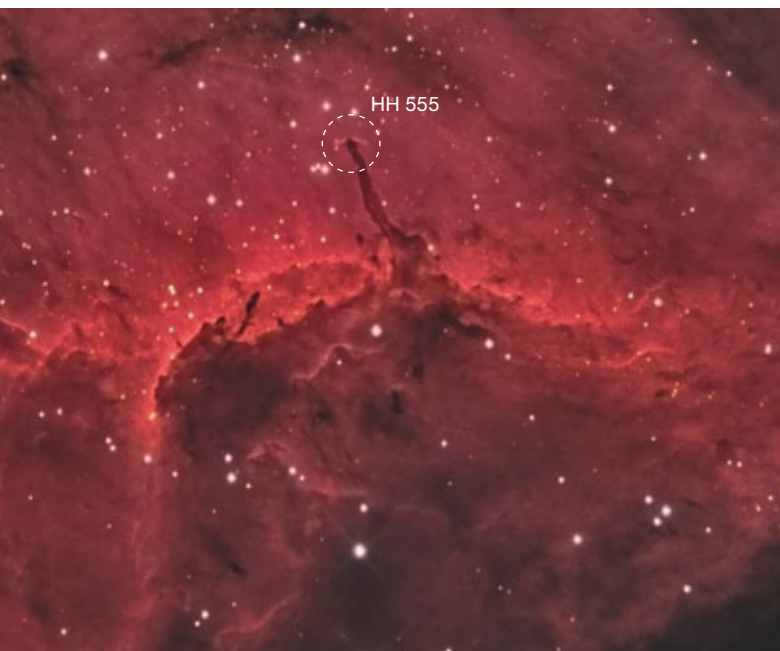


Restoring Detail *with* Deconvolution



Recover information in your deep-sky images with this powerful technique.

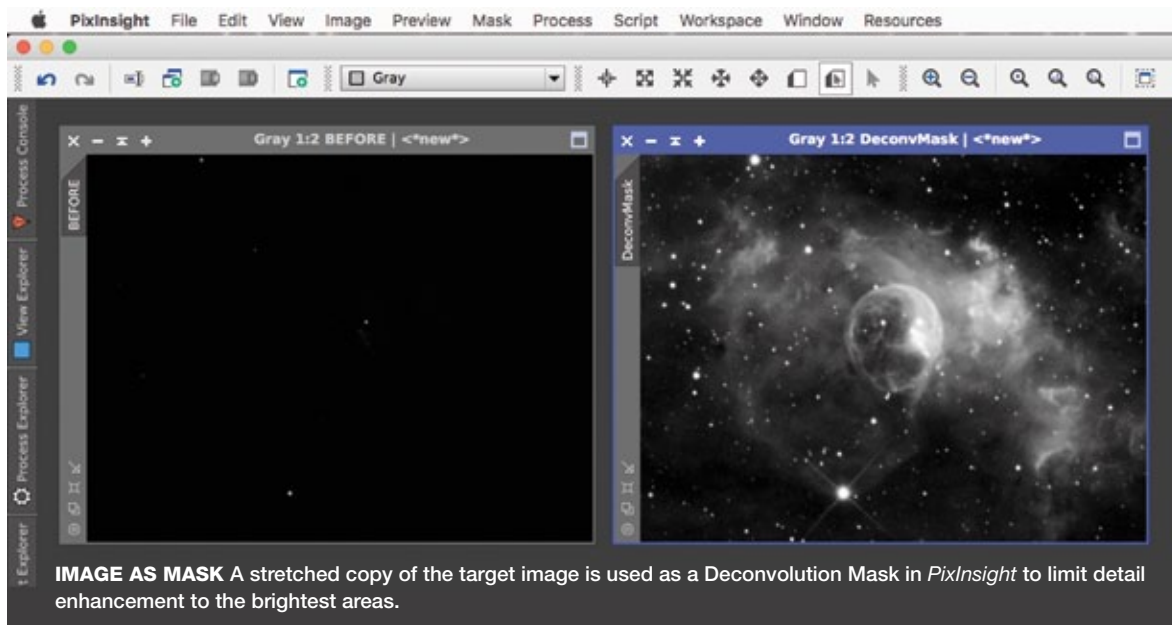
Most of us don't have the luxury of imaging with an orbiting space telescope, where there's no atmosphere to degrade our images. For us Earth-based imagers, the reality is that turbulent air inevitably blurs detail in our deep-sky shots. Even in the steadiest seeing conditions, the "true" image — as it would be with no degradation — is *convolved*, or mixed, with the blurring effect of the atmosphere and distortions caused by imperfect optics. Fortunately, many image-processing software packages include powerful deconvolution and sharpening tools that can recover much of the detail buried in your frames.

Sharpening vs. Deconvolution

Sharpening and deconvolution tools work in very different ways. Sharpening primarily increases contrast along well-defined edges in images, whereas deconvolution performs an iterative pixel-by-pixel restoration using a mathematical model of the blurring function, leading to an overall sharper image.

Deconvolution is rooted mainly in work done by Norbert Wiener of MIT. He published these findings in the 1949 book *Extrapolation, Interpolation and Smoothing Stationary Time Series with Engineering Applications*. Since then, deconvolution has been used in weather forecasting, seismology, spectroscopy, microscopy, forensic photography, and many other scientific and engineering applications, including, of course, astronomy. In one famous example, deconvolution was used to improve early Hubble Space Telescope images impaired due to the orbiting observatory's flawed primary mirror (*S&T*: Oct. 1990, p. 352). In the nearly 70 years since its development, deconvolution has become an essential image-processing step for most professional and many amateur astrophotographers.

◀ **NOTABLE DIFFERENCE** Deconvolution can restore faint stars and small-scale detail hidden by the blurring effects of our atmosphere. This pair of images show a close-up of Herbig-Haro Object 555 (circled) in the Pelican Nebula. The bottom image uses Regularized Richardson-Lucy deconvolution in *PixInsight* to tighten up many stars, as well as features within the nebula itself.



When to Apply Deconvolution

While most astrophotographers have success improving their images using standard sharpening tools like the popular Unsharp Mask tool in *Adobe Photoshop*, they often report that deconvolution either didn't work or made their images appear worse. I've learned that, to be applied successfully, deconvolution must be performed at the right place in the workflow.

The technique is best applied to linear images, before the image is non-linearly stretched to reveal both the brightest areas and faintest regions simultaneously. Non-linear processing alters the relationships between pixel values in the original data, and deconvolution won't work properly after that point. (Standard sharpening tools may work well on these stretched files, however.)

Deconvolution works best on luminance images, which tend to have the highest signal-to-noise ratio. A luminance image can be created by shooting through a luminance filter, or synthesized from the combined red, green, blue, or narrowband photos, and can even be extracted from a color image. While most astronomical image-processing software includes some form of deconvolution tool, my preference is to use *PixInsight* (pixinsight.com). For more information on where deconvolution fits in a *PixInsight* workflow, see *S&T*: Aug. 2016, p. 66.

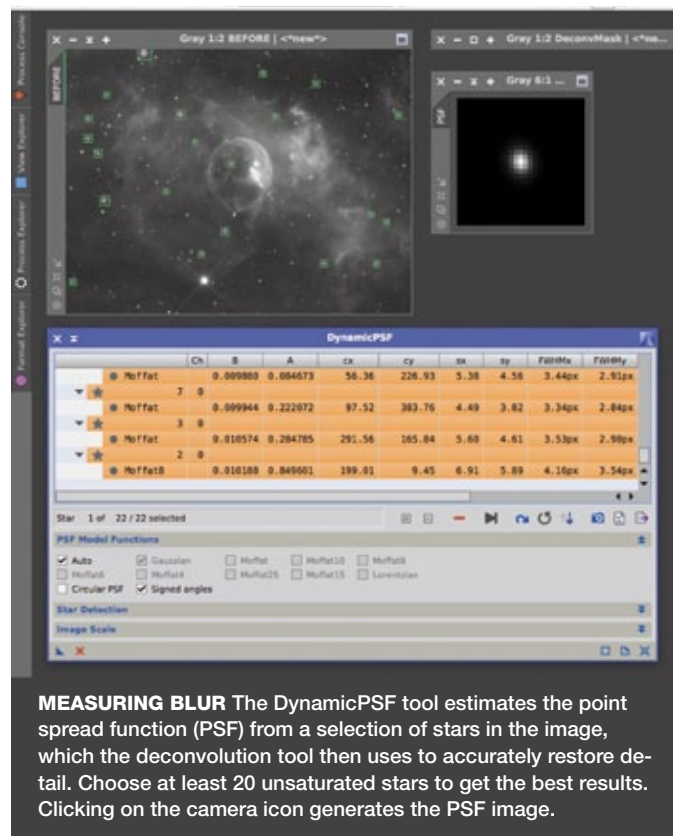
Preparation

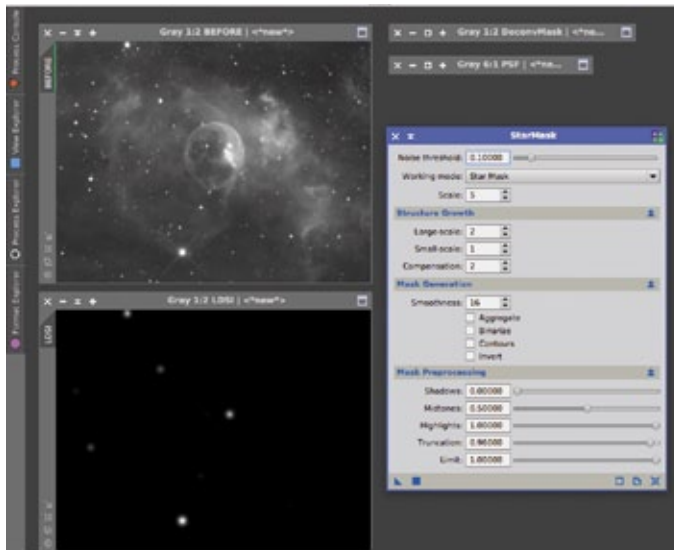
To perform deconvolution in *PixInsight*, three support images need to be generated from the image that you want to process.

The first support image is a deconvolution mask. Because the background in your image contains little detail, deconvolution in these areas will only enhance noise. So you should generate a mask that protects these areas from the deconvolution process. You can make it in varying ways, including creating a copy of the image and stretching it using HistogramTransformation. Or you can apply the RangeSelection

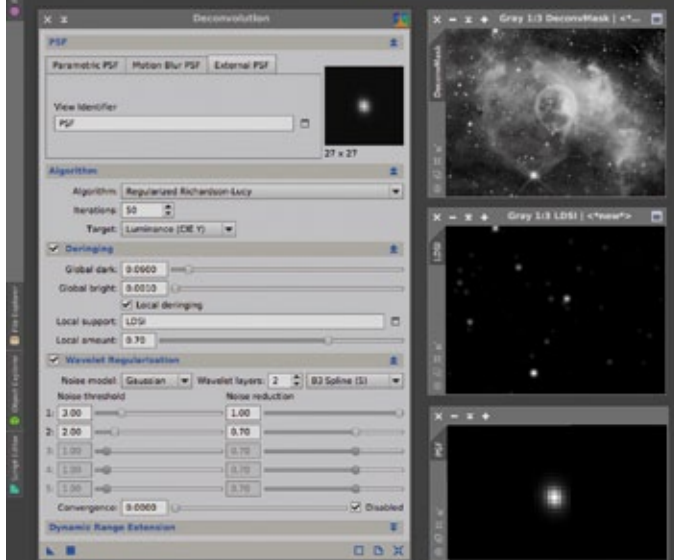
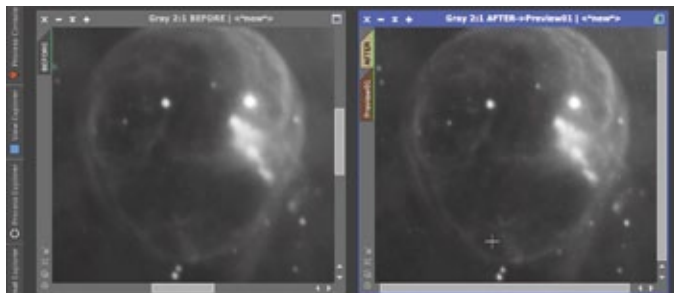
tool, found in the pulldown menu at PROCESS > MaskGeneration > RangeSelection.

In this process window, increase the lower limit and the smoothness settings, then click the "apply" square at the bottom left to produce the mask. You might need to experiment with these settings and apply them a few times until you construct a mask that blocks everything but the stars and the brightest area you want to deconvolve.





NO DARK DONUTS A “local deringing support image” (LDSI) at bottom left is created using the StarMask tool, and prevents dark circles from appearing around the brighter stars — a common processing artifact that often results from deconvolution.



APPLYING DECONVOLUTION Compared to the “before” image of the Bubble Nebula, NGC 7835, at top left, the “after” image to its right shows increased detail, and faint stars are made more apparent. Getting this result required applying the three support images at right with *PixInsight*’s Deconvolution tool.

Next, you need to generate a point spread function (PSF) image. This file contains the information needed to deconvolve your image properly. The PSF estimates how each point source in the image has been spread out due to blurring. This image is prepared by selecting PROCESS > Image > DynamicPSF and then manually clicking about 20 or more stars in your target image. Try to choose fainter stars in your linear image; the best choices will show a value of between 0.25 and 0.9 in column A. Once you’ve clicked on enough stars, select them all in DynamicPSF with Control+A and click the camera icon to generate the PSF image.

The last support file needed to perform deconvolution is a local deringing support image (LDSI). The brightest stars in the target image need extra protection to avoid introducing artifacts that appear as dark rings in the deconvolved result. The LDSI is a grayscale image that is completely black except for the brightest stars, and can be made by applying StarMask (PROCESS > MaskGeneration > StarMask) to the target image using its default settings. The Deconvolution tool uses this file to provide special deringing protection for the brightest stars. To include more stars in the LDSI, reduce the value in the Midtones slider.

Adjusting the Settings

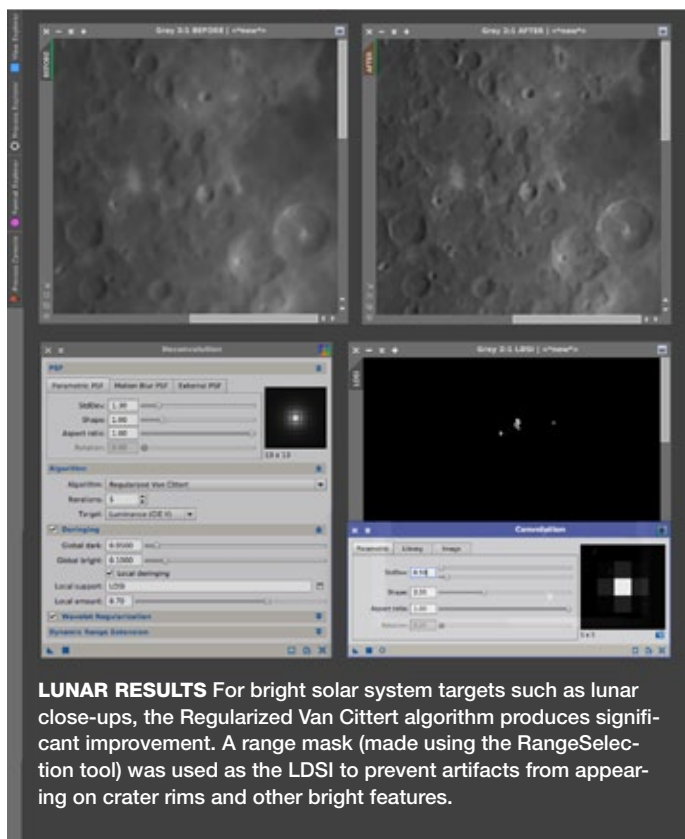
Now that you have created the support files, apply the deconvolution mask image to the target image by selecting MASK > Select Mask and choosing your deconvolution mask image. Next, open the Deconvolution tool from the pulldown menu (PROCESS > Deconvolution > Deconvolution), select the External PSF tab in the deconvolution tool window, and choose the PSF image in View Identifier.

Check the box next to Deringing, as well as the Local Deringing option, and choose your LDSI image in the Local Support section.

For most deep-sky images, the Richardson-Lucy deconvolution algorithm works best. The Van Cittert algorithm sometimes works well on lunar and solar images, as we’ll see shortly.

For both these algorithms, *PixInsight* includes a “regularized” version that suppresses noise during deconvolution. I usually tweak the settings on a small portion of the image made using the Preview menu option (Alt-N). The Preview should contain both high and low signal areas. This speeds up the task of optimizing settings for detail restoration, background protection and suppression of ringing artifacts around stars. I focus on finding the best settings for Global Dark Deringing and the number of iterations. For Global Dark Deringing, find the lowest value that prevents ringing artifacts around the stars. You can use a small amount of Global Bright Deringing to suppress bright artifacts, but a gentle touch is recommended since deconvolution is extremely sensitive to tiny changes.

Once you’re satisfied with the Preview result, apply the tool to the image by clicking the Apply square at the bottom left corner of the tool window. At this early stage in the workflow, the improvements produced by deconvolution might appear subtle. But make no mistake: They will definitely



LUNAR RESULTS For bright solar system targets such as lunar close-ups, the Regularized Van Cittert algorithm produces significant improvement. A range mask (made using the RangeSelection tool) was used as the LDSI to prevent artifacts from appearing on crater rims and other bright features.

► **TRAILING FIX** Using the Motion Blur PSF mode in the Deconvolution tool can correct slightly elongated stars.

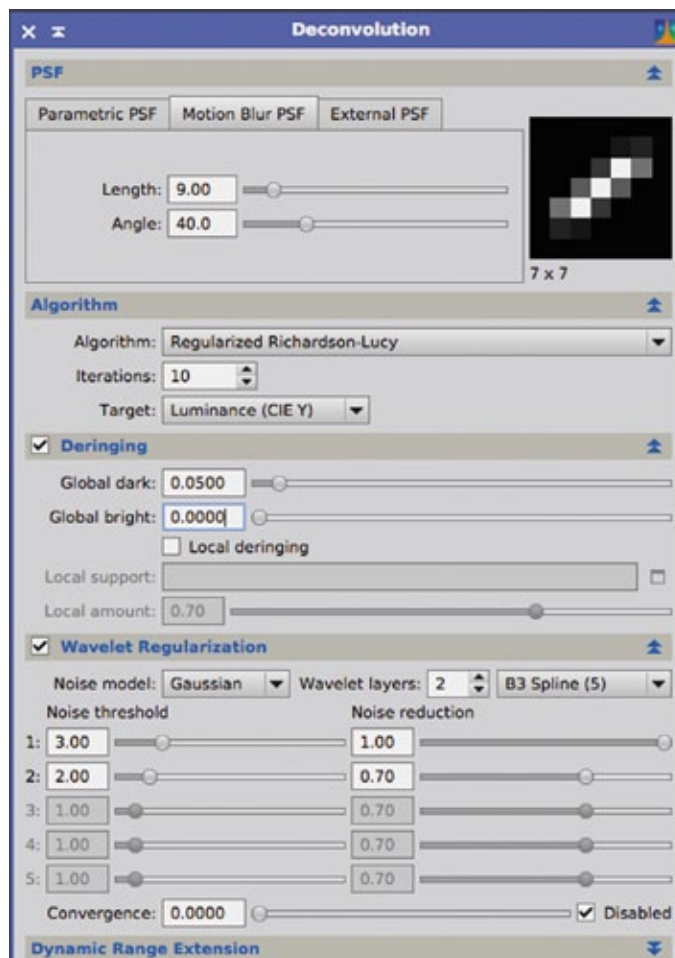
improve the amount of detail in the final result. You can also bring to bear sharpening tools later in the processing workflow to further enhance details recovered with deconvolution.

Other Uses

Images of solar system objects, including the Sun, Moon, and planets, can greatly benefit from deconvolution. For these bright targets, the Regularized Van Cittert algorithm works well in Parametric PSF mode, but it takes some experimentation to dial in the best settings. As with deep-sky imagery, make a deconvolution mask of your target image as described above. If you're processing a lunar picture, you can generate the LDSI file from the deconvolution mask using the RangeSelection tool to select just the brightest features.

Once again, create a Preview on which to experiment and try to find the best setting for the StdDev slider first, ignoring artifacts that might occur. Next, adjust the Global dark and Global light sliders in the Deringing section to taste. As for deep-sky objects, choose the lowest settings that achieve the desired result. If the outcome still looks a little too sharp after Van Cittert deconvolution, applying a slight blur can give the image a more natural appearance. The Convolution tool works well for this purpose.

PixInsight's Deconvolution tool can also fix slightly elongated stars, as long as the direction and amount of elongation



(eccentricity) of all stars are similar; it won't fix field rotation issues. Of course, it's much better to correct the root causes of the eccentricity — usually an issue related to the optics, tracking, or polar alignment. With realistic expectations in hand, make a star mask from a stretched copy of the image and apply it to protect nonstellar features and background.

Open the Deconvolution tool and select the Motion Blur PSF tab. Here is where you'll adjust the length and angle to match the amount of elongation in your target image. One or two iterations of deconvolution is usually sufficient, though you'll need to experiment with the Global dark slider in the Deringing section to home in on the best setting that prevents dark artifacts appearing around the stars.

Although the examples in this article demonstrate deconvolution using *PixInsight*, you'll find many tutorials online on how to perform deconvolution with other image-processing software. Deconvolution has the ability to reveal the hidden small-scale detail in deep-sky and solar system images, and it can even help fix out-of-round stars. Don't be afraid to experiment — the improved clarity and detail in your photos will be well worth the effort.

■ **RON BRECHER** hunts faint deep-sky targets from his backyard observatory in Guelph, Ontario.