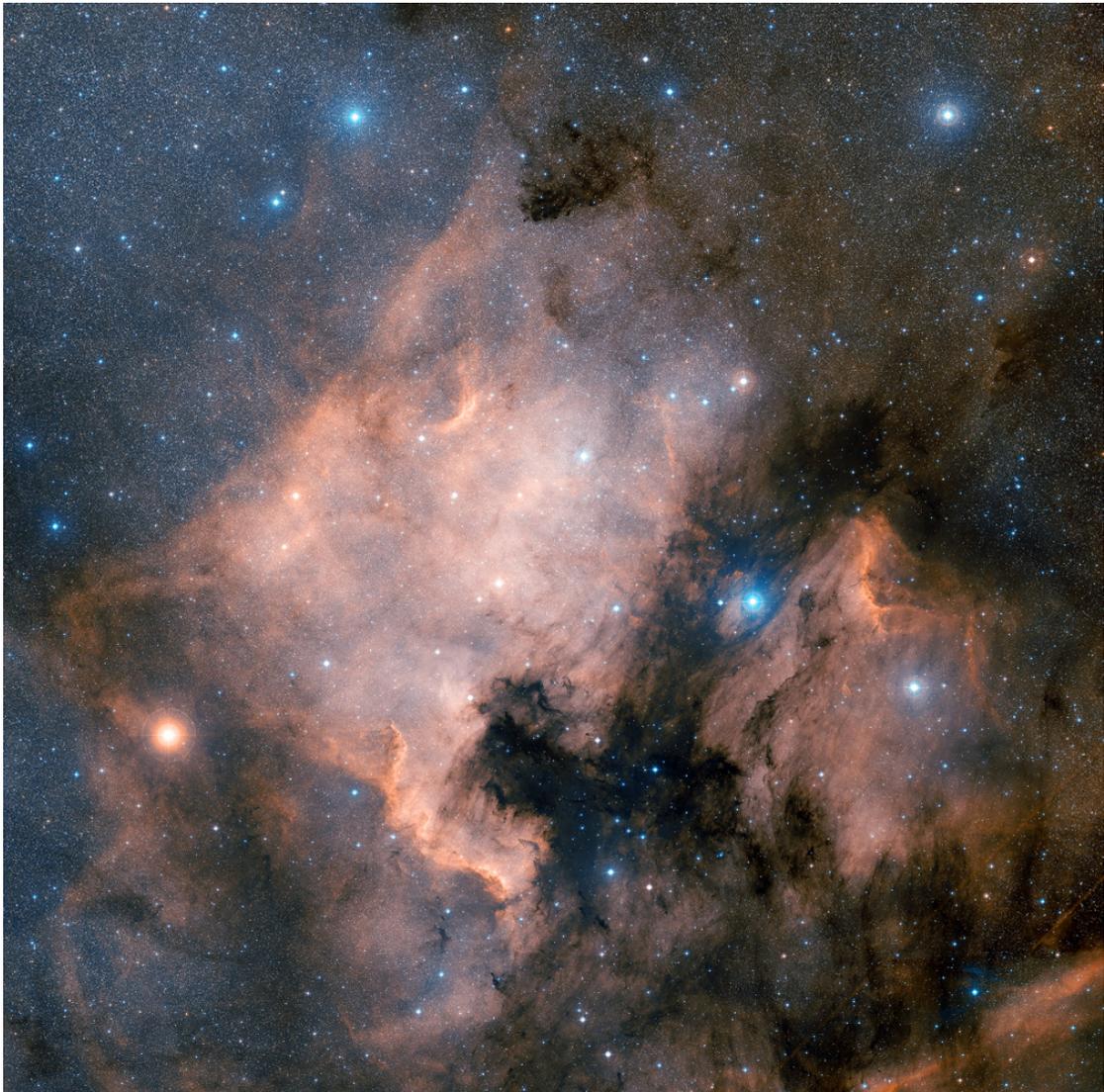


User's Guide

The ESA/ESO/NASA Photoshop FITS Liberator v.2





Colophon

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Acknowledgements

FITS is an abbreviation for Flexible Image Transport System. FITS has been a standard since 1982 and is recognized by the [International Astronomical Union](#).

The ESA/ESO/NASA Photoshop FITS Liberator uses [NASA's CFITSIO](#) library, TinyXML and T-Rex.

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We kindly ask users to acknowledge the use of this plug-in in publicly accessible products (web, articles, books etc.) with the following statement: "*This image was created with the help of the ESA/ESO/NASA Photoshop FITS Liberator*".

Cover:

This image is a composite of black and white images from the Digitized Sky Survey 2 taken with the Palomar Observatory's 48-inch (1.2-metre) Samuel Oschin Telescope as a part of the second National Geographic Palomar Observatory Sky Survey (POSS II). The images were recorded on two glass photographic plates - one sensitive to red light and the other to blue and then digitised. In order to produce the colour image seen here a total of 62 different frames were processed by the Italian amateur astronomer Davide De Martin, 31 for each colour band, taken from 4 different plates dating between 1990 and 1993. The original file is 14,264 x 15,429 pixels with a resolution of about 1 arc-seconds per pixel. The image covers an area of sky larger than 4° x 4.3° (for comparison, the full moon is about 0.5° in diameter).

Credit: Davide De Martin (<http://www.skyfactory.org/>) & Digitized Sky Survey 2.

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1 Introduction to the FITS Liberator



This image of the star-forming region NGC 346 was composed in FITS Liberator from two individual exposures taken through a V filter (555 nm, shown in blue) and a near-infrared filter (814 nm, shown in red). Credit: NASA/ESA Hubble Space Telescope/Zolt Levay.

The release of version 2 of the popular ESA/ESO/NASA Photoshop FITS Liberator image processing software means that it is now easier and faster than ever before to create colour images using raw observations from a range of telescopes, including the NASA/ESA Hubble Space Telescope, NASA's Spitzer Space Telescope, ESO's Very Large Telescope and ESA's XMM-Newton telescope.

Version 1 of the ESA/ESO/NASA Photoshop FITS Liberator was completed in July 2004 by imaging scientists at The European Space Agency, the European Southern Observatory and NASA. FITS stands for Flexible Image Transport System. This single file format archives nearly all images of stars, nebulae and galaxies produced by major telescopes around the world. Before July 2004, this file format was only accessible to a very few people besides scientists working with highly specialised image processing tools.

Since the release of v.1 in July 2004, more than 50,000 laypeople, educators and amateur astronomers have started using the Liberator. The FITS Liberator has also become the industry standard for professional imaging scientists at the European Space Agency, the European Southern Observatory and NASA.

Using version 2 of the FITS Liberator stunning images such as the iconic Hubble image "Pillars of Creation" (Figure 1) can be created in a matter of minutes. Version 2 has been improved in several areas, notably:

- FITS images with up to 4 billion greyscales can be processed (32 bit support).
- FITS images with up to 500 million pixels or more can be processed (100 times larger than standard images from a digital camera).
- an improved user interface and a re-designed order of operations to simplify the overall process – for example the plug-in now remembers previous settings.
- new options for advanced scaling and stretching to fine tune images for optimal results.
- a whole section dedicated to inputting metadata, i.e. information about the image and what it shows. Metadata will be an important tool for future efforts to make archives of 'pretty pictures' more accessible.
- user access to a text version of the original FITS header.

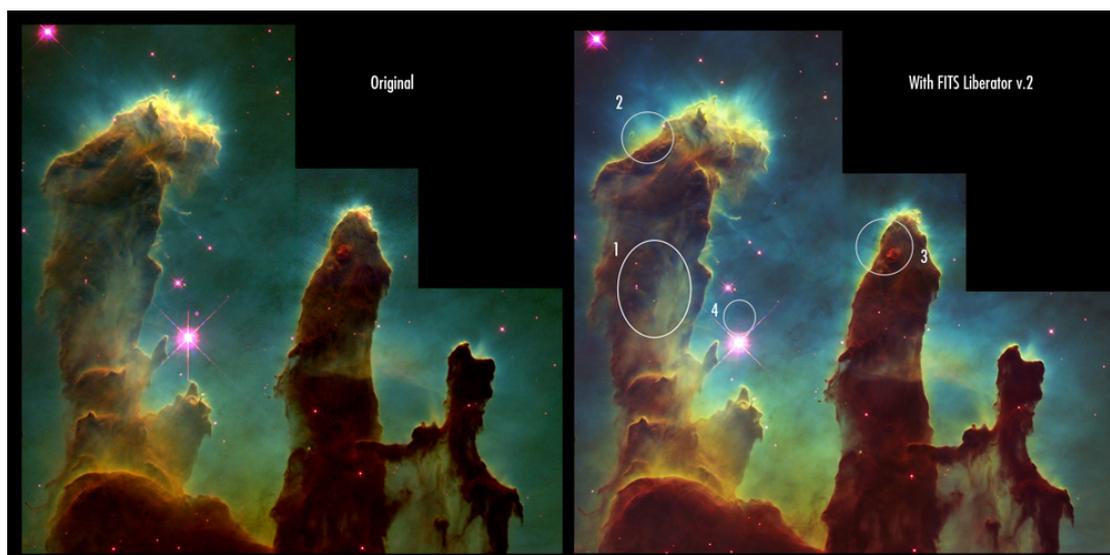


Figure 1 Version 2 of the FITS Liberator makes it even easier to create stunning images. The iconic Hubble image “Pillars of Creation”, seen here, can be created in a matter of minutes. The three-colour dataset used to create this image can be downloaded from:

http://www.spacetelescope.org/projects/fits_liberator/eagledata.html.

The advantages of using FITS Liberator over professional image processing tools are indicated in the right-hand image: 1. Added detail in the shadows. 2. Increased gamut (colour space, more nuances) 3. Slightly better noise characteristics. 4. Easier access to advanced cosmetic cleaning tools as demonstrated by the removed ghosts.

Employing an easy-to-use interactive interface (Figure 2) that shows each change to the processed image, Liberator preserves the many greyscales in the original observations to create better images by providing added detail in the shadows and an increased gamut (colour space) in the finished colour images.

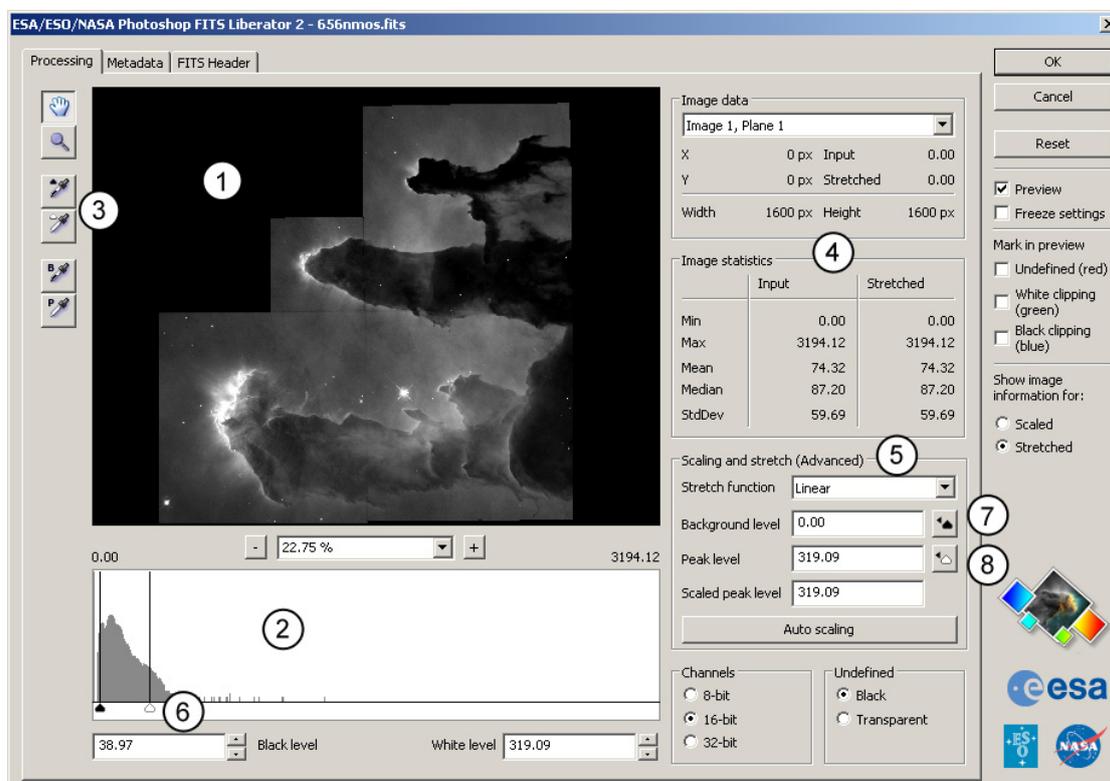


Figure 2 The Liberator's Graphical User Interface Credit: ESA, ESO & NASA. A more detailed overview can be seen in Figure 10.

The first stage of producing spectacular images is handled by the Processing Tab of the Liberator's Graphical User Interface which consists of the following elements (numbers refer to items in figure 2):

1. Preview window
2. Histogram
3. Tools
4. Statistics
5. Advanced tools for Scaling and Stretch

The simple working procedure after opening a FITS image, is to study it in the Preview window, adjust the black- and white levels (6) to give a reasonable contrast, and then set the input range that scales the image by clicking the Auto Scale Button (7). Now different values of the Scaled Peak Level can be tested to change the scale of the image to fit better with one of the possible Stretch functions (8).

A complete overview of all the controls in the Liberator can be found in Chapter 4.

2 Installation of the FITS Liberator



Figure 3 The Carina Nebula is located in the southern portion of our Milky Way galaxy, 10,000 light-years from Earth. This colossal cloud of gas and dust stretches across 200 light-years of space. Though it is dominated by Eta Carinae, it also houses the star's slightly less massive siblings, in addition to the younger generation of stars.

This image was taken by the infrared array camera on Spitzer. It is a four-colour FITS Liberator composite of invisible light, showing emissions from wavelengths of 3.6 microns (blue), 4.5 microns (green), 5.8 microns (orange), and 8.0 microns (red).

Credit: NASA Spitzer Space Telescope/Robert Hurt

2.1 Windows Installation

FITS Liberator can be installed on Windows either by using a setup programme or manually. In both cases, a local administrator must install the plug-in. By default, all users on Windows XP machines are local administrators.

2.1.1 Installing with the Setup programme

The recommended way of installing the FITS Liberator on Windows is to use the setup program. This will install all the necessary files and optionally register FITS files with Photoshop.

2.1.2 Manual installation

To perform a manual installation, download the manual installation package and extract the files to a directory. Next, move the files into the correct locations in the file system. Please be aware that if you are using a localised version of Photoshop the folder names may also be localised.

File	Location and example
FitsLiberator.8bi	{Program Files}\{Photoshop}\{Plug-Ins}\{File Formats} e.g.: C:\Program Files\Adobe\Adobe Photoshop CS2\Plug-Ins\File Formats
cfitsio.dll	{Program Files}\{Photoshop}\ e.g.: C:\Program Files\Adobe\Adobe Photoshop CS2
VR1.xmp, VR2.xmp, VR3.xmp, VR4.xmp, VR5.xmp	{Program Files}\{Common Files}\Adobe\XMP\ Custom File Info Panels e.g.: C:\Program Files\Common Files\Adobe\XMP\Custom File Info Panels

If there is an additional plug-ins folder, the FitsLiberator.8bi file can be placed in that folder.

2.2 Mac OSX Installation

IMPORTANT INFORMATION FOR VERSION 1 USERS:

Uninstall version 1 of the ESA/ESO/NASA Photoshop FITS Liberator before installing version 2. This is essential. Do this by deleting the file named FitsFormat in the Adobe Photoshop CS2 folder. This folder is most likely named /Applications/Adobe Photoshop CS2, or similar for other versions of Photoshop.

The installation of FITS Liberator on a Mac system is a simple drag-and-drop operation:

1. Drag the plug-in file (FitsLiberator2) from the disk image to the local Adobe Photoshop plug-in folder. This folder is most likely /Applications/Adobe Photoshop CS2/Plug-Ins, or similar for other versions of Photoshop. Be aware that the folder name may differ on localised versions of Adobe Photoshop. If there is an additional plug-ins folder, the FitsLiberator2 file can be placed in that folder.
2. Drag the Colour_composite Action file from the disk image to the local Adobe Photoshop Actions folder. This folder is most likely /Applications/Adobe Photoshop CS2/Presets/Photoshop Actions .

3. “Eject” and discard the disk image.

When first accessed within Photoshop, the FITSLiberator2 will automatically install the files VR1.xmp, VR2.xmp...VR5.xmp into the Adobe Application Support directory. If the account from which it is run has administrator privileges they will be installed in /Library/Application Support/Adobe/XMP/Custom File Info Panels (making them available to all user accounts). Otherwise they will be installed in /Users/{USERNAME}/Library/Application Support/Adobe/XMP/Custom File Info Panels (available only to specified users).

3 Using the FITS Liberator



Figure 4 This image is a composite made with the FITS Liberator from black and white images taken with the Palomar Observatory's 48-inch (1.2-metre) Samuel Oschin Telescope as a part of the second National Geographic Palomar Observatory Sky Survey (POSS II). The images were recorded on two glass photographic plates - one sensitive to red light and the other to blue light and later digitised. In order to produce the colour image seen here, a total of 66 different frames were processed, 33 for each colour band, coming from 8 different plates taken between 1988 and 1997. The original file is 17,067x13,508 pixels with a resolution of about 1 arc-seconds per pixel. The image shows an area of sky extending over $4.7^\circ \times 3.8^\circ$ (for comparison, the full moon is about 0.5° in diameter).

Credit: Davide De Martin (<http://www.skyfactory.org/>) & Digitized Sky Survey 2.

3.1 A Cookbook Example

Below is a simple step-by-step example for how to import a FITS file into Photoshop using a specific FITS file from the examples on the FITS Liberator web page. The numbers refer to Figure 10:

1. Go to the example data sets on the FITS Liberator web page:
http://www.spacetelescope.org/projects/fits_liberator/datasets.html
2. Download a data set.
3. Open the images one by one in FITS Liberator.
4. Set White and Black levels (15, 16) to give a good contrast without too much black and over saturated areas.
5. Click Auto Scaling (52).
6. Try different Stretch functions (46) to enhance the fainter parts of the image.
7. Click OK.

The rest of the work needed to construct a beautiful image is described in Section 3.6. The basic steps for this are:

1. Copy the layers together in Photoshop
2. Colourise the layers
3. Use adjustment layers to finalise the image

3.2 Basics

In the usual sequence of processing an image it typically takes on the following four different names:

1. **Input image**: The reduced, cleaned image from the astronomical processing
2. **Scaled image**¹: The input image scaled up or down so as to let the pixel values fall in the range where the Stretch function works best. If the input image contains, for instance, pixel values in the range [5:50,000], the Scaled image might be chosen to contain pixel values from [0:100] to fit better with a logarithmic Stretch function.
3. **Stretched image**: The Scaled image transformed by the stretch function, for instance a logarithmic Stretch.
4. **Output image**: The image that arrives in Photoshop for further processing. This is qualitatively the same as the Stretched image, but is scaled to the desired bit depth in Photoshop (e.g. 16 bit: [0, 65535])

Note that the FITS Liberator defines Logarithm as $\text{Log} = \log_{10}(\text{Scaled_image} + 1)$ for consistent behaviour around the background or zero level.

¹ Defined as $\text{Scaled_image} = \text{ScaledBackgroundLevel} + (\text{ScaledPeakLevel} - \text{ScaledBackgroundLevel}) * (\text{Input_Image} - \text{BackgroundLevel}) / (\text{PeakLevel} - \text{BackgroundLevel})$

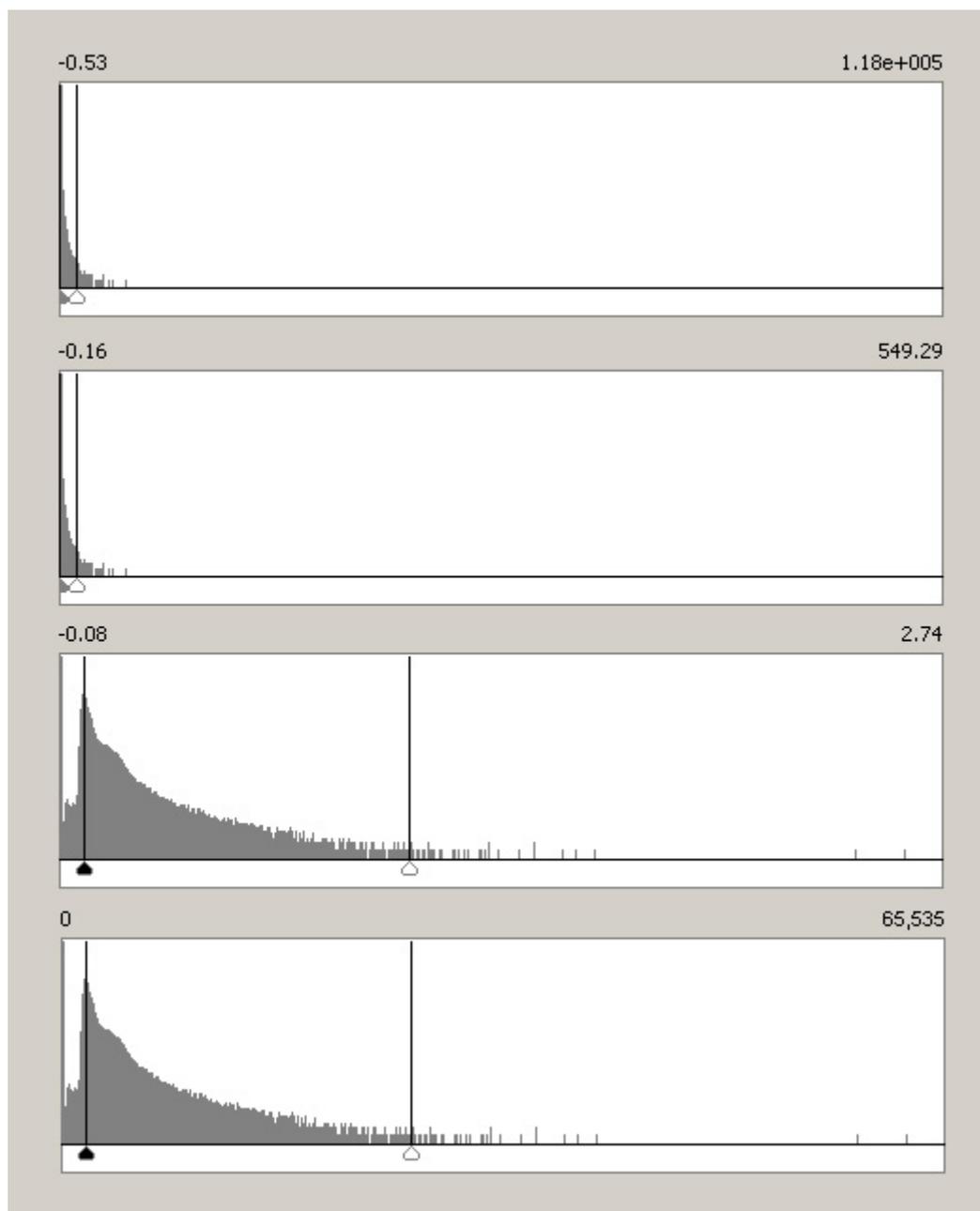


Figure 5: Example histograms for the four different images created during a typical workflow process: a) Input image, b) Scaled image, c) Stretched image (here with a Logarithmic Stretch function) and d) Output image (in Photoshop).

3.3 Stretched Images

Many astronomical images have a very high dynamic range, or many greyscales. This means that the brightest areas of interest may be many thousands (or even millions) of times brighter than the faintest structures in the image.

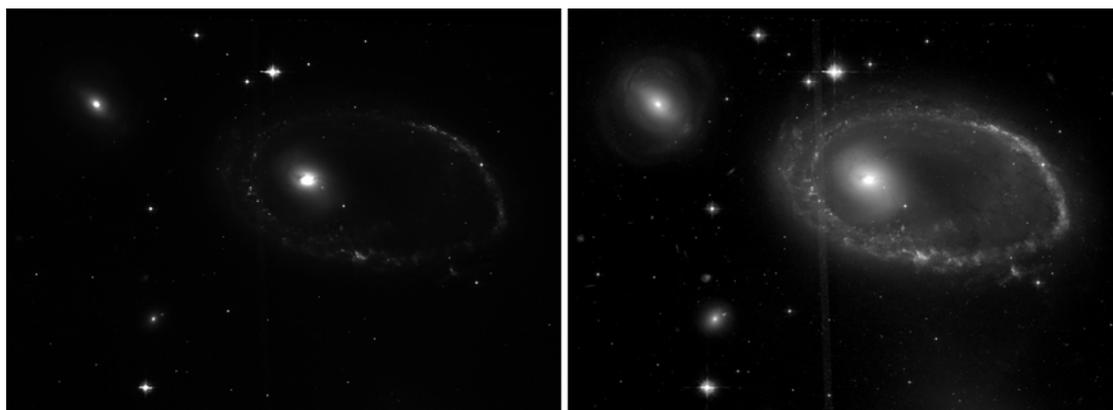


Figure 6 *Astronomical images contain many more greyscales than can be viewed on a computer monitor or printed. In the image to the left a 'normal' or linear representation of the image is shown. To the right the effect of a non-linear scaling, a logarithmic scaling, is shown. By using non-linear scaling it is possible to enhance some greyscales in the image more than and so to make faint details visible without saturating the brighter parts of the image.*

However, on a computer screen, one only can see 256 levels of brightness (8 bit greyscale). If the original high dynamic range image is imported directly into Photoshop using simple linear Scaling, either the detail in the fainter structures is lost in the black background, or the brightest objects over-saturate (or burn in).

Photoshop can partially compensate for this by applying Levels or Curves transformations after the FITS image has been imported. However, an image that has been reduced to 8 bit greyscales can only be adjusted a little bit before it begins to posterize, obscuring low-level features. Even extreme curve adjustments cannot bring out the faintest detail in some of these images.

For this reason, the FITS Liberator has an advanced Scaling and Stretch section that offers many options for compressing this dynamic range before the data sets are imported. The Stretch Function pop-up lists a variety of mathematical functions that are useful for this task, including log, square root, cube root, and inverse hyperbolic sine (ASinh). These functions mimic the operation of the human eye, which can accommodate to perceive dramatically different levels of brightness simultaneously.

To see how these stretch functions work, try opening a FITS file with high dynamic range. Images of galaxies are a good starting point for this experiment since their central bulges are many orders of magnitude brighter than their faint arms. Make sure that all of the Mark Pixels options (63-65) are selected on the right side of the window. These will highlight any areas that have been clipped due to the Levels setting (15, 16). Now, drag the white level slider (15) until all the green masked pixels have disappeared. The faintest parts of the image will probably have faded to black.

Now choose Sqrt() from the Stretch Function pop-up (46). The preview image (10) should update after a moment to show an increase in brightness in the fainter areas. This should also be evident in the histogram window (14) as the distribution shifts, with the fainter areas on the left shifting more to the right. However, the clipped black (blue pixels) and white (green pixels) levels will remain the same. Switch back and forth a few times between Linear and Sqrt() to see the effect on the image.

Next try CubeRoot(). The fainter parts of the image should get even brighter. In fact, each function will stretch the image in a slightly different way. The choice of the best stretch function really depends on the aesthetic and scientific needs for each image. The FITS Liberator offers a wide variety of options to give the user flexibility.

3.4 Scaling Images for Better Stretches

The Stretch functions in the FITS Liberator are simple mathematical functions that provide the best overall results for data. But some mathematical functions behave differently² when operating on images with pixel values between 0 and 1, for example, than they do on images with pixel values between 0 and 10000. For this reason, the Liberator offers a set of Scaling controls that can be used to change, or scale, the pixel values in an image.

Since the FITS Liberator user will probably have no control over how the FITS images were originally produced, the plug-in allows the minimum and maximum brightness levels (Background and Peak levels, 47 and 48) and the Scaling level (with the Scaled Peak level, 49) to be set by hand. These numeric fields under Scaling and Stretch (Advanced) include:

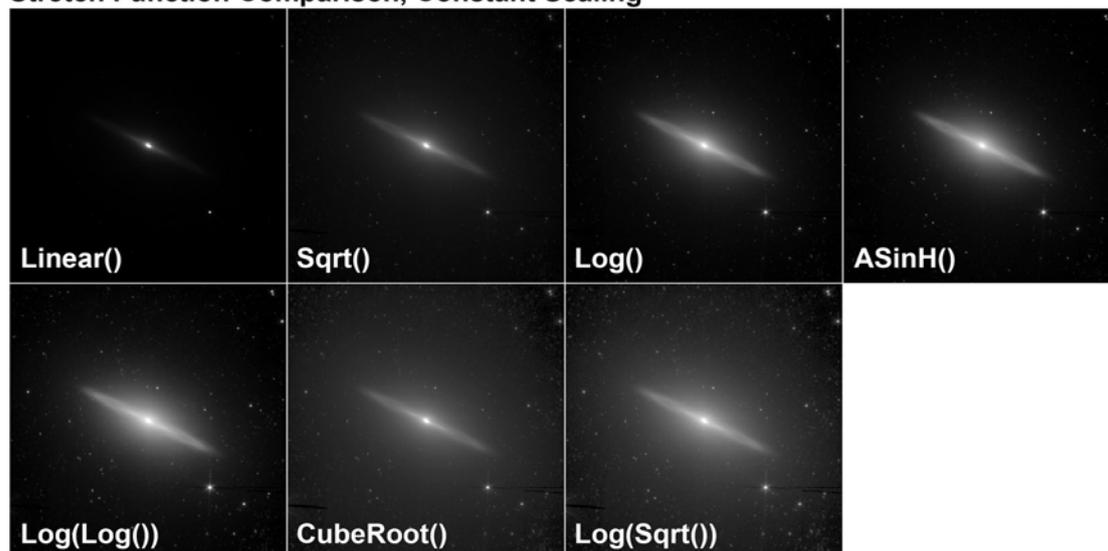
- Background level (the numeric value of the noise level in the image, 47)
- Peak level (the numeric value of the brightest sources of interest, 48)
- Scaled Peak level (the desired value for the brightest sources *after* Scaling, 49)

To Scale an image quickly, click Auto Scaling (52) and experiment with different values of the Scaled Peak level and different Stretch functions.

In the image (Figure 7) below the effect of different Stretch functions and different values of the Scaled Peak level are illustrated.

² Note that the Linear(), Sqrt(), and CubeRoot() Stretch functions are not affected by scaling.

Stretch Function Comparison, Constant Scaling



Log Stretch Comparison, Varying Scaled Peak Levels

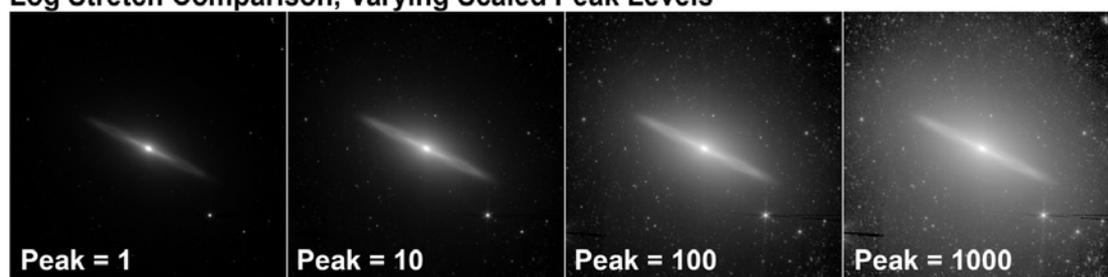


Figure 7 The range of available FITS Liberator stretch functions are shown here. The top two rows show all the stretch functions, in approximate order of their effect. Image scaling is constant for all of these, with the white level of the galaxy nucleus set to 10.0. The bottom row shows the effect of changing the peak scaling while using the Log() function. Note that this single function allows for a continuously variable enhancement of faint structure. All of the stretch functions (except Linear(), Sqrt(), and CubeRoot()) will show similar results when varying this parameter.

3.5 Entering Metadata

Metadata can be summarised as “information about the data”. Image metadata includes information about what is in the image and where the telescope was pointed among other things. Version 2 of the FITS Liberator can now tag an image with a full set of metadata, some of which is extracted directly from the FITS header while the rest is entered by the user. The metadata is saved within the image file itself and can be read by anyone who later opens the image in Photoshop or another metadata-aware program.

The screenshots below (Figure 8) show an example. The user either fills in the metadata fields directly or by choosing from a dropdown list. Some fields retain the values from the last opened image.

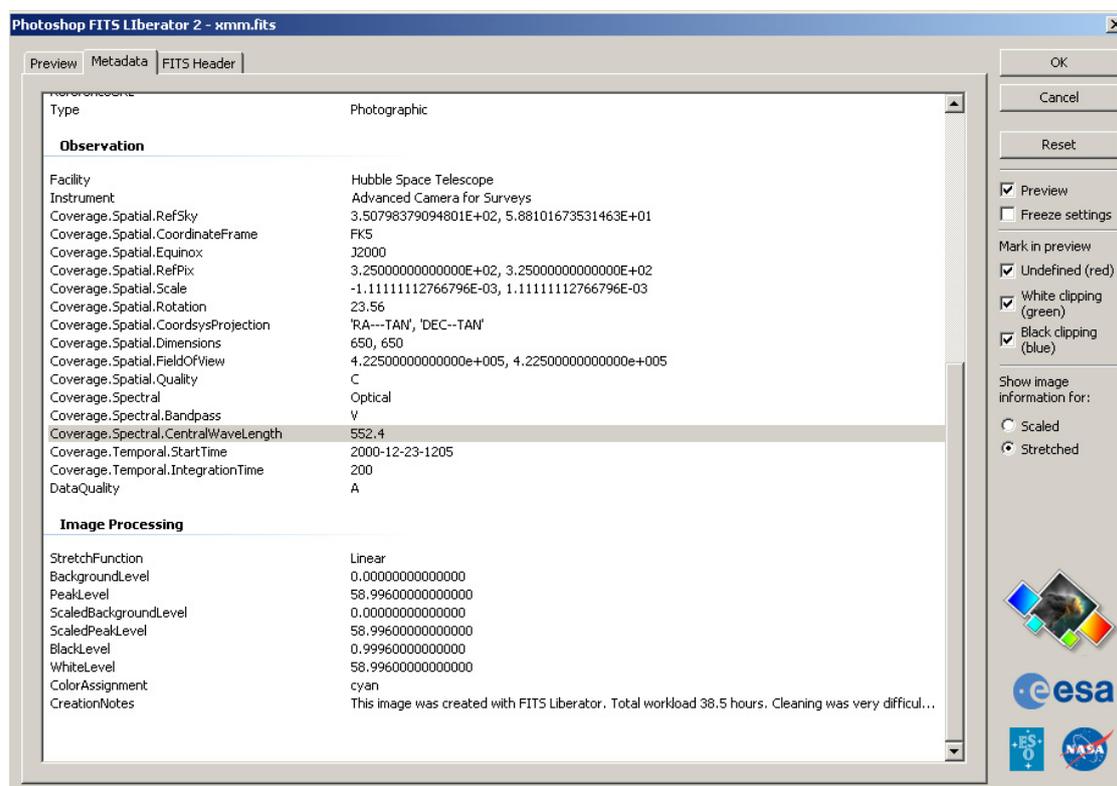
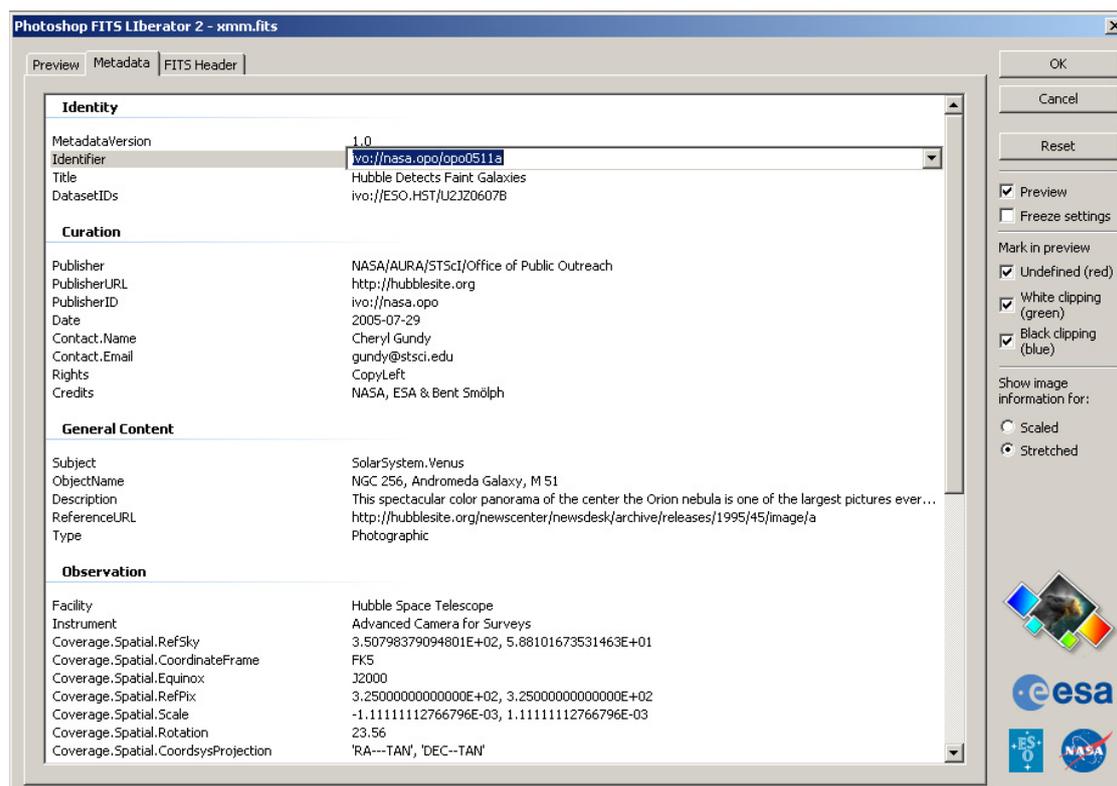


Figure 8 An example of the type of information that is typically entered in the FITS Liberator metadata fields.

The steps needed to attach metadata to images are:

1. Open the image in Liberator.
2. Liberator transfers any relevant FITS keywords that are present in the FITS header.

3. Liberator retains some standard Metadata info from the previous session.
4. The user fills out any remaining fields.
5. User clicks OK.
6. Liberator fills out the image processing fields.
7. The same procedure is repeated for 2 or more other exposures
8. Using the (currently non-existent) "Concatenator" tool³:
 - Three (or more) exposures are merged into a layered file (possibly even with the right adjustment layers such as the Colour_Composite action), and
 - Three (or more) sets of metadata are concatenated.
 - This tool could be a Photoshop Script or perhaps an Automatic plug-in. The XMP data will then approximately correspond to the example in Appendix B.
9. The user completes the image, adds optional comments to the CreationNotes and fills in the Coverage.Spectral.ImageColormap.
10. The user saves the image as a tiff file.

Since the final image will probably have been rotated and cropped during step 9 above, the coordinate info from the FITS header will no longer be correct. This can be corrected by the following procedure:

11. The user opens the STScI WCSTool together with the original FITS file with the highest S/N.
12. The user clicks to connect the same stars in the two images.
13. The tool overwrites the coordinate keywords in the XMP data
14. The tiff file is saved again.

Metadata entered through FITS Liberator is also accessible and can be edited with Photoshop's File>File Info... dialog box. If the VR1.xmp, VR2.xmp, etc. files have been properly installed (see section 2 for install locations), this dialog will show five new sections (such as "Astro Identity") that display the same metadata fields. Photoshop also offers many useful features for entering Metadata in this interface, including recent histories for each field, and user-definable templates for entire sections. Consult the Photoshop documentation for more information on these features.

3.6 Making Colour Composites

The basic principles for making colour composites are:

- Copy the layers together in Photoshop
- Colorise the layers
- Use adjustment layers to finalise the image

A colour composite image is created by assembling two or more greyscale images of the same object taken in different colours, or wavelengths, of light. These may be from the visible part of the spectrum or beyond.

An example Photoshop Action (Colour_composte.atn) is supplied on the FITS Liberator download page:

http://www.spacetelescope.org/projects/fits_liberator/download_v2.html

and can be used to speed up the process. The file should be saved in the local Actions directory, e.g. /Applications/Adobe Photoshop CS/Presets/Photoshop Actions).

³ We are currently working on the issue of how to combine metadata from three or more different exposures once they have been imported into Photoshop.

To load the Action: In the Action Window (Window -> Action) select Load Actions -> Colour_composite.atn (the small arrow in the upper right corner). A series of new commands will appear in the local Actions palette.

This action acts on three (aligned) greyscale exposures of the same object in Photoshop. Open three images using the FITS Liberator and copy the three files into three layers of the same file. First select the layer that should appear as blue in the final image and play the "Blue Layer" part of the Action. Answer "Don't Merge", if that question comes. Repeat for the red and green layers. For more information on creating colour composites consult the tutorial at:

http://www.spacetelescope.org/projects/fits_liberator/stepbystep.html

4 Advanced User's Guide

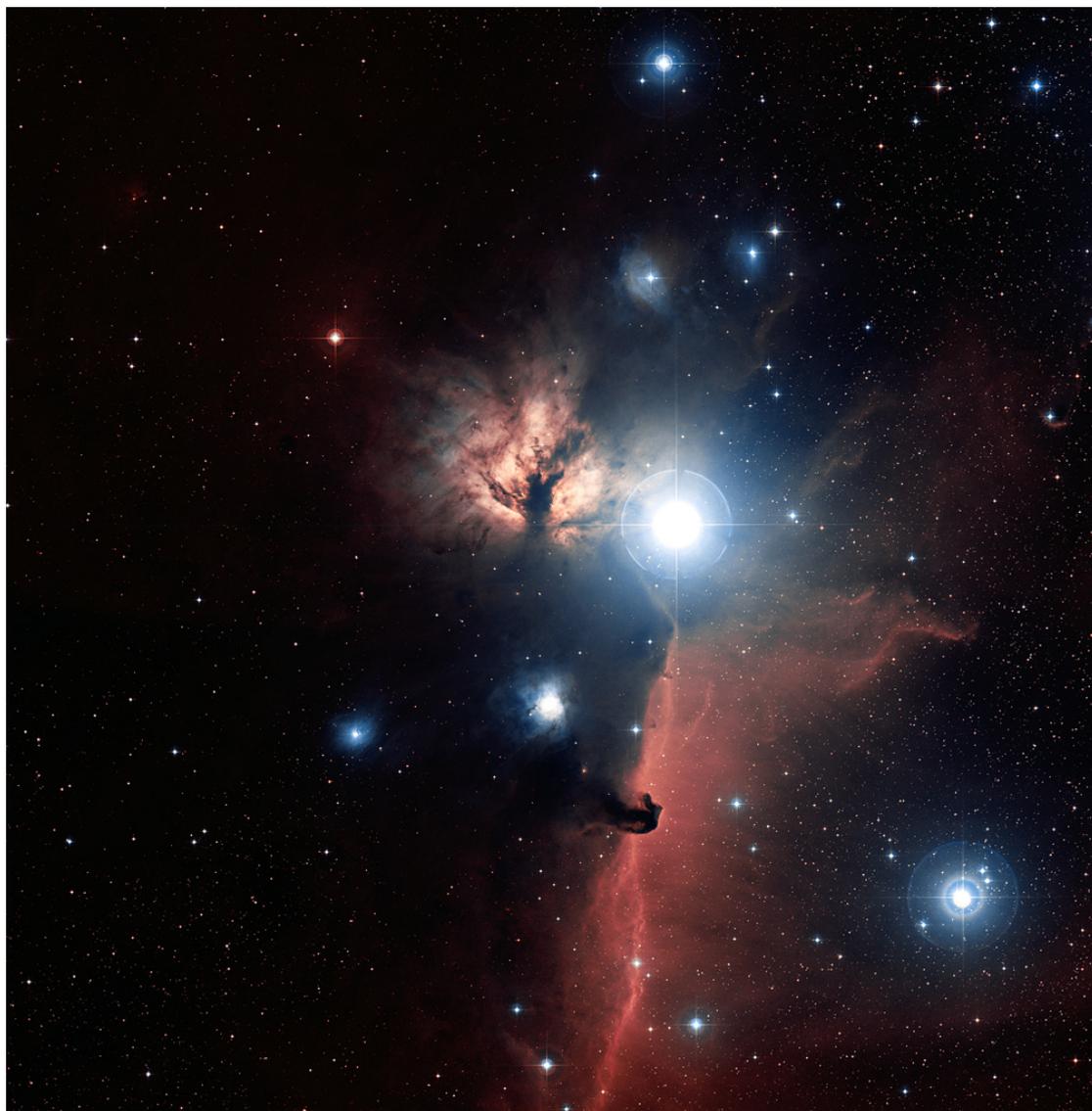


Figure 9 *The Horsehead Nebula made from Digitized Sky Survey 2.*

Daive De Martin (<http://www.skyfactory.org/>) & Digitized Sky Survey 2

In this section, we provide more in-depth information about the many different options that FITS Liberator v.2 provides. To give the full overview we will first list all the components in the Graphical User Interface.

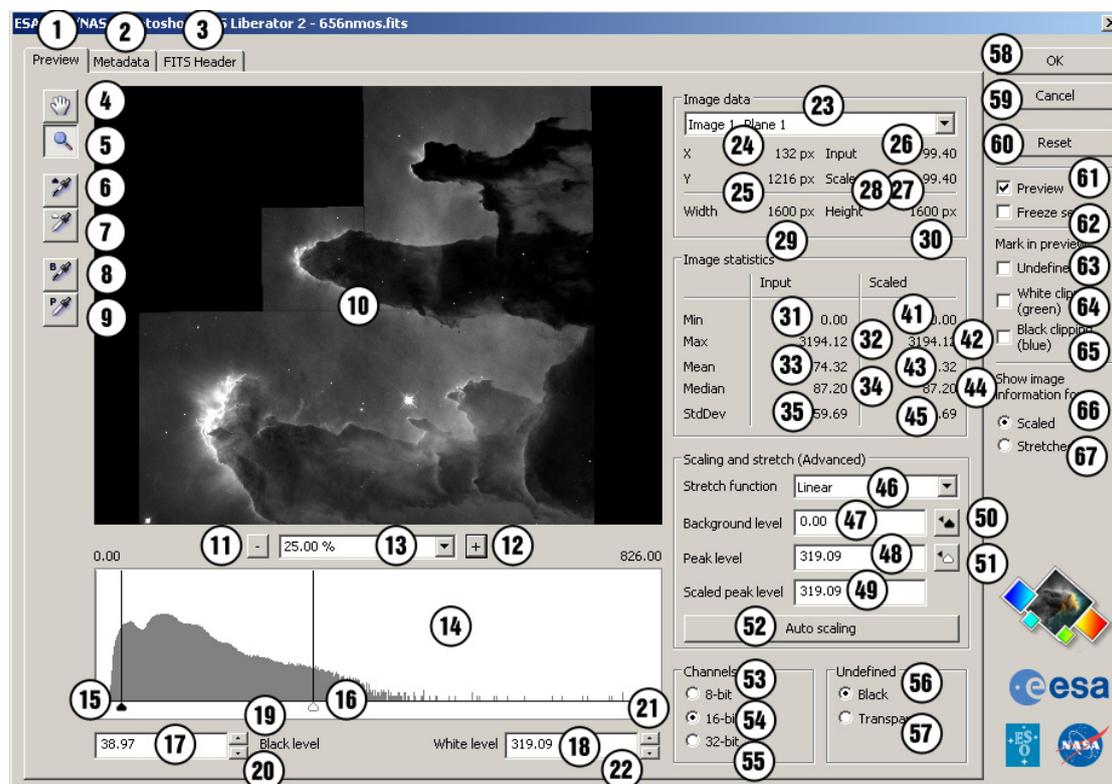


Figure 10 FITS Liberator screen shot with all tools and functions marked. These are described below. Note that the Image statistics can be shown for either the Scaled version of the image (as here) or for the Stretched version of the image. The numbers 36-40 are therefore absent.

Tabs

- | | |
|--------------------|-----------------------------------|
| 1. Processing Tab | Preview image and import settings |
| 2. Metadata Tab | Metadata input |
| 3. FITS Header Tab | FITS Header information |

Tools

- | | |
|----------------------------|-----------------------------|
| 4. Move Tool | Move tool (v) |
| 5. Zoom Tool | Zoom tool (z) |
| 6. Black level Picker | Black level Picker tool (s) |
| 7. White level Picker | White level Picker tool (w) |
| 8. Background level Picker | Background Picker tool (b) |
| 9. Peak level Picker | Peak level Picker tool (p) |

Preview Window

- | | |
|--------------------|-----------------------------------|
| 10. Preview Window | 8-bit representation of the image |
| 11. Minus Button | Decrease zoom factor |
| 12. Plus Button | Increase zoom factor |
| 13. Zoom Popup | Choose a zoom factor |

Histogram Window

- | | |
|-----------------------------|---|
| 14. Histogram Window | Shows the distribution of greyscales in the image |
| 15. Black level Slider | Drag to change the black level |
| 16. White level Slider | Drag to change the white level |
| 17. Black level Text Field | Black level |
| 18. White level Text Field | White level |
| 19. Black level Button Up | Increase the black level |
| 20. Black level Button Down | Decrease the black level |
| 21. White level Button Up | Increase the white level |
| 22. White level Button Down | Decrease the white level |

Image Data

23. Image/Plane Selector	Change image and/or plane
24. X-coordinate	X-coordinate
25. Y-coordinate	Y-coordinate
26. Input value	Input value
27. Stretched value	Stretched value
28. Scaled value	Scaled value
29. Width	Image width
30. Height	Image height

Image Statistics

31. Minimum Input	Minimum of Input image
32. Maximum Input	Maximum of Input image
33. Mean Input	Mean of Input image
34. Median Input	Median of Input image
35. Standard Deviation Input	Standard deviation of Input image
36. Minimum Stretched	Minimum of Stretched image
37. Maximum Stretched	Maximum of Stretched image
38. Mean Stretched	Mean of Stretched image
39. Median Stretched	Median of Stretched image
40. Standard Deviation Stretched	Standard deviation of Stretched image
41. Minimum Scaled	Minimum of Scaled image
42. Maximum Scaled	Maximum of Scaled image
43. Mean Scaled	Mean of Scaled image
44. Median Scaled	Median of Scaled image
45. Standard Deviation Scaled	Standard deviation of Scaled image

Scaling and Stretch (Advanced)

46. Stretch function Popup	Select Stretch function
47. Background level Text Field	Set Background level
48. Peak level Text Field	Set Peak level
49. Scaled peak level Text Field	Set Scaled peak level
50. Set Background level Button	Inserts Black level as Background level
51. Set Peak level Button	Inserts White level as Peak level
52. Auto Scaling Button	Insert Black level from input image as Background level, insert White level from input image as Peak level, Set Scaled peak level to 10

Channels

53. Channels 8-bit Radio Button	Import as 8-bit image
54. Channels 16-bit Radio Button	Import as 16-bit image
55. Channels 32-bit Radio Button	Import as 32-bit image

Undefined Values

56. Undefined Black Radio Button	Import undefined values as black
57. Undefined Transparent Radio Button	Import undefined values as transparent

Other Settings

58. OK Button	Import image into Photoshop
59. Cancel Button	Unload plug-in
60. Reset Button	Reset settings
61. Preview Check-box	Enabled/disable preview
62. Freeze settings Check-box	Keep current settings
63. Undefined (red) Check-box	Show/hide undefined pixels
64. White clipping (green) Check-box	Show/hide white clipped pixels
65. Black clipping (blue) Check-box	Show/hide black clipped pixels
66. Scaled Radio Button	Show scaled values
67. Stretched Radio Button	Show stretched values

The FITS Liberator Graphical User Interface (shown above) controls all elements of the import by means of three panels accessed by the tabs along the top row (1-3) and a selection of buttons and options along the right side. The first Processing Tab (1) contains all of the controls for adjusting the input FITS image. The next Metadata Tab (2) accesses the image and creation tags that are useful for documenting the image and interfacing with services like the Virtual Observatory. Finally the FITS Header Tab (3) shows the content of the header for the input image. The OK/Cancel buttons (58, 59) accept/abort the input, and the Reset button (60) clears any user settings and returns the image to the default best-guess settings. The esc key can also be used to cancel the plug-in.

Text entered into the text fields is accepted when either the 'enter' or 'tab' keys are pressed. The 'enter' key maintains focus on the current field while 'tab' advances to the next one. Note that the 'enter' key is not equivalent to clicking the OK button since it is used for data entry. Copy/paste commands are recognised within the text fields.

4.1 Tabs

There are three Tabs (1-3) long the top of the Liberator interface:

1. Processing Tab where the image processing is handled
2. The Metadata Tab where Metadata can be entered
3. The FITS Header Tab where a text version of the FITS header is listed.

4.2 Tools

The available Tools are found on the left side of the interface in three groups: Move/Zoom (4,5), Black/White Level Pickers (6,7), Background/Peak Level Pickers (8,9).

The top hand-shaped tool (4) is for panning in the preview and histogram windows. When selected the user can simply click and drag in either window to move items into view. The pan tool may also be temporarily activated by holding down the space bar.

The Zoom tool (5) allows interactive zooming within the preview (10) and histogram windows (14). Clicking in either window will zoom in a step around the area clicked. Holding down the alt/option key will zoom out. The user may also drag out a rectangular region to zoom exactly into that portion.

The Black/White and Background/Peak level eyedroppers (6-10) are similar in use but apply to different portions of the interface. They allow their corresponding parameters to be set interactively by clicking within the preview window. The upper two (6, 7) set the Black/White levels (17, 18) under the Histogram Window; they use a single-pixel sample. The lower two (8, 9), distinguished by the "B" & "P" labels, set the Background/Peak levels (47, 48) in the Scaling and Stretch pane.

Keyboard shortcuts may be used to activate the tools:

- v for Move tool
- z for Zoom tool
- w for White Picker
- s for Black Picker
- b for Background level Picker
- p for Peak level Picker.

4.3 Preview Window

The large window in the upper left part of the Processing Tab is the greyscale Preview (10) of the imported image. It reflects the current Black and White levels and Stretch settings and shows how the image will look if imported. Any update to the display settings will trigger an immediate redraw, which may take some time on slower systems/larger images. Underneath the window are readouts and controls for setting the zoom level (11-13). A specific zoom level may be selected from the pop-up menu (13), or the +/- buttons (11, 12) can be used to increment/decrement the zoom value.

4.4 Histogram Window

The display window on the lower left of the FITS Liberator window (14) shows the current histogram of the image that is displayed in the Preview Window. This is similar to the histograms generated within Photoshop, except that the histogram here changes depending on whether the image is the Input image, the Scaled version of the image or the Stretched version of the image. Changes to the Scaling and Stretch settings (see below) will cause the histogram to be regenerated, reflecting any changes to the brightness distribution. The histogram window may be zoomed in or out using the Zoom Tool (5) and moved using the Move Tool (4).

The White and Black levels are set underneath the histogram with the small black/white triangles (15, 16). These controls function much like the Levels dialog box in Photoshop. The black/white sliders may be dragged within the window, or numeric values may be typed into the text fields. Tab or enter will cause the number to be accepted. The up/down arrows (20, 22) by each field will adjust the level in increments of 1/10th of a displayed column to allow for finer adjustments than dragging allows. The up/down arrows on the keyboard will work the same way if the text field is highlighted.

4.5 Image Data

Image/Plane Selector (23): The pop-up menu selector (defaults to "Image 1, Plane 1") allows the user to select the desired sub-image within a complex data file. While FITS files contain a single image, some datasets allow multiple images to be included in a single file. These can include multiple concatenated images strung together (identified by the Image number), or 3-D data cubes (identified by the Plane number).

Multiple images are sometimes combined when they form a series taken of a single source, possibly at different positions or using different filters. Data cubes usually use the third axis to include multiple values of a third parameter, such as steps in wavelength for spectral line imaging.

The FITS Liberator can read in one image at a time by selecting the desired image from the pop-up menu. If multiple images need to be read in using identical settings (as is often the case with a data cube), the user may select the Freeze settings checkbox (62) as the first one is read in to retain all Black/White/Background/Peak/Stretch settings (see Other Settings below).

The information area underneath the Image/Plane Selector (23) is used in conjunction with moving the cursor over the Preview Window. The left column shows the absolute X & Y coordinate (24, 25) of the cursor in the original image relative to the upper left corner. The right column gives the data value at that position for both the Input image (26) and the Scaled (28) (the data after the background level and scaling factor has been applied) respectively or the Stretched (27) (after a Stretch function has been applied) images (depending on the setting of the radio button setting for Show image information for on the far right side of the interface (66, 67)).

Further down there is the width and height of the image (in pixels (29, 30)).

4.6 Image Statistics

The Image Statistics information area (31-45) provides overall statistics for the whole image. As with Image Data these values are presented for both the original Input image and either the Scaled or Stretched image. The statistics provided include the

minimum and maximum data values (31/41, 32/42) as well as the mean (or average) (33/43), median (34, 44), and standard deviation (35, 45).

4.7 Scaling and Stretch (Advanced)

The Scaling and Stretch functions (46-49) in FITS Liberator apply a mathematical stretch to the raw data values to bring out faint details in the image without having to over-saturate the brightest areas of interest. Such stretches are needed in datasets with high dynamic range.

The Stretch function pop-up (46) provides a list of mathematical functions that can be applied to the raw data before it is translated to levels of grey for display. Linear() is equivalent to no stretch at all. The other basic options include the base 10 Logarithm/Log(), Inverse Hyperbolic Sine /ASinH(), Square root/Sqrt(), and Cube root/CubeRoot(). There are two compound logarithms as well that include Log(Log()) and Log(Sqrt()). Each function provides a slightly different bias to the bright and dark features, and often experimentation is the only way to determine which function is best for a given file.

All of the stretch functions in the Liberator work best when the Background level of the data (i.e. the value of the darkest parts of the image) is close to zero. In many astronomical datasets this is not the case due to the way the data were collected or processed. One can examine the data values of the background values in an image by passing the cursor over the darkest regions and study the Input value readout in the Image Data section. If these values are not clustered around zero, the user should provide an offset to zero them out (explained below).

Some of the stretch functions provide very different results depending on the level of the Peak value of the data (the largest data values of interest). These functions include ASinH() or any Log() function. If the Peak level is much smaller than 1, the result will be very similar to an unstretched, or Linear, function. If the entire image is scaled upwards (by multiplying by a constant) these stretch functions will enhance the fainter parts of the image relative to the brightest peaks. This enhancement increases as the Scaled Peak level (49) is scaled to larger numbers (100, 1000, etc.).

The FITS Liberator can zero the background properly and adjust the value of the peak. These are set using the values in the Background Level (47), Peak Level (48), and Scaled Peak level (49) text boxes. Before a stretch function is applied to an image, its data will be rescaled using the formula:

$$\text{Scaled Image} = \text{Scaled Peak level} * (\text{Input Image} - \text{Background level}) / (\text{PeakLevel} - \text{BackgroundLevel})^4$$

The Background Level (47) should be set to equal the numeric value of the pixels in the image that should be rendered as black. These numbers can be determined, for example, by running the cursor over the darkest parts in the preview image and looking at the Input values under Image Data (26).

The Peak Level (48) should be set to equal the numeric value of the brightest areas of interest in the image. Note that this may not be the absolute brightest object in the image! Often the important part of an image is a nebula or galaxy that is much fainter

⁴ The parameter Scaled Background level mentioned in 3.2 has been set explicitly to zero in FITS Liberator v.2.

than the brightest stars. In this case, the Peak level should be set to the very brightest level of the nebula or galaxy.

The Scaled Peak level (49) is a free parameter that the user can adjust to obtain the best visual result after the Background Level (47) and Peak Level (48) have been set appropriately. Note that this will only affect the results of a `Log()` or `ASinH()` stretch function. Useful values tend to be in the range of 10 to 10,000, with the larger values bringing up more of the faint detail. Values as small as 0.1 are nearly indistinguishable from a simple `Linear()` function and will not enhance faint structure at all.

The FITS Liberator allows the Background Level (47) and Peak Level (48) to be set in four different ways:

1. **Auto Scaling button (52):** Clicking this button will use the existing settings for the Black Level and White Level indicators on the histogram and set the Scaled Peak level to 10. This is often a good first guess.
2. **Background/Peak levels from Black/White levels buttons under the histogram display (15, 16):** The buttons to the right (50, 51) allow the user to individually set their levels based on the respective Black/White level settings. Unlike the Auto Scaling button, only one of the values is updated at a time, and the Scaled Peak Level (49) keeps its current value. Note that the histogram range (14) will be adjusted when the Scaling takes place (as the Background and Peak level changes), i.e. the histogram now shows the pixel value distribution of the Scaled image and not the input image (the image that was opened to begin with).
3. **Background/Peak level pickers (8, 9):** The bottom two eyedropper tools in the toolbox will directly sample Background/Peak levels from within the image. They take a median of a 10x10 box around the click location.
4. **Text field entry (47, 48):** Values can be typed directly into the text fields. Hitting either the tab or enter keys is necessary for the change to take effect. Scientific notation of the form "1.25e5" may be used if desired.

NOTE: The Background Level must logically be smaller than the Peak Level. Any attempt to violate this using any input method will be ignored. Note also that the initial values for Peak Level and Scaled Peak Level are set to the best guess for the White Level; this means that the default result for the Scaled data will be equal to the Input value (i.e. no scaling).

To experiment with these adjustments, open an image with high dynamic range (for example a galaxy or nebula image). Use one of these methods to set the Background Level to the value of the background noise in the image and the Peak Level to the brightest area of interest. Now choose either the `Log()` or `ASinH()` stretch function.

To see how Scaled Peak Level (49) affects the stretch, experiment by entering different numbers in this field. Start with values around 0.1 and switch back to `Linear()` for comparison; they should look very similar. Switch back to the other function and start increasing the Scaled Peak Level by factors of 10 to 1, 10, 100, 1000. Notice how the larger values better enhance the faint structures. Figure 7 illustrates the effects of the different stretch functions and peak levels on a single image.

NOTES: While `Sqrt()` and `CubeRoot()` will give the best results with a proper choice of Background Level, they produce identical results for any choice of peak scaling. The `Log(Sqrt())` function does depend on the Scaled Peak Level. Note also that `Sqrt()` and `CubeRoot()` are undefined for negative numbers, making a correct choice for Background Level especially important (mathematically the cube root *is* defined for

negative numbers; this is a limitation of the current FITS Liberator implementation). The scaling settings have no effect on Linear() stretches.

4.8 Channels

The Channels radio buttons (53-55) determine the bit depth read into Photoshop. Photoshop 7 and CS can both handle 8 or 16 bit channels, while CS2 can handle 32 bit channels.

The default for this is 16 bit channels, which gives a lot of flexibility in later adjustments in Photoshop without risk of posterizing. It is possible to use 8 bit as well, but this is suggested only for extremely large images, since it will reduce the file size by a factor of two.

4.9 Undefined Values

Some data values in an image may be undefined because there was no data for that region, or because a stretch function could not provide a value for a given pixel. For instance, Sqrt() is undefined for negative numbers.

The Undefined Values Radio Buttons (56, 57) determine how undefined values are read into Photoshop. If Black (56) is selected, then they simply appear as black pixels. If Transparent (57) is selected, the image is read in as a Photoshop layer with transparent areas wherever the image is undefined.

4.10 Other Settings

The far right column (58-67) of the FITS Liberator provides a number of useful settings. In addition to OK (58) and Cancel (59), the user can use the Reset button (60) to return to the best initial guesses for the parameters. The Preview Checkbox (61) enables the preview display (10) on the left (it may be useful to turn this off to improve performance on large files).

The Freeze Settings checkbox (62) will force the Liberator to use all of the current image settings (Black/White levels, Background level, Peak level, Scaled Peak level, and Stretch function) the next time any FITS file is opened. The file may be different or the same one. This is useful when a series of images need to be opened with identical settings so they can be directly compared. Note that the Liberator also retains the abovementioned settings for the individual images when they are opened again, even if Freeze Settings is off.

The Mark pixels in preview settings (63-65) allow the user to see where data may be lost in the preview window. The checkboxes allow all three options to be toggled on and off. Red (63) is used to mark undefined pixels, from either missing data or from the application of certain stretch functions. Green (64) indicates areas where highlights are clipped because they exceed the White Level setting. Conversely, blue (65) shows where the pixel values fall below the Black Level setting. These pixel previews can be helpful in seeing whether the black and white levels are set too close together.

The radio buttons under Show image information for (66, 67) allow the user to switch between readouts of Scaled or Stretched data. This setting affects the Image Data and Image Statistics readouts.

4.11 More about Metadata

The Programme Group called Virtual Repository (VR) under the International Astronomical Union Working Group Communicating Astronomy with the Public has the goal:

“To construct the framework for a virtual repository to allow outreach resources across projects and country borders to be ‘catalogued’ in a virtual repository and accessed by educators, press, students and public through specialized visual tools combined with search engines.”

More information are available in documents linked from:

<http://www.communicatingastronomy.org/repository>

One vital ingredient of this is to tag all outreach products with proper Metadata tags that will allow a much more coordinated and widespread utilization of the products. The inclusion of Metadata tags for astronomical colour images are included in the FITS Liberator v.2 as the forerunner of a more general use in all future outreach products.

The Virtual Repository system content envisages that the Metadata are transported within the resource files, i.e. embedded within the actual TIFF or JPEG images. See Appendix B for an example of how the Liberator stores the metadata in Photoshop's XML format called XMP.

The Virtual Repository (VR) standard for embedded data is intended to make individual resources (e.g. a JPEG file) essentially self-documenting. The files should contain sufficient information to be searched and indexed by a variety of data-mining solutions. For instance one could imagine, an “Astro-Google” that could find any VR-tagged file on the internet and add it to its own searchable interface.

4.11.1 Metadata Tags Example

The v.1.0 specification of image Metadata tags is listed here. For more descriptions of the individual tags see Appendix A.

Also indicated here with a superscript are the different types of Metadata fields in the FITS Liberator v.2 (i.e. where the content comes from):

1. Retain from last document
2. Empty, but dropdown contains value from last document, editable
3. Empty, dropdown box contains limited values, editable
4. Empty
5. From FITS header, editable
6. From Liberator internally, read-only

<i>Identity Metadata</i>	
1. MetadataVersion ¹	1.0
2. Identifier ²	<i>ivo://nasa.opo/opo0511a ivo://esa.heic/heic0503b</i>
3. Title ⁴	<i>Hubble Detects Faint Galaxies</i>
4. DatasetIDs ²	<i>ivo://ESO.HST/U2JZ0607B ivo://ESO.HST/U2JZ0603B ivo://ESO.HST/U2JZ0605B</i>
<i>Curation Metadata</i>	
5. Publisher (string) ¹	<i>NASA/AURA/STScI/Office of Public Outreach</i>
6. PublisherURL ¹	<i>http://hubblesite.org</i>
7. PublisherID ¹	<i>ivo://nasa.opo</i>
8. Date ²	<i>2005-07-29</i>
9. Contact.Name ¹	<i>Cheryl Gundy</i>
10. Contact.Email ¹	<i>gundy@stsci.edu</i>
11. Rights ¹	<i>CopyLeft</i>
12. Credit ²	<i>NASA, ESA & Bent Smölpf</i>
<i>General Content Metadata</i>	
13. ObjectType ³	<i>SolarSystem.Mars</i>
14. ObjectName ²	<i>NGC 256, Andromeda Galaxy, M 51</i>
15. Description ⁴	<i>This spectacular color panorama of the center the Orion nebula is one of the largest pictures ever assembled from individual images taken with the Hubble Space Telescope. The picture, seamlessly composited from a mosaic of 15 separate fields, covers an area of sky about five percent the area covered by the full Moon.</i>
16. ReferenceURL ²	<i>http://hubblesite.org/newscenter/newsdesk/archive/releases/1995/45/image/a</i>
17. Type ¹	<i>Photographic</i>
<i>Observation Metadata</i>	
18. Facility ²	<i>Hubble Space Telescope Hubble Space Telescope Hubble Space Telescope</i>
19. Instrument ²	<i>Advanced Camera for Surveys Advanced Camera for Surveys Advanced Camera for Surveys</i>

20. Coverage.Spatial.RefSky ⁵	<i>123.50, -59.56 [degrees]</i>
21. Coverage.Spatial.CoordinateFrame ⁵	<i>FK5</i>
22. Coverage.Spatial.Equinox ⁵	<i>J2000</i>
23. Coverage.Spatial.RefPix ⁵	<i>250.5, 250.5</i>
24. Coverage.Spatial.Scale ⁵	<i>-0.056, 0.056 [arcsec/pixel]</i>
25. Coverage.Spatial.Rotation ⁵	<i>23.56 [degrees East of North]</i>
26. Coverage.Spatial.CoordsysProjection ⁵	<i>RA-TAN, DEC-TAN</i>
27. Coverage.Spatial.Dimensions ⁵	<i>2048, 2048 [pixels]</i>
28. Coverage.Spatial.FieldOfView ⁵	<i>123, 143 [arcsec]</i>
29. Coverage.Spatial.Quality ³	<i>A</i>
30. Coverage.Spectral ³	<i>Optical Optical Infrared</i>
31. Coverage.Spectral.Bandpass ²	<i>B [SII] I</i>
32. Coverage.Spectral.CentralWavelength ²	<i>552.4 [nm] 659.1 [nm] 820.3 [nm]</i>
33. Coverage.Temporal.StartTime ²	<i>2000-12-23-1205 [UT] 2001-11-29-1707 [UT] 2002-07-02-0005 [UT]</i>
34. Coverage.Temporal.IntegrationTime ²	<i>200 [seconds] 400 [seconds] 800 [seconds]</i>
35. DataQuality ³	<i>A</i>
<i>Image Processing Metadata</i>	
36. StretchFunction ⁶	<i>Logarithmic Logarithmic Logarithmic</i>
37. BackgroundLevel ⁶	<i>103.75 95.54 17.32</i>
38. PeakLevel ⁶	<i>37506.52 17346.45 34523.34</i>
39. ScaledBackgroundLevel ⁶	<i>0 0 0</i>
40. ScaledPeakLevel ⁶	<i>10 10 10</i>
41. BlackLevel ⁶	<i>0.754 0.293 0.191</i>
42. WhiteLevel ⁶	<i>9.7 8.5</i>

	8.7
43. ColorAssignment³	<i>Blue Green Red</i>
44. CreationNotes⁴	<i>This image was created with FITS Liberator. Total workload 38.5 hours. Cleaning was very difficult. Had problems with the CMYK gamut.</i>

4.12 FITS Header

This Tab ([reference to figure](#)), selected along the top of the FITS Liberator interface, allows the user to view the raw FITS header. This can contain useful, if cryptically encoded, information about the original data. Text from this window can be selected and copied to the clipboard. More information about FITS headers and keywords may be found at:

<http://fits.gsfc.nasa.gov/>

4.13 Usage Notes & Version Compatibility

Minimum Technical requirements

- Windows PC
- Mac (OS X 10.3+)
- Screen resolution of 1024 x 768 pixels or better
- Photoshop 7.0 or later; Photoshop Elements 2.0 or later

Limitations by version, Elements vs CS, known issues

- Photoshop CS2 (32 bit colour depth), or
- Photoshop CS (16 bit), or
- Photoshop Elements 3 (16 bit), or
- Photoshop 7.0 (only 15 bit colour, and only partial functionality for more than 8 bit colour), or
- Photoshop Elements 2 (only 8 bit colour) (Elements 1.0 NOT supported)

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6 Appendix A: Metadata Tags Description

In the following list of VR metadata tags, the format has been chosen to match the VO system as closely as possible. Notations are made for those that have modified meanings from the existing standard, or are new extensions to it. Unless otherwise specified, fields follow the definitions for the VO.

6.1 Identity Metadata

1. MetadataVersion Required

Definition: This is the version of the applied Metadata definition (as per this document).

2. Identifier (URI) Required

Definition: Identifier for the resource (VO-compliant URI, Universal Resource Identifier).
Comment: As different organisations can release the same image, there can be more than one valid identifier. All identifiers should be included.

3. Title (string) Required

Definition: Name given to the resource.
Comment: For images this would be the title of the image.

4. DatasetID (URI, list) Required

Definition: VO-compliant reference to the dataset (the exposure) used to construct the final image (if available). The format is [ivo://AuthorityID/ResourceKey]. One DatasetID per exposure.

6.2 Curation Metadata

These tags identify the source of the resources and are unlikely to change much from product to product.

5. Publisher (string) Required

Definition: Original Publisher and Creator of the resource.
Comment: Examples of a Publisher include a person or an organisation.

6. PublisherURL (URL)

Definition: A simple URL pointing to the (top level) (outreach) web page for the original publisher.

7. PublisherID (URI) Required

Definition: ID of publishers registered as VR providers.
Comment: For instance a simple sign-up sheet on the central IAU server.

8. Date (string)

Definition: Date that the resource was created or made available. (YYYY-MM-DD).
Comment: Also known in daily use as release date.

9. Contact.Name (string)

Definition: Name of the primary contact for the resource.

10. Contact.Email (string)

Definition: E-mail of the primary contact for the resource.

Comment: In some cases, a contact may have a more reliable long-term email address than URL, so this could be a useful optional tag.

11. Rights (string)

Required

Definition: Copyright and related intellectual property rights description.

Three different types exist:

- *CopyLeft*: Free license. The use of the materials offered for use under a Copyleft license, does not require any prior approval, or any financial transaction between the User and the Publisher. It is mandatory when publishing to mention the Credit.
- *CopyMiddle*: Free license with the provision that use must be approved in advance.
- *CopyRight*: Pay license ("copyright").
The use of the Documents offered for use under a Pay license ("copyright") requires an individual preliminary negotiation between the Producer and the User. With this negotiation, amendments to this License can be agreed.

12. Credit (string)

Definition: The minimum information that the Publisher would like to see mentioned when the resource is used.

Comment: It is mandatory for users of the resource to mention the Credit in the end-product. See also Rights.

6.3 General Content Metadata

13. ObjectType (string)

Definition: The type of object or objects in the resource. The types should be selected from a well-defined list of object types.

Comment: A preliminary list is offered in Appendix C. There are some ongoing coordinated efforts to coordinate such a list, see e.g. <http://monet.uni-sw.gwdg.de/twiki/bin/view/VOEvent/UnifiedContentDescriptors> .

14. ObjectName (string)

Definition: Simbad/NED compatible identifiers for all of the key objects in the image field.

Comment: This also contains common names like Whirlpool etc. Whether the data provider will use one or more of the frequently used names for an object (e.g. Messier and NGC numbers) is optional.

15. Description (string, free text)

Definition: Full caption and related description text for the image resource.

16. ReferenceURL (URL)

Definition: Web page containing more information about this specific image.

17. Type (string)

Definition: The type of resource.

Comment: For all astronomical publication images, this should by default be set to "Photographic". Perhaps the VO definition of type should be expanded to include

different EPO types such as 3D models, videos etc. The list of existing types in the VO is in Appendix D.

6.4 Observation Metadata

Much of this section can be derived from information in imported FITS datasets, but some fields will naturally become incorrect after subsequent manipulation in Photoshop.

Note that as astronomical colour images are usually composed of N exposures that an extension is needed for the Virtual Repository. Essentially, each of the N filters that are combined to form a single colour image need to be tracked separately. Below the vector "List" with dimension N x 1 contains the appropriate information for each exposure.

18. Facility (string, list)

Definition: Telescopes or observatories used for the observations. One Facility per exposure.

Comment: For this keyword, the list should reference facilities in order of the elements in the composite image.

19. Instrument (string, list)

Definition: Instrument used to collect the data. One Instrument per exposure.

Comment: For this keyword, the list should reference instruments in order of the elements in the composite image.

20. Coverage.Spatial.RefSky (string)

Definition: Reference coordinate for the image (in decimal degrees).

Comment: This and subsequent Coverage.Spatial tags deviate from existing VO standards for sky coordinates to more closely follow standards for FITS Keywords. This field would be populated from the FITS keywords: CRVAL1, 2

21. Coverage.Spatial.CoordinateFrame (string)

Definition: Coordinate system reference frame.

Comment: This field would be populated from the FITS keyword: CFRAME (ICRS, FK5, FK4, ECL, GAL, SGAL).

22. Coverage.Spatial.Equinox (string)

Definition: Equinox for Coverage.Spatial.CoordinateFrame.

Comment: This field would be populated from the FITS keyword: Equinox. It usually defaults to J2000, except that the default for FK4 is B1950.

23. Coverage.Spatial.RefPix (string)

Definition: Coordinate of the pixel in the image to which the reference coordinate (Coverage.Spatial.Center) refers.

Comment: FITS Keywords: CRPIX1,2; In many common FITS files the reference pixel is not the centre pixel in the image.

24. Coverage.Spatial.Scale (float)

Definition: Spatial scale of the X and Y axes of the image in number of arc-seconds per pixel.

Comment: FITS Keywords: CDEL1,2 (or derived from CD matrix; FITS default is degrees/pixel, but adopting arcsec/pixel in this standard makes it easier to interpret). Negative values indicate a 'flipped' axis.

25. Coverage.Spatial.Rotation (float)

Definition: Position angle of the Y axis in degrees measured east from north (counter-clockwise).

Comment: FITS Keywords: CROT1, 2 (the FITS standard allows for two values, but typically only one is used).

26. Coverage.Spatial.CoordsysProjection (string)

Definition: A combination of the coordinate system and the projection of the image.
Comment: An example is "RA-TAN, Dec-TAN" for a Right ascension/Declination coordinate system with a tangent projection. Other coordinate systems can include "GLAT, GLON" (galactic coordinates), and other projections can include "SIN," "CAR" (Cartesian flat projection), "AIT" (AITOFF equal-area all-sky), among others. This keyword follows the definition of the standard FITS Keywords: CTYPE1,2.

27. Coverage.Spatial.Dimension (integer)

Definition: Size of the image in pixels.

Comment: FITS Keywords: NAXIS1, 2 (also equivalent to image dimensions).

28. Coverage.Spatial.FieldOfView (float)

Definition: Field of view of the image in degrees.

Comment: This would be a derived quantity from the product of Coverage.Spatial.Scale & Coverage.Spatial.Dimension above. While redundant, this is often the quantity that is needed for reference.

29. Coverage.Spatial.Quality (char)

Definition: This qualitatively describes the reliability of the spatial coordinate information in this metadata.

Comment: This value needs to be set by the user. Possible values include:

A: Fully registered WCS coordinates.

B: Approximate registration with WCS, possibly some field distortion.

C: Very rough approximation; no systematic registration attempted.

U: Registration quality unknown or undefined; if set to this value, all other coverage.spatial fields are to be considered null.

30. Coverage.Spectral (string, list)

Definition: Waveband of the component exposure from a pre-defined list. One Coverage.Spectral per exposure.

Comment: The elements in the list should be in the same ordering as for Facility and Instrument above to specifically identify each contributing image in a colour composite. This list specifically includes text descriptors of the band: Radio, Millimetre, Infrared, Optical, Ultraviolet, X-ray, Gamma-ray.

31. Coverage.Spectral.Bandpass (string, list)

Definition: Bandpass of the individual exposure. One Coverage.Spectral.Bandpass per exposure.

Comment: This list includes specific text bandpasses (e.g. B, V, J, Halpha, SIII).

32. Coverage.Spectral.CentralWavelength (float, list)

Definition: Central wavelength of the filter used for the individual exposure measured in nanometres. One Coverage.Spectral.CentralWavelength per exposure.

33. Coverage.Temporal.StartTime (string, list)

Definition: Start time of the exposure in format YYYY-MM-DD-HHMM [UT]. One Coverage.Temporal.StartTime per exposure.

34. Coverage.Temporal.IntegrationTime (float, list)

Definition: The exposure time the exposure in seconds. One Coverage.Temporal.IntegrationTime per exposure.

Comment: This is usually a more interesting quantity for general purposes than specific stop time, and more meaningful if the start time is only approximately known.

35. DataQuality (char)

Definition: Qualitative data quality assessment.

Comment: The existing data quality assessment in the VO is not defined appropriately for PR resources.

Grades could include:

A: Cleaned, publication-ready image

B: Some flaws in the image, but of good quality

C: Degraded quality; background unevenness, significant artifacts, but still acceptable for reference

6.5 Image Processing Metadata

Please see Appendix E for an example workflow for how a 'standard' E/PO image processing would look.

36. StretchFunction (string, list)

Definition: Stretch function applied to the input data in the processing. One StretchFunction per exposure.

Comment: Some possibilities include: Linear, Logarithmic, Square-root, Inverse hyperbolic sine, Cube Root, LogarithmicLogarithmic, Logarithmic(Square-root).

37. BackgroundLevel (float, list)

Definition: Lower value of input range for the Scale function. One BackgroundLevel per exposure.

Comment: This value will become min in the Scaled image.

38. PeakLevel (float, list)

Definition: Upper value of input range for the Scale function. One PeakLevel per exposure.

Comment: This value will become max in the Scaled image.

39. ScaledBackgroundLevel (float, list)

Definition: The target lower value of the range of the Scaled image. One ScaledBackgroundLevel per exposure.

Comment: This value is the defined min in the Scaled image.

40. ScaledPeakLevel (float, list)

Definition: The target upper value of the range of the Scaled image. One ScalePeakLevel per exposure.

Comment: This value is the defined max in the Scaled image.

41. BlackLevel (float, list)

Definition: The Stretched Scaled input pixel value, which was set to define the colour black in the output image. One BlackLevel per exposure.

42. WhiteLevel (float, list)

Definition: The Stretched Scaled input pixel value, which was set to define the colour white in the output image. One WhiteLevel per exposure.

43. ColorAssignment (string, list)

Definition: The output colour, which is assigned to an exposure. One ColorAssignment per exposure.

Comment: The options should include: purple, blue, cyan, green, yellow, orange, red, magenta. For a single-channel image the choices would be: greyscale, pseudocolor.

44. CreationNotes (string)

Definition: Free-form notes about the image creation process.

7 Appendix B: Photoshop XML example

```

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