Millisecond Pulsar Timing: Flux Density

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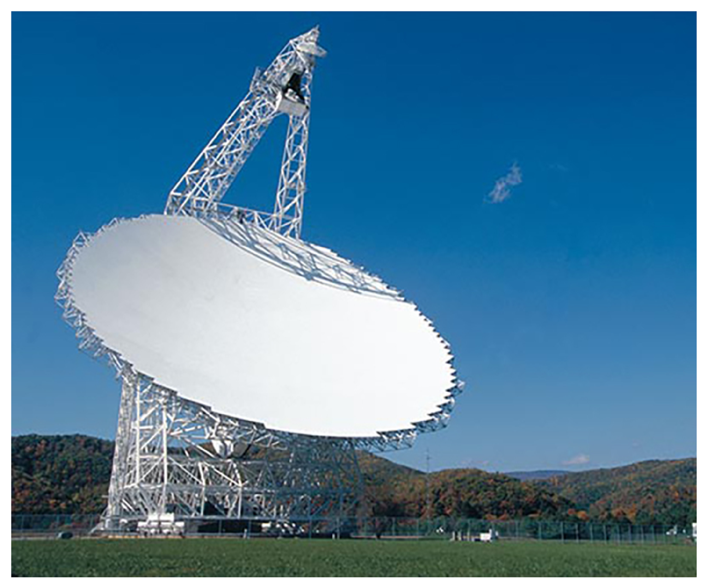
Pulsar Research and Data Collection

A pulsar is a rapidly rotating neutron star that emits pulses of radio waves at regular time intervals. These pulses are measured with the use of large telescopes. The data we use is collected from the Green Bank and Arecibo Observatories by NANOGrav. The data consist of the pulse's time of arrival to the telescope, frequency, flux density, etc. NANOGrav is using pulsar timing to try to detect gravitational waves.

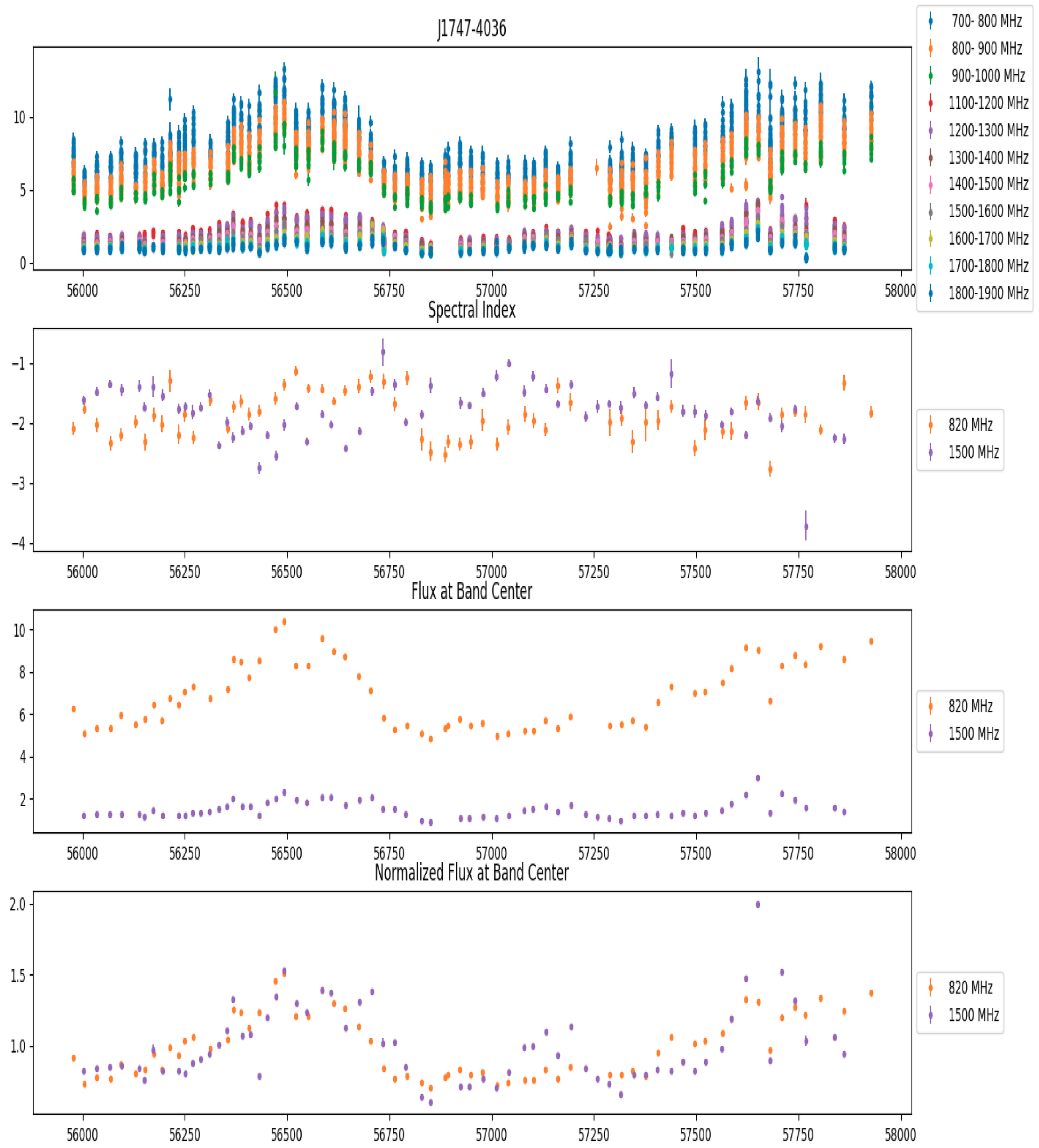


Arecibo image: https://www.space.com/20984-arecibo-observatory.html
Green Bank image: https://public.nrao.edu/telescopes/gbt/

The Green Bank Observatory (left) is located in West Virginia and is about 100 meters in diameter. The Arecibo Observatory (right) is located in Puerto Rico and is about 300 meters in diameter.

Fluxes of High and Low Frequencies

We model flux data for each day using $S(f) = S_0(f/f_0)^\alpha$, where f_0 is the center frequency of the band, S_0 is the flux at band center, and α is the spectral index. We separately analyze data from high frequencies (1,100-1,900 MHz) and low frequencies (700-1,000 MHz). In the plot on the bottom, both are normalized around 1 so we can see how the fluxes at high and low frequencies track each other.

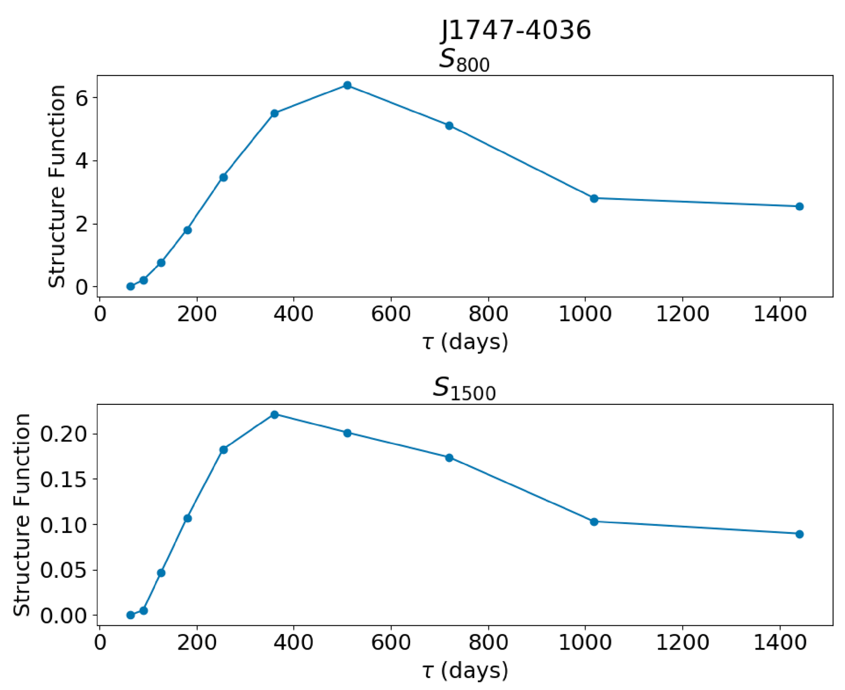


Structure Function

Structure functions show a time scale associated with the physical phenomena causing fluctuations in the data. It takes two points separated by a certain number of days, τ, takes the square of the difference between them, and averages that with all the other points with the same separation.

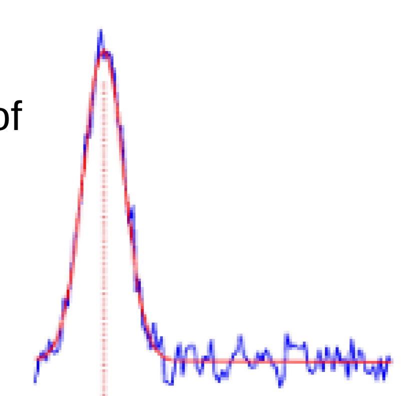
$S_s(\tau) = \langle (S(t) - S(t+\tau))^2 \rangle$

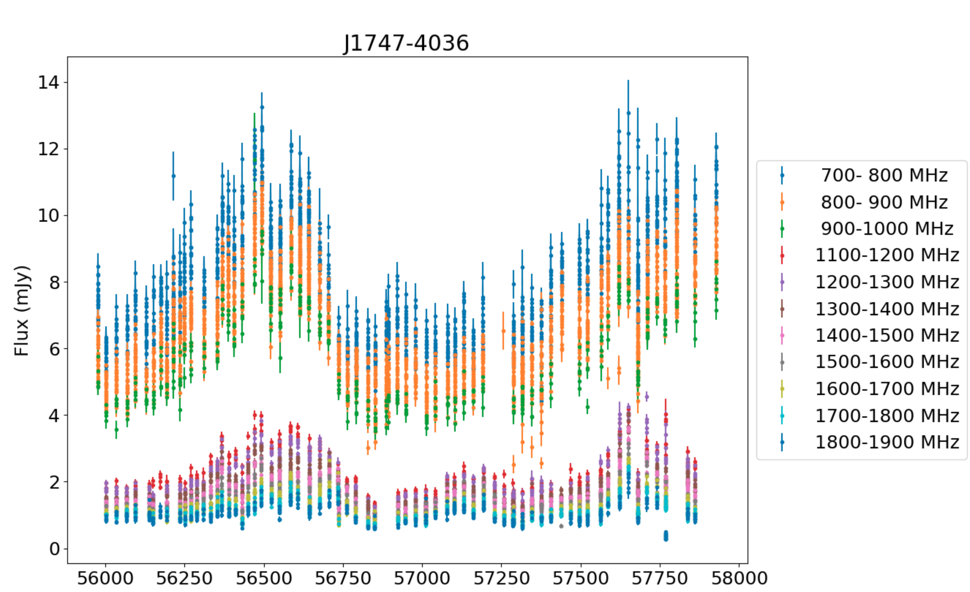
The plot should stop increasing and level off. The time τ that it levels off is the time scale of the physical effects causing scintillation. The saturation point seems to be similar between the high and low frequency bands.



Flux Density

Flux density describes the strength of the electromagnetic pulse. It is measured from the area under a pulse profile curve in units of power divided by the area of the telescope divided by the band of frequencies over which the measurements are taken. Flux measurements are affected by scintillation, which is the uneven scattering of radio waves. *The goal of this project is to study scintillation patterns on long time scales.*

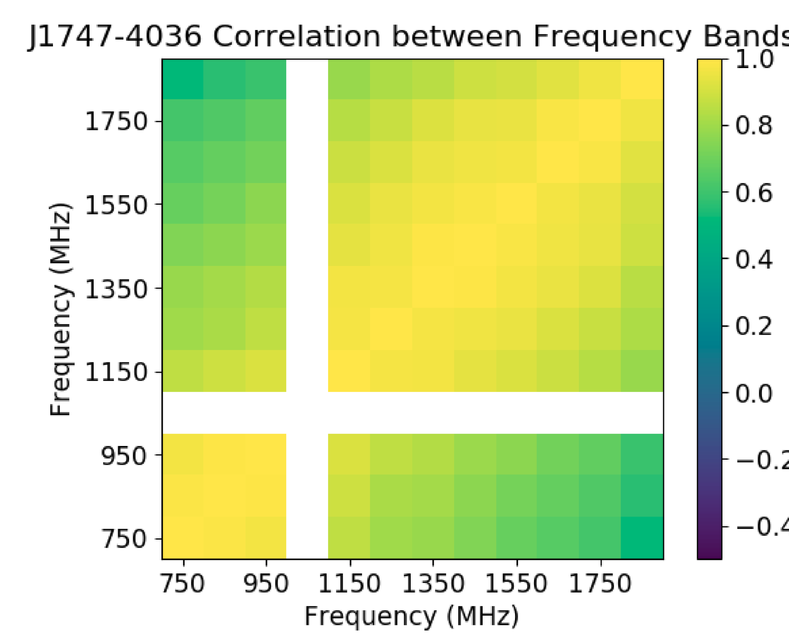




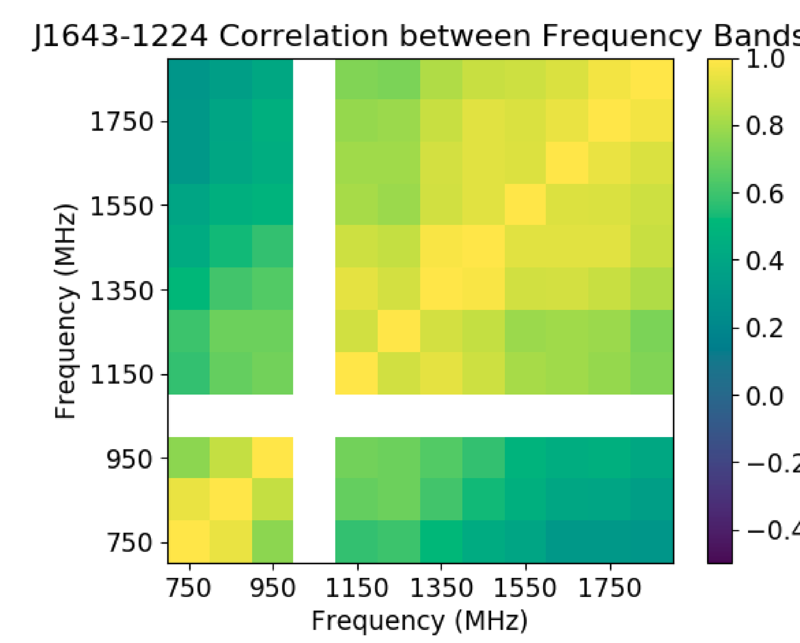
The effects of scintillation are more clearly observed in distant pulsars, such as J1747-4036. Observations are made over a wide range of radio frequencies. The plot to the left seems to indicate a correlation in flux between high and low frequencies, as the fluxes rise and fall on the same time scale.

Correlation Between Frequency Channels

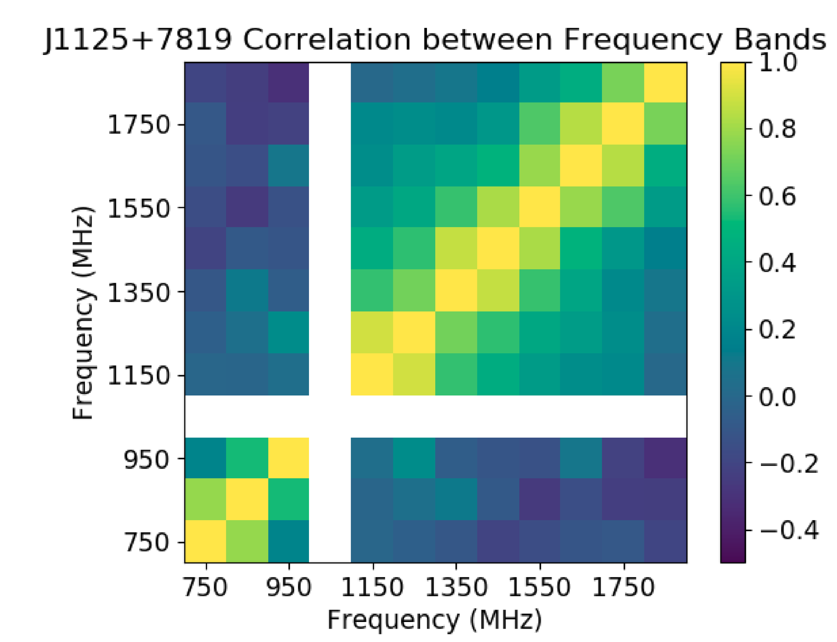
These plots show correlations between each 100 MHz channel. The more yellow the square is, the more correlated the two frequency channels are. Since the high and low frequencies are measured about a day apart, a high correlation between high and low frequencies could not be due to chance.



J1747-4036 shows the most correlation among frequencies out of all the pulsars we observe. It's average correlation coefficient is 0.751 and has a p-value of 9.7×10^{-11}.



J1643-1224 shows the second most correlation among frequencies out of all the pulsars we observe. It's average correlation coefficient is 0.523 and has a p-value of 1.1×10^{-6}.



J1125+7819 shows the least correlation among frequencies out of all the pulsars we observe. It's average correlation coefficient is -0.078 and has a p-value of 0.64.

Acknowledgments

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