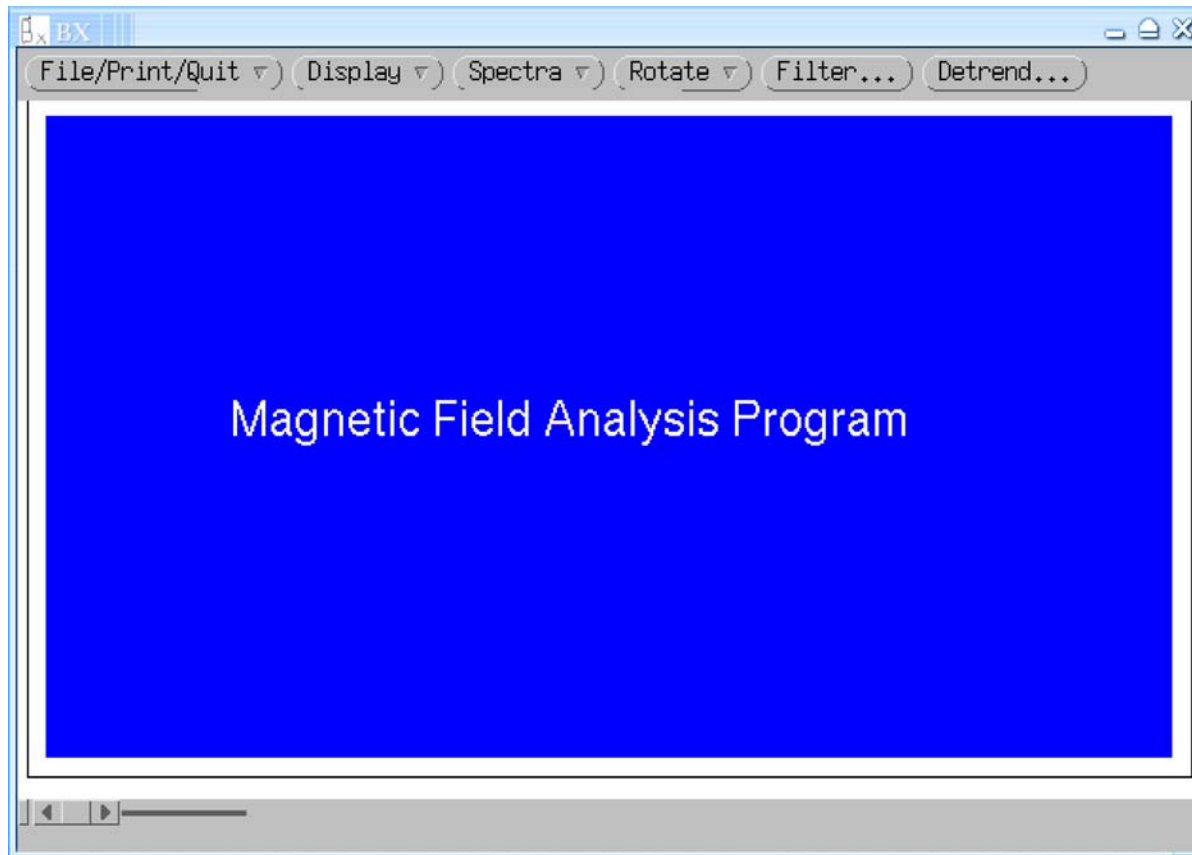# Introduction to bx Program (BANAL)

To accompany Exercise 2

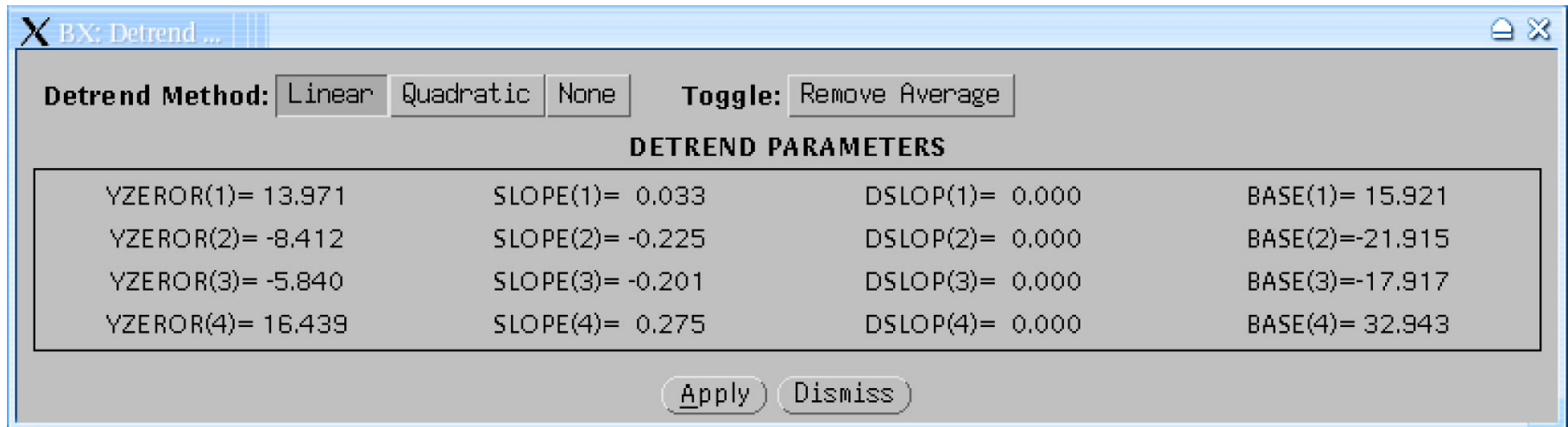C.T. Russell

April 9, 2008

Front Page: Getting Started

- The first thing you need is a dataset. Pull down the menu from the file button and select "Example"
- In this exercise get the "Shock lo Beta M/Mc=0.56" example and then use the shock coplanarity option under the rotate button to place the data in the shock coordinate system
- Next pull down the Spectra menu and select Spectrum A

Fourier Analysis: A primer

- Fourier analysis decomposes a signal into a series of orthogonal sine and cosine waves of frequency and to the fundamental of the data set to the Nyquist frequency, half the sample rate.

- N points in a time series can produce N Fourier amplitudes.

- A fundamental assumption of Fourier analysis is that the time series REPEATS and ad infinitum. Thus a slope turns into a saw tooth wave with frequency content over the entire frequency band.

- To remove this power detrending is recommended. Remove the slope!

- A power spectrum is constructed from the squared amplitudes of the cosine and sine waves (a and b coefficients). It is normalized so that the square root of the integral under the power spectral density curve is the root mean square amplitude.

- When you have 2 or 3 signals you can define the coherence and the phase difference between the time series

- With multiple signals you can define spectral matrices that give the in phase and out of phase power

- A minimum variance analysis or principal axis analysis on the cospectrum (in phase power) gives the direction of propagation of waves. A different but equivalent process works for circularly polarized waves using the quaspectrum.

Detrending

BX: Detrend ...

| Detrend Method: | Linear | Quadratic | None | | Toggle: | Remove Average |

DETREND PARAMETERS

YZEROR(1)= 13.971	SLOPE(1)= 0.033	DSLOP(1)= 0.000	BASE(1)= 15.921
YZEROR(2)= -8.412	SLOPE(2)= -0.225	DSLOP(2)= 0.000	BASE(2)=-21.915
YZEROR(3)= -5.840	SLOPE(3)= -0.201	DSLOP(3)= 0.000	BASE(3)=-17.917
YZEROR(4)= 16.439	SLOPE(4)= 0.275	DSLOP(4)= 0.000	BASE(4)= 32.943

(Apply) (Dismiss)

- Detrending removes the slope in the field that will add uninformative power spectral density to the spectrum
- Linear and quadratic detrending are available. Always keep the average field if you are going to do wave analysis
- Remember to push the apply button

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# Power Spectral Density Calculation
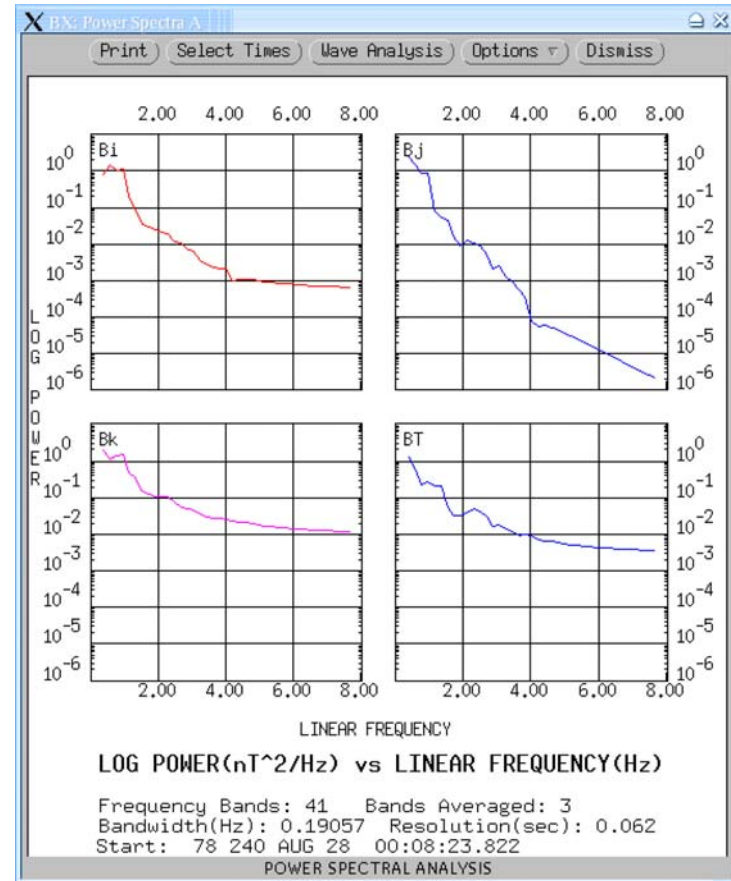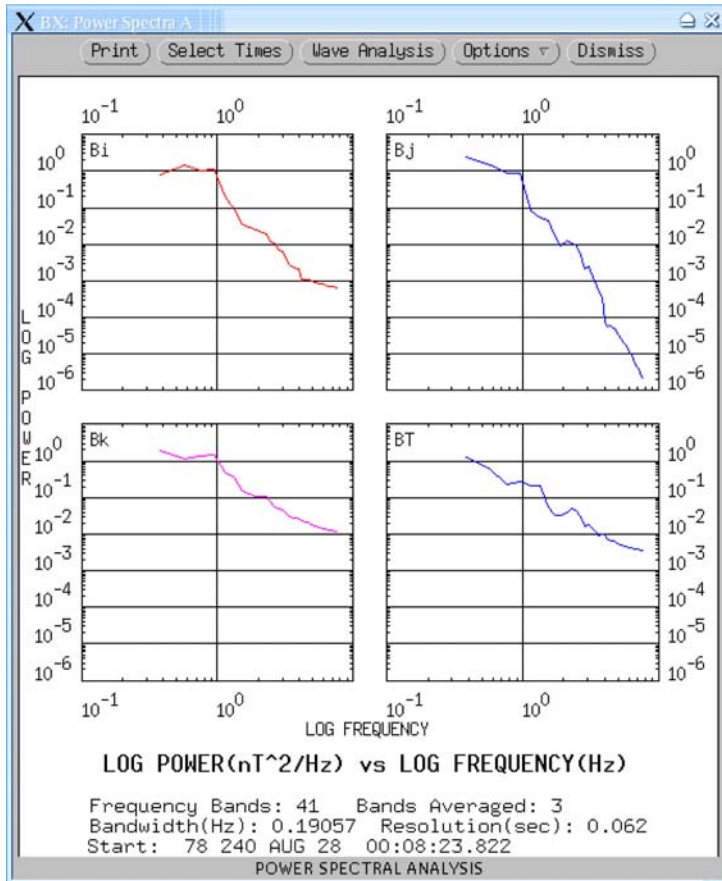
- When we choose a time interval after we have selected 'Spectra', a power spectral density plot will be displayed
- We initially show a log-log plot but a semi log plot can be selected from the options list

Options

- "Options" allow you to determine the coherence between pairs of signals; their phase difference, or both at the same time

- Sum of power allows you to combine power from different sensors. In particular you can calculate the power in the field strength (compressional power) and then subtract it from the summed power to obtain the transverse wave power. Regular power brings you back to the original display.

- Band width allows you to smooth the spectrum by adding up the power over a broader (sliding) window.

- W/O grid removes the grid.

- Number of spectral decades enables you to tailor the plot. I prefer log-log plots to have square decades.

- Frames allows you to plot a single frame of the 2 x 2 panel

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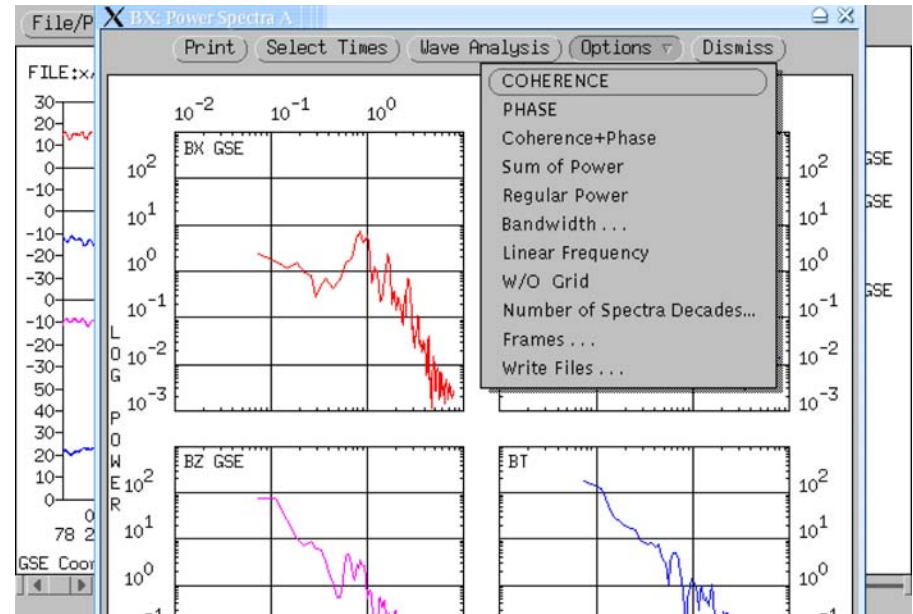
Options continued
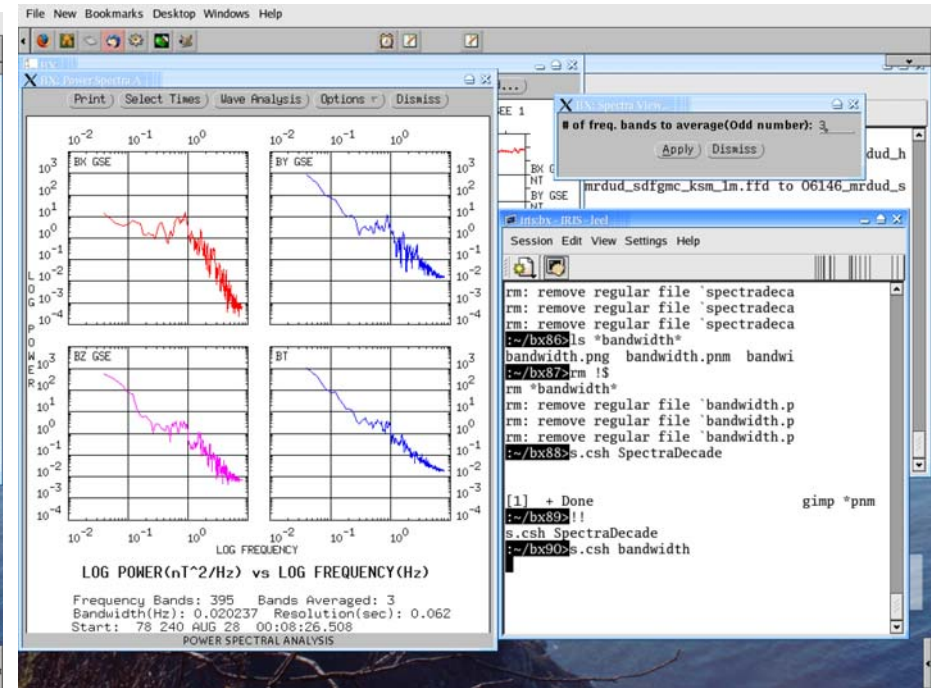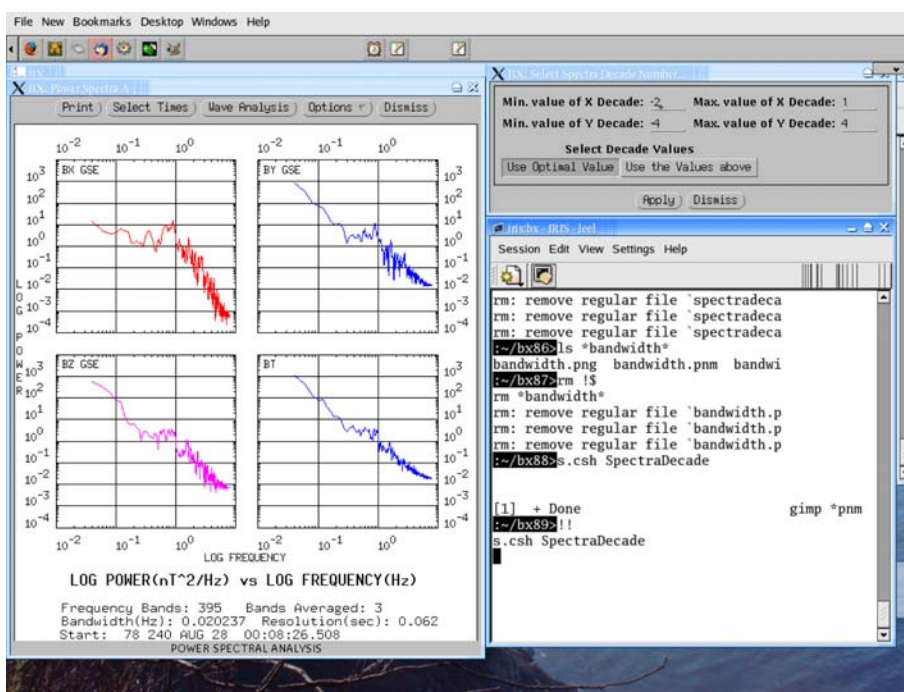
- Remember to push the "Use the values above" button.
- Remember to push the "Apply" button.

Coherence and Phase
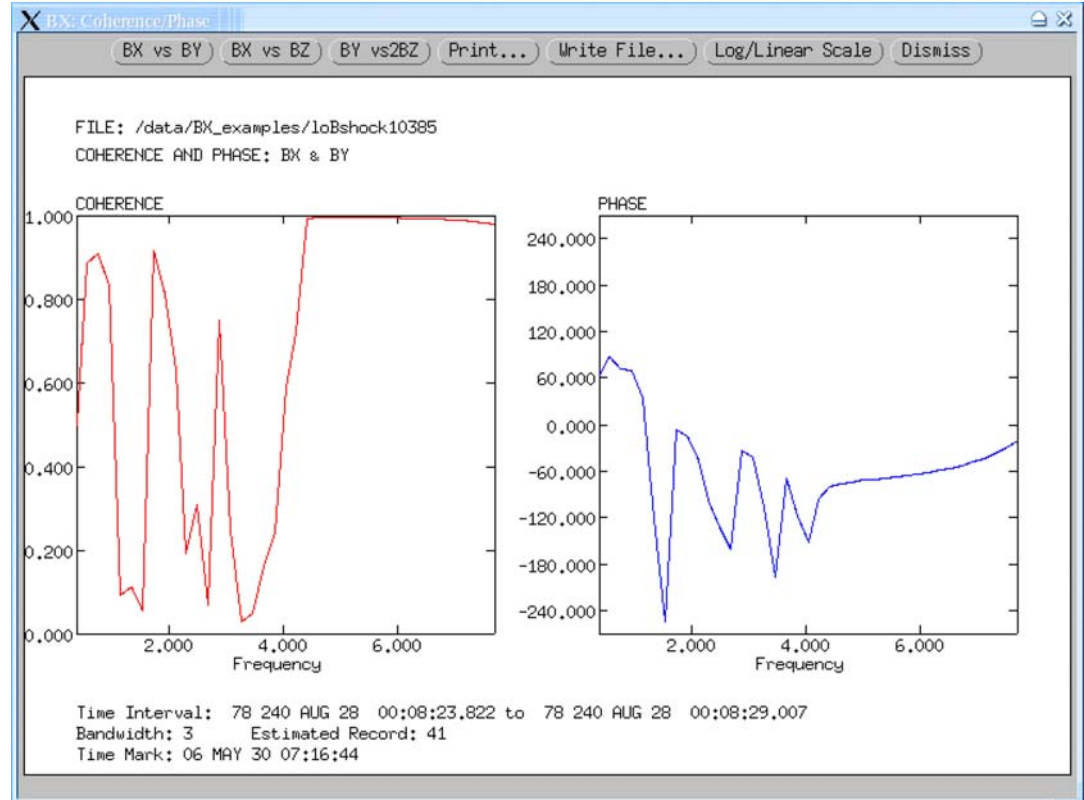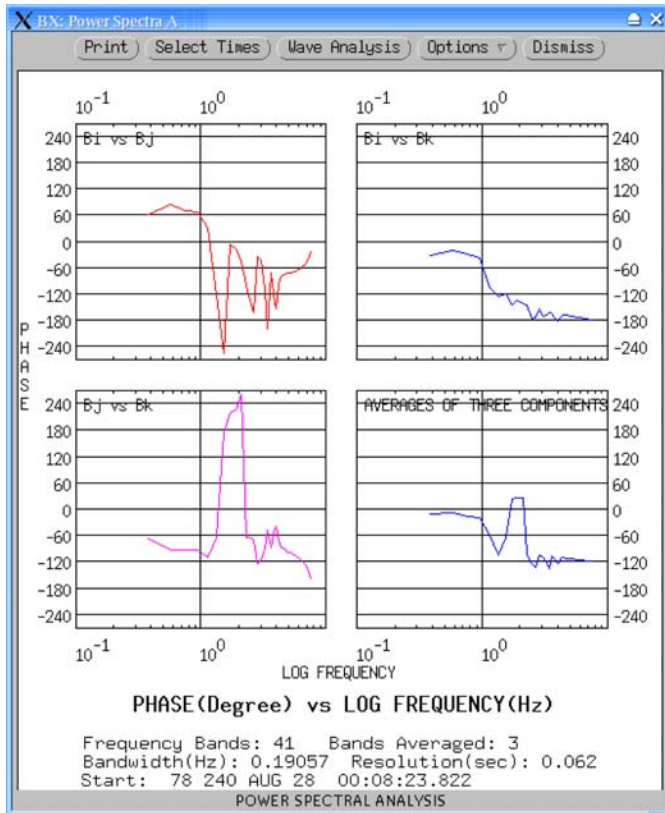
- When you select coherence or phase you get a 2 by 2 display. The average coherence has some meaning but the average phase does not
- Linear frequency displays sometimes are helpful
- Coherence sometimes brings out relationships in otherwise featureless spectra

Wave Analysis

```
--- Data Interval ---                              --- Power Spectra Parameters ---
Start: 78 240 AUG 28 00:08:00.333  Stop : 78 240 AUG 28 00:08:55.744
                                                  Power Spectra Trace (nT^2) =    3.7183986
--- Frequency Interval(Hz) ---                       Trace Amplitude (nT) =       1.9283149
                                                Compressional Power (nT^2) =     1.3911248
min: 0.09013   max: 0.12619   Wgtd Freq: 0.10639   Norm Freq: 0.31432   Compressional Amplitude (nT) =  1.1794596
                                             Compressional Fraction Amplitude =    0.05314
--- Field Data Average ---                         Total Fraction Amplitude =       0.08688
                                                     Compressional Ratio =         0.37412
BX:  14.594   BY:  -13.067   BZ:  -10.176   BT:  22.195
```

--- Real and Imaginary Power Spectral Matrices (nT^2)---

	RP			IP	
0.0577006	-0.1638372	-0.1065867	0.0000000	0.0841499	-0.1632216
-0.1638372	1.7616366	0.3287636	-0.0841499	0.0000000	1.7939365
-0.1065867	0.3287636	1.8990614	0.1632216	-1.7939365	0.0000000

--- Transformed Values of Real and Imaginary Power Spectral Matrices ---

	RP'			IP'	
2.1825457	0.0000001	-0.0000000	0.0000000	-1.8032761	-0.0003891
0.0000001	1.4968913	-0.0000000	1.8032761	0.0000000	-0.0113041
-0.0000000	-0.0000000	0.0389624	0.0003891	0.0113041	0.0000000

	RM'			IM'	
2.1462443	0.1533551	-0.0130047	0.0000001	1.8033111	-0.0000000
0.1533552	1.5331080	-0.0033946	-1.8033111	0.0000000	0.0000000
-0.0130047	-0.0033946	0.0390467	0.0000000	0.0000000	-0.0000000

--- Principal Axis analysis ---

EIGENVECTORS			EIGENVALUES
-0.087	0.634	0.768	2.18255
0.040	-0.768	0.639	1.49689
0.995	0.087	0.042	0.03896

ANGLE BK: 54.019   KK: 0.357

--- Joe Means Analysis (JGR 77,5551 1972) ---

```
Propagation:   0.995  0.091  0.047   Angle: 54.366
LinearVariance: 0.860 -0.279 -0.428   Angle: 21.454
```

--- Born-Wolf Analysis (JGR 75,5444 1970) ---

	Born-Wolf	JoeMeans
% Polarization:	99.775	99.779
Ellipticity (+RH,-LH):	-0.828	0.828
Azimuth Angle:	13.288	

FILE: /data/BX_examples/loBshock10385

Time Mark: 08 APR 09 11:30:16

Select Frequency) Upgrade) Print) Save) Dismiss)

POWER SPECTRAL ANALYSIS

- Wave analysis uses the cospectrum and quaspectrum to learn useful things about the wave
- It needs the average field for reference. Detrend but do not subtract the average field
- The first time called "wave Analysis" averages over the entire spectrum. Select a frequency band for the most useful results
- Sometimes analysis of the cospectrum and quaspectrum can give a useful consistency check

Hodograms
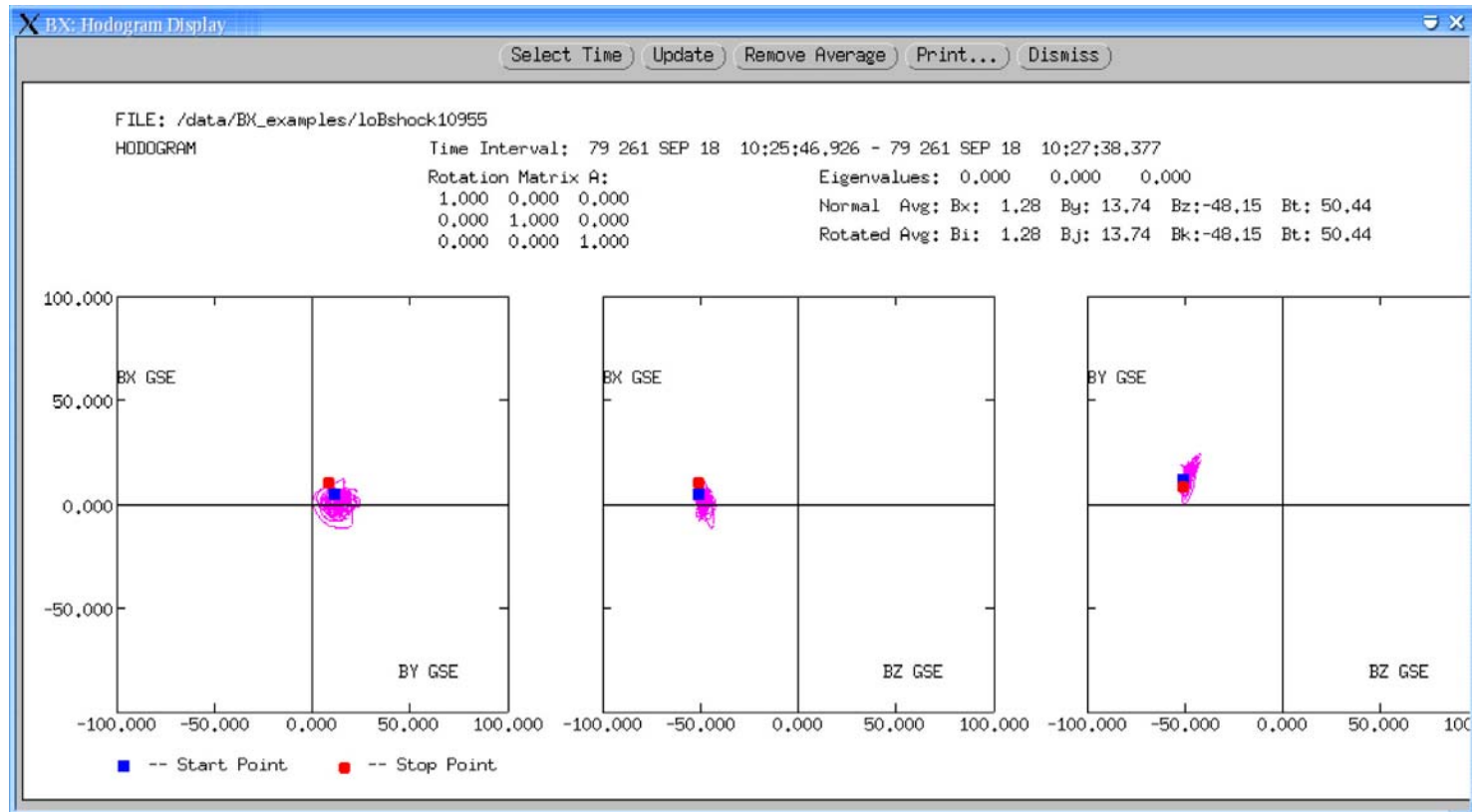
- Hodograms can be very informative about the nature of a signal if the signal is two dimensional or deviates simply from a two dimensional behavior
- Select hodograms from the display pull down menu and then select a particular hodogram (A, B, C,...)
- Select a time interval. You may remove the average from the display but usually it is better not to remove the average before first plotting it because the background field provides useful information on the handedness of the wave

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