NATIONAL GEOGRAPHIC SOCIETY – PALOMAR OBSERVATORY SKY ATLAS

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The National Geographic Society - Palomar Observatory Sky Survey has been extended to the declination zone -30° containing 56 fields.

The 112 plates obtained in this zone are of slightly lower average quality than those taken at smaller zenith distances. Some plates with noticeably poor seeing had to be included. The limiting magnitude reached in this zone is therefore less uniform than for the main part of the Survey. In addition, limiting magnitude and on the red plates the image quality suffer from the unavoidable effects of the atmospheric absorption and refraction of a zenith distance of 63°.

THE NATIONAL GEOGRAPHIC SOCIETY–PALOMAR OBSERVATORY SKY ATLAS

The National Geographic Society–Palomar Observatory Sky Atlas contains photographic reproductions of red- and blue-sensitive photographs of 879 fields obtained with the 48-inch Schmidt telescope of the Palomar Observatory for the National Geographic Society–Palomar Observatory Sky Survey. This atlas covers the entire sky north of -27° declination.

The sky survey was made financially possible by generous grants from the National Geographic Society. The Society provided the photographic materials and equipment required, the salaries of the personnel employed full or part time on the survey, and in addition, the production of two contact positives on glass of each survey photograph. One set of these positives was used to print the reproductions for the sky atlas.

The observing time with the 48-inch Schmidt telescope required to obtain the sky survey photographs was made available by the Palomar Observatory of the California Institute of Technology.

The Telescope. The 48-inch Schmidt telescope is at the Palomar Observatory, located on Palomar Mountain in Southern California, about 60 miles northeast of the city of San Diego. The exact location of the Schmidt camera, based on positions determined by the United States Coast and Geodetic Survey is: longitude 116° 51′ 32″.04 West, and latitude 33° 21′ 26″.35 North; the elevation is approximately 5500 feet (1700 meters).

The telescope is of the standard Schmidt type. The spherical mirror is 72 inches (183 centimeters) in diameter and has a radius of curvature of 241 inches (612 centimeters). The correcting plate is made from 3/8-inch (0.95 centimeters) plate glass which transmits half intensity at about λ3500, and actually has a clear aperture not of 48 inches but of 49.5 inches (125.7 centimeters). The effective focal length of the system is 121 inches (307 centimeters), giving a focal ratio of f/2.44.

In an instrument of the focal length and aperture of the 48-inch telescope the chromatic aberrations of the correcting plate are not entirely negligible. To ensure satisfactory performance over a wide range of wavelengths, a careful selection had to be made of that wavelength for which the correction was to be precise. Computations showed that adequate image quality can not be obtained simultaneously for wavelengths shorter than λ3600 and longer than λ10,000. It was decided to eliminate the ultraviolet below about λ3600 by the use of ordinary plate glass for the correcting plate. The transmission characteristics of this glass are exhibited in Figure 1. The correcting plate was figured precisely for λ4861 ($H\beta$). The resulting smallest image diameters for various wavelengths have been computed and are given in the following table.

λ	3400	3600	3800	4000	4400	4861	5500	6000	7000	10000
diameter in microns	50	40	30	21	10	0	5	13	24	34

The spacing between the mirror and plate holder is maintained by invar rods so that no focus correction is necessary for moderate temperature changes. Usually, focus plates need be taken only once or twice a month. However, variations in thickness of the photographic plates or filters used may introduce focus errors. A focus difference of 0.05 millimeters is apparent in the quality of the images.

The photographic plates employed are 14 inches (35.5 centimeters) square and only one millimeter thick, so that they can be curved in the plate holder into a 121-inch radius along the focal surface which is concentric with the spherical mirror. The image scale is 67.1 seconds of arc per millimeter. The smallest stellar images have a diameter of about 0.03 millimeters, about the average limit of resolution of the photographic emulsions used. The total field covered on a plate is 6.6 degrees square.

The non-vignetted field of the telescope, determined by the respective sizes of the mirror and correcting plate, is 5.4 degrees in diameter. The computed loss in limiting magnitude because of vignetting at the extreme corners of a 14 x 14-inch plate is less than 0.2 magnitudes.

The 48-inch Schmidt is equipped with two ten-inch (25 centimeters) refracting guiding telescopes of 156 inches (396 centimeters) focal length mounted on opposite sides of the Schmidt's tube. Usually an eyepiece is used for guiding which gives an angular magnification of from 300 to 400. Guide stars of magntidue 9 or brighter can be used. The eyepiece and reticle assemblies of each guiding telescope are mounted on a double slide with micrometric motion; they can be offset by measured amounts in right ascension and declination. The optical axis of the Schmidt can thus be directed at an arbitrary field center and a guide star for that field located by offsetting the eyepiece of the most convenient guiding telescope.

The Sky Survey. The portion of the sky to be covered by the survey was divided into 879 fields. The centers of these fields lie along declination circles at six-degree intervals from $+90^{\circ}$ to -24° inclusive, and are so spaced in right ascension that adjacent photographs overlap along a zone at least 0.6 degrees wide on all four edges. The nominal positions of the field centers are for the epoch 1855, except for the fields along the parallel -24° which are for the epoch 1875, corresponding to the epochs of the Bonn and Cordoba Durchmusterung, respectively.

The nearest BD (or CD) star to each 1855- (or 1875-) epoch field center was chosen as a guide star for that field. Guide-star positions were taken from the Astrographic Catalogue and were precessed, with the field centers, to the dates of their respective observations.

Each field was photographed with the Schmidt telescope on both blue- and red-sensitive photographic emulsions. The two exposures were taken in immediate succession. The order of the exposures was, however, arbitrary, being generally dictated by convenience or efficiency in arranging the observing schedule.

All exposures were made on photometrically clear nights in the absence of moonlight, and when the seeing disc of a stellar image was not more than three seconds of arc in diameter. Further, all exposures, particularly the long ones, were made as near to the meridian as practicable (with very few exceptions, within two hours), to minimize extinction, differential refraction, and instrumental distortions.

For the blue exposures, the Eastman 103a-0 emulsion was used, with a wavelength range of from λ3500 (the short-wave transmission limit of the correcting plate) to λ5000 (Figure 1). For the red exposures, the Eastman 103a-E emulsion in combination with a red Plexiglass filter was used, with a wavelength range of from λ6200 (filter cut off) to λ6700 (Figure 2). Number 2444 red Plexiglass has transmission characteristics similar to those of the Wratten Number 29 filter, and was used here because it can be readily obtained in the large sizes required.

The exposure times were chosen to reach the faintest stars which can be recorded by the instrument under average observing conditions. They were separately determined by test exposures for each shipment of plates and range from 10 to 15 minutes for the blue exposures and from 40 to 60 minutes for the red. All plates were developed in standard formula D-19 developer for five minutes, while being agitated by an electrically operated mechancial rocking device designed to insure uniform development. The contrasts (ratios of density to the logarithm of the exposure for the approximately linear part of the characteristic curves for the emulsions) are between gamma 1.5 and 2.0.

Magnitudes of stellar images on the blue and red plates are approximately on the same color system as that of international photographic magnitudes and the red magnitudes of Kron and Smith. The differences between blue and red magnitudes of stars on the survey plates are approximately 1.6 times their international color indices. The limiting photographic magnitude of the blue plates is 21.1. The limiting red magnitude of the red plates is 20.0. Here, by limiting magnitude is meant the faintest magnitude for which every star produces an image on plates of average or better quality. However, on the poorest plates included in the Atlas the limiting magnitude may be up to about 0.3 magnitudes brighter. The values of the limiting magnitudes are based on photoelectric measures by Baum of stars in Selected Area 57. A star with an international color index of 0.7 appears about equally bright on the blue and red plates.

Each pair of photographs of a field was inspected for quality and judged acceptable for reproduction in the atlas or rejected. Plates were rejected because of meteorological conditions (such as clouds, haze, too bright a sky, or bad seeing), for misleading emulsion defects, or for operational difficulties (such as focus, breakage, star trails due to improper alignment of the polar axis of the telescope, airplane trails, etc.). Rejection of one member of a pair automatically caused rejection of the other. Many fields had to be photographed several times before acceptable pairs of plates could be obtained.

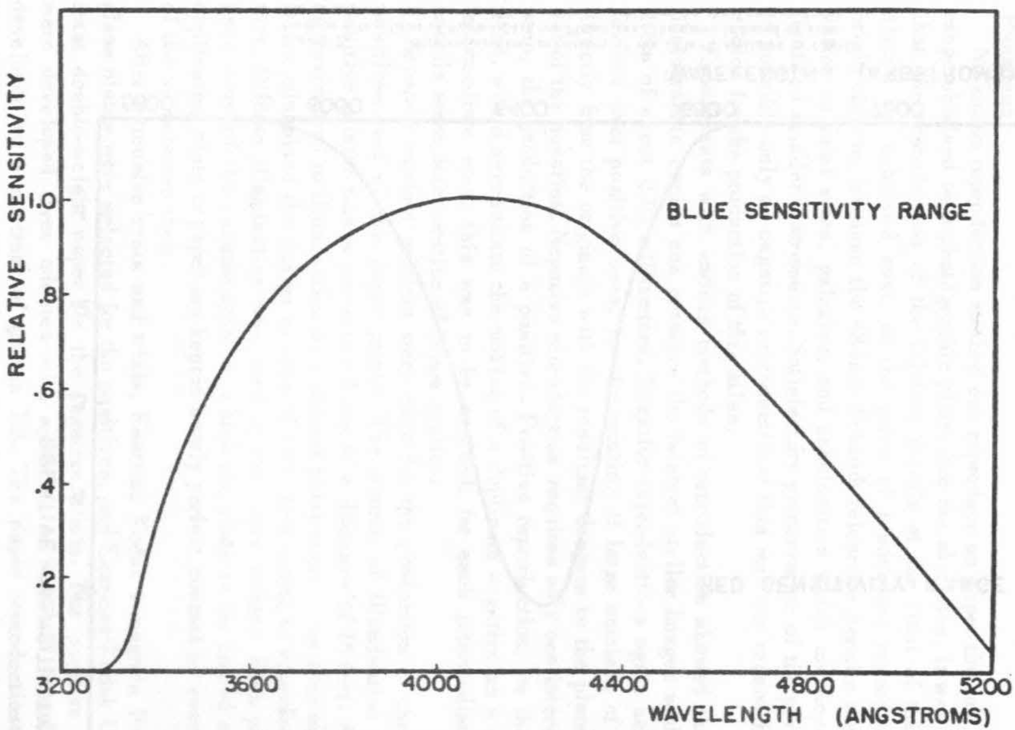

Figure 1. Relative spectral sensitivity of the 103a-0 emulsion in combination with the correcting plate of the telescope. The left side of the curve is determined by the transmission characteristics of the plate glass. The right side of the curve is based on spectral sensitivity data for the 103-0 emulsion published by the Eastman Kodak Company, and is approximate only.

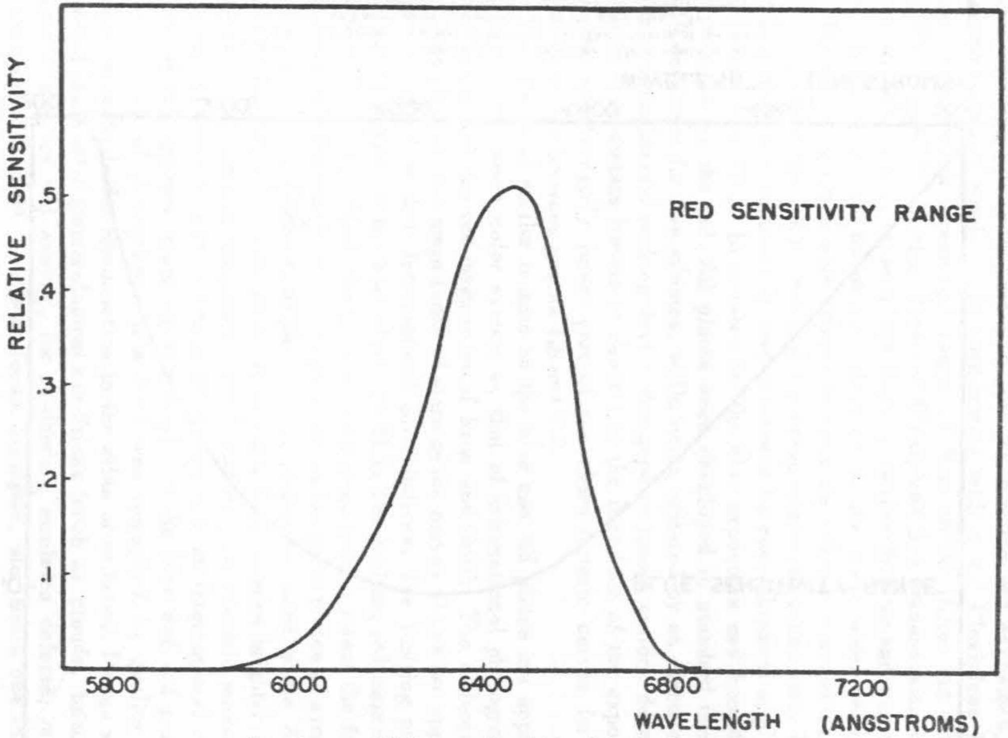

Figure 2. Relative spectral sensitivity of the 103a-E emulsion in combination with a filter of Number 2444 red Plexiglass. The curve is based on spectral sensitivity data for the 103-E emulsion published by the Eastman Kodak Company, and is approximate only.

The Reproduction. The reproduction of the sky-survey photographs on positive transparencies, and the printing of the atlas were carried out by the Graphic Arts Facilities of the California Institute of Technology in Pasadena.

No known reproduction method can reproduce on paper the full density range obtained on a photographic plate. For the sky atlas, it was decided that the reproduction of the faintest details at the limit of the plates should be achieved even at the price of inadequate reproduction of bright objects, because the 48-inch Schmidt telescope permits the observation of faint stars, galaxies, and nebulosities which are beyond the limits of smaller instruments. Satisfactory preservation of the plate limit is possible only on negative reproductions; this was one reason for their choice for the production of this atlas.

Experiments with various methods of reproduction showed that only photographic copies can preserve the faintest stellar images with diameters of about 0.03 millimeters. Negative reproductions again had to be favored over positive ones, for the printing of large numbers of copies directly from the originals with the resultant dangers to the plates was out of the question. Negative reproduction requires only one intermediate step, the production of a positive. Positive reproduction, on the other hand, would necessitate the making of a duplicate negative as a second intermediate step; this was to be avoided, for each intermediate step entails some deterioration of image quality.

Separate contact printers were used for the production of the glass positives and of the paper prints. The source of illumination in the positive printer was a projection lamp at a distance of 16 feet. A close approximation to illumination by a distant point source was thus obtained which minimized the danger of loss of definition owing to imperfect contact. Diffuse illumination was used in the paper printer. Both printers used were of the vacuum type, in which the plate to be copied and the duplicating plate or paper are kept in nearly perfect contact by evacuation of the air between them.

After extensive tests and trials, Eastman Kodak Finegrain Positive glass plates were selected for the positives, and Eastman Kodak Unicontrast double-weight paper for the negative prints. The positive plates were developed three minutes with agitation in standard formula 16D developer to a contrast of gamma 1.8. The paper reproductions were developed in standard formula D-72 developer. The contrast of the paper is gamma 2.0, practically independent of development.

The original plates show considerable variation in background density which depends upon the sky brightness. It was found that the most satisfactory reproduction could be obtained by printing all positives to a density of 1.4 without regard to the densities of the originals. This was achieved by measuring the background density of the originals and adjusting the exposure time for the positives with rigid control of the illumination and carefully standardized development. Originals with background densities below 0.3 and above 0.9 were found to give inferior results and, therefore, were rejected.

The paper prints were found to be most satisfactory with a background density of 0.2 or slightly higher. Since they could be processed in yellow light of sufficient brightness for visual control of development, and since the operators learned to control the development adequately, strict production controls were not used for the development of the paper prints.

The prints were fixed for three minutes in each of two fixing baths. They were then washed with agitation until a starch-iodine test indicated that every trace of the sodium thiosulfate from the fixing bath had been removed. They were finally treated with a commercial print flattening solution which minimizes the danger of the emulsion cracking with handling. It is believed that every possible care has been taken to ensure a long life for the prints.

The Sky Atlas. Each sheet of double-weight paper of 14 x 17-inch size has a margin of one inch on one side and two inches on the other. The wider margin is on the west edge of photographs in the blue, and on the east edge of those in the red. On the back of each print is stamped the nominal position of the field center (1855 epoch, except for the -24° declination zone which is in the 1875 epoch).

In the northeast corner of each photograph is a label which was projected on the original plate after it was exposed, giving the serial number of that plate, the date of the exposure, and the 1950 coordinates of the field center. These field centers may vary one or two millimeters from the geometrical centers of the photographs owing to the fit of the original plates in the plate holders. The "O" or "E" preceding a plate number denotes whether the exposure was on the 103a-O or 103a-E emulsion. In a very few cases, owing to physical irregularities along the edge of an original plate, it was found necessary to project the label on a corner other than the northeast. In all cases, however, the paper prints are oriented as described above.

Handling the paper prints involves a certain risk of damaging them, particularly by cracking or creasing. At the Mount Wilson and Palomar Observatories, it has been found that a very satisfactory procedure for reducing this possibility is to cover the reproductions with glass plates while viewing. The most advantageous illumination is with the light source low and to the rear.

Defects. Throughout the entire program, every effort has been made to maintain the highest standards of quality. However, on photographic plates of the size used here, some imperfections are inevitable. Where defects have occurred which are felt to be particularly misleading or unsightly, the appropriate original or reproduction has been rejected.

Many minor defects, however, which have common characteristics and can be easily recognized, had to be allowed to pass. As an aid to the users of the atlas, the more common of these imperfections are described in the list below, with references to prints where examples may be found. The position of a particular example on a print is denoted by x and y, its respective horizontal and vertical distances in centimeters from the northeast corner of the print.

1. Ghosts: "Ghost" images of bright stars are formed at a location on the plate symmetrically opposite the plate center from the star. They arise from light successively reflected by the emulsion, mirror, correcting plate, and mirror. An example occurs on prints 0 and E-148, at x = 9.2 and y = 31.3.

2. Reflected-light streaks: Light from a bright star, entering the telescope and striking the flat struts which support the plate holder in the tube, or an outside edge of the plate holder itself, will be reflected and finally imaged in an irregular streak on the plate. These streaks are always parallel to an edge of the plate. The bright star itself may or may not be in the field; if it is, an extension of the light streak will intersect it. Examples may be found on the following prints:

0 and E-148	x = 7.5 to 11.5	y = 3.4
0 and E-137	x = 7.0 to 10.0	y = 8.4
0 and E-199	x = 15.4	y = 0.0 to 10.5.

3. Flare from star just off field: Starlight striking the inside edge of the plate holder may be reflected onto the emulsion, forming a "flare" at the edge of the plate. Examples are:

0 and E-148	x = 1.5	y = 34.5
0 and E-121	x = 16.3	y = 34.5

4. Filter defects: (a) A spot on the filter may produce a light spot on the plate. Example on E-91; x = 13.7; y = 7.5.

(b) A scratch in the filter near a star may produce a defect somewhat resembling reflection nebulosity (but appearing only on the red plate). Example on E-143; x = 23.5, y = 3.2.

5. Discharge marks: Electrical discharges, usually occurring during the loading or unloading of the plate in the plate holder, cause marks of density intermediate between these of the background and stars. These defects vary from an irregular "worm-like" appearance to round symmetrical spots. For examples, see:

0-156	Southeast corner	(many irregular shapes)
0-125	x = 19 y = 21	(irregular shapes)
0-120	x = 19.0 y = 21.3	(round spot)

6. Emulsion defects: These are of many types and can usually be immediately recognized as defects by comparing the prints of the blue and red plates. Some common examples are listed:

0-143	x = 12.5 y = 13.2	(insensitive spot)
E-199	Northwest corner	(black spots with concentric circles)
E-193	x = 2.2 y = 26.6	(black spot)