The Maria Mitchell Observatory Plate Collection as a Mirror of the Evolution of Astronomical Photographic Emulsions

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Abstract The recently digitized astronomical plate collection of the Maria Mitchell Observatory (MMO) was used to study the evolution of limiting stellar magnitudes of the plates as various astronomical emulsions were used over the years. The information on limiting magnitudes was obtained by eye photometry of the weakest detectable stars on the digitized images of the open cluster NGC 6819. In total, 174 plate copies containing NGC 6819 and covering the period of time from the 1920s to about 1990 were evaluated. A remarkable increase of the limiting magnitude during these seven decades was revealed. The best plates with the early astronomical emulsions, Speedway, Presto, and HiSpeed, showed limiting magnitudes 14.4, 15.7, and 16.4, respectively, whereas the limiting magnitude on the best plates with the post-1950s emulsions, 103aO and IIaO (some hyper-sensitized with N_2), are 17.4 and 17.2, respectively. The scatter of the limiting magnitudes from plate to plate gradually decreased from about three magnitudes in the 1920s to about one magnitude in the 1980s. The scatter of the limiting magnitudes must be due not only to the scatter of the conditions of observations, but also to the quality and homogeneity of the batches of plates, which appears to steadily increase with time, together with the sensitivity of the plates.

1. Introduction

The photographic plate collection of the Maria Mitchell Observatory (MMO) was created by the MMO variable star observers and it has often been used by other members of the community to recover light curves of variable stars. The collection contains more than 8,000 plates taken with the MMO 7.5-inch Cooke/Clark refractor from 1913 to the mid-1990s (Friel 1993). In 2002, the Observatory completed the 1.5-year long task of digitizing its whole plate collection. A catalog of the digitized plates was created and is available on-line (http://www.aas.org/%7Epboyce/mma/catalog-comma.htm). The MMO provides digital copies of the plates on CD-ROM, on request.

The purpose of the initial project that led to this paper was to provide the users of the MMO plate catalog with the data on limiting star magnitudes on the plates. However, while accumulating the data on the limiting magnitudes, an obvious evolution of the plate limits, especially in the first half of the 20th century, was revealed. The increase of the limiting magnitude on the plates must be attributed to the increase of the sensitivity of astronomical emulsions. A quantitative report on this finding is the goal of the present paper. The author hopes that this information will be interesting not only to the potential users of the digitized MMO plate collection, but also to astronomers in general, as a part of the history of the development of astronomical observational techniques in the 20th century. The preliminary results of this study were reported by Davis and Strelnitski (2003).

2. Emulsions

Before 1950, the MMO used three main types of emulsions, Speedway, Cramer Presto, and Cramer HiSpeed. After 1950, only Eastman Kodak 103aO and IIaO were used. During the late 1980s and into the 1990s, the MMO practiced a technique of "hyper-sensitization" of the plates—the treatment of the emulsion with nitrogen gas (N_2) before the exposure.

3. The sampled plates and the evaluation procedure

To make the results for different plates comparable, plates containing the open cluster NGC 6819 were located using the catalog, and the digital copies of those with the exposure times 30, 45, and 60 minutes were selected for evaluation. In total, 174 plate copies containing NGC 6819 and covering the period of time from the 1920s to 1990s were evaluated. Among them were plates covered with Presto, HiSpeed, Speedway, 103aO, and IIaO emulsions, and the latter two emulsions were, sometimes, hyper-sensitized with N_2.

The limiting photographic (approximately $= B$) magnitudes of the stars on the plates were estimated by the standard method of eye photometry and by using the published photoelectric V magnitudes and B–V color indices of the stars in the cluster (Auner 1974).

4. Results and discussion

4.1. Limiting magnitudes and the sensitivity of the plates

We investigated separately the plates with the 30-, 45-, and 60-minute exposure times (98, 63, and 13 plates, respectively). The results for the two more full samples, 30 and 45 minutes, are presented in Figures 1 and 2.

It is obvious from both figures that the limiting magnitudes gradually increased with time. For the plates with the highest determined values of the limiting magnitude, our measurements revealed limiting magnitudes for Speedway emulsions at 14.4, Presto at 15.7, HiSpeed at 16.4, 103aO at 17.4, IIaO at 17.2, and 103aO+N_2 at 17.4. It should be noted, that although the hyper-sensitized 103aO gave the same highest limiting magnitude, the higher values of the limiting magnitude appeared on the hyper-sensitized plates more often than on the plates without hyper-sensitization.

This remarkable increase of the limiting magnitudes on the plates taken with the same telescope, with the same exposure time and in comparable conditions, certainly reflects a continuing effort to improve the sensitivity of astronomical emulsions, both by improving the technology of production and by applying various techniques of hyper-sensitization.

4.2. The scatter of the limiting magnitudes

In both Figures 1 and 2, there is a considerable scatter of limiting magnitudes from plate to plate. An interesting fact, seen especially well in Figure 2, is a decrease of the scatter over the years, from as much as about three magnitudes in the 1920s to as low as about one magnitudes in the 1980s. We suppose that the scatter in limiting magnitude is due not only to the natural variation of the conditions of observations, but also to the quality and homogeneity of the batches of plates, which appear to considerably improve with time.

4.3. High- vs. low-resolution digitized plate copies

Each MMO plate has been digitized with two resolutions: 840 dpi and 2,500 dpi (Barkume and Strelnitski 2001; Shaeffer 2003). The low-resolution scans were meant to serve as auxiliary, overview images. The high-resolution scans (corresponding to a resolution of 10 microns on the plate, virtually the size of the developable grains of the emulsion) were expected to be used for scientific research.

All the results on the limiting magnitudes reported above were obtained with the low-resolution copies of the plates. In order to see whether the resolution is important for revealing the faintest stars on the plates, we evaluated a sample of 21 plates with both the high and the low resolutions. Simple visual inspection shows that the higher resolution did make the image clearer and more defined (see Figures3a and 3b). However, only rarely a star was obviously seen on a high-resolution scan that was not visible on the low-resolution scan. In some cases, a star that may have looked like a single image on the low-resolution scan may prove to be two stars with the higher resolution. Of the 21 plates evaluated, there were only three of the high-resolution scans that did show stars not found on the low-resolution scans.

6. Conclusions

The limiting *B* magnitudes of stars on the MMO photographic plates increased from about 14–15th to 16–17th magnitude, and the scatter of the limiting magnitudes from plate to plate decreased from about three to about one magnitude from the 1920s to the 1980s. The potential users of the digital copies of the MMO plates can use these numbers while working with the catalog of the plates and preparing their orders of the copies.

The major cause of the evolution of the limiting magnitudes on the MMO plates shown by this study must have been a gradual improvement of the sensitivity and homogeneity of commercially available astronomical photographic emulsions, especially in the first half of the century.

The limiting magnitudes of the stars on the low-resolution, "overview" scans of the MMO plates are, typically, only 0.2 magnitude brighter than on the high-resolution scans; the low-resolution scans seem to be useful for many photometric purposes.

6. Acknowledgements

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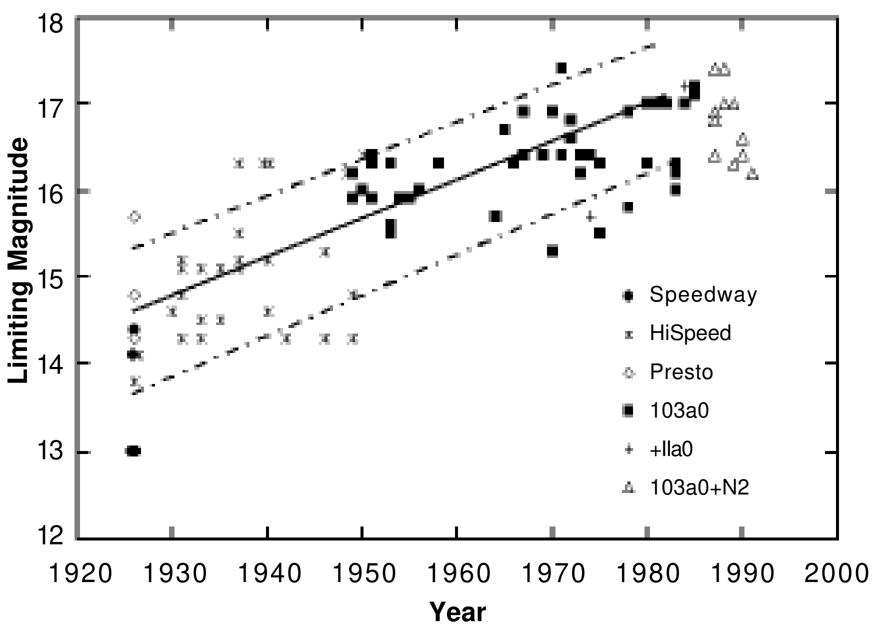

Figure 1. Limiting *B* magnitudes of stars on a sample of the MMO plates with the 30-minute exposure time, as a function of the year. See the legend for the symbols of various emulsions. The straight dashed-dotted lines show linear regressions for the highest and lowest values of the limiting magnitudes for various emulsions (the upper and the lower lines, respectively), and the solid line—a linear regression for all the points taken together.

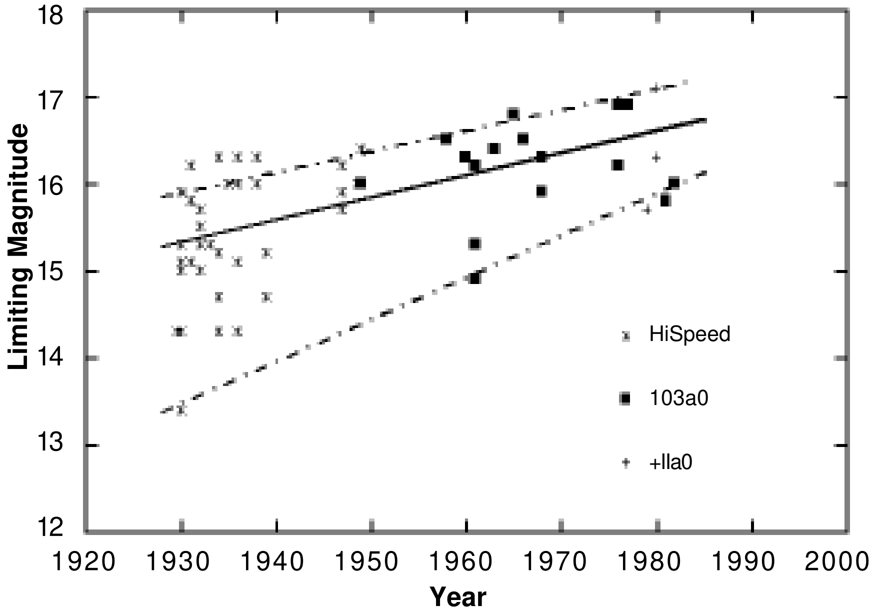

Figure 2. Same as in Figure 1, but for the sample of plates with the 45-minute exposure time.

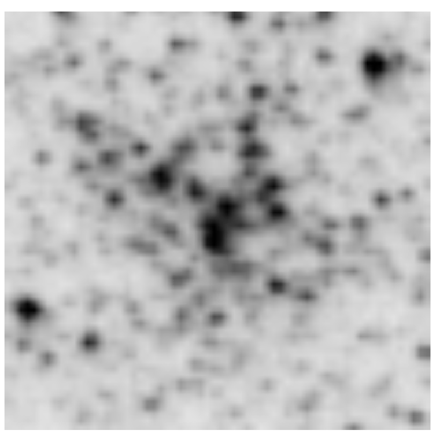

Figure 3a. An example of a low-resolution (840 dpi) scan. An area around the open cluster NGC 6819 in Plate NA3003.

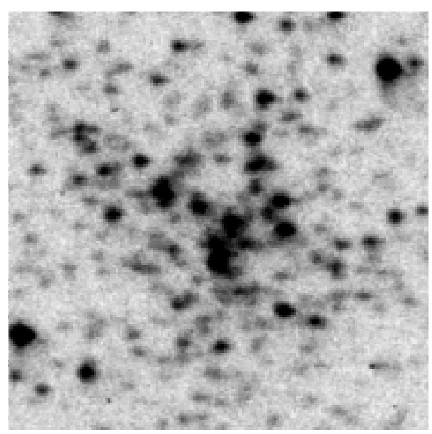

Figure 3b. Same as in Figure 3a, with the resolution 2500 dpi.