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Self-consistent 3D radiative transfer for kilonovae

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We computed three-dimensional radiative transfer calculations for the ejecta from a neutron star merger with line-by-line opacities for tens of millions of atomic transitions, composition from an r-process nuclear network, and time-dependent thermalization of decay products from individual ⊠ and ⊠− decay reactions. In contrast to expansion opacities and other wavelength-binned treatments, a line-by-line treatment enables us include fluorescence effects and associate spectral features with the emitting and absorbing lines of individual elements. We find variations in the synthetic observables with both the polar and the azimuthal viewing angles. The spectra exhibit blended features with strong interactions by Ce III, Sr II, Y II, and Zr II that vary with time and viewing direction. We demonstrate the importance of wavelength-calibration of atomic data using a model with calibrated Sr, Y, and Zr data, and find major differences in the resulting spectra, including a better agreement with AT2017gfo. The synthetic spectra for near-polar inclination show a feature at around 8000 Angstrom, similar to AT2017gfo. However, the spectra evolve on a more-rapid timescale, likely due to the low ejecta mass (0.005 M⊠) as we take into account only the early ejecta. The comparatively featureless spectra for equatorial observers gives a tentative prediction that future observations of edge-on kilonovae will appear substantially different from AT2017gfo. We also show that 1D models obtained by spherically averaging the 3D ejecta lead to dramatically different direction-integrated luminosities and spectra compared to full 3D calculations. Going beyond the paper, I will also show some recent unpublished results for low-noise virtual-packet spectra using newly-available atomic data that have been calibrated to match known transition wavelengths.

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