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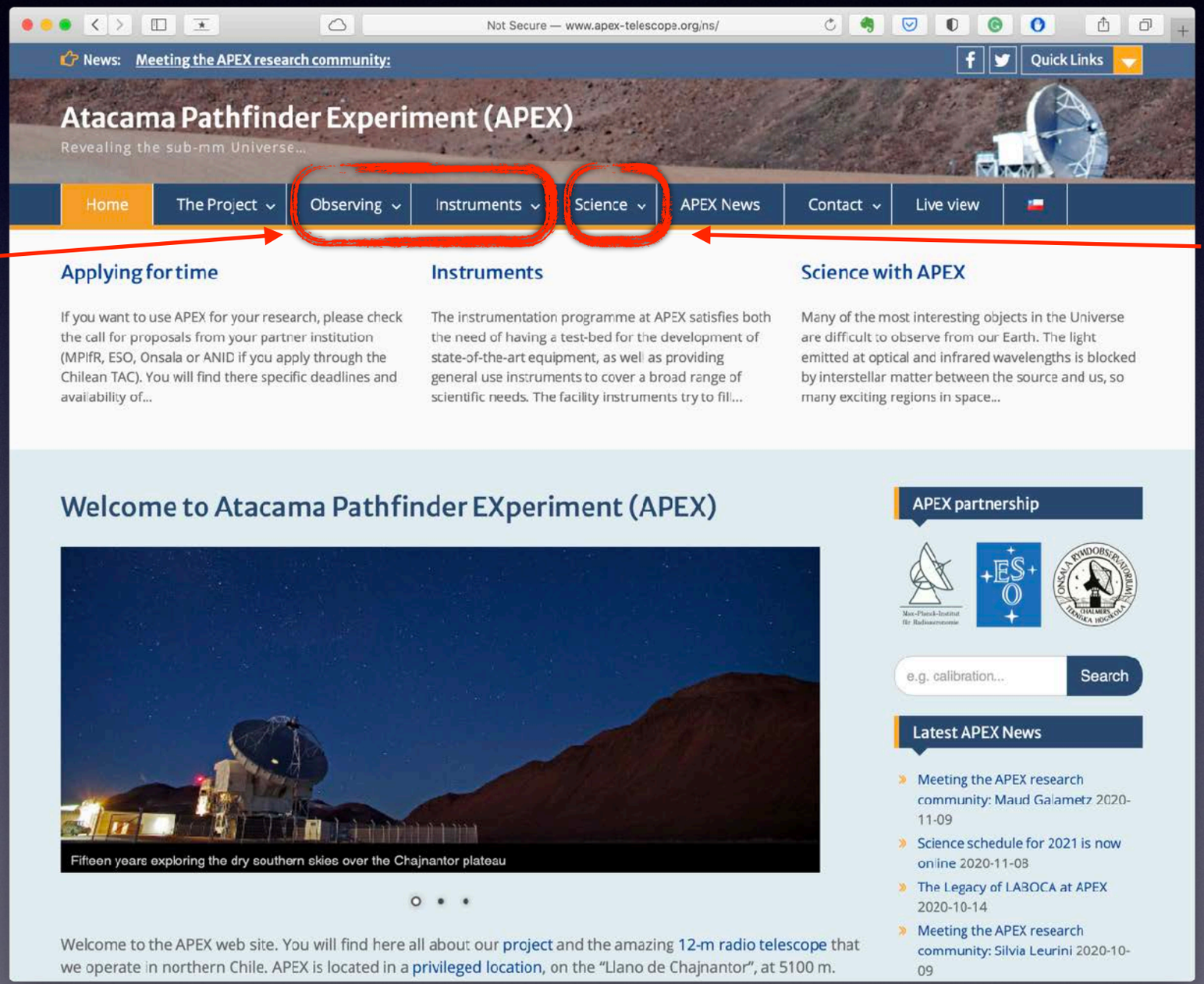
APEX Observations

Instruments, capabilities and tools

http://www.apex-telescope.org/ns/

Main content of this talk

Science examples and inspiration

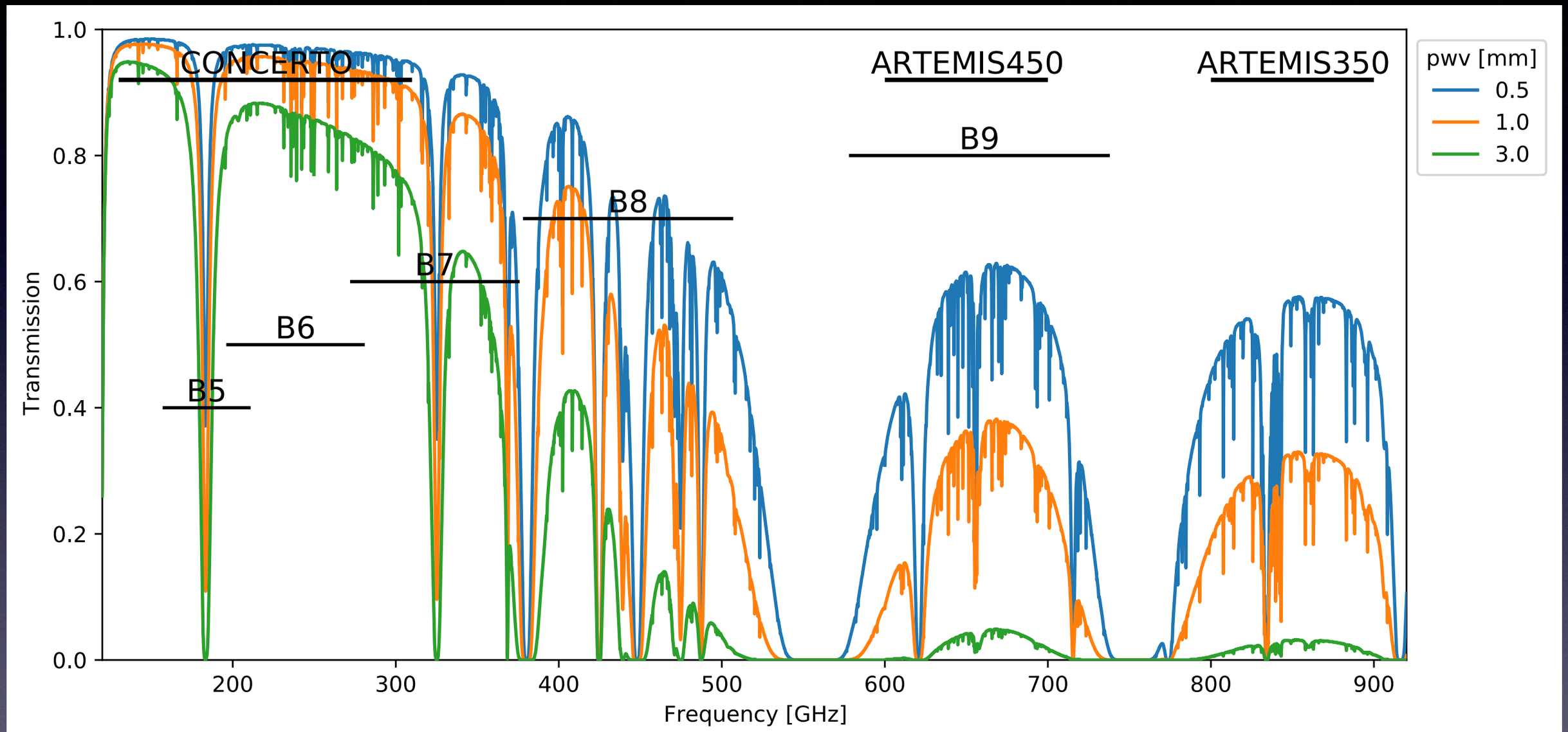


Why APEX?

http://www.apex-telescope.org/ns/

- For large structures single dish is what you want/need
- APEX offers high instantaneous dual polarization bandwidth at high resolution (for a single dish telescope) B5 - B9
- Artemis offers large FOV simultaneous 450um and 350um bolometer observations
- Quick turnover, apply now and have your data in 6-9 months
- APEX can be used to find the best candidates for ALMA observations in your sample and make for a stronger proposal
- Single dish observations are also often a complement to higher resolution observations with e.g. ALMA
- It’s a great place for students to learn mm/sub-mm observing techniques and data reduction

Chajnantor atmosphere



- Bolometer cameras (continuum): ARTEMIS450/350
- CONCERTO: Wide field-of-view low-resolution spectrometer
- Single pixel heterodyne instruments (spectral lines): B5 - B9

Instruments

Beam width: 7.″8 × (800 / f [GHz])

Heterodyne RX - single pixel spectral lines

- B5: SEPIA180 (open PI)
  pwv < 5mm
- B6: NFLASH230
  1.5 < pwv < 5mm
- B7: SEPIA345
  pwv < 1.5mm
- B8: NFLASH460
  pwv < 1.0mm
- B9: SEPIA660
  pwv < 0.7mm

Bolometers - continuum cameras

- Artemis 450/350μm (open PI)
  pwv < 0.7mm

CONCERTO (PI)

- LF 130-270 GHz pwv < 3mm
  HF 195-310 GHz pwv < 2mm

PI - MPI

- PI230
- LASMA345
- CHAMP690/810

Instruments

http://www.apex-telescope.org/ns/instruments/

Facility instrumentation overview

Instrument (FE/BE)	Type	Freq [GHz]	HPBW (arcsec)	IF range [GHz]	Beams	Pol	Cabin	Status	Notes
nFLASH230 FFTS1	Het SIS (2SB)	196-281	32-22	4-12	1	Dual	A	OK	Inst. 2020 Q1
SEPIA345 FFTS1	Het SIS (2SB)	272-376	23-17	4-12	1	Dual	A	OK	Inst. 2020 Q1
nFLASH460 FFTS4G	Het SIS (2SB)	378-507	17-12	4-8	1	Dual	A	OK	Inst. 2020 Q1
SEPIA660 FFTS1	Het SIS (2SB)	578-738	10-9	4-12	1	Dual	A	OK	

PI instrumentation overview

Instrument (FE/BE)	Type	Freq [GHz]	HPBW (arcsec)	IF range [GHz]	Beams	Pol	Cabin	Status	Notes
SEPIA180 FFTS1	Het SIS (2SB)	157-211	39-31	4-8	1	Dual	A	OK	
PI230 FFTS4G	Het SIS (2SB)	200-270	31-23	4-12	1	Single	B	OK	Dual polarisation before 2020.
LASMA FTTS4G	Het SIS (2SB) array	268-375	23-17	4-8	7	Single	B	OK	
ARTEMIS450 BEAR	Bolometer array	666 (450 µm)	9		2300		C	OK	Dual colour with ARTEMIS350
ARTEMIS350 BEAR	Bolometer array	856 (350 µm)	7		2300		C	OK	Dual colour with ARTEMIS450
CHAMP690 FFTS4G	Het SIS (DSB) array	620-720	9-7	4-8	7	Single	B	NO	Dual colour with CHAMP810
CHAMP810 FFTS4G	Het SIS (DSB) array	780-850	7-6	4-8	7	Single	B	NO	Dual colour with CHAMP690
CONCERTO									

Heterodyne observations overview

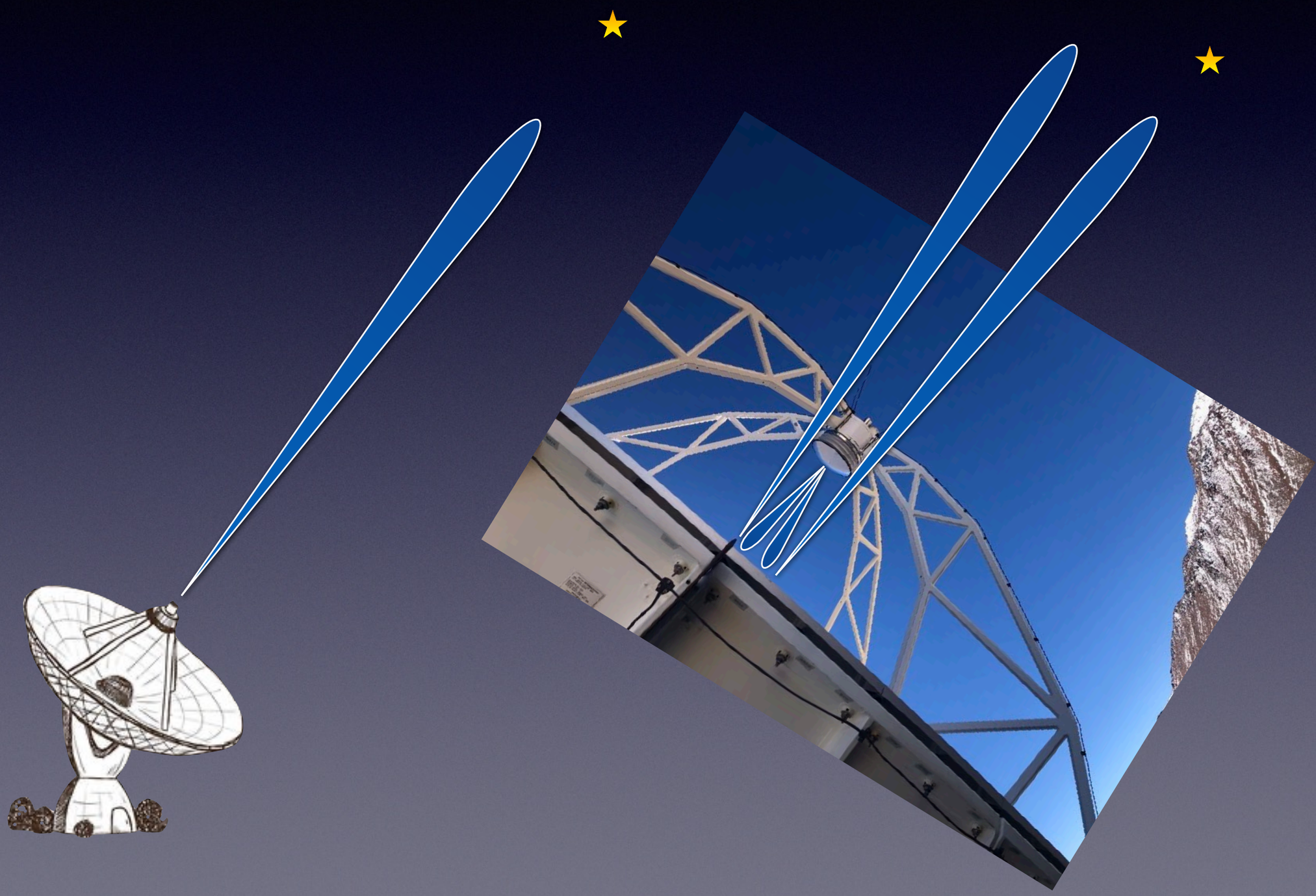
- Observing modes
  - Single position (or small raster map)
    - Wobbler (beam switching)
    - Total power (position switching)
  - Mapping mode (OTF)
- Instrument setup
- Observing time calculators (OTC)

Heterodyne observing modes

- ON-OFF (single position or raster map)
  - Wobbler (beam switching)
    - Provides better baselines
    - Max throw 10’ (amplitude 300”)
    - Compact sources e.g. stars and extragalactic (z) sources.
  - Total power (position switching)
    - Galactic clouds and and nearby galaxies (to avoid OFF position contamination). Crucial to select a good OFF position.
- OTF (on-the-fly mapping)
  - Mapping (no wobbler) and again crucial to select (and test) a suitable OFF position.

Wobbler observations - beam switching

Moving the sub-reflector provides better baselines and is used for compact sources e.g. stars and extragalactic observations. Cannot be used in mapping (OTF) mode. Wobbler throw up to 10’ and frequency up to 2 Hz.



Total power - position switching

Used for extended sources, single point and OTF's, e.g. galactic clouds and nearby galaxies. An absolute (or relative) OFF position needs be specified to make sure the science spectra are not contaminated by emission in the OFF position.

Use e.g. SkyView / Planck 353 I to find emission en emission free region
https://skyview.gsfc.nasa.gov/current/cgi/query.pl

Total power - position switching

Used for extended sources, single point and OTF's, e.g. galactic clouds and nearby galaxies. An absolute (or relative) OFF position needs be specified to make sure the science spectra are not contaminated by emission in the OFF position.

Use e.g. SkyView / Planck 353 I to find emission en emission free region

https://skyview.gsfc.nasa.gov/current/cgi/query.pl

SkyView

SkyView
The Internet's Virtual Telescope
Home Query Form Help

SkyView Query Form

Use **static Non-JavaScript Query Form**

Initiate request: Submit Reset forms: Reset Display results in new window

Required Parameters:

Coordinates or Source: M16
(*e.g.* "Eta Carinae", "10 45 3.6, -59 41 4.2", or "161.265, -59.685" [omit the quotes])

Surveys: Select at least one survey

SkyView Surveys Clear Survey Selections

Gamma Ray:
Fermi 5
Fermi 4
Fermi 3
Fermi 2
Fermi 1
EGRET (3D)
EGRET <100 MeV

Hard X-ray:
INT GAL 17-35 Flux
INT GAL 17-60 Flux
INT GAL 35-80 Flux
INTEGRAL/SPI GC
GRANAT/SIGMA
RXTE Allsky 3-8keV Flux
RXTE Allsky 3-20keV Flux

X-ray: Swift BAT:
BAT SNR 14-195
BAT SNR 14-20
BAT SNR 20-24
BAT SNR 24-35
BAT SNR 35-50
BAT SNR 50-75
BAT SNR 75-100

Soft X-ray:
SwiftXRTCnt
SwiftXRTExp
SwiftXRTInt
HEAO 1 A-2

ROSAT w/sources:
RASS-Cnt Soft
RASS-Cnt Hard
RASS-Cnt Broad
PSPC 2.0 Deg-Int
PSPC 1.0 Deg-Int
PSPC 0.6 Deg-Int
HRI

ROSAT Diffuse:
RASS Background 1
RASS Background 2
RASS Background 3
RASS Background 4
RASS Background 5
RASS Background 6
RASS Background 7

UV:
GALEX Near UV
GALEX Far UV
ROSAT WFC F1
ROSAT WFC F2
EUVE 83 A
EUVE 171 A
EUVE 405 A

Swift UVOT:
UVOT WHITE Intensity
UVOT V Intensity
UVOT B Intensity
UVOT U Intensity
UVOT UVW1 Intensity
UVOT UVM2 Intensity
UVOT UVW2 Intensity

Optical:DSS:
DSS
DSS1 Blue
DSS1 Red
DSS2 Red
DSS2 Blue
DSS2 IR

Optical:SDSS:
SDSSg
SDSSi
SDSSr
SDSSu
SDSSz
SDSSdr7g
SDSSdr7i

Other Optical:
TESS
Mellinger Red
Mellinger Green
Mellinger Blue
H-Alpha Comp
SHASSA H
SHASSA CC

IR: IRAS:
IRIS 12
IRIS 25
IRIS 60
IRIS 100
SFD100m
SFD Dust Map
IRAS 12 micron

IR: 2MASS:
2MASS-J
2MASS-H
2MASS-K

IR: UKIDSS:
UKIDSS-Y
UKIDSS-J
UKIDSS-H
UKIDSS-K
UKIDSS-1-0S1

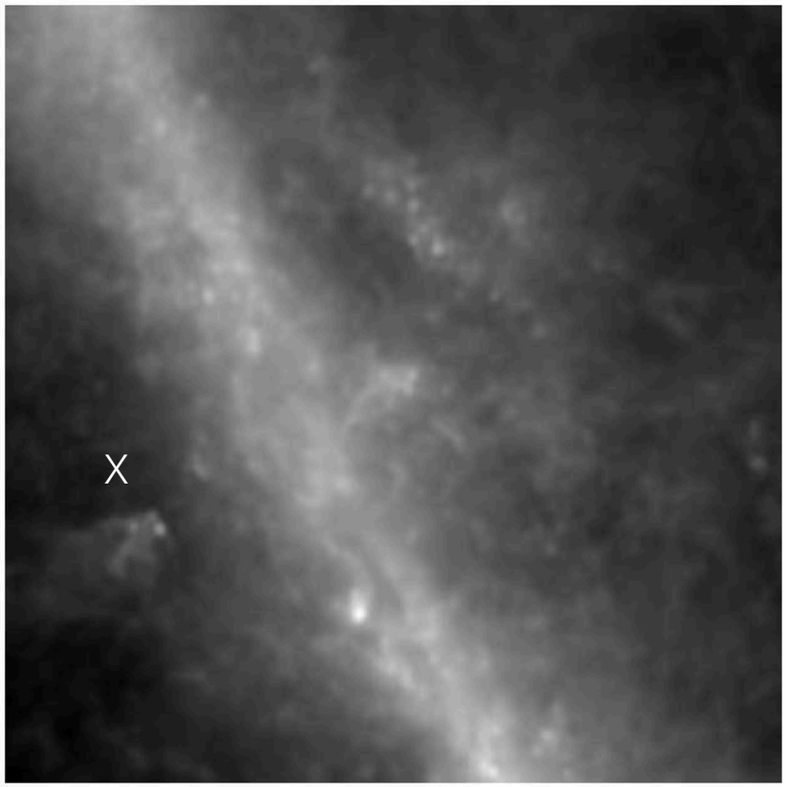
IR: WISE:
WISE 3.4
WISE 4.6
WISE 12
WISE 22

IR: AKARI:
AKARI N60
AKARI WIDE-S
AKARI WIDE-L
AKARI N160

IR: Planck:
Planck 857 I
Planck 545 I
Planck 353 I
Planck 353 Q
Planck 353 U

IR: WMAP & COBE:
WMAP ILC
WMAP Ka
WMAP K
WMAP Q
WMAP V

Planck 353 I: Planck 353 GHz Survey: I



X,Y: 32,116 -> J2000.0: 18 32 47.16 -14 45 28.7 Zoom

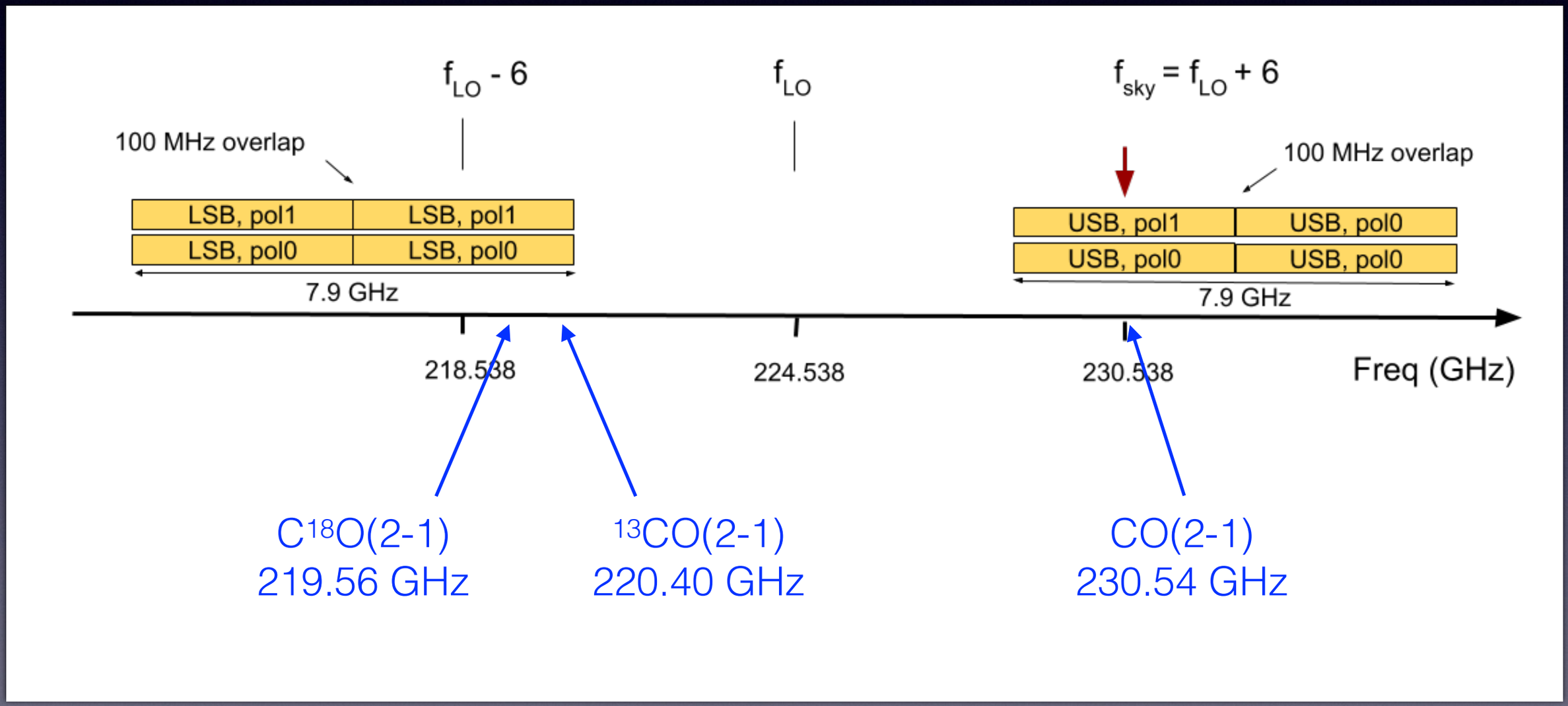
Use 350um continuum as a proxy for e.g. CO emission.

Or better if you have lower resolution CO data.

Heterodyne setup example

http://www.apex-telescope.org/ns/nflash/

CO/^{13}CO/C^{18}0 (2-1) example

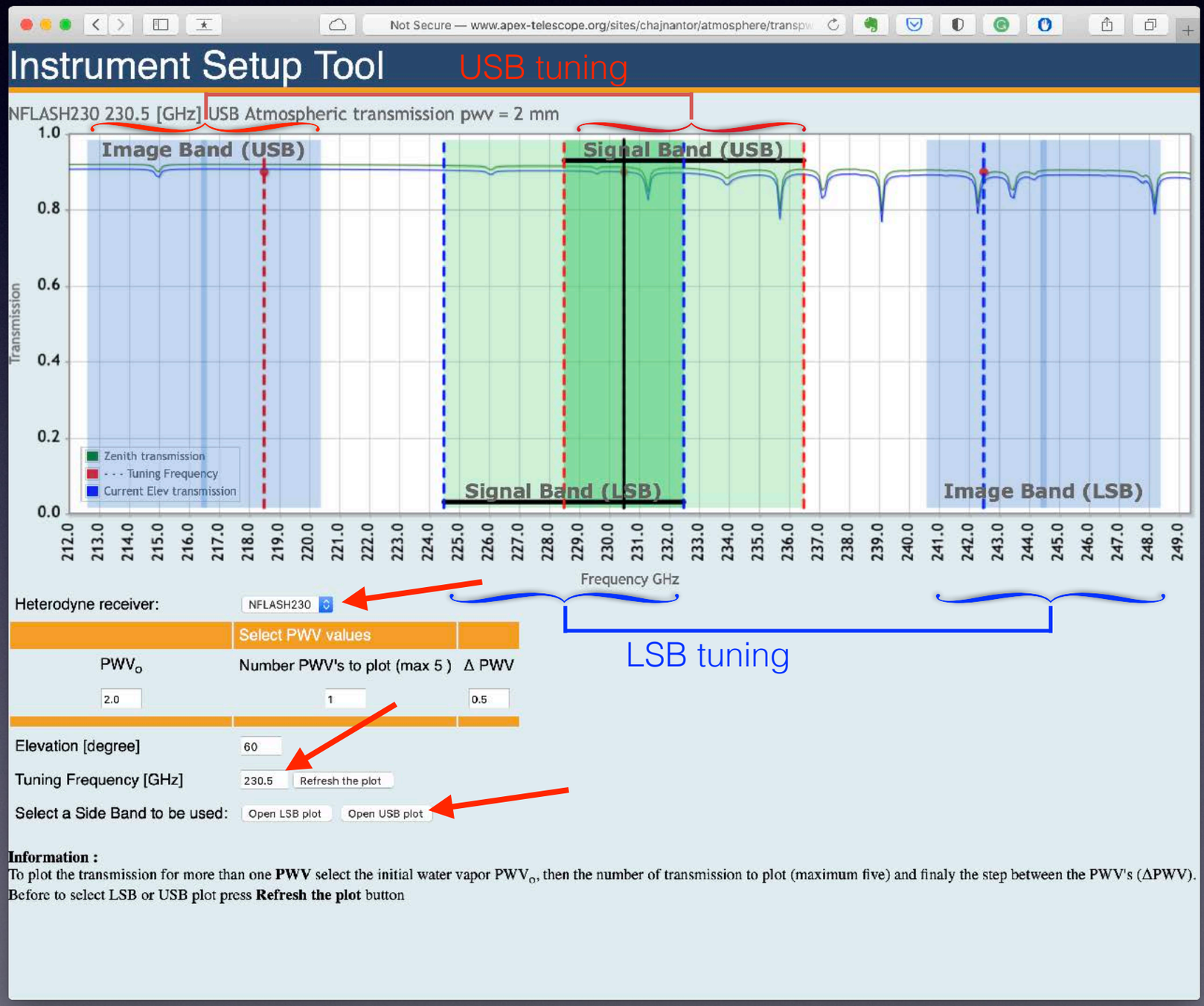


Heterodyne setup

http://www.apex-telescope.org/ns/instrument-setup-tool/

- **Instrument selection**
  - PWV's
  - Elevation
- **Tuning frequency**
  - Sidebands displayed for both LSB and USB tuning.
- **Select sideband**
  - Opens next window with line frequencies.

CO/13CO/C180 (2-1) example

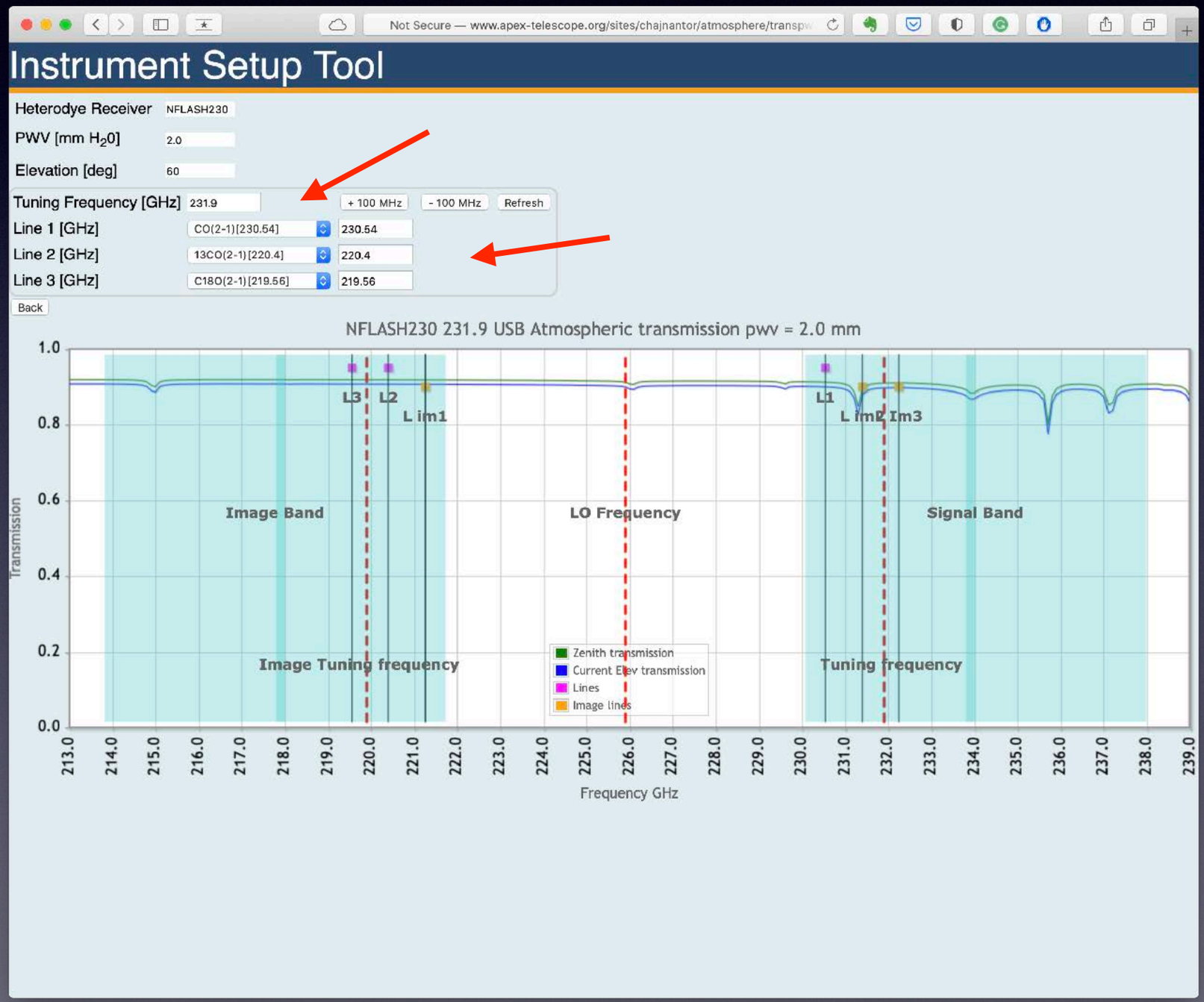


Heterodyne setup

http://www.apex-telescope.org/ns/instrument-setup-tool/

- Add scientific lines of interest.
- Change “Tuning frequency” to avoid overlap of lines.
- Do not “fine-tune” pwv and elevation, use reasonable values.

CO/13CO/C180 (2-1) example



Time estimators (OTC)

http://www.apex-telescope.org/ns/observing-time-calculators/

Heterodyne instruments

Depending on the observing strategy you will be using, you must choose the time estimator for ON/OFF observations (valid for beam- and position-switching observations), or for on-the-fly mapping.

OTC (on/off)

OTC (on-the-fly)

Bolometer cameras

You can also estimate your observing times for the current continuum cameras. These require less input parameters since they operate at fixed bands.

Time estimator - ON/OFF

ON/OFF Integration time estimator V 7.3

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.

System overheads include telescope movements, software overheads, observing mode efficiency, etc. Setup + calibration overheads include source acquisition, pointing, focus, receiver tuning and calibration scans. Note about overheads.

For an overview of the atmospheric transmission and the possible backend configurations for each receiver, check our instrument setup tool.

Back to OTCs page

Heterodyne receiver:	NFLASH230
Tuning Freq:	231.9 [GHz]
Line Freq [+6 & -2 GHz from tuning]:	230.5 [GHz]
Side Band:	USB
Full resolution Δv [channels] :	0.079 [km/s]
Manual resolution Δv:	0.25 [km/s]
pwv :	2 [mm H_2O]
Source elevation:	45 [deg]
rms (0.005 [K]) :	5 [mK]

Process

Results

Tau (@ elev 45 deg)	0.135
Transmission (@ elev 45 deg)	0.874
Trec [K]	72.5
Tsys [K] (source elev 45 deg)	145.5
TsysImage [K] (source elev 45 deg)	136.9
Beam [arcsec]	26.9
Position Switching On time	1.218 [hr]
Position Switching Off time	1.218 [hr]
Position Switching OverHead time	3.045 [hr]
Total Position Switching time	5.481 [hr]
Beam Switching On time	1.218 [hr]
Beam Switching Off time	1.218 [hr]
Beam Switching OverHead time	3.045 [hr]
Total Beam Switching time	5.481 [hr]

RMS estimator

When you are satisfied with your time estimate, please copy and paste this text in your proposal time justification:

We have used the ON-OFF observing time calculator at APEX V7.3 to estimate the total time needed to achieve our goal. Using NFLASH230 tuned to 231.9 GHz in the USB, selecting a spectral resolution of 0.25 km/s and assuming a typical source elevation of 45 deg and a typical PWV of 2 mm, we could get down to a noise of 5 mK[Ta*] in 5.5 hours (including telescope and calibration overheads).

Time estimator - OTF

OTF time estimator V10.0

Heterodyne receiver:	NFLASH230	
Side Band:	USB	
Tuning Freq:	231.9	[GHz]
Line Freq [+6 & -2 GHz from tuning]:	230.5	[GHz]
Resolution Δv:	0.25	[km/s]
pwv :	2.0	[mm H_2O]
Source elevation:	45	[deg]
Length axis in scanning direction:	300	[arcsec]
Length in the orthogonal axis:	300	[arcsec]
Dumptime (0.1 <= dt <= 4 [s]):	1	[sec]
rms or sigma requested : (0.05 [K])	50	[mK]

Time per sub map [sec]	33.4
Calibrations per coverage	1
Total map area covered [arcsec^2]	90000
Number of submaps	34
Tau (@ elev 45 deg)	0.138
Transmission (@ elev 45 deg)	0.871
Trec [K]	72.5
Tsys [K] (source elev 45 deg)	146.839
HPBW [arcsec]	26.9
Beam solid angle [arcsec^2]	910.7
Rows per off position (reference pos.)	1
Scanning speed [arsec/ s]	9
Number of coverages	13
Sigma reached after 1 coverage [mK]	175.2
Sigma reached after 13 coverage(s) [mK]	**48.6**
On-source time [min,hr]	246.4 I 4.1
Off-source time [min,hr]	73.8 I 1.2
Overhead Sys, Cal, Pointing, Focus [min,hr]	159.8 I 2.7
Telescope time [min,hr]	**480 I 8**

Other Tools

OTF Simulator	Helps you to design a map
Instrument setup tool	Check your tuning
ON/OFF OTC Calculator	Estimate on/off integration time
Note about Overheads	Overhead estimates
Back to instruments page	

Process Data

When you are satisfied with your time estimate, please copy and paste this text in your proposal time justification:

> We have used the OTF observing time calculator at APEX V10.0 to estimate the total time needed to achieve our goal. We plan to do an OTF of 300 x 300 arcsec and for the calculation we assume a dumptime of 1 seconds and a sampling corresponding to 1/3 of the beam. Using NFLASH230 tuned to 231.9 GHz in the USB, selecting a spectral resolution of 0.25 km/s and assuming a typical source elevation of 45 deg and a typical PWV of 2.0 mm, we could get down to a noise of 50 mK[Ta*] in 8 hours (including telescope and calibration overheads).

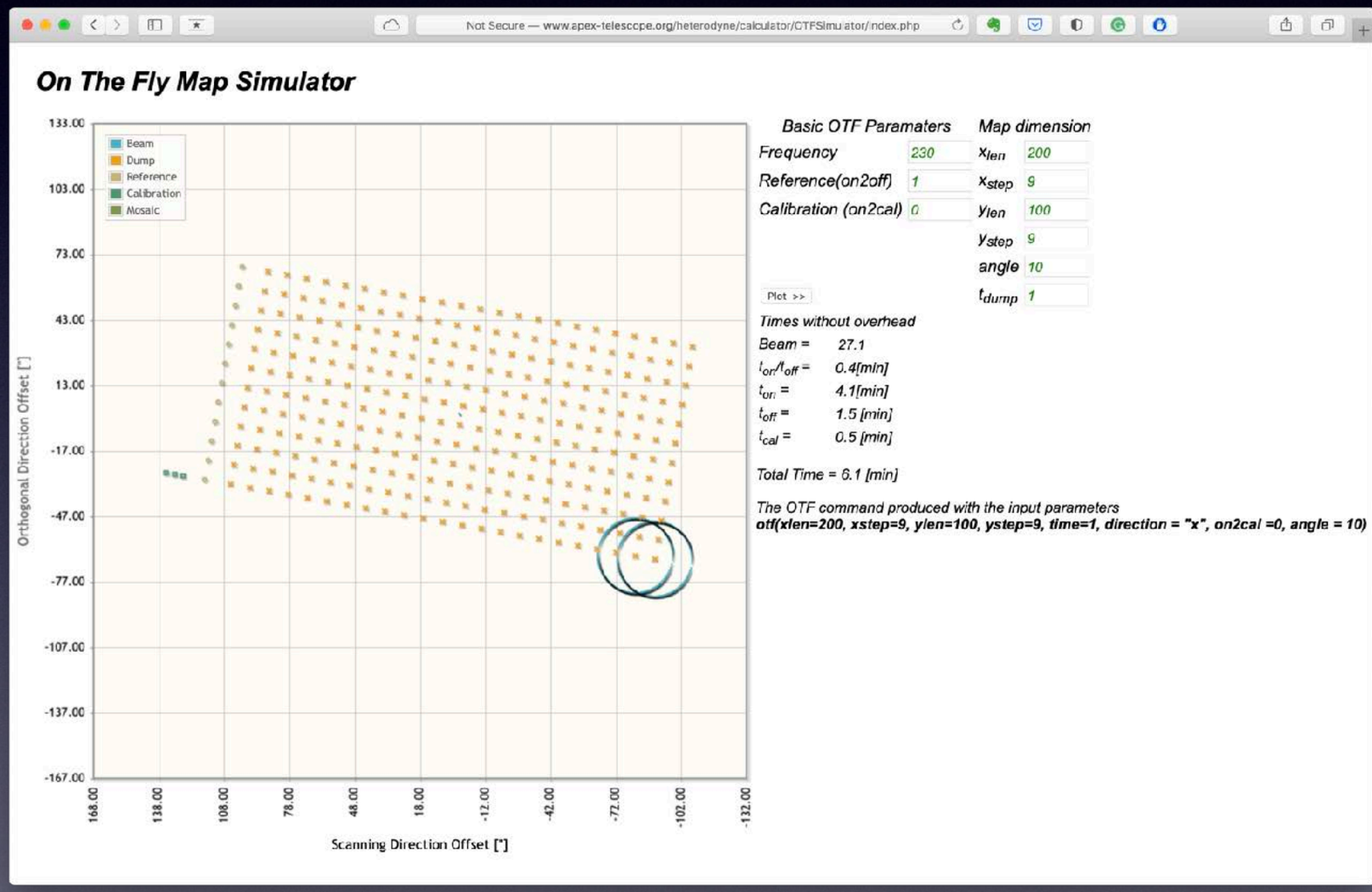
Heterodyne OTF (phase 2)

http://www.apex-telescope.org/heterodyne/calculator/OTFSimulator/

Can be used as a compliment to the observing time calculator.

Mainly to illustrate how calibrations and reference (OFF) positions are observed during the OTF.

It is also useful for larger maps that needs to be split up in mosaics, aim to keep single maps < 1h.



Time estimator - Artemis

Home > Instrumentation > PI instruments > Artemis > Artemis Observing time calculator Version 1.0

Artemis observing time calculator, Ver 2.0

Calculate Integration time for a given RMS

Select observing mode

Mapping mode:

(•) Point source(s) ( ) Extended source(s)

Scanning area [> 10](arcmin^2): 20

RMS (mJy/beam): 100

Elevation (degrees): 60

PWV [<3](mm) : 0.5

Reset Submit

Result:

Using the input PWV of 0.5 mm, you would get:
Tau: 1.269
Integration time needed: 1.9 hours (6957 seconds).
Total observation time including 90% overhead: 3.2 hours (11479 seconds).

Select for the proposal one of these times in Good, Poor or Average weather condition (with overhead).

Expected Tint [min]	Good weather [min] pwv =0.2 mm	Poor weather [min] pwv =0.8 mm	Average weather [min] pwv =0.5 mm
191.3	65.5	530.6	191.3

Time estimator - CONCERTO

https://mission.lam.fr/concerto/pages/instrument.html

- Frequency range: 125-310 (360) GHz
- Telescope: APEX 12m
- Field of view: Round diameter of 20'
- Number of pixels: 2x2152
- Focal plane: KIDS detectors
- Cryostat: closed cicle 3He-4He dilution
- Absolute spectral resolution: >1GHz
- Relative spectral resolution: 1-300
- Spectrometer: Martin-puplett interferometer
- Data rate: 128 MBytes/sec

More details on the instrument are given in the paper "A wide field-of-view low-resolution spectrometer at APEX: instrument design and science forecast", CONCERTO collaboration 2020, A&A 642, 60.

A first sensitivity estimate (before on-sky measurement) can be computed using this python code: Downloadable File. Details of the assumptionq and equations are given in the above mentionned paper. The estimate, based on NIKA2 on-sky measurements, will be revised at the end of the on-sky commissioning.

Visibility plot (Gildas - ASTRO)

https://www.iram.fr/IRAMFR/GILDAS/

xterm

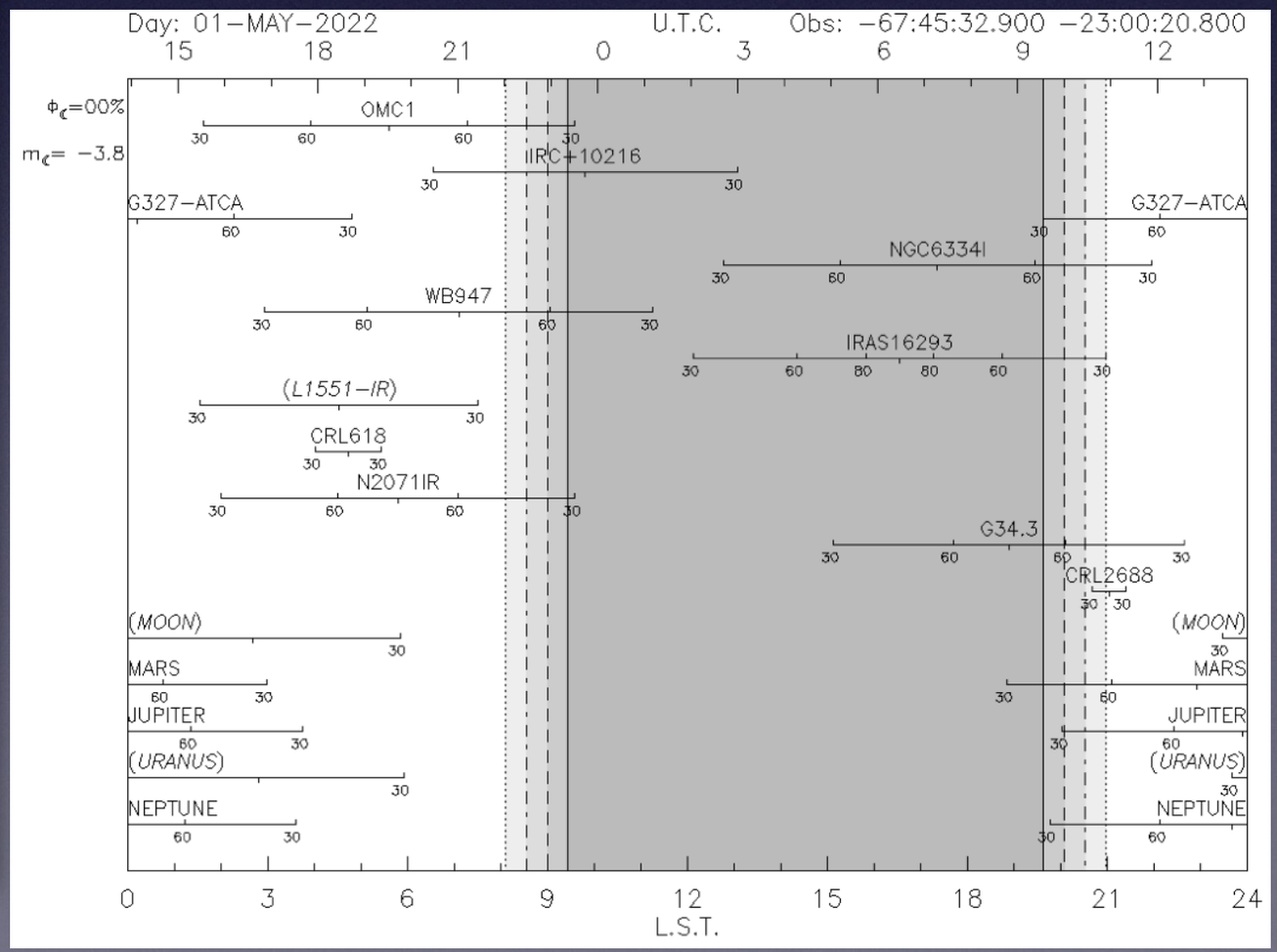
```
ASTRO> @ sepia345.astro
I-OBSERVATORY,  Selected APEX observatory
W-SOURCE,  No source defined, nothing to reset
I-CATALOG,  New source catalog is sepia345.cat
OMC1          Sun distance   49.8 Avoidance 03-JUN-2022 to 25-JUN-2022
IRC+10216     Sun distance  104.4 Avoidance 16-JUL-2022 to 19-SEP-2022
G327-ATCA     Sun distance   61.1 No Avoidance
NGC6334I      Sun distance  136.9 Avoidance 16-NOV-2022 to 11-JAN-2023
WB947         Sun distance   73.0 No Avoidance
IRAS16293     Sun distance  150.1 Avoidance 02-NOV-2022 to 02-JAN-2023
L1551-IR      Sun distance   28.9 Avoidance 29-APR-2022 to 02-JUL-2022
CRL618        Sun distance   36.1 Avoidance 07-MAY-2022 to 04-JUL-2022
N2071IR       Sun distance   50.4 Avoidance 27-MAY-2022 to 09-JUL-2022
G34.3         Sun distance  113.3 Avoidance 17-DEC-2022 to 24-JAN-2023
CRL2688       Sun distance   75.1 No Avoidance
I-HARDCOPY,  sepia345.png created
ASTRO> $ cat sepia345.astro
obs apex
time 00:00:00 01-MAY-2022
cata sepia345.cat
hor 30 60 80 /night /source /planet uranus jupiter mars neptune  moon
ha sepia345.png /dev png /fitpage /over /geo 1200 840
ASTRO> $ cat sepia345.cat
OMC1            EQ 2000  05:35:13.92   -05:22:22.8
IRC+10216        EQ 2000  09:47:57.291   13:16:42.864  LSR -25.0    !
! SgrB2(N)         EQ 2000  17:47:20.40   -28:23:07.1
G327-ATCA        EQ 20000  15:53:07.80   -54:37:06.4
NGC6334I         EQ 2000  17:20:53.4   -35:47:01
!cp.edb
WB947            EQ 2000  07:05:16.9   -12:20:00
IRAS16293        EQ 2000  16:32:22.6   -24:28:33
L1551-IR         EQ 2000  04:31:34.1    18:08:05
CRL618           EQ 2000  04:42:53.5    36:06:53
! OMC1             EQ 2000  05:35:14.3   -05:22:32
N2071IR          EQ 2000  05:47:04.8    00:21:47
G34.3            EQ 2000  18:53:18.5    01:14:58
CRL2688          EQ 2000  21:02:18.7    36:41:37
! NGC7027          EQ 2000  21:07:01.5    42:14:10
ASTRO>
```

output

script

catalog

- Define sources as in e.g. sepia345.cat
- Create a small macro like sepia345.astro
- Run your macro in Gildas “astro”



Summary

- Use the wobbler for heterodyne observations of compact sources < a few arc minutes.
- Use total power for heterodyne observations of extended sources and OTF's (remember to select a suitable OFF position).
- For high red-shift sources use the red-shifted frequency to get the right tuning frequency, instrument, and sideband e.g. Splatalogue https://splatalogue.online/
- For strong/multiple lines use the heterodyne setup tool to adjust the tuning to avoid line overlaps.
- Use realistic elevation and pwv for your time estimates.
- http://www.apex-telescope.org/ns/send-us-a-message/ or apex-astro@apex-telescope.org
- Apply and we'll help you sort out the observing setup and data reduction.