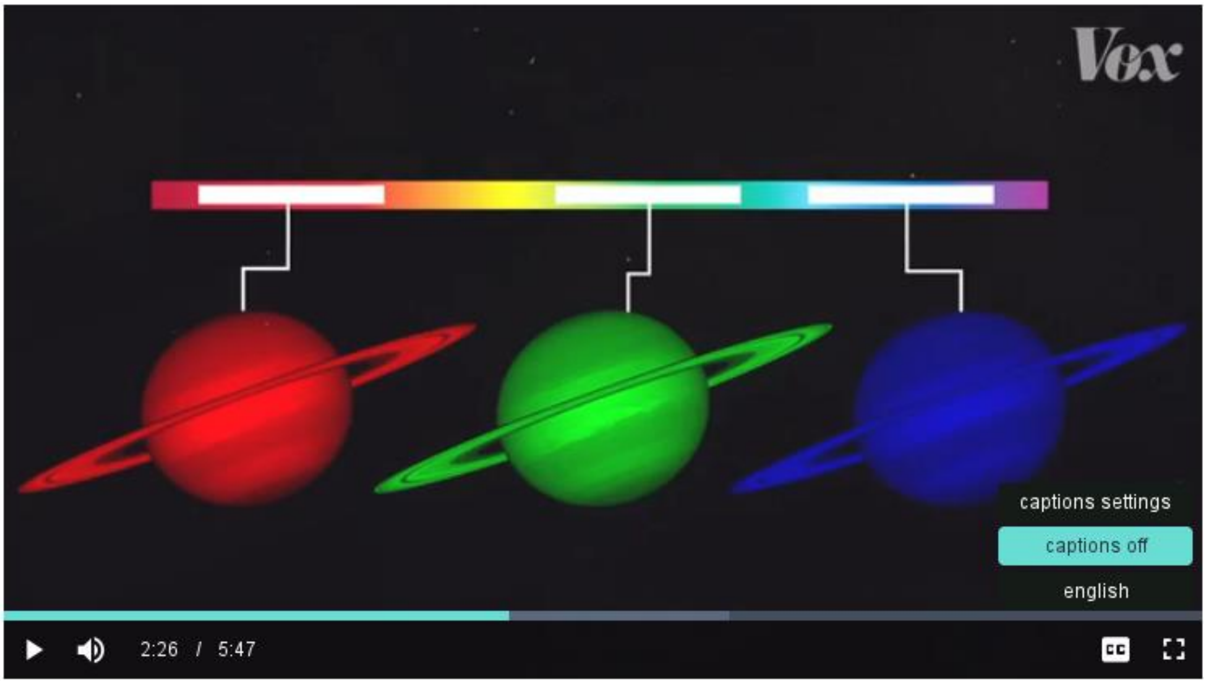
Telescopes take only photos in black and white. To make those beautiful space photos you've probably seen, scientists add the colour later, using a technique developed around the turn of the 20th century that imitates how our eyes naturally perceive colour.

A telescope collects a light that is recorded by a camera. If you use filters only a certain range of wavelengths are recorded. Only the intensity of the collected radiation is saved as a picture. So the first, raw pictures read by the camera are in grey scale. **If you want to see colours, the astropictures must be colourised.**

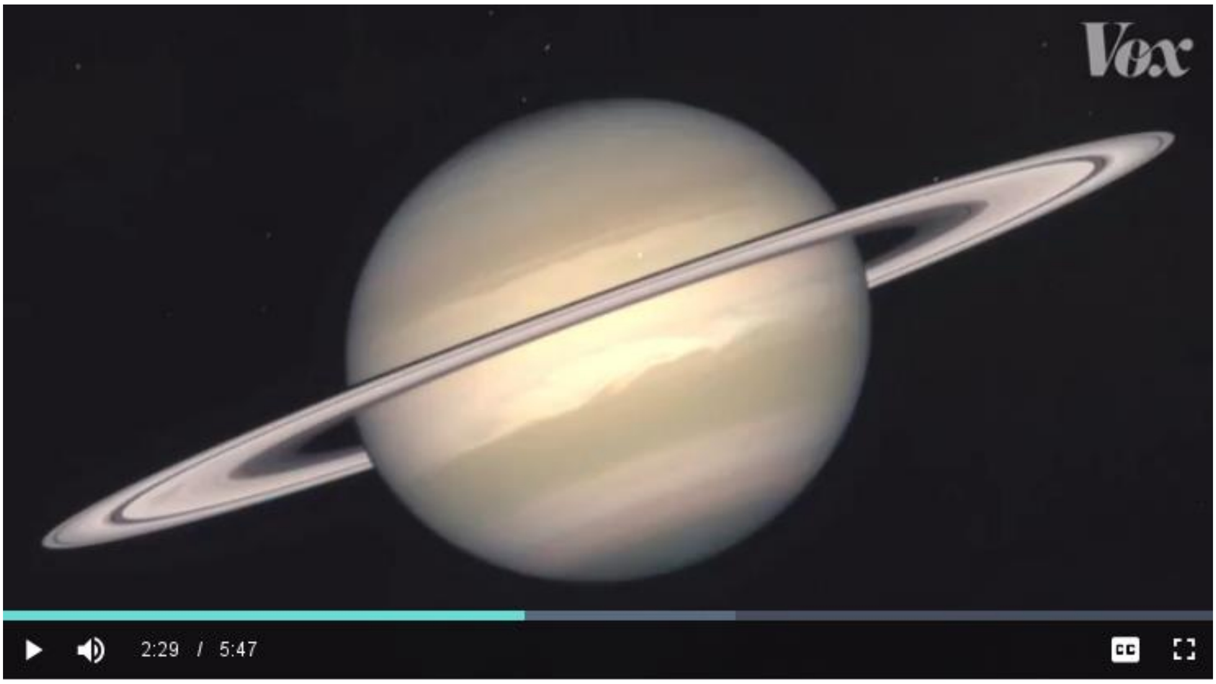
Raw picture taken by the Hubble Space Telescopes at different wavelengths:




Colourised pictures in separate filters:



The final astrophoto:




[The full video is available here: https://www.facebook.com/watch/?v=377485392950754]

# Prepare your own astrophoto

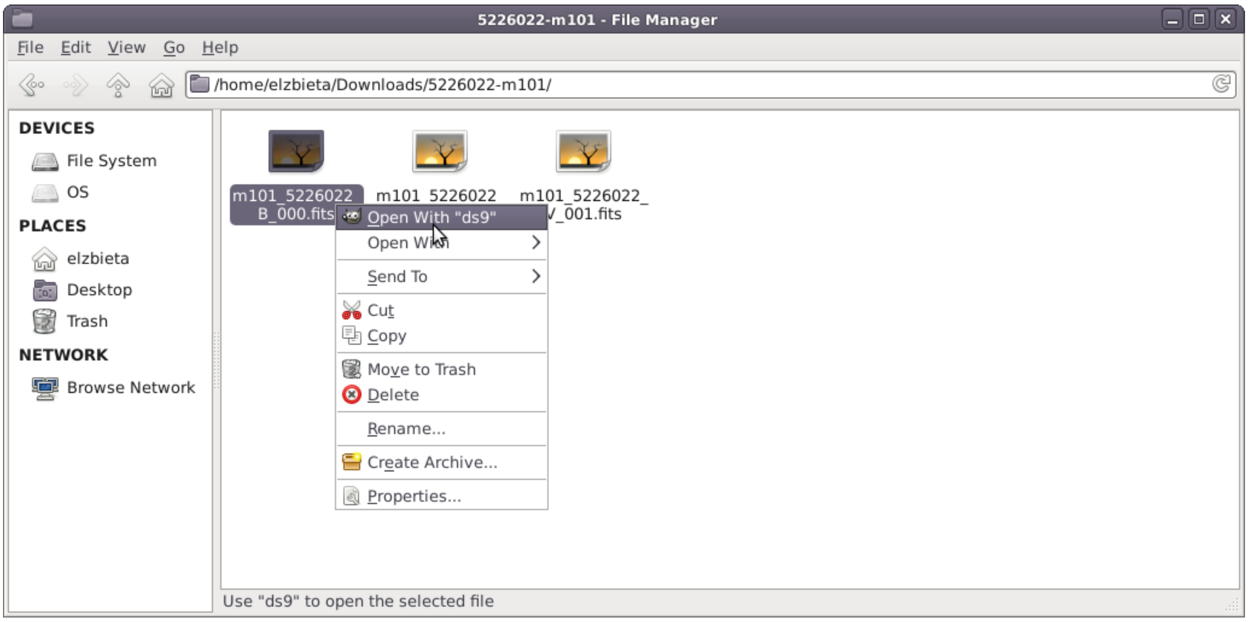
1. Download source data - pictures of spiral galaxy M101 (Pinwheel Galaxy) from **http://byk.oa.uj.edu.pl/~elzbieta/m101/**

# Index of /~elzbieta/m101

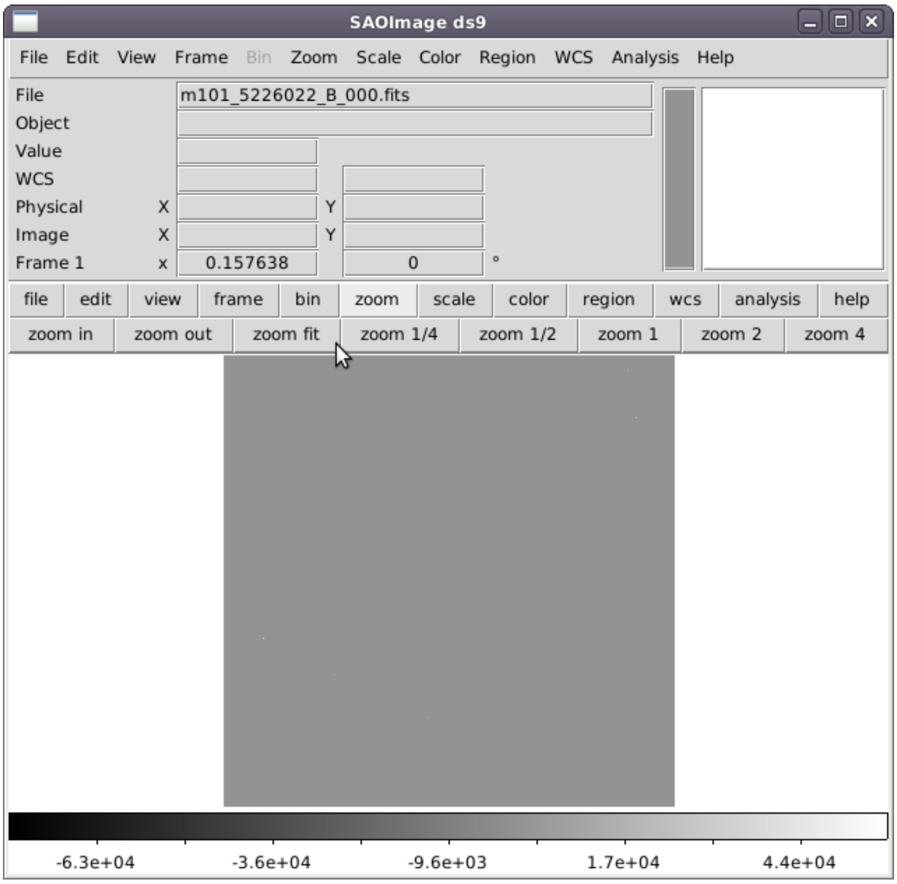
| Name | Last modified | Size | Description |
| --- | --- | --- | --- |
| Parent Directory | | - | |
| m101_5226022_B_000.fits | 19-Apr-2021 09:32 | 16M | |
| m101_5226022_R_002.fits | 19-Apr-2021 09:32 | 16M | |
| m101_5226022_V_001.fits | 19-Apr-2021 09:32 | 16M | |

*Apache/2.2.22 (Debian) Server at byk.oa.uj.edu.pl Port 80*

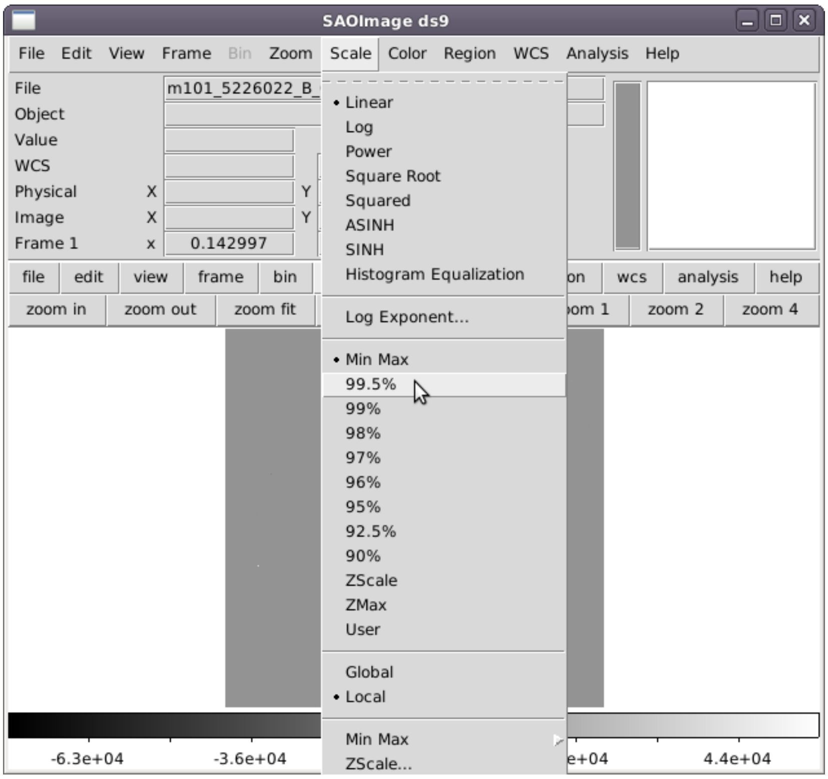
2. Inspect photos of an object in the sky: set of photos taken in colour filters unpacked and then opened using the DS9 program: first the photo in filter B (blue, m101_5226022_B_000.fits), then V (visible light, yellow-green, m101_5226022_V_001.fits) and R (red, m101_5226022_R_002.fits).



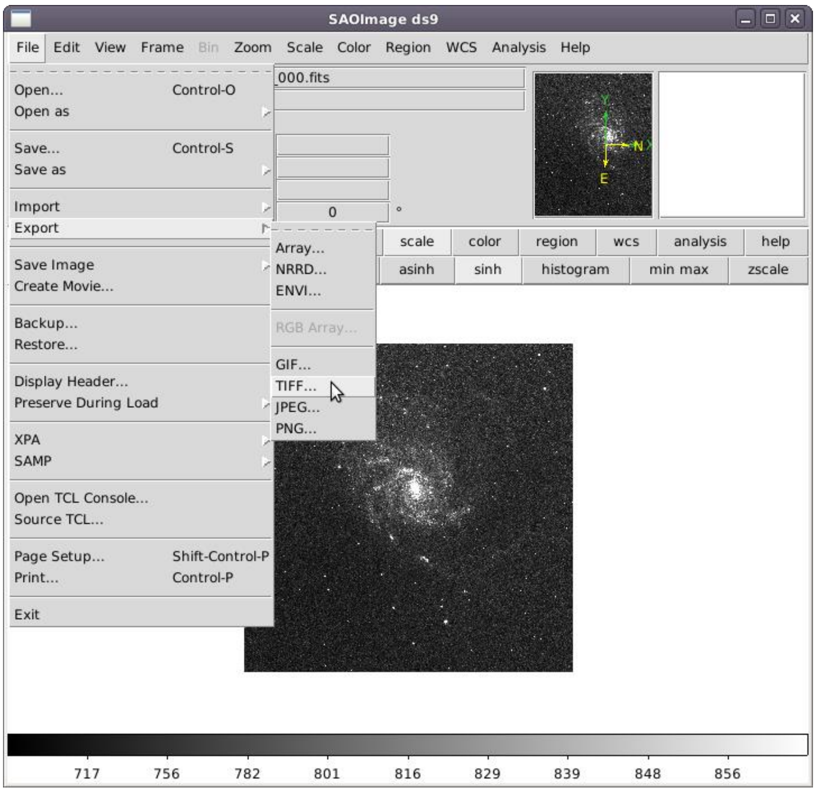

3. In the DS9 program we set:
   - the **Zoom parameter**, i.e. the magnification of the image of the object we are interested in in the sky (it is usually safe to simply select the Zoom fit option),



- the **Scale parameter** (we choose until the image of a galaxy or other object is clearly visible).



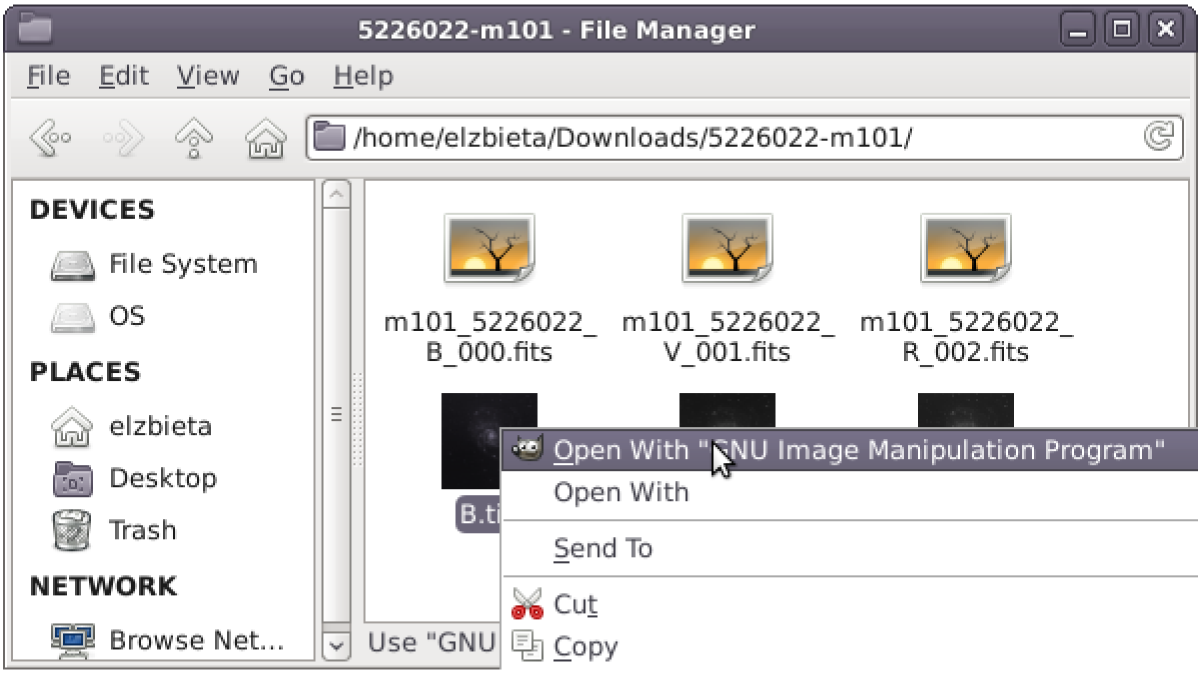

4. After setting the correct scale (image dynamics), save (export) the finished graphic in the TIFF format, and give the image (here in the B filter) an appropriate name, e.g. B.tiff.



5. Do the same for images in V and R filters (it is worth paying attention to the differences in the brightness of individual parts of the image, blurring of the recorded image, and the light distribution visible for the object at different lengths of visible light).

6. Inspect the obtained tiff images for filters B, V and R.

7. Choose the first one (in filter B) and open it, this time with GIMP (GNU Image Manipulation Program).




8. Observation filters of the UBVRI standard have a certain effective central wavelength listed here:

**B: 435.3 nm**

**V: 547.7nm**

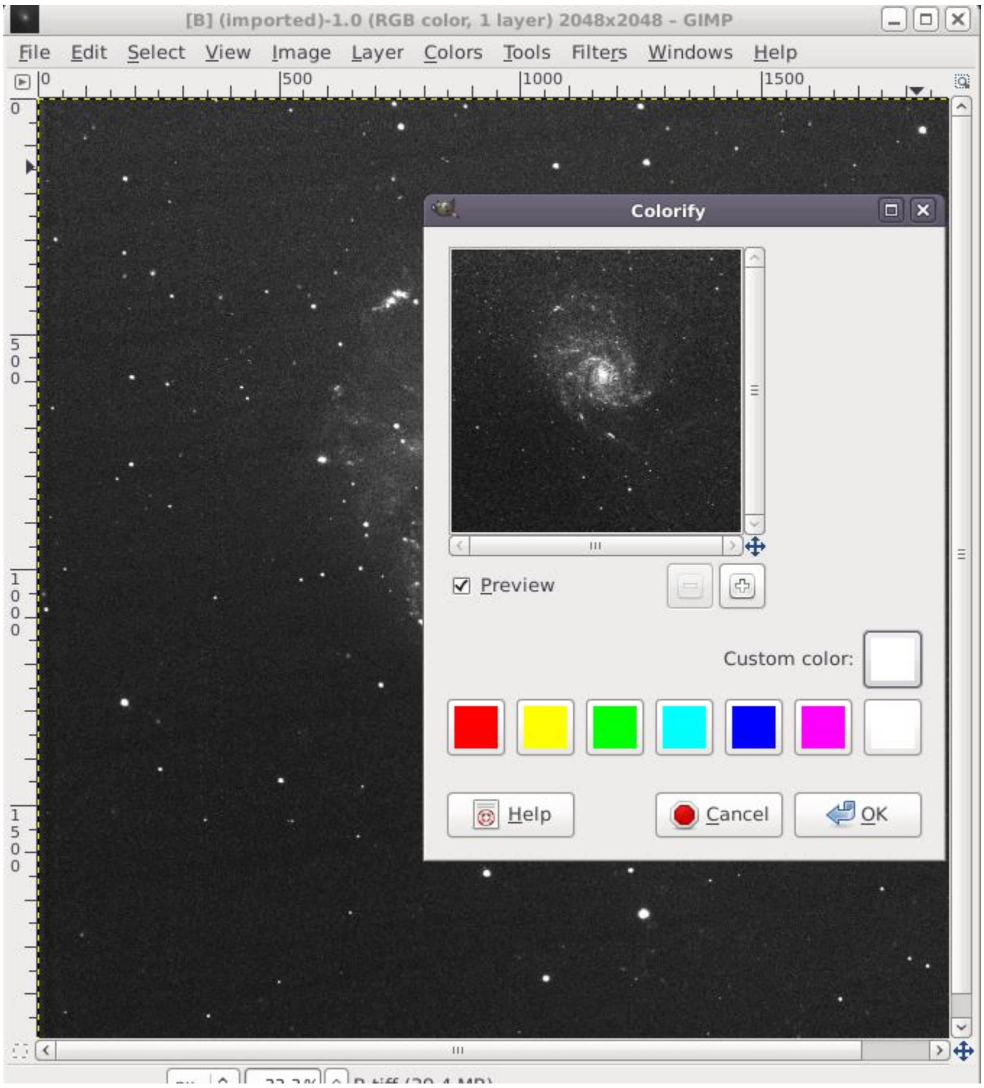
**R: 634.9 nm**

This value must also be converted into a computer and GIMP colour code in HTML notation (hex, RGB).

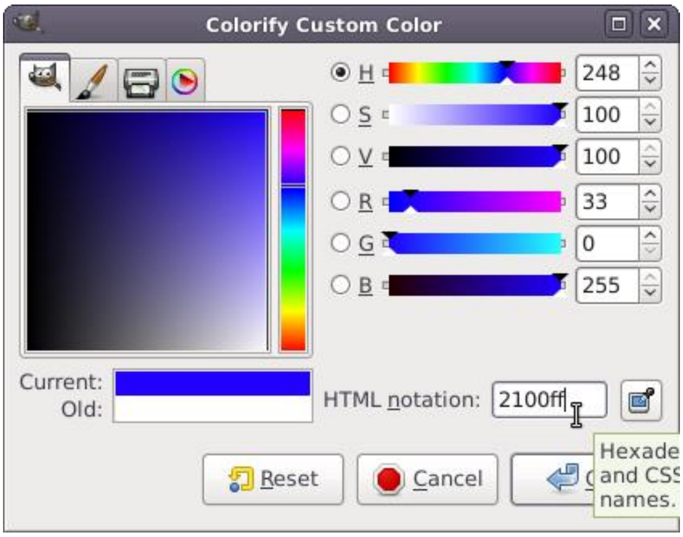
The tools is available here: https://www.johndcook.com/wavelength_to_RGB.html

Read the RGB / hex colour value for a given length of light - in the case of the B filter, its value of **2100ff**.


9. Go back to GIMP. With the M101 galaxy image open in filter B, choose the **Colors** → **Colorify tool**. After the dialog box appears, select the **Custom Color** field.

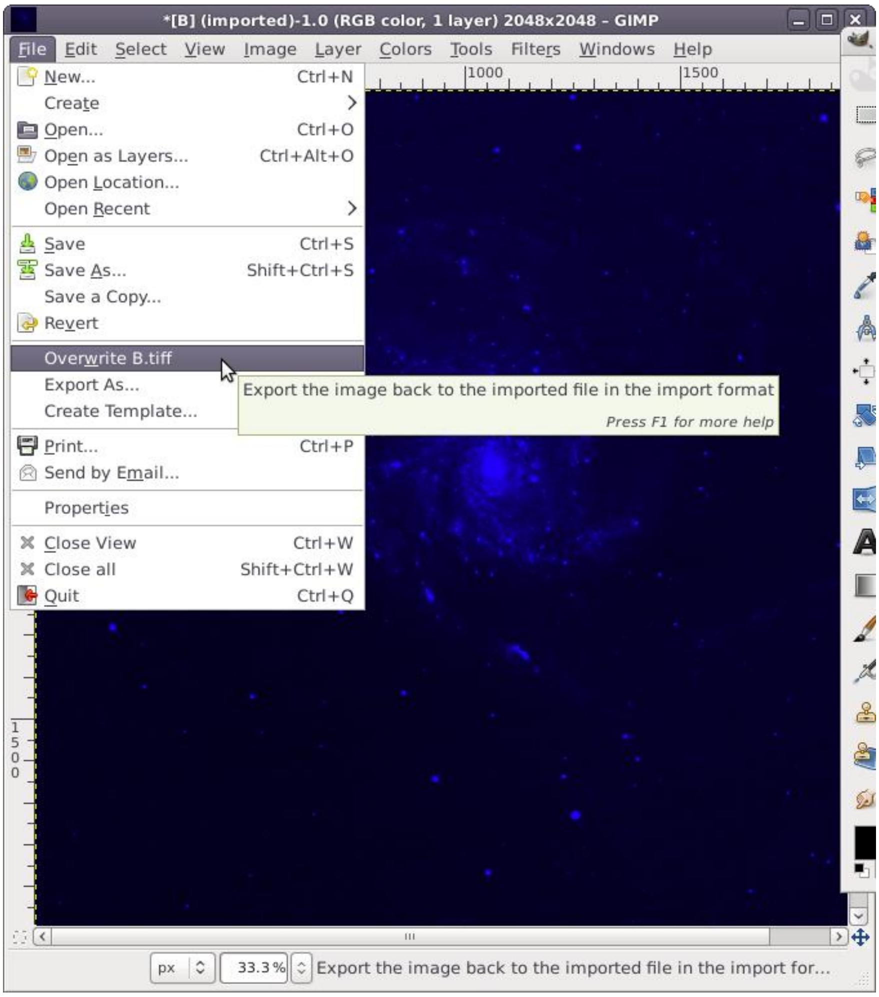


10. In the Custom Color field, enter or paste the RGB / hex code obtained a few steps above: for the B filter: 2100ff, confirm with the "OK" button.



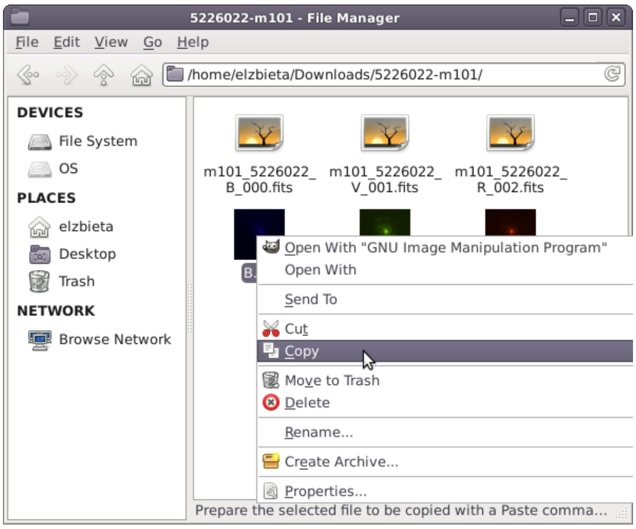

[For Windows users this option can be find in the **Color** button]

11. Save the received image in blue with the command: **File → Overwrite B.tiff** (or use the **Export As…** option).

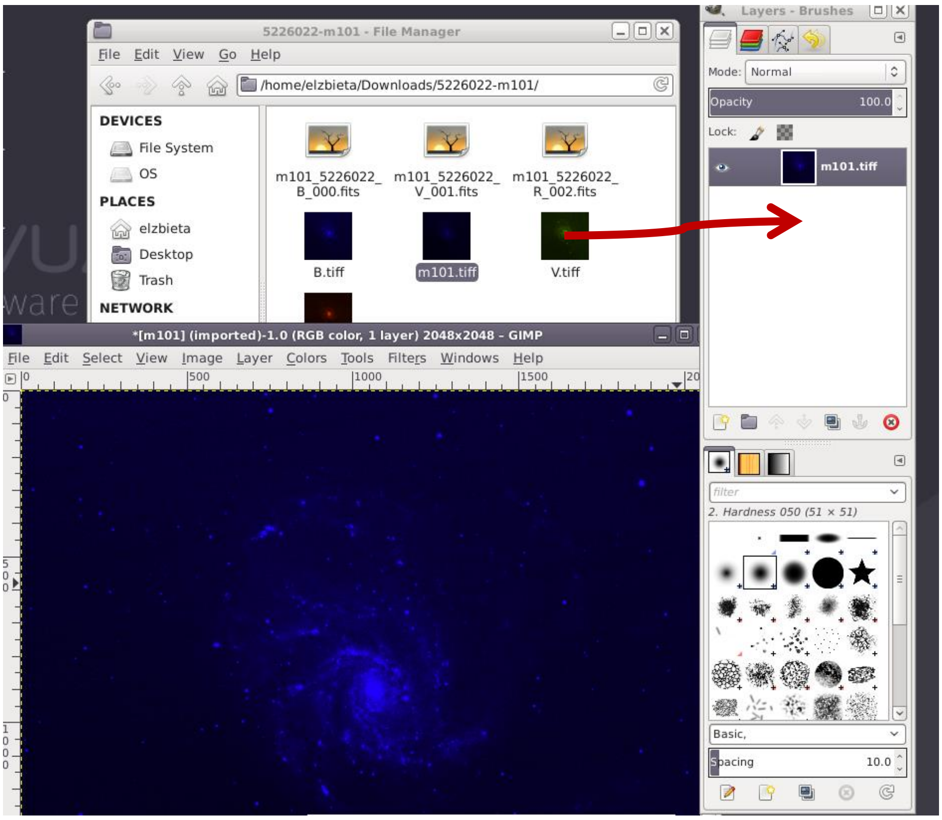


12. Do the same in the case of tiff images for V and R filters - using the program that converts the length of light to color and the GIMP program. As a result, we should get three photos of the same galaxy - blue, yellow-green and red.

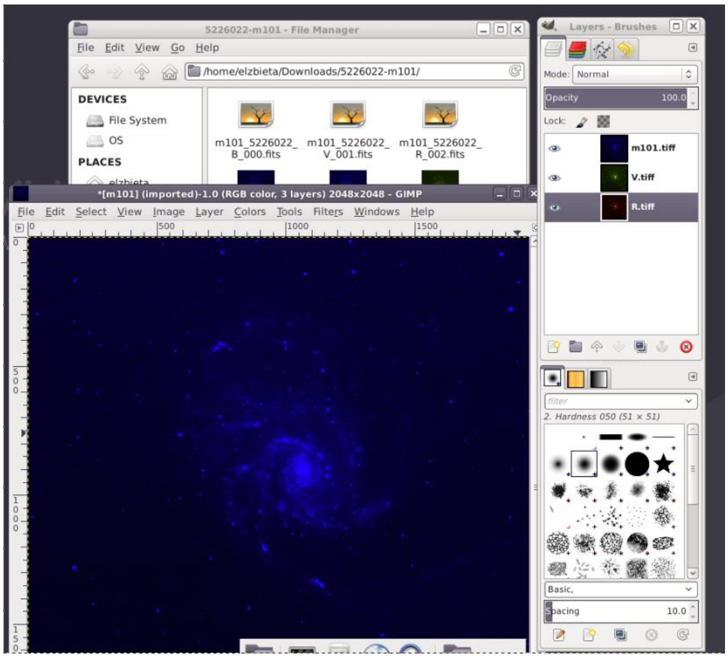
13. Make a copy of the B.tiff image and save in the same directory as m101.tiff.



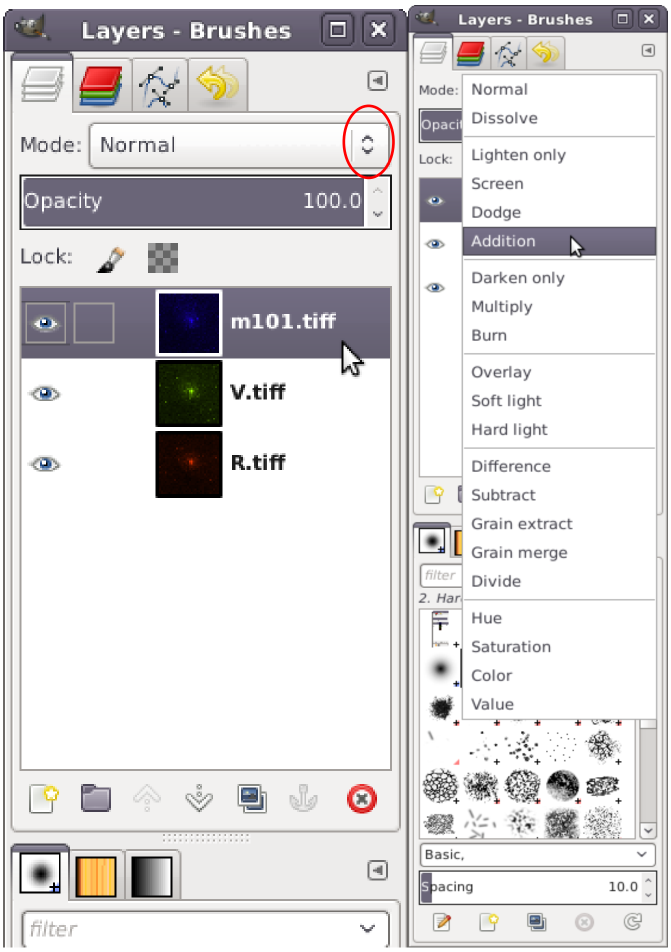

14. Open the m101.tiff image you created in the previous step in a new GIMP window. Check if there is a dialog named **Layers** (if not, start it by selecting from the top menu: **Windows → Dockable Dialogs → Layers**). With the m101.tiff file open and the folder with colour photos in tiff format open separately on the screen, we move the mouse to the Layers dialog box ("picking up" them in the folder and "dropping" them in this window) the V.tiff and R colour images. tiff.



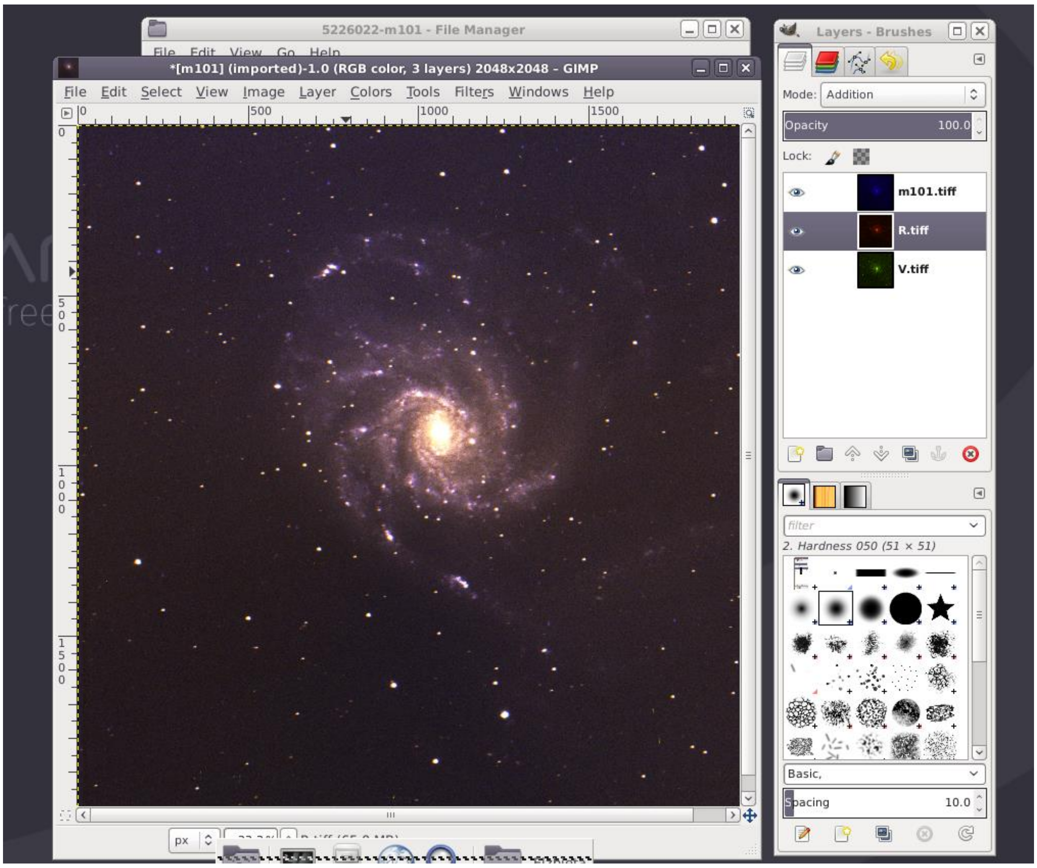
15. Finally. in the Layers window there should be 3 layers - a copy of the image in the B filter (m101.tiff) and the tiff images corresponding to the V and R filters.



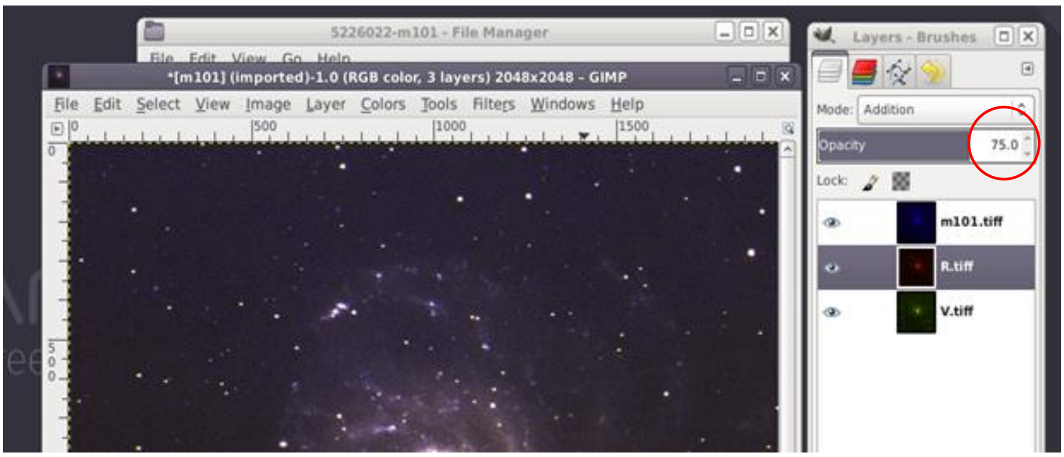

16. Click on the first layer visible from the top - here: m101.tiff. Give it the **Mode: Addition parameter**, which is dropped down in the **Layers window** (at the top).



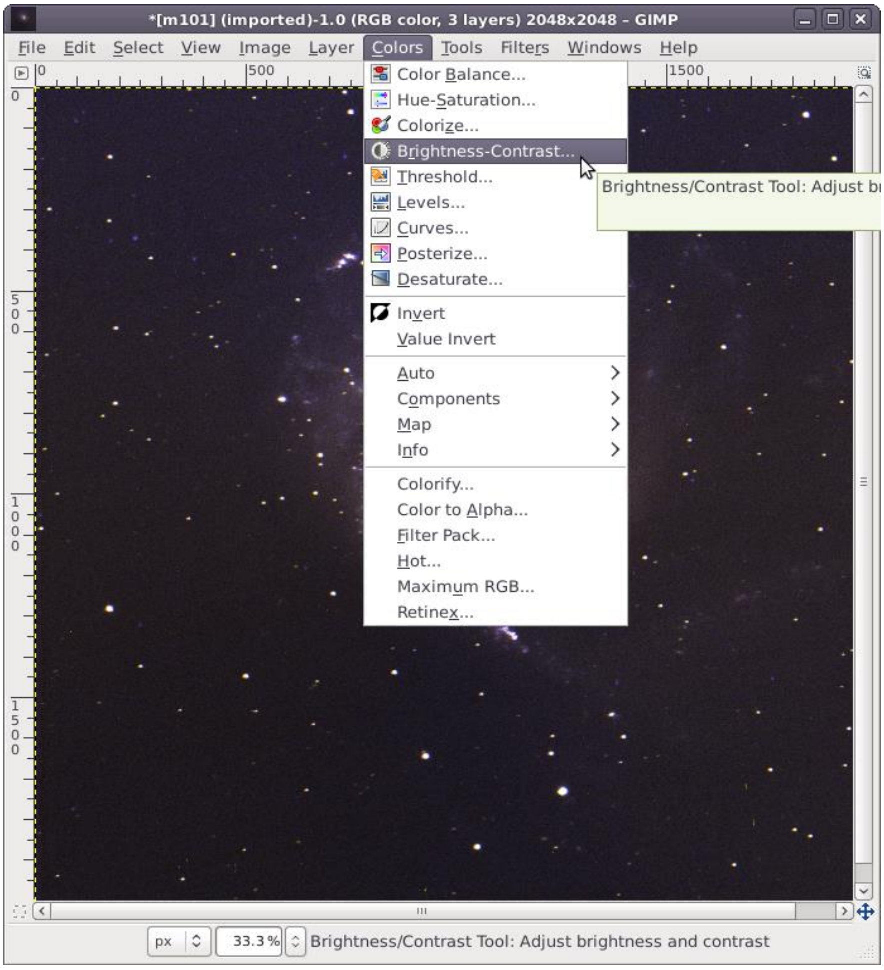
17. After this, the preview of the galaxy photo in the window should change - it should be more "white". We perform the same operation for the next layer, i.e. in the R filter in the example below (if necessary, we move it earlier in the **Layers window** to the second position, between layers B and V. Our colour image is now a composite (addition) of images made in individual filters (colours): B, V and R.




18. We can see that the image of the galaxy is too red in relation to the images of this object that can be found on the web (e.g. on NASA websites). This is due to the different sensitivity of the CCD camera chip to light of a given wavelength. However, we can artificially lower the red filter element into the image. To do this, click on the R.tiff layer in the Layers window (selecting it), and then, in the **Opacity** bar above, reduce its opacity from 100% to 75-80%. After this operation, the galaxy appears less red, and the visible contribution from blue increases.



19. Now, you have M101's colour composition in BVR filters, it can still be digitally sharpened using GIMP (or other software, eg Adobe Photoshop). Use: **Colors → Brightness-Contrast** tool. Reduce the **brightness** of the image and increase the **contrast** by 10 (each time you can experiment with different parameters!)




20. Now, export the photo, e.g. as m101.tiff (it is a graphic format that allows you to save images in high quality and resolution).

    It may be useful to flatten the picture before you save it. You can do it by selecting **Image -> Flatten image**.

# The result