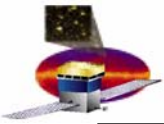


# **Deadtime modeling and power density spectrum**

**Warren Focke**

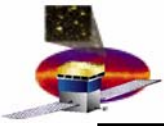
**June 8, 2004**



# Motivation

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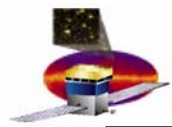
- **Timing matters! HEP experiments just count events, deadtime matters only because of lost efficiency. But, when signals vary with time, deadtime causes distortion due to its nonlinear effects on the observed rate.**
- **GLAST will be used to study variable sources:**
  - **GRB**
  - **Pulsars**
  - **AGN**



# The Power Spectrum

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- The power spectrum (PSD) is a common tool in timing analysis
  - Measures variability at different time scales, more detail later.
- Different theoretical models for origin of variability predict different PSDs.
- Distribution of times between adjacent events alone may not enable us to model effects of detector electronics on PSD
- References:
  - Numerical Recipes
  - Van der Klis, M. in *Timing Neutron Stars*, pp27-70



# Power Spectrum Details

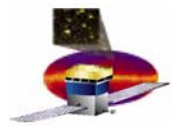
- **Distribution of signal power as a function of frequency**
  - **A common estimate of the power spectrum of a signal is the squared modulus of its discrete Fourier transform.**

$P_j$  = power at  
 frequency  $j$   
 $x_k$  = events in time  
 bin  $k$   
 $N$  = number of time  
 bins

$$P_m = \frac{2 \left| \sum_{n=0}^{N-1} x_n e^{\frac{-2\pi i m n}{N}} \right|^2}{\sum_{n=0}^{N-1} x_n}$$

Every bin  $k$ , in time series contributes to power at every Fourier frequency  $j$ .

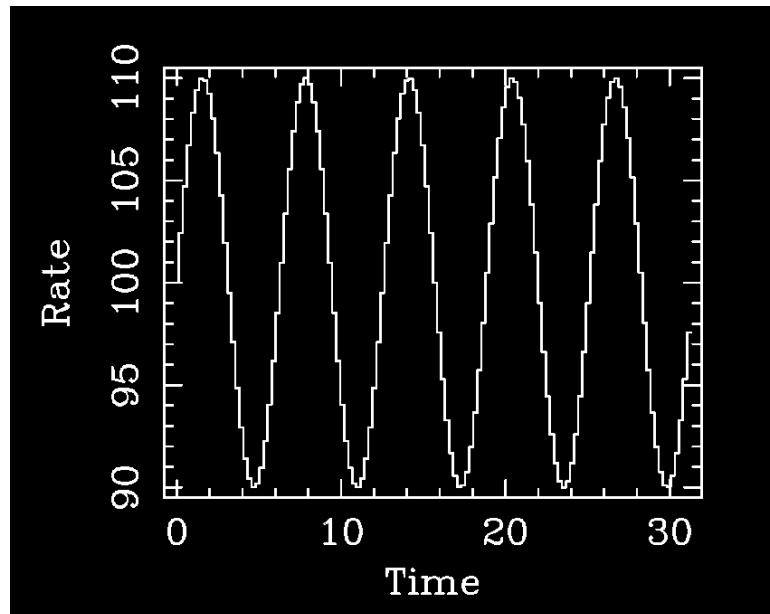
- **Fourier frequencies**
  - **essentially mathematical constructs, 1-dimensional analogues to multipoles in spherical harmonic decomposition in Cosmic Microwave Background (CMB)**
  - **Not related to deadtime or event rate, determined only by length of observation and the bin time.**
- $P_j$  is not really a physical power, but is calculated using the same math as the power spectrum of an acoustic or electrical signal.



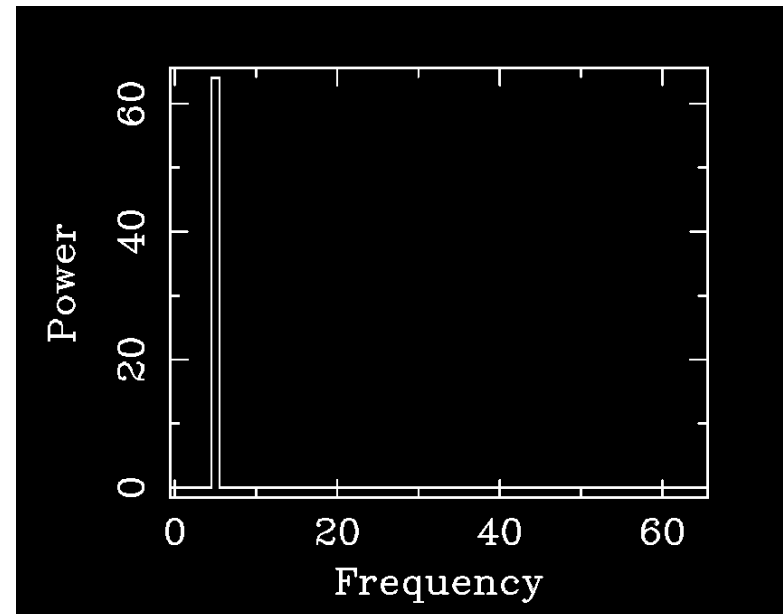
# Characteristic power spectra 1

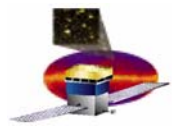
- A single sine wave gives a delta function.

Time Series



Power Spectrum

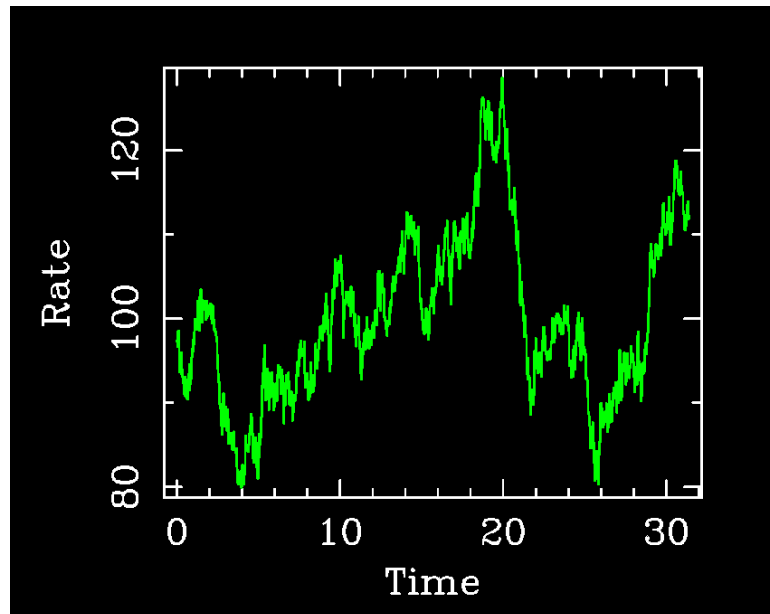




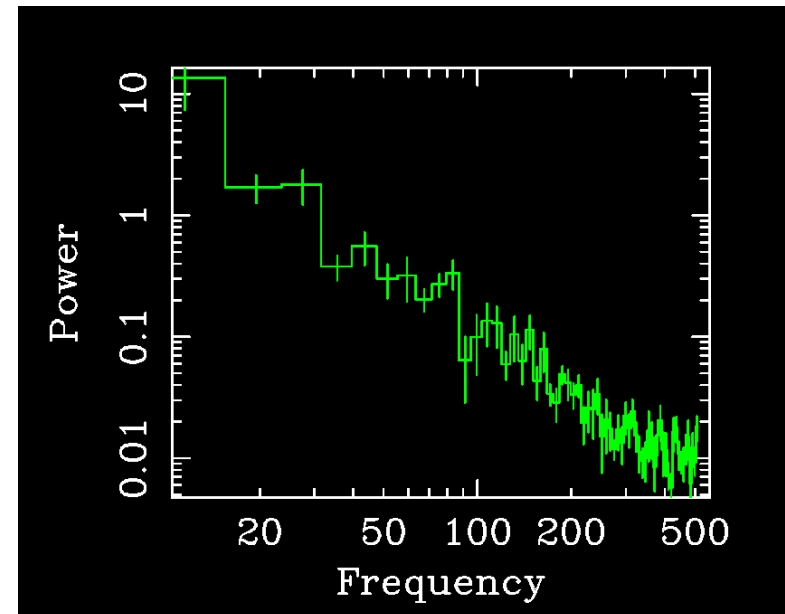
# Characteristic power spectra 2

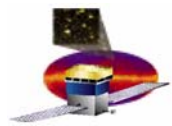
- Signals with random variations have continuum power.

Time Series



Power Spectrum

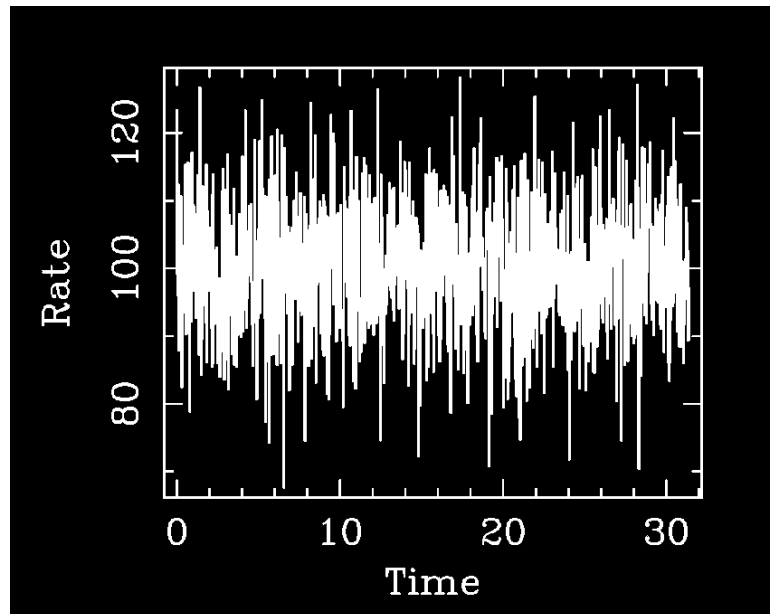




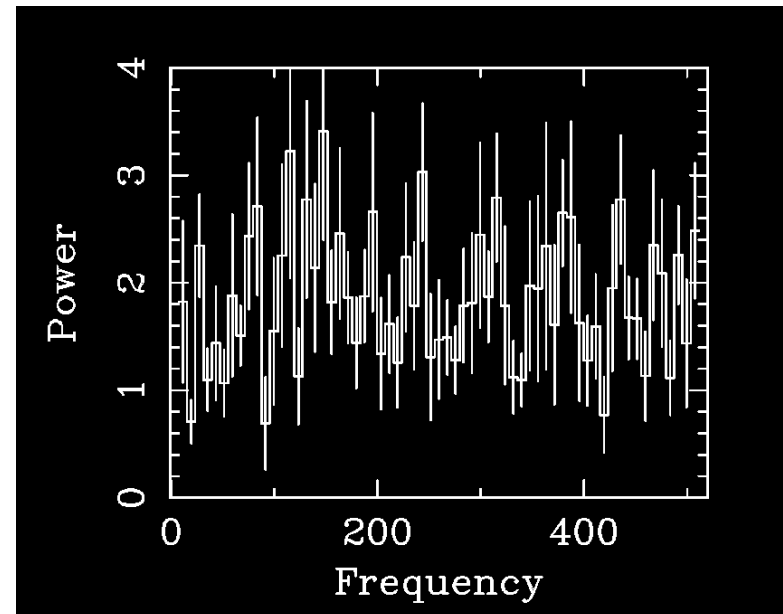
# Characteristic power spectra 3

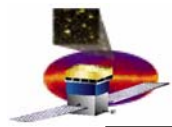
- Poisson counting statistics introduce a frequency-independent "noise floor," expected level of 2.0.

Time Series

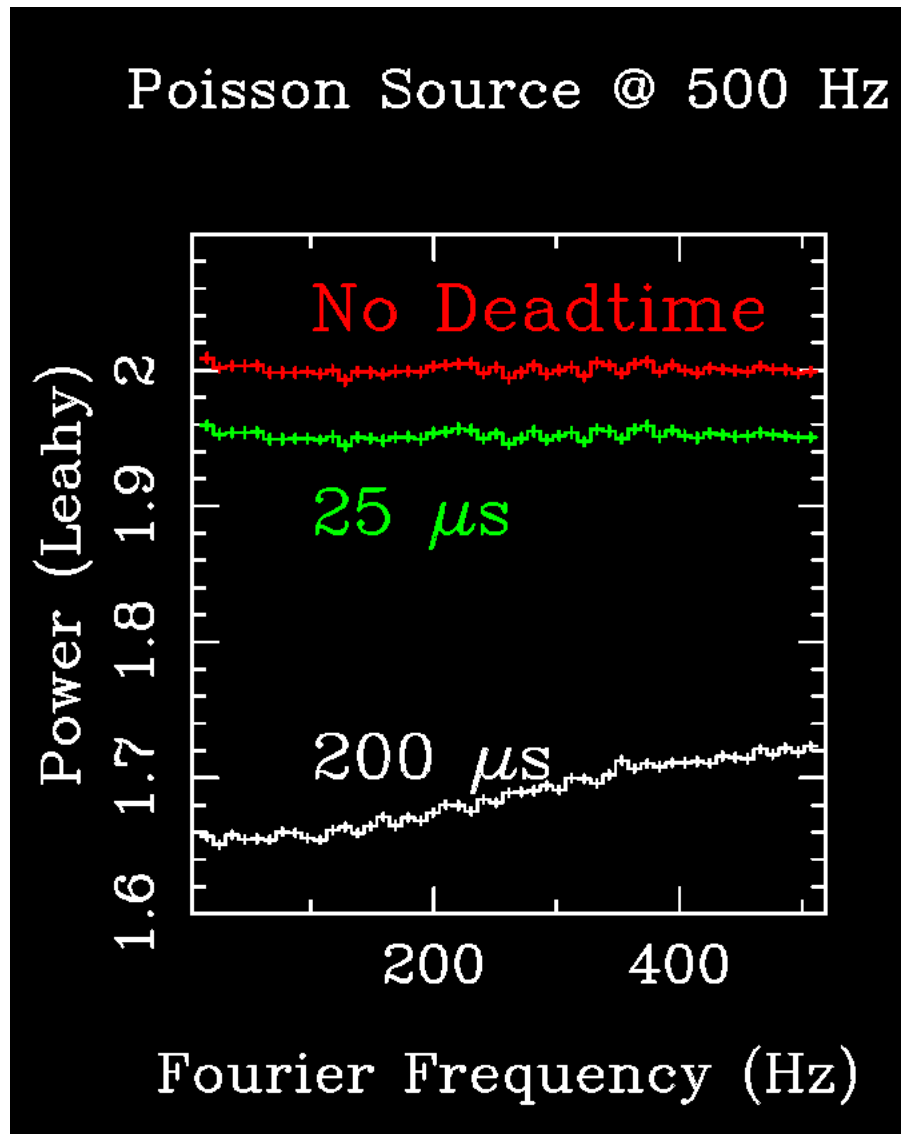


Power Spectrum



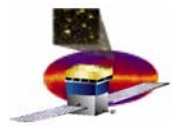


# Deadtime Effects on Power Spectrum

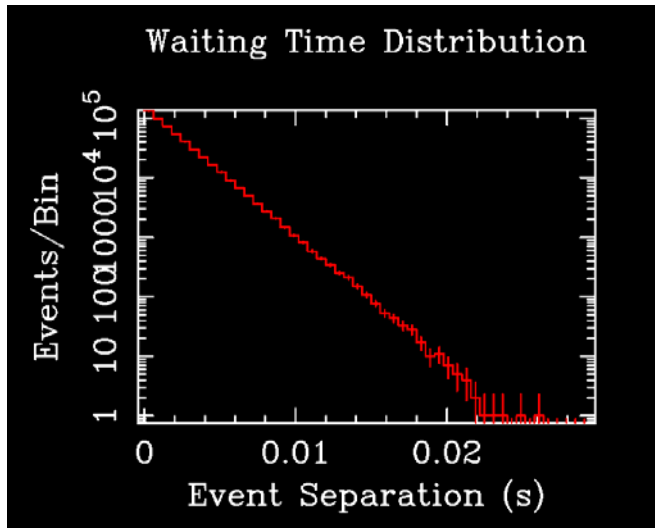


- Deadtime affects PSD
  - Reduced power at low frequencies.
  - Oscillatory at high frequencies (not shown here).
- Deviations from theoretical deadtime models make prediction of effects difficult, thus we would prefer to measure them.
- Example used 9 Hr simulated data.



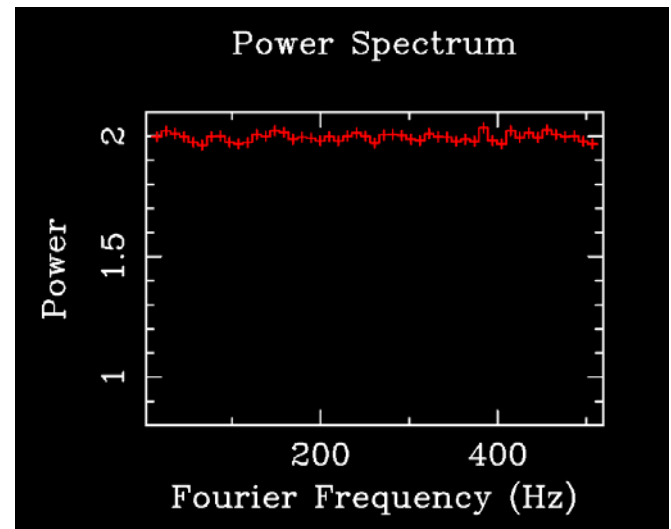


# Deadtime Effects in CR Ground Data



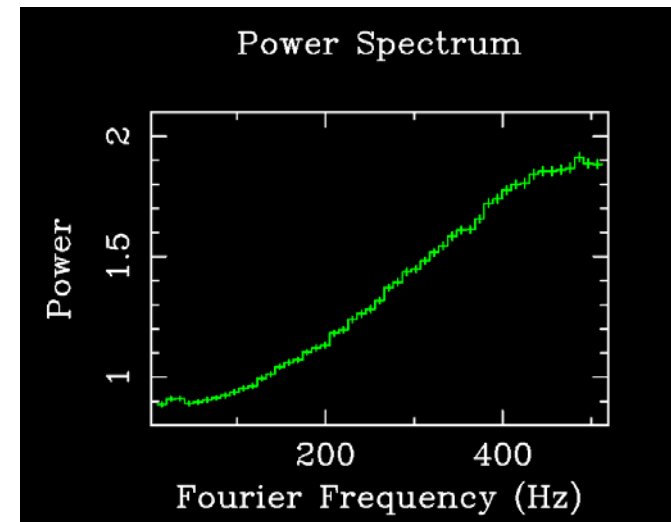
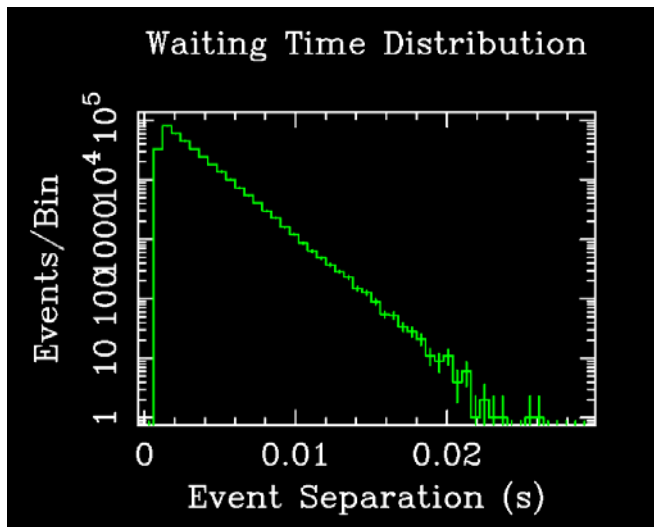
No Deadtime

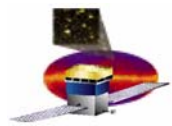
500 Hz  
1024 s



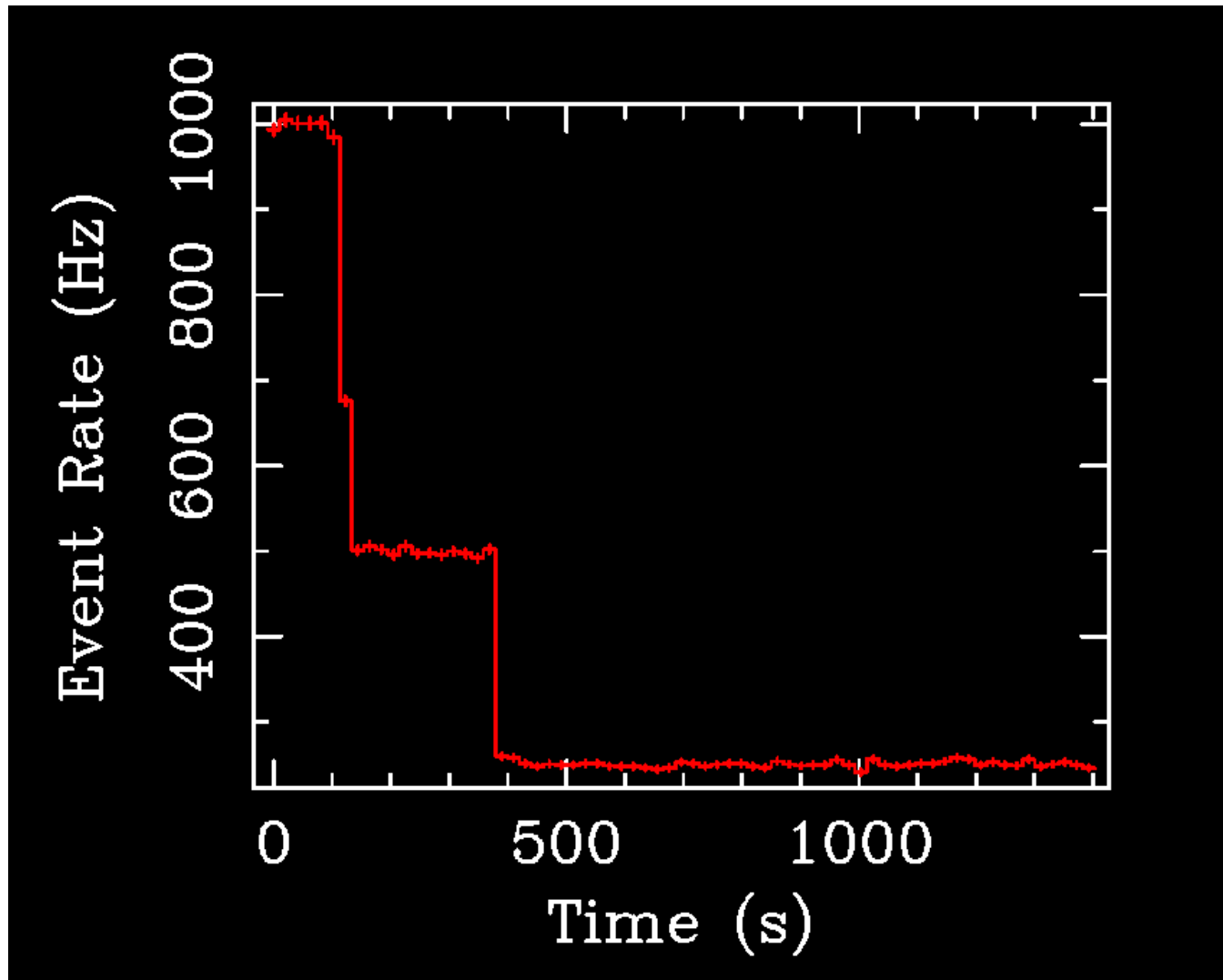
With Deadtime

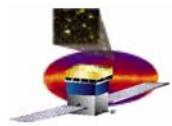
1 ms



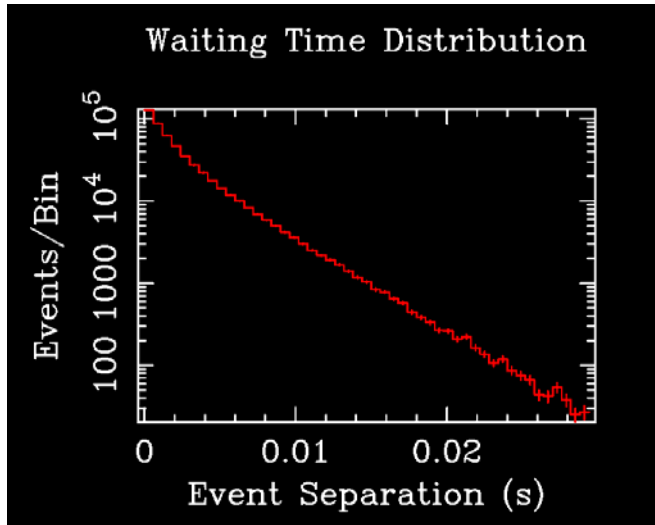


# Simulated VdG Time Series

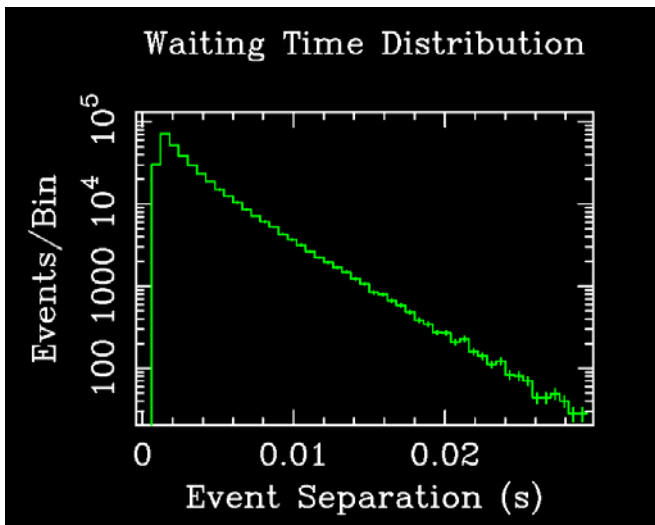
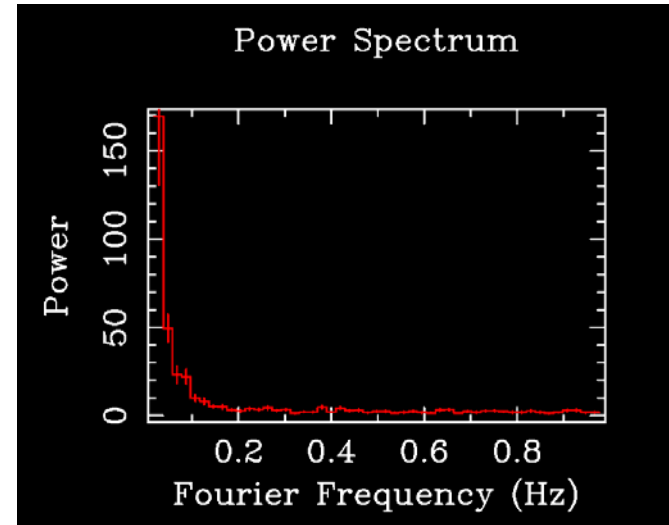




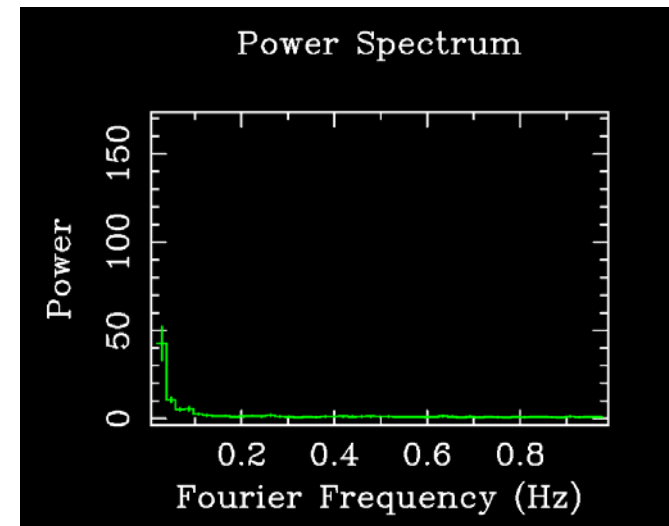
# Deadtime Effects in VdG Ground Data

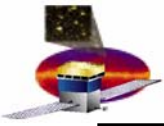


No Deadtime



With Deadtime





# Conclusions

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- **Timing matters.**
- **The shape of the power spectrum can be affected in not necessarily predictable ways by effects in the detector electronics.**
- **We'd like to get this right.**