

Making Pretty Pictures from Scientific Data

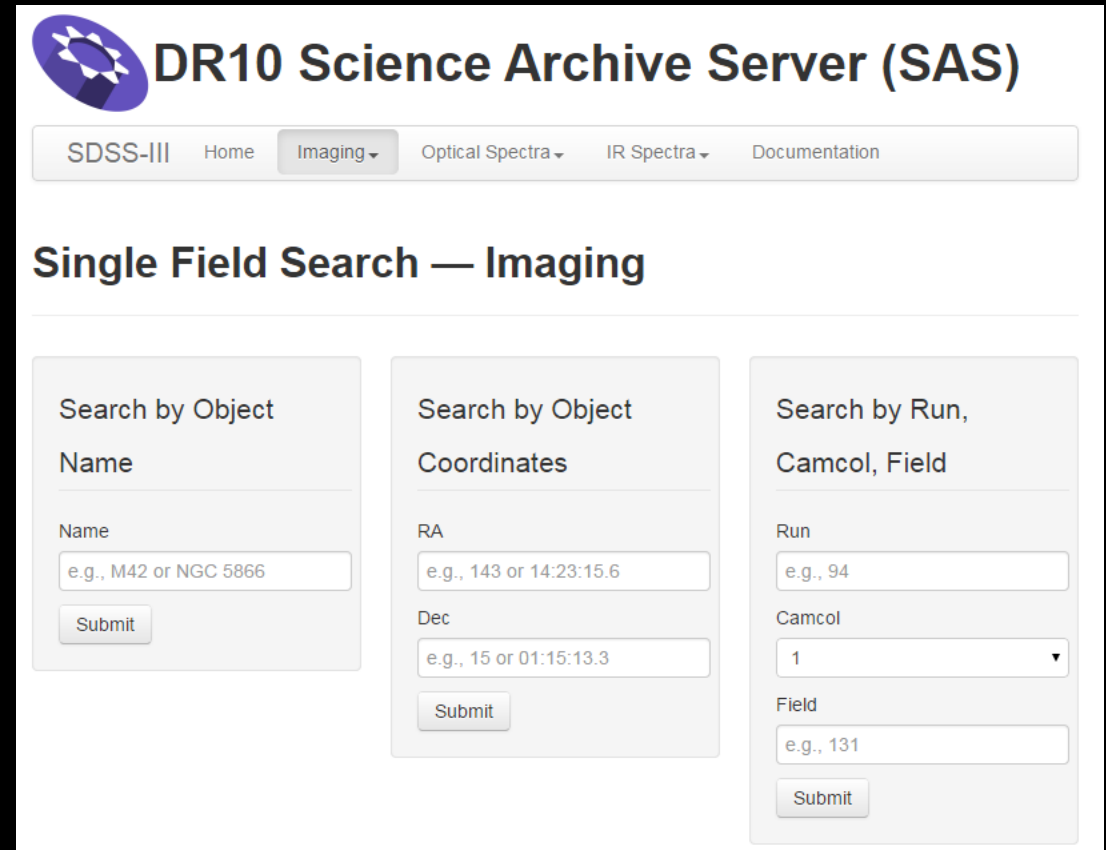
David Ault

Many Sources Available

- Sloan Digital Sky Survey (SDSS)
<http://data.sdss3.org/fields>
- Hubble Legacy Archive (HLA)
<http://hla.stsci.edu/hlaview.html>
- ESO Image Archive
 - http://archive.eso.org/eso/eso_archive_main.html
- Space Telescope Science Institute
https://archive.stsci.edu/cgi-bin/dss_form
- Local Observatories
 - For example, I know the professor at Southwestern University and have helped some of his students with processing image data for posting on their website
- And many more!
 - Spitzer, WorldWideTelescope and probably many more I couldn't find or remember

Sloan Digital Sky Survey

- Uses Sloan filters
 - Wideband but not centered around RGB
 - Steep cutoff with little overlap between filters
- Anyone can access the data
- Very easy to use interface, especially for mosaic data
- Downloads all files individually
- Easy to determine exactly what portion of the spectrum is captured in each image



The screenshot displays the DR10 Science Archive Server (SAS) interface. At the top, there is a navigation bar with the following links: SDSS-III, Home, Imaging (selected), Optical Spectra, IR Spectra, and Documentation. Below the navigation bar, the page title is "Single Field Search — Imaging". The main content area is divided into three search panels:

- Search by Object Name:** A text input field with the placeholder "e.g., M42 or NGC 5866" and a "Submit" button.
- Search by Object Coordinates:** Two text input fields for "RA" (placeholder: "e.g., 143 or 14:23:15.6") and "Dec" (placeholder: "e.g., 15 or 01:15:13.3"), each with a "Submit" button.
- Search by Run, Camcol, Field:** Three input fields: "Run" (placeholder: "e.g., 94"), "Camcol" (a dropdown menu with "1" selected), and "Field" (placeholder: "e.g., 131"). Each field has a "Submit" button.

Sloan Digital Sky Survey

- Example Search for NGC524
 - 1 – shows the Search by object name field
 - 2 – the preview image
 - 3 – shows the download links, there's one for each filter

DR10 Science Archive Server (SAS)

SDSS-III Home Imaging Optical Spectra IR Spectra Documentation

Single Field Search — Imaging

Search by Object Name

Name

NGC524

Submit

Search by Object Coordinates

RA

21.1987792

Dec

9.5387917

Submit

Search by Run, Camcol, Field

Run

7767

Camcol

3

Field

76

Submit

1

Image

2

Download

JPG Image | u-band FITS | g-band FITS | r-band FITS | i-band FITS | z-band FITS

index	1048823				
run	7767				
rerun	301				
camcol	3				
field	76				
mjd	54767				
ra	21.2150949016				
dec	9.5051209141				

u	g	r	i	z
4731899886.11	4731900029.41	4731899742.82	4731899814.47	4731899957.76

3

Sloan Digital Sky Survey

- There is also a mosaic tool
 - Provide the desired central location, image scale and field of view
 - 1 – The entry form
 - 2 – The results, with small previews
 - 3 – Download button
 - There are also controls for which filters and which tile to select so you can target your downloads

DR10 Science Archive Server (SAS)

SDSS-III Home Imaging Optical Spectra IR Spectra Documentation

Imaging Mosaics — Imaging

You requested a $0.125^\circ \times 0.125^\circ$ mosaic of (21.1987792, 9.5387917) using only primary fields (18 fields total) with a pixel scale = 0.396 arcseconds / pixel.
[Click here to submit request.](#)

Mosaic Form

RA: 21.1987792
Dec: 9.5387917
Image Size (degrees): 0.125
Pixel Scale ("/pixel): 0.396
☐ Use all covering fields
Filters to mosaic: ☒ u ☒ g ☒ r ☒ i ☒ z

Clear Filters Table as Comma-Delimited Text (CSV) Filters to Download: ☒ u ☒ g ☒ r ☒ i ☒ z

Run	Camcol	Field	RA (degrees)	Dec (degrees)	Filters	Open in CAS	Thumbnail
7767	3	74	20.91184	9.51951	☐	CAS	
7767	3	75	21.06347	9.51235	☐	CAS	
7767	4	75	21.08403	9.93154	☐	CAS	
7767	3	76	21.21509	9.50512	☐	CAS	
7767	4	76	21.23584	9.92431	☐	CAS	
7767	3	77	21.36671	9.49783	☐	CAS	
7767	4	77	21.38764	9.91701	☐	CAS	
7767	5	78	21.51832	9.49047	☐	CAS	

Hubble Legacy Archive

- Mix of wideband and narrowband filters and
- Anyone can access the data
- Uses a cart system to accumulate data into one big compressed archive
- Good documentation on their site
- Easy to determine exactly what each file represents (i.e. filter, imager, etc.)
- Contains some pre-processed data that has mixed colors as well as the raw calibrated data



Hubble Legacy Archive

- Results for NGC524

- The ‘Help Center’ button gives you a lot of great information about decoding everything
- There’s a good description of what each column represents at the bottom of the page
- A lot of information is included in the file name for ease of use when constructing your images

</

ESO Image Archive

- Mix of wideband and narrowband filters and
- Must sign up for an account (free)
- Some data locked for scientific research & publication
- Download tools are flaky. I had to use their download script on a linux machine.
- Good documentation on what each imaging system is capable of



ESO Archive Query Form

[ESO Archive Overview](#)
[Help Page](#)
[FAQ](#)
[Archive Facility HOME](#)
[ESO HOME](#)

If you would like to query the Archive for instrument specific parameters, please use the [dedicated query forms](#).
 To search for **reduced Data Products**, please have a look at the [ESO Data Products](#) page and the [Advanced Data Products](#) query form.
 To search through the science data products generated by the observers, please refer to the [Phase 3 query form](#).

The checkboxes on the right of the parameters define whether or not they will be displayed on the query result page.

Output preferences: html table

Target, Program and Scheduling Information

Target Name ☒ RA DEC J2000 Search Box Input RA(h) DEC(deg) Output ☒ Sexagesimal (h, deg) List of Targets Choose File No file chosen	Night ☐ (YYYY MM(M) DD) <i>Otherwise give a query range using the following start/end dates</i> Start 12 hrs [UT] End 12 hrs [UT] Program ID ☒ Program Type ☐ Any PI CoI ☐ SV ☐ Any Title ☐
--	--

Observing Information

Imaging ☐ ALL ☐ NONE ☐ EFOSC2/LaSilla ☐ EMMI/LaSilla ☐ FORS1/VLT ☐ FORS2/VLT ☐ HAWKI/VLT ☐ GROND/LaSilla ☐ ISAAC/VLT ☐ NACO/VLT ☐ OMEGACAM/VST ☐ SOFI/LaSilla ☐ SPHERE/VLT ^{operational} ☐ SUSI2/LaSilla ☐ TIMMI2/LaSilla ☐ VIMOS/VLT ☐ VIRCAM/VISTA ☐ VISIR/VLT ☐ WFI/LaSilla	Spectroscopy ☐ ALL ☐ NONE ☐ CES/LaSilla ☐ CRILES/VLT ☐ EFOSC2/LaSilla ☐ EMMI/LaSilla ☐ FEROS/LaSilla ☐ FORS1/VLT ☐ FORS2/VLT ☐ GIRAFFE/VLT ☐ HARPS/LaSilla ☐ ISAAC/VLT ☐ KMOS/VLT ☐ MUSE/VLT ☐ NACO/VLT ☐ SINFONI/VLT ☐ SOFI/LaSilla ☐ SPHERE/VLT ^{operational} ☐ TIMMI2/LaSilla ☐ UVES/VLT ☐ VIMOS/VLT ☐ VISIR/VLT ☐ XSHOOTER/VLT	Interferometry ☐ ALL ☐ NONE ☐ AMBER/VLT ☐ MIDI/VLT ☐ PIONIER/VLT ☐ VINCI/VLT Polarimetry ☐ ALL ☐ NONE ☐ EFOSC2/LaSilla ☐ FORS1/VLT ☐ FORS2/VLT ☐ ISAAC/VLT ☐ NACO/VLT ☐ SOFI/LaSilla ☐ SPHERE/VLT ^{operational} Coronagraphy ☐ ALL ☐ NONE ☐ NACO/VLT	Other ☐ ALL ☐ NONE ☐ BQ/APEX ☐ HET/APEX ☐ LGSF ☐ MAD ☐ MASCOT ☐ WFCAM/UKIRT	Data Product Info Type ☒ Any Mode ☒ Any Dataset ID Orig Name Release Date OB Name OB ID Instrumental Setup Exptime ☒ Filter ☒ Grism ☐ Grating ☐ Slit ☐
---	---	---	---	---

Category ☒ ☐ SCIENCE ☐ CALIB ☐ ACQUISITION

Instrument & Mode ☒

Additional Tools and Parameters

☒ Airmass	☐ Distance	☒ Number of Frames / Instrument
☒ DIMM Seeing	☐ Position Angle	☒ Cumulative Exptime / Filter
☒ FITS Header Display	☒ MJD-OBS	☒ Sky Map

Display Options

Sort by... Nothing (Faster)

ESO Image Archive

- This archive encompasses data from multiple installations, instruments and filters, making it more confusing to find the data you want
- Clicking on a column will take you to a section of the documentation describing what it means
- I've marked a few columns:
 - 1 – Selection, so you can target specific downloads
 - 2 – Type showing where this is an image, spectrum, etc
 - 3 – Filter

ESO Archive Query Results

ESO Archive Overview | Help Page | FAQ | Archive Explorer | HOME | ESO HOME

To request data please select the datasets in the results table by marking the checkbox in the left-most column, then press the **Request marked datasets** button.
(You will be prompted for your ESO User Portal username and password. If you do not yet have an ESO User Portal account, please fill out the [registration form](#).)
Datasets for which the proprietary period is over are highlighted in green and are publicly available.
Datasets that are still under the proprietary period are highlighted in red and can only be downloaded by the corresponding PI.
Datasets that are not yet available in the Archive are marked with a "N/A".

SIMBAD coordinates for NGC524 : 01 24 47.7, +09 32 19.6.

☒ Request marked datasets | Reset | MarkAll | MarkPublic | MarkProprietary | New query | Programmatic | Your Requests

M	More	HDR	OBJECT	Target Ra, Dec	Program_ID	Instrument	Category	Type	Mode	Dataset ID	Release_Date	Exptime	Filter	MJD-OBS	Airmass	Ambient
☒	More	Header	SN2000CX	01:24:48.16 +09:30:23.4	60 A-9016(A)	EFOSC/3.8	SCIENCE		IMAGE	EFOSC 2001-09-14T03:15:46.465	Sep 14 2002	1199.996	U#640	52166.135954	2.103	DIMM Seeing?
☒	More	Header	SN2000CX	01:24:48.17 +09:30:13.7	60 A-9016(A)	EFOSC/3.8	SCIENCE		IMAGE	EFOSC 2001-09-14T03:36:27.561	Sep 14 2002	1199.996	U#640	52166.150319	1.878	DIMM Seeing?
☒	More	Header	SN2000CX	01:24:47.52 +09:30:12.7	60 A-9016(A)	EFOSC/3.8	SCIENCE		IMAGE	EFOSC 2001-09-14T03:57:08.530	Sep 14 2002	1199.996	U#640	52166.164682	1.711	DIMM Seeing?
☒	More	Header	SN2000CX	01:24:47.56 +09:30:22.4	60 A-9016(A)	EFOSC/3.8	SCIENCE		IMAGE	EFOSC 2001-09-14T04:17:49.553	Sep 14 2002	1199.996	U#640	52166.179046	1.585	DIMM Seeing?
☒	More	Header		01:24:46.15 +09:30:30.9	67 D-0134(C)	FORS1	SCIENCE	OBJECT	IMAGE	FORS1 2001-09-13T05:54:33.710	Oct 2 2002	299.983	V_BESS	52165.246223	1.231	DIMM Seeing?
☒	More	Header		01:24:46.83 +09:30:30.9	67 D-0134(C)	FORS1	SCIENCE	OBJECT	IMAGE	FORS1 2001-09-13T06:00:29.683	Oct 2 2002	299.983	V_BESS	52165.250344	1.225	DIMM Seeing?
☒	More	Header		01:24:47.50 +09:30:30.9	67 D-0134(C)	FORS1	SCIENCE	OBJECT	IMAGE	FORS1 2001-09-13T06:06:25.074	Oct 2 2002	299.983	V_BESS	52165.254457	1.220	DIMM Seeing?
☒	More	Header		01:24:46.15 +09:30:30.9	67 D-0134(C)	FORS1	SCIENCE	OBJECT	IMAGE	FORS1 2001-09-13T06:12:41.896	Oct 2 2002	299.983	I_BESS	52165.258818	1.215	DIMM Seeing?
☒	More	Header		01:24:46.83 +09:30:30.9	67 D-0134(C)	FORS1	SCIENCE	OBJECT	IMAGE	FORS1 2001-09-13T06:26:57.076	Oct 2 2002	299.983	I_BESS	52165.268716	1.209	DIMM Seeing?
☒	More	Header		01:24:47.50 +09:30:30.9	67 D-0134(C)	FORS1	SCIENCE	OBJECT	IMAGE	FORS1 2001-09-13T06:41:12.212	Oct 2 2002	299.983	I_BESS	52165.278614	1.208	DIMM Seeing?
☒	More	Header		01:24:46.15 +09:30:30.9	67 D-0134(C)	FORS1	SCIENCE	OBJECT	IMAGE	FORS1 2001-09-13T06:58:45.352	Oct 2 2002	399.984	B_BESS	52165.290803	1.213	DIMM Seeing?
☒	More	Header		01:24:46.83 +09:30:30.9	67 D-0134(C)	FORS1	SCIENCE	OBJECT	IMAGE	FORS1 2001-09-13T07:06:21.149	Oct 2 2002	399.983	B_BESS	52165.296078	1.218	DIMM Seeing?
☒	More	Header		01:24:47.50 +09:30:30.9	67 D-0134(C)	FORS1	SCIENCE	OBJECT	IMAGE	FORS1 2001-09-13T07:13:56.463	Oct 2 2002	399.974	B_BESS	52165.301348	1.225	DIMM Seeing?
☒	More	Header		01:24:46.15 +09:30:30.9	67 D-0134(C)	FORS1	SCIENCE	OBJECT	IMAGE	FORS1 2001-09-13T07:21:54.070	Oct 2 2002	399.987	R_BESS	52165.306876	1.233	DIMM Seeing?
☒	More	Header		01:24:46.83 +09:30:30.9	67 D-0134(C)	FORS1	SCIENCE	OBJECT	IMAGE	FORS1 2001-09-13T07:29:29.200	Oct 2 2002	399.987	R_BESS	52165.312144	1.243	DIMM Seeing?
☒	More	Header		01:24:47.50 +09:30:30.9	67 D-0134(C)	FORS1	SCIENCE	OBJECT	IMAGE	FORS1 2001-09-13T07:37:06.073	Oct 2 2002	399.987	R_BESS	52165.317431	1.254	DIMM Seeing?
☒	More	Header		01:24:46.15 +09:30:30.9	68 D-0114(A)	FORS1	SCIENCE	OBJECT	IMAGE	FORS1 2001-10-10T03:13:59.043	Nov 28 2002	749.977	R_BESS	52192.134711	1.336	DIMM Seeing?
☒	More	Header		01:24:46.83 +09:30:30.9	68 D-0114(A)	FORS1	SCIENCE	OBJECT	IMAGE	FORS1 2001-10-10T03:27:23.147	Nov 28 2002	418.329	R_BESS	52192.144018	1.301	DIMM Seeing?
☒	More	Header		01:24:46.15 +09:30:30.9	68 D-0114(A)	FORS1	SCIENCE	OBJECT	IMAGE	FORS1 2001-10-17T03:33:25.889	Nov 28 2002	649.971	I_BESS	52199.148216	1.240	DIMM Seeing?

Southwestern University

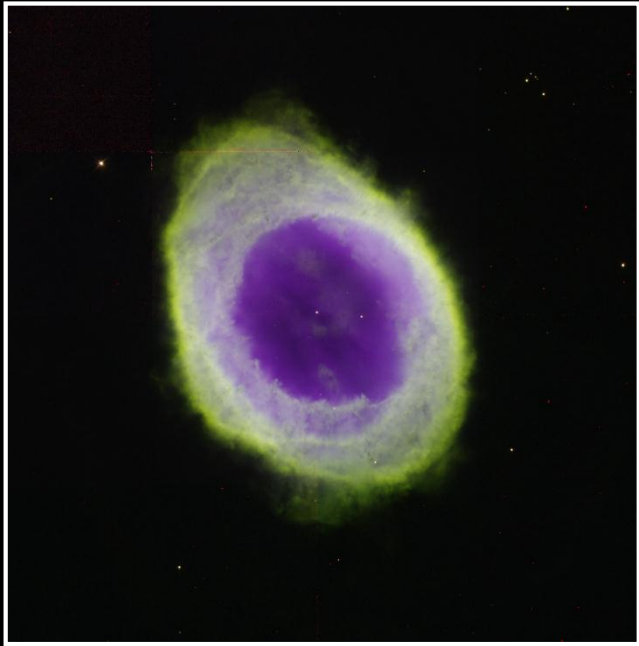
- Uses Johnson Filters
 - Wideband but not centered around RGB
 - Gradual cut-off with a fair amount of overlap between filters
- I've asked that they publish any data that is not being held for publication



Dealing with alternate spectra in an RGB world

- Most scientific data is not RGB
- Sloan, Johnson, Washington, Stromgen and various IR and narrowband filters are common
- Since all astrophotography is technically false color in terms of what the human eye is capable of seeing, there is no right or wrong way to combine the data to make RGB images
- SHO is a common method of combining narrowband data from Sulfer-II, Hydrogen- α and Oxygen-III where S, H & O are mapped to R, G & B respectively
- You can also approximate the spectra of typical RGB filters using overlap of the spectra of the scientific filters

Channel Substitution (aka SHO, HSO, etc.)



R = H II
G = N II
B = O III

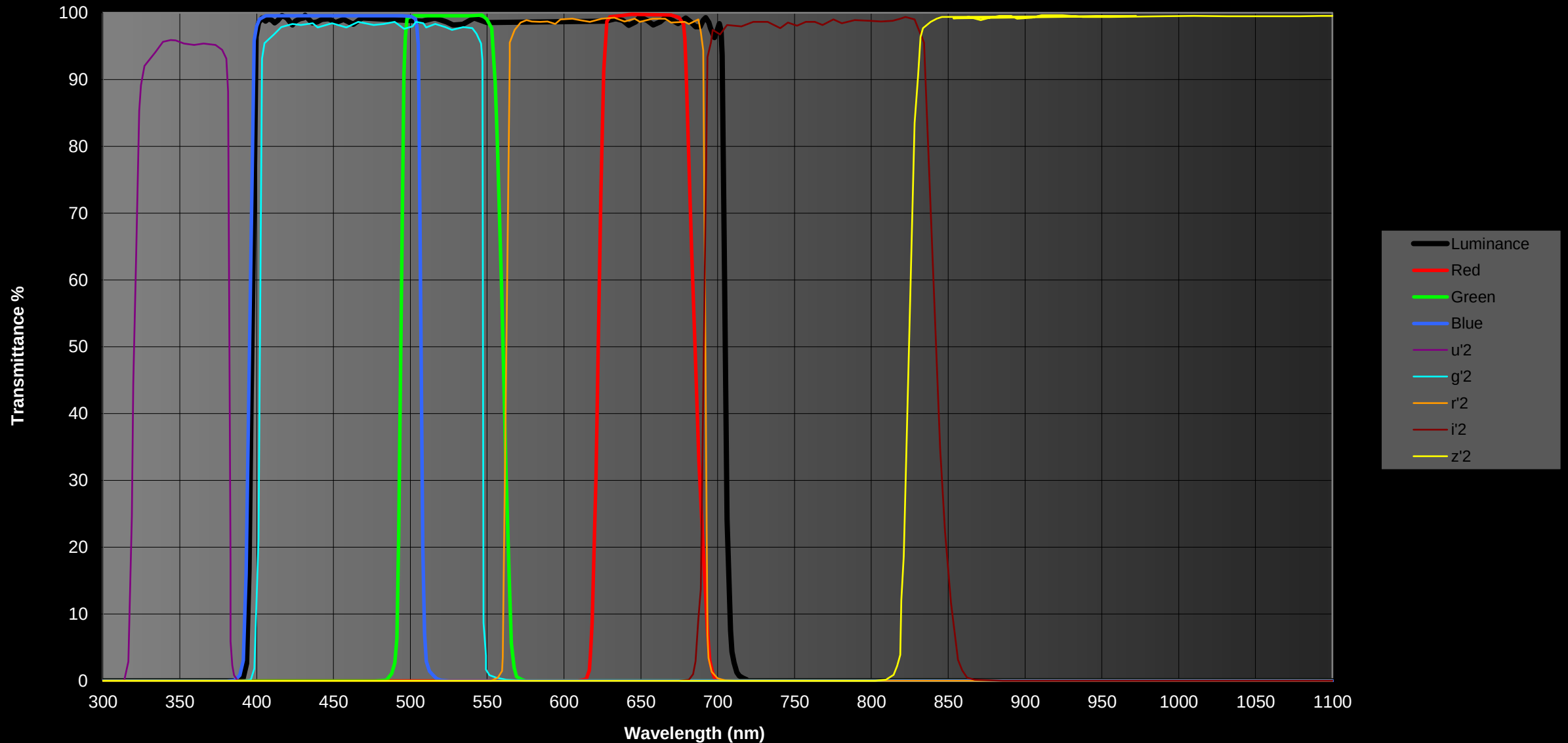


R = N II
G = H II
B = O III



R = (H II + N II)/2
G = O III
B = O III

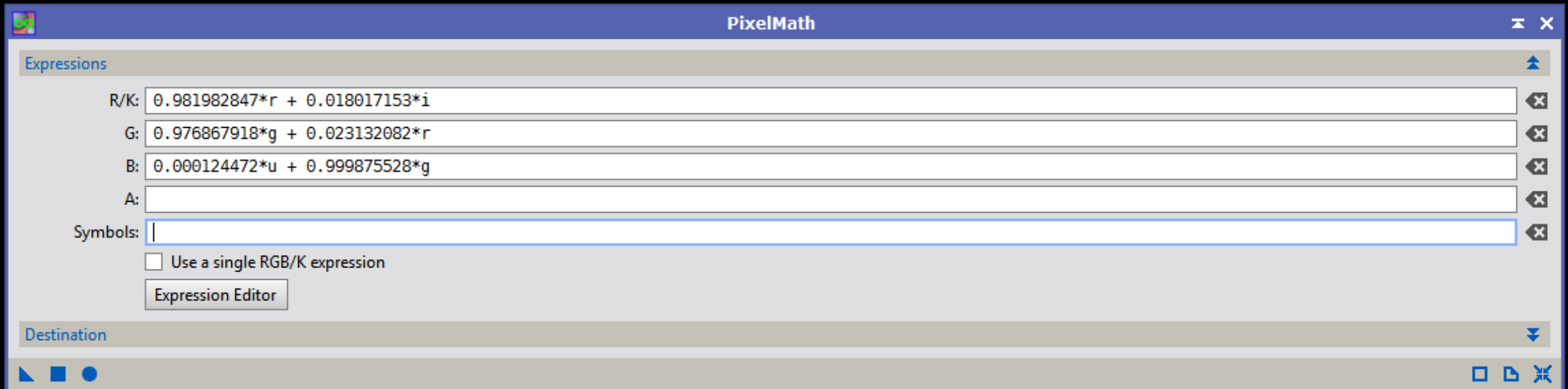
Overlap of Spectra From Astrodon LRGB and Sloan filters



Area Overlap Between Filters

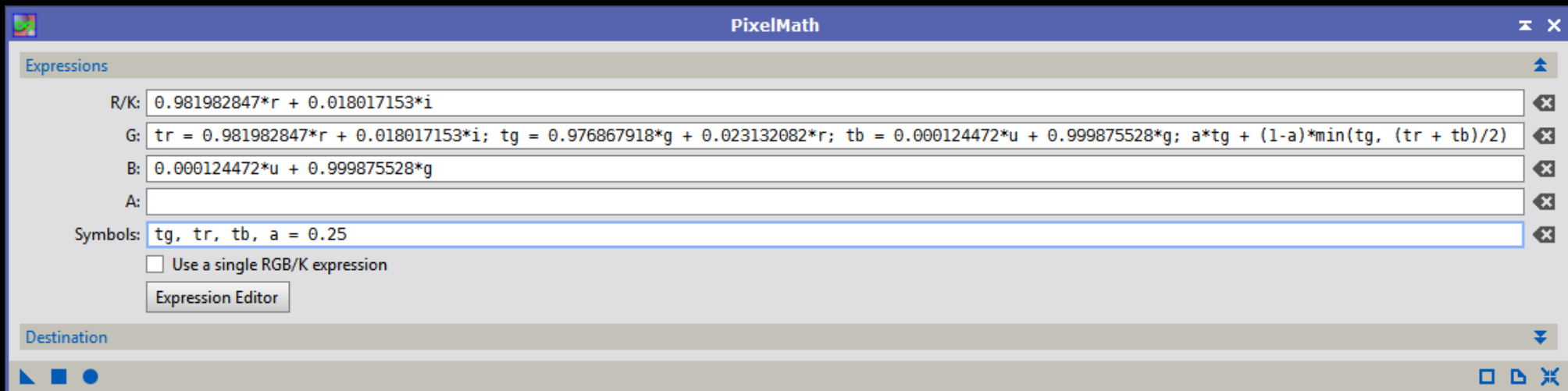
- The graph shows that the z filter has no overlap with any of the LRGB filters
- The g filter almost entirely overlaps B & G and because the cut-offs are so steep colors will appear cyan instead of blue or green
- Since we rarely see green objects in astronomical scenes we can blend it with the other colors using various

Sloan UGRI to RGB				
	U	G	R	I
R	0	0	0.98198	0.01802
G	0	0.97687	0.02313	0
B	0.00012	0.99988	0	0



Average Neutral Blend

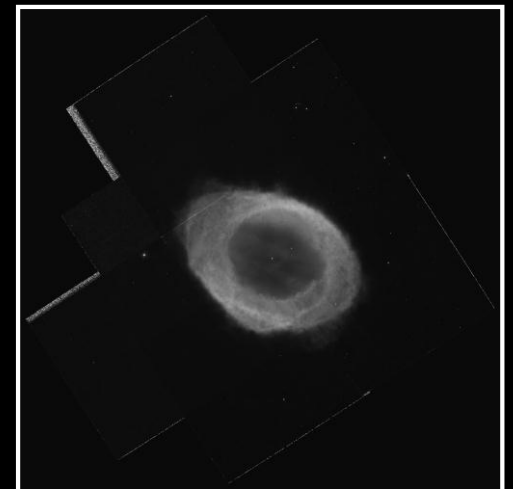
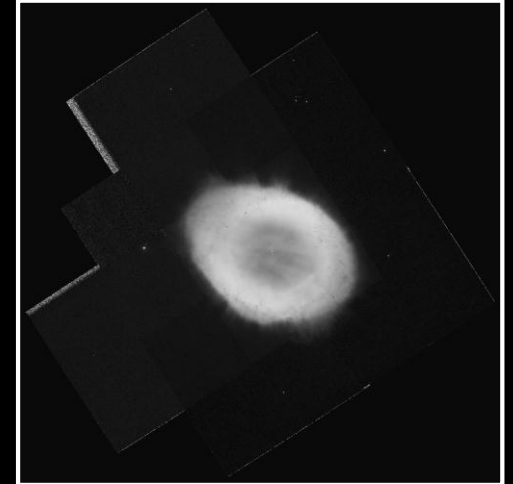
- The average neutral blend picks between the minimum of the green value and the average of the red and blue (taken from PixInsight SCNR algorithm)
- If the green value is higher this indicates the resulting color would have been predominately green, when lower it's value is protected
 - $g' = \min(g, (r+b)/2)$
- In addition to the protection I usually blend it back in some percentage with the original green data
 - $g' = \alpha * g + (1 - \alpha) * \min(g, (r+b)/2)$



Linear Fit

- Because the blending factors are normalized the data needs to be as well
- If the histograms of your raw data are very different, then the results will not be what you expect
- PixInsight has a tool called LinearFit that does this, but it can be done in most imaging programs

Three raw frames
with the same stretch
applied



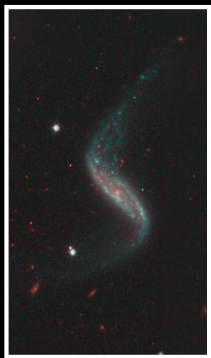
Average Neutral Blend



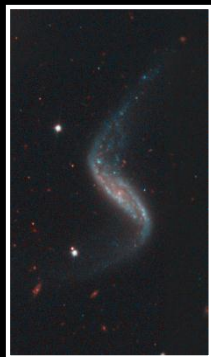
No blend



With blend ($\alpha=0.25$)



No blend



With blend ($\alpha=0.5$)

No blend



With blend
($\alpha=0.25$)



2 Color Blends

- Here I only used the Sloan r & g filters
- I used the same average neutral blend for the green channel to make it look more natural

$$R = r$$

$$tg = 0.97 * g + 0.03 * r$$

$$G = 0.25 * tg + 0.75 * \min(tg, (r+g)/2)$$

$$B = g$$



Getting Really Fancy

- In addition to different blending methods you can also use curves and levels to adjust the color
- I started with:
$$R = (H\text{EII} + N\text{II})/2$$
$$G = O\text{III}$$
$$B = O\text{III}$$
- Then I used curves to push the pinks towards red and greens towards blue
- This yields something a little closer to the daytime white balance DSLR/OSC results



Getting Really Fancy



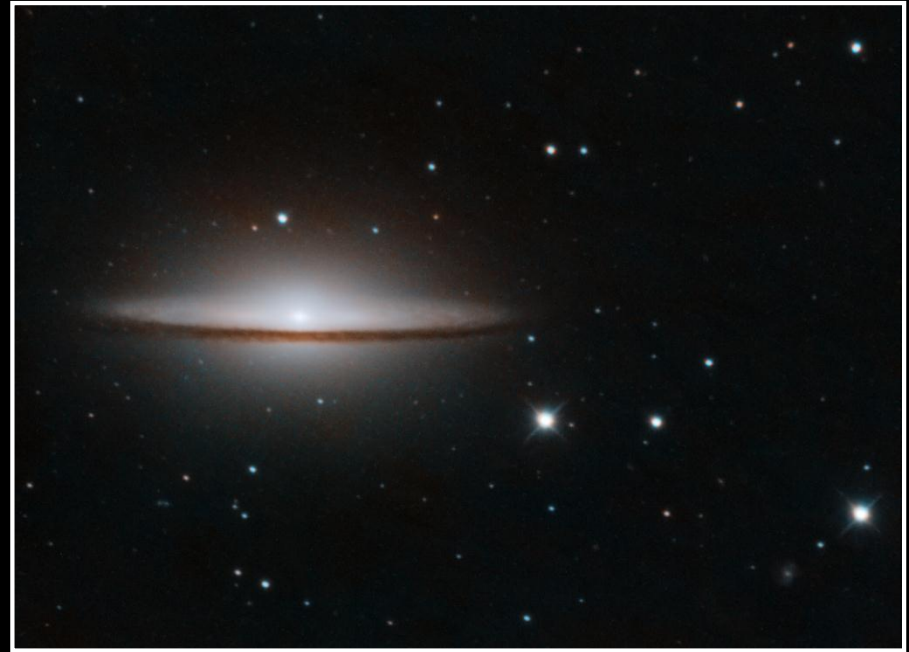
Two different views of M57 w/ Spitzer + Hubble Data

Other Examples



M51

Southwestern University
Filters: Johnson B,V



M104

Southwestern University
Filters: Johnson B,V

Other Examples



M81 & M82
SDSS-III Data
Filters: Sloan r,g

NGC2903
SDSS-III Data
Filters: Sloan u,g,r,i,z



Other Examples



NGC3628
SDSS-III Data
Filters: Sloan u,g,r,i



NGC3628
SDSS-III Data
Filters: Sloan u,g,r,i,z

Other Examples



ARP188
Hubble
Filters: F483W,
F555W, F814W

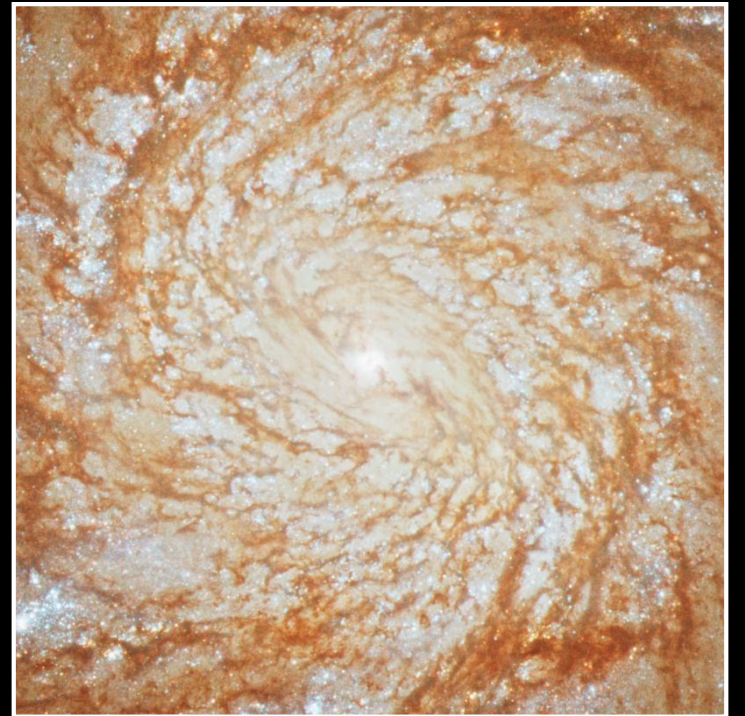


ARP188 - Crop
Hubble
Filters: F483W,
F555W, F814W

Questions?



M51
Hubble
Filters: F483W, F555W, F814W



M51 – Central Bar
Hubble
Filters: F483W, F555W, F814W