Analyzing phasecamera images

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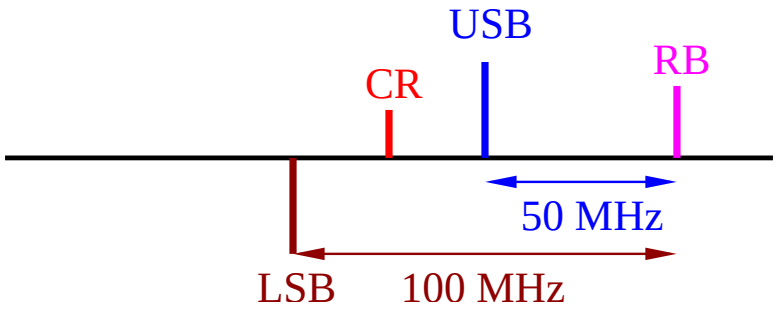
California Institute of Technology

Workshop: “Spatial Mode Properties of IFOs”,
Caltech, Feb 02nd, 2005

The PhaseCamera Data

- In this Talk we discuss: AS port PhaseCamera images taken by Luca & Keita in 3rd week of September'2004 under various Thermal Compensation States:
  - Fibre-carried reference beam(RB) from PSL at 75 MHz is mixed with dark port beam consisting of carrier and upper (+25MHz) & lower (-25MHz) SB
  - Images for beams demodulated at 100MHz, 75 MHz and 50 MHz are captured for LSB, CR and USB respectively in Quad and In phase [and also at DC]



Various TCS states considered

(Typically 20-100 measurements in each set each day)

- Repeated 3-4 days
  - NOTCS
  - AX330_CY75
  - AX600_CY75
- 1 Day
  - AX100_CY75
- AX330_AY330
  - CX150_AY660
  - CX30_CY30
  - CX75_AY330
  - CX75_CY75

What can we expect from Analysis of Images?

- To know about each Sideband at dark port
- To quantify how they differ from each other
- How modal content and basis vary with Thermal compensation
- To know about astigmatism

➢ Luca,Keita's Analysis: H1 elog Sept 29, 2004

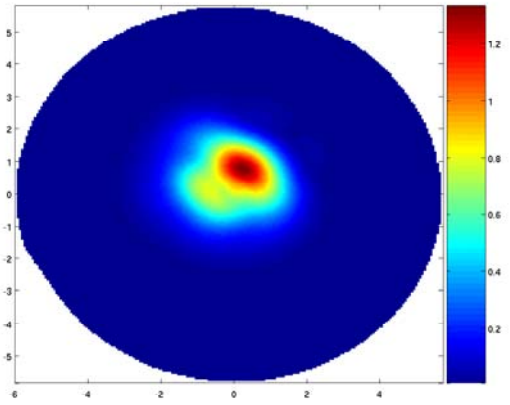
[Preliminary analysis of Average Data for each set of measurement: Using Contour plots, Zeroth Order Fit, …] …. Talk by Joe Betzwieser

Our Analysis (i.e. mode-decomposition)

- Demodulated Image (say at 100MHz):
  DemodImage = K X (LSB.real + i LSB.imag)

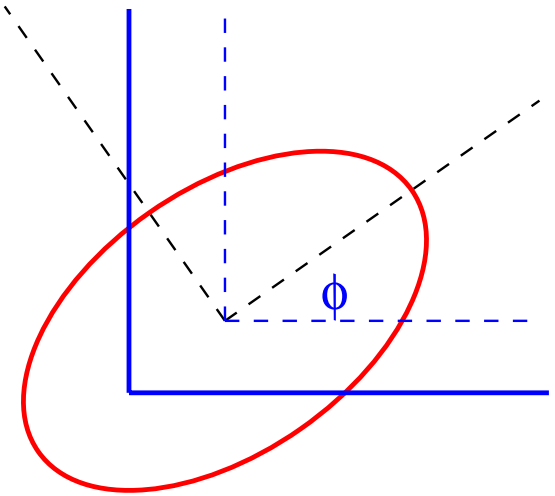
➢ K is supposed to be a constant with assumption that
(i) Width of reference beam is wider than dark port beam so that it does not have much variation in amplitude over the phasecam dimension
(ii) The radius-of-curvature of the reference beam
is large so that it does not have much variation in phase over the phasecam dimension.

- What do we fit? – The Complex Amplitude of "DemodImage" which is proportional to the amplitude of,e.g. LSB



Fitting of Images (using Matlab)

- Fitting is done with Hermite-Gaussian modes (astigmatic basis) upto 4^{th} order (15 modes)
- Total number of parameters: 5+15+15=35
  - Phi (angle of the X-axis of the elliptical beam in transverse plane), Xoffset, Yoffset, widthX, widthY
  - 15 amplitudes for 15 mode-coefficients
  - 15 phases for 15 mode-coefficients

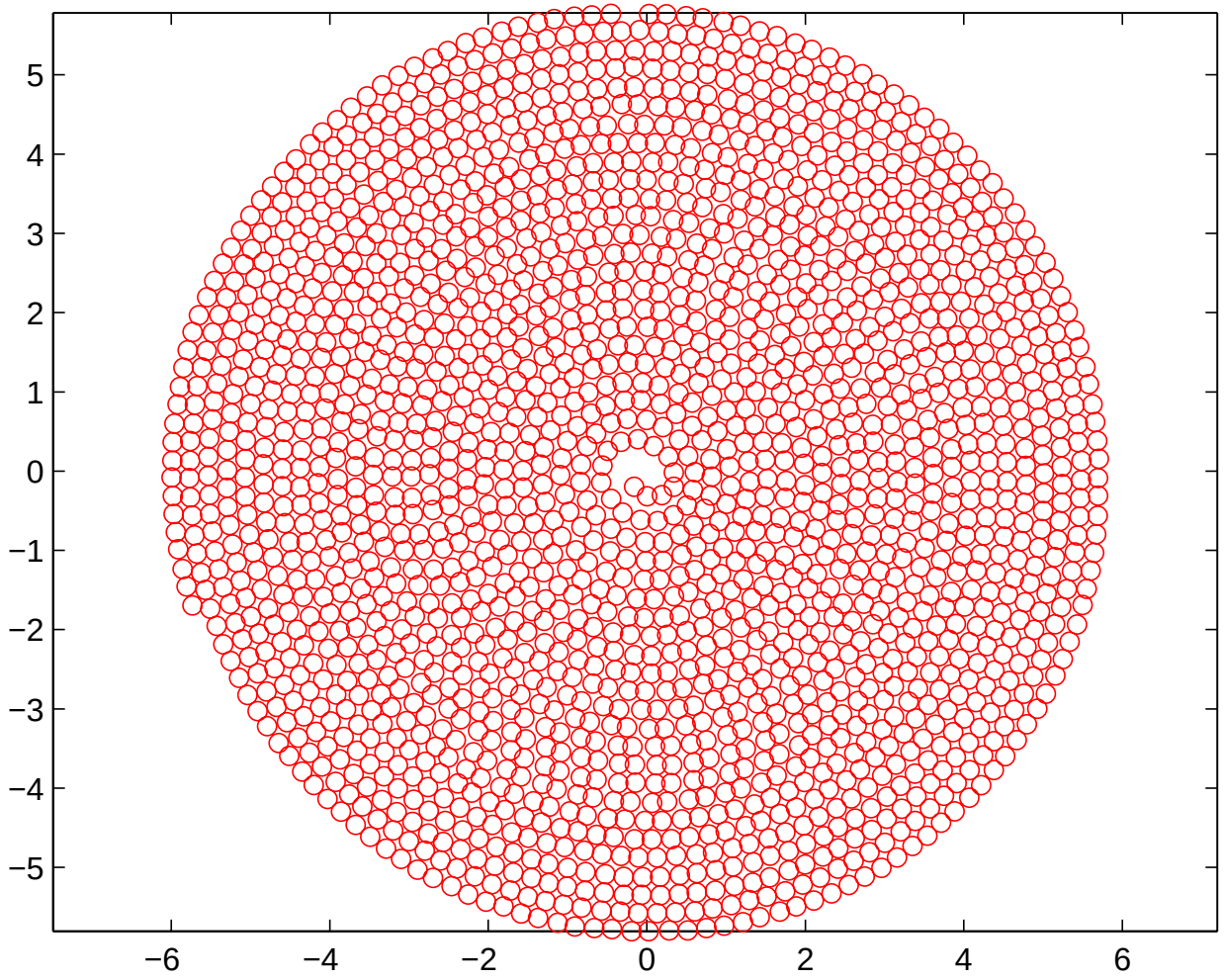


Thanks: Hiro Yamamoto

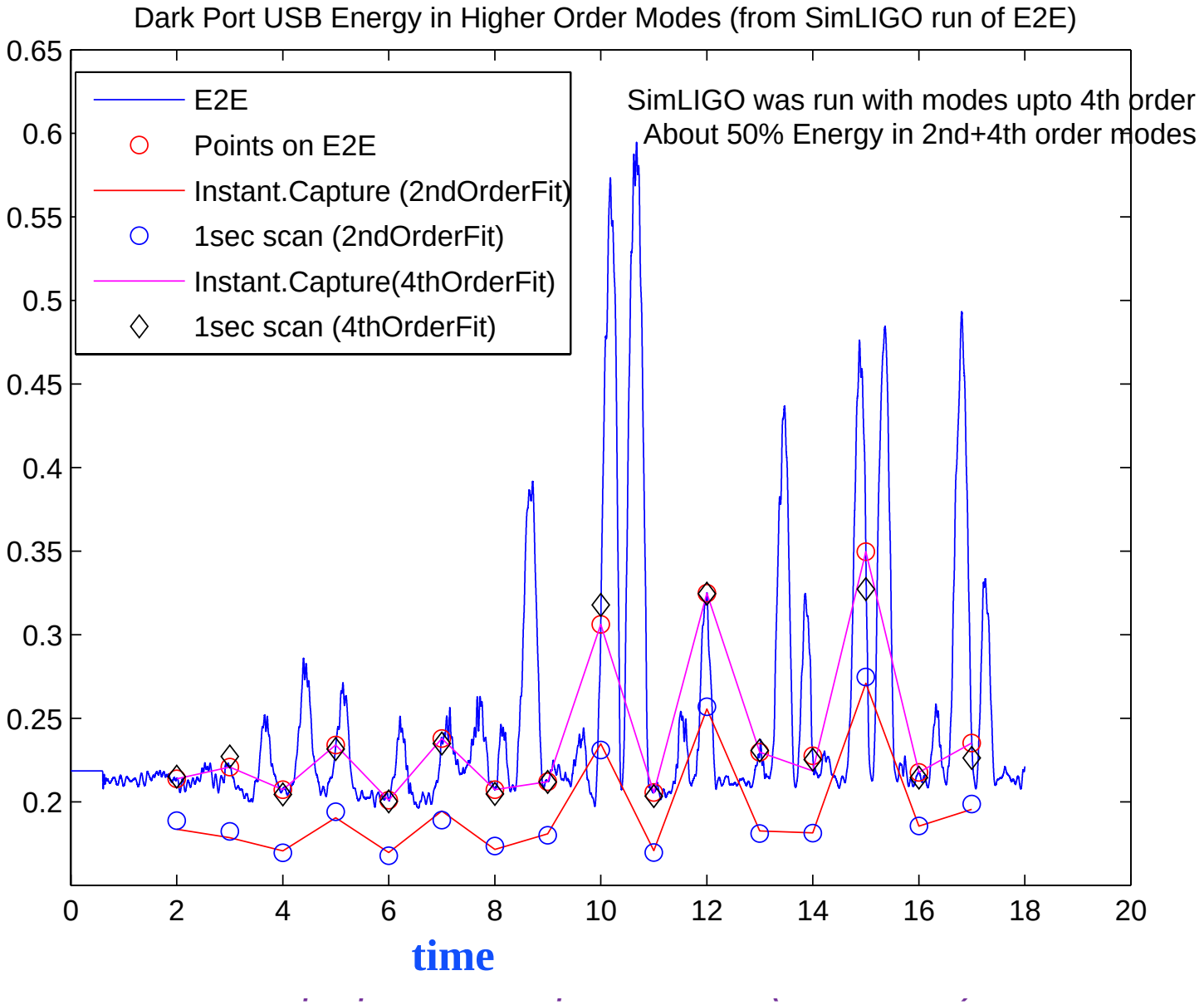
Does 1 sec Scan Time Distort the Modal Info?

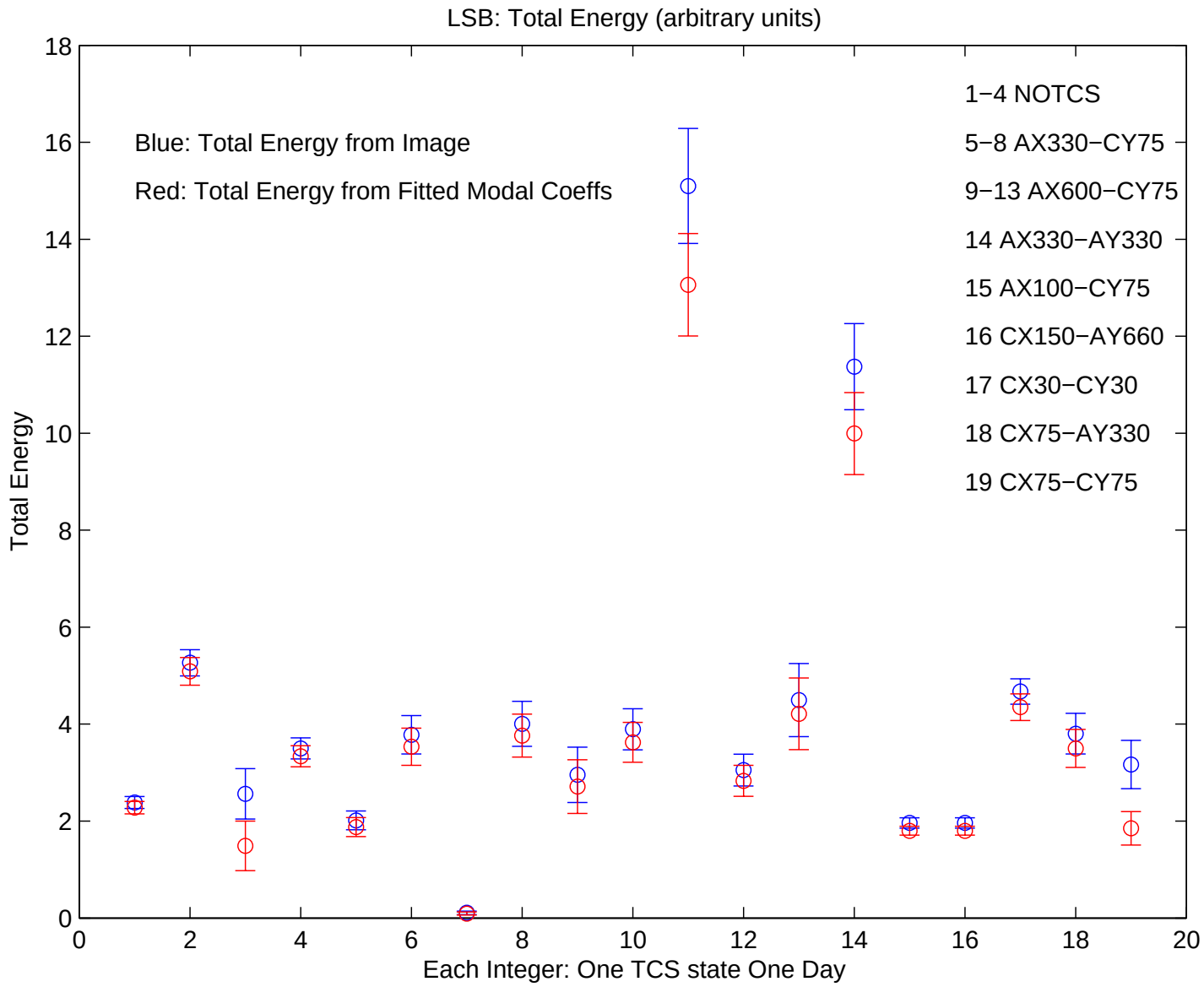
2000 pixels

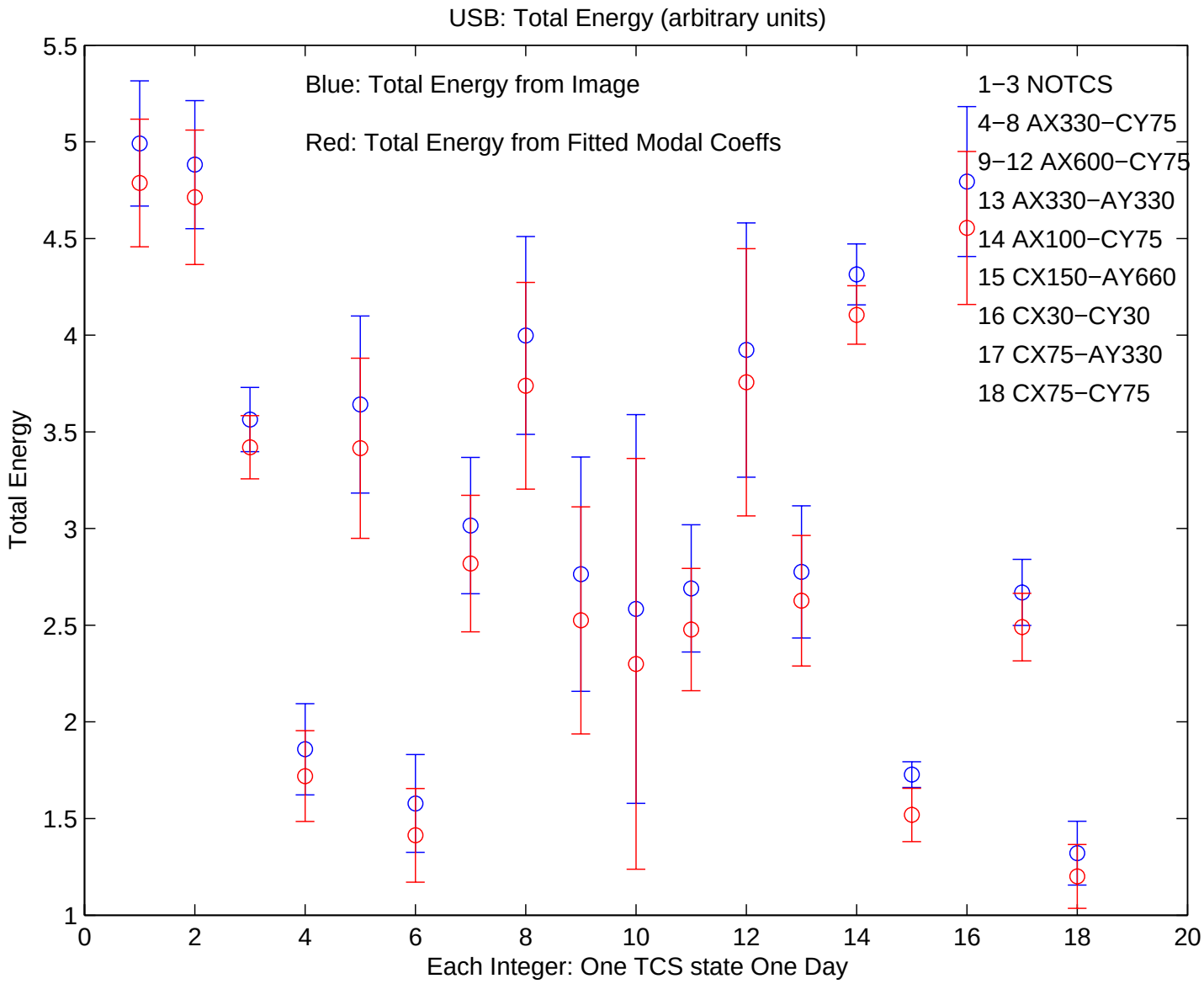
Does 'Averaging' of all measurements in a particular state suppress/distort modal info?



Fitting Exercise: for SimLIGO output

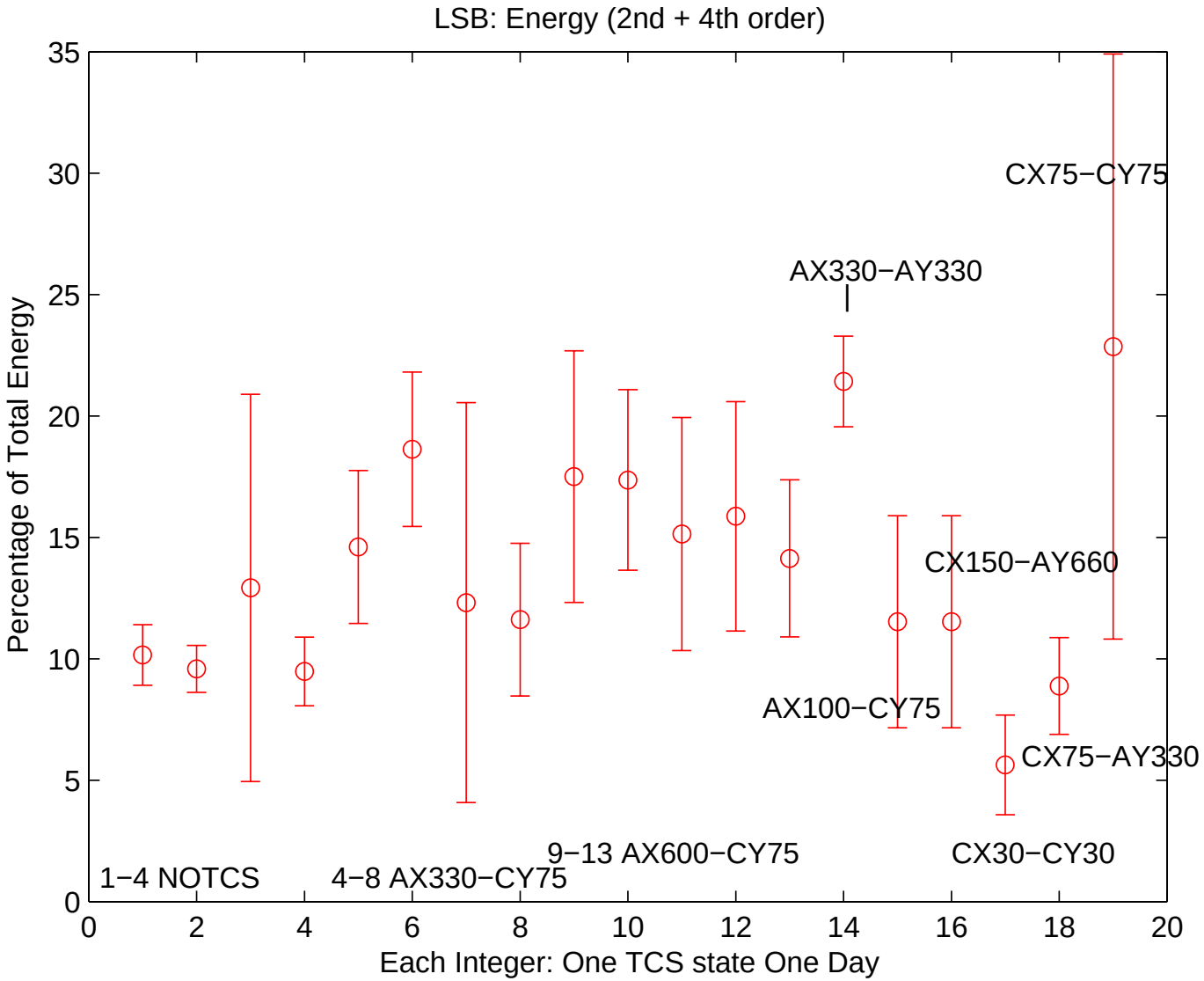


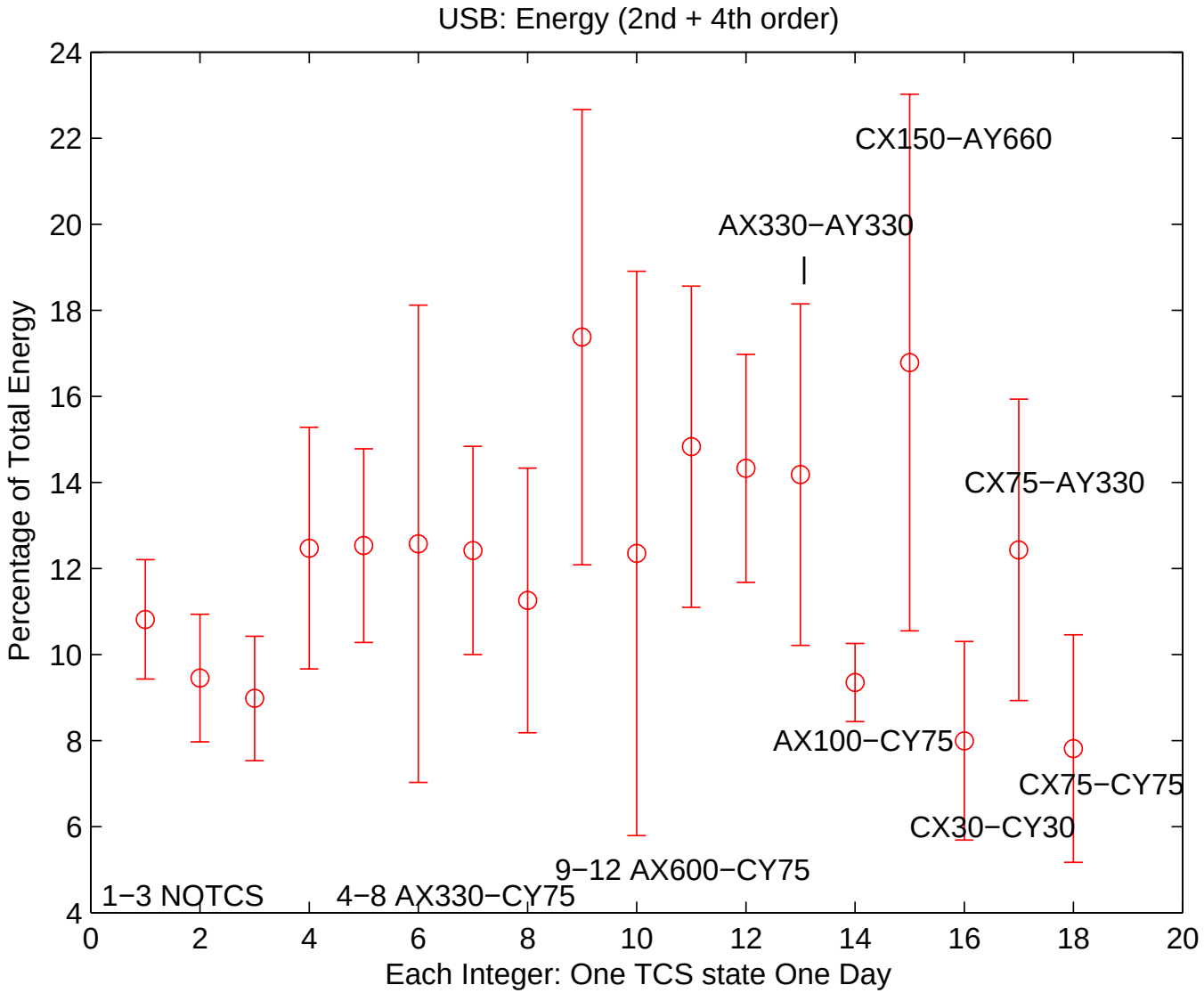

LSB: Total Energy (arbitrary units)
Blue: Total Energy from Image
Red: Total Energy from Fitted Modal Coeffs
1−4 NOTCS
5−8 AX330−CY75
9−13 AX600−CY75
14 AX330−AY330
15 AX100−CY75
16 CX150−AY660
17 CX30−CY30
18 CX75−AY330
19 CX75−CY75
Total Energy
Each Integer: One TCS state One Day
0
2
4
6
8
10
12
14
16
18
20

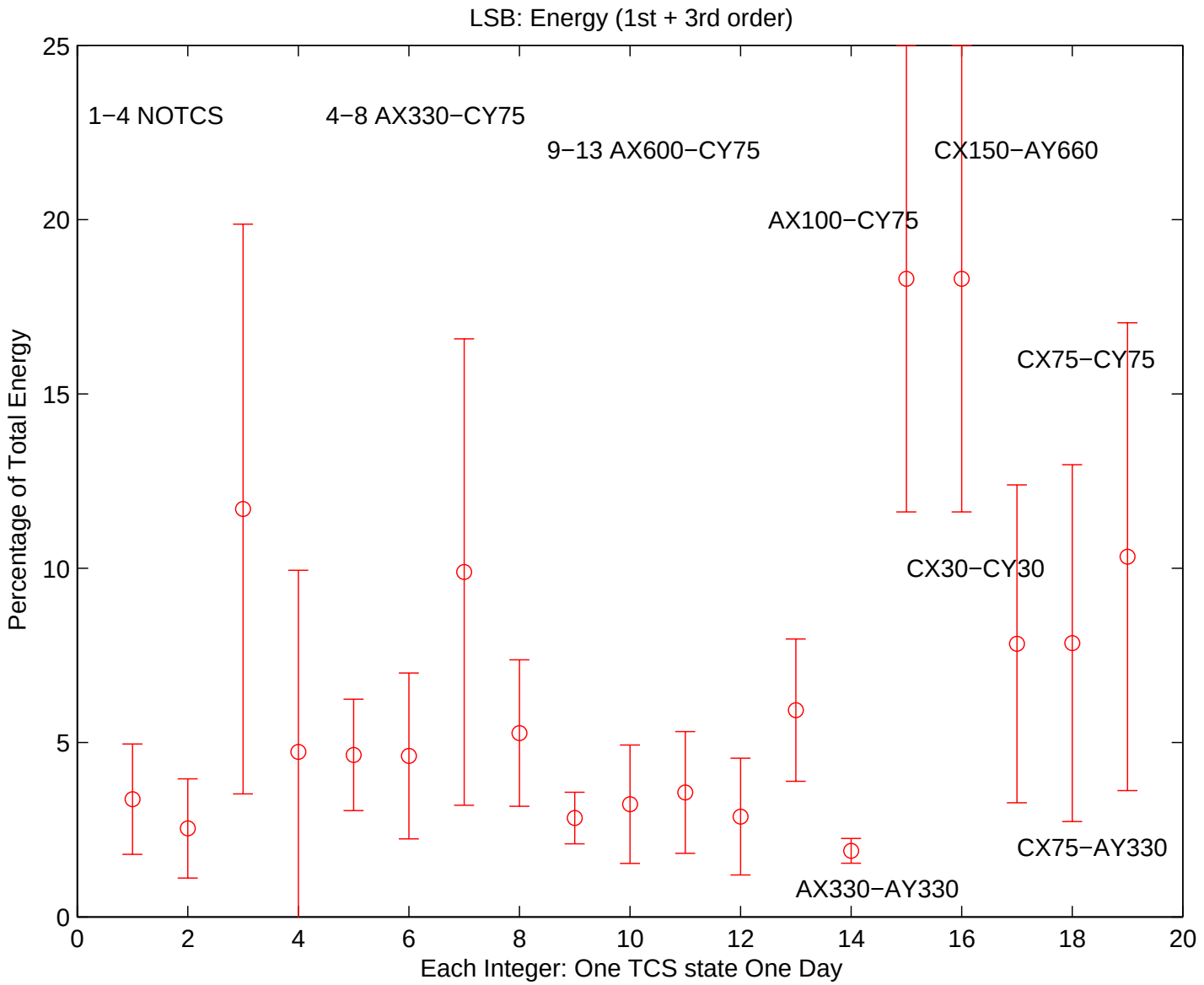

USB: Total Energy (arbitrary units)
Blue: Total Energy from Image
Red: Total Energy from Fitted Modal Coeffs
1−3 NOTCS
4−8 AX330−CY75
9−12 AX600−CY75
13 AX330−AY330
14 AX100−CY75
15 CX150−AY660
16 CX30−CY30
17 CX75−AY330
18 CX75−CY75
Total Energy
Each Integer: One TCS state One Day
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0
2
4
6
8
10
12
14
16
18
20

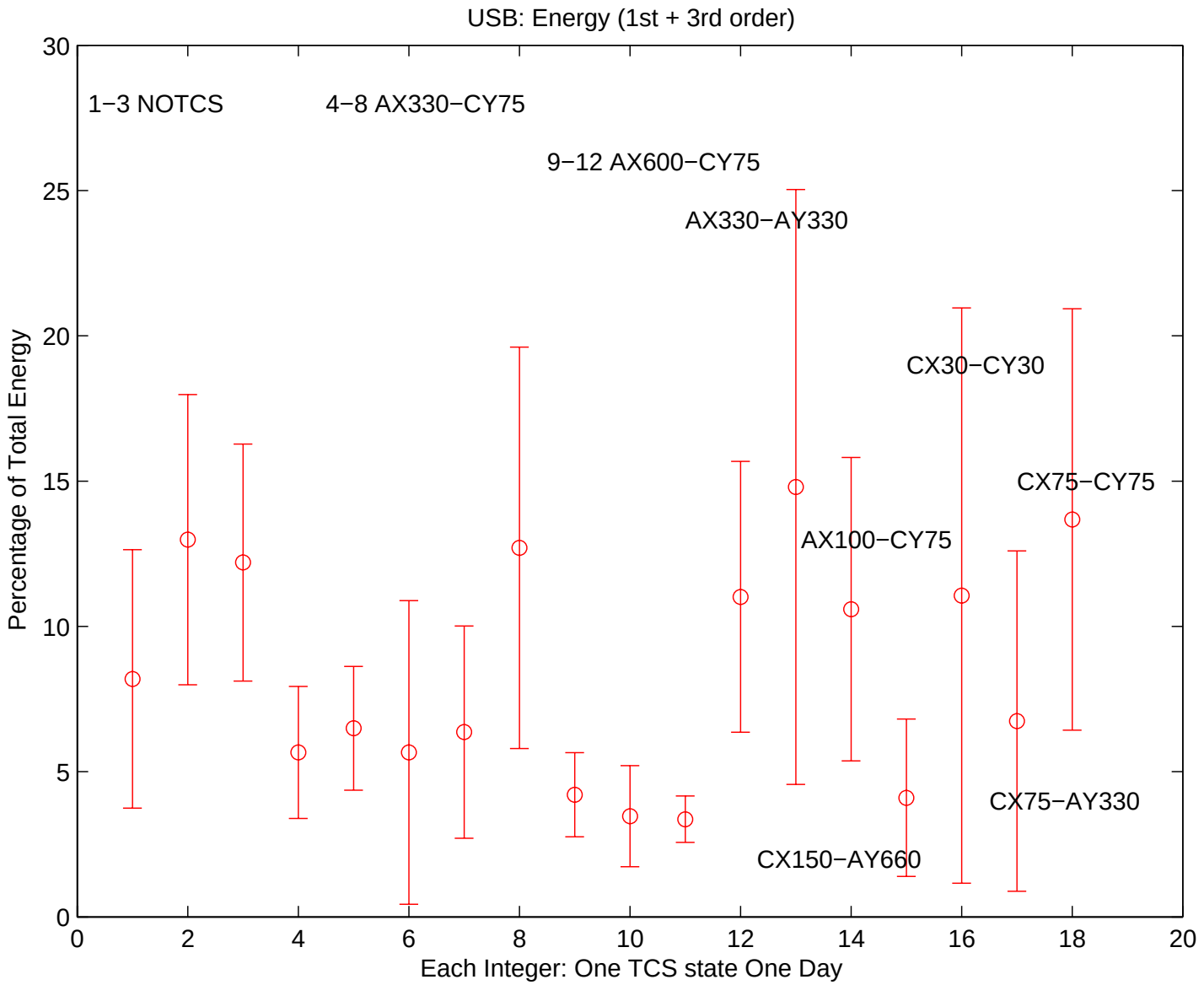
Idea about Modal Content from FFT Simulation

- From FFT run (without pitch/yaw):
- In Cold State:
  - 72% energy in modes 0-4 order
  - 47% energy in zeroth order
  - 25% energy in 2+4 order modes
- In Hot State:
  - 97% energy in modes 0-4 order
  - 89% energy in zeroth order
  - 8% energy in 2+4 order modes

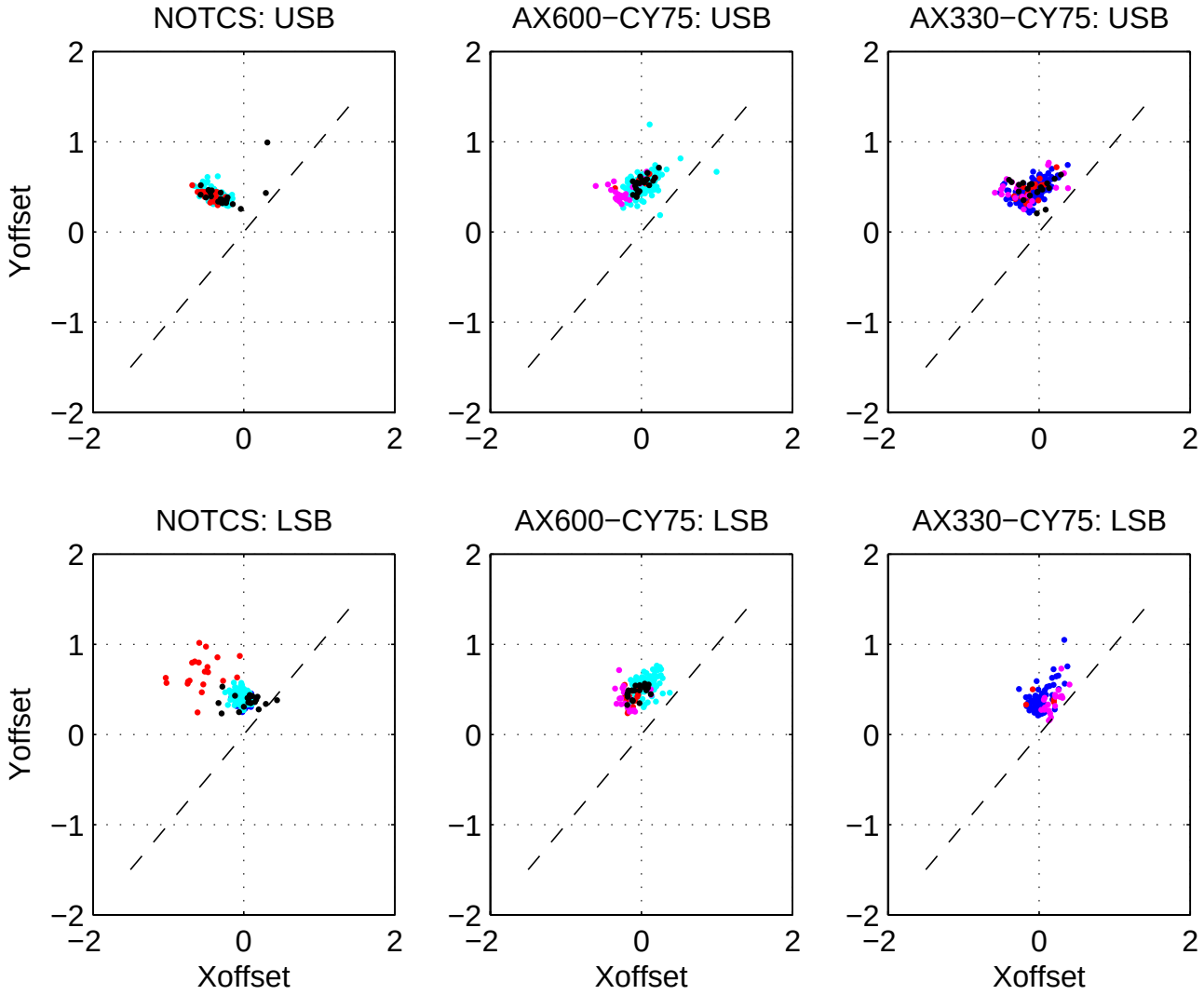

LSB: Energy (2nd + 4th order)
Percentage of Total Energy
Each Integer: One TCS state One Day
CX75−CY75
AX330−AY330
CX150−AY660
AX100−CY75
CX75−AY330
CX30−CY30
9−13 AX600−CY75
4−8 AX330−CY75
1−4 NOTCS
0
5
10
15
20
25
30
35
0
2
4
6
8
10
12
14
16
18
20


USB: Energy (2nd + 4th order)
Percentage of Total Energy
Each Integer: One TCS state One Day
CX150−AY660
AX330−AY330
CX75−AY330
AX100−CY75
CX75−CY75
CX30−CY30
9−12 AX600−CY75
1−3 NOTCS
4−8 AX330−CY75

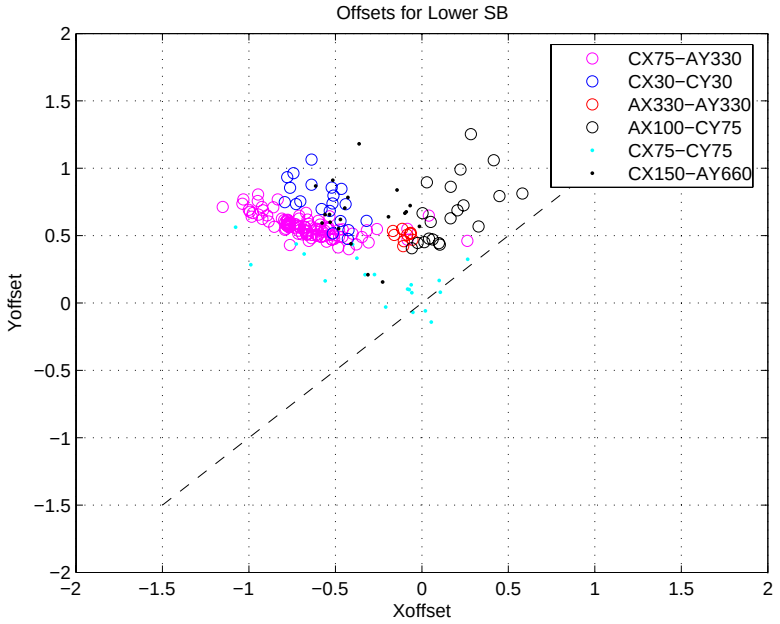

LSB: Energy (1st + 3rd order)
1−4 NOTCS
4−8 AX330−CY75
9−13 AX600−CY75
AX100−CY75
CX150−AY660
CX75−CY75
CX30−CY30
CX75−AY330
AX330−AY330
Percentage of Total Energy
Each Integer: One TCS state One Day
0
5
10
15
20
25
0
2
4
6
8
10
12
14
16
18
20

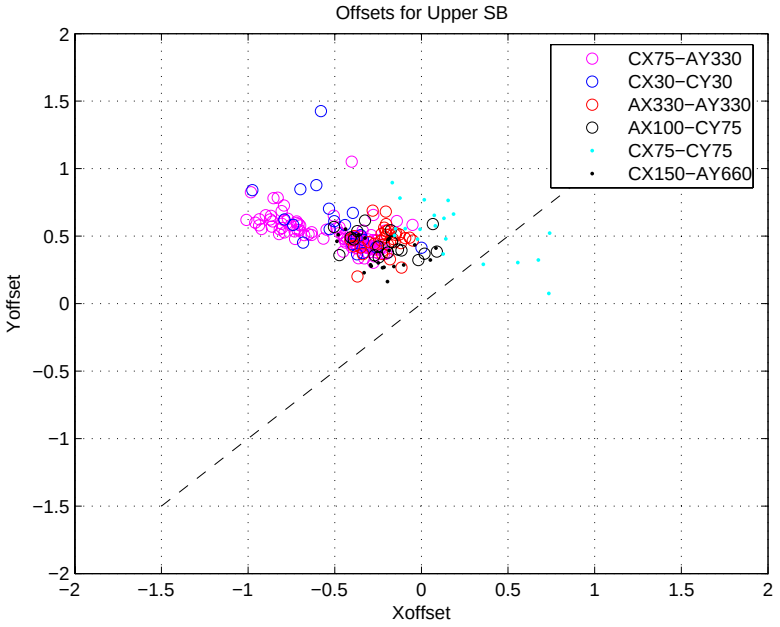

USB: Energy (1st + 3rd order)
1−3 NOTCS
4−8 AX330−CY75
9−12 AX600−CY75
AX330−AY330
CX30−CY30
CX75−CY75
AX100−CY75
CX75−AY330
CX150−AY660
Percentage of Total Energy
Each Integer: One TCS state One Day
0
5
10
15
20
25
30
0
2
4
6
8
10
12
14
16
18
20

Offsets of USB and LSB



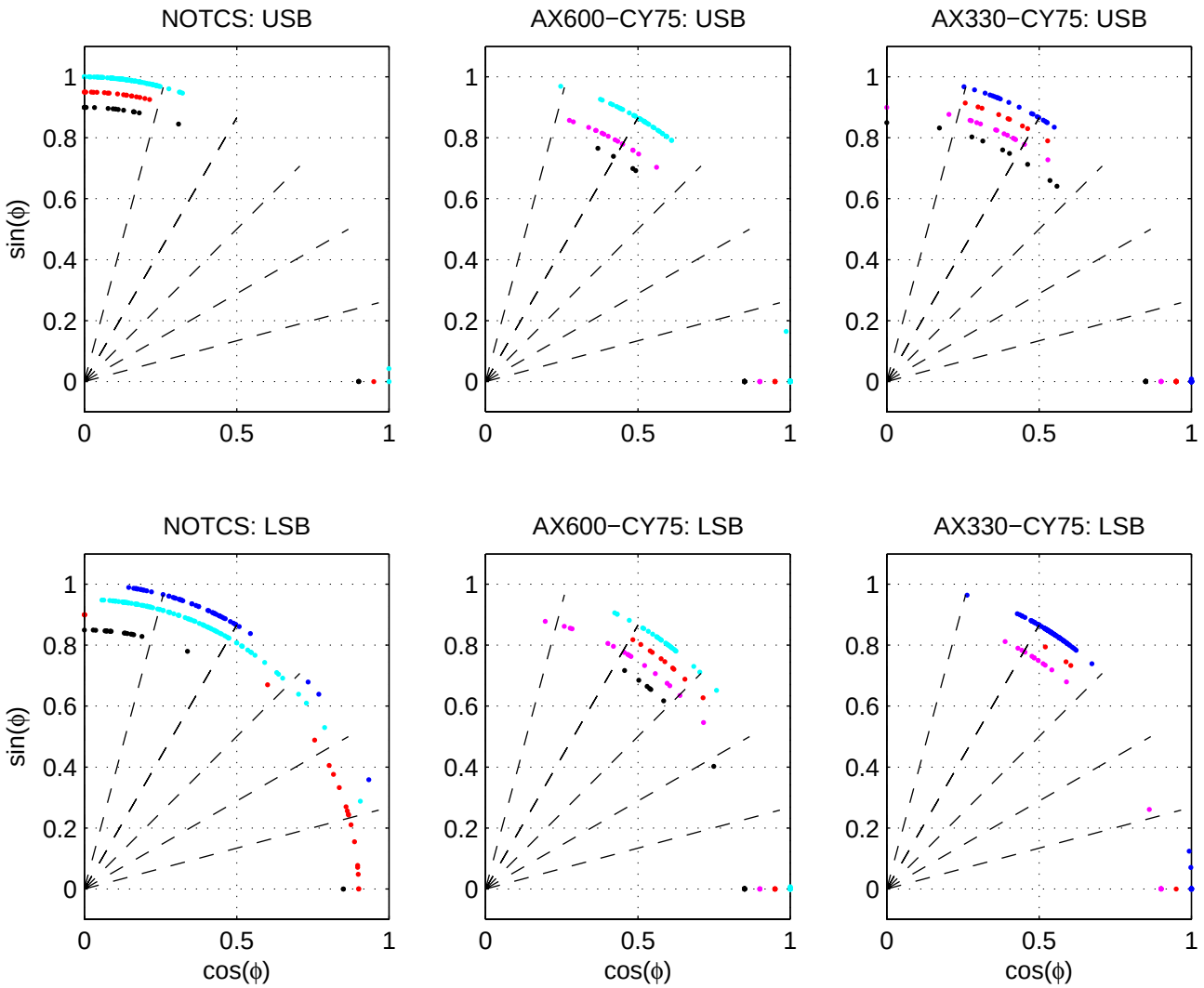
Offsets in Other TCS states



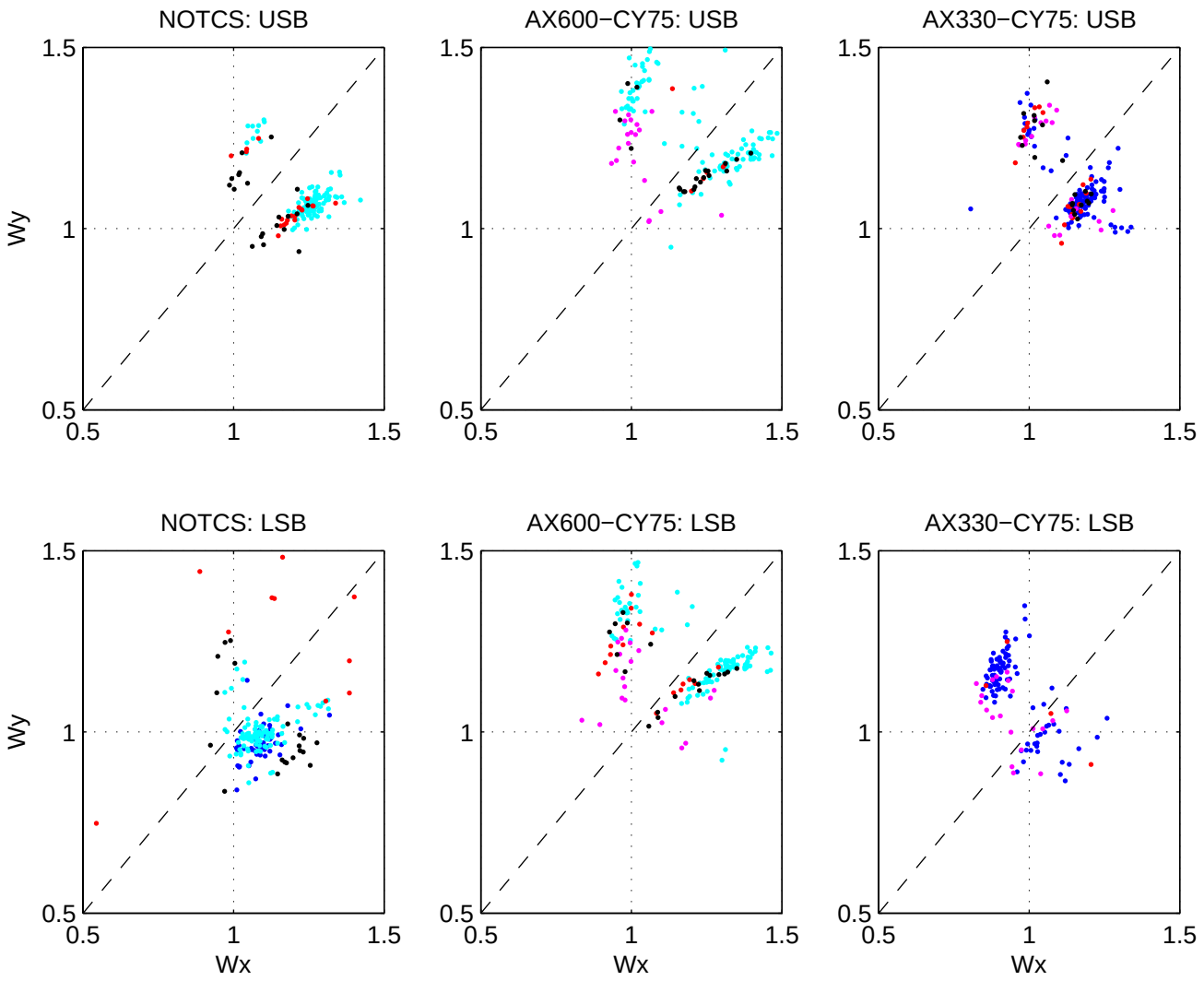


Variation in 'Phi' for USB & LSB

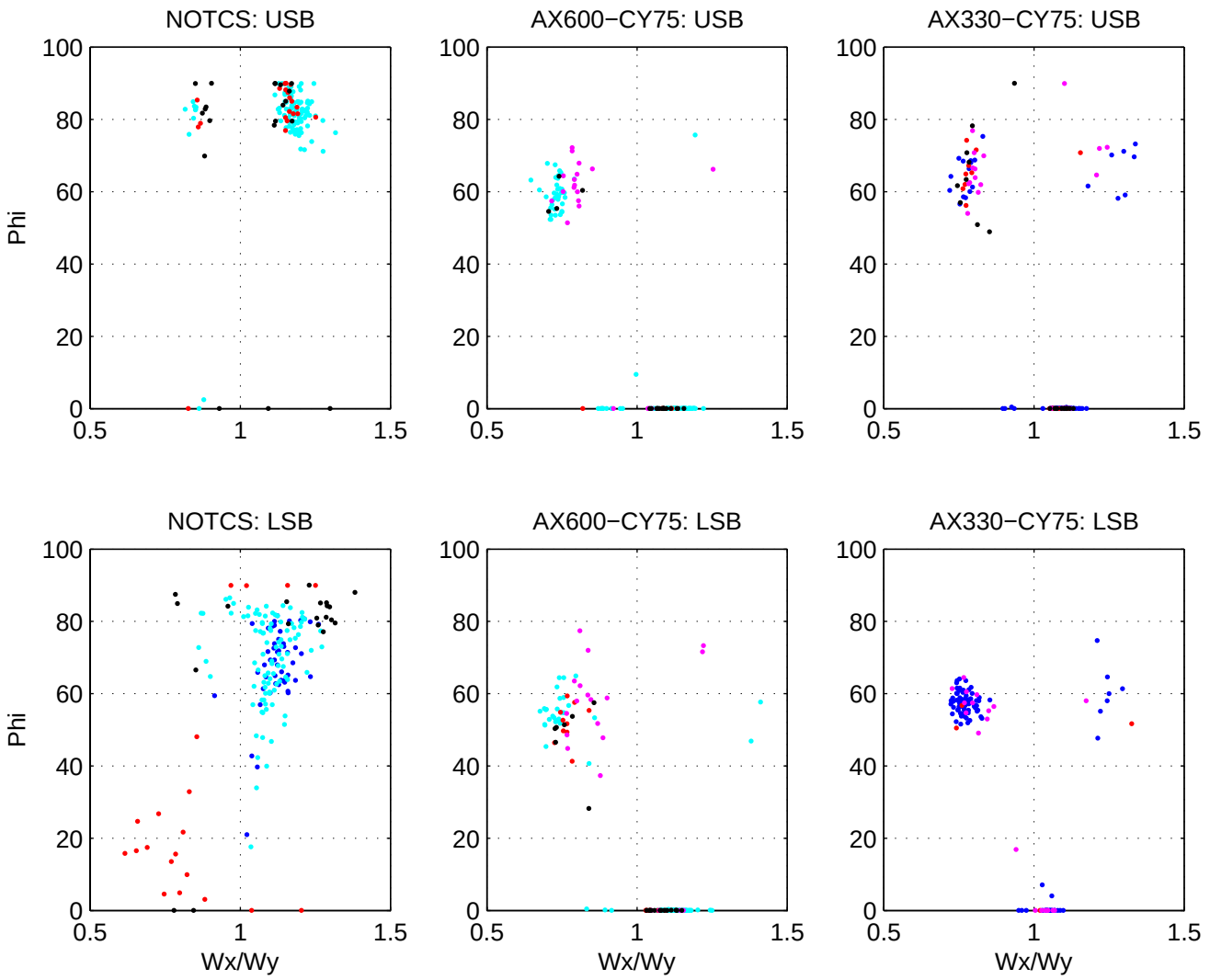
- Each color represents measurements made on a particular day
- cos^2+sin^2 made to differ from 1.0 (in all except one in each plot) to have better visibility for the distribution of different days



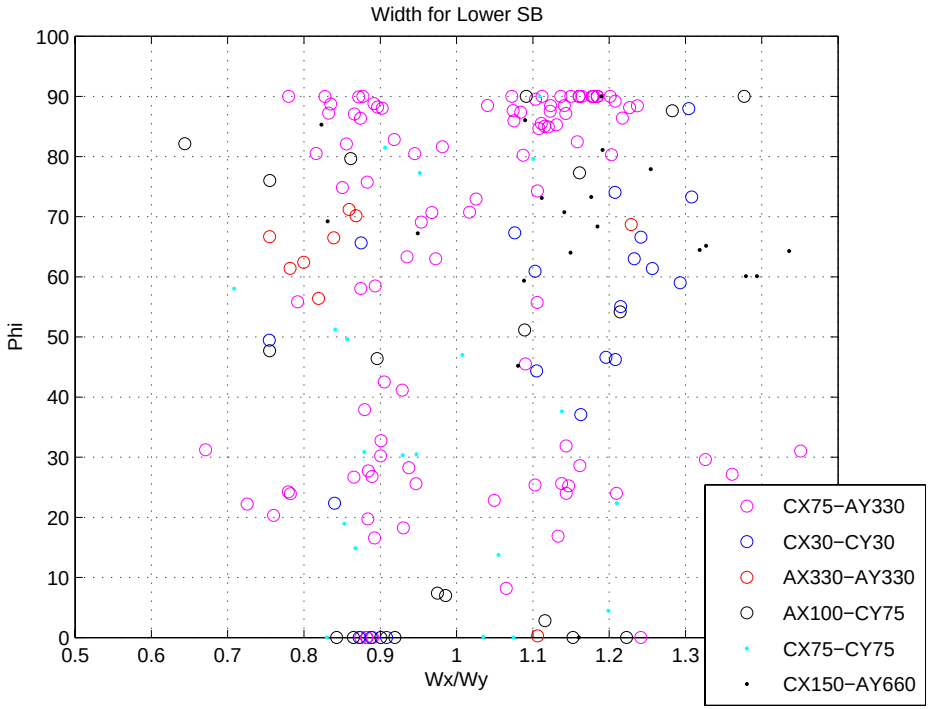
Variation in Beam Widths of USB and LSB

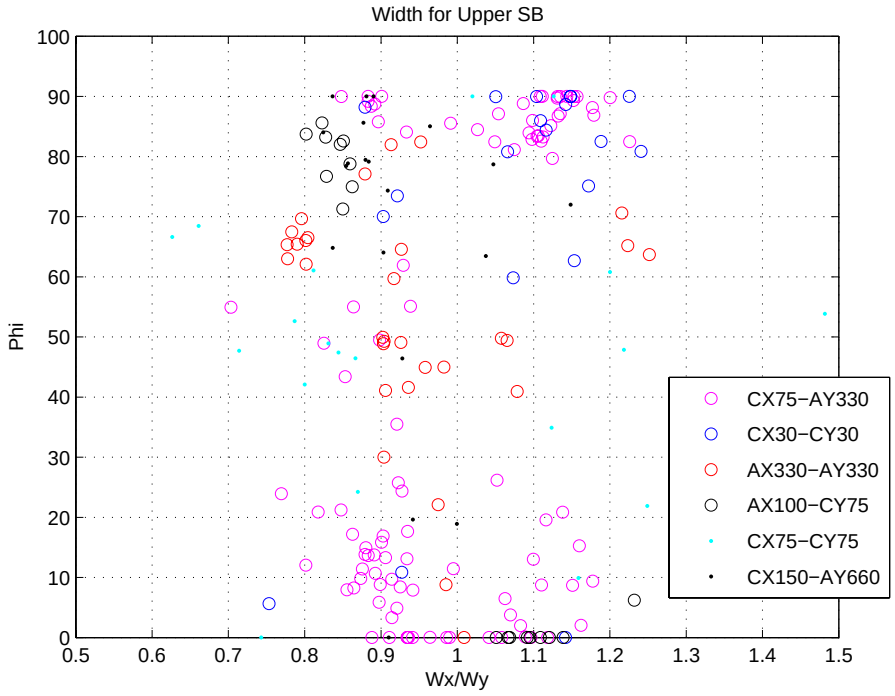


Variation in Phi & Width for USB & LSB



Variation in Phi & Width for other TCS states





Analysis data @

- All modal-decomposition analysis data are available at

  http://www.ligo.caltech.edu/~bbhawal/PC_modal_data

- Read "1README" file first
- Data are divided among directories for 9 TCS states
- Directory "1Stat" contains Summary Statistics for all TCS states on all days (total 37 files)
- Directory "1Energy" contains Energy data for all TCS states on all days (total 37 files)

Concluding remarks

Connection between Images and IFO states need to be understood

- Remember: effects from both IFO and OO are present
- "FFTprop" package: Can propagate a beam through lenses and distances; Phasemaps for mirrors or lenses can be included in its calculation ('back-calculation' possible) Download from http://www.ligo.caltech.edu/~bbhawal/FFTprop.tar.gz
- To Fit "changing widths" in different directions at different distances (i.e. rotation) in Keita's measurements [elog Oct21, 2004] …Hiro's talk