

APEX Control System (APECS)



APECS 2.7/3.0, MPIfR 03/2014

LETTER TO THE EDITOR

APECS – the Atacama pathfinder experiment control system

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ABSTRACT

APECS is the distributed control system of the new Atacama Pathfinder EXperiment (APEX) telescope located on the Llano de Chajnantor at an altitude of 5107 m in the Atacama desert in northern Chile. APECS is based on Atacama Large Millimeter Array (ALMA) software and employs a modern, object-oriented design using the Common Object Request Broker Architecture (CORBA) as the middleware. New generic device interfaces simplify adding instruments to the control system. The Python based observer command scripting language allows using many existing software libraries and facilitates creating more complex observing modes. A new self-descriptive raw data format (Multi-Beam FITS or MBFITS) has been defined to store the multi-beam, multi-frequency data. APECS provides an online pipeline for initial calibration, observer feedback and a quick-look display. APECS is being used for regular science observations in local and remote mode since August 2005.

Key words. telescopes – methods: data analysis – methods: numerical – astronomical data bases: miscellaneous

APECS Design

- APECS is designed as a pipeline system starting with a scan description (“scan object”) and eventually leading to data products
- This pipeline is coordinated by the central “Observing Engine”
- Most APECS applications are written in Python, but they use a lot of compiled libraries to speed up computations and transactions
- The astronomer interface is an IPython shell with special commands to set up and start the observations

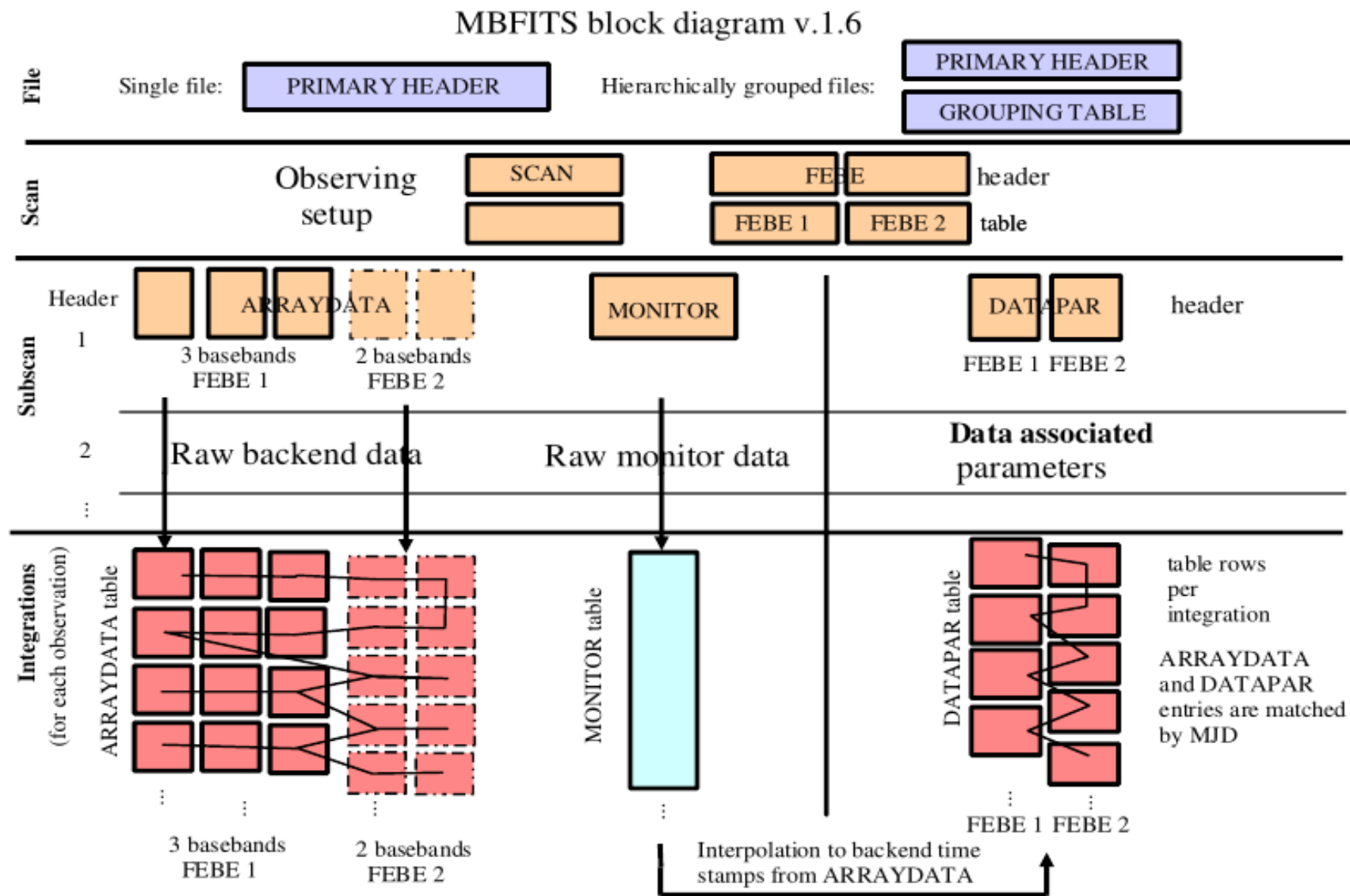
Connection to ALMA

- APECS is an object-oriented system that re-uses software from ALMA:
 - ALMA Common Software (ACS) which provides the middleware for communication between the hard- and software components
 - ACS @ APECS is kept up-to-date with ALMA's latest versions, currently APECS 2.7 / ACS 12.1, soon APECS 3.0 / ACS 12.3 / Scientific Linux 6.5
 - Test Interferometer Control Software (TICS) for conversion of astronomical to horizontal coordinates, pattern elements and real-time antenna control

Multi-Beam FITS (MBFITS)

- The lack of a good format to store array receiver data of single-dish radio telescopes led to the development of the MBFITS raw data format
- MBFITS stores the instrument and telescope data as a number of FITS files in a hierarchically organized directory structure
- MBFITS is being used at APEX, Effelsberg, IRAM 30m, Yebes 40m and the SRT telescopes

MBFITS Structure



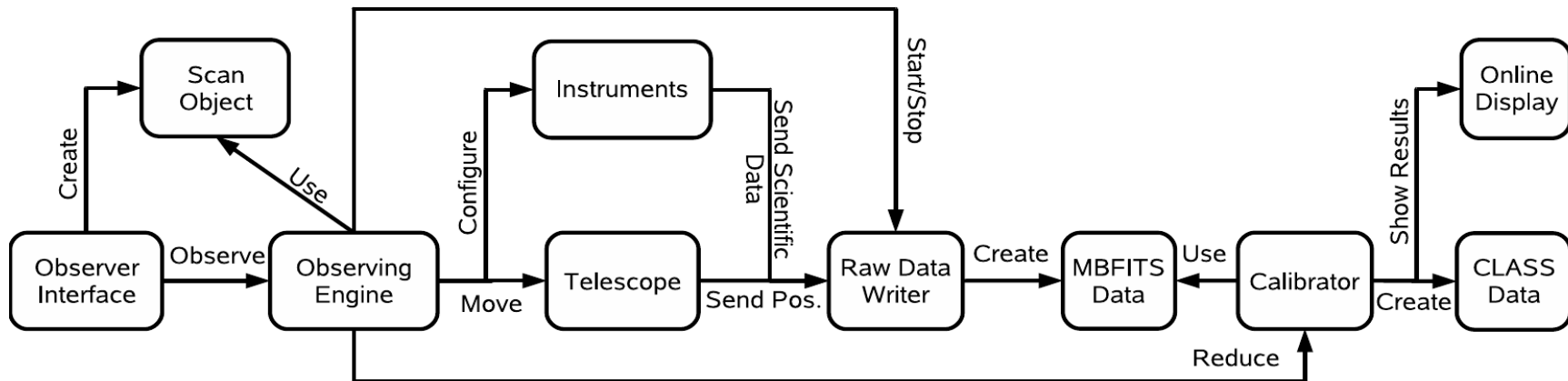
“apecs” Command Line Interface

- IPython based CLI with extensible scripting language including user macros
- High-level commands to set up:
 - Catalogs (source, line)
 - Targets (coordinates, velocity)
 - Instruments (frontends, backends)
 - Calibrations (sky-hot-cold, skydip, point, focus)
 - Switch modes (total power, wobbling, freq. sw.)
 - Patterns (single, raster, OTF, (spiral))

Observing Engine

- Central coordinating process that sets up all devices according to the “Scan Objects” sent via the “apecs” CLI
- Pattern loop to set up receivers, IF, backends, antenna motion and start / stop FitsWriter and backends
- Background threads to update weather and IERS parameters needed for coordinate and refraction calculations

Observing Engine Interactions



MBFITS Writer

- The FitsWriter creates MBFITS data sets by collecting telescope, backend and monitoring data via a set of pipelines
- Each pipeline consists of pipes and filters and feeds a particular type of MBFITS binary table
- A flexible mechanism allows to store any CORBA property at any given rate in the MONITOR table

Calibrator

- The calibrator provides the online pipeline to process the MBFITS files after each subscan
- Spectral line data is calibrated to T_A^* scale using ATM and written to CLASS format
- Bolometer data is processed using the BoA modules
- Pointing & focus results are automatically made available to the “apecs” CLI for corrections

Observation Logger

- Automatic creation of the observer's log (XML & HTML) using the online information
- Allows editing a comment field for each scan
- Visible columns can be selected individually

Scan	Project ID	LST	Source	Source Velocity	Az	EI	CA	IE	Type	PWV	Temperature	Humidity	FEBEs	Lines	Comment
35818	M-00.F-0042-2005	03:45	Mars	0.0	-27.1	47.6	-2.9	-18.8	POINT	0.4	-1.0	8.17	CONDOR-PBE_A	CO(13-12) (1496.923) -	
35819	M-00.F-0042-2005	03:47	Mars	0.0	-27.5	47.5	-2.9	-18.8	POINT	0.4	-1.5	8.91	CONDOR-PBE_A	CO(13-12) (1496.923) -	
35820	M-00.F-0042-2005	03:48	Mars	0.0	-28.4	47.2	-2.9	-18.8	CAL	0.4	-1.44	8.54	CONDOR-PBE_A	CO(13-12) (1496.923) -	
35821	M-00.F-0042-2005	03:50	Mars	0.0	-28.6	47.1	-2.9	-18.8	POINT	0.4	-1.87	9.54	CONDOR-PBE_A	CO(13-12) (1496.923) -	
35822	M-00.F-0042-2005	03:51	Mars	0.0	-29.1	47.0	-2.9	-14.6	POINT	0.4	-2.31	9.92	CONDOR-PBE_A	CO(13-12) (1496.923) -	
35823	M-00.F-0042-2005	03:53	Mars	0.0	-29.4	46.9	-2.9	-14.6	POINT	0.4	-2.11	9.72	CONDOR-PBE_A	CO(13-12) (1496.923) -	
35824	M-00.F-0042-2005	03:55	Mars	0.0	-30.1	46.6	0.7	-14.6	POINT	0.4	-1.9	9.5	CONDOR-PBE_A	CO(13-12) (1496.923) -	
35825	M-00.F-0042-2005	04:00	Ori-IRc2	6.1	55.8	61.2	0.7	-14.6	CAL	0.4	-1.8	9.46	CONDOR-FFTS	CO(13-12) (1496.923) -	Scan canceled.
35826	M-00.F-0042-2005	04:03	Ori-IRc2	6.1	54.9	61.7	0.7	-14.6	CAL	0.4	-1.84	9.31	CONDOR-FFTS	CO(13-12) (1496.923) -	
35827	M-00.F-0042-2005	04:06	Ori-IRc2	6.1	53.8	62.3	0.7	-14.6	CAL	0.4	-1.75	9.37	CONDOR-FFTS	CO(13-12) (1496.923) -	
35828	M-00.F-0042-2005	04:08	Ori-IRc2	6.1	53.1	62.7	0.7	-14.6	ONOFF	0.4	-1.74	9.37	CONDOR-FFTS	CO(13-12) (1496.923) -	
35829	M-00.F-0042-2005	04:11	Ori-IRc2	6.1	51.8	63.3	0.7	-14.6	CAL	0.4	-1.77	9.75	CONDOR-FFTS	CO(13-12) (1496.923) -	
35830	M-00.F-0042-2005	04:13	Ori-IRc2	6.1	51.1	63.6	0.7	-14.6	ONOFF	0.4	-1.81	9.89	CONDOR-FFTS	CO(13-12) (1496.923) -	
35831	M-00.F-0042-2005	04:17	Ori-IRc2	6.1	49.7	64.3	0.7	-14.6	ONOFF	0.4	-2.35	10.44	CONDOR-FFTS	CO(13-12) (1496.923) -	
35832	M-00.F-0042-2005	04:20	Ori-IRc2	6.1	48.3	64.9	0.7	-14.6	CAL	0.4	-2.5	10.9	CONDOR-FFTS	CO(13-12) (1496.923) -	
35833	M-00.F-0042-2005	04:22	Ori-IRc2	6.1	47.6	65.1	0.7	-14.6	ONOFF	0.4	-2.18	10.62	CONDOR-FFTS	CO(13-12) (1496.923) -	
35834	M-00.F-0042-2005	04:23	OriS-FIR4	7.2	46.9	65.4	0.7	-14.6	CAL	0.4	-1.88	10.34	CONDOR-FFTS	CO(13-12) (1496.923) -	
35835	M-00.F-0042-2005	04:25	OriS-FIR4	7.2	46.2	65.7	0.7	-14.6	ONOFF	0.4	-1.81	10.31	CONDOR-FFTS	CO(13-12) (1496.923) -	
35836	M-00.F-0042-2005	04:26	OriS-FIR4	7.2	45.8	65.9	0.7	-14.6	ONOFF	0.4	-1.9	10.33	CONDOR-FFTS	CO(13-12) (1496.923) -	
35837	M-00.F-0042-2005	04:27	OriS-FIR4	7.2	45.7	65.9	0.7	-14.6	ONOFF	0.4	-2.07	11.08	CONDOR-FFTS	CO(13-12) (1496.923) -	
35838	M-00.F-0042-2005	04:30	OriS-FIR4	7.2	45.7	65.9	0.7	-14.6	CAL	0.4	-1.97	10.67	CONDOR-FFTS	CO(13-12) (1496.923) -	
35839	M-00.F-0042-2005	04:32	OriS-FIR4	7.2	45.7	65.9	0.7	-14.6	ONOFF	0.4	-1.77	10.61	CONDOR-FFTS	CO(13-12) (1496.923) -	
35840	M-00.F-0042-2005	04:36	NGC2024-I	7.2	45.7	65.9	0.7	-14.6	CAL	0.4	-1.97	10.79	CONDOR-FFTS	CO(13-12) (1496.923) -	
35841	M-00.F-0042-2005	04:39	NGC2024-I	7.2	45.7	65.9	0.7	-14.6	CAL	0.4	-2.29	11.08	CONDOR-FFTS	CO(13-12) (1496.923) -	
35842	M-00.F-0042-2005	04:40	NGC2024-I	7.2	45.7	65.9	0.7	-14.6	ONOFF	0.4	-1.97	10.85	CONDOR-FFTS	CO(13-12) (1496.923) -	
35843	M-00.F-0042-2005	04:45	NGC2024-I	7.2	45.7	65.9	0.7	-14.6	CAL	0.3	-1.77	10.61	CONDOR-FFTS	CO(13-12) (1496.923) -	
35844	M-00.F-0042-2005	04:46	NGC2024-I	7.2	45.7	65.9	0.7	-14.6	ONOFF	0.7	-2.04	10.79	CONDOR-FFTS	CO(13-12) (1496.923) -	
35845	M-00.F-0042-2005	04:51	NGC2024-I	7.2	45.7	65.9	0.7	-14.6	CAL	0.4	-2.29	11.08	CONDOR-FFTS	CO(13-12) (1496.923) -	
35846	M-00.F-0042-2005	04:52	NGC2024-I	7.2	45.7	65.9	0.7	-14.6	ONOFF	0.4	-1.97	10.85	CONDOR-FFTS	CO(13-12) (1496.923) -	
35847	M-00.F-0042-2005	04:56	NGC2024-I	7.2	45.7	65.9	0.7	-14.6	CAL	0.4	-2.13	10.79	CONDOR-FFTS	CO(13-12) (1496.923) -	
35848	M-00.F-0042-2005	04:58	NGC2024-I	7.2	45.7	65.9	0.7	-14.6	ONOFF	0.4	-1.83	10.64	CONDOR-FFTS	CO(13-12) (1496.923) -	
35849	M-00.F-0042-2005	05:02	NGC2024-I	7.2	45.7	65.9	0.7	-14.6	CAL	0.4	-1.95	10.71	CONDOR-FFTS	CO(13-12) (1496.923) -	
35850	M-00.F-0042-2005	05:04	NGC2024-I	7.2	45.7	65.9	0.7	-14.6	ONOFF	0.4	-2.03	10.81	CONDOR-FFTS	CO(13-12) (1496.923) -	
35851	M-00.F-0042-2005	05:08	NGC2024-I	7.2	45.7	65.9	0.7	-14.6	CAL	0.4	-1.96	10.69	CONDOR-FFTS	CO(13-12) (1496.923) -	
35852	M-00.F-0042-2005	05:10	NGC2024-I	7.2	45.7	65.9	0.7	-14.6	ONOFF	0.4	-1.91	10.64	CONDOR-FFTS	CO(13-12) (1496.923) -	
35853	M-00.F-0042-2005	05:14	NGC2024-I	7.2	45.7	65.9	0.7	-14.6	CAL	0.4	-2.35	11.17	CONDOR-FFTS	CO(13-12) (1496.923) -	
35854	M-00.F-0042-2005	05:18	NGC2024-I	7.2	45.7	65.9	0.7	-14.6	CAL	0.4	-2.55	11.46	CONDOR-FFTS	CO(13-12) (1496.923) -	
35855	M-00.F-0042-2005	05:19	NGC2024-IRS2	11.5	14.8	68.3	0.7	-14.6	ONOFF	0.4	-2.28	11.41	CONDOR-FFTS	CO(13-12) (1496.923) -	

Select Column

Columns

- Geometry
- Humidity
- IE
- Lines
- LST
- Mode
- Observer ID
- Offsets
- Operator ID
- Pressure
- Project ID
- PWV

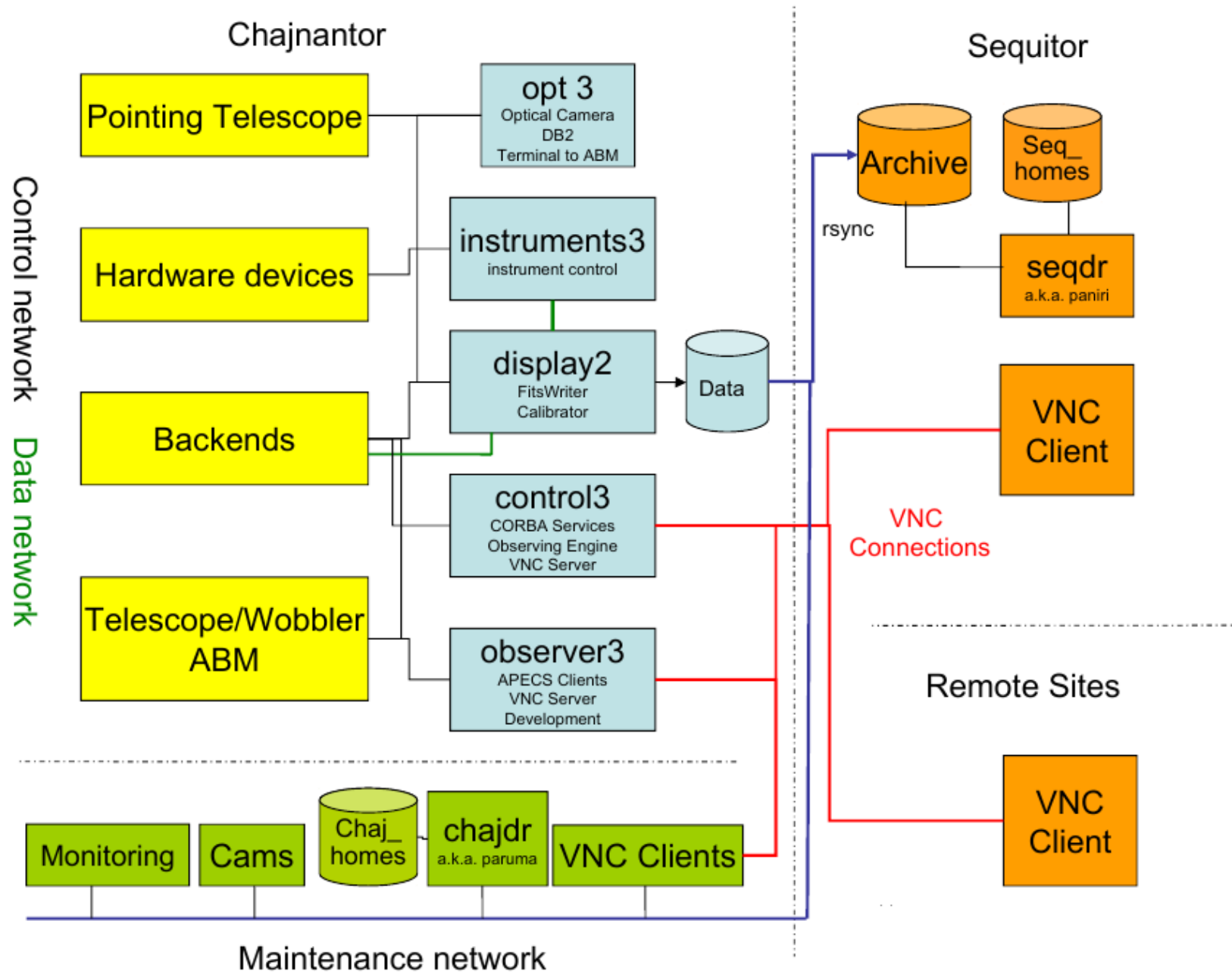
OK Cancel

Edit Comment <@control>

Scan: 35833


Line OK

OK



APECS Manual

<http://www3.mpifr-bonn.mpg.de/staff/dmuders/> and on the APEX web pages

	<p>Atacama Pathfinder EXperiment</p> <hr/> <p>User Manual</p>	<table border="1"><tr><td>APEX-MPI-MAN-0011</td></tr><tr><td>Revision: 2.7</td></tr><tr><td>Release: March 5, 2014</td></tr><tr><td>Category: 4</td></tr><tr><td>Author: Dirk Muders</td></tr></table>	APEX-MPI-MAN-0011	Revision: 2.7	Release: March 5, 2014	Category: 4	Author: Dirk Muders
APEX-MPI-MAN-0011							
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Author: Dirk Muders							

APECS User Manual

apecs CLI Commands

- General
- Catalogs
- Instruments
- Target
- Calibration
- Observing Pattern
- Stroke mode
- Switch mode
- Antenna

The “apecs” commands are organized in a number of areas matching the typical observation setups.

Type “help apecs” in the CLI to get a summary of those sections.

apecs CLI philosophy

- All commands have sensible defaults
- But check: `help (<command>)` will show all options currently set
- Then individual options can be changed easily:
 - e.g.: `point(length=120)` just changes length, rest untouched. Parameter names can be skipped if values are in sequence: “`point(120,'arcsec')`” and since it is IPython also “`point 120`” works.
 - Aliases for instruments: “`frontends het345`”
 - NOTE: in scripts all the brackets are needed!

General

3.2.1	General
3.2.1.1	project_id
3.2.1.2	operator_id
3.2.1.3	observer_id
3.2.1.4	show
3.2.1.5	load
3.2.1.6	go
3.2.1.7	track
3.2.1.8	cancel
3.2.1.9	exec_apecs_script
3.2.1.10	save_history
3.2.1.11	save_defaults
3.2.1.12	load_defaults
3.2.1.13	reset_defaults
3.2.1.14	observe
3.2.1.15	continuous_data
3.2.1.16	skip_hardware_setup
3.2.1.17	remote_control

Catalogs

3.2.1.17	remote_control
3.2.2	Catalogs
3.2.2.1	sourcecats
3.2.2.2	ephemerides
3.2.2.3	linecats

► Source catalogs

APEX source catalogs have the suffix `.cat`. Comment lines (or comment part of source lines) are preceded by a "!" effect. A source line will contain source name, coordinate system, epoch, RA (h:m:s), Dec (d:m:s), velocity (current supported), and (maybe) comments. Its syntax looks like the following:

```
R-And    EQ 2000  00:24:01.939  38:34:37.12  LSR -15.0  ! Pointing source
```

Currently, the only possible coordinate system is equatorial with equinox J2000.

Example: [APEX-2A line pointing catalog](#).

In APECS, the source catalogs are loaded by the `sourcecats` command, which allows to specify one or more catalogs:

```
sourcecats(['mystars.cat', 'mygalaxies.cat'])
```

When one of the loaded catalogs contains the target source, you can select this source by entering the `source` command parameter:

```
source('R-And')
```

► Line catalogs

APEX line catalogs have the suffix `.lin`. Each line should contain transition name, frequency, unit, sideband, and like the following:

```
C0(3-2)  345.79599  GHz  LSB  ! main isotope
```

Example: [APEX-2A spectral line catalog](#).

The syntax to load a line catalog in APECS is very similar to that for source catalogs, and the line selection also is contained in one of the loaded line catalogs. It is actually part of the general receiver setup command.

```
linecats(['mylines.lin'])  
setup_shfi(fename='het230', linename='MyLine(2-1)', sideband='', mode='spec', cats='user')
```

Instruments

Basic setup with the “frontends” and “<frontend>.backends” commands.

Some instruments need very special IF shifts. There are pre-defined scripts for those setups which can be loaded with “exec_apecs_script”:

- shfi_commands
- flash_commands
- champ_commands

With the arrival of the XFFTS backend, the setup for heterodyne projects is much simpler than before.

Example 1: LABOCA

```
frontends(['laboca'])  
laboca.backends(['abba'])
```

Example 2: APEX-1

```
exec_apecs_script('shfi_commands')  
setup_shfi(fename='het230',linename='co(2-1)',sideband='',mode='spec', cats='sys')
```

Target

For projects with just one (or a few) sources it is probably easier to specify all source information using the `source` command of APECS instead of preparing a source catalog. An example would be:

```
source(name='R-And',x=('00:24:01.939','hms'),y=('38:34:37.12','dms'),system='eq',epoch=2000.0,velocity=-15.0,frame='LSR')
```

Major **solar system objects** are known to APECS. It suffices to just set them up with the “source” command using their name, e.g.

```
source 'mars'  
source 'titan'  
source '1 ceres'  
source 'c/2012 s1 (ison)'
```

This setup ensures the proper motion tracking for the given time. It is not recommended to work with fixed coordinate tables, especially for fast objects close to the sun.

Object ephemeris files should be up-to-date. Currently, this still needs to be coordinated with the APEX staff since the “ephemerides” user command is not yet implemented.

Calibration

```
focus( amplitude=<Amplitude in mm or arcsec>,
        time=<Time per subscan>,
        points=<Number of points>,
        axis='z' | 'y' | 'x' | 'xtilt' | 'ytilt',
        mode='pos' | 'neg' | 'sym')
```

```
point( length=<Number>,
        unit='arcsec',
        time=<Time per subscan in seconds>,
        mode='otf' | 'ras',
        points=<Number>,
        direction='x' | 'y')
```

```
calibrate( mode='cold | hot',
           time=<Time per point in seconds>,
           autolevel='on' | 'off')
```

3.2.5	Calibration	.....
3.2.5.1	calibrate	.....
3.2.5.2	skydip	.....
3.2.5.3	point	.....
3.2.5.4	pcorr	.....
3.2.5.5	pcorr_reset	.....
3.2.5.6	focus	.....
3.2.5.7	fcorr	.....
3.2.5.8	fcorr_reset	.....
3.2.5.9	use_foc_temp_corr	.....
3.2.5.10	set_tilts	.....
3.2.5.11	reset_tilts	.....
3.2.5.12	use_linear_sensors	.....
3.2.5.13	use_tiltmeters	.....
3.2.5.14	set_cold_params	.....
3.2.5.15	reset_cold_params	.....

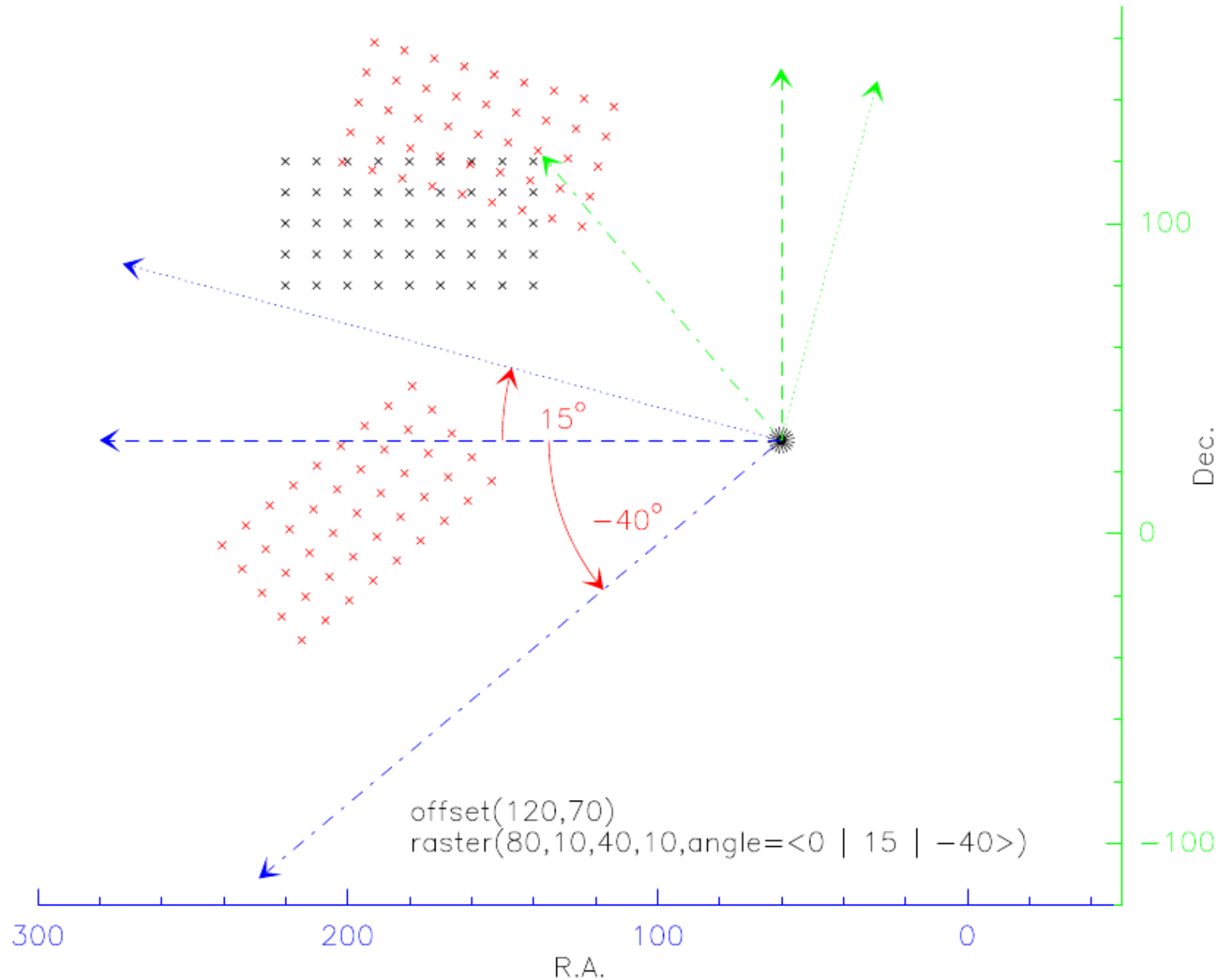
Observing Pattern

- reference: abs or rel.
- offset
- on, raster, otf, ...

```
otf( xlen=<x-Length>,  
     xstep=<x-Step>,  
     ylen=<y-Length>,  
     ystep=<y-Step>,  
     time=<Time per OTF map point>,  
     direction='x' | 'y',  
     zigzag=1 | 0,  
     angle=<Position Angle>,  
     size_unit='arcsec' | 'arcmin' | 'deg',  
     angle_unit='deg' | 'arcmin' | 'arcsec',  
     system='eq' | 'ho',  
     epoch=2000.0,  
     mode='ordered' | 'jiggle',  
     on2cal=<Number of "on" subscans between calibrations>) )14
```

3.2.6	Observing Patterns . .
3.2.6.1	offset . . .
3.2.6.2	reference .
3.2.6.3	use_ref . .
3.2.6.4	on
3.2.6.5	raster . . .
3.2.6.6	hexa
3.2.6.7	hexa25 . . .
3.2.6.8	otf
3.2.6.9	drift . . .
3.2.6.10	repeat . . .

Rotated Coordinate Systems in APECS



Stroke mode

- Mostly relevant for bolometers
 - → Axel's talk

3.2.7	Stroke Mode
3.2.7.1	linear
3.2.7.2	spiral
3.2.7.3	lissajous

Switch mode

- tp
 - Provide sensible reference position
- wob
 - Throw (+/- !) and rate
- fsw
 - Tested but rarely used

3.2.8	Switch Mode .
3.2.8.1	tp .
3.2.8.2	wob .
3.2.8.3	fsw .

Antenna

- Instrument switch:
 - Zenith (check sun)
 - switch_c_optics
- But for antenna commands like stow/unstow (and also closing/opening the shutter) check with operator/astronomer on duty

3.2.9	Antenna
3.2.9.1	tolerance
3.2.9.2	park
3.2.9.3	zenith
3.2.9.4	stow
3.2.9.5	unstow
3.2.9.6	stow_wobbler
3.2.9.7	init_wobbler
3.2.9.8	reset_wobbler
3.2.9.9	switch_c_optics

Think Python: How to Think Like a Computer Scientist

Allen B. Downey

Version 2.0.6

February 2013

- Preface
 - The strange history of this book
 - Acknowledgments
 - Contributor List
- The way of the program
 - The Python programming language
 - What is a program?
 - What is debugging?
 - Formal and natural languages
 - The first program
 - Debugging
 - Glossary
 - Exercises
- Variables, expressions and statements
 - Values and types
 - Variables
 - Variable names and keywords

APECS Simulator

- For development purposes we have set up a simulation environment which allows setting up fake observations exactly like at APEX
- This simulator could be used to test scripts
- If there is some interest in this facility, we could organize a demo session