GRB 170817A as a Refreshed Shock Afterglow Viewed Off-axis

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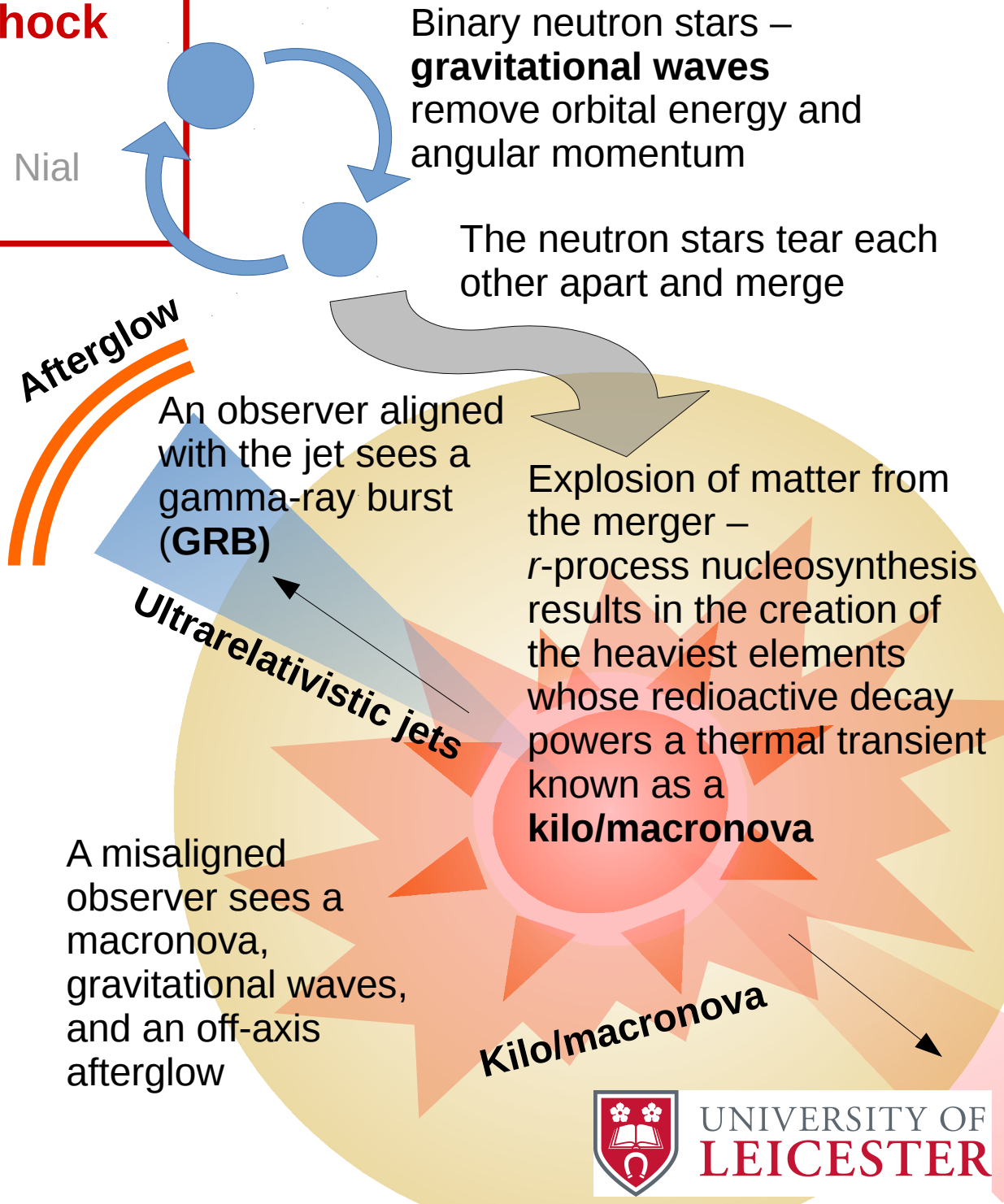
The merger of a neutron star binary system produces detectable gravitational wave emission. The extreme environment of these mergers results in multiple outflows of material producing radioactive kilo/macronova, a site for heavy element nucleosynthesis, and narrow bipolar jets with a velocity close to the speed of light. The late-time electromagnetic transients following the near simultaneous gravitational wave detected merger and gamma-ray burst, GW170817 and GRB 170817A respectively, were initially explained as revealing the lateral energy structure of these collimated jets, however, a new interpretation of the data shows that the observed lightcurves are consistent with a narrow and uniform jet that is refreshed at late times by a period of energy injection.
Such energy injection has been observed in the afterglows to some short-duration gamma-ray bursts, systems that are analogous to GW170817 but viewed with the jet pointing towards the observer.
The resultant shock system due to the jet's interaction with the circum-burst material, can be energised (or refreshed) by long-lived central engine activity, which produces variability in the resultant electromagnetic afterglow. One example of a refreshed/energised afterglow is that of GRB 160821B, where the inclusion of energy injection in the modelling of the afterglow is required to explain the broadband temporal and spectral features. For the afterglow to GRB 160821B, inclusion of energy injection for the afterglow clearly reveals the associated kilo/macronova. Here we show how such a refreshed shock afterglow can explain the observed temporal behaviour of the late-time electromagnetic emission to GW170817/GRB 170817A. The energy injection that is responsible for a refreshed shock can be used as a probe of the central engine activity and potentially the accretion history of these high energy systems.



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Gravitational waves and a GRB, GW170817 and GRB 170817A

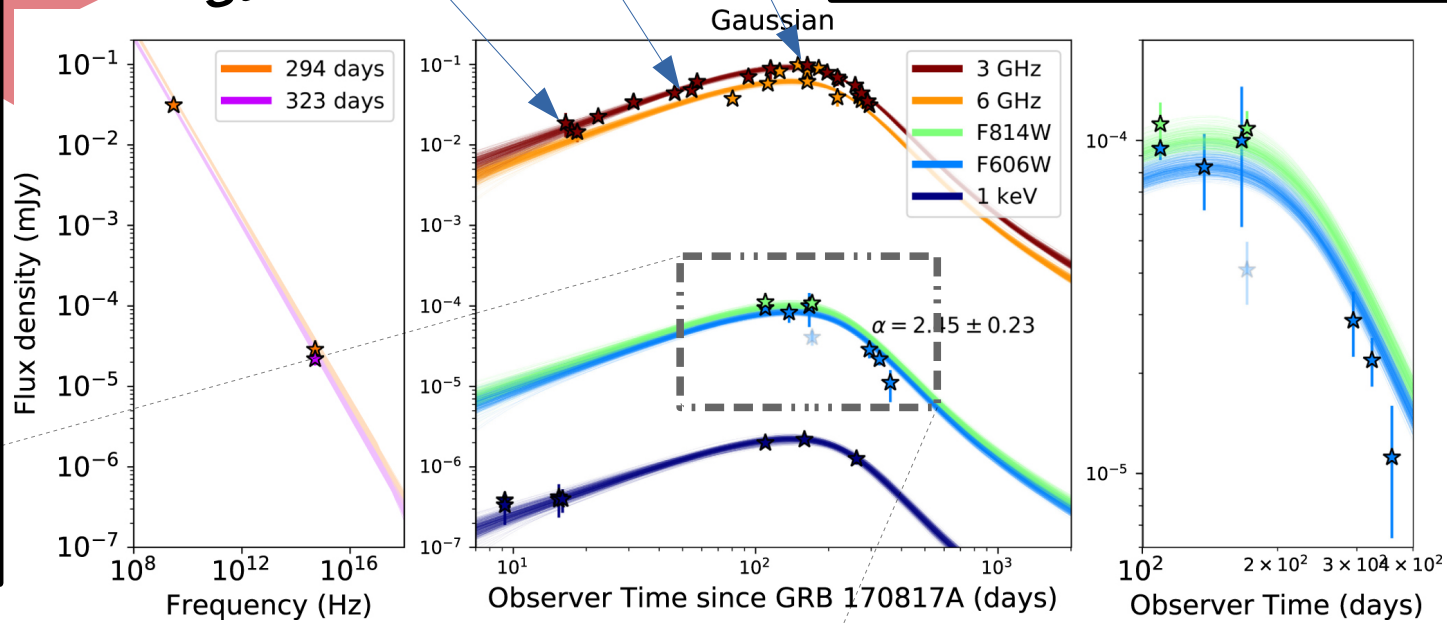
Gavin P Lamb

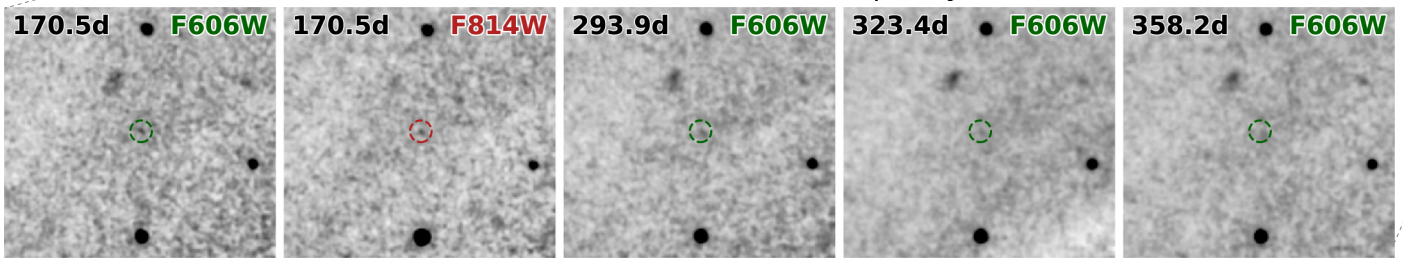
The **gravitational wave** detected binary neutron star merger, GW170817, was acompanied by a **GRB** and a **kilo/macronova**.
At late times, the emission was dominated by an **afterglow**, viewed from off-axis.

The temporal behaviour of the lightcurve was that of a Gaussian structured jet (Lamb & Kobayashi 2017)

Figure below is a Gaussian **structured jet** model fit to the **afterglow** observations (Lamb at el. 2019a)

Continued observations of the **afterglow** showed a steep decline, confirming the `core-dominated', or **structured jet**, nature of the outflow (Lamb, Mandel & Resmi 2018)





Hubble Space Telescope observations

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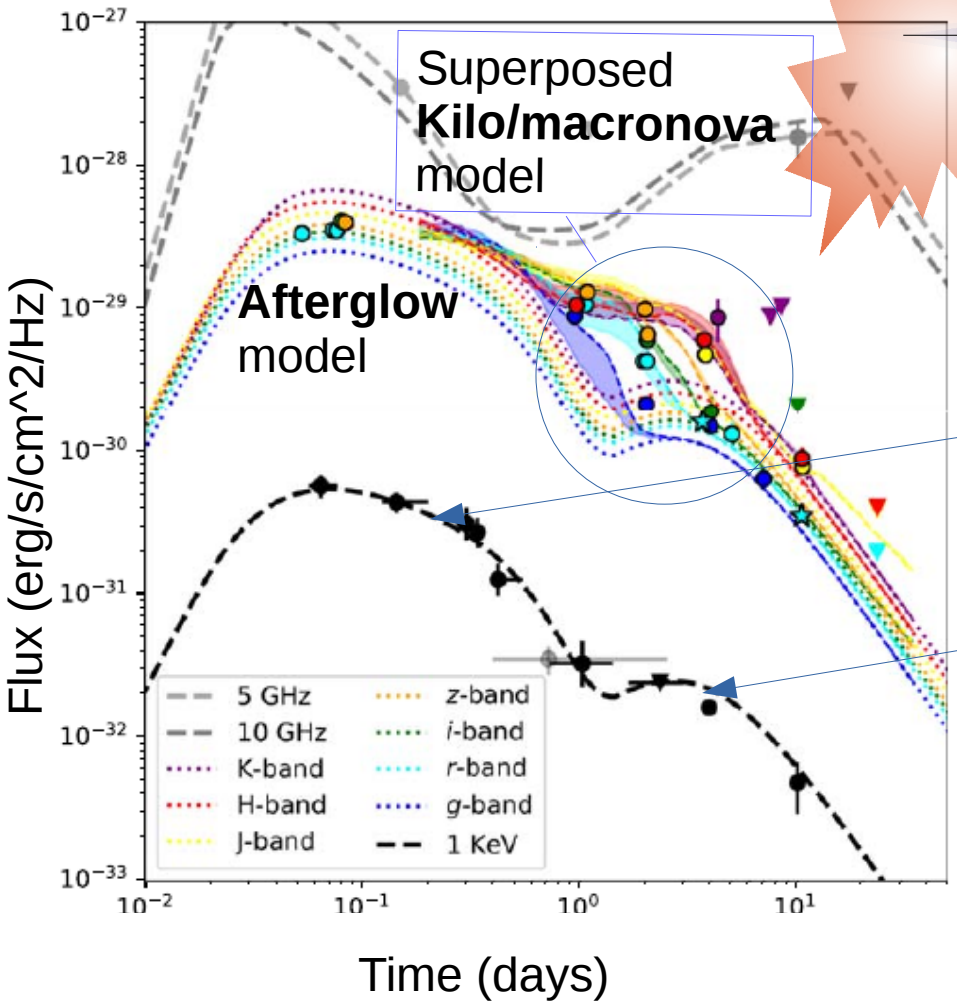
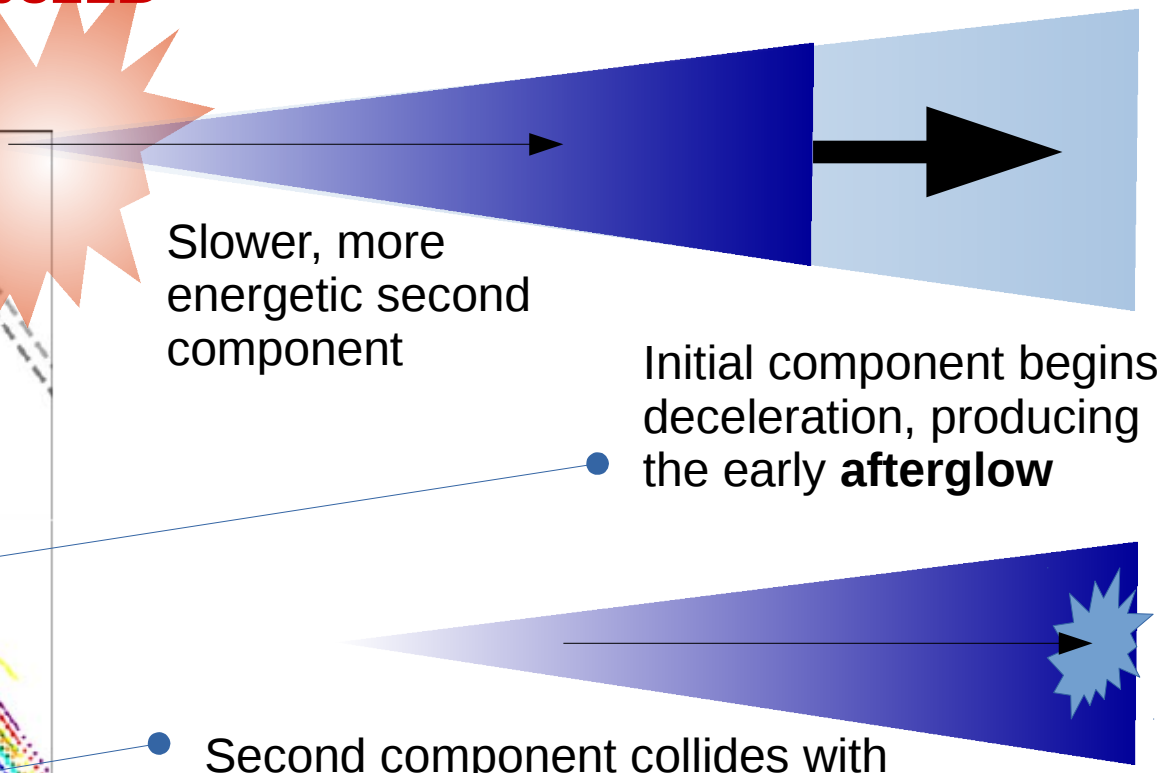
On-axis Short GRBs – GRB 160821B

Gavin P Lamb





Slower, more energetic second component

Initial component begins deceleration, producing the early **afterglow**

Second component collides with the initial and energises the shock, refreshing the **afterglow**

This is different to the **structured jet** that is thought to be responsible for the 'off-axis' GRB 170817A **afterglow**!?

The 'on-axis' analogue to GW170817 is a short **GRB**.
The GRB 160821B has a complex **afterglow** that contains a **kilo/macronova** and variability consistent with a **refreshed shock** (Lamb et al. 2019b).

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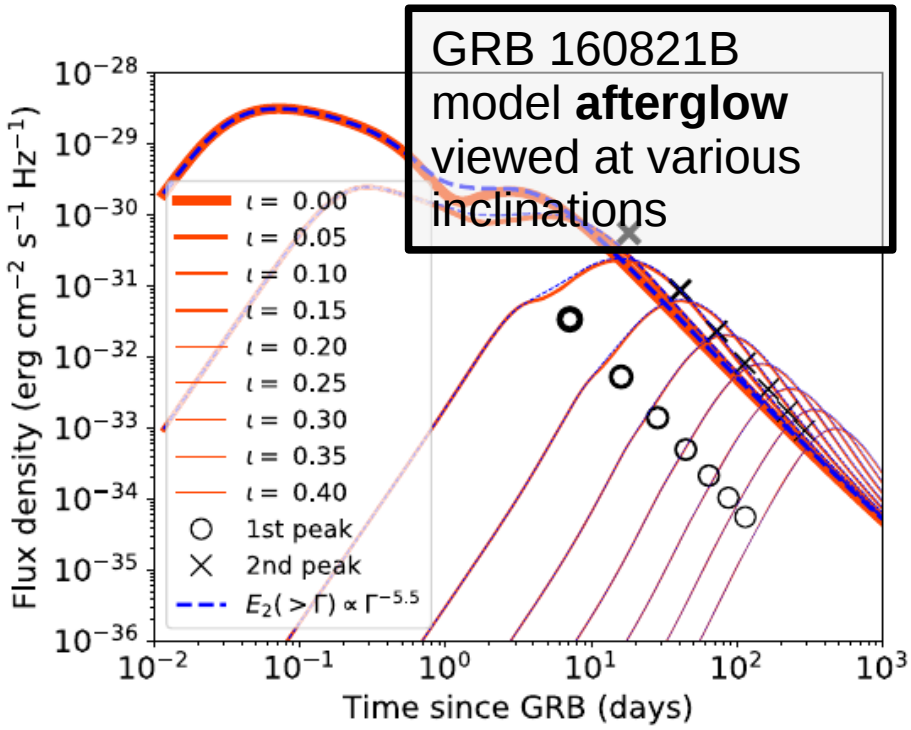
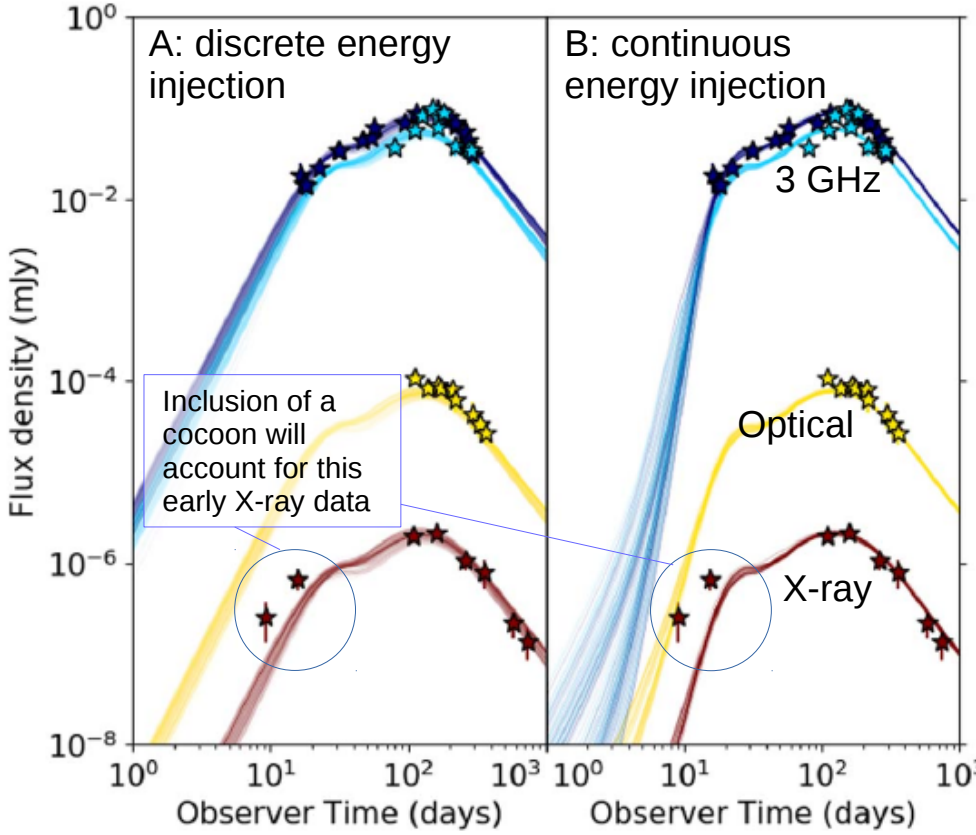
The GRB 170817A afterglow as an 'off-axis' viewed refreshed shock

Gavin P Lamb



- Refreshed shock **aftrerglows** have been seen for 'on-axis' **GRB**s
- 'Off-axis', a refreshed shock **afterglow** can show temporal structure similar to a **structured jet** (see the above figure)
- **Can GRB 170817A be a refreshed shock afterglow?**

Fitting the **afterglow** data for GRB 170817A with two refreshed shock models:



The GRB 170817A afterglow **can be explained as a refreshed shock** viewed from ~17 degrees. In this model, the jet energetics are consistent with the 'on-axis' short GRB population.
See, Lamb, Levan & Tanvir 2020

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