

Tutorial T-10
Amber Data Reduction (practical point of view)

EuroSummer School

Observation and data reduction with the Very Large Telescope Interferometer

Goutelas, France
June 4-16, 2006

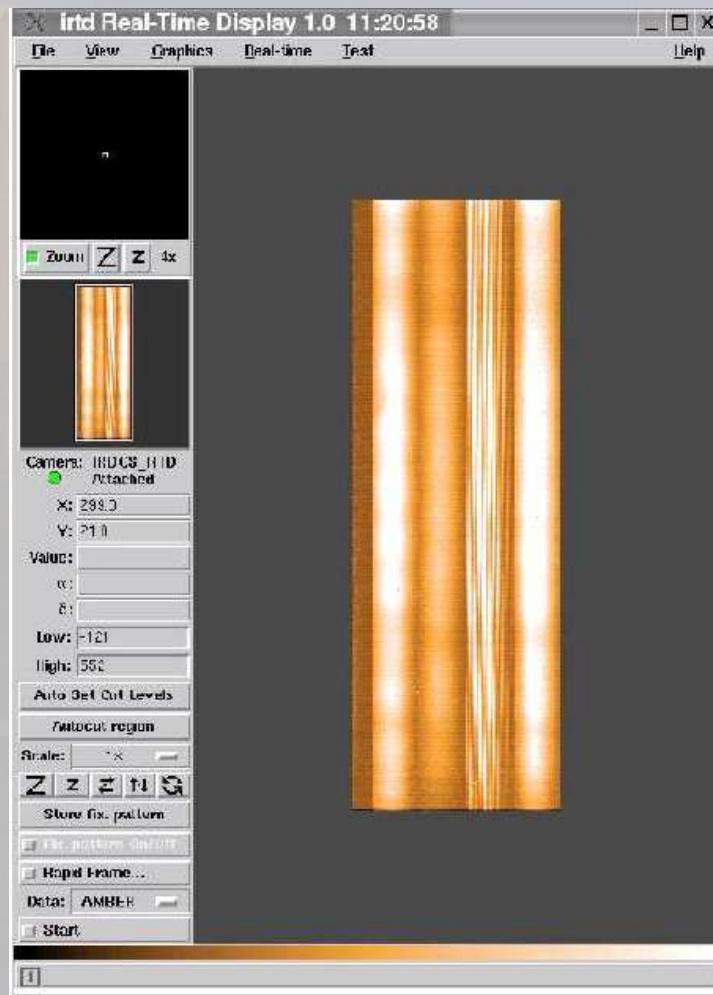
G. Duvert
LAOG/JMMC
13 June 2006

AMBER DATA REDUCTION OVERVIEW

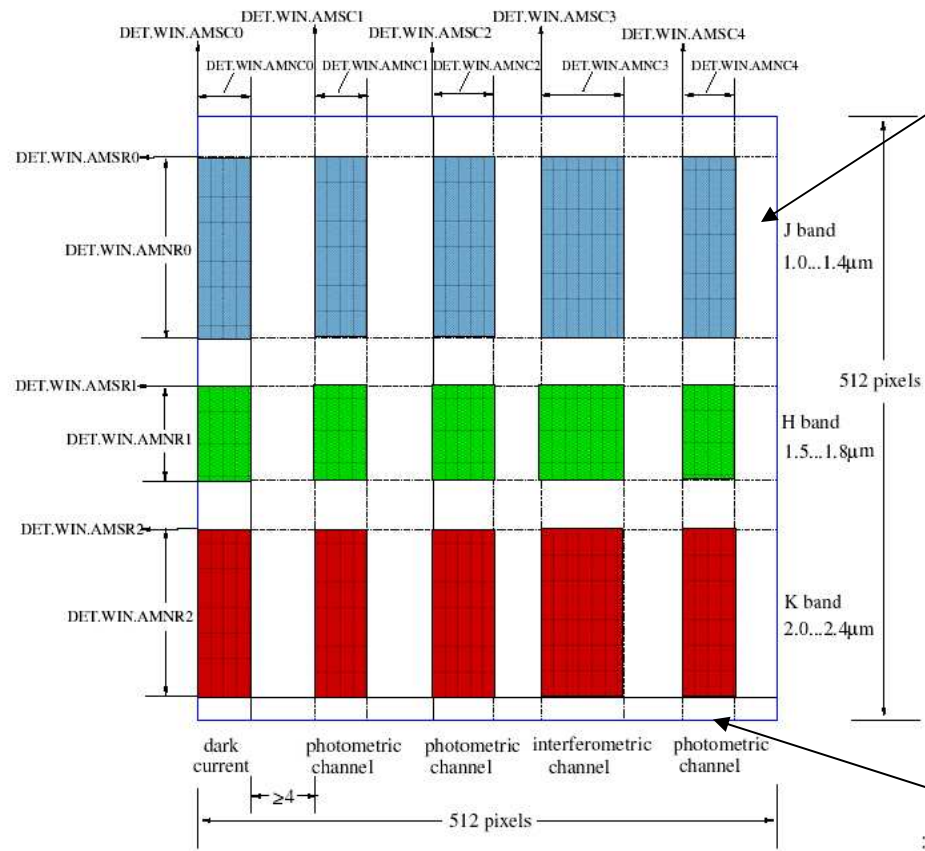
AMBER paradigm: ***spatially coded, spectrally dispersed, photometrically monitored, fringes.***

- **fringes** ... on an infrared Hawaii Camera:
 - camera readout mode
 - camera windowing, readout timing
 - camera readout noise, bad pixels, flat, etc...
- **spectrally dispersed** ... needs spectral calibration
 - wavelength calibration
- **spatially coded** ... needs spatial coding calibration:
 - the P2VM

. fringes ...



.... on an infrared Hawaii Camera:

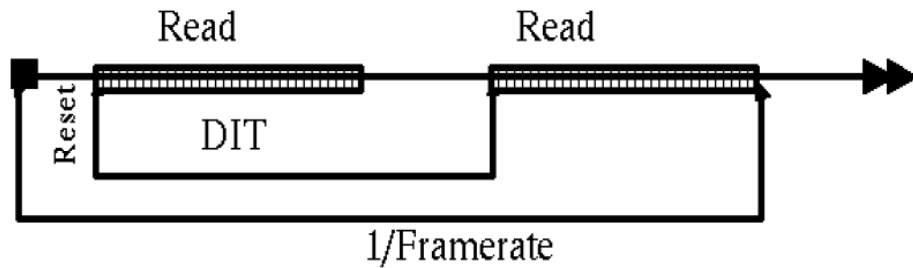


« row »

The camera is ALWAYS illuminated (NO shutter)

The camera is divided in (max 3) ROWS of (4 or 5) , regions:
Dark, P1 , P2, I [, P3]

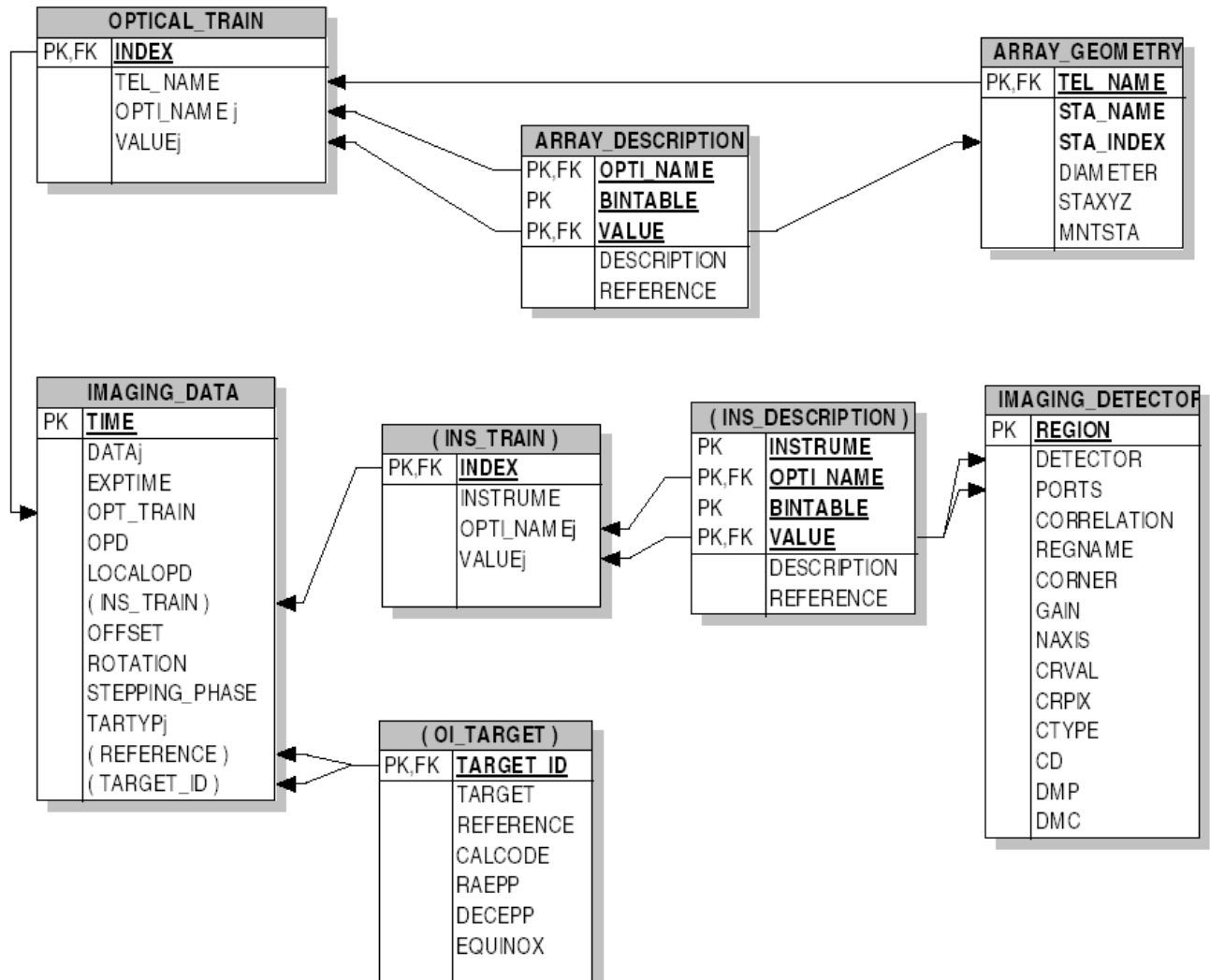
« channel »



The READOUT mode used is DOUBLE-CORRELATED

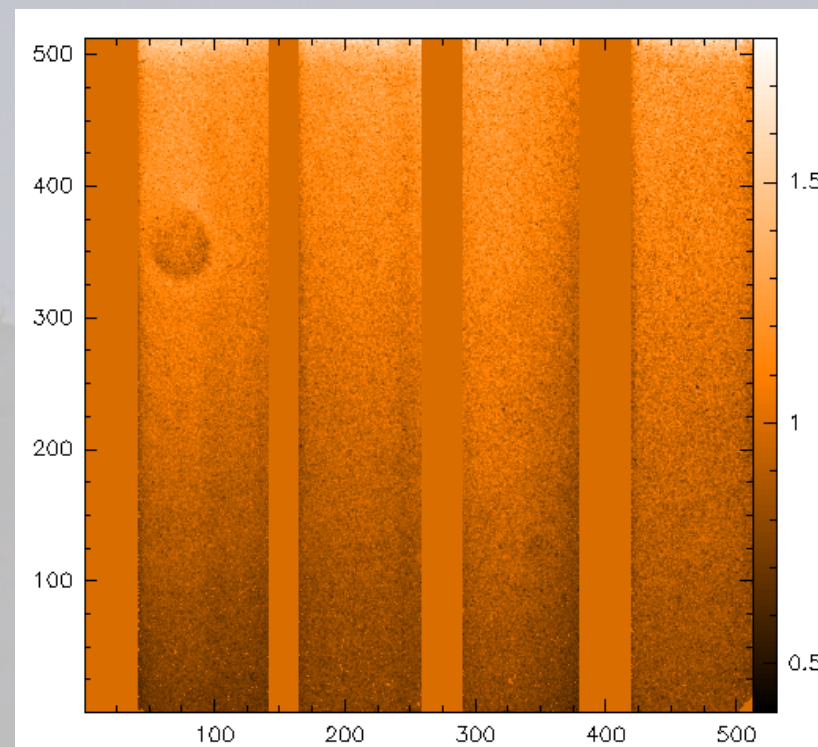
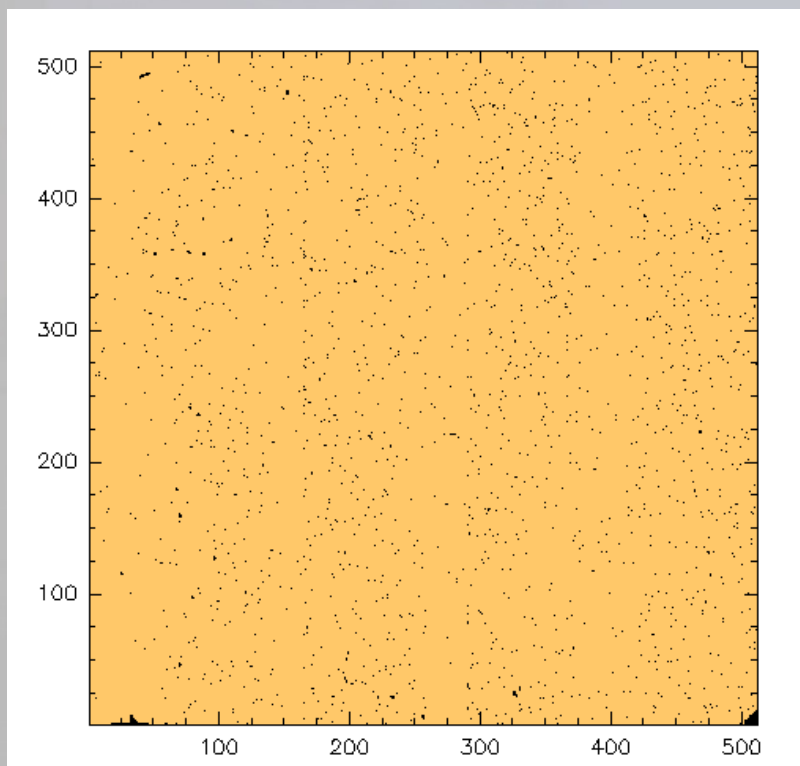
RAW DATA Fits file: sequence of FITS Tables, described in ESO Doc. No.: VLT-SPE-ESO-15000-2764

The NDIT camera readouts of duration “DIT” are saved in a raw data fits file containing several Tables. This is the basic product of AMBER



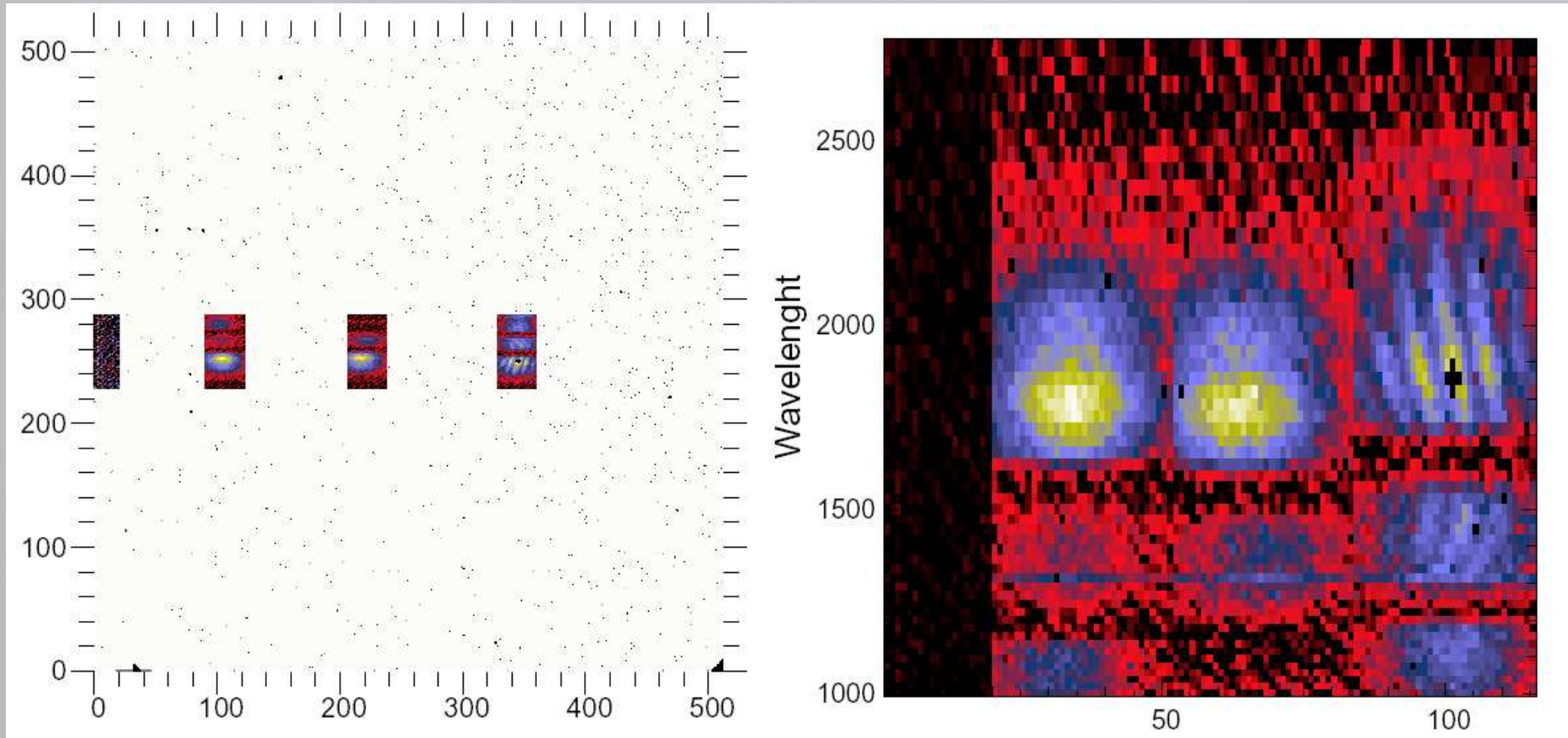
(a supplementary table, AMBER_WAVELENGTH, contains the spectral calibration)

- camera readout noise, bad pixels, flat, etc...



1. Bad Pixels -> “Bad Pixel Map” File
2. BIAS depends on the illumination of the camera and EXPOSURE TIME -> “Dark” Files
3. Relative pixel-to-pixel gain -> “Flat Field Map” File

. spectrally dispersed ...



...displacement of photometric « channels » - **CALIBRATE** – 3 or 4 Files
...accurate wavelength calibration of the Interferometric « channel »? **NO**

• **spatially coded ... the P2VM: 5 (2T) or 9 (3T) files**

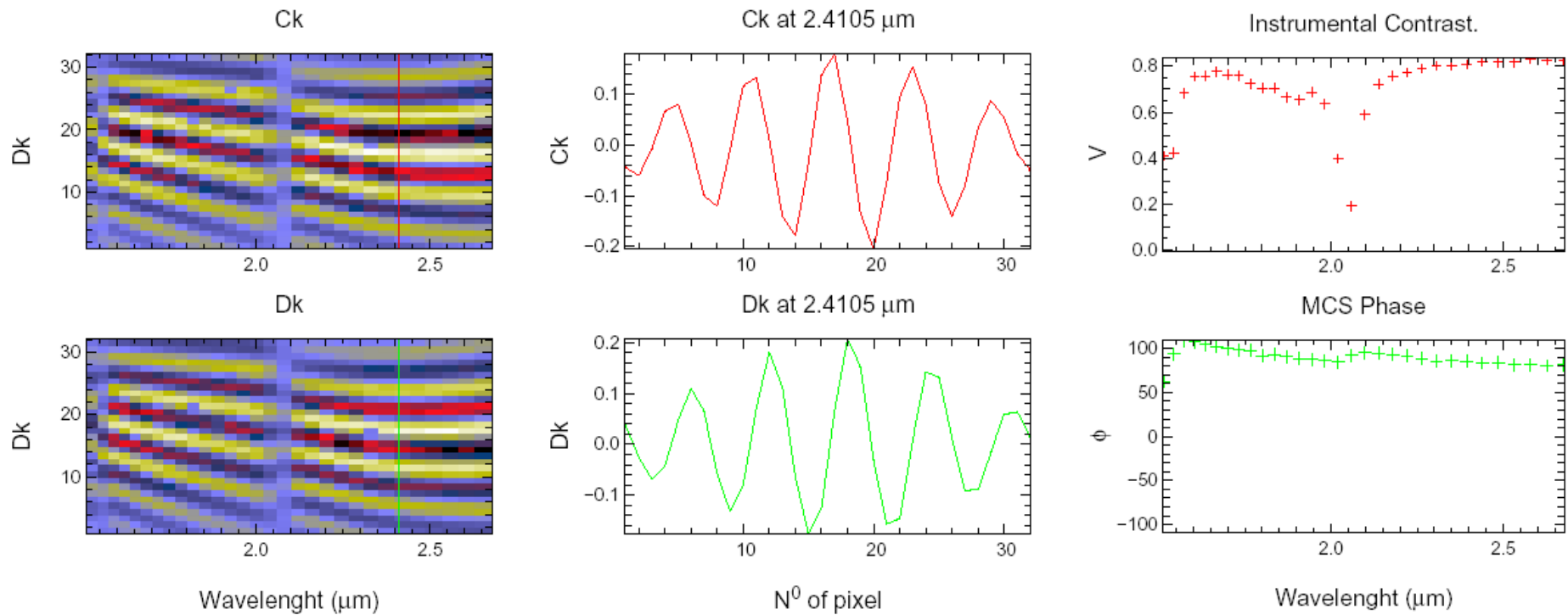
Shutter 1	Shutter 2	Shutter 3	Delaying plate	file Name	figure
Close	Close	Close	No Delay	AMBER_3TSTD_CAL_0001.fits	
Open	Close	Close	No Delay	AMBER_3TSTD_CAL_0002.fits	
Close	Open	Close	No Delay	AMBER_3TSTD_CAL_0003.fits	
Open	Open	Close	No Delay	AMBER_3TSTD_CAL_0004.fits	
Open	Open	Close	1/2 Delayed	AMBER_3TSTD_CAL_0005.fits	

Figure 3. Complete calibration sequence for 2 telescopes

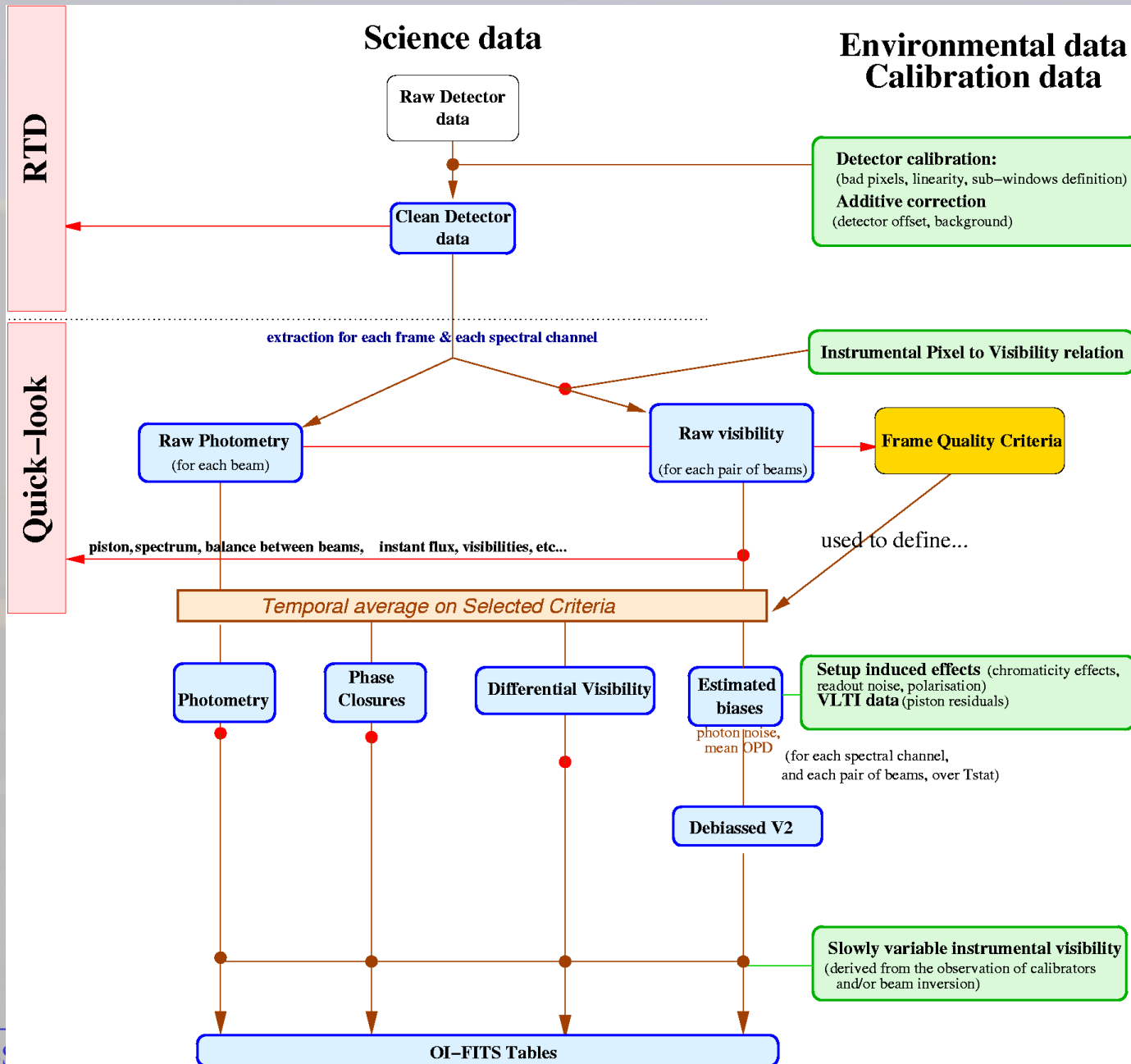
Shutters and P2VM calibration files

Step	Shutter 1	Shutter 2	Shutter 3	Phase γ_0	DPR key
1	Open	Closed	Closed	NO	2P2V, 3P2V
2	Closed	Open	Closed	NO	2P2V, 3P2V
3	Open	Open	Closed	NO	2P2V, 3P2V
4	Open	Open	Closed	YES	2P2V, 3P2V
5	Closed	Closed	Open	NO	3P2V
6	Open	Closed	Open	NO	3P2V
7	Open	Closed	Open	YES	3P2V
8	Closed	Open	Open	NO	3P2V
9	Closed	Open	Open	YES	3P2V

the P2VM: the « carrying waves: Ck and Dk »



Data Reduction Layout



Sequence of observations:

File	TPL.ID	DATE-OBS	ORIGFILE	OCS.OBS.SP...	OBS.TARG.N...	DPR.CATG	DPR.TYPE
200147568 HD124454-Hummel-Cal							
AMBER.2005-02-24T04:32:19.375.fits.gz	AMBER_2Tstd...	2005-02-24T...	AMBER_ADJUST_COLPO5055_0003...	Low_JHK	hd124454	CALIB	STD
AMBER.2005-02-24T04:33:20.472.fits.gz	AMBER_2Tstd...	2005-02-24T...	AMBER_2TSTD_ACQ055_0017.fits	Low_JHK	hd124454	CALIB	WAVE,2TEL
AMBER.2005-02-24T04:33:29.317.fits.gz	AMBER_2Tstd...	2005-02-24T...	AMBER_2TSTD_ACQ055_0018.fits	Low_JHK	hd124454	CALIB	WAVE,2TEL
AMBER.2005-02-24T04:33:41.750.fits.gz	AMBER_2Tstd...	2005-02-24T...	AMBER_2TSTD_ACQ055_0019.fits	Low_JHK	hd124454	CALIB	WAVE,2TEL
AMBER.2005-02-24T04:34:28.205.fits.gz	AMBER_2Tstd...	2005-02-24T...	AMBER_2TSTD_ACQ055_0020.fits	Low_JHK	hd124454	CALIB	2P2V
AMBER.2005-02-24T04:34:47.999.fits.gz	AMBER_2Tstd...	2005-02-24T...	AMBER_2TSTD_ACQ055_0021.fits	Low_JHK	hd124454	CALIB	2P2V
AMBER.2005-02-24T04:34:48.999.fits		2005-02-24T...	AMBER_P2VM_2T_2005-02-24T0...	Low_JHK	hd124454	CALIB	P2VM
AMBER.2005-02-24T04:35:00.527.fits.gz	AMBER_2Tstd...	2005-02-24T...	AMBER_2TSTD_ACQ055_0022.fits	Low_JHK	hd124454	CALIB	2P2V
AMBER.2005-02-24T04:35:13.453.fits	AMBER_2Tstd...	2005-02-24T...	AMBER_2TSTD_ACQ055_0023.fits	Low_JHK	hd124454	CALIB	2P2V
AMBER.2005-02-24T04:35:26.200.fits.gz	AMBER_2Tstd...	2005-02-24T...	AMBER_2TSTD_ACQ055_0024.fits	Low_JHK	hd124454	CALIB	2P2V
AMBER.2005-02-24T05:18:33.557.fits.gz	AMBER_2T_cal...	2005-02-24T...	AMBER_BASE12_CAL055_0023.fits	Low_JHK	hd124454	CALIB	WAVE,2TEL
AMBER.2005-02-24T05:26:48.689.fits.gz	AMBER_2T_cal...	2005-02-24T...	AMBER_BASE12_CAL055_0024.fits	Low_JHK	hd124454	CALIB	WAVE,2TEL
AMBER.2005-02-24T05:33:02.551.fits.gz	AMBER_2Tstd...	2005-02-24T...	AMBER_2TSTD_DARK055_0007.fits	Low_JHK	hd124454	SCIENCE	DARK
AMBER.2005-02-24T05:33:51.335.fits.gz	AMBER_2Tstd...	2005-02-24T...	AMBER_2TSTD_OBS055_0031.fits	Low_JHK	hd124454	SCIENCE	OBJECT
AMBER.2005-02-24T05:34:36.498.fits.gz	AMBER_2Tstd...	2005-02-24T...	AMBER_2TSTD_OBS055_0032.fits	Low_JHK	hd124454	SCIENCE	OBJECT
AMBER.2005-02-24T05:35:22.560.fits.gz	AMBER_2Tstd...	2005-02-24T...	AMBER_2TSTD_OBS055_0033.fits	Low_JHK	hd124454	SCIENCE	OBJECT
AMBER.2005-02-24T05:36:25.715.fits.gz	AMBER_2Tstd...	2005-02-24T...	AMBER_2TSTD_SKY055_0007.fits	Low_JHK	hd124454	CALIB	SKY
AMBER.2005-02-24T05:38:13.629.fits.gz	AMBER_2Tstd...	2005-02-24T...	AMBER_2TSTD_DARK055_0008.fits	Low_JHK	hd124454	SCIENCE	DARK
AMBER.2005-02-24T05:39:32.361.fits.gz	AMBER_2Tstd...	2005-02-24T...	AMBER_2TSTD_OBS055_0034.fits	Low_JHK	hd124454	SCIENCE	OBJECT
AMBER.2005-02-24T05:40:52.249.fits.gz	AMBER_2Tstd...	2005-02-24T...	AMBER_2TSTD_OBS055_0035.fits	Low_JHK	hd124454	SCIENCE	OBJECT
AMBER.2005-02-24T05:42:07.442.fits	AMBER_2Tstd...	2005-02-24T...	AMBER_2TSTD_OBS055_0036.fits	Low_JHK	hd124454	SCIENCE	OBJECT
AMBER.2005-02-24T05:43:38.720.fits.gz	AMBER_2Tstd...	2005-02-24T...	AMBER_2TSTD_SKY055_0008.fits	Low_JHK	hd124454	CALIB	SKY
AMBER.2005-02-24T05:55:59.195.fits.gz	AMBER_2Tstd...	2005-02-24T...	AMBER_2TSTD_OBS055_0037.fits	Low_JHK	hd124454	SCIENCE	OBJECT
AMBER.2005-02-24T05:57:14.516.fits.gz	AMBER_2Tstd...	2005-02-24T...	AMBER_2TSTD_OBS055_0038.fits	Low_JHK	hd124454	SCIENCE	OBJECT
AMBER.2005-02-24T05:58:46.843.fits.gz	AMBER_2Tstd...	2005-02-24T...	AMBER_2TSTD_SKY055_0009.fits	Low_JHK	hd124454	CALIB	SKY
AMBER.2005-02-24T06:01:28.562.fits.gz	AMBER_2Tstd...	2005-02-24T...	AMBER_2TSTD_DARK055_0009.fits	Low_JHK	hd124454	SCIENCE	DARK
AMBER.2005-02-24T06:02:47.447.fits.gz	AMBER_2Tstd...	2005-02-24T...	AMBER_2TSTD_OBS055_0039.fits	Low_JHK	hd124454	SCIENCE	OBJECT
AMBER.2005-02-24T06:04:02.198.fits.gz	AMBER_2Tstd...	2005-02-24T...	AMBER_2TSTD_OBS055_0040.fits	Low_JHK	hd124454	SCIENCE	OBJECT

*A dedicated library, **amdlib**, is pivotal for both observation & data reduction.*

It is used at the time of observation to find fringes, etc...

*All the steps for data reduction are available as functions in the **amdlib** library.*

*These functions can be called from external programs, but **amdlib** provides also command-line programs to perform the data reduction.*

Each raw data file (including those used to obtain calibration files such as the P2VM) must be calibrated for camera cosmetics.

Internally each calibrated file is converted to a simpler structure, called ScienceData:

- The temporal sequence of 2D Interferograms, untouched.
- Each 2D photometric channel is replaced by a 1D photometry vector (1 instantaneous photometry per beam and per wavelength), and associated errors.

A P2VM must be obtained before any Science Data;
The P2VM File is computed by the amdlib command
amdlibComputeP2vm

Using the 5- or 9- calibration files obtained on the internal
source of AMBER

```
Usage: amdlibComputeP2vm [-s o1,o2,o3] badPixelMap flatFieldMap dark file1
... file9 p2vmFile
    or
    amdlibComputeP2vm [-s o1,o2,o3] badPixelMap flatFieldMap dark file1
... file4 p2vmFile
    where o1,o2... is a comma-separated list of shifts for the 2 or 3
photometric channels
```

The DATA necessary to get visibilities on a Science Object are:

- RAW DATA on a Science Object (AMBER_XXX_OBS_YYY)
- Associated Pixel Bias Map (aka DARK)
- [eventually an associated SKY]
- The P2VM in use at time of the observation.

The command `amdlibExtractVis` does the complete sequence of calibration and visibility, etc., computation using the P2VM, and produces an `OI_FITS` file:

```
Usage: amdlibExtractVis [-f] [-s] [-b num] [-p PHASOR|PHASE][  
-e STATISTIC|THEORIC] badPixelMap flatFieldMap p2vm dark sky input  
output
```

```
Options: -f to force the use of another P2VM  
         -s split OI-FITS; one file per band  
         -b 'num' to average (bin) over 'num' frames  
         -p PHASOR or PHASE (default) for piston algorithm  
         -e THEORIC or STATISTIC (default) for error bars estimation  
         -c FRG or FLUX criterion for frame selection  
         -r ratio for frame selection
```


A number of programs already call amdlib and provide an interface to it:

- ammYorick, a Yorick implementation by F. Millour (et al).
- a scripting interface in the ESO's gasgano file sorter (to be used this evening)
- The ESO pipeline, now to be delivered with a flexible workflow bench, "taverna" and the gasgano interface (next september).
- The Final OI_FITS product can be read and used by many generalist data visualisation programs (IDL, gildas, etc...)

OI_FITS Product:

Normalized by the IAU commission and published. (Pauls, T. A.; Young, J. S.; Cotton, W. D.; Monnier, J. D., "A Data Exchange Standard for Optical (Visible/IR) Interferometry", 2005, The Publications of the Astronomical Society of the Pacific, Volume 117, Issue 837, pp. 1255-1262.). Has a number of Extensions:

File Edit Tools					Help				
Index	Extension	Type	Dimension	View					
<input type="checkbox"/> 0	Primary	Image	0	Header	Image		Table		
<input type="checkbox"/> 1	OI_ARRAY	Binary	5 cols X 3 rows	Header	Hist	Plot	All	Sele	
<input type="checkbox"/> 2	OI_TARGET	Binary	17 cols X 1 rows	Header	Hist	Plot	All	Sele	
<input type="checkbox"/> 3	OI_WAVELENGTH	Binary	2 cols X 158 rows	Header	Hist	Plot	All	Sele	
<input type="checkbox"/> 4	OI_VIS	Binary	14 cols X 1500 rows	Header	Hist	Plot	All	Sele	
<input type="checkbox"/> 5	OI_VIS2	Binary	10 cols X 1500 rows	Header	Hist	Plot	All	Sele	
<input type="checkbox"/> 6	OI_T3	Binary	14 cols X 500 rows	Header	Hist	Plot	All	Sele	
<input type="checkbox"/> 7	AMBER_DATA	Binary	16 cols X 1500 rows	Header	Hist	Plot	All	Sele	

OI-ARRAY Table

The screenshot shows a software window titled "OI-ARRAY Table" with a menu bar containing "File", "Edit", "Tools", and "Help". Below the menu bar, there are several checkboxes and labels: TEL_NAME, STA_NAME, STA_INDEX, DIAMETER, and STAXYZ. Underneath these are the values "8A", "8A", "I", "E", and "3D". There is also a "Select" label and a "3D" label. Below these are checkboxes for "All" and "m", and buttons for "Invert" and "Expand".

1	UT2	U2	32	8.000000E+00	Plot
2	UT3	U3	33	8.000000E+00	Plot
3	UT4	U4	34	8.000000E+00	Plot

At the bottom of the window, there are two input fields: "Go to:" and "Edit cell:".

OI-TARGET Table:

The screenshot shows a software window with a menu bar (File, Edit, Tools, Help) and a table. The table has columns for TARGET_ID, TARGET, RAEP0, DECEP0, EQUINOX, and RA_ERR. The first row of data is highlighted. Below the table is a 'Go to' field and an 'Edit cell' field.

	<input type="checkbox"/> TARGET_ID	<input type="checkbox"/> TARGET	<input type="checkbox"/> RAEP0	<input type="checkbox"/> DECEP0	<input type="checkbox"/> EQUINOX	<input type="checkbox"/> RA_ERR
Select	I	16A	D	D	E	D
<input type="checkbox"/> All			deg	deg	year	deg
Invert						
1	1	alfara	2.6296045000000E+02	-4.9876440000000E+01	2.0000000E+03	0.0000000000000E+00

Go to: Edit cell:

OI_WAVELENGTH TABLE

File Edit Tools Help

EFF_WAVE EFF_BAND

Select E E

All m m

Invert

1	2.106147E-06	6.829834E-10
2	2.106830E-06	6.829834E-10
3	2.107513E-06	6.829834E-10
4	2.108196E-06	6.828613E-10
5	2.108879E-06	6.828613E-10
6	2.109562E-06	6.829834E-10
7	2.110245E-06	6.829834E-10
8	2.110927E-06	6.828613E-10
9	2.111610E-06	6.828613E-10
10	2.112293E-06	6.828613E-10
11	2.112976E-06	6.828613E-10
12	2.113659E-06	6.828613E-10
13	2.114342E-06	6.828613E-10

Go to: Edit cell: