Astronomical Data Analysis Software and Systems IX
ASP Conference Series, Vol. 216, 2000
N. Manset, C. Veillet, and D. Crabtree, eds.

QuickLook Data Reduction Pipeline – Keck Adaptive Optics Real Time Data Reduction Software

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Abstract. When observing with adaptive optics, it is often necessary to reduce the images in real–time to adapt to varying conditions and to adopt the correct observing strategy. For example, the integration time can vary with fluctuating Strehl ratio, or the adaptive optics system can be tuned to produce the same image quality on the PSF calibrator and on the object of scientific interest.

To this end, a "QuickLook" data reduction pipeline was developed at the W.M. Keck Observatory, designed specifically to reduce adaptive optics infrared observations. The pipeline allows the observer to clean–up the images cosmetically using of FITS keywords and a library of calibration files (darks, flat fields, etc.), to examine the images in many modes, to compute image quality parameters (FWHM, Strehl) and to piece various images together (in mosaics or shift and add). Furthermore, the pipeline accepts data acquired with various observing techniques (dithering, separate sky exposure, etc.).

In this paper, we describe the general philosophy, and general overlay of the pipeline. Different screens of the User Interface are shown to illustrate the principle and feel of the tool, and finally some examples of scientific targets reduced with the pipeline are presented to demonstrate the efficiency of the "QuickLook" data reduction tool.

1. Introduction – Pipeline

Schematically, the pipeline consists of 4 distinct steps: reducing the data (cosmetic, camera defects, noise, etc.); viewing and examining the data; extracting quantitative image quality estimates; and assembling the images with mosaicing or shift and adding.

This is achieved with the QuickLook Data Reduction Pipeline, where all this can be done without typing a command at the keyboard: a menu driven set of applications, specific to this detector, are used in *real–time* to streamline adaptive optics observations.

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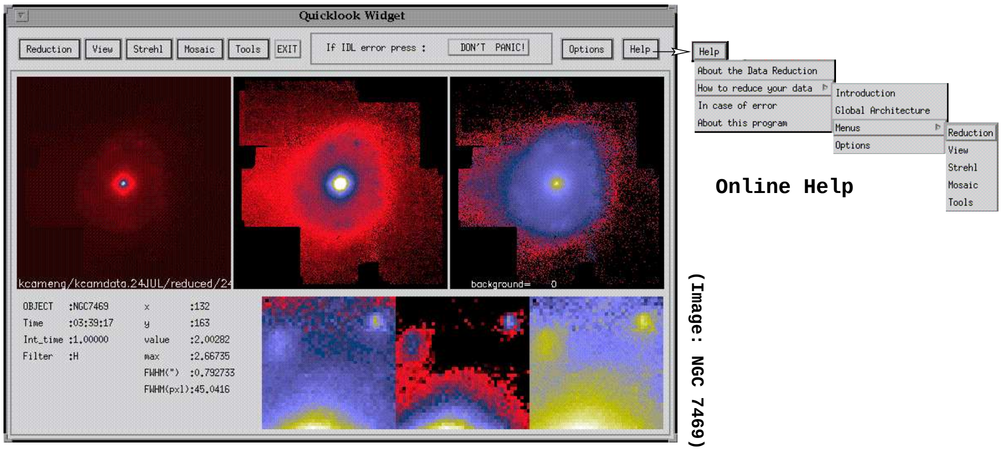

Figure 1. Data reduction pipeline Look&Feel.

2. Data Reduction

The data reduction consists of selecting an image frame (or series thereof) to reduce and a sky frame; there are a variety of ways to do this (extracting the sky from a dither pattern, combining various sky frames together, etc.) with a variety of interfaces.

Once the files are in the pipeline, all the relevant information is extracted from the FITS header, and the images are reduced: each frame is divided by the number of co-adds. If the integration time is different between the object and sky, the appropriate dark frame (if it exists) is subtracted from both, and the residual of both is normalized to a one second exposure. The images are then flat–fielded and dead–pixel corrected. An option can be toggled on or off to try to remove any periodic noise. Finally, some detector specific operations are performed (the quadrants are shifted by one pixel), the FITS headers are updated and the processed images are written to disk.

2.1. File Architecture

Each nightly directory contains two subdirectories named `reduced` and `calib`. All the reduced files go in the `reduced` directory, keeping their original filename with a suffix describing the processing they have undergone. The `calib` directory contains the most recent flat–fields, darks and dead pixel maps. The file name contains the information about the file parameters (e.g. `flat_H.fits`, `dark_005.0s.fits`).

3. Image Displays

3.1. XDisplay

The images from KCam (Keck Camera) are acquired through a PC at the summit, controlled remotely with PCAnywhere. The images are written to disk on a workstation. This tool checks the disk for newly written FITS files. These

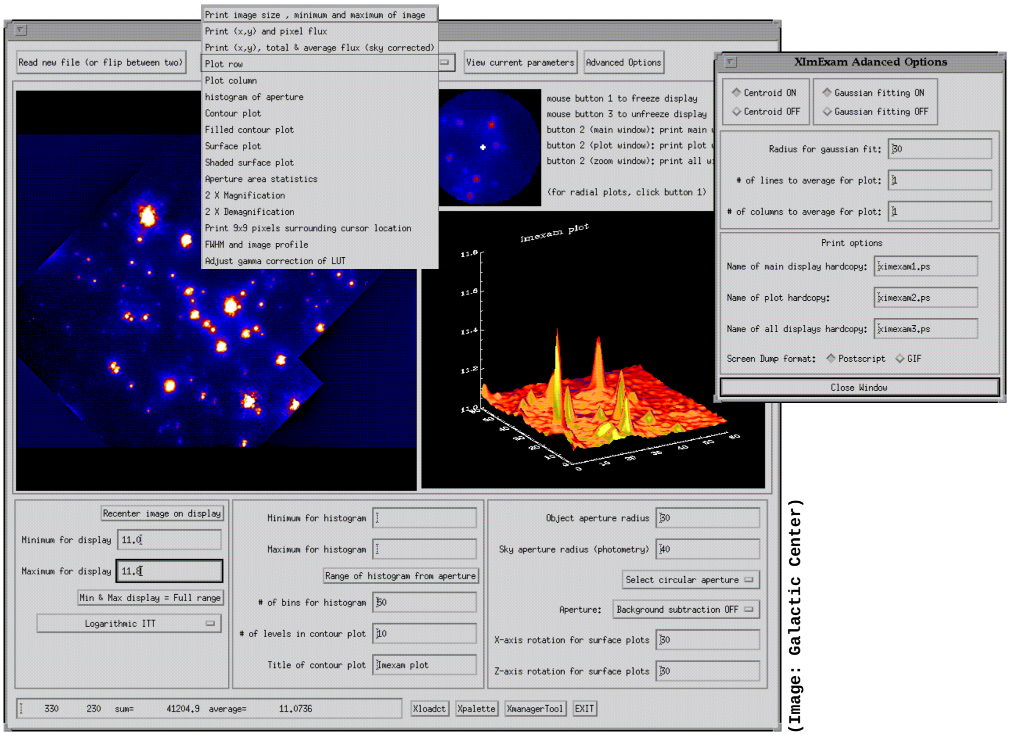

Figure 2. XImExam: a widget that includes all the functions of IRAF's imexamine routine (cuts, surface and contour plots, aperture statistics, PSF fitting, etc.).

are read in and displayed (Figure 1, from left to right: linear scale, linear scale with cuts at $\pm 3\sigma$, and log scale). Image parameters from the FITS header are displayed. The three lower windows display a zoomed area around the cursor, for which statistics are also displayed.

3.2. XImExam

This program, entirely written in IDL, emulates most of the function of the IRAF "imexamine" routine. The major difference is the use of a widget wrapper: the main pull down menu indicates the action of the mouse as it is dragged across the main display window. Most parameters can be adjusted with interactive text areas. Some more advanced parameters can be modified by opening a dedicated window. The screens can be dumped into PostScript or GIF files, either individually or altogether.

The many functions available include: plotting rows, columns (or averages thereof) and histograms; printing image or area statistics and values; plotting contour maps (line or filled) and 3D surface plots (mesh or shaded), image magnification and demagnification, radial plots and Gaussian fitting, Look Up Table adjustments (as in saoimage), linear, square root, logarithmic or wrapped Intensity Transfer Table, etc.

4. Image Quality Evaluation

Strehl ratio and FWHM: the wavelength (i.e. the filter used) is extracted from the FITS header and a theoretical PSF for the Keck pupil geometry is estimated. The image is filtered in the Fourier Domain to increase its SNR, and is also rebinned by a factor 4 in the Fourier domain. Both images (the observed and theoretical) are normalized. Since the determination of the background is so crucial at this step two methods are implemented: one is using a median of the pixels on the periphery of the selected image, the other extrapolates the 2^{nd} and 1^{st} frequencies in the Fourier Domain back to the zeroth frequency. With the images thus normalized, the maximas are compared, and the ratio of the two is the Strehl ratio. The Full Width at Half Maximum is found by computing the square root of the number of pixels that are above half the maximum, divided by π.

5. Combining Images

Mosaics and shift&adding: the sole difference between mosaics and shift and adding is the in the mosaic process; the images can (and indeed need to be) approximately placed with respect to one another on a larger canvas. This is done interactively, but if a sufficiently prominent feature allows it, a first estimate is done using the center of gravity of the image; this is often enough as the images don't need to be placed to better than half a dozen of pixels. Each image is then placed on the canvas and adjusted to the previous ones by cross correlating over common features. Each common area is rebinned by a factor four and cross correlated again to provide quarter pixel accuracy. The average background and slopes of the images are also computed (over the common area) and set to zero; this produces seamless mosaics. Finally two files are produced, one being the median of all the images which have overlapping features, the other the average. It is always important to compare the two as the median will not have any of the camera remanence effects (whereas the average might, at a low level), but generally the average seems to have a better SNR.

section above for details on how to

References

Many thanks to Francois Rigaut for providing the core imexamine IDL code.

Thanks are extended to Ian McLean and James Larkin (UCLA) for making KCam available to the Keck Adaptive Optics program.