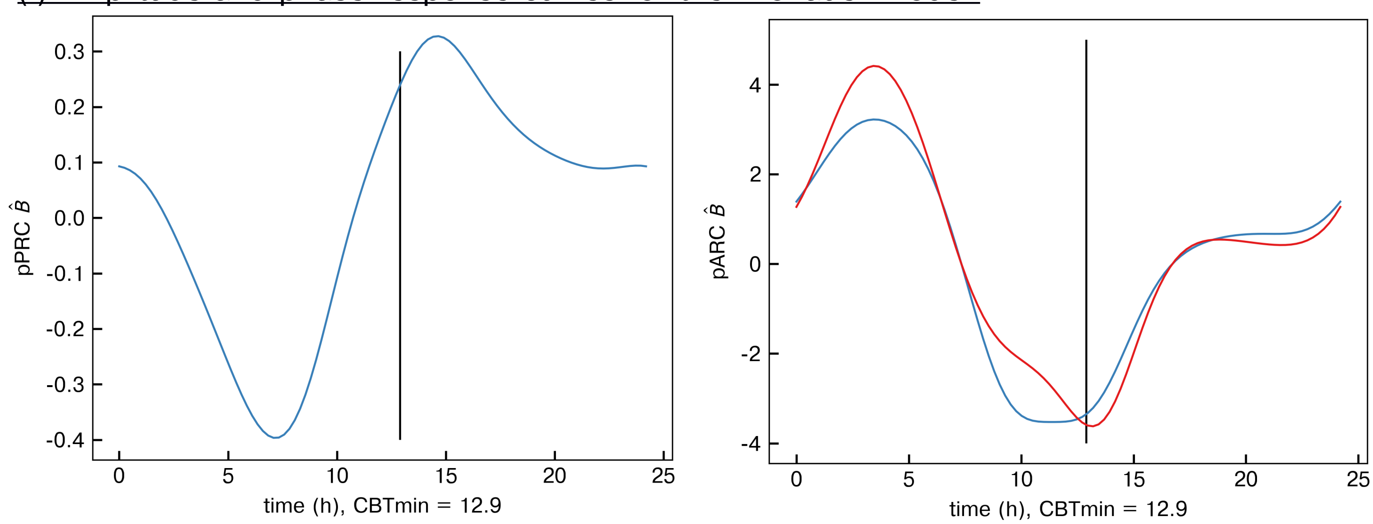
Light-induced critical resetting of the human clock

General idea/goal:
We want to be able to perform "critical" phase shifting - force the oscillator close to the critical point, then reset it from there simply because the phases are condensed.

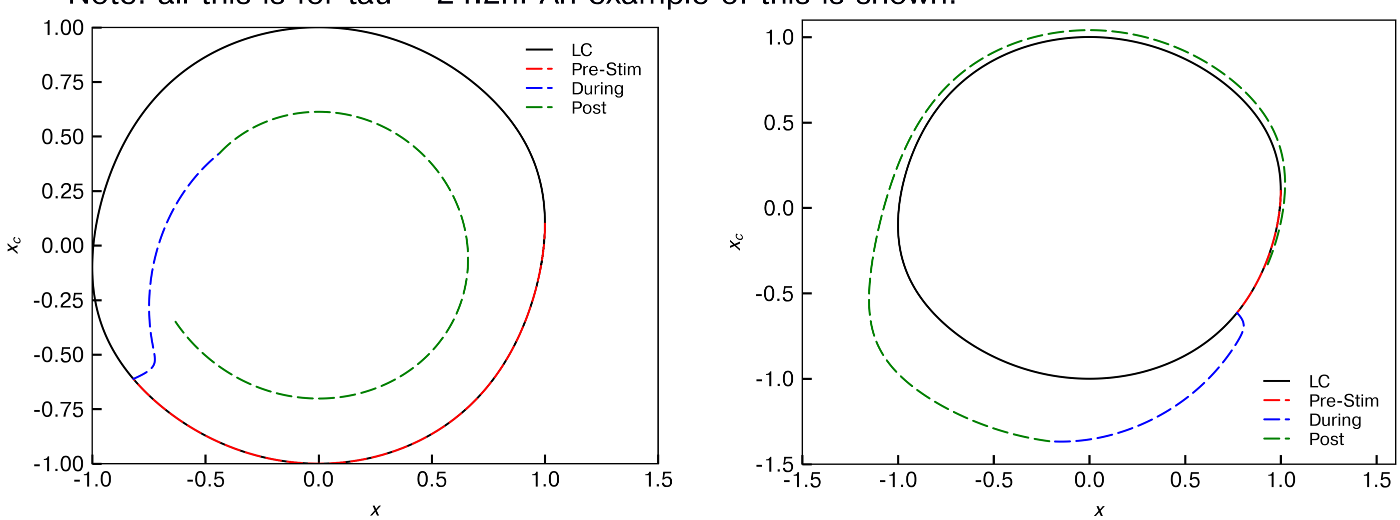
Approach:
Use model predictive control to do it, figure out the amplitude response curve, and hit the oscillator where the amp response is negative to drive it to the critical point.

Results thus far:

<u>(i) Amplitude and phase response curves for the Kronauer model.</u>



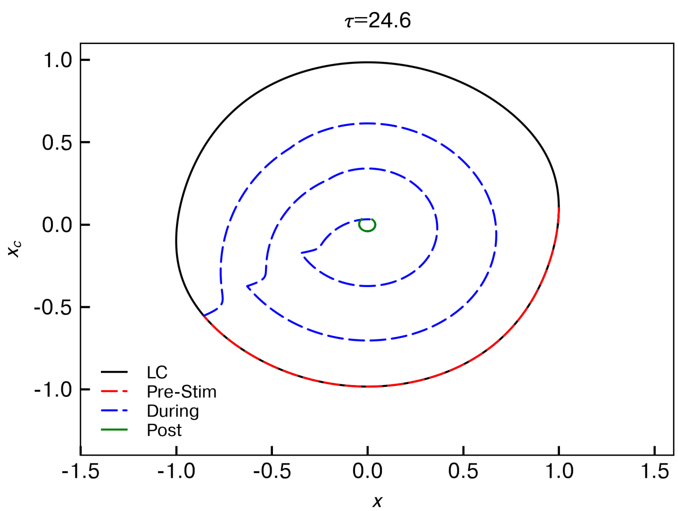
These plots are the PRC (left) and ARC (right, for each state) for an infinitesimal perturbation to \hat B. Because \hat B is the route by which light enters the model, this is the parameter we would use to formulate the control. Notably, a pulse centered at CBTmin would indeed reduce the amplitude of the oscillator if it consistently hit that area. Note: all this is for tau = 24.2h. An example of this is shown:

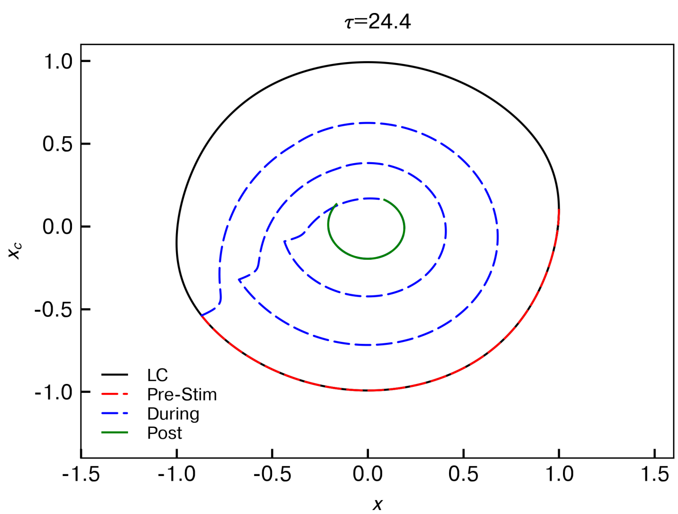


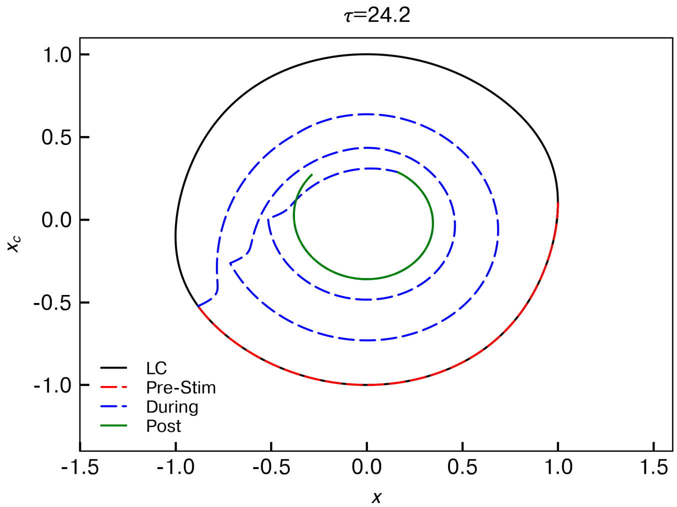
On the left is stimulation from 10-15. This clearly pushes the clock inside the limit cycle. On the right is stimulation from 3-5. This increases the amplitude, in both cases consistent with the ARC. I am to this point ignoring the PRC because the original three-pulse experiment was phase-agnostic: the pulses were 24h apart.

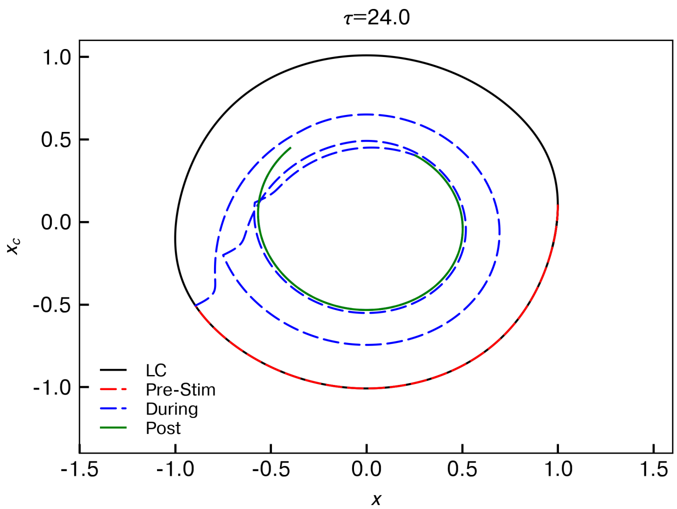
<u>(ii) Recreation of the three-pulse experiment and testing for varying period</u>

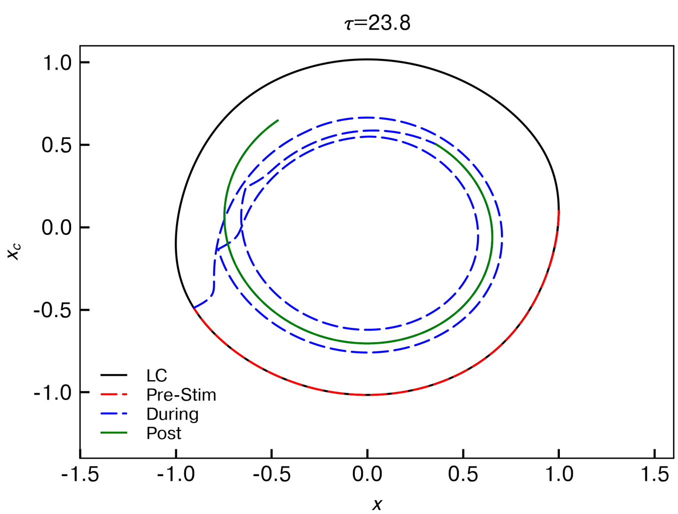
The purpose of the three-pulse experiment was to get a "type-0" reset, which we are calling "critical" because in reality it is close to the critical point. The phases there are very close in phase space, so you can easily jump between phases. Here, I'm recreating the three-pulse experiment to see if we get near the critical point. To do this, I apply the first pulse from 10.4-15.4h, and then repeat every 24h. (We don't know exactly what the threshold for a critical reset is, but nevertheless it is some closeness to the critical point.) If only 25% of individuals critical reset in the study, it's possible that different periods/phase responses are causing the light to be imprecisely timed. So, in short: changing the period between 24.6 and 23.8 and recreating the three-pulse experiment.





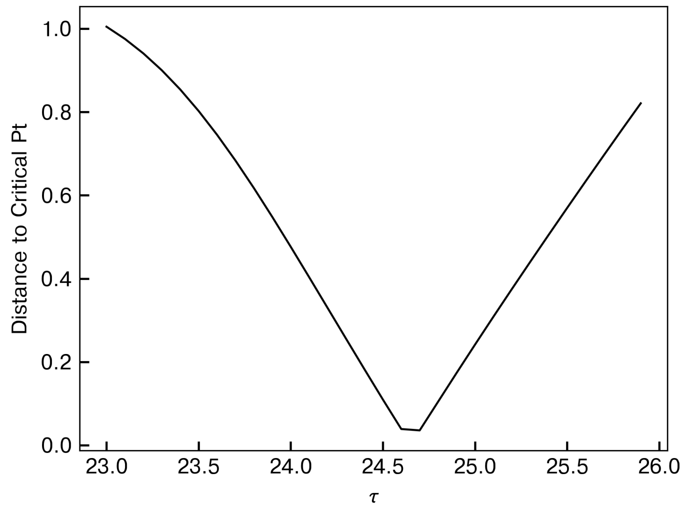






Why would a shorter period lead to a less precise critical reset? This is possibly because of the shape of the PRC. Each cycle, the phase is advancing slightly (due to shorter period), and therefore the PRC is hit in the positive region (top of this doc), advancing it further.

A similar idea holds for periods > 24.6h, where the delay is exacerbated. So, we're aiming for a pretty sensitive region completely blind. To see this, I plotted the distance to the singularity at the end of the final pulse for each period:



So only a narrow range of periods allows this to work in an open-loop (no feedback) fashion, which might explain the limited number of subjects who attained the critical reset.

<u>(iii) Correction using feedback control</u>

(working on it)