ESO Garching, February 1-3 , 2017



# APEX Proposal Preparation tools and phase 2 Tutorial

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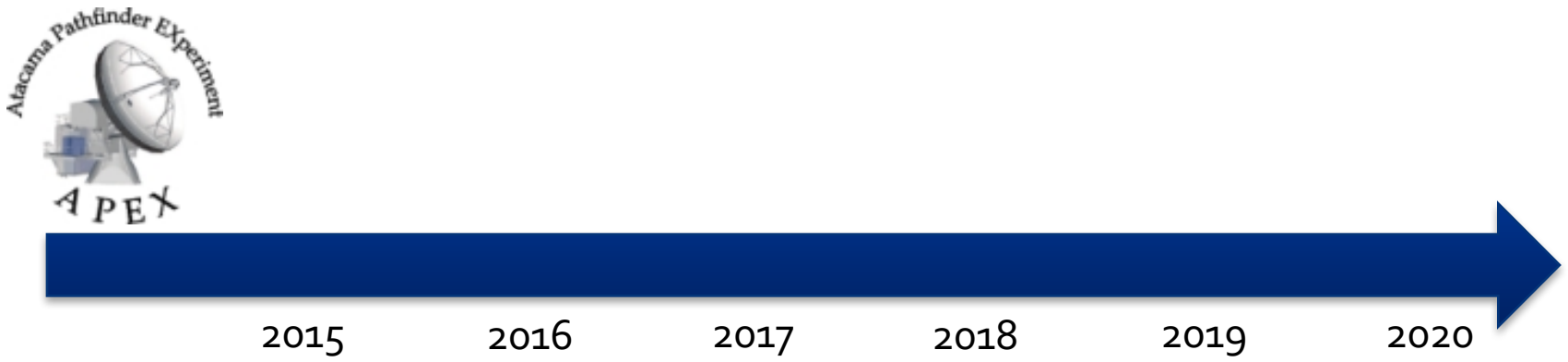
Getting Ready for ALMA Band 5 - Synergy with APEX/SEPIA

# Introduction

- APEX in the last few years
- 5-year extension (2018-2022)
- APEX in 2017



# Introduction

- APEX in the last few years
  - Facility instrumentation
    - LABOCA, SABOCA
    - SHeFI (APEX1, APEX2, APEX3)
  - PI Instrumentation
    - FLASH+, CHAMP+ (MPIfR)
    - ArTéMiS (ESO)
  - Other visiting instruments

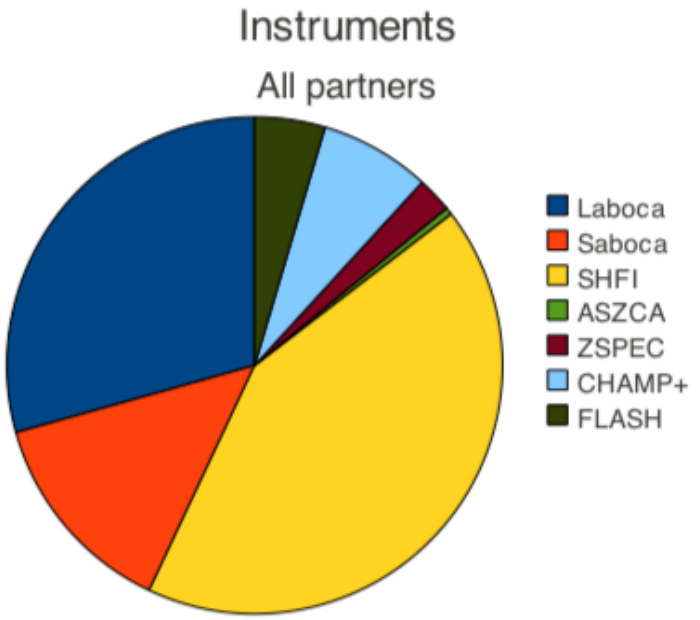

2015 2016 2017 2018 2019 2020

LABOCA
SHeFI
FLASH+
others…

# Introduction

- APEX in the last few years

Proposal instrument requests statistics (2012-2014)





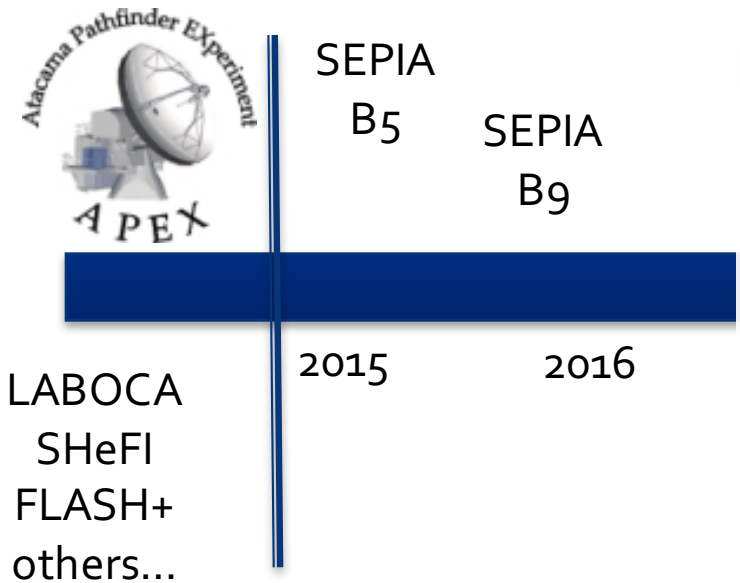
2015

LABOCA
SHeFI
FLASH+
others...

2020

# Introduction

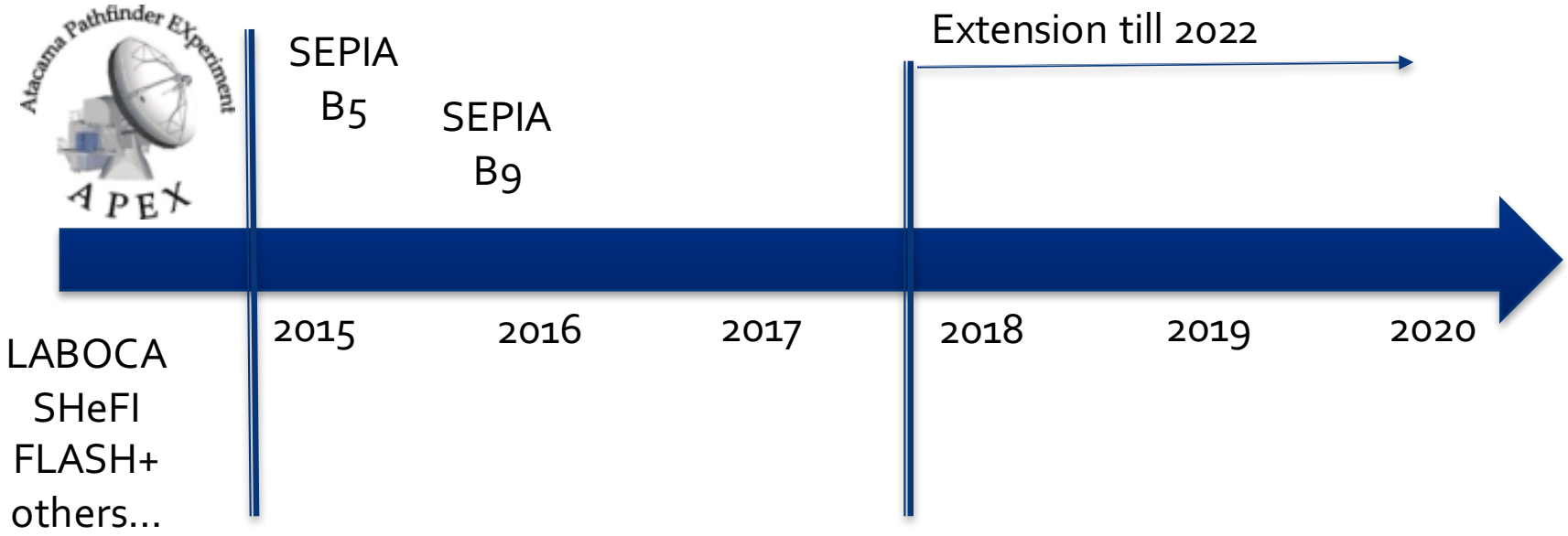
- New heterodyne receivers: SEPIA




- SEPIA B5
  - First light: Feb 2015.
  - Science Verification: Jul-Sep 2015
- SEPIA B9
  - First light: Feb 2016
  - Science Verification started in 2016-Q2

# Introduction

- 5-year extension (2018-2022)
- APEX in 2017

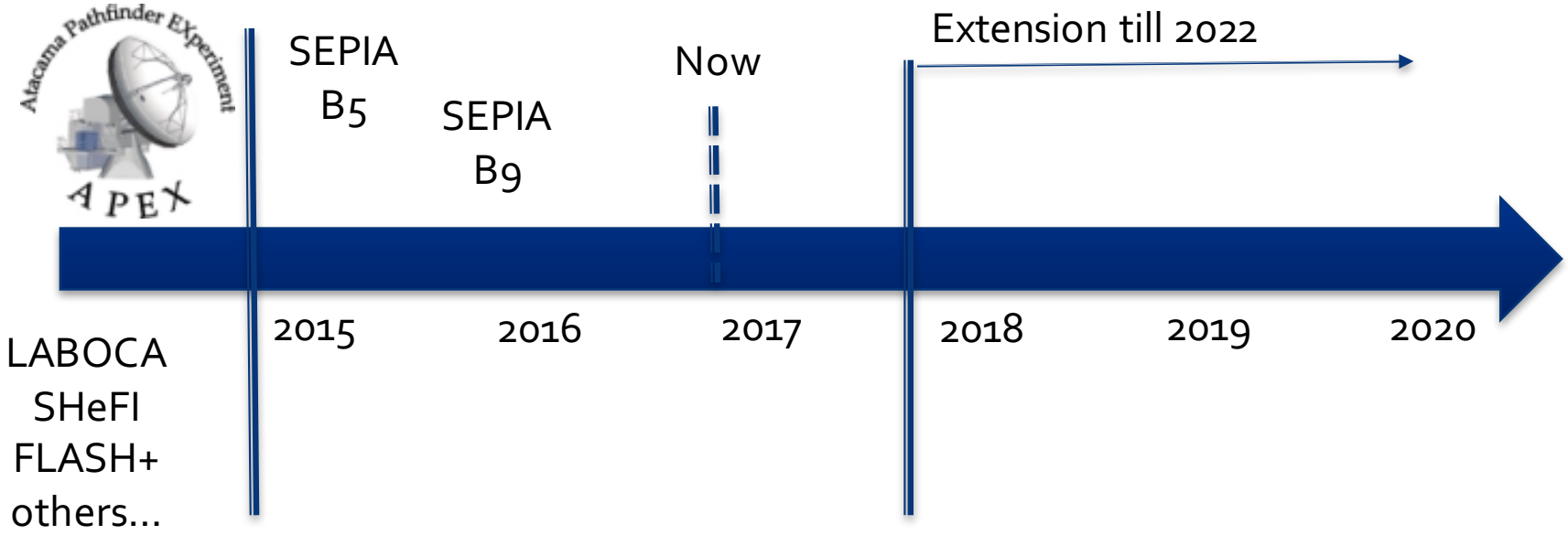


# APEX 5-year extension

- New suite of facility instrumentation
- Improved heterodyne instruments (larger IF bandwidth, dual polarization, 2SB, some in common with ALMA: synergies)
- Improved (multicolour, kpixel) bolometer cameras
- Improvements in the antenna (power generation and cooling capacity)
- Sciops-R (remote operations)

# APEX in 2017

- APEX in 2017



# APEX in 2017

- Observing periods P99, P100
- Short year for science operations (Mar-Sep)
- Extended 2018 shutdown period (Oct-Mar 18)

- APEX community needs to **get used to work with new receivers**

# Proposal preparation tutorial

- Have an interesting scientific project
- Select the proper tuning for your lines
- Get time estimates to achieve your goal
- Submit your proposal and get the time
- Prepare phase-2 submission
- Wrong practices to avoid
- Final considerations

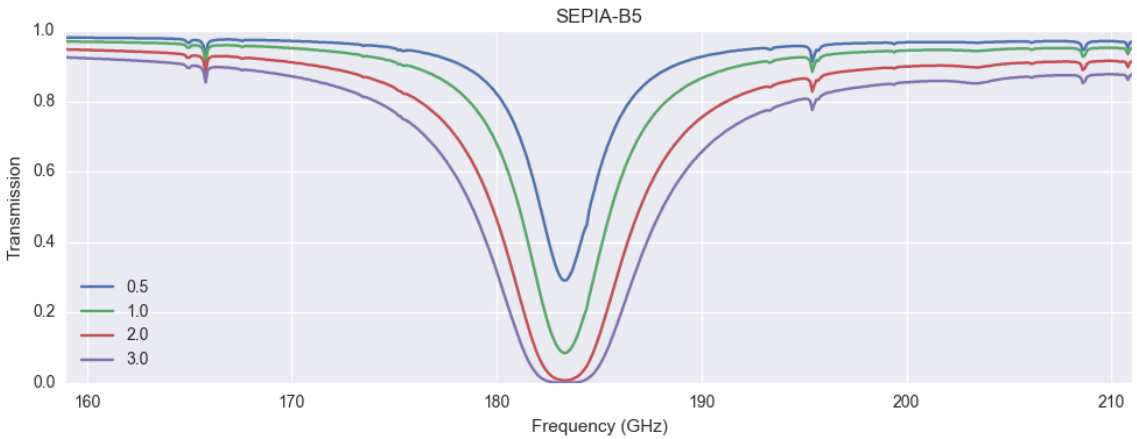
# Overview

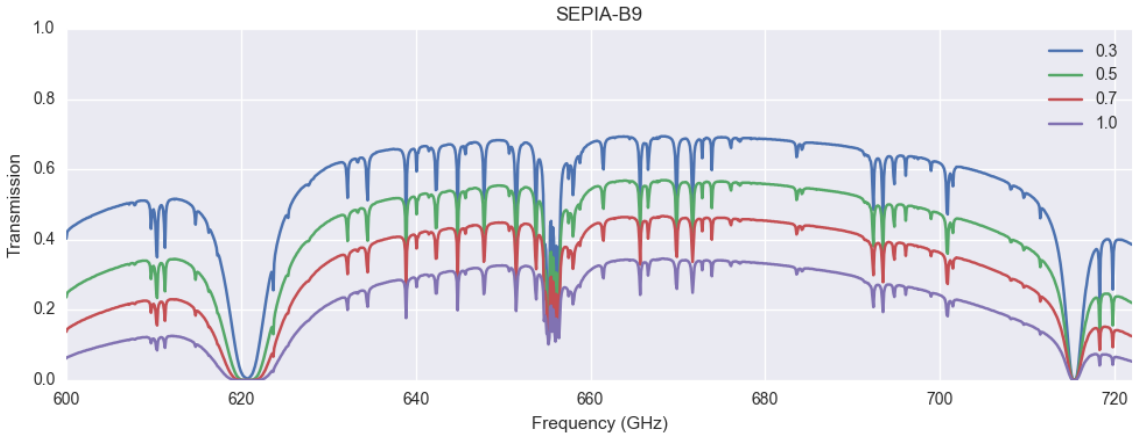
- Atmospheric model
- On/Off time calculator
- OTF Simulator (mapping)
- OTF time calculator
- APEX phase 2 submission
- Your observations

# Two demo cases

- SEPIA-B5 OTF
  - CS(4-3) 195.95 GHz
  - OTF simulator
- SEPIA-B9 On/Off
  - C18O(6-5) 658.55 GHz
  - 13CO(6-5) 661.07 GHz
  - C17O(6-5) 674.01 GHz

# Chajnantor B5/B9 transmission




## Atacama Pathfinder EXperiment APEX
## Atmosphere at Chajnantor

Home > APEX Sites > Chajnantor > Atmosphere at Chajnantor > Transmission calculator

### Atmospheric transmiss

**Plot the transmission at the signal and image bands**

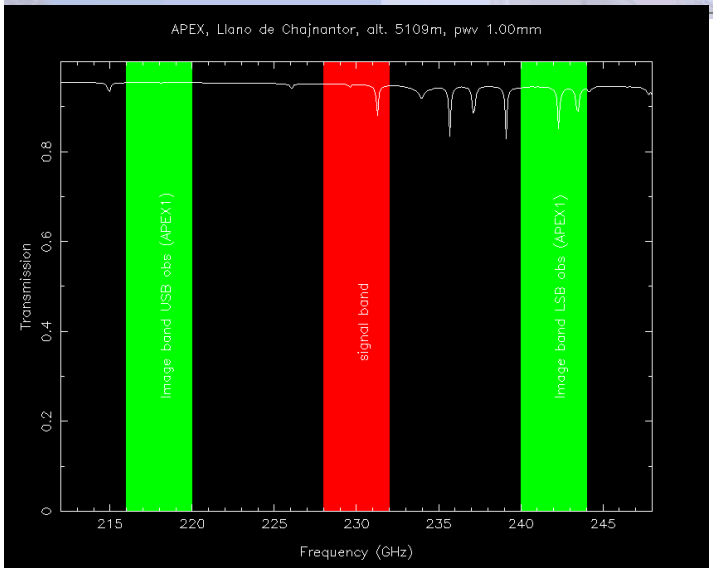
The calculator plots the zenith atmospheric transmission on Llano de Chajnantor, for a specified freq
assuming the respective frequency separation between signal and image band, which is specific for
care has to be taken when selecting LSB or USB, since a atmospheric lines will have a negative imp
but they are not affected to the same extent. Common for both types of receivers it is important to av
atmospheric absorption.

This plot shows the PWV as function of month as measured by the ALMA radiometer.

Center frequency 230 GHz

PWV value 1.0 mm

Reset Plot



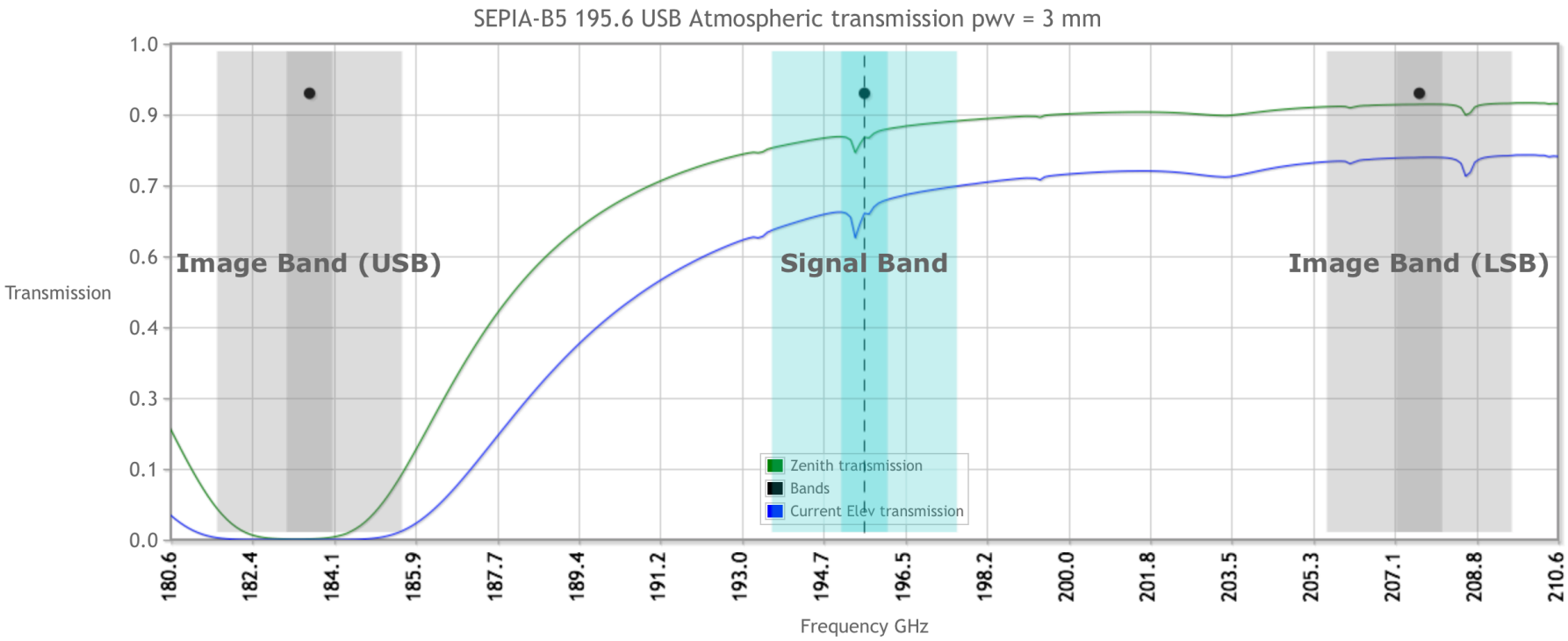
# "New" atmospheric calculator

- Uses the same tabulated data (ATM)
- Include our new instruments
  - Different parameters (SB separation, BW)
- Visualize science frequencies


http://www.apex-telescope.org/sites/chajnantor/atmosphere/

# SEPIA-B5

## APEX Chajnantor atmospheric transmission




Heterodyne receiver: SEPIA-B5 (2SB)

PWV [mm H2O] 3

Elevation [degree] 30

Tunning Frequency [GHz] 195.55

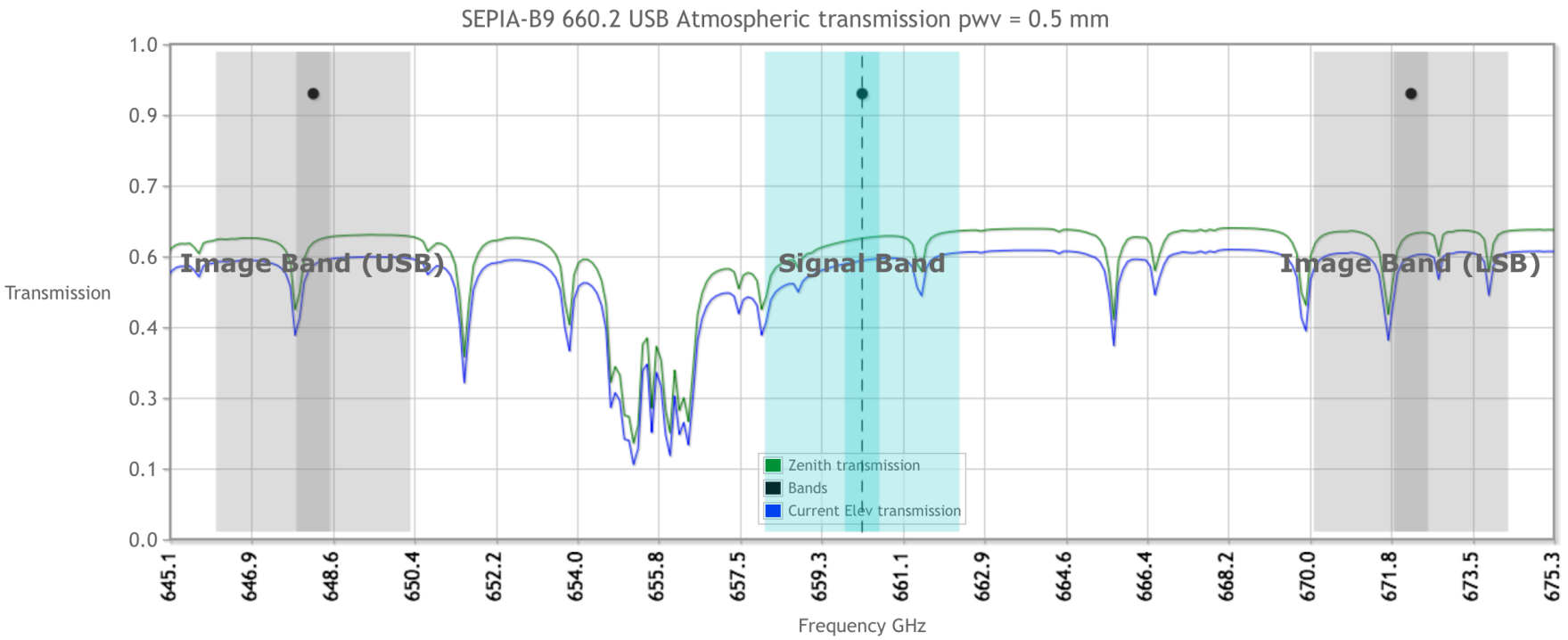
Refresh the plot

Select a Side Band to be used: LSB

Open LSB plot

# SEPIA-B9 #1

## APEX Chajnantor atmospheric transmission




Heterodyne receiver: SEPIA-B9 (DSB)

PWV [mm H2O] 0.5

Elevation [degree] 60

Tunning Frequency [GHz] 660.2

Refresh the plot

Select a Side Band to be used: LSB

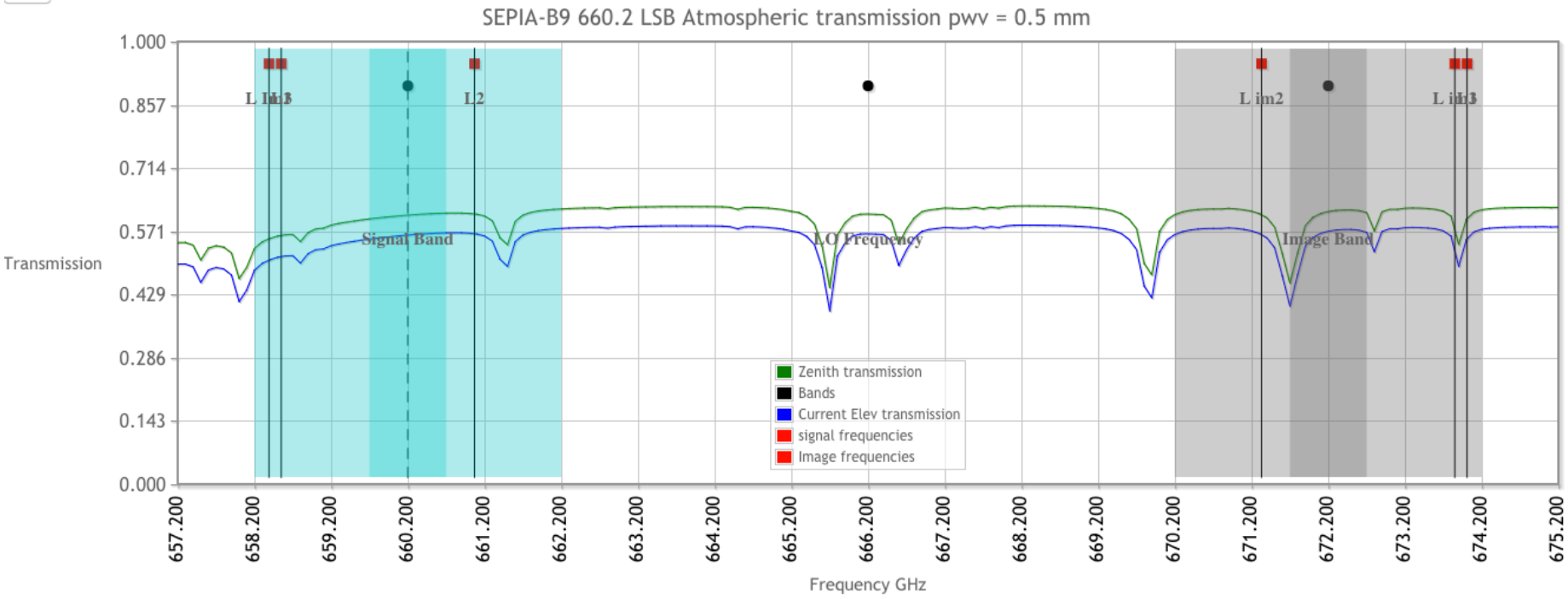
Open LSB plot

# SEPIA-B9 #2

| | |
|---|---|
| Heterodye Receiver | SEPIA-B9 |
| PWV [mm $H_20$] | 0.5 |
| Elevation [deg] | 60 |

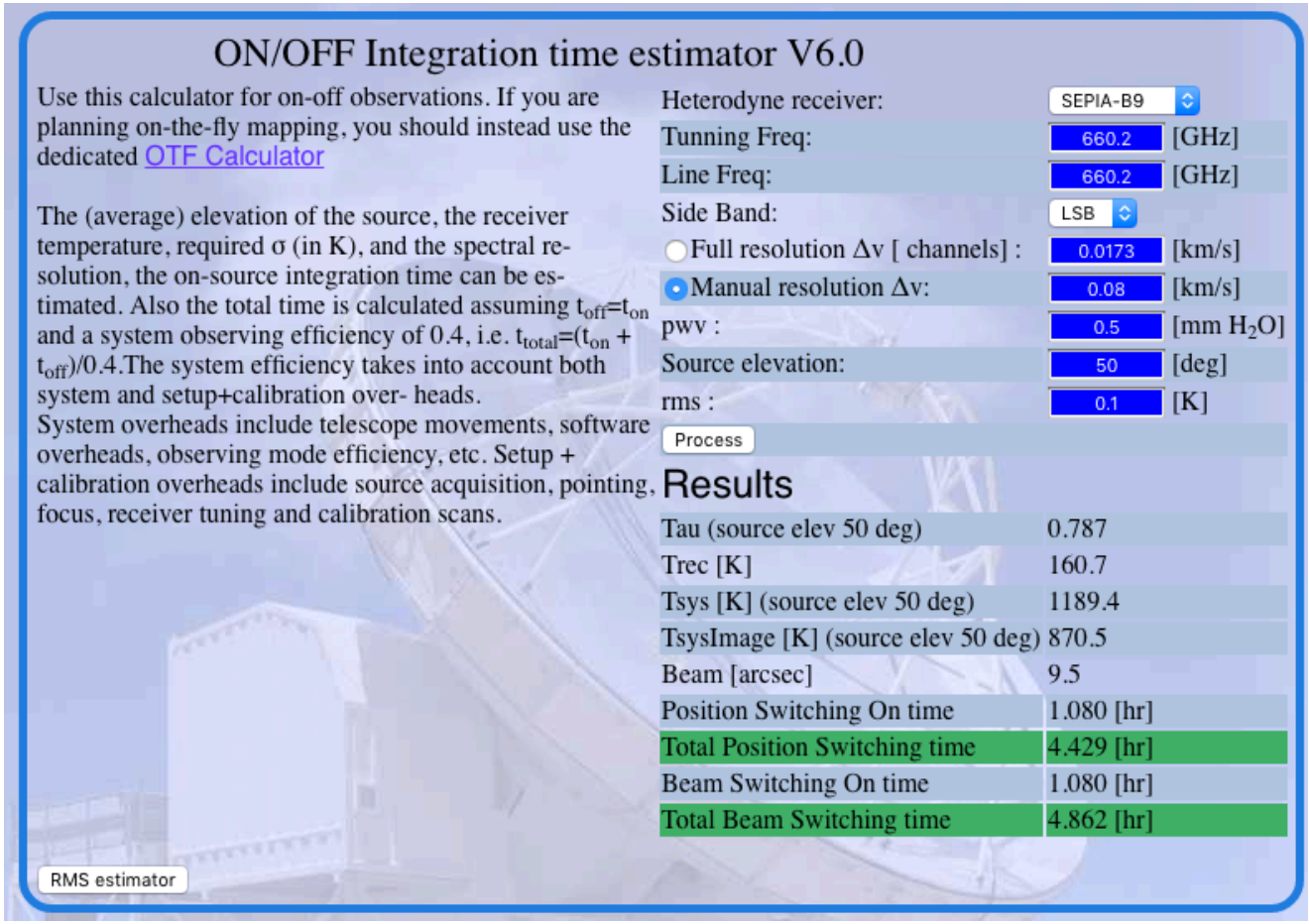
| | | | | |
|---|---|---|---|---|
| Sky Frequency [GHz] | 660.2 | + 100 MHz | - 100 MHz | Refresh |
| Line 1 [GHz] | [0] | 658.55 | | |
| Line 2 [GHz] | [0] | 661.07 | | |
| Line 3 [GHz] | [0] | 674.01 | | |

Back



# OTC

- V6 available for the next CfP



## ON/OFF Integration time estimator V6.0

Use this calculator for on-off observations. If you are planning on-the-fly mapping, you should instead use the dedicated OTF Calculator

The (average) elevation of the source, the receiver temperature, required σ (in K), and the spectral resolution, the on-source integration time can be estimated. Also the total time is calculated assuming $t_{off}=t_{on}$ and a system observing efficiency of 0.4, i.e. $t_{total}=(t_{on}+t_{off})/0.4$.The system efficiency takes into account both system and setup+calibration over- heads.
System overheads include telescope movements, software overheads, observing mode efficiency, etc. Setup + calibration overheads include source acquisition, pointing, focus, receiver tuning and calibration scans.

| | | |
|---|---|---|
| Heterodyne receiver: | SEPIA-B9 | |
| Tunning Freq: | 660.2 | [GHz] |
| Line Freq: | 660.2 | [GHz] |
| Side Band: | LSB | |
| Full resolution Δv [ channels] : | 0.0173 | [km/s] |
| Manual resolution Δv: | 0.08 | [km/s] |
| pwv : | 0.5 | [mm $H_2O$] |
| Source elevation: | 50 | [deg] |
| rms : | 0.1 | [K] |

Process

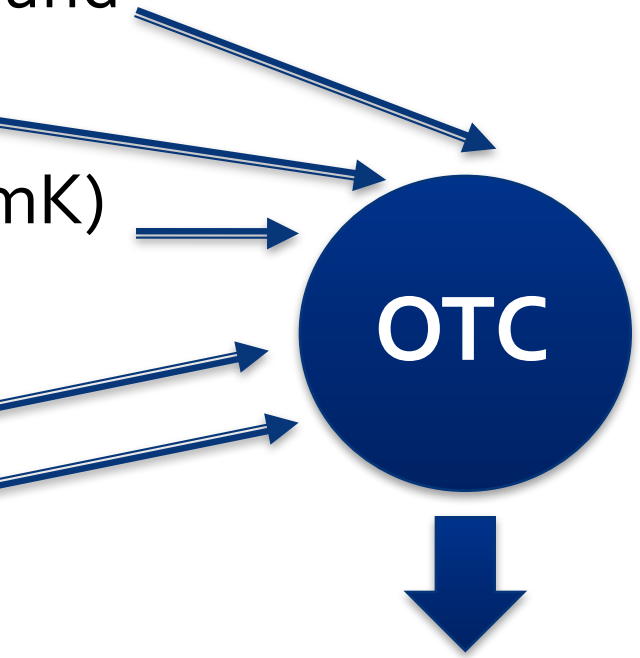
### Results

| | |
|---|---|
| Tau (source elev 50 deg) | 0.787 |
| Trec [K] | 160.7 |
| Tsys [K] (source elev 50 deg) | 1189.4 |
| TsysImage [K] (source elev 50 deg) | 870.5 |
| Beam [arcsec] | 9.5 |
| Position Switching On time | 1.080 [hr] |
| Total Position Switching time | 4.429 [hr] |
| Beam Switching On time | 1.080 [hr] |
| Total Beam Switching time | 4.862 [hr] |

RMS estimator

# OTC

- Parameters that you need to know
  - Tuning frequency and sideband
  - Spectral resolution (km/s)
  - RMS to achieve your goal (mK) at selected resolution
  - Elevation
  - PWV




**Estimated time**
(with/without overhead)

# OTC

- Radiometer equation $\sigma_T \approx \frac{T_{sys}}{\sqrt{\Delta\nu \cdot \tau}}$
- Parameters from receiver
  - Receiver temperature
  - Image gain
  - Forward efficiency
  - Number of polarizations
- Parameters from sky
  - Opacity (El, pwv)
  - ATM model

# OTC

- Overhead: calibrated with real datasets
  - Pointing, focus
  - Calibrations
  - Duty cycle (on/off or wobbler)
  - Tuning
  - Control system overhead

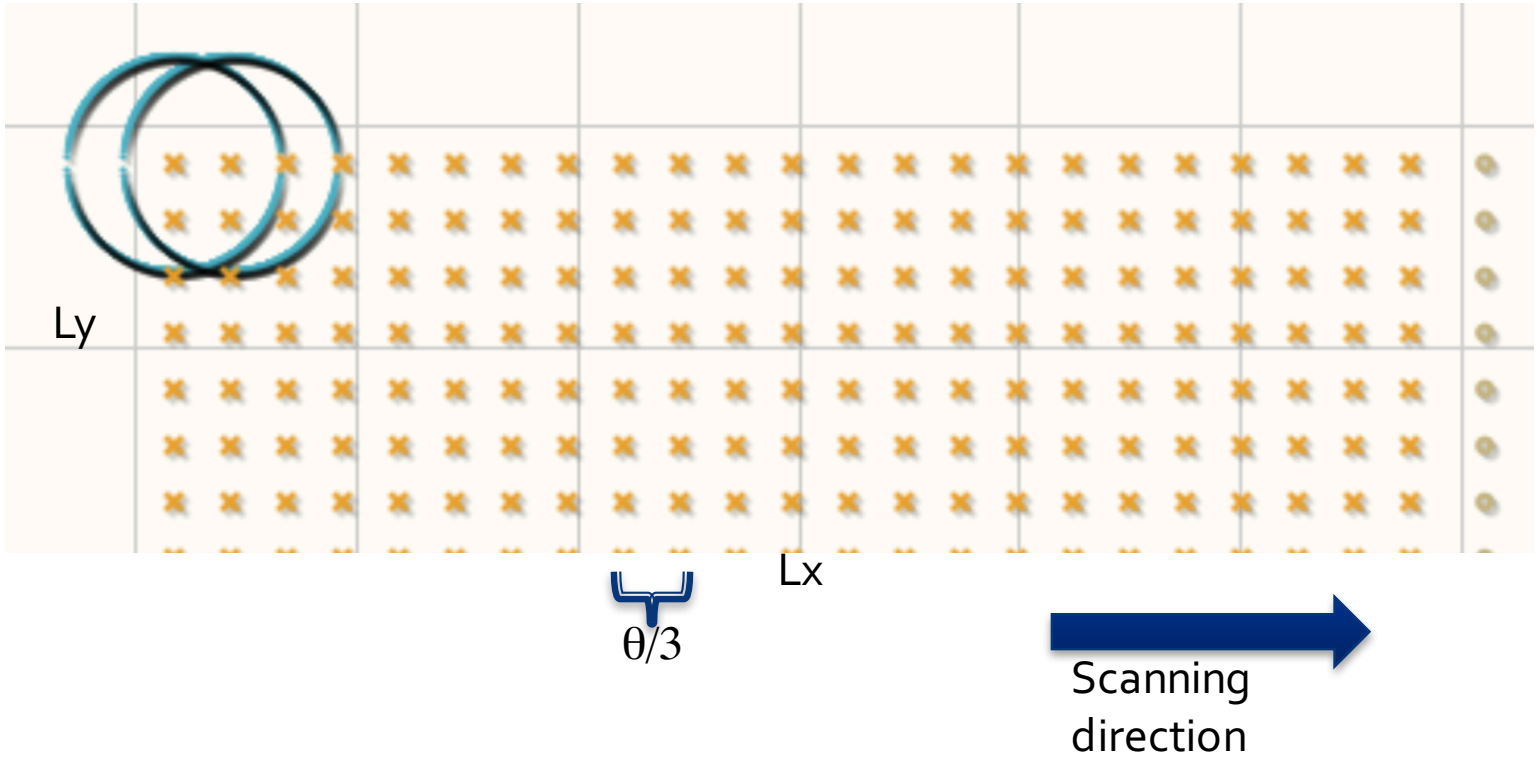
# OTF

- Tools
  - Observing Time Estimator
    - Estimate the total time to reach a rms
  - OTF simulator
    - Setup a map to cover an area

# OTF

- OTF time estimator
  - Method

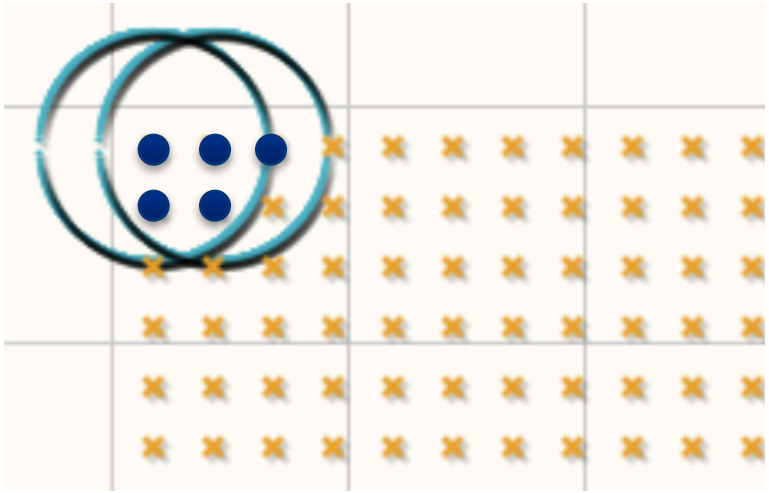
Estimate the rms



# OTF

- OTF time estimator
  - The radiometer equation

$$\sigma = \frac{T_{sys}}{\sqrt{Npol \cdot \Delta f}} \sqrt{\frac{1}{t_{on}} + \frac{1}{t_{off}}}$$



# OTF

- OTF estimator
  - On time
    - Area Map $A_{map} = L_x \cdot L_y$
    - Area Beam
    - Number Beams in the map

$$N_{beams} = \frac{A_{map}}{A_{beam}}$$

# OTF

- OTF estimator
  - Number of dump in map

$$N_{dump}^{map} = \left(\frac{L_x}{\Delta x}\right) \cdot \left(\frac{L_y}{\Delta y} + 1\right)$$

  - Number of dump per beam

$$N_{dump}^{beam} = \frac{N_{dump}^{map}}{N_{beams}}$$

  - On time per beam

$$t_{on}^{beam} = N_{dump}^{beam} \cdot t_{dump}$$

# OTF

- OTF estimator
  - Off time
    - Time off

$$t_{off} = \alpha t_{on}$$

$$\alpha = \frac{beam}{\frac{beam}{3}} \sqrt{\frac{\frac{beam}{3} n_{dump}}{beam}} \sqrt{n_{on2off}} = \sqrt{3 n_{dump} n_{on2off}}$$

  - RMS reached after only one cover

$$\sigma^1 = \frac{T_{sys}}{\sqrt{Npol \cdot \Delta f \cdot t_{on}^{beam}}} \sqrt{1 + \frac{1}{\sqrt{3 \cdot N_{dump}^{subMap}}}}$$

  - Number of covers to reach final RMS

# OTF

- OTF estimator
  - Number of coverages

$$N_{cover} = \left(\frac{\sigma^1}{\sigma}\right)^2$$

  - Final RMS

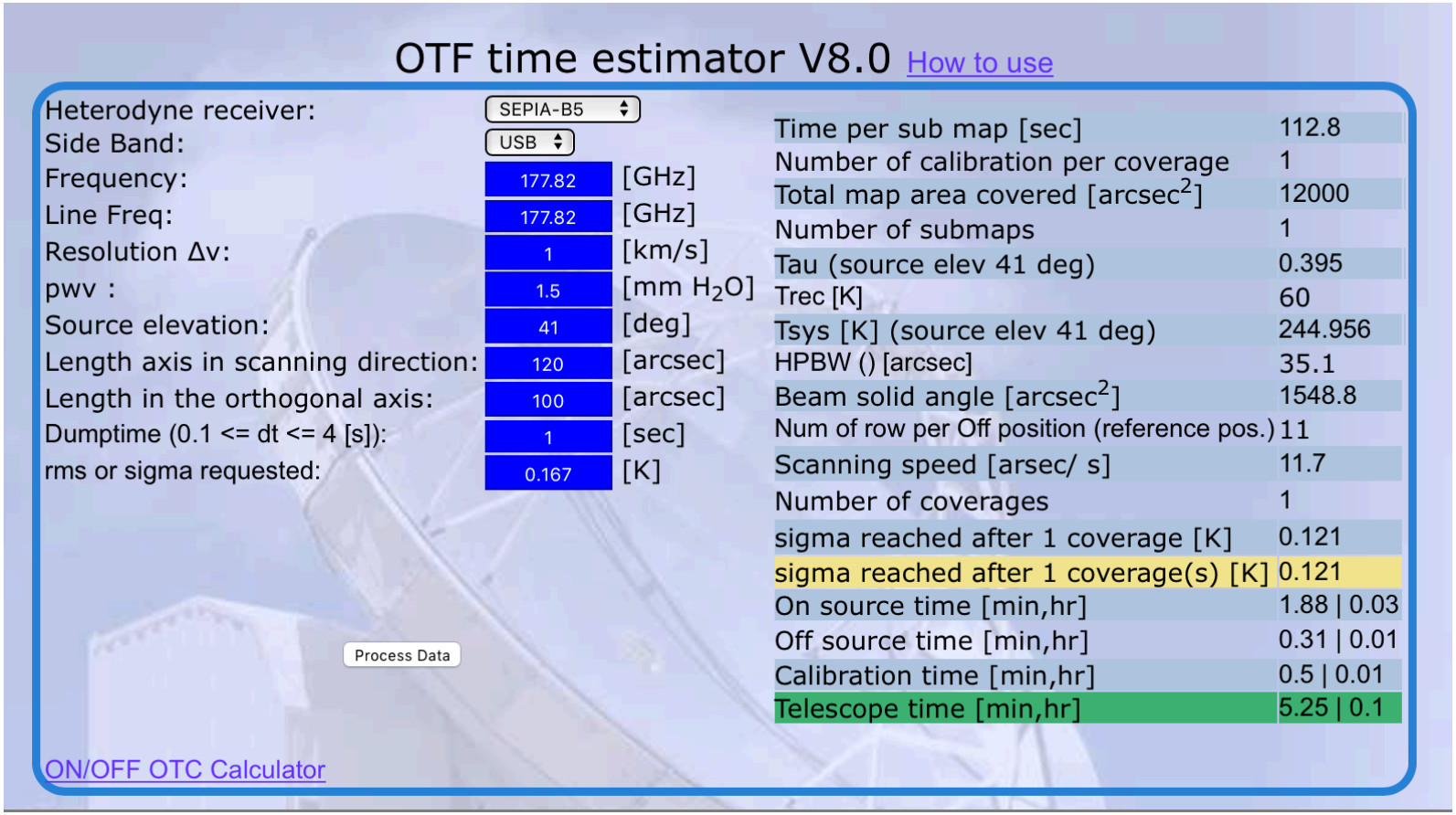
$$\sigma = \frac{T_{sys}}{\sqrt{Npol \cdot \Delta f \cdot N_{cover} \cdot t_{on}^{beam}}} \sqrt{1 + \frac{1}{\sqrt{3 \cdot N_{dump}^{subMap}}}}$$

# OTF

- OTF estimator
  - Example
    - 177.82  +41.0  1.46  1
    - otf(xlen=120,xstep=12,ylen=100,ystep=12,time=1.0,direction=x, angle=0.0)

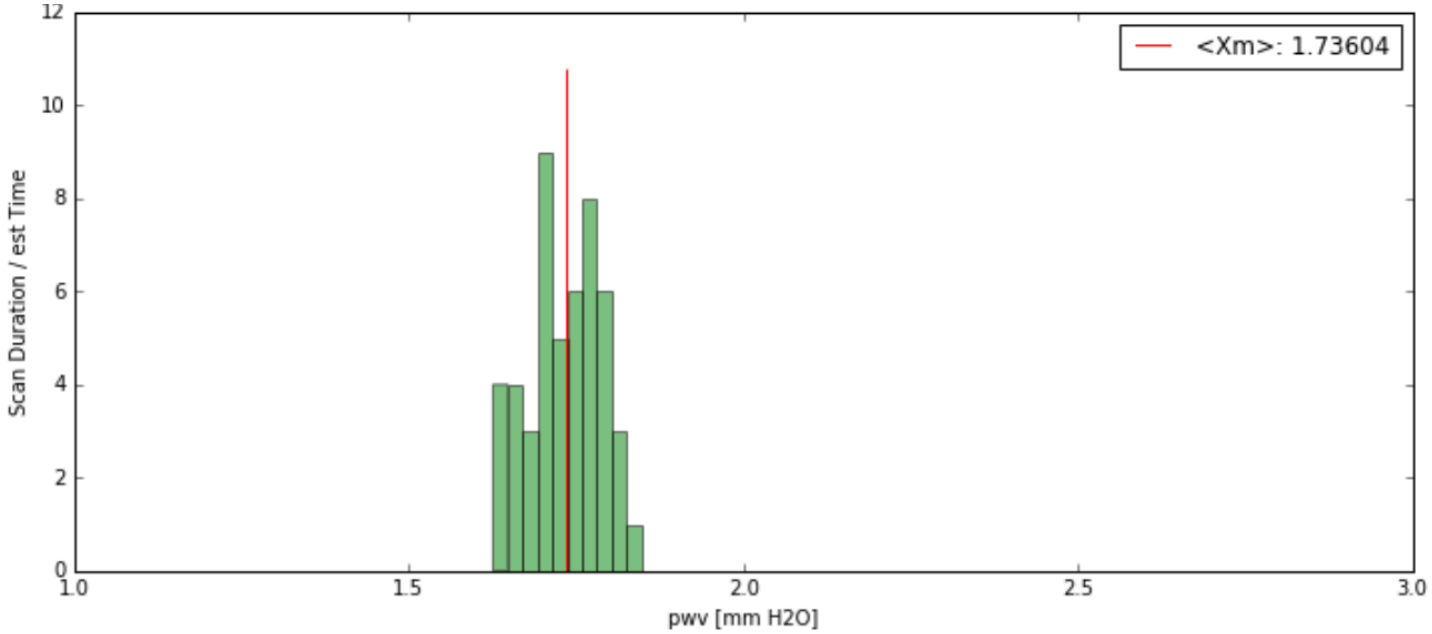
# OTF

- OTF time estimator (V8.o)



# OTF

- OTF estimator
  - Estimated time versus scan duration SEPIA-B5



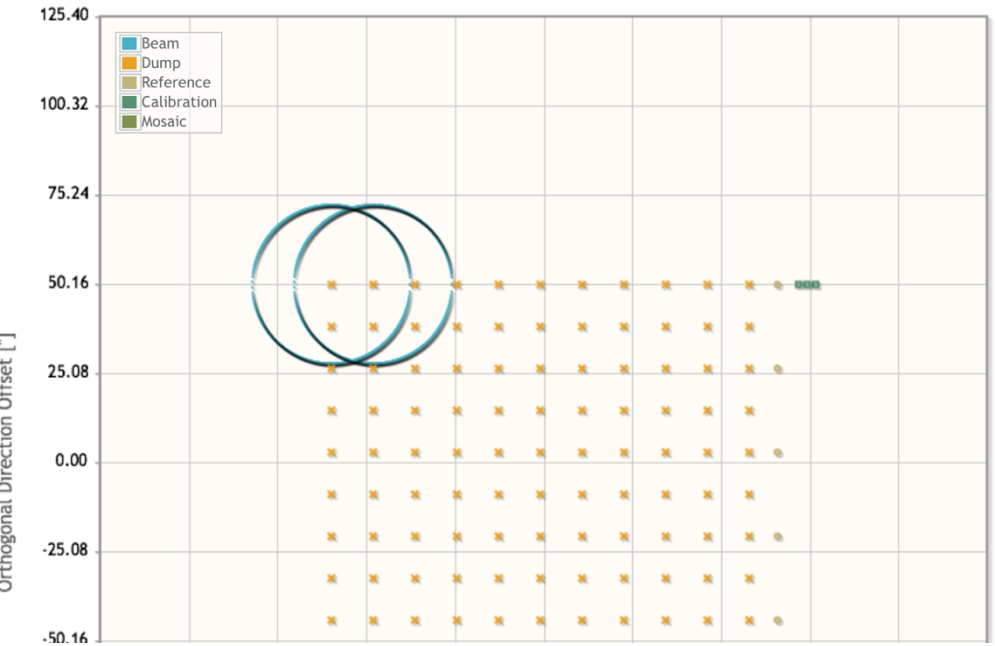
# OTF

- OTF map simulator
  - Important parameters
    - Duration
    - On2Off
    - On2Cal

# OTF

- OTF map simulator

***On The Fly Map Simulator***




| *Basic OTF Paramaters* | | *Map dimension* | |
|---|---|---|---|
| *Frequency* | *177* | $x_{len}$ | *120* |
| *Reference(on2off)* | *2* | $x_{step}$ | *11.8* |
| *Calibration (on2cal)* | *0* | $y_{len}$ | *100* |
| | | $y_{step}$ | *11.8* |
| | | *angle* | *0* |
| Plot >> | | $t_{dump}$ | *1* |

*Times without overhead*

*Beam = 35.3*

$t_{on}$ = *1.4[min]*

$t_{off}$ = *0.6 [min]*

$t_{cal}$ = *0.5 [min]*

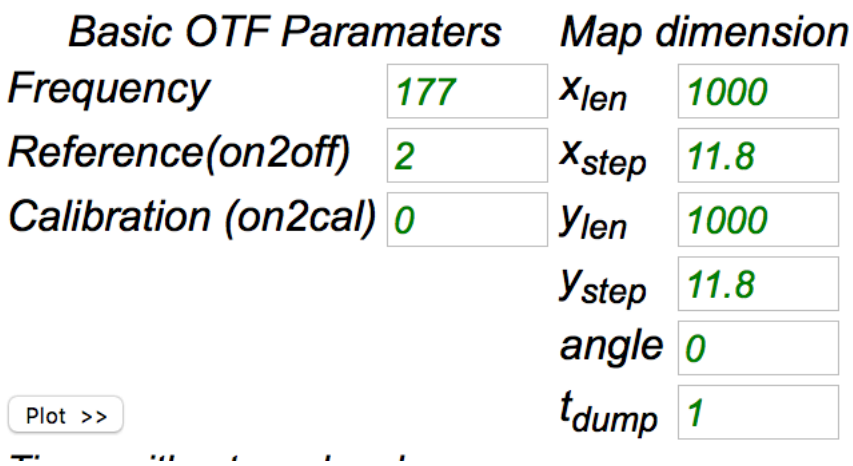
*Total Time = 2.5 [min]*

*The OTF command produced with the input parameters*

***otf(xlen=120, xstep=11.8, ylen=100, ystep=11.8, time=1, direction = "x", on2cal =0, angle = 0)***

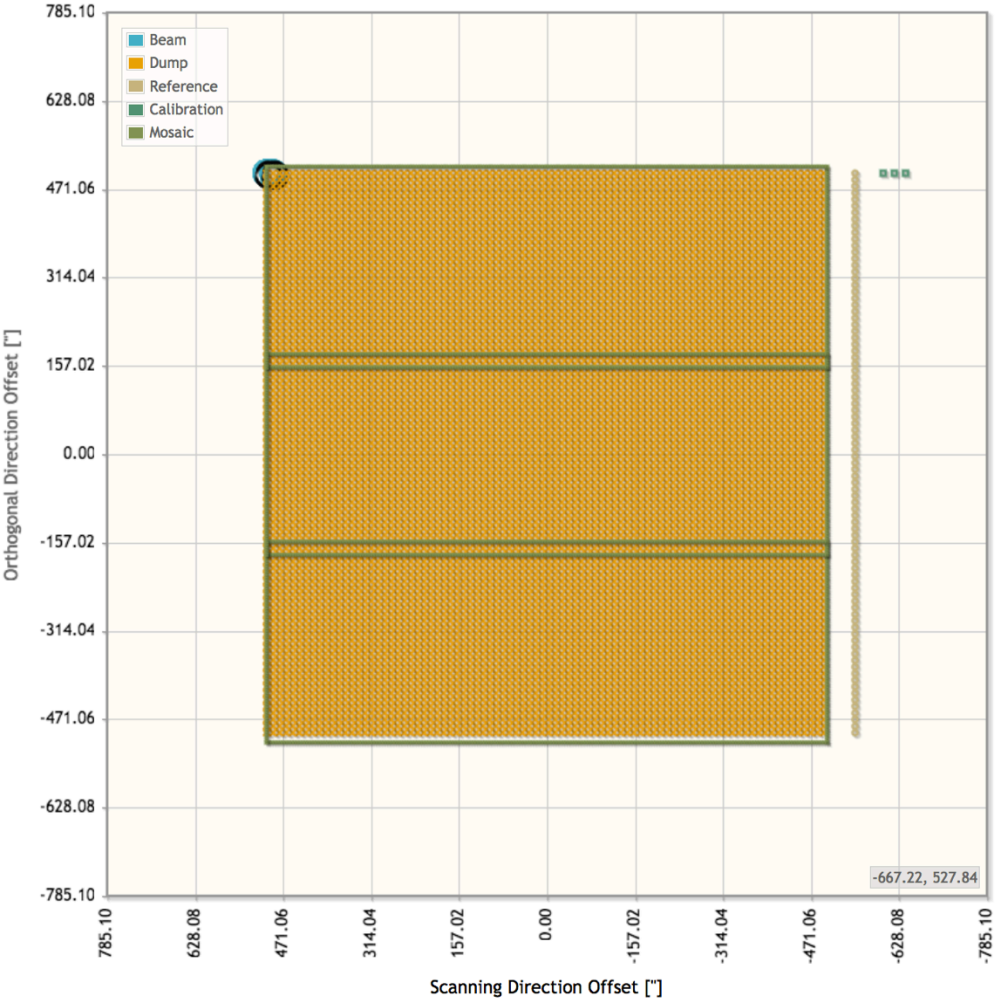
# OTF

- OTF map simulator
  - Example



# OTF

## *On The Fly Map Simulator*




| *Basic OTF Paramaters* | | *Map dimension* | |
|---|---|---|---|
| *Frequency* | *177.8* | $x_{len}$ | *1000* |
| *Reference(on2off)* | *1* | $x_{step}$ | *11.7* |
| *Calibration (on2cal)* | *0* | $y_{len}$ | *1000* |
| | | $y_{step}$ | *11.7* |
| | | *angle* | *0* |
| Plot >> | | $t_{dump}$ | *1* |

*Times without overhead*

*Beam = 35.1*

*$t_{on}$ = 121.8[min]*

*$t_{off}$ = 22.8 [min]*

*$t_{cal}$ = 0.5 [min]*

*Total Time = 145.1 [min]*

*The OTF command produced with the input parameters*
***otf(xlen=1000, xstep=11.7, ylen=1000, ystep=11.7, time=1, direction = "x", on2cal =0, angle = 0)***

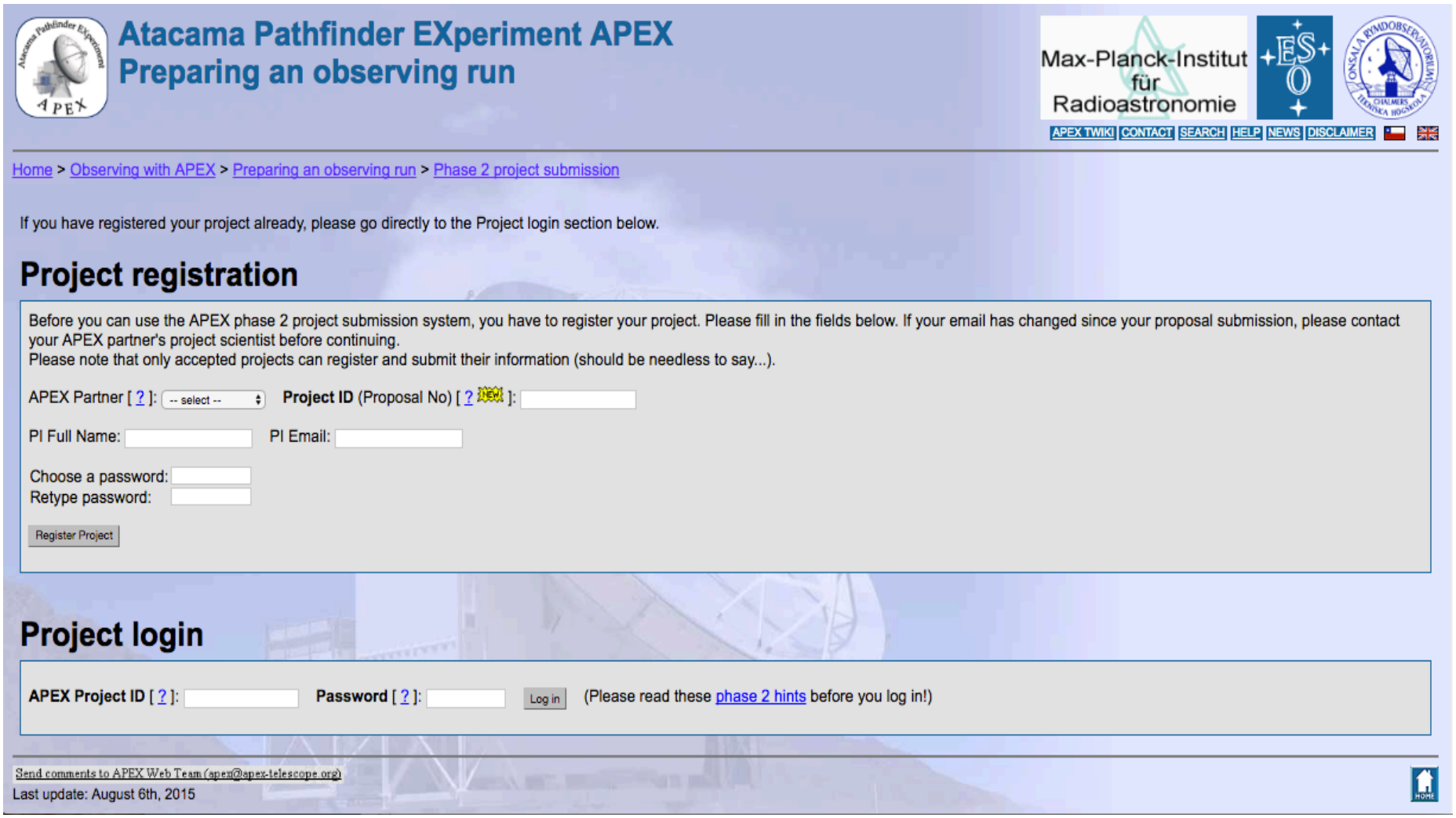
*The map need to be done in mosaic mode ...*
*Number of mosaic = 3*

*# Mosaic number 1*
*# New map dimension = (1000,356.7)*
*Offset = (0,-333.33)*
*otf(xlen=1000, xstep=11.7, ylen=356.7, ystep=11.7, time=1, direction = "x", on2cal =0, angle = 0)*
*#----------*
*# Mosaic number 2*
*# New map dimension = (1000,356.7)*
*Offset = (0,0)*
*otf(xlen=1000, xstep=11.7, ylen=356.7, ystep=11.7, time=1, direction = "x", on2cal =0, angle = 0)*
*#----------*
*# Mosaic number 3*
*# New map dimension = (1000,356.7)*
*Offset = (0,333.33)*
*otf(xlen=1000, xstep=11.7, ylen=356.7, ystep=11.7, time=1, direction = "x", on2cal =0, angle = 0)*
*#----------*

# Overview

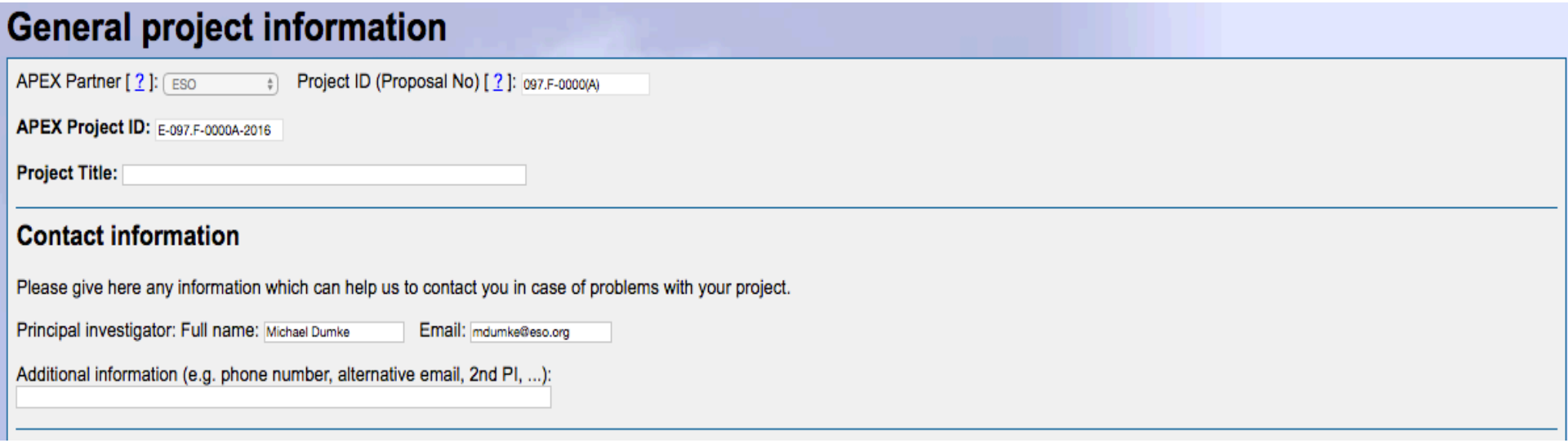
- Introduction
- Sections on APEX phase 2 submission
- Tutorial

# Front of the observing form



# Sections on APEX phase 2

- Section 1



# Sections on APEX phase 2

- Section 2

  Target – catalogues – Receiver

**Target sources**

For your target sources, you need to specify the source name, the coordinates, and the velocity.
For equatorial coordinates (which is usually the case), note that you MUST give your coordinates in J2000.0! The APEX staff will not calculate your coordinates from B1950.0 or whatever! Use the NED Coordinate Transformator if you don't have your coordinates in J2000.0.
For high-redshift sources, you should give a velocity of "0.0" and enter the redshifted frequency in the "Line information" section further below.

There are two ways of submitting source information. You can either prepare a source catalog offline, following the syntax rules for APEX source catalogs, and upload it through this web form, or enter the source parameters online. For more than 10 target sources, you must prepare the source catalog offline.

- (•) I will enter the source parameters online (only possible for up to 10 targets).
- ( ) I will prepare a catalog offline and upload it.

Please select the number of targets. The form will dynamically change to accomodate more than one target, if necessary.

Number of targets: 1

Fill out the following fields for all your targets. The "Comment" field is optional.
Format for coordinates: hh:mm:ss.s for RA and dd:mm:ss.s for Dec (i.e. colon as separator), e.g. 2:29:15.312, -26:05:55.71

| | Source name | RA(2000) | Dec(2000) | v(LSR)[km/s] | Comment (e.g. priority, required S/N, ...) |
|---|---|---|---|---|---|
| #1 | | | | | |

**Receiver usage**

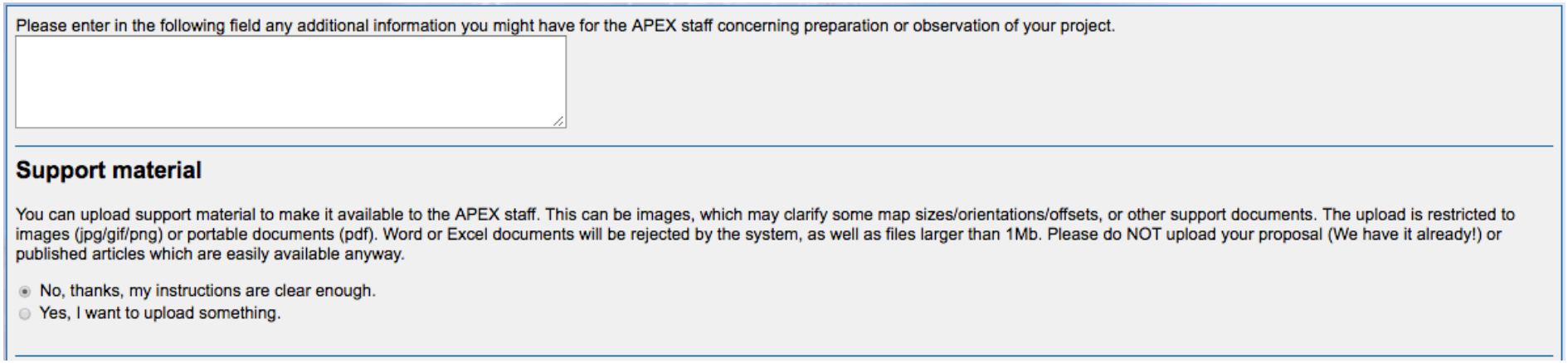
Please check all receivers which will be used for your project. Please note that you can **not** submit heterodyne and bolometer setups together.
If you have been granted time for both types of observation within one project, you have to submit them separately using different Run-IDs:

- [ ] APEX-1 (230GHz)
- [ ] APEX-2 (345GHz)
- [ ] APEX-3 (460GHz)
- [ ] APEX-T2 (1.3THz)
- [ ] FLASH+ (345/460)
- [ ] CHAMP+ (690/810)
- [ ] SEPIA Band 5 (180GHz)
- [ ] SEPIA Band 9 (660GHz)
- [ ] LABOCA (870µm)
- [ ] SABOCA (350µm)
- [ ] ARTEMIS (450µm)

# Sections on APEX phase 2

- Section 3

  Additional information



# Before getting started

- ✓ Less than 10 sources – More than 10 sources
- ✓ Less than 8 spectral setup – More than 8 spectral setups
  - ✓ Source Names and Tuning names characters have limits in MBFITS (30) and CLASS (12) e.g **NO** HCN(2-1)_apexBand5
  - ✓ Careful to introduce bad characters (minus/hyphens)
- ✓ Sources at high redshift
- ✓ Please add supplementary material (maps, reference positions, check atmospheric transmission)
- ✓ Always you can save your info. This does not mean that you are submitting.

# Example 1

- Example Project ID: E-097.F-0000A-2016
  password: apex4guests

- Band 5 / OTF
  - **Syntax for target**

```
ORION-KLEQ    2000   05:35:14.46    -05:22:30.6   LSR +8.0
IRC+10216 EQ    2000   09:47:57.41    +13:16:43.6   LSR -25.0
ETA_CAR  EQ    2000   10:45:03.59    -59:41:04.3   LSR -25.0
```

  - **Syntax for line catalog**

    Tuning at 195.95GHz (LSB) .

```
CS(4-3)     195.959421   GHz   LSB  ! comment
```

http://www.apex-telescope.org/observing/phase2/login.php

# Example 2

- Example Project ID: E-097.F-0000A-2016
  password: apex4guests

- Band 9 / ON-OFF
  - **Syntax for target / More than 10 sources.**
    - **Upload a catalog.**

sourceB9Cat.cat

```
! source catalog for Band 9
! 01.20.2017

APEX01-1        EQ  2000 01:03:11.50    +18:14:15.3    LSR 0.0   !Comment
APEX01-2        EQ  2000 01:25:48.25    -51:53:52.9    LSR 0.0   !Comment
APEX03-3        EQ  2000 03:52:45.83    -50:35:54.0    LSR 0.0   !Comment
APEX04-4        EQ  2000 04:33:45.83    -50:58:02.1    LSR 0.0   !Comment
APEX05-5        EQ  2000 05:29:03.09    -53:56:41.7    LSR 0.0   !Comment
APEX06-6        EQ  2000 06:32:51.04    -54:36:40.0    LSR 0.0   !Comment
APEX07-7        EQ  2000 07:50:00.56    -50:18:42.2    LSR 0.0   !Comment
APEX07-8        EQ  2000 07:51:39.42    -46:21:24.3    LSR 0.0   !Comment
APEX08-9        EQ  2000 08:47:19.05    -50:38:20.9    LSR 0.0   !Comment
APEX08-10       EQ  2000 08:57:16.84    -45:38:53.9    LSR 0.0   !Comment
```

  - **Syntax for line catalog**

    Tuning at 660.2GHz (LSB) .

```
C18O(6-5)     658.553600  GHz  LSB  ! comment
13CO(6-5)     661.0681    GHz  LSB  ! comment
C17O(6-5)     674.0093    GHz  LSB  ! comment
CO_isotop     660.2000    GHz  LSB  ! comment
```

http://www.apex-telescope.org/observing/phase2/login.php

# Your observations

- Pointing
  - SEPIA-B5: Planets, HCN, SiO masers
  - SEPIA-B9: Planets, CO, H2O maser (challenging)
- Focus
- Calibration spectra (as for facility rx)
  - IRC+10216, OMC1, SgrB2 …
- Calibration
  - Online calibration done per 2.5GHz baseband
  - Offline channel by channel (or chunk) calibration?
- Aliasing at band edges
  - Flag 100Mhz (4%) in the overlap region

- Send us an email: apex-astro@apex-telescope.org