Amber Data Reduction (amdlib v.3 « core » library) instrument, algorithms, limitations.

G. Duvert
LAOG/JMMC
21 April 2010

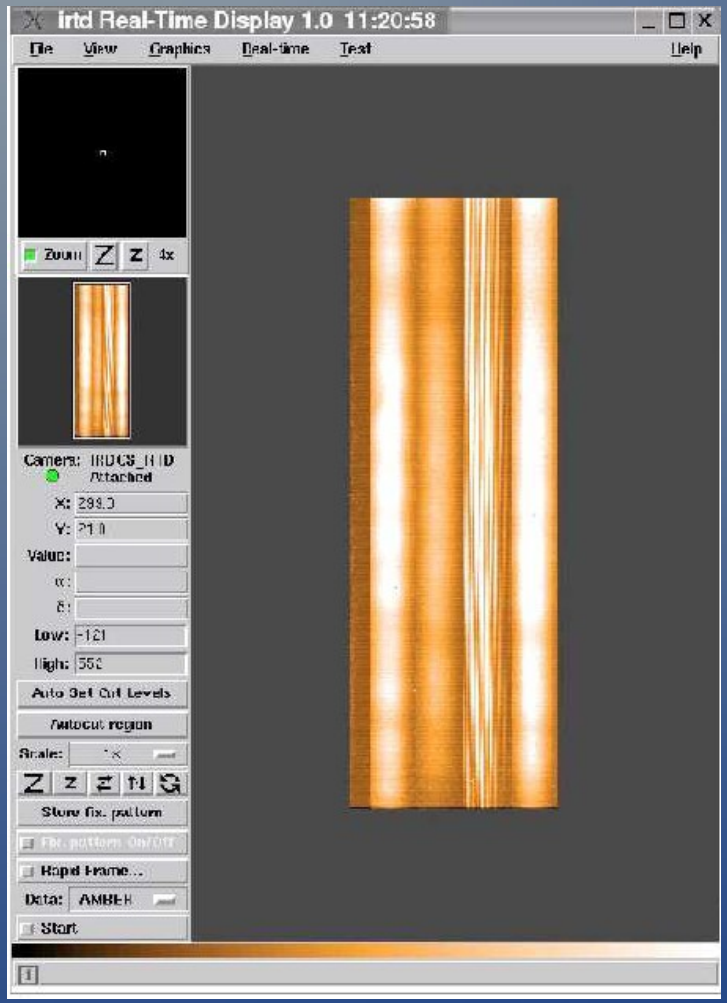
AMBER DATA OVERVIEW

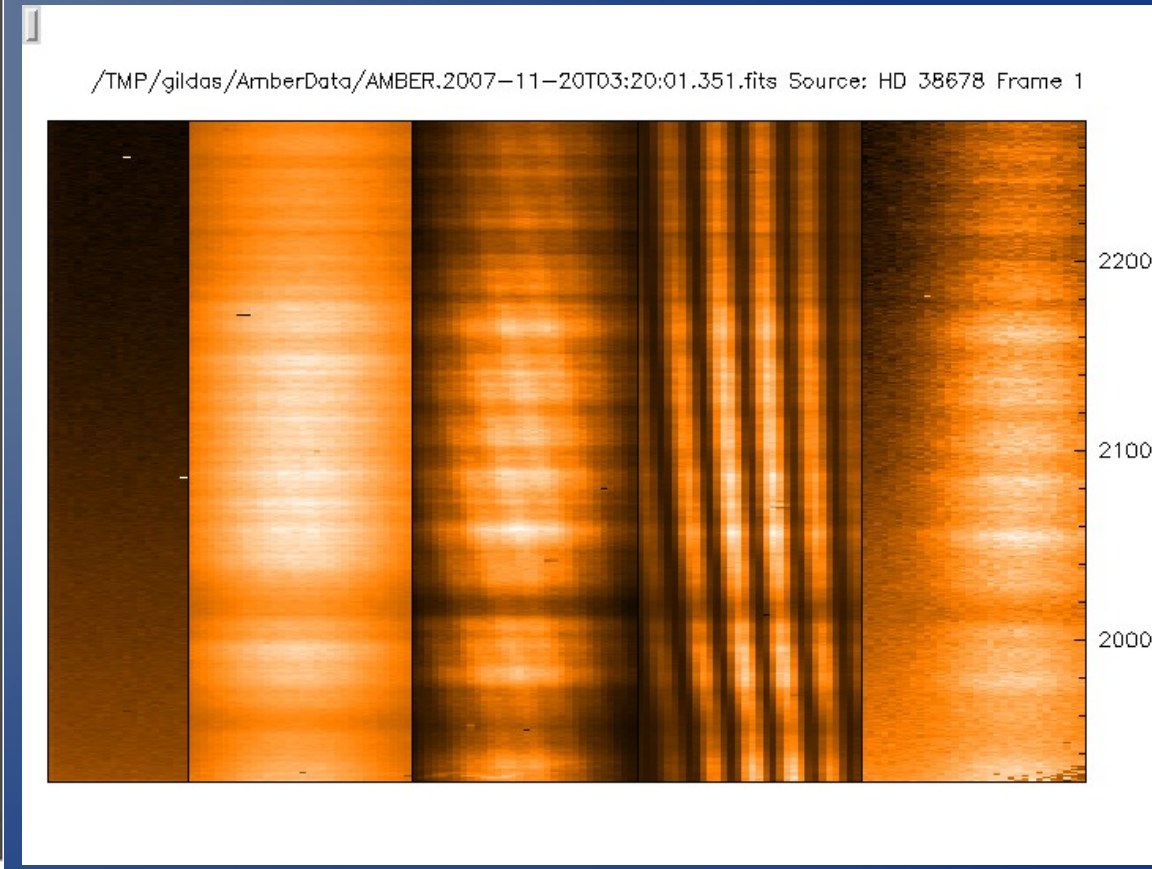
AMBER paradigm: ***spatially coded, spectrally dispersed, photometrically monitored, fringes.***

See Amber by Eric Tatulli

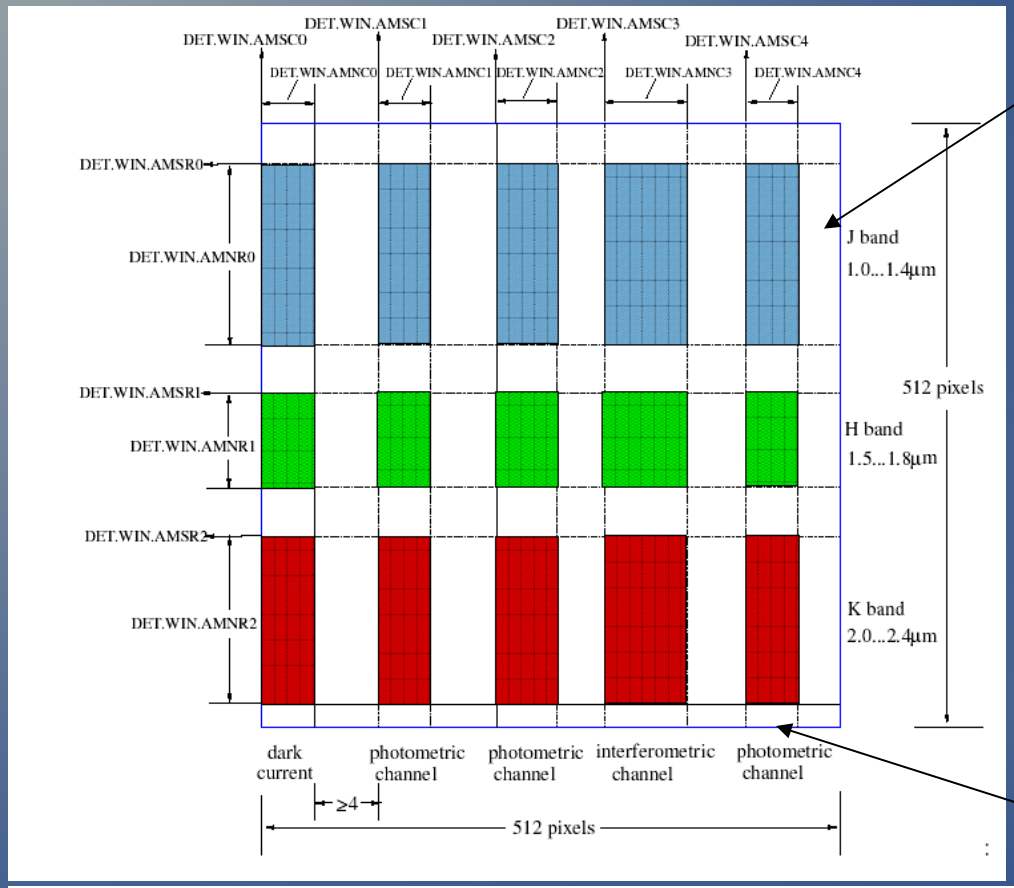
- **fringes** on an infrared Hawaii Camera:
  Cosmetics : *camera readout mode*
  camera windowing, readout timing
  camera readout noise, dark frames,
  bad pixels, flat fields
- **spectrally dispersed** ... needs spectral calibration
  wavelength calibration
- **spatially coded** ... needs spatial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

- **fringes …**


Irtd Real-Time Display 1.0 11:20:58
File
View
Graphics
Real-time
Text
Help
Zoom
4x
Camera: IRDCS_HD
Attached
X: 288.0
Y: 21.0
Value:
α:
δ:
Low: -121
High: 552
Auto Set Cut Levels
Autocut region
Scale:
Store fix. pattern
Rapid Frame...
Data: AMBER
Start


/TMP/gildas/AmberData/AMBER.2007-11-20T03:20:01.351.fits Source: HD 38678 Frame 1
2200
2100
2000

- … on an infrared Hawaii Camera:

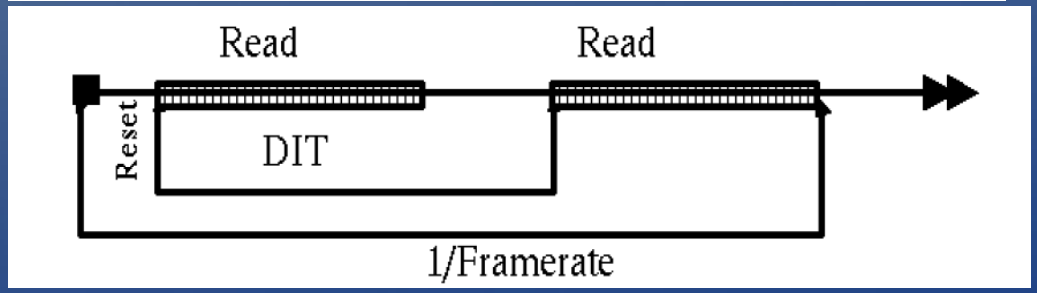


« row »

« channel »

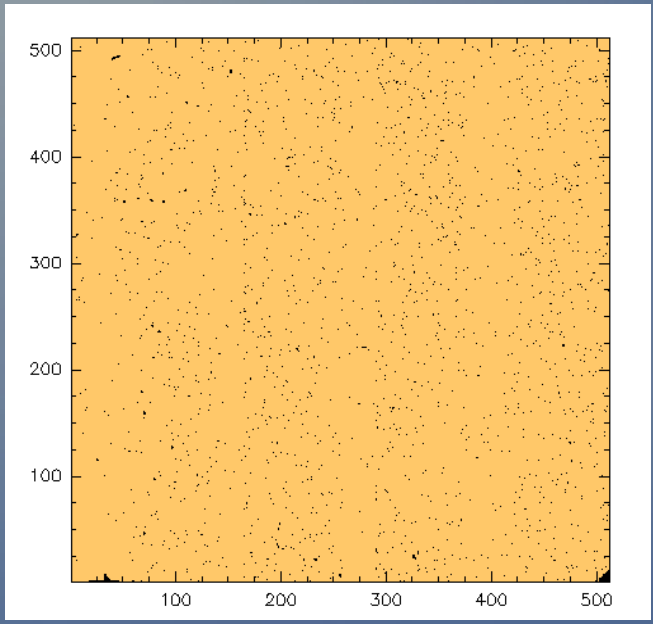
The camera is ALWAYS illuminated (NO shutter)

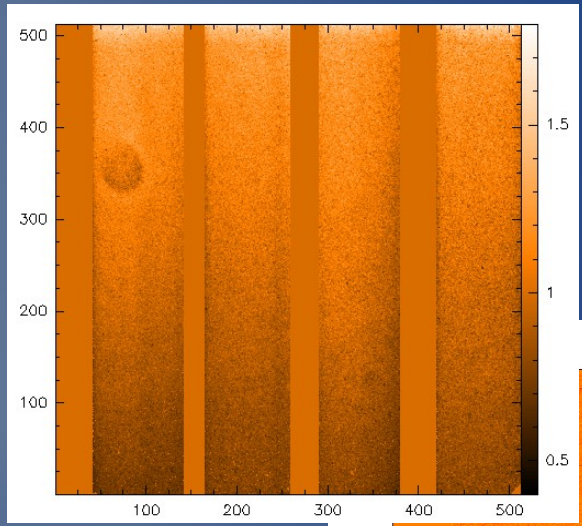
The camera is divided in (max 3) ROWS of (4 or 5) , regions: Dark, P1 , P2, I [, P3]

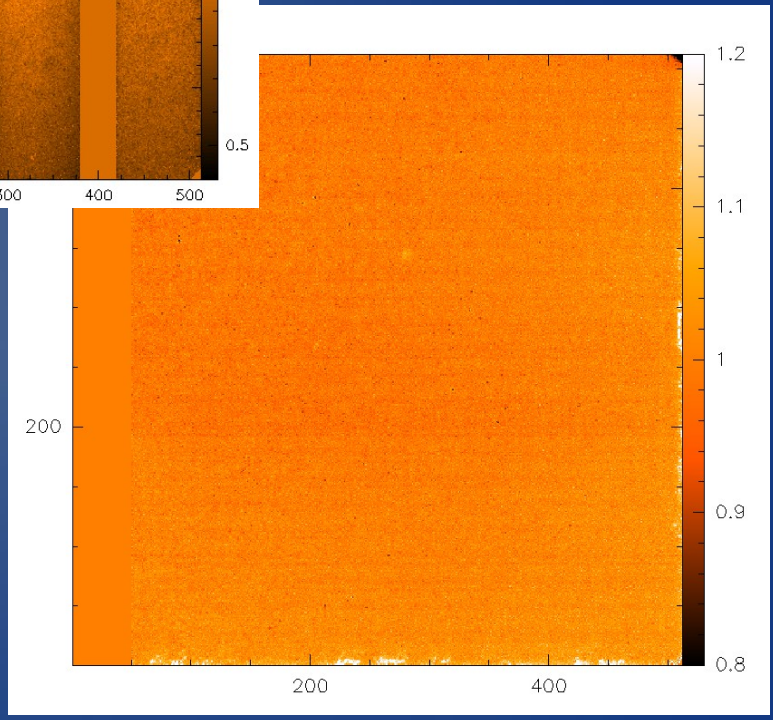


The READOUT mode used is DOUBLE-CORRELATED

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

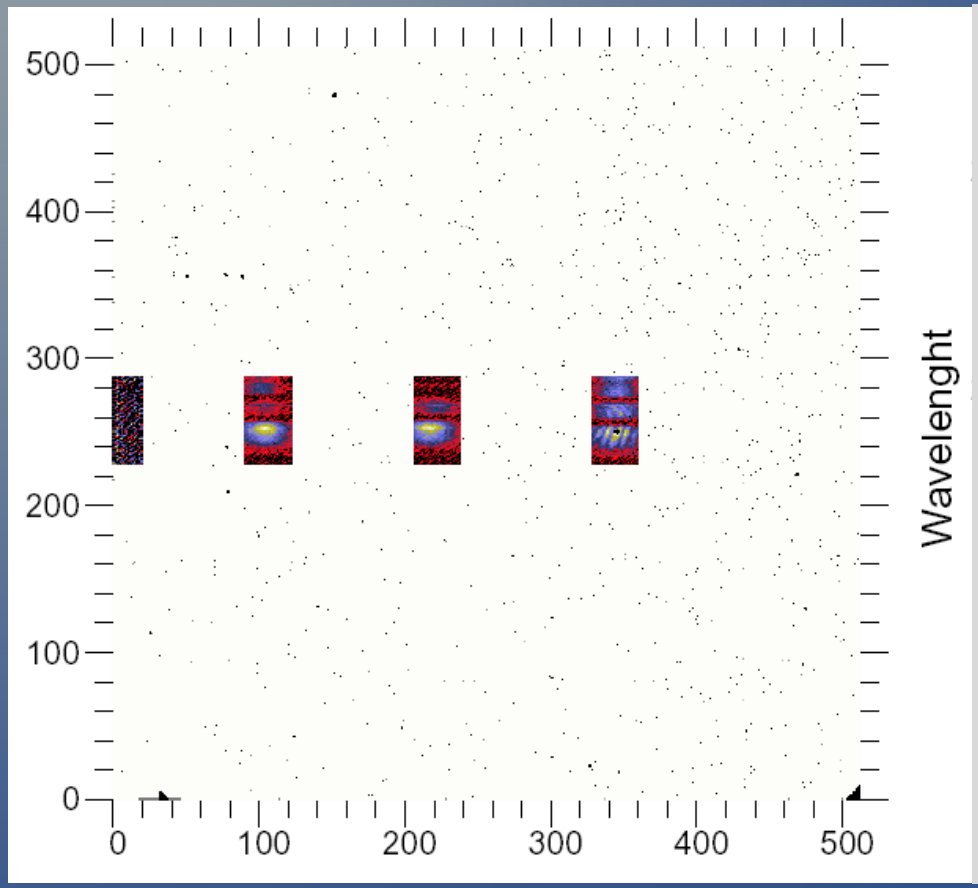


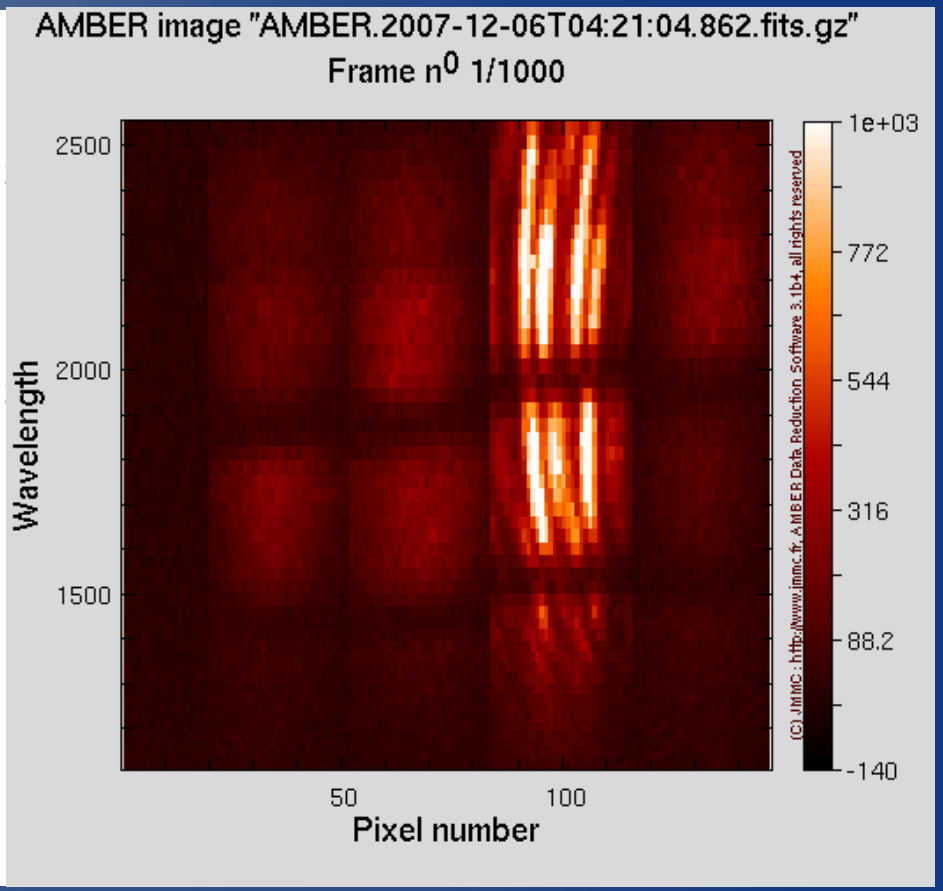




Bad Pixels -> "Bad Pixel Map" File. *Changes with time*
BIAS depends on the illumination of the camera and *EXPOSURE TIME* –> "Dark" Files. Used in amdlib3 to compute pixel-per-pixel readout noise.
Relative pixel-to-pixel gain? -> "Flat Field Map" File (use with caution)

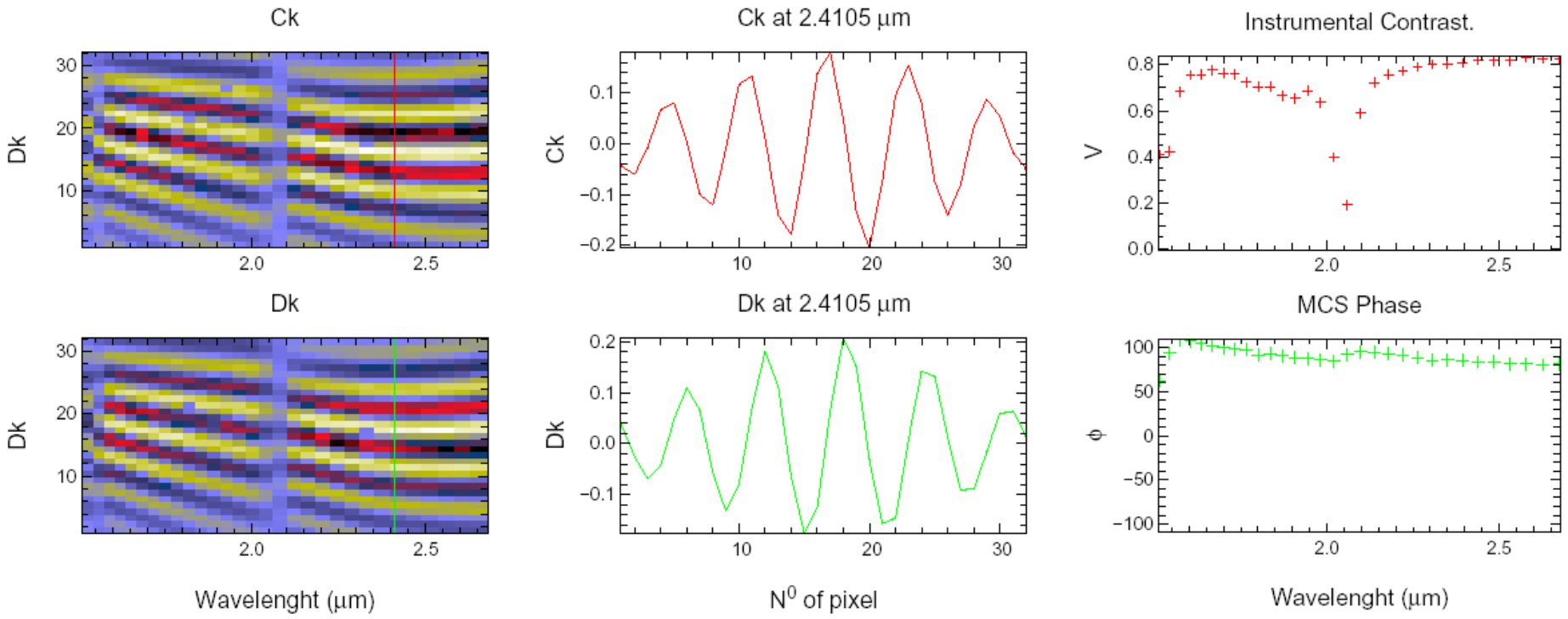
- **spectrally dispersed ...**



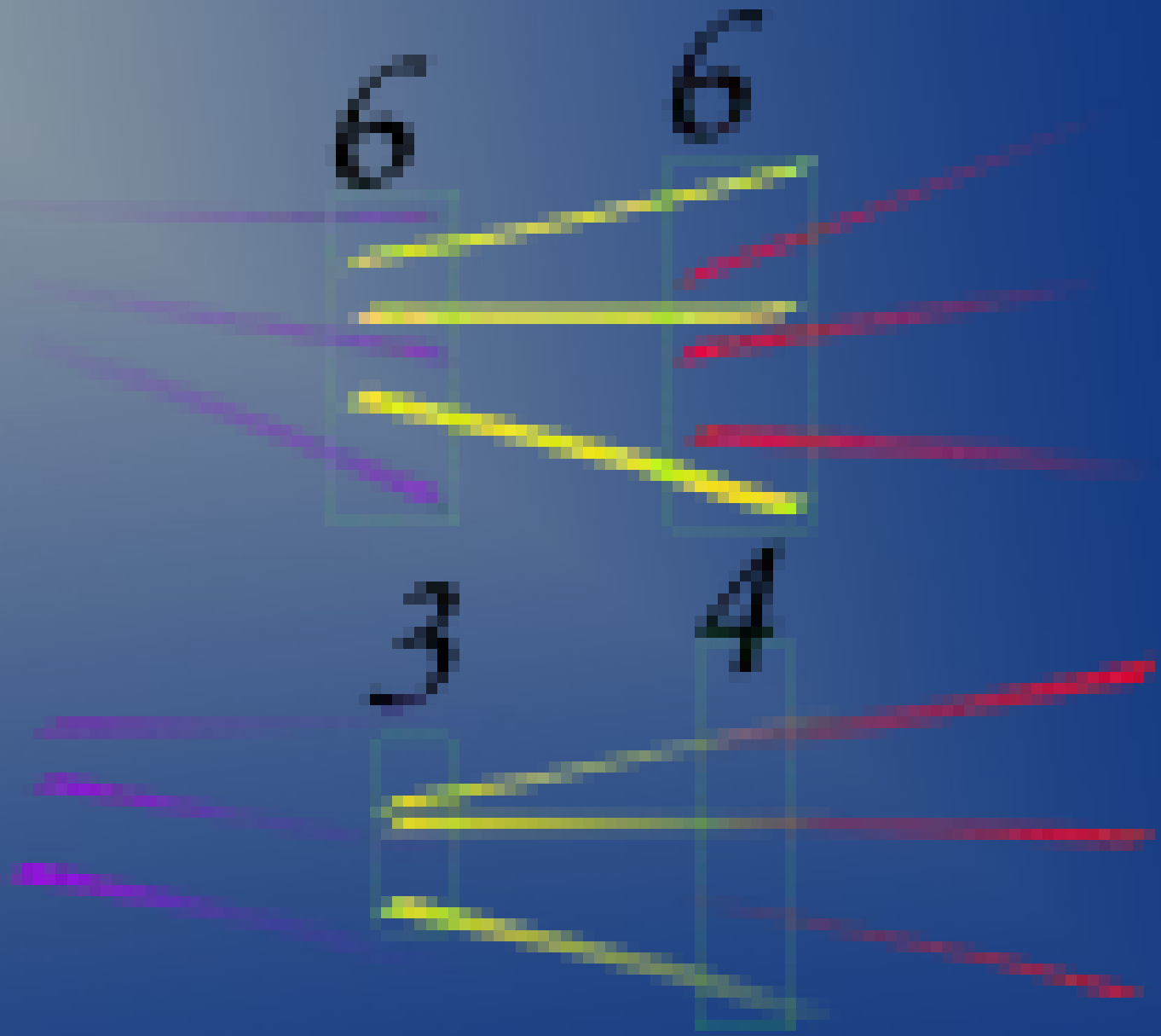


Note the displacement of photometric « channels »
Not very important with amdlib3, displacement monitored however.
...accurate wavelength calibration of the Interferometric « channel »?
NO for Low Resolution.

the P2VM:
Calibrates each of the 3 fringe patterns present in the image.
(gives matrix coefficients ck and dk to convert pixels values to complex visibilities for each baselines)



The P2VM calibration file does more: it contains all the calibrations.


6
6
3
4

Shutters and P2VM calibration files

The parameters to be calibrated to convert pixels to visibilities are 9: 3 for the flux ratio wrt the photometric channel+ 3 'ck' and 3 'dk': the P2VM calibration uses 9 files + 1 dark

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

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

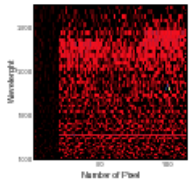
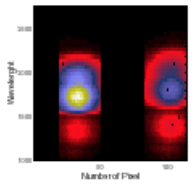
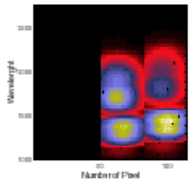
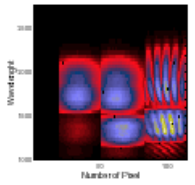
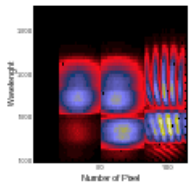
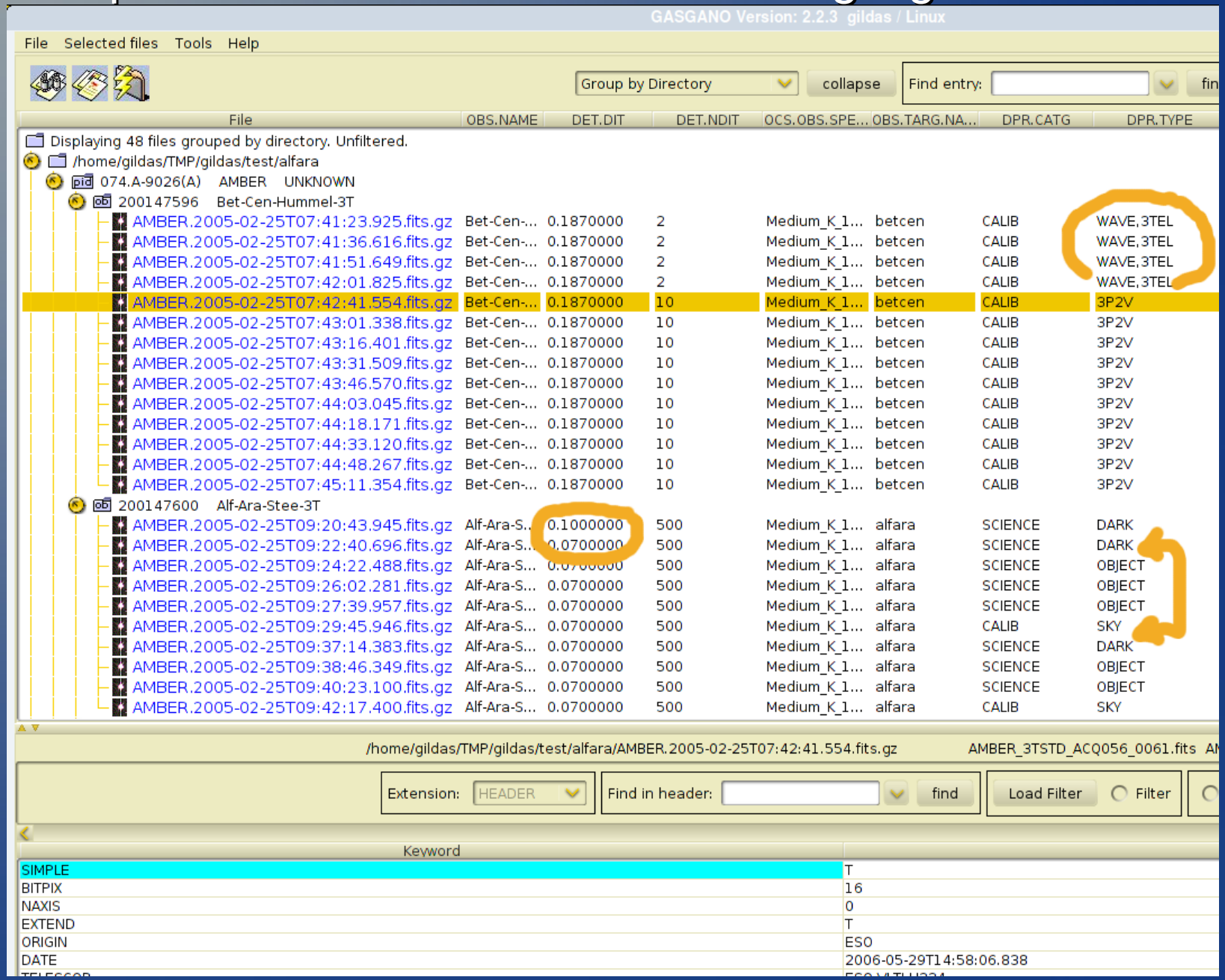
Shutter 1	Shutter 2	Shutter 3	Delaying plate	file Name	figure
Close	Close	Close	No Delay	AMBER_3TSTD_CAL_0001.fits	
Open	Close	Close	No Delay	AMBER_3TSTD_CAL_0002.fits	
Close	Open	Close	No Delay	AMBER_3TSTD_CAL_0003.fits	
Open	Open	Close	No Delay	AMBER_3TSTD_CAL_0004.fits	
Open	Open	Close	1/2 Delayed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

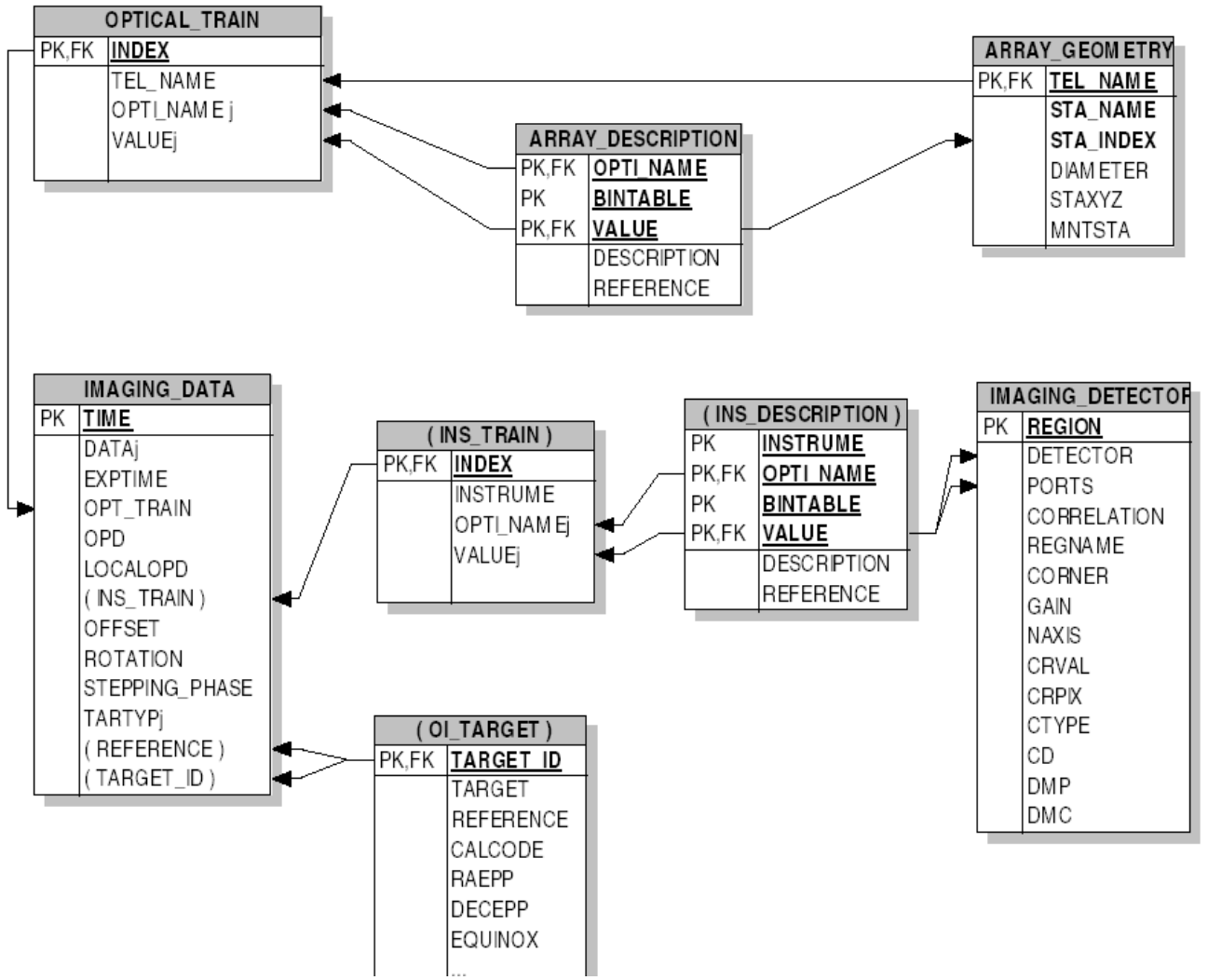
Figure 3. Complete calibration sequence for 2 telescopes

Sequence of observations as seen in gasgano:



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

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



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

A dedicated C “core” library, **amdlib**, is pivotal for both observation & data reduction.

Amdlib version 1 (and up to 2.2) was delivered by the AMBER consortium and is used inside the instrument at the time of observation to provide instantaneous estimates of visibilities, etc...

Amdlib version 3 benefits from years of instrument followup by JMMC users. It solves several calibration problems of amdlib v2 and gives additional robustness to the data reduction.

Amdlib may be used standalone, and is called by higher-level data reduction programs, such as the one in yorick, distributed by the JMMC in the same package.

All the steps for data reduction are available as functions in the amdlib library, and can also be called directly with a simple command-line interface.

Basically, the processing is as such:

- Computing the P2VM (amdlibComputeP2vm) provides all the necessary calibrations;
- Processing each raw data file to compute instantaneous correlated fluxes (complex numbers, typically 3x128x1000 values) with amdlibComputeOiData;
- From all, or a selection of, these values, compute time averaged values of all relevant interferometric observables (V2, differential visibility, phase closure) with amdlibSelectFrames.

These are yet not 'absolute values'...

- Do the same for a calibrator
- Calibrate the science with the calibrator to get 'absolute' values (better done with yorick contributions to amdlib presented in the next talk).

Product:

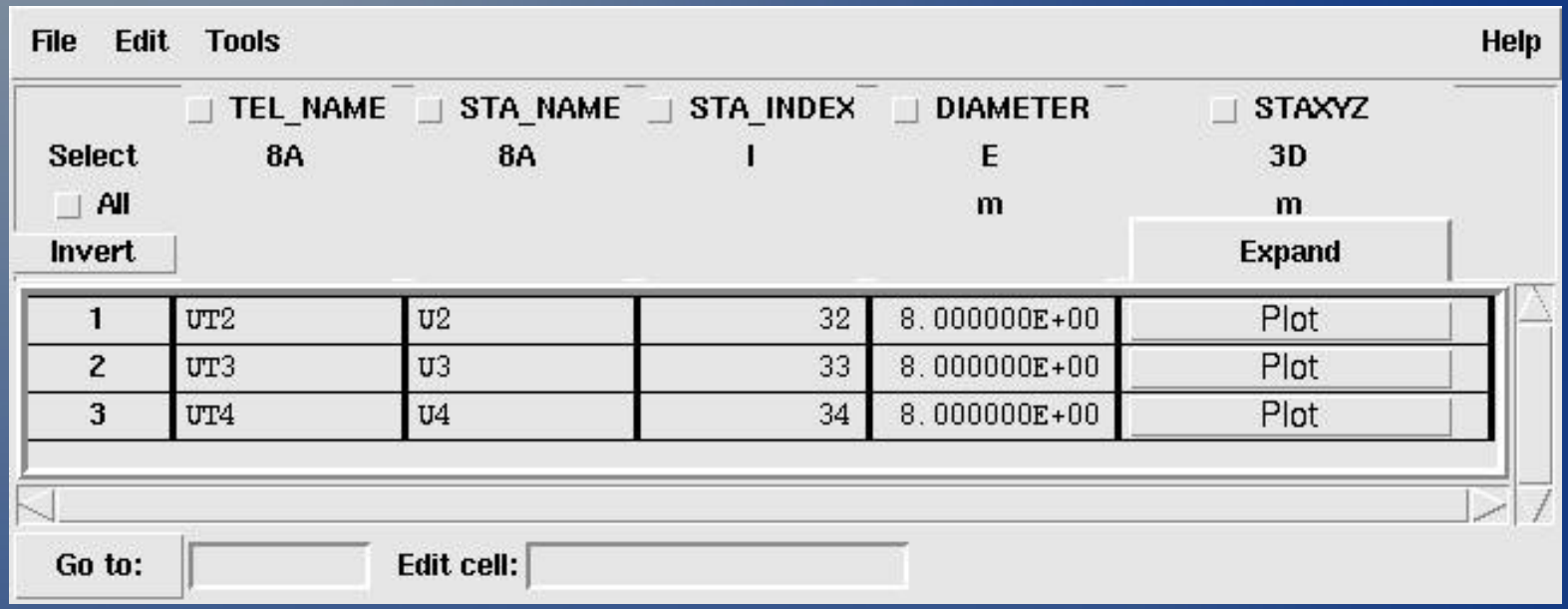
it is an “OI-FITS” file, a type of FITS file designed for exchange of interferometric data.

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:

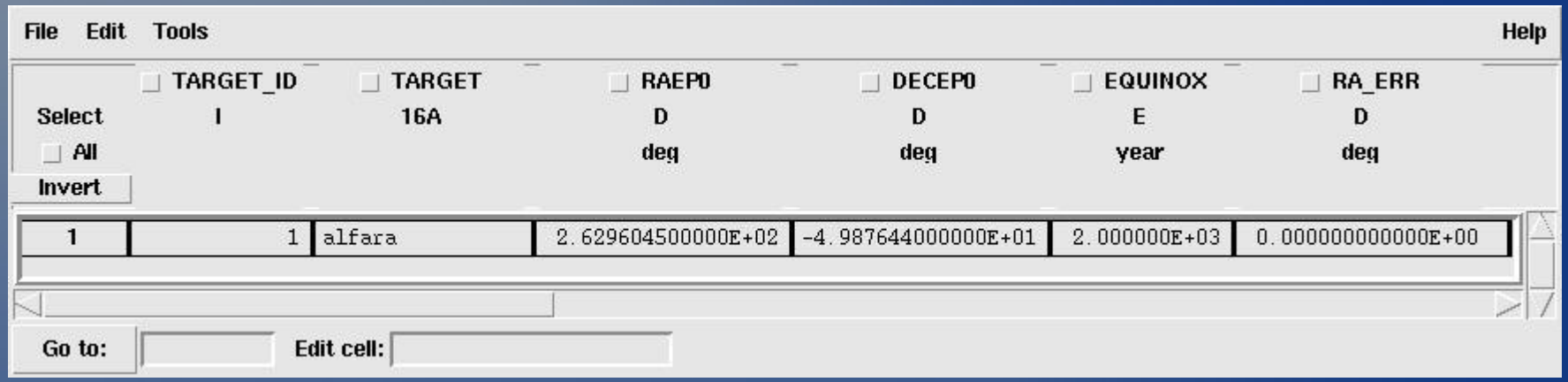
File Edit Tools Help

Index	Extension	Type	Dimension	View
0	Primary	Image	0	Header Image Table
1	OI_ARRAY	Binary	5 cols X 3 rows	Header Hist Plot All Sele
2	OI_TARGET	Binary	17 cols X 1 rows	Header Hist Plot All Sele
3	OI_WAVELENGTH	Binary	2 cols X 158 rows	Header Hist Plot All Sele
4	OI_VIS	Binary	14 cols X 1500 rows	Header Hist Plot All Sele
5	OI_VIS2	Binary	10 cols X 1500 rows	Header Hist Plot All Sele
6	OI_T3	Binary	14 cols X 500 rows	Header Hist Plot All Sele
7	AMBER_DATA	Binary	16 cols X 1500 rows	Header Hist Plot All Sele

OI-ARRAY Table



OI-TARGET Table:



OI_WAVELENGTH TABLE

File Edit Tools Help

Select	EFF_WAVE	EFF_BAND
All	E	E
Invert	m	m
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:

OI_VIS2 Table:

TARGET_ID	I (1)	Target number as index into OI_TARGET table
TIME	D (1)	UTC time of observation (seconds)
MJD	D (1)	Modified Julian Day
INT_TIME	D (1)	Integration time (seconds)
VIS2DATA	D (NWAVE)	Squared Visibility
VIS2ERR	D (NWAVE)	Error in Squared Visibility
UCOORD	D (1)	U coordinate of the data (meters)
VCOORD	D (1)	V coordinate of the data (meters)
STA_INDEX	I (2)	Station numbers contributing to the data
FLAG	L (NWAVE)	Flag

OI_T3 Table:

TARGET_ID	I (1)	Target number as index into OI_TARGET table
TIME	D (1)	UTC time of observation (seconds)
MJD	D (1)	Modified Julian Day
INT_TIME	D (1)	Integration time (seconds)
T3AMP	D (NWAVE)	Triple Product Amplitude
T3AMPERR	D (NWAVE)	Error in Triple Product Amplitude
T3PHI	D (NWAVE)	Triple Product Phase in degrees
T3PHIERR	D (NWAVE)	Error in Triple Product Phase in degrees
U1COORD	D (1)	U coordinate of baseline AB of the triangle (meters)
V1COORD	D (1)	V coordinate of baseline AB of the triangle (meters)
U2COORD	D (1)	U coordinate of baseline BC of the triangle (meters)
V2COORD	D (1)	V coordinate of baseline BC of the triangle (meters)
STA_INDEX	I (3)	Station numbers contributing to the data
FLAG	L (NWAVE)	Flag

OI_VIS Table:

TARGET_ID	I (1)	Target number as index into OI_TARGET table
TIME	D (1)	UTC time of observation (seconds)
MJD	D (1)	Modified Julian Day
INT_TIME	D (1)	Integration time (seconds)
VISAMP	D (NWAVE)	Visibility amplitude
VISAMPERR	D (NWAVE)	Error in visibility amplitude
VISPHI	D (NWAVE)	Visibility phase in degrees
VISPHIERR	D (NWAVE)	Error in visibility phase in degrees
UCOORD	D (1)	U coordinate of the data (meters)
VCOORD	D (1)	V coordinate of the data (meters)
STA_INDEX	I (2)	Station numbers contributing to the data
FLAG	L (NWAVE)	Flag

Amdlib3 specific features.

The code implements most of the algorithms published by Chelli et al. 2009 as well as workarounds of some of the problems audited by the ATF team (see ATF report):

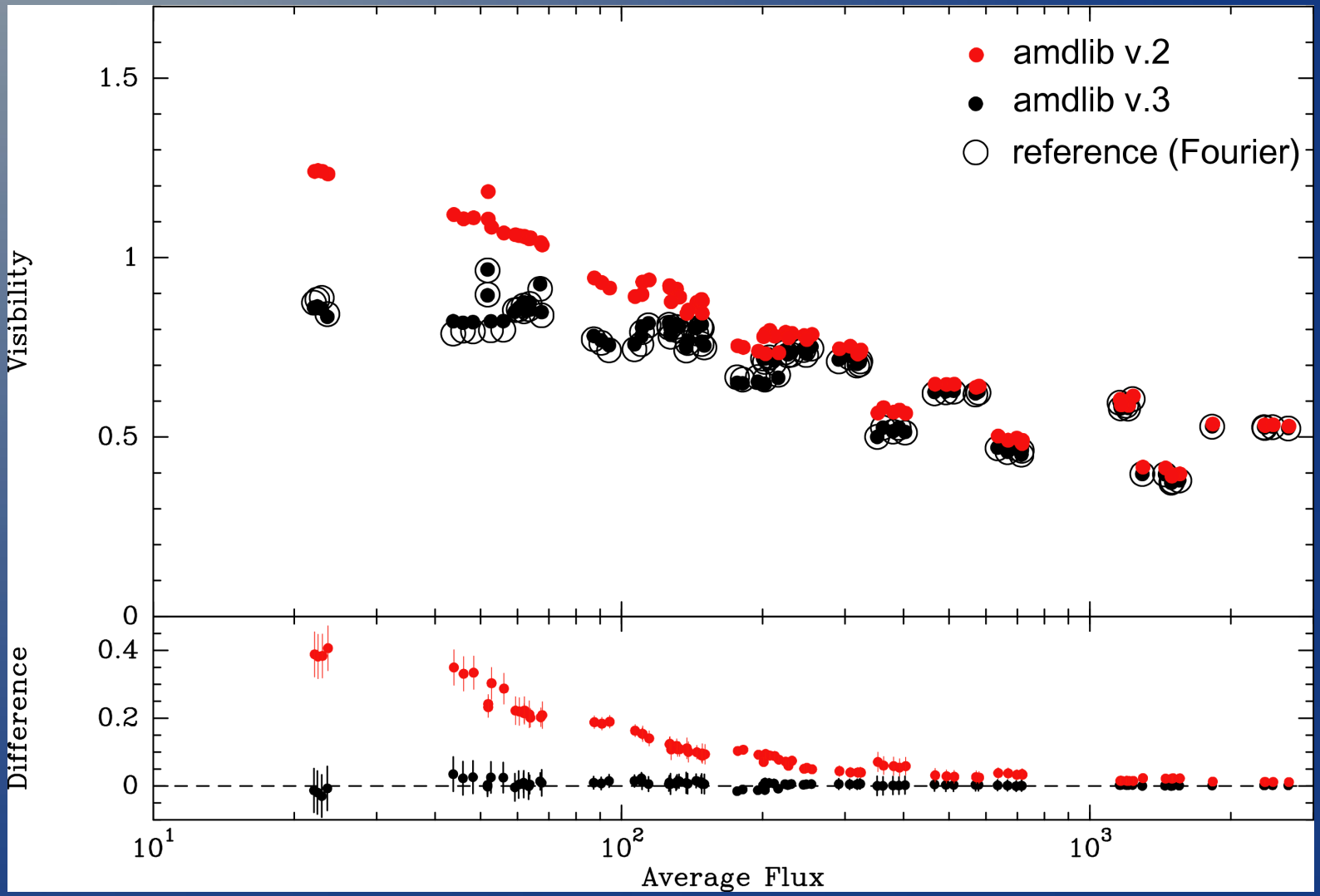
- new instrument model (crosstalk between beams, non-linearity of detector, simpler cosmetics, care in dropping the bad frames at start of scans)

- better noise model (use only 1 dark/sky file, readout noise computed pixel-per-pixel, on-the-fly bad pixel detection)

- algorithms improvements.

References:
Chelli, Hernandez & Duvert, A&A 502, 705-709 (2009)
Malbet, Duvert, Chelli & Kern, arXiv:0808.1315 (ATF report)

new instrument model + better nois model =
→ Visibilities not biased wrt flux
→ Calibrators can be of higher flux.



Amdlib3 specific features (cont).

- The **wavelength displacement** between the three photometric beams is automatically taken into account.
- In low-resolution mode, the algorithm compensates the defects of repositioning of the spectrograph prism.
- uses a refined algorithm to compute pistons, and an heuristic scheme to evaluate this piston "goodness of fit". Also, we added a piston closure algorithm to improve piston estimate.
- many new options (command-line & yorick). Important: the number of frames dropped at the beginning of each observation (unless the camera is not resetted anymore)

Quality improvement and data Tagging:

- uses a **goodness of fit test to tag individual visibilities** which are not well fitted by the carrying waves of the interferogram.
- similarly, the program tags all visibilities where one of the photometries is below a used-defined value (0 being the default).
- Finally, all bad values of the instantaneous or averaged interferometric observables are tagged in the OI- FITS file using the FLAG columns.

Amdlib3 specific features (cont).

Closure Phase sign not the same as amdlib v2.

Frame selection (my point of view):
- provided as backward compatibility with amdlib2 and the "habits" of the early observers.
- not necessary anymore, **except for low-resolution** (without FINITO -?-) where at least a threshold on maximum piston (say, 15 microns) should be applied.

Amdlib3

Find the last version at
http://www.mariotti.fr/data_processing_amber.htm

You can 

To keep in touch.
Also, read the manual...
and the Release Notes that are continously updated