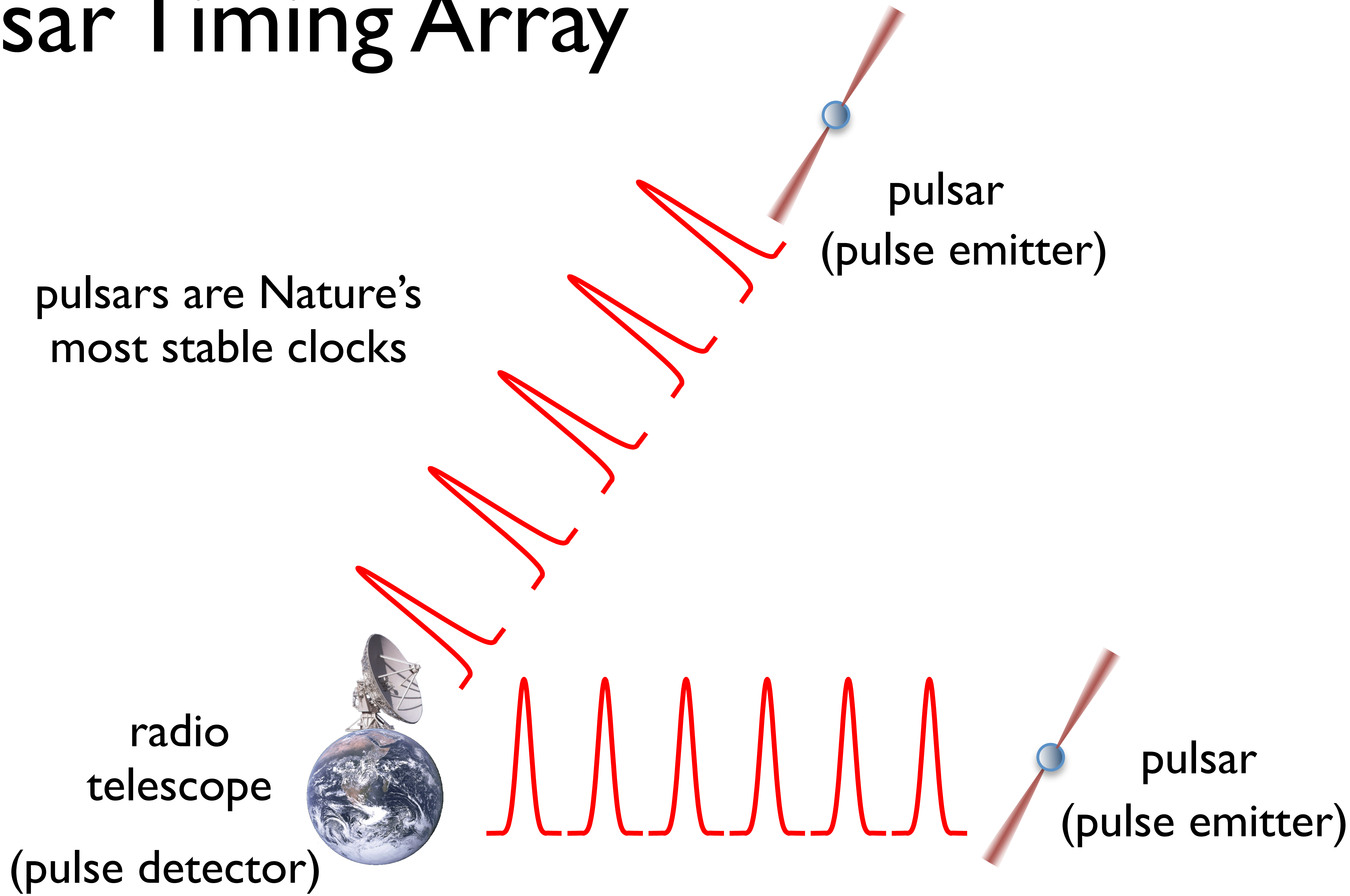
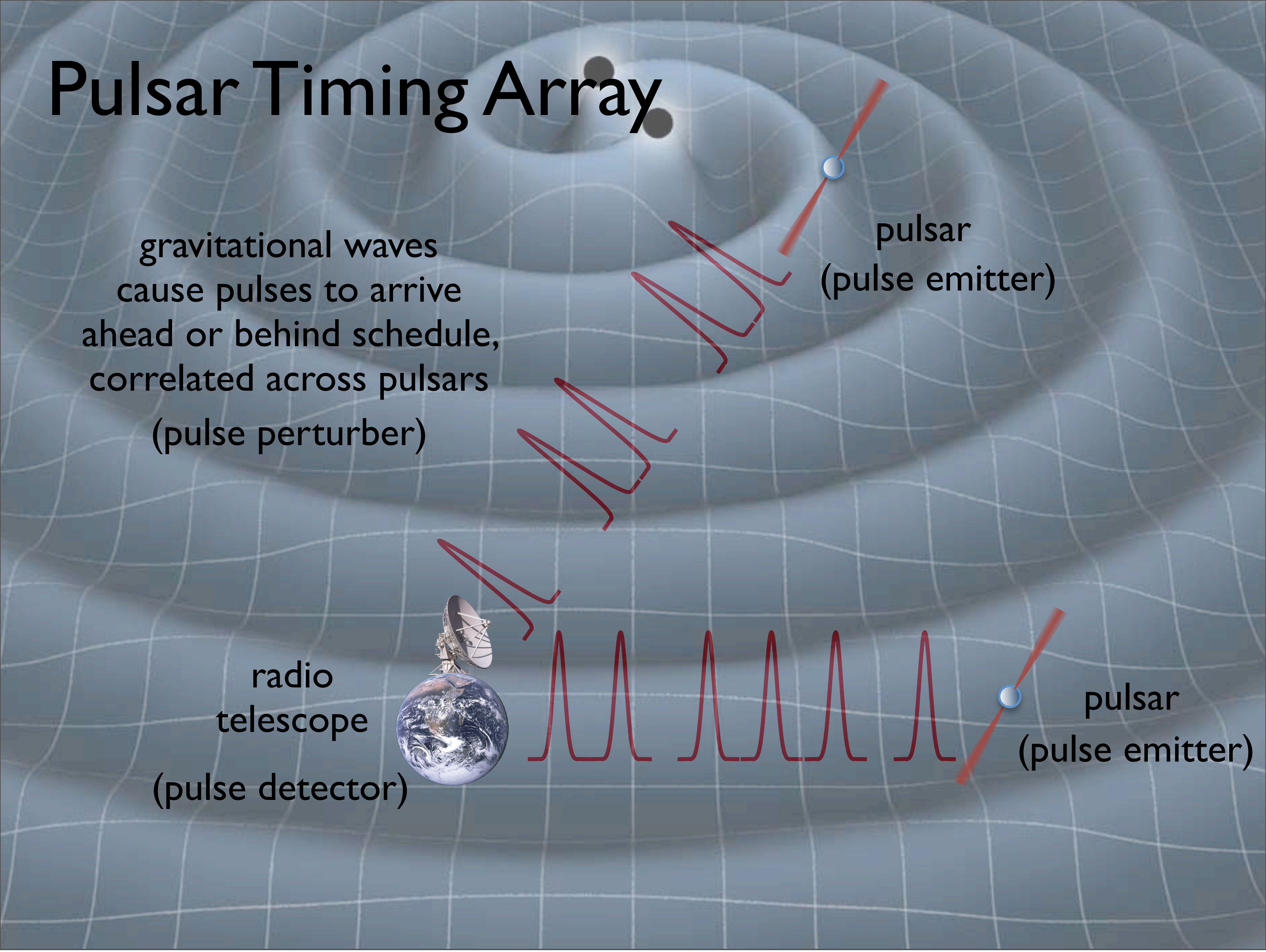
Using metronomes & microphones to model a pulsar timing array

Pulsar Timing Array

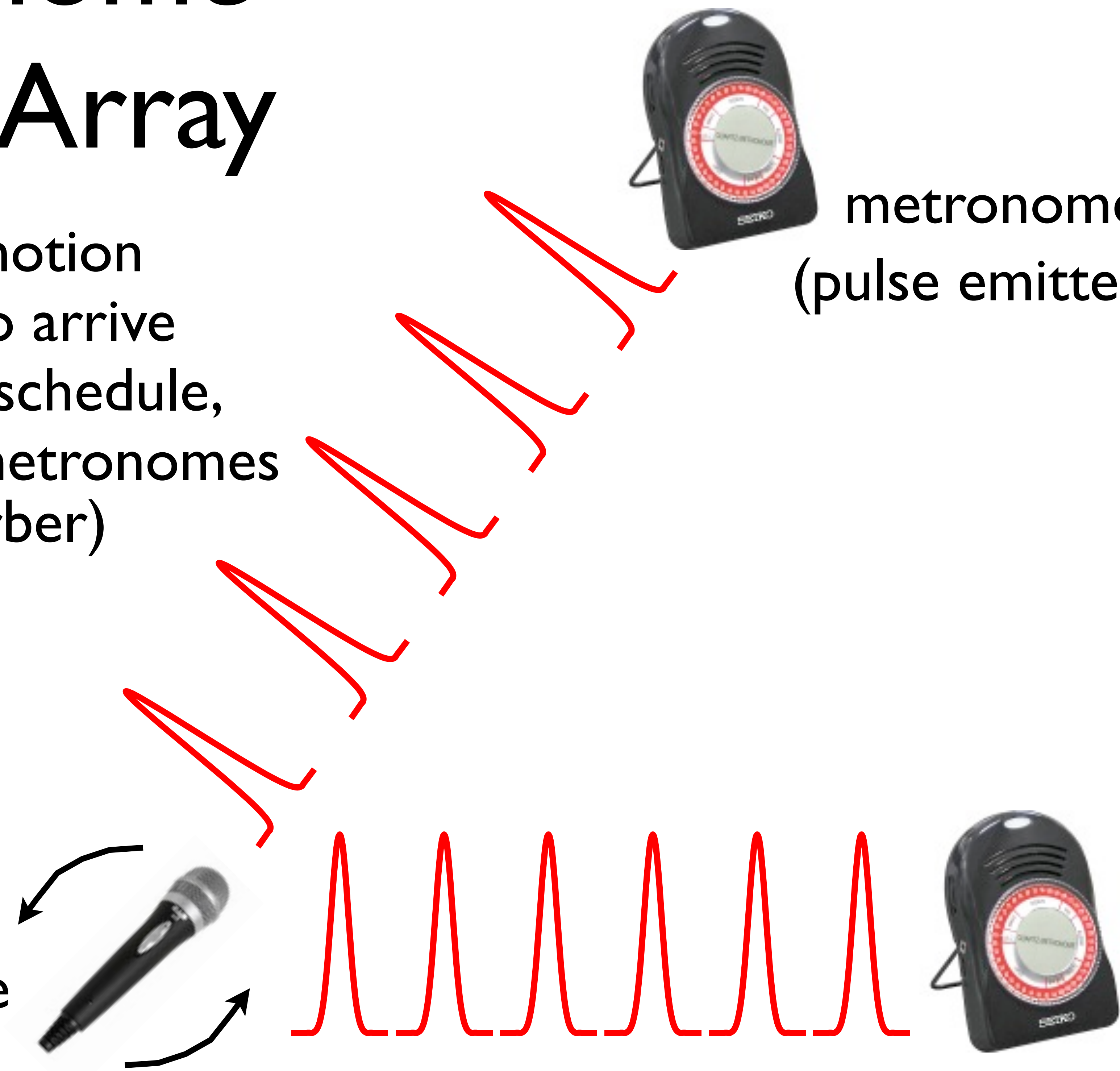


Pulsar Timing Array



Metronome Timing Array

microphone motion
causes pulses to arrive
ahead or behind schedule,
correlated across metronomes
(pulse perturber)



Key quantities to calculate

pulse period T_p

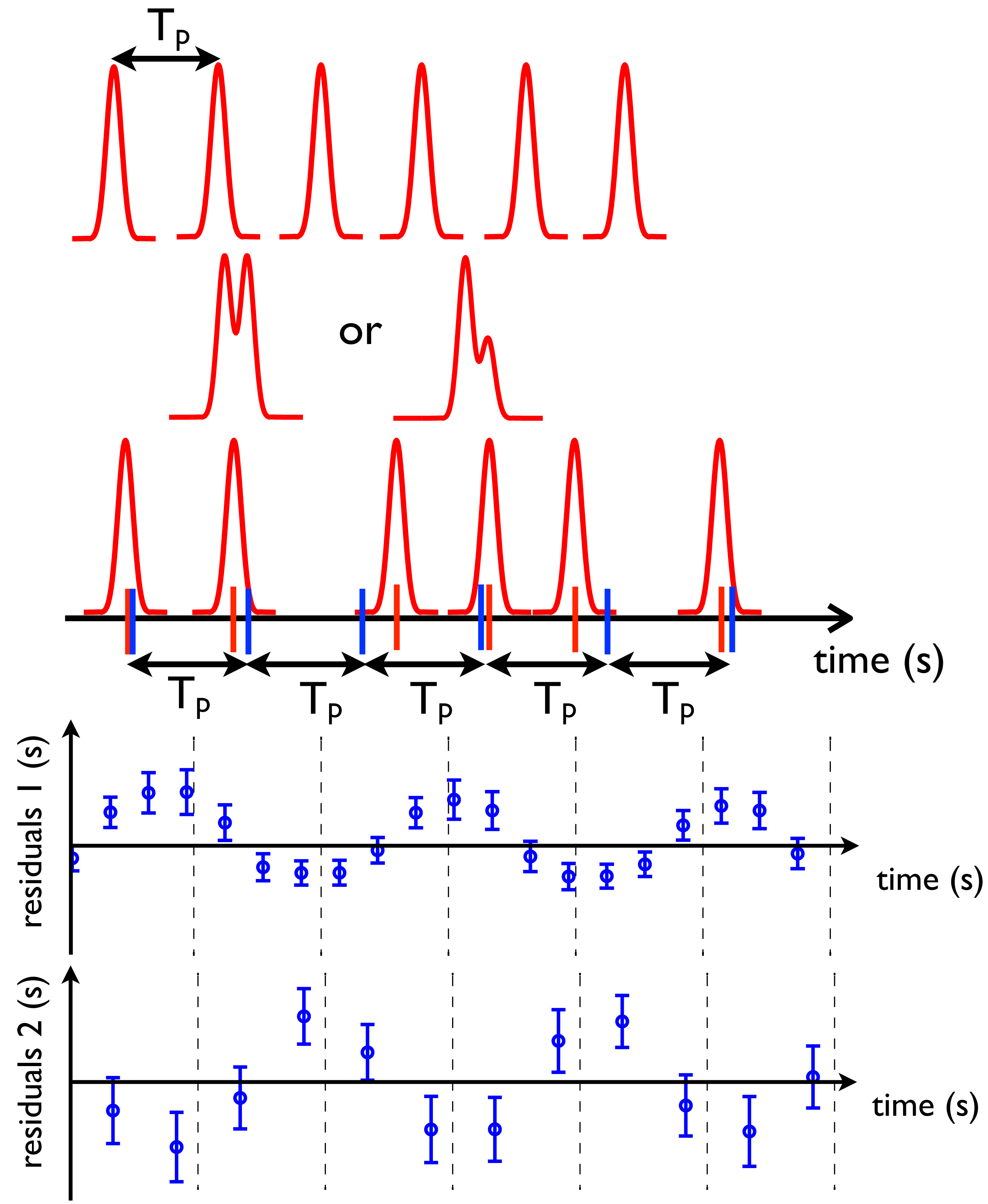
pulse shape (profile)

measured times of arrival (TOAs)

expected TOAs

residuals = measured − expected

correlations between pairs of residuals



Some numbers to keep in mind

v_{sound} = 340 m/s (in air)

amplitude $\approx$ 10 cm

amplitude / v_{sound} = 3 x 10^{-4} sec

120 bpm: T_P = 0.5 sec

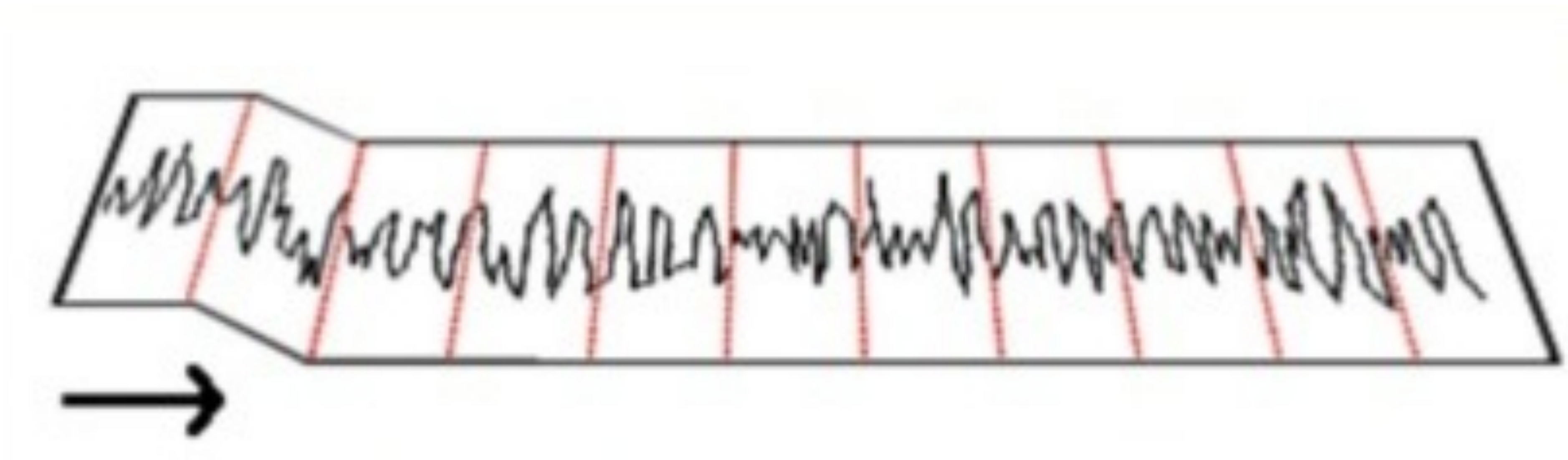
200 bpm: T_P = 0.3 sec

PTAdemo0GUI.py

m200a.txt

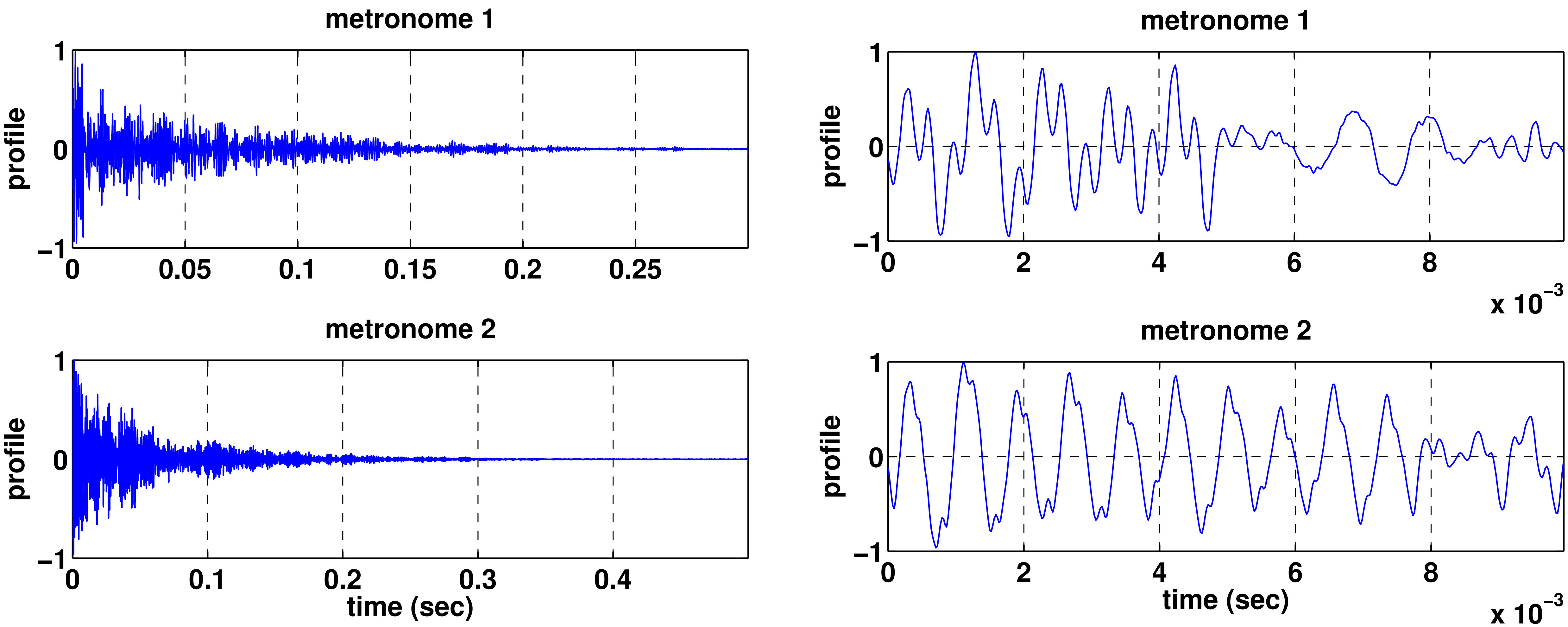
m120b.txt

Data folding to determine pulse period and pulse profile

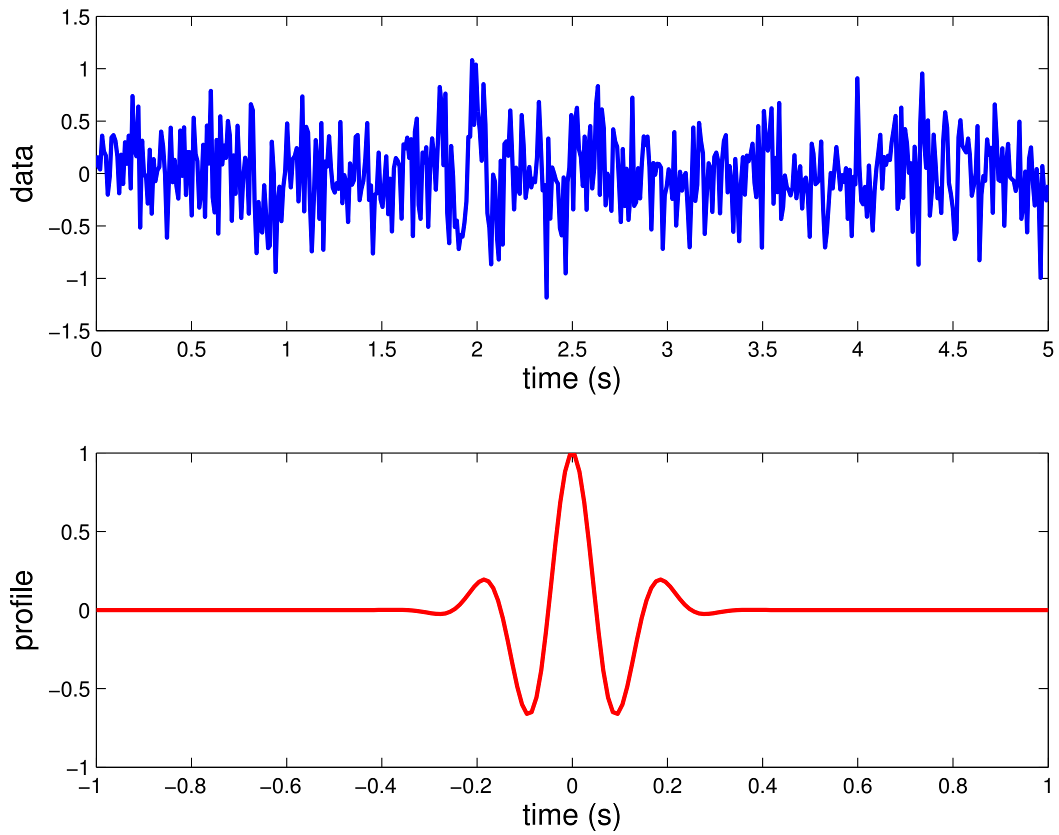


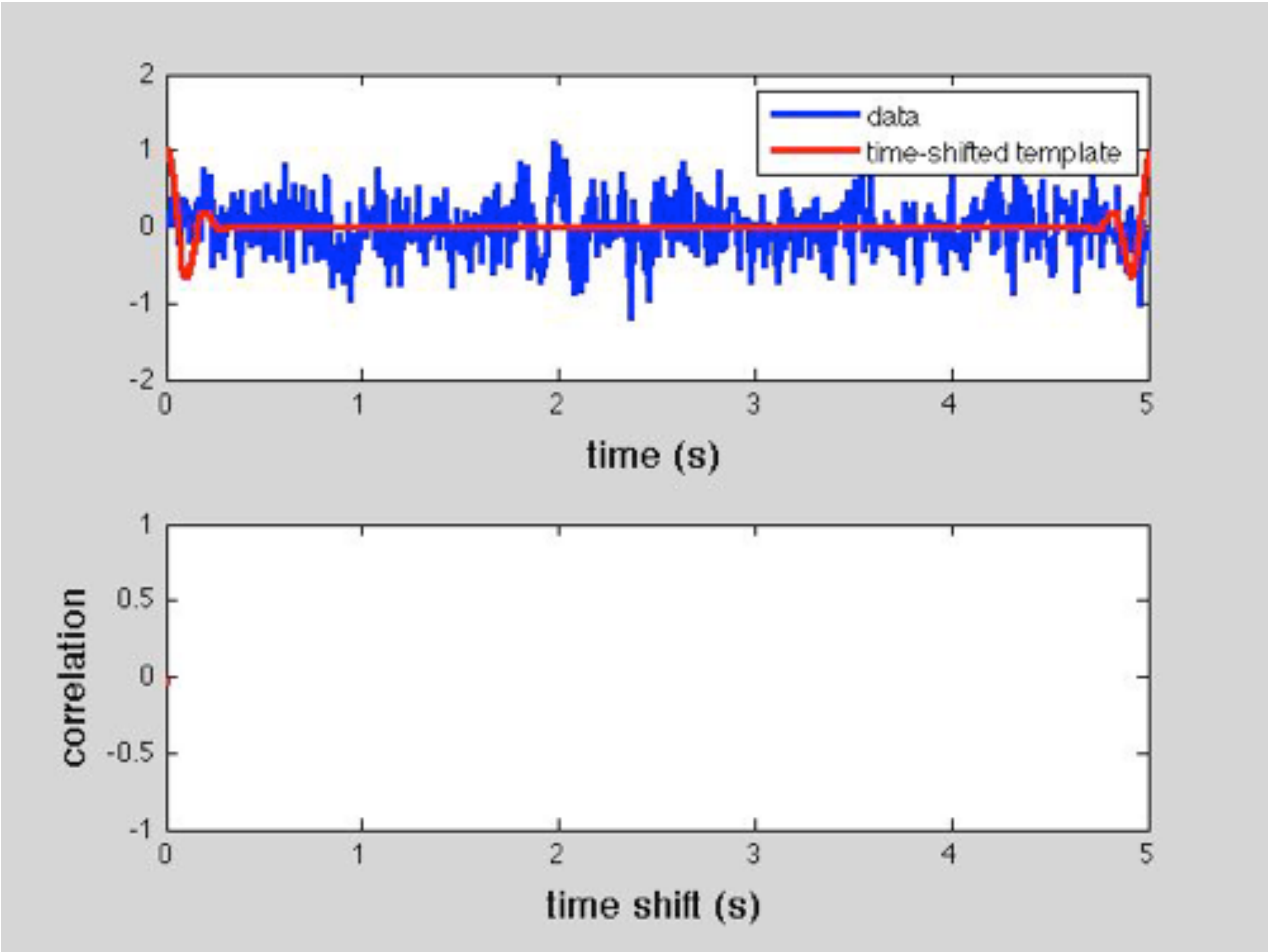
- break data into chunks of duration T
- fold (stack) chunks, then add together
- get maximum sum when T is the period of the signal (noise cancels, signal combines coherently)

Metronome pulse profiles



Estimating TOAs by correlating data with the pulse profile

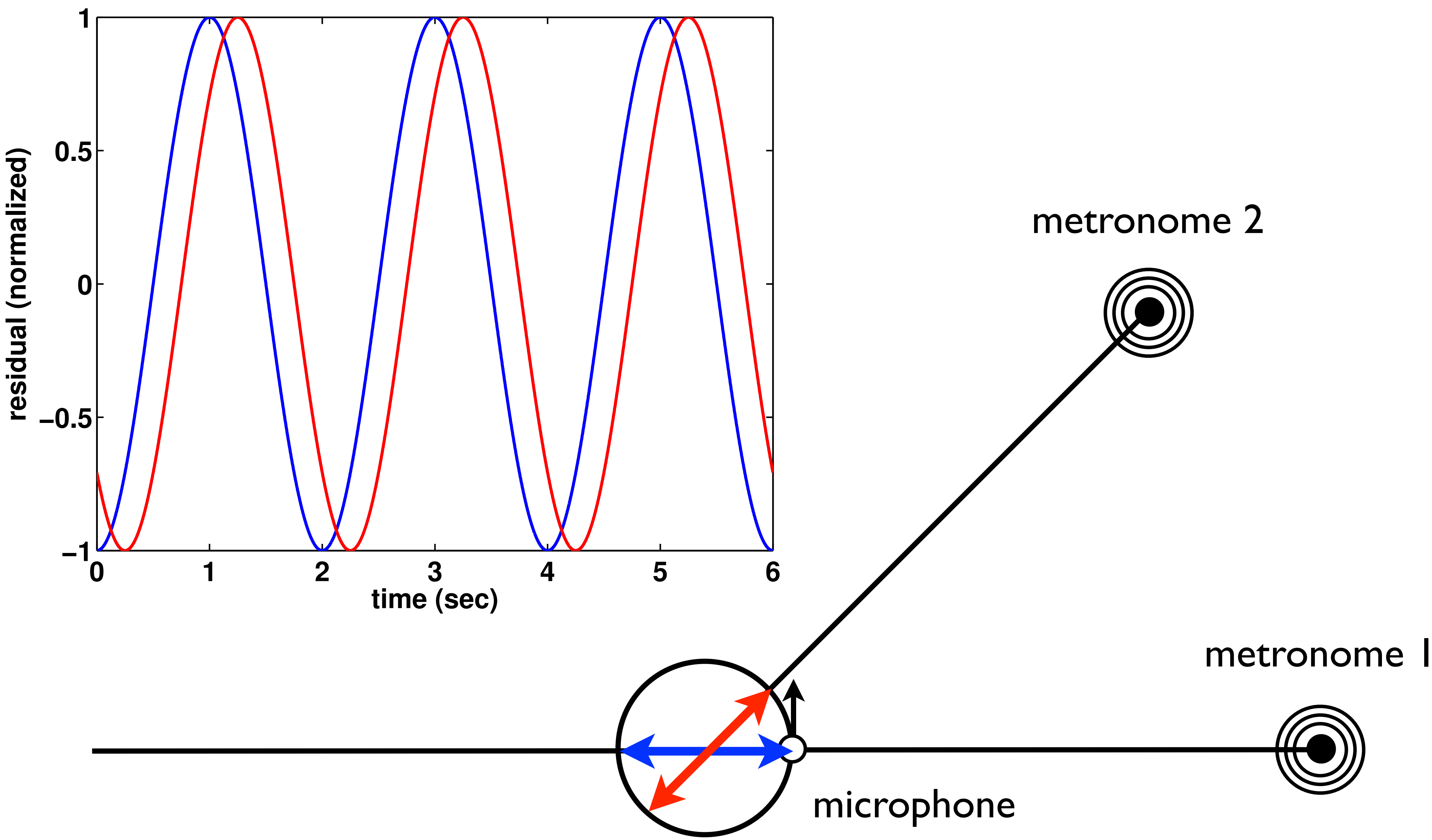




PTAdemo2GUI.py

m200a120b0.txt

Expected residuals for circular microphone motion



PTAdemo2GUI.py

m200a120b180.txt
m200a120b90.txt
m200a120b45.txt
m200a120b135.txt

Metronome timing array illustrates several techniques from pulsar timing

1. Estimate pulse period and pulse shape (profile) by folding data
2. Estimate pulse times of arrival (TOAs) by correlating data with pulse profile
3. Calculate timing residuals by subtracting expected TOAs (based on a model) from the measured TOAs
4. Improve estimate of pulse period by removing a linear trend from residuals
5. Timing residuals for a pair of pulsars are correlated as a function of their angular separation