



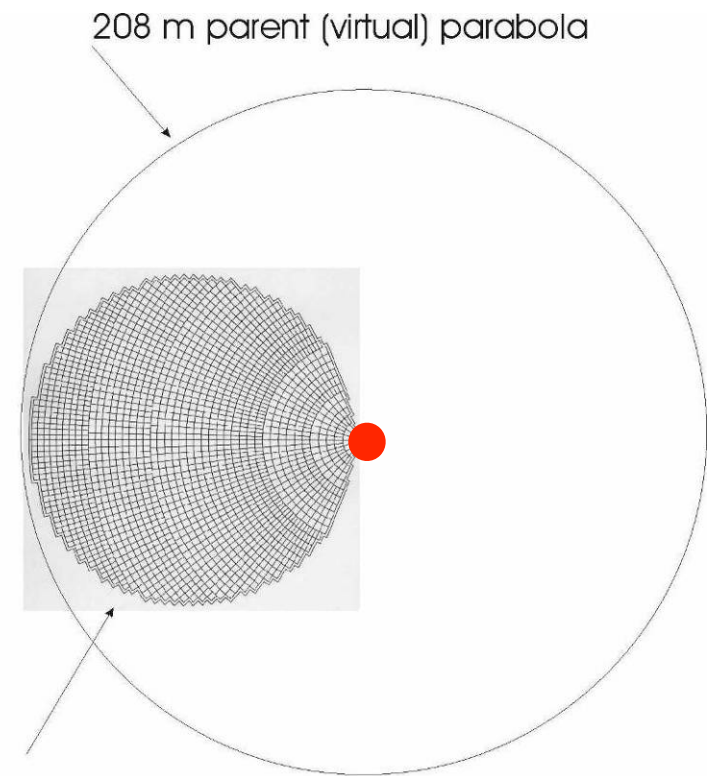
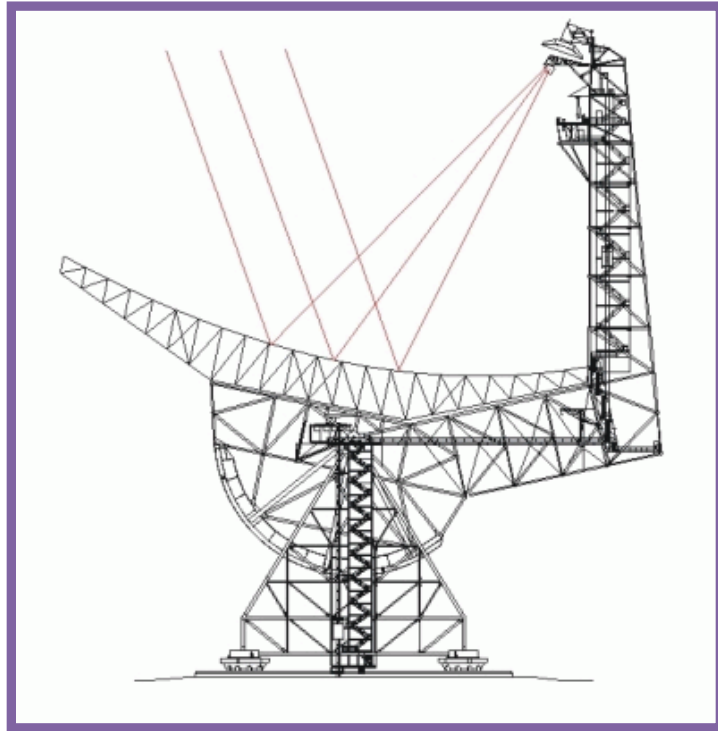
# High Frequency GBT Corrections

Emily Moravec (GBO Postdoc)



# GBT Telescope Optics

- 110m x 100m of a 208m parent paraboloid
  - Effective diameter: 100 m (high sensitivity)
  - Off axis - Clear/Unblocked Aperture (low sidelobes, high dynamic range imaging)



GBT 100 x 110 m Parabola Section

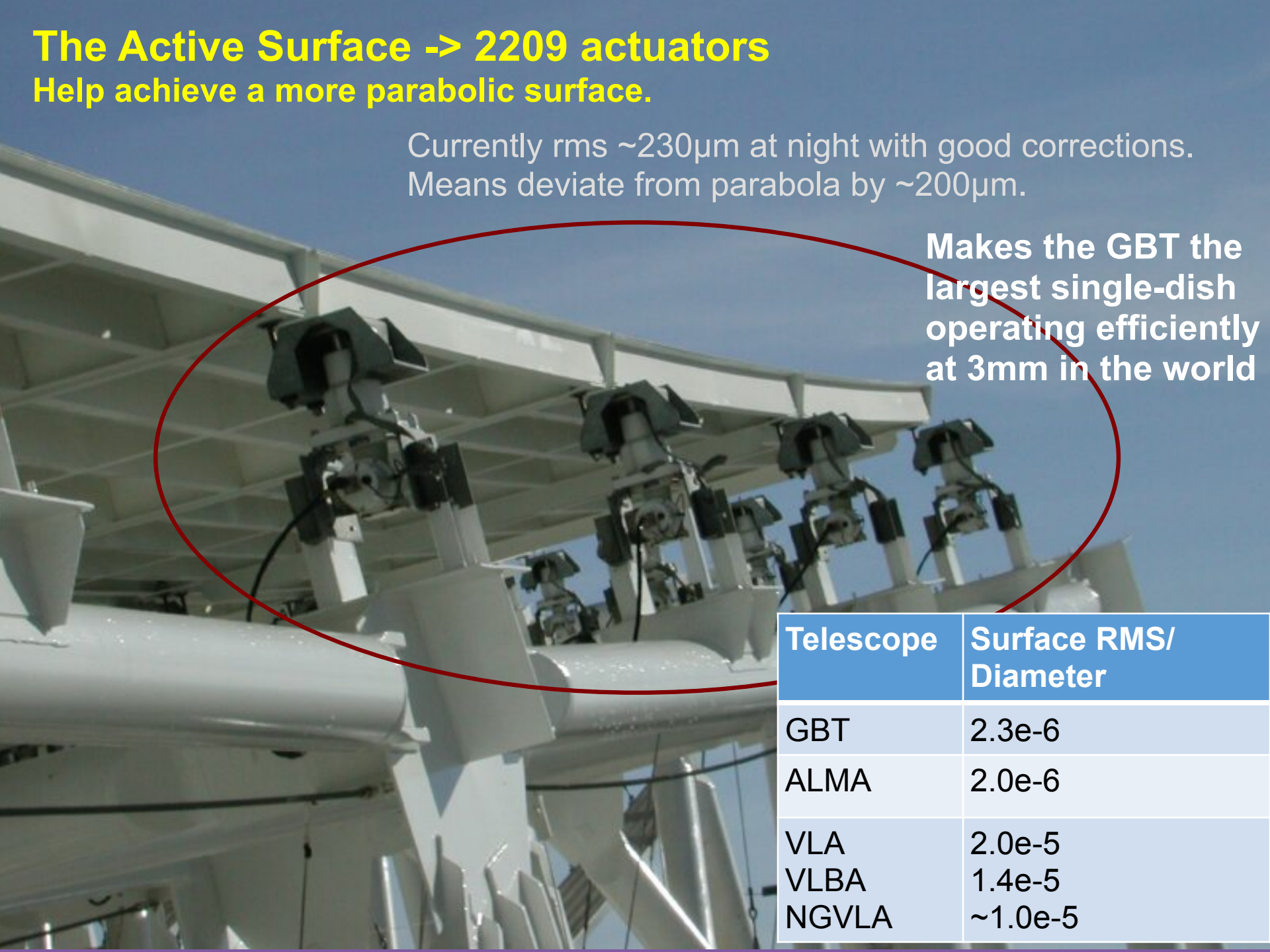


# The Active Surface -> 2209 actuators

## Help achieve a more parabolic surface.

Currently rms  $\sim 230\mu\text{m}$  at night with good corrections.  
Means deviate from parabola by  $\sim 200\mu\text{m}$ .

Makes the GBT the  
largest single-dish  
operating efficiently  
at 3mm in the world



Telescope	Surface RMS/ Diameter
GBT	2.3e-6
ALMA	2.0e-6
VLA	2.0e-5
VLBA	1.4e-5
NGVLA	$\sim 1.0\text{e-}5$

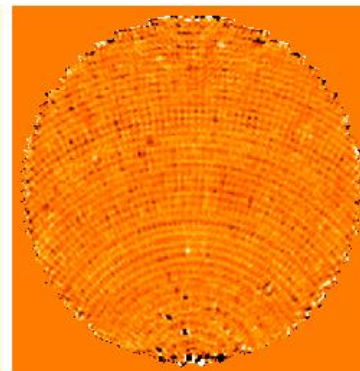
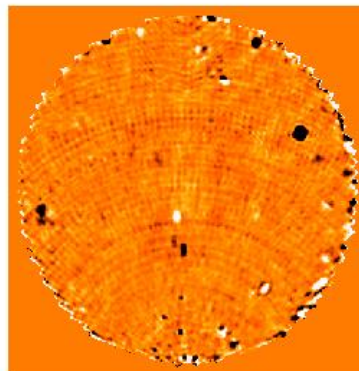
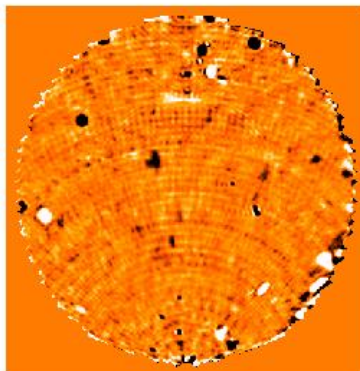
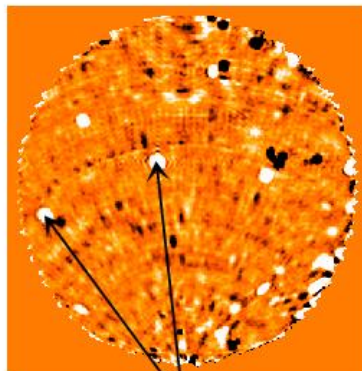
# Improvements to Active Surface in 2009

January 2009

February 2009

March 2009

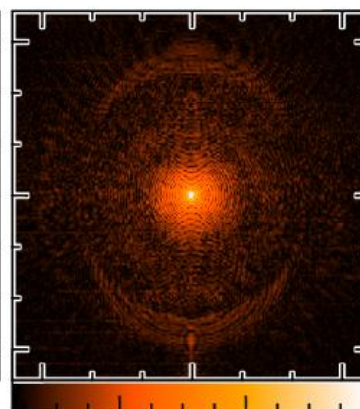
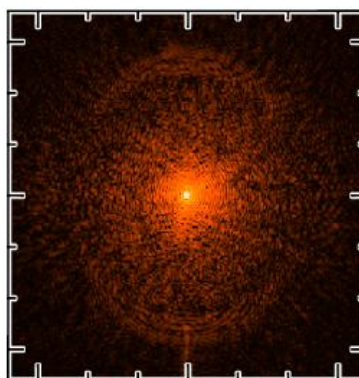
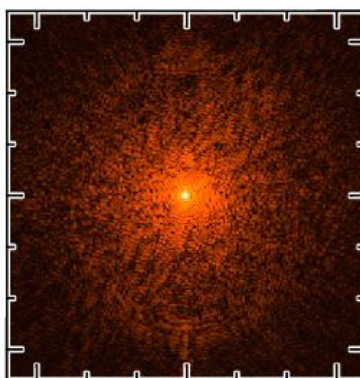
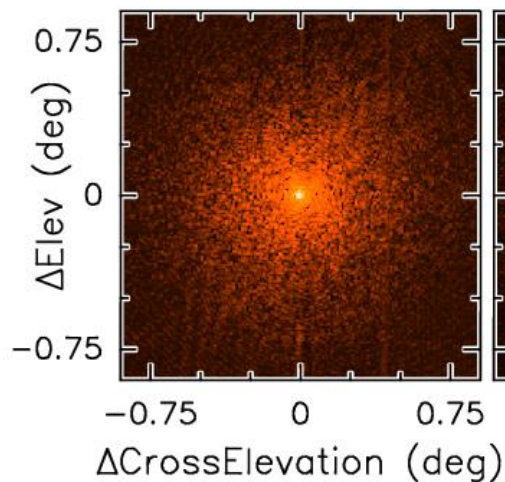
September 2009



Broken Actuators



-500 0 500 Microns



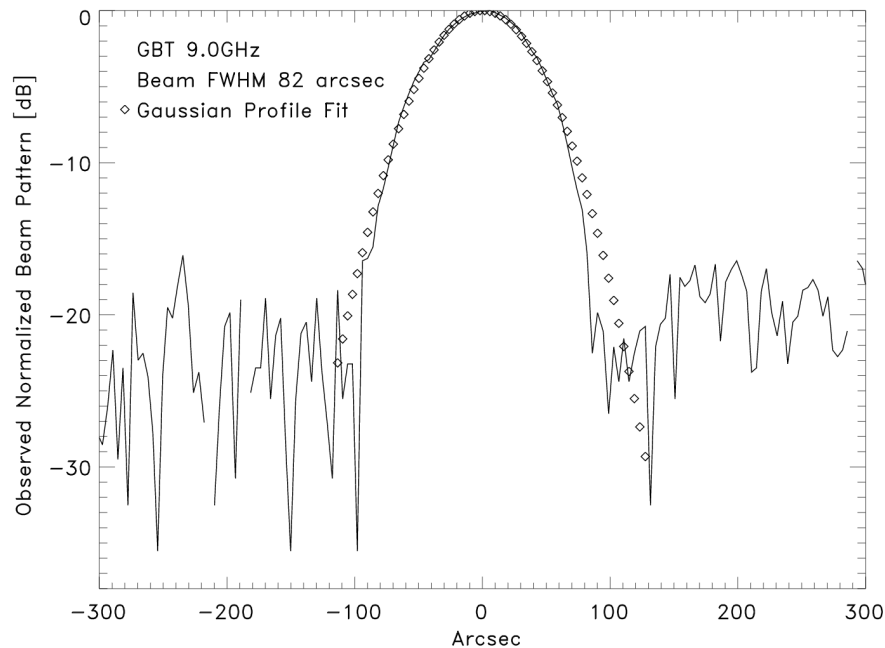
11.7 GHz beam pattern

dB = -40 -20 0

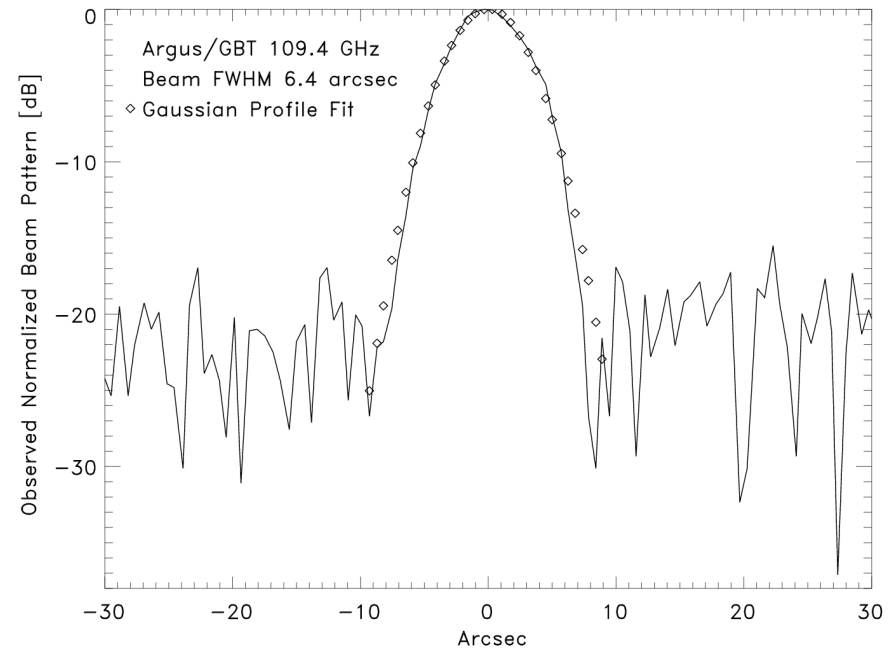


# The GBT Achieves its Theoretical Beam at 110 GHz

GBT memo #296 – demonstrates the success of the pointing-and-control system and the gravity and thermal modeling with active surface corrections – lots of work by many people over the last decade....



GBT/X-band 9.0 GHz

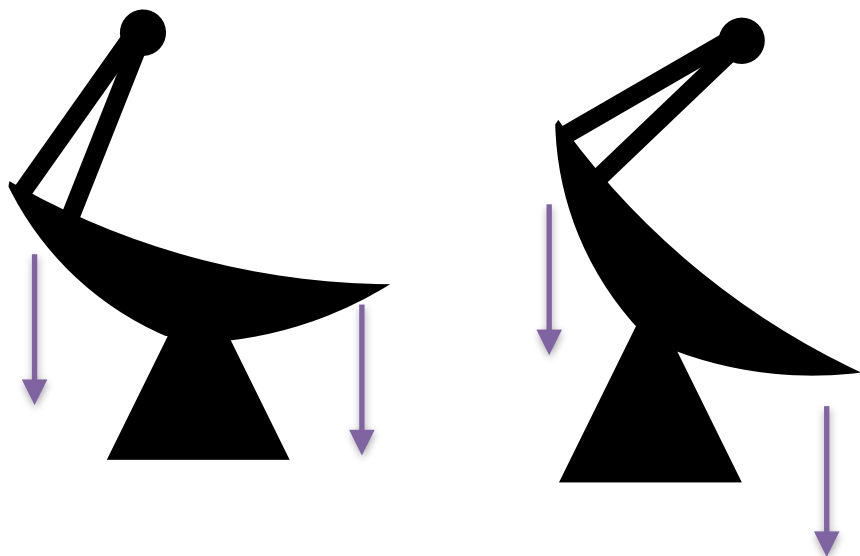


GBT/Argus 109.4 GHz

# What can cause deviations from perfect parabola and theoretical beam?

## Deformations caused by:

Gravity



Changes with elevation

Differential Heating



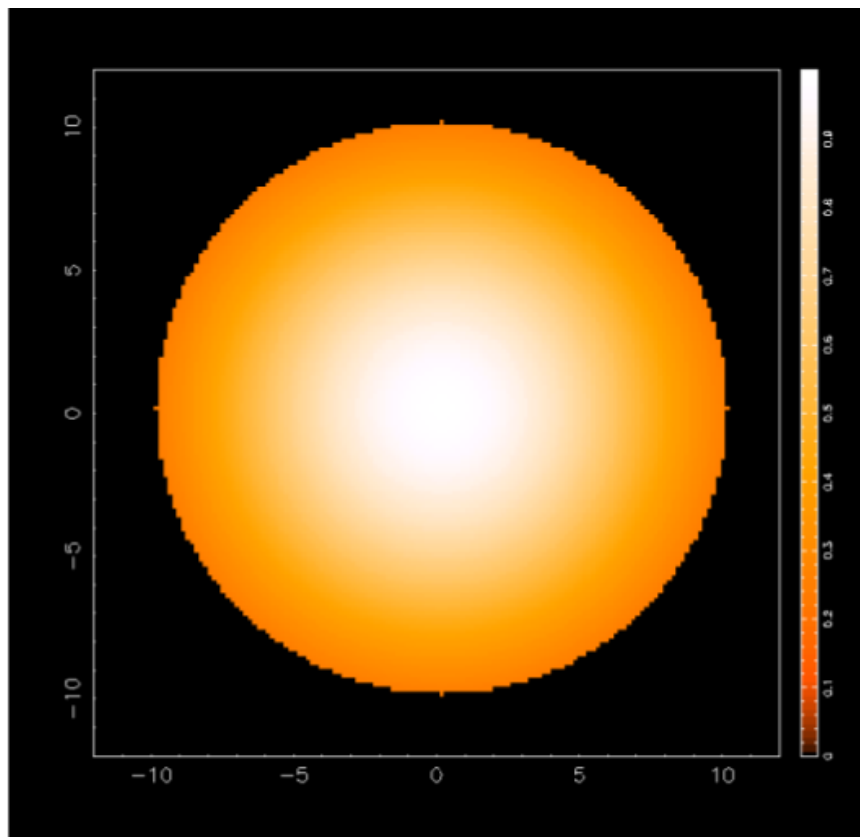
## Why do these deformations matter at high frequency and not at low frequency?

Quite simply, in the mm range this is where these deviations in the dish are larger than the wavelength.

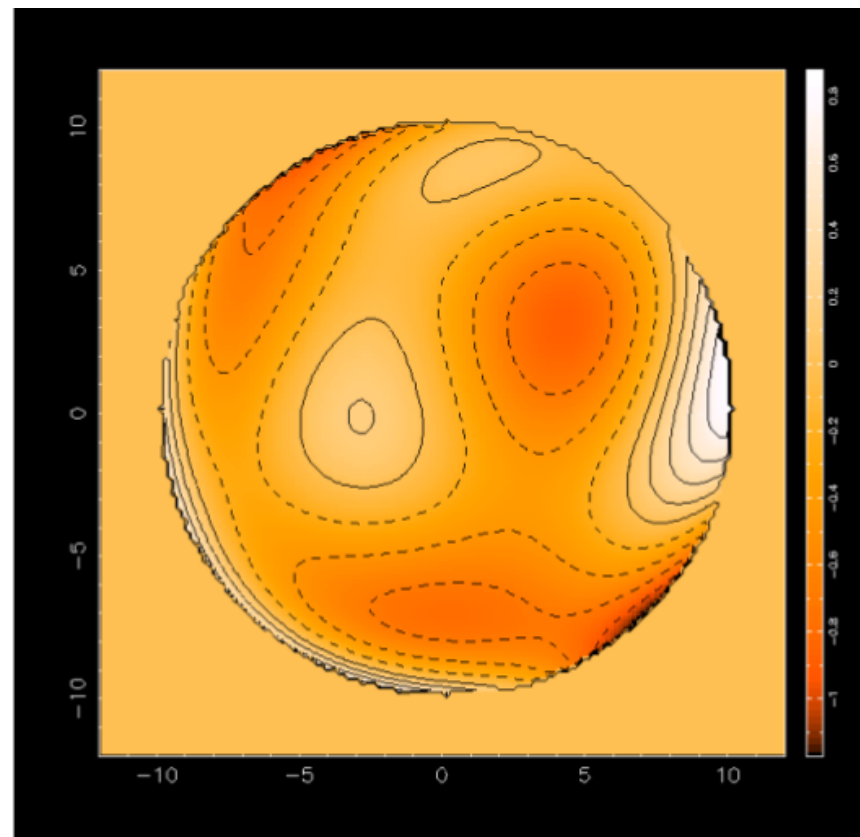


# A Surface with random large-scale errors

Receiver Response  
(Taper/Apodisation/...)



Surface Errors  
(Projected to an imaginary surface)



# Model Surface Using Zernike Polynomials

Set of orthogonal polynomials that are used to reconstruct geometric features across a circular aperture.

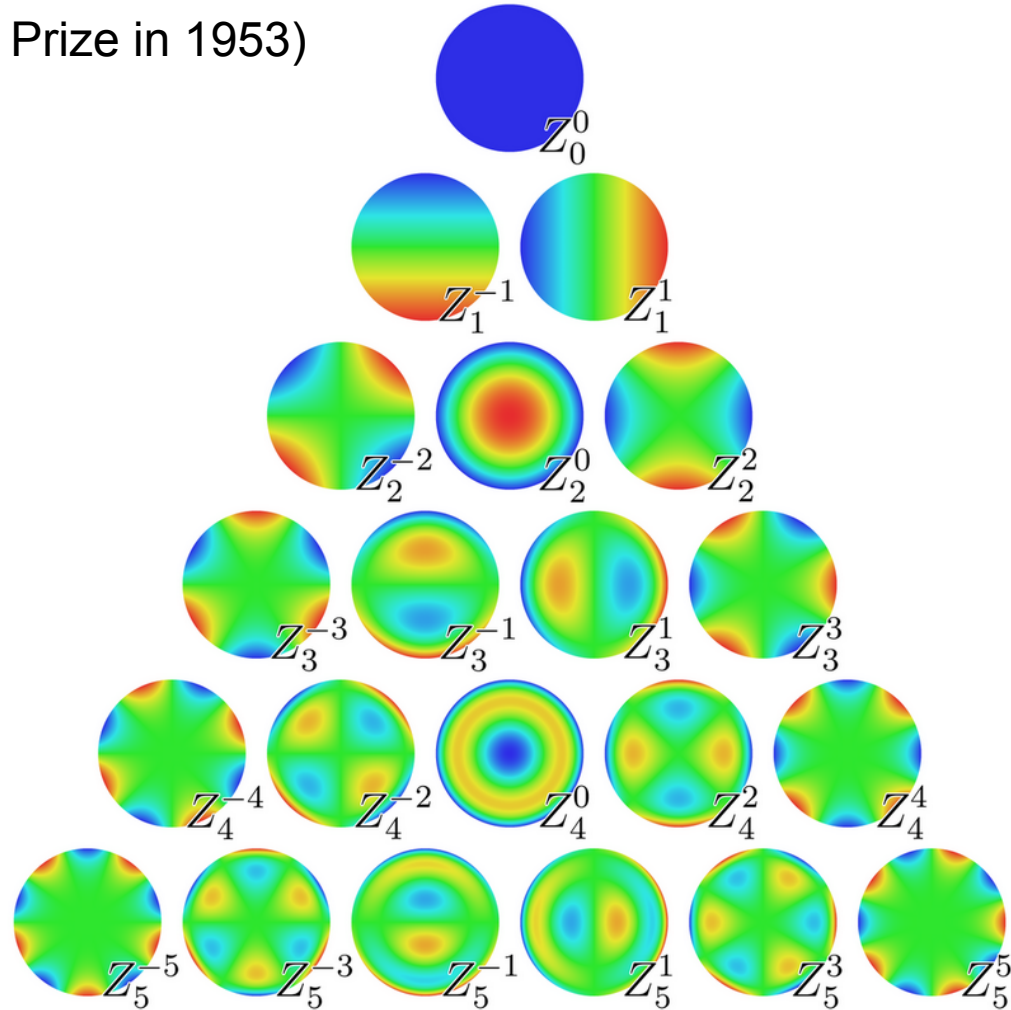
Derived by Frits Zernike in 1934 (Nobel Prize in 1953)

## Zernike polynomials [\[ edit \]](#)

The first few Zernike modes, with [OSA/ANSI](#) and [Noll](#) single-indices, are shown below.

$$\int_0^{2\pi} \int_0^1 Z_j^2 \rho d\rho d\theta = \pi.$$

↔	OSA/ANSI index (j)	↔	Noll index (j)	↔	Radial degree (n)	↔	Azimuthal degree (m)	↔	$Z_j$	↔
	$Z_0^0$	0	1	0	0		0		1	
	$Z_1^{-1}$	1	3	1	1		-1		$2\rho \sin \theta$	
	$Z_1^1$	2	2	1	1		+1		$2\rho \cos \theta$	
	$Z_2^{-2}$	3	5	2	2		-2		$\sqrt{6}\rho^2 \sin 2\theta$	
	$Z_2^0$	4	4	2	0		0		$\sqrt{3}(2\rho^2 - 1)$	
	$Z_2^2$	5	6	2	2		+2		$\sqrt{6}\rho^2 \cos 2\theta$	
	$Z_3^{-3}$	6	9	3	3		-3		$\sqrt{8}\rho^3 \sin 3\theta$	
	$Z_3^{-1}$	7	7	3	1		-1		$\sqrt{8}(3\rho^3 - 2\rho) \sin \theta$	
	$Z_3^1$	8	8	3	1		+1		$\sqrt{8}(3\rho^3 - 2\rho) \cos \theta$	
	$Z_3^3$	9	10	3	3		+3		$\sqrt{8}\rho^3 \cos 3\theta$	
	$Z_4^{-4}$	10	15	4	4		-4		$\sqrt{10}\rho^4 \sin 4\theta$	
	$Z_4^{-2}$	11	13	4	2		-2		$\sqrt{10}(4\rho^4 - 3\rho^2) \sin 2\theta$	
	$Z_4^0$	12	11	4	0		0		$\sqrt{5}(6\rho^4 - 6\rho^2 + 1)$	
	$Z_4^2$	13	12	4	2		+2		$\sqrt{10}(4\rho^4 - 3\rho^2) \cos 2\theta$	
	$Z_4^4$	14	14	4	4		+4		$\sqrt{10}\rho^4 \cos 4\theta$	





# GBT Zernike-Gravity Model

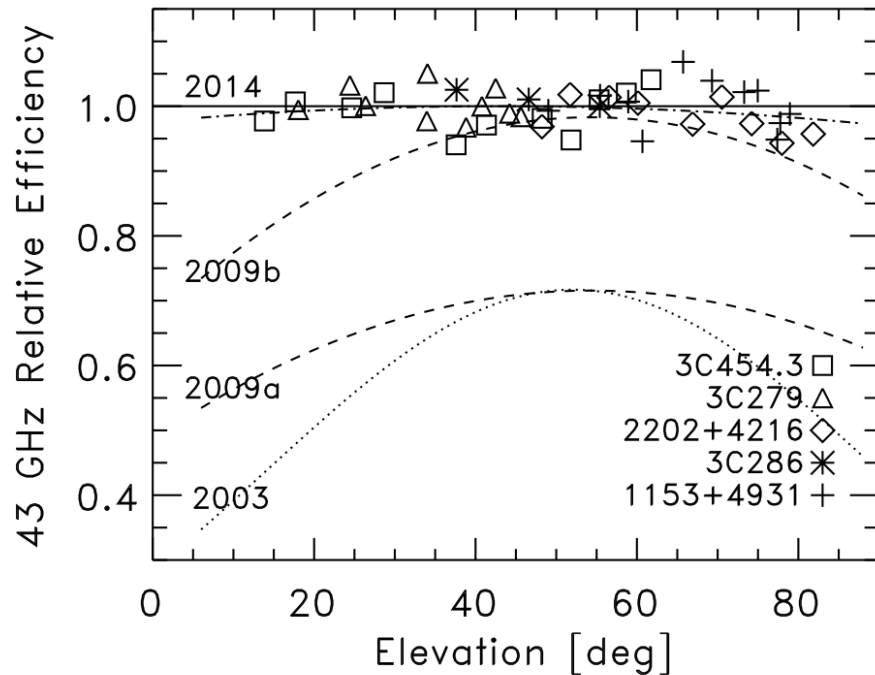
Each Zernike parameter fitted as a function of elevation:

$$Z_n = A_n \sin(el) + B_n \cos(el) + C_n$$

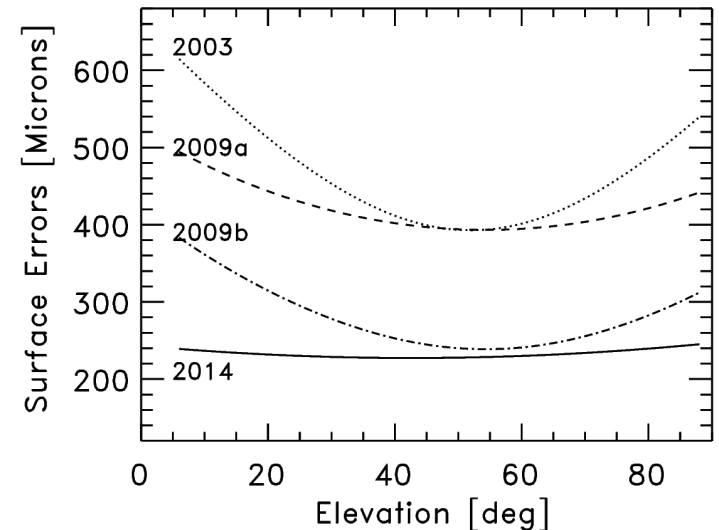
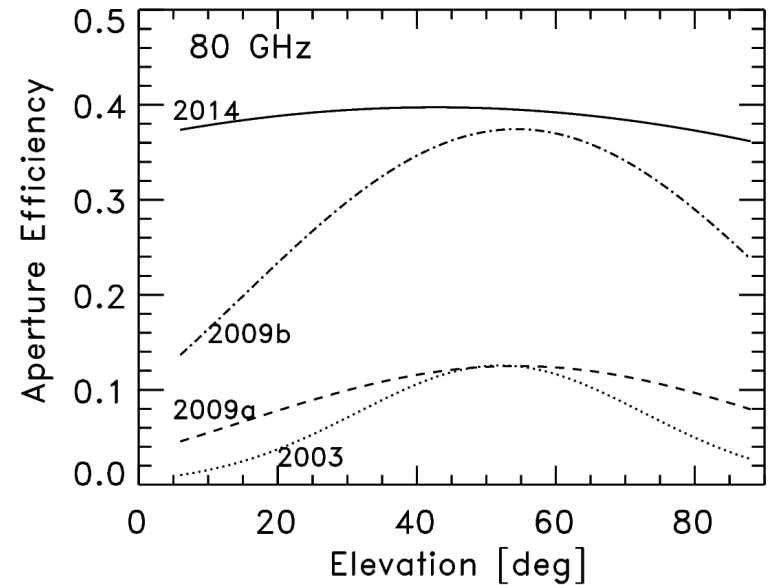
The updated 2014 gravity model improved telescope performance (PTCS PN#76)

<b>Z</b>	<b>A</b>	<b>B</b>	<b>C</b>	<b><math>\sigma_A</math></b>	<b><math>\sigma_B</math></b>	<b><math>\sigma_C</math></b>	<b>rms</b>
4	-697.71	697.91	550.68	905.87	775.82	1137.56	517.55
5	-148.22	-482.95	136.07	540.74	463.11	679.05	308.94
6	319.46	154.68	-535.72	319.70	273.80	401.46	182.65
7	-554.68	-327.02	632.92	378.25	323.95	475.00	216.11
8	-65.60	53.89	108.34	268.56	230.01	337.25	153.44
9	588.39	1305.77	-1063.37	341.03	292.07	428.25	194.84
10	932.92	542.64	-1119.48	481.14	412.07	604.20	274.89
11	136.83	923.46	-288.13	329.68	282.35	414.01	188.36
12	-532.04	-177.33	440.51	238.51	204.27	299.52	136.27
13	360.71	62.38	-94.13	160.01	137.04	200.94	91.42
14	-38.56	15.16	-160.13	188.20	161.18	236.34	107.52
15	-622.70	-414.96	744.87	288.93	247.45	362.83	165.07
16	121.80	-38.60	16.58	293.75	251.58	368.89	167.83
17	-210.31	-198.02	203.98	161.70	138.48	203.05	92.38
18	71.68	3.62	-266.29	142.96	122.44	179.53	81.68
19	579.23	-51.98	-392.41	178.29	152.70	223.89	101.86
20	243.95	-121.70	-6.45	194.88	166.91	244.73	111.34
21	593.36	1065.48	-1287.78	304.57	260.84	382.46	174.01

# Surface Improvements with Gravity Model + Active Surface



Improvements to the gravity model in 2014 yields a flat gain curve with elevation and has significantly improved the GBT performance at high-frequency (GBT Memo#301)

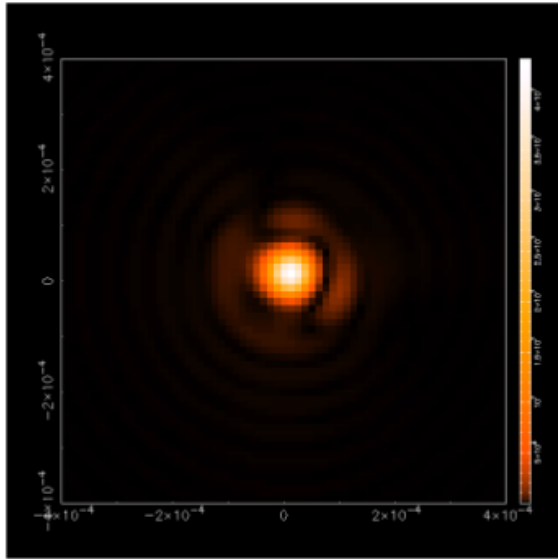




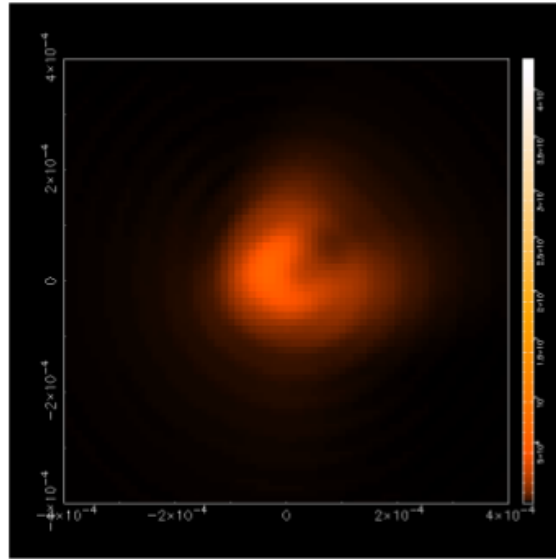
# Surface Improvements with OOF

Use Out Of Focus (OOF) mapping (holography) observations of bright point sources to derive Zernike parameters and correct for deviations in dish away from perfect parabola

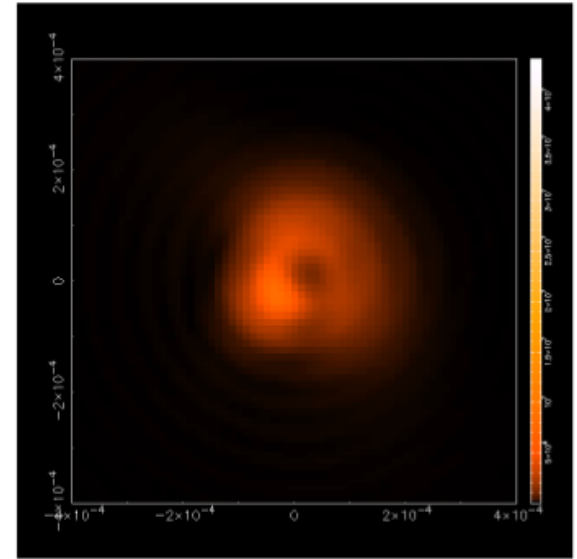
In-Focus



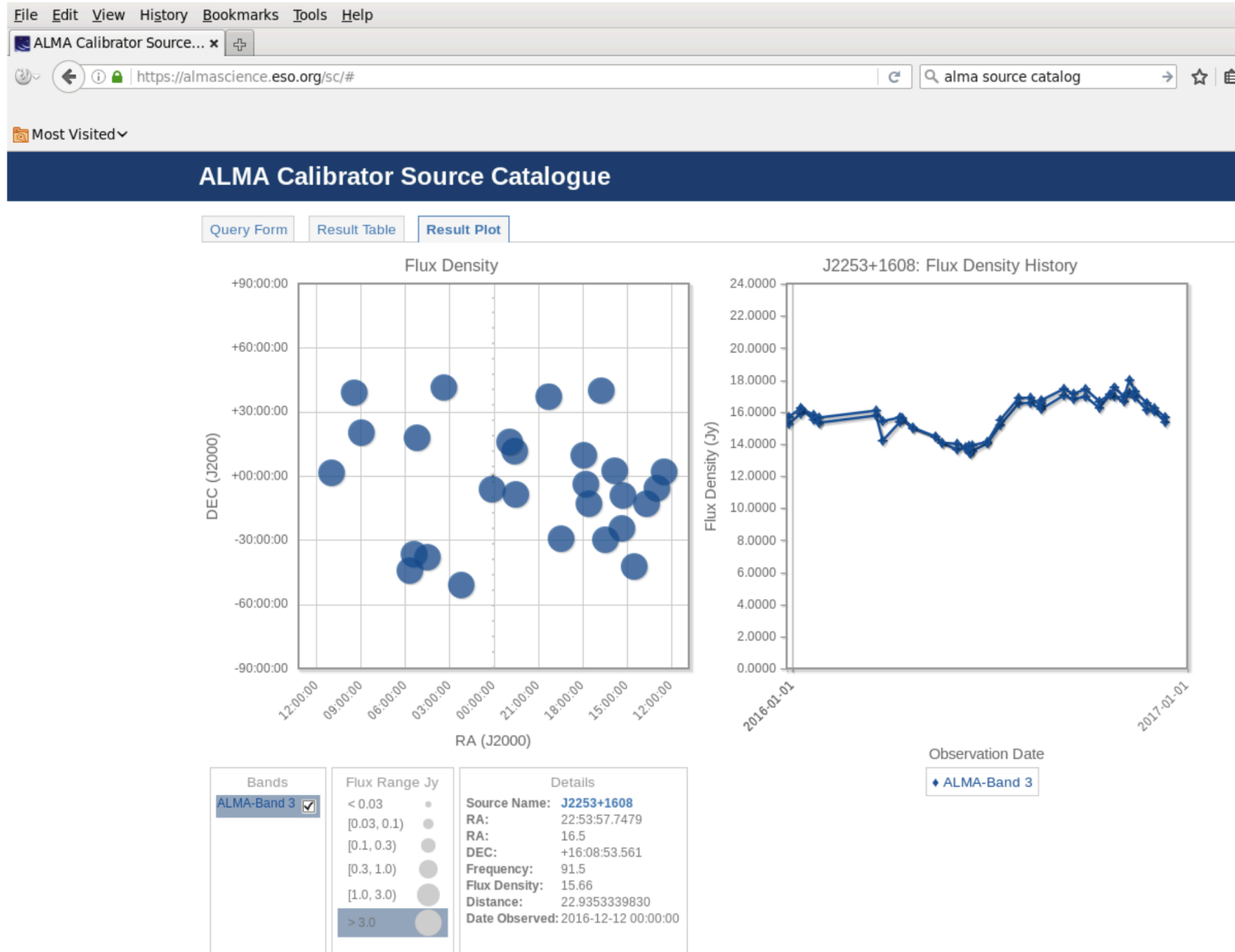
-ve De-Focus



+ve De-Focus



# ALMA Calibrator Source Catalogue

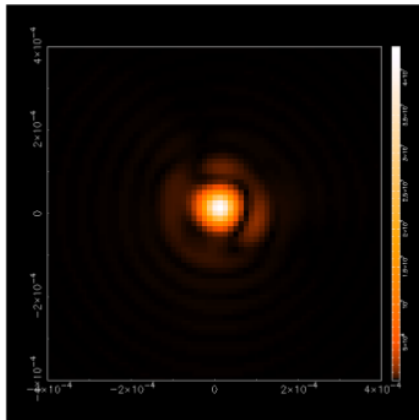




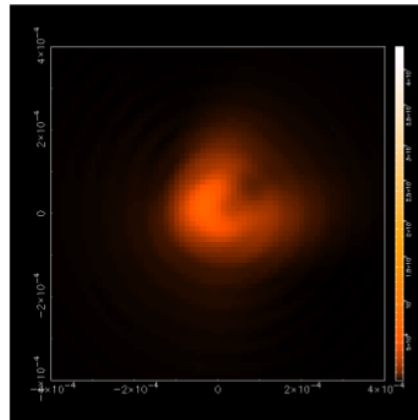
# Surface Improvements with OOF

Out Of Focus (OOF) - AutoOOF - active surface (RMS + map), pointing (Az,El), focus corrections (mm)

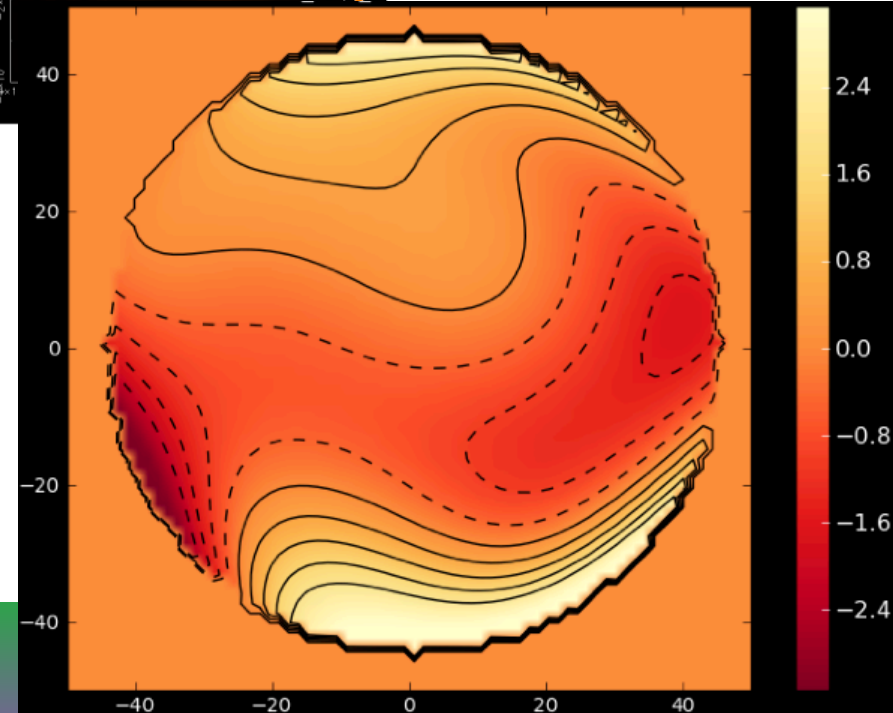
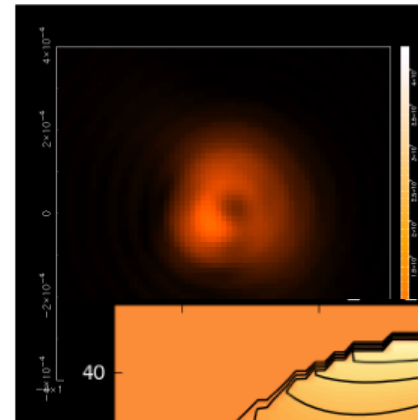
In-Focus



-ve De-Focus



+ve De-Focus

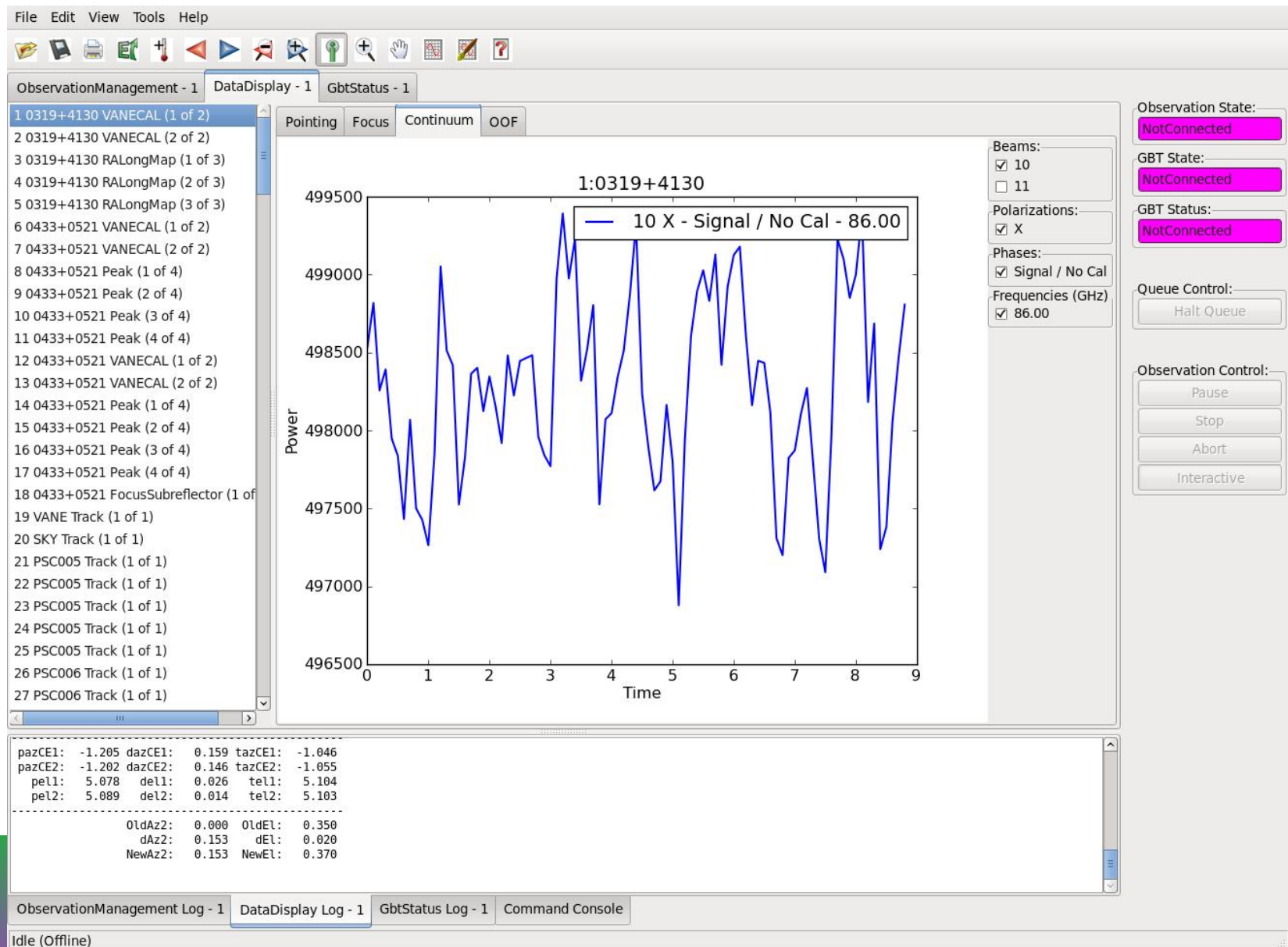


Surface RMS = 207 microns



# Example of Argus AutoOOF Observations:

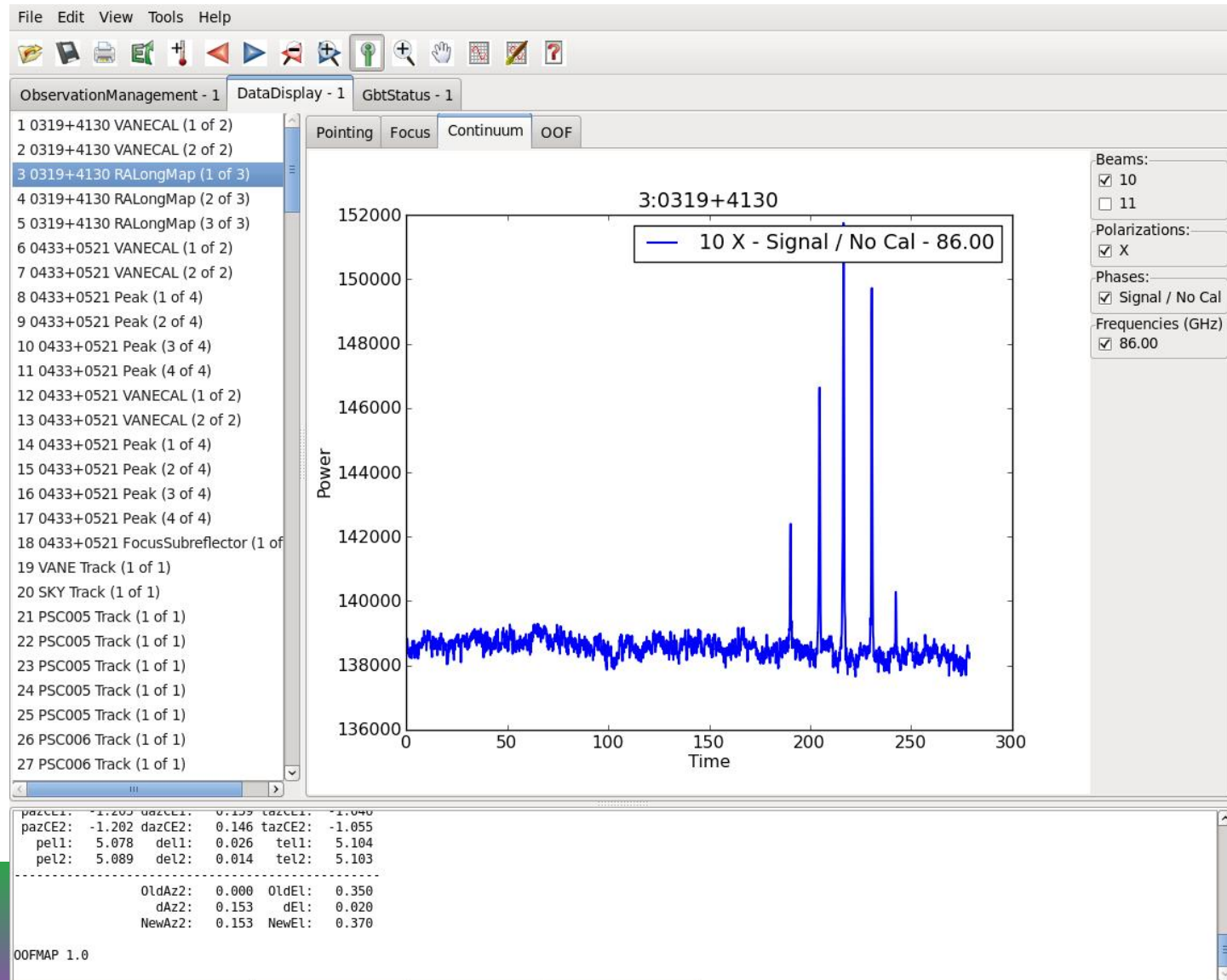
## Early Scans - setup



# Example of Argus AutoOOF Observations:

(scan 3) Argus OOF map-1 data - default focus

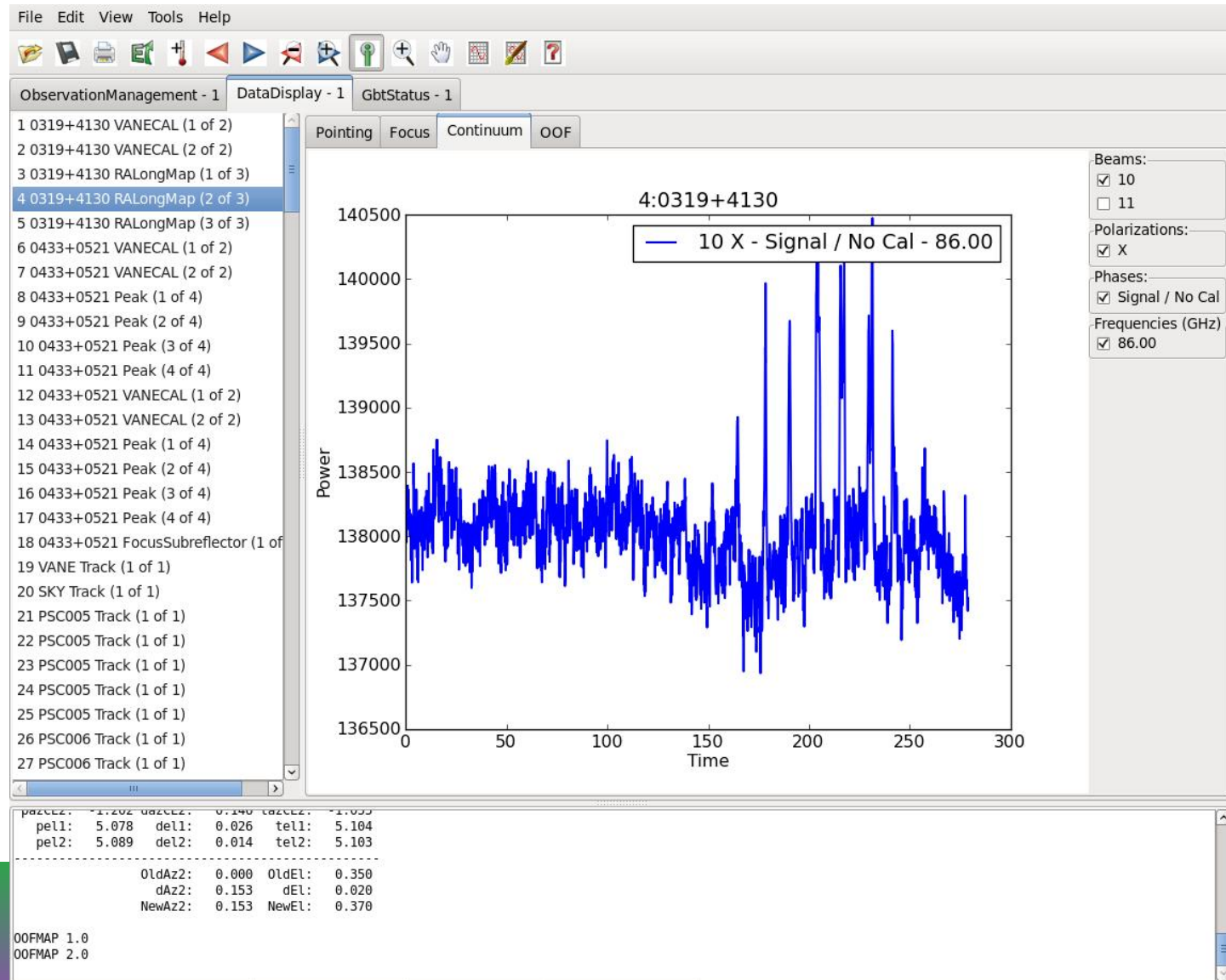
First map at default focus and should see source at good S/N.



# Example of Argus AutoOOF Observations:

(scan 4) Argus OOF map-2 data at +12mm

Counts lower  
since map  
made out of  
focus (+12mm)



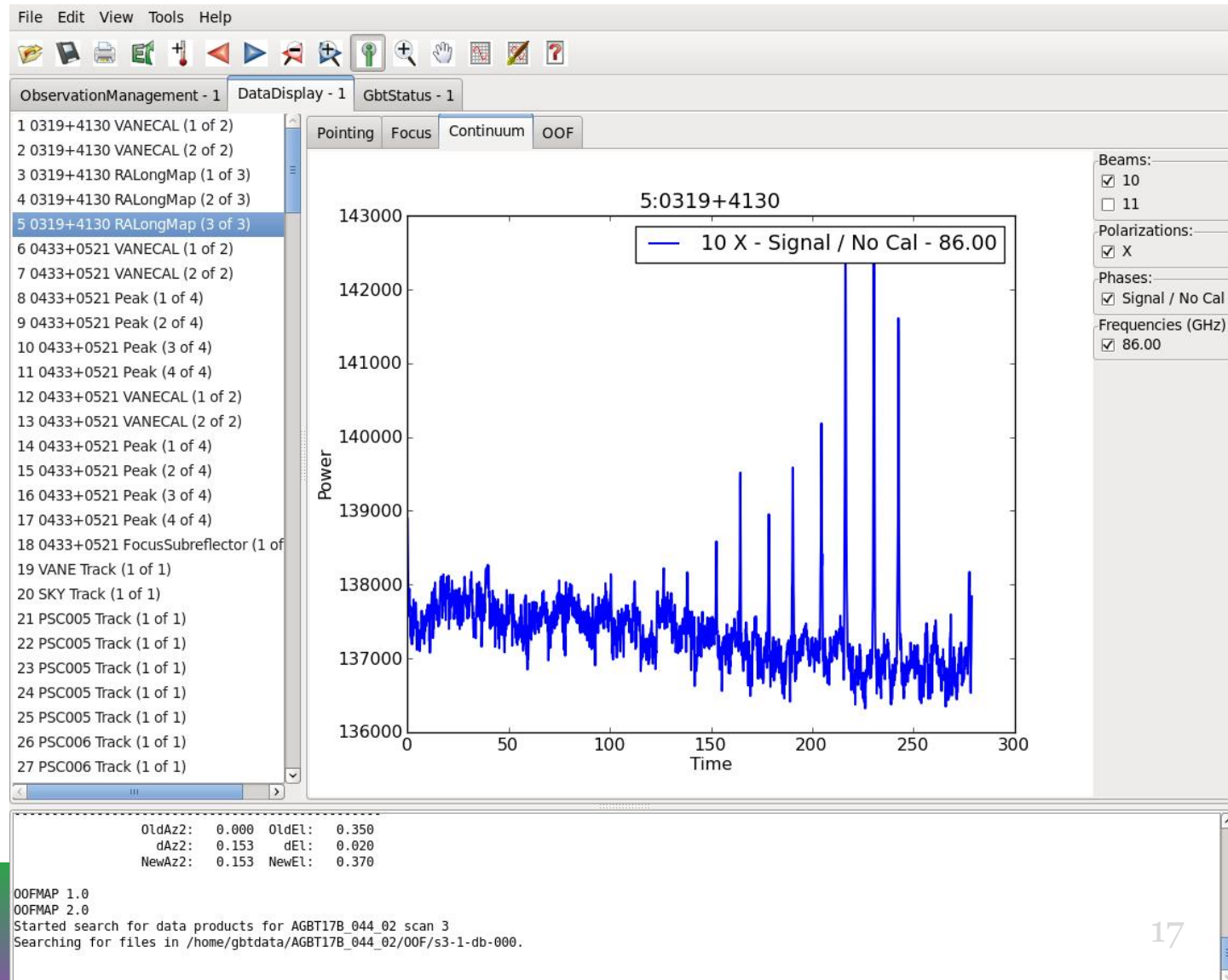


# Example of Argus AutoOOF Observations:

(scan 5) Argus OOF map-3 data at -12mm

3rd OOF map  
with focus at  
-12mm

peaks higher  
than +12mm  
map so focus  
LFC will be  
negative



# AutoOOF Solutions

20 min to complete

File Edit View Tools Help

ObservationManagement - 1 DataDisplay - 1 GbtStatus - 1

1 0319+4130 VANECA (1 of 2)

2 0319+4130 VANECA (2 of 2)

3 0319+4130 RALongMap (1 of 3)

4 0319+4130 RALongMap (2 of 3)

5 0319+4130 RALongMap (3 of 3)

6 0433+0521 VANECA (1 of 2)

7 0433+0521 VANECA (2 of 2)

8 0433+0521 Peak (1 of 4)

9 0433+0521 Peak (2 of 4)

10 0433+0521 Peak (3 of 4)

11 0433+0521 Peak (4 of 4)

12 0433+0521 VANECA (1 of 2)

13 0433+0521 VANECA (2 of 2)

14 0433+0521 Peak (1 of 4)

15 0433+0521 Peak (2 of 4)

16 0433+0521 Peak (3 of 4)

17 0433+0521 Peak (4 of 4)

18 0433+0521 FocusSubreflector (1 of 1)

19 VANE Track (1 of 1)

20 SKY Track (1 of 1)

21 PSC005 Track (1 of 1)

22 PSC005 Track (1 of 1)

23 PSC005 Track (1 of 1)

24 PSC005 Track (1 of 1)

25 PSC005 Track (1 of 1)

26 PSC006 Track (1 of 1)

27 PSC006 Track (1 of 1)

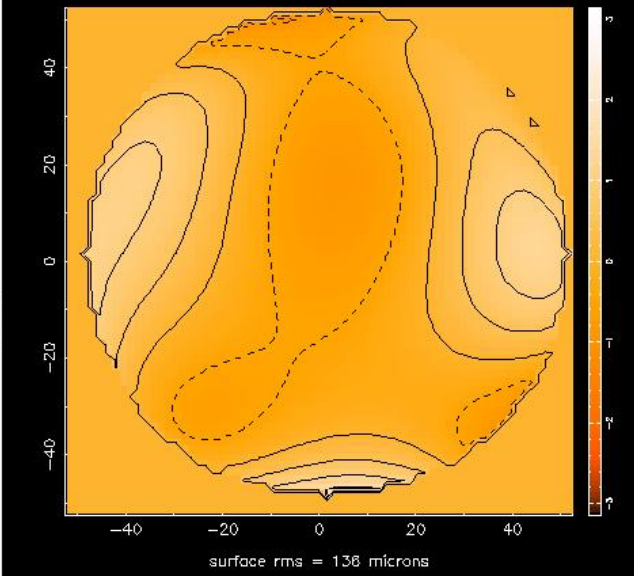
Pointing

Focus

Continuum

OOF

/home/gbtdata/AGBT17B\_044\_02 s3-1-db-000 z5 aperture-no tilt.fits



Zernike Solutions LPCs (az2, el) LFCy

☐ z2

☐ z3 (+0.06,+0.35) -3.75 mm

☐ z4 (+0.06,+0.35) -2.55 mm

☒ z5 (+0.06,+0.35) -2.60 mm

☐ z6

☐ raw data

☐ fitted beam map

☒ Show Fixed-Scale Image

☐ Show Solutions with Focus Removed

AutoOOF Processing Status: Complete

Project Name:  
AGBT17B\_044\_02

Scan Number:  
3

Send Selected Solution with Point and Focus Corrections (new, recommended method)

Reanalyze OOF (Online Only)

Send Selected Solution with no Point or Focus Correction (original method)

Zero and Turn Off Thermal Zernike Solution

Observation State:  
NotConnected

GBT State:  
NotConnected

GBT Status:  
NotConnected

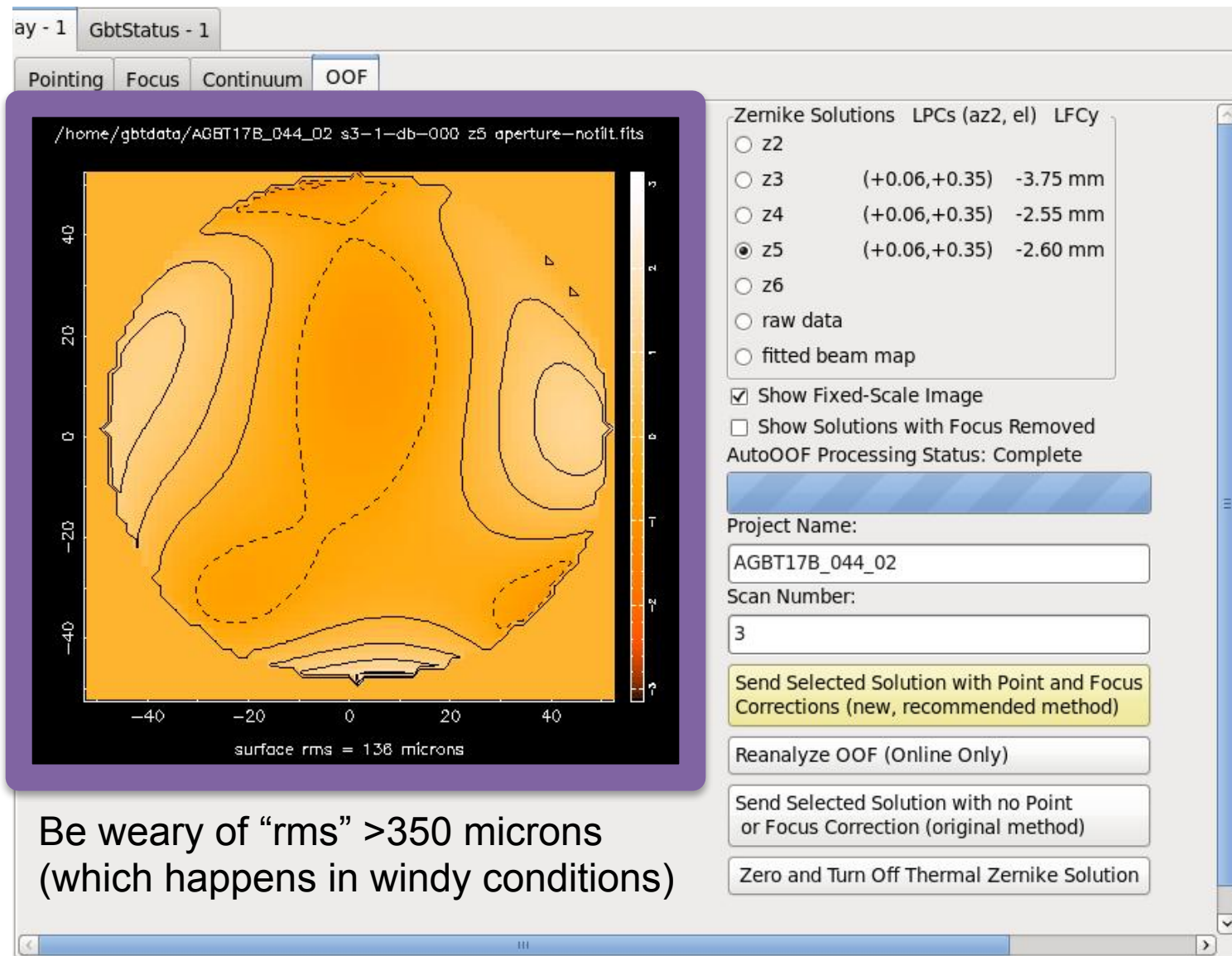
Queue Control:  
Halt Queue

Observation Control:  
Pause  
Stop  
Abort  
Interactive

OldAz2: 0.000 OldEl: 0.350  
dAz2: 0.153 dEl: 0.020  
NewAz2: 0.153 NewEl: 0.370

OOFMAP 1.0  
OOFMAP 2.0  
Started search for data products for AGBT17B\_044\_02 scan 3  
Searching for files in /home/gbtdata/AGBT17B\_044\_02/OOF/s3-1-db-000.

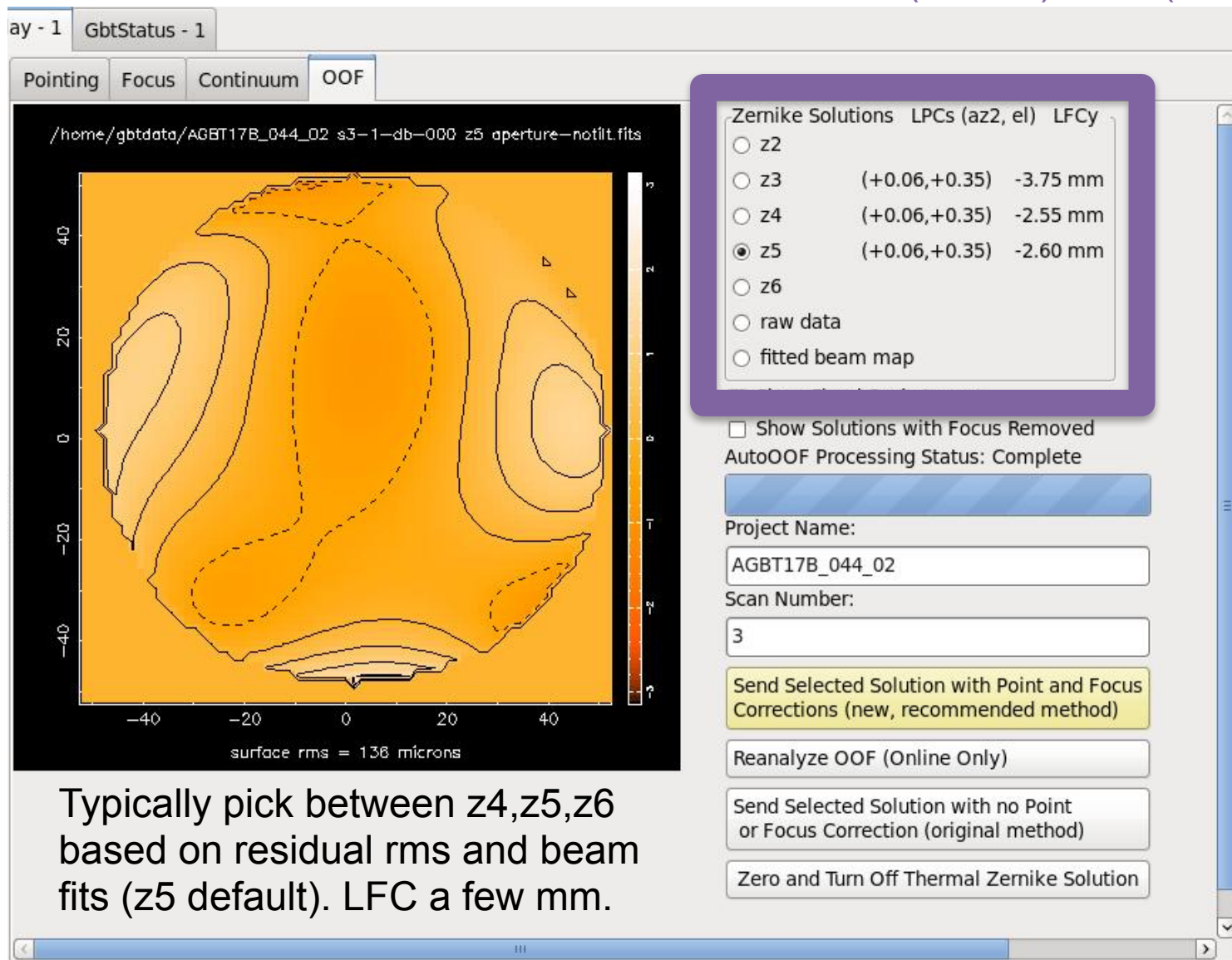
ObservationManagement Log - 1 DataDisplay Log - 1 GbtStatus Log - 1 Command Console



Be weary of “rms” >350 microns  
(which happens in windy conditions)

# AutoOOF Solutions

Zernike, LPCs (arcmin), LFC (mm)



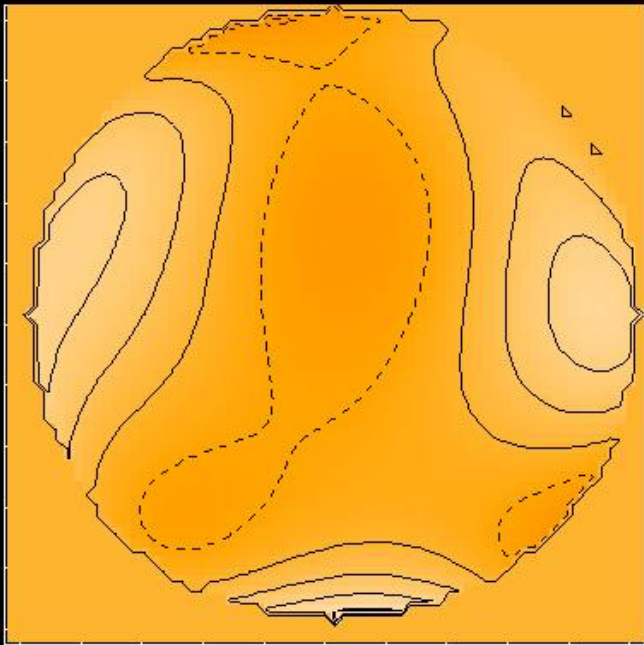
Typically pick between z4,z5,z6 based on residual rms and beam fits (z5 default). LFC a few mm.



ay - 1 GbtStatus - 1

Pointing Focus Continuum **OOF**

/home/gbtdata/AGBT17B\_044\_02 s3-1-db-000 z5 aperture-notilt.fits



surface rms = 138 microns

Zernike Solutions LPCs (az2, el) LFCy

- ☐ z2
- ☐ z3 (+0.06,+0.35) -3.75 mm
- ☐ z4 (+0.06,+0.35) -2.55 mm
- ☒ z5 (+0.06,+0.35) -2.60 mm
- ☐ z6
- ☐ raw data
- ☐ fitted beam map

☒ Show Fixed-Scale Image  
☐ Show Solutions with Focus Removed

AutoOOF Processing Status: Complete

Project Name:  
AGBT17B\_044\_02

Scan Number:  
3

**Send Selected Solution with Point and Focus Corrections (new, recommended method)**

Reanalyze OOF (Online Only)

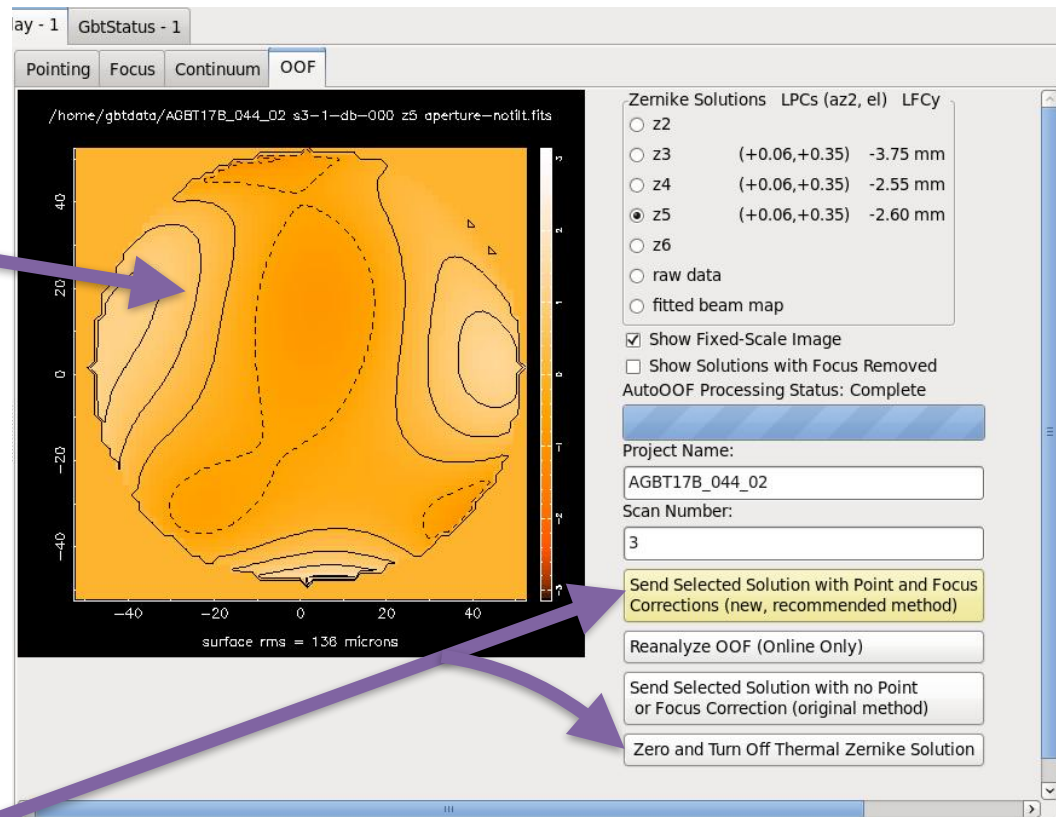
Send Selected Solution with no Point or Focus Correction (original method)

Zero and Turn Off Thermal Zernike Solution

Click yellow button after OOF processing to send corrections to GBT and turn on the thermal zernike's.

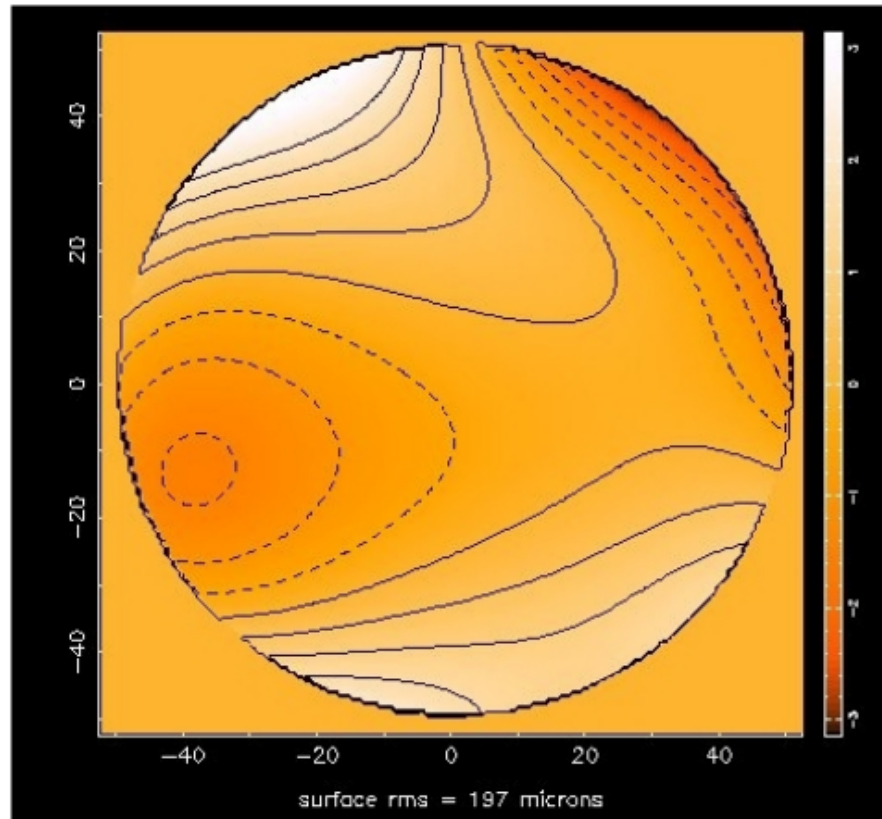
# AutoOOF Solutions

- **OOF image** - displays the measured  $\Delta$ 's from the current surface to the computed optimal surface from the OOF measurements. The algorithm takes raw data, fits Zernikes to that data, and produces the  $\Delta$  map (the combination of these Zernikes builds the surface corrections).
- $Z_{\text{tot}} = Z_{\text{grav}} + Z_{\text{thermal}}$ 
  - OOF measures the  $z_{\text{tot}}$  at the elevation of your OOF target, refers to models for  $z_{\text{grav}}$  and then derives  $z_{\text{thermal}}$
  - $z_{\text{thermal}}$  is the difference between measured  $z_{\text{tot}}$  and the models ( $z_{\text{grav}}$ ).
    - Thus the **solutions** are often called “Zernike Thermal Solutions” or “Thermal Coefficients” for short

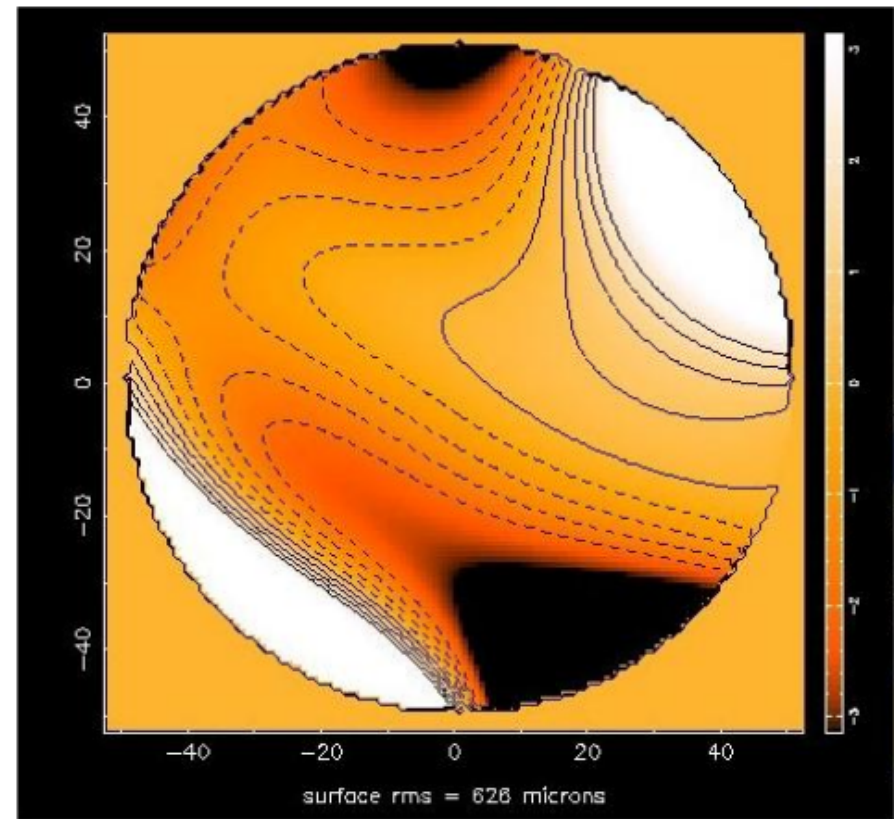


# AutoOOF Example Solutions

Acceptable OOF results typically have an RMS of less than 400-microns in comparison to the gravity model



(a) Acceptable OOF solution.

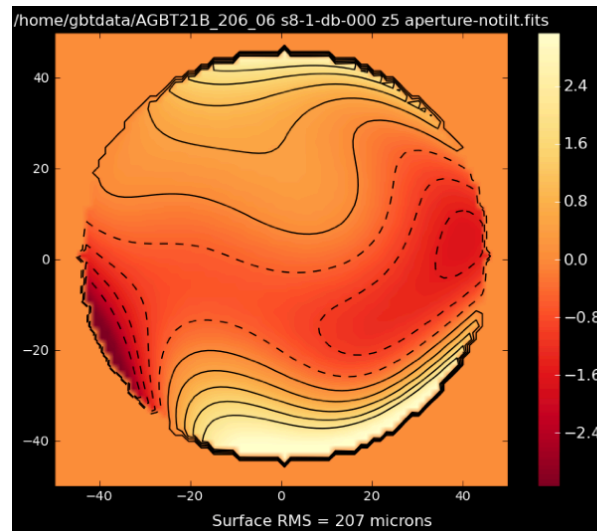
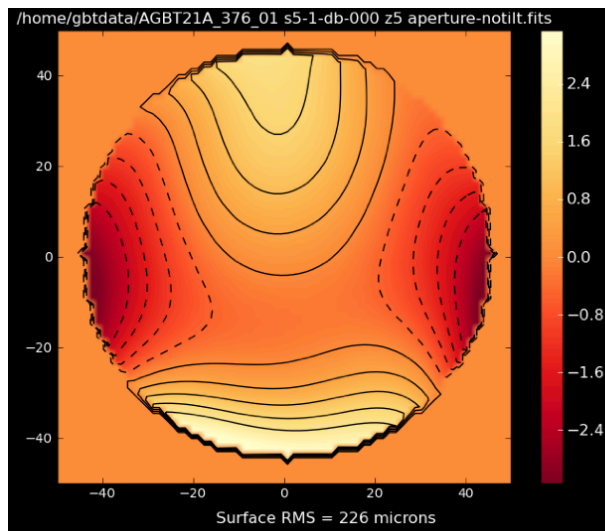


(b) Unacceptable OOF solution.

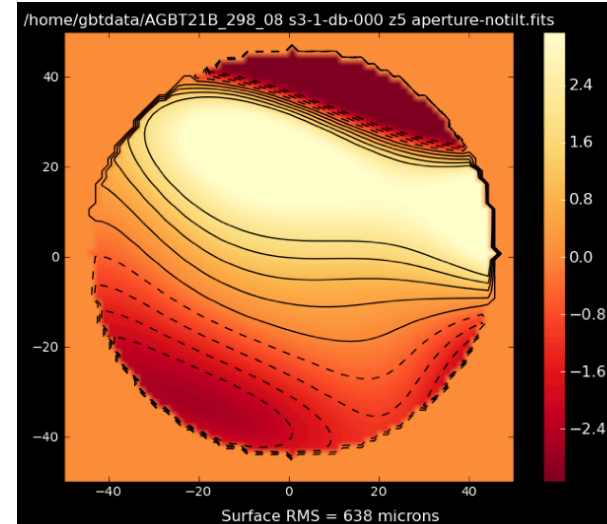
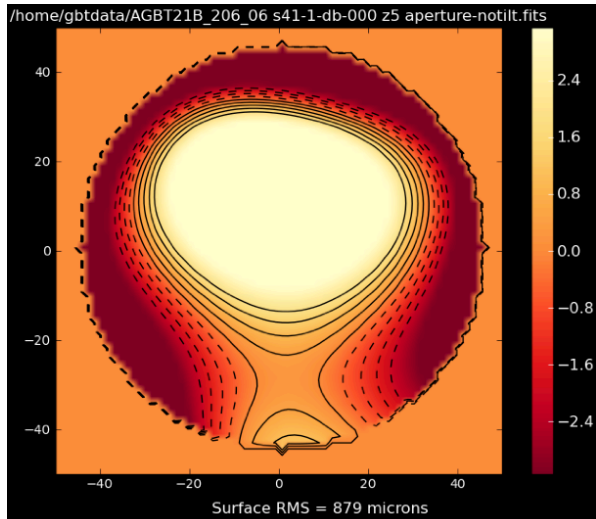
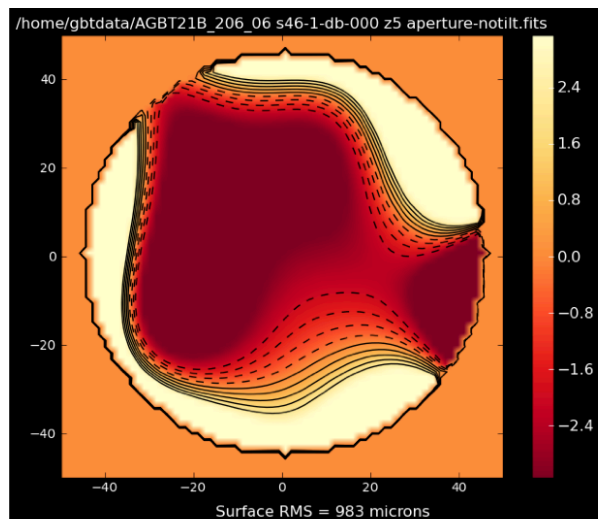
Figure 5.8: Figure 5.8a shows broad features ( $\pm 1.5$  radians of phase) with a surface rms of  $197 \mu\text{m}$ . Figure 5.8b shows steep contour lines ( $\pm 15$  radians of phase) and a surface rms of  $626 \mu\text{m}$ . This is likely the result of poor quality raw data and should not be used.



Good



Bad





# Cleo Status Window

File Launch Help

Status **Error** State **Running** LST **07:09:19** UTC **07:18:45**

Device	Status	State
Antenna	Info	Running
LO1	clear	Running
IFRack	clear	Running
ConverterRack	clear	Running
SwitchingSignalSelector	clear	Running
Measurements	clear	Running
ActiveSurface	clear	Running
QuadrantDetector	<b>Error</b>	Running
VEGAS	clear	Running
RcvrArray75_115	clear	Running
IFManager	clear	Running

Source **CORE06** Scan # **65**

Project **AGBT16B\_119\_02** SS Master **VEGAS**

Start **07:17:02** Length **120.0**

Countdown **---:--** Remaining **00:00:18**

Observer **Youngmin Seo**

Obs. Type **LINE** Switching **FSW1ENOCAL**

Proc Name **Track** Sequence **1 / 1**

Rest Freq **89188.5247** Velocity **/**

Frame **KinematicLSR** Vel Def **Radio**

Time to Set **04:19:29** Encoder **---**

Indicated Azimuth **266.84786** Elevation **53.43131**

Commanded Azimuth **266.84780** Elevation **53.43125**

Rate (°/min) **10.9** **-11.4**

Difference **-0.00006** **-0.00006**

Servo Err (") **-0.3** **-0.1**

On Source **Az LPC -0.0801** **EI LPC 0.0047**

X FC **0.0** Y FC **0.6** Z FC **0.0** Xt FC **0.00** Yt FC **0.00** Zt FC **0.00** **LFC** **FOC**

Config Model **Guiding**

Model 5r - Latest Coord Mode **J2000**

Temp **-5.9** Wind:2 Temp:2a V(m/s) T(C)

Dynamic Corrections

**DC Pointing** **DC Focus** Az1 **0.00** Az2 **0.05** EI **0.07** Focus **-13.91**

ActiveSurface

Num Disabled **37** **OOF Zernike Mode** **Sim Mode**

Cmd RMS **33.693** **Zero Offsets** **real**

Peak Resid **34625** **FEM Model** **Ctrl Mode**

Cmd IQ RMS **37.065** **Zernike Coeff** **Enabled**

Cmd Resid **160** **Z Thermal Coeff**

**Random Offsets**

VEGAS

J1	-19.33	J5	-18.76	J9	-19.81	J13	-19.48
J2	-19.73	J6	-19.63	J10	-19.97	J14	-19.95
J3	-19.84	J7	-19.12	J11	-19.58	J15	-19.53
J4	-20.29	J8	-19.63	J12	-19.76	J16	-19.46

Auto Scroll **Off** **10**

Phase Table... Other Devices **---** Retrace IF

Az,EI LPCs

Focus YFC

Active Surface ON with Thermal corrections from OOF

VEGAS balance values on sky: ~-20(+/-3)



# AutoOOF 'Raw Data'

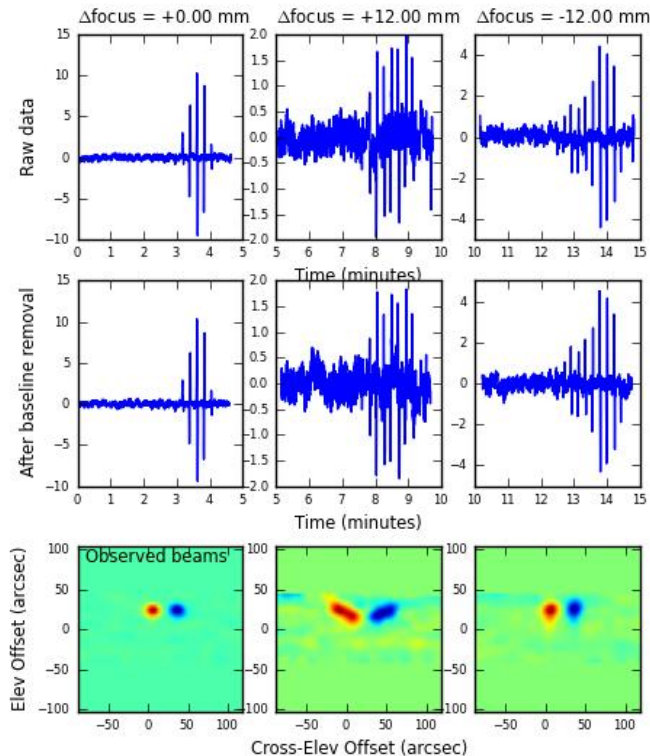
File Edit View Tools Help



ObservationManagement - 1 DataDisplay - 1 GbtStatus - 1

1 0319+4130 VANECA (1 of 2)  
2 0319+4130 VANECA (2 of 2)  
3 0319+4130 RALongMap (1 of 3)  
4 0319+4130 RALongMap (2 of 3)  
5 0319+4130 RALongMap (3 of 3)  
6 0433+0521 VANECA (1 of 2)  
7 0433+0521 VANECA (2 of 2)  
8 0433+0521 Peak (1 of 4)  
9 0433+0521 Peak (2 of 4)  
10 0433+0521 Peak (3 of 4)  
11 0433+0521 Peak (4 of 4)  
12 0433+0521 VANECA (1 of 2)  
13 0433+0521 VANECA (2 of 2)  
14 0433+0521 Peak (1 of 4)  
15 0433+0521 Peak (2 of 4)  
16 0433+0521 Peak (3 of 4)  
17 0433+0521 Peak (4 of 4)  
18 0433+0521 FocusSubreflector (1 of 1)  
19 VANE Track (1 of 1)  
20 SKY Track (1 of 1)  
21 PSC005 Track (1 of 1)  
22 PSC005 Track (1 of 1)  
23 PSC005 Track (1 of 1)  
24 PSC005 Track (1 of 1)  
25 PSC005 Track (1 of 1)  
26 PSC006 Track (1 of 1)  
27 PSC006 Track (1 of 1)

Pointing Focus Continuum OOF



Zernike Solutions LPCs (az2, el) LFCy

- ☐ z2
- ☐ z3 (+0.06,+0.35) -3.75 mm
- ☐ z4 (+0.06,+0.35) -2.55 mm
- ☐ z5 (+0.06,+0.35) -2.60 mm
- ☐ z6

- ☒ raw data
- ☐ fitted beam map

☒ Show Fixed-Scale Image

☐ Show Solutions with Focus Removed

AutoOOF Processing Status: Complete

Project Name:

AGBT17B\_044\_02

Scan Number:

3

Send Selected Solution with Point and Focus Corrections (new, recommended method)

Reanalyze OOF (Online Only)

Send Selected Solution with no Point or Focus Correction (original method)

Zero and Turn Off Thermal Zernike Solution

Observation State:

NotConnected

GBT State:

NotConnected

GBT Status:

NotConnected

Queue Control:

Halt Queue

Observation Control:

Pause

Stop

Abort

Interactive

OldAz2: 0.000 OldEl: 0.350  
dAz2: 0.153 dEl: 0.020  
NewAz2: 0.153 NewEl: 0.370

OOFMAP 1.0

OOFMAP 2.0

Started search for data products for AGBT17B\_044\_02 scan 3

Searching for files in /home/gbtdata/AGBT17B\_044\_02/OOF/s3-1-db-000.

# AutoOOF Beam Fits

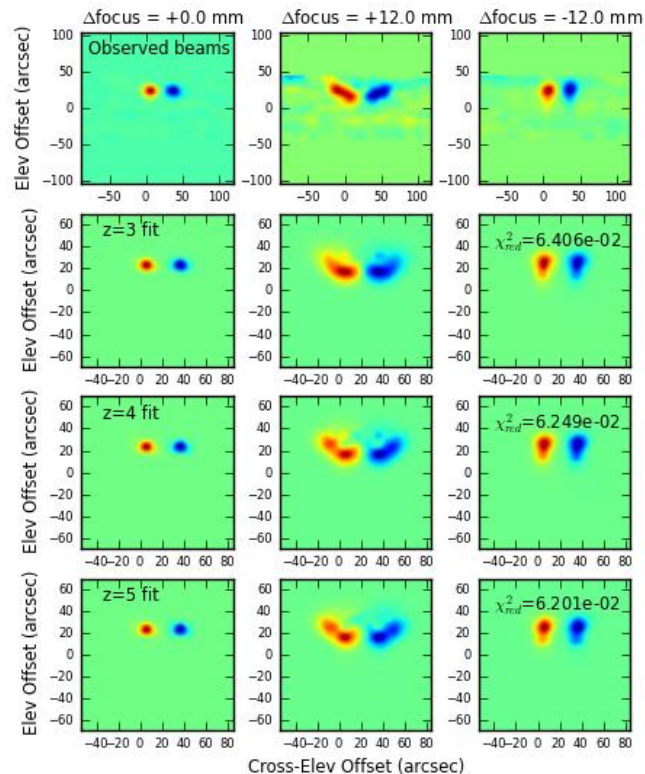
File Edit View Tools Help



ObservationManagement - 1 DataDisplay - 1 GbtStatus - 1

1 0319+4130 VANECA (1 of 2)  
2 0319+4130 VANECA (2 of 2)  
3 0319+4130 RALongMap (1 of 3)  
4 0319+4130 RALongMap (2 of 3)  
5 0319+4130 RALongMap (3 of 3)  
6 0433+0521 VANECA (1 of 2)  
7 0433+0521 VANECA (2 of 2)  
8 0433+0521 Peak (1 of 4)  
9 0433+0521 Peak (2 of 4)  
10 0433+0521 Peak (3 of 4)  
11 0433+0521 Peak (4 of 4)  
12 0433+0521 VANECA (1 of 2)  
13 0433+0521 VANECA (2 of 2)  
14 0433+0521 Peak (1 of 4)  
15 0433+0521 Peak (2 of 4)  
16 0433+0521 Peak (3 of 4)  
17 0433+0521 Peak (4 of 4)  
18 0433+0521 FocusSubreflector (1 of 1)  
19 VANE Track (1 of 1)  
20 SKY Track (1 of 1)  
21 PSC005 Track (1 of 1)  
22 PSC005 Track (1 of 1)  
23 PSC005 Track (1 of 1)  
24 PSC005 Track (1 of 1)  
25 PSC005 Track (1 of 1)  
26 PSC006 Track (1 of 1)  
27 PSC006 Track (1 of 1)

Pointing Focus Continuum OOF



Zernike Solutions LPCs (az2, el) LFCy  
☐ z2  
☐ z3 (+0.06,+0.35) -3.75 mm  
☐ z4 (+0.06,+0.35) -2.55 mm  
☐ z5 (+0.06,+0.35) -2.60 mm  
☐ z6  
☐ raw data

☒ fitted beam map

☒ Show Fixed-Scale Image

☐ Show Solutions with Focus Removed

AutoOOF Processing Status: Complete

Project Name:

AGBT17B\_044\_02

Scan Number:

3

Send Selected Solution with Point and Focus Corrections (new, recommended method)

Reanalyze OOF (Online Only)

Send Selected Solution with no Point or Focus Correction (original method)

Zero and Turn Off Thermal Zernike Solution

Observation State:

NotConnected

GBT State:

NotConnected

GBT Status:

NotConnected

Queue Control:

Halt Queue

Observation Control:

Pause

Stop

Abort

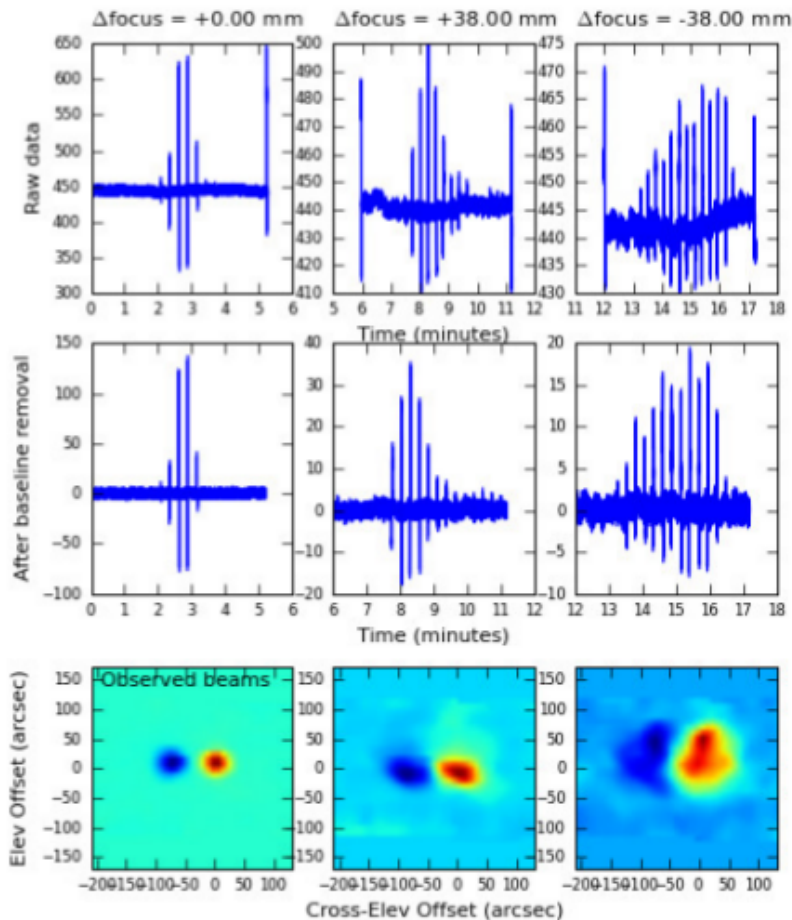
Interactive

OldAz2: 0.000 OldEL: 0.350  
dAz2: 0.153 dEL: 0.020  
NewAz2: 0.153 NewEL: 0.370

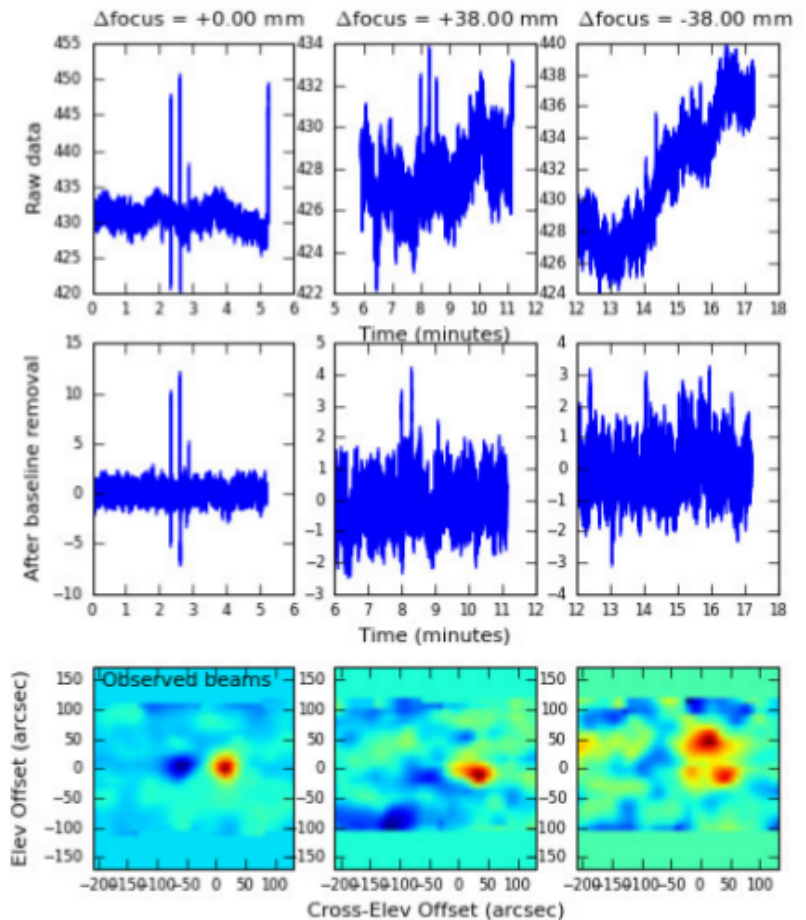
OOFMAP 1.0  
OOFMAP 2.0  
Started search for data products for AGBT17B\_044\_02 scan 3  
Searching for files in /home/gbtdata/AGBT17B\_044\_02/OOF/s3-1-db-000.



# AutoOOF 'Raw' Data Streams



(a) A plot of the raw OOF data on a fairly clean Ka-band/CCB dataset.



(b) A plot of raw OOF data on a source which is too faint.

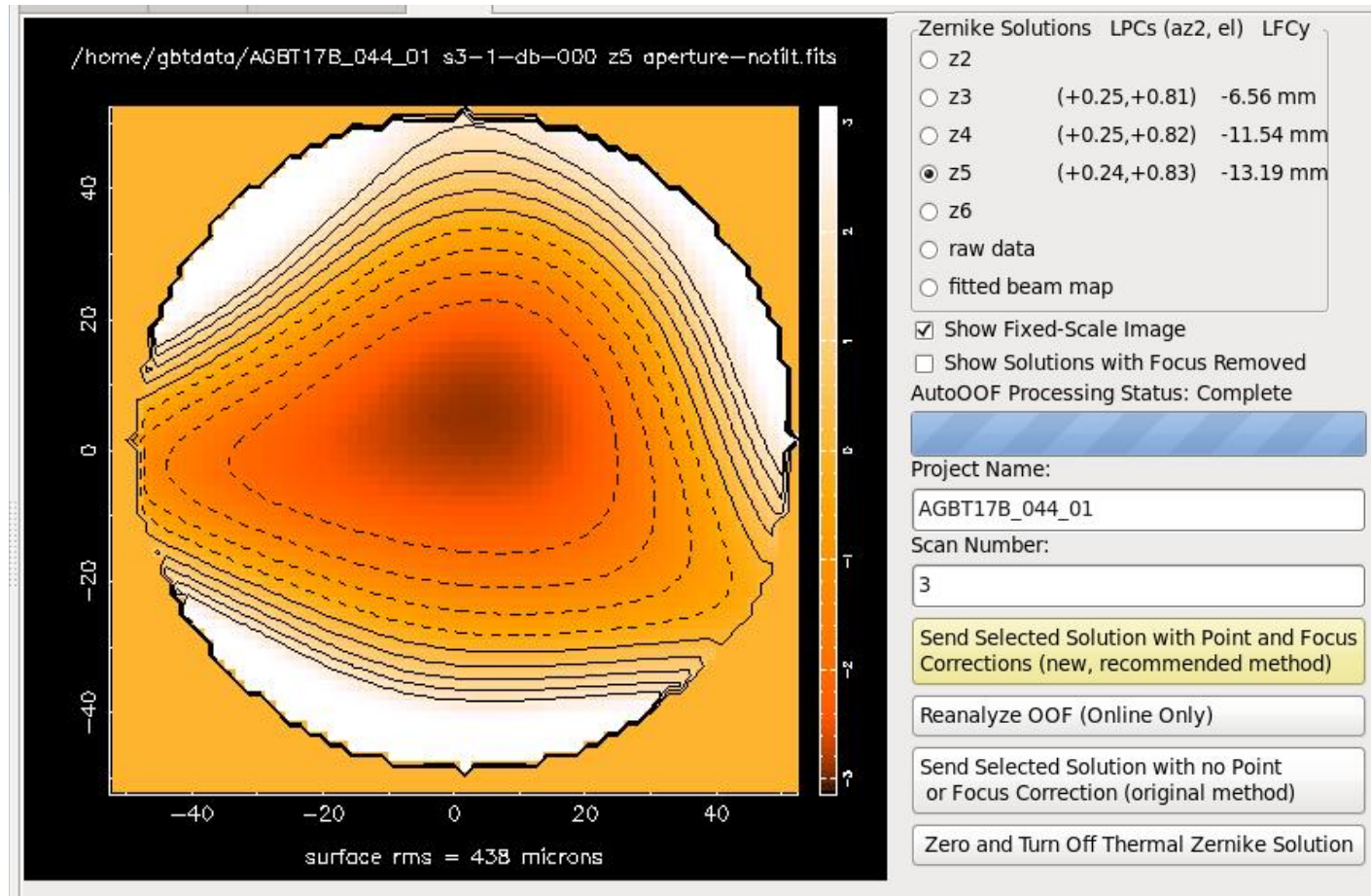


# Example of a Bad AutoOOF Solution

In this case observations were done in the keyhole at  $>85^\circ$  and OOF “rms” 438  $\mu\text{m}$  with a large implied focus and EL pointing offset.

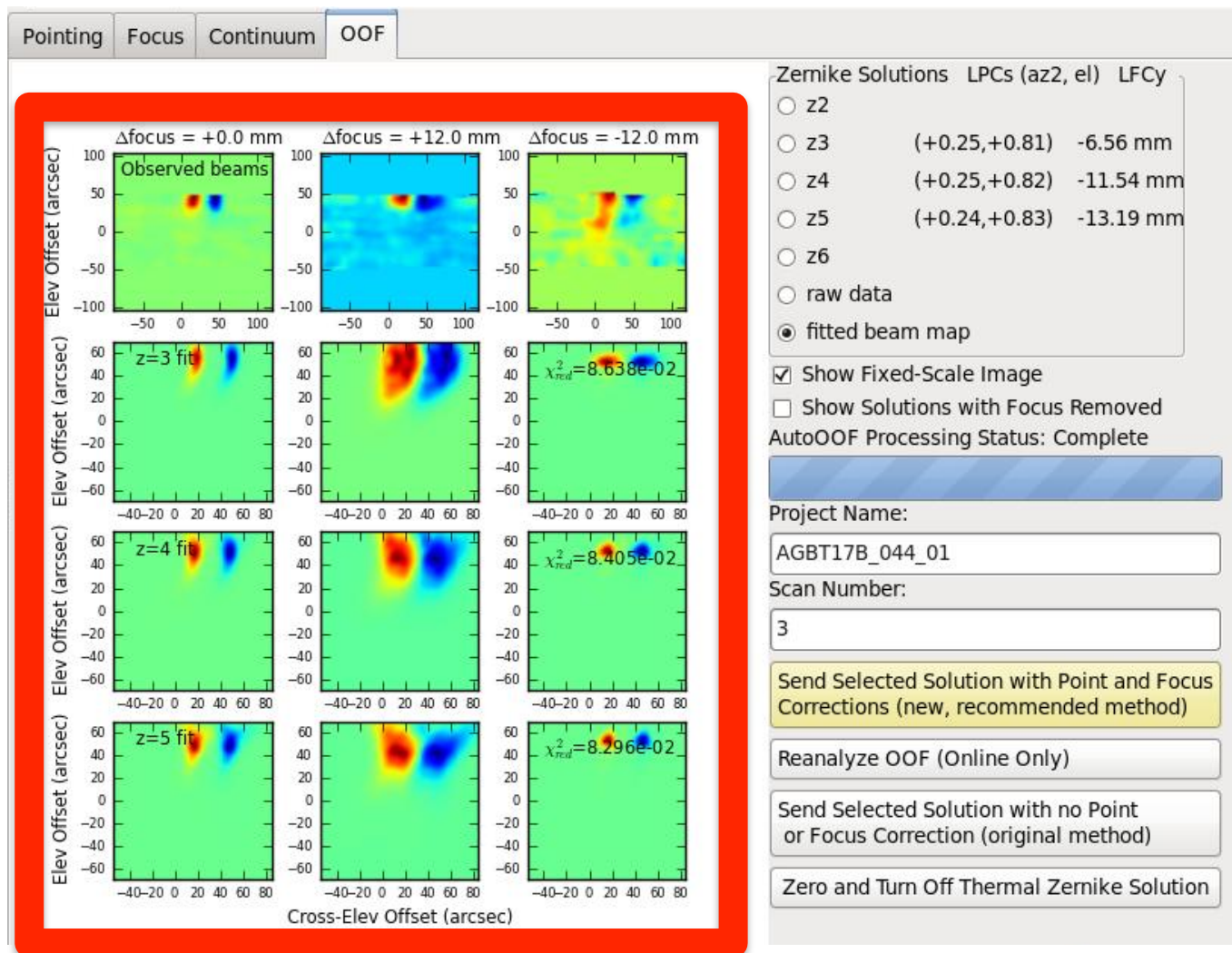
Solution with large rms  $>400\ \mu\text{m}$  should not be used.

Check the raw data and fitted beam maps.



# Beam Maps of Example Bad OOF

The “observed” beams should not be streaks or very elongated. This can happen in windy conditions.

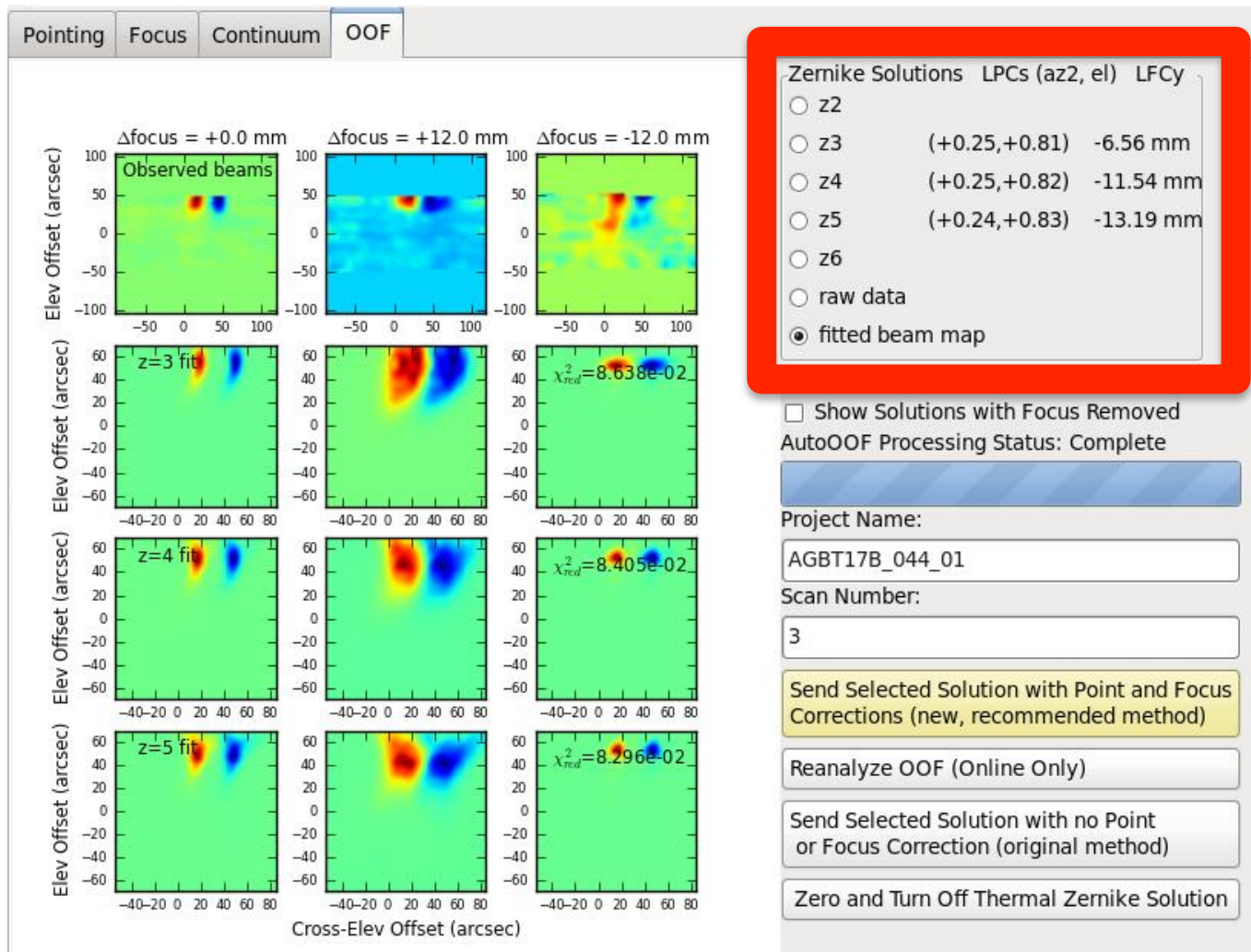


# Beam Maps of Example Bad OOF

The “observed” beams should not be streaks or very elongated. This can happen in windy conditions.

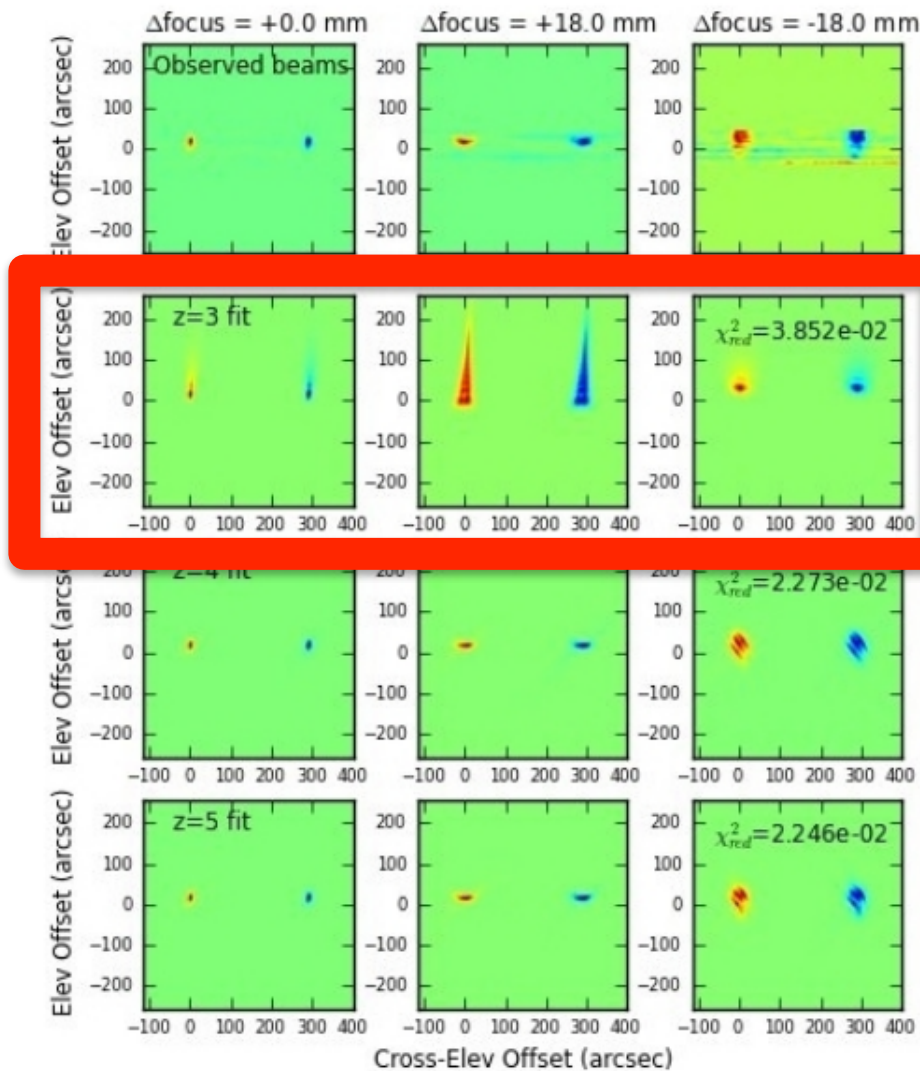
In this case data were taken in the keyhole causing the apparent focus correction to be very large and a large EL LPC.

Do not apply OOF corrections if you cannot trust the results. Redo.





# Another Bad OOF (avoid Z3 Solution)



Zernike Solutions	LPCs (az2, el)	LFCy
<input type="radio"/> z2		
<input type="radio"/> z3	(+0.04,+1.00)	-22.63 mm
<input type="radio"/> z4	(-0.05,+0.17)	-8.41 mm
<input type="radio"/> z5	(-0.09,+0.12)	-6.11 mm
<input type="radio"/> z7	(Unk,Unk)	Unk mm
<input type="radio"/> raw data		
<input checked="" type="radio"/> fitted beam map		

Figure 5.10: The AutoOOF fitted beam maps (left). The observed beam maps are plotted on the top row with the z3, z4 and z5 fits to the observed beams plotted below. The z3 solution (2<sup>nd</sup> row down) shows an obvious artifact and should not be used. Also note the significant jump in LPCs and the LFC between the z3 and z4 solutions (above).

Take the solution that has better fitted beam maps and reasonable values. In this case z5.



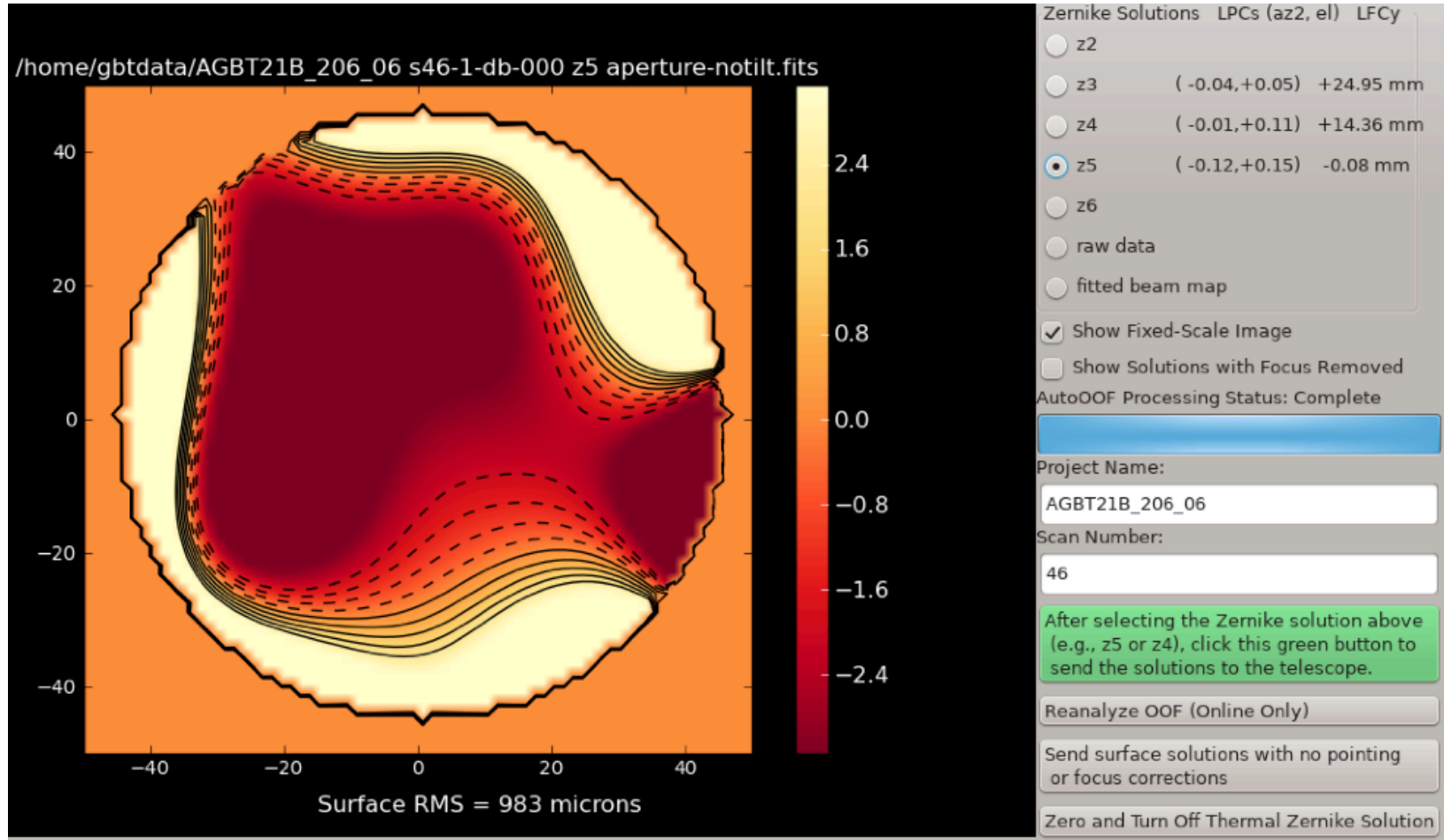
# Bad OOF with ARGUS? What do you do?

- ARGUS Example
  - Redo
  - Don't apply corrections
  - Recommended to OOF with Ka-band if on telescope

## Notes on Telescope Corrections When Using ARGUS

- OOF surface corrections should be done with Ka+CCB system if available for highest S/N, but can also be done with Argus if Ka+CCB is not available
- Pointing and focus corrections can be done with Argus or at lower frequency (e.g., X-band)
- Users can struggle and waste a lot of time trying to point/focus with Argus (e.g., faint sources/marginal conditions). You should point+focus in X-band if problems arise or if in doubt.

# Bad OOF with MUSTANG-2? What do you do?



Zero solutions AND LFCy (ask operator) and Re-OOF (submit OOF script again)

# Observing Strategies: Antenna Optimization

- Should point+focus (AutoPeakFocus) every 30min-50min depending on conditions (point+focus takes ~5min)
  - MUSTANG-2 - point every 30 minutes
- AutoOOF (which takes ~20min) is used to correct the surface for thermal effects at night.
  - Not recommended before 21:00 or 22:00
  - Daytime surface changes <1hr time scales
    - Due to these rapidly changing conditions, the AutoOOF solutions (which are on a similar timescale) can cause more harm than good from the AutoOOF. So it is typically not useful to use the “thermal” corrections during the day.
  - OOF solution good for 2-6 hours at night

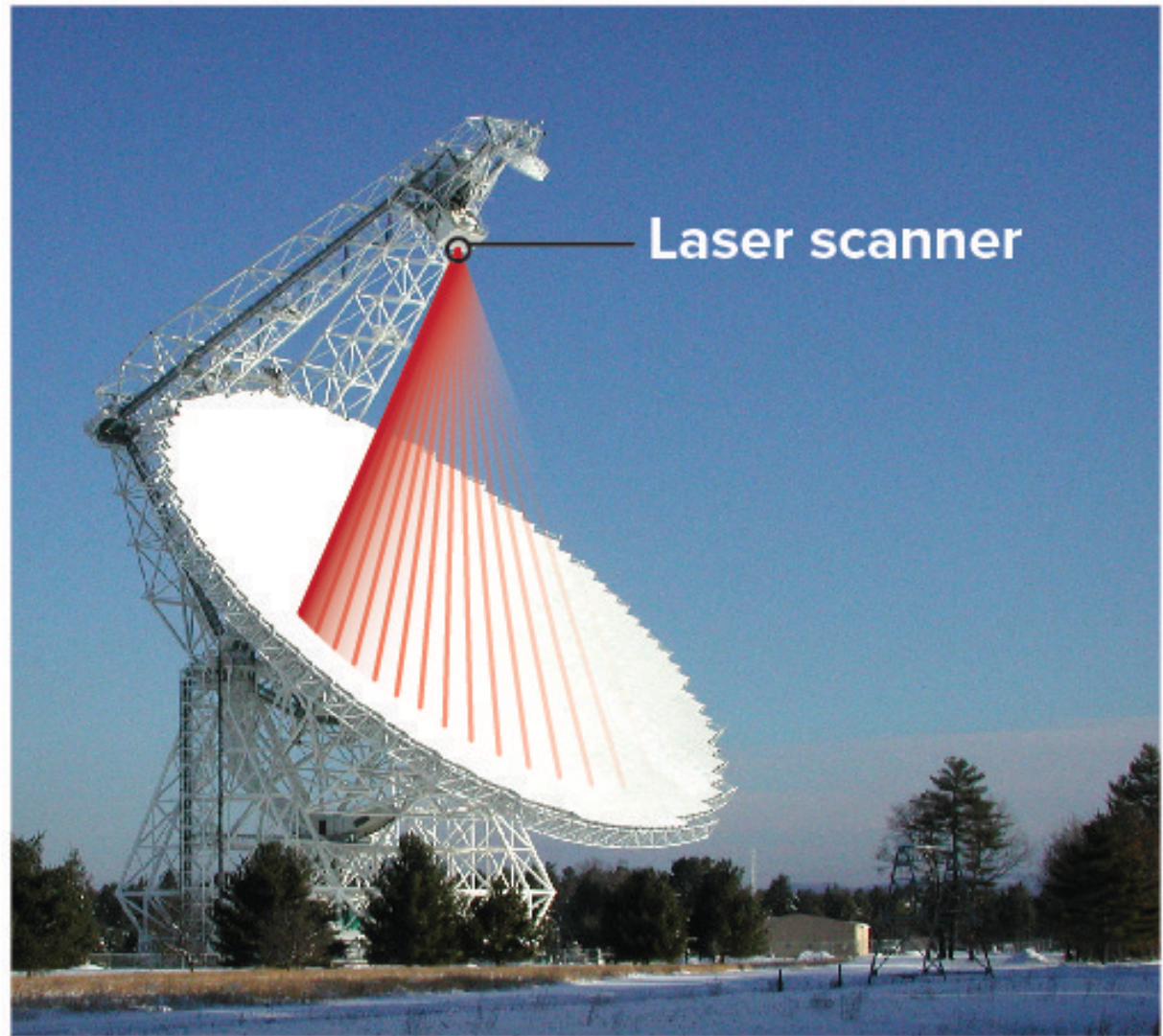
# LASSI: Laser Antenna Surface Scanning Instrument

Commercial laser scanner that will scan the dish and detect deviations from previous measurements.

To be used in conjunction with OOF. Not giving an absolute correction but deviations from previous solutions.

Processing time takes 6 minutes (compared to the 20-30 minutes for OOF scans)

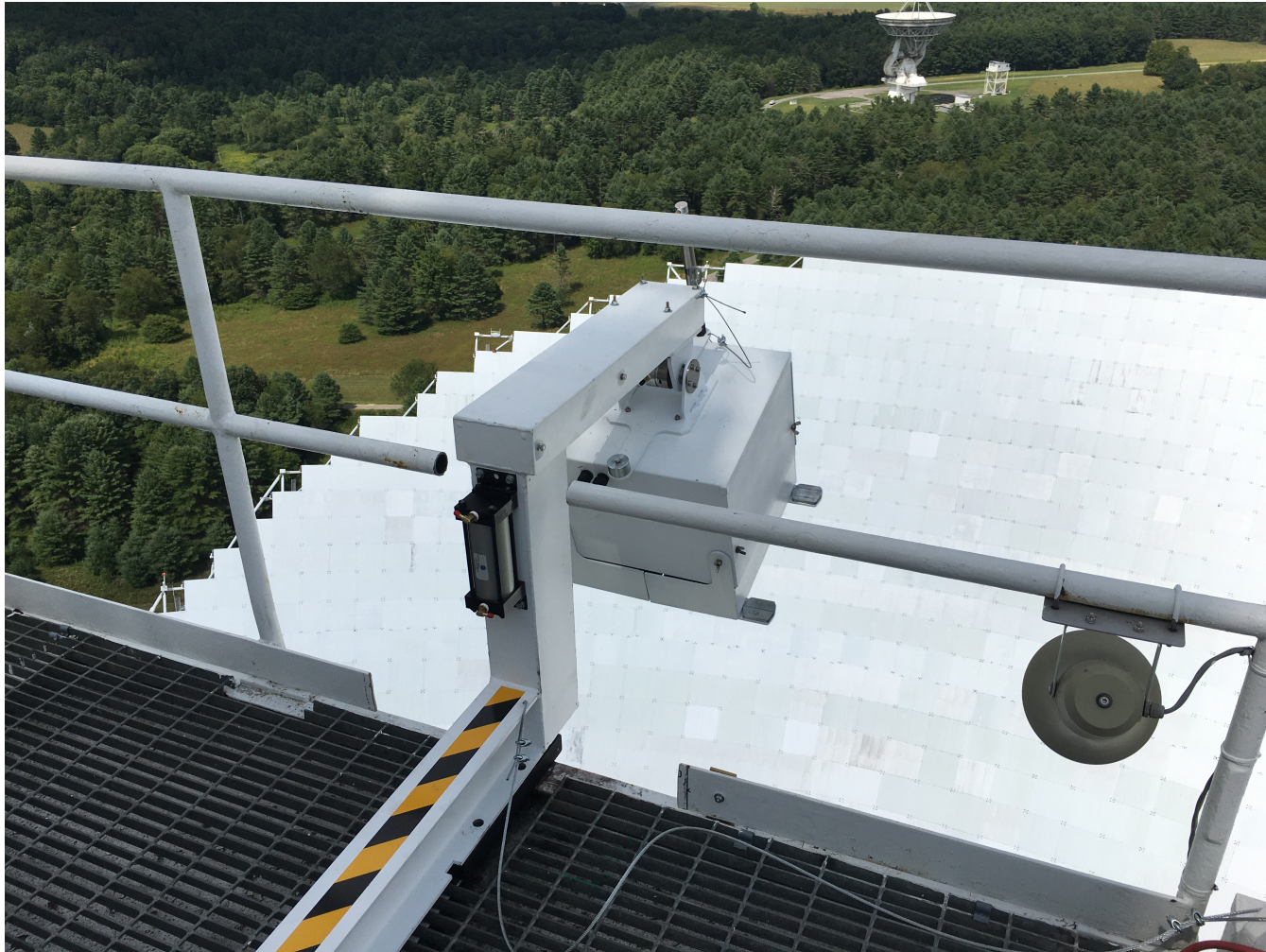
Opens up more day time observing for high frequency.



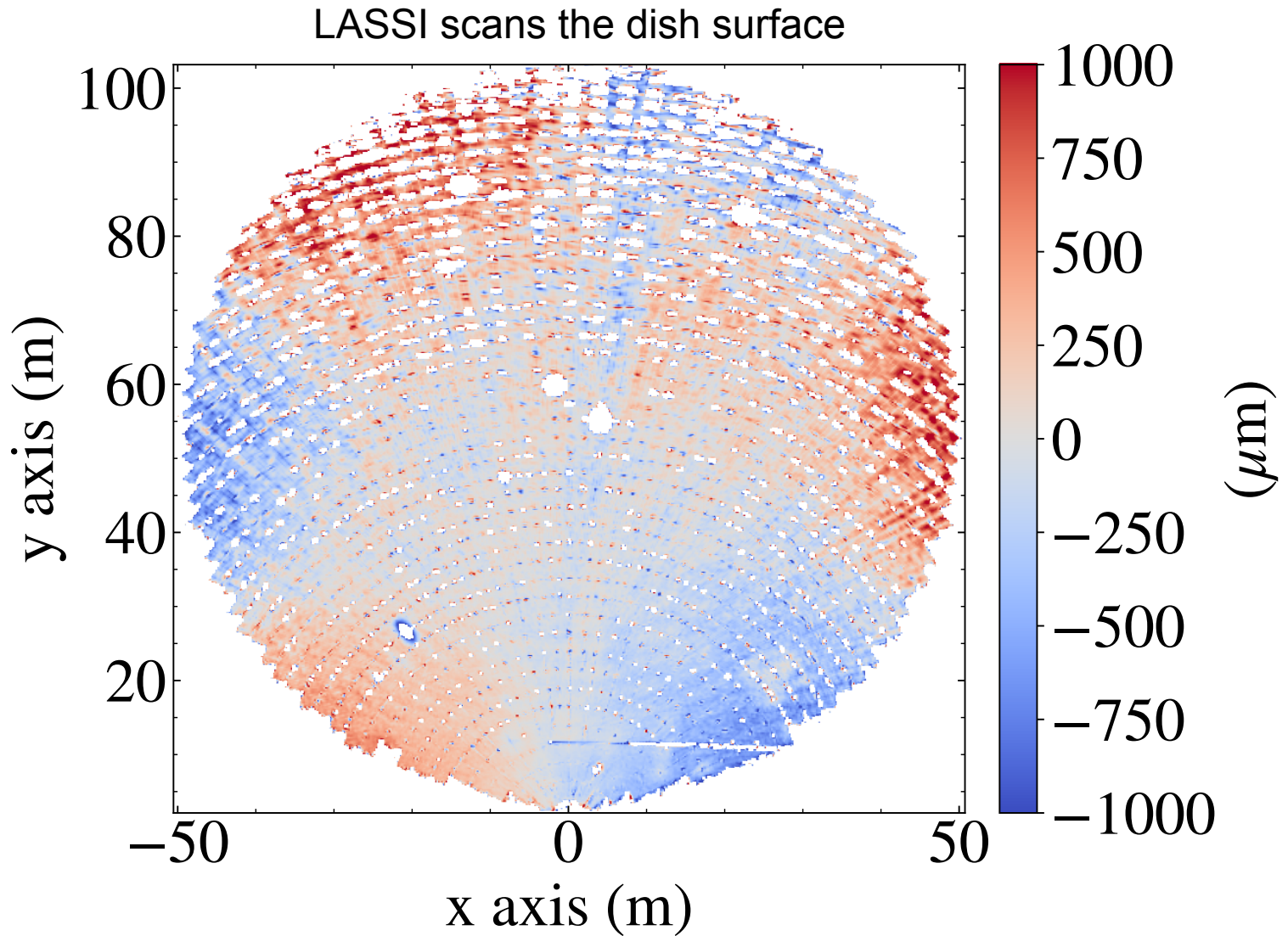


# LASSI: Laser Antenna Surface Scanning Instrument

Photo of LASSI installed on the GBT



# LASSI: Laser Antenna Surface Scanning Instrument





# GREEN BANK OBSERVATORY

**[greenbankobservatory.org](http://greenbankobservatory.org)**

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operated under cooperative agreement by Associated Universities, Inc.*

