Pulsar Observing

2021 Winter Observer Training Workshop

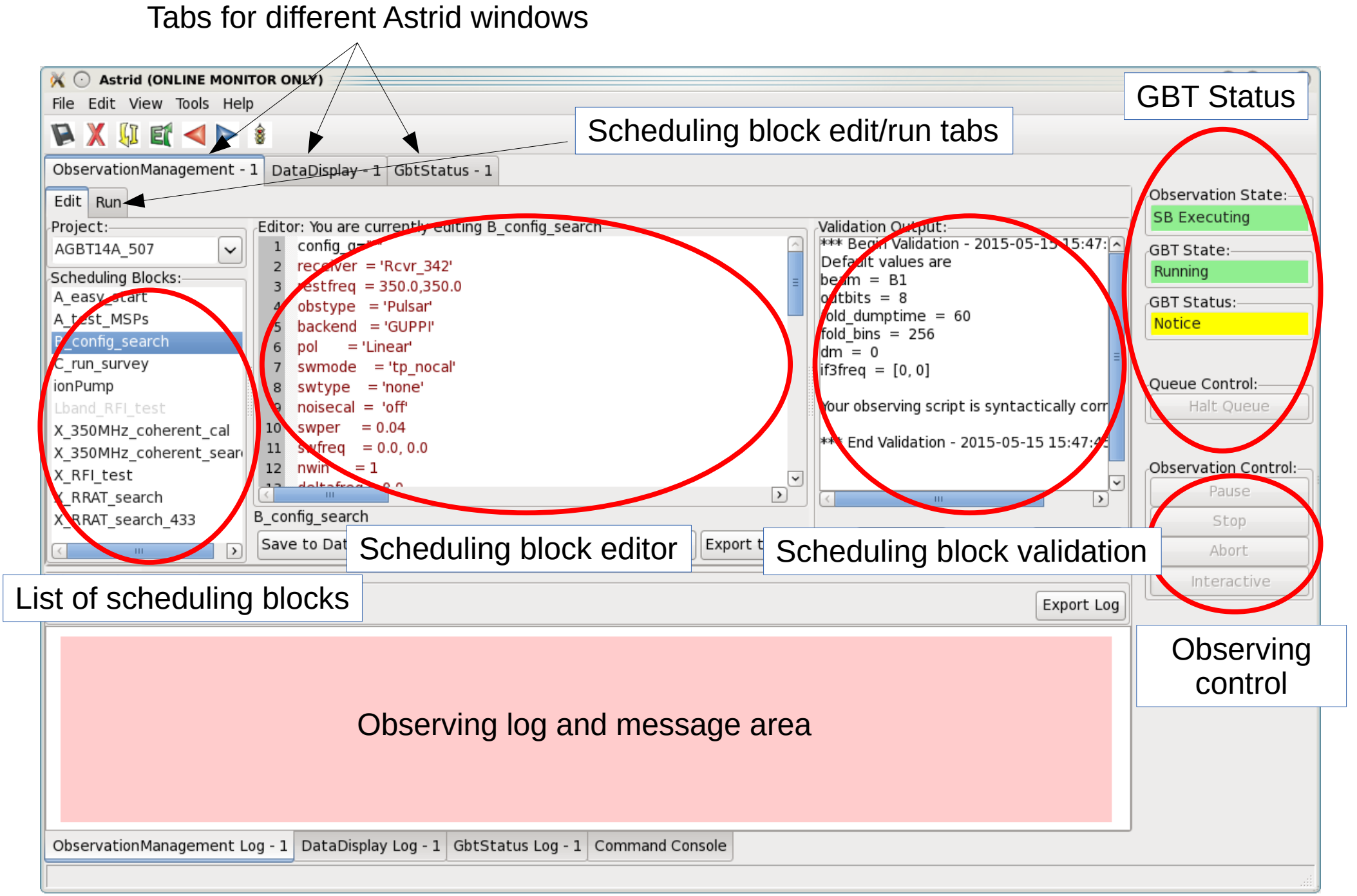
NSF

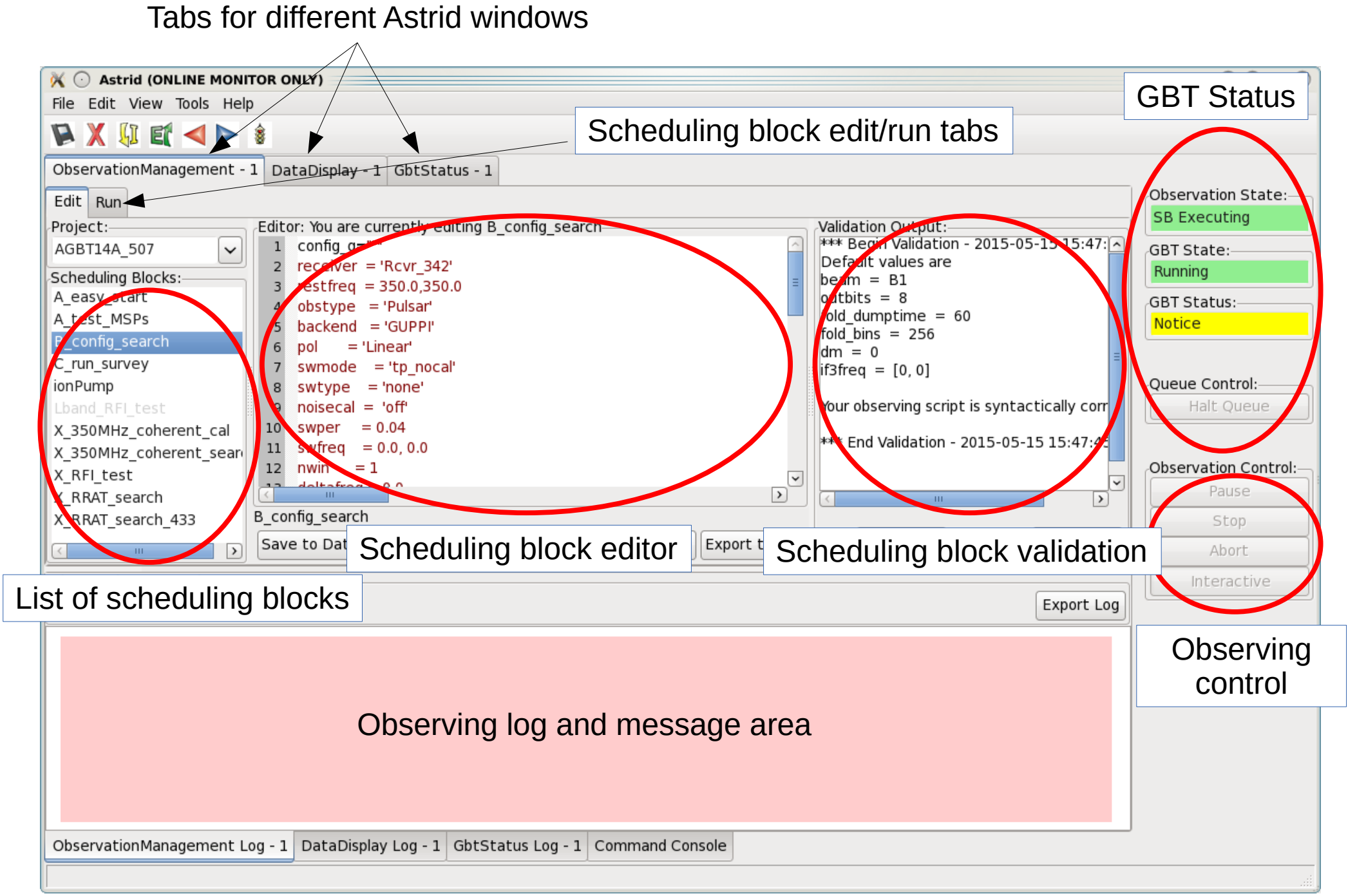
AUI

GREEN BANK OBSERVATORY

Some import terms...

- **Astrid**: *Astronomers Integrated Desktop*; Interface for controlling the GBT and monitoring observations
- **Scheduling Block**: A list of observing commands submitted through Astrid
- **Configuration/Config**: A special set of keywords and values that are used to setup the GBT for various types of observations
- **CLEO**: *Control Library for Operators and Engineers*; Useful tools + expert control of all GBT systems
- **Talk & Draw**: A CLEO chat tool


Tabs for different Astrid windows
Astrid (ONLINE MONITOR ONLY)
File Edit View Tools Help
ObservationManagement - 1
DataDisplay - 1
GbtStatus - 1
Scheduling block edit/run tabs
GBT Status
Edit
Run
Project:
AGBT14A_507
Scheduling Blocks:
A_easy_start
A_test_MSPs
B_config_search
C_run_survey
ionPump
Lband_RFI_test
X_350MHz_coherent_cal
X_350MHz_coherent_sear
X_RFI_test
X_RRAT_search
X_RRAT_search_433
Editor: You are currently editing B_config_search
config_g="
receiver = 'Rcvr_342'
restfreq = 350.0,350.0
obstype = 'Pulsar'
backend = 'GUPPI'
pol = 'Linear'
swmode = 'tp_nocal'
swtype = 'none'
noisecal = 'off'
swper = 0.04
swfreq = 0.0, 0.0
nwin = 1
B_config_search
Save to Dat
Export t
Validation Output:
*** Begin Validation - 2015-05-15 15:47:
Default values are
beam = B1
outbits = 8
fold_dumptime = 60
fold_bins = 256
dm = 0
if3freq = [0, 0]
Your observing script is syntactically corr
*** End Validation - 2015-05-15 15:47:4
Scheduling block editor
Scheduling block validation
List of scheduling blocks
Observation State:
SB Executing
GBT State:
Running
GBT Status:
Notice
Queue Control:
Halt Queue
Observation Control:
Pause
Stop
Abort
Interactive
Observing control
Export Log
Observing log and message area
ObservationManagement Log - 1
DataDisplay Log - 1
GbtStatus Log - 1
Command Console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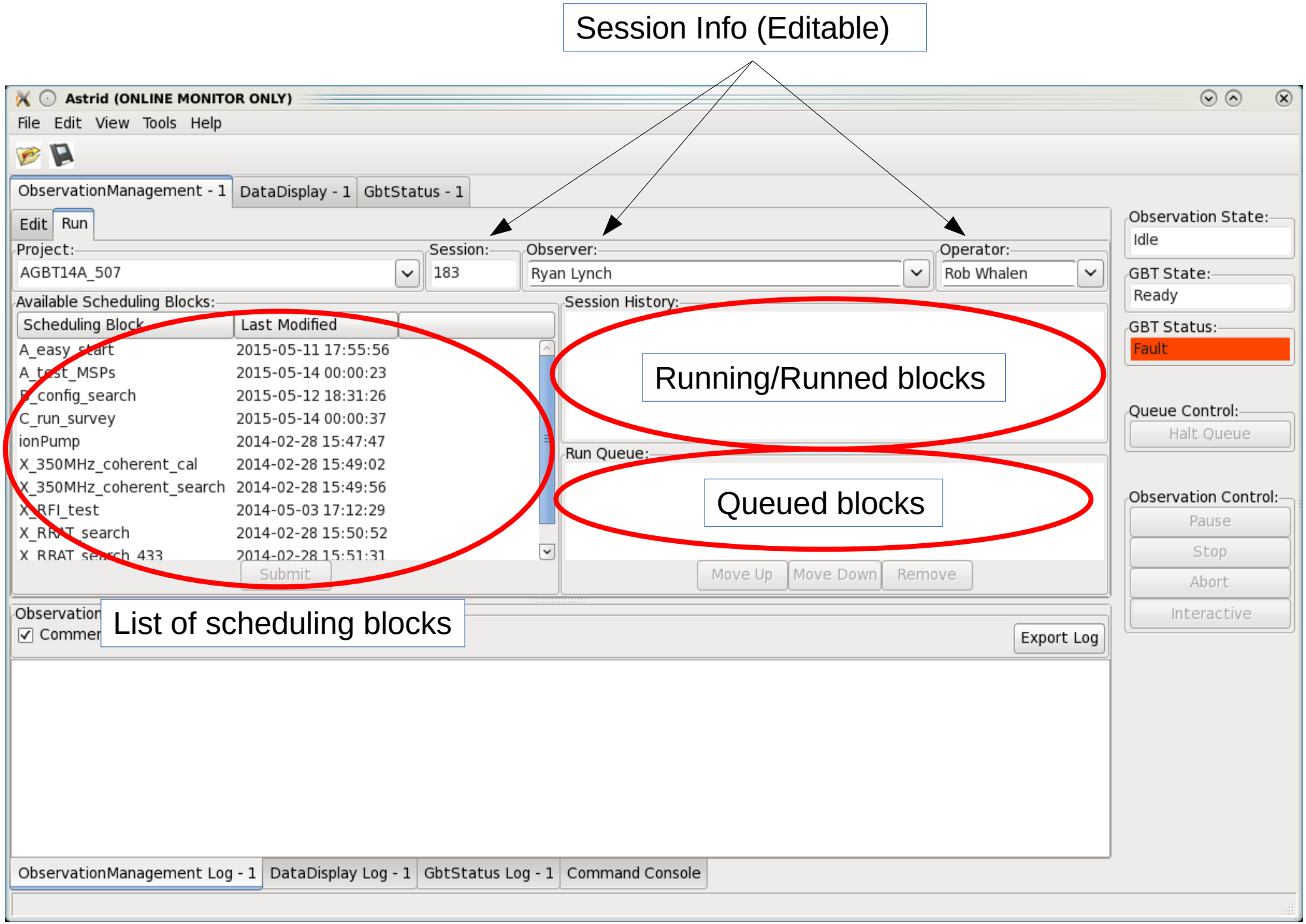
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Astrid (ONLINE MONITOR ONLY)
File Edit View Tools Help
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DataDisplay - 1
GbtStatus - 1
Edit
Run
Project:
AGBT14A_507
Session:
183
Observer:
Ryan Lynch
Operator:
Rob Whalen
Available Scheduling Blocks:
Scheduling Block
Last Modified
A_easy_start 2015-05-11 17:55:56
A_test_MSPs 2015-05-14 00:00:23
B_config_search 2015-05-12 18:31:26
C_run_survey 2015-05-14 00:00:37
ionPump 2014-02-28 15:47:47
X_350MHz_coherent_cal 2014-02-28 15:49:02
X_350MHz_coherent_search 2014-02-28 15:49:56
X_RFI_test 2014-05-03 17:12:29
X_RRAT_search 2014-02-28 15:50:52
X_RRAT_search_433 2014-02-28 15:51:31
Submit
Session History:
Running/Runned blocks
Run Queue:
Queued blocks
Move Up
Move Down
Remove
List of scheduling blocks
Observation
Commer
Export Log
Observation State:
Idle
GBT State:
Ready
GBT Status:
Fault
Queue Control:
Halt Queue
Observation Control:
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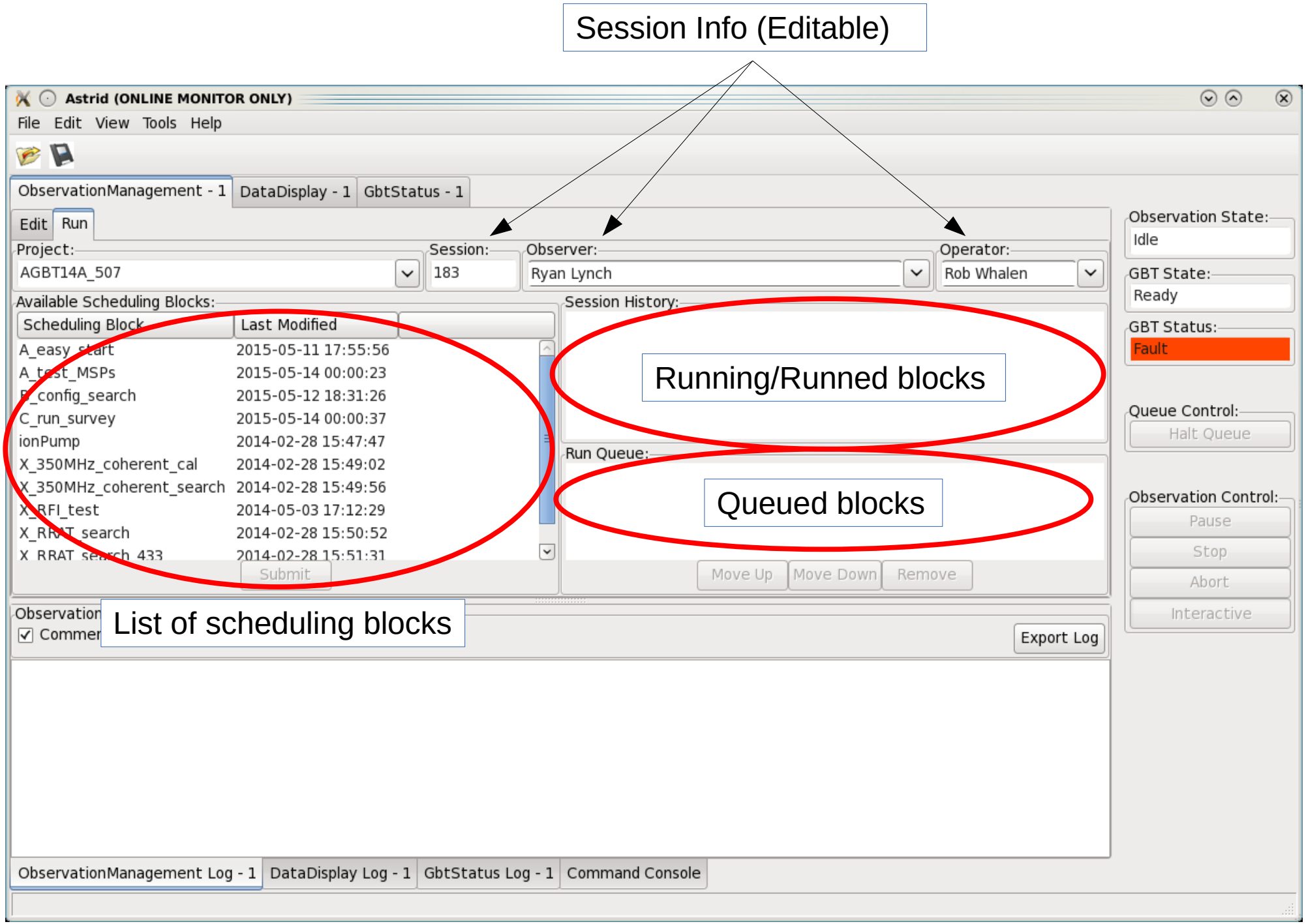
Abort
Interactive
ObservationManagement Log - 1
DataDisplay Log - 1
GbtStatus Log - 1
Command Console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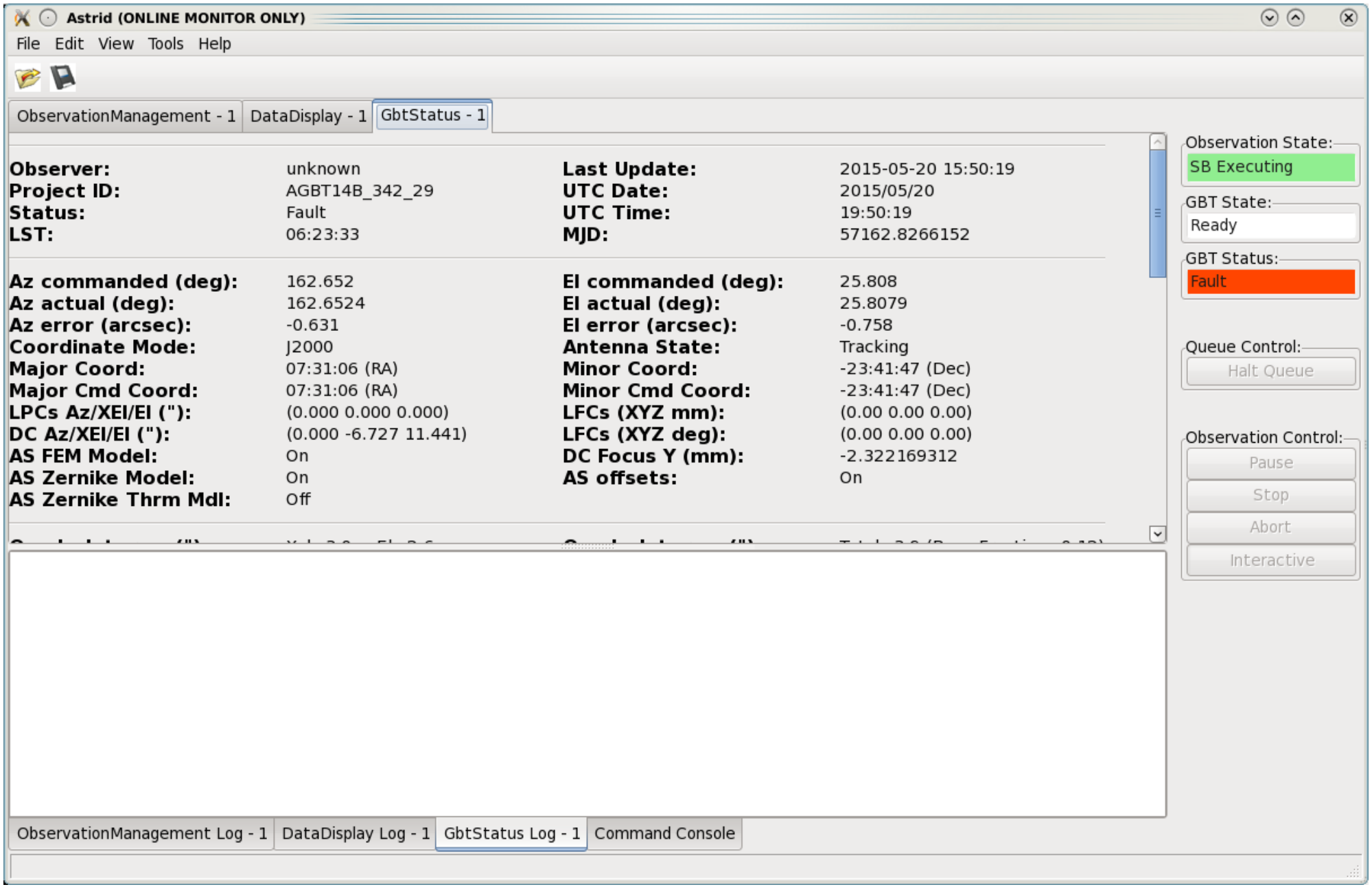
Astrid (ONLINE MONITOR ONLY)
File Edit View Tools Help
ObservationManagement - 1
DataDisplay - 1
GbtStatus - 1
Observer: unknown
Project ID: AGBT14B_342_29
Status: Fault
LST: 06:23:33
Last Update: 2015-05-20 15:50:19
UTC Date: 2015/05/20
UTC Time: 19:50:19
MJD: 57162.8266152
Az commanded (deg): 162.652
Az actual (deg): 162.6524
Az error (arcsec): -0.631
Coordinate Mode: J2000
Major Coord: 07:31:06 (RA)
Major Cmd Coord: 07:31:06 (RA)
LPCs Az/XEl/El ("): (0.000 0.000 0.000)
DC Az/XEl/El ("): (0.000 -6.727 11.441)
AS FEM Model: On
AS Zernike Model: On
AS Zernike Thrm Mdl: Off
El commanded (deg): 25.808
El actual (deg): 25.8079
El error (arcsec): -0.758
Antenna State: Tracking
Minor Coord: -23:41:47 (Dec)
Minor Cmd Coord: -23:41:47 (Dec)
LFCs (XYZ mm): (0.00 0.00 0.00)
LFCs (XYZ deg): (0.00 0.00 0.00)
DC Focus Y (mm): -2.322169312
AS offsets: On
Observation State:
SB Executing
GBT State:
Ready
GBT Status:
Fault
Queue Control:
Halt Queue
Observation Control:
Pause
Stop
Abort
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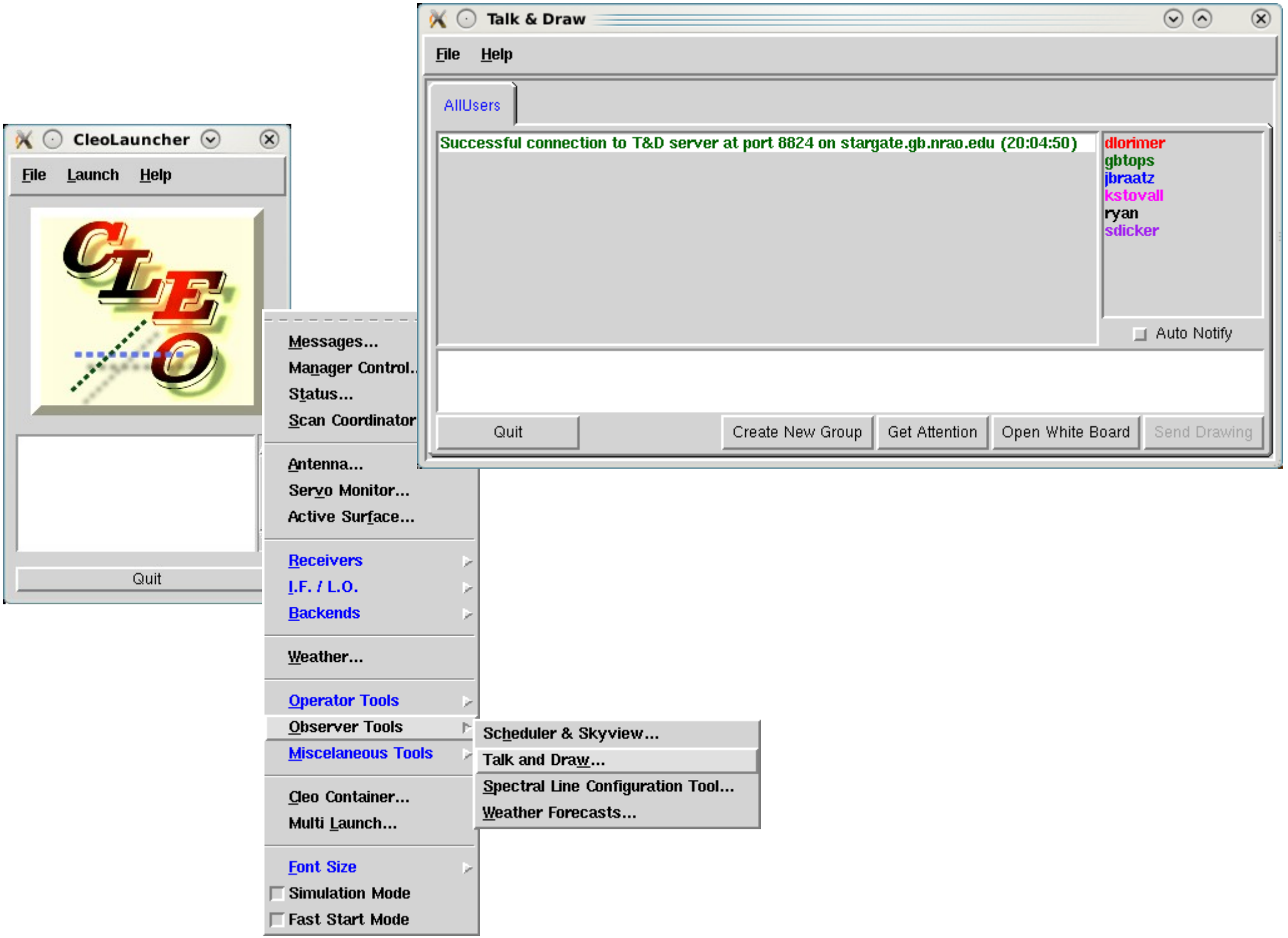

Talk & Draw
File
Help
AllUsers
Successful connection to T&D server at port 8824 on stargate.gb.nrao.edu (20:04:50)
dlorimer
gbtops
jbraatz
kstovall
ryan
sdicker
Auto Notify
Quit
Create New Group
Get Attention
Open White Board
Send Drawing
CleoLauncher
File
Launch
Help
Quit
Messages...
Manager Control...
Status...
Scan Coordinator
Antenna...
Servo Monitor...
Active Surface...
Receivers
I.F. / L.O.
Backends
Weather...
Operator Tools
Observer Tools
Miscelaneous Tools
Cleo Container...
Multi Launch...
Font Size
Simulation Mode
Fast Start Mode
Scheduler & Skyview...
Talk and Draw...
Spectral Line Configuration Tool...
Weather Forecasts...

- Key parts of scheduling block are
  - Catalog(<catalog>): Loads a list of sources
  - Slew(source): Moves the telescope to a source
  - config: Defines backend and IF/LO parameters
  - Configure(config): Executes config instructions
  - Balance: Adjusts power levels to optimal range
  - Observing Directive
- There are *lots* of Astrid commands, and you can use python to make fairly complicated scripts
  - When in doubt, try Catalog(pulsars_all_GBT)
  - Note that this catalog may not be up-to-date with the brand new pulsars
- Let’s look at the config portion more carefully…

receiver = 'Rcvr1_2'

restfreq = 1500.0

obstype = 'Pulsar'

backend = 'VEGAS'

pol = 'Linear'

swmode = 'tp_nocal'

swtype = 'none'

noisecal = 'off'

swper = 0.04

swfreq = 0.0

nwin = 1

deltafreq = 0

ifbw = 0

bandwidth = 800

tint = 81.92e-6

vlow = 0

vhigh = 0

vframe = 'topo'

vdef = 'Radio'

vegas.obsmode = 'search'

vegas.numchan = 2048

vegas.polnmode = 'full_stokes'

vegas.scale = 10000

vegas.outbits = 8

vegas.fold_dumptime = 10

vegas.fold_bins = 256

vegas.fold_parfile = “/users/rlynch/myparfile.par”

vegas.dm = 50

- swmode: Switching mode (‘tp’ or ‘tp_nocal’)
- swtype: Only used for frequency switching
- noisecal: Controls noise diode (‘lo’ or ‘hi’ or ‘off’)
- swper: Switching period (always 0.04 [25 Hz] for pulsar observing)
- swfreq : Only used for frequency switching
- nwin: Number of spectral windows (usually 1 for pulsar observing)
- deltafreq: Offset of spectral windows (always 0 for pulsar observing)
- ifbw: BW of filter in IF rack (80 for 100 MHz total bandwidth, otherwise 0)

- vegas.obsmode
  - fold, cal, search, coherent_{fold,cal,search}
- vegas.numchan
  - 2^n, n = 6…11 (64…4096 [8192])
  - Max depends on bandwidth
- vegas.polnmode
  - full_stokes or total_intensity
- vegas.scale
  - Varies with setup, but fairly stable
- vegas.outbits
  - Always 8

- vegas.fold_dumptime
  - Typically 10
- vegas.fold_bins
  - Typically 256, higher for coherent modes
- vegas.fold_parfile
  - Always make sure this is correct!!
- vegas.dm = 50
  - Specific to coherent_search

A word on tint

tint = acc_len * vegas.numchan/bandwidth

- acc_len is a hardware parameter not directly set by the user
  - acc_len > 4 for 100 and 200 MHz modes
  - acc_len > 16 for 800 MHz mode
  - acc_len < 100 recommended

- Write a simple observing script to observe B1937+21 in search mode for 30 minutes
  - 2048 channels, 40.96 us time resolution, total intensity, 800 MHz bandwidth
  - L-Band receiver
  - Center frequency of 1500 MHz
- Ask yourself
  - How will Astrid know the location of the source?
  - How do things need to be configured?
  - Is the system balanced?
  - How do I tell Astrid to start taking data?
- You may reference
  https://safe.nrao.edu/wiki/bin/view/CICADA/VegasPulsarObservingInstructions#Example_Configurations

Catalog(<path on disk>)

config_string = ‘’’’’
receiver = ‘Rcvr1_2’
…
’’’’’

Configure(config_string)

Slew(<source name>)

Balance()

Track(<source name>, None, 1800)

```
head=name ra                  dec
0034+69   00:33:13.03200000   +69:43:45.4800000
0510+38   05:09:31.78854365   +38:01:18.0575238
0636+51   06:36:04.84542630   +51:28:59.9831111
0742+66   07:40:45.79660905   +66:20:33.5892639
1124+78   11:25:59.83760878   +78:19:48.7496278
1649+80   16:41:20.84202477   +80:49:52.9304759
1816+45   18:16:35.93390826   +45:10:33.8680587
1939+66   19:38:56.91758504   +66:04:31.7513018
1309-23   13:09:27.42463533   -23:33:25.1647258
```

```
format=spherical
coordmode=J2000
head = name  jname         alias      ra             dec              S1400_Jy
# Flux calibration sources from PSRCHIVE fluxcal.cfg
1413+1509    J1413+1509    1413+15    14:13:41.660   +15:09:39.524    0.525662
3C48         J0137+3309    0137+33    01:37:41.300   +33:09:35.13     16.2554
3C123        J0437+2940    0437+29    04:37:04.375   +29:40:13.82     48.3292
J0444-2809   J0444-2809    0444-28    04:44:37.708   -28:09:54.403    6.88461
J0519-4546   J0519-4546    PicA       05:19:49.723   -45:46:43.855    67.1838
3C138        J0521+1638    0521+16    05:21:09.900   +16:38:22.12     8.56402
3C147        J0542+4951    0542+49    05:42:36.127   +49:51:07.23     22.1705
3C196        J0813+4813    0813+48    08:13:36.056   +48:13:02.64     14.4286
3C218        J0918-1205    HydA       09:18:05.669   -12:05:43.95     44.0132
3C274        J1230+1223    M87        12:30:49.423   +12:23:28.04     212.310
3C286        J1331+3030    1331+30    13:31:08.284   +30:30:32.94     15.0838
3C295        J1411+5212    1411+52    14:11:20.647   +52:12:09.04     22.4993
3C348        J1651+0459    HerA       16:51:08.024   +04:59:34.91     47.6466
3C353        J1720-0058    1720-00    17:20:28.150   -00:58:46.80     57.4059
3C380        J1829+4844    1829+48    18:29:31.781   +48:44:46.159    13.142
3C405        J1959+4044    CygA       19:59:28.357   +40:44:02.097    1579.96
3C444        J22214-1701   2214-17    22:14:25.752   -17:01:36.290    9.07134
3C190        J0801+1414    0801+14    08:01:33.52    +14:14:42.2      2.46364
1445+0958    J1445+0958    1442+101   14:45:16.440   +09:58:35.040    2.35757
3C43         J0129+2338    0129+23    01:29:59.79    +23:38:19.4      2.83034
3C394        J1859+1259    1859+129   18:59:23.3     +12:59:12        2.88127
B2209+080    J2212+0819    2212+08    22:12:01.5685  +08:19:15.5868   1.70936
NGC7027      J2107+4214    2107+42    21:07:01.530   +42:14:11.500    1.43339
```

- How do we calibrate pulsar data?
  - Raw data are recorded in units of “counts”, which change depending on how the system is balanced
  - We want physical units (Jansky)

1) Observe a standard source of known flux density
2) Use this to measure the strength of the GBT noise diode
3) Balance the system at the position of the pulsar and observe the noise diode
4) Observe the pulsar **without rebalancing**, and use the noise diode to calibrate the pulsar data

- Write a simple observing script to observe J1713+0747 using coherent fold mode for 20 minutes
  - 512 channels, 800 MHz bandwidth, (what is tint?)
  - Include all the necessary steps to fully **calibrate** the data
- You may reference

  https://safe.nrao.edu/wiki/bin/view/CICADA/VegasPulsarObservingInstructions#Example_Configurations

- Scheduling blocks use Python!

```
sources = [“B1937+21”, “J1713+0747”]
for src in sources:
  Slew(src)
  Balance()
  Track(src, None, 20*60)
```

```
for src in sources:
   config = """
   ...
   vegas.fold_parfile = "/home/gpu/tzpar/{src}.par"
   ...
   """.format(src=src)


srcdict = {
   "B1937+21":{"DM":50,"parfile":"mypar"},
   "J1713+0747":{"DM":100,"parfile":"mypar2"}}
for src in srcdict:
   config = """
   ...
   vegas.fold_parfile = {parfile}
   ...
   """.format(parfile=src["parfile"])
```

- Astrid has a number of useful convenience functions and options
  - Track() can take startTime and stopTime instead of scan length
  - Horizon() objects can be used to define times based on a source's elevation (.e.g., start observing when a source rises or stop when it sets)
  - OnOff() is useful for flux calibration scans
    - Observe an On source and Off source position automatically
  - AutoPeakFocus() necessary at high frequencies (roughly C-band and above)

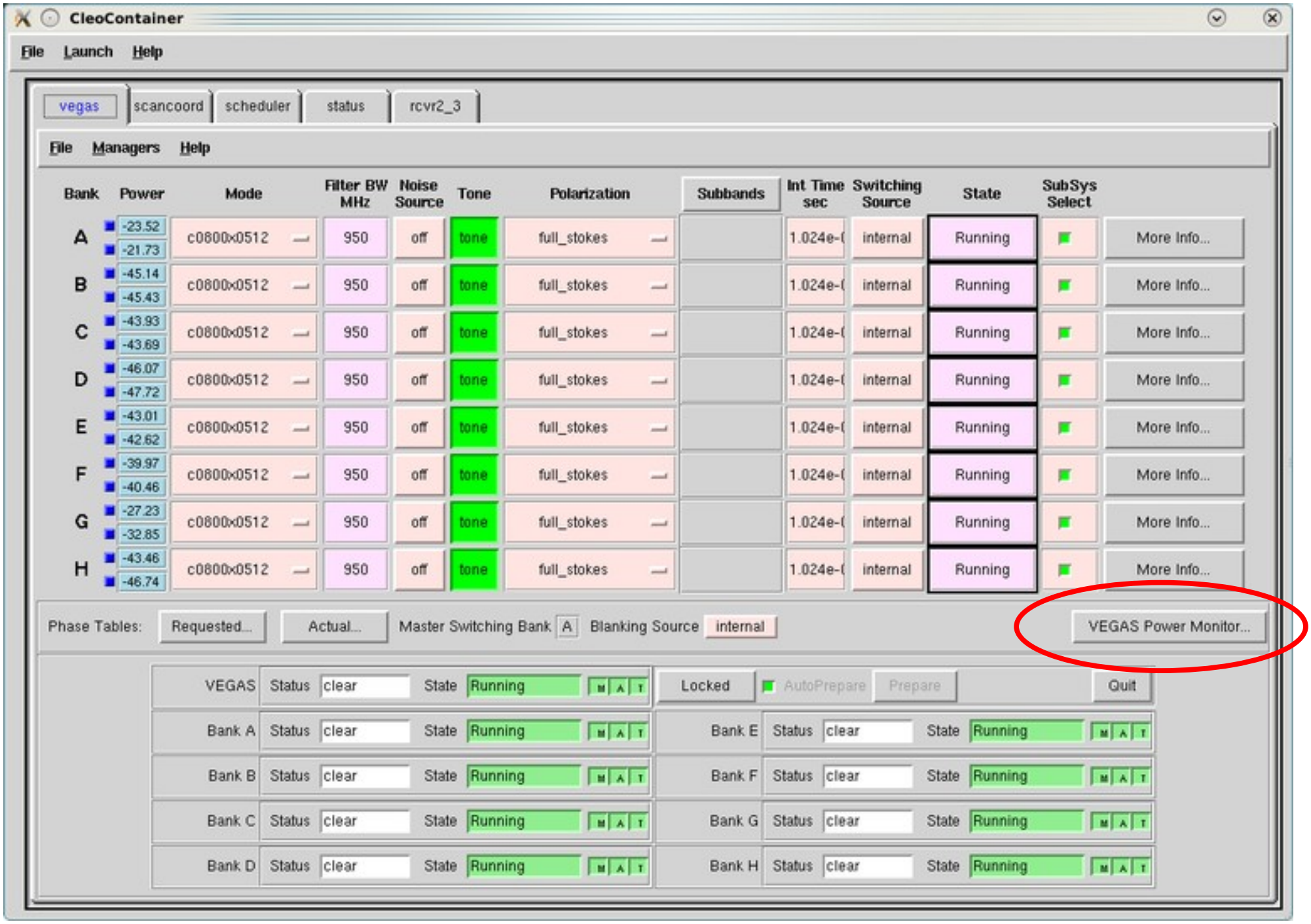
- Track(src, None, 3600)
- Track(src, None, 3600, startTime=”15:15:00”)
- Track(src, None, startTime=”15:15:00”, stopTime=”16:15:00”)

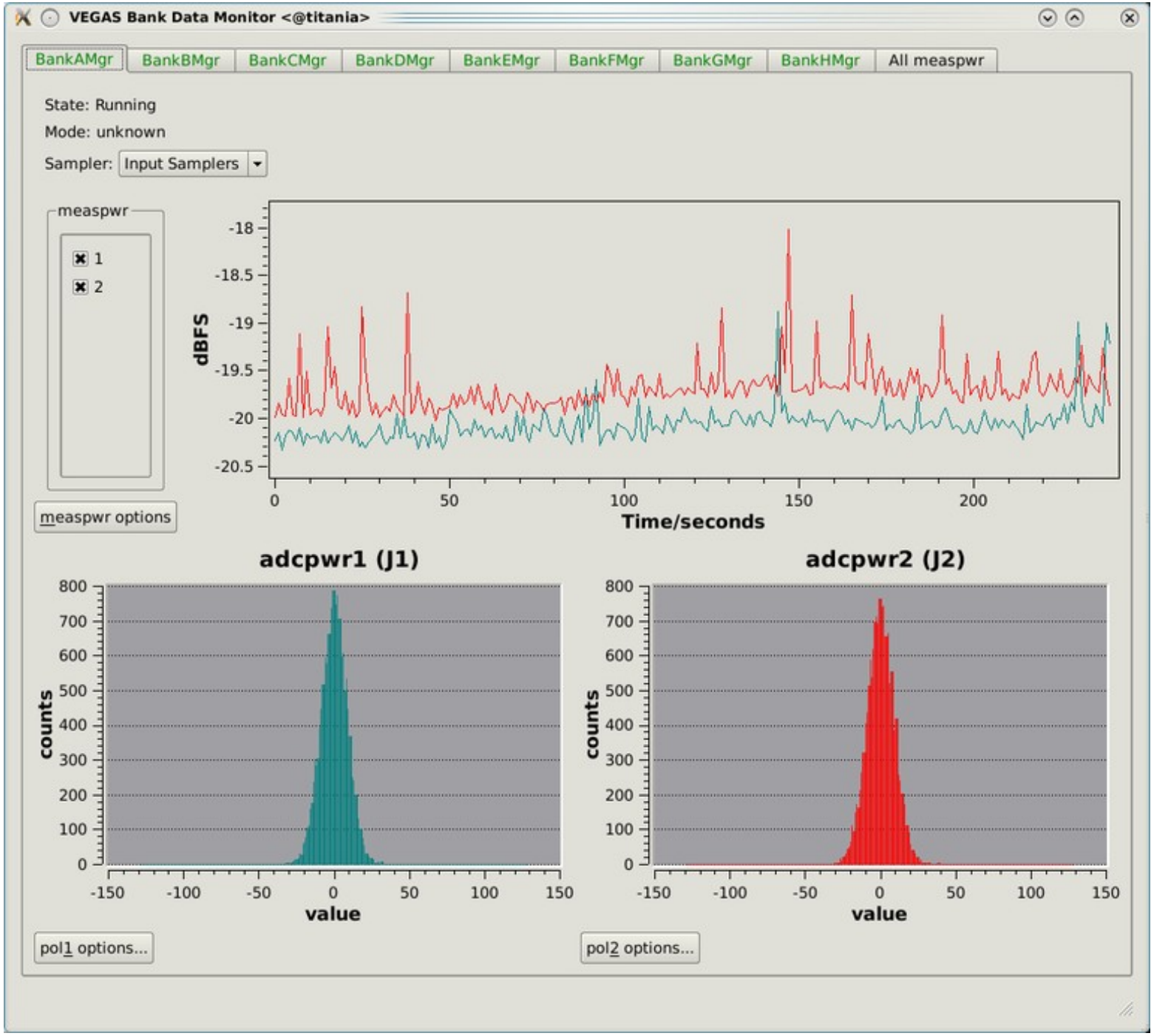
- myhorizon = Horizon(6.0)
  - Track(src, None, stopTime=myhorizon)
  - Track(src, None, startTime=”15:15:00”, stopTime=myhorizon)

- OnOff(“3C48”, Offset(0,1,cosv=False), 90)

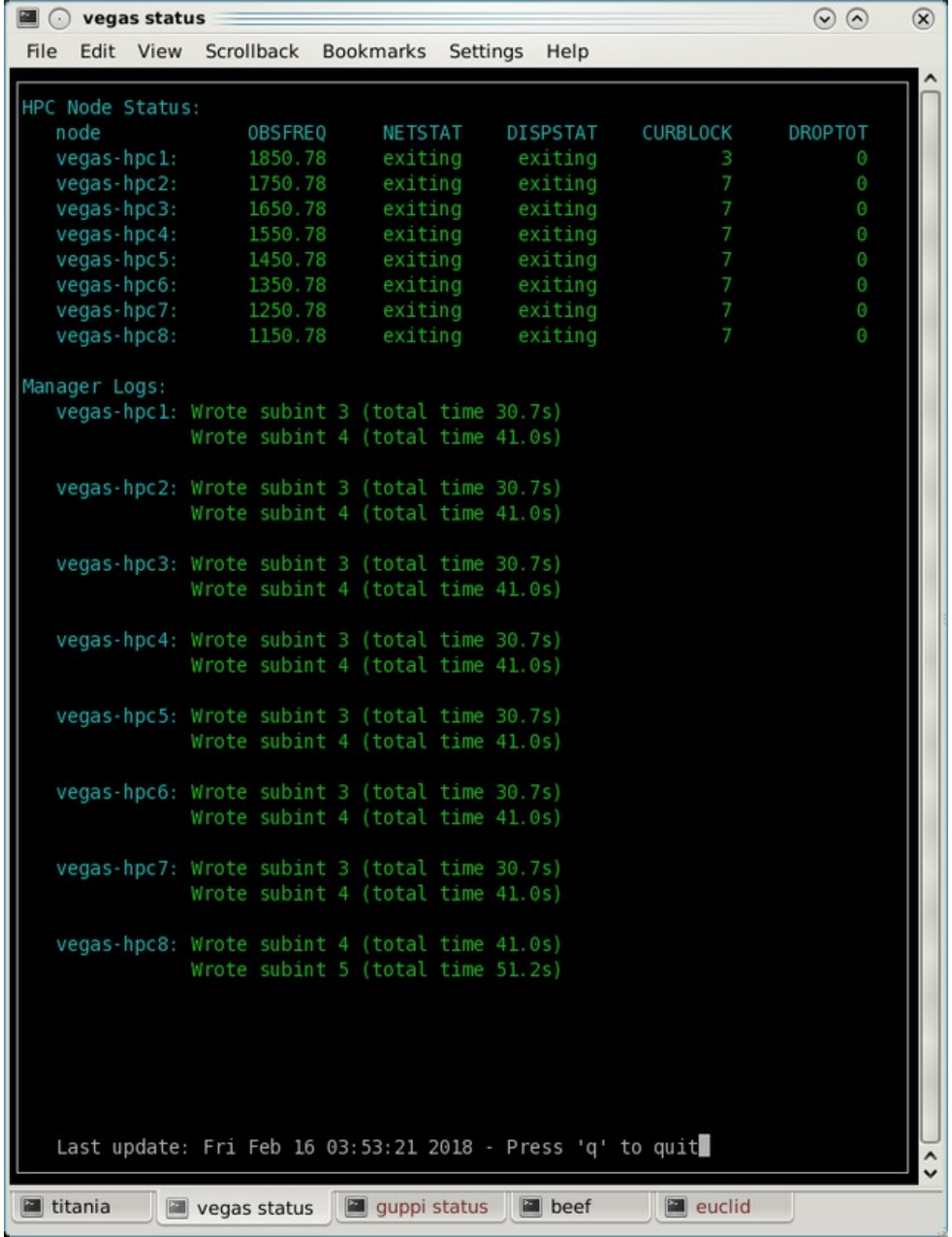
- Write an observing script that will loop over B1937+21, J1713+0737, and J1124+78
  - Perform a cal scan and online folding scan on each using coherent modes
  - You may specify the parfile in any way you choose
  - Do a 90 second cal scan and a 20 minute pulsar scan

- VEGAS is controlled through the GBT but there are standalone tools used to monitor observations
- Some are always used, some are specific to coherent and incoherent modes


CleoContainer
File Launch Help
vegas scancoord scheduler status rcvr2_3
File Managers Help
Bank Power Mode Filter BW MHz Noise Source Tone Polarization Subbands Int Time sec Switching Source State SubSys Select
A -23.52 -21.73 c0800x0512 950 off tone full_stokes 1.024e-(internal Running More Info...
B -45.14 -45.43 c0800x0512 950 off tone full_stokes 1.024e-(internal Running More Info...
C -43.93 -43.69 c0800x0512 950 off tone full_stokes 1.024e-(internal Running More Info...
D -46.07 -47.72 c0800x0512 950 off tone full_stokes 1.024e-(internal Running More Info...
E -43.01 -42.62 c0800x0512 950 off tone full_stokes 1.024e-(internal Running More Info...
F -39.97 -40.46 c0800x0512 950 off tone full_stokes 1.024e-(internal Running More Info...
G -27.23 -32.85 c0800x0512 950 off tone full_stokes 1.024e-(internal Running More Info...
H -43.46 -46.74 c0800x0512 950 off tone full_stokes 1.024e-(internal Running More Info...
Phase Tables: Requested... Actual... Master Switching Bank A Blanking Source internal
VEGAS Power Monitor...
VEGAS Status clear State Running M A T
Locked AutoPrepare Prepare Quit
Bank A Status clear State Running M A T
Bank B Status clear State Running M A T
Bank C Status clear State Running M A T
Bank D Status clear State Running M A T
Bank E Status clear State Running M A T
Bank F Status clear State Running M A T
Bank G Status clear State Running M A T
Bank H Status clear State Running M A T


VEGAS Bank Data Monitor <@titania>
BankAMgr
BankBMgr
BankCMgr
BankDMgr
BankEMgr
BankFMgr
BankGMgr
BankHMgr
All measpwr
State: Running
Mode: unknown
Sampler: Input Samplers
measpwr
1
2
measpwr options
dBFS
-18
-18.5
-19
-19.5
-20
-20.5
0
50
100
150
200
Time/seconds
adcpwr1 (J1)
counts
800
700
600
500
400
300
200
100
0
-150
-100
-50
0
50
100
150
value
pol1 options...
adcpwr2 (J2)
counts
value
pol2 options...

- Launched by typing `vpmStatus`
- Must logged be `vegas-hpc1` (or `vegas-hpc2`, `vegas-hpc3...`)



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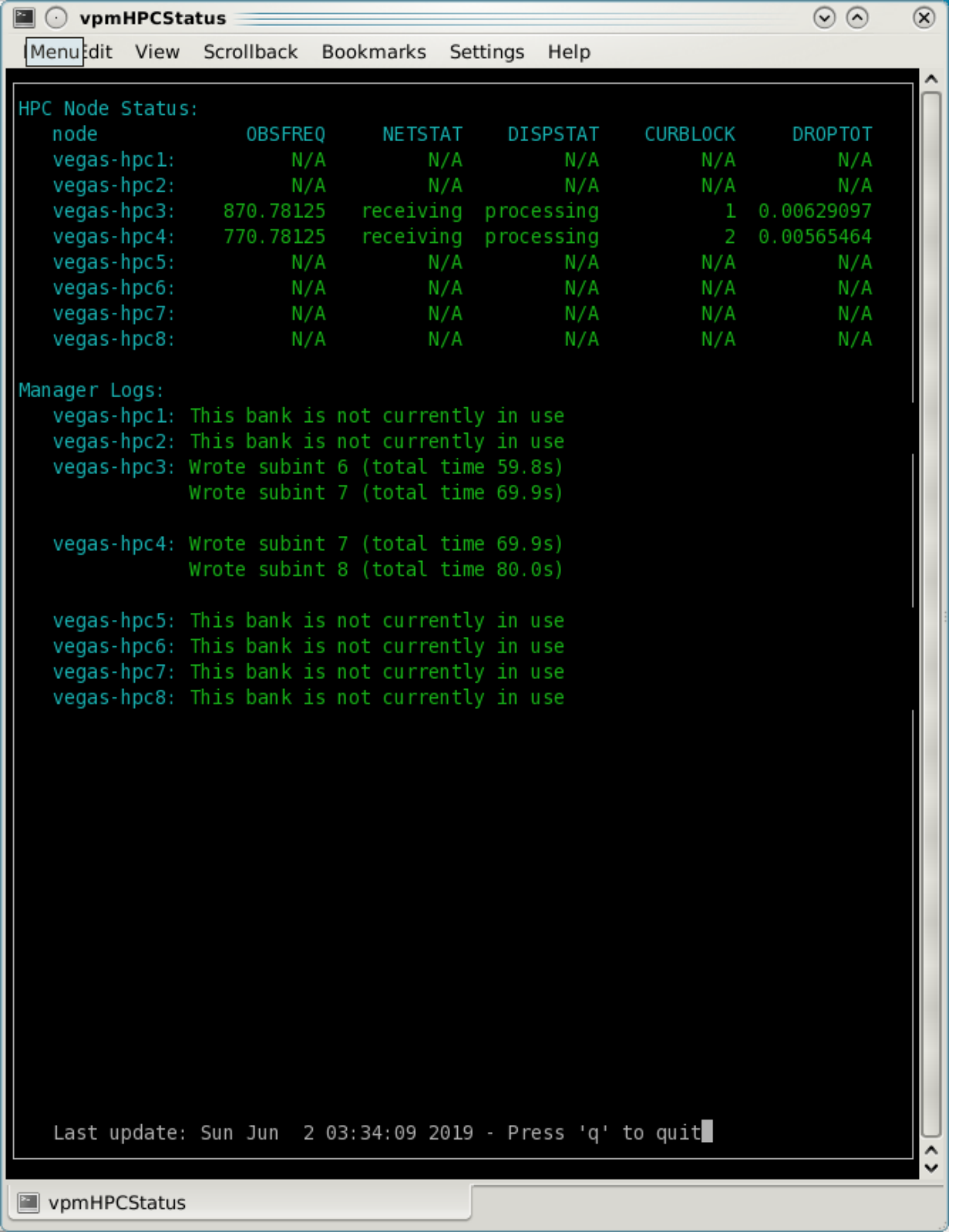
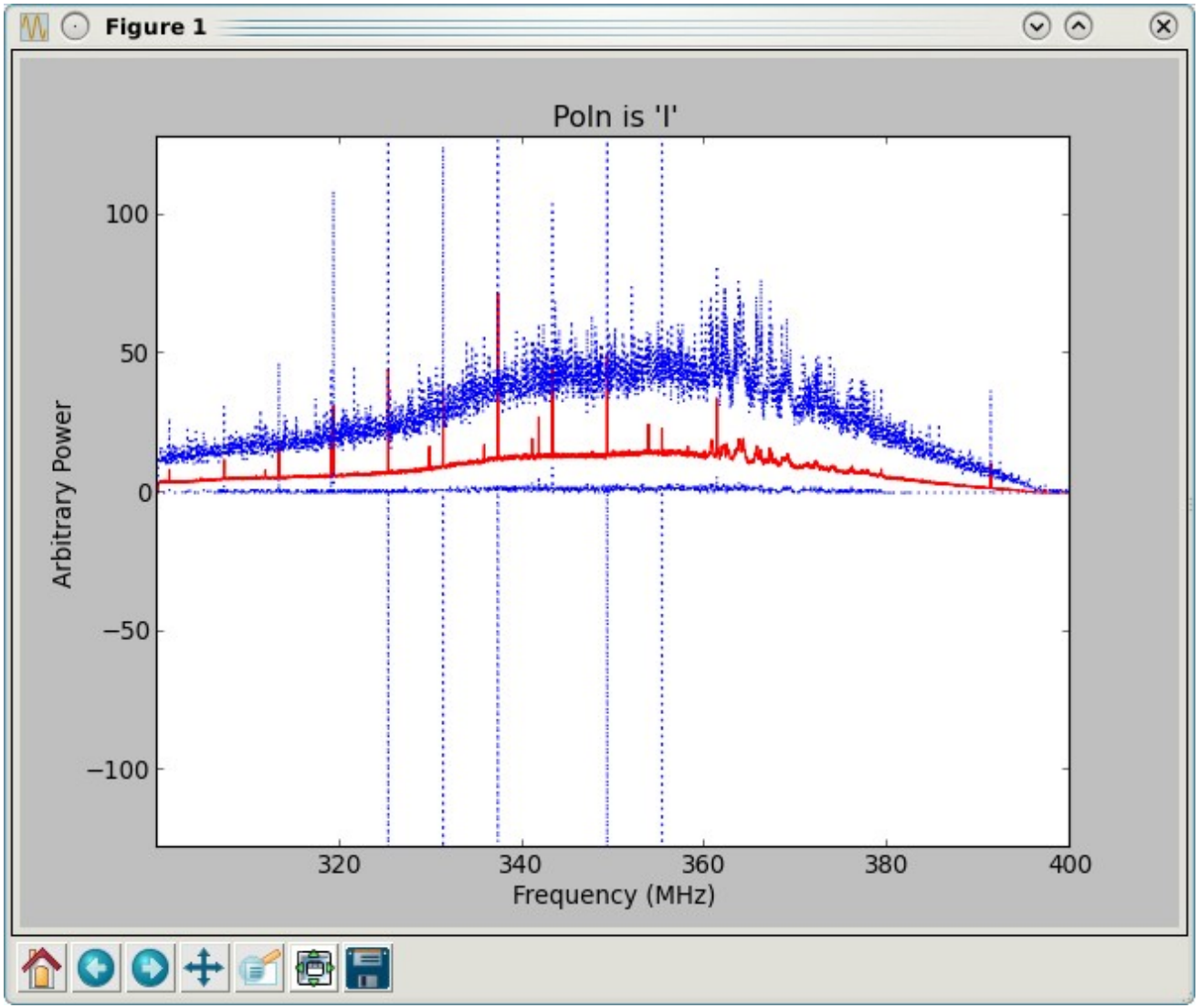
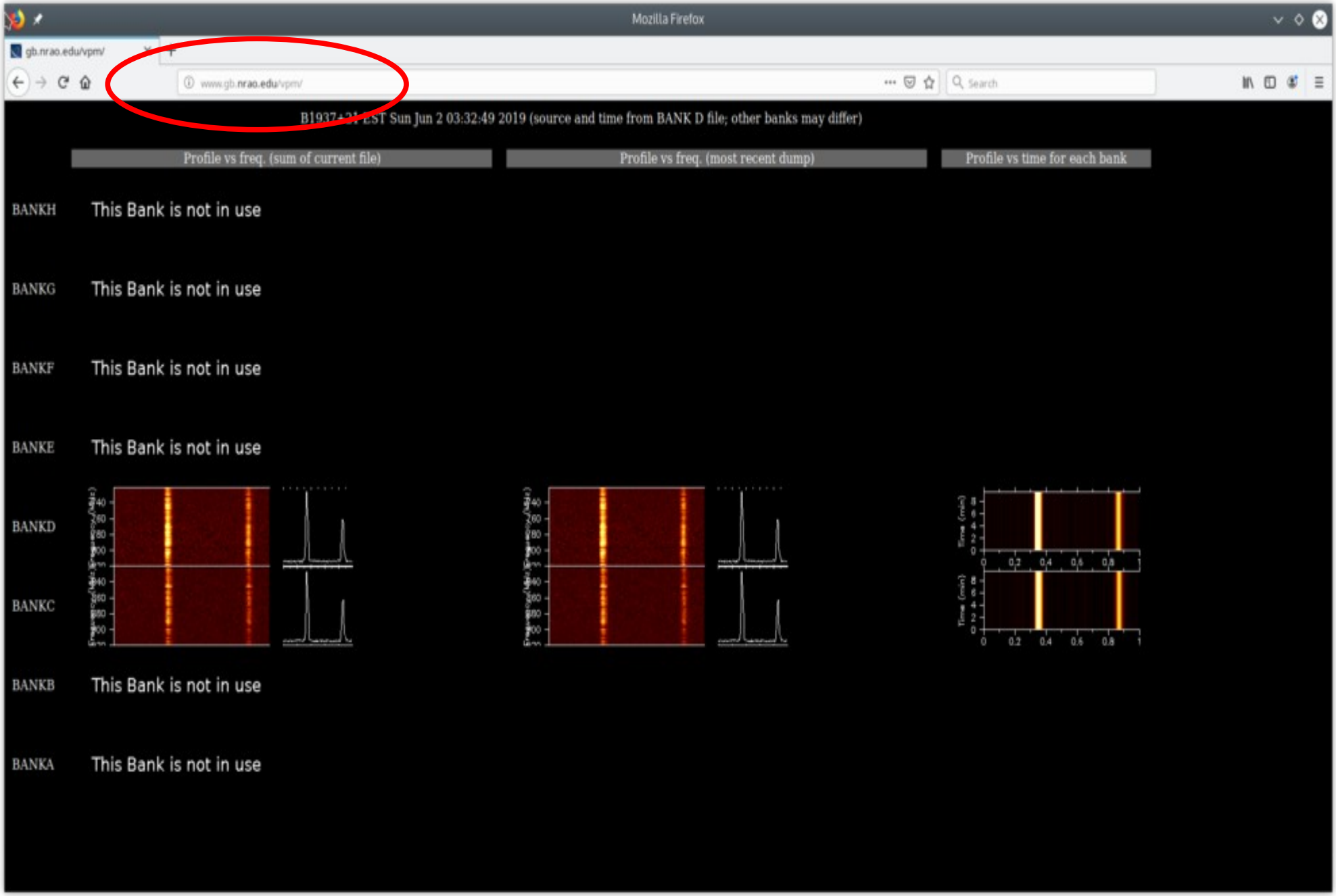


- Launched by typing `vpmHPCStatus`



- Launched by typing `vpmMonitor` while data is flowing or by visiting www.gb.nrao.edu/vpm/vpm_monitor



www.gb.nrao.edu/vpm

- Final task: Write an observing script to observe some pulsars tonight, using incoherent search mode
  - Limit yourself to L-Band for tonight
  - You may choose sources, but they can’t be part of an active project
  - Include a cal scan
  - You can be as pythonic as you want, or you can hard code things by hand
- When you are done, ask me to check your work