A Guide to the Reduction of ULTRACAM data
Version 0.1

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Abstract

This document is a manual on the reduction of high-speed CCD photometry taken with ULTRACAM. The aim is to give a coherent picture not afforded by the individual program descriptions. This is a very rough first draft.

1 Introduction

While it is possible to get near-publication quality reduced data directly at the telescope with ULTRACAM, the main purpose of the near real-time reduction is to monitor data quality and to help with observing decsions. Therefore you may well want to re-reduce the data yourself. This document is a guide as to how one goes about this. Note that there are lots of detailed program descriptions avaliable, and so this document does not try to repeat these, rather its purpose is serve as a guide for the whole reduction process and is based upon experience of having used ULTRACAM for a while.

If you view this with acroread, then get a web browswer running in the same window to be able to go to the hyper-links.

2 Getting the software

If you are going down this route, you will need to install some software. Please look at the software web pages for details of how to do this. Let me know of problems that you encounter.

3 Getting the data

At some point we hope to make an automated database where you can pick the files that you need. Until this point I'm afraid that it is a matter of asking us for your data. At Warwick I have much of the data on-line and can transfer it to a web server for download.

ULTRACAM data comes in the form of raw data files of the form 'run034.dat' and for each one a corresponding XML file, e.g. 'run034.xml'. Both files must exist in order to be able to do anything with the data.

4 Reduction

4.1 First steps – getting oriented

Once you have the data the first thing is to see if you can plot some of it. fire up the software and try out the command rtplot. You may need to point it at the right source of data the first time you use it; look at the help.

Having done this to a few files, you might want to grab a few files which you can then look at in more detail with plot or cplot. The files are stored as files with the extension '.ucm'. For instance you might end up with 'run034_001.ucm', 'run034_002.ucm' etc. Ecah of these contains all three CCDs plus some header info. Try the program uinfo to get a little basic data on a ucm file. The image display facilities in the pipeline software are crude by comparison with 'ds9' or 'gaia'; it has not been my intent to replicate such programs. If you want to use them then you should convert the files to FITS which can do using ucm2fits for ucm files, or more directly using grab2fits.

I now go through the reduction steps in the order in which you should approach them. If you want a quick look you could at this point jump to the section on apertures (section **??**).

4.2 Making bias frames

Almost the first thing you should do is to create a mean bias frame. With the two readouts/CCD of ULTRACAM the different bias levels can make it hard to view images easily, so you will typically want to remove the bias level fairly early on. Find a bias run, check the comments to see that things were OK and then grab the entire run. Make a list containing all the names of the resulting ucm files (e.g. 'ls run034*.ucm ¿ bias.lis') and apply the program combine. It is much better to use the clipped mean method of combination rather than the median which suffers from digitisation noise. You should use the 'bias' adjustment to allow for variable bias levels.

Warning: ULTRACAM sometimes suffers from a problem in which the bias levels are incorrect immediately after a power-on. Be careful to check that such frames match other ones. Only use biases affected by odd bias levels if your data suffer from the same problem.

4.3 Making dark frames

The ULTRACAM chips run at $-40\,\mathrm{C}$ and have non-negligible dark current, especially for exposures longer than a few seconds. Although the mean dark current is less than 1 count per second, but there are various 'hot pixels' which can be far higher than this (the worst of all is at 423, 902 on CCD and counts at hundreds per second). Look at your data with rtplot and see if you can see obvious hot pixels. If you can then you might want to make a dark frame. To do so you need a dark run, preferably taken during the night because it very difficult to guard against light leakage during the day. Grab these to ucm files, kick out any with non-standard exposures times (probably the very first and very likely the last one) and average together with combine. You should either use the 'bias' or 'ignore' adjustment; I don't think it should matter which.

Once you made the dark frame *subtract the bias frame from it* otherwise it will not work properly during reduction.

4.4 Making flat fields

ULTRACAM flats are typically taken as a long sequence at the start and end of the night. The small deadtime of ULTRACAM is of great advantage and means that we do not bother changing the exposure time as a rule. Typically the flats start or end saturated in 2 or 3 of the chips, with the u' CCD being the least sensitive and therefore coming out or going into saturation las of all. One wants to median these for cosmic rays but this cannot be done directly because of the changing mean level. On the other hand simply taking the median after dividing out the mean level overweights low signal flats. Thus the routine makeflat has been developed which takes the median of small groups of normalised flats of similar mean level (prior to normalisation) and then adds the results together with appropriate weights. It also knows how to ignore saturated and 'peppered' (see below) flats.

makeflat works on lists of ucm files. *You must subtract the bias before using it.* If you have a dark frame, you should subtract it before running makeflat using dsub which scales by the ratio of exposure times. For most pixels this should hardly matter, but there is no reason not to try to correct hot pixels properly if possible.

Beware the last frame of a run! Typically sky flats are terminated by stopping the run in the middle of an exposure so the last exposure is not to be relied upon. I always delete it after I have downloaded a run using grab. It only does not matter for bias frames.

4.4.1 Peppering

At high counts levels, but well below saturation, the ULTRACAM chips show a pattern in which neighbouring pixels are high and low. This looks a bit like pepper in the centres of the chips at high count levels, and thus we call it peppering. This peppering occurs short of 30,000 counts in the green and ultra-violet chips and at about 50,000 in the red CCD. *You should set the levels in makeflat to avoid frames affected by peppering!* Use rtplot to find out the levels. The maximum values I use are 48000, 30000 and 26000 for the red, green and ultraviolet CCDs respectively (numbers 1, 2 and 3 as far as the software is concerned). Peppering looks terrible when you first see it, but it really switches off as long as one is below the thresholds.

4.5 Making bad pixel frames

— to be done — not usually too important; many a data quality control exercise.

4.6 Setting up apertures

The software is not clever about apertures. You have to tell it where each star that you want to reduce is. This has the advantage that it is possible to cope with cases where a star disappears from view completely – you can still get an extracted count rate for what it is worth. Once you have set them up at the start, the apertures are adjusted automatically frame by frame you may be relieved to hear.

First of all you need to make an average frame of your target field. Use grab to get a few suitable frames, combine to average them, and subtract the bias. No need to flat-field, unless you are trying for really accurate positions which you expect to keep fixed in some way.

You then run setaper on each CCD of the image. This gives you options to link a faint star to a brighter reference stars and so on. You may want to set a clean, isolated, bright star as a 'reference' in any case is you are likely to want to measure the seeing or use apertures with sizes that scale with the seeing. There are also options to mask stars that might contaminate the sky apertures. See setaper for details.

The program writes an ASCII file which can be edited by hand as well, although the format is fairly specific.

4.7 Reducing your data

You are now almost ready to reduce your data. You need only set up a data file to specify the reduction that you want. This consists of an ASCII file with many options, for instance the names of the calibration files, the method of extraction to use (optimal or normal), whether to vary the aperture radii or hold them fixed, etc. If you have several runs, I would strongly advise picking a 'typical' one first and adjusting the parameters for it before running on all of the others. It is in partciular tricky to pick the optimal aperture scale if your using variable aperture radii. In tim Naylor's optimal photometry paper, he recommends an aperture radius of about 1.5 times the FWHM seeing. I find this to be OK for faint targets, but it is an underestimate for bright ones. This can mean that one should use ratios or order 1.8 for the red and green CCDs versus 1.5 for the ultraviolet. Use the multiple aperture radius option together with the splitr script to reduce with many scale factors quickly.

Once you have the ASCII file ready, then run it using reduce. The result is a large ASCII file with many columns but it is self-documenting. Use your favourite program to read the columns. You are on your own from this point; I am developing a program to help but it is in a rather primitive state.