A short introduction to the ASTEP400 Data Pipeline

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Status of the pipeline

- **Custom pipeline**
  - Developed by Djamel Mékarnia from mid 2009 (tests in Nice)
  - Based on some routines developed for ASTEP-South
  - Extensive use of DAOPHOT routines

- **Input data format**
  - raw 4k×4k FITS image files
  - 4 categories of images: SCIENCE, SKYFLAT, DARK, BIAS (basically just identifiers)

FITS headers

basic FITS

```
SIMPLE  =                    T / file does conform to FITS standard
BITPIX  =                   16 / number of bits per data pixel
NAXIS   =                    2 / number of data axes
NAXIS1  =                 4096 / length of data axis 1
NAXIS2  =                 4096 / length of data axis 2
EXTEND  =                    T / FITS dataset may contain extensions
COMMENT   FITS (Flexible Image Transport System) format is defined in 'Astronomy
COMMENT   and Astrophysics', volume 376, page 359; bibcode: 2001A&A...376..359H
BZERO   =                32768 / offset data range to that of unsigned short
BSCALE  =                    1 / default scaling factor
```

observatory

```
COMMENT = '*** File section ***'
ORIGFILE= '2010-04-30_11.25.58_SCIENCE.fits' / Original file name
COMMENT = '*** Observatory & Instrument section ***'
OBSERVAT= 'Concordia Station, Dome C' / Observatory name
OBSGEO  = '-123.32417 -75.10028' / Observatory geographical coordinates
OBSALT  =                 3233 / Observatory altitude [m]
TELESCOP= 'ASTEP400'           / Telescope name
INSTRUM = 'ASTEP400'           / Instrument name
OBSERVER= 'ASTEP Team'         / Observer full name
```

~~soft. status~~

```
COMMENT = '*** Camera description section ***'
MAINMODE= 'OFF     '           / Software running mode
MONT    = 'OFF     '           / MONT module running mode
CAMS    = 'OFF     '           / CAMS module running mode
CAMG    = 'OFF     '           / CAMG module running mode
TSYNC   = 'OFF     '           / TSYNC module running mode
RFS     = 'OFF     '           / RFS module running mode
PSWI    = 'OFF     '           / PSWI module running mode
STP     = 'OFF     '           / STP module running mode
CPLE    = 'OFF     '           / CPLE module running mode
```

camera desc.

```
COMMENT = '*** Camera description section ***'
CAMMODEL= 'flipro0 '           / Model of the camera
PIXSIZEX=             9.0E-006 / Pixel x size [mic]
PIXSIZEY=             9.0E-006 / Pixel y size [mic]
PIXSCALX=             0.924609 / Pixel scale in X [arcsec]
PIXSCALY=             0.924609 / Pixel scale in Y [arcsec]
MAXPIXX =                 4151 / Max number of pixels in X
MAXPIXY =                 4127 / Max number of pixels in Y
ULEFTX  =                   36 / Abscissa of upper left sensor corner
ULEFTY  =                   21 / Ordinate of upper left sensor corner
LRIGHTX =                 4131 / Abscissa of lower right sensor corner
LRIGHTY =                 4116 / Ordinate of lower left sensor corner
GAIN    =                   2. / Gain in e-/ADU
RDNOISE =                   9. / Readnoise in e- RMS
SATLEVEL=                65535 / Saturation level [ADU]
```

times

```
COMMENT = '*** Time section ***'
TSERVID = '10.10.0.8 GPS [1]'  / Time server IP, type and stratum
DATE-OBS= '2010-04-30T11:25:58.964' / UTC Date of beginning of data acq.
DATEFILE= '2010-04-30T11:28:29.401' / UTC Date of file creation
DATESYNC= '2010-04-30T11:25:49.356' / Last NTP sync UTC date
TSYNCOFF=             1.51906 / Local to NTP time offset [ms]
TSYNCJTR=           0.2270755 / Time sync jitter [ms]
MJD-OBS =     55316.4763768981 / Modified Julian date
LST     = '10:12:29.9s'        / Local sideral time
```

field desc.

```
COMMENT = '*** Field description section ***'
FIELDTYP= 'TRANSIT_OBJ'        / Field type
FIELDNAM= 'WASP19  '           / Field name
OBSNAME = 'WASP19  '           / Observation name
OBJECT  = 'WASP19  '           / Object name
EQUINOX = 'J2000   '           / Equinox
GST-CRD = '09:53:30.50-45:42:58.50' / Guide star coords
GSTDCRD = '148.37708 +45.71625' / Guide star coords [degrees]
SCI-CRD = '09:54:06.00-45:43:19.00' / Science star coords
SCIDCRD = '0.00000 +0.00000'   / Science star coords [degrees]
MNT-CRD = '09:53:55.79-45:45:32.00' / Coords from mount
MNTDCRD = '148.48250 -45.75889' / Coords from mount [degrees]
GST-VMAG=                -999. / Guide star V-mag
SUNELEV =    -18.9246446322667 / Calculated Sun elevation (deg)
AIRMASS =                   0. / Air mass
CTYPE1  = 'X       '           / WCS: coordinate value at reference point
CTYPE2  = 'Y       '           / WCS
CRPIX1  =                   0. / WCS: reference point in pixel (axis1)
CRPIX2  =                   0. / WCS: reference point in pixel (axis2)
CRVAL1  =                   0. / WCS: coord 1 at reference point
CRVAL2  =                   0. / WCS: coord 2 at reference point
CD1_1   =                   0. / WCS: linear transf matrix coef 1_1
CD1_2   =                   0. / WCS: linear transf matrix coef 1_2
CD2_1   =                   0. / WCS: linear transf matrix coef 2_1
CD2_2   =                   0. / WCS: linear transf matrix coef 2_1
```

acquisition param.

```
COMMENT = '*** Acquisition settings section ***'
EXPTIME =                 130. / Exposure time [s]
ACQTYPE = 'SCIENCE '           / Acquisition type
READOUT = '1 Mhz   '           / Read out speed
FILTER  = 'C       '           / Filter ID
DENSITY = 'None    '           / Optical density ID
FOCPOS  =               -5900. / RFS position [mic]
```

~~meteo~~

```
COMMENT = '*** Meteorological parameters section ***'
TEMPERAT=                -999. / Meteo station temperature [Cdeg]
PRESSURE=                -999. / Meteo station pressure [mb]
WINDSPD =                -999. / Meteo station wind speed [m/s]
WINDDIR =                -999. / Meteo station wind direction [deg]
RELHUM  =                -999. / Meteo station relative humidity [%]
```

temperatures

```
COMMENT = '*** Temperature section ***'
TCAMSCCD=              -47.4375 / CAMS CCD temp
TCAMSCAS=               3.8125 / CAMS case temp
TCAMGCCD=                -999. / CAMG CCD temp
TCAMGCAS=                -999. / CAMG case temp
TIME-CEA= '1272626907976'      / CEA file timestamp
TCAMSAMB=                 0.4 / CEA file: CAMS ambient temp
TCAMGAMB=                -4.9 / CEA file: CAMG ambient temp
TICRON  =                 0.5 / CEA file: ICRON (USB) temp
TOPT2   =               -25.2 / CEA file: optics temp probe #2
TBOXGLOB=                -8.1 / CEA file: global box temp
TWINDOW =                -29.9 / CEA file: window temp
TOUTSIDE=                -68.9 / CEA file: outside temp
TALPHA  =                  15. / CEA file: alpha axis temp
TDELTA  =                12.4 / CEA file: delta axis temp
END
```

Data storage

- **/DATA/astep/astep-400/** (on merak)
  - **YYYY-MM-DD**
    - **YYYY-MM-DD-CAMS**
      - 2010-04-30_08.25.46_SCIENCE.fits
      - 2010-04-30_08.26.55_DARK.fits
      - 2010-04-30_08.28.04_BIAS.fits
    - **YYYY-MM-DD-CAMG**
      - CAMG_2010-04-30_09.01.19.fits
    - **YYYY-MM-DD-SKYFLATS**
      - 2010-04-30_12.37.03_SKYFLAT.fits
      - 2010-04-30_12.37.37_DARK.fits
      - 2010-04-30_12.38.11_BIAS.fits

Pipeline routines

- **Written in IDL (v7, modified routines from v6 or earlier)**

  Main routines (user)

  - **a400_flat**, date
  - **a400_best_flat**, date1,date2
  - **a400_process**, date
  - **a400_photometry**, date
  - **a400_calibcurves**, date

Routine description

1. a400_flat, date

- Generates the MASTER_FLAT using image files SKYFLAT and BIAS from a given night

➔ MASTER_FLAT is generated against median value of randomly shifted sky images (see yesterday's talk)

- Computes MASTER_DARK and MASTER_BIAS (over 30 images)

2. a400_best_flat, date1, date2

- Determines best MASTER_FLAT (low dispersion) amongst MASTER_FLAT from several nights (from date1 and date2) and creates a « super » MASTER_FLAT used for all nights

3. a400_process, date

- Determines the reference image (best PSF around the centre of image) amongst a ten of images

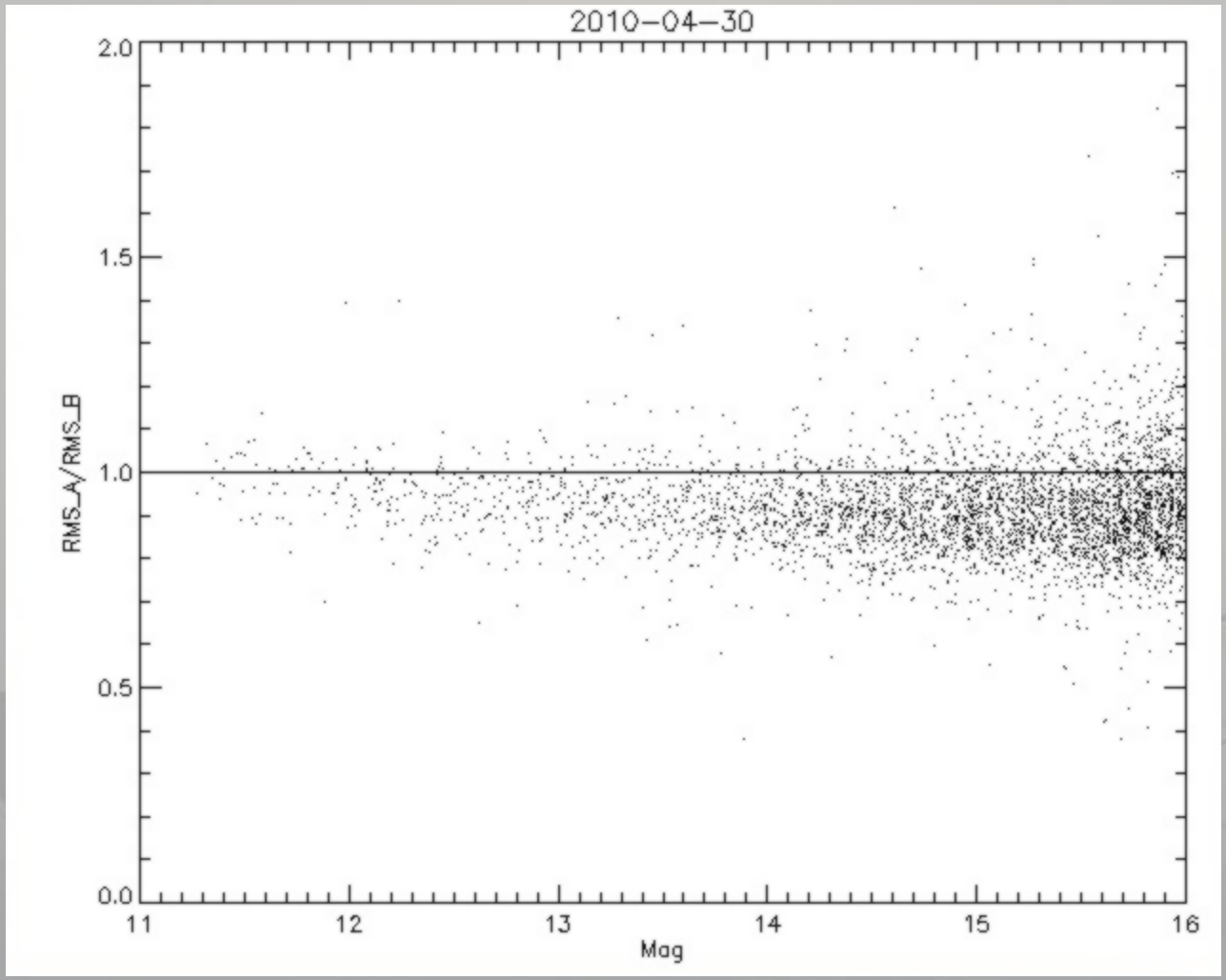
- Calibrate images: (SCIENCE-BIAS)/MASTER_FLAT, recenters (relative to ref. image) and selects « usable » images. Saves calibrated and recentered images.

Routine description

4. a400_photometry, date

- Field recognition (no dist. correction yet) on the reference image (e.g. ~4000 stars for WASP19)
- Evaluates photometric aperture for each star
- Mesures LC for all stars kept by aperture photometry according to two methods:
  - method A: remove background, thresholds then integrates over the aperture
  - method B: bkg subtraction, classical integration over an aperture (only one specified radius(!))
- Note: method A seems better if the star is not too faint (clouds or frosting)
- raw LC are saved

Routine description



Routine description

5. a400_calibcurves, date

- LC Calibration (for each night) using several reference stars:

Two reference LC are generated:

- target star is compared to ~all stars (1/4)
- Sum LC of reference stars if dispersion of target star is lessened (after dividing and normalization), ignores other stars → first reference LC

- Sums up 10 best reference LC → second ref. LC

➔ Final LC is the sum of first and second reference LC

- Each star is calibrated using its own final reference LC
  - Flux = flux/flux_ref
  - Flux_cal = flux/median(fluxes)

- This calibration is done night by night (it therefore suppresses global variations)

Few numbers

- Number of SCIENCE images: ~300 per night
- Number of SKYFLAT and BIAS: 0~100 per night
- Size of input files: ~15 GiB per night (SCIENCE: 10GiB, FLAT: 5 GiB)
- Total amount of data for 2010 campaign: ~6 TiB
- Size of output files: ~2 times input file volume
- Runtime for one night (Intel Quad Core CPU, SATA 7200 RPM Disks): ~4h

Improvements

- **Database? (to be discussed)**
- **Global calibration of LC with same group of reference stars**
  - global variation of stars are preserved
- **Use of a systematic error calibration algorithm: SYSREM, TFA,...**
  - refer to yesterday's discussion ➔ test on data to tune these algorithms
- **Suppress residual background fluctuations**
  - however no noticeable effect up to now
- **Set up a database for data mining and partially processed data**
- **Apply a transit detection algorithm (BLS,...)**
- **Develop an automated pipeline for DC operation**

Thank you...

