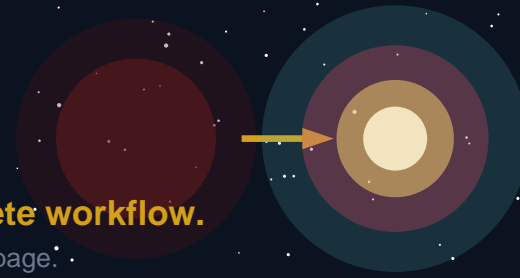


Image Processing Deep Dive

From flat RAW stack to portfolio-quality image — the complete workflow.

Calibration · stacking · stretching · star handling · color · sharpening · the diagnostic page.



Why processing is half the hobby

Out of your camera, the master stack of 100 long-exposure sub-frames looks like a barely-visible smudge on a near-black field. The signal is there — it's just locked in the bottom 1% of the histogram. **Processing is the craft of extracting that signal without destroying it.** Done well, processing reveals what the camera actually captured. Done badly, it overcooks the file into garish, banded, fake-looking results.

Every famous deep-sky imager — Adam Block, Rogelio Bernal Andreo, Russell Croman, Trevor Jones — spends more time processing than capturing. The capture is the easy half. **This guide is the complete workflow**, from your stacked TIFF to a finished image you'd print. We'll cover the full PixInsight / Siril / Photoshop pipeline with the reasoning behind each step.

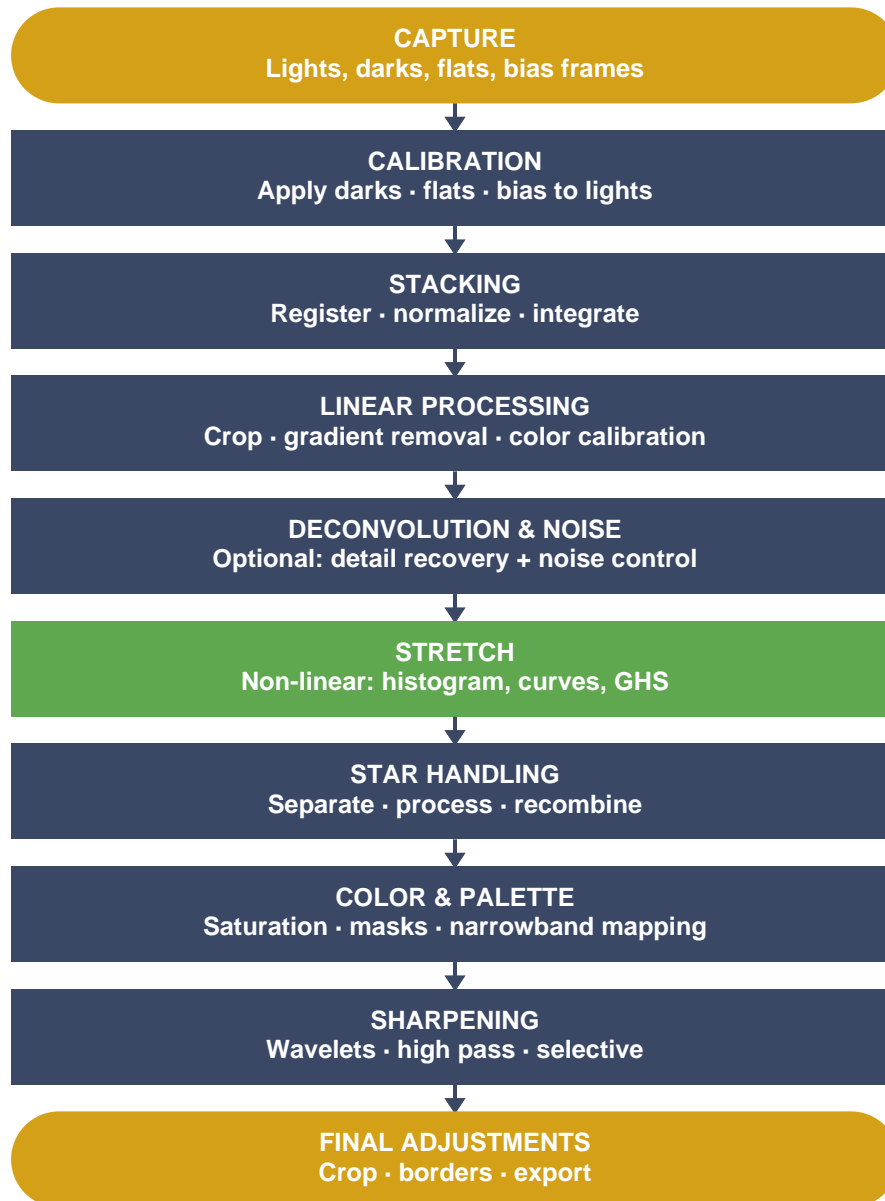
Software prerequisites

This guide assumes you can use one of the major processing platforms. **PixInsight (\$290 one-time)** is the industry standard — the deepest, most flexible. **Siril (free, open-source)** is the modern free alternative — surprisingly powerful, lower learning curve. **AstroPixelProcessor (\$60/year)** specializes in stacking and mosaics. **Adobe Photoshop** handles final aesthetic processing. Workflow concepts here apply to all of them; specific commands referenced are usually PixInsight names.

The complete workflow at a glance

From raw to final, every major step

Every step in this guide maps to one of these nodes. Keep this chart open while reading — it's the structure underneath everything.



Linear vs non-linear data

Astrophotography splits into two regimes. **Linear data** is your raw stack — pixel values directly represent photon counts. Calibration, registration, color calibration, and deconvolution all work best on linear data.

Non-linear data is data after a stretch (a histogram transformation). Once stretched, you can't easily go back. Most aesthetic processing (saturation, sharpening, masking) happens on non-linear data. The transition from linear to non-linear is the most important moment in your workflow.

Calibration frames

The unglamorous foundation of clean data

Calibration frames are images you shoot specifically to characterize your sensor's quirks and your optical system's flaws. Without them, your final image carries every dust mote, every hot pixel, every vignetting gradient as 'real' signal that processing struggles to remove cleanly.

How calibration frames combine



The four calibration frame types

Light frames	Your actual sub-exposures of the target. Everything else exists to clean these up. Goal: hours of total integration time across many short subs (60–300 sec typical).
Dark frames	Same exposure length, ISO/gain, temperature, and sensor as your lights — but with the lens cap on (no light). Captures thermal noise and hot pixels. Take 20–50. Critical: temperature must match. A dark frame at 25°C does little for light frames shot at 5°C. Cooled astro cameras solve this; DSLR users should shoot darks the same night as lights.
Flat frames	Captures vignetting (light falloff in corners) and dust spots on the sensor or filters. Shoot at twilight pointing at an evenly-lit white surface, or use a flat panel/LED tracing pad over the scope. Same optical configuration as lights — same focus, filters, orientation. Shutter speed adjusted so histogram peaks around 1/3 to 1/2 max value. 20–50 frames.
Bias frames	Captures sensor read noise — what the sensor records with zero exposure. Shoot at the fastest shutter speed (1/4000+ sec), lens cap on, same ISO/gain as lights. 50–100 frames. Modern bias-free cameras (some ZWO ASI models) include bias offset in dark frames automatically — check your camera.
Dark flats (optional but recommended)	Calibration for the flat frames themselves. Same exposure as flats, lens cap on. Replaces bias frames specifically in the flat calibration. 20 frames. Becoming standard practice for serious imaging.

When you can skip calibration

Bright targets (M42, M45, M31) with short total integration (<1 hour) often look fine with just lights. You'll see slight gradients and maybe one or two hot pixels but nothing dramatic. Faint targets or long integrations (10+ hours) make calibration essential — every uncorrected imperfection gets amplified by stretching. **Habit: always shoot calibration frames.** You can decide later whether to apply them, but you can't add them after the night.

Stacking — signal vs noise

Why 100 short exposures beat one long one

Each sub-exposure captures both the **signal** (photons from your target) and **noise** (random per-frame variation from sensor electronics, sky background, and statistics). When you stack frames, the signal is consistent across frames (it adds up), while noise is random and partially cancels out.

The square root law

Signal-to-noise ratio improves as \sqrt{N} , where N is the number of frames. 4 frames is 2x cleaner than 1 frame. 16 frames is 4x cleaner. 100 frames is 10x cleaner. Doubling the number of frames gives you $\sqrt{2} \approx 1.41x$ improvement. This is why people shoot 100+ subs — and why the difference between 50 and 100 frames is bigger than the difference between 100 and 200 frames (diminishing returns).

Stacking algorithms

Average (mean)	Average each pixel across all frames. Maximum signal-to-noise. Best when frames are clean — no satellite trails, no clouds, no hot pixels. The mathematical optimum but vulnerable to outliers.
Median	Take the median value at each pixel. Rejects outliers automatically. Slightly worse SNR than average (~25% worse). Use when frames have problems — satellite trails, planes, occasional cloud.
Sigma-clipped average	The best compromise. Average all pixels except those more than 2–3 standard deviations from the mean (outliers). Rejects bad pixels while keeping the SNR advantage of averaging. Default in PixInsight ImageIntegration; called 'Winsorized sigma clipping' or 'Linear fit clipping' in advanced settings.
Sum / additive	Simply add pixel values. Higher SNR per frame counts but you must normalize for different exposure times. Less common now — sigma-clipped average is essentially always preferred.
Drizzle	Sub-pixel registration technique. Improves resolution if you've dithered (shifted slightly between exposures). Requires more frames (50+) and dithered captures. Worth using only when you want maximum detail and have the frames.

How many subs are 'enough'?

Beginner first project	30 subs of 60 seconds = 30 minutes total. Sees results on bright targets (M42, M45, M31). Won't go deep on faint subjects.
Solid amateur image	60–120 subs totaling 2–4 hours. Good signal-to-noise for typical targets. Most published amateur images sit here.
Serious project	200+ subs totaling 6–10 hours. Reveals faint structure, allows aggressive stretching. The standard for Astrobin-worthy images.

Faint targets (IFN, very dim nebulae)

500+ subs totaling 15–30 hours. Integrated flux nebulae, faint OIII shells, ancient supernova remnants. Multi-night projects.

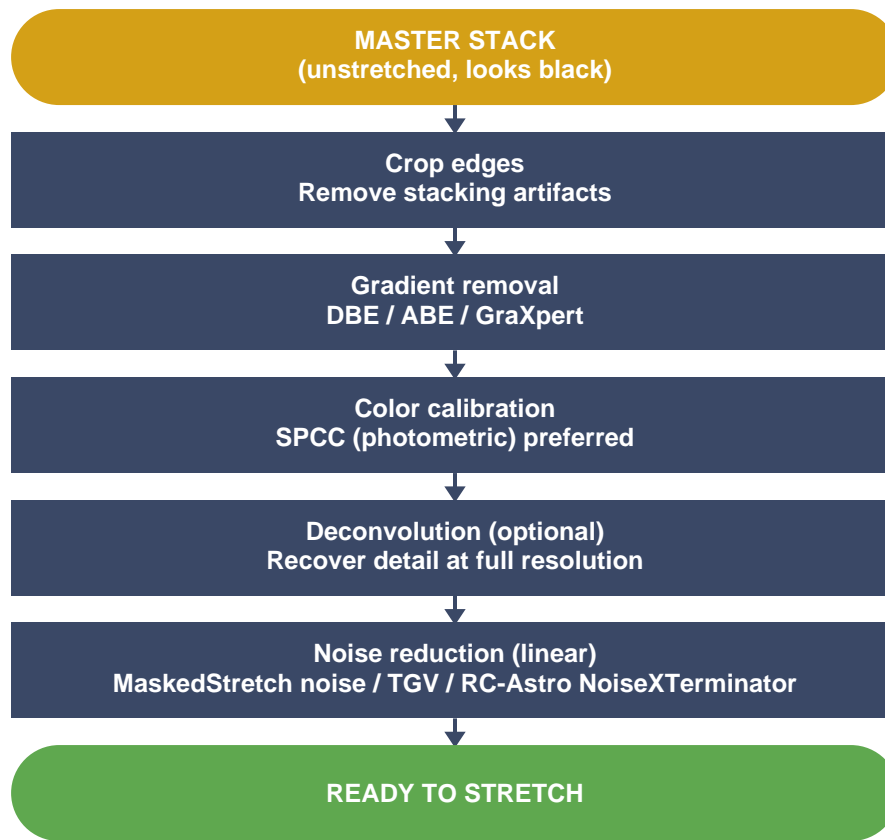
Diminishing returns warning

After ~30 hours total integration on any one target, additional frames make tiny visible difference. The marginal value of frame 1000 is much less than frame 100. Sky conditions, focus drift, and your patience all matter more than another night of data.

Linear processing

Work on the unstretched master stack

After stacking, the master image is still in linear space — pixel values are proportional to photon counts. **This is the right time to fix optical and atmospheric issues**, before stretching amplifies them. The visual is unsatisfying (mostly black) but the math is at its cleanest.



Gradient removal

Light pollution, moonlight, and uneven atmosphere create background gradients — uneven sky brightness across the frame. **Stretching amplifies these dramatically**, so they must be removed in linear space.

PixInsight: DynamicBackgroundExtraction (DBE) User-placed sample points across the image background; PixInsight fits a model and subtracts. The professional standard. Takes 10–20 sample points placed in background sky (away from nebulae, galaxies).

PixInsight: AutomaticBackgroundExtraction (ABE) Automated alternative to DBE. Simpler but less control. Good for images without complex nebulosity covering the field.

GraXpert (free, cross-platform) Standalone tool that does excellent automated gradient removal. AI-assisted. Available as PixInsight plugin too. Often used by Siril and standalone users.

Siril: Background Extraction	Built-in. Manual or automatic placement of sample points. Comparable to DBE for most workflows.
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Color calibration

Stars have known colors based on their spectral types. Color calibration adjusts your image's color balance so stars match their actual colors — and as a side effect, gives the background sky neutral gray and the nebulae their real colors.

SPCC — Spectrophotometric Color Calibration (PixInsight)	The current gold standard. Plate-solves your image, identifies hundreds of stars, looks up their actual spectral data, calibrates color to match. No subjective decisions. Used on essentially every published image in 2024+.
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PCC — Photometric Color Calibration (PixInsight, Siril)	Older photometric calibration. Less accurate than SPCC but works without internet. Still solid.
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Manual color calibration	Adjust RGB channels to make stars white-ish in aggregate. Used when plate-solving fails. Less precise but workable.
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Noise reduction in linear space

RC-Astro NoiseXTerminator	The current AI-driven gold standard (\$75 one-time). Available as PixInsight, Photoshop, and Affinity plugin. Removes noise while preserving fine detail. Russell Croman developed it. Standard recommendation for all modern processing.
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MaskedStretchNoise / MMT (PixInsight built-in)	Multiscale Median Transform noise reduction. Good results, takes more tuning than NoiseXTerminator. Free with PixInsight.
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TGV — Total Generalized Variation	PixInsight noise reduction algorithm. Preserves edges well. Use with masks to limit noise reduction to background.
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Siril: Wavelet denoising	Built-in wavelet-based noise reduction. Effective when used with care.
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Stretching — the art and science

Where the image actually appears

Stretching is the histogram transformation that takes pixel values from their linear photon-count range and remaps them to a perceptual brightness range you can actually see. **This is the single most consequential aesthetic decision in your workflow.** A great stretch reveals the target; a bad stretch crushes shadows, blows highlights, or creates ugly transitions.

The histogram conceptually

Your master stack has a histogram heavily concentrated in the low brightness values. Stretching remaps this — pulling the midtones up while keeping the black point near zero. The general goal: spread the data across the available dynamic range without crushing the black point (creates black background that hides faint detail) or clipping the white point (blows out bright cores).

Stretching methods, in order of sophistication

Histogram Transformation (basic)	The slider approach — pull the midpoint up to brighten the image. Workable for first images. Limited control over how the stretch affects different brightness ranges.
Curves	Draw a custom transformation curve in PixInsight/Photoshop. Lets you precisely control which brightness ranges get boosted vs preserved. The workhorse of careful stretching.
Masked Stretch (PixInsight)	Built-in algorithm that automatically protects the brightest pixels from over-stretching. Good for galaxies (preserves core) and bright nebulae.
Arcsinh Stretch (Siril, PixInsight)	Mathematical stretch that preserves star color while bringing up faint detail. Excellent for star-rich images. Lower learning curve than GHS.
Generalized Hyperbolic Stretch (GHS)	The current state-of-the-art. Developed by Mike Cranfield. Available as PixInsight script, in Siril, and standalone. Multiple control points let you stretch different brightness ranges independently. Best result by a wide margin for any moderately complex image.

The GHS workflow

Generalized Hyperbolic Stretch breaks the histogram into regions and lets you control each independently. Typical workflow: **(1)** apply a mild GHS to bring midtones up while protecting the black point; **(2)** apply a second GHS targeting the brighter midtones to bring out nebula structure; **(3)** apply a final touch-up GHS or curves to balance. Two or three iterative stretches give finer control than one big stretch. The GHS PixInsight script has saved presets that work as starting points for emission nebula, galaxies, and star fields.

Stretching different target types

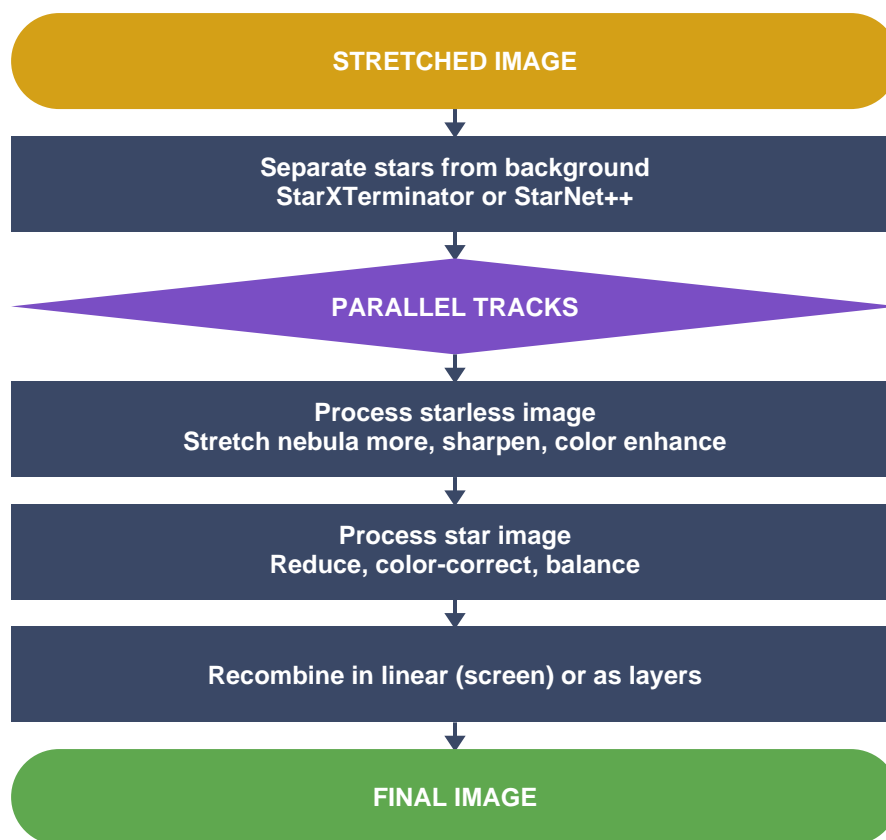
Emission nebulae (Hα-rich)	Strong stretch on H α channel. Watch for color casts as you push it. Background stars get bright fast — masking helps.
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Galaxies	Protect the bright core (Masked Stretch or GHS with high-end protection). Bring out outer arms with a stretch targeted at midtones. Watch the core for clipping.
Reflection nebulae	Stretch carefully — these are inherently low contrast. Star reduction (next section) helps prevent bright stars from dominating.
Wide-field Milky Way (nightscape)	Mild stretching. Aggressive curves push noise. The Milky Way is already bright enough; aim for natural-looking result.
Integrated Flux Nebulae (IFN)	Extreme stretching, but you need 20+ hours of integration to have signal to stretch in the first place. Aggressive gradient removal mandatory before stretching.

Star handling

Separate, process, recombine

Bright stars can overwhelm the nebulae behind them — the image becomes a star field with a vague glow rather than a nebula with stars. **Modern processing separates the star layer from the nebula layer**, processes each appropriately, then recombines them. This single technique has the most dramatic effect on a finished image of any post-stretch step.



Star removal tools

StarXTerminator (RC-Astro, \$75)

The current gold standard. AI-driven, single-click separation. Russell Croman's tool. Used by essentially every professional amateur in 2024. PixInsight, Photoshop, Affinity plugins. The investment that pays back fastest.

StarNet++ v2 (free, cross-platform)

Free alternative. Slightly less accurate than StarXTerminator but very capable. Works as PixInsight tool, Siril plugin, or standalone.

Manual masking

Old method — create a star mask using StarMask tool in PixInsight, then process the inverse. Worked for years before AI tools but tedious. Largely obsolete now.

Why star reduction helps

After separating stars, you can reduce their size/intensity before recombining. A 30% star size reduction makes nebula detail dramatically more visible without the image feeling unnaturally starless. Premium tools have settings for this directly; manual approaches use Photoshop's Minimum filter or PixInsight's MorphologicalTransformation.

Don't go too far

Over-reduced stars look unnatural — the image reads as 'CGI' rather than 'photograph.' A 20-40% reduction is plausible; 80% is obviously fake. Real images preserve some stellar dominance. Test by viewing the original side-by-side with the reduced version.

Color processing and narrowband palettes

Where the visual character of your image is decided

If you shot broadband RGB (DSLR, OSC camera) and applied SPCC, your colors are already calibrated — you can move to final adjustments. If you shot narrowband ($H\alpha$, OIII, SII separately through filters), now you decide how to map those channels to the RGB color you actually display.

The major narrowband palettes

HOO (Hydrogen-Alpha + Oxygen-III)	$H\alpha$ → red, OIII → green and blue. The 'most natural' narrowband palette — gives a result similar to true-color but with much higher contrast. Standard starting point for new narrowband imagers.
SHO (Hubble Palette)	SII → red, $H\alpha$ → green, OIII → blue. Famously used by Hubble Space Telescope images. Produces gold-and-teal palette. Most common 'serious narrowband' palette. If you've seen it on Astrobin, it was probably SHO.
Bicolor ($H\alpha$-OIII)	Two-channel imaging combined into RGB. $H\alpha$ HaO mapping or similar. Good when you only have two filters (or are starting narrowband).
Foraxx palette	Modern variant developed by Bill Blanshan. Uses PixelMath formulas to blend $H\alpha$, OIII, and SII into more nuanced colors than basic SHO. Cleaner-looking, less harsh than classic Hubble.
Dynamic palettes	Custom blends using PixelMath formulas. Star color from RGB shots blended with narrowband nebulae. The route to publishable, distinctive results — but requires more skill.

Workflow: making narrowband look natural

Combine channels in linear	After calibration and gradient removal of each narrowband channel separately, combine using ChannelCombination or PixelMath. SHO: R=SII, G= $H\alpha$, B=OIII.
Color calibrate the combined image	Narrowband doesn't have 'natural' stars (each filter shows different stars at different brightnesses). Use StarXTerminator to remove the combined-channel stars, replace with RGB stars from a separate broadband capture if available. Result: nebula in narrowband color, stars in natural color.
Saturation control	Narrowband images tend to look over-saturated by default. Use SCNR (Subtractive Chromatic Noise Reduction) to remove magenta cast in SHO, or selective masking to bring colors back to plausible vibrancy.
Background neutralization	After all processing, the sky background should be neutral gray, not cyan or magenta. BackgroundNeutralization in PixInsight handles this.

Sharpening and detail enhancement

Final detail recovery

Sharpening is the last major creative step. Done well, it brings out fine detail in nebula structure, galaxy arms, and globular cluster cores. Done badly, it amplifies noise and creates artifacts that scream 'over-processed.'

Sharpening tools

RC-Astro BlurXTerminator (\$75) **The single most transformative modern processing tool.** AI-driven sharpening that recovers detail without amplifying noise. Available for PixInsight, Photoshop, Affinity. Russell Croman developed it. **Used in conjunction with NoiseXTerminator and StarXTerminator from the same developer, this trio has reshaped what's possible in amateur image processing.**

Wavelet sharpening (Siril, ImagesPlus) Multi-scale wavelet decomposition. Sharpens different detail scales independently. Free in Siril. Slightly more learning curve than BlurXT but produces excellent results.

MultiscaleLinearTransform (PixInsight) Similar to wavelets. Sharpens specific spatial scales. Highly tunable for experienced users.

LocalHistogramEqualization (PixInsight) Brings out contrast in small regions. Good for showing dust lanes in galaxies, structure in nebulae.

High pass filter (Photoshop) Classic Photoshop technique. Duplicate layer, apply High Pass filter, blend in Overlay mode. Quick and dirty but effective for final 'pop.'

When and where to sharpen

Apply after stretching, not before Sharpening is non-linear by nature. Apply in non-linear space. Sharpening linear data amplifies noise without proportional detail recovery.

Use masks aggressively Sharpen the nebula/galaxy structure, not the background sky. A range mask or luminance mask limits sharpening to relevant areas. PixInsight's RangeSelection or a simple luminance mask works.

Don't sharpen the same image multiple times Repeated sharpening pyramids artifacts. Apply once, evaluate, undo if too much. Don't 'add a little more' iteratively.

Final at 100% zoom Always evaluate sharpening at 100% pixel-for-pixel view. Over-sharpening that looks fine at 25% zoom shows obvious halos and grain at 100%.

Common processing mistakes

The diagnostic page — symptom and fix

The image looks like cotton candy

Over-stretched and over-saturated. Pull back on saturation (try 50% of current). Re-stretch with less aggressive curves. The Milky Way and most nebulae have subtle natural colors — saturation of 25–35% is plausible; 70%+ looks cartoonish.

Bands or stripes across the background sky

Over-stretched linear data, or gradient removal was insufficient before stretching. Go back to linear, do better gradient removal, re-stretch more gently. Banding once introduced is very hard to remove.

Bright stars have purple halos

Chromatic aberration from the optics (usually) or over-aggressive star reduction (sometimes). Optical CA can be reduced with SCNR (remove magenta) or per-star manual correction. Star reduction artifacts: redo with less aggression.

The galaxy core is white and featureless

Stretched too aggressively, clipping the highlights. Use Masked Stretch or GHS with high-end protection to preserve the dynamic range in the core. The core should show structure (band, bar, knots).

Subtle pattern noise (vertical or horizontal stripes)

Sensor walking noise from uncooled cameras, or missing dark frame calibration. If darks weren't applied, apply them. If cooled camera, check that temperature matches between lights and darks. Some sensors have residual patterns even calibrated — dithering during capture removes them.

Stars look square or have spikes that aren't diffraction spikes

Aggressive sharpening artifacts. Step back, undo sharpening, reapply with less strength or with a star mask protecting the stars.

Foreground / nebula has a halo around it

Sharpening edge artifact, or aggressive HDR pulled the edges. Reduce sharpening radius. Use feathered selections rather than hard edges.

The image is dark and dim despite long integration

Probably under-stretched. Apply more aggressive stretch — especially if your monitor calibration is making the image appear dimmer than it actually is. Compare your histogram to published examples for similar targets.

Color is washed out / monochromatic

Either under-saturated, or color calibration failed. Re-run SPCC. Make sure RGB channels weren't accidentally desaturated during processing.

Background is too dark / pure black

Black point clipping. The background sky should never be pure black — it should be a deep gray (histogram should not touch the left edge). Adjust the black point higher. Pure-black background hides the faint structure you worked so hard to capture.

Tile/grid pattern visible at high zoom

Drizzle resampling artifact or stacking issue. Check stacking parameters. The drizzle algorithm requires dithering during capture; if you didn't dither, don't use drizzle.

Stars are oval or comet-shaped

Tracking error during capture, not processing. Re-shoot with better polar alignment, or use BlurXTerminator's PSF correction which can fix mild oval stars retroactively.

Top-tier learning resources

Where to go after this guide

Image processing is too deep to fully cover in one document. These are the few resources I consider truly authoritative — selected for genuine expertise, not engagement metrics. Skip the YouTube quick-tips channels; learn from people who've spent decades on this craft.

Adam Block Studio

adamblockstudios.com. The single best resource for PixInsight learning, full stop. Adam Block is the most respected amateur image processor working today — his images from Mount Lemmon SkyCenter are technical references for the entire community, and his teaching style is exceptional. Two flagship offerings:

Fundamentals of CCD Astro Imaging	Multi-hour video course on the principles. Sensor physics, signal-to-noise, the math underneath every processing decision. Watching this once changes how you understand everything else.
The Horizons program	Long-form subscription-based PixInsight tutorials. Each session works through a real image start-to-finish, showing every decision in context. If you're serious about PixInsight, this is the deepest training available.
YouTube channel	Free public videos. Less structured than the paid courses but excellent introductions. Search 'Adam Block PixInsight' for hours of free authoritative content.

Other top-tier resources

Russell Croman tutorials — RC-Astro	rc-astro.com. The creator of StarXTerminator, NoiseXTerminator, and BlurXTerminator publishes excellent videos demonstrating his tools and the underlying techniques. His Webb-like deep-sky images set the standard.
Inside PixInsight by Warren Keller	Book (Springer Praxis, 2nd edition 2018). The most thorough printed reference for PixInsight. Warren Keller's online courses are comparable quality. insidepixinsight.com.
Light Vortex Astronomy	lightvortexastronomy.com. Steve Cannistra's comprehensive free written tutorials. Slightly older but still extremely thorough. Excellent for narrowband palette decisions.
Mike Cranfield's GHS resources	ghsastro.co.uk. The creator of Generalized Hyperbolic Stretch publishes free documentation and example workflows. If you'll use GHS (you should), read these.
Cuiv The Lazy Geek (YouTube)	Practical, modern, no-nonsense video tutorials. Often demonstrates new tools quickly after release. Best for keeping current with the rapidly-evolving toolchain.
PixInsight Forum	forum.pixinsight.com. The official community. Process-specific questions answered by experts. Search before posting — most questions are already answered.

Bill Blanshan's narrowband resources

Creator of the Foraxx palette and various PixelMath techniques. Active in the imaging community. Search 'Foraxx narrowband' for current best practices in narrowband palette mapping.

The learning order I'd recommend

(1) Adam Block's Fundamentals of CCD Astro Imaging — get the physics right. **(2)** Several months of practical processing with this guide and Light Vortex tutorials. **(3)** Adam Block's Horizons sessions — by now you have specific questions and the deeper examples will make sense. **(4)** Russell Croman's tool videos to integrate the AI-assisted modern workflow. **(5)** Inside PixInsight book as reference. After this sequence, you'll have all the foundational knowledge to be among the better amateur processors. The rest is practice and personal style.

Final thought

Image processing is genuinely a craft — it takes years to develop intuition for the right balance of each step on each target. Your tenth processed image will be dramatically better than your first, and your hundredth dramatically better than your tenth. The processing community is remarkably generous with knowledge — every published image on Astrobin includes the workflow in detail. Read other people's workflows. Try their techniques on your data. Pretty soon you'll have a style of your own — the goal isn't to reproduce another photographer's images, but to develop the skills to make your own data look like what only your eye sees in it.