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How to use This Book

1.1 Foreword

Asturias, the beautiful European region where I live, is probably one of the worst places in the world for amateur astronomers. Heavy clouds coming from the Bay of Biscay are maintained over Asturias by an impressive natural wall created by a high range of mountains located near the province's South border. As a result, the average number of cloudless sky nights does not exceed two or three per month!

Cloudy nights mean that if I want to enjoy dark and clear skies, I must travel more than 100 Km. southwards, deep inside the near province of Leon. In order to increase the chance to enjoy dark skies, whenever I travel abroad (for work or holidays) I carry my telescope out with me so, I need very light and portable equipment. That means heavy use of low-aperture optical instruments combined with light handheld computer devices.

This guide comprises my experience observing the sky with such small kinds of instruments. The observation records are divided into constellations and are restricted to those objects of the Northern Hemisphere that can be easily observed using binoculars or small and portable telescopes (about 70 mm. of aperture).

I hope you will enjoy using this document as much as I did it writing it.

1.2 Compatible Observation Instruments

The visibility of all the objects included in this guide (with the sole exception of those included in the Faint Objects section) has been verified using a small Meade ETX-70AT telescope, a Barlow 3x lenses and a combination of 4 mm, 12 mm. and 25 mm. eyepieces. Many of the objects were also observed using small 10x50 binoculars.

Since the 70 mm. diameter and 350 mm. local length of this telescope makes it one of the smallest amateur telescopes in the market, I assume that all these objects are reachable by any kind of amateur telescope. Some of them are ever better viewed using binoculars.

1.3 Updates and Comments

I plan to update this document on a regular basis adding the constellations that I have not already observed using my amateur equipment. The latest version of this document is freely available from my web page, currently located at `http://www.martin-gonzalez.es`.

You can also download it from the on-demand on line publishing LULU service (`http://www.lulu.com`) where you can also order a printed version of the document at production cost.

Updates and Comments

Fig. 1: Meade ETX-70AT telescope.

If you have any suggestion or comment to improve this document, please do not hesitate to contact me.

Chapter Two

Constellations

2.1 Constellation Catalog

This chapter describes a collection of constellations, including detailed information about their most important celestial bodies. Each constellation section is divided into the following subsections:

1. **Stars**: Includes information about binary star systems, variable starts, etc.

2. **Deep Space**: Open and Globular star clusters, Nebulae, Galaxies, etc.

3. **Faint Objects**: Objects of magnitude higher than 8. Although they are very difficult to observe using small amateur telescopes, they could be reached under exceptional atmospheric conditions or by long exposure photos.

The objects included in each of those sections are classified by their magnitude values, showing the brightest objects first. Depending on the kind of object, different information is included:

2.1.1 Stars

– **BSC**: Star's reference code in the *Bright Start Catalog*.

– **SAO**: Star's identification in the *Smithsonian Astrophysical Observatory Catalog* (SAO).

– **Coordinates**: Right Ascension (hours, minutes, and seconds) and Declination (degrees, minutes, and seconds) for the star.

– **Mg**: Magnitude.

– **B-V**: Color of the star in the UBV system (see spectral star types and colors in section 3.1 in page 33 for details).

– **Type**: Spectral type of the star (see section 3.1 in page 33 for more information).

2.1.2 Deep Space

– **Reference**: Object's identification code in any of the classic catalogs (Messier, Caldwell, etc.).

– **NGC**: Object's reference in the NGC (*New General Catalog*).

– **Object Type**: Open Cluster, Globular Cluster, Planetary Nebula, Diffuse Nebula, Dark Nebula, Spiral Galaxy, Elliptical Galaxy, Quasar, etc.

- **Coordinates**: Right Ascension (hours, minutes, and seconds) and Declination (degrees, minutes, and seconds) for the object.
- **Mg**: Magnitude.
- **AD**: Apparent Dimension.

For example, the reference for the *Betelgeuse* star in the constellation of *Orion* is coded as: [BSC2061; SAO113271; RA: 5Hr 55m 10.3s; Dec: 7° 24m 25s; Mg: 0.5; B-V: 1.85; Type: M1-2Ia-Iab] and the information for the great *Orion Nebula* (M42) in the same constellation is shown as: [M42; NGC1976; Type: Diffuse nebula; RA: 5Hr 35m 24s; Dec: -5° 27m 0s; Mg: 2.9; AD: 66x60']

Since every object includes a reference code for at least a celestial objects catalog, it is easy to locate the object using this code as the reference key in the *goto* function available in some computer-controlled telescopes.

If this function is not available in your telescope, the Right Ascension and Declination coordinates should be used instead.

2.2 CMa (*Canis Major*): Larger Dog Â§

[RA: -11Hr to -33Hr; Dec: 6° 15m to 7Âº 30m; Area: 380 sq. deg. **Ranked 43rd**] [20]

2.2.1 Stars

- α **CMa** (*Sirius*, Greek: *Sparkling*) [BSC2491; SAO151881; RA: 6Hr 45m 8.9s; Dec: -16° 42m 58s; Mg: -1.46; B-V: 0; Type: A1Vm]. I am **the brightest star in the night sky** [8]. Has a **White Dwarf companion** of Mg. 8 at a distance of approx. 10" called ***Sirius B***. The two stars revolve around each other about every 50 years. For the ancient Egyptians, Sirius was known as the "Nile's Star", since when this star appeared just before dawn, it indicated the next underflow of river Nile [6]. Â§

- β **CMa** (*Mirzam*, Greek: *The Announcer* (of *Sirius*)) [BSC2294; SAO151428; RA: 6Hr 22m 41.9s; Dec: -17° 57m 22s; Mg: 1.98; B-V: -0.23; Type: B1II-III]. **Blue giant**. Â§

- δ **CMa** (*Wezen*, Arabic: *Weight*) [BSC2693; SAO173047; RA: 7Hr 8m 23.4s; Dec: -26° 23m 35s; Mg: 1.84; B-V: 0.68; Type: F8Ia]. Several interesting stars and objects can be found next to it:

  - Variable Star **EW CMa** [BSC2745; SAO173264; RA: 7Hr 14m 15.1s; Dec: -26° 21m 9s; Mg: 4.66; B-V: -0.19; Type: B3IIIe]. Â§
  - Variable Star **UW CMa** [BSC2781; SAO173444; RA: 7Hr 18m 40.3s; Dec: -24° 33m 32s; Mg: 4.98; B-V: -0.15; Type: O7e+O7]. Â§
  - τ **CMa** [BSC2782; SAO173446; RA: 7Hr 18m 42.4s; Dec: -24° 57m 15s; Mg: 4.4; B-V: -0.15; Type: O9Ib]. **Blue giant** surrounded by the ***Mexican Jumping Star*** (NGC2362) described later. Â§

- ϵ **CMa** (*Adhara*, Arabic: *The Virgins*). [BSC2618; SAO172676; RA: 6Hr 58m 37.5s; Dec: -28° 58m 20s; Mg: 1.5; B-V: -0.21; Type: B2II]. **Blue giant**. Has a Mg. 8 companion which is difficult to observe since it nearly vanishes in the glare of the main star. Â§

2.2.2 Deep Space

- **Mexican Jumping Star** [NGC2362; Type: Open cluster; RA: 7Hr 18m 48s; Dec: -24° 57m 0s; Mg: 4.1; AD: 8']. **Contains about 60 stars** and it is of youngest clusters already discovered ([6], page 30). Â§

CMa (*Canis Major*): Larger Dog Â§

– **M41** [NGC2287; M41; Type: Open cluster; RA: 6Hr 47m 0s; Dec: -20° 44.0 m 0s; Mg: 4.6; AD: 38']. **Contains about 100 stars**. Lies about 4 degrees nearly exactly south of *Sirius*.

2.3 CMi (*Canis Minor*): Little Dog

[RA: 8Hr; Dec: 5° ; Area: 183 sq. deg. **Ranked 71st**] [21]

2.3.1 Stars

- α **CMi** (*Procyon* Greek: *Before the Dog*) [BSC2943; SAO115756; RA: 7Hr 39m 18.1s; Dec: 5° 13m 30s; Mg: 0.38; B-V: 0.42; Type: F5IV-V]. Has a **white dwarf** companion of Mg 10.8 called ***Procyon B***.

- β **CMi** (*Gomeisa* Arabic: *The bleary-eyed one*) [BSC2845; SAO115456; RA: 7Hr 27m 9s; Dec: 8° 17m 21s; Mg: 2.9; B-V: -0.09; Type: B8Ve].

2.4 Com (*Comae Berenices*): Berenice's Hair Â§

[RA: 12Hr 46m; Dec: 21° 49m; Area: 386 sq. deg. **Ranked 42nd**] [22]

2.4.1 Stars

- α **Com** (*Diadem*) [BSC4968; SAO100443; RA: 13Hr 9m 59.2s; Dec: 17° 31m 46s; Mg: 5.22; B-V: 0.45; Type: F5V] and [BSC4969; SAO100443; RA: 13Hr 9m 59.2s; Dec: 17° 31m 46s; Mg: 5.22; B-V: 0; Type: F5V]. **Binary** which cannot be split into its components by amateur telescopes [7]. **Has the same diameter of the Sun**, so it which gives us an idea of how faint the Sun would appear seen from only **27 light years away**. Â§

- γ **Com** [BSC4737; SAO82313; RA: 12Hr 26m 56.2s; Dec: 28° 16m 6s; Mg: 4.36; B-V: 1.13; Type: K2IIICN+1]. The loose collection of stars below this one is known as the **Coma Star Cluster** [Mel 111]. **About 30 stars** form a triangular-shaped group between 5th and 10th magnitudes and are best observed with binoculars. Â§

- **24 Com** [BSC4791; SAO100159; RA: 12Hr 35m 6.3s; Dec: 18° 22m 38s; Mg: 6.56; B-V: 0.25; Type: A9Vm] and [BSC4792; SAO100160; RA: 12Hr 35m 7.7s; Dec: 18° 22m 37s; Mg: 5.02; B-V: 1.15; Type: K2III]. **Orange giant** (BSC4792), which contrasts beautiful with the **blue-white companion** (BSC4791). Â§

2.4.2 Deep Space

- **M53** [NGC5024; M53; Type: Globular cluster; RA: 13Hr 12m 54s; Dec: 18° 10.0m 0s; Mg: 7.7; AD: 3.3']. On small telescopes, it appears as a misty patch. Â§

2.4.3 Faint Objects

- **Black Eye Galaxy** [NGC4826; M64; Type: Spiral galaxy; RA: 12Hr 56m 42s; Dec: 21° 41m 0s; Mg: 8.5; AD: 7.8x1.5']. It got its name from the **dark patch of dust** near its center. Telescopes with 150 mm. aperture and higher and good optics show this eye in the galaxy. Â§

- **M85** [NGC4382; M85; Type: Elliptical galaxy; RA: 12Hr 25m 24s; Dec: 18° 11m 0s; Mg: 9.3; AD: 2.1x1.7']. The **type I supernova 1960R** was discovered in M85 on Dec 20, 1960, and reached an apparent magnitude of 11.7. Â§

- **M100** [NGC4321; M100; Type: Spiral galaxy; RA: 12Hr 22m 54s; Dec: 15° 49m 0s; Mg: 9.4; AD: 5.3x4.5']. There have been **five supernovae** discovered within it. Â§
- **M88** [NGC4501; M88; Type: Spiral galaxy; RA: 12Hr 32m 0s; Dec: 14° 25m 0s; Mg: 9.5; AD: 5.5x2.4']. Â§
- **NGC4565** [NGC4565; Type: Spiral galaxy; RA: 12Hr 36m 18s; Dec: 25° 59.0m 0s; Mg: 9.6; AD: 14.4x1.2']. Sb - superb edge-on. Â§
- **M99** [NGC4254; M99; Type: Spiral galaxy; RA: 12Hr 18m 48s; Dec: 14° 25m 0s; Mg: 9.8; AD: 4.6x3.9']. **Multiple-arm spiral galaxy**. Â§
- **M91** [NGC4548; M91; Type: Spiral galaxy; RA: 12Hr 35m 24s; Dec: 14° 30m 0s; Mg: 10.2; AD: 3.7x3.2']. Â§

2.5 Cyg (*Cygnus*): The Swan Â§

[RA: 20Hr 37m; Dec: 42° 2m; Area: 804 sq. deg. **Ranked 16th**] [23]

2.5.1 Remarks

The bird extends over the *Milky Way* appearing to fly south. When watching this area on a clear night one discovers that the *Milky Way* is divided into two parts by a lane of dust that absorbs a good deal of the starlight. This lane is known as ***The Cygnus Rift***, or sometimes called the ***Northern Coalsack***.

2.5.2 Stars

- α **Cyg** (*Deneb*, Arabic: *The Tail*) [BSC7924; SAO49941; RA: 20Hr 41m 25.8s; Dec: 45° 16m 49s; Mg: 1.25; B-V: 0.09; Type: A2Iae]. **Blue super giant**. It forms the swan's tail the upper end of the *Northern Cross*, and one of the vertices of the *Summer Triangle* asterism. It has the size of 60 times the Sun.

- β **Cyg** (*Albireo*, Arabic: *The Hen's Beak*) [BSC7417; SAO87301; RA: 19Hr 30m 43.2s; Dec: 27° 57m 35s; Mg: 3.08; B-V: 1.13; Type: K3II+B0.5V] and [BSC7418; SAO87302; RA: 19Hr 30m 45.2s; Dec: 27° 57m 55s; Mg: 5.11; B-V: -0.1; Type: B8Ve]. Even a binocular reveals the **reddish giant** (BSC7417) with its **blue-white companion** (BSC7418). The brighter component is a double itself but it is seen as a single star in amateur telescopes.

- γ **Cyg** [BSC7796; SAO49528; RA: 20Hr 22m 13.6s; Dec: 40° 15m 24s; Mg: 2.2; B-V: 0.68; Type: F8Ib]. Next to this star is located one of the strongest radio sources known, **Cygnus A**. This object is far beyond everything an amateur can reveal. It is a **radio galaxy** of Mag 18. This galaxy is either undergoing an explosion or is colliding with another galaxy.

- η **Cyg** [BSC7615; SAO69116; RA: 19Hr 56m 18.3s; Dec: 35° 5m 0s; Mg: 3.89; B-V: 1.02; Type: K0III]. **If black holes exist then Cygnus X-1** was the first one ever identified lying near η Cyg. The existence of this black hole was discovered in 1972 due to its strong X-ray radiation.

- χ **Cyg** [BSC7564; SAO68943; RA: 19Hr 50m 33.8s; Dec: 32° 54m 51s; Mg: 4.23; B-V: 1.82; Type: S6+/1e]. Variable star. **Shows one of the largest variations in magnitude known**. At the maximum χ Cyg is Mg 3.62 while at the minimum it is Mg 15.00.

- **61 Cyg** [BSC8085; SAO70919; RA: 21Hr 6m 53.7s; Dec: 38° 44m 57s; Mg: 5.21; B-V: 1.18; Type: K5V] and [BSC8086; RA: 21Hr

6m 55.2s; Dec: 38° 44m 30s; Mg: 6.03; B-V: 1.37; Type: K7V]. This **binary orange dwarf star system** became famous not only because it is an attractive and easily resolvable object for small telescopes, but because it lies in a distance of only 11.1 light-years [9]. **It is the first star whose distance to the Earth was actually measured**.

2.5.3 Deep Space

– **M39** [M39; NGC7092; Type: Open cluster; RA: 21Hr 32m 12s; Dec: 48° 26.0m 0s; Mg: 4.6; AD: 32']. Nice view of red and blue stars. Number: 30.

– **North America Nebula** [NGC7000; Type: Diffuse nebula; RA: 20Hr 58m 48s; Dec: 44° 20.0m 0s; Mg: 6; AD: 120x100']. **Covers an area of more than ten times the size of the full moon**, but its surface brightness is low so it cannot be seen with the unaided eye. Binoculars and telescopes with large fields of view (approximately 3Â°) will show it as a foggy patch of light in dark skies. Â§

– **M29** [M29; NGC6913; Type: Open cluster; RA: 20Hr 23m 54s; Dec: 38° 32.0m 0s; Mg: 6.6; AD: 7']. Although officially an open cluster, it looks more like a globular cluster when observed with binoculars, having the shape of a white cloud. Using lateral vision, it is possible to see many small stars inside. Number: 50.

2.5.4 Faint Objects

– **Veil Nebula** [NGC6960; Type: Diffuse nebula; RA: 20Hr 45m 42s; Dec: 30° 43.0m 0s; Mg: 8; AD: 70x6']. The western half of a faint nebula, which is so sometimes called *Wreath*, sometimes *Loop* or *Network*. More than 50.000 years ago a supernova exploded south of ϵ **Cyg** [BSC7949; SAO70474; RA: 20Hr 46m 12.6s; Dec: 33Âº 58m 13s; Mg: 2.46; B-V: 1.03; Type: K0III], close to the southern border of Cygnus. Nowadays the after glowing gas forms this large nebula which shows a circular shape.

– **NGC6992** [NGC6992; Type: Diffuse nebula; RA: 20Hr 56m 24s; Dec: 31° 43.0m 0s; Mg: 8; AD: 60x8']. Eastern and brighter part of the above mentioned **Veil Nebula**. It is a challenge for binoculars. Using a wide-angle telescope at low power will show NGC6992. The complete nebula is too faint to be observed; it can only be seen in total on long-exposure photographs.

– **Blinking Nebula** [NGC6826; Type: Planetary nebula; RA: 19Hr 44m 48s; Dec: 50° 31.0m 0s; Mg: 8.8; AD: 27x24']. When looking at this **planetary nebula it seems to twinkle**. When looking at it or away from it seems to blink on and off. It is required a telescope of at least 75 mm. aperture to **show the pale blue disk**. Â§

- **The Pelican Nebula** (IC5070) is close to the *North America Nebula* [NGC7000; Type: Diffuse nebula; RA: 20Hr 58m 48s; Dec: 44° 20.0m 0s; Mg: 6; AD: 120x100']. Extremely faint for telescopic observations. Only visible through long exposure photographs.

2.6 Mon (*Monoceros*): The Unicorn Â§

[RA: 7Hr 9m; Dec: -5° 44m; Area: 482 sq. deg. **Ranked 35th**] [26]. This constellation is located in the darkest region of the *Milky Way* [6].

2.6.1 Stars

- β **Mon** [BSC2356; SAO133316; RA: 6Hr 28m 48.9s; Dec: -7° 1m 59s; Mg: 4.6; B-V: -0.1; Type: B3Ve], [BSC2357; SAO133317; RA: 6Hr 28m 49.4s; Dec: -7° 2m 4s; Mg: 5.4; B-V: -0.07; Type: B3ne] and [BSC2358; RA: 6Hr 28m 49.4s; Dec: -7° 2m 4s; Mg: 5.6; B-V: 0; Type: B3e]. **Triple star system**, the three stars form a triangle that seems to be fixed. **William Herschel discovered it in 1781** and commented it as 'one of the most beautiful sights in the heavens. Â§

- ϵ **Mon** [BSC2298; SAO113810; RA: 6Hr 23m 46s; Dec: 4° 35m 34s; Mg: 4.44; B-V: 0.18; Type: A5IV]. **Fixed binary** with visual magnitudes of 4.5 and 6.5. Â§

- **S Mon** (also known as **15 Mon**) [BSC2456; RA: 6Hr 40m 58.6s; Dec: 9° 53m 44s; Mg: 4.66; B-V: -0.25; Type: O7Ve]. **Bluish white variable star** located at the center of NGC2264 (*Xmas Tree Cluster* and *Cone Nebula*, see below). However, the variation of its magnitude is not too great. It has a companion star of visual magnitude 8. Â§

- **V0640** [BSC2422; SAO114146; RA: 6Hr 37m 24s; Dec: 6° 8m 7s; Mg: 6,06; B-V: 0,05; Type: O8V+O8f]. Canadian astronomer John Stanley Plaskett discovered this giant double-star system in 1922, which is recognized as the most massive pair yet discovered. Plaskett'star has 100 times the size of the Sun and is located 4.500 light years from the Earth. The star is located near Open Cluster NGC2244 (see below) [6].Â§

2.6.2 Deep Space

- **NGC2251** [NGC2251; Type: Open Cluster; RA: 6Hr 34m 36s; Dec: 8° 22m 0s; Mg: 3.3; AD: 10"]. Number: 30. Â§

- **Xmas Tree Cluster and Cone Nebula** [NGC2264; Type: Open cluster; RA: 6Hr 41m 6s; Dec: 9° 53m 0s; Mg: 3.9; AD: 20']. The *Cone Nebula* is part of the nebula surrounding the ***Christmas Tree Cluster***. The designation of NGC2264 in the New General Catalog refers to both objects and not the nebula alone. Â§

Mon (*Monoceros*): The Unicorn Â§

- **Rosette Nebula** [NGC2237; Type: Diffuse nebula; RA: 6Hr 32m 18s; Dec: 5° 3.0m 0s; Mg: 0; AD: 80x60']. **Surrounds Open Cluster NGC2244**. Â§
- **NGC2244** [NGC2244; Type: Open cluster; RA: 6Hr 32m 24s; Dec: 4° 52m 0s; Mg: 4.8; AD: 24']. Number: 16. Â§
- **M50 Nebula** [NGC2323; M50; Type: Open cluster; RA: 7Hr 3m 12s; Dec: -8° 20m 0s; Mg: 5.9; AD: 10.0x5.5']. Number: 80. Â§
- **NGC2506** [NGC2506; Type: Open cluster; RA: 8Hr 0m 12s; Dec: -10° 47m 0s; Mg: 7.6; AD: 6']. Number: 150. Â§

2.7 Gru (*Grus*): The Crane

[RA: 22Hr; Dec: -47° ; Area: 366 sq. deg. **Ranked 45th**] [24]

2.7.1 Remarks

Constellation was created by Pieter Dirkszoon Keyser and Frederick de Houtman between 1595 and 1597. It first appeared in Johann Bayer's *Uranometria* (1603). In the Medieval Ages, it was also known as the Flamingo constellation or *Phoenicopterus* ([5]).

2.7.2 Stars

– α **Gru** (*Al Na'ir*, Arabic: *The luminous*) [BSC8425; SAO230992; RA: 22Hr 8m 13.9s; Dec: -46° 57m 40s; Mg: 1.74; B-V: -0.13; Type: B7IV]. **Blue sub giant**.

– β **Gru** (*Gruid*, Latin: *Crane*) [BSC8636; SAO231258; RA: 22Hr 42m 40s; Dec: -46° 53m 5s; Mg: 2.1; B-V: 1.6; Type: M5III]. **Red giant**.

– δ **Gru** [BSC8556; SAO231154; RA: 22Hr 29m 16,1s; Dec: -43° 29m 45s; Mg: 3.97; B-V: 1.03; Type: G6-8III] and [BSC8560; SAO231161; RA: 22Hr 29m 45.4s; Dec: -43° 44m 58s; Mg: 4.,11; B-V: 1.57; Type: M4,5IIIa]. **Double visible even with naked eye** [10].

– θ **Gru** [BSC8787; SAO231444; RA: 23Hr 6m 52,7s; Dec: -43° 31m 14s; Mg: 4.28; B-V: 0.42; Type: F5m¡04¿Del]. A telescope with an aperture of 60 mm. should easily resolve this **binary system**.

– μ **Gru** [BSC8486; SAO231055; RA: 22Hr 15m 36.9s; Dec: -41° 20m 48s; Mg: 4.79; B-V: 0.8; Type: G8III+G] and [BSC8488; SAO231063; RA: 22Hr 16m 26.5s; Dec: -41° 37m 39s; Mg: 5.1; B-V: 0.92; Type: G8III]. **Both starts are G8 giants** and are visible with the eye.

2.8 Ori (*Orion*)

[RA: 4Hr 40m to 6Hr 20m; Dec: 23° to 8Âº; Area: 594 sq. deg. **Ranked 26th**] [27]

2.8.1 Remarks

Orion has more bright stars than any other constellation in the Sky [6].

2.8.2 Stars

- α **Ori** (*Betelgeuse*, Arabic: *Hand of the central one (Gemini)*) [BSC2061; SAO113271; RA: 5Hr 55m 10.3s; Dec: 7° 24m 25s; Mg: 0.5; B-V: 1.85; Type: M1-2Ia-Iab]. **Variable red giant** (Mg 0.4 to 1.3 with no set period). During some periods of time, it is brighter than *Rigel* (see below) [6]. During its pulsations the diameter of the star varies from 300 to 400 times the diameter of the Sun [11].

- β **Ori** (*Rigel*, Arabic: *The Foot*) [BSC1713; SAO131907; RA: 5Hr 14m 32.2s; Dec: -8° 12m 6s; Mg: 0.12; B-V: -0.03; Type: B8Iae]. **Blue-white giant**.

- The Belt of Orion (from West to East):

  - δ **Ori** (*Mintaka*, Arabic: *Upper end of the Girdle*) [BSC1852; SAO132220; RA: 5Hr 32m 0.3s; Dec: 0° 17m 57s; Mg: 2.23; B-V: -0.22; Type: B0II+O9V] and [BSC1851; SAO132221; RA: 5Hr 32m 0.4s; Dec: 0° 17m 4s; Mg: 6.85; B-V: -0.16; Type: B2V]. **Blue-white star** (BSC1852) with an Mg 7 companion (BSC1851).

  - ϵ **Ori** (*Alnilam*, Arabic: *String of Pearls*) [BSC1903; SAO132346; RA: 5Hr 36m 12.7s; Dec: -1° 12m 7s; Mg: 1.7; B-V: -0.19; Type: B0Iae]. **Blue giant**.

  - ζ **Ori** (*Alnitak*, Arabic: *The Belt*): [BSC1948; SAO132444; RA: 5Hr 40m 45.5s; Dec: -1° 56m 34s; Mg: 2.05; B-V: -0.21; Type: O9.5Ibe] and [BSC1949; RA: 5Hr 40m 45.5s; Dec: -1° 56m 34s; Mg: 4.2; B-V: 0; Type: B0III]. **Triple star system**. The third companion is of 10th magnitude. For resolving the tight double of *Alnitak* (separated 2.6"), scopes with an aperture of at least 75 mm. and a high resolution are required. The *Alnitak* system is bathed in the nebula of [IC434; Type: Diffuse nebula; RA: 5Hr 41m 0s; Dec: -2Âº 24m 0s; Mg: 2.1; AD: 60x10']. (***Horsehead Nebula***).

- λ **Ori** [BSC1879; SAO112921; RA: 5Hr 35m 8.2s; Dec: 9° 56m 3s; Mg: 3.66; B-V: -0.18; Type: O8e] and [BSC1880; RA: 5Hr 35m 8.4s;

Dec: 9° 56m 6s; Mg: 5.56; B-V: 0; Type: B0.5V]. Tight pair of Mg 4 and Mg 6 stars.

– σ **Ori** [BSC1931; SAO132406; RA: 5Hr 38m 44.7s; Dec: -2° 36m 0s; Mg: 3.81; B-V: -0.24; Type: O9.5V]. Using binoculars this **blue-white star** of Mg 4 and its Mg 7 companion can be resolved; using a small telescope two closer companions of Mg 7 and Mg 10 are revealed. **These stars are grouped in a way that looks like a planet with moons**.

– This group of stars was formed from the gas of the *Orion Nebula*, which now glows in their light. They form a rectangular figure called ***The Trapezium***.

θ **Ori** [BSC1893; RA: 5Hr 35m 15.8s; Dec: -5° 23m 14s; Mg: 6.73; B-V: 0.02; Type: O7], [BSC1894; RA: 5Hr 35m 16s; Dec: -5° 23m 7s; Mg: 7.96; B-V: 0.24; Type: B0V], [BSC1895; SAO132314; RA: 5Hr 35m 16.4s; Dec: -5° 23m 23s; Mg: 5.13; B-V: 0.02; Type: O6], [BSC1896; RA: 5Hr 35m 17.2s; Dec: -5° 23m 16s; Mg: 6.7; B-V: 0.09; Type: B0.5Vp] and [BSC1897; SAO132321; RA: 5Hr 35m 22.8s; Dec: -5° 24m 58s; Mg: 6.39; B-V: -0.09; Type: O9.5Vep]. θ **Ori** is the northern star of the ***Dagger of the Hunter***; it is located in the heart of the Orion nebula.

Fig. 2: Meade ETX70-AT and Orion.

2.8.3 Deep Sky

- **NGC1980** [NGC1980; Type: Open Cluster and Diffuse Nebula; RA: 5Hr 35m 26s; Dec: 5° 54m 35s; Mg: 2.5; AD: 14”]. Number: 15 is surrounded by a faint nebula.

- **Orion Nebula** [M42; NGC1976; Type: Diffuse nebula; RA: 5Hr 35m 24s; Dec: -5° 27m 0s; Mg: 2.9; AD: 66x60’].

- **NGC1662** [NGC1662; Type: Open Cluster; RA: 4Hr 48m 29s; Dec: 10° 55m 48s; Mg: 6.4; AD: 20”]. Number: 10.

- **DeMairan Nebula** [M43; NGC1982; Type: Diffuse nebula; RA: 5Hr 35m 36s; Dec: -5° 16m 0s; Mg: 6.9; AD: 20x15’]. **Part of the Orion Nebula**.

2.8.4 Faint Objects

- **IC434** [IC434; Type: Diffuse nebula; RA: 5Hr 41m 0s; Dec: -2° 24m 0s; Mg: 2.1; AD: 60x10’]. ***Horsehead*** nebula. It can only be observed by means of astrophotography techniques.

- **M78** [M78; NGC2068; Type: Diffuse nebula; RA: 5Hr 46m 42s; Dec: 0° 3m 0s; Mg: 8.3; AD: 8x6’]. **Comet Shaped**. Brightest diffuse reflection nebula of a group of nebulae that include [NGC2064; Type: Diffuse nebula; RA: 5Hr 46m 18s; Dec: 0Âº 0m 0s; Mg: 9.9; AD: 11x2’].

- **NGC2186** [NGC2186; Type: Open Cluster; RA: 6Hr 12m 6s; Dec: 5° 28m 0s; Mg: 8.7; AD: 4”]. Number: 30.

2.9 Sex (*Sextans*): Sextant Â§

[RA: 10Hr; Dec: 0° ; Area: 314 sq. deg. Ranked 47th] [28]

2.9.1 Stars

– α **Sex** [BSC3981; SAO137366; RA: 10Hr 7m 56.2s; Dec: 0° 22m 18s; Mg: 4.49; B-V: -0.04; Type: A0III]. **White A-type giant**. Â§

– β **Sex** [BSC4119; SAO137608; RA: 10Hr 30m 17.4s; Dec: 0° 38m 13s; Mg: 5.09; B-V: -0.14; Type: B6V]. **Blue-white B-type main sequence dwarf** approximately 345 light years from Earth. Its brightness varies from magnitude 5.00 to 5.10. The period of this variability is unclear but maybe around 15.4 days. Â§

2.9.2 Deep Space

– **Spindle Galaxy** [NGC3115; Type: Elliptical galaxy; RA: 10Hr 5m 12s; Dec: -7° 43m 0s; Mg: 9.2; AD: 4.0x1.2']. Discovered by **William Herschel** on February 22, 1787. Â§

2.10 Sge (*Sagitta*): Arrow

[RA: 19.83Hr; Dec: 18.66° ; Area: 80 sq. deg. **Ranked 86th**] [29]

2.10.1 Stars

– α **Sge** (*Sham*, Arabic: *The Arrow*) [BSC7479; SAO105120; RA: 19Hr 40m 5.7s; Dec: 18° 0m 50s; Mg: 4.37; B-V: 0.78; Type: G1III]. **Yellow giant star** about 475 light years from Earth. The star's radius is roughly 20 times solar while its mass is 4 times the solar mass.

– ζ **Sge** [BSC7546; SAO105298; RA: 19Hr 48m 58.6s; Dec: 19° 8m 31s; Mg: 5; B-V: 0.1; Type: A3V]. **Has a 9th magnitude companion**. Small telescopes can resolve this pair.

2.10.2 Faint Objects

– **M71** [NGC6838; M71; Type: Globular cluster; RA: 19Hr 53m 48s; Dec: 18° 47.0 m 0s; Mg: 8.3; AD: 6.1']. Classified as a globular cluster, but **it looks much more like an open cluster**. In binoculars and small telescopes, M71 appears as a misty patch of a spherical shape [12].

2.11 UMa (*Ursa Major*): Great Bear Â§

[RA: 10Hr 40m; Dec: 55° 23m; Area: 1280 sq. deg. **Ranked 3rd**] [30]

2.11.1 Remarks

Ursa Major is a good starting point to find other stars and constellations in the sky:

- Following the line leading from α **UMa** (*Dubhe*, Arabic: *The Bear*) to β **UMa** (*Merak*: Arabic: *The loins (of the Bear)*), one can find easily the pole star (*Polaris*, α **UMi** star of the Ursa Minor).
- *The Charioteer* constellation can be found when following the line leading from δ **UMa** (*Megrez*, Arabic: *The insertion-point (of the Bear's tail)*) to α **UMa** (*Dubhe*, Arabic: *The Bear*). It's leading directly to *Capella* (α **Aur**). Â§
- Drawing a line from δ **UMa** (*Megrez*, Arabic: *The insertion-point (of the Bear's tail)*) to β **UMa** (*Merak*: Arabic: *The loins (of the Bear)*) and beyond, you will find *Castor* (α **Gem** star of the *Twins* constellation). Â§

2.11.2 Stars

- ζ UMa (*Mizar*, Arabic: *Girdle*) [BSC5054; SAO28737; RA: 13Hr 23m 55.5s; Dec: 54° 55m 31s; Mg: 2.27; B-V: 0.02; Type: A1VpSrSi] and ***Mizar B*** [BSC5055; SAO28738; RA: 13Hr 23m 56.3s; Dec: 54Âº 55m 18s; Mg: 3.95; B-V: 0.13; Type: A1m]. ***Mizar B*** was discovered by Benedetto Castelli (pupil of Galilei) in 1617. The two take thousands of years to revolve around each other. ***Mizar A* and *Mizar B* are also spectroscopic binaries** [13]. Â§
- **80 UMa** (*Alcor*, Arabic: *Black Horse*) [BSC5062; SAO28751; RA: 13Hr 25m 13.4s; Dec: 54° 59m 17s; Mg: 4.01; B-V: 0.16; Type: A5V] companion of δ **UMA** (*Mizar*). The two stars lie more than a quarter of a light year apart and it is still unknown whether they form a true binary star system and not an optical binary as currently thought. The two are **often called the horse** (*Alcor*) and the **rider** (*Mizar*), and the ability to see the first is a **traditional test of eyesight**. Â§
- ξ **UMa** [BSC4374; SAO62484; RA: 11Hr 18m 10.9s; Dec: 31° 31m 45s; Mg: 4.87; B-V: 0; Type: G0V] and [BSC4375; SAO62484; RA: 11Hr 18m 10.9s; Dec: 31° 31m 45s; Mg: 4.41; B-V: 0.59; Type: G0V]. **Binary** with an orbiting period of 60 years. At the point when they seemed to be farthest away from each other they can be viewed with smaller scopes (as was the case 1975), but at their

closest (in 1992) it is needed at least an aperture of 150 mm to resolve the components. Â§

– **47 UMa** [BSC4277; SAO43557; RA: 10Hr 59m 27.9s; Dec: 40° 25m 49s; Mg: 5.05; B-V: 0.61; Type: G0V]. **Has a planetary system with two confirmed planets** 2.54 times and 0.76 times the mass of Jupiter. Â§

2.11.3 Deep Space

– **Bode's Galaxy** [M81; NGC3031; Type: Spiral galaxy; RA: 9Hr 55m 36s; Dec: 69° 4.0m 0s; Mg: 6.9; AD: 18x10']. **One of the brightest galaxies in the sky**. Under exceptional viewing conditions and truly dark skies in a remote location far from light pollution, it can be seen with the naked eye. Â§

– **Pinwheel Galaxy** [M101; NGC5457; Type: Spiral galaxy; RA: 14Hr 3m 12s; Dec: 54° 21.0m 0s; Mg: 7.7; AD: 22x20']. The brightest member of the M101 group of galaxies. Â§

2.11.4 Faint Objects

– **Cigar Galaxy** [M82; NGC3034; Type: Irregular galaxy; RA: 9Hr 55m 48s; Dec: 69° 41.0 2m 0s; Mg: 8.4; AD: 8x3']. Astronomers have postulated that M82 would contain **the first known mid-mass black hole** of roughly 500 solar masses. Â§

– **M40** [M40; WNC 4; Type: Double star; RA: 12Hr 22m 24s; Dec: 58° 5.0m 0s; Mg: 9.1; AD: 50"']. Double star that Messier nonetheless included in his catalog. In 1991 the separation between the components was measured at 51".7, an increase since Messier's time. The general consensus is that this is merely an **optical double star** rather than a physically connected system. Â§

– **M109** [M109; NGC3992; Type: Spiral galaxy; RA: 11Hr 57m 36s; Dec: 53° 23m 0s; Mg: 9.8; AD: 6.2x3.5']. **Spiral barred galaxy**. As of 2005, our Milky Way galaxy was confirmed to be a barred spiral galaxy, and most astronomers think M109 would be the most likely twin of our own galaxy. Â§

– **Surfboard Galaxy** [M108; NGC3556; Type: Spiral galaxy; RA: 11Hr 11m 30s; Dec: 55° 40.0m 0s; Mg: 10.1; AD: 7.7x1.3']. Â§

– **Owl Nebula** [M97; NGC3587; Type: Planetary nebula; RA: 11Hr 14m 48s; Dec: 55° 1.0m 0s; Mg: 12; AD: 3.4x3.0']. The 16th magnitude central star has about 0.7 solar masses and the nebula itself weighs about 0.15 solar masses. The nebula formed roughly 6,000 years ago. Â§

2.12 UMi (*Ursa Minor*): Little Bear

[RA: 15Hr; Dec: 70° ; Area: 256 sq. deg. **Ranked 56th**] [31]

2.12.1 Stars

- α **UMi**, (*Polaris*, Latin: *Pole Star*) [BSC424; SAO308; RA: 2Hr 31m 50.5s; Dec: 89° 15m 51s; Mg: 2.02; B-V: 0.6; Type: F7:Ib-IIv]. This white-yellow **Super giant cepheid variable star** [14] has a diameter 32 times longer than the Sun, its mass is six times bigger, and is 2,200 times brighter [4]. Within a period of 4 days, the brightness varies between Mg 2.02 and Mg 2.2. Additionally, α UMi is a triple star. The main companion, a star of the 9th magnitude, can be separated with small telescopes (the separation is 18"), is located 2,400 AU away from the main star, has a mass 1.5 times bigger than our Sun and was discovered by William Herschel in 1780 [4]. There is a third companion star called Ab which is located at only at 18.5 AU away from the main star. It was found in 1929 and is not reachable by amateur telescopes [4]. Polaris is famous because it lies **just 0.7Âº away from the true North Pole** [4]. By the year 2101 *Polaris* will be at its closest position from the North Pole ([6], page 28).

- β **UMi** (*Kochab*, Arabic: *The Star*) [BSC5563; SAO8102; RA: 14Hr 50m 42.2s; Dec: 74° 9m 20s; Mg: 2.08; B-V: 1.47; Type: K4IIIBa0.3]. Together with γ **CMa** UMi (called *Pherkad*, see next) makes a small asterism often known as *The Guardians of the Pole* or simply *The Guards*, since both seem to move around *Polaris*, protecting it.

- γ **CMa** UMi (*Pherkad Major*, Arabic: *Calf*) [BSC5735; SAO8220; RA: 15Hr 20m 43.6s; Dec: 71° 50m 2s; Mg: 3.05; B-V: 0.05; Type: A3II-III]. **A3 giant**. Close to it lies the Mg 5 star **11 UMi** (*Pherkad Minor*, Arabic: **Calf**) [BSC5714; SAO8207; RA: 15Hr 17m 5.8s; Dec: 71° 49m 26s; Mg: 5.02; B-V: 1.37; Type: K4III]. These two stars **appear double although they are unrelated**. 11 UMi c**can be seen with the naked eye under good conditions** (otherwise binoculars are sufficient to show the star).

2.13 Vul (*Vulpecula*): The Fox Â§

[RA: 20Hr; Dec: 25° ; Area: 268 sq. deg. **Ranked 55th**] [32]

2.13.1 Remarks

The **first pulsar** was discovered in this constellation in 1967 by Antony Hewish and Jocelyn Bell (Cambridge). It is called *PSR 1919+21* standing for *PulSaR at RA 19h 19m and Declination +21 degrees.*

2.13.2 Stars

– α Vul (*Anser* Latin: *The Goose*) [BSC7405; SAO87261; RA: 19Hr 28m 42.2s; Dec: 24° 39m 54s; Mg: 4.44; B-V: 1.5; Type: M0III]. **Red giant**. It forms an **optical binary** with **8 Vul** [BSC7406; SAO87267; RA: 19Hr 28m 56.9s; Dec: 24Âº 46m 7s; Mg: 5.81; B-V: 1.03; Type: K0III] that can be split using binoculars. Â§

2.13.3 Deep Space

– **Brocchi's Cluster** [Collinder399; Type: Asterism; RA: 19Hr 25m 24s; Dec: 20° 11m 0s; Mg: 3.6; AD: 60"] is an asterism formerly thought to be an open cluster. It is also called the ***Coathanger*** because of its distinctive star pattern when viewed with binoculars or a low-power telescope [15]. The asterism is made up of ten stars ranging from fifth to seventh magnitude which form the conspicuous *Coathanger*, a straight line of six stars with a hook of four stars on the south side. Â§

– **Dumbbell Nebula** [NGC6853; M27; Type: Planetary nebula; RA: 19Hr 59m 36s; Dec: 22° 43m 0s; Mg: 7.6; AD: 8x4']. It can be seen with good binoculars appearing as a dimly glowing disk. Large telescopes and photographs show a double-lobed shape.

Chapter Three

Knowledge Pills

3.1 Spectral Star Types and Colors

3.1.1 Spectral Types

Spectral Star Types Classification is sorted by temperature, starting with the hottest stars (class O) and ending with the coldest (class M). The original classification also included classes R, N, S, following the M class.

- **Class O**: Brightest, biggest, hottest, short-lived (rare) stars.
- **Class S**: Dimmest, coolest, smallest, long-lived (common) stars.

Class	**Temperature (°K)**	**Color**	**Example**
O	> 25,000	Blue	*Lacertra*
B	11,000 - 25,000	Blue	*Rigel*, *Spica*
A	7,500 - 11,000	Blue	*Sirius*, *Vega*
F	6,000 - 7,500	Blue to White	*Procyon*, *Canopus*
G	5,000 - 6,000	White to Yellow	*Sun*, *Capella*
K	3,500 - 5,000	Orange to Red	*Arcturus*, *Aldebaran*
M	2,000 - 3,500	Red	*Betelgeuse*, *Antares*

Table 1: Spectral Star Types.

A good mnemonic to learn this table is: *Oh Be A Fine Girl/Guy/Gay, Kiss Me (Right Now Sweetly)*. Spanish-speaker astronomers may use this mnemonic instead: *Otros Buenos Astronomos Fueron Galileo, Kepler y Messier*. (Other good astronomers were Galilei, Kepler, and Messier). Hello

3.1.2 Luminosity

Luminosity is sorted by the size of the stars, beginning with the biggest stars (class I) and ending with the smallest (class VII).

Class	**Type**
Ia, Ib	Supergiants
II	Bright giants
III	Normal giants
IV	Sub giants
V	Main sequence
VI	Sub dwarfs
VII	White dwarfs

Table 2: Luminosity.

3.1.3 B-V Color Index

UBV photometric system (or Johnson-Morgan system), is a wide band photometric system for classifying stars according to their color index.

In order to obtain the color index of an object, its magnitude is observed successively through different filters, such as U, B, and V, where U is sensitive to ultraviolet rays, B is sensitive to blue light, and V is sensitive to visible (green-yellow) light. The difference in magnitudes found with these filters is called the U-B or B-V color index, respectively.

In the B-V Color Index used by the Bright Star Catalog (BSC), **the smaller the color index, the more blue** (or hotter) the star is and, **the larger the color index, the more red** (or cooler) the object is.

For example, the **blue star** *Rigel* in **Orion** [BSC1713; SAO131907; RA: 5Hr 14m 32.2s; Dec: -8° 12m 6s; Mg: 0.12; B-V: -0.03; Type: B8Iae] **has a B-V index of -0.03** while the **red giant** *Betelgeuse* in the same constellation [BSC2061; SAO113271; RA: 5Hr 55m 10.3s; Dec: 7Âº 24m 25s; Mg: 0.5; B-V: 1.85; Type: M1-2Ia-Iab] has a **B-V index of 1.85**.

3.2 Notes about Magnification

3.2.1 Erecting Eyepieces

– Refracting telescopes show the images inverted horizontally and vertically.

– Refracting prisms show the image in an erect vertical position (but do not invert the image horizontally).

– Erecting eyepieces invert the image, both horizontally and vertically.

– Barlow lens has not effect on image inversion.

3.2.2 Barlow Magnification

– Barlow lens may be placed immediately before an eyepiece to effectively decrease the eyepiece's focal length by the amount of Barlow's divergence. This has the effect of increasing the magnification of the image by this amount (2x, 3x, etc).

– The use of more than one Barlow lens multiplies the magnification effect. For example, when using a 2x plus a 3x Barlow, a 6x magnification is obtained $(2 * 3)$.

3.2.3 Magnitude Limit

This formula obtains the maximum magnitude reachable by your optic instrument:

$$MaximumMagnitude = 7.5 + 5 * \log_{10} D.$$

D is the diameter of the instrument (in centimeters).

Note however that in order to observe objects of the maximum magnitude with any other medium-long exposure photographs, perfect seeing, and extraordinary atmospheric conditions are required.

As a rule of thumb, for visual observation, I'd rather recommend reducing 2 levels for rural areas and 3 or 4 levels when observing in urban areas.

Instrument	Magnitude
Naked Eye	6
Binoculars	8
Telescope 70 mm. diameter	11
Telescope 200 mm. diameter	16

Table 3: Maximum observable magnitude.

3.3 Albedo

The Albedo is the ratio of radiation reflected by the surface of an object. Although this parameter is commonly used for visible light, it can also be used for other different types of wavelengths such as radio, X-rays, etc. Albedo assumes a value between 0 and 1.

- 0 represents an object that does not reflect light at all. They **usually have dark colors** and since they absorb huge amounts of energy, **their internal temperature is high**.
- 1 is used for objects that reflect all the light received. Those objects are usually white and cold.

Object	Albedo (average)
Planet Earth	0,31
Oceans	0,05
Average clouds	0,5
Brightest clouds	0,78
Snow	0,8
Asphalt	0,04
Forests	0,08
Deserts	0,4
Prairies	0,2
Moon (average)	0,073
Moon (seas)	0,03
Moon (highlands)	0,24
Enceladus (Saturn's moon)	0,99 (highest albedo in the Solar System)

Table 4: Albedo typical values for common objects [19].

3.3.1 Watch out!

One of the worst places to place your telescope is on hot asphalt (albedo's 0,04). Energy absorbed during the day is slowly liberated by night, creating turbulences that affect your seeing. It is also a pole of attraction area for animals like snakes or frogs!

3.4 Measuring the Sky

It is actually possible to estimate the elevation angle (altitude) at which an object is in the sky using different parts of our hand as units of measurement (see figure 3). To *calibrate this tool*, you should know that **the diameter of the full moon in the sky is about half a degree (30s)**.

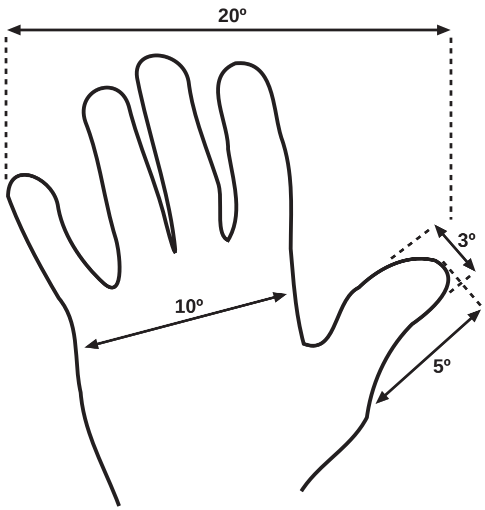

Fig. 3: Our hand may be used to estimate visual angles.

3.5 Astrophotography

A good image of the sky is the result of several individual frames combined into a single picture. Some of the individual frames contain real data about the sky, that is, the signal we want to represent in the final image. Others contain information about the digital background noise or defects in the optical system. The combination process will increase the data/noise ratio by subtracting the noise from the data.

This process is called image stacking and is performed by special software. One of the best options available is the freeware software **DeepSkyStacker** that can be downloaded from `http://deepskystacker.free.fr`.

3.5.1 Light Frames

They are the frames containing real information, the signal, that is, the image of the sky. These frames will be stacked together creating a single image. This image will have an exposure time equivalent to the sum of the exposure time for all the stacked images.

As the background noise increases with longer exposure times the stacking process increases the signal over the noise ratio.

So instead of taking a single image of 10 minutes, it would be better to take 20 images of 30 seconds each. The exposure time will be almost the same but the signal/noise ratio will be higher, so the more light frames captured the better.

3.5.2 Dark Frames

Even short exposure time captures background noise produced by the CCD chip at specific temperatures. This noise introduces red or black pixels in the picture, which tend to appear in the same locations for a given value of temperature and exposure time. The goal of capturing dark frames is to subtract this noise from the stacked light frames.

A dark frame is an exposure of the CCD chip in complete darkness using the same exposure time and temperature used for capturing the light frames, **but putting on the lens/telescope cap**.

In order to avoid random noise values (also produced by cosmic rays hitting the CCD sensor), it is recommended to take several dark frames and average them using special software. This will produce a unique noise signature for a specific CCD chip at a specific temperature and at a given exposure time. The signature can be then subtracted from the light frames and reused for other images taken at the same temperature and at the same exposure time.

Dark frames taken closer to the time of a light frame **will be closer in system noise levels and compensate more accurately for that noise**.

3.5.3 Flat Frames

The optical system can be affected by several aberrations including vignetting, internal reflections, dust motes, etc. All of them are reproduced in the final picture.

A flat frame reproduces all these effects in a single picture which can be subtracted from the light frames in a similar fashion as the dark frames are used to eliminate background noise. However, **flat frames are not temperature dependent**.

As every optical system is unique and the footprint changes over time (some dust motes can be cleaned from take to take, but others can be added) **flat fields can not be reused** and have to be taken from time to time (usually at the end of every session).

A flat field is obtained by taking a picture of an evenly illuminated object (the sky at twilight, the inside of the observatory dome, a luminescent panel, an LCD screen, etc.). The optical system **must have the same focus used to take the light frames**. Only one picture is required as is not temperature dependant, **so the flat field is taken only once per imaging session or whenever a change in focus is required**.

Flat fields are images and therefore need their own dark frames. **It is recommended to take 10 dark frames at the same temperature as the flat fields** and median combining them using stack imaging software.

3.5.4 Bias Frames

The information contained in a dark frame includes noise related to the chip electronics and noise coming from charge accumulation. The second depends on the exposure time. Both depend on the temperature.

A bias frame is an image taken with no actual exposure time. It is actually taken using the fastest speed of the optical system putting on the lens cap and at the same temperature as the light and dark frames are taken.

The image contains noise due to the electronics only, which can be subtracted from a dark frame in order to get noise coming from charge accumulation. In other words, a bias frame is complementary to a dark frame and is used to obtain an image representing only the noise coming from charge accumulation.

In practical terms a bias frame **is used to create virtual dark frames** for exposure times different from those the dark frames were taken.

So for example, imagine that there are dark frames taken for an exposure time of 30 seconds but the light frames were taken at an exposure time of 60 seconds. The original dark frames can be converted into virtual dark frames for 60 seconds of exposure time subtracting the bias frame (that is, the chip electronic noise) from the dark frames (obtaining the exposure dependant noise), multiplying it by two, and adding the bias frame again. The complete process may be performed by image stacking software.

This technique is **less accurate than shooting dark frames** for each specific exposure time, but it has the advantage of dramatically **reducing the time required to obtain dark frames**.

Whenever it is possible, shoot dark frames for the exposure time of your light frames but shot a bias frame at the end of your imaging session (just in case you need a bias frame to create virtual dark frames!) **Don't forget to shoot the bias frame at the same temperature as the dark and light frames**.

3.5.5 Basic procedures in Astrophotography

3.5.5.1 Camera Preparation Checklist

1. Turn off all the camera options that drain battery life including the image preview option.
2. Turn off **Auto-Focus (AF)**.
3. Set white balance to **auto or daylight**.
4. Set the camera to **manual mode**. BULB mode is recommended (it keeps the shutter open as long as the shutter button is pressed).
5. Attach a remote release cable.
6. Turn off high **ISO noise reduction**.
7. Set your ISO to 200, 400 or 800.
8. Turn on **mirror lock**.
9. Turn off **noise reduction**.
10. Set the image type to JPG (at its highest quality).

3.5.5.2 Checklist for Camera preparation on a fixed tripod or on PiggyBack mount

Complete the generic *Camera Preparation Checklist* by performing the following operations:

1. Use the **fastest and widest lens** in your arsenal (f/2 or f/2.8 and an 18 mm. focal length lens instead of a 55 mm.).
2. Pre-focus **on infinity** using the Moon or a bright light in the distance.
3. Open the lens diaphragm **all the way**.

3.5.5.3 Procedures for Camera on fixed tripod

1. Set the exposure time to the maximum possible. Depending on whether you like to capture star trailing a time limit applies. **20 seconds is the limit for a 18 mm focal length** in order to **avoid star trailing**. **6.4 seconds should be the maximum exposure time when using a 55 mm focal length**. Use the formulas coded in the AOS for other focal lengths.

2. Take pictures using a delayed/remote shutter to avoid vibrations.

3.5.5.4 Procedures for Camera on the driven mount (Piggy-Back or telescope mounted)

1. Set the exposure time to **30 seconds** as a starting reference.

2. Take some pictures using a delayed/remote shutter to avoid vibrations.

3. Check the focus.

   (a) If you are taking images through the telescope, you can use a Bathinov mask to help you to get focus on a bright star.

4. Check the exposure time increasing it or reducing it.

   (a) Reduce the exposure time to **avoid blooming**. The goal is to expose long enough to make bright objects come close to (but not go over) the top of the brightness scale.

5. Set the camera to **RAW format**.

6. Take some dark frames for the current temperature (at least 3-5).

7. Take images without moving anything. The more frames the better (**at least 10 images**).

   (a) Although the images might look faint, detail will show up during the stacking process.

   (b) It is better to take more frames to compensate for under-expositions rather than over-expose.

8. **Take some additional dark frames** for the current temperature (at least 3-5). All of them will be averaged during image stacking. The closer in time, the dark frames are taken to the light frames the best.

   (a) If you are imaging a very bright star, **it can leave some ghost trails** in the first dark frames taken after completing the last light frames. To avoid this negative effect, wait a little bit after the light frame session before start taking dark frames.

9. Take a **bias frame** (put on the lens/telescope cap and shoot a picture using the **shortest exposure time available**).

10. Take a flat field whenever a change in focus is required.

    (a) Take 5 dark frames for this flat field.

11. Use a software program for image stacking.

    (a) Averaging or median combining dark frames is essential. **Median combining is safer** in order to avoid the negative effects produced by a cosmic ray hitting one of the dark frames.

3.5.6 Photographing the Moon

In the North Hemisphere is recommended to avoid taking pictures of the moon during the summer since this is the period of the year when the moon is at its lower position over the horizon, being affected by the bad seeing conditions [16].

Moon Phase	Best Period
Waxing moon	January to April
Full Moon	Winter
Waning moon	Autum

Table 5: Best dates to take pictures of the moon [16].

It is not recommended to take pictures of the moon when it has an altitude lower that 40Âº.

3.5.6.1 Shutter speed

The moon can be photographed without sidereal tracking **only if the camera's shutter speed is 1/60 seconds or faster**. This shutter speed is easy to obtain for almost all the moon phases. When using telescopes with apertures near 100 mm. the shutter speed required would be about 1/200 to 1/1000 seconds for the brigthests moon phases [17].

3.5.6.2 Watch out!

Since the camera measures light for the whole picture frame which is mostly dark (excepting the moon itself), the resulting speed is usually one or two steps lower than required and as result the picture becomes overexposed. In order to avoid this effect, it is recommended to:

- Reduce the dark areas in the picture zooming on the moon as much as possible.

– Setting the shutter speed manually one or two steps slower than indicated by the camera's photometer. e.g. if the photometer reads 1/1000, set the shutter to 1/500 or 1/250. It is also recommended to take several pictures at different speeds.

3.6 Understanding Energy

A popular unit of electric charge is the **ampere-hour** or **amp-hour**. It is commonly represented in high-capacity batteries as Ah, AHr, AÂ·h, or A h. However, in low-capacity batteries, it is usually represented with its sub-units **milliampere-hour** (**mAh**).

The amount of energy liberated by a battery is a product of the battery's charge and its voltage.

So for example a 1.2 volts rechargeable battery storing 2000 mAh of electric charge (that is 2Ah), will produce 2Ah * 1.2 = 2.4 Wh (2.4 watts-hour).

If we use two of those fully charged batteries to feed a device consuming 2W they will last for at least (2 * 2.4 Wh) / 2W = 2.4 hours of continuous operation.

Chapter Four

Appendix

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B Greek Alphabet

Symbol	**Character**
α	Alpha
β	Beta
γ	Gamma
δ	Delta
ϵ	Epsilon
ζ	Zeta
η	Eta
θ	Theta
ι	Iota
κ	Kappa
λ	Lambda
μ	Mu
ν	Nu
ξ	Xi
o	Omicron
π	Pi
ρ	Rho
σ	Sigma
τ	Tau
υ	Upsilon
ϕ	Phi
χ	Chi
ψ	Psi
ω	Omega

Table 6: Greek Alphabet.

C Abbreviations and Acronyms

Abbreviation	Meaning
AD	Apparent Dimension
AU	Astronomic Units
Barnard	Barnard Catalog
BSC	Bright Star Catalog
B-V	Color Index
C	Caldwell Catalog
Collinder	Collinder Catalog
Dec	Declination
Hr	Hour
Km	Kilometer
M	Messier Catalogue
Mel	Melotte Catalogue
Mg	Magnitude
m	Minute
mm	Millimeters
NGC	New General Catalogue
RA	Right Ascension
s	Second
SAO	Smithsonian Astrophysical Observatory

Table 7: Abbreviations and Acronyms.