The Observer's Sky Atlas

WITH 50 STAR CHARTS COVERING THE ENTIRE SKY

E. Karkoschka

THIRD EDITION

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Cover photograph: Based on a photograph by the author, it shows the southwest part of the constellation Sagittarius together with the brightest Milky Way clouds. North is to the upper left. The red nebula near the left edge is the Lagoon Nebula M8. Many other objects can be identified with the help of chart E20.

Frontispiece: The sword of Orion, containing the Orion Nebula. Looking at it with a large telescope on a dark night gives one of the grandest views in the universe. The faint reflection nebula NGC 1973 lies half way up to the top of the photograph where the stellar group NGC 1981 can be seen.

With 50 star charts, 245 black and white photographs, and 6 line drawings.

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Contents

Explanatory Notes

Introduction

Can you remember being impressed by a clear starry sky? Look at the Milky Way through binoculars and it will reveal its many hundreds of thousands of stars, double stars, stellar clusters, and nebulae. If you are a new observer, it is not that easy to find your way in this swarm of stars, but this atlas tries to make it as easy as possible. So now it is not just experienced amateurs that can enjoy looking at the heavens.

Two additional observing aids are recommended. The first is a planisphere, where one can dial in the time and day in order to see which constellations are visible and where they are in the sky. The second is an astronomical yearbook listing the current positions of the planets and all important phenomena.

So, let us begin our journey around the night sky, and see what the universe can reveal to us!

Sky Atlases

Most sky atlases can be classified into one of two major groups according to the number of stars they contain. Some atlases only show the stars visible to the naked eye. As there are not more than a few thousand such stars, such charts can be simple and clear and can be arranged in a handy format. They are ideal for all naked-eye

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Facing page, top: The constellation Cygnus (Swan) in the midst of the northern Milky Way. The photograph gives an impression of the uncountable stars in our Milky Way. This becomes more conspicuous when you sweep through Cygnus with binoculars. Under a very dark sky, one can try to find the North America Nebula, Pelican Nebula, and Veil Nebula (see p. 45). These are difficult nebulae and are only barely visible on this photograph as well. For orientation: Deneb is the bright star on the left side; Albireo is near the right edge, nearly as high as Deneb

Facing page, bottom: The region around the constellation Crux (Southern Cross) in the southern Milky Way. Aside from the Magellanic Clouds, this part is a special attraction of the southern sky. Directly to the lower left of the cross is a dark nebula, the Coalsack. It displays beautiful detail in binoculars. In the right part of the photograph is the bright Eta Carinae Nebula, surrounded by bright clusters. The star Eta Carinae illuminates the nebula and is currently not visible to the naked eye, although it was the second brightest star in the sky during two decades of the nineteenth century. It is a candidate for the next supernova explosion in our part of the Milky Way. The enormous flash of the explosion might already be on its 8000-year journey to us observations. The other group of atlases contains the stars visible through binoculars or telescopes. As there are a million stars within the reach of binoculars, such atlases need hundreds of charts, often arranged in several volumes. They are ideal for observations with binoculars and telescopes.

This atlas steers a middle course. It contains the whole sky visible to the unaided eye (limiting magnitude 6), and finder charts for 250 interesting objects for binoculars and small telescopes (limiting magnitude 9). Since these finder charts only cover approximately ten percent of the whole sky, it was possible to put all this information into a very convenient format.

Some atlases contain as many codes and labels as possible for each object. They are quite useful for work at home at the desk. The other extreme is represented by photographic atlases containing no labels at all. They are recommended when it comes to comparison with the real sky. This atlas again lies between the two extremes. The star charts are clear and contain just one label for important objects, since all the other data can always be found on the page facing the chart. This new edition also contains photographs of all the selected interesting objects (pp. 119–149).

Catalogs

As well as a naked-eye atlas and a binocular atlas, observers also use a catalog to look up important data such as double-star separations or the magnitudes of nebulae. This atlas combines these three functions. To work with different books can be troublesome because, between them, object selection and labeling may be quite different. In this atlas all objects labeled in the charts are listed in the tables on

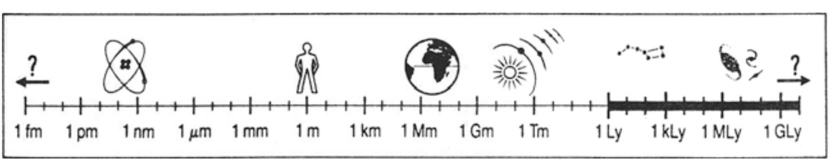

Figure 1: Between the size of an atomic nucleus and the furthest known objects in the universe, we have explored 41 orders of magnitude. This atlas contains objects further than one light-year: that means the last ten orders of magnitude. Nobody can really imagine these distances. But if we shift these ten orders of magnitude to the left, to the sizes we feel comfortable with, then we can get at least a feel for the world of stars and galaxies.

Table 1: The mean relative uncertainty of stellar distances. It has significantly improved due to the publication of the Hipparcos Catalogue in 1997. All data of this book consider this progress.

distance (light years)	10	20	40	80	150	300	600	1 200	2 500	5 000
uncertainty until 1997 (%)	3	6	12	25	35	45	50	50	50	50
uncertainty since 1997 (%)	0.25	0.5	1	2	4	8	15	25	40	50

the facing page, naturally with the same designation, and all objects in the tables are labeled in the facing star charts. This makes observing as easy as possible.

Until 1997, many data on binaries (double stars) such as magnitude, color, and separation were based on more or less reliable estimates from observers. The Hipparcos satellite revealed previous errors and often provides data more accurate than sufficient for an observer. The new knowledge is included in this book. Other sources are: *Sky Catalogue 2000.0*, the *Yale Bright Star Catalogue*, the *Smithsonian Astrophysical Observatory* (SAO) *Star Catalog, Ovschni Katalog Peremenich Zvjezd, Synopsis der Nomenklatur der Fixsterne, Délimitation Scientifique des Constellations, Burnham's Celestial Handbook*, and the *Webb Society Deep-Sky Observer's Handbook*.

Object Selection

This atlas contains 250 nonstellar objects listed under the general term "nebula": planetary nebulae, diffuse nebulae, open or galactic star clusters, globular star clusters, and galaxies. In addition to all 110 Messier objects, 140 additional nebulae that have magnitudes like those of many Messier objects have been selected. Among similar nebulae, those further north were slightly favored in the selection. All these nebulae can be observed with an amateur's telescope. Following each table of nebulae is a short description of each object for binoculars or a telescope under good sky conditions. Here the term "amateur's telescope" is considered to be a telescope with an aperture lying in the range 100–200 mm (4–8 in.). Today, many amateurs own still larger telescopes. This atlas is also useful for them, but it only satisfies part of their telescopes' capabilities.

These 250 nebulae constitute the core of this atlas, since they are featured five times: First, they are marked in the the star charts of the whole sky. Second, they all have magnified finder charts. Third, their data is listed in the catalog of nebulae. Fourth, they all have descriptions, and fifth, their photographs are shown.

The catalog of stars contains 900 naked-eye stars. It is complete up to magnitude 4.0. There are 556 stars up to this magnitude. Most of the fainter listed stars are doubles or variables.

Explanatory Notes

Many thousands of double and multiple stars are observable with amateurs' telescopes. 250 interesting ones are listed in the table of binaries. Their components are at least magnitude 8.0, their combined light brighter than 6.0. Apart from a few very close binaries, all these can be separated in an amateur's telescope.

The tables also list data for 81 variable stars visible to the naked eye. Variable stars with a variation of at least a quarter of a magnitude were considered. All those which get brighter than fifth magnitude (and a few fainter ones) are included.

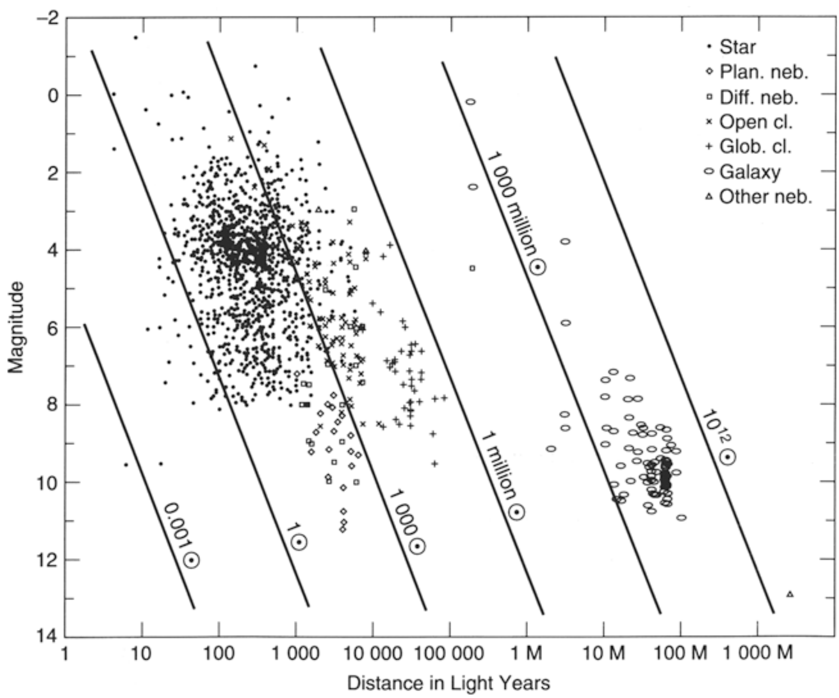

Figure 2: Apparent magnitude and distance of all 1427 objects cataloged in this atlas; binary components are indicated individually. The steep lines show the luminosity relative to the solar luminosity (if interstellar absorption is neglected).

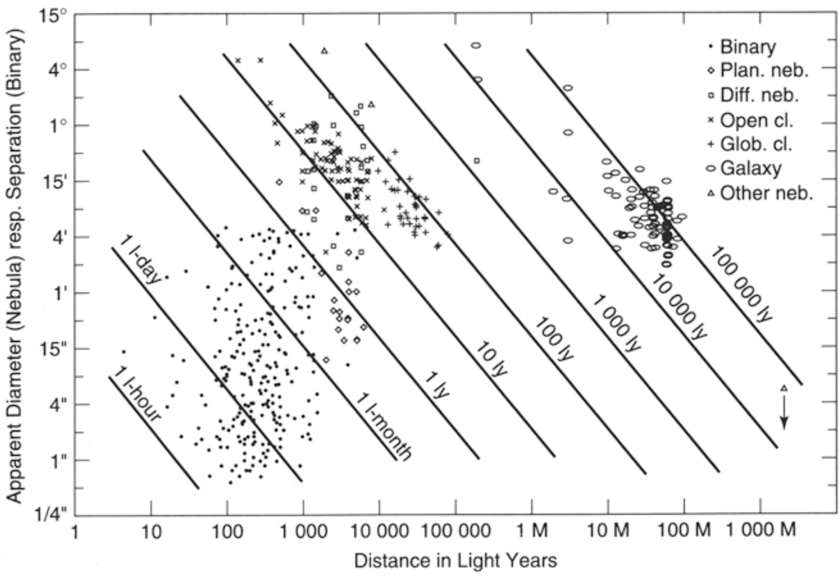

Figure 3: True size (inclined lines) as a function of apparent size and distance. The true size refers to the extent perpendicular to the line of sight. The radial extent is unknown for most objects. One light-hour is approximately 1000 million kilometers or seven astronomical units (AU).

Celestial Coordinates

In astronomy, many different coordinate systems are commonly used. To enjoy the night sky it is not necessary to tangle with the mathematics of coordinates. However, it is quite useful to become familiar with the most important coordinate system, the celestial equatorial system. One can imagine the equatorial system as a projection of the earth's longitude and latitude circles from the center of the earth onto the celestial sphere. Right ascension corresponds to geographical longitude; declination corresponds to geographical latitude. In the same way that Greenwich marks the zero meridian on earth, the first point of Aries serves as the zero point for the right ascension: it is the location of the sun on March 20/21. From there, right ascension is measured towards the east from 0° to 360°, or, more often, from 0^{h} to 24^{h} (hours) with $1^{\mathrm{h}} = 15°$. Declination increases as geographical latitude from 0° at the equator to 90° at the poles. Northern declinations are positive, southern ones negative. The position of a star is uniquely determined by its right ascension and declination.

Explanatory Notes

Precession

Since the first point of Aries slowly moves across the constellations, the coordinates of the stars are constantly changing. The coordinates in this atlas refer to the standard reference frame of J2000.0. By 2015, the coordinates will have changes by 0.2° or less so that the given coordinates can be used for most practical purposes without applying any correction.

Sidereal Time

The starry sky and the celestial coordinate system complete one revolution every day. Stars at the same declination describe the same orbit on the celestial sphere. After one sidereal day of 23^h56^m, every star is back at its original position. The sidereal time indicates the rotation since the first point of Aries passed the meridian. The meridian stretches from south to north, passing through the zenith. All stars reach their highest point on the meridian. At 0^h00^m sideral time the first point of Aries is on the meridian. At 1^h sidereal time stars with the right ascension 1^h are passing across the meridian, and so on. Knowing the current sidereal time defines the region of the sky which is visible best. Many planispheres have a dial to read off the approximate sidereal time.

Arrangement of Star Charts

In this atlas the whole sky is divided into 48 regions which are grouped into three sections: N = northern sky, E = equator and ecliptic, S = southern sky. The northern sky here means the area north of about 30° declination. From mid-northern latitudes, for example, it is clearly visible every night. The very first chart (NP = north polar region) contains stellar magnitudes to mag. 13 for estimating the limiting magnitude to the unaided eye, binoculars, and telescopes. The section for the equator and ecliptic contains declination zones where the sun, moon, and planets have their paths. Constellations in this region are only visible at certain times. Of course, they are best visible near the meridian. The sky south of −36° declination is labeled here as the southern sky. It cannot be observed north of 50° latitude. But further south more and more of the southern sky becomes visible. Northern-hemisphere observers should not miss the opportunity to observe the beauties of the southern sky when traveling south.

Within each of the three groups the charts are ordered in right ascension from 0 to 24. For example, the charts N12, E12, and S12 all display regions near 12^h right ascension. The objects in the tables are also ordered in right ascension, which increases from right to left in the charts. Furthermore, the even-numbered charts E0, E2, … mostly contain regions south of the equator, while E1, E3, … display regions mostly north of the equator. To find a particular chart quickly, consult the key chart at the end of the book.

Within each chart, bright stars and nebulae are labeled in the highlighted section. Data for these objects are listed on the page facing the chart. Objects in the grey section are labeled on other charts. Neighboring chart numbers can be found at the white-grey boundary.

In the catalog, each entry of a constellation is followed by a rectangle which represents the facing star chart greatly reduced. The object's location in the chart is indicated by a dot for the main star charts and by a small circle for the round enlargements (finder charts). This way, the object's position on the chart is located more easily than with coordinates and coordinate grids.

Directions in the Sky

On the earth we are very familiar with the direction of the four cardinal points. In the same way, directions are defined at each point in the sky. North is the direction to the celestial north pole near Polaris. West is the direction in which the sky is carried by the diurnal rotation of our planet. Therefore west is sometimes called preceding, and east is called following. When looking up at a constellation lying in the south, north is up, west is right, south is down, and east is left. We note that east and west on star charts are opposite to east and west on maps. However, in common with maps, all charts in this atlas have north at their top.

When comparing a chart with the sky it is important to know the directions in the sky in order to turn the charts until they match the sky. For comparison with rising constellations, the charts need to be turned somewhat counterclockwise, and clockwise for setting constellations. In an inverting telescope, directions are particularly important, even if they are not so clear. If you are not sure of them, just watch the motion of the stars through the eyepiece (clock drive off). They always move to the west. Further, notice that a standard diagonal gives a mirror image (if the total number of reflections is odd). You would need to look through a mirror at the charts in order to match the view in the eyepiece. Therefore the use of a standard diagonal is not recommended for deep-sky-object hunting. Diagonals with two reflections are only slightly more expensive than those with one reflection. They are the recommended choice for every work with star charts.

Size and Scale

Distance and size in the sky are measured in degrees, arc minutes, and arc seconds ($1^\circ = 60', 1' = 60''$). In this atlas, declination is given in degrees, the size of nebulae in arc minutes, and the separation of double stars in arc seconds. There are no mixed entries like 8°48′ or 3′12″. This latter practice is continuing to disappear from astronomical tables.

When using star charts it is important to have an idea about the scale of the charts. The star charts in this atlas have a scale of 4°/cm (10°/in.), the round enlarged sections 1°/cm (2.5°/in.). Distances in the sky can be quite accurately estimated with your hand. If you hold it about 60 cm from your eye, 1 cm on your hand corresponds to 1° in the sky. Once you have measured some sizes on your hand, you will always have a "handy" aid present at your observation sessions.

When observing with binoculars and telescopes it is very helpful to know the diameter of the field of view. You can estimate this by comparing it with the disk of the full moon, which is about 30′ = 0.5° across. Better still are data from the manufacturer, or your own measurements. For example, a field of 5° in binoculars corresponds to a 5 cm (2 in.) circle in the round enlarged sections of this atlas. For an observer with such binoculars, a transparency with circles of 1.25 and 5 cm (0.5 and 2 in.) diameter is a helpful aid since it shows the visible field in the main and finder charts. Trying to work with star charts can be difficult for the inexperienced observer, but it becomes easy by knowing direction and scale.

All maps and charts are somewhat distorted, because the sky is spherical and charts are flat. Therefore the scale is not constant. Star charts containing a large fraction of the whole sky (e.g. p. 164) necessarily have large distortions. For all other charts the distortion is kept low by using appropriate projections. These projections show all right-ascension circles as straight lines, perpendicularly intersecting the declination circles throughout. The scale in the direction north–south (declination) is 4°/cm (10°/in.), while the scale in the direction east–west varies a little around this value as shown in Fig. 4. The round enlarged sections are stereographic projections and are practically free of distortion because of the small area of sky shown.

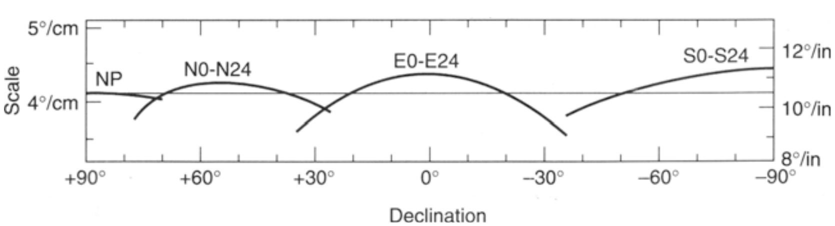

Figure 4: The scale of the star charts in the east-west direction, in the direction of right ascension (curves). The scale in the perpendicular direction (in declination) is 4°/cm everywhere (horizontal line). The difference between both scales is small; the charts are nearly undistorted.

Designations

There are many types of designation for astronomical objects. For the observer it is sufficient to be familiar with just the most important ones. Constellations are designated by their 88 official Latin names. Abbreviations for, and meanings of, the constellations are listed on pp. 158, 159. Bright stars are designated by the Bayer Greek letter and/or Flamsteed number, with the constellation name in the genitive, for example α Ori = Alpha Orionis = 58 Orionis. Latin letters are used for variables and stars without a Bayer or Flamsteed designation. Some stars also have names which are mostly spelled here according to their original form. Today their spelling varies in different languages. Names are not that useful for the identification of stars, except the most common ones which are printed bold in the tables. The pronunciation of these foreign names poses problems for many people who are not familiar with Latin, Greek, and Arabic. For simplicity the names are often pronounced just as if they were English. Actually, the original pronunciation is much simpler than today's English, since every letter is always used in the same way: a as [ah], e as [eh], i as [ee], u as [oo], c as [k], etc. ξ Cep is pronounced [ksee keh-feh-ee]. Of course, there is no right and wrong in pronunciation, just as a dialect is not a right or a wrong language.

Lower-Case Greek Alphabet

α	alpha	ε	epsilon	ι	iota	ν	nu	ϱ	rho	φ	phi
β	beta	ζ	zeta	κ	kappa	ξ	xi	σ	sigma	χ	chi
γ	gamma	η	eta	λ	lambda	o	omicron	τ	tau	ψ	psi
δ	delta	ϑ	theta	μ	mu	π	pi	υ	upsilon	ω	omega

In the eighteenth century, Messier cataloged 103 nebulae which were later extended to 110 objects. In a few cases his description is not clear, so that some people disagree with the generally accepted identification. Messier objects are designated by an "M". A much more complete list of nonstellar objects is the *New General Catalogue* (NGC) with the *Index Catalogue* (IC). NGC objects are labeled by the number alone, while *Index Catalogue* objects start with "IC". All the nebulae in this atlas are listed on p. 154.

Resolution

The eye has a resolution of $5' = 300''$: it can resolve double stars of $5'$ separation or more. Very good eyes can resolve closer binaries, like ε Lyrae, of $3.5'$ separation. Double stars with a very faint companion are more difficult. When observing with binoculars and telescopes, the resolution increases to 300″/power, assuming perfect optics. This equation yields the resolution data listed in Table 2 for six instruments. In the catalog of binaries, the visibility is indicated by a dice symbol showing how many of these six instruments each binary is accessible to. The binaries observable with each instrument are thus easily identified.

The resolution is also limited by the aperture and is in the best case 120″/aperture in mm (5″/aperture in in.). The resolution of the eye and the telescope match each other if the magnification is 2.5 times the aperture in mm (60 × aperture in in.). This is the highest efficient power. It can be used for binaries under good conditions. On the other hand, most nebulae require a much lower power.

Unfortunately, most standardly equipped telescopes come with high, and completely useless, magnifications, while the so-important low powers, with large fields of view, are missing. A long focal-length eyepiece can easily close this gap. The useful standard magnification is about ten times lower than the highest efficient magnification, that is aperture/4 (6 × aperture in in.). Many binoculars are optimal in this respect and easier to use than a telescope where such a magnification is missing. Many manufacturers like to save money on another part of the telescope as well: the finder. Many finders are made for long searching rather than quick finding. A good finder should have at least a 50 mm aperture and a 5° field of view. The purchase of a good finder can change frustrating searching into exciting observing. Note also that observing with binoculars is much more enjoyable if they are mounted on a tripod.

Table 2: Limiting magnitude and resolving power of six instruments under good conditions (dark sky, steady air, high in the sky, good optics). For nebulae one should decrease the limiting magnitude by one. For each instrument, the approximate true field of view and the true size of an apparently lunar-size object is also listed. The last column lists the number of observable binaries of the catalog. The visibility of binaries is classified into the six instrument classes by a dice symbol.

Instrument	Power	Aperture	Limit. mag.	Field of view	Lunar size	Resolution	Vis.	# of binaries
unaided eye	1×	6 mm	6	120°	30′	300″	⚅	–
opera glasses	3×	20 mm	8	15°	10′	100″	≥⚄	36
finder	6×	30 mm	9	7°	5′	50″	≥⚃	55
binoculars	12×	50 mm	10	4°	2.′5	25″	≥⚂	93
guide scope	60×	75 mm	11	50′	30″	5″	≥⚁	169
telescope {	35× 350×	150 mm	13	80′ 8′	50″ 5″	8″ 0.″8	≥⚀	247

Explanatory Notes

Adaption of the Eye

The human retina has cones and rods. The rods are the sensitive detectors necessary for the observation of nebulae. They are concentrated toward the edge of our field of view. Therefore, the experienced observer looks somewhat away from and not directly at faint nebulae in order to make them detectable. This important observing technique is called indirect vision.

When the rods have been blinded, even only for a moment, they need some 30 minutes to regain their full sensitivity. Since rods are sensitive to blue and green light, but not to red light, a deep-sky observer needs a red flash light. This way, one can read star charts without losing the adaption.

Magnitude

Brightness in astronomy is measured in (stellar) magnitudes, abbreviated mag. and sometimes denoted by a superscript ^{m}. The unaided eye can see stars to approximately magnitude 6, depending on sky conditions. Binoculars and telescopes reach to much fainter stars (see Table 2). The main star charts in this atlas represent the naked-eye view (limiting magnitude 6), while the round enlarged sections (finder charts) match the view in a finder or small binoculars (limiting magnitude 9).

Preceding the magnitude entry in the catalog is a small black dot indicating the printed size of the star in the main star chart. This simplifies the comparison between catalog and star chart. The brightest stars in the catalog are thus obvious.

Magnitudes of stars are accurately known. They are listed with one decimal. On the other hand, nebulae do not have well-defined circumferences. Thus their magnitude is very dependent on the area regarded as part of the nebula. It is not surprising that the magnitude of a nebula may differ by a full magnitude in different sources. Therefore, nebular magnitudes are given here to half magnitudes as was done in the New General Catalogue (NGC) more than one hundred years ago. The size and magnitude of a nebula refer in this atlas to what can be seen under a very dark sky. Under less-favorable conditions nebulae will appear fainter and smaller, while professional equipment can trace them further out. Table 3 lists magnitude systems for theoretically interested readers. For practical purposes, the difference of a few tenths of a magnitude between different magnitude systems is not noticeable and thus negligible.

When you actually observe nebulae, the total magnitude is often not as important as the surface brightness or brightness density per square arc-minute. (Both the total magnitude and the surface brightness are listed in the catalog under "v-Mag.") Nebulae with a high surface brightness (10/□′) allow high power (magnification). Thus they can be observed in moonlight or artificial light pollution. Fainter