Kilonova emission from realistic neutron star merger simulations

Christine Collins
GSI

With: Andreas Bauswein, Stuart Sim, Vimal Vijayan,
Gabriel Martínez-Pinedo, Oliver Just and Luke Shingles

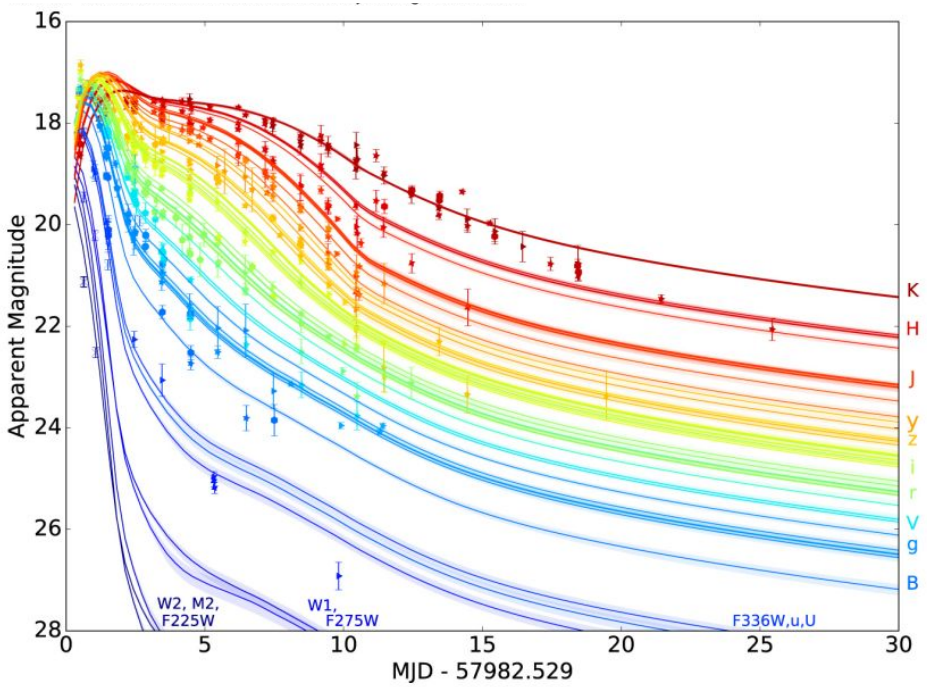
Introduction - What is a kilonova?

- Binary neutron stars spiral inwards and merge through the emission of gravitational waves
- When the binary neutron stars merge, r-process elements are synthesised in the neutron rich ejecta
- An optical counterpart (thermal emission), called a kilonova, is powered by the radioactive decays of r-process elements

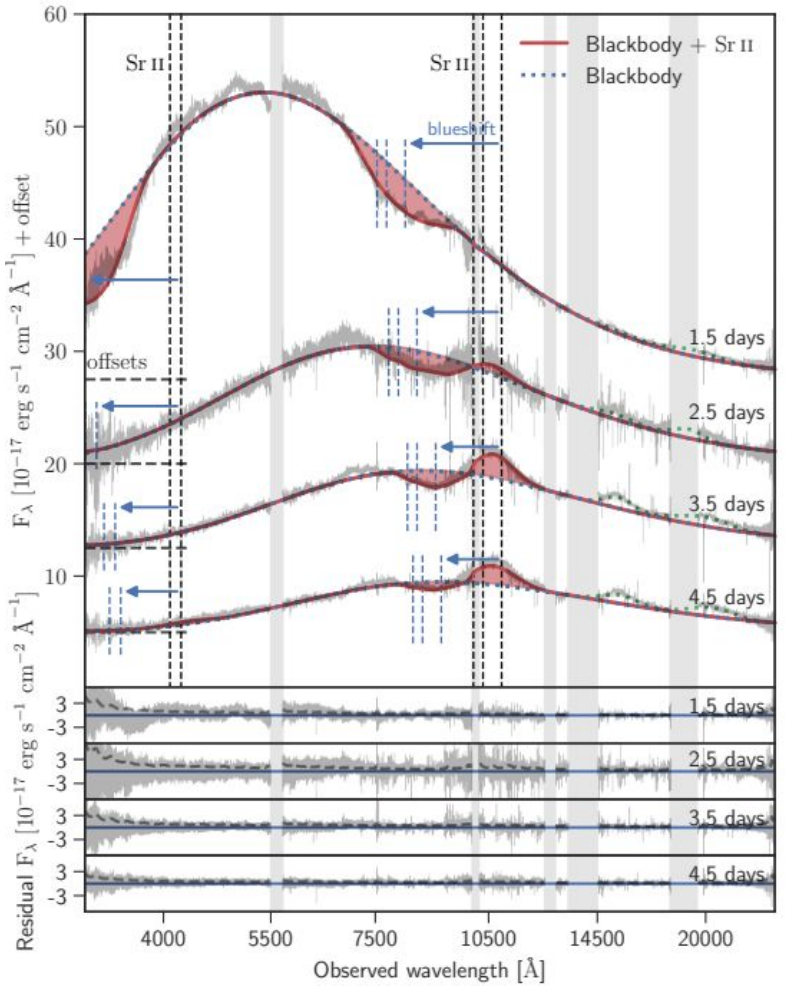
https://esahubble.org/

Observations of AT2017gfo/GW170817

- Modelling required to understand observations
- Many approaches have used parameterised 1D models to fit observations



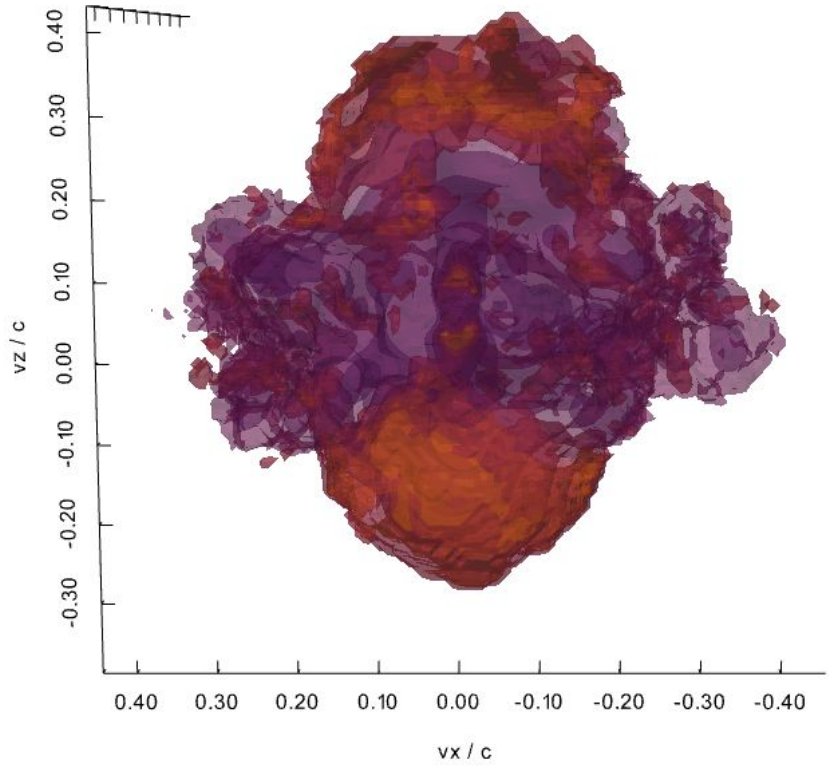
Villar et al. 2017



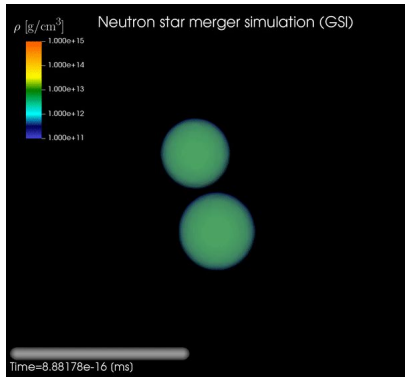
Watson et al. 2019

Merger simulations predict asymmetric ejecta

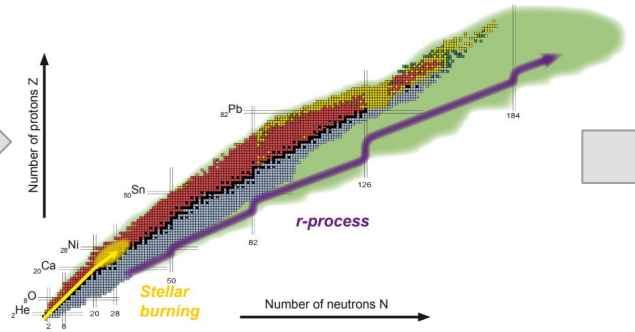
- Dynamical ejecta from binary neutron star merger simulation
- Need to connect merger simulations to observations



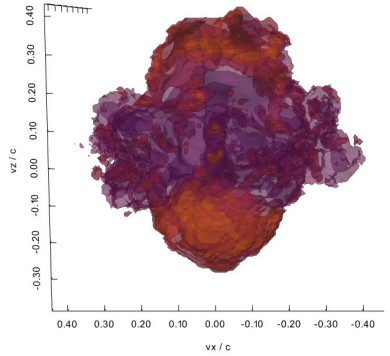
3D kilonova modelling pipeline



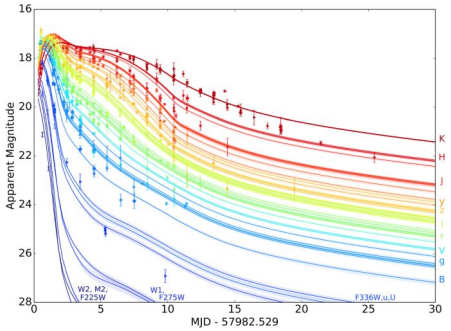
NS-NS merger simulation
by A. Bauswein, V. Vijayan



Nuclear network calculation by
G. Martínez-Pinedo
credit: EMMI, GSI/Different Arts



Radiative transfer
calculation based on
ejecta snapshot

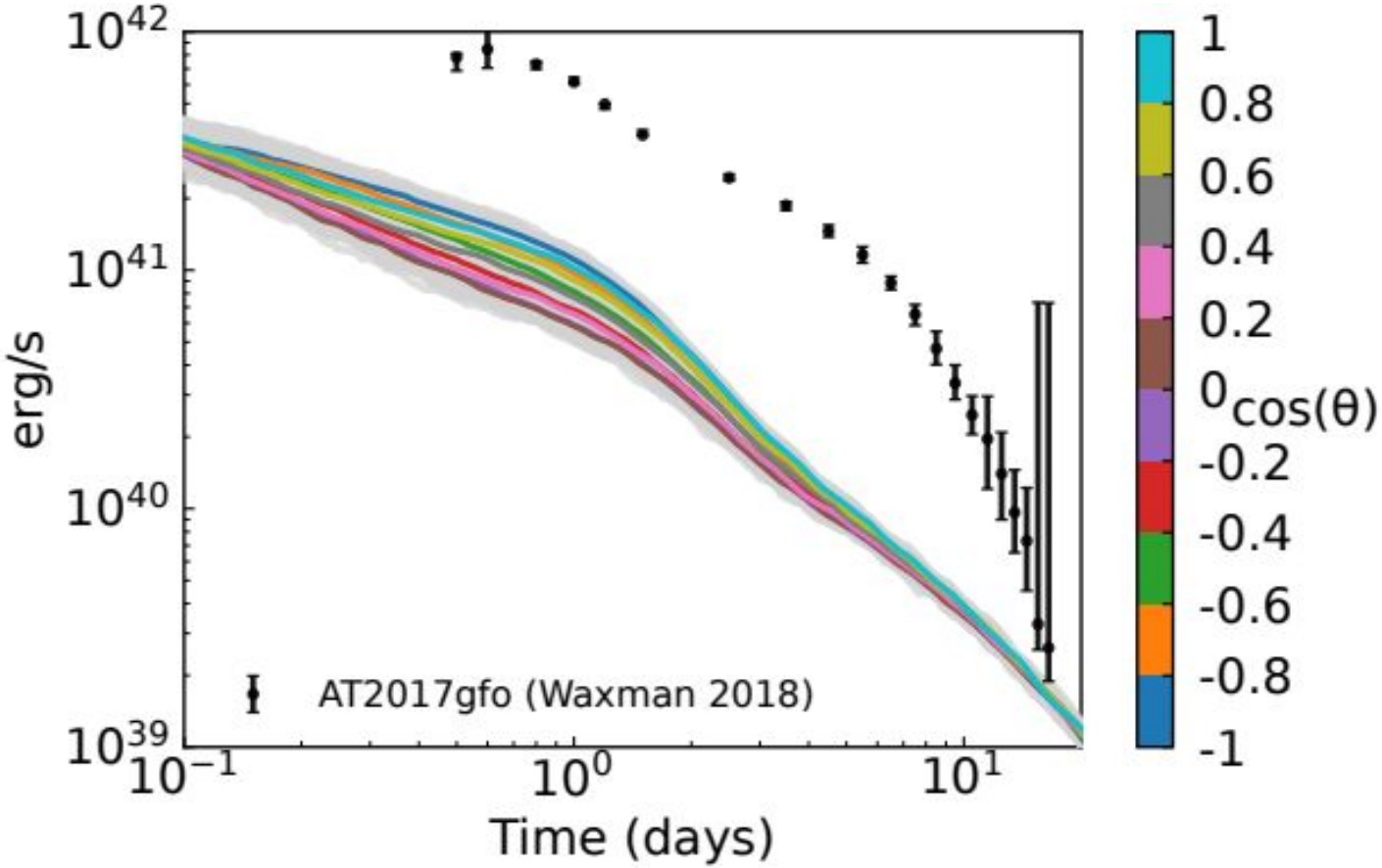


Compare to observations
Image: light curves of the
kilonova AT2017gfo
(Villar et al. 2017)

- Our simulations are among the first in 3D using realistic merger simulations as input to radiative transfer
- We combine detailed simulations of the merger, the r-process nucleosynthesis and radiative transfer to compare to observations
- Important to understand the r-process and learn about the underlying physics of mergers e.g. high density Equation of State

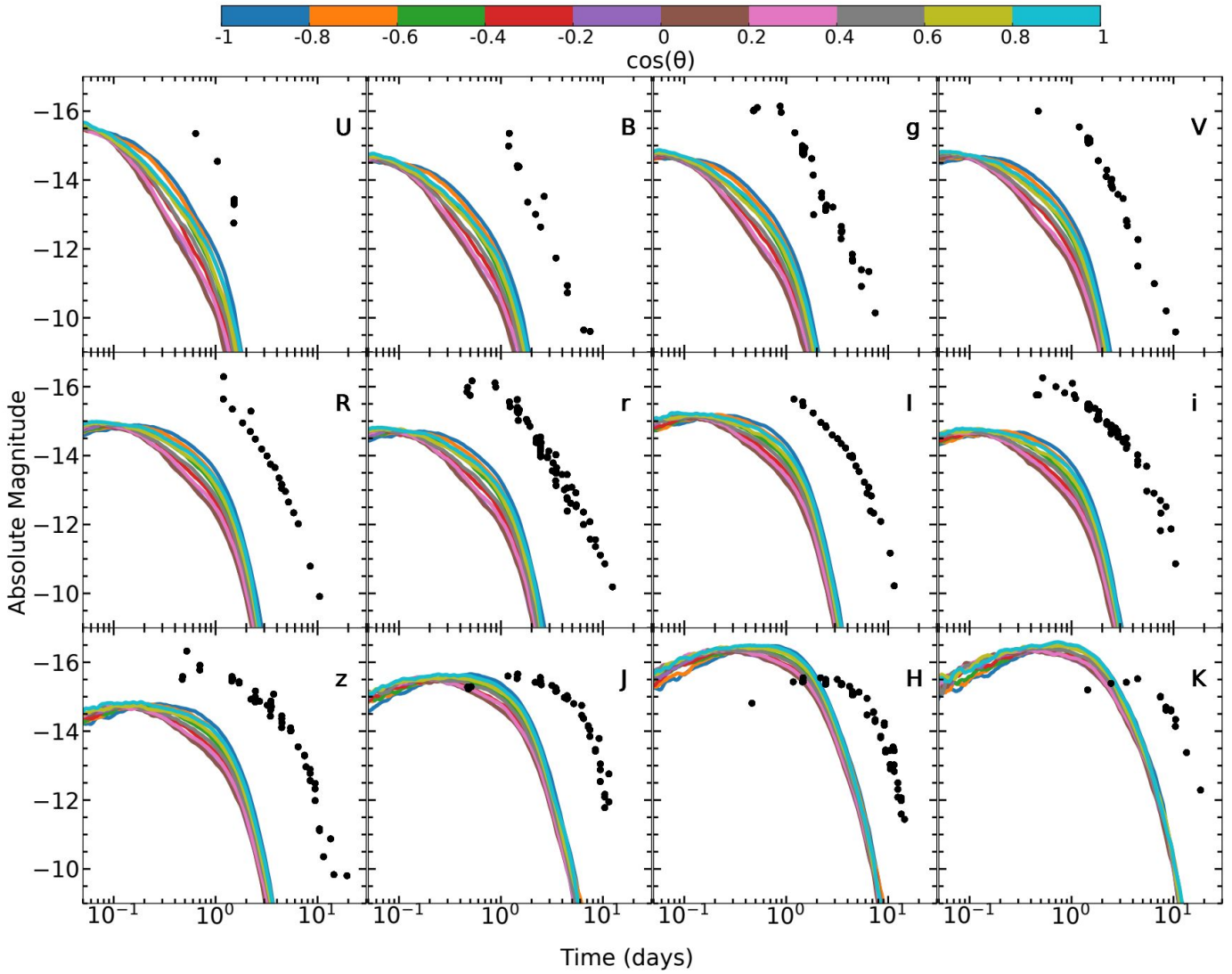
Angle-dependent bolometric light curves

- UV-IR angle-dependent bolometric light curves
- Lines of sight in the polar directions are brighter due to lower opacities and lower densities
- The asymmetric ejecta leads to an angle variation of a factor of ~2
- The chosen model is less massive than the mass inferred for AT2017gfo, and therefore we do not expect model to be as bright



Approximate band-limited light curves from black body spectra

- We obtain approximate band-limited light curves from black body distributions at the radiation temperature where radiation escaped
- The light curves show a similar evolution to AT2017gfo, although on shorter timescales



AT2017gfo light curves from Villar+2017

Conclusions

- We can compare 3D simulations directly to observations. The self-consistent modelling pipeline reduces uncertainties in the modelling.
- The asymmetric ejecta from a realistic merger simulation leads to an angle variation of a factor of ~2 in brightness in the bolometric light curves, highlighting the importance of 3D simulations.
- We find a similar evolution of the band-limited light curves to AT2017gfo, although on shorter timescales. This is a promising result from our simulations.