Creating near true color images for nebulae from narrow band data using PixInsight

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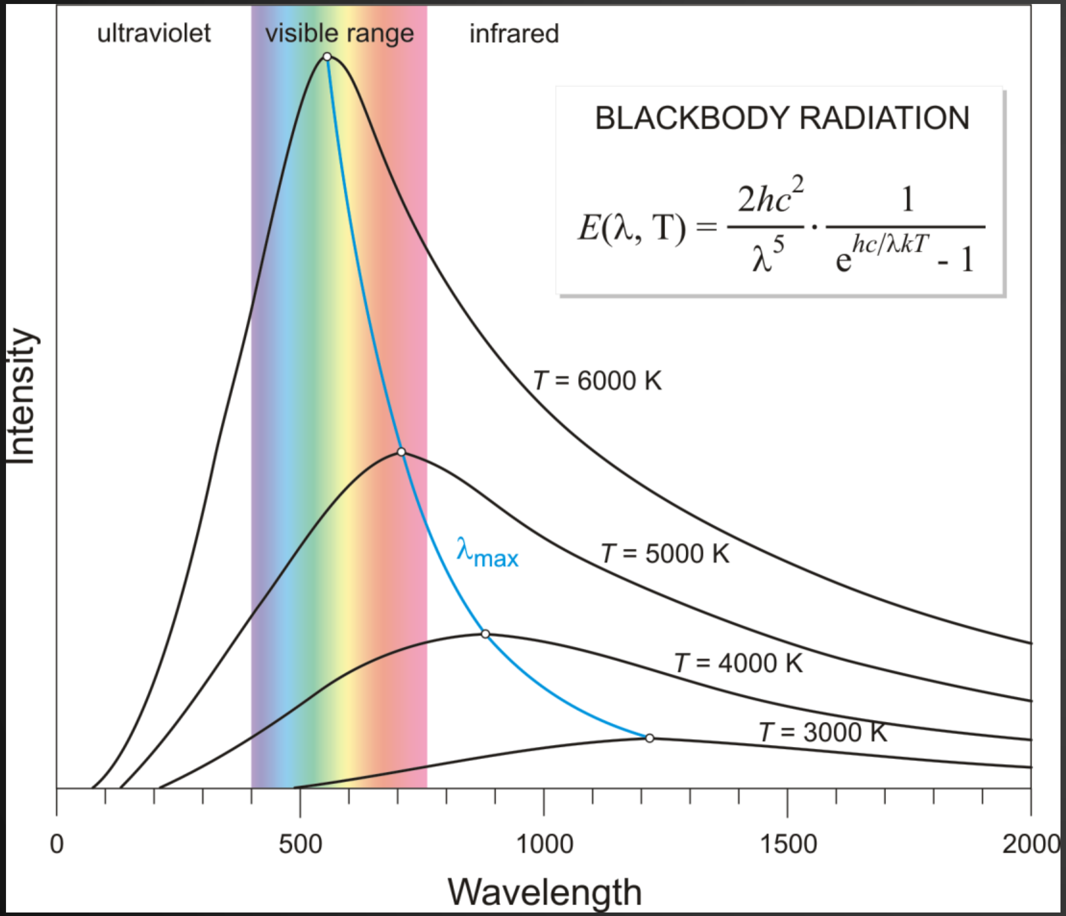
Light emission from celestial bodies

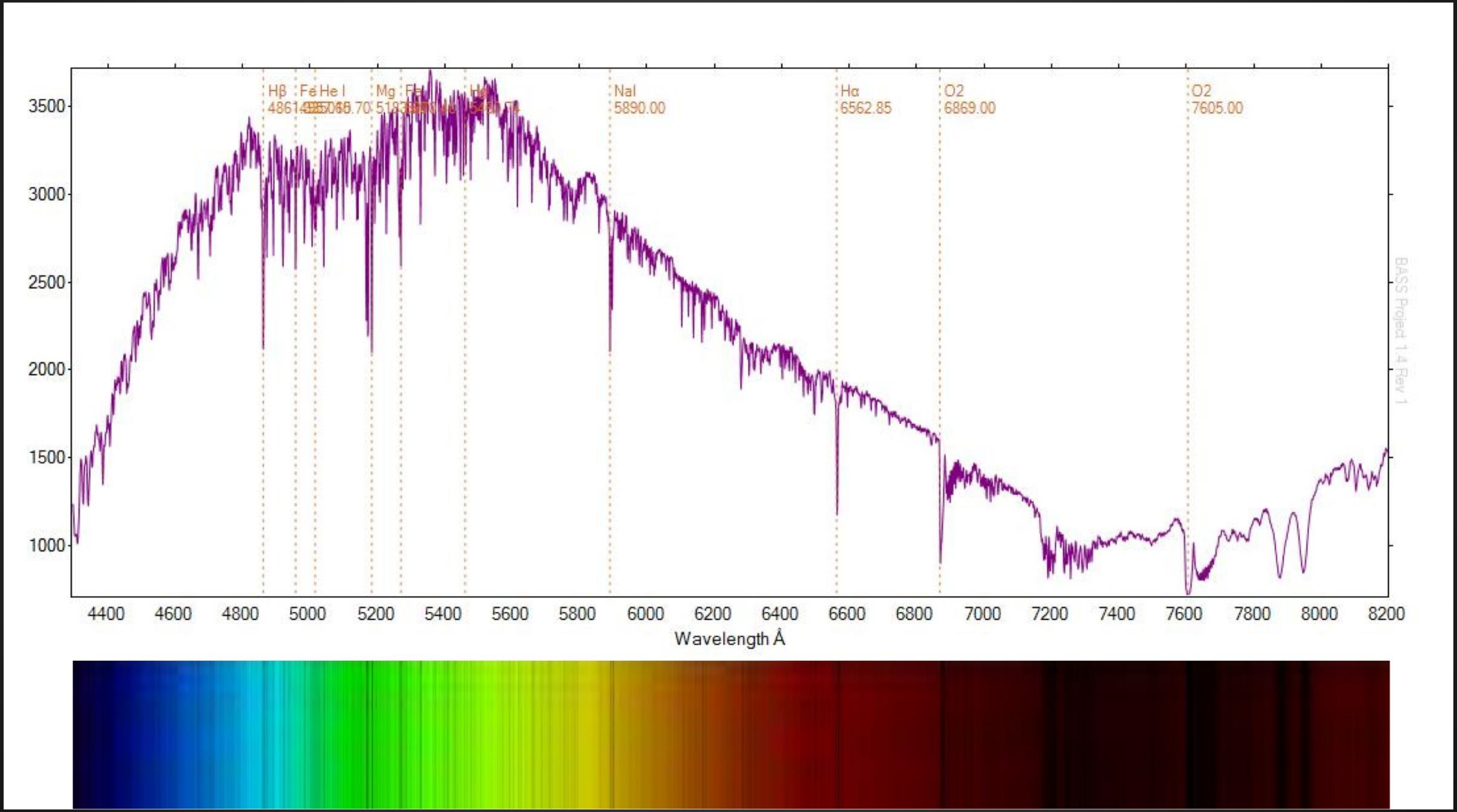
- Continuous emission
  - “Black body” emission
- Line emission
  - Ionized gas recombination

Black body emission



- Emission of stars
- Continuum emission at all the wavelength

Example: Solar spectra



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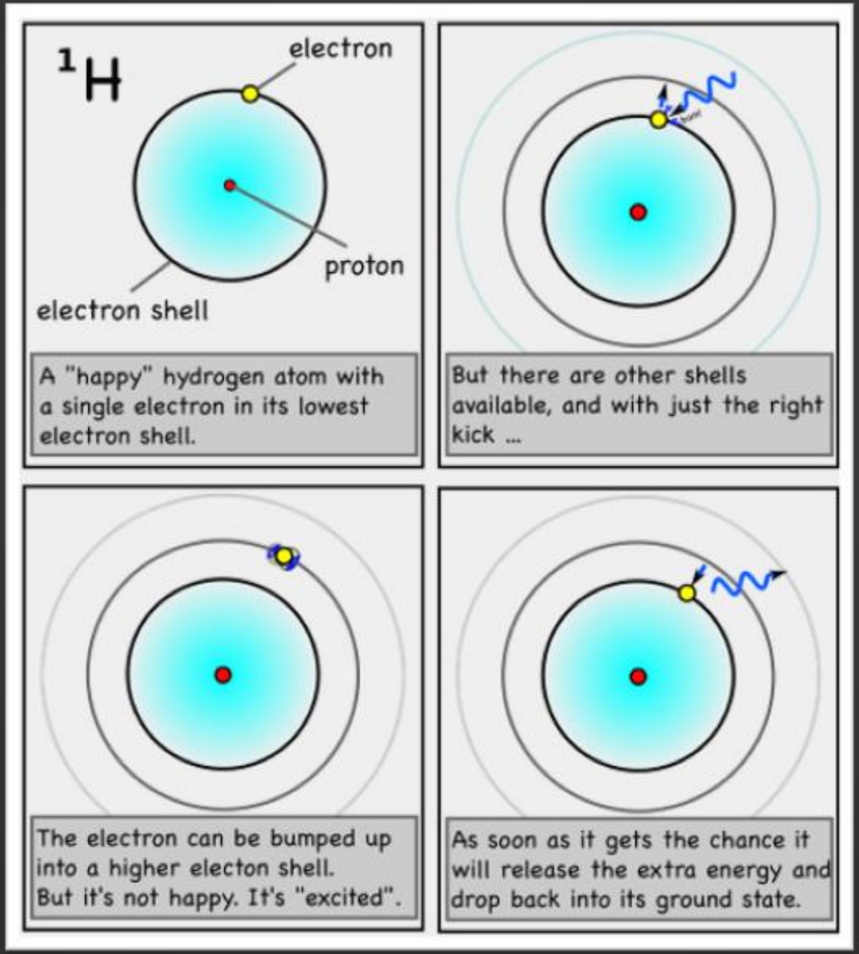
Ionized gas emission



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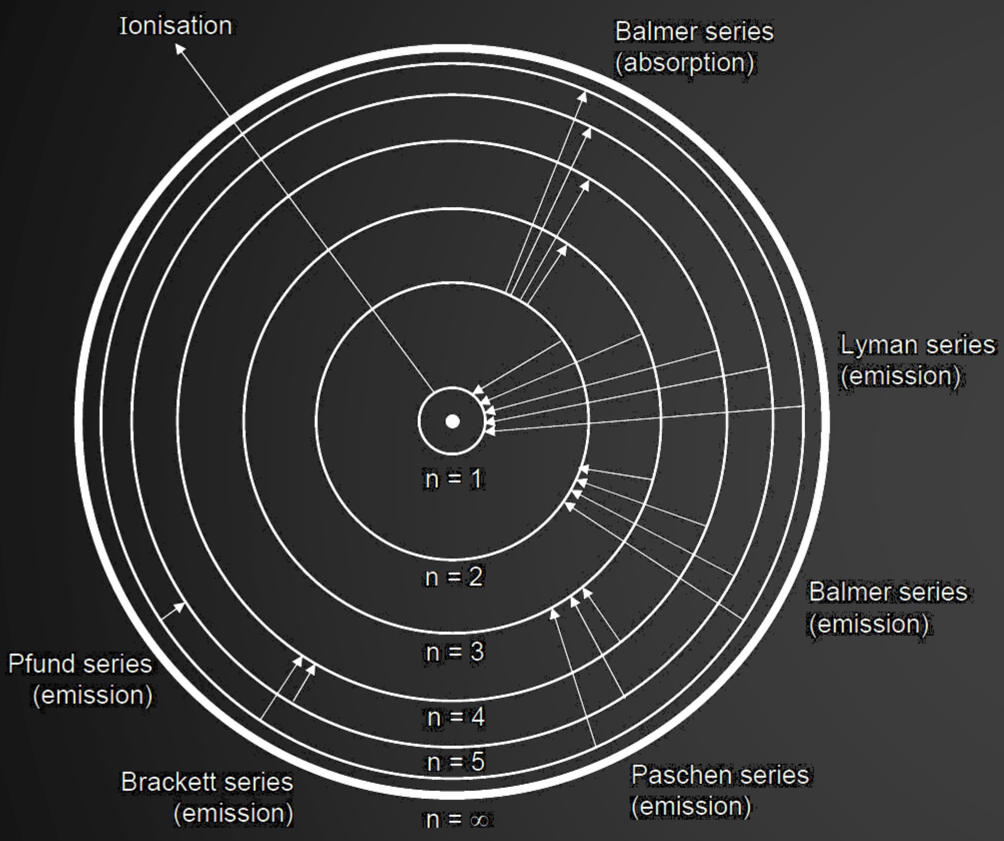
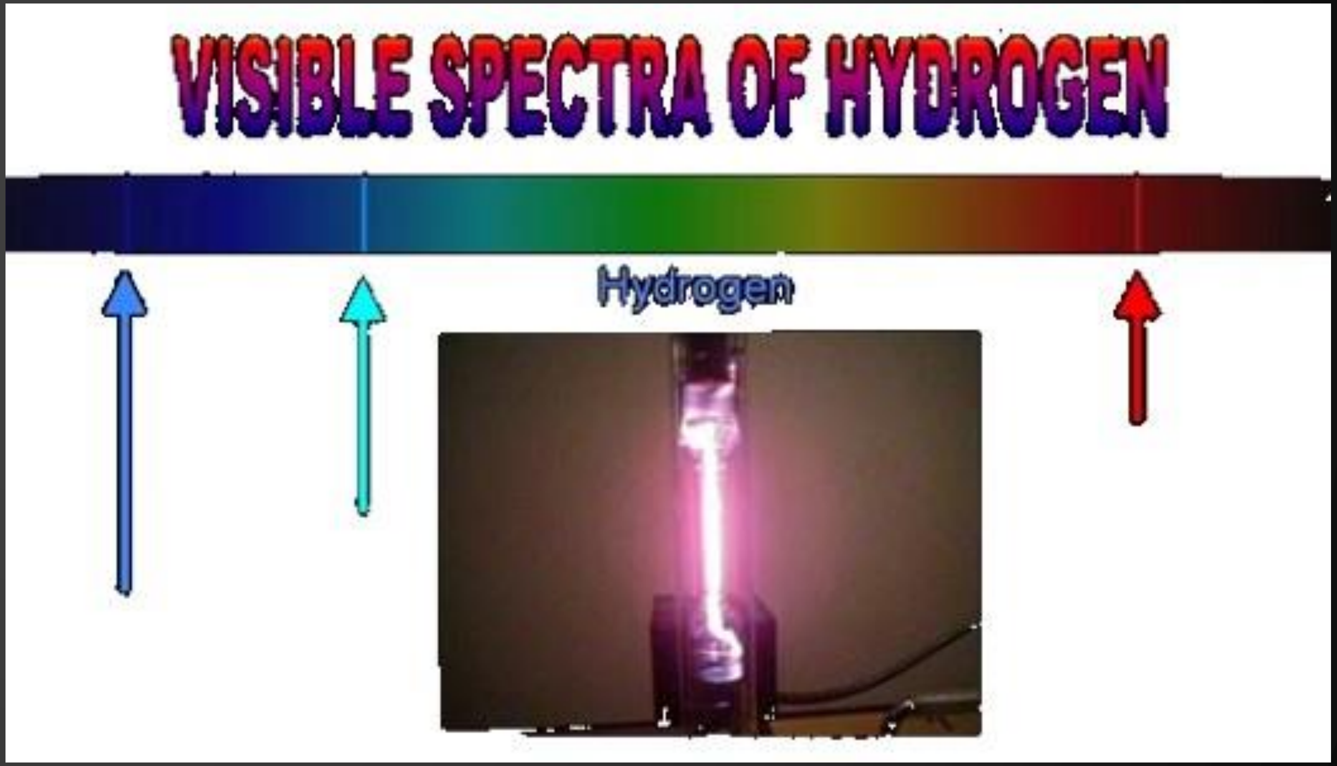
In reality the matter is "slightly" more complex

Bohr Model of the Hydrogen Atom



Spectral series	Emission	Absorption	Frequency
Lyman series	Down to n = 1	Up from n = 1	Ultraviolet
Balmer series	Down to n = 2	Up from n = 2	Visible light
Paschen series	Down to n = 3	Up from n = 3	Near infrared
Brackett series	Down to n = 4	Up from n = 4	Far infrared
Pfund series	Down to n = 5	Up from n = 5	Far infrared



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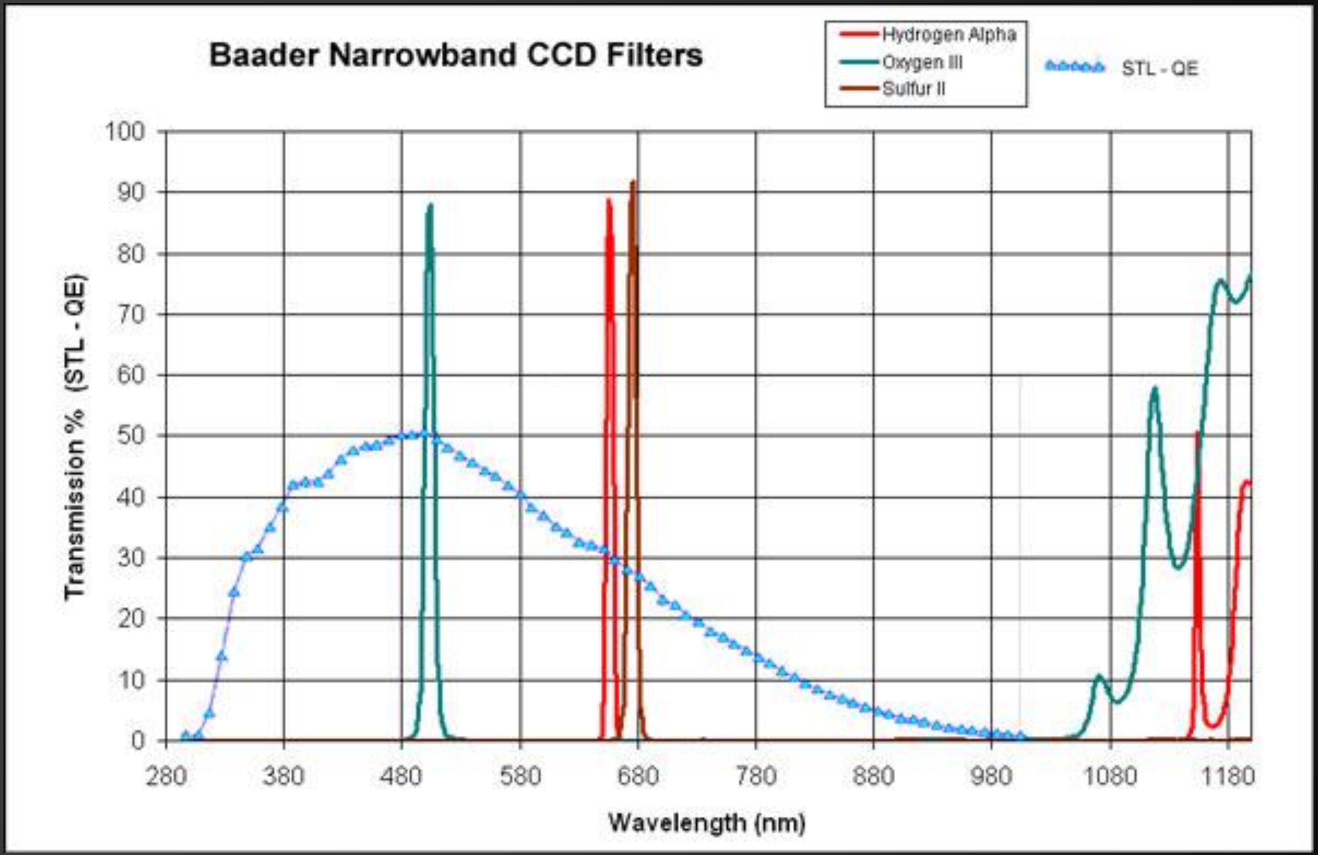
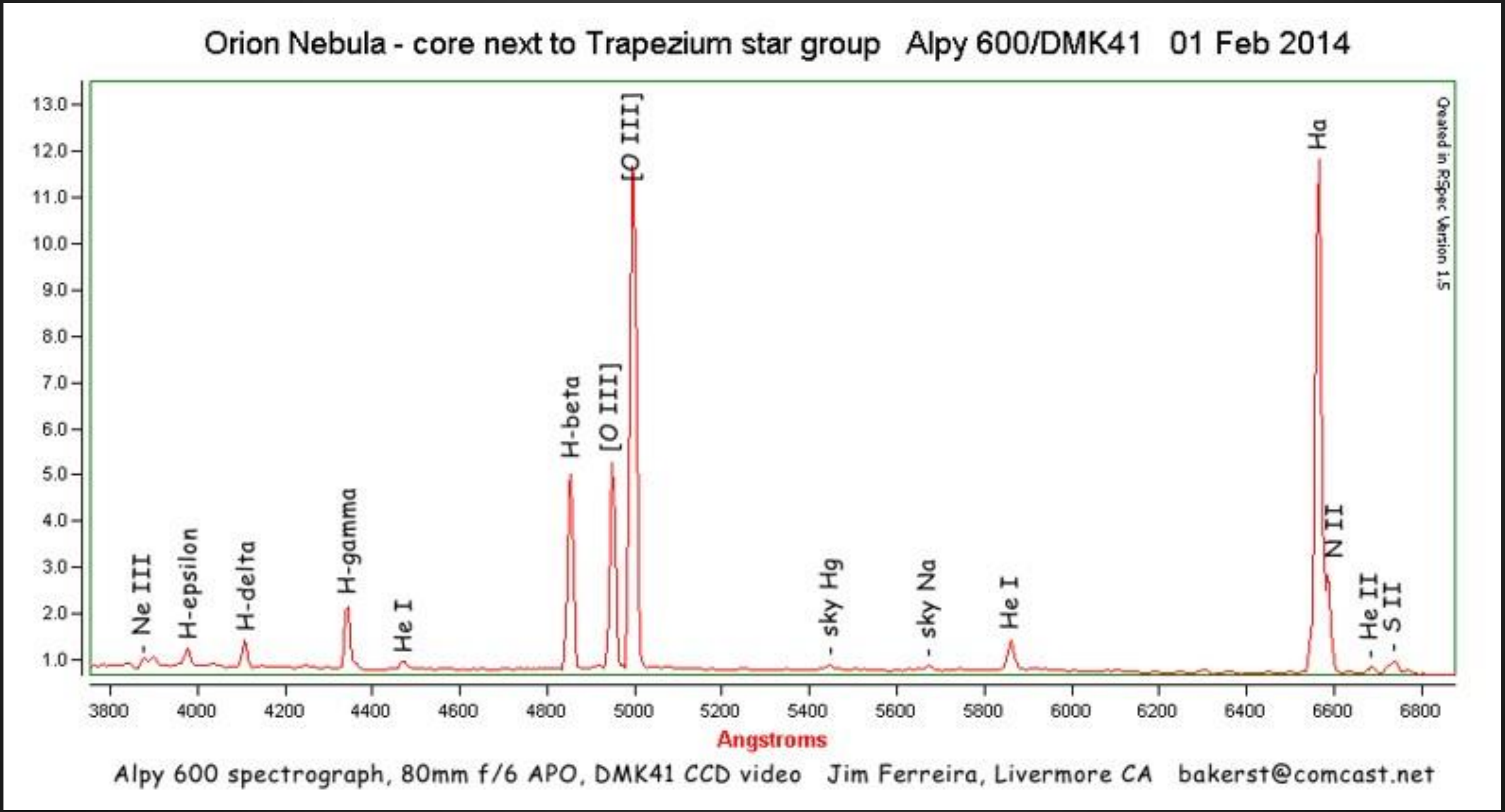
Astrophotograpy filters

- Narrowband filters
  - SII: 672 nm
  - NII: 658 nm
  - Hα: 656 nm
  - OIII: 496-500 nm
  - Hβ: 486 nm

- Typical bandwidth: few nm (< 10)



Example: Orion nebula spectra



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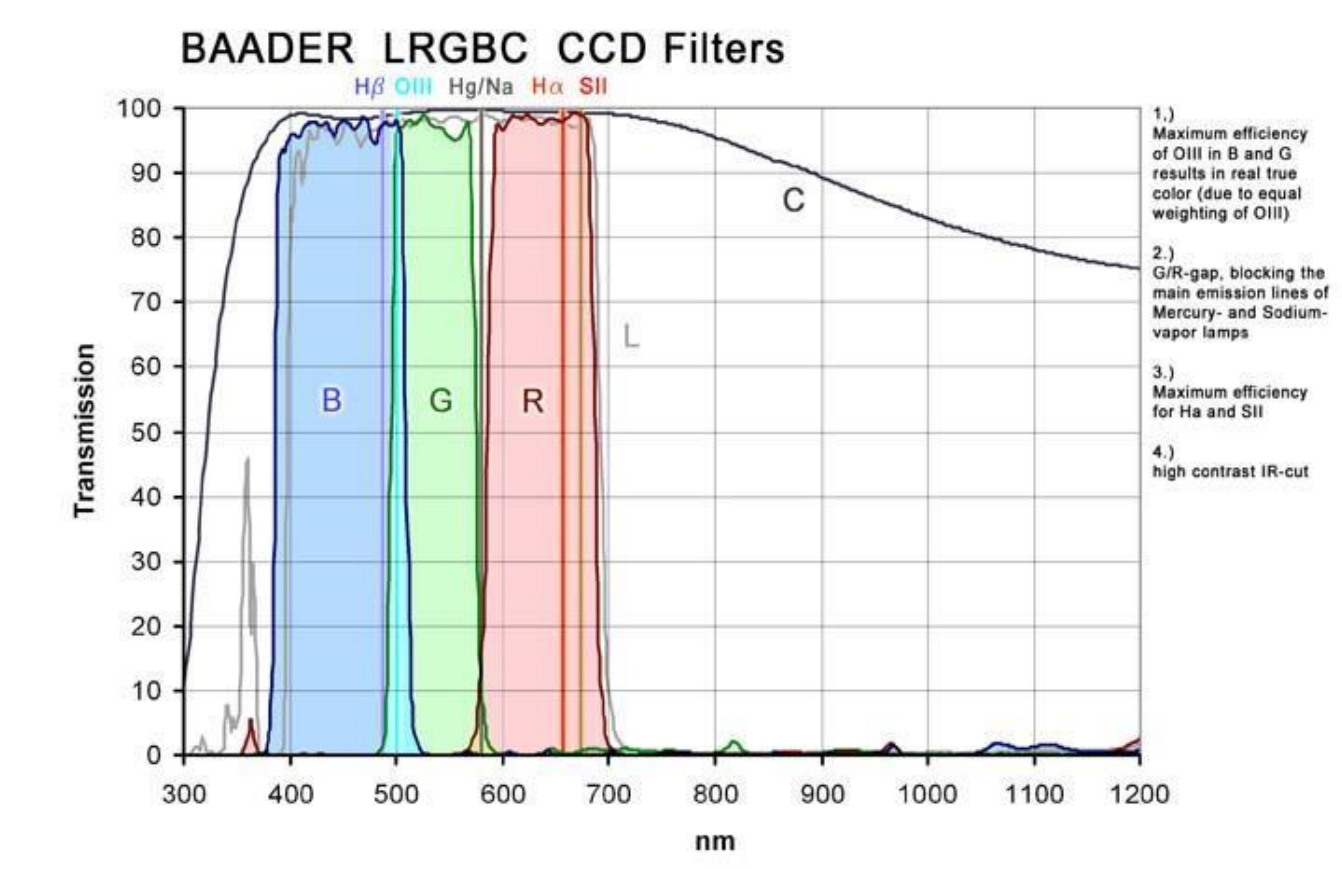
Astrophotograpy filters

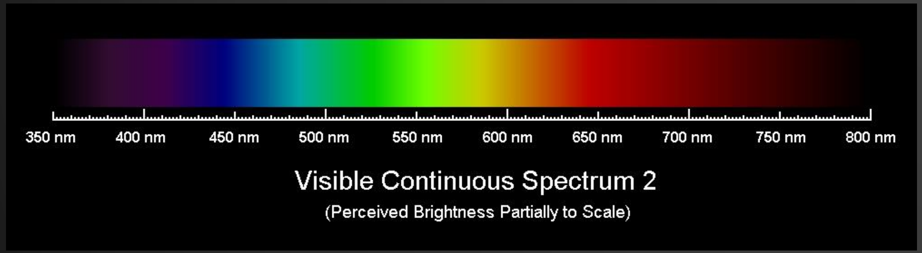
- Broadband filters
  - Clear
  - Luminance
  - Red
  - Green
  - Blue
  - IR-PASS
  - Light pollution

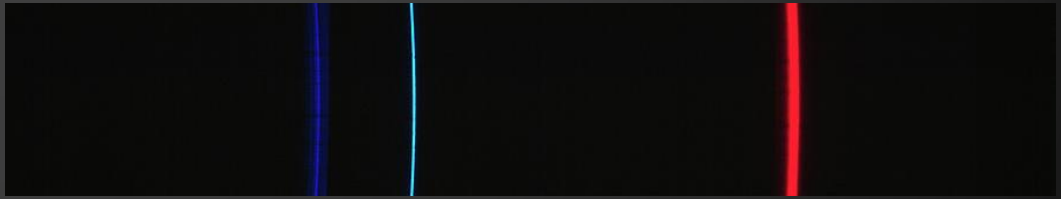


- Typical bandwidth: from a few tens to a few hundred nm

Broadband vs narrowband

- Broadband traits:
  - Intensity of the light is proportional to the filter bandpass
  - RGB Filter composition gives a good rendition of stars colors
- Narrowband traits:
  - Intensity of the light is independent from filter bandpass
  - RGB Filter Composition cannot reproduce the right color of monochromatic light





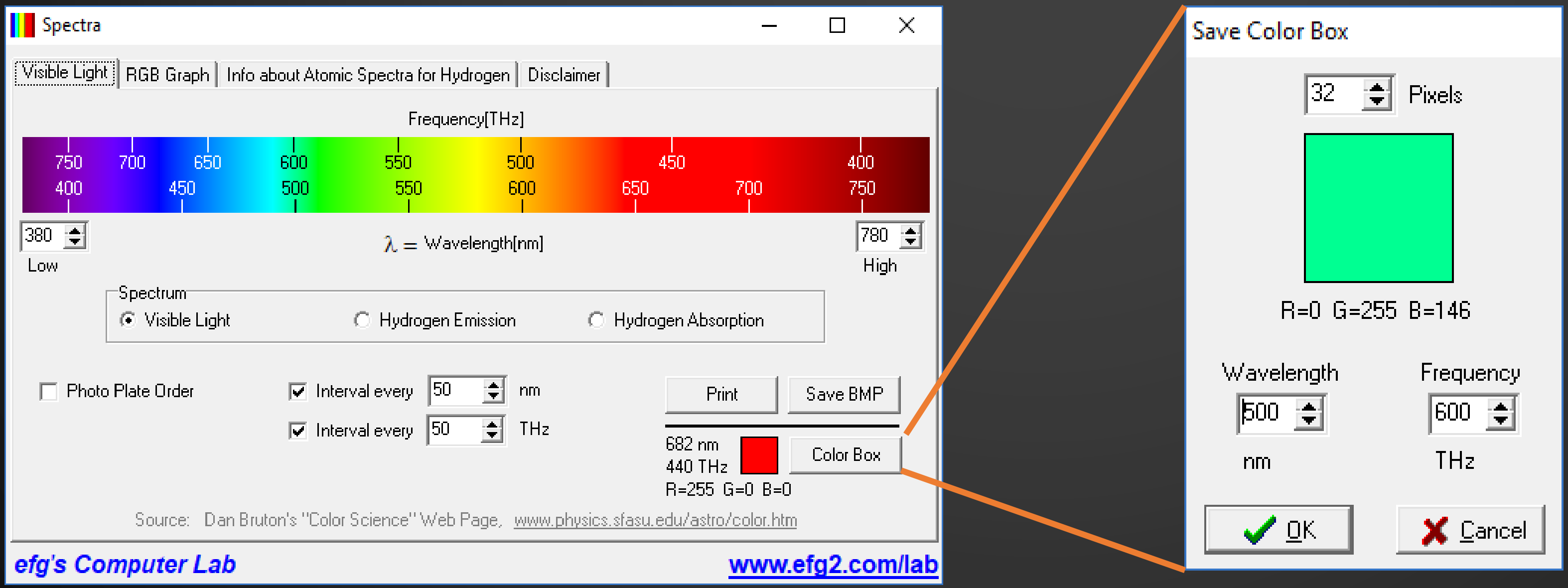
Visible Hydrogen emission spectrum

In a narrowband image the stars are dimmer than in a broadband one with the same exposure but the nebula has the very same brightness:

Narrowband filters act as “contrast boosters”

Spectral colors

- Spectral (monochromatic) colors lays outside the sRGB gamut
  - Conversion between Spectral color and RGB values is not unique
  - Cannot be correctly displayed on RGB monitors
- Heuristic approach
  - https://aty.sdsu.edu/explain/optics/rendering.html



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Spectral colors

SII:	672 nm	R: 255	G: 0	B: 0
NII:	658 nm	R: 255	G: 0	B: 0
Hα:	656 nm	R: 255	G: 0	B: 0
OIII:	500 nm	R: 0	G: 255	B: 146
OIII:	496 nm	R: 0	G: 255	B: 192
Hβ:	486 nm	R: 0	G: 239	B: 255

The workflow

1. Start with linear, registered, gradient-corrected master lights
    1. Choose a narrowband "**reference**" image
    2. Normalize "**target**" narrowband images for different background level (additive normalization)
    3. Normalize "**target**" narrowband for different exposure/quantum efficiency (multiplicative normalization)
2. You get a "normalized" set of narrowband B/W images
    1. Colorize images with its spectral color based on wavelength
    2. Add all the colorized images together
3. You get the "real" color narrowband (with UGLY stars colors)
4. Prepare the color calibrated RGB Image
5. Blend the narrowband color image with the RGB one to restore natural stars colors using the ***maximum*** *operator*
    1. Since the narrowband stars are much dimmer then the broadband ones the narrowband image can be boosted.
    2. The final image blends the narrowband nebula with broadband stars

Narrowband “real” colors

Hα + OIII + Hβ

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What if I don’t own an Hβ filter?

- Hα and Hβ lines comes from the very same gas (Hydrogen)
- The general shape of the nebula in Hα and Hβ is the same
- The observed ratio between Hβ and Hα (Balmer decrement) is set by the conditions in the nebular environment and by the interstellar reddening
- Its value lays between 0.15 and 0.33 (typical 0.2)
- in some cases the value can be found in the literature

I can create a synthetic Hβ image from the Hα one

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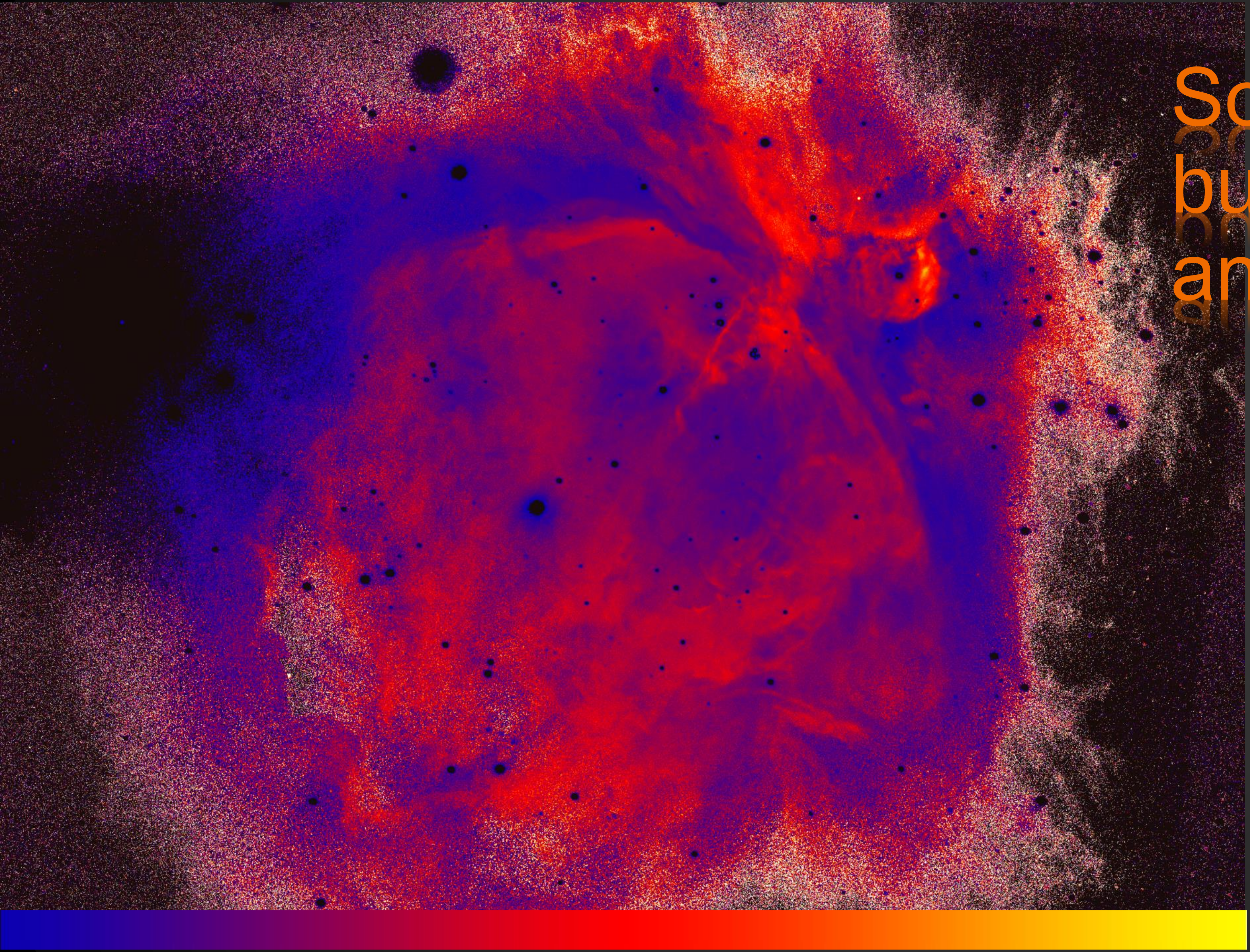

So… Is it worth buying
an Hβ filter?

Yes!

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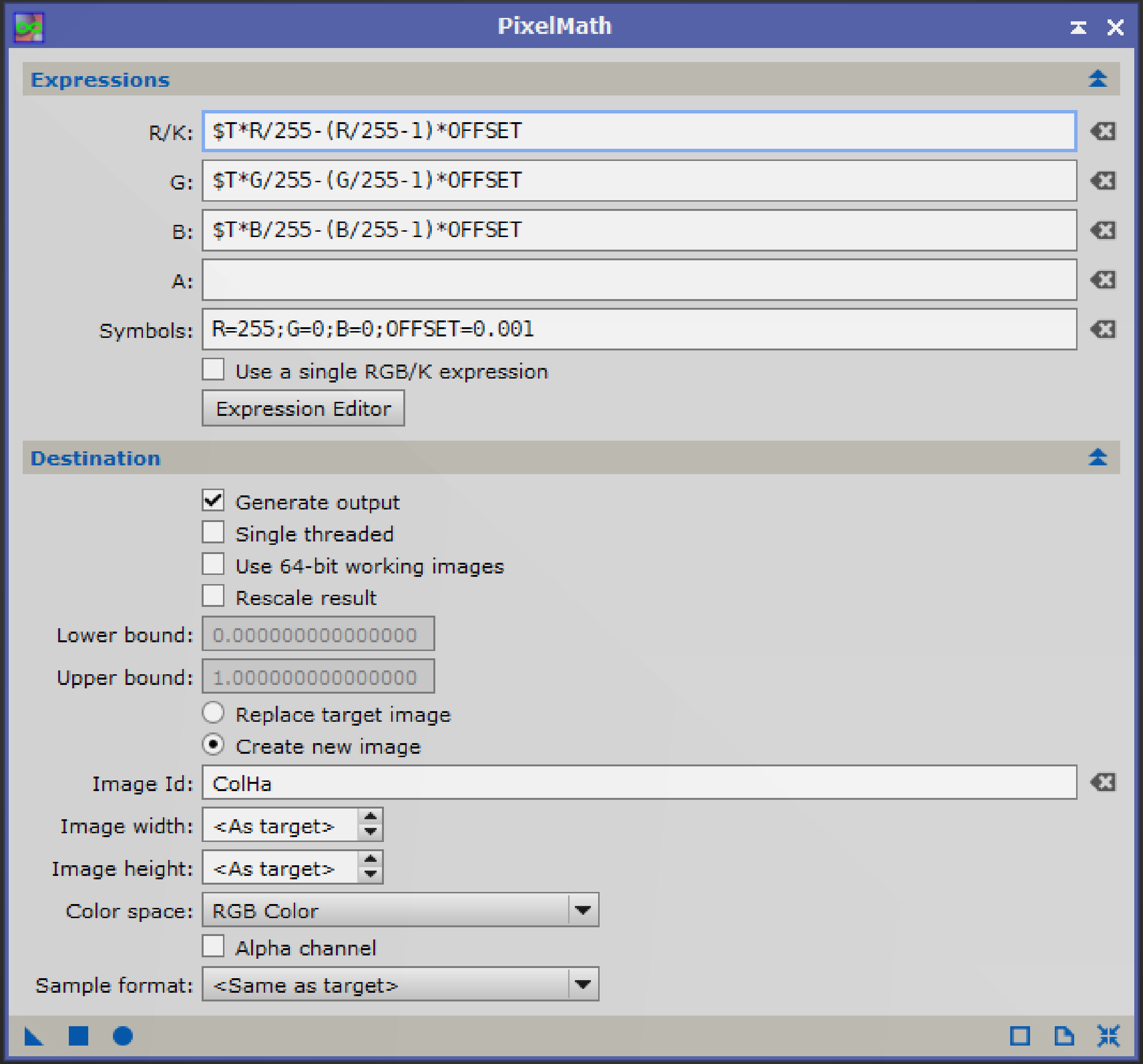
Our main tool: PixelMath



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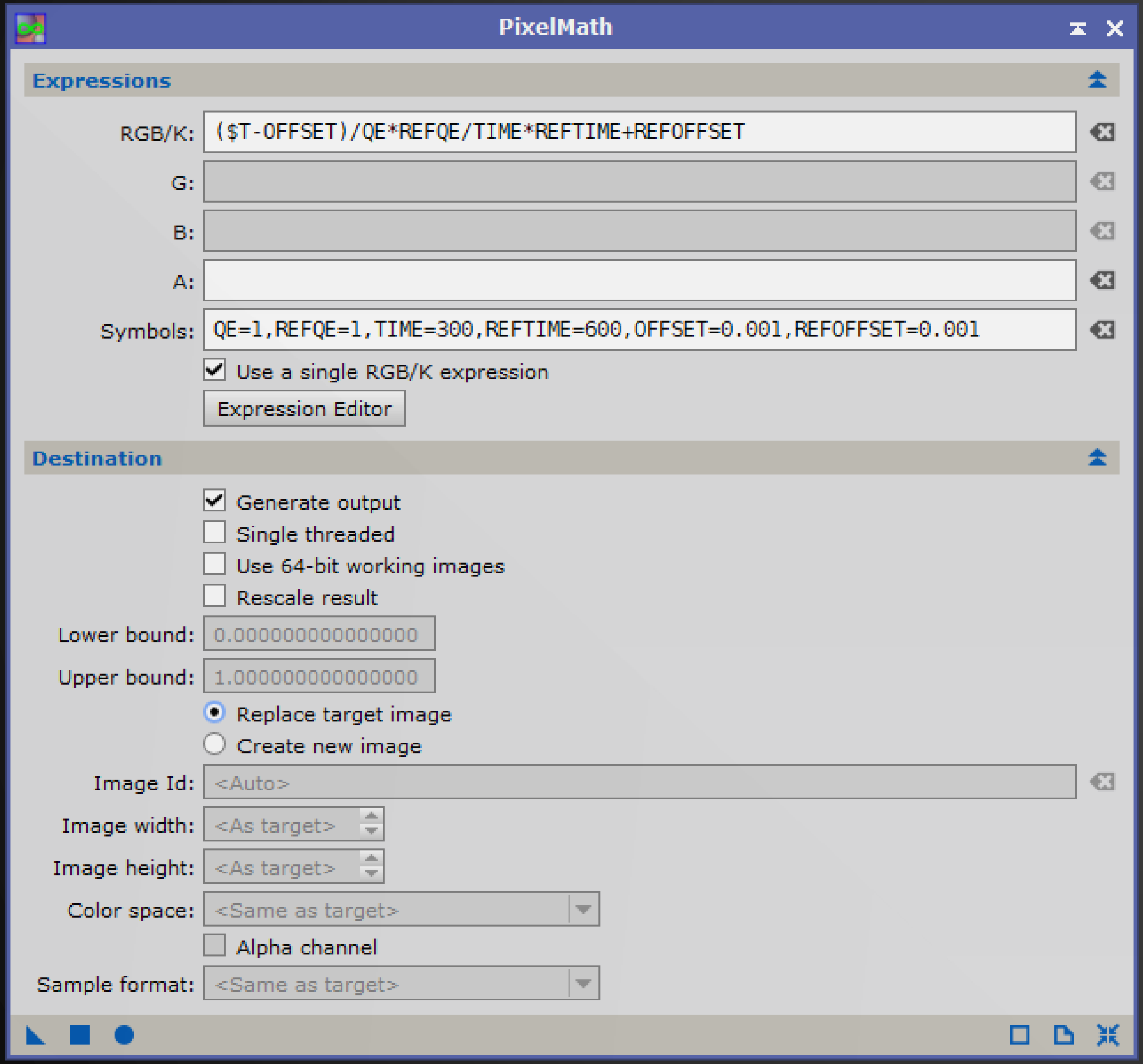
Let's try!

Normalization expression



- QE
  - quantum efficiency at the wavelength of the **target** image
- REFQE
  - quantum efficiency at the wavelength of the **reference** image
- TIME
  - Exposure time of the **target** image
- REFTIME
  - Exposure time of the **reference** image
- OFFSET
  - Median level of the background of the **target** image
- REFOFFSET
  - Median level of the background of the **reference** image

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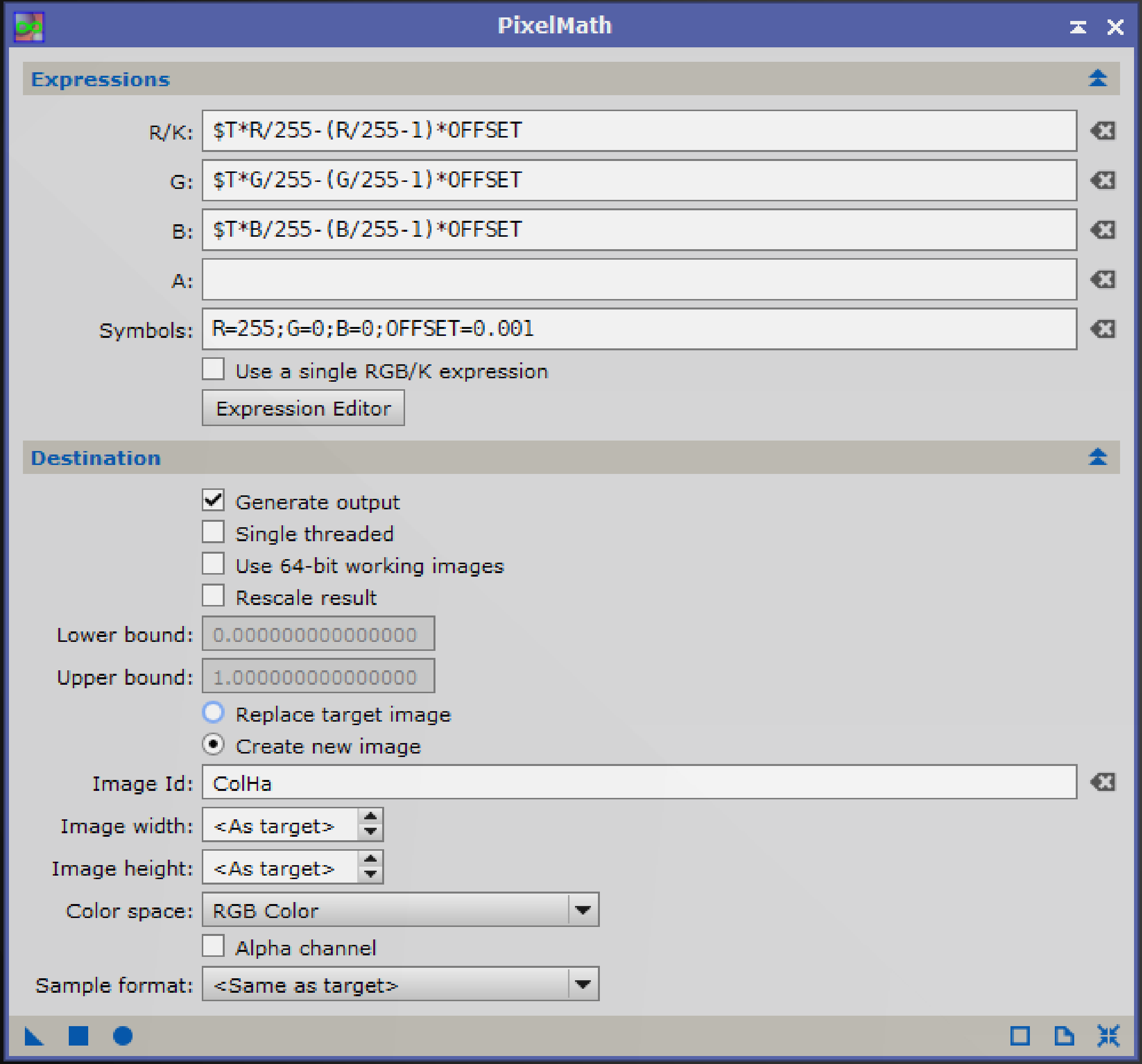
Colorization expression



- R
  - Quantity of RED (0-255)
- G
  - Quantity of GREEN (0-255)
- B
  - Quantity of BLUE (0-255)
- OFFSET
  - Median level of the background of the **target** image
- Create a new image
- Since **target** images are B/W force *RGB Color* as Color space

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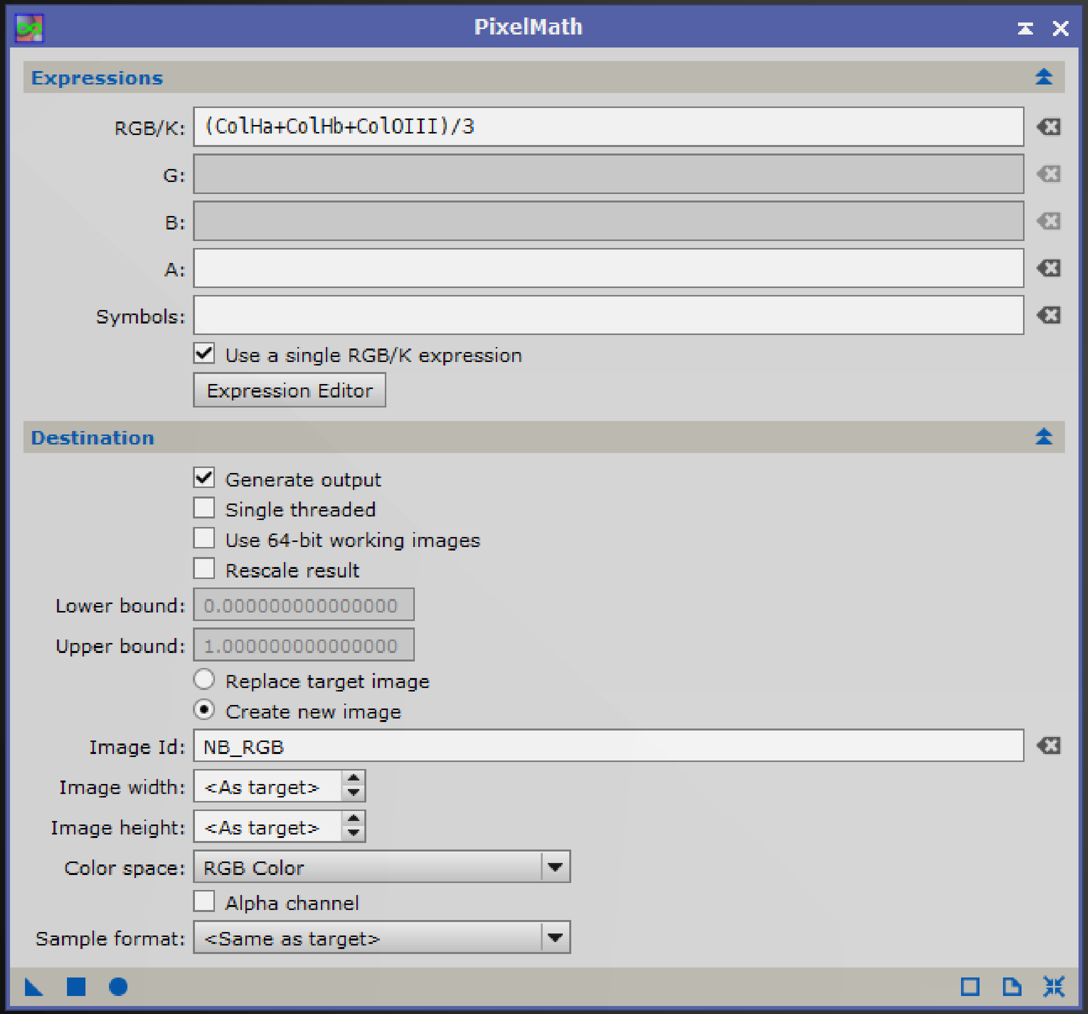
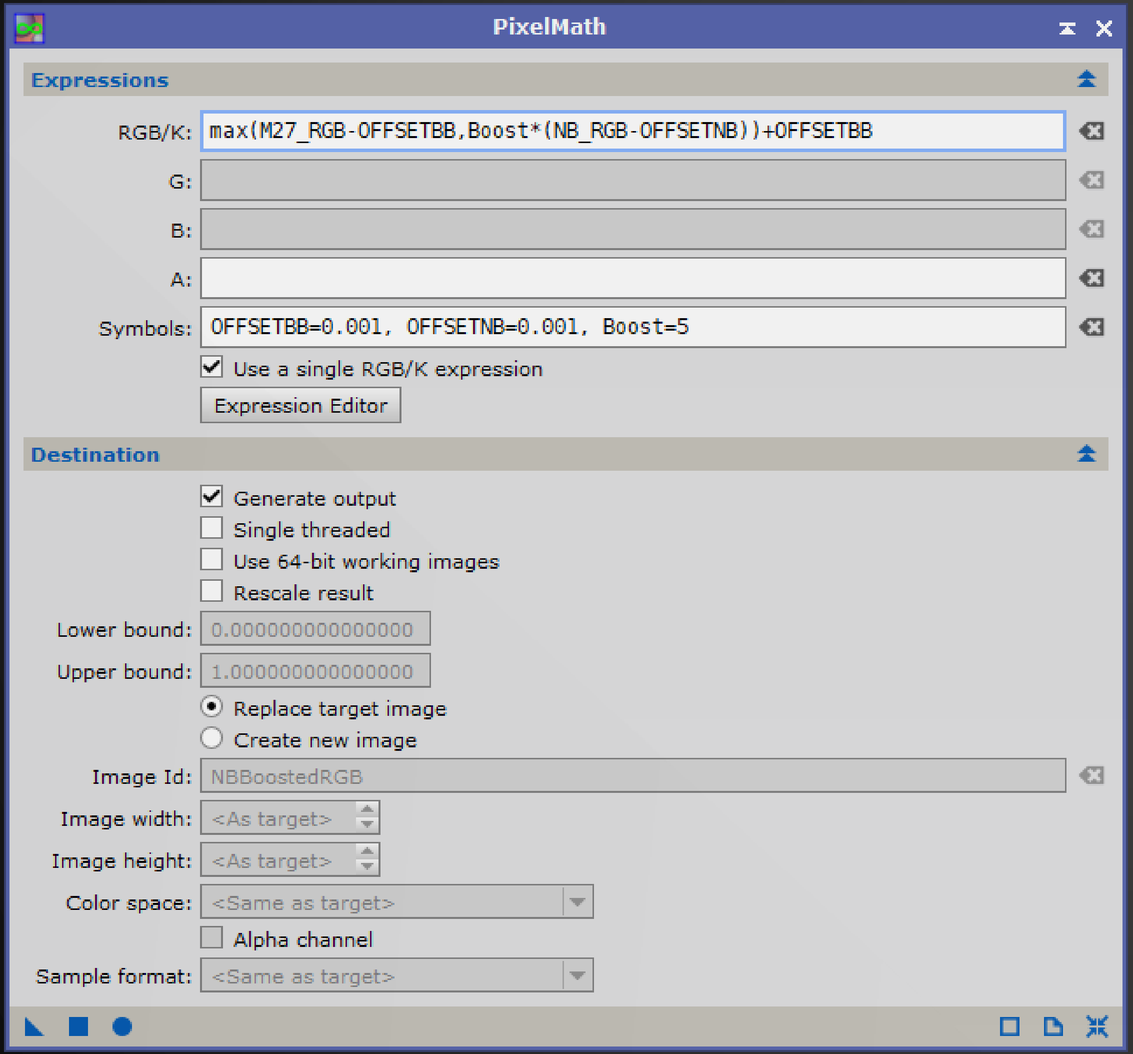
Creating the narrowband color composite



- The division by 3 is to prevent saturation

Blending Narrowband and Broadband



- OFFSETBB
  - Median level of the background of the **broadband** image
- OFFSETNB
  - Median level of the background of the **narrowband** image
- Boost
  - Boosting factor of narrowband data
  - Change to “tune” blending

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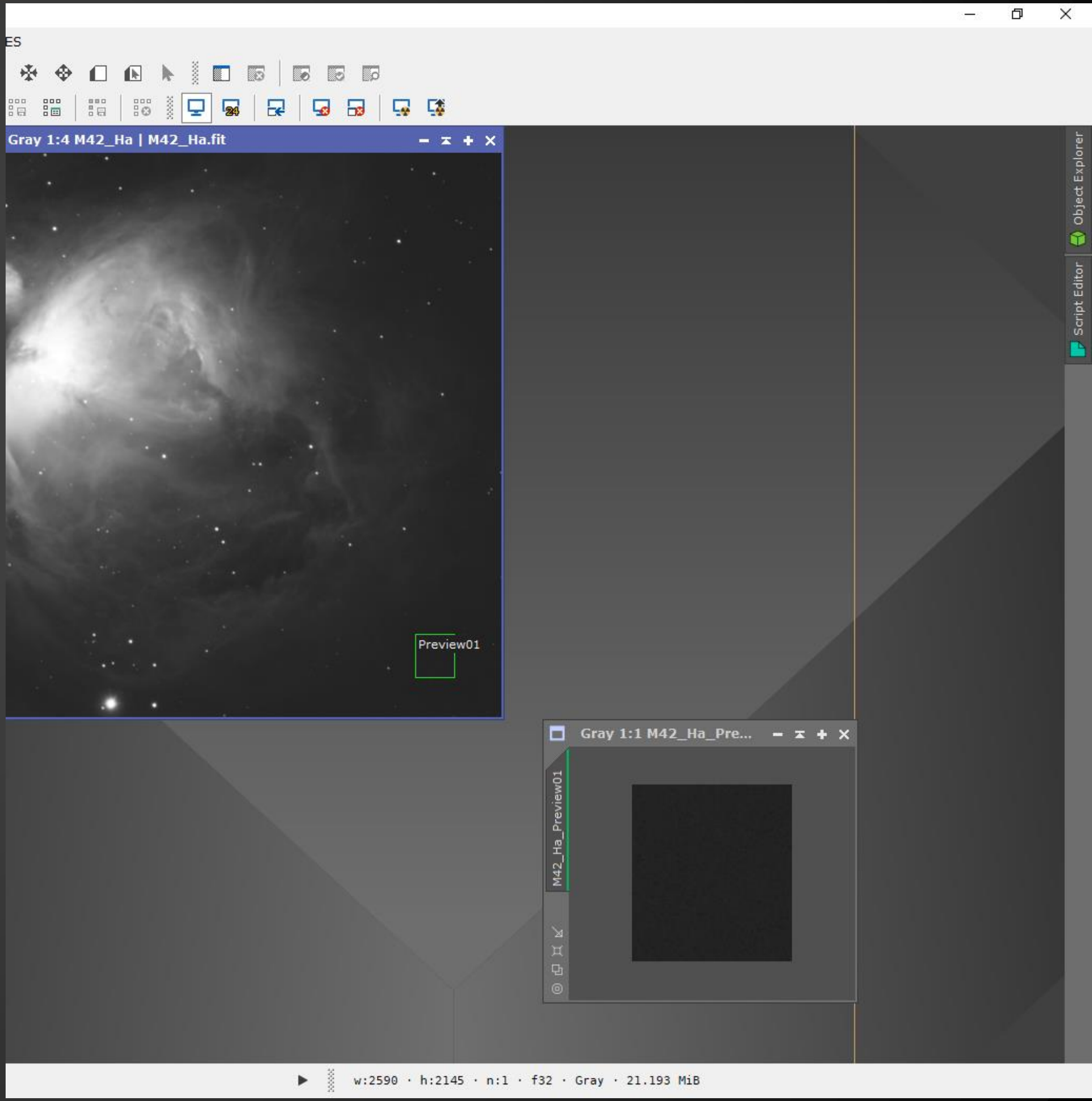
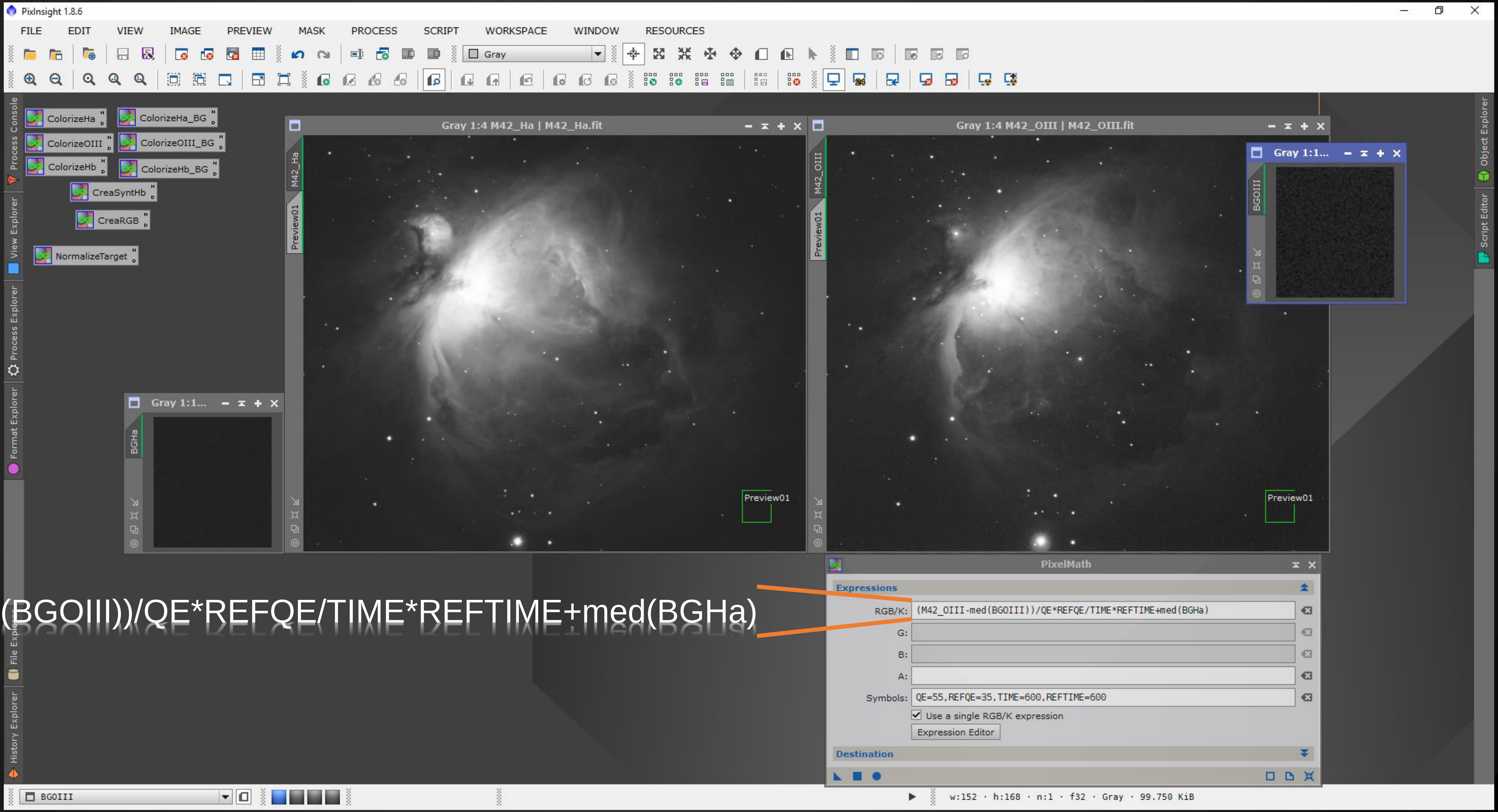
Evaluating the OFFSET

- OFFSET can be evaluated with the ***med()*** function in PixelMath
  - Create a small preview on the background
  - Drag and Drop the Preview label on the Workspace to create a new image
  - The OFFSET can be expressed as **med(ImageID)**

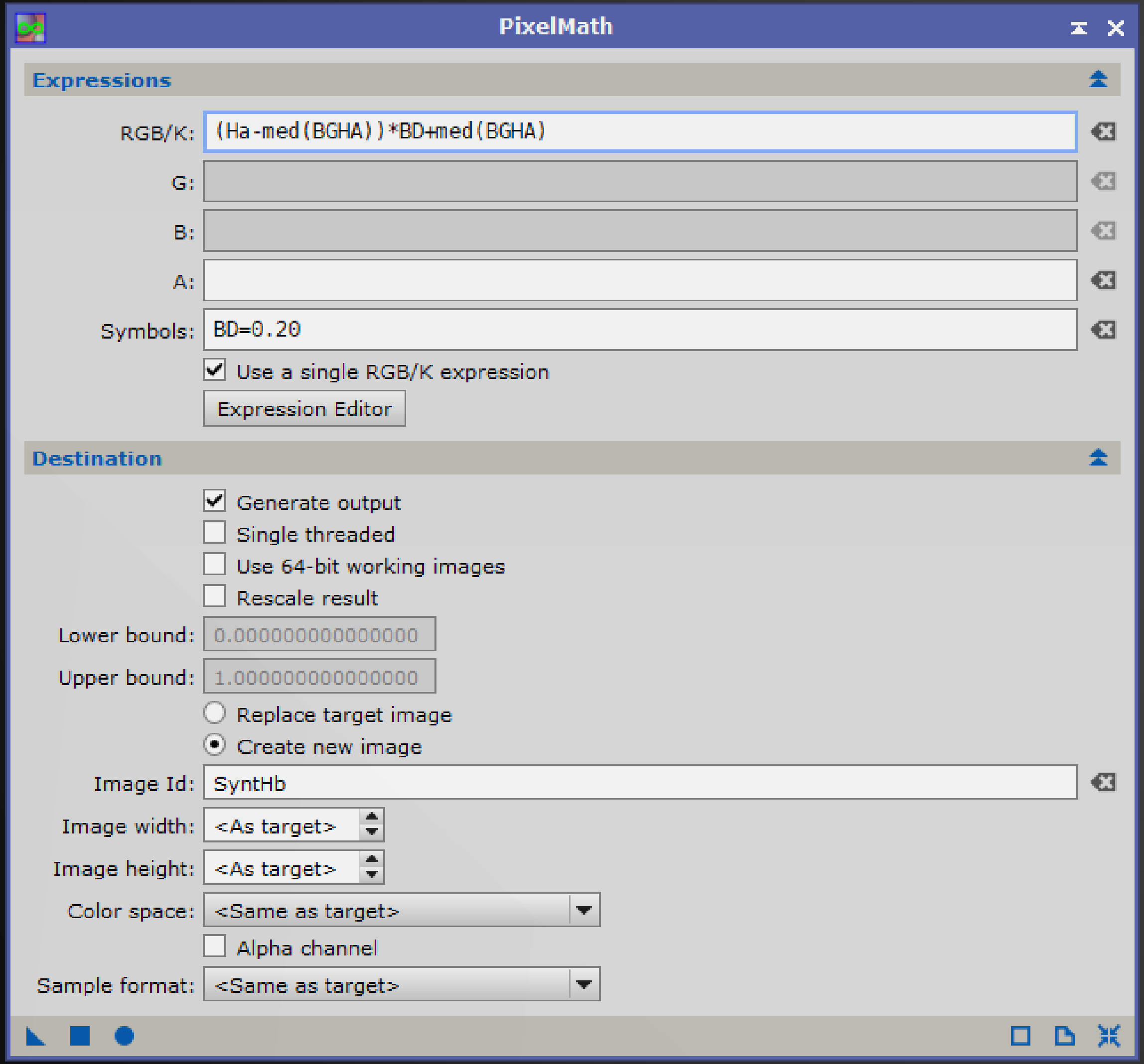


Example: Normalization of M42_OIII Image



(M42_OIII-med(BGOIII))/QE*REFQE/TIME*REFTIME+med(BGHa)

Creating a synthetic Hβ image



- BGHA
  - is an image containing a small patch of background sky from the Hα image
- BD
  - is the Balmer decrement (typical values between 0.15-0.30)

Thank you!

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http://www.arciereceleste.it

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