Imaging Peculiar Galaxies

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June 25, 2025

Abel 1656, Coma Cluster
Constellation: Coma Berenices
Distance: 321 million ly

Outline

- Equipment
- Software
- Process Flow
- Light Pollution
- Gain, exposure, number of subs, and SNR
- Images

In 2024:

Less than a dozen clear moonless nights in Florida

7 successful imaging sessions

Equipment

- Telescope:
  - Orion 190mm (7.5 inches) Maksutov-Newtonian Astrograph
  - focal length: 1 meter
  - focal ratio: f/5.3
  - flat field
- Cooled CMOS camera:
  - G26 – 26 Mega pixels, APS-C format, 16 bit
  - Sony IMX571
- Filters:
  - Orion SkyGlow Imaging Filter – Reduces light pollution
  - Backyard astronomy in Melbourne, Florida
  - Lots of light pollution
- Orion StarShoot Auto Guider used with a 60mm guide scope
- Orion Atlas II Eq-G Equatorial Goto Mount

Software

- SharpCap: ($$)
  - Image Acquisition Software
  - Setting the exposure, gain, and output formats
  - Polar alignment and assistant focusing
  - Sensor analysis
  - SharpCap has plate solving - I also use ASTAP, All Sky Plate Solver
    - Essential in knowing where the telescope is pointing and to sync the mount to that location
- Stellarium (free):
  - Planetarium software: Locating celestial objects and faint galaxies and slewing the telescope to the target
- PhD2 (free):
  - Guiding software integrated with SharpCap
  - Remember to dither
- ASCOM platform ensures the communication between the drivers, SharpCap, Stellarium, and guiding software

Process Flow: PixInsight

- Subframe Selector: Image review
  - Check for elongated stars (eccentricity, caused by small errors in guiding), FWHM, and the number of stars
  - Remove images that fall outside the normal range from the process chain
- Weighed Batch Preprocessing: Does the calibration, registration, and integration
- Dynamic Background Extraction: Subtracts the background from the image
- Blur Xterminator ($$) - add on: AI-powered tool that corrects for aberrations and recovers detail in nonstellar objects
- Stretching: linear to nonlinear
- Gradient removal
- Noise Xterminator ($$) – add on: AI-powered noise reduction tool for astrophotography
- Star Xterminator ($$) – add on: AI-powered tool to extract the stars in the image

Add-ons available at cost at RC Astro

Process Flow: Photoshop

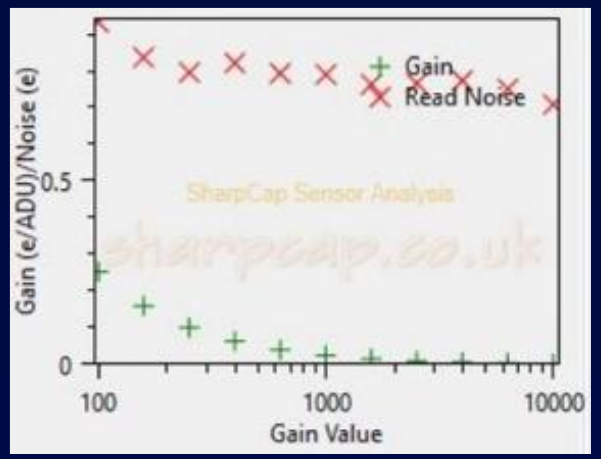
- Copy and paste target image and star image from Pixinsight into PhotoShop
- Smoothing, adjusting color and image parameters and noise reduction for greater detail in each of the 2 images

Gain, Exposure, and N

- It is all about SNR!
- What Gain should I use?
- What sub exposure should I use?
- How many subs should I take?

Gain

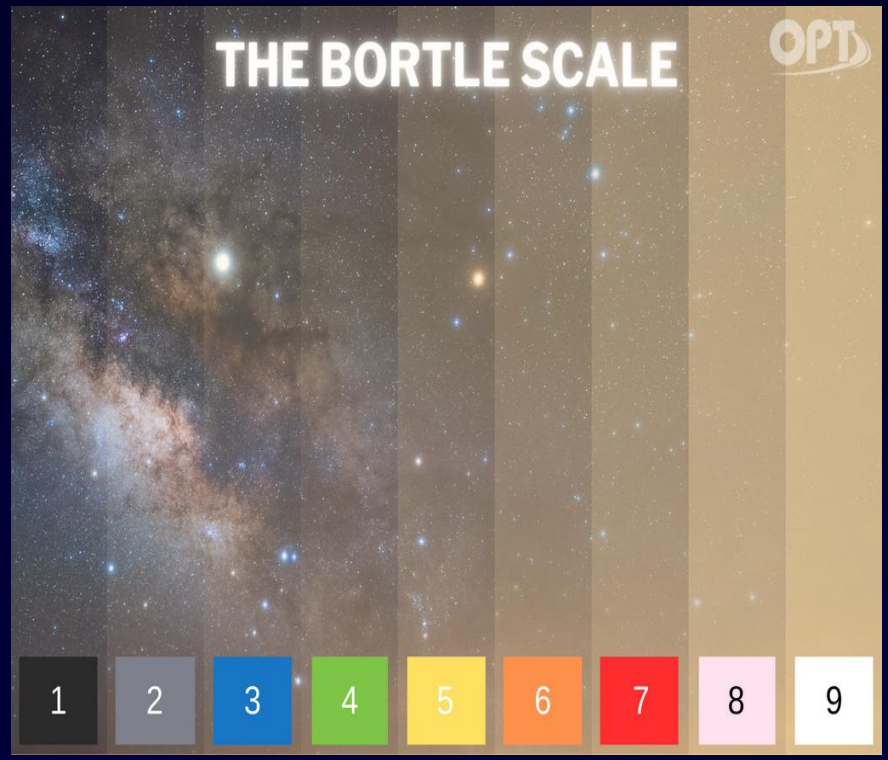
- Output from SharpCap: Sensor Analysis
- Choose High Conversion Gain (HCG)
  - Faint galaxies and nebula
  - Smaller read noise
- Gain: Goal is:
  - Small read noise
  - Large full well and dynamic range.
- In the table the optimum gain is about 300
  - This gives me a small read noise of 0.8, a dynamic range of 13, and a full well of about 6,000
  - I used a gain of 500 during most of my imaging sessions in 2024 and 2025



Gain Value	e/ADU	Read Noise (e)	Full Well (e)	Relative Gain	Rel. Gain (db)	Dynamic Range (Stops)
100	0.25	0.94	16614.88	1.00	0.00	14.12
158	0.16	0.84	10509.53	1.58	3.98	13.61
251	0.10	0.80	6612.75	2.51	8.00	13.02
398	0.06	0.82	4208.91	3.95	11.93	12.32
630	0.04	0.80	2654.28	6.26	15.93	11.70
1000	0.03	0.79	1673.56	9.93	19.94	11.04
1584	0.02	0.77	1058.44	15.70	23.92	10.43
2511	0.01	0.77	669.32	24.82	27.90	9.77
3981	0.01	0.78	421.50	39.42	31.91	9.09

Light Pollution

- I live in Bortle class 5 to 6.
- When the moon is in the sky, it's worse.
- There is a stadium nearby with more lights that are on some evenings.
- Optimal sub exposure depends on the amount of Sky Glow.



Calculated Sky glow from the SharpCap web site

Your Sky Brightness

Sky Magnitude	19.80	magnitude per arcsec^2
or Bortle Number	5.0	(Suburban sky)
or Naked Eye Limiting Magnitude	5.8	

Your Telescope

F Ratio	5.3	

Your Camera

Pixel Size	3.76	microns
Quantum Efficiency	80	%

○Monochrome ◉Colour

Your Filter

Selected Filter	None (Luminance)	
Bandwidth	100	nm

The Result

Sky Electron Rate	**1.62 e/pixel/s**

Sky brightness measured by SharpCap during an imaging session: 1.05 e/pixel/s

* Sky Background Calculator (sharpcap.co.uk)
or https://tools.sharpcap.co.uk/

Sub Frame Exposure

$$\text{Optimal Sub Exposure} = C*\frac{R^2}{P} = \frac{1}{(1+E)^2-1}\ \frac{R^2}{P/3\ (multiply\ by\ \frac{1}{3}\ due\ to\ filter)}$$

- R = Read Noise = 0.8 electron as measured by SharpCap
- P = Sky Glow = 1.05 e/pixel/s
  - Measured by SharpCap during imaging session
- E = Noise tolerance = 1% increase in noise

- Results:
  - Sub exposure = ~90 s (using filter)
  - I took 2 minutes sub exposures, unless otherwise specified

- 1.) Deep Sky Astrophotography With CMOS Cameras by Dr Robin Glover, Deep Sky Astrophotography With CMOS Cameras by Dr Robin Glover (youtube.com)
- 2.) Sub-Exposure Times and Signal-to-Noise Considerations, John Smith, Revised February 2010
- 3.) Finding the Optimal Sub-frame Exposure Length for Astrophotograph, Chuck Anstey, February 2007,Cloudy Nights

Sub Frame Exposures

Small sub frame exposure offers benefits such as:

- Reduced tracking requirements
- Less likelihood of interference from airplanes, satellites, or clouds
- Less star “bloating” – less saturation

Disadvantage:

- More images to stack – requiring more storage and greater computational power.

If the exposure is too large in light polluted skies, the CMOS sensor becomes saturated with the sky glow, ruining the image of faint galaxies and stars.

Bortle number 8 and 9, city lights → Smaller sub exposure

Bortle number 1 and 2, dark skies → Longer sub exposure

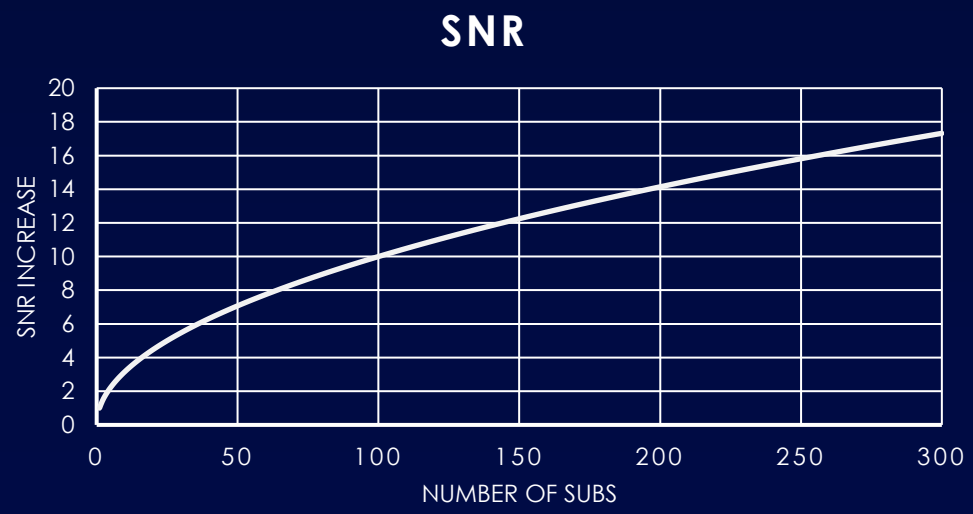
Number of Subs

For faint galaxies and nebula

- No maximum limit on number of subs
- A large number of subs requires more disk space and more computational power.
- There is limited improvement in SNR for anything more than 100 subs

n = number of subs
t = sub exposure time in minutes
P = E_{sky} = Sky background flux in electrons per minute
S = E_{target} =target flux in electrons per minute
R = Readout noise in electrons
Camera is cooled to 0C, assume dark current is 0
Assume noise is random

$$SNR = \frac{Signal}{Noise} = \frac{n \times t \times (S+P)}{\sqrt{n \times R^2 + n \times t \times (S+P)}} \sim \sqrt{n}\ S_{n=1}$$



Summary

Gain: 500

Sub frame Exposure: 2 minutes

Number of images: greater than 100

Expect 10 to 15 % to fail inspection after the review

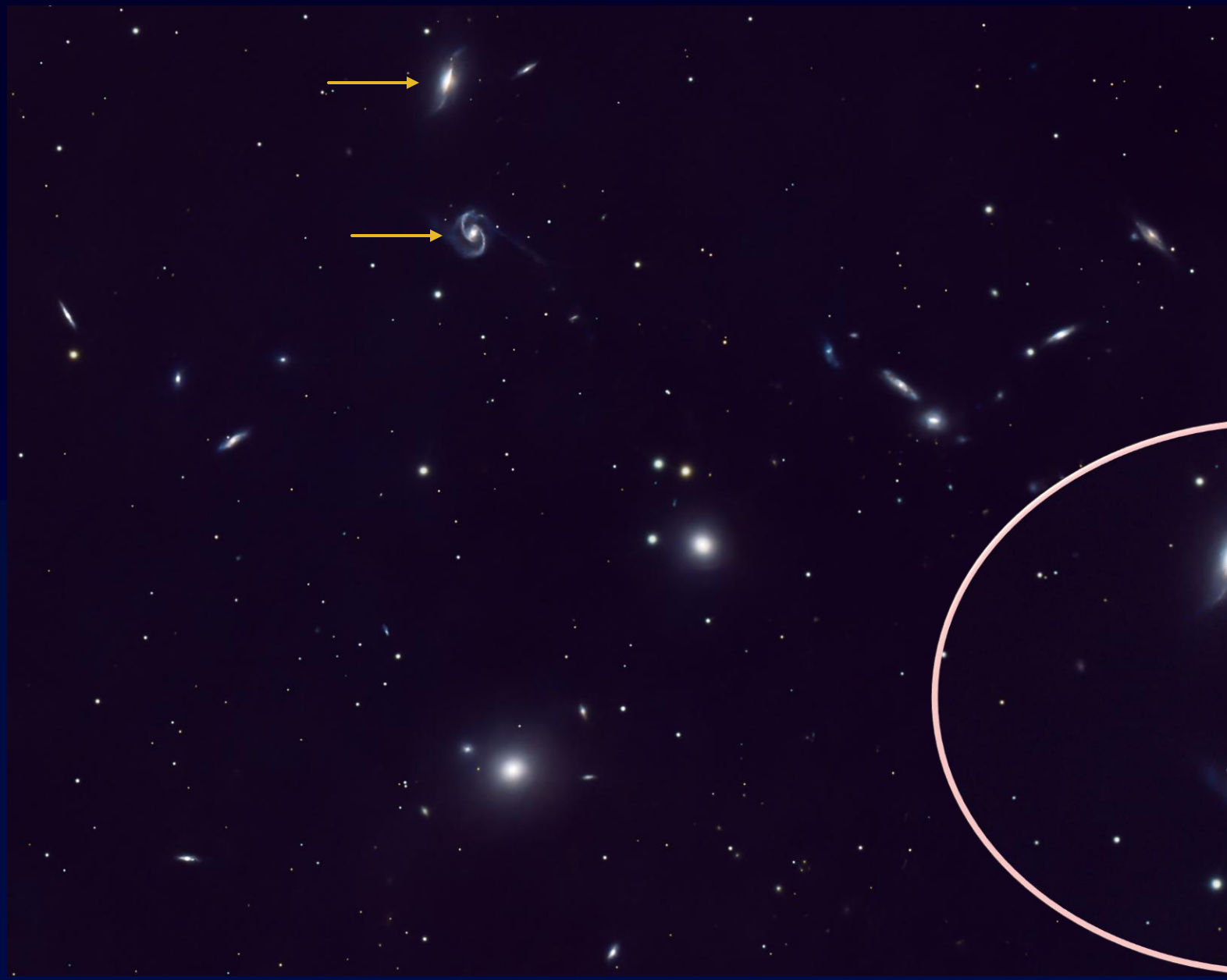
Arp 55, Grasshopper, UGC 4881(A and B)

Galaxy merger
Constellation: Lynx
Distance: 575 MLY
Magnitude: 15.6
Size: 0.7' x 0.5 arcmin

Gain: 500
Subframes: 28 subs @ 5 minutes
Total exposure: 2 hours and 20 minutes

Hubble Space Telescope

Arp 65, NGC 90 and NGC 93



Interacting pair of spiral galaxies
There are several galaxies captured in this one image
Constellation: Andromeda
Distance: 333 MLY
Magnitude: 13.7

Gain: 500
Subframes: 72 images @ 2 minutes
Total exposure: 2 hours and 24 minutes

Arp 85, Whirlpool Galaxy

Constellation: Canes Venatici
Distance: 25 million light years
Magnitude: 8.4

Full frame camera with a 600 mm zoom lens at f/6.3 (92 mm lens)
Mount: Sky-Watcher, Star Advenutrer
ISO: 5000
Subframes: 51 images @ 20 seconds minutes
Total exposure: 17 minutes

NGC 5198
Magnitude (V): 11.8
Distance: 129 million light years

IC 4263
Magnitude (V): 14.1
Distance: 140 million light years

IC 4278
Magnitude (B): 17.8

Arp 116, M60 and NGC 4647

Constellation: Virgo
Distance: 63 MLY
Magnitude: 8.8 and 11.3

M60-UCD: Ultra Compact Dwarf Galaxy

Number of subframes:
70 subs @ at 2 minutes
Total exposure: 2 hours 20 minutes

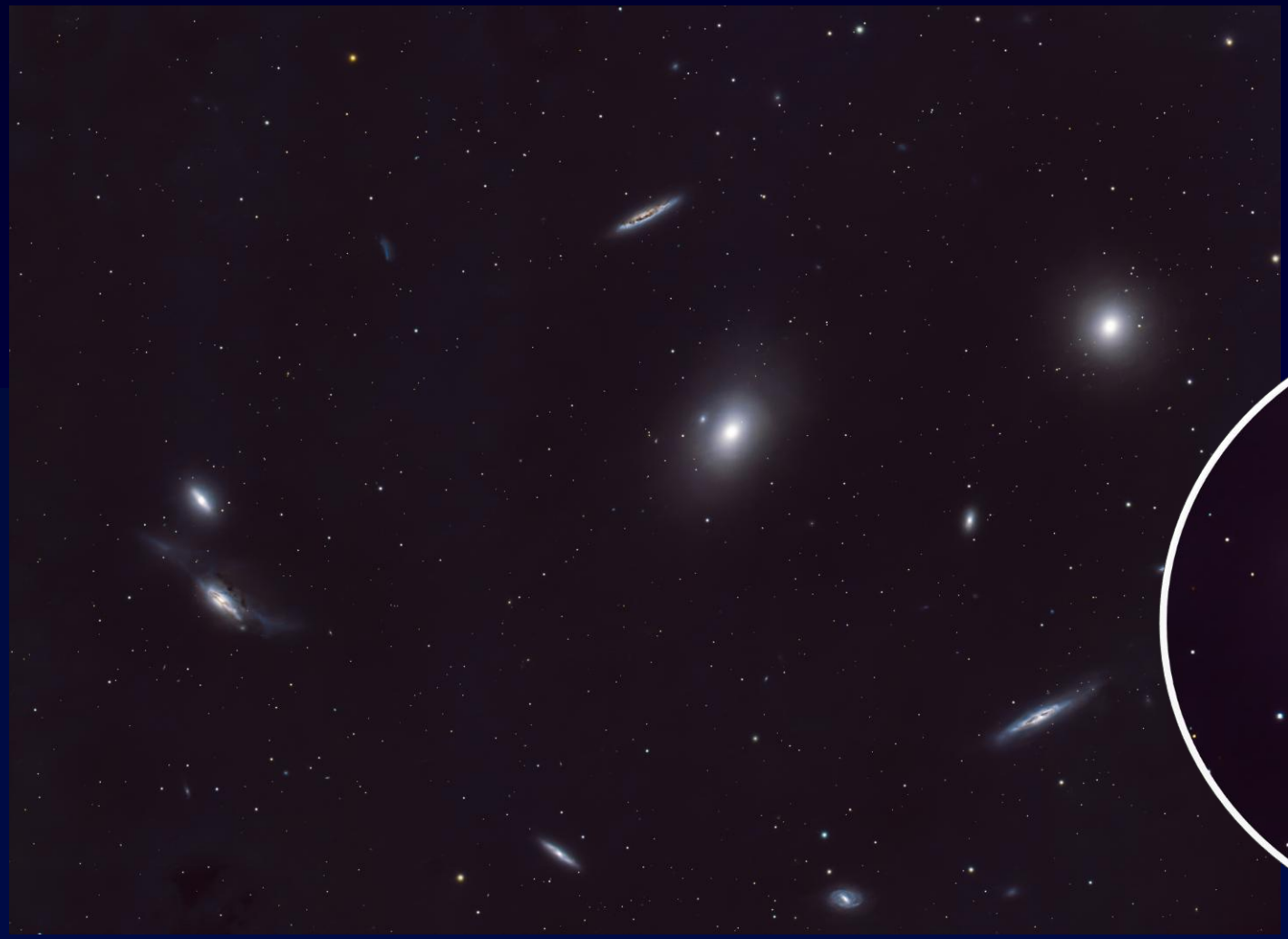
Arp 116, Supernova type 1a

SN 2022hrs, type 1a supernova, binary system, used as a “standard candle” to determine distances
Magnitude: ~12.5 – almost as bright as the galaxy
Discovered by: Kōichi Itagaki (amateur astronomer)
April 16, 2022

This image was taken (by me) May 4th, 2022

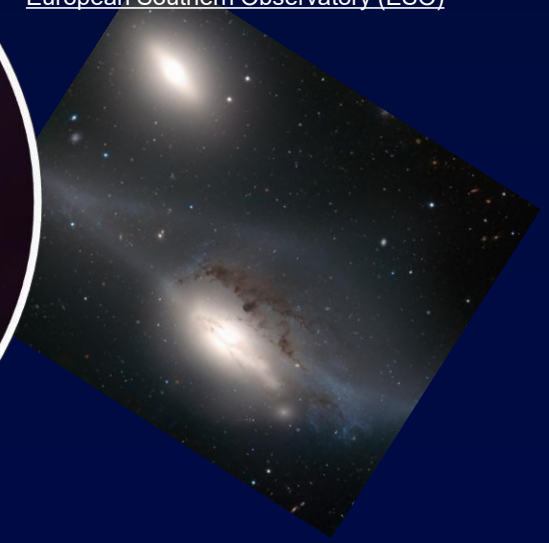
This image was taken April 16th, 2025

Arp 120 (Eyes Galaxies, NGC 4438 and NGC 4435)



Also in the image: M84, M86, the Markarian Chain
There are 25+ galaxies in this one image – part of the Virgo Cluster of galaxies and the Markarian Chain of Galaxies.
Constellation: Virgo
Distance: 50 to 60 MLY
Magnitude: Eyes about 10. M84 and M86 about 9

Gain: 500
Number of subs: 88 @ 2 minutes
Total integration time: 2 hour 56 minutes



The Eyes Galaxies

Preprocessing and background subtraction
Shot noise is visible

After Post Processing

Virgo Cluster of Galaxies

Arp 142, The Penguin and the Egg (or Porpoise) Galaxy

Constellation: Hydra
Distance: 352 MLY
Magnitude: 12.8

Gain: 500
Number of subs: 96 @ 2 minutes
Total integration time: 3 hour 12 minutes

James Webb

Arp 143, triangular –shaped star birth region

Colliding galaxies
Constellation: Lynx
Distance 190 million light years
Magnitude: 12.9

Gain: 1000
Number of subs: 109 @ 2 minutes
Total integration time: 3 hours 38 minutes

NASA, ESA, STScI, Julianne Dalcanton Center for Computational Astrophysics, Flatiron Inst. / UWashington) IMAGE PROCESSING: Joseph DePasquale (STScI)

Arp 147, IC 298

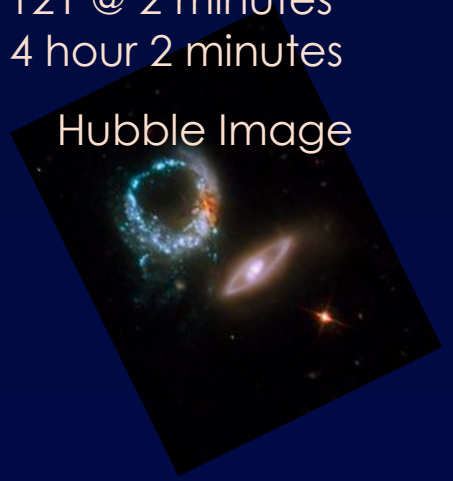
Formed by the collision of 2 spiral galaxies
Central region of the ring galaxy largely devoid of stars and dust

Constellation: Cetus
Distance: 440 MLY
Magnitude: 14.3
Apparent size: 0.650' x 0.286'

Main ring source of bright X-ray emissions from black holes
Contains about 9 black holes having a mass of 10 to 20 solar masses

Gain: 500
Number of subs: 121 @ 2 minutes
Integrated time: 4 hour 2 minutes

Hubble Image



Arp 148, Mayall's Object

Constellation: Ursa Major
Distance: 450 Million Light Years
Magnitude: about 15

Gain: 500
Exposure: 77 subs at 2 minutes
Total exposure: 2 hours 34 minutes

Hubble image

Arp 195, "Grasshopper 2" or "Scorpion"

A trio of interacting galaxies
Constellation: Lynx
Distance: 763 Million Light Years
Magnitude: 13.6

Gain: 500
Exposure: 87 subs at 2 minutes
Total exposure: 2 hour 54 minutes

Hubble Space Telescope image

Arp 271, NGC 5426 and NGC 5427

Constellation: Virgo
Distance: 127 MLY
Magnitude: 11.4
July 2022

Gain: 500
Number of subs: 17 subs @ 5 minutes
Total exposure: 1 hour 25 minutes

ESO's Very Large Telescope

Arp 273, the "Rose", UGC 1810 and 1813

Constellation Andromeda
Distance: 300 million light years
Magnitude: 13.7
Interacting pair of galaxies

Number of subframes: 120 subs @ 2 minutes
Total exposure: 4 hours

Arp 319, Stephan's Quintet, includes NGC 7320C, NGC 7319 NGC 7318 A&B, and NGC 7317

Grouping of 5 galaxies (indicated by the arrow)
Constellation: Pegasus
Distance: 210 to 340 MLY
Magnitude: 14 to 17

NGC 7320 ('blue' galaxy) is not part of the group and is a local galaxy about 39 million ly distance

Gain: 500
Number of subframes: 112 subs @ 2 minutes
Total exposure: 3 hour 44 minutes

"Phantom Frisbee" Galaxy

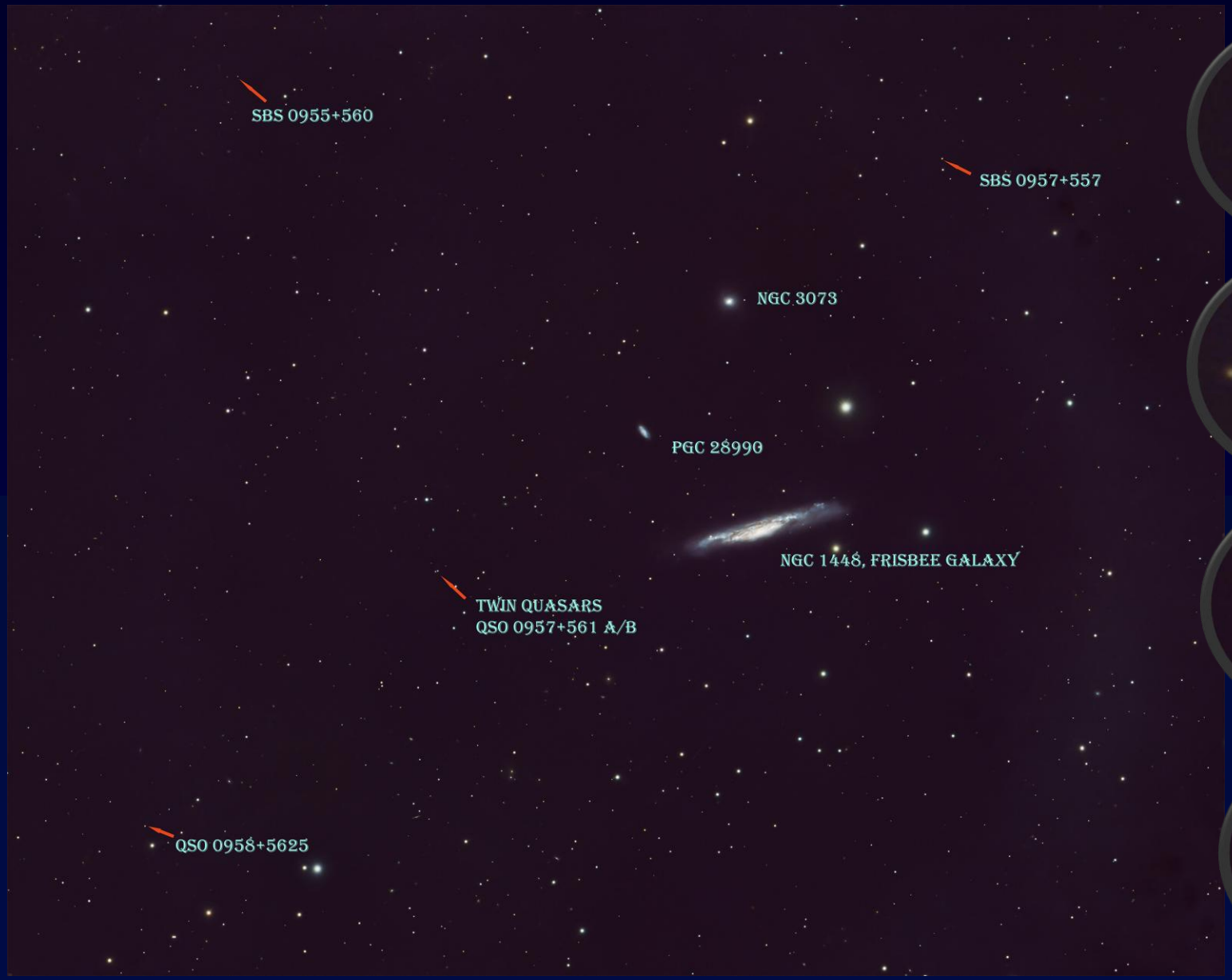
NGC 3079, The "Phantom Frisbee" Galaxy
Constellation: Ursa Major
Distance: 64 million ly
Magnitude: 10.9

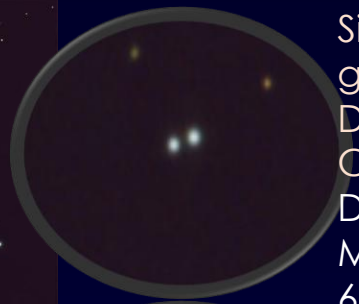
Spiral galaxies, NGC 3073
Distance: 65 million ly
Magnitude: 13.4

Spiral galaxy PGC 28990
And other galaxies are visible in this image

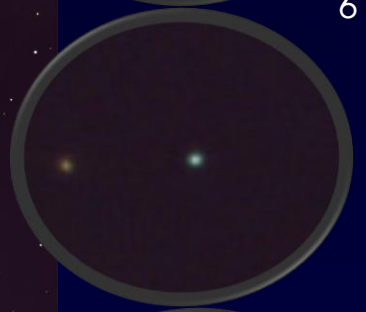
Gain: 500
Number of subs: 42 @ 2 minutes
Total time: 1 hour, 24 minutes

Twin Quasars and more





Twin Quasars, QSO 0957+561 A/B
Single quasar that appears as 2 due to gravitational lensing
Discovered in 1979
Constellation: Ursa Major
Distance: 8.7 billion ly
Magnitude: 16.5, 16.7
6 arcsecond separation



Quasar, SBS 0955+560
Distance: 7.6 bly
Magnitude: 17.6

Quasar, SBS 0957+557
Distance 10.1 bly
Magnitude: 17.5

Quasar, QSO 0958+5625


Questions