ASTROPHOTOGRAPHY

Art and Science

A Complete Guide for Beginners and Advanced Astrophotographers

From First Steps with a DSLR to Advanced Equipment

AstroHopper · 2026

Foreword

This book was born from the conviction that astrophotography is not the privilege of professional observatories and expensive instruments — it is accessible to anyone who is willing to learn, to be patient, and to look up.

The inspiration for this expanded edition comes from the thousands of beginners who have asked the same questions: Which lens should I buy? How do I focus in the dark? Why are my stars streaks? What is DBE and why is it ruining my image? This guide answers all of those questions — step by step, from the first attempt with a smartphone to an advanced narrowband setup.

Special thanks to astrophotographer Wolfgang Promper, whose images from Namibia inspire generations of European astrophotographers, and to Adam Leaković, whose SkyArrow HD17 V5 mount represents the pinnacle of Croatian astrophotographic engineering.

The sky does not belong only to astronomers. It belongs to everyone who has the courage to look up.

— AstroHopper, 2026

How to Use This Book

Chapters 01–02 provide context and history — we recommend them as an introduction, but you can jump straight to Chapter 03 if you are a beginner ready to start buying gear.

Beginners should read Chapters 03, 06, 08, 10, and 11 — everything needed for the first year of astrophotography is there.

Advanced users will find new material in Chapters 04, 07, 09, and 12 — detailed PixInsight workflow, narrowband combining, and mosaics.

CONTENTS

Chapter 01

Origins in the 1840s, pioneers, film vs. digital era

Introduction and History of Astrophotography

Astrophotography is a discipline that fuses a passion for the universe with the craft of photography. Almost from the moment photography was invented, astronomers tried to capture celestial objects on a sensitive medium — and that fascination continues to this day. Its roots go back to 1840, when John W. Draper photographed the Moon using daguerreotype. That was only the beginning of something that would change astronomy forever.

Early Beginnings (1840s – 1900)

A few years after Draper, in 1850, William Cranch Bond and John Adams Whipple imaged the star Vega — the first star ever recorded on a photographic medium. These pioneering images were crude by today's standards, but revolutionary for their time. Photography gave astronomers something unprecedented: an objective, permanent record of the sky that could be measured, compared, and shared.

By the end of the 19th century, major observatories had begun systematically photographing the sky. The Henry Draper Catalogue project (1890) was the first attempt to classify stellar spectra by photographic means — covering more than 10,000 stars.

The Film Era (1900 – 2000)

Throughout the 20th century, astrophotography became the backbone of professional astronomy. Long exposures on glass plates and film revealed galaxies, nebulae, and star clusters invisible to the naked eye. Edwin Hubble used photographic plates to prove in 1923 that the Great Andromeda Nebula was a separate galaxy — millions of light-years away.

Great observatories such as Mt. Wilson, Palomar, and ESO created photographic sky atlases that were the gold standard in astronomy for decades. Amateur astrophotography in this era was expensive, technically demanding, and limited to a small number of enthusiasts who mixed their own chemicals and developed plates in total darkness.

The Digital Revolution (2000 – present)

The arrival of CCD and CMOS digital sensors democratized astrophotography. It was no longer the preserve of professional observatories. Hobbyists could suddenly use their DSLR cameras to image nebulae and galaxies from their own back yards. The development of image stacking and processing software further unlocked the potential of amateur astrophotography.

Today amateur astrophotography matches and sometimes surpasses the quality of professional images from just a few decades ago. The global community shares knowledge, software, and enthusiasm — and that is what makes this hobby so special. Platforms such as AstroBin, Cloudy Nights, and Reddit r/astrophotography provide daily inspiration and technical support to thousands of astrophotographers around the world.

Missions such as the Hubble Space Telescope, the James Webb Space Telescope, and ESA programs regularly release raw data to the public — so today an experienced amateur astrophotographer can process images from professional telescopes and produce astonishing results.

The Global Astrophotography Community

The global astronomical and astrophotography community is extremely active and continues to grow. The **AstroMax Studio** platform was created precisely to connect enthusiasts, share experiences, and democratize astrophotography knowledge at every level — from complete beginners to seasoned astrophotographers with years of imaging.

Services such as **AstroBin** and numerous **Facebook groups** (Astrophotography, DeepSkyObservers, regional groups) allow you to share and compare images with users from around the world — a valuable learning and inspiration base for every astrophotographer. Regularly browse images from locations similar to yours (Bortle class, equipment) — you will quickly understand what is realistically achievable and in which direction to develop.

Where to Start?

If you are reading this book, you have already taken the first step. The next ones are concrete: go outside tonight, raise your eyes to the sky, and ask yourself which star field looks interesting. Find the nearest dark-sky site (app: **Light Pollution Map**), grab whatever you have — a smartphone or a DSLR — and start. The equipment can always be better, the sky can always be darker, the software can always be more advanced — but the perfect moment to begin is always *now*.

”The cosmos is within us. We are made of star-stuff.”

— Carl Sagan

Chapter 02

Discoveries, role in astronomy, aesthetics

Astrophotography as Science and Art

Astrophotography occupies a unique niche between exact science and creative art. On one hand, every image can contain valuable scientific data. On the other hand, a photograph of the Orion Nebula or the Andromeda Galaxy evokes emotions that go far beyond mere documentation.

The Scientific Dimension

Professional and amateur astrophotographers contribute to astronomical research every day. Discovery of new comets, asteroid tracking, measuring the brightness of variable stars, documenting supernovae — these are all areas in which the amateur community actively participates. The AAVSO network collects data from thousands of hobbyists worldwide.

Amateur astrophotographers have discovered dozens of new comets, hundreds of asteroid objects, and recorded new stellar explosions. Every data point contributes to our understanding of the universe.

The Artistic Dimension

But space photography is not only science. The choice of framing, the exposure ratio, the color palette in processing — all of these are creative decisions that transform a technical capture into a work of art. Emission filters such as H-alpha, OIII, and SII open an entirely new visual language invisible to the naked eye.

The difference between a good and an outstanding astrophotograph often lies in the processing — in the artistic choices made by the photographer, not in the equipment itself. Every astrophotographer develops a personal style recognizable through palette, contrast, and choice of subjects.

Impact on Public Perception of Space

It is hard to overstate the impact that photographs of space have had on humanity. The Pale Blue Dot photograph changed the way we look at Earth. Images from the Hubble Space Telescope — from the Pillars of Creation to the Ultra Deep Field — have become cultural icons that inspire millions.

Today every amateur astrophotographer can produce images that were accessible only to elite observatories thirty years ago. This democratization of space photography is one of the most significant cultural contributions of the digital revolution.

The James Webb Space Telescope, launched in 2021, opened a new era in astronomy — and the amateur community was quick to use JWST public data for their own processing, creating images of breathtaking beauty shared on social media with millions of curious eyes.

Chapter 03

DSLR, lenses, trackers, tripod — brands and recommendations

Beginner Equipment — Widefield Astrophotography

Widefield astrophotography — imaging wide angles of sky with the Milky Way, constellations, and landscapes — is the ideal starting point for every beginner. It requires neither a telescope nor expensive equipment. With a good camera, lens, tripod, and perhaps a cheap tracker, you can achieve results that will amaze you.

Camera — DSLR or Mirrorless?

For a start, almost any modern DSLR or mirrorless camera can serve for astrophotography. The key characteristics are sensor size (Full Frame or APS-C preferred) and noise level at high ISO values.

Canon EOS Ra is the only Canon modified for astrophotography straight from the factory, with enhanced H-alpha transmission. **Sony A7 III**, A7C, and **Nikon Z6 II** are excellent mirrorless choices. For widefield imaging, Sony APS-C models (A6400, A6600) are particularly popular due to their compactness and excellent sensitivity.

For Nikon users, models such as the **Nikon D5300** and **D7500** have an excellent sensor for astrophotography and broad software support. The Nikon D5300 is particularly popular as a beginner body because it has natively high H-alpha transmission (without modification) and a sensor that generates little noise.

Every one of these cameras must shoot in **RAW format** — JPEG compression destroys astronomical data and makes processing nearly impossible.

Device	Brand / Model	Level	Rating
DSLR camera	Nikon D5300 / D7500	Beginner	□□□□□
DSLR camera	Canon EOS Ra	Beginner	□□□□□
Mirrorless	Sony A7 III	Beginner–mid	□□□□□
Mirrorless	Sony A6400	Beginner	□□□□□
Nikon mirrorless	Nikon Z6 II	Mid-level	□□□□□

Samyang 135mm f/2 — The Gold Standard for Beginners

Samyang 135mm f/2 (also known as Rokinon 135mm f/2) is without doubt one of the most acclaimed lenses for beginner to intermediate astrophotography. The combination of a 135mm focal length and a maximum aperture of f/2 makes it an extremely powerful tool for imaging emission nebulae, star clusters, and galactic fields.

Unlike wide-angle lenses, 135mm brings significantly more detail into the frame — the structure of the Orion Nebula, the Rosette Nebula, or the Heart/Soul Nebula becomes clearly visible in just 2-minute exposures. At f/2 it gathers an exceptional amount of light, and by f/2.8 or f/3.2 most coma at the corners disappears completely.

Wide-Angle Lenses for the Milky Way

For imaging the Milky Way and landscapes, wide-angle lenses with maximum apertures of f/2.8 or f/1.8 are ideal. **Samyang/Rokinon 14mm f/2.8** is one of the most popular choices due to its low price and solid optical performance. **Sigma 14mm Art f/1.8** is the premium option with excellent corner sharpness. **Sony FE 20mm f/1.8** is an excellent choice for Sony users.

For slightly longer focal lengths (50–135mm), almost any quality portrait lens can deliver great results for star fields and constellations. The key is to choose a lens that does not show too much coma (comet-like star tails) at the corners when shot wide open.

Lens	Focal / Aperture	Note
Samyang 135mm f/2	135mm f/2	Gold standard
Samyang 14mm f/2.8	14mm f/2.8	Milky Way
Sigma 14mm Art f/1.8	14mm f/1.8	Premium wide
Sony FE 20mm f/1.8	20mm f/1.8	Sony native
Tokina ATX-I 11-20 f/2.8	11-20mm f/2.8	Zoom wide

Star Tracker — The Most Important Investment for Beginners

A tracker is a device that compensates for Earth's rotation, allowing longer exposures without star trailing. For widefield astrophotography this is a key investment that opens up exposures of several minutes instead of 15–30 seconds.

Sky-Watcher Star Adventurer 2i is one of the world's best-selling trackers — compact, with Wi-Fi control, and a 5 kg payload. **iOptron SkyGuider Pro** is an alternative with slightly better precision at longer focal lengths. **Vixen Polarie Star Tracker** is ideal for travel setups due to its exceptional compactness and low weight. For lenses up to 135mm focal length, any of these trackers is sufficient for 3–5 minute exposures with careful polar alignment. With the Samyang 135mm f/2 and Star Adventurer 2i you can image the Orion Nebula, Rosette, or Heart/Soul at a level that would have required professional equipment just 10 years ago.

Tracker	Payload	Note
Sky-Watcher Star Adventurer 2i	5 kg	Most popular, Wi-Fi
iOptron SkyGuider Pro	4.5 kg	High precision
Vixen Polarie Star Tracker	2 kg	Ultra-compact

GOLDEN RULE FOR BEGINNERS

Start with the equipment you already have! Even a smartphone with night mode can serve for the first steps. Buy gradually — tracker first, then a better camera, and only then a telescope. Samyang 135mm f/2 + Sky-Watcher Star Adventurer 2i + Nikon/Canon DSLR is the ideal beginner package.

Tripod and Accessories

A stable tripod is the foundation of every astro session. For a tracker setup I recommend **Benro TMA37C** (carbon) or **Manfrotto MT190XPRO4** (aluminium). Carbon tripods absorb vibrations better and are lighter to carry. A **remote shutter release** (intervalometer) is essential to prevent camera shake with each shot. USB releases or Bluetooth devices, e.g. **MIOPS Smart+**, automate capture without touching the camera.

A **battery-powered lens heater** (dew heater) prevents condensation that can ruin an entire night of imaging. For a widefield setup cheap USB heaters are perfectly adequate.

For lighting in the field use exclusively a **red flashlight** — white light destroys your eyes's dark adaptation.

Smartphone — First Steps

Many astrophotographers start with literally what they have in their pocket. Modern smartphones, especially the **iPhone Pro** series and **Google Pixel**, have a night mode that can capture the Milky Way with exposures of 3–10 seconds. This is not "real" astrophotography in the technical sense, but it is perfect for the first steps and for inspiration.

For more advanced smartphone use: apps such as **NightCap Camera** (iOS) or **ProCamera** allow manual control of ISO, exposure, and RAW capture. With a cheap phone-tripod adapter and a tracker, you can achieve surprisingly good results.

Small Refractor for Beginners — Introduction to Telescope Astrophotography

Once you have mastered widefield imaging with a tracker and the Samyang 135mm, the logical next step is a small apochromatic refractor. This brings you into telescopic astrophotography without enormous cost.

William Optics RedCat 51 (f/4.9) is an excellent transition telescope — compact, light (1.4 kg), sharp to the edges, and with an FOV that fits on a Sky-Watcher Star Adventurer 2i. **Askar FMA135** (135mm f/4.8) is an even more compact and affordable choice.

These small apochromats give an FOV of approximately 2.5° × 1.7° (Full Frame) which is perfect for the Orion Nebula, Pleiades, Crescent Nebula, or the Triangulum Galaxy.

Telescope / Lens	Focal	Aperture	Weight	Level
Samyang 135mm f/2	135mm	f/2	0.8 kg	Beginner
Askar FMA135	135mm	f/4.8	0.9 kg	Beginner
WO RedCat 51	250mm	f/4.9	1.4 kg	Beginner+
Askar FRA400	400mm	f/5.6	2.5 kg	Mid
WO GT71	418mm	f/5.9	2.5 kg	Mid

□ RECOMMENDED PURCHASE ORDER FOR BEGINNERS

1. Tripod → 2. Tracker SA2i or SkyGuider Pro → 3. Samyang 135mm f/2 → 4. Nikon D5300 / Sony A6400 → 5. Flat panel for flat frames → 6. Small apochromat RedCat 51 / FMA135.

Chapter 04

Telescopes, mounts, astro cameras

Advanced Equipment — Deep Sky Astrophotography

Once you cross the threshold from beginner equipment, a fascinating and expensive world of advanced astrophotography hardware opens up. Real telescopes, precise equatorial mounts, cooled astro sensors, and autoguiding systems allow you to photograph details that are out of reach with a beginner setup.

Telescopes — Optical Types and Purpose

There are three main types of telescopes in astrophotography:

Refractors (apochromatic lenses) — such as the William Optics RedCat 51 or Takahashi FSQ-106 — deliver outstanding images without coma or astigmatism at the frame corners, ideal for nebulae and galaxies.

Reflectors (Newtonian telescopes) — offer large aperture at lower cost, but require periodic adjustment (collimation) and are more sensitive to thermal changes.

Catadioptric systems (SCT, Ritchey-Chrétien) are compact and suitable for planetary photography and deep sky at long focal lengths. Celestron and Meade are the leading brands in this category.

For a start in deep sky photography, an apochromatic refractor of 80–100mm f/6–f/7 is an excellent and relatively affordable option.

Telescope	Type	Aperture	Recommendation
William Optics RedCat 51	APO refractor	51mm f/4.9	Widefield deep sky
Askar FRA500	APO refractor	100mm f/5	Versatile
Sky-Watcher Esprit 100ED	APO refractor	100mm f/5.5	Classic
TS Optics RC 8"	Ritchey-Chr.	203mm f/8	Galaxies
Celestron C8 SCT	SCT	203mm f/10	Planets/galaxies

Equatorial Mounts (EQ) — The Heart of the Setup

A precise equatorial mount is the heart of an advanced astrophotography setup. **Sky-Watcher EQ6-R Pro** and **EQ8-R Pro** are the gold standard for amateurs — excellent payload, precision, and service availability. **iOptron CEM40** and **CEM60** are exceptionally precise mounts with center-balanced design that eliminates torsional forces.

SkyArrow HD17 V5 — Harmonic Drive by Adam Leaković

The **SkyArrow HD17 V5** is a mount designed and hand-built by Croatian astrophotographer **Adam Leaković**. It is a high-class *harmonic drive* mount representing the pinnacle of amateur astrophotographic engineering.

The harmonic drive eliminates backlash present in conventional equatorial mounts — the mount can begin tracking the sky instantly with zero initial error. This is critical for autoguiding and sub-arcsecond precision.

A payload of 14–20 kg in a compact, portable form makes the SkyArrow HD17 V5 one of the finest mounts in its class. It is compatible with ASCOM/INDI drivers and integrates with N.I.N.A., SGP, EKOS/KStars, and AsiAir software. This is definitively an **advanced** mount for serious astrophotographers who demand compactness and maximum precision, with no compromises.

Mount	Type	Payload	Level
Sky-Watcher EQ6-R Pro	EQ worm gear	20 kg	Beginner/mid
iOptron CEM40	EQ center-balanced	18 kg	Mid/advanced
Rainbow Astro RST-135	Harmonic	13–20 kg	Advanced
SkyArrow HD17 V5 (Leaković)	Harmonic	14–20 kg	Advanced/Pro
10Micron GM1000	EQ direct drive	30 kg	Pro

SkyArrow HD17 V5 — harmonic drive by Adam Leaković

Advanced Astro Cameras

For serious work, dedicated astro cameras have clear advantages over DSLRs: a cooled sensor (reducing thermal noise by up to 90%), monochrome or colour sensors optimized for emission lines, greater dynamic range, and dedicated input ports for a filter wheel. **ZWO ASI2600MM Pro** and **ASI533MM** are popular and affordable options. **QHY268M** and **QHY600** are high-end Full Frame choices.

Monochrome cameras combined with LRGB or narrowband filters deliver maximum results, but require more time for data collection — each channel is captured separately. For narrowband photography from a Bortle 7 location, a mono camera with narrowband filters is a true game-changer.

Camera	Sensor	Cooling	Recommendation
ZWO ASI533MC Pro	OSC 1" Sony IMX533	Yes, -40°C	Beginner OSC
ZWO ASI2600MC Pro	OSC APS-C Sony IMX571	Yes, -35°C	Mid OSC
ZWO ASI2600MM Pro	MONO APS-C Sony IMX571	Yes, -35°C	Mid mono
QHY268M	MONO APS-C Sony IMX571	Yes, -40°C	Advanced mono
QHY600	MONO FF Sony IMX455	Yes, -40°C	Pro mono

Autoguiding and Focus System

Guide scope — a small secondary telescope (30–60mm aperture) or an off-axis guider for tracking the guide star. It just needs to be cheap and light. **ZWO ASI120MM Mini** or **QHY5LII-M** are ideal guide cameras.

Electronic focuser (motorized focuser) enables automatic focusing from the warmth of a car or house via software. **ZWO EAF** and **Pegasus Astro Focus Cube 3** are the most popular options.

Filter wheel — an automated filter wheel enables programmatic filter changes in the middle of the night. **ZWO EFW 5x2"** or **7x36mm** are standard options for an advanced setup.

Advanced Equipment — Comparative Configuration Table

Level	Telescope	Mount	Camera	Filters	
Entry deep sky	WO RedCat 51	EQ6-R Pro	DSLR mod. / ASI533	CLS/LP filter	
Mid-level	Askar FRA500 100mm	CEM40	ASI2600MC Pro	L-Pro + Ha	4,000–6,000 €
Advanced	WO GT71 / APO 100	CEM60	ASI2600MM + FW	Ha/OIII/SII	6,000–10,000 €
Pro/semi-pro	RC8 / Tak FSQ	SkyArrow HD17 V5	QHY600 + FW	Full NB set	12,000+ €

The recommendation is to build your setup gradually — do not buy everything at once. Start with a mid-level telescope and EQ mount, learn the software and workflow, and only then invest in a more advanced camera and filters. Equipment alone does not guarantee good results — experience and processing knowledge are far more important than the brand on the telescope housing.

Every setup level has its own limitations and advantages. The key is to understand what your goal is: visual observing with a camera, widefield Milky Way, emission nebulae from a Bortle 5 suburban sky, or full narrowband with a mono camera? The answer to that question determines every component you will buy.

Golden Rule of Equipment Purchase

It is better to have a modest telescope and an EQ6-R mount than an expensive telescope on a cheap EQ5. The mount is the foundation of everything — a poor mount ruins every exposure longer than 30 seconds. Always invest more in the mount than in the telescope.

Gallery

Wolfgang Promper — Namibia, Bortle 1–2

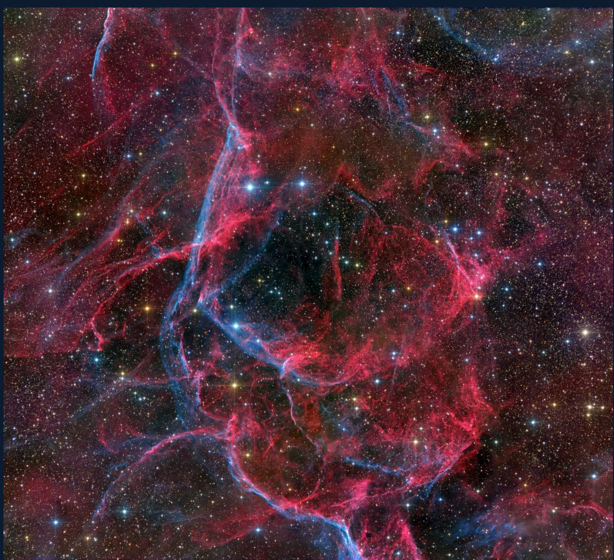
Wolfgang Promper is one of the most prominent European amateur astrophotographers. From his private observatory in Namibia, at one of the darkest locations on Earth (Bortle 1–2), he produces images that surpass in quality many professional observatories equipped with smaller telescopes.

The Namibian sky offers conditions that are unattainable for European astrophotographers from their own back yards: atmospheric seeing below 2", an absence of light pollution at a level of SQM > 22 mag/arcsec², and a view of the southern celestial hemisphere rich in the Milky Way, Magellanic Clouds, and deep nebulae invisible from the northern hemisphere.

Setup — Wolfgang Promper, Namibia

Telescope: ASA 600 · Mount: ASA DDM200 · Camera: Moravian Instruments C3-61000 PRO (monochrome) · Filters: FLI Blue/Green/Red/Lum 50×50 mm · Reducer: ASA 4" 0.63 RC Reducer · Software: PixInsight · Adobe Photoshop · BlurXTerminator · Location: Namibia · Bortle: 1–2

The images that follow illustrate the ultimate reach of amateur astrophotography — what is possible to achieve with top-tier equipment, perfect conditions, and years of experience. Use them as inspiration and as a reference standard for your own development.



Chapter 05

Differences, SHO, HOO palette — visual comparison

Broadband vs. Narrowband — Color Palettes

One of the most fascinating topics in astrophotography is the difference between broadband and narrowband imaging — and how different color palettes completely transform the visual impression of the same nebula.

Broadband Photography — Natural Colors

Broadband astrophotography uses standard RGB filters or shoots directly without filters — similar to ordinary photography. The result is natural colors that you would see if our eyes were sensitive enough. The dominant color of emission nebulae in broadband is red (H-alpha) and blue-turquoise (OIII), with warm tones of dust and stars.

Broadband photography works especially well for reflection nebulae, star clusters, and galaxies where true physical color contrasts matter. For emission nebulae from light-polluted locations broadband can be challenging because city lights contaminate all channels.


Rho Ophiuchi · Lagoon Nebula (M8) — broadband examples

Narrowband Photography — Filtered Universe

Narrowband astrophotography uses narrow (3–10 nm) filters that pass only the specific emission line of a gas in the nebula:

- **H-alpha (Ha)** — 656 nm — hydrogen — the dominant emission in most nebulae
- **OIII** — 500 nm — oxygen — turquoise emission, common in planetary nebulae
- **SII** — 672 nm — sulphur — red-orange emission in HII regions

These filters virtually eliminate city light and moonlight. Narrowband is a revolution for astrophotographers from light-polluted sites. The downside is that filters are expensive and each channel requires separate imaging.

For a beginner narrowband setup we recommend starting with **Ha + OIII** combination which gives the HOO palette — sufficient for most objects and less expensive than a full SHO set.

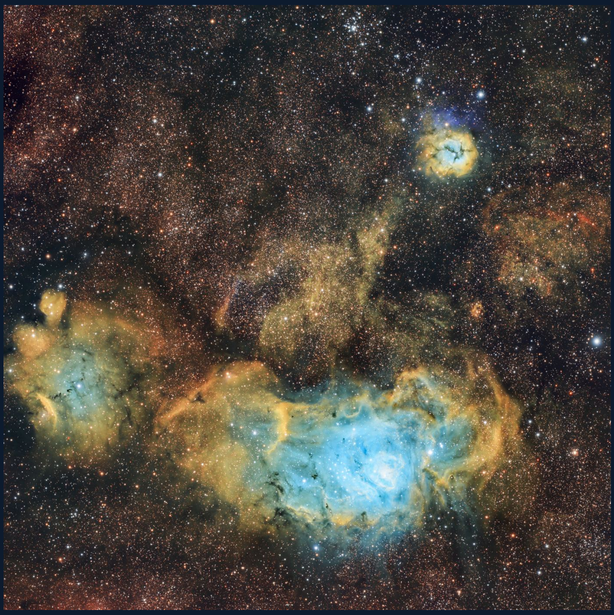
HOO Palette — Dramatic and Emotional

The HOO palette maps the H-alpha signal to the red channel and OIII to the green and blue channels. The result is a dramatic red-blue contrast that immediately draws the eye. The HOO palette emphasizes the difference between hydrogen clouds (red) and oxygen zones (blue-turquoise) — giving nebulae an almost three-dimensional appearance.

SHO Palette — The Hubble Palette

The SHO palette maps SII (sulphur) to the red channel, H-alpha to the green, and OIII to the blue channel. This is the famous Hubble palette — the characteristic golden-green color of Hubble images of the Pillars of Creation and the Eagle Nebula. The SHO palette gives nebulae a rich, complex structure.

The green color in the SHO palette often produces a green cast on stars — this is corrected with the SCNR (Selective Color Noise Reduction) module in PixInsight, which selectively removes the green component while preserving green nebular detail.



Palette	R channel	G channel	B channel	Character	Location
HOO	Ha	OIII	OIII	Dramatic red-blue	All locations
SHO	SII	Ha	OIII	Golden-green (Hubble)	All locations
LRGB	L+R	G	B	Natural colors	Dark sky
HaRGB	Ha+R	G	B	Enhanced H-alpha	City+dark

WHICH FILTER TO CHOOSE?

From a city location (Bortle 6–8): start with an Ha filter, then add OIII. The HOO palette with two filters delivers great results. For dark sky (Bortle 3–5): LRGB broadband is ideal for galaxies and reflection nebulae. For maximum depth on emission nebulae — a full SHO setup.

Light Pollution Filters for Beginners

For beginners who want to image emission nebulae from light-polluted locations without an expensive narrowband set, practical compromise filters exist:

Dual-narrowband filters (Optolong L-eNhance, SkyTech CLS-CCD, Astronomik UHC) pass Ha and OIII in a single filter — they can be used with OSC (color) cameras and give a "pseudo-narrowband" effect. The result is far from true narrowband but dramatically better than unfiltered images from a Bortle 6–7 location.

- **Optolong L-eNhance** — dual-band Ha+OIII, excellent for OSC cameras and DSLR
- **Astronomik UHC** — wider passband, good for reflection nebulae
- **Baader Moon&Skyglow** — cheaper, blocks sodium lamps
- **Optolong L-Pro** — balanced broadband LP filter for galaxies and clusters

For monochrome cameras: quality 3–5 nm Ha, OIII and SII plus LRGB filters (Antlia, Chroma).

Filter	Type	Bandwidth	For
Optolong L-eNhance	Dual-NB (Ha+OIII)	7nm	OSC/DSLR, city
Optolong L-Pro	Broadband LP	Wide	Galaxies, clusters
Astronomik Ha 6nm	Narrowband Ha	6nm	Mono camera
Antlia Ha 3.5nm	Narrowband Ha	3.5nm	Pro mono
ZWO OIII 7nm	Narrowband OIII	7nm	Mono camera
Baader Moon&Skyglow;	LP broadband	Wide	Beginner LP

Sensors in Astrophotography — Full Frame vs. APS-C vs. Micro 4/3

Sensor size directly affects the Field of View (FOV) and overall sensitivity:

Full Frame (FF) — 36×24mm sensor gives the widest FOV. Ideal for widefield nebulae and mosaics. Models: Sony A7 III, Nikon Z6 II, Canon EOS R6. FF astro cameras: ZWO ASI6200, QHY600.

APS-C — ~24×16mm, crop factor 1.5–1.6x. A compromise between size and cost. The most popular category for astrophotography. Models: Sony A6400, Nikon D7500, Canon 90D. Astro: ZWO ASI2600, QHY268.

Micro 4/3 (MFT) — ~17×13mm, crop factor 2x. A compact system that pairs excellently with small telescopes. Olympus/OM System and Panasonic. Less popular for deep sky but perfectly competent for widefield imaging.

Format	Sensor size	Crop factor	FOV (100mm lens)	Recommendation
Full Frame	36 × 24 mm	1.0x	~20° × 13.5°	Widefield, mosaics
APS-C	24 × 16 mm	1.5x	~13° × 9°	Versatile, recommended
MFT	17 × 13 mm	2.0x	~10° × 7°	Compact setup

Chapter 06

Exposure, ISO, focusing, session planning

Beginner Imaging — Widefield Techniques

This chapter is aimed at those using a DSLR or mirrorless camera with or without a tracker. Widefield imaging is the most accessible form of astrophotography and an excellent place to learn the fundamental principles of exposure, focusing, and session planning. With widefield imaging you control all parameters directly on the camera — ISO, exposure, aperture. There is no complex software or sequences between you and the sky.

Session Planning

Stellarium (free, desktop and mobile) and **SkySafari** help you locate objects, simulate your horizon, and find the optimal imaging time. **PhotoPills** is especially useful for planning Milky Way and Moon shots. For weather forecasts use **Clear Outside** or **Astrospheric** — specifically calibrated for astronomical conditions (transparency, seeing, moonlight).

Check the **Bortle class** of your location on *lightpollutionmap.info* and plan sessions around new Moon (new to first quarter) when the sky is darkest. Plan your target high in the sky — the higher it is, the less atmosphere light must pass through and the sharper the result.

Stellarium Web is accessible directly in the browser without installation. **Sky Map** (Android/iOS) uses AR to display stars in real time, making it an excellent tool in the field.

Tracker Polar Alignment

For widefield trackers, **SharpCap Polar Alignment** (software method) or visual alignment to Polaris is usually perfectly sufficient. Polaris does not sit exactly at the celestial pole — it is offset by about 0.7° — but for exposures up to 3–5 minutes at short focal lengths the difference is negligible.

Always try to make polar alignment as precise as possible — every minute invested in good alignment pays back as less star drift in the final frames. For more precise alignment without extra software, use the built-in polarscope that comes with most trackers.

Exposure, ISO and Histogram

Start with short test exposures (30–60 s) and check the histogram on the camera screen. The goal is to push the histogram to the right (**ETTR — Expose To The Right**) without overexposing the brightest stars. The histogram should be visibly shifted away from the left side (black = too little light) but must not clip the right side (white = blown out).

For Milky Way widefield shots the recommendations are: **ISO 1600–6400**, exposure **15–30 seconds** (depending on focal length and tracker), aperture **as wide as possible** (f/2.8 or f/1.8). With a tracker you can extend to 2–5 minutes, which dramatically increases image depth.

There is no perfect ISO for every situation — it will depend on your camera, exposure duration, and light pollution. Modern sensors (Sony, Nikon Z, Canon R) show a smaller difference between ISO 800 and 6400 than older generations, giving you more flexibility.

The 500 Rule and NPF Rule (without tracker)

If you do not have a tracker, use the **500 Rule** to estimate the maximum exposure without star trailing:

Max. exposure (s) = 500 ÷ focal length (mm)

For example, with a 24 mm lens: 500 ÷ 24 = 20 seconds. For APS-C sensors divide by the crop factor (usually 1.5x): 500 ÷ (24 × 1.5) = 13 seconds.

NPF Rule (Nasim, Pearce, Friek) is more precise:
t = (35 × AP + 30 × pixel_pitch) ÷ (crop × focal)

This also accounts for the sensor pixel pitch. Apps such as **PhotoPills** automatically calculates the NPF value for your camera and lens. This is only a guideline — in practice you can adjust depending on how much star trailing bothers you.

Focusing

Precise focusing is one of the most difficult skills in astrophotography. For widefield imaging with a lens, use **Live View** at the highest zoom on the camera screen and focus on a bright star until it becomes as small and sharp a point as possible. Always disable autofocus — AF does not work at night.

A **Bahtinov mask** (a cheap metal or 3D-printed mask for the lens) creates a characteristic diffraction pattern that makes focusing much easier and more precise. When all three spikes of the mask are perfectly aligned, focus is ideal.

Another method: focus at the infinity marker on the lens and in Live View zoom fine-tune until stars are sharpest. Mark the focus position with a marker on the lens so you can find it more easily the next night.

Calibration — Flat and Bias Frames

Even for widefield imaging, capturing **flat frames** dramatically improves the final image. Flat frames are shot in daylight against a uniformly illuminated white surface (e.g. a light panel at dawn) or at night against a uniform part of the sky — they eliminate *vignetting* (darkening at the corners) and visible dust particles on the sensor.

Bias frames are zero-length exposures with a covered lens that calibrate the electronic baseline levels of the sensor. For a start, even just flat frames give a visible improvement — capture **20–30 flats** the same night at a similar temperature.

Dark frames (only for cameras without an offset system) are captured with a covered camera at the same ISO and exposure as the light frames — they calibrate thermal noise and hot pixels on the sensor.

GOLDEN RULE OF WIDEFIELD IMAGING

Shoot as many frames of the same scene as possible — stacking them dramatically reduces noise and reveals detail that no single frame can show. RAW format is mandatory — JPEG compression destroys astrophotographic data. Verify that the camera is set to RAW or RAW+JPEG.

Steps for Your First Session

1. **Plan** the session — check Moon phase, Bortle class of the location, target visibility in Stellarium
2. **Prepare** equipment at home in daylight — check batteries, SD card, camera settings (RAW, manual mode)
3. **Drive** to the location early — allow about 30 minutes for setup and equipment cool-down (sensor, air)
4. **Polar alignment** — align the tracker to Polaris with the built-in polarscope
5. **Focus** — Live View + Bahtinov mask on a bright star
6. **Test exposure** — 30 s, ISO 3200, check the histogram
7. **Image** — enable intervalometer, 2–5 min exposures, 20–50 frames
8. **Flat frames** — immediately after imaging, while the same lens is on
9. **At home** — import and stack in Siril, PixInsight, or another program

Chapter 07

Sequence software, dithering, meridian flip, autoguiding

Advanced Imaging — Deep Sky Techniques

Advanced Deep Sky imaging differs fundamentally from the widefield approach. Here you no longer control the camera manually — software sequences automatically run the entire night while you monitor parameters on screen or sleep. The layering of techniques and equipment is significantly greater. This chapter assumes you have an EQ mount, a dedicated astro camera, a telescope, and a basic autoguiding system.

Acquisition Software — Session Management

For advanced imaging, use dedicated sequence software that automates the entire night:

• **N.I.N.A.** (Nighttime Imaging N Astronomy) — free, open-source, the gold standard for amateurs and professionals alike. Actively developed with a rich plugin ecosystem.
• **Sequence Generator Pro (SGP)** — paid, stable, excellent for full system automation
• **EKOS/KStars** — cross-platform (Linux/Mac), integrated with INDI drivers

These programs automatically: *platesolve* (determine the exact telescope position), slew to target, focus, run autoguiding, and capture a defined number of exposures per filter.

Polar Alignment — Advanced Methods

For deep sky imaging with long exposures, polar alignment precision is critical. **SharpCap Pro Polar Alignment** uses plate-solving for sub-arcminute accuracy in under a minute. **Drift alignment** (manual method) gives exceptional precision but requires 30–60 minutes of patience.

iPolar (iOptron) and **PoleMaster** (QHY) are all-sky cameras with dedicated software for automatic polar alignment — an investment that pays off for those who regularly set up and tear down equipment. For permanent installations a one-time drift alignment setup lasts for years.

Autoguiding — Without It There Are No Long Exposures

Autoguiding is the process by which a secondary telescope and camera continuously track a guide star and send milli-arcsecond corrections to the mount in real time. Without autoguiding, exposures longer than 2–3 minutes almost always show star drift at longer focal lengths.

PHD2 (Push Here Dummy) is the gold standard for autoguiding software — free, extremely reliable, and compatible with virtually all guide cameras and mounts. The guide scope can be small (30–60 mm aperture) because resolution is not needed — just a sufficiently bright guide star.

The target autoguiding RMS is below 1 arcsecond total error — for most amateur setups 0.5–0.8" is an excellent result. Below 0.3" is the level of professional setups.

Dithering — Eliminating Fixed Pattern Noise

Dithering is a technique by which the software shifts the telescope by a few pixels in a random direction between each exposure. This means that thermal noise from the sensor (hot pixels) remains fixed in the sensor pixel coordinates, but falls on different sky coordinates in every frame. During stacking, these randomly positioned errors are completely eliminated by averaging.

Sigma clipping combined with dithering is one of the most powerful tools for clean final images. N.I.N.A. and SGP have built-in dither functionality — it is recommended to enable it for all deep sky sessions.

Meridian Flip — Automatic Switching

An equatorial mount can track an object only up to the meridian (the imaginary north-south line across the sky). When the object approaches the meridian, the mount must perform a **meridian flip** — physically swinging the telescope to the other side. Sequence software automatically detects and executes the flip, then resumes plate-solving and imaging without user intervention.

It is important to verify that the mount has enough clearance for the flip without colliding with the tripod or cables. Always test the meridian flip during the day on a safe part of the sky.

Narrowband Filters and Filter Wheel

For advanced imaging of emission nebulae, narrowband filters (H-alpha, OIII, SII) are a key tool — especially from urban locations. An automatic filter wheel (such as **ZWO EFW** or **Pegasus Astro FW**) enables programmatic switching between filters without touching the equipment, even in the middle of the night.

A typical narrowband session is planned so that H-alpha is captured when the object is highest in the sky (maximum SNR), with OIII and SII supplementing the session. For the HOO palette you need only H-alpha and OIII channels — SII is added for the full SHO palette.

Plate Solving — Automatic Navigation

Plate solving is a technique whereby software analyses the star field captured by the camera and determines precisely where the telescope is pointing in the sky. This eliminates the need for manual object centering and enables sub-arcminute pointing accuracy.

N.I.N.A. has a built-in plate solver (**ASTAP** or **Astrometry.net**). Plate solving typically takes 3–10 seconds and fully automates frame centering. Use it for: slewing to targets, confirming the meridian flip, and tracking field rotation.

ADVANCED SESSION PLANNING

Use Telescopius or Astroplanner for a detailed night plan: visualize Field of View (FOV) on the sky atlas, predict the object's altitude track, optimize filter order, and budget total collection time. For long-term projects (an object requiring 20+ hours of exposure), plan sessions over multiple nights, accounting for Moon phase, field rotation, and seasonal target availability.

Starting Your First Automated Session in N.I.N.A.

1. **Connect** all equipment via ASCOM/INDI (camera, mount, focuser, filter wheel, guide camera)
2. **Polar alignment** via SharpCap Pro or iPolar
3. **Plate solve** — auto-slew to target, verify centering
4. **Auto-focus** routine — define focus criterion (HFR target)
5. **PHD2** calibrate guide sensor and guide star
6. **Define the sequence** — filter, exposure, number of frames, dithering
7. **Start the sequence** — N.I.N.A. automatically runs the entire night
8. **Morning** — calibration frames,

Typical Narrowband Session — Time Schedule

Planning the filter capture order is not trivial. Here is a recommended schedule for a typical 6-hour summer night (target in Cygnus):

- **21:30 – 22:00** — Setup, polar alignment, thermal adaptation
- **22:00 – 22:20** — Plate solve, auto-focus, PHD2 calibration
- **22:20 – 01:00** — H-alpha imaging (target culminates ~23:30), 20×5 min = 100 min + breaks
- **01:00 – 03:00** — OIII imaging (target descending, lower SNR), 12×5 min = 60 min
- **03:00 – 03:30** — SII imaging (short session for SHO palette), 6×5 min = 30 min
- **03:30 – 03:45** — calibration, log check

Image H-alpha first (strongest signal for most objects), OIII second, SII as needed. On very cold nights, DSLR dark frames are captured immediately after the session ends.

PHD2 — Settings for Optimal Results

PHD2 Guiding has many parameters, but for a start you only need the basics:

• **Calibration** — always calibrate near the celestial equator (declination 0±20°) for accurate parameters
• **Exposure time** — 0.5–3 seconds for the guide camera (longer for fainter stars, shorter for better seeing)
• **Aggressiveness** — RA: 70–80, Dec: 50–60 to start
• **Min motion** — 0.15–0.25 arcseconds (below this value, no correction is applied — eliminates overcorrection noise)
• **Backlash compensation** — only if your mount has a constant Dec drift

The goal is a total RMS guide error below 1.0". For short focal lengths (100–400mm) and a 1.5 arcsec/pixel scale, 0.7–1.0" RMS is perfectly adequate.

Modular Principles of Advanced Setup

An advanced astrophotography setup is like a living organism — every component must communicate with the others. Typical connections:

• **N.I.N.A.** ↔ Camera (ZWO/QHY ASCOM driver)
• **N.I.N.A.** ↔ Mount (EQ6-R ASCOM driver or iOptron commander)
• **N.I.N.A.** ↔ Focuser (EAF ASCOM driver)
• **N.I.N.A.** ↔ Filter Wheel (EFW ASCOM driver)
• **N.I.N.A.** ↔ PHD2 (DirectGuider or SocketGuider protocol)
• **N.I.N.A.** ↔ Plate Solver (ASTAP local or Astrometry.net online)

The ASCOM platform (Windows) or INDI/KStars (Linux/Mac) form the foundation of the communication architecture. Each device has its own driver that is installed separately. It is recommended to test each component individually before the first automated imaging run.

Chapter 08

Stacking, calibration, Siril, PixInsight and more

Basic Astrophotography Processing

Astrophotography processing is just as important as the imaging itself. An outstanding image is born in the sky, but developed in software. The process is divided into **integration (stacking)** of raw data and **final artistic processing** of the image.

Stacking — The Foundation of Everything

Stacking combines hundreds of short exposures into one clean image using the mathematical power of averaging. The signal (your nebula) is consistent across frames, while noise is random — 100 exposures give a 10x better signal-to-noise ratio than a single exposure. This is the fundamental reason why astrophotographers capture so many frames.

Combined with stacking, calibration with dark/flat/bias frames dramatically improves the final result by eliminating sensor artifacts and optical flaws. Rejection algorithms (Sigma clipping, Winsorized sigma) automatically detect and eliminate frames damaged by clouds, satellites, or aircraft.

Siril — Free Alternative for Beginners

Siril is an open-source software that has made enormous strides in quality in recent years. It offers a complete workflow from calibration and registration to stacking and post-processing — completely free. It is particularly impressive for narrowband processing and includes a built-in Script Editor for automation.

For beginners who want to learn the fundamentals without financial pressure, Siril is the ideal entry point. It has an active community and detailed documentation in multiple languages.

Siril Workflow — Step by Step

1. Data Organization
Sort your exposures into folders: *lights/, darks/, flats/, biases/*

2. Calibration
Siril > Image Processing > Preprocessing — define the paths for dark, flat, and bias folders. Siril automatically processes the calibration.

3. Registration
Siril aligns all exposures to a reference frame — using star patterns for sub-pixel accuracy.

4. Stacking
Choose the method: Sigma Clipping (for most setups) or Winsorized Sigma for fewer exposures. Click Stack — the result is one clean master image.

5. Stretch
The image arrives in linear form (dark). Use AutoStretch for a first look, then Histogram Transformation for a controlled stretch.

6. Gradient Removal
Background Extraction (BXT) — click on uniformly dark areas (background) and Siril computes a polynomial that eliminates uneven background illumination.

Lightroom and Affinity Photo for Final Processing

After stacking, many astrophotographers move to **Adobe Lightroom** or **Affinity Photo** for final processing. Lightroom handles colors, contrast, and detail excellently for broadband images. **Affinity Photo** (one-time purchase, no subscription) offers powerful layer-based tools for composites and color fine-tuning.

Photoshop (Adobe CC subscription) remains the gold standard for complex composites, but Affinity Photo now offers 95% of the same functionality for a one-time price of around €70.

For a beginner workflow we recommend: **Siril for stacking → Affinity Photo or Lightroom for final processing**. This makes for a free or inexpensive solution that delivers solid results.

THE GOLDEN RULE OF PROCESSING

Less is more. Over-processing — little noise but lost detail, oversaturated colors, aggressive sharpening — is always worse than moderate processing that preserves detail and realistic tones. Compare your result with reference images of similar objects — that is the fastest way to learn and develop your own style.

Chapter 09

DBE, stretch, noise reduction, deconvolution, color palettes

Advanced Processing — PixInsight Workflow

PixInsight is dedicated software used by the vast majority of serious astrophotographers. The higher price (one-time license) is justified by powerful algorithms that have no equivalent in generalist editors. The learning curve is steep, but the results are incomparable.

Project Organization in PixInsight

PixInsight works with an **Image Container** and **Process Container** system. Each image has its own window. Processes are applied from the *Process menu* or toolbar icons. The typical workflow is: calibration → stacking → linear state processing → stretch → non-linear state processing → final aesthetic processing.

The key distinction in PixInsight: we differentiate between **linear state** (before stretch, dark image) and **non-linear state** (after stretch, visible detail). Many processes only work correctly in linear state.

ImageCalibration — Calibration

ImageCalibration (Process > ImageCalibration) applies the master dark, master flat, and master bias to each light frame. Use *Optimize Dark Frames* for better calibration of dark frames captured at varying temperatures. The output is calibrated frames ready for registration and stacking.

StarAlignment i ImageIntegration

StarAlignment aligns all calibrated frames to a reference frame. Use *Triangle Similarity* or *Distortion Correction* for sensors with optical aberrations.

ImageIntegration (stacking) — choose a method:
• *Average Sigma Clipping* — for multi-hour or multi-night sessions
• *Winsorized Sigma Clipping* — for fewer than 10–30 frames
• *Linear Clipping* — for larger frame counts with dithering

The output of ImageIntegration is the **master light** — a clean integrated image in linear state.

DynamicBackgroundExtraction (DBE) — Gradient Removal

DBE is one of the most important tools in PixInsight. It removes uneven background illumination caused by light pollution.

Procedure:
1. Open DBE (Process > Background Modeling > DynamicBackgroundExtraction)
2. Click on 20–50 points in uniformly dark background areas (avoid stars and nebulosity)
3. *Compute* — PixInsight builds a gradient model
4. Apply (*Execute*) to the image — PixInsight subtracts the gradient

For images with stronger gradients (city glow, field edges), use more points and a larger *Sample radius*.

Stretch — Histogram Stretching

Stretch converts the linear (dark) image into a visible one with detail. There are several methods:

• **HistogramTransformation** — manual, maximum control. Use the midtones (M) slider.
• **MaskedStretch** — automatic stretch that protects the background. Excellent for a first attempt.
• **ArcsinhStretch** — non-linear stretch that preserves stellar core brightness better than logarithm.
• **GeneralizedHyperbolicStretch (GHS)** — the most modern method (plugin), excellent control.

Always stretch **after** DBE and color calibration — these operations must be done in linear state. Keep stars as small white points and the background uniformly dark.

Noise Reduction — Removing Noise

MultiscaleLinearTransform (MLT) — the most powerful noise reduction tool in PixInsight. Works on multiple wavelet scales:
• Noise threshold per layer controls aggressiveness
• Layers 1 and 2 for fine noise, layers 3–4 for coarser noise
• Use a *luminance mask* to protect bright areas

GraXpert Denoise (AI-based, free plugin/standalone) is outstanding for a beginner workflow — automatically detects and removes noise without manual adjustments.

NoiseXTerminator (plugin, RC-Astro) AI noise reduction that delivers outstanding results with one click — available as a one-time purchase.

Deconvolution and Sharpening

Deconvolution sharpens stellar cores and nebula detail by compensating for the blurring caused by atmospheric seeing and optical aberrations. It must be applied exclusively in **linear state**.

BlurXTerminator (plugin, RC-Astro) — AI-based deconvolution that automatically estimates the PSF (Point Spread Function) and applies corrections. The gold standard among modern plugins.

Lucy-Richardson Deconvolution (built into PixInsight) — the classical method that requires manual PSF definition but gives full control.

Color Calibration — SPCC and ColorCalibration

SpectrophotometricColorCalibration (SPCC) — a modern PixInsight tool that calibrates colors based on photometric star catalogs. It delivers accurate, consistent colors for broadband and LRGB images.

ColorCalibration (older method) uses white stars as a reference — a good alternative for images without SPCC support.

For **narrowband SHO** processing: after combining channels with ChannelCombination, use **SCNR (Selective Color Noise Reduction)** to remove the green cast that commonly appears on stars in the SHO palette.

Final Aesthetic Processing

After all processing steps, the final workflow includes:

• **CurvesTransformation** — precise control of contrast, saturation and individual colors through curves
• **LocalHistogramEqualization (LHE)** — enhances local contrast of detail in the nebula without burning the brightest areas
• **RangeSelection + Masks** — apply processes selectively to background, stars, or nebula separately
• **StarReduction (StarNet++ or StarXTerminator)** — temporarily removing stars to process nebula without affecting stellar cores
• **SCNR** — selectively removing the unwanted green component in the SHO palette

At the end always compare with the original stack — if processing has gone too far in saturation or contrast, all steps are reversible.

Tool	Type	Application
PixInsight	Software	Complete workflow
Siril	Software	Stacking + basic processing
GraXpert	AI plugin	DBE + Denoise AI
BlurXTerminator	AI plugin	Dekonvolucija AI
NoiseXTerminator	AI plugin	Noise reduction AI
StarXTerminator	AI plugin	Star removal

Affinity Photo	Software	Final processing

□ RC-ASTRO BUNDLE

BlurXTerminator + NoiseXTerminator + StarXTerminator are available as a bundle. For serious PixInsight processing, this AI package is the most precise solution on the market and dramatically accelerates the workflow.

Complete PixInsight Workflow — Reference Table

Step	Tool	State	Note
1. Calibration	ImageCalibration	Linear	Dark+flat+bias master
2. Alignment	StarAlignment	Linear	Triangle method
3. Stacking	ImageIntegration	Linear	Sigma Clipping
4. Remove gradient	DynamicBackgroundExtraction	Linear	DBE: 20–50 points
5. Color cal.	SPCC / ColorCalibration	Linear	Photom. catalog
6. Deconvolution	BlurXTerminator (plugin)	Linear	AI PSF proc.
7. Noise Reduction	NoiseXTerminator / MLT	Linear	AI or wavelet
8. Stretch	GHS / ArcsinhStretch	L→NL	Controlled stretch
9. Stars	StarXTerminator	NL	Temp. removal
10. Detail	LHE + CurvesTransf.	NL	Local contrast
11. Stars back	PixelMath merge	NL	Pixel Math Layer
12. Export	File > Save As TIFF 16-bit	NL	For print or web

Narrowband Combining in PixInsight — HOO and SHO

For narrowband processing, each channel (Ha, OIII, SII) is processed separately up to the stacking and DBE phase, then combined:

HOO palette:
Image Integration: R = Ha, G = OIII, B = OIII
ChannelCombination: R←Ha.fit, G←OIII.fit, B←OIII.fit

SHO palette:
ChannelCombination: R←SII.fit, G←Ha.fit, B←OIII.fit

After combining, stars in the SHO palette have a strong green cast (because H-alpha maps to the green channel). Use:
SCNR (Process > Color Calibration > SCNR) — Amount: 0.7–1.0, Green channel protection: 0.5–0.7. This selectively removes the green component from stars while preserving green nebular regions.

Then apply linear stretching (GHS recommended for narrowband), followed by CurvesTransformation for fine-tuning individual colors.

Chapter 10

Dark sky, light pollution map, seasonal object calendar

Choosing a Location and the Bortle Scale

The imaging location is one of the most important factors in astrophotography — sometimes even more so than the equipment. The same settings and the same telescope can yield radically different results depending on sky darkness.

The Bortle Scale — Measuring Sky Darkness

The Bortle scale (1–9) is the standard system for evaluating sky darkness:

• **Bortle 1–2** — perfectly dark sky (Namibia, deserts, mountain summits). Zodiacal Light, IFN, and Magellanic Clouds visible with naked eye.
• **Bortle 3–4** — dark village/mountain. Milky Way clearly visible with dark lanes. Ideal for amateur astrophotographers.
• **Bortle 5** — rural suburb. Milky Way visible but without detail. Good compromise for many astrophotographers.
• **Bortle 6–7** — suburb. Milky Way barely perceptible. Narrowband filters are essential.
• **Bortle 8–9** — city/center. No Milky Way. Only planets, Moon, and double stars visible with naked eye.

Each step on the Bortle scale represents roughly a twofold difference in the number of visible stars and the depth of accessible objects.

How to Find Dark Sky

lightpollutionmap.info — interactive light pollution map based on the World Atlas of Artificial Night Sky Brightness. Displays the Bortle class for any location.

Stellarium — can simulate the sky for different Bortle classes and show how many stars are visible with the naked eye.

Clear Outside and **Astrospheric** — weather models specifically calibrated for astronomical conditions: transparency, seeing, humidity. Always check both parameters — you can have a Bortle 3 sky but poor seeing that makes detail blurry.

In Croatia, **Gorski Kotar**, **Lika plateau**, the **islands** (especially Lastovo, Vis, and Palagruža) and the **Dalmatian hinterland** offer some of the darkest skies in Europe — Bortle 2–4 depending on the location.

Seeing vs. Transparency

These two parameters are independent and both are critical:

Seeing — atmospheric stability. Good seeing means sharp stars without twinkling. Measured in arcseconds (1" = excellent, 3" = poor). For planetary photography, seeing is the dominant factor. For deep sky with short focal lengths it is less critical.

Transparency — atmospheric clarity. Good transparency means you can see faint objects without absorption losses. Moisture, dust, and aerosol layers reduce transparency. For narrowband photography from suburban skies, transparency matters more than seeing.

Seasonal Calendar of Popular Objects

Object	Type	Season	Bortle OK	Note
Orion Nebula (M42)	Emission	Winter (Dec–Mar)	All	Golden starting point
Rosette Nebula	Emission	Winter (Dec–Mar)	All	Ha excellent
Crescent Nebula (NGC6888)	Emission	Summer (Jun–Sep)	All	HOO/SHO
Heart & Soul (IC1805/1848)	Emission	Autumn (Sep–Nov)	All	Mosaic project
Pelican Nebula (IC5070)	Emission	Summer (Jun–Sep)	All	SHO-rich
M31 — Andromeda	Galaxy	Autumn (Sep–Nov)	Bortle 4–	Broadband
Milky Way — core	Widefield	Summer (Jun–Aug)	Bortle 4–	No tracker needed
Rho Ophiuchi	Broadband	Summer (May–Jul)	Bortle 4–	Color and dust

Practical Tips for Field Setup

Arrive early — minimum 30 minutes before planned imaging. The camera needs to acclimatize to the outdoor temperature (sensor condensation!), and you need time to let your eyes adapt to darkness.

Dark adaptation — the eye takes 20–30 minutes to fully adapt to darkness. Use **only a red flashlight** for moving around. White light destroys adaptation immediately.

Warm clothing — temperatures at dark-sky sites can be drastically lower than forecasts, especially in summer at altitude. Always bring more layers than you think you need.

Condensation — a dew heater is mandatory for any session longer than one hour. For a tracker setup a cheap USB lens warmer is sufficient. For more advanced setups: Pegasus Astro Dew Controller or ZWO Dew Heater.

Batteries and power banks — in cold conditions camera batteries drain 30–50% faster. Bring spare batteries and a USB power bank (min. 20,000 mAh). For a laptop and EQ mount, a 12V lithium battery is recommended (Jackery, EcoFlow or DIY 12V LiFePO4).

Session Planning Applications

Application	Platform	Purpose
Stellarium	Desktop/iOS/Android	Sky view, simulation
SkySafari 7	iOS/Android	Telescope control, object database
PhotoPills	iOS/Android	Milky Way, Moon, sun planning
Clear Outside	Web/iOS	Astro weather model
Astrospheric	Web/iOS	Seeing + transparency model
Telescopius	Web	FOV planning, Deep Sky database
Light Pollution Map	Web	Bortle map, WA Night Atlas
The Photographer's Ephemeris	iOS/Android	Milky Way, galactic center

Recommended session planning flow: one week ahead, check **Clear Outside** and **Astrospheric** for seeing and transparency forecasts. One day ahead confirm the forecast and select your target in **Telescopius** based on visibility and your FOV. In the field use **Stellarium** for navigation and coordinate confirmation.

For Milky Way planning, **PhotoPills** and **The Photographer's Ephemeris** are indispensable — they show exactly when and at what position the galactic center will appear in frame, with a landscape simulation.

Weather Models for Astrophotography

Standard weather forecasts (AccuWeather, NOAA) are not precise enough for astrophotography. Clear Outside and Astrospheric use ECMWF and GFS models specifically calibrated for seeing, cloud transparency, and humidity index — parameters that are critical for astrophotographic conditions.

Chapter 11

Problems with focusing, mount, processing and planning

Most Common Mistakes and How to Avoid Them

Every astrophotographer has been through the same frustrations: blurry stars, green tint, hot pixels that survive stacking, banding noise… This chapter covers the most common mistakes and concrete solutions.

Imaging Mistakes

1. Poor Focus — Stars Are Discs, Not Points

The most common beginner mistake. **Cause:** autofocus left on, focus set in the dark without verification, thermal drift (focus shifts with temperature).

Solution: Always use Live View + a Bahtinov mask. Disable AF. For automation: an electronic focuser with an auto-focus routine (N.I.N.A. HFR-based AF). Focus on a 2nd or 3rd magnitude star — not too bright (saturated) or too faint (hard to focus).

2. Star Trailing — Streaks Instead of Points

Cause A — Without tracker: Exposure too long. Use the 500 Rule/NPF.
Cause B — With tracker: Poor polar alignment. Imprecise polar alignment results in spiral star drift. Improve alignment with SharpCap or visual method.
Cause C — Vibrations: Windy night, soft ground, unstable tripod. Use Mirror Lock Up (DSLR) and wait for vibrations to settle.

3. Condensation on Lens/Sensor

Cause: Humid night without a dew heater. Condensation forms when the lens temperature drops below the dew point.
Solution: Always use a dew heater. Check relative humidity (>70% — high risk). For a dedicated camera sensor: seal the housing with silica gel.

4. Poor Polar Alignment

Symptom: star trails that are rotated (arcs rather than straight lines). For widefield trackers: Polaris alignment is usually sufficient. For more advanced deep sky setups: SharpCap Pro or drift alignment.

5. ISO Too High — Too Much Noise

High ISO does not ruin an image if you have enough frames for stacking. 100 frames at ISO 6400 give less noise than 10 frames at ISO 800. The bigger problem is too short an exposure per frame (background too dark), not high ISO.

Calibration Mistakes

6. Flat Frames Shot with Wrong Settings

Flat frames must be captured with **the same lens/telescope and the same sensor orientation**. If you rotate the camera between light and flat frames, vignetting will not be correctly corrected. The ISO for flat frames should match the light frames (or be as close as possible). Flat exposure should be short (0.02–0.5 s) so the sensor is not saturated — the flat histogram should sit between 30–50% of full scale.

7. Dark Frame Temperature Does Not Match Light Frames

Dark frames must be captured at **the same temperature** as the light frames. For cooled cameras this is automatic — the sensor temperature is controlled. For DSLR cameras, shoot dark frames immediately after finishing the light frames.

Processing Mistakes

8. Over-Saturation — Electric Colors

All astrophotography processing risks over-inflated saturation. Nebulae look attractive with vivid colors, but overdoing it destroys fine gradients and makes the image look unconvincing. **Solution:** Compare with reference images. Use CurvesTransformation with the *Saturation* curve instead of a global Hue/Saturation slider.

9. Too Much Sharpening — Edge Artifacts

Aggressive sharpening (Unsharp Mask, deconvolution with too many iterations) creates white rings around stars and false detail. For deconvolution in PixInsight: max 30–50 iterations, regularization >0.01.

10. Stack Without Dithering — Horizontal Banding

Without dithering, fixed sensor noise (banding, hot pixels) remains visible even in a stack of 100 frames. Enable dithering in N.I.N.A./SGP — 5–10 pixels of dither amplitude is sufficient.

QUICK FAULT DIAGNOSIS

Stars are streaks → trailing → check polar alignment or shorten exposure. Stars are discs → focus. Uneven background → gradient → DBE in PixInsight / BGE in Siril. Green cast in SHO → SCNR module. Horizontal bands → banding → enable dithering. Hot pixels surviving the stack → calibration.

Equipment Category Mistakes (Specific to This Book)

One of the most common mistakes in equipment recommendations is mixing beginner and advanced gear in the same category. It is especially important to emphasize:

Harmonic drive mounts (Rainbow Astro RST, SkyArrow HD17 V5 Adam Leaković, 10Micron) are *advanced/professional* class equipment — they are not suitable for a first setup due to configuration complexity, cost, and the technical knowledge required. Beginners should start with conventional mounts such as the Sky-Watcher EQ6-R Pro or iOptron CEM40.

Similarly, narrowband filters, automatic filter wheels, and mono cameras belong in the advanced category — they are not recommended as a first purchase.

Chapter 12

Multi-panel mosaics, long-term projects, final presentation

Advanced Compositions and Mosaics

Once you master the basics of imaging and processing, a new level of creativity opens up: multi-panel mosaics covering large star fields, long-term projects spanning weeks, and final image presentation that makes them worthy of a wall.

What Is a Mosaic in Astrophotography?

A mosaic is a technique in which the same object (or sky region) is photographed in multiple panels that are then stitched into one large final image. This is necessary when the object is larger than your Field of View (FOV).

Examples of objects that require a mosaic:
• Heart and Soul Nebula (IC1805+IC1848) — 7° × 3.5°
• Cygnus Loop — 3° × 3°
• Orion Nebula Complex — 4° × 3°
• Barnard's Loop — 14° × 10°

For reference: a typical FOV with a 100mm refractor and APS-C sensor is approximately 2° × 1.4°.

Mosaic Planning

Telescopius and the **Mosaic Planner** (inside N.I.N.A.) visualize which panels you need to capture and with what overlap. Minimum panel overlap should be **15–20%** for a reliable stitch.

Capture the same number of frames and the same filter set for every panel. Always image each panel at a similar airmass — changes in airmass between panels can affect color calibration.

N.I.N.A. has a built-in **Advanced Sequence Mosaic** plugin that automatically generates and executes the sequence for each panel in order.

Stitching a Mosaic in PixInsight

1. **Process each panel** separately up to DBE + linear stretch
2. **GradientMergeMosaic** (PixInsight) automatically stitches the panels and corrects differences in background illumination
3. **Or**: Use the free **Hugin** or **Microsoft ICE** for stitching, then import into PixInsight for final processing
4. **Final color calibration** on the stitched image — SPCC or ColorCalibration on the full frame

Long-Term Projects

Some of the finest astrophotographs have been built by accumulating data over **multiple imaging nights**. This is especially valuable for:

• **Faint IFN structures** (Integrated Flux Nebulae) — dust clouds in the galactic halo requiring 50+ hours of exposure
• **Extended galaxy halos** — visible only with 30–100 hours
• **Comets** — short exposures but maximum frame count
• **Narrowband mosaics** — each panel in 3 filters × multiple panels

For long-term projects, consistency is key: same gain/offset, same filters, same FOV (verified by plate solving).

Final Presentation and Sharing

AstroBin — the leading platform for sharing astrophotography. Detailed metadata (equipment, exposure, location, processing) is automatically displayed alongside the image. Excellent for community feedback and inspiration.

Instagram — square format (1:1) or 4:5 portrait is ideal for astrophotographs. Use relevant hashtags for reach (#astrophotography, #deepsky, #milkyway).

Print — astrophotographs look spectacular at large format. For print use **minimum 300 DPI** in the final export. A2 format (420×594mm) requires at least 4,950×7,016 pixels. **Export from PixInsight:** File > Save As > TIFF 16-bit for maximum quality, or JPEG at quality 95–100 for web sharing.

Motivation and Community

Astrophotography can be a solitary night-time pursuit, but the global community of astrophotographers is remarkably open and welcoming. Key places for learning and inspiration:

• **Cloudy Nights** (cloudynights.com) — the longest-running astronomy forum, technical discussions, equipment reviews
• **Reddit r/astrophotography** — active daily community, feed of fresh images and technical questions
• **AstroBin** — social network dedicated to astrophotography
• **YouTube** — channels such as Patriot Astro, Nebula Photos, and Cuiv The Lazy Geek offer free tutorials
• **Local astronomy clubs**

Do not compare your first images with finished masterworks — every capture is a step forward. The fastest way to improve is through community feedback.

TIP FOR LONG-TERM PROGRESS

Keep notes for every session: location, temperature, seeing, transparency, and exposure settings. This lets you reproduce successful sessions and diagnose failed ones. N.I.N.A. automatically logs all sessions — review the logs in xlsx format.

Appendix

Quick References and Useful Resources

Formulas, settings tables, recommended resources

This appendix contains quick reference tables and formulas that you can use in the field without needing to search the internet.

Key Formulas

Formula	Expression	Example
500 Rule (no tracker)	t = 500 ÷ (focal × crop)	500 ÷ (24 × 1.5) = 13s
Field of View (FOV)	FOV = sensor_mm ÷ focal × 57.3°	24mm ÷ 135 × 57.3 = 10.2°
Pixel scale (arcsec/px)	PS = 206 × pixel_μm ÷ focal_mm	206 × 3.8 ÷ 135 = 5.8"/px
Signal-to-Noise (stack)	SNR □ sqrt(N) × √t × aperture	100 exposures = 10x SNR vs 1
Dawes limit (arcsec)	θ = 116 ÷ D_mm	116 ÷ 100mm = 1.16"
Étendue (efficiency)	$E = Aperture^2 \times FOV^2$	Larger → deeper images

Recommended Starting Settings — Widefield Tracker Setup

Object	ISO	Exposure	Aperture	No. of Frames	Note
Milky Way	3200	90–120s	f/2–f/2.8	20–40	No Moon
Orion Nebula (M42)	1600	120–180s	f/2.8	30–60	Winter (Dec–Feb)
Rosette Nebula	1600	180–300s	f/2.8	40–60	Ha filter recommended
Andromeda (M31)	800	120–240s	f/2–f/2.8	30–60	Dark sky
Star clusters	800	60–120s	f/4	20–40	Short focal length

Recommended Starting Settings — Deep Sky Setup

Object/Filter	Gain	Offset	Temp	Exp. (min)	No. of Frames
Ha (7nm)	100	50	-10°C	5–10	20–40
OIII (7nm)	100	50	-10°C	5–10	20–30
SII (7nm)	100	50	-10°C	5–10	10–20
L (LRGB)	0	50	-10°C	2–5	30–60
R, G, B	0	50	-10°C	2–3	15–20 each

Recommended Resources and Useful Links

Software (free):

- Siril — siril.free.fr — stacking and processing
- Stellarium — stellarium.org — planning
- PHD2 — openphdguiding.org — autoguiding
- N.I.N.A. — nighttime-imaging.eu — sequence software
- ASTAP — han.astronomy.net/astap — plate solver
- GraXpert — graxpert.com — AI DBE + denoise

Software (paid):

- PixInsight — pixinsight.com
- SharpCap Pro — sharpcap.co.uk
- Affinity Photo — affinity.serif.com

Community and learning:

- AstroBin — astrobin.com — sharing, inspiration
- Cloudy Nights — cloudynights.com — forum
- r/astrophotography — Reddit community
- Nebula Photos (YouTube) — PixInsight tutorials
- Patriot Astro (YouTube) — N.I.N.A. and deep sky
- Cuiv The Lazy Geek (YouTube) — narrowband processing

Maps and planning:

- lightpollutionmap.info — Bortle map
- clearoutside.com — astro weather forecast
- telescopius.com — FOV planning, object list

Bortle Scale — Summary

Bortle	Location Description	Milky Way	What Can Be Imaged
1	Perfectly dark (desert/Namibia)	Exceptional, IFN visible	Everything — no filters
2	Extremely dark (mountain/islands)	Excellent, details clear	All deep sky objects
3–4	Rural/dark suburb	Visible, dark lanes	Galaxies, nebulae
5	Suburb	Clear but no detail	Nebulae with filter
6–7	Urban suburb	Barely visible	NB filters essential
8–9	City/center	Not visible	Moon, planets

Thank you for reading this guide.

The sky is accessible to everyone — all you need is patience, knowledge, and the will to look up.

— AstroHopper, 2026