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REDUCING X-ray BRIGHT GALAXY GROUPS IMAGES WITH THELI PIPELINE

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ABSTRACT

Before analyzing the images taken with a Mosaic CCD imager, the images have to reach a state which can be used for further scientific analysis. The transformation of raw images into calibrated images is called data reduction. Transforming HEavely Light into Images (THELI) is a nearly fully automated reduction pipeline software (Erben et al., 2005). This pipeline works on raw images to remove instrumental signatures, mask unwanted signals, and perform photometric and astrometric calibration. Finally THELI constructs a deep co-added mosaic image and a weight map. In this poster, THELI data reduction procedures will be reviewed and the reduction process for raw images of seven X-ray bright groups, extracted from GEMS groups (Osmond & Ponman, 2004) obtained by the Wide Field Imager (WFI) mounted on MPG/ESO telescope at La Silla in March 2006 will be discussed.

Key words: journals: individual: PKAS

1. INSTRUMENTS & RAW DATA

The image data studied here was taken by S. Raychaudhury, A. Dariush, H. Khosroshahi and T. Ponman during 5 nights in March 2006 at the the MPG/ESO 2.2m telescope. The telescope is located on La Silla at an altitude of 2335 meters. The MPG/ESO 2.2m telescope hosts the Wide Field Imager (WFI) which is mounted at the Cassegrain focus of the MPG/ESO 2.2m telescope. WFI is a mosaic camera consisting of eight 2k×4k CCDs with a pixel size of 15μm. The pixel scale is 0.238"and the total field-of view in the sky is 34'×33'. The instrument characteristic is optimal for observations in wavelength ranges from the UV to near IR.
The data set consists of B, R and I optical board band filters (FWHM $\geq$ 35nm) and the frames are divided into SCIENCE, BIAS, SKYFLAT and STANDARD.
For their survey, they proposed to obtain deep BRI photometry of seven nearby groups of galaxies which are relatively bright in X-rays (e.g. HCG042, HCG048, NGC3557, NGC3923, NGC4697, HCG062, HCG067), have deep ROSAT and Chandra/XMM observations and about 20 galaxies 6dF redshifts in each. It has been investigated whether these richer groups have a bimodal luminosity function like the X-ray poor groups of Miles et al., (2004), thought to be the result of enhanced mergers in a dynamically sluggish environment.

2. THELI PIPELINE

Transforming HEavely Light into Images (THELI) is a nearly fully automated reduction pipeline software (Erben et al., 2005).
This pipeline was initially developed for the reduction of the 20 square degree Garching-Bonn Deep Survey, conducted with the Wide Field Imager (WFI) at the 2.2m MPG/ESO telescope in La Silla.
It is entirely instrument-independent. All camera-specific parametres are contained in an instrument configuration file. The reduction steps are very similar, independent of what kind of data one reduces. In particular, this extends from optical to mid-IR wavelengths, and from single to multi-chip instruments.
The main pillars of THELI are the available stand-alone software packages such as SExtractor, Scamp, Swarp etc,. Most of these packages were slightly modified to better suit our purposes and wrapped with UNIX/bash shell scripts to form this pipeline. Nearly the whole system is implemented in C/C++ and UNIX bash shell scripts. Parallelisation is fully supported for multi-core CPUs and for cluster architectures.

3. DATA-PROCESSING

THELI data-processing, which aims at the production of co-added images from dithered observations of different targets, happens in two major steps, Pre-Reduction (or RUN processing) and Reduction (or SET processing).
The pipeline splits the raw science and calibration CCD mosaics into single chips, which are then processed indi-

vidually. The processing of the individual chips contains the basic data reduction: overscan correction, master bias subtraction, flat-fielding with skyflats and superflats and defringing. The next processes, such as astrometric, photometric calibration and coaddition, can not be completely parallelized and are performed on the master computer.

4. PRE-REDUCTION (RUN PROCESSING)

PreReduction (or Run processing) steps which take care of instrumental contaminations are done on each CCD chip independently, except for sky-background equalization. A RUN represents a period for which the same calibration (bias, flat, fringe correction etc.) can be applied to science images. Obviously observations in different passbands represent different RUNS. THELI does:

4.1. Preparation for Data Processing

If data is stored in Multi-Extension FITS (MEF), THELI extracts all the images into separate files. In addition, THELI updates each file's header with necessary keywords for the pipeline. Then images are divided into chips (8 CCD chips in a WFI mosaic). From now on, we will work on individual chips rather than whole images, which enhances the speed, and also enables us to do multi chip processing on multi CPUs, here with four cores.

4.2. Frame Processing

Each frame is Overscan Corrected (OC), then trimmed (overscan region is trimmed off the image) and a Master BIAS is created by stacking OC frames. FLAT frames are OC, trimmed, BIAS subtracted and stacked, forming a Master FLAT.
SCIENCE frames are OC, trimmed, Master BIAS subtracted and Master SKYFLAT divided. A SUPERFLAT image is created by mode rescaling and median stacking of all SCIENCE images objects.
ILLUMINATION from SUPERFLAT, FRINGING frame is produced. SCIENCE frames are FRINGING corrected (OFCSF).
A binned mosaic (4 to 1 pixel scaled) of corrected SCIENCE frames is created to check the run process.

4.3. Manual Eyeballing, Mask Creation

At this stage, we looked at binned mosaics to check if the prereduction has gone well. We did manual masking for extended defects like satellite tracks and bright star reflections using DS9 for OFCSFs. Masks were then converted to SAOimage format by THELI. A nice feature of THELI is that it can detect and mask most of the effects automatically.

4.4. Creating Weight Frames

Hot/cold pixels are detected using Master DARK, saturated pixels are identified by thresholding the SCIENCE frames, cosmic rays are discovered by SExtractor in connection with EyE and manual masks are added using LDAC utilities.
At this stage weights for individual frames are created. Global Weight and Flag frames are made for each CCD chip. Flags are integer FITS of zero for good pixels and values denoting different defects, considered in producing weights. Global Weights contain information about bad pixels applied to all images from that chip.

5. REDUCTION (SET PROCESSING)

After PreReduction (RUN processing), images are rearranged into sets which represent the different targets (possibly in different filters) which should result in coadded stacks from THELI processing. On SETS the operations of astrometric calibration, final photometric calibration and co-addition are performed. A target can have been observed in different RUNs.

5.1. Standard Stars Processing

At this point, THELI processes STANDARD images as above and then does the photometric calibration via cross correlation with Landolt catalog (Landolt 1992).

5.2. Set Distribution

THELI puts the series of all science exposures of the same target in a particular filter, called a set, into one directory. These are the frames that will be finally coadded.

5.3. Astrometric Calibration

THELI extracts catalogs from high S/N objects for each chip using SExtractor, calculates a linear shift with a reference catalog (we used 2MASS) and then merges the catalogs. A full astrometric solution taking into account the gaps between the chips and overlap objects is calculated. THELI uses LDAC catalog file format and SCAMP package.

5.4. Preparation for Coadding

Sky background is calculated with Sextractor BACKGROUND check image for every large-object-subtracted image and is subtracted from all SCIENCE frames.

5.5. Coaddition

THELIs SWarp first undistorts and resamples all input SCIENCE and WEIGHT frames according to the astrometric solution. With all resampled input images belonging to a given output pixel present, Swarp calculates the final results using a weighted mean method.

6. RESULTS

Finally you will be provided with the final Co-added and Weight map images. In addition, we have described the implementation of an automatic first quality check on the Co-added mosaics. Basic tests on extracted object catalogues, like galaxy counts and a check on the clustering of sources are done without any user interaction and are performed for each individual pointing and filter.

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