Analyzing the Turnover Point in the Light Curve of the Neutron Star Binary Merger Event GW170817

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Abstract

Binary neutron stars merger events could lead to gamma-ray bursts. We plotted the radio light curve (flux density vs. time) of GW170817 using data we gathered from relevant literature and performed statistical convergence tests for smooth broken power laws for the purpose of determining the shape of the emission: successful or choked, on-or-off axis, cocoon or jet.

Introduction

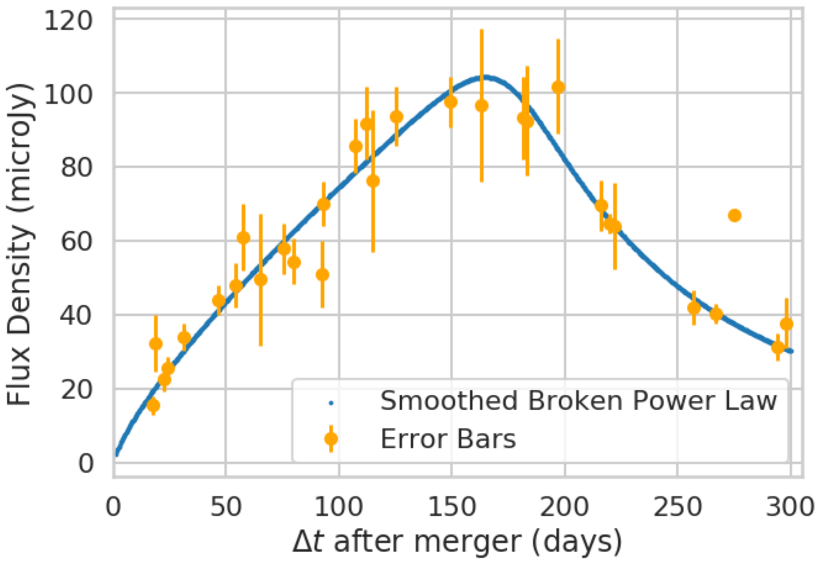
Neutron stars are very dense; formed from the collapsed center of giant stars, they have approximately 1.4 solar masses compressed into an average 10 km radius. When two neutron stars are in close proximity to each other, they spiral inward, gradually losing energy in the form of gravitational radiation. GW170817 was observed by the joint detection of the gravitational waves and low-luminosity gamma-ray burst by the LIGO/Virgo collaboration in August 2017 (K.D. Alexander). Subsequent analysis of electromagnetic radiation allowed astronomers to characterize the nature of the ejection produced in the merger. The rate of the rise to the peak allows us to classify the jet produced as on-axis or off-axis and the shape of the jet (K.P. Mooley) (R. Margutti). The total amount of gamma-ray energy released provide insight as to the relativistic nature of the jet as well as it's interaction with the surrounding neutron-rich material (R.Margutti) (K.P. Mooley)

Methodology

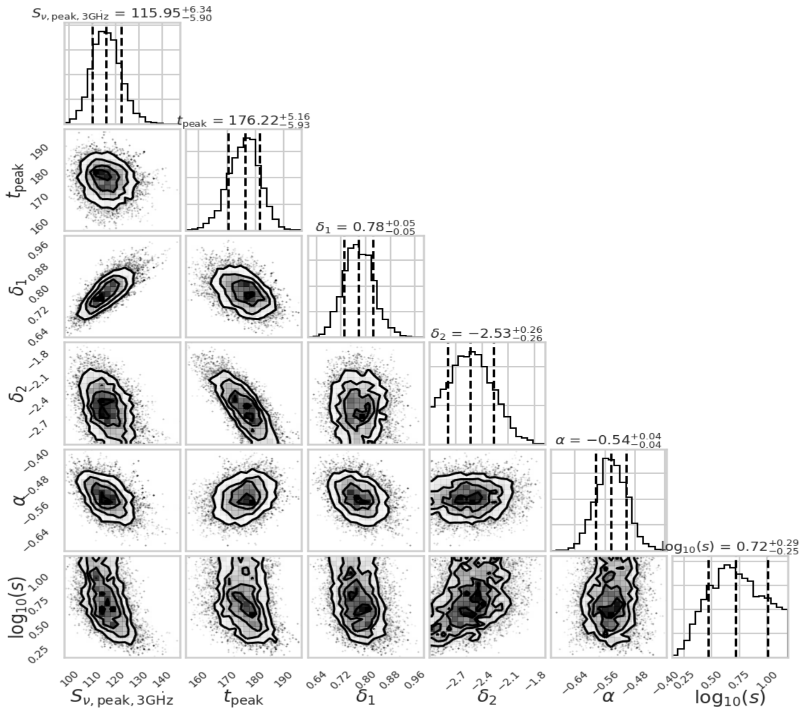
Gathering observational data recorded from VLA, ATCA, GMRT, and meerKAT telescopes (K.D. Alexander) (R. Margutti) (K.P. Mooley) we created a graph of the flux density of electromagnetic radiation with respect to time. Data analyzed ranged from 17 to 298 days after the merger. This broad range in time allows us to ensure that a peak was reached, followed by a steady decline in emission. Observational data spanning multiple frequencies was scaled so we were able to plot the flux density as a variable with respect to time. We ran MCMC analysis to derive a spectral index and a smooth broken power law to model the data to a single curve.

Results

Our scaled light curve shows a slow rise and a late peak in flux density at approximately 160 days after the merger event.



The nature of the light curve allows us to place constraints on the model, but it does not provide definite insight as to the relativistic nature of the jet. The slow rise and late peak of the curve rule out a on-axis relativistic jet, since the model would have a much earlier peak in flux density. This behavior of the curve is consistent with an quasi-spherical cocooned jet model or a wide-angled mildly relativistic outflow with or without a successful relativistic jet. Both of these models have a spectral index and light curve very similar to the one we produced in our research. It's important to note that our research, derived a single value for α which assumes that the power-law index stays the same through observations. This may or not be the case and deeper analysis is required for further classification.



Conclusion and Future Work

Overall, our corner plot, parameters, and flux density light curve agree very closely with current research and conclusions regarding the nature of GSW170817. Based on current data, it is insufficient to definitively determine the nature of the emission, as both cocoon and successful jet could lead to a late-time light curve as the one we perceived. A combination of light curve and other sources of information (constraints on the geometry of the relativistic outflow in the polarization measurements) could provide more insights about this neutron star merger event.

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