The APEX calibration plan: Goals, implementation and achievements

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Motivation

- Get to know the real time efforts and dedicated measurements at APEX currently in use.
- To share the latest developments of the APEX calibration plan.
- Will only cover the APEX facility instruments: **SHeFI, LABOCA and SABOCA**

Introduction

- The quality of scientific data depends on the accuracy of the **absolute intensity calibration**.
- The data needs to be calibrated.
- **Uncertainty** in the calibration must be determined.

SHeFI Calibration Plan

- Swedish Heterodyne Facility Instrument (SHeFI)

- Four single-pixel heterodyne receiver

- Central frequencies of 230, 345, 460 and 1300 GHz

SHeFI Calibration Plan

- SHeFI calibration plan HET230 & HET345
- Results and analysis available online
  - http://www.apex-telescope.org/heterodyne/shfi/calibration/
- Intensity calibration stability
  - Strong spectral lines in several sources over the whole frequency range.
  - Observations performed in regular basis during technical time.
  - Monitor the calibration stability as function of time and frequency

SHeFI Calibration Plan

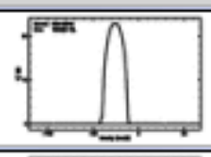
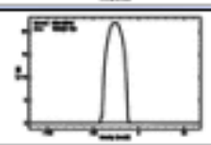
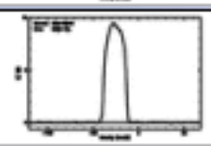
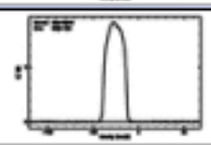
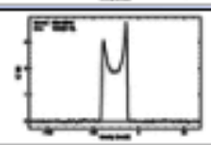
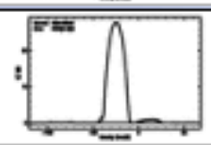
SHeFI HET230 (APEX-1)								
	12CO(2-1) LSB	12CO(2-1) USB	CS(5-4) LSB	CS(5-4) USB	13CO(2-1) LSB	HCN(3-2) USB	H2CO(3-2) LSB	CH3OH(5-4) LSB
OMC1	✓	✓	✓	✓	✓	✓	✓	✓
WB947	✓	✓			✓			
IRAS16293	✓	✓	✓	✓	✓	✓	✓	
M17SW	✓	✓	✓	✓	✓	✓		
G34.3	✓	✓	✓	✓	✓	✓	✓	✓
IRC+10216	✓	✓	✓	✓	✓	✓		
L1551-IR	✓	✓	✓			✓	✓	
O-Ceti	✓	✓			✓			
IRAS15194	✓	✓			✓			
OH231.8	✓	✓			✓	✓		
CRL2688	✓	✓	✓	✓	✓	✓		
N207IR	✓	✓	✓	✓	✓	✓	✓	✓
CRL618	✓	✓			✓	✓		
NGC6334I	✓	✓	✓	✓	✓	✓	✓	✓

SHeFI Calibration Plan

SHeFI HET345 (APEX-2)													
	12CO(3-2) LSB	12CO(3-2) USB	13CO(3-2) LSB	13CO(3-2) USB	C18O(3-2) LSB	CS(6-5) LSB	CS(7-6) LSB	HCO+(4-3) USB	HCN(4-3) USB	H2CO(5-4) USB	CH3OH(7-6) LSB	OCS304 LSB	OCS304 USB
OMC1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
WB947	✓	✓	✓	✓									
IRC+10216	✓	✓	✓	✓		✓	✓		✓				
M17SW	✓	✓	✓	✓	✓	✓	✓	✓				✓	✓
IRAS16293	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓
G34.3	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
L1551-IR	✓	✓	✓	✓	✓	✓		✓					
OH231.8	✓	✓	✓					✓	✓				
O-Ceti	✓	✓	✓	✓									
IRAS15194	✓	✓	✓										
CRL2688	✓	✓	✓	✓			✓		✓				
N207IR	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		
CRL618	✓	✓	✓	✓				✓	✓				
NGC6334I	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		

SHeFI Calibration Plan

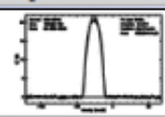
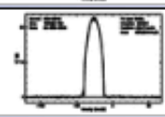
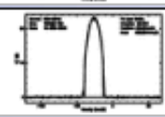
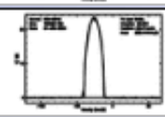
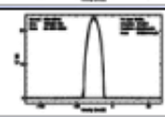
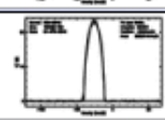
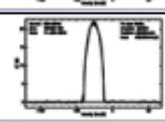
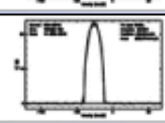
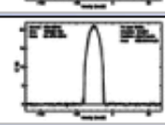
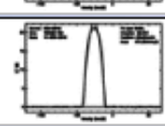
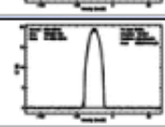
IRC+10216

Line	Frequency [GHz]	Maximum [K]	Area [K*km/s]	Position [km/s]	Linewidth [km/s]	Spectrum
12CO(2-1)L	230.538000	23.92	507.36	-25.59	21.21	
12CO(2-1)U	230.538000	22.71	481.77	-25.52	21.22	
CS(5-4)L	244.935644	9.69	207.54	-25.70	21.42	
CS(5-4)U	244.935644	9.36	200.73	-25.62	21.46	
13CO(2-1)L	220.398677	1.82	65.46	-26.04	35.89	
HCN(3-2)U	265.886180	28.60	564.96	-24.53	19.75	

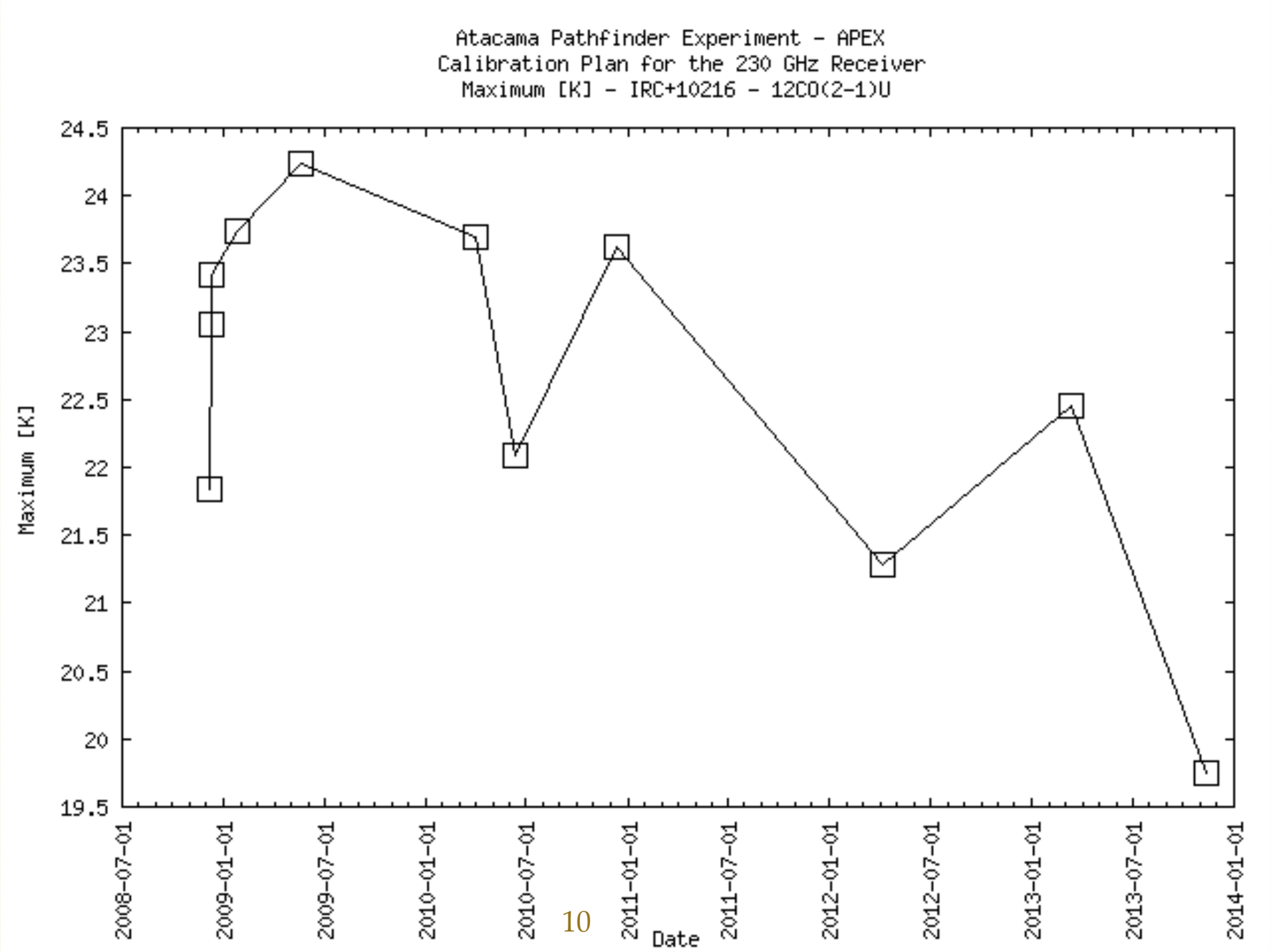
SHeFI Calibration Plan

Source : IRC+10216

Line : 12CO(2-1)U

Date	pwv [mm]	El [°]	Maximum [K]	Area [K*km/s]	Position [km/s]	Linewidth [km/s]	Spectrum
2008-12-08	5.26	30.6	21.84	458.53	-25.76	20.99	
2008-12-09	4.86	50.5	23.05	487.64	-25.70	21.16	
2008-12-10	3.85	40.3	23.42	492.82	-25.85	21.04	
2009-01-24	1.24	53.6	23.74	502.14	-25.70	21.15	
2009-05-20	1.80	50.2	24.23	512.51	-25.69	21.15	
2010-04-01	0.86	52.7	23.69	502.82	-25.59	21.22	
2010-06-11	1.36	44.1	22.09	470.42	-25.67	21.30	
2010-12-14	0.18	40.5	23.62	502.77	-25.68	21.28	
2012-04-05	2.84	37.4	21.29	453.44	-25.70	21.30	
2013-03-14	0.83	53.1	22.46	471.77	-25.61	21.01	
2013-11-14	1.83	34.2	19.75	422.24	-25.43	21.38	

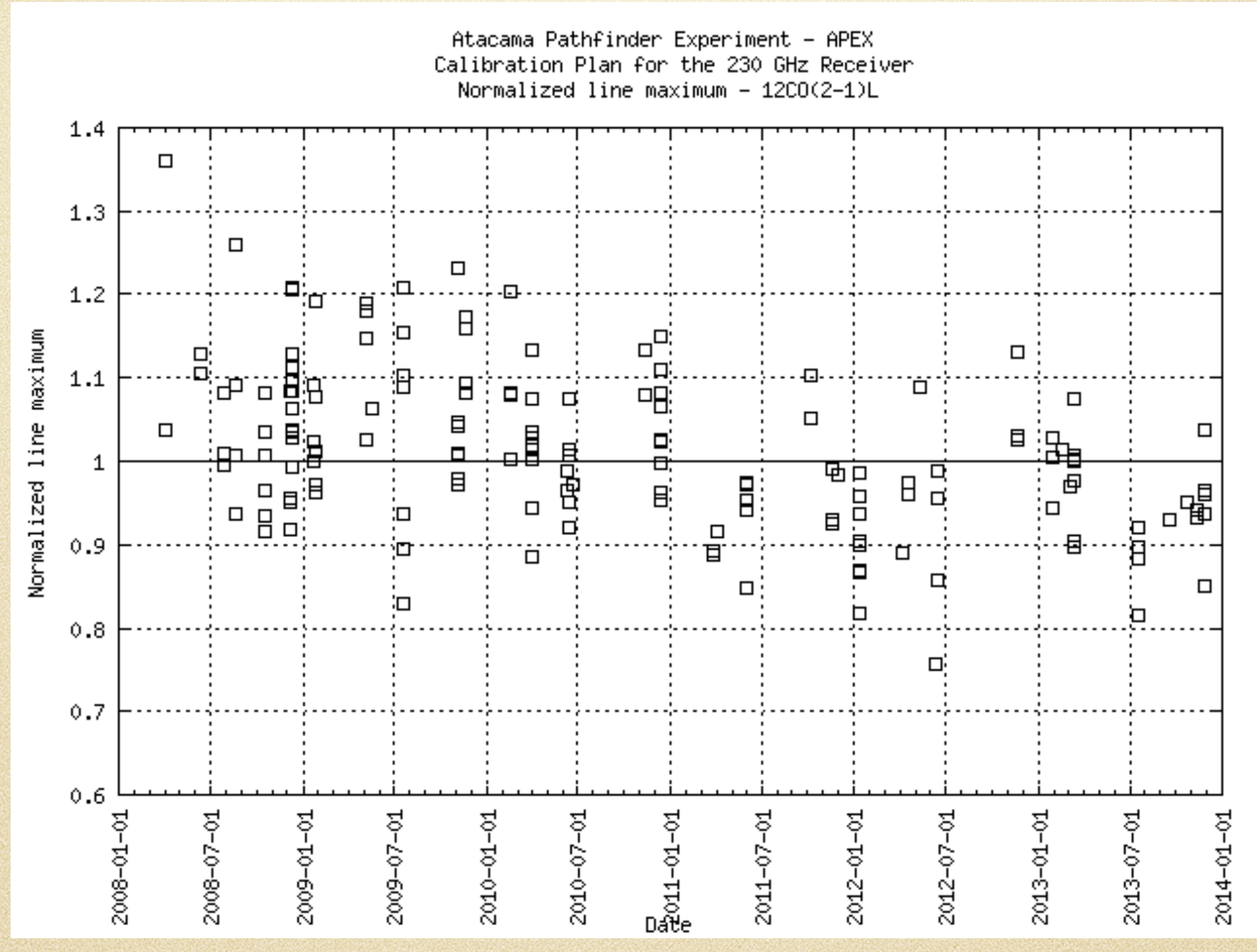
SHeFI Calibration Plan



SHeFI Calibration Plan

- Monitoring of normalised parameters
  - Source-independent data
  - Better detect time-variations of the measured parameters for the various frequencies.

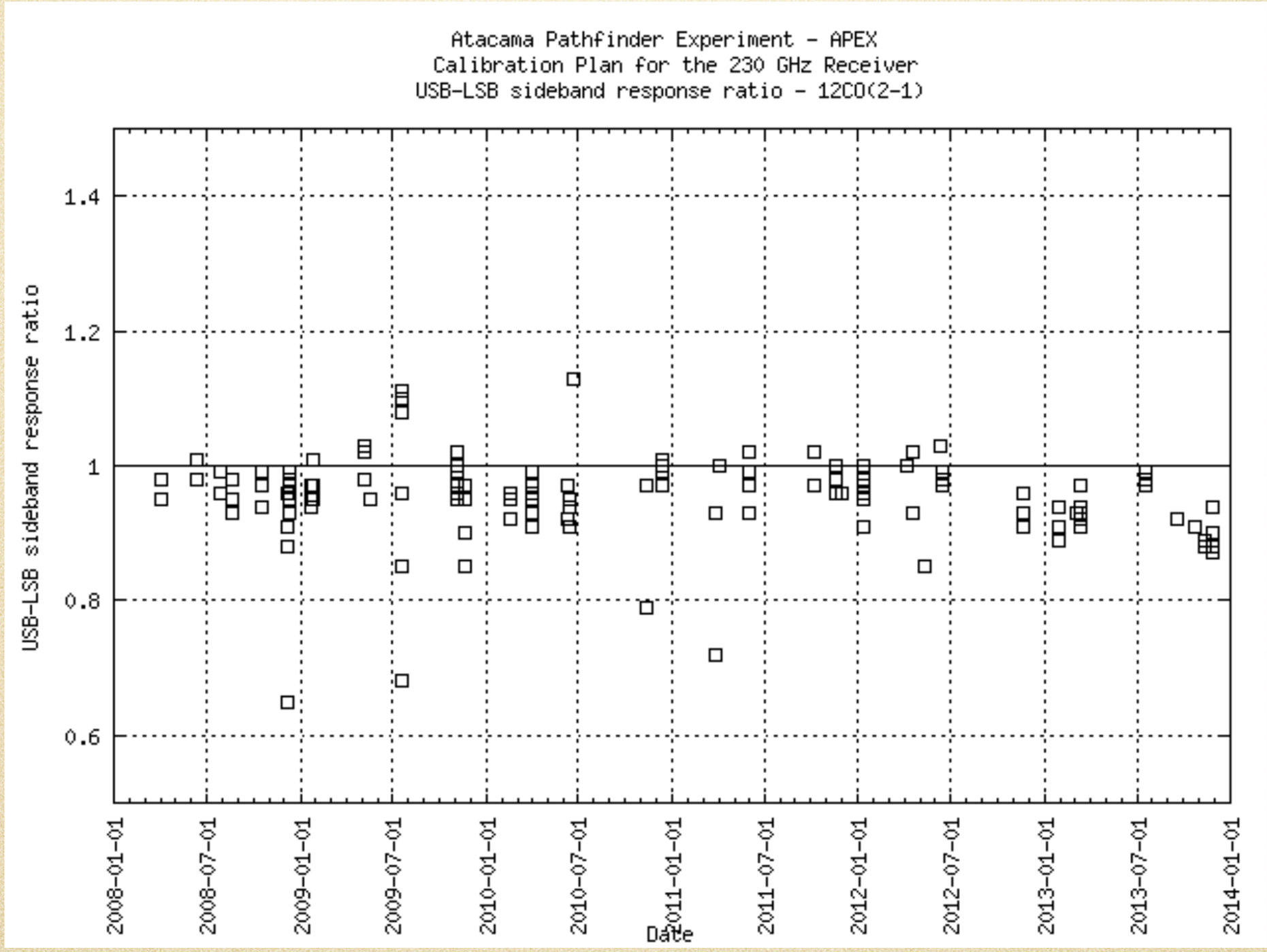
SHeFI Calibration Plan



SHeFI Calibration Plan

- SHeFi Sideband response.
  - USB vs LSB observations (Both tunings should give identical results).
  - We monitor the line ratios USB/LSB for some lines over the band, to detect problems with the receiver or the calibrator software.

SHeFI Calibration Plan



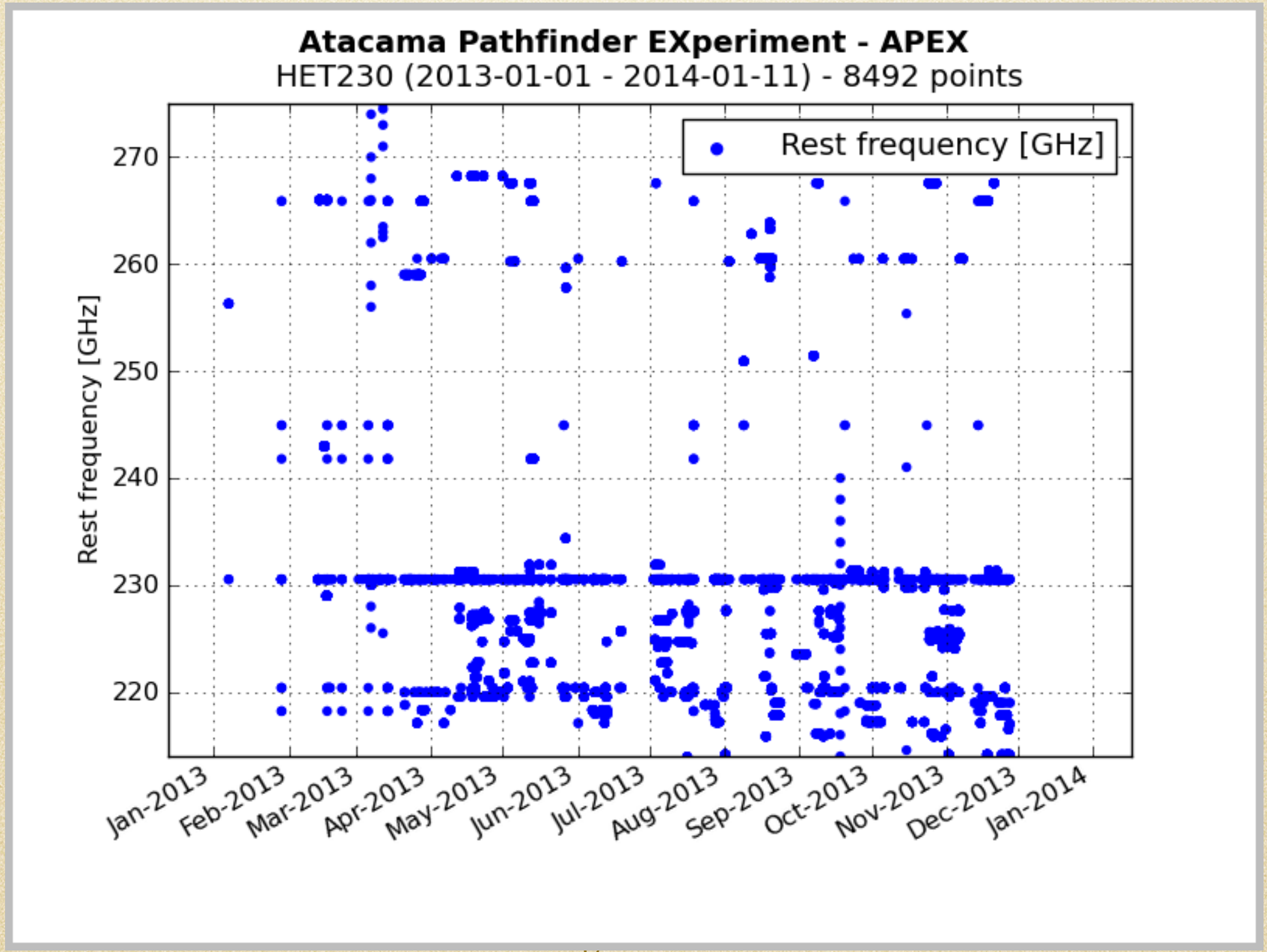
SHeFI Calibration Plan

- Frequency stability.
  - Monitor the stability of our complete LO system, from Doppler shift calculation to backend properties.
  - Through the line-width monitoring we can detect any extra broadening, e.g. because of LO frequency fluctuations.
  - WB947 suits the needs for this type of monitoring (narrow emission, Gaussian)

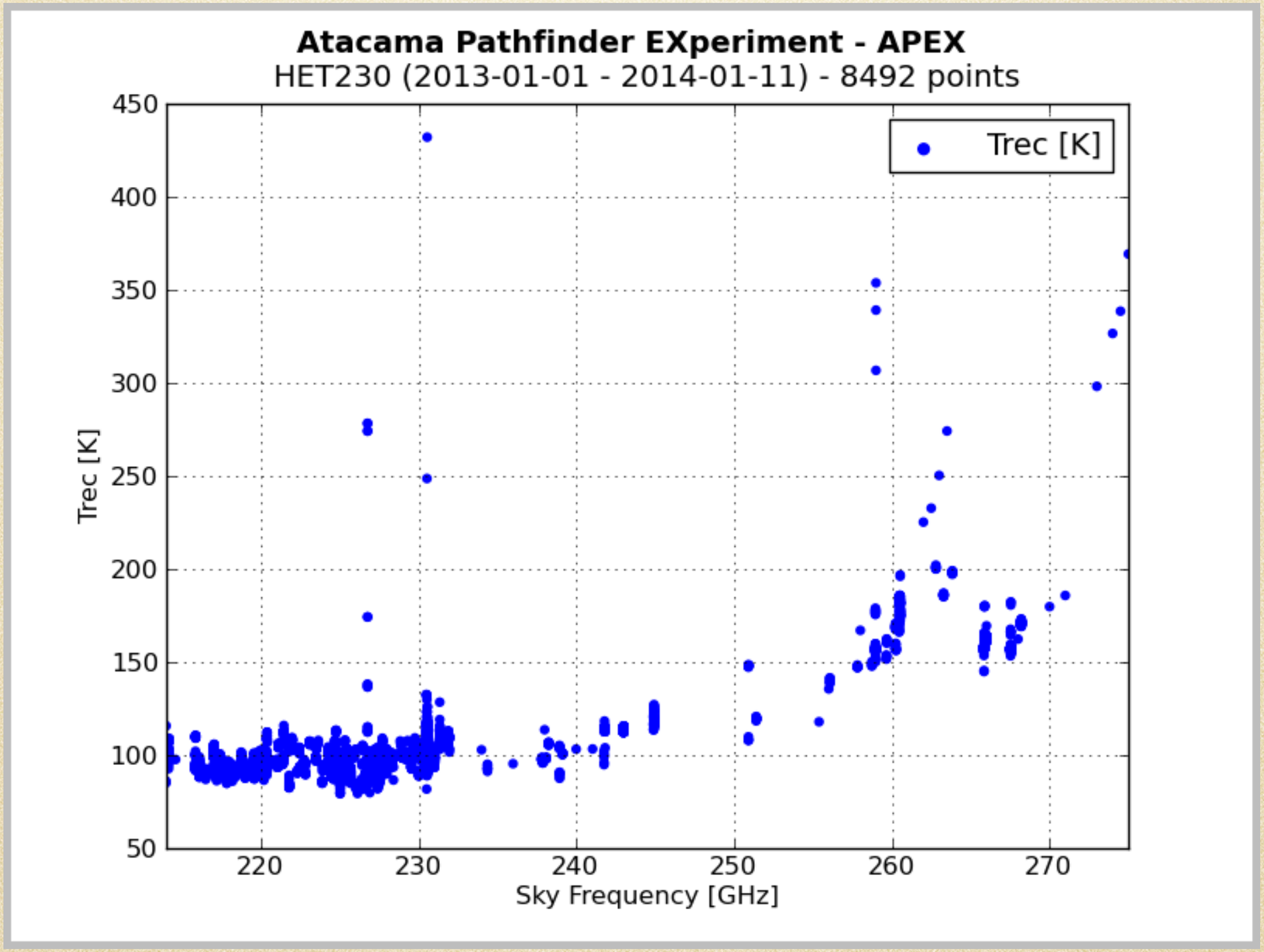
SHeFI Calibration Plan

- What's new in the SHeFI calibration plan ?
  - SHeFI usage and performance monitor
    - Monitoring of the used frequencies
    - Monitoring of Trec performance over the band in time.

SHeFI Calibration Plan



SHeFI Calibration Plan



SHeFI Calibration Plan

- SHeFI Reference Spectra Database.
  - Reference spectra for line calibrators as well as line pointing sources (HET230, HET345 and HET460)
  - Available at: http://www.apex-telescope.org/heterodyne/shfi/calibration/database/

SHeFI Calibration Plan

Atacama Pathfinder EXperiment APEX Calibration

Max-Planck-Institut für Radioastronomie

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Home > Instrumentation > SHeFI receivers > Calibration > Reference Spectra Database

SHeFI Reference Spectra Database

We maintain a database of reference spectra for line calibrators as well as line pointing sources. Use this interface to search for and display these spectra.

Source type: (•) Line Calibrator ( ) Line Pointing Source

Receiver: (•) HET230 ( ) HET345 ( ) HET460

Source name: OMC1 **Spectral line:** CO(2-1)

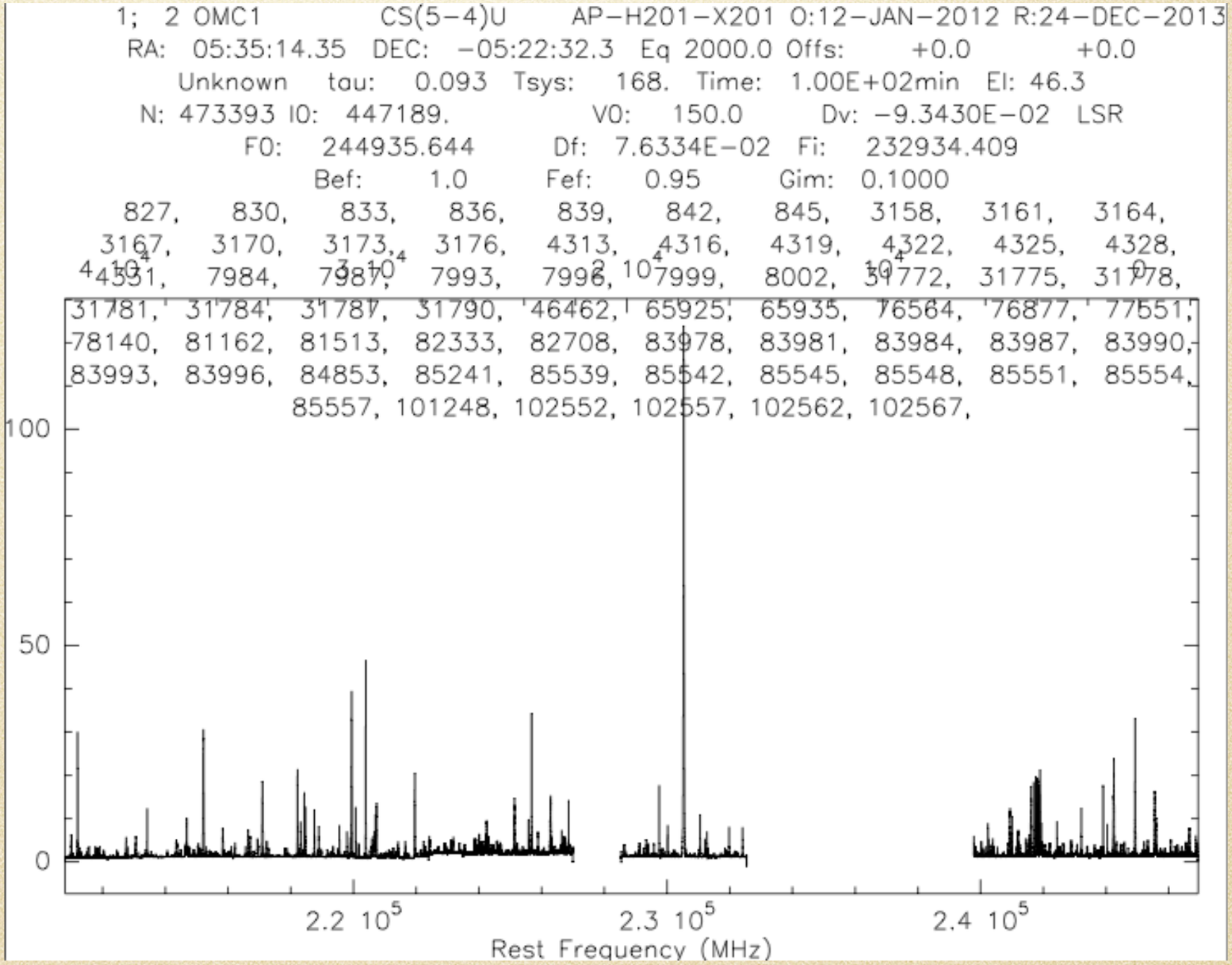
Submit: Search & display spectra

SHeFI Calibration Plan

- The calSpec(src,line) function
  - Observes a calibrated spectrum on a calibrator, either in the current configuration, or using a standard Calibration Plan setup and line.
  - OMC1, IRC+10216, and SGRB2(N)
  - Use **line='current'** to observe the calibration source using the 'current' spectral setup (line, velocity)
  - No need to retune and point on calibration source!
  - Note that you should have a reliable pointing and focus

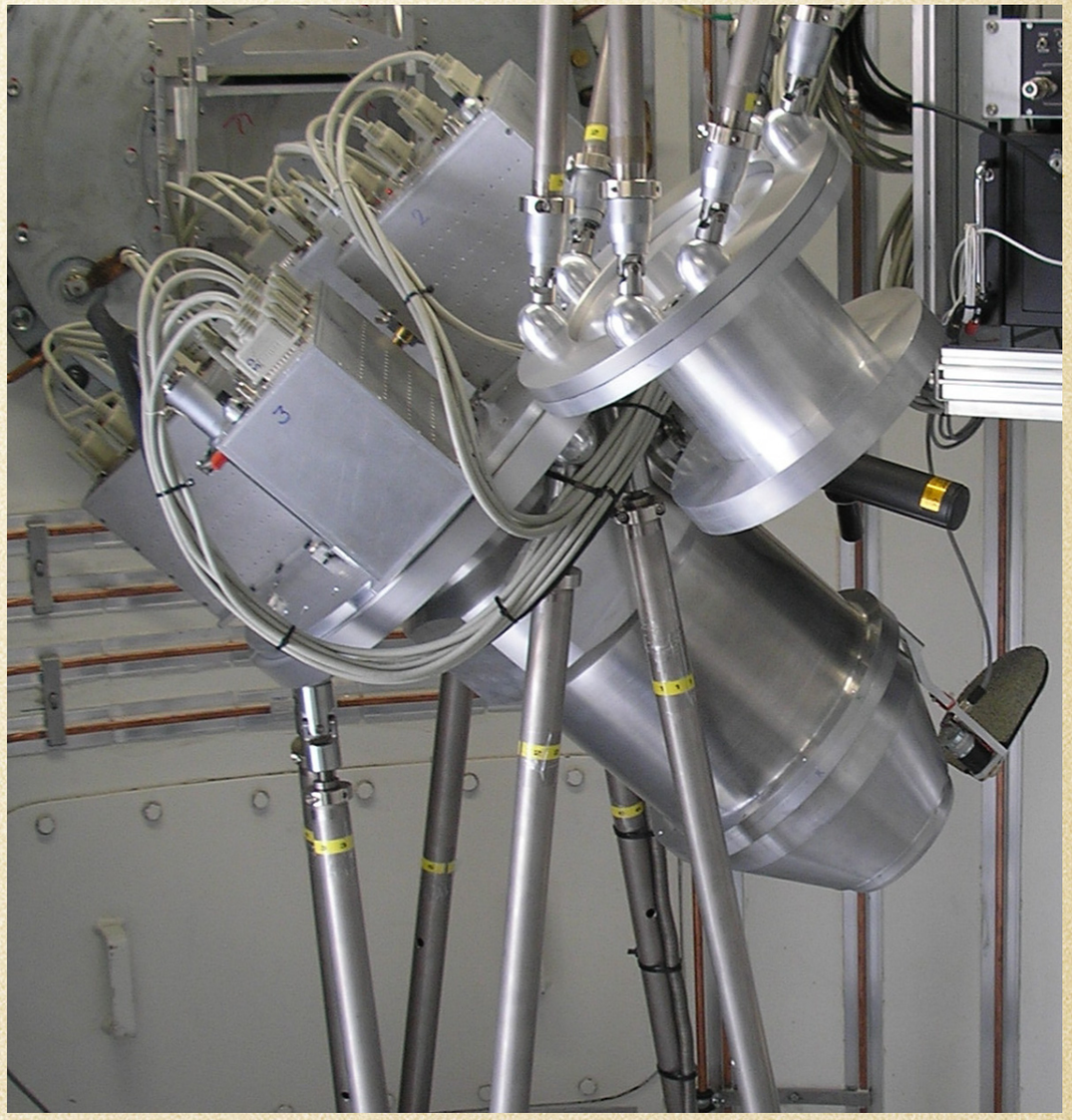
SHeFI Calibration Plan

- OMC1 / HET230
- 214 - 250 GHz
- June 2011 - December 2013 (More than 2 years of data)
- Bonus track: Line survey of calibration sources for free!



LABOCA Calibration plan

- **LA**rge **BO**lometer **CA**mera.
- Array of 295 channels, arranged in 9 concentric hexagons around a central channel.
- It operates in the 870 μm (345 GHz) atmospheric window.
- Angular resolution is 18.6″ (HPBW)
- Field of view is 11.4′
- Available since May 2007



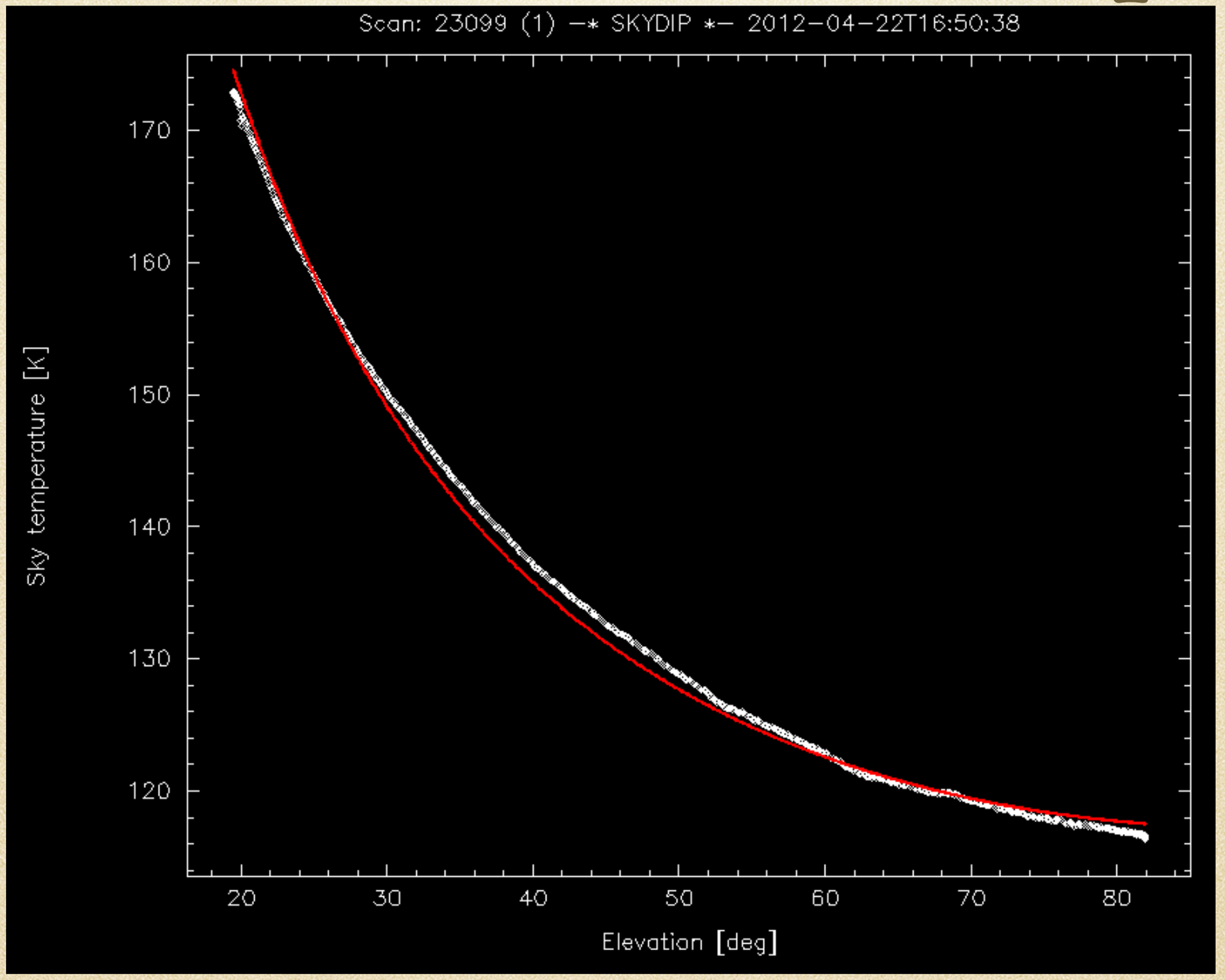
LABOCA Calibration plan

- Intensity calibration
  - Zenith opacities
  - Absolute calibration scale
  - Calibrators (primary & secondary)
- Pointing and focus
- Beam shape and angular resolution
- Array parameters
- Results and analysis available online at http://www.apex-telescope.org/bolometer/laboca/calibration/

LABOCA Calibration plan

- Zenith opacities
  - The opacity of the sky is usually determined by skydip measurements.
  - Continuous scan from El = 82° down to El ~ 23°
  - Atmospheric emission is measured and its dependence on the elevation fitted by a model.

LABOCA Calibration plan



LABOCA Calibration plan

- Need to recalibrate opacities!
  - Official BoA releases underestimate the opacity resulting from the skydip reduction.
  - Assumption that sky temperature equals the ambient temperature.
  - BoA use the ambient temperature as the best guess for the sky temperature during the fit.
  - **Overestimates** the sky temperature and therefore **underestimates** the opacity.
  - Solution: Combine skydips, taumeter measurements and calibrators fluxes.

LABOCA Calibration plan

- Calibrated sky opacity (aka tau_mean)
  - tau_sd : Tau derived from sky dips (redsky function in BoA)
  - tau_rm : Computed from PWV radiometer and atmospheric model.
    - tau_mean = (1.3*tau_sd + 0.9*tau_rm)/2.0
- Online database tool at : http://www.apex-telescope.org/bolometer/laboca/calibration/opacity/
- Online help is available with BoA examples.

LABOCA Calibration plan

Atacama Pathfinder EXperiment APEX LABOCA

Max-Planck-Institut für Radioastronomie

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LABOCA Zenith opacities

LABOCA zenith opacities as a function of time. For each entry in the output table, we provide three values for the zenith opacity:

- tau_sd, derived by reducing a Skydip scan with redsky(scannr).
- tau_rm, computed from the precipitable water vapour (PWV) and an atmospheric model.
- A linear combination of these two: tau_mean = (1.3*tau_sd + 0.9*tau_rm)/2.0

The latter usually provides the best estimate of the true zenith opacity; but users are strongly encouraged to carefully and critically check all these values and their variations during the time interval covering their science observations.

Download all opacities (BoA format) which is generated automatically using a pipeline reduction.
Need help using these pages ?

UT Date start [yyyy-mm-dd] 2013-05-01
UT Date stop [yyyy-mm-dd] 2013-12-01
Scan quality factor Ok
Submit Reset

LABOCA Calibration plan

LABOCA Sky opacities

Date range = 2013-05-01 to 2013-12-01

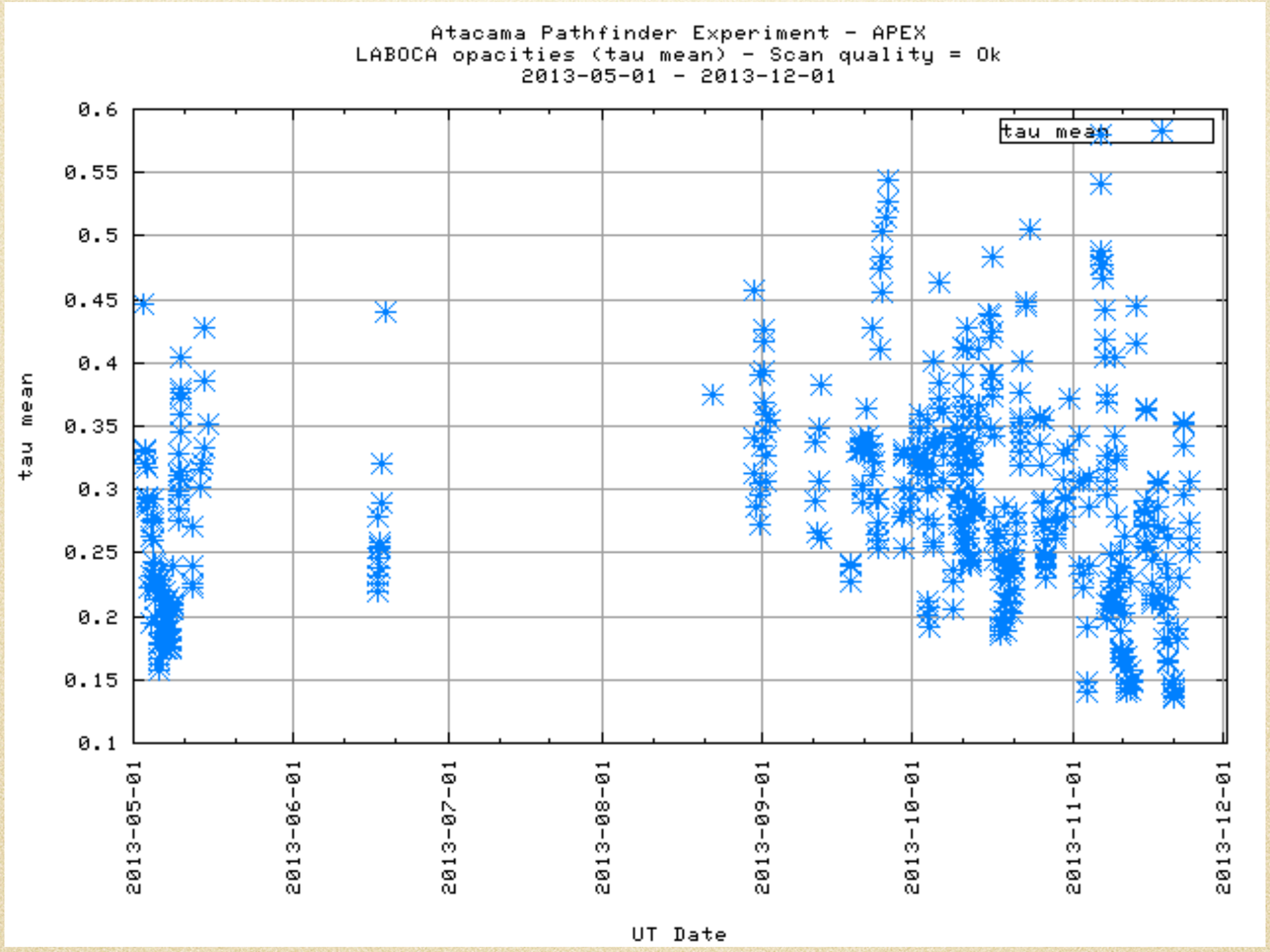
Scan quality factor = Ok

Number of records = 486

Open BoA opacities file | Plot opacities (tau_mean) | Help | Close window

scan	yyyy-mm-dd hh:mm:ss	mjd	tau_mean	tau_rm	tau_sd	pwv	scan quality
27060	2013-05-02 18:17:46	56414.7623432060	0.446	0.485	0.350	1.425	0.041
27348	2013-05-03 07:40:00	56415.3194453125	0.332	0.370	0.255	0.945	0.004
27367	2013-05-03 09:31:01	56415.3965460648	0.330	0.369	0.252	0.940	0.013
27390	2013-05-03 11:42:51	56415.4881033218	0.320	0.357	0.245	0.894	0.008
27426	2013-05-03 13:24:26	56415.5586508218	0.293	0.324	0.227	0.769	0.012
27438	2013-05-03 14:29:42	56415.6039574306	0.286	0.328	0.213	0.785	0.065
27453	2013-05-03 15:39:35	56415.6524942824	0.317	0.326	0.261	0.778	0.144
27480	2013-05-03 17:51:29	56415.7440918403	0.294	0.350	0.209	0.869	0.149
27494	2013-05-03 18:32:26	56415.7725244097	0.290	0.293	0.243	0.654	0.181
27697	2013-05-04 05:56:22	56416.2474902778	0.222	0.243	0.173	0.484	0.026
27726	2013-05-04 07:57:50	56416.3318388773	0.195	0.223	0.145	0.418	0.063
27785	2013-05-04 14:15:04	56416.5938063773	0.232	0.258	0.179	0.532	0.003
27797	2013-05-04 15:24:19	56416.6418871296	0.263	0.285	0.207	0.626	0.049
27811	2013-05-04 16:04:23	56416.6697175000	0.275	0.298	0.217	0.675	0.049
27824	2013-05-04 17:11:37	56416.7164060301	0.274	0.307	0.209	0.704	0.015
27840	2013-05-04 18:19:39	56416.7636541782	0.260	0.277	0.208	0.597	0.083

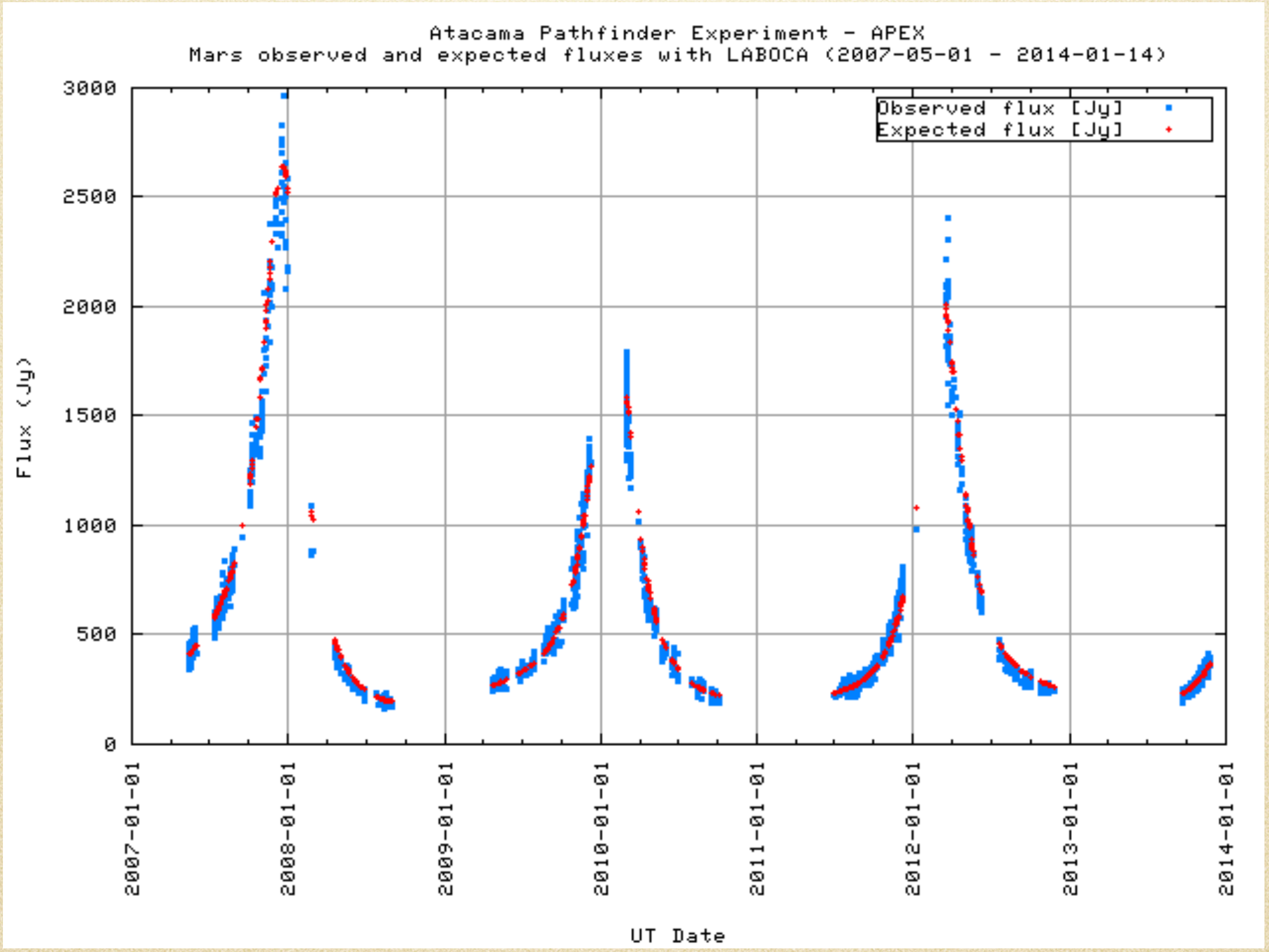
LABOCA Calibration plan



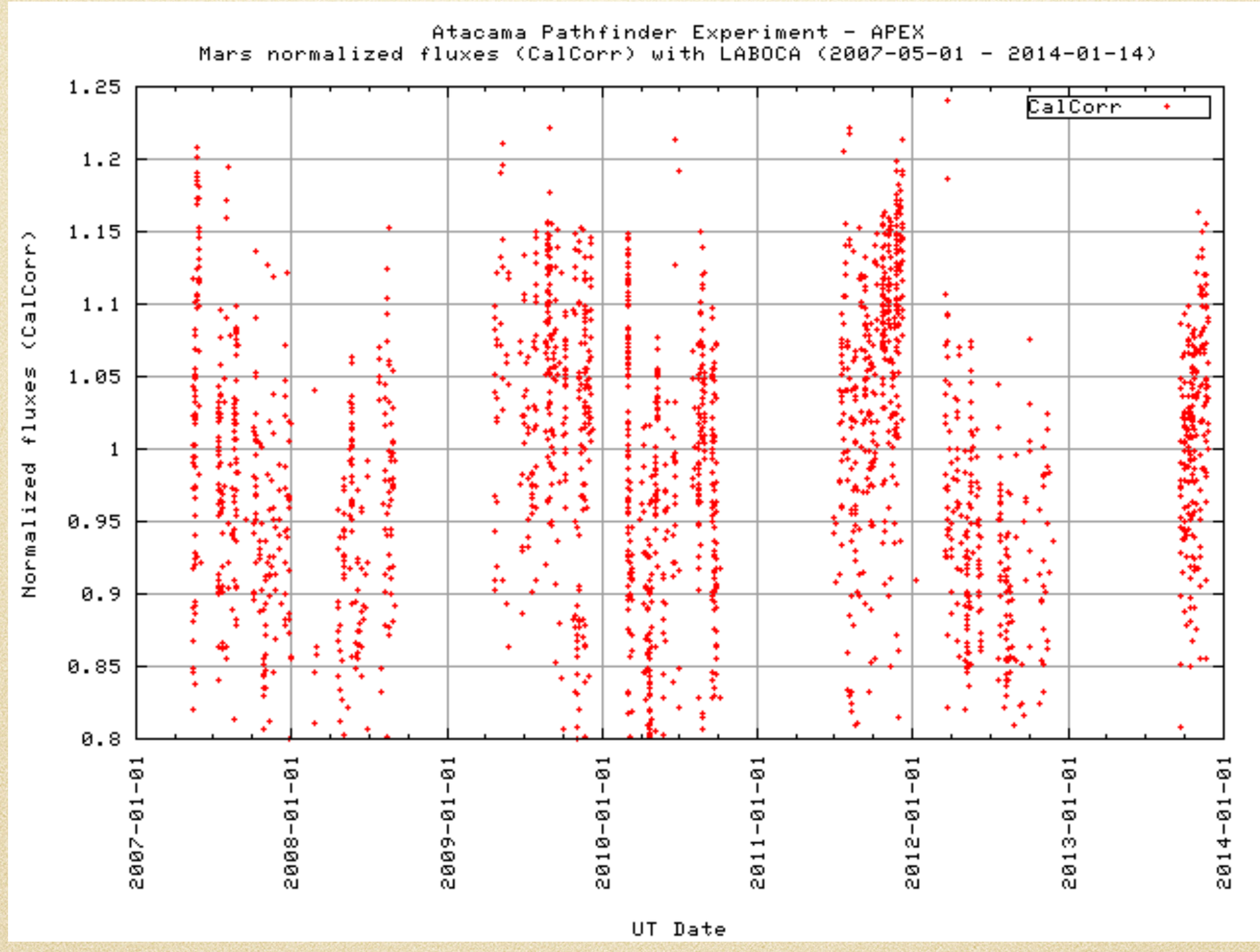
LABOCA Calibration plan

- Primary calibrators
  - Mars, Uranus and Neptune
  - Flux densities can be well predicted based on models (distance, diameter and illumination)
- At APEX, we use the Astro program (GILDAS software)

LABOCA Calibration plan



LABOCA Calibration plan



LABOCA Calibration plan

- Secondary calibrators

Source name	RA (J2000)	DEC (J2000)	Flux [Jy]± sigma	Alt name
HLTAU	04 31 38.45	+18 13 59.00	2.0 ± 0.2	
CRL618	04 42 53.60	+36 06 53.70	4.8 ± 0.5	
V883-ORI	05 38 19.00	-07 02 20.00	1.4 ± 0.3	
N2071IR	05 47 04.85	+00 21 47.10	9.1 ± 0.8	
VYCma	07 22 58.33	-25 46 03.20	1.5 ± 0.1	VY-CMA
CW-LEO	09 47 57.38	+13 16 43.60	4.1 ± 0.3	IRC+10216
B13134	13 16 43.15	-62 58 31.60	12.9 ± 1.3	
IRAS16293	16 32 22.90	-24 28 35.60	16.1 ± 1.3	
G5.89	18 00 30.37	-24 04 00.40	27.6 ± 0.2	J1800-241
G10.62	18 10 28.66	-19 55 49.70	33.0 ± 1.8	
G34.3	18 53 18.50	+01 14 58.60	55.3 ± 3.7	
G45.1	19 13 22.07	+10 50 53.40	8.0 ± 0.6	
K3-50A	20 01 45.69	+33 32 43.50	14.7 ± 1.4	
CRL2688	21 02 18.80	+36 41 37.70	5.5 ± 0.9	

LABOCA Calibrators

- Pipeline reduction of LABOCA primary and secondary calibrators using the opacities file in Laboca_opacities.dat and the standard calibration factor of 6.3 Jy/μV.
- The data file can be used to correct for the typically small deviations from the standared calibrations in the BoA reduction of LABOCA data.
- It is up to the user to check the entries in the file for consistency.
- Need help using this pages ?

Filter by date range and quality factor

UT Date start [YYYY-MM-DD] 2013-05-01

UT Date stop [YYYY-MM-DD] 2013-12-01

Scan quality factor Ok

Submit Reset

Filter by date range, primary calibrators and quality factor

UT Date start [YYYY-MM-DD] 2013-05-01

UT Date stop [YYYY-MM-DD] 2013-12-01

Scan quality factor Ok

Primary calibrators All

Submit Reset

Filter by date range, secondary calibrators and quality factor

UT Date start [YYYY-MM-DD] 2013-05-01

UT Date stop [YYYY-MM-DD] 2013-12-01

Scan quality factor Ok

Secondary calibrators All

Submit Reset

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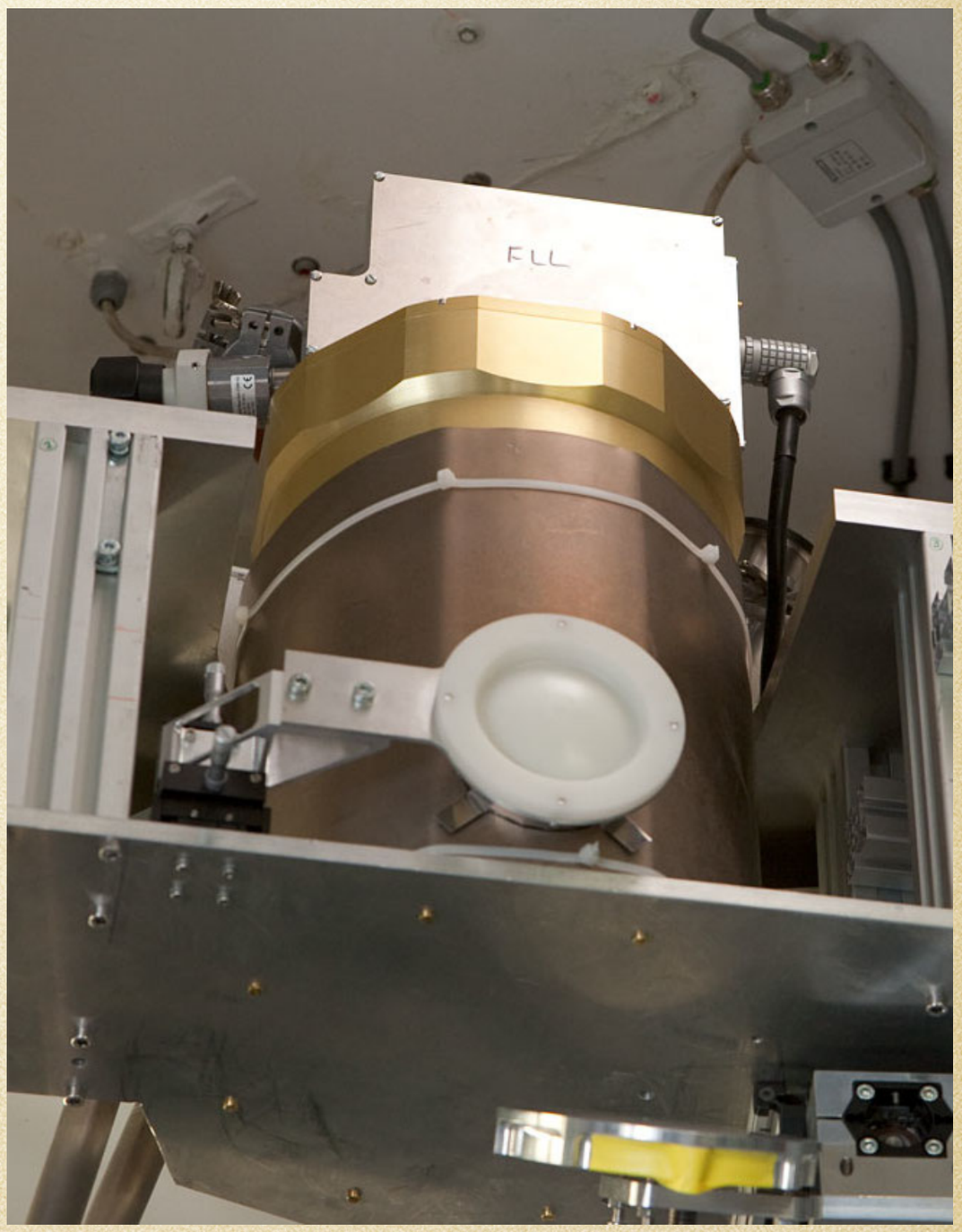
http://www.apex-telescope.org/bolometer/laboca/calibration/calibrators/

LABOCA Calibration plan

- Array parameters
  - RCP files (Receiver Channel Parameter)
  - Suspicious channels files
  - Available for download at: http://www.apex-telescope.org/bolometer/laboca/calibration/array/

SABOCA Calibration plan

- **S**ubmillimeter **A**PEX **BO**lometer **CA**mera
- 39 channel TES bolometer array
- It operates in the 350 μm (850 GHz) atmospheric window.
- Field of view is 1.5′
- Angular resolution is 7.8″ (HPBW)



SABOCA Calibration plan

- Intensity calibration
  - Zenith opacities
    - http://www.apex-telescope.org/bolometer/saboca/calibration/opacity/
  - Calibrators (primary & secondary) and absolute calibration scale
    - http://www.apex-telescope.org/bolometer/saboca/calibration/calibrators/
- Pointing and focus
- Beam shape and angular resolution
- Array parameters
  - http://www.apex-telescope.org/bolometer/saboca/calibration/array/

SABOCA Calibration plan

- Raw data coming from SABOCA just have the detector voltage output as intensity.
- In order to obtain the intensity in astronomical units, the data have to be multiplied with a conversion factor VtoJ [Jy/mV], as shown in the next table.
- BoA function implemented to apply the correct conversion factor.
- Results available online.

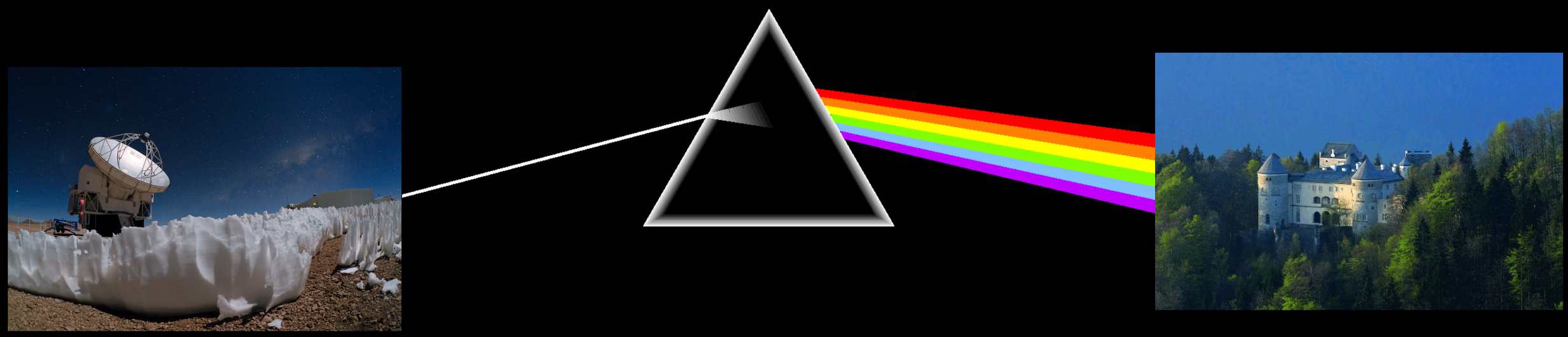
Time period	VtoJy [Jy/mV]
2009-01-01 to 2010-01-01	3.900
2010-01-01 to 2010-04-27	4.450
2010-04-27 to 2010-08-30	4.540
2010-08-30 to 2011-01-01	3.780
2011-01-01 to 2011-05-30	4.660
2011-05-30 to 2012-01-01	4.130
2012-01-01 to 2012-05-27	4.570
2012-05-27 to 2012-08-24	4.680
2012-08-24 to 2013-01-01	4.260
2013-01-01 to now	4.500

- The “APEX Calibration Plan” is a science operations team effort.

- Astronomers, Observing Specialists (OS) and Telescope & Instruments Operators (TiO’s) are deeply involved in every aspect (Observations, reduction pipelines, analysis and publication).

- APEX Science Operations group
  Frederic Schuller (Leader), Michael Dumke, Francisco Montenegro, Rodrigo Parra, Felipe Mac Auliffe, Francisco Azagra, Claudio Agurto, Mauricio Martinez, Paulina Venegas & Edouard Gonzalez.

- Software: CLASS, BoA, Crush, Python, php, MySql among many others.



The time is gone
The talk is over
Thought I'd something more to say