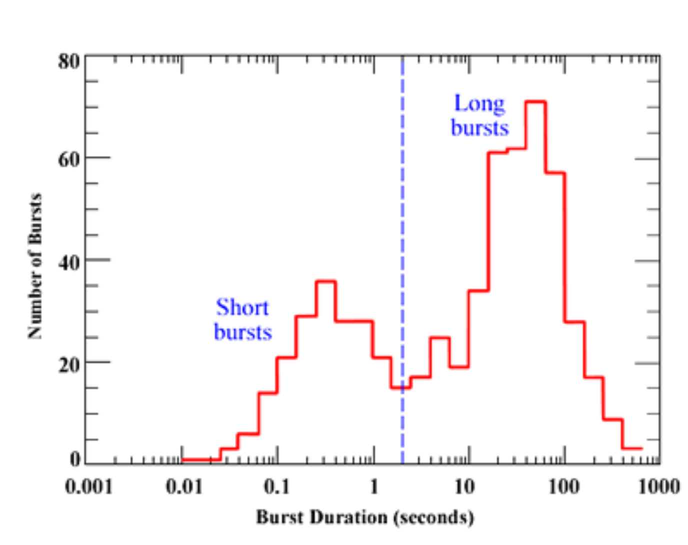
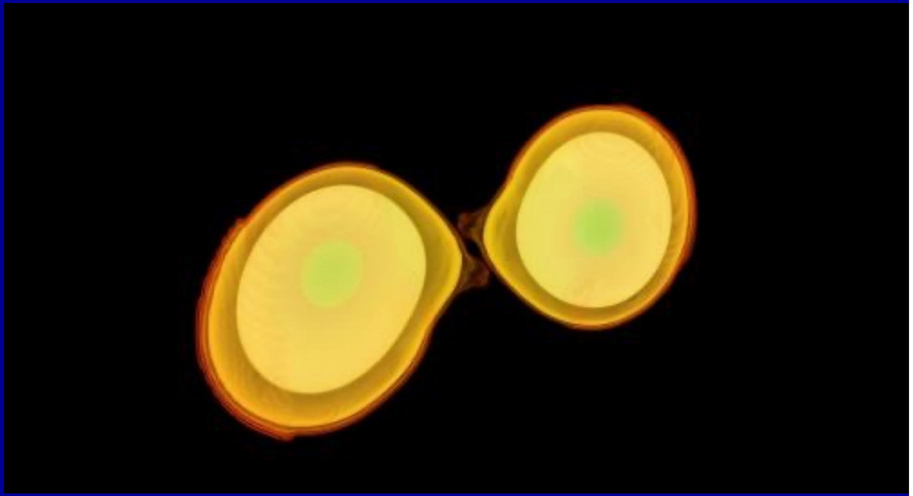
GRB Quasi-Periodic Oscillation?

- A practical application of your statistical approach
- GRB=gamma-ray burst.
- QPOs could give us insights
- I will give you the bare facts about a possible QPO that we identified. You will discuss in groups how to test its significance, and what it might mean

Short Gamma-Ray Bursts

- Long=collapsar
  Short=NS-NS/NS-BH
- But some long-duration GRBs have characteristics of sGRB
- Example:
  GRB 211211A has a kilonova, so it likely came from a merger



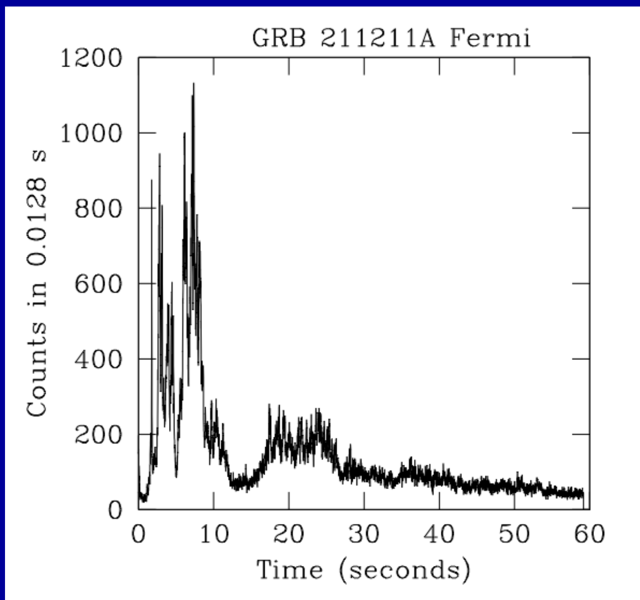


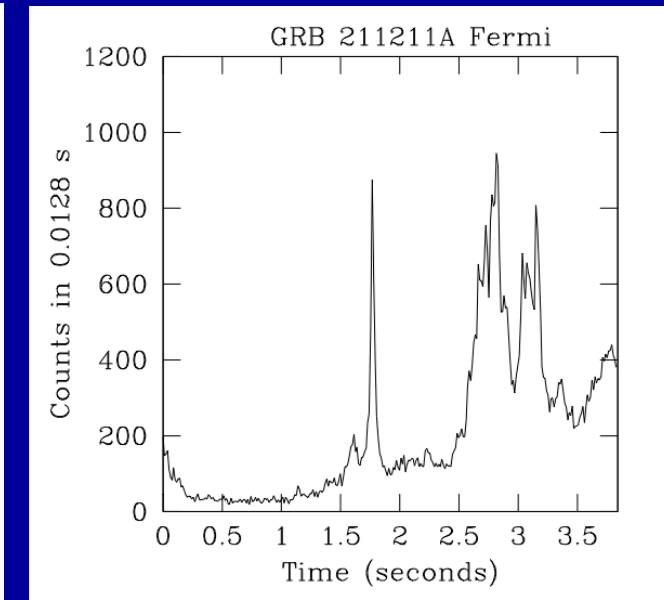
http://www.aei.mpg.de/bildobjekte/pm_news/neutronenstern08/NScollision_Zoom.jpg

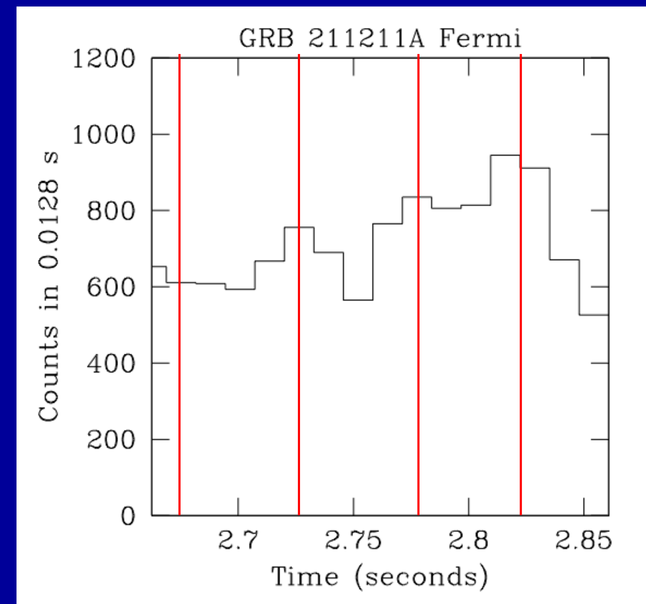
What could a QPO tell us?

- Periodic, or quasi-periodic, oscillations indicate some characteristic frequency of a system. Think about stellar oscillations, which can tell us about a star's properties
- But discerning a QPO in a GRB is tough, because GRB light curves are spiky and vary a lot from one burst to the next. How can we tell whether a QPO is real?

Fermi Light Curve of 211211A

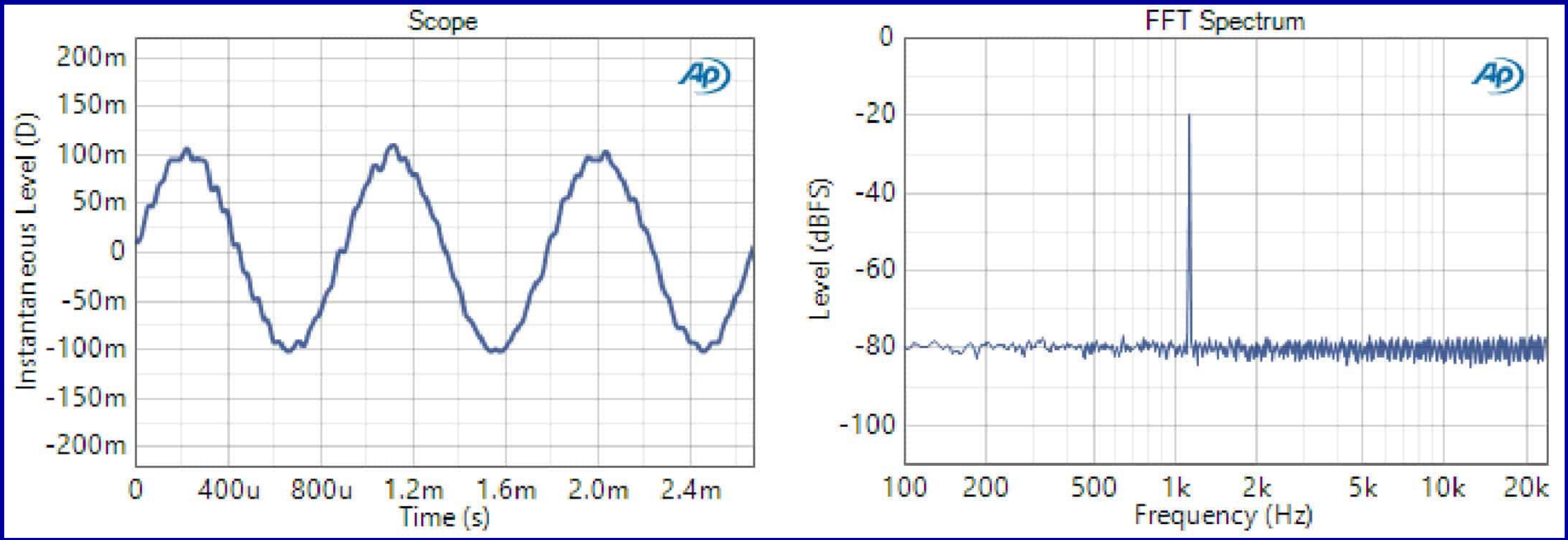






Zoom-ins of GRB 211211A. The kilonova suggests that this is likely a merger, despite being ~1 minute long. The rightmost panel shows that multiple successive peaks come in regular time intervals. But to pursue this further we need to look in the time domain with a *power spectrum*

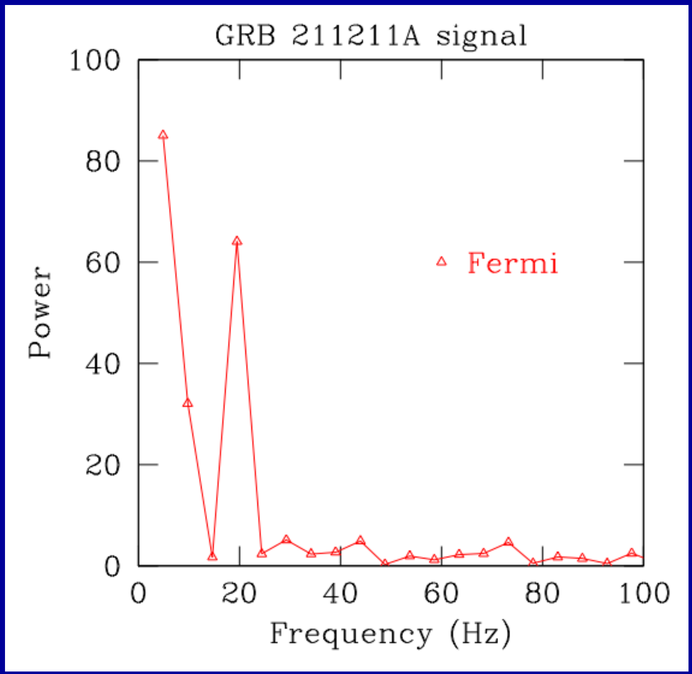
Power Spectra

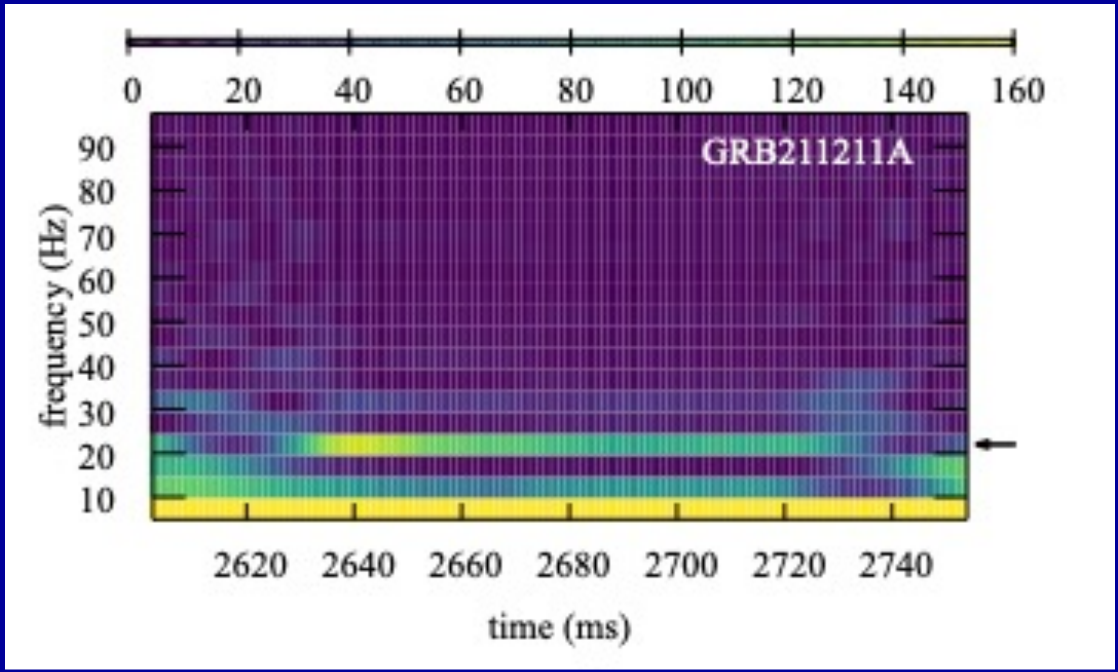


https://www.ap.com/blog/fft-spectrum-and-spectral-densities-same-data-different-scaling

A signal can be decomposed into a sum of sines/cosines (this is called a Fourier transform). Left: signal as a function of time. Right: amplitude squared of sines of different frequency, which add up to the signal. The "power spectrum" is the square of the amplitude as a function of frequency. A "Fast Fourier Transform" or FFT has the advantage that each frequency is statistically independent of all the others. So what is the power spectrum of our Fermi signal?

Fermi Power Spectrum





Left: power spectrum. Right: dynamic power spectrum (i.e., as a function of time). Normalization is such that the probability of a power P or higher from an intrinsically constant signal with just Poisson fluctuations is e^{-P}. We see "red noise", i.e., noise well beyond Poisson, increasing at low frequencies. What about the bump at ~20 Hz? Real or happenstance?

Your tasks:

- In your groups, come up with several ways to test, statistically, whether the signal is special rather than just being red noise, an instrumental artifact, or something else
- In your groups, assuming that the signal is special (a QPO characteristic of something in the probable NS-NS merger), come up with some possible physical mechanisms