FERMILAB-POSTER-23-204-STUDENT

Kilonova Detection

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Introduction

The first observation of gravitational waves (GW) from a binary neutron star collision, known as GW170817, was detected by Laser Interferometer Gravitational-Wave Observatory (LIGO) and Virgo GW observatories in August of 2017. This event marked a profound discovery of the kilonova, which occurs when two neutron stars collide, resulting in an energetically explosive release of gamma-ray bursts (GRBs) and emitting bright electromagnetic radiation.

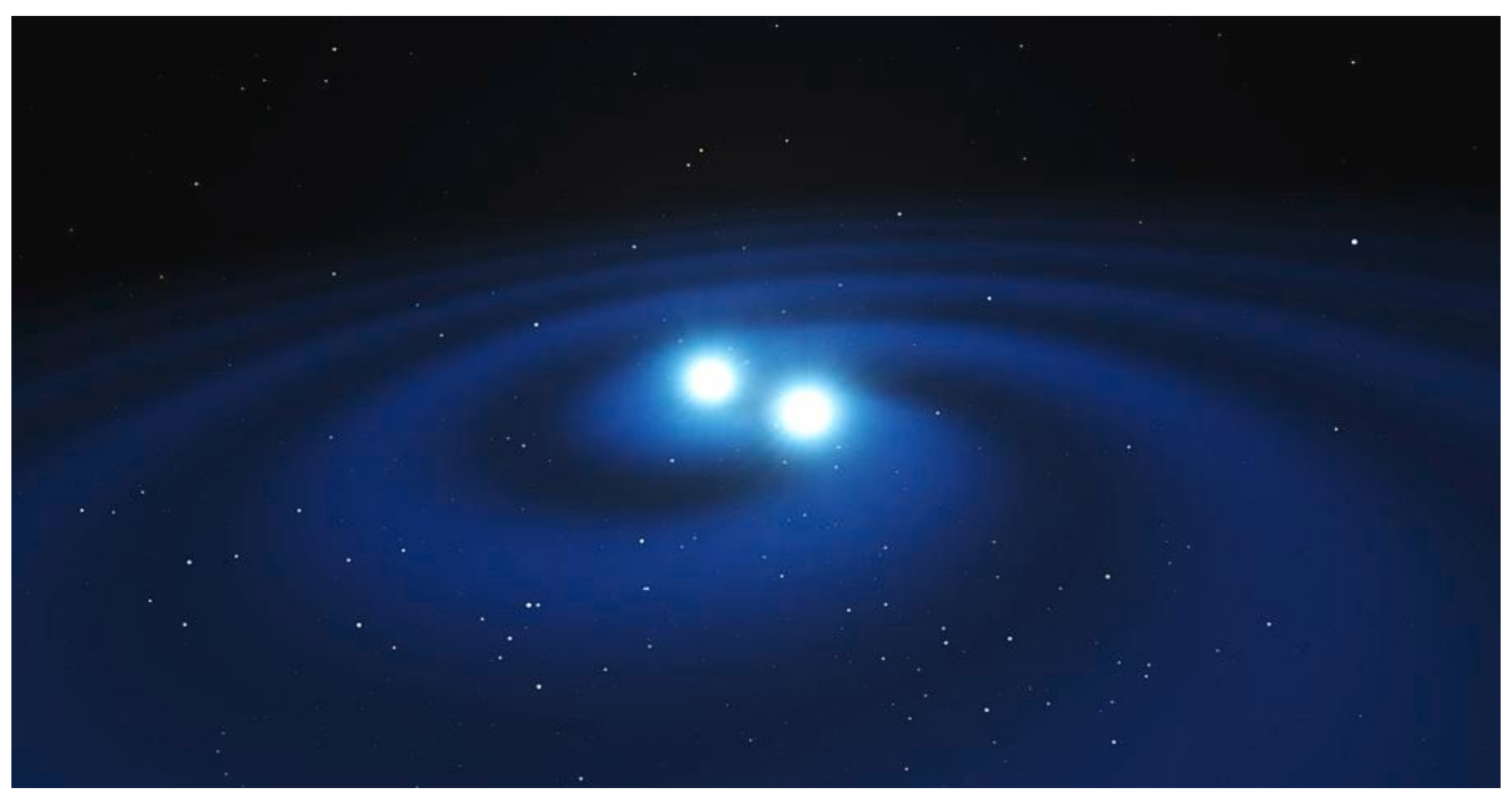

Fig. 1 – Artist's impression of neutron stars about to collide (ESO / L. Calçada / M. Kornmesser)

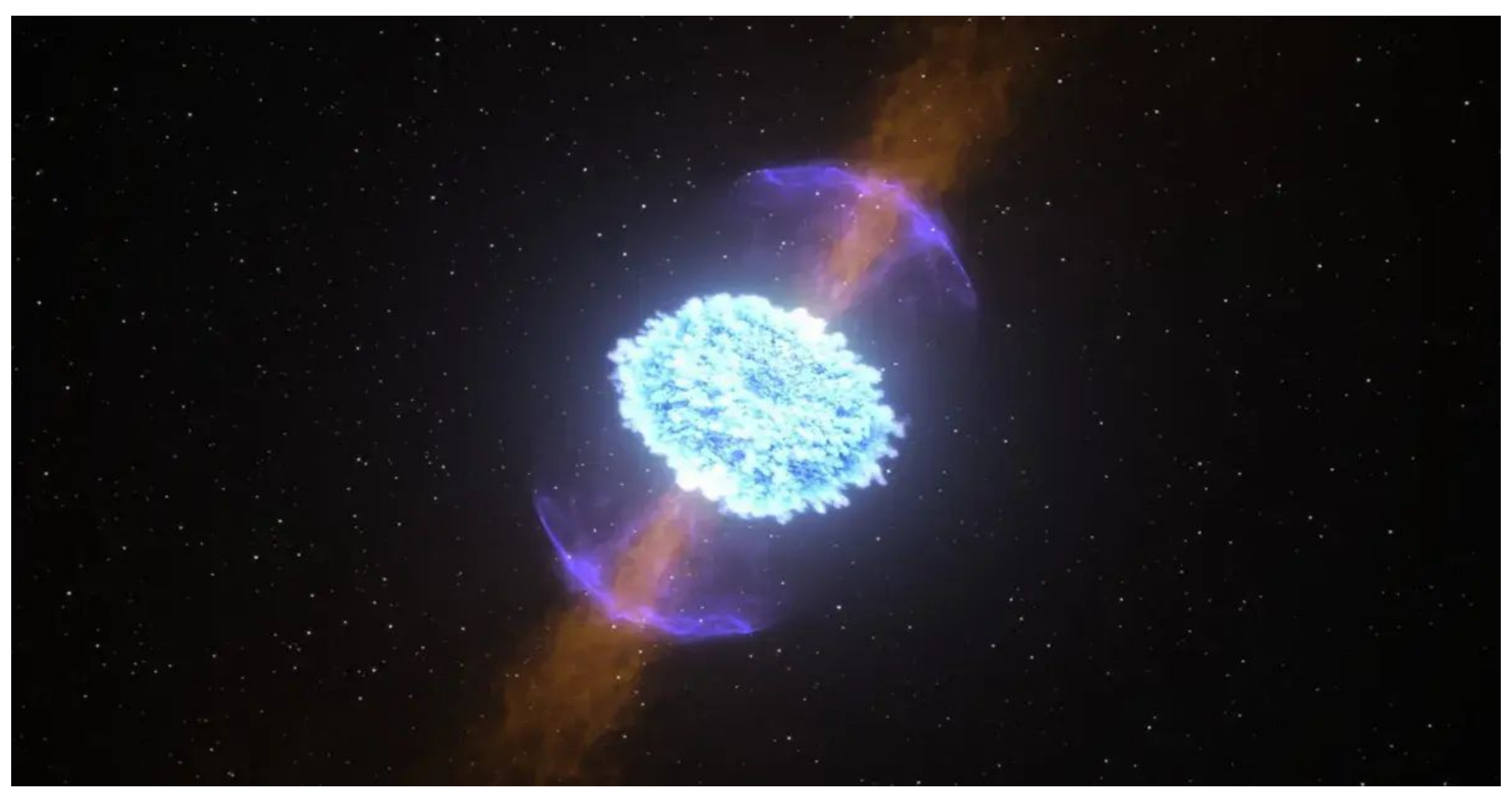

Fig. 2 – The explosion after the merger of two neutron stars (NASA's Goddard Space Flight Center/CI Lab)

Vera C. Rubin Observatory

The Vera C. Rubin Observatory, located on Cerro Pachón in Chile, is a powerful new telescope under construction. It will observe the entire southern sky every 3 days and be used to study a wide range of astronomical objects and phenomena, including kilonovae. The telescope features a 8.4 meter mirror, a 3.2 gigapixel camera and six filters (u, g, r, i, z, y) covering the wavelength range 320–1050 nm. The Rubin Observatory's main goal will be to conduct the 10-year Legacy Survey of Space and Time (LSST).

Fig 3 – Credit: Rubin Observatory/NSF/AURA/B. Quint

Project

This project focuses on assessing how well kilonovae will be detected in the LSST at the Rubin Observatory. We use theoretical models of kilonova light emission (Kasen et al. 2017), which provide the UV to IR spectrum at every 0.1 days after the merger, with varying ejecta mass, ejecta velocity, and lanthanide fraction. In total, we analyze these 329 models and create kilonova light curves to assess the number of visible kilonovae at a given redshift for each band, based on its minimum brightness.

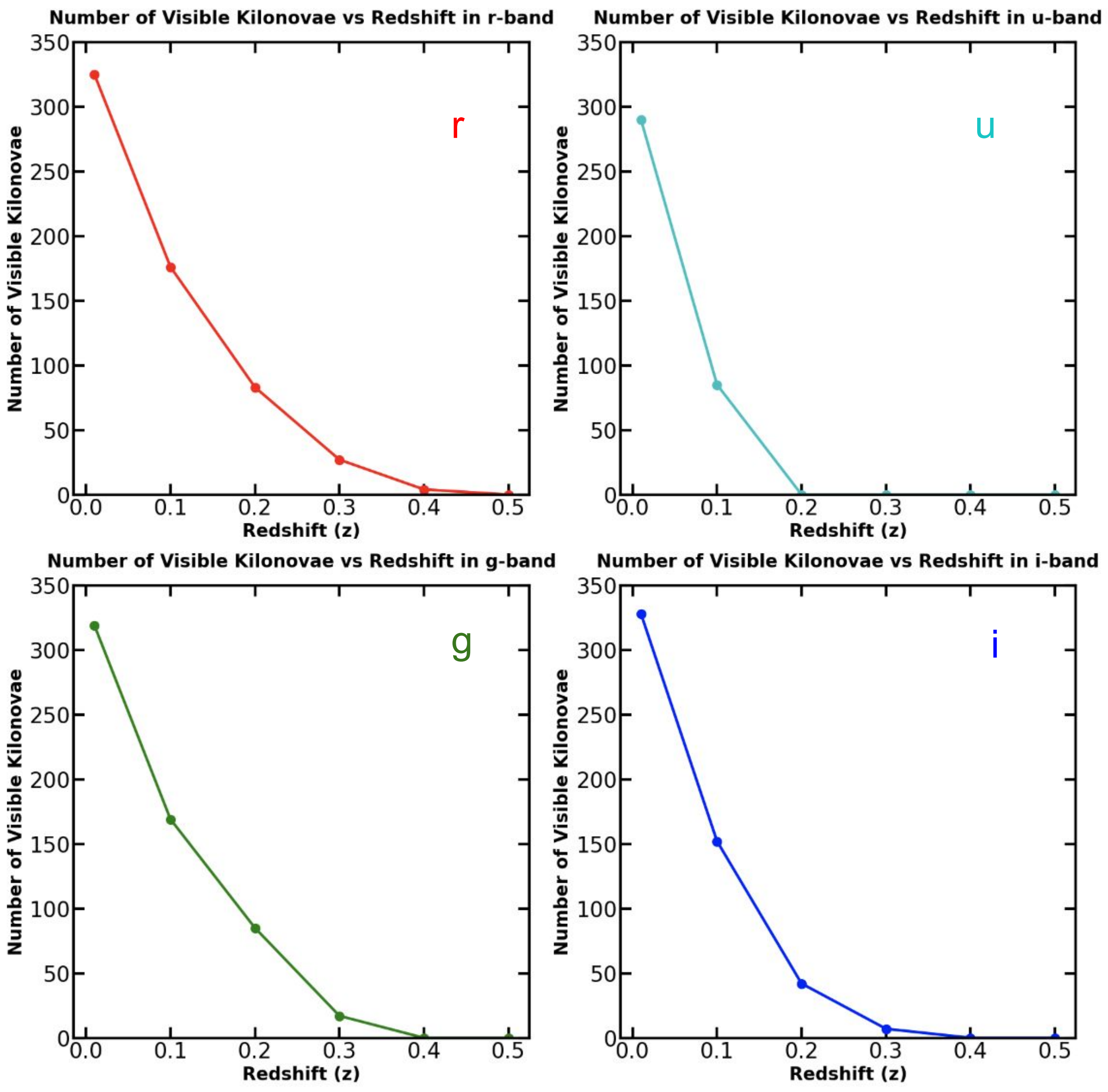

Fig. 6 – Number of Visible Kilonovae vs Redshift Plots

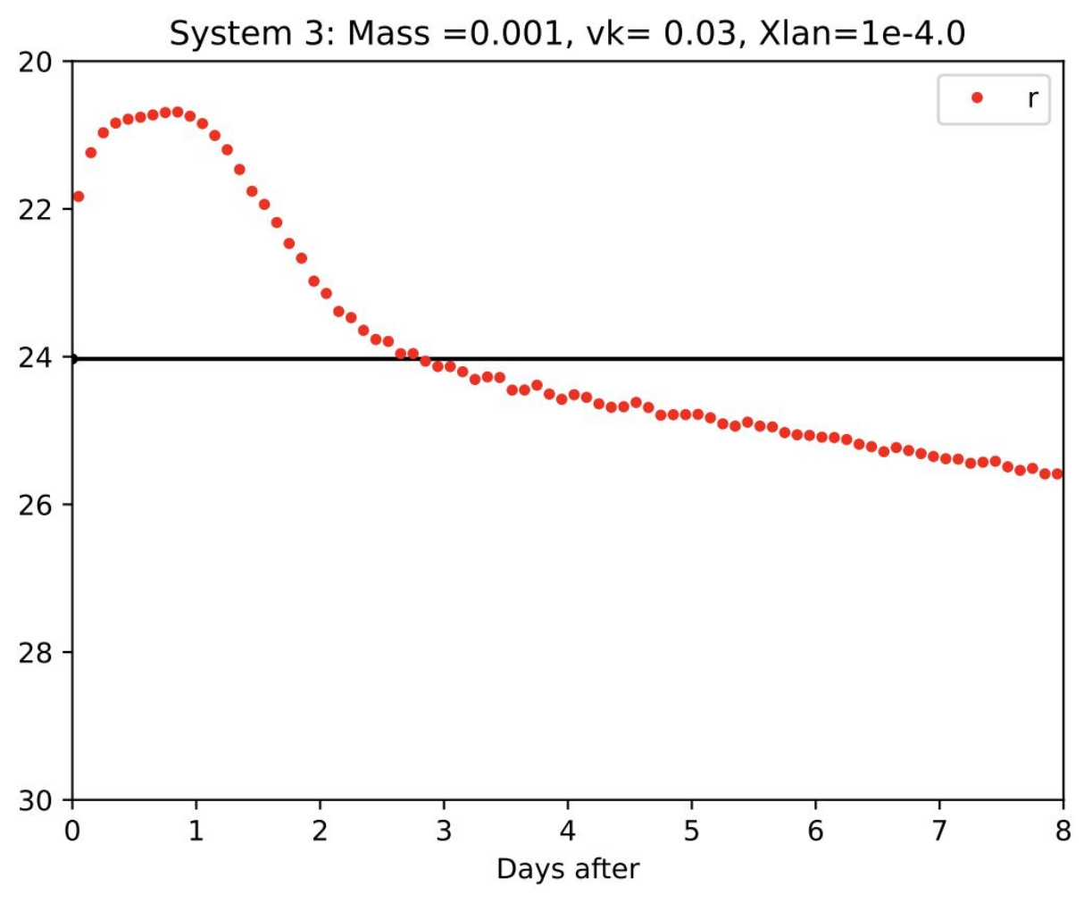

Fig. 4 – Kilonova Light Curve #3 at z = 0.0099 showing r-band limiting magnitude.

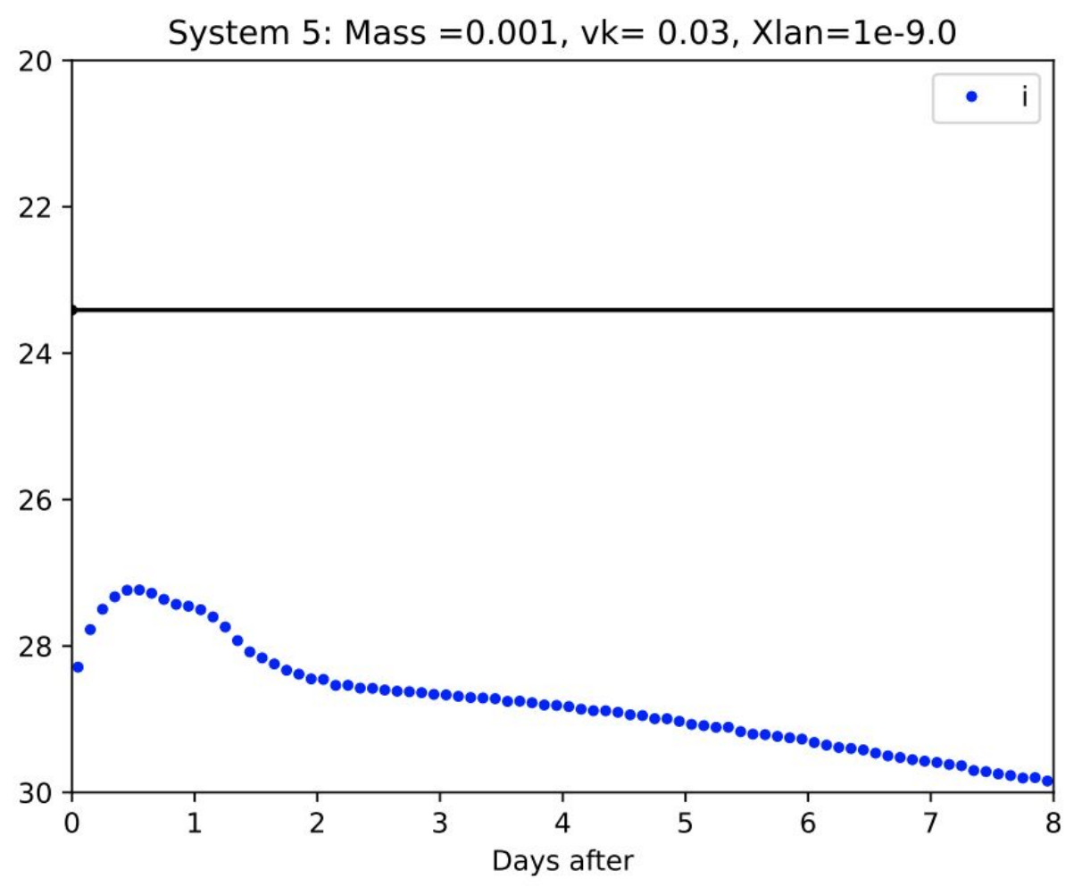

Fig. 5 – Kilonova Light Curve #5 at z = 0.2 showing i-band limiting magnitude.

Results

LSST calculates its limiting magnitude for different filters by considering the total system throughput, atmospheric transmission, optics, and detector sensitivity. We used Kasen models to create kilonovae light curves and then compared these light curves to the limiting magnitude. Kilonovae that fall below the limiting magnitude would be too dim to be observable in single exposures in LSST, while those that remain above it can be detected, as shown in Figure 4 & 5.

In Figure 6, we illustrate the number of Kasen kilonova models that are predicted to be observable in LSST single visit images. These predictions are based on whether each of the Kasen models becomes bright enough in a specific filter band at some point in its light curve to surpass the LSST limiting magnitude in that band. We reran the light curve predictions at a series of increasing redshifts. As expected, we found that as the redshift increased, the number of visible models rapidly decreased.

This manuscript has been authored by Fermi Research Alliance, LLC under Contract No. DE-AC02-07CH11359 with the U.S. Department of Energy, Office of Science, Office of High Energy Physics.
This work was supported in part by the U.S. Department of Energy, Office of Science, Office of Workforce Development for Teachers and Scientists (WDTS) under the Visiting Faculty Program (VFP).