3-D Topography of Oscillatory Patterns in the Hippocampus of a Behaving Rat

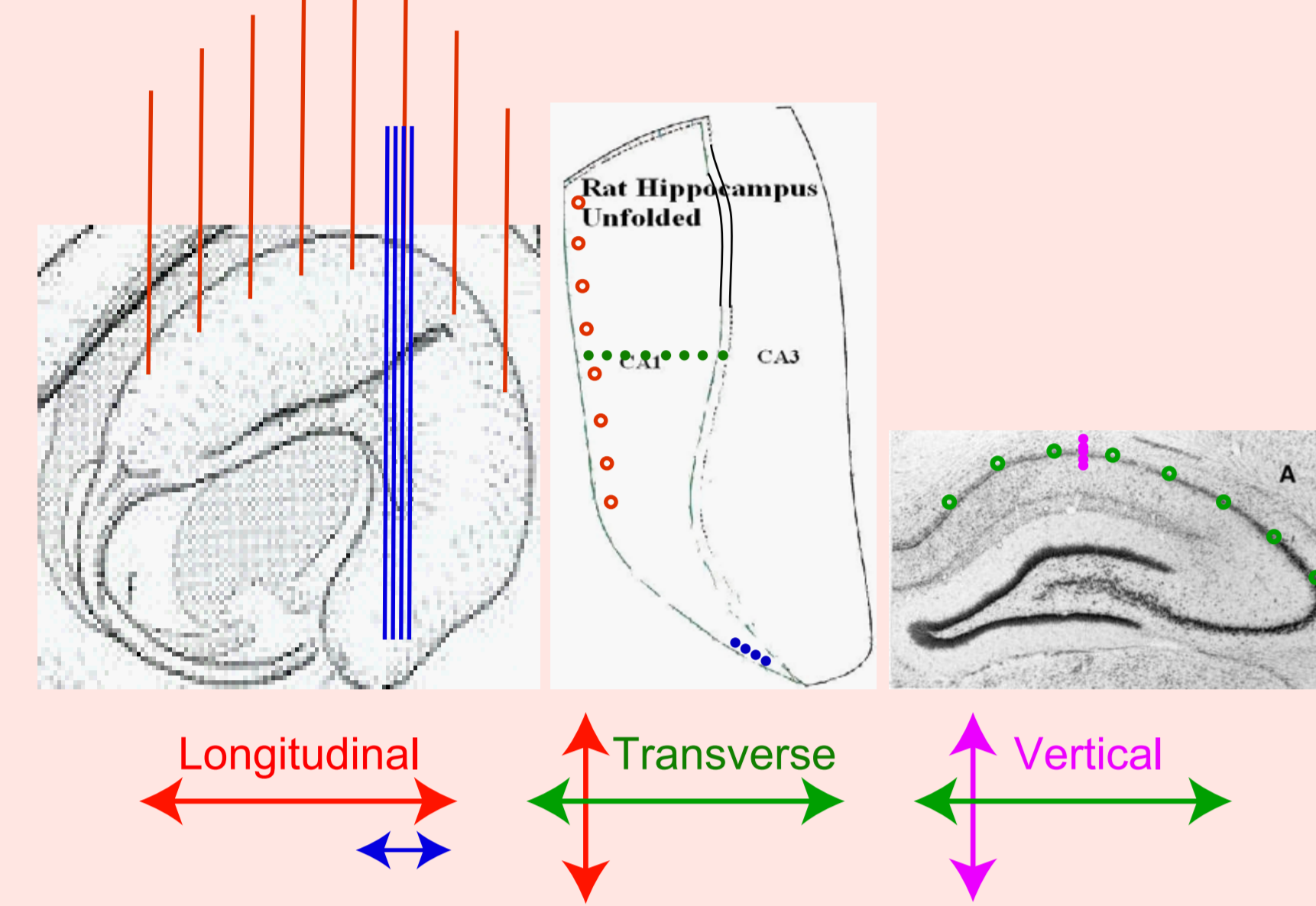Jagdish Patel, Sebastien Royer & Gyorgy Buzsaki   Center for Mol & Behav Neuroscience, Rutgers University, Newark, NJ
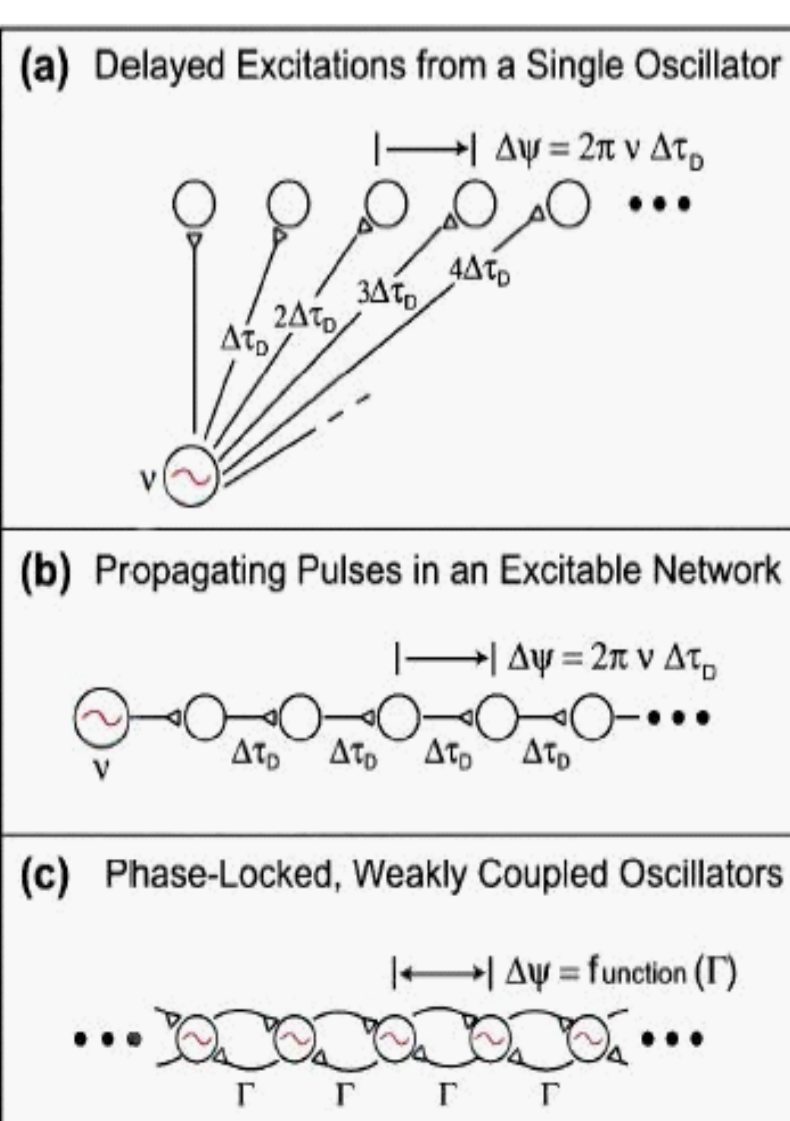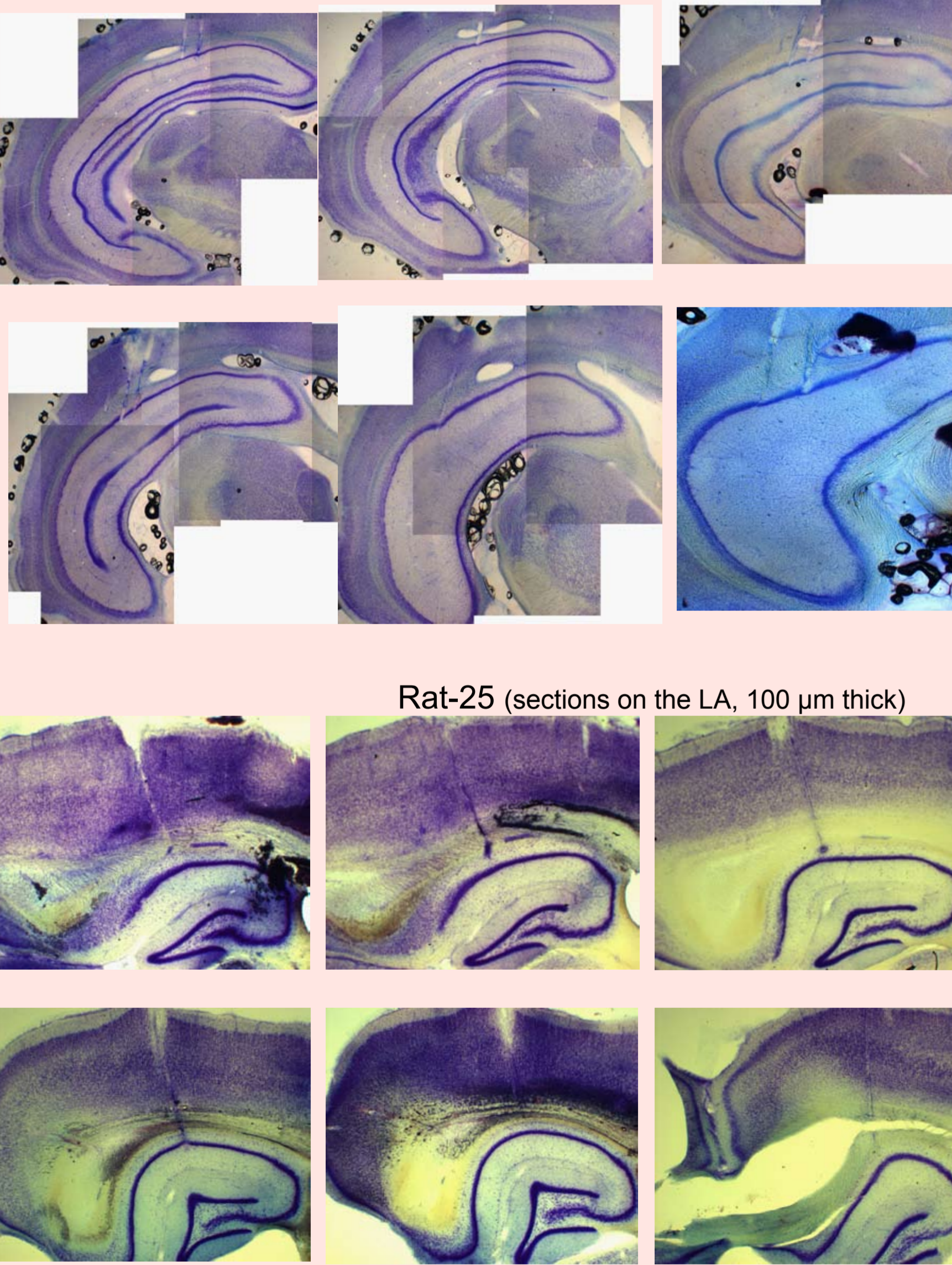
Introduction

1) Hippocampus is distinctly organized in all 3-dimensions
2) Hippocampus is known to serve multiple functions.
3) Dynamics of oscillatory patterns may reveal similar or different types of representations along the 3-D.

Question:
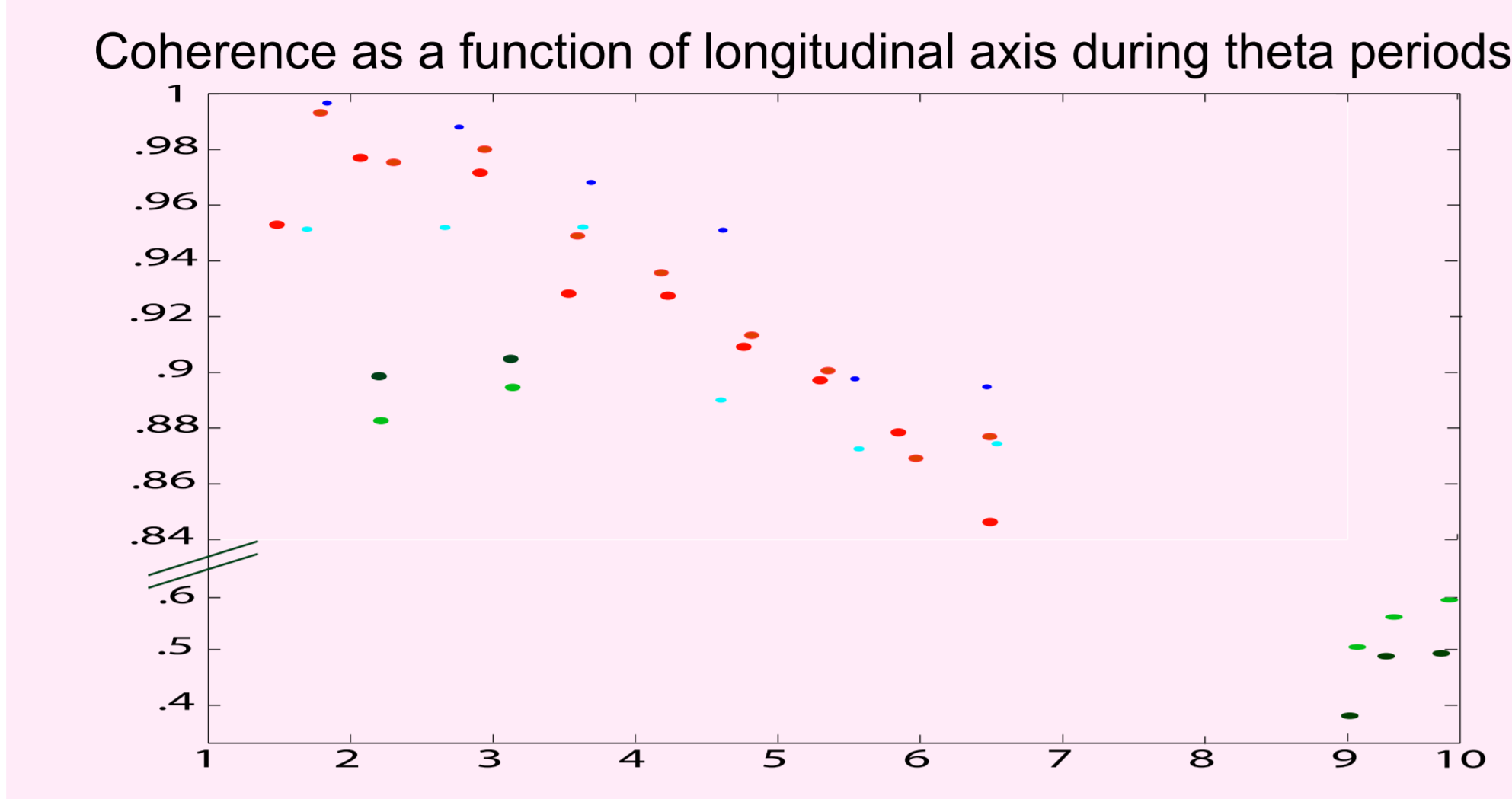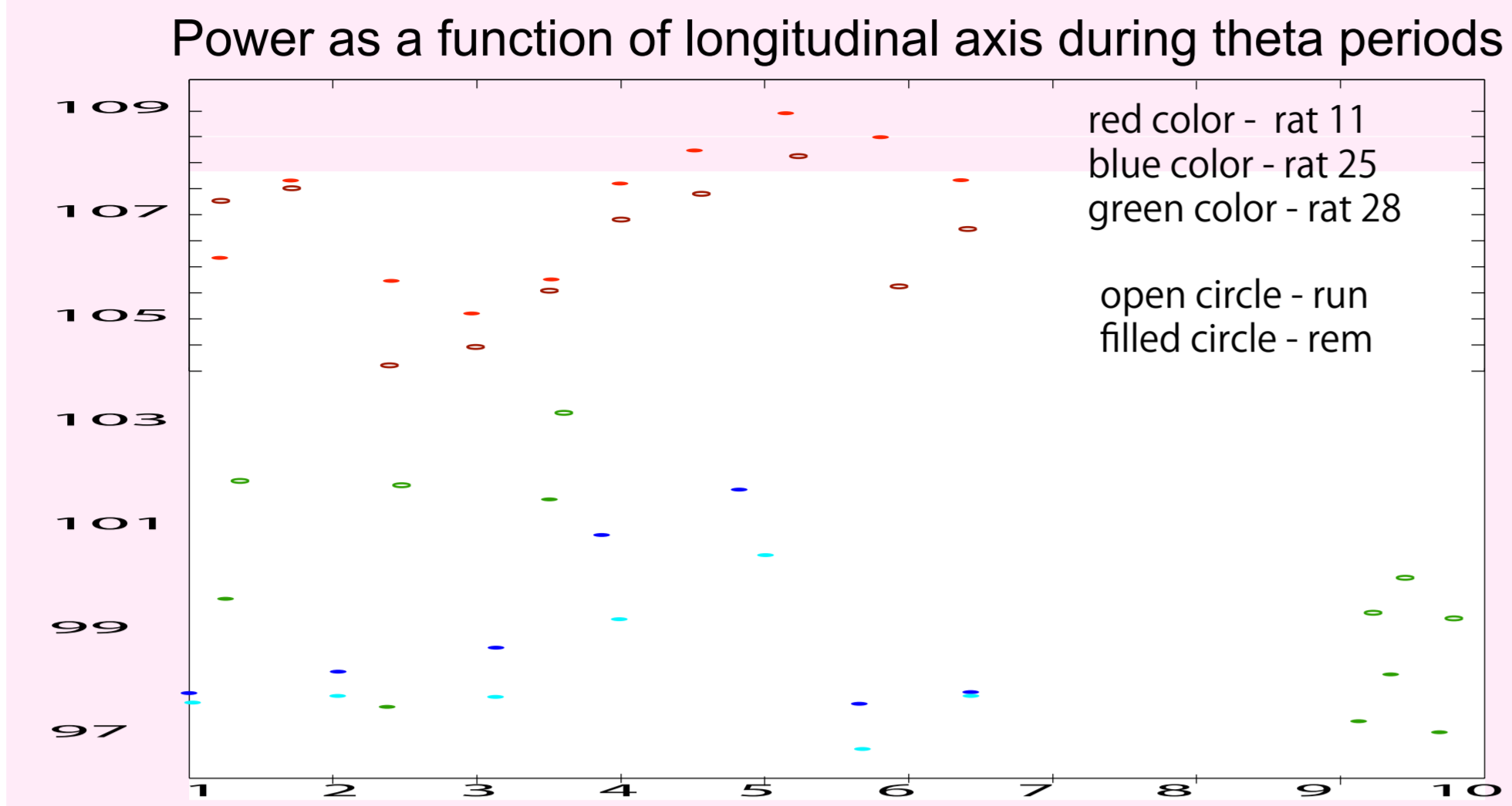Are hippocampal representations continuous or modular?

Methods: Record LFP and multiple single units from CA1 using a) single wires b) tetrodes c) silicon probes, during a) sleep/immobility b) active exploration
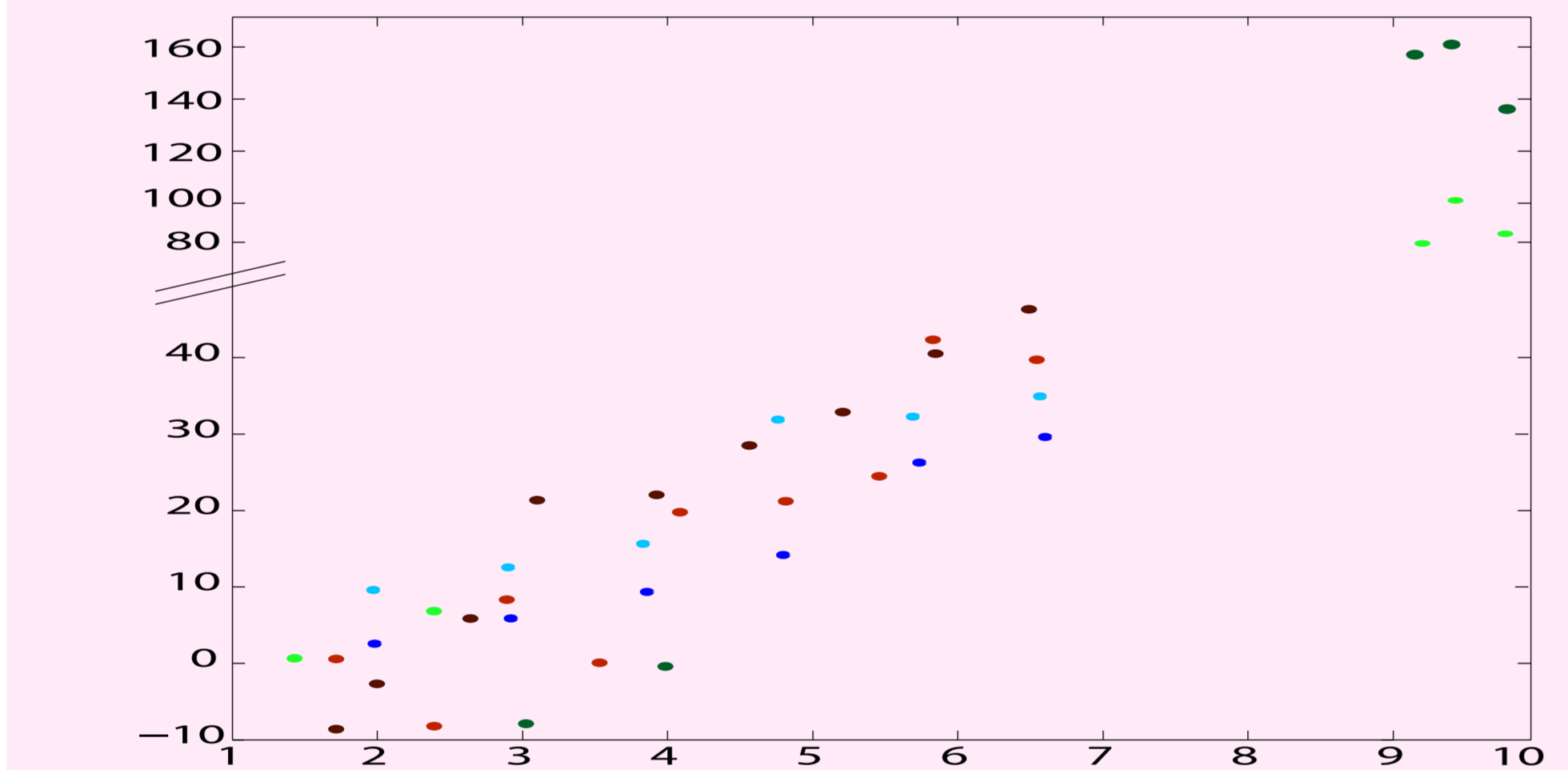

Longitudinal   Transverse   Vertical

Histology

Rat-11 (para-saggital sections, 100 µm thick)

Rat-25 (sections on the LA, 100 µm thick)

(a) Delayed Excitations from a Single Oscillator
(b) Propagating Pulses in an Excitable Network
(c) Phase-Locked, Weakly Coupled Oscillators

Longitudinal Axis

Power as a function of longitudinal axis during theta periods

red color - rat 11
blue color - rat 25
green color - rat 28

open circle - run
filled circle - rem

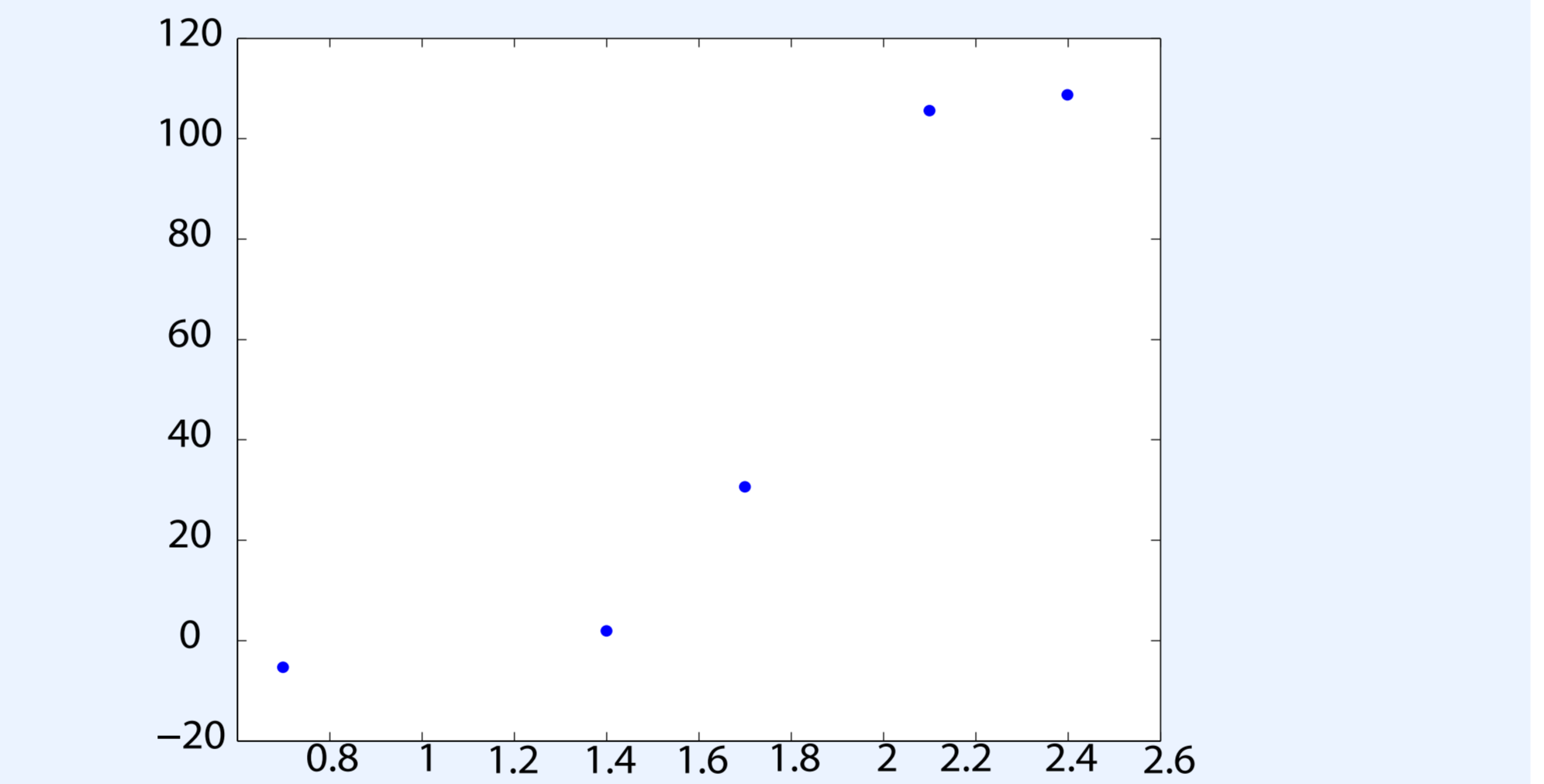Coherence as a function of longitudinal axis during theta periods

Phase variation as a function of longitudinal axis during theta periods

Transverse Axis

Power as a function of transverse axis during theta periods

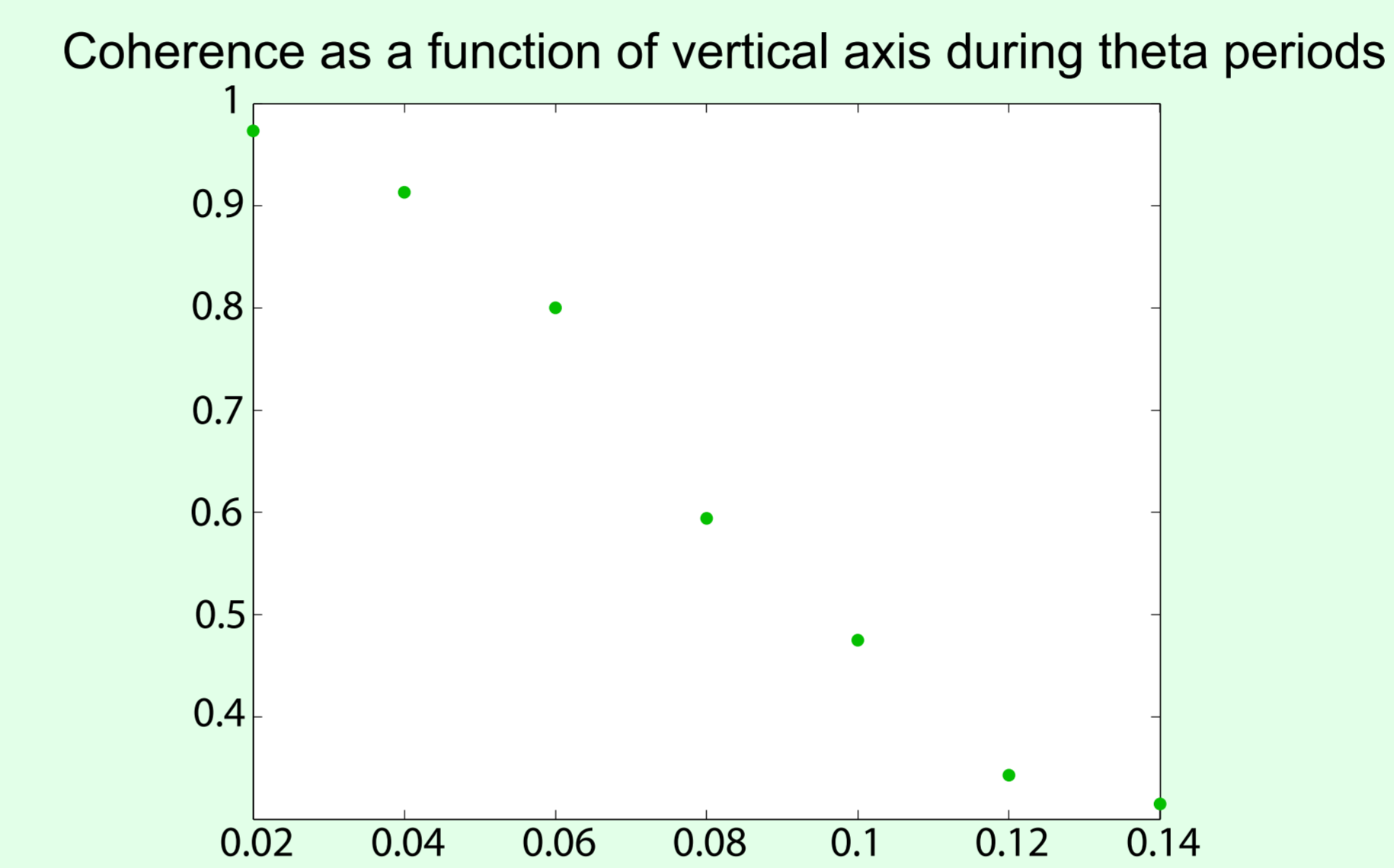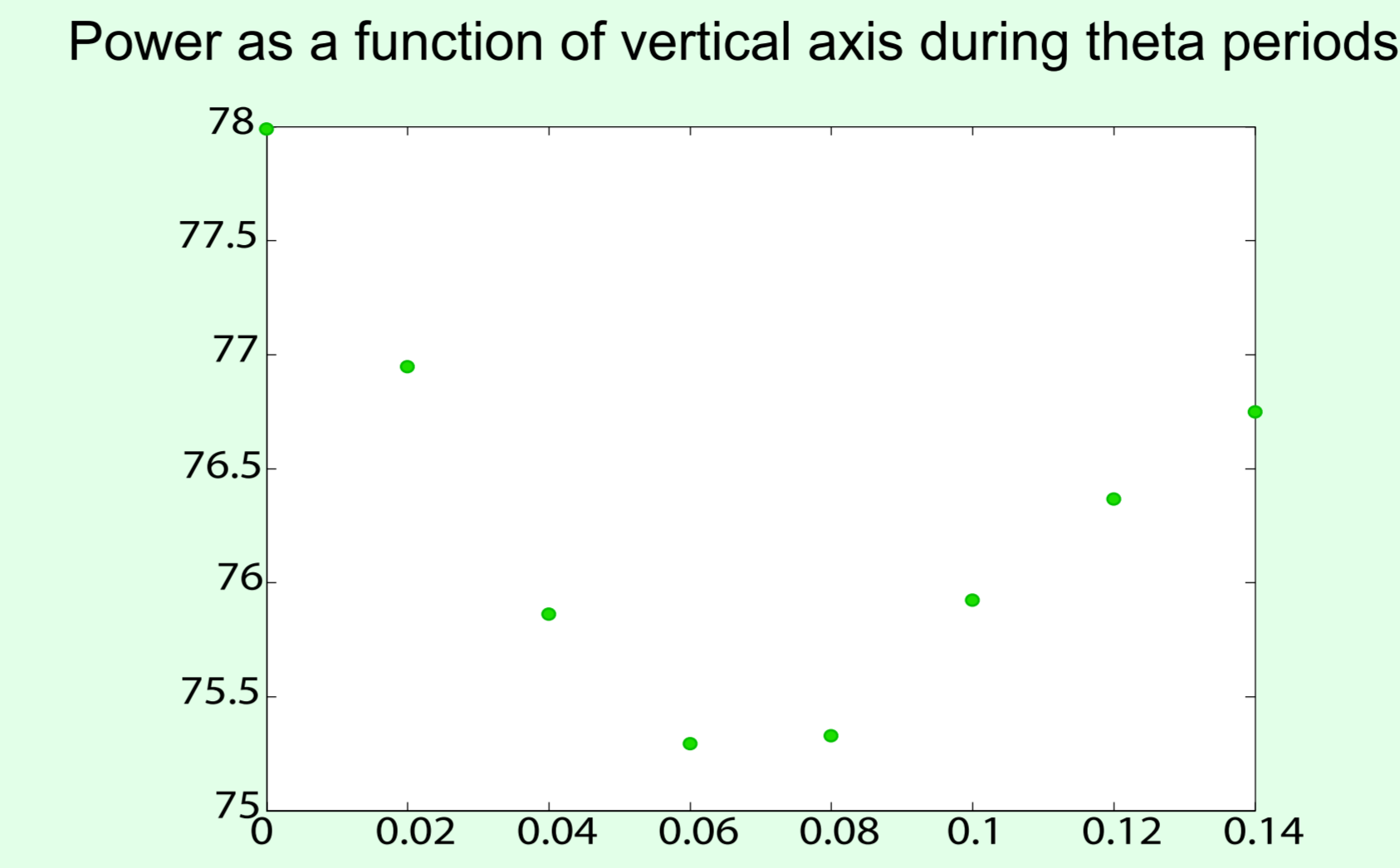

Coherence as a function of transverse axis during theta periods
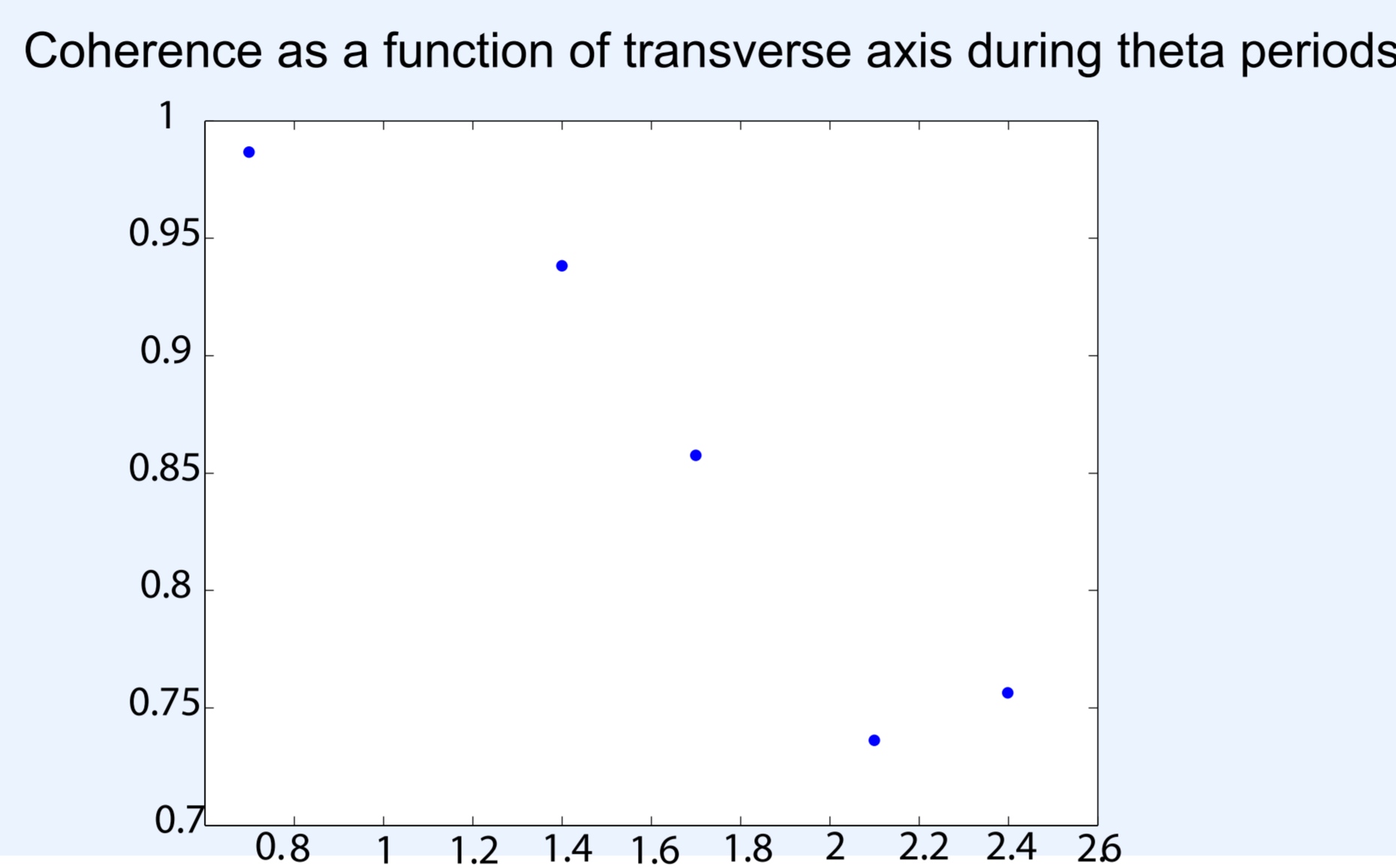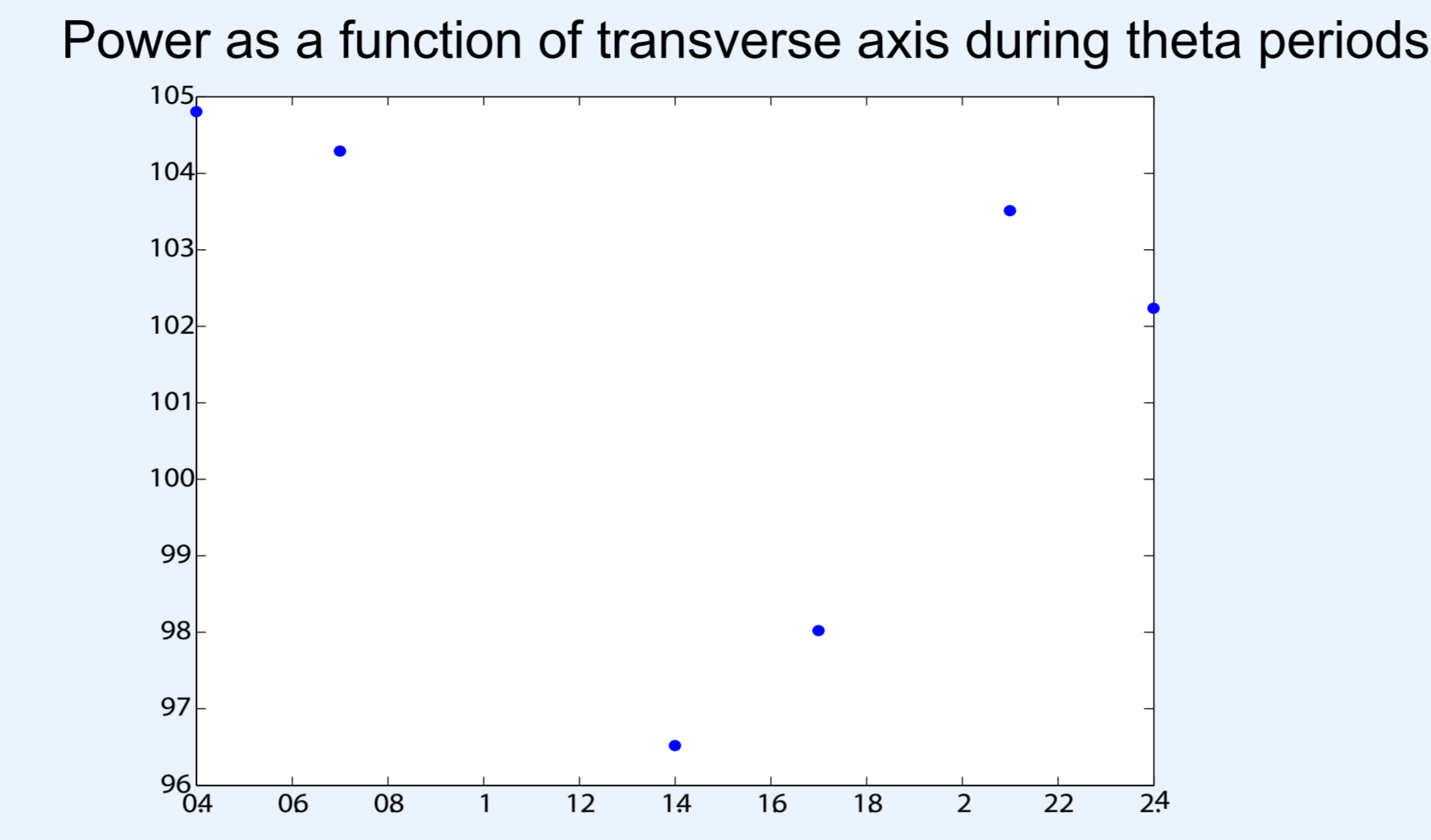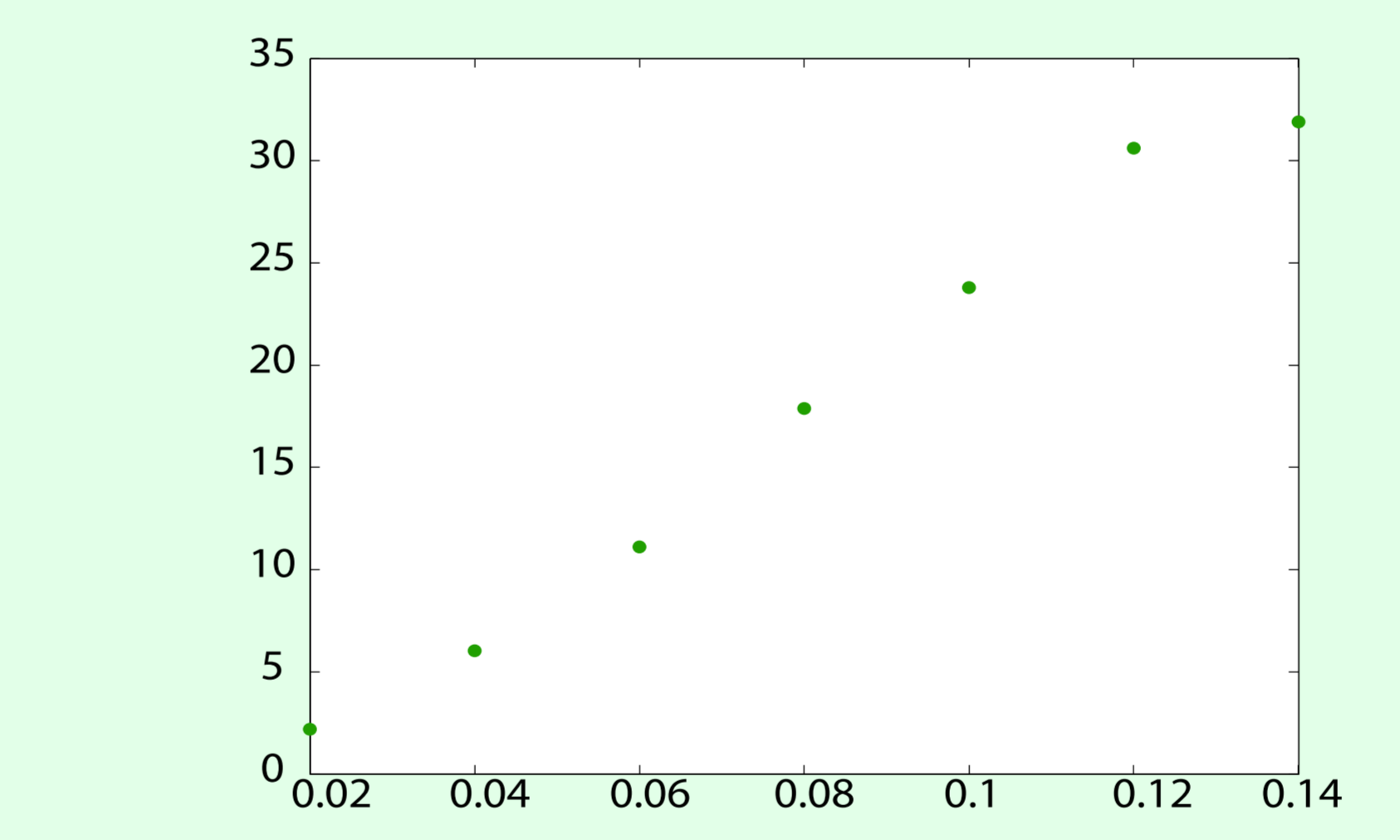

Phase variation as a function of transverse axis during theta periods

Vertical Axis

Power as a function of vertical axis during theta periods

Coherence as a function of vertical axis during theta periods

Phase as a function of vertical axis during theta periods

Conclusions:

1) Phase shifts investigated at higher resolution (20 micron steps) within CA1 pyramidal layer and found to exist (Winson, 1973).

2) Phase shifts investigated along the transverse axis i.e. from CA1 to CA3 at every 300 microns until CA2.

3) Phase measurement in the longitudinal axis revealed moderate shift in the septal 2/3rd of the CA1 i.e. about 8 deg/mm.

4) Phase measurements at the two ends of the longitudinal axis revealed a 180 deg shift.

5) Theta in the Ventral pole of the hippocampus is highly intermittent and has low power.

6) However, selective high coherence in the theta band may permit integration of representation along the whole axis.

7) SWR occurrence decreases gradually along the axis. However , a significant fall is only observed at the most ventral pole.

Question: Are these changes gradual or sudden?

Are hippocampal representations continuous or modular?