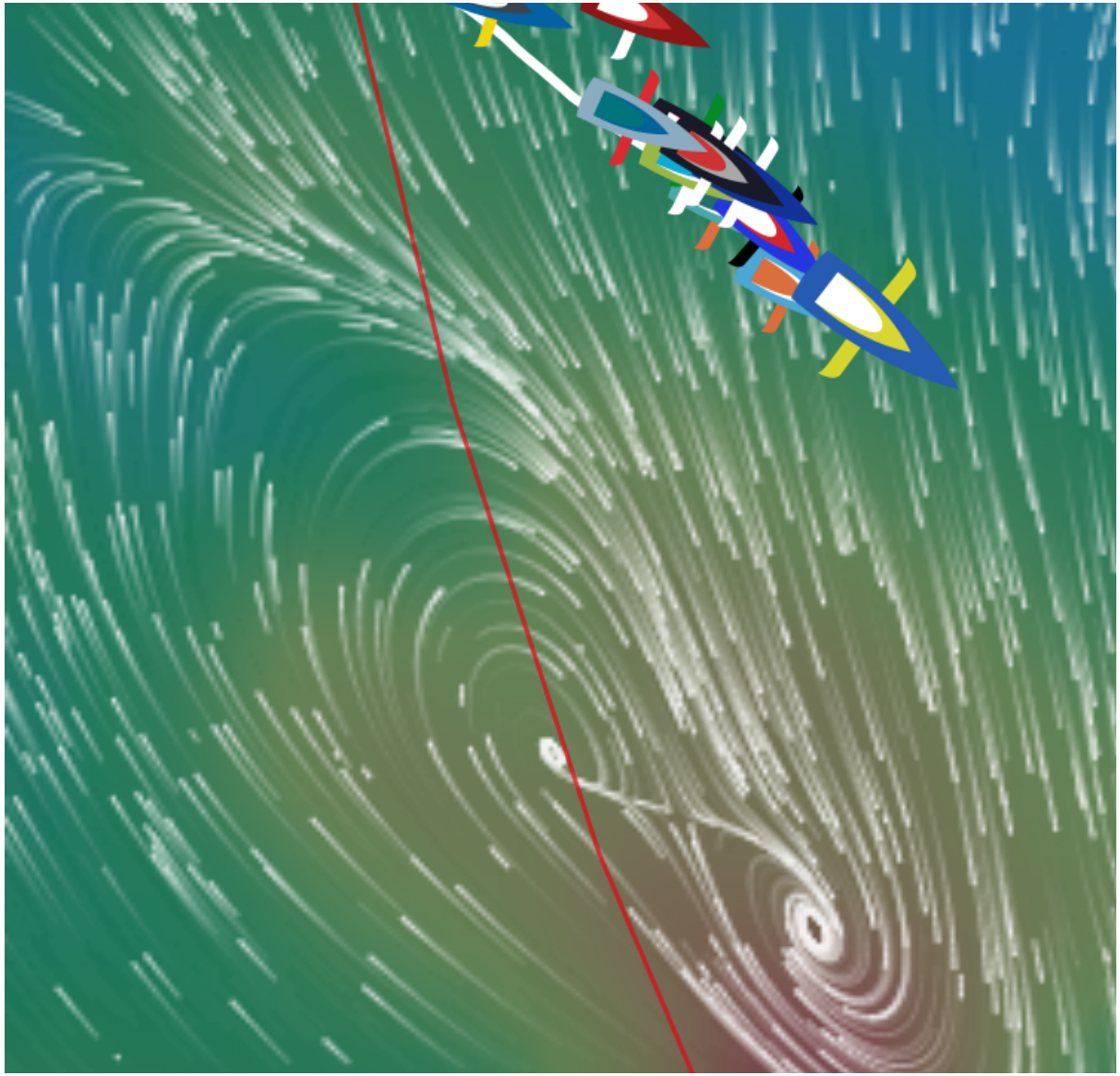
# Chap 6. Entrainment and synchronization of phase oscillators

**2024 Vendée Globe 24/11**



What do you see ?

# CHAPTER 6
# Entrainment & synchronisation of oscillators

## Entrainment of phase oscillators

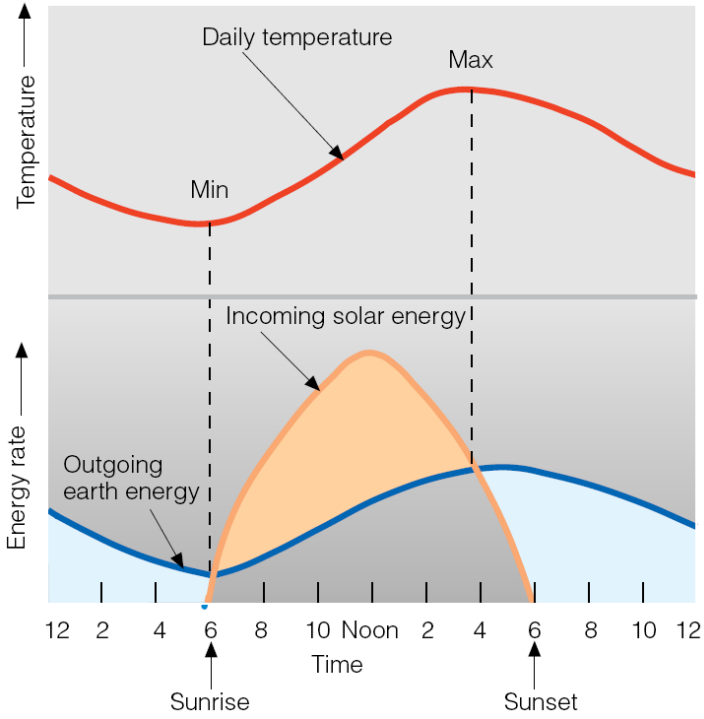
- Continuous sine coupling
- Pulsed sine coupling (sine map)

## Kuramoto model

- Collective synchronization in a population of oscillators

# Let’s talk about entrainement

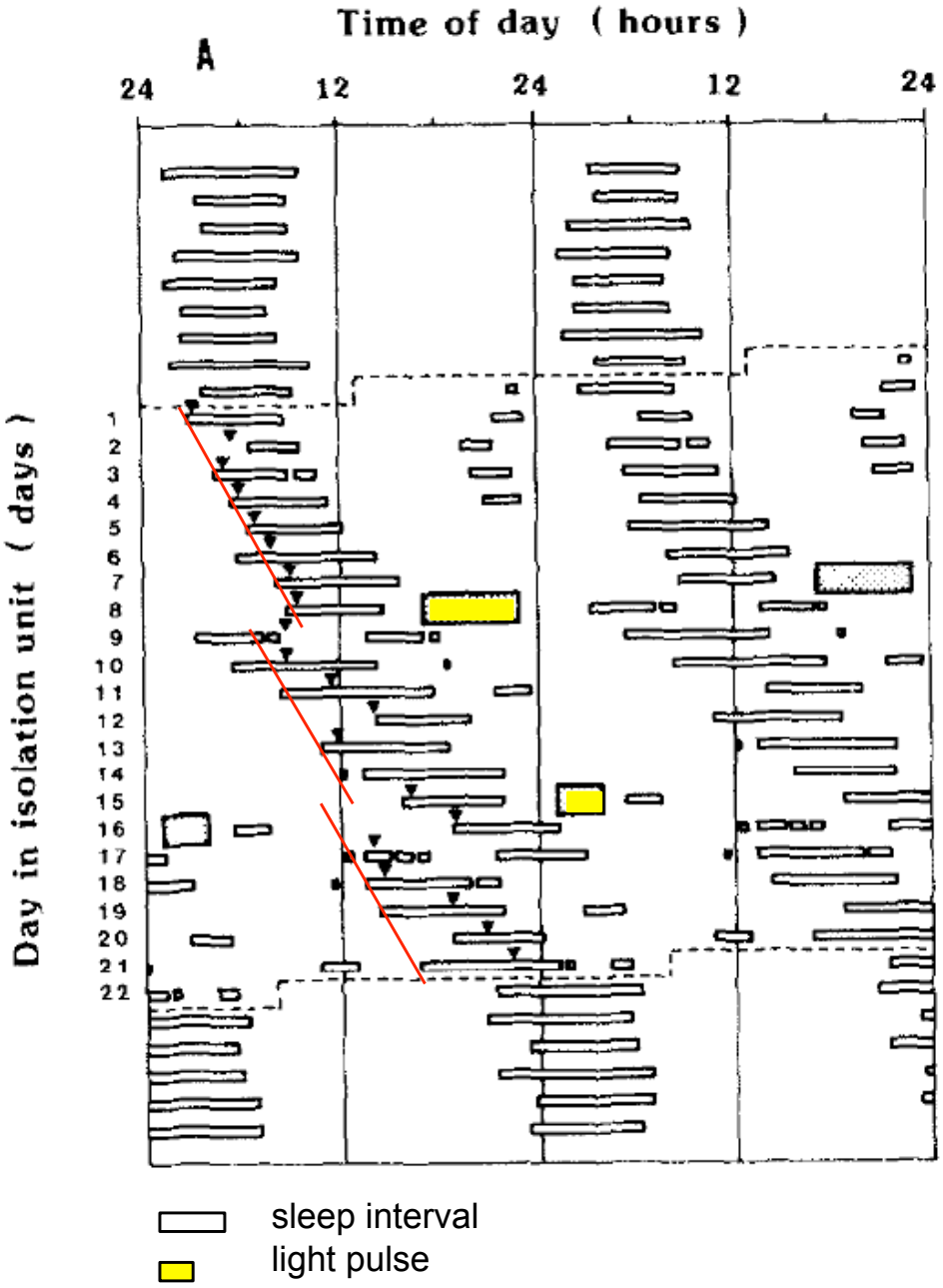
# Humans are resonating too




# Humans resonate to the ligh-dark cycle

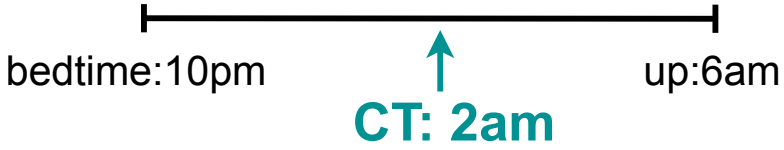
**Phase-dependent shift of free-running human circadian rhythms in response to a single bright light pulse**

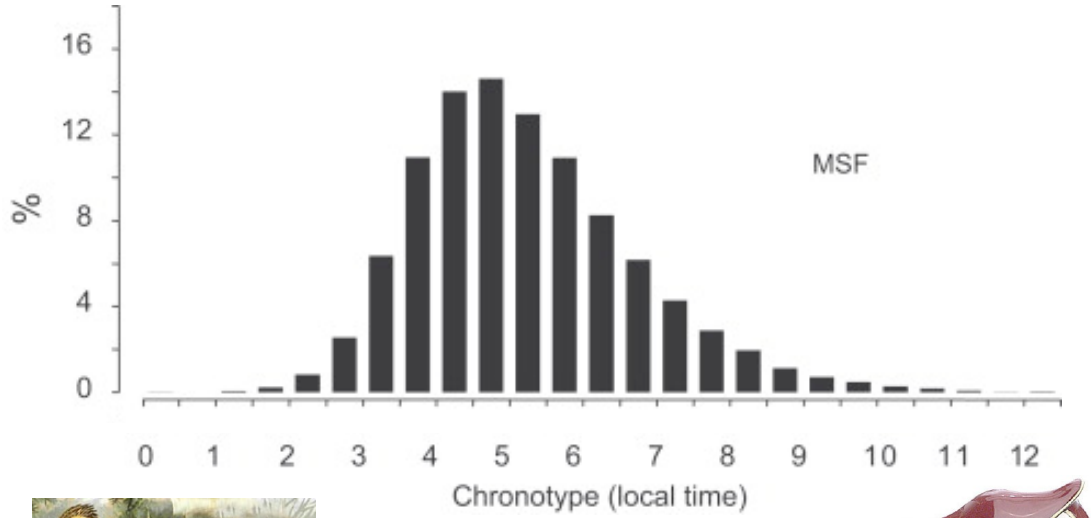
K. Honma, S. Honma and T. Wada* Experientia 43 (1987), Birkhäuser Verlag, CH–4010 Basel/Switzerland



# Chronobiology, larks and owls

**ChronoType (CT)**: time corresponding to mid-point in sleep




*from Roenneberg et al. Epidemiology of the human circadian clock. Sleep Med Rev (2007)*

larks

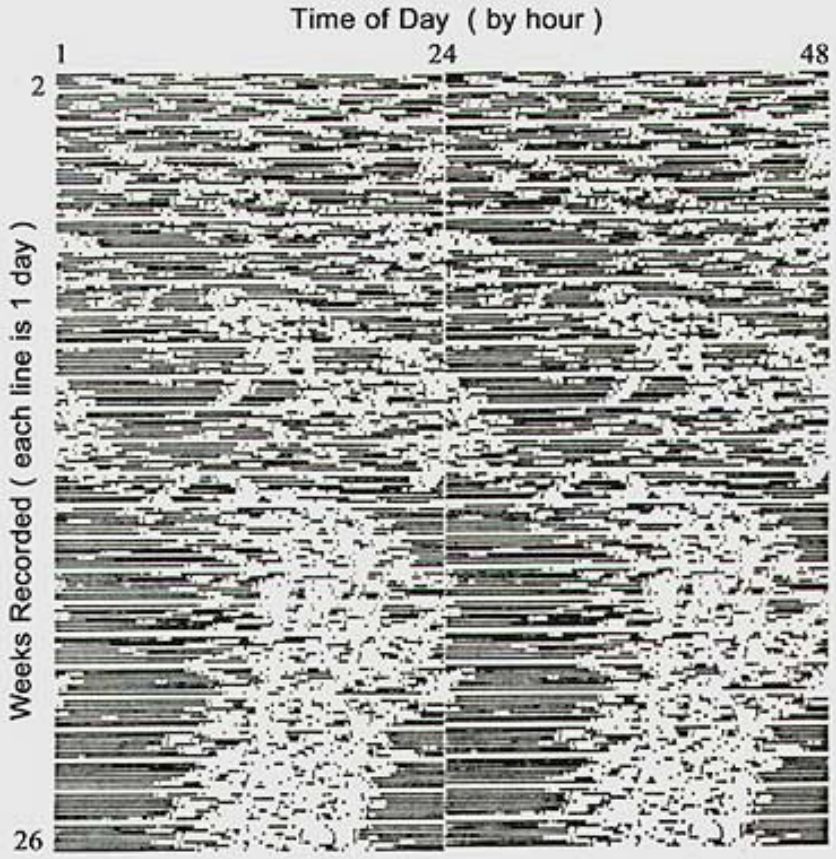
owls

Interpretation: Chronotype as a fixed point $\varphi^*$ (see 6.1)

# Circadian disruption: loss of sync with the environment

- Jetlag
- Shift work
- Intensive care unit (ICU)
- Early life

sleep rhythms in newborns

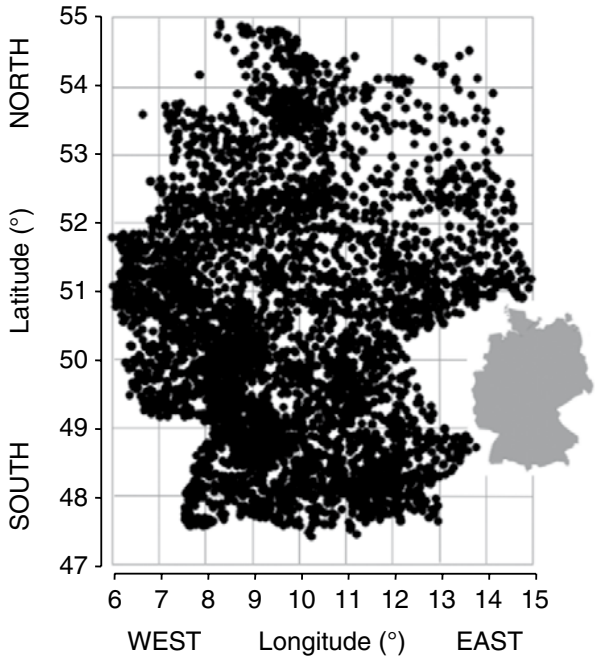


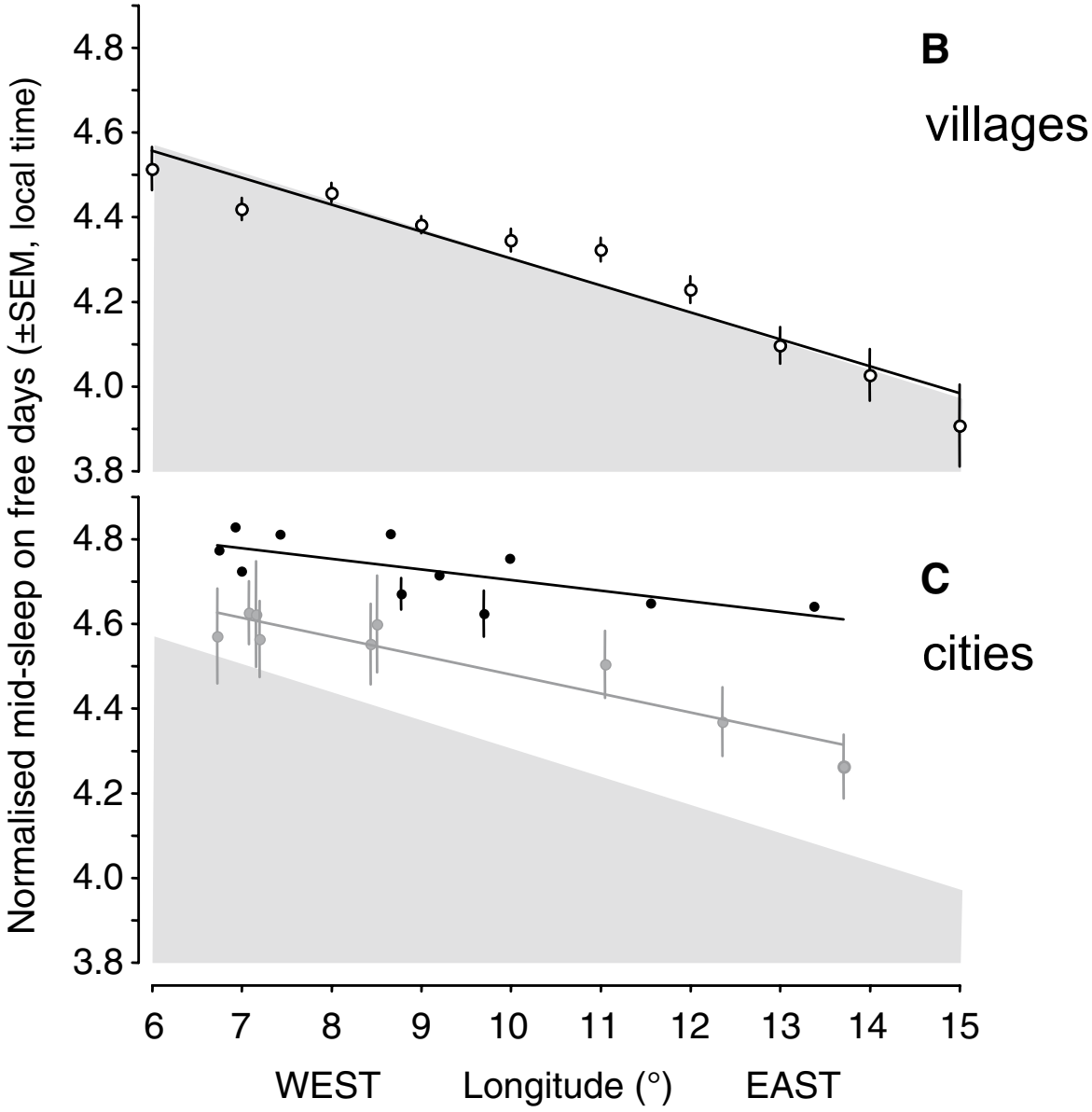

The sleep-wake record of a human baby. The record is double plotted so that the horizontal axis is 48th; the record extends from the second to the 26th week after birth.

# Humans (mostly) resonate with solar time, not social time

## The human circadian clock entrains to sun time

Till Roenneberg[1],
C. Jairaj Kumar[2] and
Martha Merrow[3]



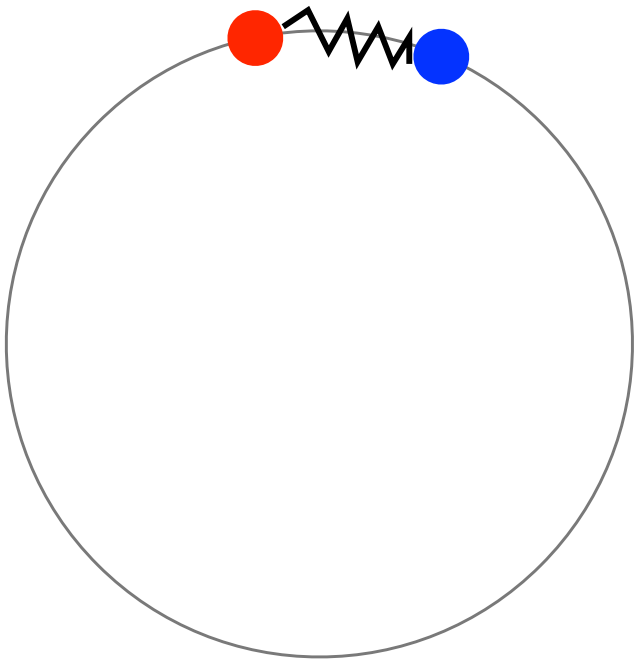




Current Biology

# Two model of coupling: continuous and pulsed

Model I (6.1)

- $\dot{\alpha} = \Omega$
- $\dot{\theta} = \omega + K \sin(\alpha - \theta)$



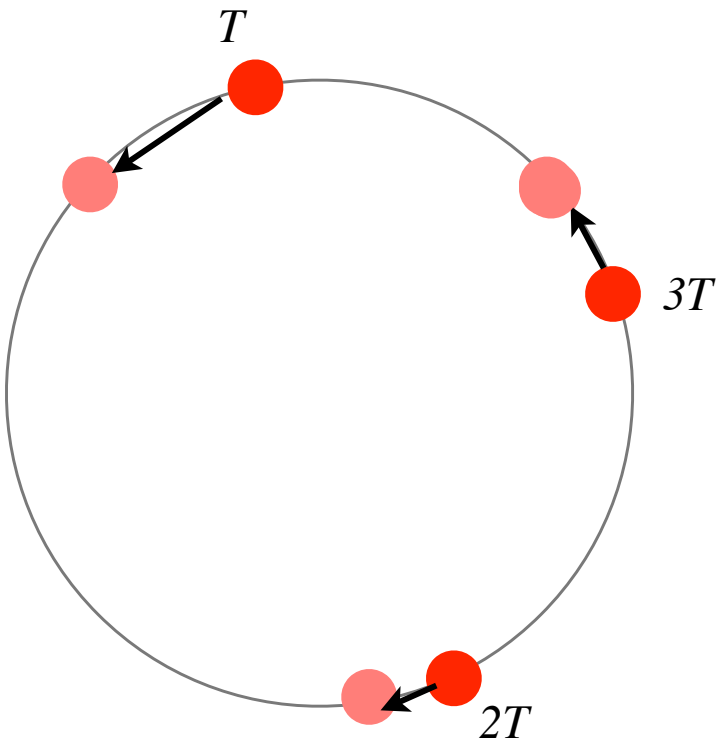
'Like a spring'

Model II (6.2)

- $\dot{\theta} = \omega + \sum_n \delta(t - n\,T) g(\theta(t))$

$$\theta_n = \theta_{n-1} + \omega\,T + g(\theta_{n-1})$$

$$g(\theta) = e\,\sin(\theta)$$




instantaneous kicks