

# Comparing the results of two CCD image reduction packages.

**R Kgoadi and C A Engelbrecht<sup>1</sup>**

Department of Physics, University of Johannesburg, Kingsway, Auckland Park, Johannesburg, South Africa

E-mail: rgkgoadi@gmail.com, chrise@uj.ac.za

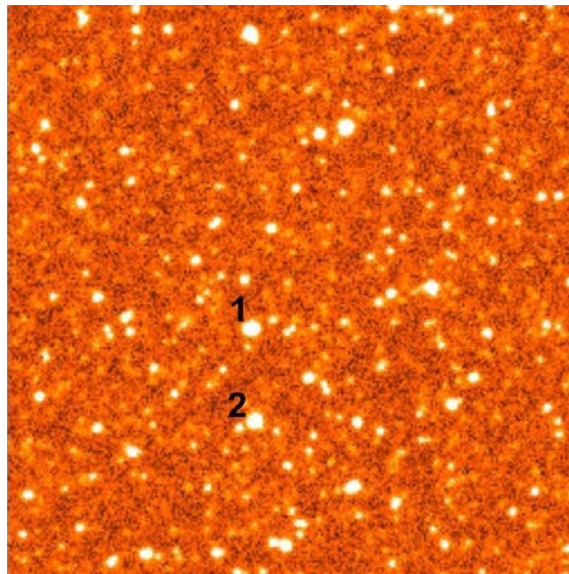
**Abstract.** One of the most critical procedures in observational studies of stellar physics is photometric data reduction. In this study, two software packages for this purpose are compared using a large volume of raw CCD data from the 1.0-m telescope based at the Sutherland site of the South African Astronomical Observatory (SAAO). The *Image Reduction and Analysis Facility* (IRAF) is developed by the National Optical Astronomy Observatory (NOAO) in the USA and runs on a Linux operating system. IRAF (version 2.16) is open source software that is commonly used for data reduction. Astronomical Image Processing for Windows Software (AIP4WIN, version 2.4.1), on the other hand, is designed for Windows and is obtained with a purchase of a textbook titled *The Handbook of Astronomical Image Processing* by Richard Berry and James Burnell. These packages are compared on the basis of the results that they produce from the same dataset. Reductions in IRAF resulted in fewer CCD frames images being rejected as compared to AIP4WIN and average magnitudes are approximately 14 with AIP4WIN extractions exhibiting a smaller variance.

## 1. Introduction

Obtaining accurate stellar magnitudes may be considered as one of the key procedures in stellar physics. It is an essential component of the extraction of information on periodic behaviour in a star and consequently, of the deduction of internal structure of a star. Hence, it is important that one tries to be as critical as possible during the reduction of astronomical photometry. A photometric reduction analysis of two chosen stars (referred to as Star 1 and Star 2 in this paper) was conducted using CCD frames obtained during three unevenly spaced observation runs at South African Astronomical Observatory (SAAO) in Sutherland to extract a time series of stellar magnitudes. The magnitudes of the target stars analysed are unknown due to data availability. This paper investigates whether the two mentioned software packages can be used irrespective of the nature of the FOV. By this we mean that, it is unavoidable that AIP4WIN and IRAF might centre the aperture differently. A crowded field of view (FOV) centred at  $\alpha = 77.7500^\circ$  and  $\delta = -68.8417^\circ$  was observed using the 1.0 m telescope with a V Johnson filter. Figure 1 shows the FOV and target stars analysed labelled 1 and 2, respectively, from one of the calibrated CCD frames used. Results show that there is some similarity from the results obtained from these packages. Further comparison of the magnitudes was done by extracting frequencies from light curves with the aid of the Lomb Scargle periodogram as part of the analysis.

## 2. Methodology

Raw CCD frames contain not only scientific data but also systematic noise from components surrounding the detector and pixel variations during observation. Hence, CCD frames must be calibrated before instrumental magnitude extraction. A typical calibration procedure involves Bias and Dark subtraction and flat fielding [1]. CCD calibrations result in frames consisting of signal mainly from celestial objects and the sky background. Even though Dark subtraction was performed during the analysis, it was not of practical benefits since the CCD camera used in the study has a liquid nitrogen cooling system attached to the detector, reducing the level of Dark current during observation to practically nil [2]. Master Bias, Dark and Flat frames were created using the median algorithm with both packages. The following subsections describe how each package was confirmed to reduce the data.



**Figure 1.** A calibrated CCD frame showing the field of view that enclosed stars 1 and 2. This CCD frame was calibrated by subtracting bias and dark levels as well as flat fielding a raw frame.

Data reduction was performed per observation session, taking climatic conditions into consideration. For consistency a number of parameters were kept constant for both IRAF and AIP4WIN during reductions, such as *zmag* and the aperture size. The value of the aperture size was based on the full width half maximum (FWHM) values from IRAF radial plots.

### 2.1. Image processing using IRAF (<http://iraf.noao.edu>)

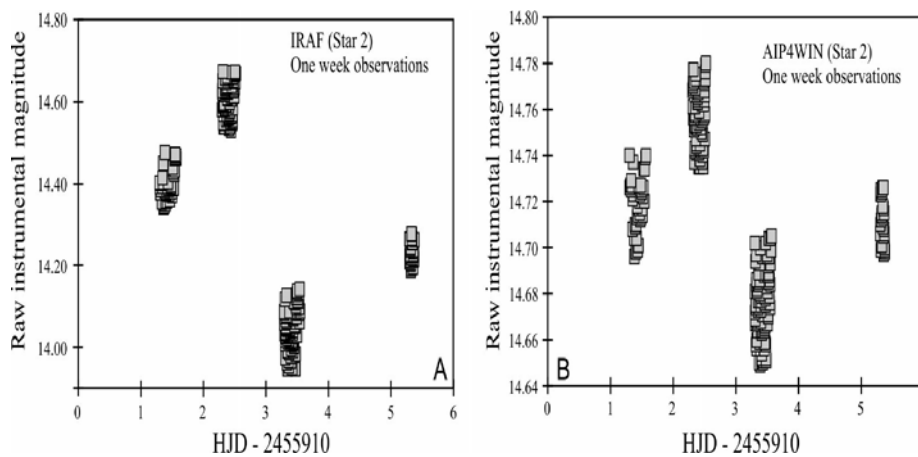
Calibration steps followed were similar to those described in [3] and the SAOimage ds9 viewer was used to display frames. The IRAF system sub-package IMRED was used for general image processing and two NOAO optical astronomy sub - sub-packages - CCDRED and DAOPHOT - were used for calibrations and photometry respectively. The task *ccdproc* was used to calibrate science CCD frames and remove the over scan region as described in [4]. Frames were aligned using *imalign* task. Photometry was only performed to calibrated frames with an average value of the FWHM not greater than 4 for Star 1. The value of the FWHM used was determined by taking a sample of the batch that was distributed evenly throughout the night. As a result, certain nights/observations were rejected for the purposes of this study and in order to remain consistent the same observations were omitted while using AIP4WIN. Aperture photometry was performed using the *digiphot.daophot.phot* task.

2.2. Image processing using AIP4WIN (<http://www.willbell.com/aip4win/aip.htm> )

A tutorial guide provided with the AIP4WIN textbook was used to perform calibrations and photometry. Since we were working with a large volume of data frames, the Multi-Image Photometry Tool (MPT) was used. Compared to IRAF, AIP4WIN is more automated: data frames can be calibrated during photometry and master calibration frames were created using chosen CCD frames from the dataset. Using a built-in display tool, an image's grey level can be adjusted to improve the visibility of the stars [5].

**3. Results**

One of the obvious arguments that may be stipulated is that IRAF requires a fair knowledge of the Linux operating system and installation maybe be to some extent a challenge as well. However AIP4WIN, is an easy installation either with the CD provided or downloading software from publishers. Figure 2 shows results of aperture photometry for one week of the sample data for the two packages respectively for star 2. There exists a similar pattern in both packages indicating that star 2 was fainter in the first two nights of observation and brighter on the third night. The change in the brightness of the star may be due to the atmospheric conditions for the specific night. AIP4WIN extracted magnitudes tend to vary less compared to IRAF magnitudes. Simple descriptive statistics was performed on the entire data; as shown in table 1. Data from AIP4WIN have a sample variance of 0.002 compared to that of 0.039 for IRAF.



**Figure 2.** Raw instrumental magnitudes extracted from IRAF and AIP4WIN respectively for star 2

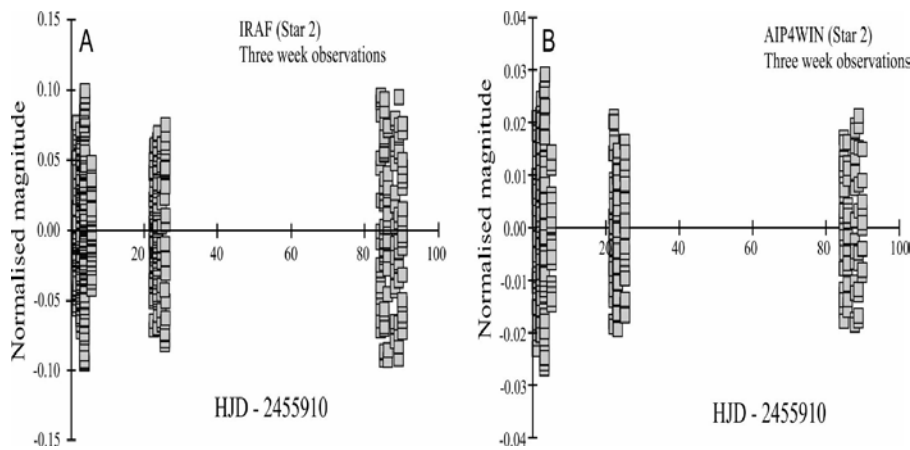
Table 1 shows basic statistics done on the overall data for respective packages. It is evident that light curves in figure 2 fully represents how the magnitudes deviate from their respective averages. As much as AIP4WIN possesses a low variance, these results may not be considered conclusive since parameters such as the airmass and *psf* fitting were not considered during extractions. Note that the value of N in table 1 differs for IRAF and AIP4WIN reductions, this is because the respective packages have distinct algorithms for rejecting frames.

**Table 1.** Statistics of extracted magnitudes for star 2, these data are from IRAF and AIP4WIN respectively.

IRAF				AIP4WIN			
N	$\bar{x}$	range	$s$	N	$\bar{x}$	range	$s$
531	14.321	0.865	0.039	451	14.694	0.158	0.002

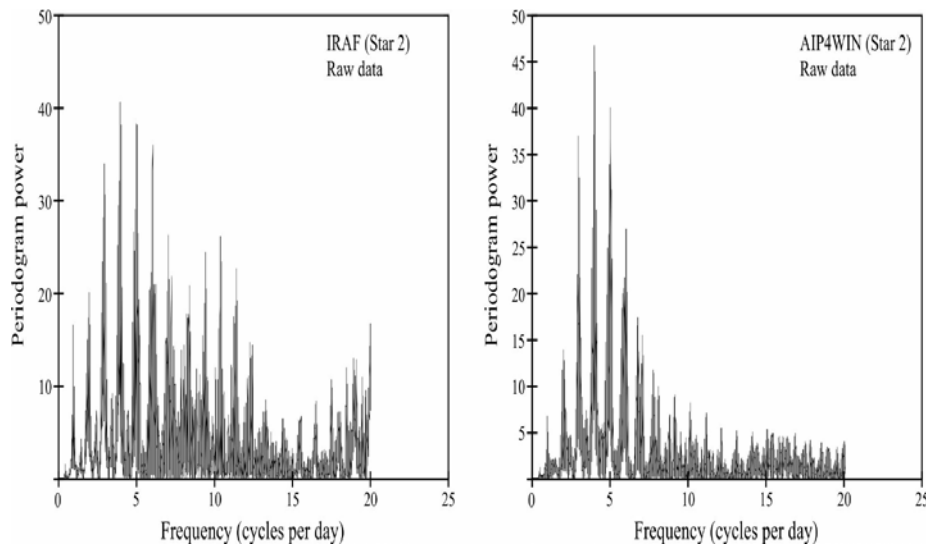
N represents the size of the data,  $\bar{x}$  the average and  $s$  is the sample variance.

The variation in the results can also be seen when light curves are plotted using normalized daily averages, as shown in figure 3. Normalized magnitudes were obtained by subtraction of the daily mean from respective magnitudes. The light curve plotted using AIP4WIN reduced data shows that the scatter is more clustered around the mean as compared to IRAF light curve. This is most probably caused by the AIP4WIN package rejecting far more frames that IRAF did.



**Figure 3.** Normalized magnitudes for star 2 for both software packages.

The raw instrumental magnitudes obtained from the two packages were used to detect periods in the respective light curves. Periodic variations were extracted using the Lomb-Scargle periodogram and gave the following results: strongest frequencies of 3.18  $c/d$  and 4.01  $c/d$  were obtained for stars 1 and 2 respectively, for both AIP4WIN and IRAF light curves. Figure 4 only shows an output for star 2 LSP analysis.



**Figure 4.** Lomb-Scargle analysis of star 2, using light curves from raw instrumental magnitudes.

#### 4. Conclusion

Although the packages produce broadly similar results (especially in the important matter of identifying the strongest peak in the periodogram), there are rather striking differences: the IRAF-generated periodogram clearly contains more structure than the 'clean-looking' AIP4WIN-generated one. This is most probably the result of AIP4WIN rejecting more frames than IRAF did, causing to a tighter scatter shown as in figures 3 and 2. The extra structure in the left-hand periodogram of figure 4 could be the result of either a more sensitive periodicity detection (which would favour IRAF) or a greater amount of noise (which would favour AIP4WIN). However, given the remarkable discrepancies between the magnitudes calculated by AIP4WIN and IRAF respectively, as displayed in figures 2 and 3, it is more likely that AIP4WIN is not suitable for the crowded field in this experiment. However, further work is necessary to make a final statements on the relative merits of the tested packages for reductions of the type of photometry presented here. In the case of crowded FOV, IRAF appears to be more suitable since further analysis like psf photometry can be done to account for fainter stars and nearby stars. AIP4WIN may be more suitable for uncrowded fields and as it is a developing package, parameters such as the airmass corrections may be considered in later developments.

#### Acknowledgments

Financial support from the NRF and the University of Johannesburg is gratefully acknowledged. The South African Astronomical Observatory is thanked for generous amounts of observing time on the 1.0-m telescope and for helpful assistance in various operational procedures.

#### References

- [1] Tody D 1986 The IRAF Data Reduction and Analysis System *Instrumentation in astronomy VI (Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series vol 627)* ed Crawford D L p 733
- [2] Howell S B 2006 *Handbook of CCD Astronomy* 2nd ed (New York: Cambridge University)
- [3] Massey P 1997 A user's guide to ccd reductions with iraf Tuscon AZ USA National Optical Astronomy
- [4] Valdes F 1988 The iraf ccd reduction package - ccdred *Instrumentation for Ground-Based Optical Astronomy* ed Robinson L B p 417
- [5] Berry R and Burnell J 2000 *Briefly Noted: The Handbook of Astronomical Image Processing* 2nd ed (Richmind VA USA Willmann-Bell)