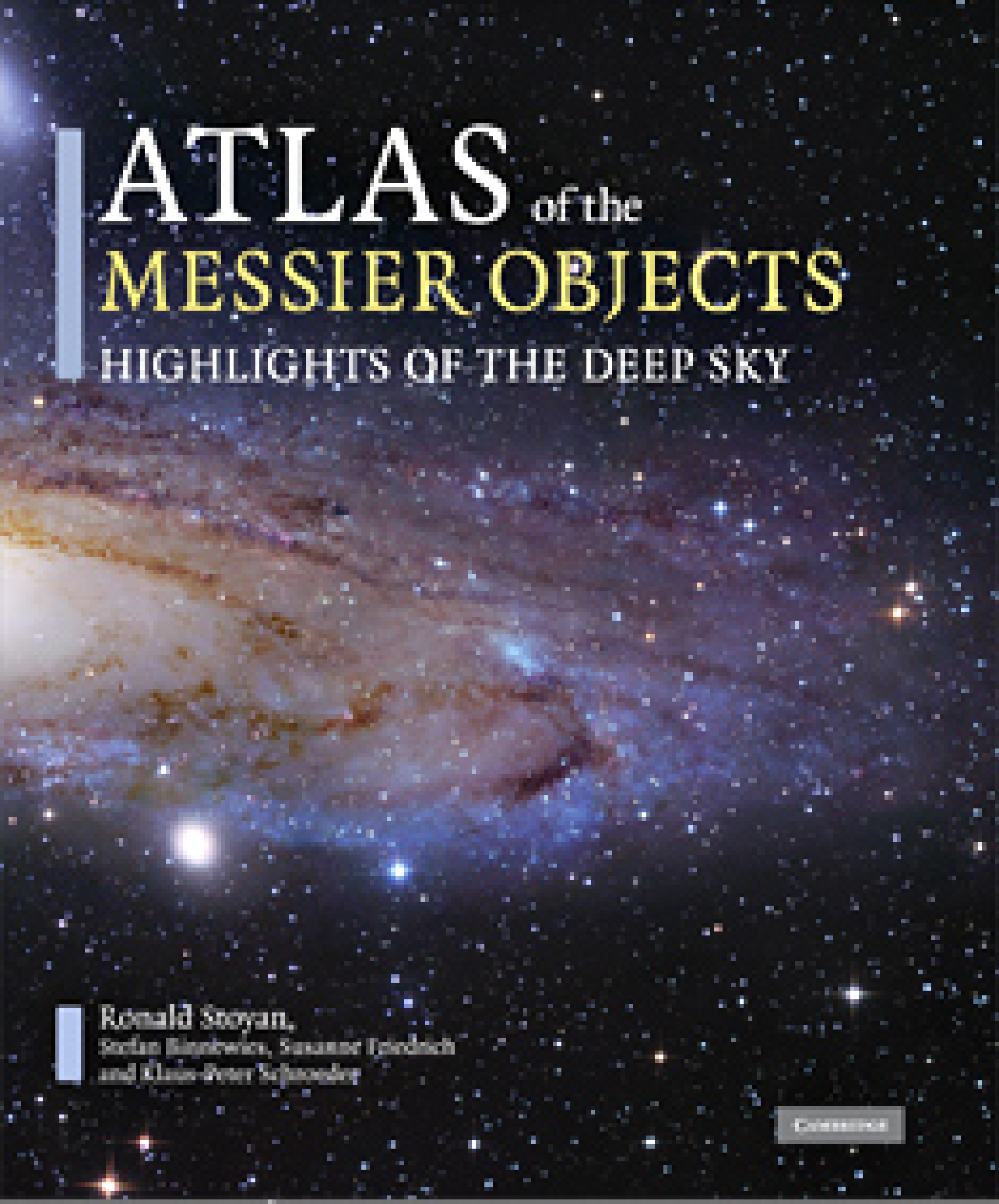


CAMBRIDGE www.cambridge.org/9780521895545

This page intentionally left blank

Atlas of the Messier Objects
Highlights of the Deep Sky

The 110 star clusters, nebulae and galaxies of Messier's catalog are among the most popular of all the deep sky objects and are beautiful targets for amateur observers of all abilities. This new atlas presents a complete account of all of the Messier objects, detailing, for each object:

- its astrophysical significance
- well-researched background on its discovery
- clear observational descriptions from naked eye through to large telescopes
- observations and anecdotes from Messier himself and other famous observers from the past

In addition, this atlas has some of the world's finest color astrophotos, inverted photos that have been labeled to point to hidden details and neighboring objects, and historical sketches alongside new deep sky drawings, helping to bring the Messier objects to life.

Painting an engaging portrait of Charles Messier's life and observations, this is the most far-reaching and beautiful reference on the Messier objects there has ever been, and one that no observer should be without!

RONALD STOYAN is editor-in-chief of *interstellarum*, one of Germany's main astronomy magazines. He was the founding director of the German deep sky organization 'Fachgruppe Deep-Sky', and has authored and coauthored six books on practical astronomy.

STEFAN BINNEWIES is a leading astrophotographer and travels around the world to get the best shots. He has worked on several amateur observatory projects, including helping to establish the Capella Observatory near Windhoek, Namibia.

SUSANNE FRIEDRICH is an editor for *interstellarum* and a visiting scientist at Max-Planck-Institute for extraterrestrial physics. A trained astrophysicist, she has been observing the sky both visually and photographically for more than 25 years.

KLAUS-PETER SCHROEDER is Professor of Astronomy at the University of Guanajauto, Mexico. An avid amateur astronomer and photographer since youth, he has published several books on astrophotography and is a regular contributor writing for amateur astronomy magazines.

Cover illustration: A majestic view of M 31, M 32, and M 110, our intergalactic neighbors. This image was taken by Robert Gendler in September and November, 2005. A 20-inch reflector was used at 4000mm focal length, total exposure was 90 hours with a SBIG CCD camera STL-11000XM, from Nighthawk Observatory, New Mexico, USA.

ATLAS of the MESSIER OBJECTS

HIGHLIGHTS OF THE DEEP SKY

Ronald Stoyan
Stefan Binnewies, Susanne Friedrich
and Klaus-Peter Schroeder

CAMBRIDGE
UNIVERSITY PRESS

CAMBRIDGE UNIVERSITY PRESS
Cambridge, New York, Melbourne, Madrid, Cape Town, Singapore, São Paulo

Cambridge University Press
The Edinburgh Building, Cambridge CB2 8RU, UK
Published in the United States of America by Cambridge University Press, New York
www.cambridge.org
Information on this title: www.cambridge.org/9780521895545

First published in print format 2008

ISBN-13 978-0-511-42329-1 eBook (EBL)

ISBN-13 978-0-521-89554-5 hardback

Dedicated to the memory of my brother Norman Stoyan (1975–2003)

Table of contents

Foreword

David H. Levy

Why yet another Messier catalog book? With Kenneth Glyn-Jones, Stephen James O'Meara, and Ken Graun, haven't we had enough? No, I say! And especially no when the latest addition to the canon is Ronald Stoyan's scholarly, historical, astrophysical, and superb look at the great comet hunter and the list of objects he compiled during his lifetime.

This book is the first scholarly look at the catalog since Glyn-Jones, and that effort is almost half a century old. Stoyan explores the latest astrophysical research concerning each of Messier's 110 deep sky objects. Stoyan could well devote his entire book to the astrophysics of Messier's first object, the Crab Nebula, and I still subscribe to the belief that I read years ago that astronomy has two parts: that of the Crab and that of everything else. From the first time I looked at M 1 on September 1, 1963, I've been fascinated by the ghostly luminescence of the Crab, but never more so than when it seemed ablaze again not with a new supernova, but with nearby Saturn visiting at nearly the same spot from which the original star first became visible on July 4, 1054.

Next comes the historical view: I cannot get enough of the life of Charles Messier, who lived, observed, searched, and suffered some two hundred years ago. This observer's life story is compelling, and Stoyan's retelling adds new material. Although he was not the first person to discover a comet with a telescope, Messier was most likely the first to organize a successful survey program specifically devoted to the search for comets. For that accomplishment he certainly deserves a place with the greats like William Herschel, Kaoru Ikeya, and Leslie Peltier. In Stoyan's biographical summary we learn a little more about Messier's famous accident, in which he fell into a pit. Although he recovered enough to resume his work, we know for the first time that he never *completely* got well again, and he finished his life with a continuing limp. A fortunate fall, to be sure, for he is lucky to have survived it in the first place.

What if Messier were to return to our time? He would be amazed at the ease by which visual comet hunting can be done, as well as the increased difficulty in finding a comet when well-funded electronic searches compete with amateur astronomers. With a computer star chart riding with my telescope, I know instantly what my telescope is showing at any particular moment. On the morning of October 2, 2006, for example, the chart showed a rich field of stars with the planet Saturn in the field center; it did not display, however, the faint fuzzy spot that turned out to be my 22nd comet discovery, a new comet that will make a close approach to the Earth when it returns at the end of 2011. Messier obviously did not have such technology at his disposal; he used his telescope and a printed star atlas, trusted friends that remained the classic way to search the sky until just a few years ago.

For all of Messier's brilliance, his famous catalog was primarily an observing tool, and Stoyan's writing confirms this crucial footnote to history: by keeping a record of the objects that could be mistaken for comets, Messier provides himself and posterity an invaluable resource. The pages you are about to read delve further into what his list looks like after 200 years, and particularly the astrophysics that lies behind each of the clusters, nebulae, and remote galaxies that constitute it. Stoyan does not take a position on one of the questions of our time – should the double cluster in Perseus be added to the list?

Yes, there is a need for "yet another" Messier catalog book. Stoyan has done a masterful job giving his readers a modern look at Messier's greatest accomplishment. May this book inspire you to learn about the man and his project, and more importantly, may it encourage you to don a coat, grab a telescope, and enjoy this window into the deep sky for yourself.

Preface

The catalog gathered by the French astronomer Charles Messier (1730–1817) has been the most popular compilation of astronomical objects beyond our Solar System for more than 200 years. It contains 110 star clusters, nebulae, and galaxies, among them most of the brightest and finest deep sky highlights that are visible from northern skies.

Amateur and professional astronomers alike have turned their telescopes time and again to the Messier objects. Numerous books have covered them, and numerous websites attest to their unwavering popularity. However, a current overall picture of the catalog and its objects was missing, as much information currently disseminated is actually outdated. So, for the first time since Robert Burnham's famous *Celestial Handbook*, a thoroughly investigated new account with historical, astrophysical, and observational information on all the objects had to be conducted.

Many discrete tasks were associated with this book. Historical information on Charles Messier, his observations and his catalog had to be compared to latest level of knowledge. In addition to our own research, the biography published by Jean-Paul Philbert in the French language proved especially helpful. The main task was the compilation of recent astrophysical information on all of the objects. More than 500 scientific papers were compiled and evaluated. These texts are complemented by extensive observational notes, which incorporate the visual use of large modern reflectors.

A major part of the book is the more than 150 fantastic photos by leading amateur astrophotographers from all over the world. Occasionally, these images are accompanied by photographs from the Hubble Space Telescope, where this adds value. In addition, an extensive collection of visual drawings is shown, both from the classical era of the nineteenth century, as well as modern sketches drawn by the author himself.

The compilation of this book took much effort over the past five years. Many of the images were prepared exclusively from such exotic spots as Greece, Chile, and Namibia. They combine more than 5000 minutes of photographical exposure and 150 hours of visual observation. From the original German edition, which was released in 2006, information and photos have been updated and improved.

I owe a very personal thank you to the co-authors of this book. Stefan Binnewies, the well-known German astrophotographer, conducted the orchestra of his colleagues. Susanne Friedrich, professional astronomer and amateur alike, ensured the quality of the astrophysical information. Finally, Prof. Klaus-Peter Schroeder, also a professional astronomer, who has worked in the United Kingdom and the United States for decades, translated and updated the texts.

A deeply felt thank you goes to the astrophotographers who contributed so much to this book, especially to the teams of Volker Wendel and Bernd Flach-Wilken, Josef Pöpsel and Dietmar Böcker, and Robert Gendler and Jim Misti. I would also like to thank Lutz Clausnitzer, Klaus Wenzel, Arndt Latusseck, Wolfgang Steinicke and Matthias Juchert, who helped in many respects on the German edition.

The fact that this book appears in an English language edition is almost a miracle. Among the many people who have helped that this dream became reality are Owen Brazell, David Eicher, Phil Harrington, Yann Pothier, and Stewart Moore. Additionally, I am greatly indebted to Sue French, who proofread the manuscripts and supported this project to a very great extent, and David Levy, who authored the foreword in his unparalleled manner. Finally, I would like to thank Vince Higgs and the team at Cambridge University Press for their support, work, and faith.

May this book give you new insights into your favorite deep sky highlights.

Erlangen, Germany
Ronald Stoyan

User guide

The data files

Degree of difficulty: rating of the observational difficulty:

1 object easily visible to the naked eye
2 object difficult to see with the naked eye
3 object easily visible in 8×30 binoculars
4 object easily visible in 10×50 binoculars
5 object difficult to see with 10×50 binoculars

For more information about visual and photographic difficulty, see page 63.

Minimum Aperture: minimum aperture required to see the object under a dark mountain sky, according to the personal experience of the first author. There are four categories:

- naked eye
- 15mm
- 30mm
- 50mm

Designation: catalog number in the NGC (New General Catalogue) or the IC (Index Catalogue).

Type: Object type. For a more detailed introduction to the different types, see page 53.

Class: Classification of the object, specific to its type:

- Galactic nebulae: distinction between emission nebula and reflection nebula, see page 53
- Open clusters: Trümpler classification, see page 55
- Globular clusters: concentration class, see page 56
- Galaxies: Hubble classification scheme, see page 61

Distance: Distance from Earth in light-years. As far as possible, uniform sources have been used, i.e.:

- galactic nebulae and open clusters: K2005 (Kharchenko, N.V., et al.: "Astrophysical parameters of galactic open clusters," Astronomy and Astrophysics 438, 1163 (2005)
- globular clusters: Rww2005 (Recio-Blanco, A., et al.: "Distance of 72 galactic globular clusters," Astronomy and Astrophysics 432, 851 (2005)
- galaxies: H2000 (multiple authors: "The Hubble Space Telescope Key Project on the Extragalactic Distance Scale," Astrophysical Journal 529, 698, 745, 786 (2000)
- Virgo cluster galaxies: V2004 (Sanchis, T., et al.: "The origin of HI-deficiency in galaxies on the outskirts of the Virgo cluster. II. Companions and uncertainties in distances and deficiencies," Astronomy and Astrophysics 418, 393 (2004)
- Virgo cluster galaxies: V2002 (Solanes, J.M., et al.: "The Three-dimensional Structure of the Virgo Cluster Region from Tully-Fisher and HI data," Astronomical Journal 124, 2440 (2002)
- extragalactic HII regions: HK83 (Hodge, P.W., Kennicutt, R.C., Jr.: "An atlas of HII regions in 125 galaxies," Astronomical Journal 88, pp. 296 (1983)

In addition, alternative results have been quoted, in order to demonstrate the uncertainty of the distances given. If available, the distance measurement method is indicated.

Size: physical diameter of the object, as calculated from its actual distance and angular diameter. The resulting values may differ from the ones stated by original sources. Spiral galaxies seen under some inclination may be underestimated.

Constellation: Latin name of the constellation in which the object is located

R.A.: Ascension for the equinox 2000.0

Decl.: Declination for the equinox 2000.0

Magnitude: apparent total visual brightness

Surface brightness: mean visual brightness in magnitudes per square arcsecond (not given for star clusters)

Apparent diameter: apparent (angular) photographic diameter

The texts

History

The historical sections include translations from the original quotations of historic observers from the seventeenth to the early twentieth century. In part, these have been translated from the original. Where not available, they had to be taken as quotes from secondary literature. English quotations are given, as far as available, in their original wording.

Frequently, the term "resolution" (of an object) is used in historic texts – not just for star clusters, but for galaxies and nebulae as well. In the nineteenth century, that did not necessarily mean the resolution into individual stars, as we use the term today, but rather resolution of any kind of detail.

A short introduction to every historic observer quoted in this book can be found on page 28.

Astrophysics

Ever since the publication of the famous "Burnham's Celestial Handbook" in the 1970s, amateur astronomers have been waiting for a new, up-to-date compilation of astrophysical data on all Messier objects. A lot of literature, internet sources in particular, refers to outdated values.

For this book, the content of over 500 professional, up-to-date publications was researched. This was made possible by the use of the Internet and the free NASA service known as the Astrophysical Data System (ADS), which is an on-line collection of almost all scientific publications in astronomy. The exact citations are given in the Appendix.

Where possible, no sources older than 10 years were used, but a few objects have received little attention in modern references. Other objects (M 1, M 31, M 42) catch a lot of professional attention, and the vast amount of literature dealing with them would easily permit a much more detailed treatment. However, space restrictions limited this book to the most relevant information.

In many cases, the research presents surprises: modern scientific results often disagree completely with what is commonly believed as the result of outdated literature. This trend will continue, as there is a steady stream of new observations and their astrophysical interpretation. Hence, the statements made in this book must be regarded as only a momentary picture of our knowledge from the years before 2007. Many questions remain unanswered, and we expect new insight into topics such as dark matter, black holes or the age of the Universe. This may affect how some aspects of the Messier objects will be explained in the future.

Another common problem is the disagreement of modern sources from one another. Different authors have different opinions, and different methods yield different results. Generally accepted knowledge grows out of long debate and testing. This is part of the lively nature of a quickly developing science such as modern astrophysics.

Observation

The information and advice given for the visual observation of each object is based on the personal experience and observation of the first author, using telescopes of different apertures. Each object has been observed on several occasions, some more than a dozen times. The instrumentation used consisted of:

- 3.5×15 opera glass, "Theatis" made by Carl Zeiss Jena
- 8×30 binoculars, "Deltrintem" made by Zeiss Jena
- 10×50 binoculars, "Dekarem" made by Carl Zeiss Jena
- 20×100 binoculars, made by Miyauchi
- 120/1020mm (4.7-inch) refractor "Star 12ED," made by Astro-Physics, magnifications from 25× to 255×, in exceptional cases 340× and more
- 360/1780mm (14-inch) Newtonian on a Dobsonian mount, magnifications from 45× to 593×, entirely manual operation, observing sites in the German countryside (Kreben, naked-eye limiting magnitude 6.5, sky surface brightness 21.0 mag/arcsecond^2) and Austrian Alps (Tiefenbachferner, naked-eye limiting magnitude 7.0 mag, sky surface brightness 21.6 mag/arcsecond^2)
- 500/2500mm (20-inch) Newtonian on a Dobsonian mount, magnifications from 63× to 625×, Farm Tivoli, Namibia (naked-eye limiting magnitude 7.5, sky surface brightness 21.8 mag/arcsecond^2)

Observing comments refer to a very experienced observer and excellent observing sites with a dark, moonless sky. We have purposely omitted star charts and all advice on finding the objects, since there is already a vast literature on these aspects, useful even to the first-time observer. However, we recommend a versatile software-based approach, "Eye & Telescope." It produces star charts and visibility information based on actual sky conditions and the instrument used.

The pictures

Selected images showcase the fantastic results of the amateur astrophotographer's community. To document astrophysical aspects beyond the reach of amateur photos, we have complemented the material with NASA pictures of many Messier objects, obtained by the Hubble Space Telescope (HST).

Some Messier objects are particularly popular with amateurs, and good images are abundant. Others grab almost no attention and only a few pictures of lower quality are available. It's virtually impossible to get photos of uniform quality for all 110 objects. For this reason, the scale and depth (i.e., limiting magnitude) of the photos vary from object to object.

The photos printed in this book were taken in the years between 1995 and 2007. The most common technique is tri-color (red, green, blue) photography with a cooled CCD camera and (L)RGB filter wheel. With a few exceptions, traditional film-based photography can no longer compete, while the new era of digital cameras and DSLRs is just about to begin. For accurate technical information on each picture, refer to the picture credits in the appendix section.

The color reproduction is neither uniform, nor should it be regarded as quantitatively correct. Color-balance and saturation depend on a number of factors, such as chip-characteristics, filter-transmission, software and personal judgment during image processing. The result is often subjective, perhaps aimed at reproducing the colors of professional photos. After all, techniques of absolute color calibration are time-consuming and do not apply to some types of astronomical objects, most notably the emission nebulae.

The techniques used by amateur astronomers for their image-processing work differ a lot from person to person, and there are no general standards. Some photographers would remove traces of planetoids, satellites or ghost-images by hand, on a pixel-to-pixel basis, others accept them as part of the authentic picture. Composite images made from several different exposures change the perception of the intensity range. This technique is used to accommodate large intensity variations and to avoid "burnt-out" central regions. But it may make stars on bright nebulous background appear significantly less brilliant than they are in reality. A good example is the Trapezium in the Orion Nebula. Hence, a quantitative interpretation of such a photo is impossible, but amateur astrophotographers are happy to accept that, in order to produce the most appealing image of an object.

Together with the photographs, historical and modern drawings have been reproduced here. The manual sketch of an object as perceived through the telescope eyepiece was the only scientific method of recording until the late nineteenth century, after which photography finally took over. This book shows a large number of fine sketches from the pre-photographic era. Differentiating real physical changes in the objects from artistically diverse sketching styles and personal

A photo in the works: M 42. At left is a single image taken with the green filter, in the middle a raw tri-color image, at right the fully processed LRGB composite.

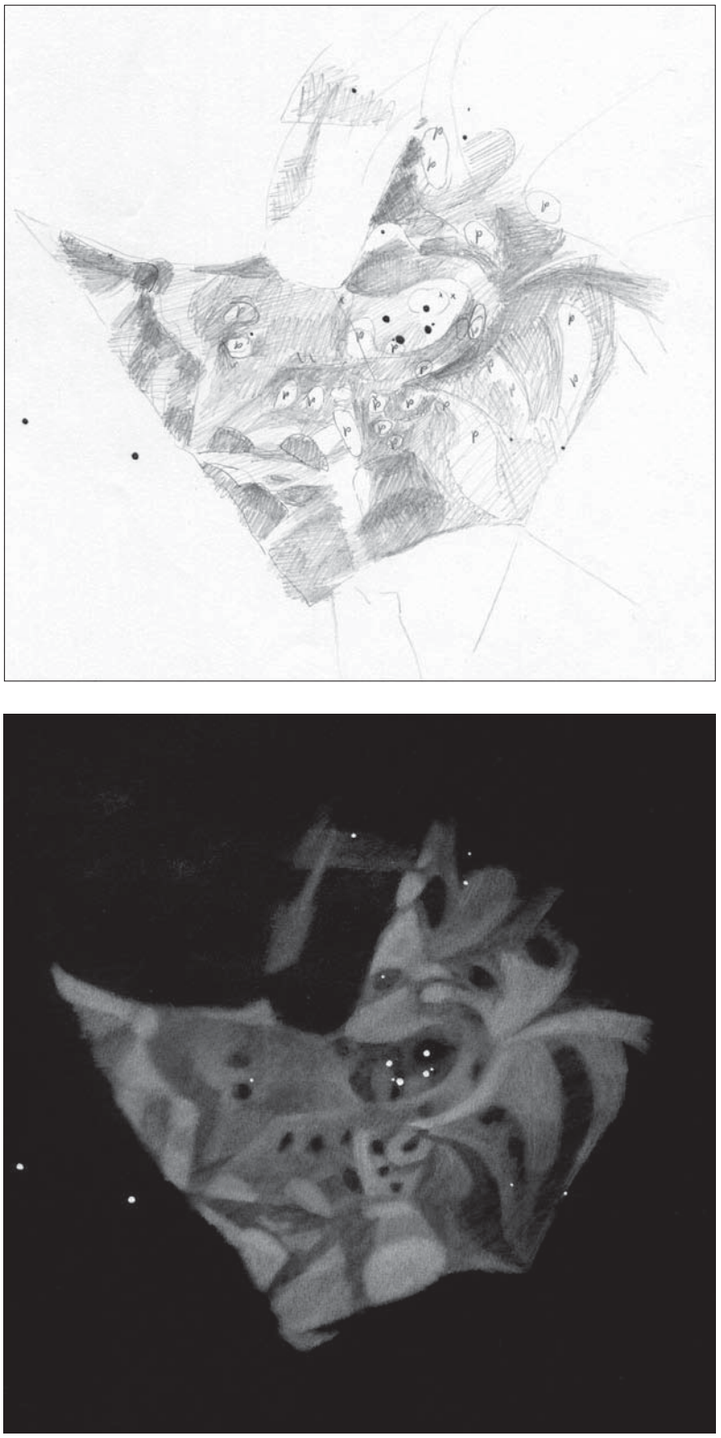
perceptions had been a continual problem. Today, amateurs keep the tradition of astronomical drawings alive, in order to sketch their visual impression of a specific object.

Drawings are subjective and contain erroneous perceptions. Nevertheless, this method is an independent recording technique, complementary to the capabilities of photography. Before criticizing historical drawings for their misconceptions, we should keep in mind that it is always easier to verify a known feature than to discover it. In that sense, the historic drawings must be regarded as more "honest" than their modern counterparts. Even the most critical modern observer cannot avoid the subconscious knowledge of an object by modern photography and its influence on his or her perception of it.

Drawings differ from photographs in a number of ways. For one, the eye can not accumulate light over a long time, as a photographic emulsion or chip can. Furthermore, the visual response to a large brightness range is much more logarithmic than the photographic response. And finally, the spectral response of the eye also differs from that of photographic emulsions or chips. With emission nebulae, in particular, visual and photographic views emphasize different features.

The author's drawings were specifically made for this book. The objects were observed several times with different apertures. Frequently, several attempts were required before an acceptable result was achieved. All the sketches are of a cumulative nature: each drawing summarizes the visual impressions of an object collected over many hours or even nights under a dark sky in the countryside, in the mountains or in the Namibian desert. The results are not to be confused with a quick sketch made by the eyepiece! The observing time involved was at least an hour, as for a simple elliptical galaxy, and up to three nights for large objects with a lot of detail.

The original sketches are drawn with pencil, black on white. So are the proper drawings, using in addition an eraser and a smudging tool. For an inversion to white on black, the drawing is scanned and the tonal range adjusted, but no further digital manipulations are made. Subtle contrasts are over-pronounced by the drawings, as they would otherwise be lost in print.



A drawing in its work-stages: M 42. Above is the original pencil sketch, below the properly redrawn and then inverted result.