DRIZZLE IMAGE RECONSTRUCTION METHOD

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What is Drizzle?

Drizzle (*Variable-Pixel Linear Reconstruction*) is a method for combining under sampled, dithered images to reconstruct a higher-resolution image.

It preserves photometric (brightness) and astrometric (position) accuracy, handles geometric distortion, and can optimally weight input images based on pixel significance.

Motivation and Problem Addressed

- **Under sampling in Astronomy**: Many astronomical cameras, have pixels that are too large to fully sample the telescope's optical resolution. This leads to loss of detail and image fidelity.
- **Dithering**: To recover lost information, astronomers take multiple images with small shifts (dithers) between exposures. However, combining these dithered images into a single, high-resolution image is challenging, especially when dealing with geometric distortions, cosmic rays, and missing data.

How Drizzle Works

Pixel Mapping: Each pixel from the input images is mapped onto a finer output grid, accounting for shifts, rotations, and distortions.

Shrinking Pixels (Drops): Instead of spreading the full pixel value over the output grid (which would blur the image), Drizzle allows the user to shrink the input pixel to a smaller "drop" before averaging it into the output image. The size of this drop is controlled by the pixfrac parameter (ratio of drop size to input pixel size).

- pixfrac = 1.0: Equivalent to shift-and-add (full pixel size, more blurring).
- pixfrac = 0.0: Equivalent to interlacing (no blurring but may leave gaps).

Weighted Averaging: The value of each input pixel is averaged into output pixels based on the area of overlap between the drop and the output pixel. Weights can be assigned based on statistical significance or inverse variance.

Handling Missing Data: Drizzle naturally accommodates missing data (e.g., cosmic rays, detector defects) by using weight maps and masks.

Advantages of Drizzle

Versatility: Handles arbitrary shifts, rotations, and geometric distortions.

Preserves Resolution: Maintains image sharpness better than traditional shift-and-add methods.

Optimal Weighting: Can use inverse variance weighting for statistically optimal results.

Robust to Missing Data: Works well even when some pixels are masked due to cosmic rays or defects.

No Signal-to-Noise Trade-off: Unlike nonlinear restoration methods, Drizzle does not sacrifice signal-to-noise ratio for resolution.

Practical Considerations

Noise Correlation: Drizzle introduces correlated noise between adjacent output pixels, which must be accounted for in subsequent analysis.

Photometric and Astrometric Accuracy: Drizzle preserves both, provided the input images are well-calibrated and the parameters are chosen appropriately.

In summary: Drizzle is a powerful, flexible method for reconstructing high-fidelity images from under sampled, dithered astronomical data. It is widely used in space-based and ground-based astronomy for its ability to combine images with arbitrary shifts and distortions, preserve resolution, and handle missing or corrupted data.

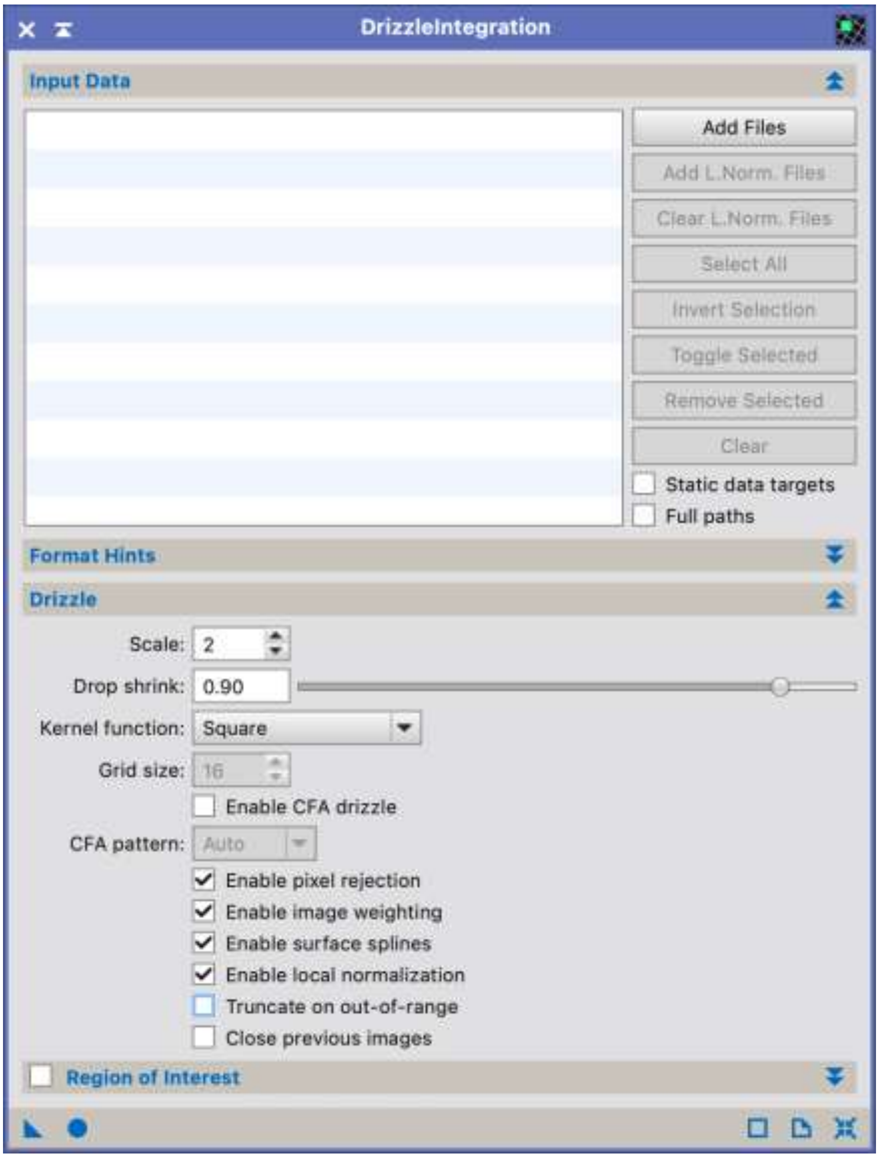
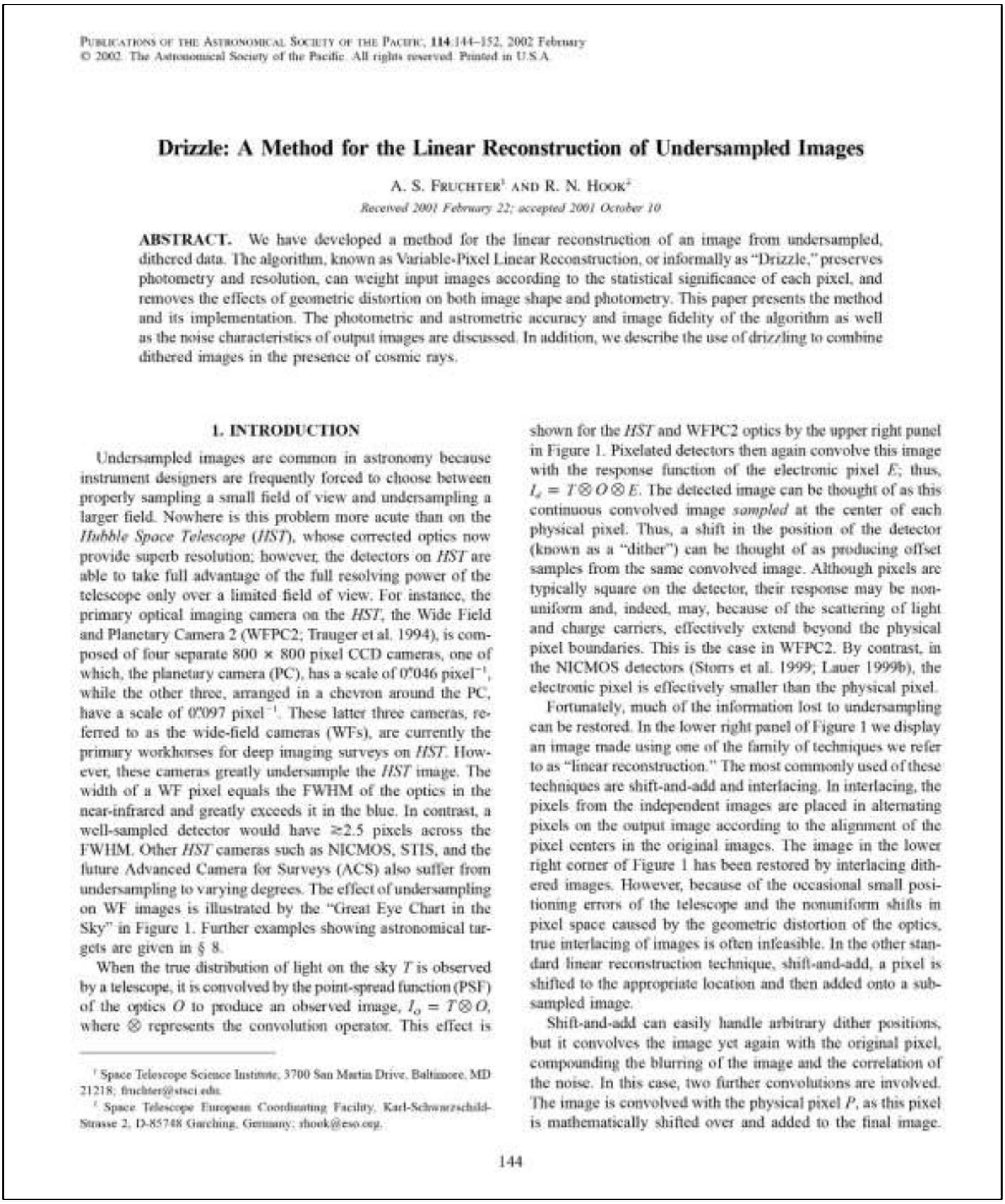


Figure 1 – DrizzleIntegration (PixInsight Menu).



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Drizzle: A Method for the Linear Reconstruction of Undersampled Images

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ABSTRACT. We have developed a method for the linear reconstruction of an image from undersampled, dithered data. The algorithm, known as Variable-Pixel Linear Reconstruction, or informally as "Drizzle," preserves photometry and resolution, can weight input images according to the statistical significance of each pixel, and removes the effects of geometric distortion on both image shape and photometry. This paper presents the method and its implementation. The photometric and astrometric accuracy and image fidelity of the algorithm as well as the noise characteristics of output images are discussed. In addition, we describe the use of drizzling to combine dithered images in the presence of cosmic rays.

1. INTRODUCTION

Undersampled images are common in astronomy because instrument designers are frequently forced to choose between properly sampling a small field of view and undersampling a larger field. Nowhere is this problem more acute than on the *Hubble Space Telescope* (*HST*), whose corrected optics now provide superb resolution; however, the detectors on *HST* are able to take full advantage of the full resolving power of the telescope only over a limited field of view. For instance, the primary optical imaging camera on the *HST*, the Wide Field and Planetary Camera 2 (WFPC2; Trauger et al. 1994), is composed of four separate 800 × 800 pixel CCD cameras, one of which, the planetary camera (PC), has a scale of 0''046 pixel^{-1}, while the other three, arranged in a chevron around the PC, have a scale of 0''097 pixel^{-1}. These latter three cameras, referred to as the wide-field cameras (WFs), are currently the primary workhorses for deep imaging surveys on *HST*. However, these cameras greatly undersample the *HST* image. The width of a WF pixel equals the FWHM of the optics in the near-infrared and greatly exceeds it in the blue. In contrast, a well-sampled detector would have ≳2.5 pixels across the FWHM. Other *HST* cameras such as NICMOS, STIS, and the future Advanced Camera for Surveys (ACS) also suffer from undersampling to varying degrees. The effect of undersampling on WF images is illustrated by the "Great Eye Chart in the Sky" in Figure 1. Further examples showing astronomical targets are given in § 8.

When the true distribution of light on the sky T is observed by a telescope, it is convolved by the point-spread function (PSF) of the optics O to produce an observed image, $I_o = T \otimes O$, where $\otimes$ represents the convolution operator. This effect is shown for the *HST* and WFPC2 optics by the upper right panel in Figure 1. Pixelated detectors then again convolve this image with the response function of the electronic pixel E; thus, $I_d = T \otimes O \otimes E$. The detected image can be thought of as this continuous convolved image *sampled* at the center of each physical pixel. Thus, a shift in the position of the detector (known as a "dither") can be thought of as producing offset samples from the same convolved image. Although pixels are typically square on the detector, their response may be nonuniform and, indeed, may, because of the scattering of light and charge carriers, effectively extend beyond the physical pixel boundaries. This is the case in WFPC2. By contrast, in the NICMOS detectors (Storrs et al. 1999; Lauer 1999b), the electronic pixel is effectively smaller than the physical pixel.

Fortunately, much of the information lost to undersampling can be restored. In the lower right panel of Figure 1 we display an image made using one of the family of techniques we refer to as "linear reconstruction." The most commonly used of these techniques are shift-and-add and interlacing. In interlacing, the pixels from the independent images are placed in alternating pixels on the output image according to the alignment of the pixel centers in the original images. The image in the lower right corner of Figure 1 has been restored by interlacing dithered images. However, because of the occasional small positioning errors of the telescope and the nonuniform shifts in pixel space caused by the geometric distortion of the optics, true interlacing of images is often infeasible. In the other standard linear reconstruction technique, shift-and-add, a pixel is shifted to the appropriate location and then added onto a subsampled image.

Shift-and-add can easily handle arbitrary dither positions, but it convolves the image yet again with the original pixel, compounding the blurring of the image and the correlation of the noise. In this case, two further convolutions are involved. The image is convolved with the physical pixel P, as this pixel is mathematically shifted over and added to the final image.

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Figure 2 - The original paper on Drizzle discusses a method for the linear reconstruction of images from under sampled, dithered data. The algorithm, known as Variable-Pixel Linear Reconstruction, preserves photometry and resolution, can weight input images according to their statistical significance, and removes geometric distortion. This method has been widely used in astronomy, particularly for combining dithered images from the Hubble Space Telescope and other telescopes.

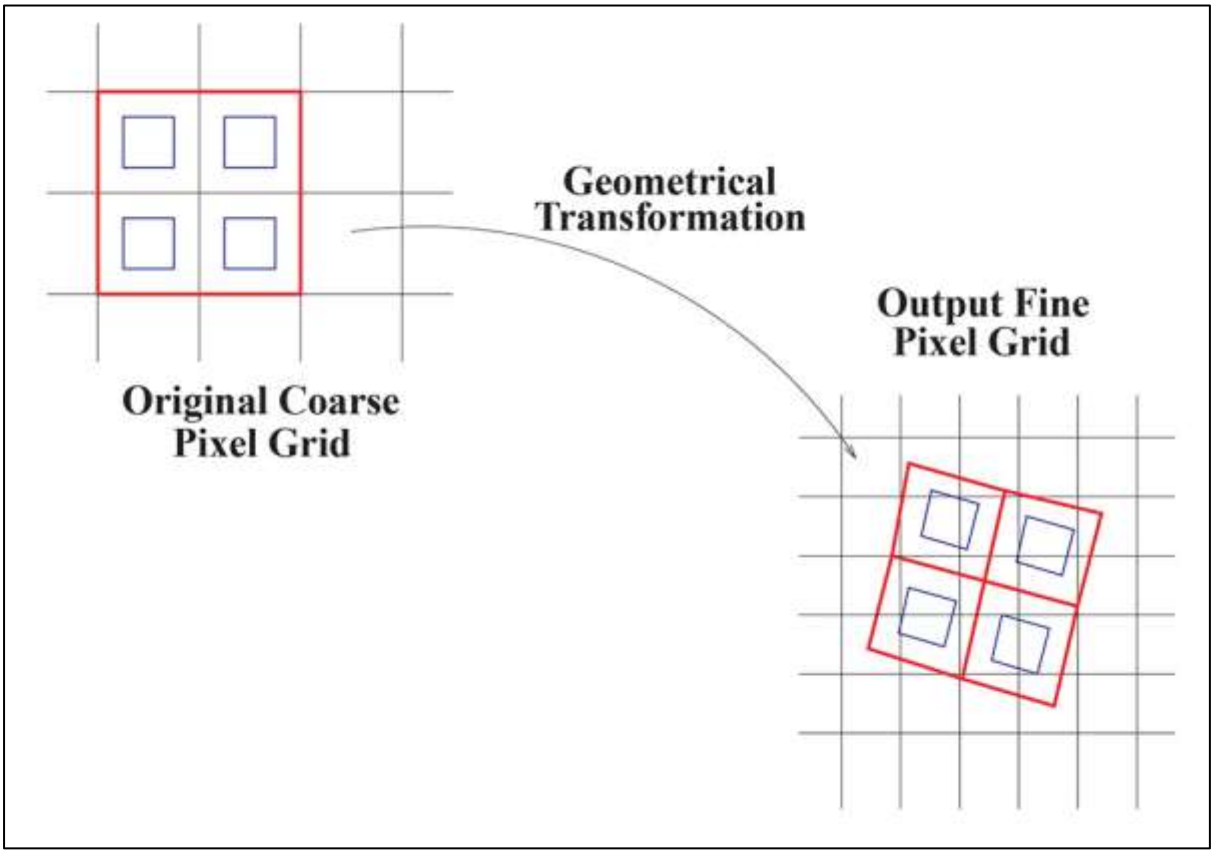

Figure 3- chematic representation of Drizzle. The input pixel grid (left) is mapped onto a finer output grid (right), taking into account shift, rotation, and geometric distortion. The user is allowed to “shrink” the input pixels to smaller pixels, which we refer to as drops (faint inner squares). A given input image only affects output image pixels under drops. In this particular case, the central output pixel receives no information from the input image.

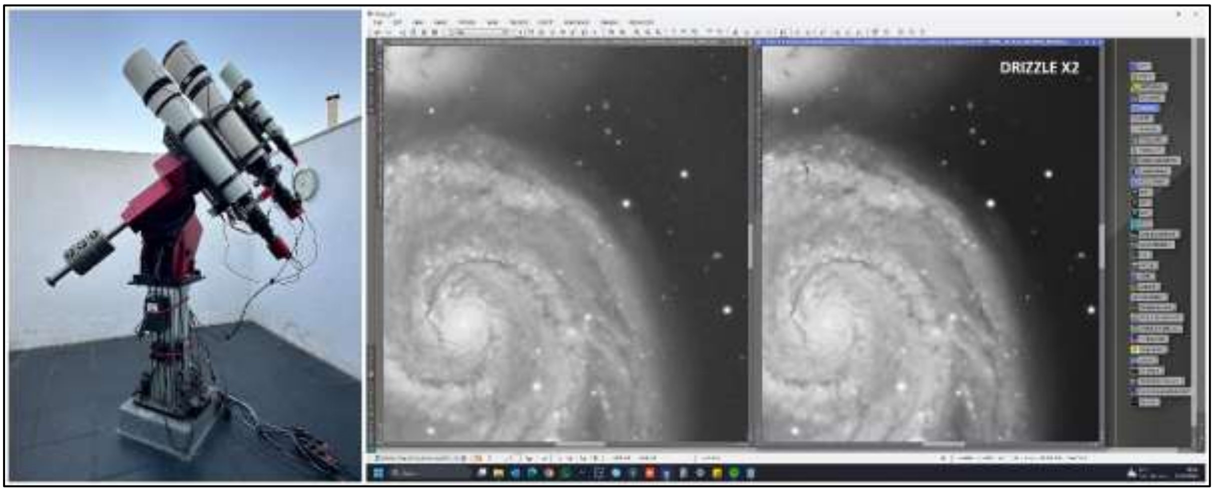

Figure 4- M051. 430Min (86x5Min). TEC140 F/7, ZWO ASI2600MM, Paramount ME. Pedro Ré (2025).

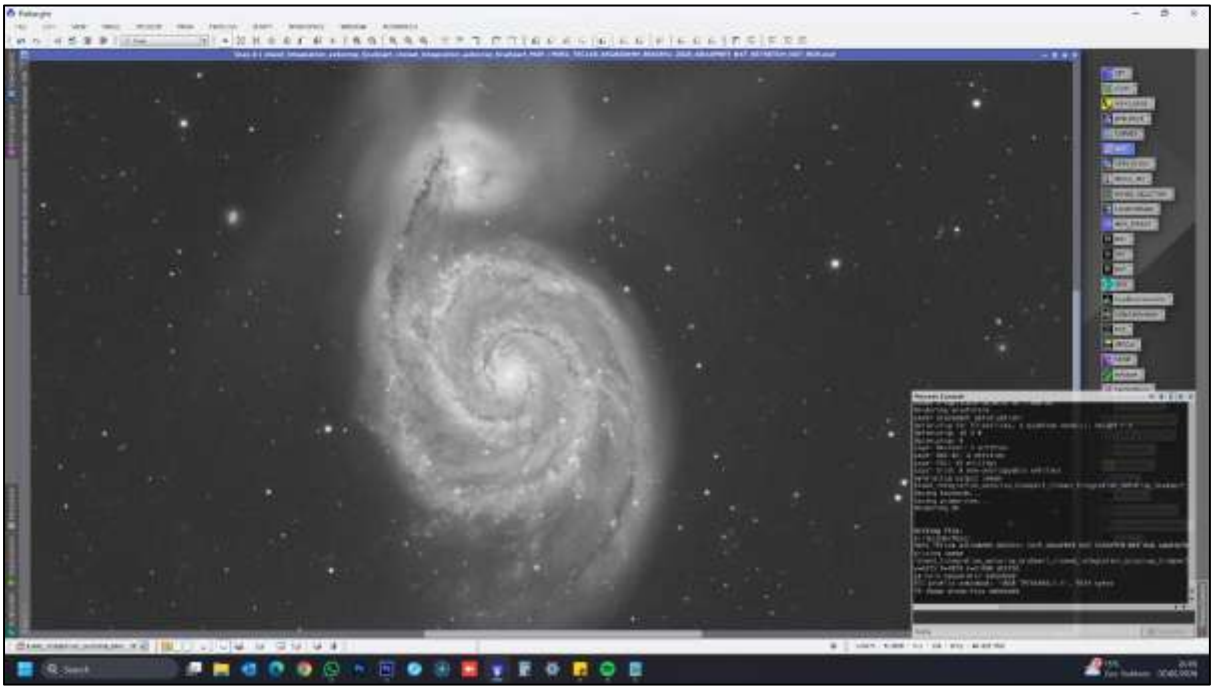

Figure 5- M051. 430Min (86x5Min). TEC140 F/7, ZWO ASI2600MM, Paramount ME. Pedro Ré (2025).

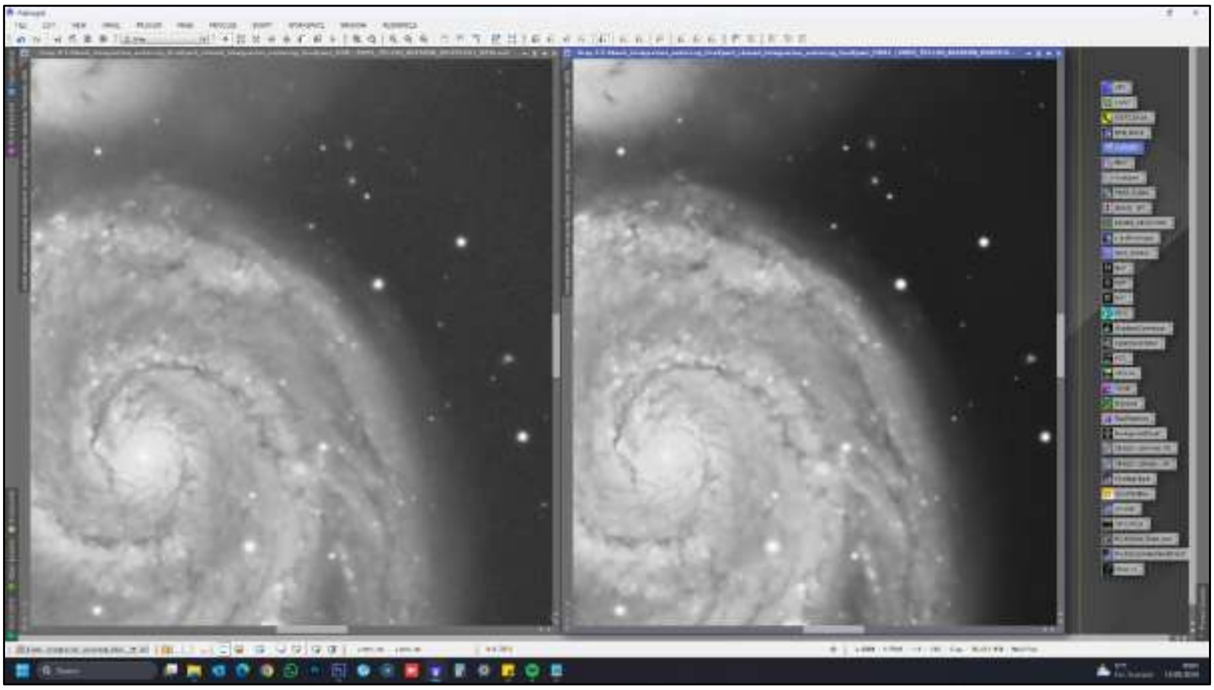

Figure 5- M051. 430Min (86x5Min). TEC140 F/7, ZWO ASI2600MM, Paramount ME. Pedro Ré (2025). Drizzle X2 (right).

Reference

Fruchter, A.s. & R.N. Hook (2002). Drizzle: A Method for the Linear Reconstruction of Undersampled Images. Publ.Astron.Soc.Pac.114:144-152,2002. arXiv:astro-ph/9808087