Report of the International Chart Working Group

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Abstract The International Chart Working Group (ICWG) is a team of expert chart and sequence makers drawn from the American Association of Variable Star Observers (AAVSO), The British Astronomical Association Variable Star Section (BAA VSS), and various other individuals that set out in 2000 to tackle what was then a chaotic situation with regards to sequences. This presentation is a summary of the group's work undertaken primarily during the years 2000–2003.

1. Introduction

Observations of variable stars would be impossible without a sequence of comparison stars that is normally included on a chart that covers the region of the variable star. The quality of the sequence has a direct impact upon the quality of the observation. At the turn of the Millennium a few problems existed with sequences:

1. Different organizations used different sequences for the same variable star. Between 1890 and 1927 the British, Americans, Japanese, French, South Africans, and New Zealanders all formed national variable star organizations and developed their own individual sequences because accurate homogeneous all sky photometry was not available. This caused problems when consolidating and analyzing data derived from the different groups.

2. Some observers did not use official sequences. Sometimes the official sequences were not to the best quality or did not look correct to the individual observer's eyes. Variable star observers like to use the best sequence available irrespective of whether or not it is the official sequence of the reporting body. This introduced risk of enhanced scatter into the databases.

3. Multiple photometric systems were in use. Photographic, photo-visual, *V*, visual (mv) were all in use. For visual (mv) there were several different methods of calculating it from *V*. The American Association of Variable Star Observers (AAVSO) had used Stanton's formula (1981) while the British Astronomical Association Variable Star Section (BAA VSS) had used Howarth and Bailey's (1980) formula.

4. Some sequences were poorly-calibrated and non-linear. Leander McCormick magnitudes used for many telescopic sequences are poorly-calibrated below magnitude 13. This has led to the production of inaccurate light curves (often flat-bottomed) for several variable stars for many years. The prototype variables Z Cam and SU UMa are such examples that are often published in books.

5. Many sequences contained a wide color range. Historically, comparison stars were selected on the basis of apparent magnitude and proximity to the variable with no regard to color. Color data were not always available prior to the Hipparcos/Tycho mission and the work of Arne Henden at the U.S. Naval Observatory. This introduced scatter into the data because different observers had different spectral responses to different colored stars.

Following the Hipparcos/Tycho mission and the advent of inexpensive CCD's, accurate photometry has become available for many variable star sequences. It confirmed what experienced visual observers had suspected for a long time, that some existing sequences were flawed. This was the catalyst for the formation of the International Chart Working Group (ICWG) at the First High-Energy Astrophysics for Amateur Astronomers (HEA) Workshop at Huntsville, Alabama, in April 2000. The ICWG was endorsed by the AAVSO, BAA VSS, and Vereniging Voor Sterrenkunde, Werkgroep Veranderlijke Sterren (VVS WVS), Belgium, who were in attendance.

2. Initial findings

In the following four years there were four meetings of the ICWG that were undertaken within various formal association meetings:

1. October 2000 AAVSO meeting, Cambridge, MA
2. November 2001 AAVSO meeting, Cambridge, MA
3. June 2002 HEA Workshop No. 2, Waikola, HI
4. October 2004 BAA VSS meeting, Preston, UK

In 2001 the ICWG set out to identify discrepancies between the existing sequences of the three largest variable star organizations; namely the AAVSO, BAA VSS, and the Royal Astronomical Society of New Zealand Variable Star Section (RASNZ VSS). There was little duplication between the BAA VSS and RASNZ VSS so both of these organizations' sequences were compared with those of the AAVSO. 1400 sequences between the AAVSO and BAA VSS were checked, of which 141 were of common stars. Of these, 59 were found to be discrepant (discrepant means a difference of 0.2 magnitude or more for the same comparison star). 1300 sequences between the AAVSO and RASNZ VSS were checked, of which 291 were of common stars. Of these 132 were found to be discrepant. So it was established that in 42%–45% of cases where duplicate sequences existed there were significant discrepancies leading to potential consistency problems with the resultant combined data.

3. Policy decisions

The ICWG developed the following policies:

1. Mission statement. The following mission statement was proposed and

agreed at ICWG meeting No. 3: "Working together to agree on guidelines for future sequences and the updating of existing discrepant sequences."

2. Standard photometric system. The goal was to eliminate multiple photometric systems in sequences and standardize on *V* that is compatible with CCD observations and recognized by professional astronomers. *V* is not visual (mv) so a rigorous quality assurance policy needs to be applied to ensure that *V* sequences look correct to the visual observer.

3. Adherence to sequence selection guidelines. A set of standard guidelines for sequence selection was developed based upon recognized best practice.

4. Existing sequences retained where possible. Where sequences contain very few discrepancies, are linear, and are reasonably calibrated, there is no intention to revise them. "If it's not broke don't fix it" became the rule.

5. Charts remain the responsibility of the individual organizations. Different organizations have different chart formats and reporting procedures; e.g. BAA VSS have lettered comparison stars whilst the AAVSO have magnitudes with decimal points omitted. The purpose is to concentrate solely on the sequences themselves.

It is generally accepted that the best possible accuracy with visual photometry is attained when comparison stars of brightness and color similar to the variable star are employed. It was recognized by the ICWG that the best solution to the problem of observers having different spectral responses to different colors is: 1) have a narrow color ($B-V$) range of comparison stars, and 2) make that range close to the color of the variable star if possible. To decide upon an acceptable color range the relationship between visual (mv) and *V* (which was adopted by the ICWG for new sequences) had to be reviewed. There are three recent studies into this relationship as follows:

1. $mv = V + 0.159\,(B-V)$ Howarth and Bailey (1980)
2. $mv = V + 0.182\,(B-V) - 0.15$ Stanton (1981)
3. $mv = V + 0.210\,(B-V)$ Stanton (1999)

All three formulae when plotted over a $B-V$ range of 0 to +2 have similar slopes and indicate that, if you want to limit the discrepancy for the average visual observer to 0.1 magnitude (the normal visual resolution limit), a $B-V$ range limit of 0.7 magnitude is required.

It is not always possible to match the color range of the comparison stars to that of the variable. There are sharp peaks in the $B-V$ distribution of stars that are linked to galactic latitude and it is advisable that the selection of comparison stars is centered on these peaks. For binocular sequences (>10th magnitude) there are two peaks due to main sequence and giant stars. The giant peak is fixed around +1.0 $B-V$ but the main sequence peak is around +0.5 $B-V$ for high galactic latitudes and around +0.1 $B-V$ for low galactic latitudes. It was recommended that future binocular sequences be drawn from one peak only and to select the peak with the color closest to that of the variable star. For telescopic sequences there is just one

peak because the field of view captures very few giant stars. The peak at high galactic latitudes is around +0.5 *B–V*, whereas at low galactic latitudes the peak shifts to around +1.0 *B–V* due to reddening.

4. Sequence selection guidelines

The sequence selection guidelines developed by the ICWG are:

1. *V* photometry accurate to 0.05 magnitude. This is certainly good enough for visual sequences that are rounded to 0.1 magnitude.
2. *B–V* range not greater than 0.7 magnitude.
3. Adopt steps between comparison stars of 0.3–0.5 magnitude. Do not have more than one comparison star of the same magnitude, as has been done in the past.
4. Exclude double stars. These can be problematic if the fainter component cannot be clearly separated and its brightness is within 2 magnitudes of the brighter component.
5. Select stars close to the variable and take position angle into account. As a general rule fainter stars should be closer to the variable. Endeavor to select comparison stars in an east/west direction if possible.
6. Avoid large spatial distances (especially between comparison stars of similar brightness).

It is important to emphasize that these are not absolute rules but highly recommended guidelines. Each sequence should be considered case by case on its own merits. However, if the chart-maker has these guidelines uppermost in mind, observers will be rewarded with the best possible sequence.

The currently recommended photometric sources for sequences are:

- Tycho 2 Vj >10.5 magnitude
- ASAS-3 9–13th magnitude
- Henden <12th magnitude
- CCD(*V*) by Misselt, Skiff, Zissell, etc.

5. Conclusions

The benefits of applying the ICWG policies are:

1. Reduced scatter in light curves. Good sequences promote smooth light curves, whereas poor sequences are scatter-prone at best.
2. Consistent personal deviation impact. Observers' differing spectral responses to color can be eliminated as a problem within the sequence, and a consistent reference sequence will allow the later application of analysis correction formulae for the variable.
3. Visual data will be compatible with CCD(*V*) data, therefore permitting consolidation of light curves.
4. Uniform data from different organizations. This has immediate benefits for

professional researchers who currently draw data from multiple organizations.

5. Facilitates future database consolidation.

It is likely that there have been 20 million visual observations of variable stars made during the 19th and 20th centuries. If optimum sequences are produced and conversion formulae are developed for the data produced using obsolete sequences, we can significantly improve the quality of data being supplied to professional researchers. It is hoped that this will become the principle legacy of the ICWG. Finally, it is the belief of the ICWG that all observers of variable stars deserve to have the use of the best possible sequences, and chart-makers of all variable star associations have a duty to provide them.

References

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