

A PHOTOGRAPHIC ATLAS OF SELECTED REGIONS OF THE MILKY WAY

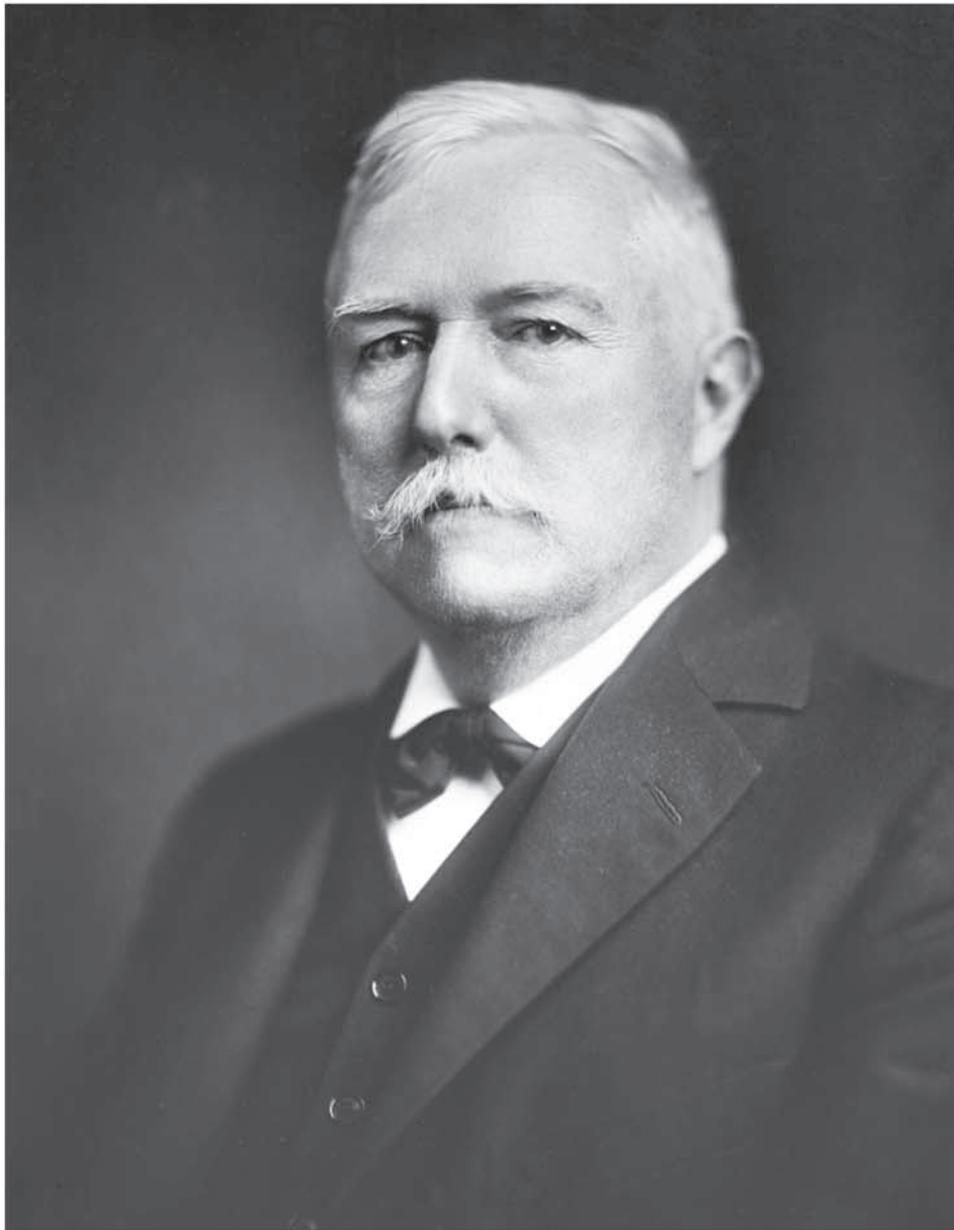
Edward Emerson Barnard's *A Photographic Atlas of Selected Regions of the Milky Way* was originally published in two volumes in 1927. Together, these volumes contained a wealth of information, including photographic plates of the most interesting portions of the Milky Way, descriptive text, charts, and data. Only 700 copies were printed, making the original edition a collector's item.

Reproduced in print for the first time, this edition combines both volumes of Barnard's *Atlas*. It directly replicates Barnard's text, and contains high-resolution images of the original photographic plates and charts, reordered so that they can be seen together. It also includes a biography of Barnard and his work, a Foreword and Addendum by Gerald Orin Dobek describing the importance of the *Atlas* and additions to this volume, and a fold-out section with a mosaic of all 50 plates combined in a single panorama.

EDWARD EMERSON BARNARD (1857–1923) is revered as one of the greatest observational astronomers of all time. He made many important contributions to astronomy, including discovering the fifth moon of Jupiter, making him the first person to discover a new moon of Jupiter since Galileo; discovering the star with the greatest proper motion, Barnard's Star, in 1916, which is named in his honor; and through his observations of a nova where he noticed the gaseous emissions and deduced that it was a stellar explosion.

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Edward Emerson Barnard
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EDWARD EMERSON BARNARD
1857–1923

A PHOTOGRAPHIC ATLAS OF SELECTED REGIONS OF THE MILKY WAY

BY

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*Professor of Practical Astronomy in the University of Chicago and Astronomer
at the Yerkes Observatory 1895–1923*

EDITED BY

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REPUBLISHED UNDER THE DIRECTION OF

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PART I AND PART II
PHOTOGRAPHS AND DESCRIPTIONS
CHARTS AND TABLES



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Most lovingly dedicated to

Kitten

for putting the twinkle into the stars in my eyes

Gerald Orin Dobek

CONTENTS

<i>Foreword</i> by Gerald Orin Dobek, FRAS	<i>page</i> ix
<i>Preface</i> from the original <i>Atlas</i>	xi
<i>Addendum</i>	xiii
Introductions to Book I and Book II from the original <i>Atlas</i>	1
Catalogue of 349 dark objects in the sky	21
Catalogue of 352 dark objects in the sky in J2000.0 co-ordinates	33
Photographs, charts, tables and descriptions	43
Biography of Edward Emerson Barnard by Gerald Orin Dobek	355

FOREWORD

I WAS twelve years old when I first discovered Edward Emerson Barnard's famous work, *A Photographic Atlas of Selected Regions of the Milky Way*. In my continued explorations of the life of E. E. Barnard and his work, and through my personal discoveries of the cosmos, I noticed a striking set of parallels between his life and mine that made strong my devotion to his work. We were both born in December exactly 100 years apart: Barnard in 1857 and I in 1957. Barnard came from an impoverished family and grew up in civil unrest and war in America. My beginnings were much the same, and although the civil unrest was in Vietnam, it had permeated into everyday American life. At the age of nine, we both entered the workforce outside the home in an effort to financially assist our families. We both struggled through our education, always keeping a focus on our passion for astronomy. And, like Barnard, I've devoted my life to observational astronomy, with a fanaticism for the dark nebosity within our Galaxy.

Barnard spent most of his astronomical career photographing the night sky. What he captured in those images provided greater detail than the eye could discern through the telescope. The most interesting regions found in these photographs were dark patches that Barnard called "black holes"; unique objects that are, of course, not the black holes that astronomers refer to today, but masses of dust and gas silhouetted against the brightness of the Milky Way. His catalogue of this dark material set the stage for future astronomers like Bart Bok, who correctly theorized that many of these dark regions are, in fact, the birthplaces for new stars. Barnard passed away in 1923 and his catalogue of these regions has been expounded upon by Khavtassi (1960) and Lynds (1962) and the list has grown to over 7000 such objects.

His finest work was not printed until four years after his passing: *A Photographic Atlas of Selected Regions of the Milky Way*, first published by the Carnegie Institution of Washington in 1927, containing 50 of

Barnard's greatest photographs. Only 700 copies of the original atlas were printed, and Barnard himself had reviewed each of the 35 700 individual photographs that were later bound into the atlases. Today, many of the original atlases are lost, while most of the remaining few reside at major institutions. Unfortunately, few in the astronomy community have had the opportunity to view the photographs.

It is my desire that the rebirth of Barnard's *Atlas* will somehow spark the interest of all astronomers, from the avid stargazer and amateur to the professional astronomers, to look beyond the bright areas of the sky and see the holistic picture of the Universe around us; and to the greatest extent that Barnard had inspired this in me.

In republishing this fine *Atlas*, I have endeavored to retain all of the original material from the two-volume set. Included in this edition is my humble attempt at fulfilling Barnard's dream of compiling a complete photographic atlas of the Milky Way. I have created a final photograph, plate number 52, which is a mosaic comprising Barnard's 50 photographs spanning the galactic plane within the regions of his work. The addendum explains the process in producing this republication along with the additions in this volume.

It is most fitting that I acknowledge those who have assisted me in putting forth this edition of Barnard's great *Atlas*. I heartily thank Dr. Graeme L. White (James Cook University (JCU), Australia), for it was his idea that I republish this *Atlas*. I wish to acknowledge Alex Hons (JCU), Dr. Miroslav Filipovic (University of Western Sydney, Australia), and Dr. Andrew Walsh (JCU) for their guidance in my studies. I also want to thank my colleagues at Northwestern Michigan College, too numerous to list, for tolerating my craziness. I want to express my appreciation to Cambridge University Press, especially Vince Higgs, Lindsay Barnes, and Chris Miller, for undertaking this reproduction. To Adam and Kelly, thank you for understanding your father's late-night work and constant busyness.

GERALD ORIN DOBEK, FRAS
Professor of Astronomy, Northwestern Michigan College
 22 December 2009

PREFACE

THE publication of this *Atlas*, in accordance with the desires of Professor Barnard, was assured by a grant made by the Carnegie Institution of Washington in 1907. The long delay in its appearance calls for an explanation. Mr. Barnard was in the throes of preparing for publication a volume of his pioneer celestial photographs made at the Lick Observatory in the years 1889-1895. He had difficulty in satisfying himself that any mode of reproduction could adequately depict the qualities of the original photographs.

That handsome work, which forms Volume XI of the *Publications of the Lick Observatory*, was not printed until 1913. It was natural and proper that the preparation of the present volume should have been delayed while the task of completing the earlier volume was in hand. The mode of reproduction to be adopted for the splendid photographs of this *Atlas* had not been selected at the time the original grant was made, and consequently considerable investigation and experiment were necessary in reaching a decision on this important matter. The attempts made with the photogravure and other processes did not give the assurance of uniformity that was desired, and finally the author was persuaded that actual photographic prints would be more satisfactory and hardly more expensive than any other available method of reproduction. After this decision had been reached and had been approved by the Carnegie Institution of Washington, Professor Barnard began the task of making the reproducing negatives, and then took upon himself the heavy duty of personally inspecting every print of the 35,700 needed in the issue of an edition of 700 copies. He made frequent trips to Chicago during the years 1915, 1916, and 1917 for this purpose and spared no pains to assure himself that the prints were uniform in quality and faithfully represented the originals.

The printed descriptions were written by him after a most careful study of the prints as well as of the original negatives. Professor Barnard's well-known eagerness to observe the heavens whenever the sky was clear left him little time for the remainder of the preparation of the work for publication. The reduction and publication of current observations had, with him, the right of way, and therefore it was not until late in 1922 that the first draft of the descriptions of the photographs was ready. Unfortunately, the form of publication of the whole of the *Atlas* had not been settled up to the time of Mr. Barnard's death, although we had had many discussions upon the subject. It had been decided that, in addition to the photographs, there should be given

pen-and-ink sketches of the fields, with a system of co-ordinates by which the positions of all distinctive markings and other objects of interest could be readily noted. The form of the tables, giving further details of objects designated on the charts, had been arranged for the most part by Professor Barnard. The plan of issuing the work in two parts, so that the student of the *Atlas* can simultaneously have before him the photograph, its description, the key charts, and the tabular data of the objects designated, has been adopted after Mr. Barnard's death, but I believe that it would have had his approval.

In the case of the text descriptive of the photographs, the wording which Professor Barnard used has been preserved as closely as possible. Square brackets have been occasionally placed about sentences or paragraphs for which responsibility could not be assigned to the author. He left many scattered notes intended for the Introduction. These have been utilized as far as possible in carrying out the author's intention. His notes and comments were written down at times within a period of nearly a decade, during which his own views were changing and becoming more definite in certain directions. For example, when the *Atlas* was first planned, Professor Barnard certainly did not entertain the view that the dark markings could be anything else than vacancies in the sky. But his minute study of his many photographs gradually convinced him of the correctness of the views advanced by some other astronomers that these were dark or faintly luminous objects. The reader may easily detect the course of this changing opinion, although it could not always be brought out in its proper chronological sequence.

The increasing interest in these dark objects, as their nature has thus come to be better understood, has seemed an adequate reason for including in Part I "The Barnard Catalogue of Dark Objects," now reaching the number of 349. These will probably be designated most conveniently in the future by their numbers in this catalogue, as B 170 or B 250, etc. Hundreds more of them will doubtless be located and described on these photographs or on others by future investigators.

The title assigned in 1907 to this work was *An Atlas of the Milky Way*. It was not until much later that the final choice of areas to be included was made by Professor Barnard. That title implied that at least a large part of the Milky Way was included. This would have required from three to four times the number of photographs for which provision could be made. Accordingly, it seemed to me best, after the

printing was begun, that the title should be changed to its present form, which correctly indicates that the *Atlas* deals with selected areas of the Galaxy and that it does not attempt to include more. The diagram on page 14 of the Introduction will give a proper idea of the distribution of the plates over the Galaxy.

During the years of work on the *Atlas*, Mr. Barnard wrote several of his most important articles on the Milky Way for appearance in the *Astrophysical Journal*. The following may be especially cited: "Dark Regions in the Sky Suggesting an Obscuration of Light," *Astrophysical Journal*, **38**, 496–501, 1913; "A Great Nebulous Region Near Omicron Persei," *ibid.*, **41**, 253–258, 1915; "Some of the Dark Markings in the Sky and What They Suggest," *ibid.*, **43**, 1–8, 1916; "On the Dark Markings of the Sky with a Catalogue of 182 Such Objects," *ibid.*, **49**, 1–23, 1919.

It was the author's expressed intention to use freely in his Introduction extracts from these papers, since, as he said, they correctly express the opinions held by him at the time of the conclusion of his work on the *Atlas*. Limitation of space has not permitted the inclusion of many such extracts, and the reader is therefore advised to consult these papers in his use of the *Atlas*. Attention is called to the bibliography of Professor Barnard's principal papers in the field of celestial photography, printed on pages 15–17 of the Introduction.

The writer could hardly have undertaken the responsibility of completing this unfinished work upon the death of Mr. Barnard, had it not been possible for the Observatory to retain the services of Miss Calvert, who, as Mr. Barnard's personal assistant, had been associated with the undertaking from its beginning. She had assisted the author in laying out a system of co-ordinates on the key charts, which she sketched under his personal supervision. She also began with him the preparation of the tables of objects noted on the charts, and later completed these, besides checking, with meticulous care, all numerical data for both parts of the *Atlas*. She also completed the supplementary list of dark objects begun by Mr. Barnard, determined their positions, and assigned them their numbers. I hereby express to her my appreciation of her large share in the editorial duties.

I wish also to thank the officials of the Carnegie Institution of Washington for their patience in waiting for so many years for the publication of this work and for the generosity with which they have supported it. I desire also to acknowledge my appreciation of the care and attention which has been given to this publication by the University of Chicago Press, and in particular by Mr. A. C. McFarland, manager of its Manufacturing Department. An acknowledgment of the fine service rendered by the photographers, Messrs. Copelin, has been given on page 13.

To all astronomers and most of the amateurs of the present generation, the remarkable observational achievements of Edward Emerson Barnard are familiar. Since this *Atlas* may come into the hands of some who have had little acquaintance with the development of astronomical photography it may be appropriate to say a few words regarding the career of Mr. Barnard to whom this *Atlas* may be considered in some sense a memorial volume.

Born at Nashville, Tennessee, on December 16, 1857, he had little opportunity for education, owing to poverty. The mystery of the starry heavens caught his attention as a lad, and almost his first purchase beyond actual necessities was a telescope with which he might penetrate farther into the illusive study of the details of the nocturnal sky. As a small boy and until young manhood, he supported himself by working at Nashville in a photographic establishment in which he learned all the details of the art, an invaluable preparation for the future application of this knowledge to the celestial field. He discovered many comets, nebulae, and other objects of interest, with his small visual telescope, and later took courses at Vanderbilt University. He made such a name for himself that he was called to be an astronomer on the staff of the Lick Observatory at its inauguration in 1888. This brilliant period of discovery and observation continued until 1895 when he came to the University of Chicago to be an astronomer at the Yerkes Observatory. Here he labored with extraordinary assiduity and with distinguished success, from the opening of the Observatory in 1897 until ill health put an end to his observations at the close of 1922.

EDWIN B. FROST
 31 May 1927

ADDENDUM

EVERY effort was made to reproduce Edward Emerson Barnard's *A Photographic Atlas of Selected Regions of the Milky Way* (hereafter referred to as the *Atlas*) in a form as close as possible to its original. Some changes will be obvious, while others are noted here. The *Atlas* was published in 1927, more than four years after Barnard's passing. It was printed in a two-volume set: "Photographs and Descriptions" as Book I, and "Charts and Tables" as Book II. This edition incorporates the two books into one single volume, and references to "Book II" should be disregarded. It was felt that combining the two books into one volume would allow for easy reading and convenience for libraries.

This edition is set out such that the Descriptions are followed by the Tables, while the Charts and Photographs are on facing pages. This allows the reader to view both the Chart and accompanying Plate side by side, and if the interim page is held vertical, one can also read the Description and view the Plate simultaneously. The layout of Description followed by Table, then Chart and Plate, is similar to the layout of the original two-volume edition. The Charts, which were hand-drawn by Mary Calvert under the direction of Professor Barnard, are very accurate in the positioning of the stars and dark objects and one can locate an object from the Chart to the Plate by using a ruler. The scale of both the Charts and Plates are provided and remain as accurate as the original edition.

The text was reset to match that of the original edition. It was decided to do this as it provides the appearance of a "facsimile," although some editing for typographical errors and spacing was necessary. The additions to the *Atlas* by this author were set in the same font. The changes and corrections may be viewed in a separate document on the website for Cambridge University Press at www.cambridge.org/9780521191432.

The process of reproducing this *Atlas* is the culmination of over two years of work. First, the entire text from an original copy of the *Atlas* from 1927 was scanned, page for page, using an Epson Expression 10000XL large-format color scanner. The Introduction, Descriptions, Tables, and Charts were scanned at 600 dots per inch (dpi) and the Plates were scanned at 2400 dpi. The scanned files were saved in Tag Image File Format (TIFF). The text files were imported into Adobe Illustrator and made into a "back layer" that was used

as a template to retype the text. A font that closely matches the original type-set was selected and all the text was retyped over the template. Adjustments were made to align the text for font size and spacing to match the original *Atlas*. Where special characters were used and not available in the modern character set, they were created so as to match the original. The "back layer" was then eliminated. The line borders for the "hand-drawn" Charts were replaced with line-art to smooth the borders. The text for the Charts was similarly retyped. All "hand-drawn items" in the Charts remain as original. The final Illustrator files were converted to Portable Document Format (PDF) files and stored on a Western Digital portable hard disk drive (HDD).

Plates from six different copies of the *Atlas* were reviewed and the best images were chosen for reproduction into this edition. The chosen Plates were downsized to 1400 dpi for final printing. These TIFFs, each at 429 megabytes (MB), were imported in Adobe Illustrator and converted to PDFs. The final PDFs are 19 MB in size, and all files were saved to a portable HDD for archive. The finest possible print for publication is currently 1200 dpi. This closely matches the original silver-tipped gelatin photographs that were produced in the 700 volumes published over 82 years ago.

It is interesting to note that there are differences between the photographs that were published in various volumes of the 1927 edition. An example of this is Plate 11, where several volumes showed this region too dark to reveal the nebulosity that Barnard describes. Only one volume showed the bright nebulous regions around Pi Scorpii. This photograph is the one reproduced as Plate 11 in this reproduction. The portrait of Edward Emerson Barnard and the photograph of the Bruce Telescope used in this edition are reprinted courtesy of the Special Collections Research Center, University of Chicago Library.

Plates 52, 52a, and 52b are additions to this *Atlas*. It was Professor Barnard's desire to produce some form of an "all sky photograph," although the process to produce such an image did not exist during the first score of years of the twentieth century. This "mosaic" of the Milky Way was produced using only the plates contained within this *Atlas*. It was tempting to add new images, even those of Professor Barnard, to fill in the open regions, but this was not done as the intent of this edition

was to maintain the feel of the original *Atlas*. The original TIFFs were combined using Adobe Illustrator. One image was placed, as close as possible by the given co-ordinates, over an accompanying reference image. Stars at the edge of the field were matched from one image to the next for best fit and the two images were combined, often on a diagonal, with one image overlaying the second. Little, if any, contrast changes were incorporated to blend the images as one. An inherent property of the Bruce Telescope was that the stars around the edge of the field showed curvature of field; this aberration can be seen on the images of this *Atlas*. To align the two plates, the stars at the corresponding edges were aligned by averaging the positions of arcs of stars equally spaced from the plate centers. The final co-ordinates for this mosaic were computed and the grid was adjusted to coincide with the current galactic latitude (b^{II}) and galactic longitude (l^{II}) co-ordinate system. The most interesting regions of this mosaic, the concentrated area near the center of the Milky Way and the region of Aquila and Cygnus, are provided as separate plates: Plate 52a and Plate 52b, respectively. A description of the entire mosaic by this author is provided.

A Second Catalogue listing of Barnard's dark objects is given to allow the reader to locate these nebulae in current co-ordinates. This Second Catalogue does not repeat the remarks provided by Professor Barnard, but does give the size of the region, if known, and the corresponding Plate(s) on which the objects can be found. Not all of Barnard's dark objects appear on the plates in this *Atlas*; hence 31 of those objects are not illustrated.

There are three of Barnard's dark objects that were omitted in the original *Atlas*; B 52, B 131a, and B 172. These objects have been added to the Second Catalogue and this author's explanations are provided. During the editing of the original *Atlas*, Edwin Frost and Mary Calvert noted three objects appeared to be repeated, and those objects were removed from the listing. This omission may have been in error.

The fields in question are very crowded – probably the most crowded in the entire sky. They are in the direction of the Milky Way, and some are close to the galactic center. They show examples of star clusters, emission nebulae, structured dark absorbing material in the forms of globules, and streamers and extended dark material (which is probably at a greater distance). All of this is on a dense background of very faint stars: the stratum. These areas of the sky are nowadays the favorite areas for modern wide-field astrophotography undertaken by professional and amateur astronomers. Interpreting the structure of the dark material is therefore subjective and also dependent on the technology applied to the task. For that reason, this author challenges the reader to confirm the descriptions that Professor Barnard had given to the dark nebulae, in the context of both his plates reproduced here and of modern astrophotographic material.

With the readmission of these three missing objects, Barnard's catalogue now consists of 352 dark objects. There remain several dark objects that are clearly seen on the plates, outlined by Barnard and Calvert, but which were never catalogued by Professor Barnard. Examples can be found on Chart 14, Chart 17, and numerous regions on Chart 49. One such area is the circle above B 170; there is no entry in the catalogue for this object. It is a possibility that Professor Barnard had intended to continue cataloguing these dark objects, adding to his listing that ended in 175, but did not do so. Perhaps these regions could be added to Professor Barnard's catalogue to "fill in" the numbers from 176 through 200, thus completing the listing with these objects.

Irrespective of this, this edition of Edward Emerson Barnard's *Atlas* is as complete as this author can make it. It is presented to a new readership as a lasting tribute to one of the greatest astronomers of all time.

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 22 December 2009