Physics 345, Fall 2020, Project #1
Microlensing

Overview. In gravitational microlensing, a star temporarily brightens when its light is focused by the gravitational field of another star that happens to be passing in front (from our perspective). In this project, you will fit microlensing models to observed light curves (brightness vs. time) in order to extract key parameters for microlensing events.

Data. The OGLE project (Optical Gravitational Lensing Experiment) provides an extensive database of microlensing events at `http://ogle.astrouw.edu.pl/ogle4/ews/2019/ews.html`. That page lists events from 2019, and provides links to events from prior years.

Setup. The basic model for a microlensing light curve – known as the Paczyński light curve – has the form

$$m(t) = m_0 - 2.5 \log_{10} \left[f_{\rm bl} A(t) + (1 - f_{\rm bl}) \right]$$

Here $m(t)$ is the apparent magnitude as a function of time, m_0 is the baseline magnitude, the "blend parameter" $f_{\rm bl}$ indicates what fraction of the total light at baseline comes from the background star, and $A(t)$ is the lensing amplification as a function of time:

$$A(t) = \frac{u(t)^2 + 2}{u(t)\sqrt{u(t)^2 + 4}} \qquad \text{where} \qquad u(t) = \left[u_{\rm min}^2 + \left(\frac{t - t_{\rm peak}}{\tau} \right)^2 \right]^{1/2}$$

Here $u(t)$ is the projected distances of the source from the lens, $u_{\rm min}$ is the minimum distance (also known as the impact parameter), $t_{\rm peak}$ is the time when the light curve reaches its peak, and τ is the time scale for the event. In this model, the parameters are $t_{\rm peak}$, τ, $u_{\rm min}$, $f_{\rm bl}$, and m_0.

Note: the model gets more complicated if either the lens or source is a binary system, or if the event lasts long enough that orbital motion (including Earth's) becomes important. We are not studying those effects here, but I wanted to mention them in case you find "weird" events that do not seem to be well characterized by the standard model.

Goals. Pick (at least) three events from the OGLE database and fit them with the model described above. In your paper and presentation, you should explain how you chose the events. I recommend looking for events that show a clear, single peak in the light curve and are not too noisy. For each event, report the best-fit values of the model parameters, and use MCMC to characterize the uncertainties.

Sub-analyses. I will be happy to discuss ideas for the individual sub-analyses for this project.