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





lonized gas emission





In reality the matter is "slightly" more complex



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

VISIBLE SPECTRA OF HYDROGEN





Astrophotograpy filters

Narrowband filters

SII:	672 nm	
NII:	658 nm	
Ηα:	656 nm	
OIII:	496-500 nr	n
Ηβ:	486 nm	

Typical bandwidth: few nm (< 10)</p>





Example: Orion nebula spectra





Astrophotograpy filters

Broadband filters

- Clear
- 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

Spectra						-		×	Save Color Box	
Visible Ligh	E RGB Graph Info	about Atomic	: Spectra for Hyd	rogen Disclai	mer				32 🛋	Pixels
			Frequen	cy[THz]					** <u> </u>	
750 400	700 650 450	600 500	 550 550 	500 600	450 650	700 I	400 750			
380 🚖 Low			$\lambda = Wave$	length[nm]			780 Hig	l ‡ h		
	Spectrum • Visible Light		O Hydrogen Er	nission	C Hydrogen	Absorption			R=0 G=255	i B=146
🗖 Phote	o Plate Order	☑ Interv ☑ Interv	val every 50 val every 50	nm		Print	Save BMP		Wavelength 500 €	Frequency
	Source: Dan Br	ruton's ''Color !	Science'' Web F	'age, <u>www.ph</u>	44(R= vsics.sfasu.edu/) THz 255 G=0 B=0		-	nm	THz
efg's Co	mputer Lab					www.	efg2.cor	n/lab		



Spectral colors

- SII: 672 nm R: 255 G: 0 B: 0
- ☑ NII: 658 nm R: 255 G: 0 B: 0
- G 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
- G 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

















What if I don't own an HB filter?

- \Box H α and H β lines comes from the very same gas (Hydrogen)
- The general shape of the nebula in H α and H β 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
- \bigcirc 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 H β image from the H α one



So... Is it worth buying an HB filter?





Our main tool: PixelMath

27	PixelMath	жX
Expressions		*
R/K:	\$T*R/255-(R/255-1)*0FFSET	•3
G:	\$T*G/255-(G/255-1)*OFFSET	•3
в:	\$T*B/255-(B/255-1)*0FFSET	•3
A:		•CI
Symbols:	R=255;G=0;B=0;OFFSET=0.001	- E3
	Use a single RGB/K expression	
	Expression Editor	
Destination		*
Lower bound: Upper bound:	 Generate output Single threaded Use 64-bit working images Rescale result 0.0000000000000 1.0000000000000 Replace target image Create new image 	
Image Id:	ColHa	•63
Image width:	<as target=""></as>	
Image height:	<as target=""></as>	
Color space:	RGB Color	
	Alpha channel	
Sample format:	<same as="" target=""></same>	
		ЪЖ



Let's try!



Normalization expression

2	PixelMath	жX	
Expressions		\$	
RGB/K:	(\$T-OFFSET)/QE*REFQE/TIME*REFTIME+REFOFFSET	•3	
G:		•3	
в:		Ð	
A:		•3	
Symbols:	QE=1,REFQE=1,TIME=300,REFTIME=600,OFFSET=0.001,REFOFFSET=0.001	•3	
	✓ Use a single RGB/K expression		
	Expression Editor		
Destination		*	
	 Generate output Single threaded Use 64-bit working images Rescale result 		
Lower bound:	0.0000000000000		K
opper bound.	Replace target image Create new image		
Image Id:	<auto></auto>	•3	
Image width:	<as target=""></as>		
Image height:	<as target=""></as>		
Color space:	<same as="" target=""> Alpha channel</same>		
Sample format:	<same as="" target=""></same>		
		ъж	

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



Colorization expression

2	PixelMath	×х
Expressions		*
R/K:	\$T*R/255-(R/255-1)*0FFSET	•3
G:	\$T*G/255-(G/255-1)*0FFSET	•3
В:	\$T*B/255-(B/255-1)*0FFSET	•3
A:		•3
Symbols:	R=255;G=0;B=0;OFFSET=0.001	•3
	Use a single RGB/K expression	
	Expression Editor	
Destination		*
Lower bound: Upper bound:	 Single threaded Use 64-bit working images Rescale result 0.0000000000000 1.0000000000000 Replace target image Oreate new image 	
Image Id:	ColHa	•3
Image width:	<as target=""></as>	
Image height:	<as target=""></as>	
Color space:	RGB Color	
	Alpha channel	
Sample format:	<same as="" target=""></same>	
		×

- Quantity of RED (0-255)
- a G

R

- 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



Creating the narrowband color composite

2	PixelMath :	× ×
Expressions		*
RGB/K:	(ColHa+ColHb+ColOIII)/3	Ð
G:		•3
В:		•63
A:		Ð
Symbols:		•3
	✓ Use a single RGB/K expression	1
	Expression Editor	
Destination		*
Lower bound: Upper bound:	 ✓ Generate output Single threaded Use 64-bit working images Rescale result 0.00000000000000000000000000000000000	
	Replace target image Oreate new image	
Image Id:	NB_RGB	•3
Image width:	<as target=""></as>	
Image height:	<as target=""></as>	
Color space:	RGB Color	
Sample format:	<same as="" target=""></same>	
		※

The division by 3 is to prevent saturation



Blending Narrowband and Broadband

2	PixelMath :	× ×
Expressions		*
RGB/K:	<pre>max(M27_RGB-OFFSETBB,Boost*(NB_RGB-OFFSETNB))+OFFSETBB</pre>	•3
G:		•3
в:		•3
A:		Ð
Symbols:	OFFSETBB=0.001, OFFSETNB=0.001, Boost=5	Ð
	✓ Use a single RGB/K expression	,
	Expression Editor	
Destination		*
Lower bound: Upper bound:	 Single threaded Use 64-bit working images Rescale result 0.0000000000000 1.0000000000000 Replace target image Create new image 	
Image Id:	NBBoostedRGB	•3
Image width:	<as target=""> 🗘</as>	
Image height:	<as target=""></as>	
Color space:	<same as="" target=""></same>	
	Alpha channel	
Sample format:	<same as="" target=""></same>	
		35

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



Evaluating the **QFFSET**

- 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



Creating a synthetic HB image

2	PixelMath :	× ×
Expressions		*
RGB/K:	(Ha -med (BGHA)) *BD+med (BGHA)	Ð
G:		Ð
В:		Ð
A:		Ð
Symbols:	BD=0.20	Ð
	✓ Use a single RGB/K expression Expression Editor	-
Destination		*
Lower bound: Upper bound:	 Generate output Single threaded Use 64-bit working images Rescale result 0.0000000000000 1.0000000000000 Replace target image Create new image 	
Image Id:	SyntHb	•CI
Image width:	<as target=""></as>	
Image height:	As target>	
Color space:	<same as="" target=""></same>	
Sample formate		
Sample format:		
		- XK

BGHA

is an image containing a small patch of background sky from the Hα image

is the Balmer decrement (typical values between 0.15-0.30)



Thank you!

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http://www.arciereceleste.it

