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# HST, uvby Photometry and System Calibration

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**Abstract.**

Galactic evolution is studied in a field in the centre of the LMC Bar. We obtain data of high quality with the HST WFPC2 and uvby photometry. To match the photometric accuracy and make use of the potential of the uvby system in terms of evolutionary parameters and chemical abundance, we need adequate calibration of the data observed. Conversion of the observing system into that of the international uvby system is made from observations of reference stars in cluster fields. These fields are first observed with a ground based telescope together with selected sets of standard stars for the uvby system. This way, the cluster field reference stars are tied into the international uvby system. Subsequently, the reference stars are observed with the HST WFPC2 used with its set of uvby filters, thus providing final system conversion. We here discuss the observations and present some initial results.

## 1. Introduction

In a study of star formation history and chemical evolution in the Large Magellanic Cloud (LMC), we use the HST to get detailed information concerning conditions at centre of the Bar (Ardeberg et al. 1997).

The LMC is a favourable platform for studies of stellar and galactic evolution. It has a distance allowing accurate detailed studies of individual main sequence stars. Also, it shows considerable variation in stellar ages and has an orientation and a structure favouring identification of stellar populations and their large scale structural features. Further, the LMC is a galaxy of an interesting type, different from that of the Galaxy.

Even with the best grounds based telescopes, and with excellent atmospheric turbulence conditions, only the brightest LMC stars can be studied for individual stellar characteristics. Thus, our understanding of the nucleosynthesis and massive star formation in the LMC has been limited to its most recent history. For the youngest generations of stars, large scale star formation processes in the LMC have shown rapid and violent bursts.

## 2. Programme

Targets of our programme are large scale star formation history, chemical evolution and the initial mass function of the stellar populations being dominant in the LMC Bar. For this purpose, we make use of stars with ages and chemical compositions that can be determined with optimum accuracy and reliability. At the same time, in order to make such studies of individual stars possible, we have to observe stars with reasonable brightnesses, although not too evolved with respect to the main sequence. In consequence, we have chosen to study stars close to the turn off point in the HR diagram. In the LMC Bar, these stars are of spectral type F. Their V magnitudes fall in the range 20.5 to 22.0.

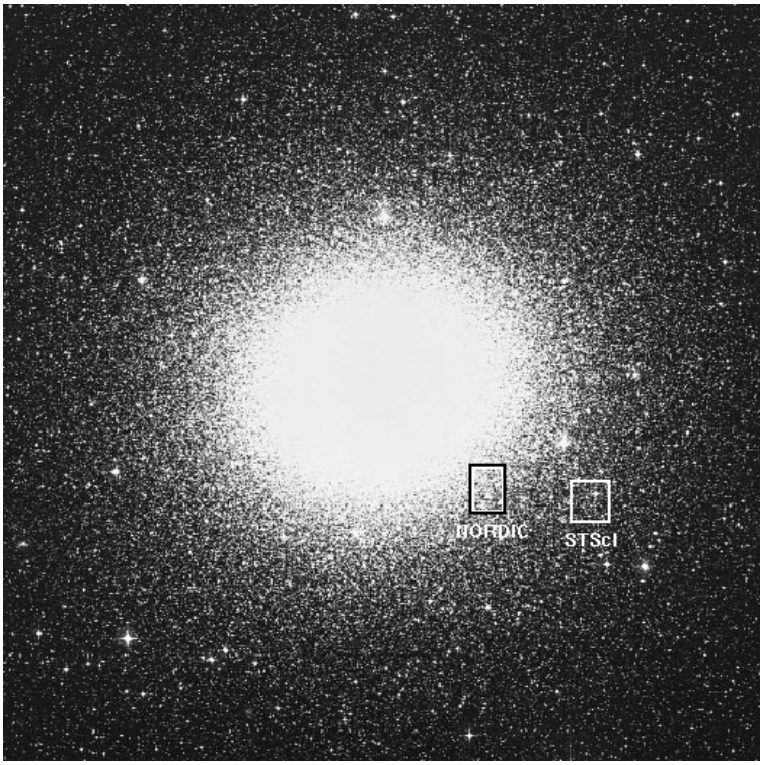


Figure 1. The $\omega$ Cen cluster. The two fields chosen for calibration purposes are marked.

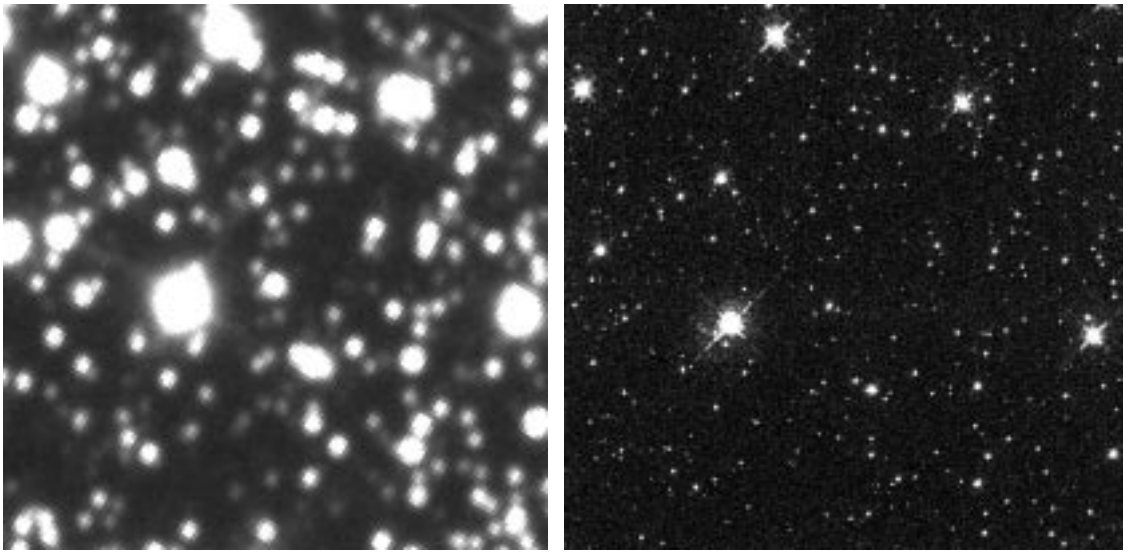

Figure 2. Left: The Nordic field as observed with the ESO 2.2m telescope. The image shown is a 5 min exposure through the y filter. The field size is 35x35 arcsec$^2$. Right: The same field, observed with the HST PC. The image shown is a 50 s exposure through the y (547M) filter.

## 3. The uvby System and its Astrophysical Relevance

For our work, we have chosen the uvby system (Strömgren 1963). The reasons for this choice are several. The system was designed and is ideally suited for exactly the type of studies defining our programme. Correctly employed, it delivers data of high accuracy having pass bands narrow enough to avoid the problems weakening broad band photometric systems. At the same time, its light collecting power is high enough to allow studies also of stars with modest brightness.

| **Field** | **Year** | $\mathbf{y}_{\rm eso}$ | $\mathbf{b}_{\rm eso}$ | $\mathbf{v}_{\rm eso}$ | $\mathbf{u}_{\rm eso}$ | $\mathbf{y}_{\rm wfpc}$ | $\mathbf{b}_{\rm wfpc}$ | $\mathbf{v}_{\rm wfpc}$ | $\mathbf{u}_{\rm wfpc}$ |
|---|---|---|---|---|---|---|---|---|---|
| Targets: | | | | | | | | | |
| NORDIC | 1986 | 62 (3) | 94 (4) | 93 (3) | 229 (6) | | | | |
| NORDIC | 1996 | | | | | 9 (2) | 30 (3) | 30 (2) | 80 (3) |
| STSCI | 1996 | | | | 30 (1) | 24 (8) | 70 (6) | 130 (7) | 135 (5) |
| Reference fields: | | | | | | | | | |
| M67A | 1986 | 6 (3) | 9 (3) | 7 (3) | 13 (3) | | | | |
| M67B | 1986 | 4 (2) | 5 (2) | 5 (2) | 8 (2) | | | | |
| NGC3680A | 1986 | 4 (2) | 6 (2) | 6 (2) | 12 (3) | | | | |
| NGC3680B | 1986 | 3 (2) | 2 (2) | 2 (2) | 4 (2) | | | | |
| IC4651A | 1986 | 9 (3) | 13 (3) | 15 (3) | 24 (3) | | | | |
| IC4651B | 1986 | 9 (3) | 15 (3) | 15 (3) | 32 (4) | | | | |
| 3 single star fields: | 1986 | (8) | (5) | (4) | (5) | | | | |
| M67A | 1996 | | | | 12 (3) | 5 (13) | 16 (12) | 22 (12) | 51 (13) |
| M67B | 1996 | | | | 22 (4) | 2 (7) | 9 (7) | 14 (7) | 33 (7) |
| NGC3680A | 1996 | | | | 5 (1) | 2 (5) | 7 (5) | 12 (5) | 28 (6) |
| NGC3680B | 1996 | | | | 10 (2) | 2 (5) | 7 (5) | 13 (6) | 27 (5) |
| 17 single star fields: | 1996 | | | | (5) | (41) | (30) | (31) | (32) |

Table 1. Summary of ground based calibration observations. For each observed field, the following is given: year of observation; uvby for ESO filters; uvby for WFPC2 filters; for each filter total exposure (min) and number of exposures.

| **Field** | **Year** | $\mathbf{y}_{\rm wfpc}$ | $\mathbf{b}_{\rm wfpc}$ | $\mathbf{v}_{\rm wfpc}$ | $\mathbf{u}_{\rm wfpc}$ |
|---|---|---|---|---|---|
| NORDIC | 1997 | 3 (4) | 27 (8) | 40 (8) | 53 (8) |
| STSCI | 1996 | 3 (7) | 5 (2) | 24 (5) | 412 (77) |
| M67-FIELD1 | 1996 | 2 (4) | 13 (4) | 24 (4) | 32 (4) |
| M67-FIELD2 | 1996 | 2 (4) | 13 (4) | 24 (4) | 32 (4) |

Table 2. Summary of space based calibration observations. For each observed field, the following is given: year of observation; uvby for WFPC2 filters; for each filter total exposure (min) and number of exposures are given. Notes: Some exposures are only partly overlapping, due to position offsets and detector rotation. The STSCI field has been observed by the STScI WFPC2 group.

From our experience with the uvby system as applied to stars in the solar neighbourhood, we know that it can give data on the abundance of heavy elements, expressed in

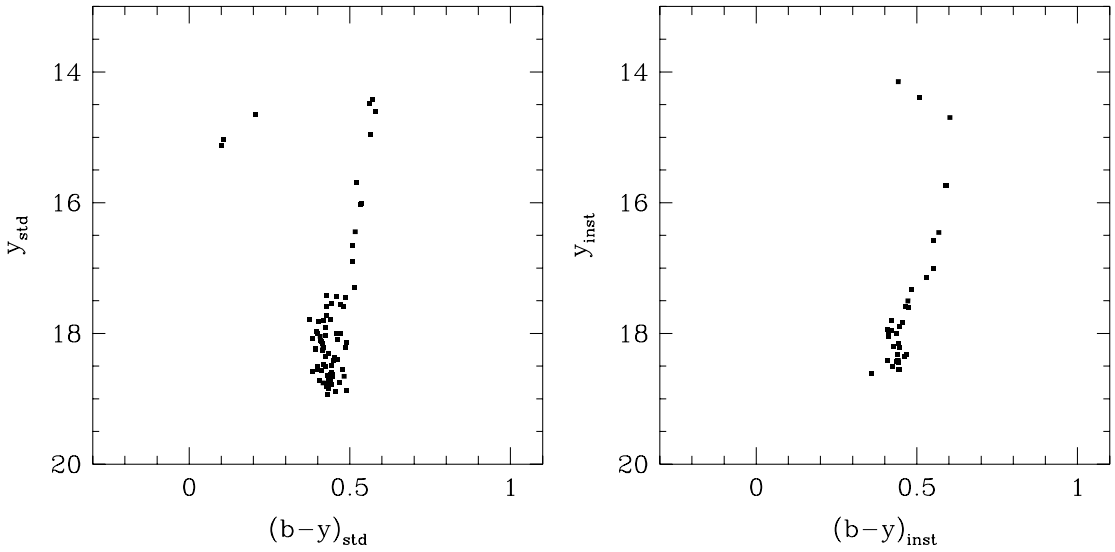


Figure 3. Left: Colour-magnitude diagram for $\omega$ Cen for the brighter stars in the ESO 2.2m observations. Right: Colour-magnitude diagram for the brighter stars in the HST PC observations.

terms of [Me/H], with an accuracy between 0.1 and 0.2 dex. Correspondingly, the accuracy obtainable in relative stellar ages is around 25 % or better. For our programme stars in the Bar of the LMC, we want to derive effective temperature, abundance of heavy elements and surface gravity or absolute (bolometric) magnitudes. Using these effective temperatures and absolute magnitudes, or their equivalents, we can, from comparisons with isochrones, determine ages of our programme stars.

The high quality of stellar parameters discussed above refers to observational data on the international uvby system. A prerequisite for solid analysis is, thus, adequate conversion of our observations from the instrumental system to corresponding data on the international uvby system. Such a system conversion must rely on a set of standard or reference stars with physical parameters, the ranges of which enclose those of our programme stars, and for which we have secured reliable and accurate data tied into the international uvby system. The present paper describes this procedure.

## 4. Observations

Our LMC programme observations were made with the HST and its WFPC2 instrument, used with uvby filters. For our system conversion observations, we use both this instrumentation and the 2.2 m telescope at the European Southern Observatory (ESO). Although our main concern is calibrating the Planetary Camera, we will also attempt calibration of the wide field (WF2, WF3, WF4) cameras.

### 4.1. Ground-based Observations

We have made two observing runs with the ESO 2.2 m, covering the two fields marked in Figure 1 as NORDIC and STSCI, respectively. The STSCI field is the same as used by Holtzman et al (1995) for Johnson photometry calibration. Table 1 gives a summary of the obtained data. The reference field in $\omega$ Cen is shown in detail in Figure 2. It measures 35x35 arcsec$^2$. To the left is seen a 5 min exposure in y obtained with the ESO 2.2 m telescope. A corresponding 50 sec y exposure made with the HST is shown to the right.

During the 1986 run, the NORDIC field was observed using ESO uvby filters. The 1986 data are reduced and have previously been reported (Linde et al. 1995).

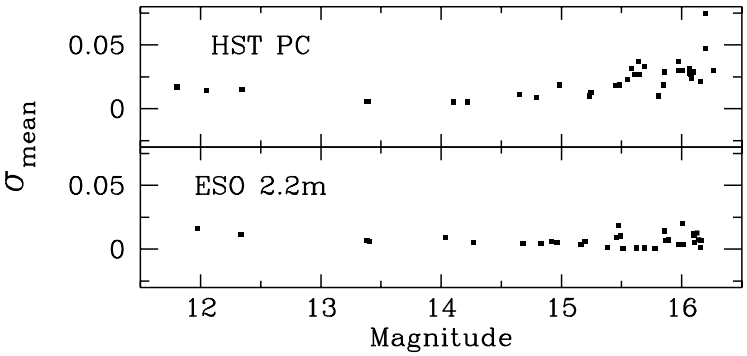


Figure 4. Photometric accuracy for the y filter.

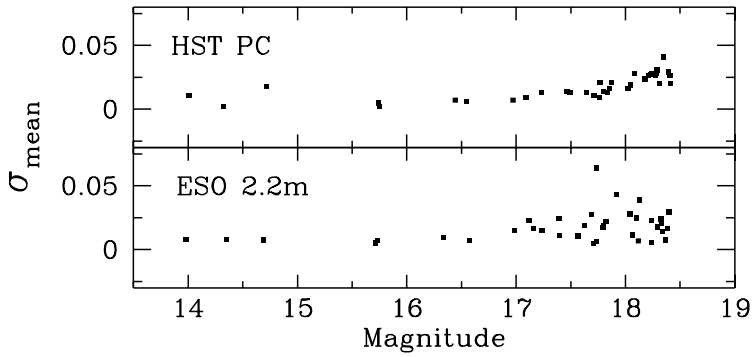


Figure 5. Photometric accuracy for the b filter.

In the 1996 run main emphasis was given to the STSCI field, while some images were also taken of the NORDIC field. Replicas of the uvby filters installed in the HST WFPC2 were used. Observations of the fields were alternated with observations of a generous amount of uvby standard stars. These observations and subsequent reductions give us a number of uvby system reference stars in $\omega$ Cen tied into the uvby system. Their colour indices covers the intervals defined by our programme stars in the LMC Bar as well as stars somewhat cooler.

### 4.2. Space-based Observations

The same fields in $\omega$ Cen were then observed with the HST and the WFPC2. Further, with the HST, we observed two fields in the old open cluster M67. Here, we selected stars that were somewhat hotter than those in our LMC Bar programme field and that had been observed photoelectrically and tied into the standard uvby system. These observations are summarised in Table 2.

## 5. Current Status and Some Results

Detailed conversion of our recently acquired HST uvby data is now in progress. Meanwhile, we have been able to test our data in some different ways. The result of one of these tests can be seen in Figure 3. For the brighter reference stars situated in the $\omega$ Cen field, the left figure shows a colour magnitude diagram as defined from our observations made with the ESO 2.2 m telescope. Right is displayed the corresponding diagram resulting

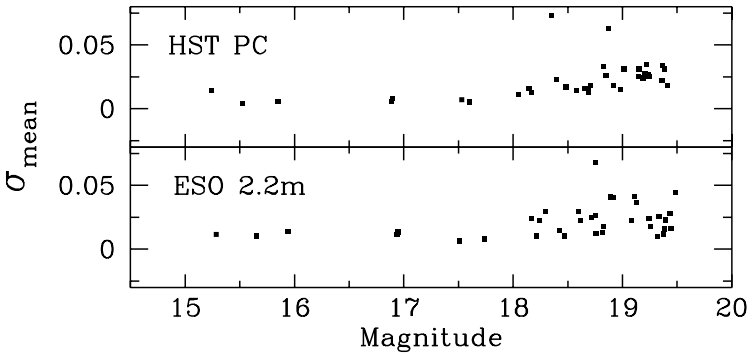


Figure 6. Photometric accuracy for the v filter.

from our observations obtained with the HST WFPC2. The photometric accuracy of our observations for system conversion may be estimated from Figures 4, 5 and 6. Here, the standard deviation of average y magnitudes are displayed versus y in Figure 4. In Figures 5 and 6, corresponding standard deviation diagrams are given for b and v, respectively.

## 6. Some Conclusions

From initial reductions we conclude that the data so far analysed look satisfactory. They indicate that a system conversion should be possible to adequate accuracy. This work is continued.

## References

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