RevMexAA (Serie de Conferencias), **39**, 36–38 (2011)

REVIEW OF "MULTICOLOR PHOTOMETRY OF STELLAR AGGREGATES" PAPER BY MENDOZA (1967)

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RESUMEN

La revisión del artículo "Multicolor Photometry of Stellar Aggregates" by E. E. Mendoza V., 1967, BOTT, 4, 29, 149 sobre agregados estelares contiene gran cantidad de datos de alta calidad, como lo contienen sus otras contribuciones sobre estrellas del campo y sobre tipos específicos de objetos. Es un material de primera clase por su precisión y exactitud, como lo demuestra el haber soportado la prueba del tiempo. Las mediciones han sido usadas por muchos otros astrónomos para sus propios trabajos. Su contribución es particularmente importante debido a que incluye datos sobre un intervalo de longitudes de onda amplios. Las citas a este artículo lo demuestran.

ABSTRACT

This paper review of "Multicolor Photometry of Stellar Aggregates" by E. E. Mendoza V., 1967, BOTT, 4, 29, 149 on stellar aggregates contains a huge amount of high quality data, as have his other papers on stars in the general field and on specific types of objects. It is first class in both precision and accuracy, and it has stood the test of time. The data have been used by many other astronomers in their own work and due to that fact that it includes data over such a wide wavelength range. Its citation record proves that fact.

Key Words: stars: fundamental parameters — techniques: photometric

1. INTRODUCTION

As an introduction to this article and to the type of work that Eugenio Mendoza has done over many years, and its quality, I start by adapting from some of my previous writing about photometry, for such relates well to this fine work that Mendoza has done with his first class photometric observing. This paper being reviewed is a prime example of his work. It is a fundamental, useful, most valuable, long lasting contribution to astronomy.

2. STELLAR PHOTOMETRY

Photometry is undoubtedly the most fundamental of all astronomical observations. It is hard to imagine any astronomical research of any nature that does not use photometric results in some way or another. The measurement of brightness and of broad and narrow band spectral features in a star or other object's flux output is at the heart of much of what is done in getting the essential data needed for our research problems. Many astronomers do photometry or use the results of someone else's previous observations in their research. However, while basically very simple, photometry is very often much misunderstood. To do good research in astronomy, it goes without question that we need accurate and precise photometry.

In astronomy, one is attempting to measure the radiant flux coming from an astronomical object, as a function of wavelength. Such flux measurements can be used in many ways, but in general one can determine the distance to a star, its chemical composition and any peculiarities, its age, whether it varies and how, and many other things. Similar information can be gotten about galaxies, and indeed about the interstellar matter in the galaxy, whether the dark absorbing matter or the bright emission material in nebulae. Essentially all methods of determining distance rely on the measure of the object's apparent brightness as we measure it.

One is generally measuring the flux over a specific range of wavelength so as to get color discrimination or other such information rather than just total brightness. The Earth's atmosphere limits the range of wavelengths that we can observe from the ground from about 320 nm to somewhat beyond 5 microns. Mendoza did this type of observation and hence maximized the usefulness of his data. The fact that the paper by Mendoza (1967), has been extensively cited by others in their work over the years up to and including even now in 2010, (43 years later!) shows its long lasting value.

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It is possible to consider photometry as the application of the following equation:

$$I(\lambda, t) = \mathrm{c} \int (I_\mathrm{s} + I_\mathrm{b})\, IM\, A\, T\, P\, F\, D\, O\, \mathrm{d}\lambda\, \mathrm{d}t\,, \quad (1)$$

where $I(\lambda, t)$ is the flux we observe and c is a normalizing constant; λ is wavelength and t is time. I_s is the item that we are usually trying to determine, the flux from the star (or other object) that we are observing. However, sometimes we are just using a star as a probe to determine something else, such as atmospheric extinction or interstellar reddening values in the direction of observation. I_b is the sky background, and might include circumstellar emission. IM is the impact of interstellar matter in the line of sight, A the impact of the Earth's atmosphere (extinction), T and P and D any impacts of the telescope or the photometer or detector, and O any other effects that can make an influence on the observed data.

$F(\lambda, t, x, y, \ldots)$ is the impact of the filter (or other wavelength discriminator) on the throughput. It is our choice of filters (or spectrometer) that gives us our information resolution. The careful choice of filters is critical to success, for many reasons. To be able to do effective research programs, it is essential to be able to compare the photometric data used with other such data. Hence, we all use standard photometric systems, such as UBV, RI, and infrared, or $uvby - \beta$, or other standard systems.

These are chosen to give the observer a number of parameters that can be related to stellar (or other) characteristics, such as brightness (in a specified wavelength range, usually a V magnitude), "color", chemical composition, temperature, effects of the intervening interstellar material on the star's flux, and so on. Quite a number of such photometric systems have been defined and used over the years. The UBV and RI systems have been the most used, with their extensions into the infrared. Intermediate and narrow band systems often offer more information resolution by measuring specific spectral features.

The observer must select an adequate number of standards stars of the needed characteristics to insure a good job of interpolation in all phases of the observation and reduction process. This may not be easy to accomplish, especially if one is observing either a wide range of "unknowns" or types of objects for which few if any standards exist. In the first case, a rule may be "the more the better". In the second case, one may have to try to develop sub-standards of the type of characteristics needed. Such objects have been a focus of Mendoza's work at times, such as supergiant stars, WR stars, and planetary nebulae.

A summary of the points extracted above: Photometry has always been of high value in astronomical research. It always will be. Such photometry must be of high precision and accuracy. The key is to understand the basic principles of photometry, and of the potential pitfalls involved. The existence of well chosen standard systems and standard stars, both for their applicability to the research job and for their intrinsic merit, is one of the most powerful tools to insure that reality. E. E. Mendoza is one observer who has been fully aware of these needs, and his observations reflect that wisdom and care. We all benefit from such careful data collection.

So now let me comment specifically on the article in question, after having made some general comments on photometry above, and why the paper is so good and has been so important over the years. The data is precise and accurate, covers a very wide range in wavelengths (nine photometric bands from 0.36 to 5.0 microns), and includes many stars in ten clusters or aggregates. It thus has provided the kind of data needed for photometric standards and calibrations, for investigations of such aggregates and galactic structure, for studies of stellar evolution, and for identifying variable stars in the aggregates. Others have followed up on all this type work and will continue to do so, proving again the value of Mendoza's fine work.

Mendoza and others have done such calibrations. Later work, including that in other photometric systems, has built on these efforts. His own work, of course, was built on earlier work of others, especially H. L. Johnson, with whom he has collaborated many times, and of W. W. Morgan, D. Harris, and others.

Let me quote one sentence in this paper: "In the standard relations [his plots in the article], there exist scatter from cluster to cluster; these differences may be due to age, chemical composition, luminosity effects, and interstellar extinction". He chose these clusters for this reason, and hence the data have been of great value in further work and in calibrations of the observed parameters to the parameters mentioned above.

The paper gives some such information on the calibrations, including determining the distances to the clusters and the interstellar reddening and absorption in front of the clusters. It includes both tables of all the observed data and the color-color and color-magnitude diagrams for all the aggregates in most of the bandwidths.

Using the data he obtained, Mendoza established clear cut zero age main sequence, obtained interstellar reddening and interstellar absorption values for the clusters and aggregates, and their distances. Again, to quote him: "The results indicate that the clusters and associations under study may differ from one another in chemical composition and certainly in age". Such uniform and accurate data allowed such firm results to be obtained, and allowed others to build on and expand this firm base.

So what now, in 2010 and beyond? The value of the paper will continue, as such fundamental and useful data live forever. Work will continue on using such data, new and old, on the questions of understanding stellar evolution and galactic structure. While much of modern day research is done with very large telescopes, exploring the furthest reaches of space and long distant look-backs in time, work with quite small telescopes on stars too bright for the very large telescopes will continue and will be of great value. It establishes the firm scaffolding on which the current frontier work will sit. Many are now calling "small telescopes" those in the aperture range of 2 to 4 meters diameter, but there is still a huge role for those in the range of 0.5 to 1.0 meters.

This work can be done nearly anywhere, in any country. Mexico has shown how well it can be done. Such quality photometric (and spectroscopic) work is essential, on stars in the field (galactic plane and at high galactic latitudes), on clusters and aggregates, and on variable stars. There is so much yet to do.

I give one example that I am involved with. GNAT, a relatively new non-profit organization, is operating several scan mode small telescopes with the goal of identifying both moving objects (such as asteroids) and variable stars. It has been collecting a vast amount of data and making many such discoveries. In its first program on a 50 minute band in declination (at about 3 degrees north declination) it observed about 2.1 million stars, of which about 26,000 proved to be variable. Of these, only 59 where known (in existing catalogs). Clearly, there is a lot of follow-on work to be done!

GNAT has begun this, with non-scan mode telescopes, but needs A LOT of others to get involved in such follow-on work. GNAT has also been scanning in other declination bands and will be adding additional scan mode telescopes to the system. A truly astronomical amount of research is needed to follow-up on this work (and think of the other telescopes and observers producing new and useful data with small telescopes). Data archiving, data analysis, follow-up new data, all are required. All will be of great value. Confirming the variability, its amplitudes and periods, correlations with catalog data, serendipitous discovery of interesting and unusual stars. irregular variable, supernovae follow-up, eclipsing variables, data in clusters, all these and more are needed and will lead to useful publications. Observers and analysts anywhere can be involved, professionals and amateurs, students, anyone.

Such a vast amount of (growing) data is useful in many other statistical studies. Standard, non-variable stars, stellar classification, frequency of variables by galactic location, and on and on.

3. CONCLUSIONS

In summary then, good quality data obtained by careful observers with small telescopes is most valuable, even (maybe especially) in these days of giant telescopes. Such work can be done by nearly anyone, anywhere in any country. It is a great resource for students, both in education (astronomy and science, and in technology). It is essential back up information of all sort for almost all others involved in astronomical research of any sort. It is valuable, useful, and interesting. It does not make the newspapers or television, but it is long lasting and essential.

As one involved in such efforts many decades ago, and still today, I want to say "Great job, Eugenio, thanks. It was a pleasure to have been a fellow graduate student with you at the University of Chicago, and to have talked and worked with you many times since then".

REFERENCES

Mendoza V., E. E. 1967, Bol. Obs. Tonantzintla Tacubaya, 29, 149