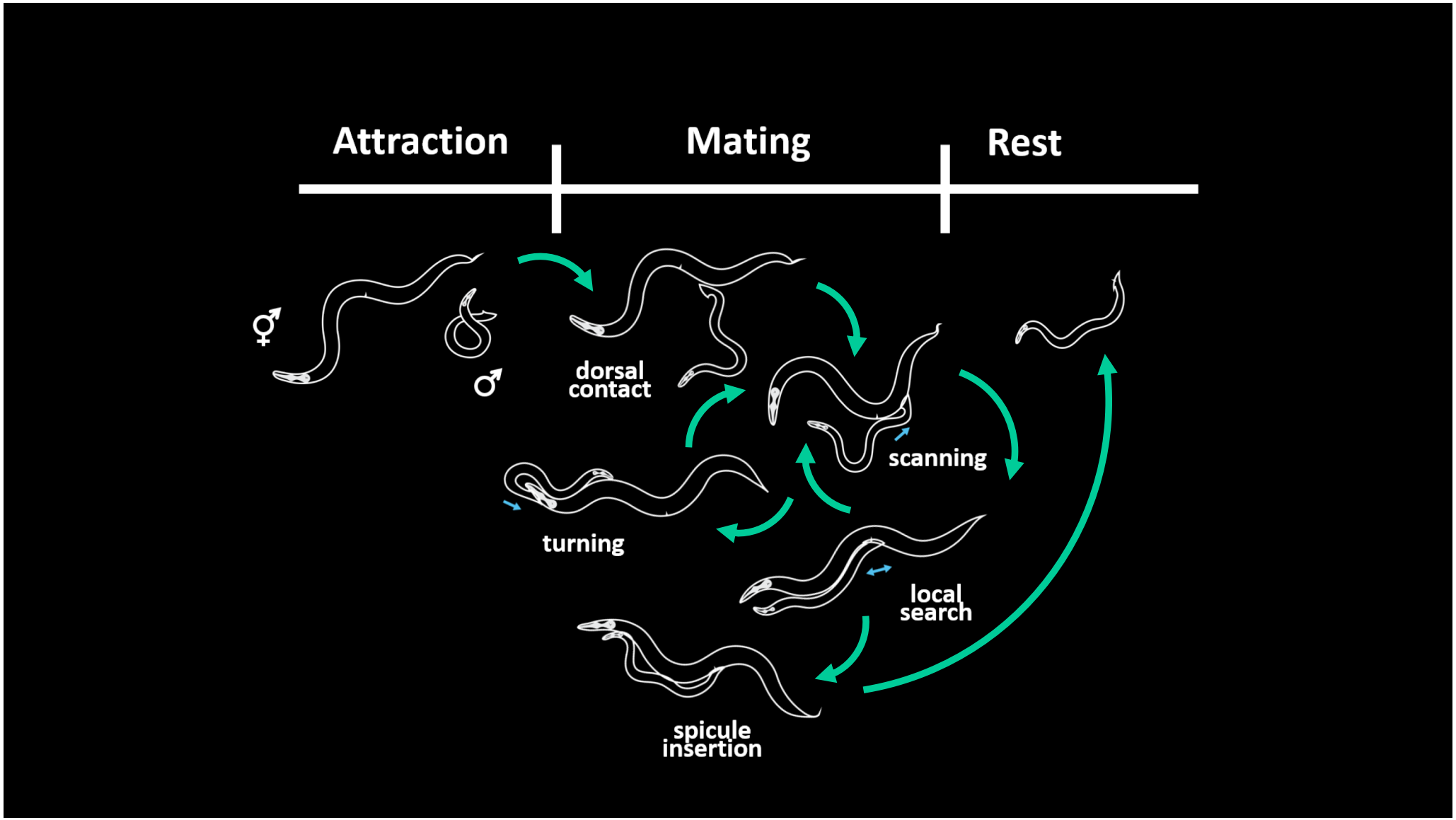
Courtship and mating in *C. elegans*

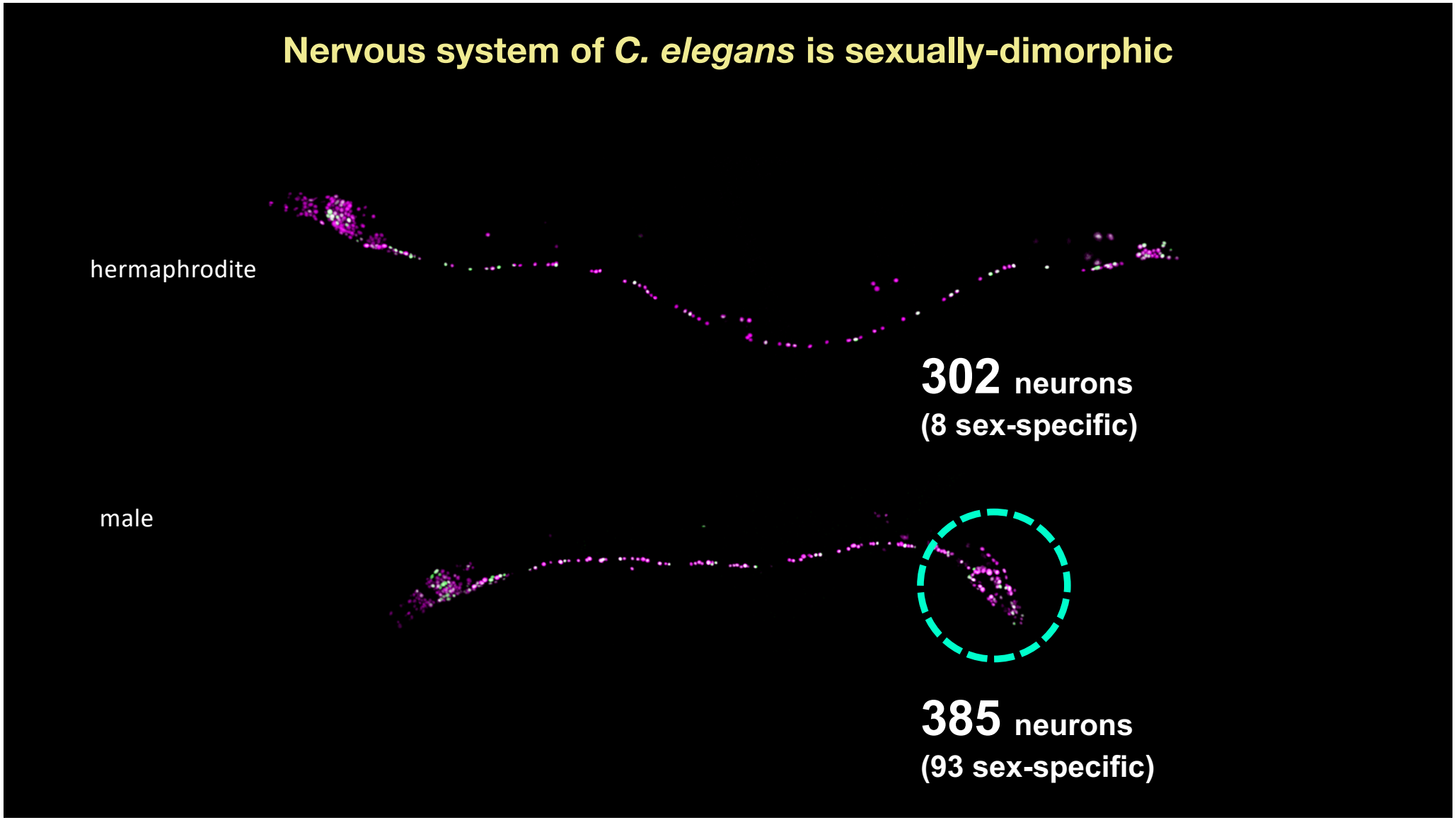
Vlad Susoy
Vivek Venkatachalam
Mei Zhen, Toronto



Complex, continuous, naturalistic, and goal-directed social behavior


Attraction
Mating
Rest
♀
♂
dorsal contact
scanning
turning
local search
spicule insertion

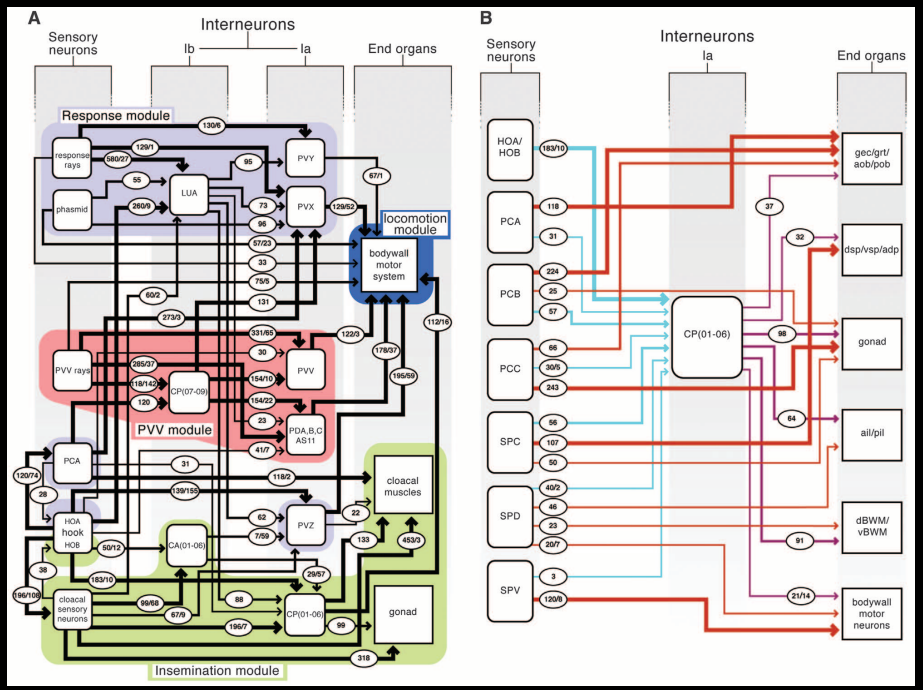
Nervous system of *C. elegans* is sexually-dimorphic



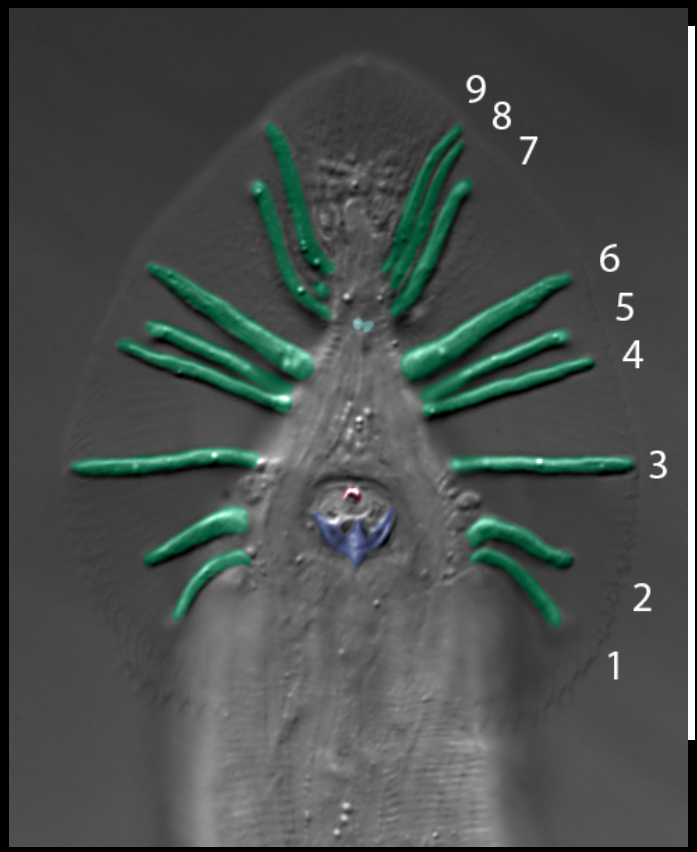
The Connectome of a Decision-Making Neural Network

Travis A. Jarrell,[1]* Yi Wang,[1]* Adam E. Bloniarz,[1]† Christopher A. Brittin,[1] Meng Xu,[1] J. Nichol Thomson,[2] Donna G. Albertson,[2]‡ David H. Hall,[3] Scott W. Emmons[1,3]§

In order to understand the nervous system, it is necessary to know the synaptic connections between the neurons, yet to date, only the wiring diagram of the adult hermaphrodite of the nematode *Caenorhabditis elegans* has been determined. Here, we present the wiring diagram of the posterior nervous system of the *C. elegans* adult male, reconstructed from serial electron micrograph sections. This region of the male nervous system contains the sexually dimorphic circuits for mating. The synaptic connections, both chemical and gap junctional, form a neural network with four striking features: multiple, parallel, short synaptic pathways directly connecting sensory neurons to end organs; recurrent and reciprocal connectivity among sensory neurons; modular substructure; and interneurons acting in feedforward loops. These features help to explain how the network robustly and rapidly selects and executes the steps of a behavioral program on the basis of the inputs from multiple sensory neurons.

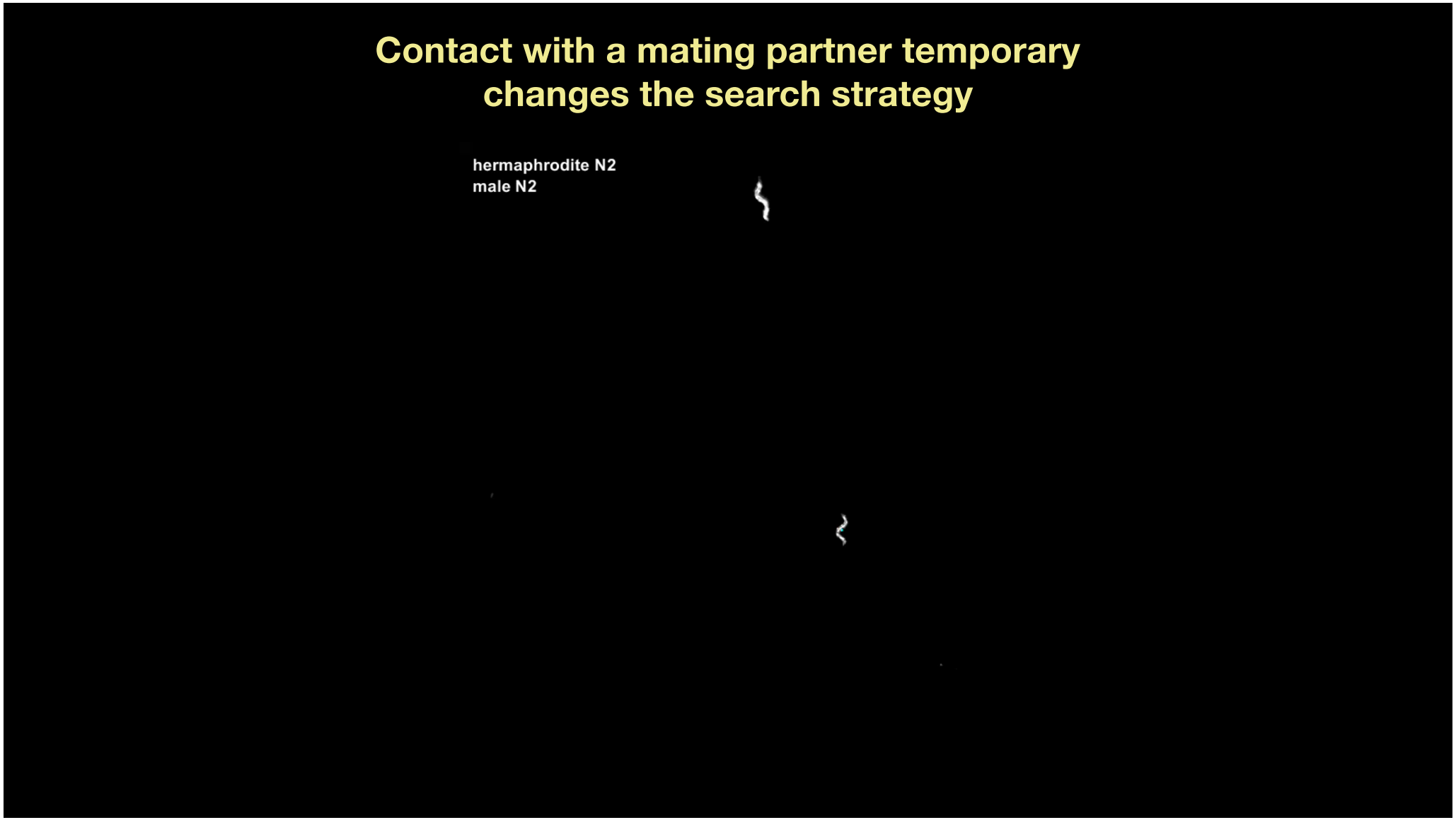


Male-specific sensilla of the tail

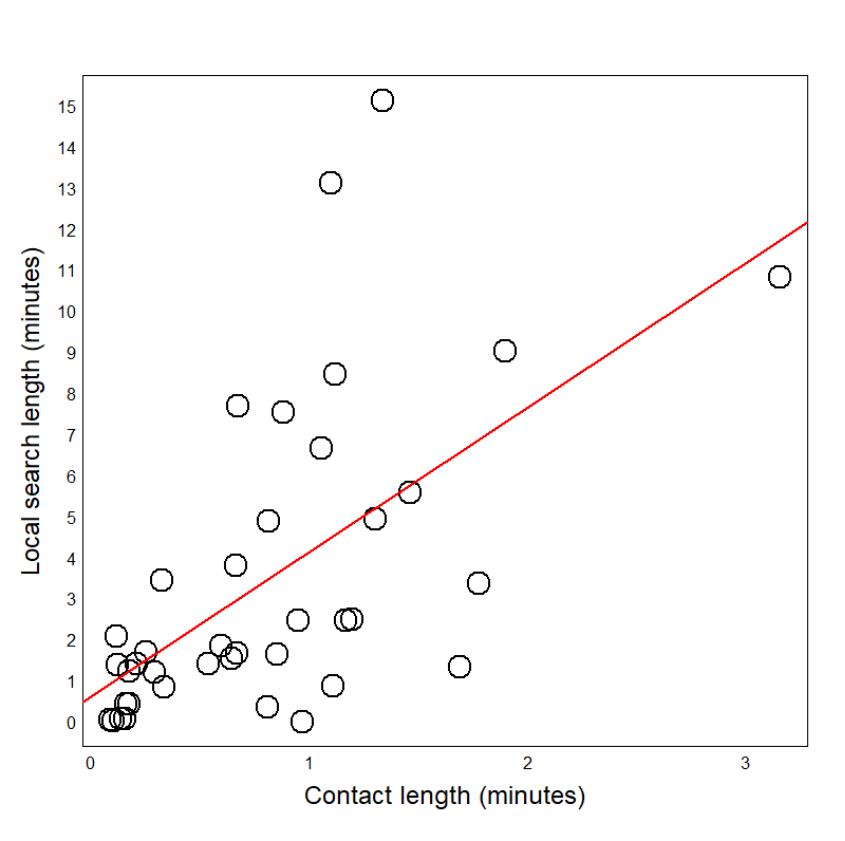


Rays 36
Hook 2
Post cloacal sensilla 6
Spicule sensilla 6

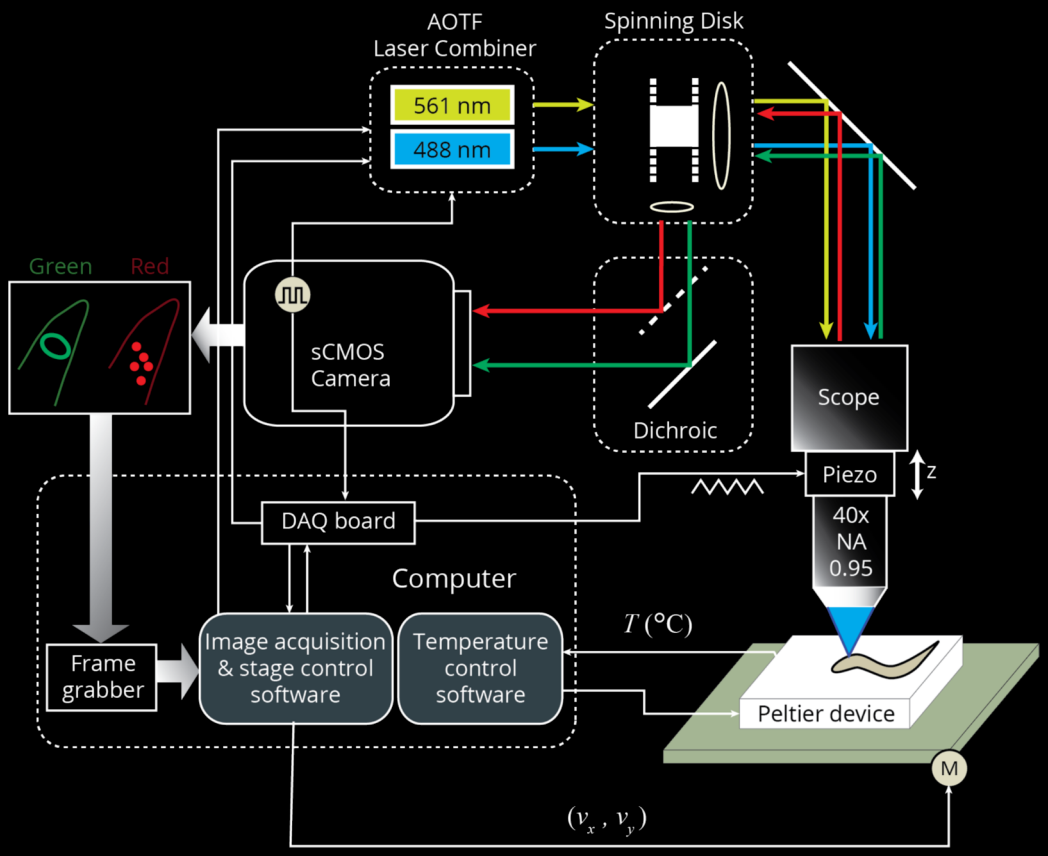
Contact with a mating partner temporary changes the search strategy



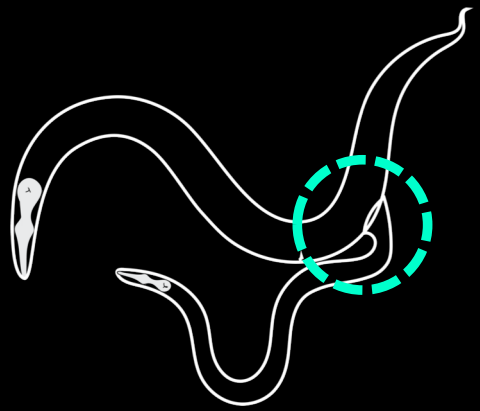
Local search length correlates with the contact length

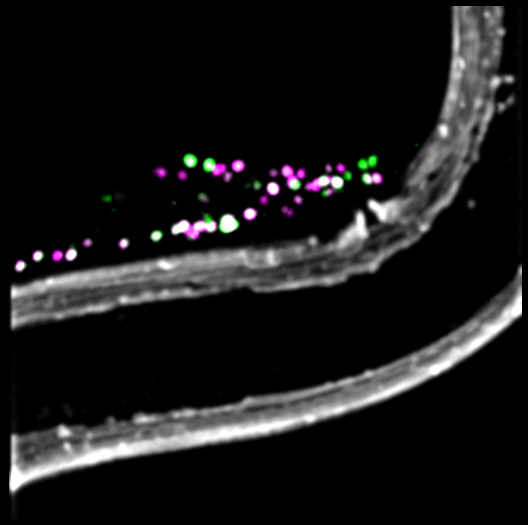


Whole brain multicolor imaging in behaving animals



Multi-neuronal imaging of *C. elegans* mating

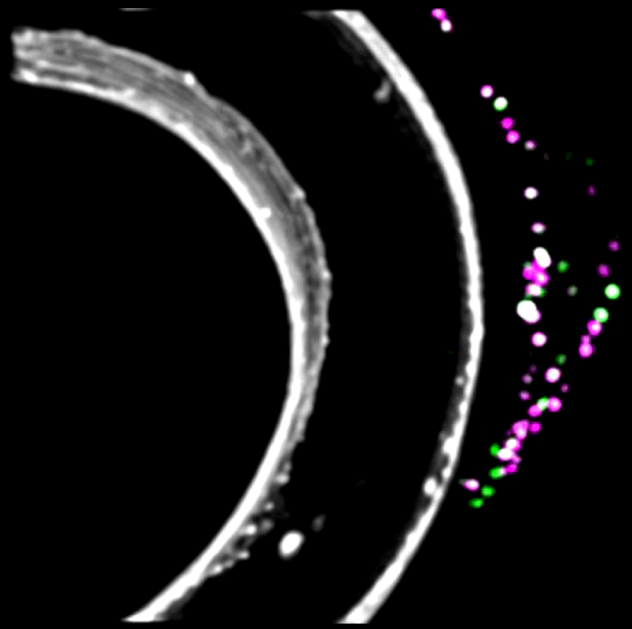




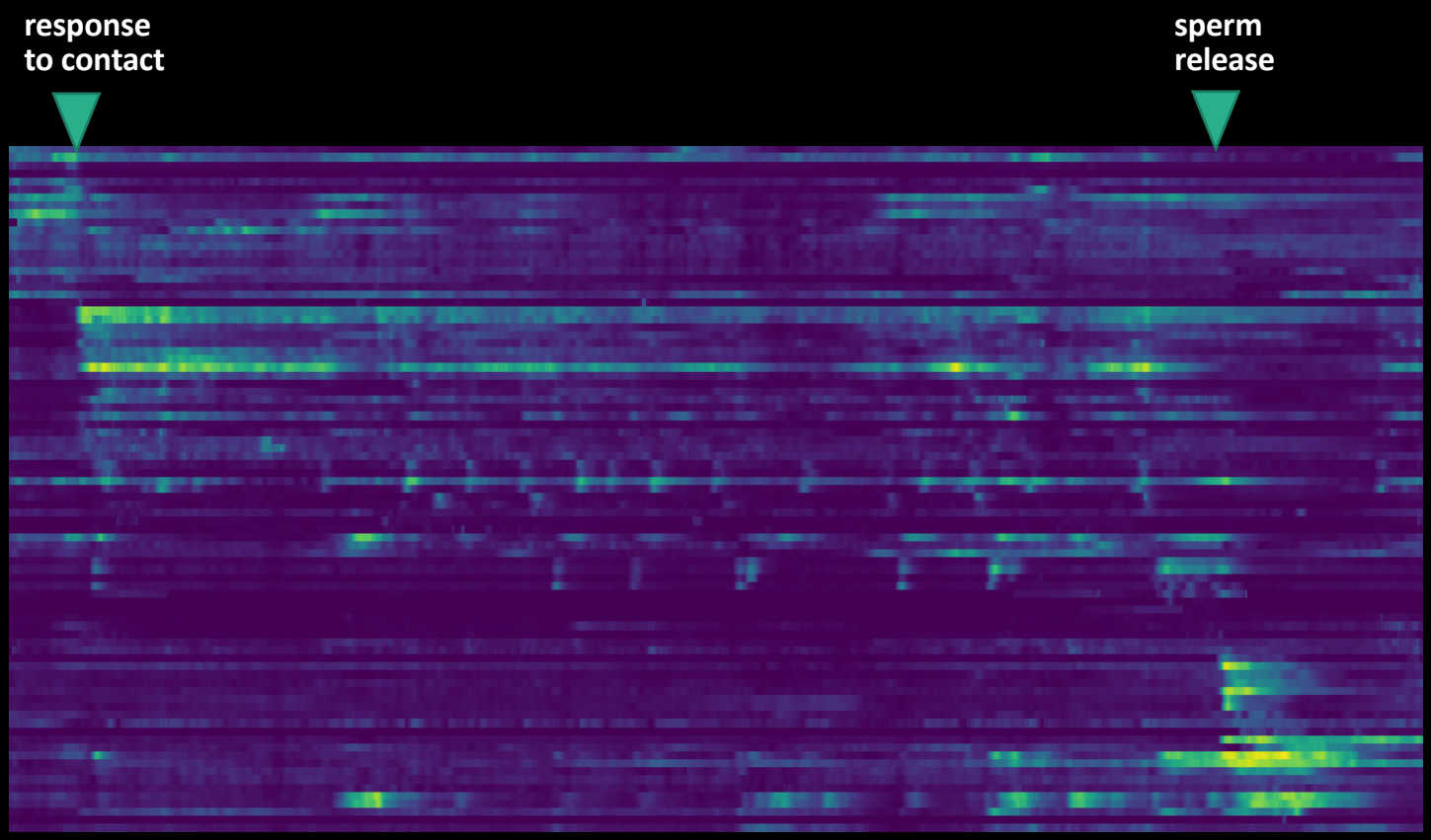
GCaMP6
mNeptune

mCherry

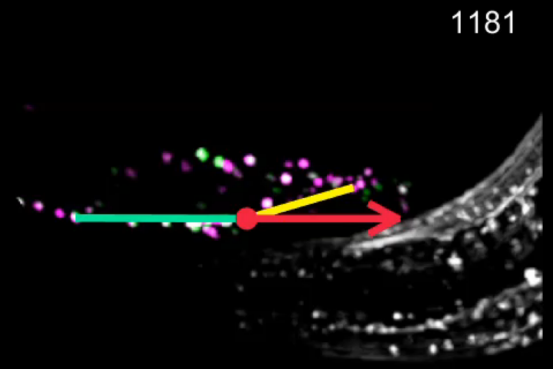
Multi-neuronal imaging of *C. elegans* mating

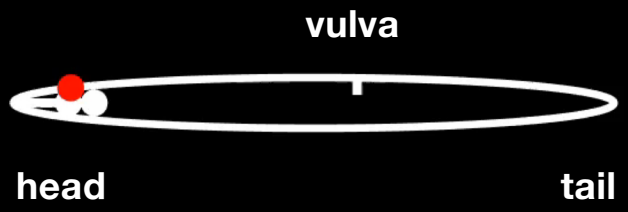


Neuronal traces from a 10-min-long mating movie

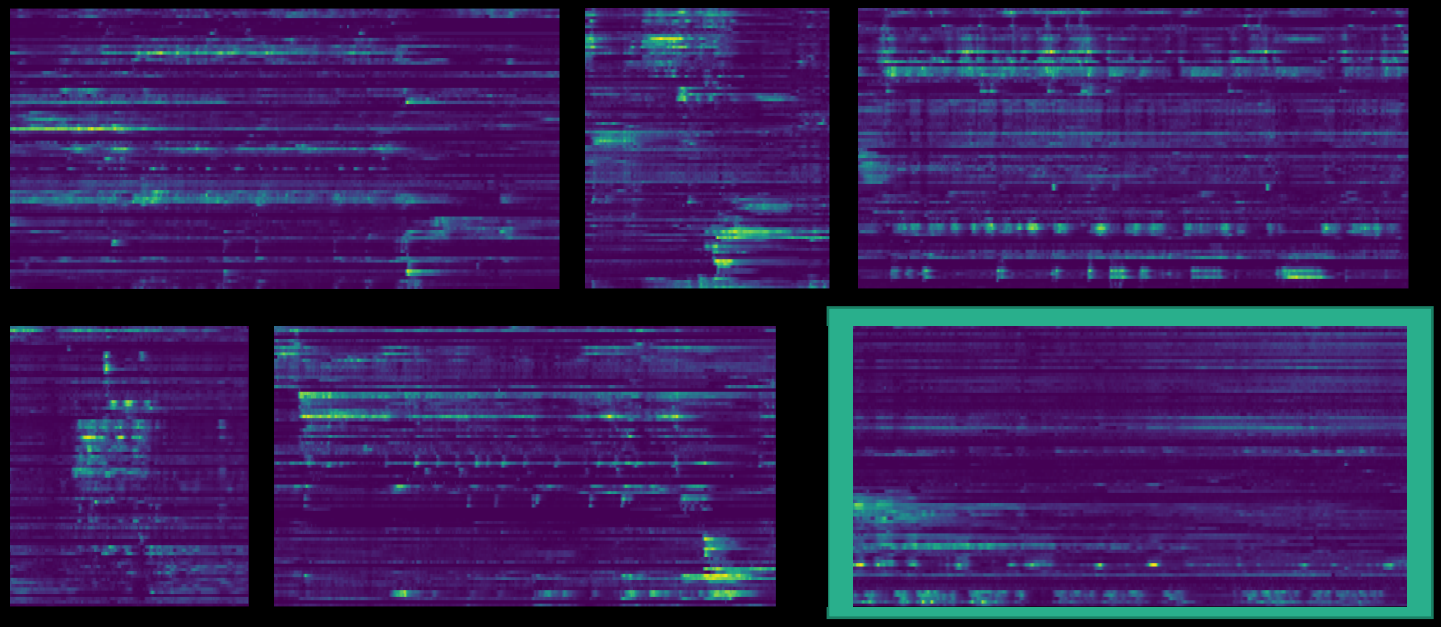


Behavior and sensory environment are recorded

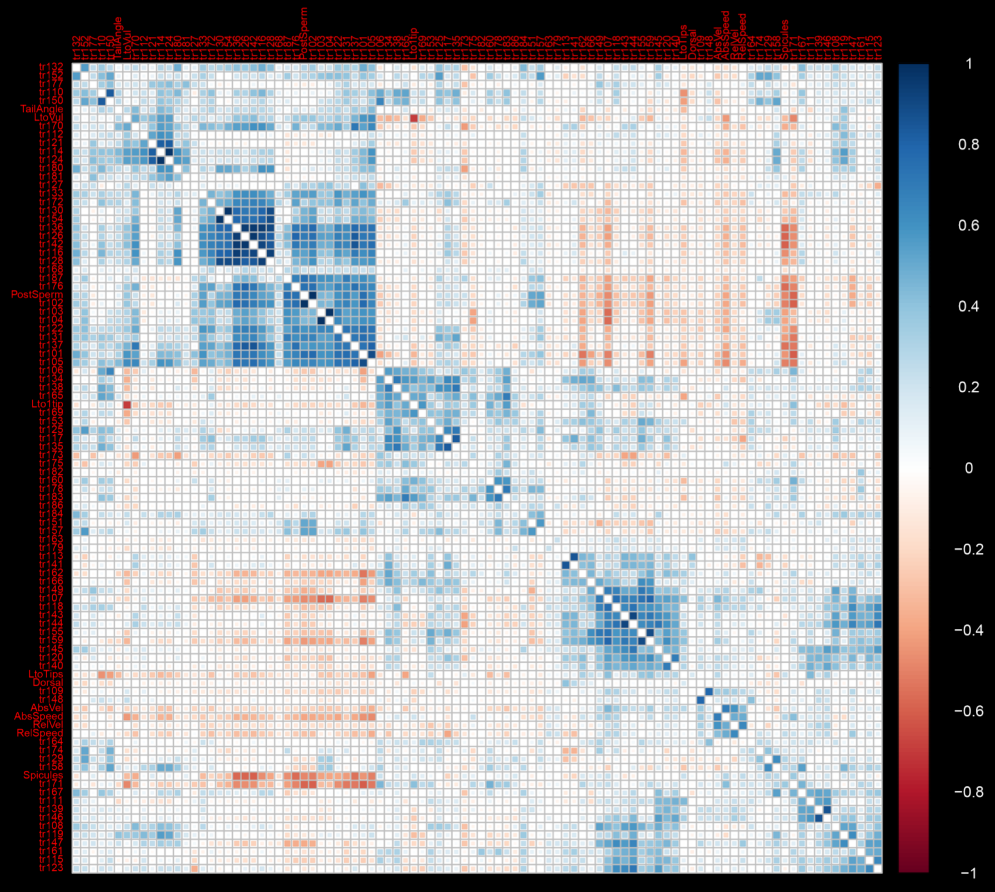




Neuronal traces from different individuals spanning 50 minutes of worm mating

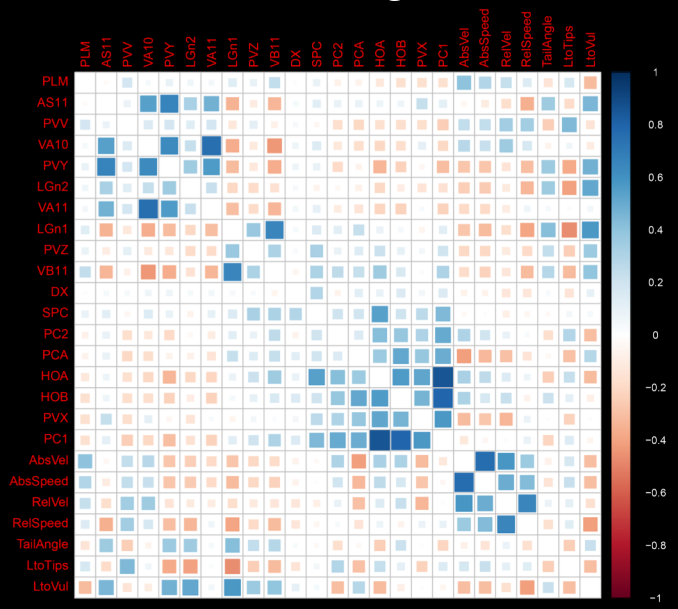


Cross correlations between neuronal and behavioral time series for one mating



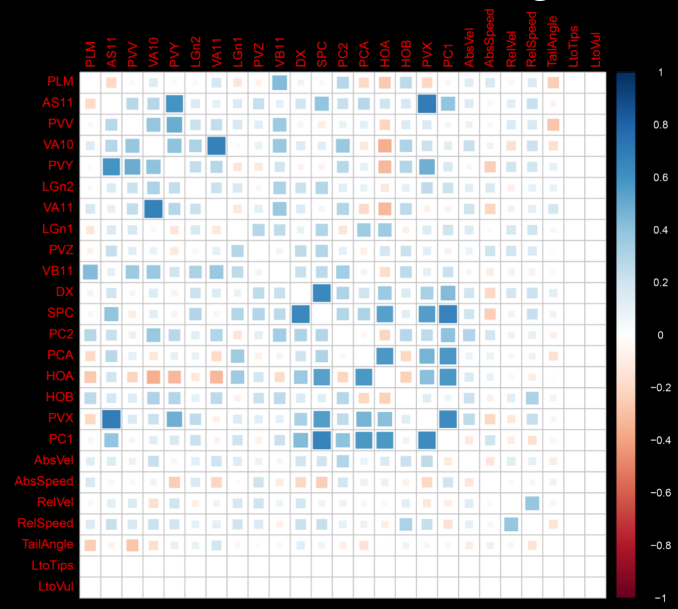
Averaged cross correlations for a subset of neurons across 5 datasets

Mating



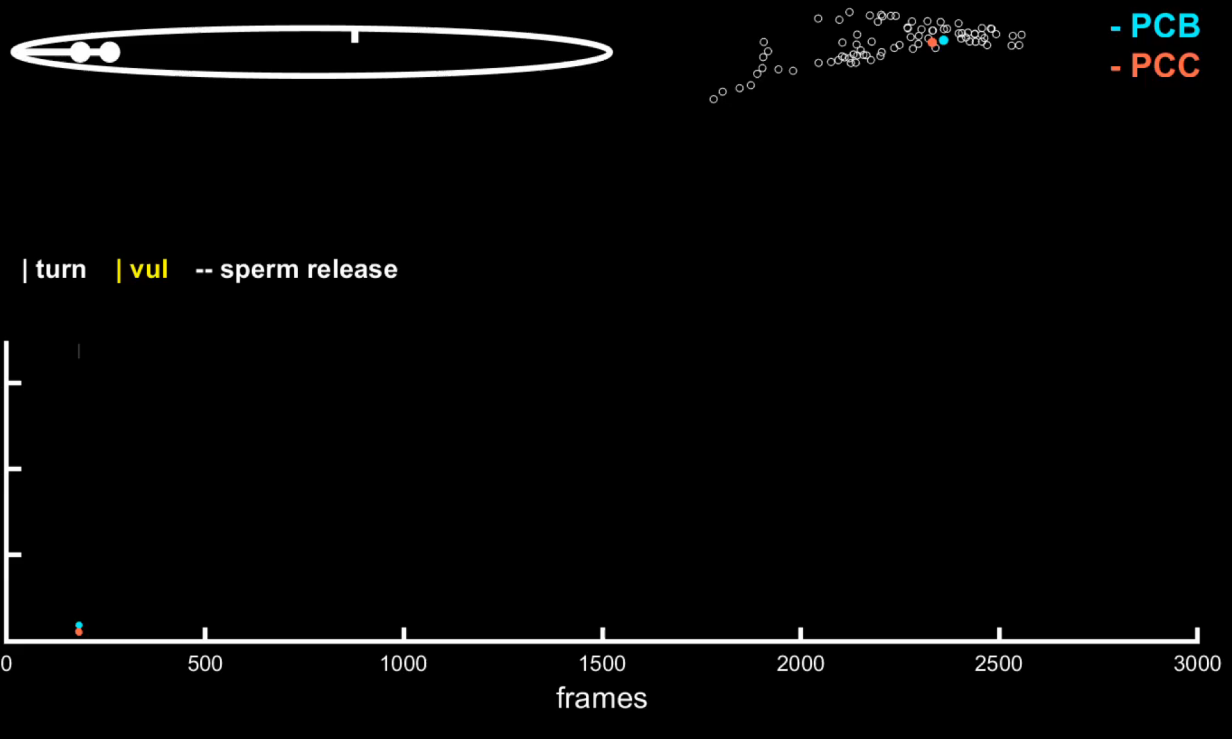
n=5

Before / after mating

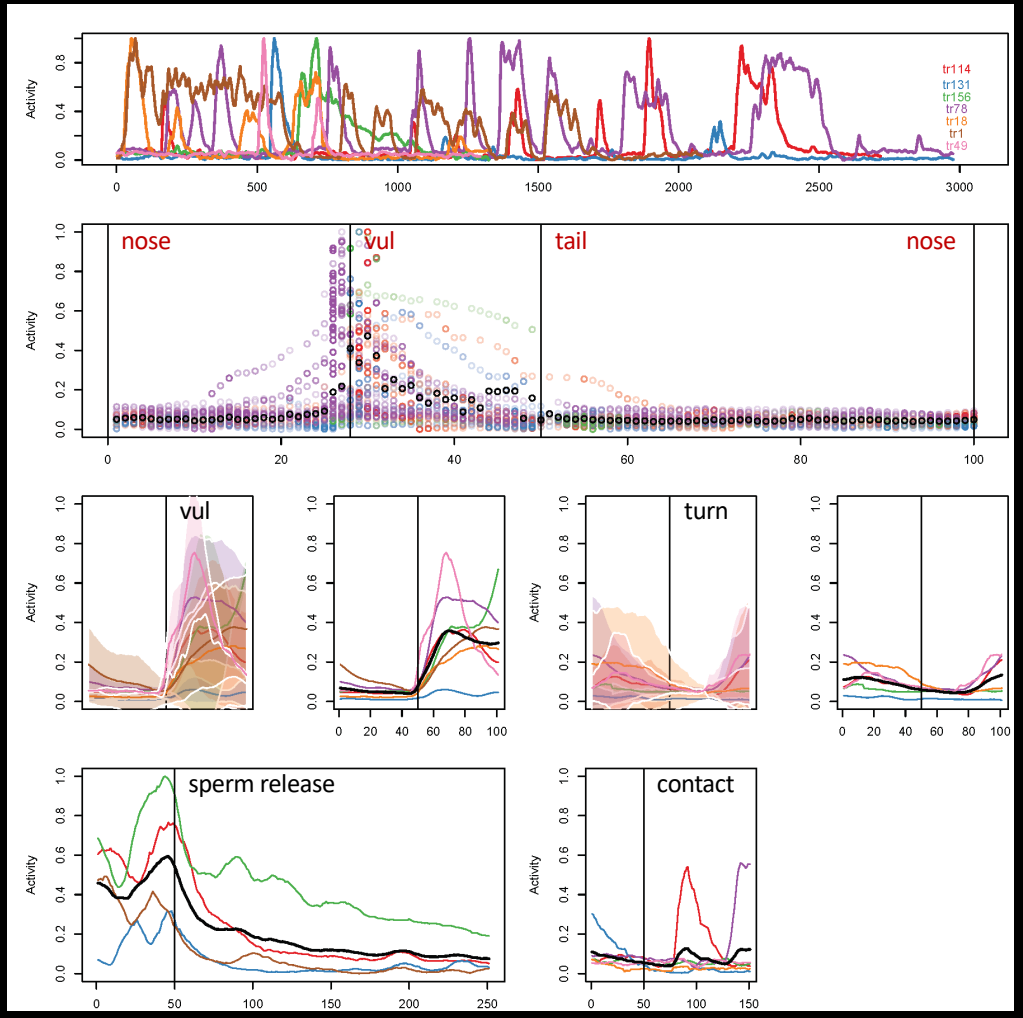


n=5

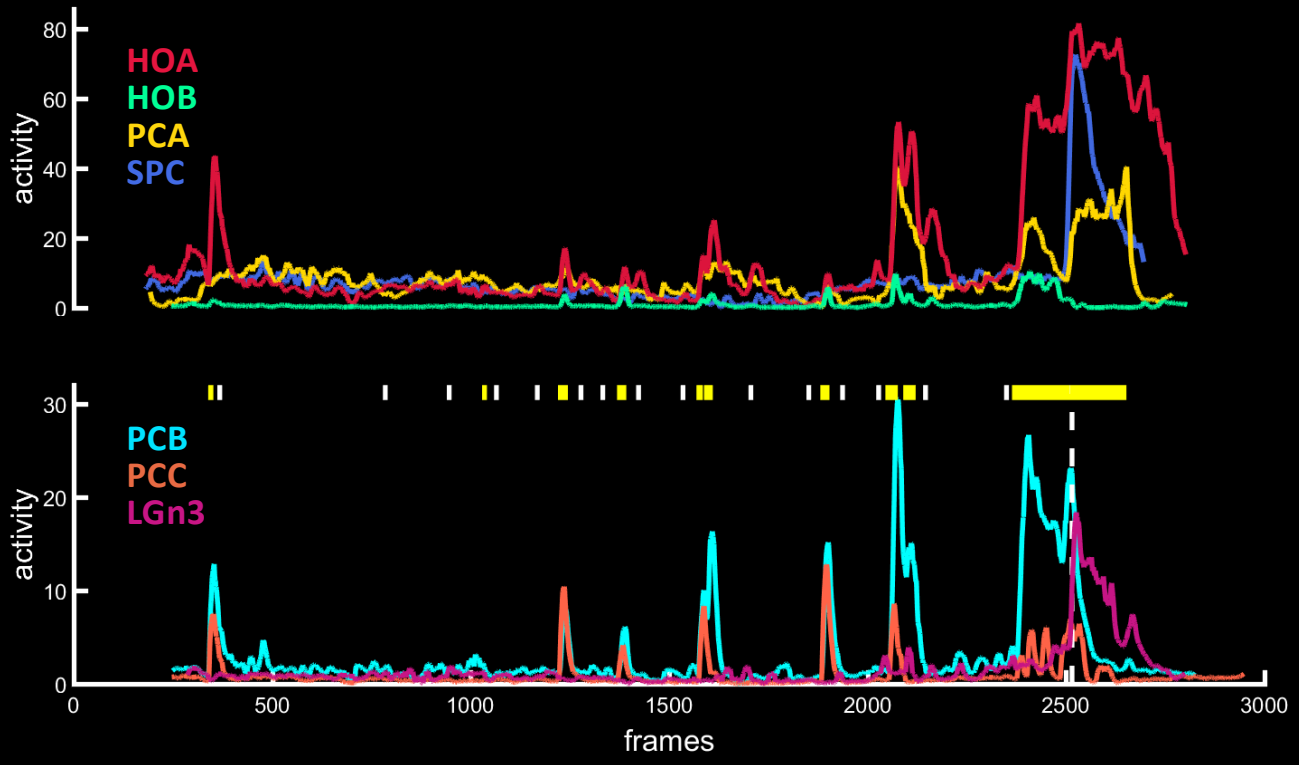
PCB and PCC become active in the proximity of the vulva



PCs activation coincides with vulva detection

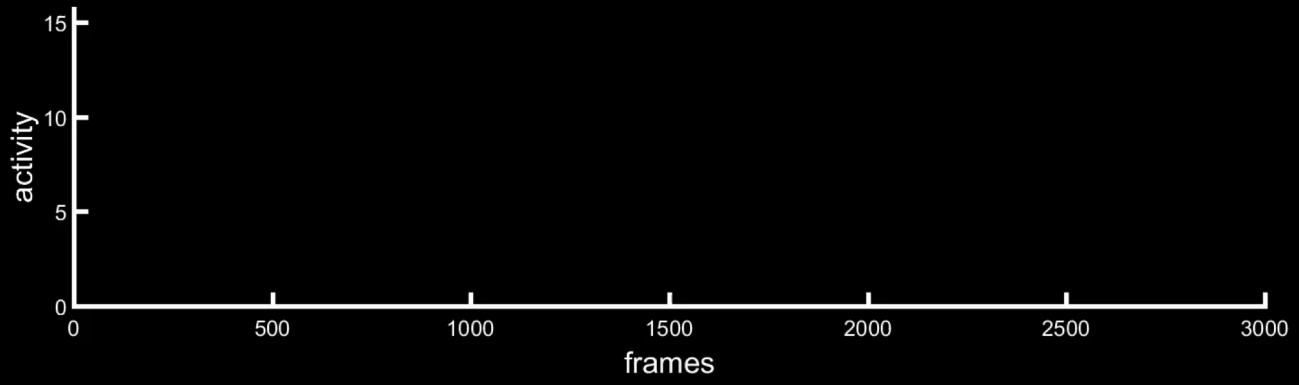


PCB, PCC, and HOB inhibition coincides with the onset of sperm release

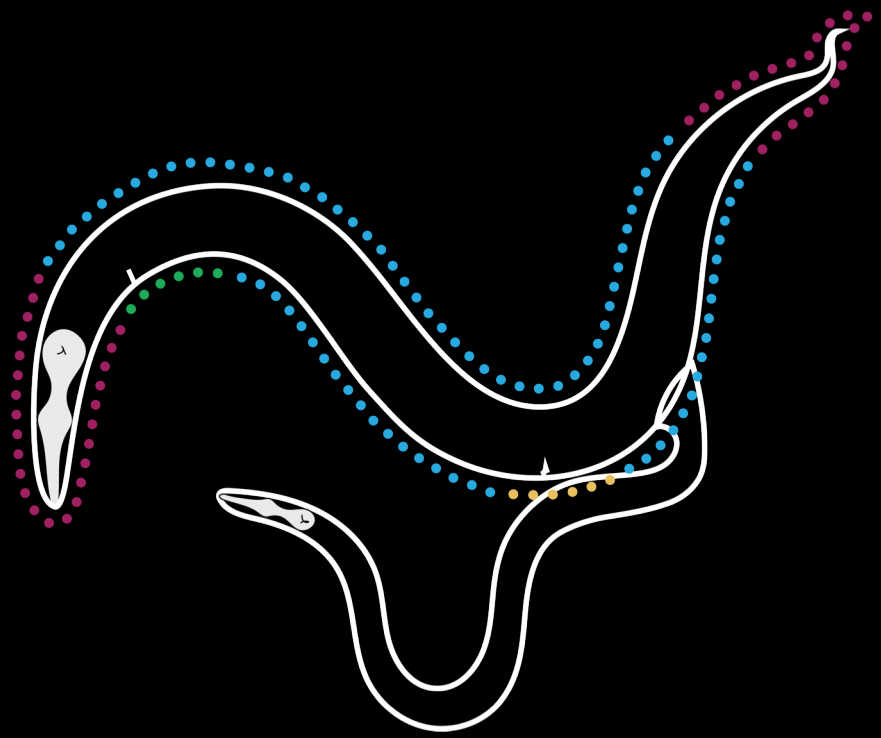


Some neurons become active exclusively when the tail is on the anterior ventral side

-
-
| turn
| vul
-- sperm release



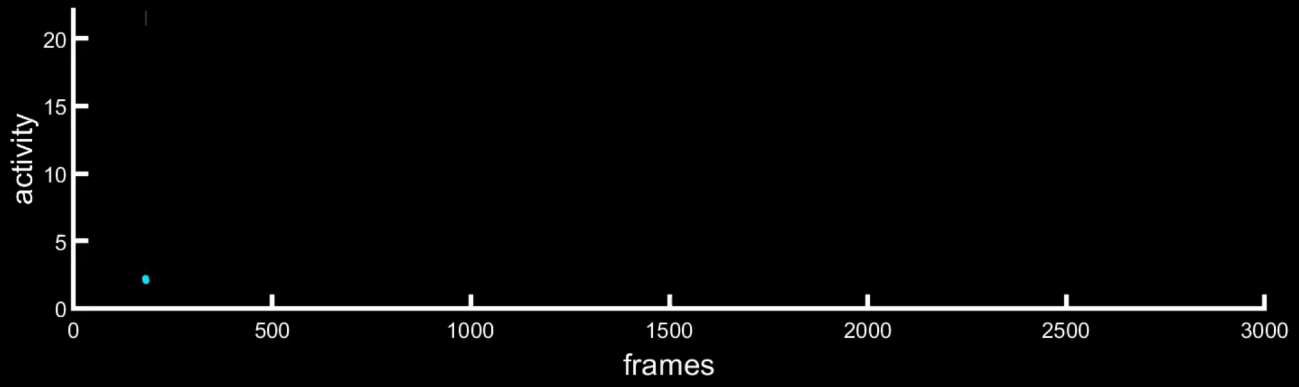
Excretory pore secretions may represent a male-guiding cue



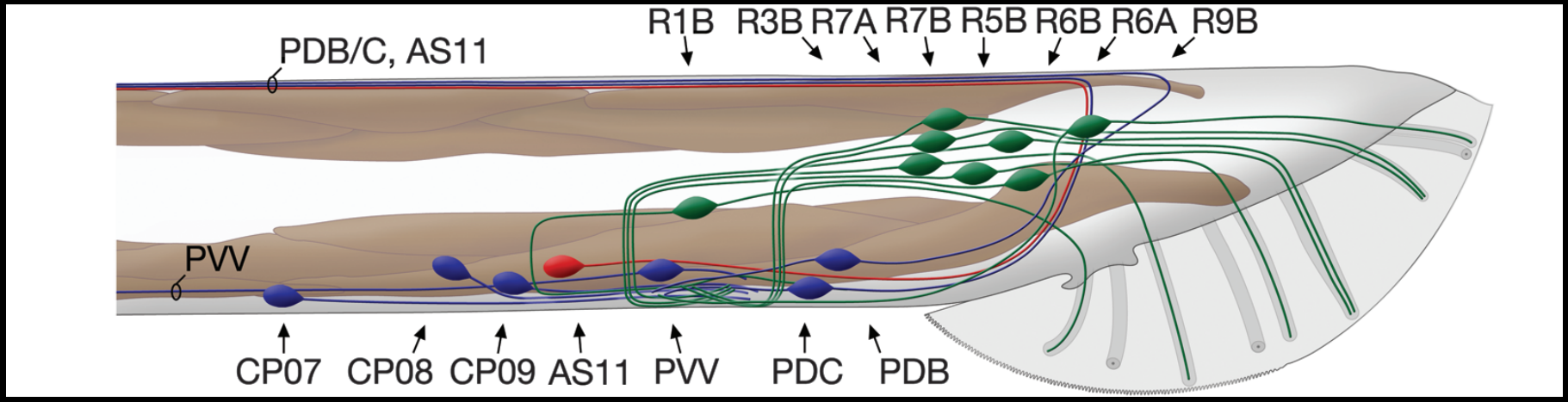
PVV activation coincides with turns

- PVV

| turn | vul -- sperm release



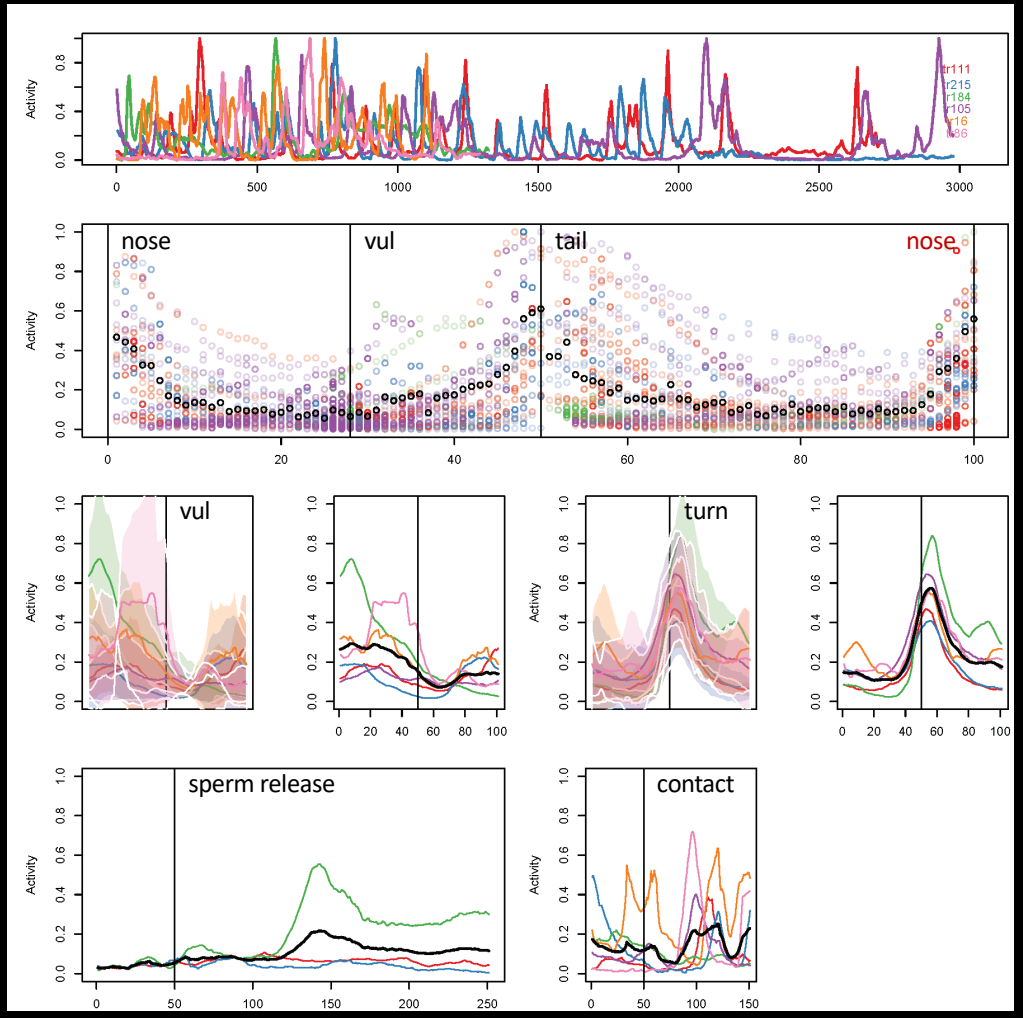
PVV module


R1B
R3B
R7A
R7B
R5B
R6B
R6A
R9B
PDB/C, AS11
PVV
CP07
CP08
CP09
AS11
PVV
PDC
PDB

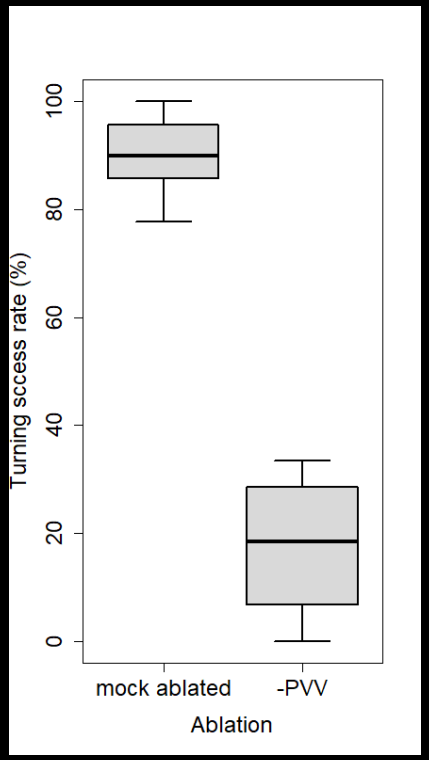
PVV activation coincides with turns

Activity along hermaphrodite body:

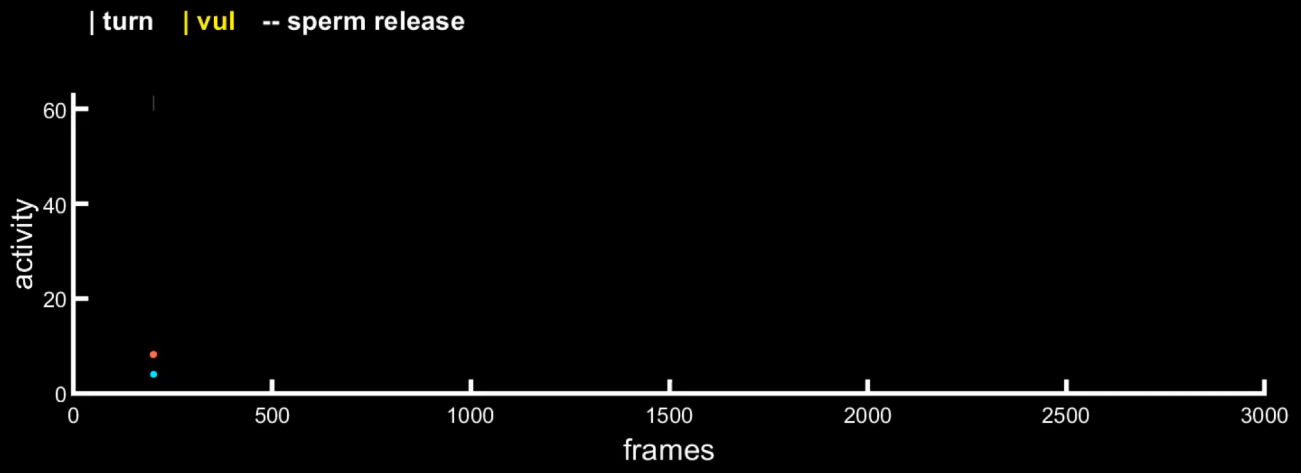
Activity aligned to events:



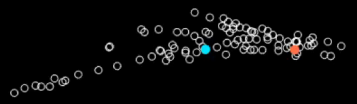
Ablation of PVV compromises turning



PVY and an LG neuron are anticorrelated

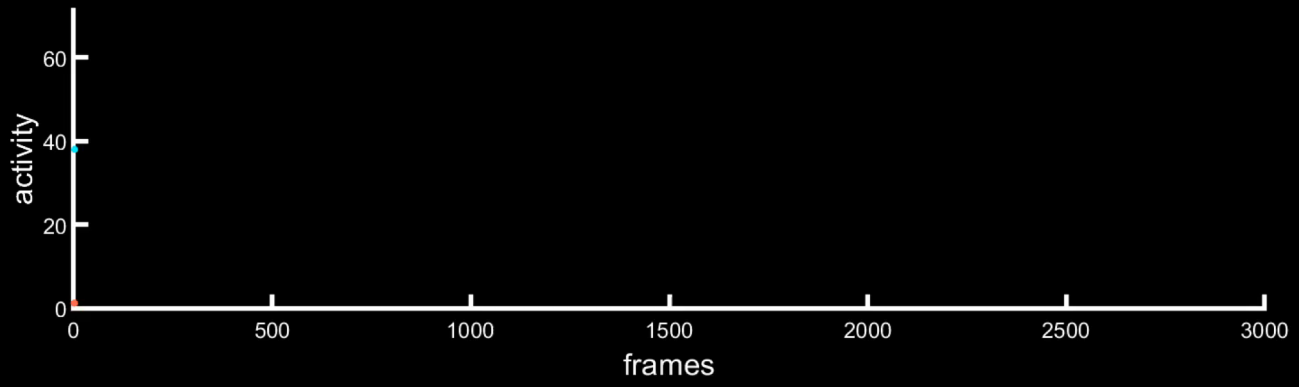


Correlation between PVY and LGn1 is state-dependent

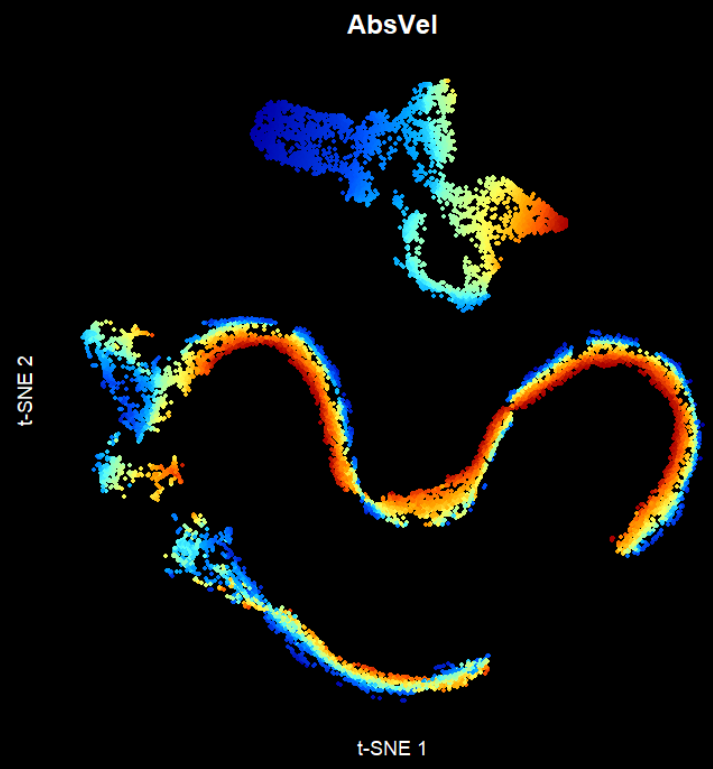


- PVY
- LGn1

| turn | vul -- sperm release



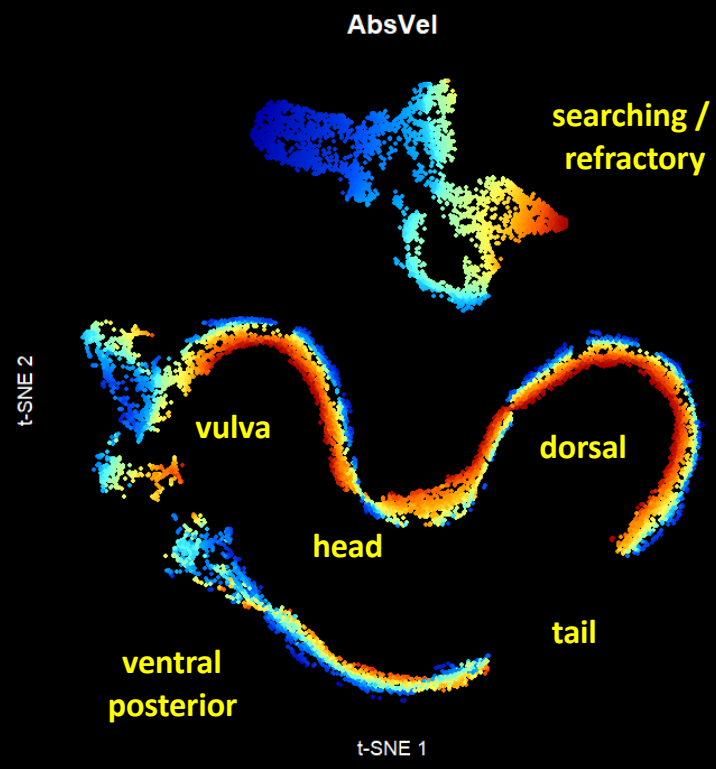
t-SNE embedding of feature series



Time series used:

- **Absolute velocity**
- **Relative velocity**
- **Position on the hermaphrodite**
- **Tail curvature**
- **Distance to vulva**
- **Distance to tips**

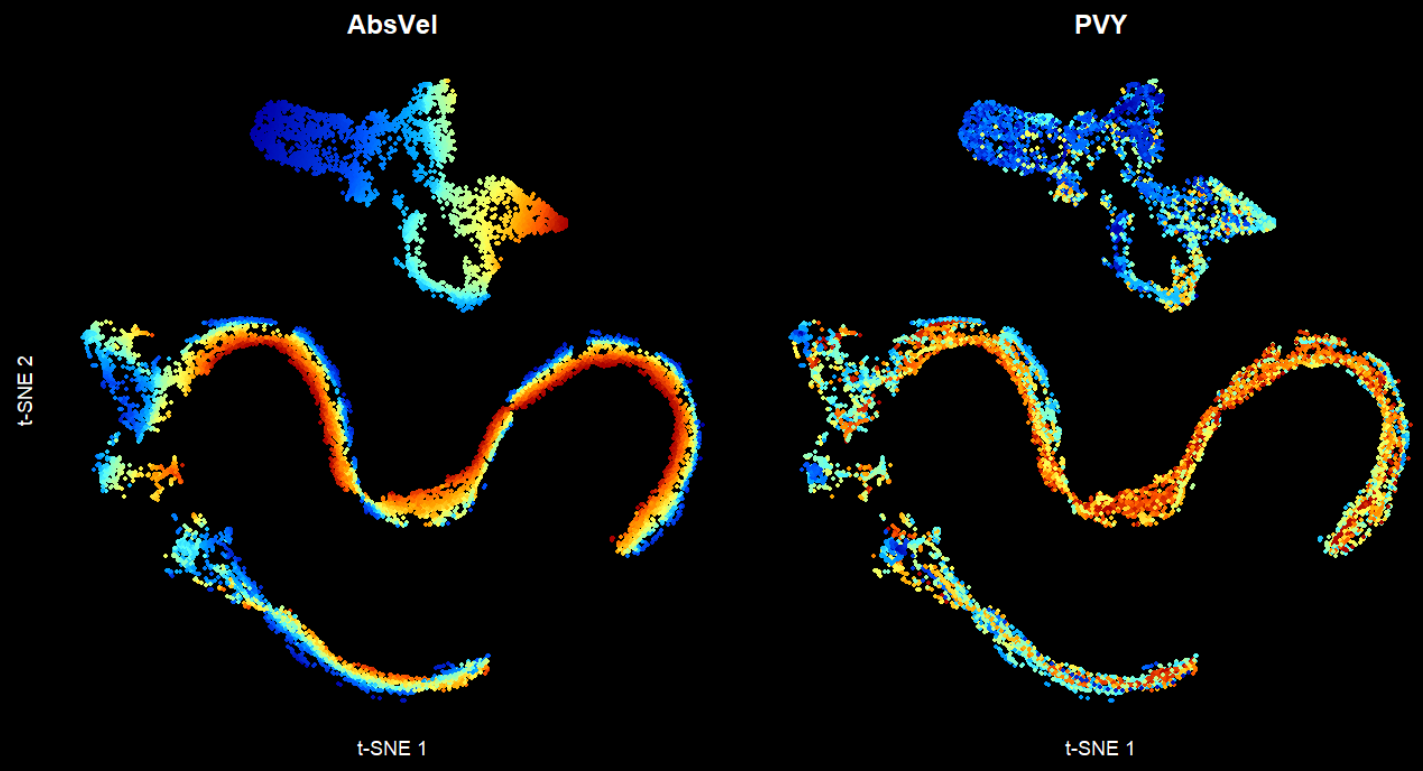
t-SNE embedding of feature series

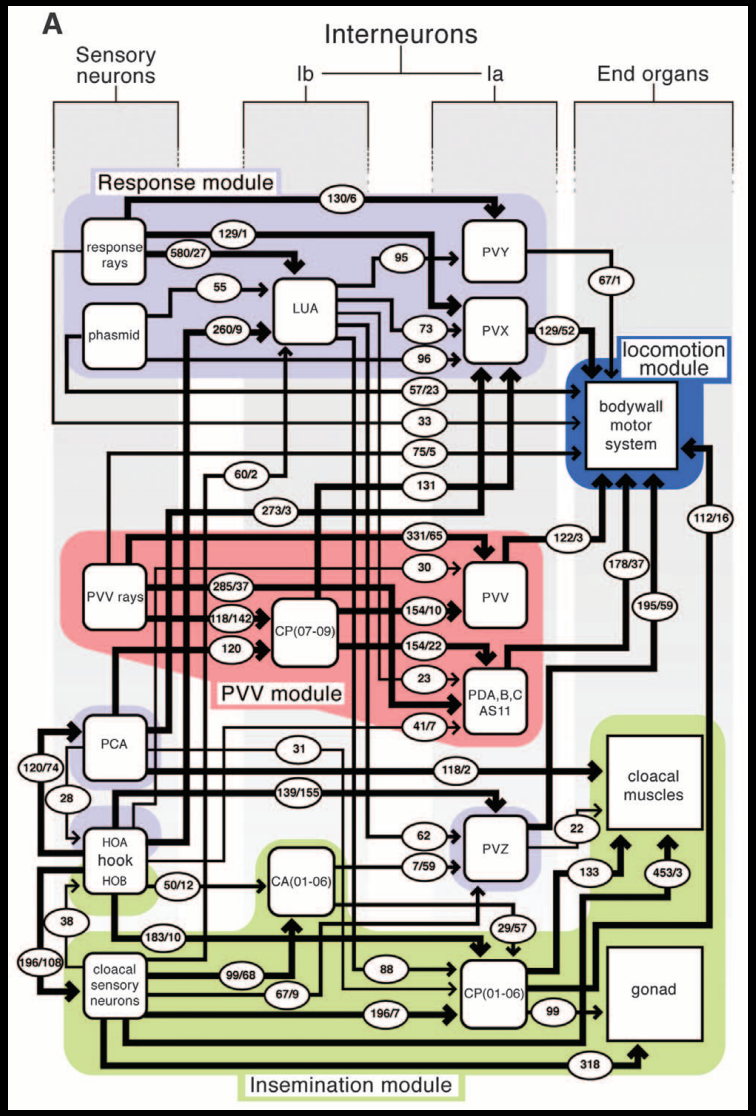


Time series used:

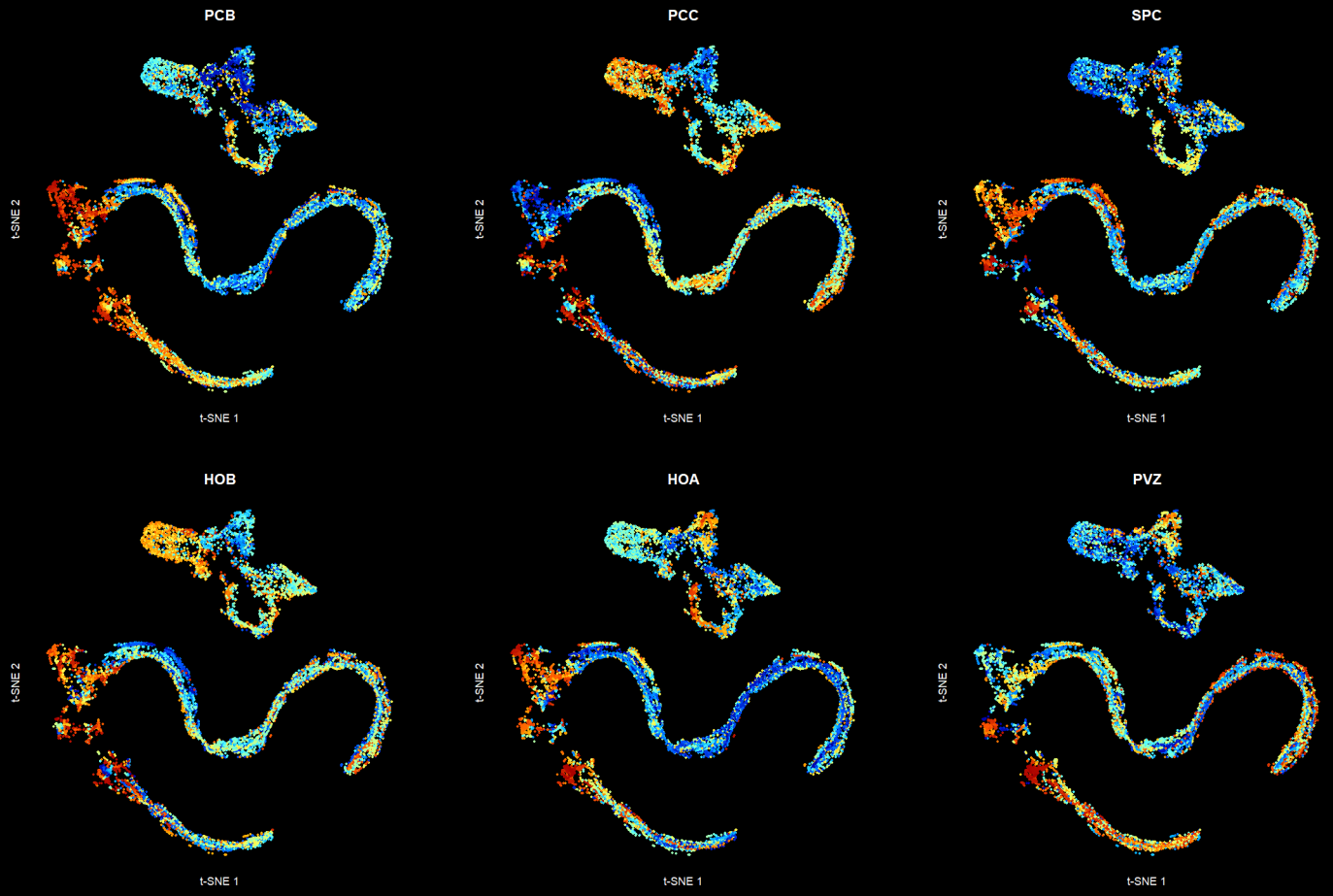
- **Absolute velocity**
- **Relative velocity**
- **Position on the hermaphrodite**
- **Tail curvature**
- **Distance to vulva**
- **Distance to tips**

Mapping neuronal activity to behavioral space

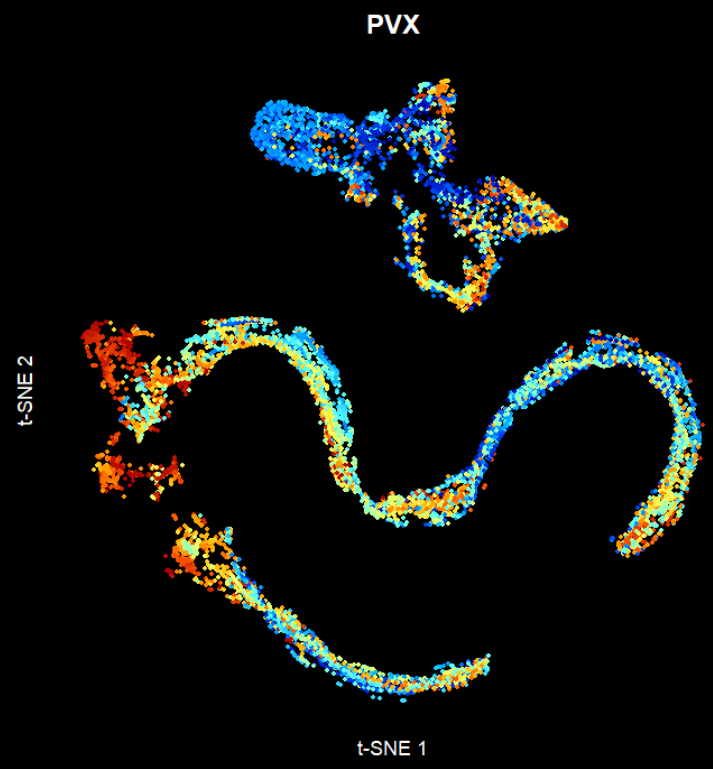


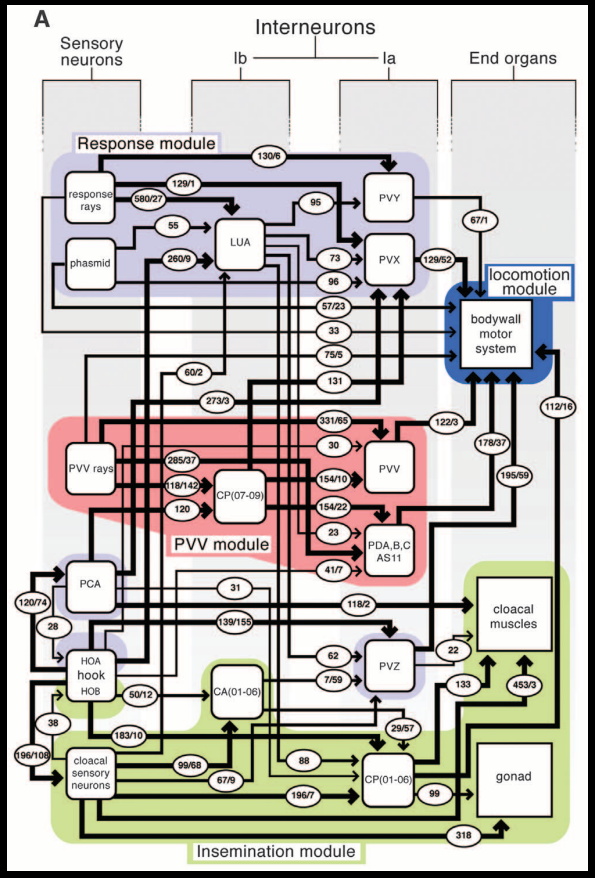

A
Sensory neurons
Interneurons
Ib
Ia
End organs
Response module
response rays
phasmid
LUA
PVY
PVX
locomotion module
bodywall motor system
PVV rays
CP(07-09)
PVV
PDA,B,C AS11
PVV module
PCA
HOA
hook
HOB
CA(01-06)
PVZ
cloacal muscles
cloacal sensory neurons
CP(01-06)
gonad
Insemination module
130/6
129/1
580/27
95
67/1
55
260/9
73
129/52
96
57/23
33
75/5
131
60/2
273/3
112/16
331/65
122/3
30
178/37
285/37
154/10
195/59
118/142
120
154/22
23
41/7
31
120/74
118/2
28
139/155
62
22
7/59
133
453/3
50/12
38
183/10
29/57
196/108
99/68
88
67/9
196/7
99
318

Subset of neurons mediating vulva detection and mating

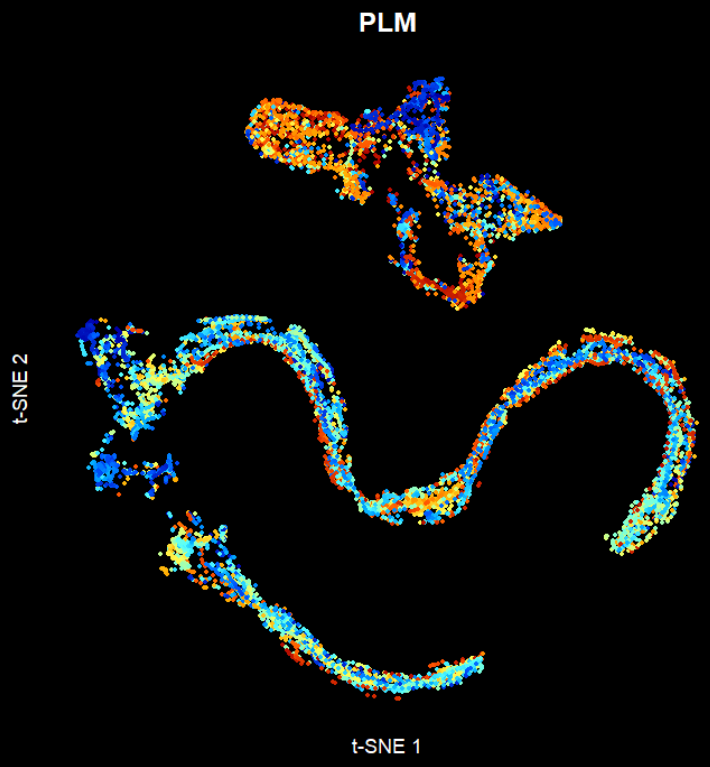


PVX is active near the vulva

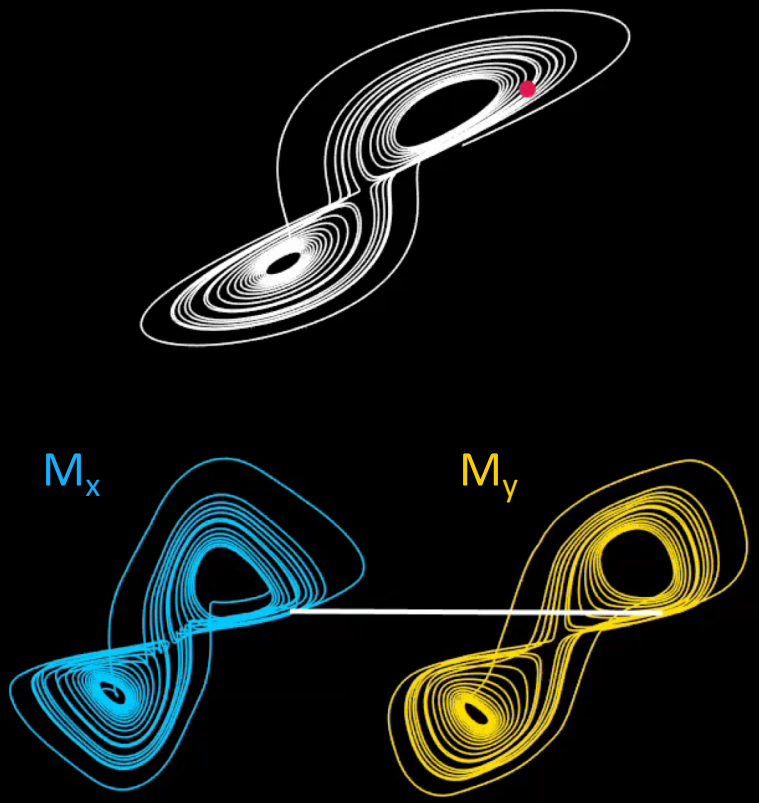


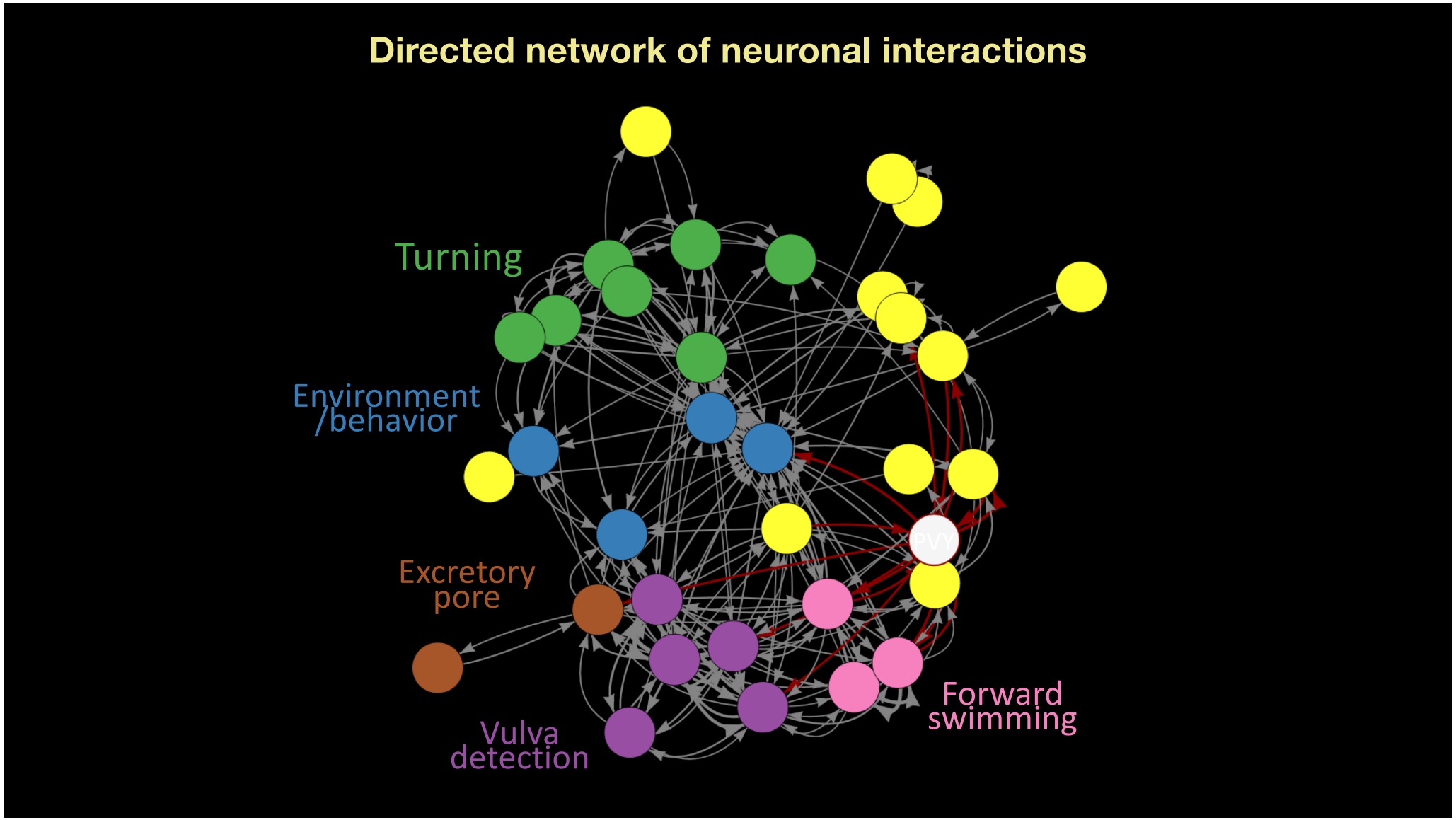


PLM is mostly active when the male is not mating

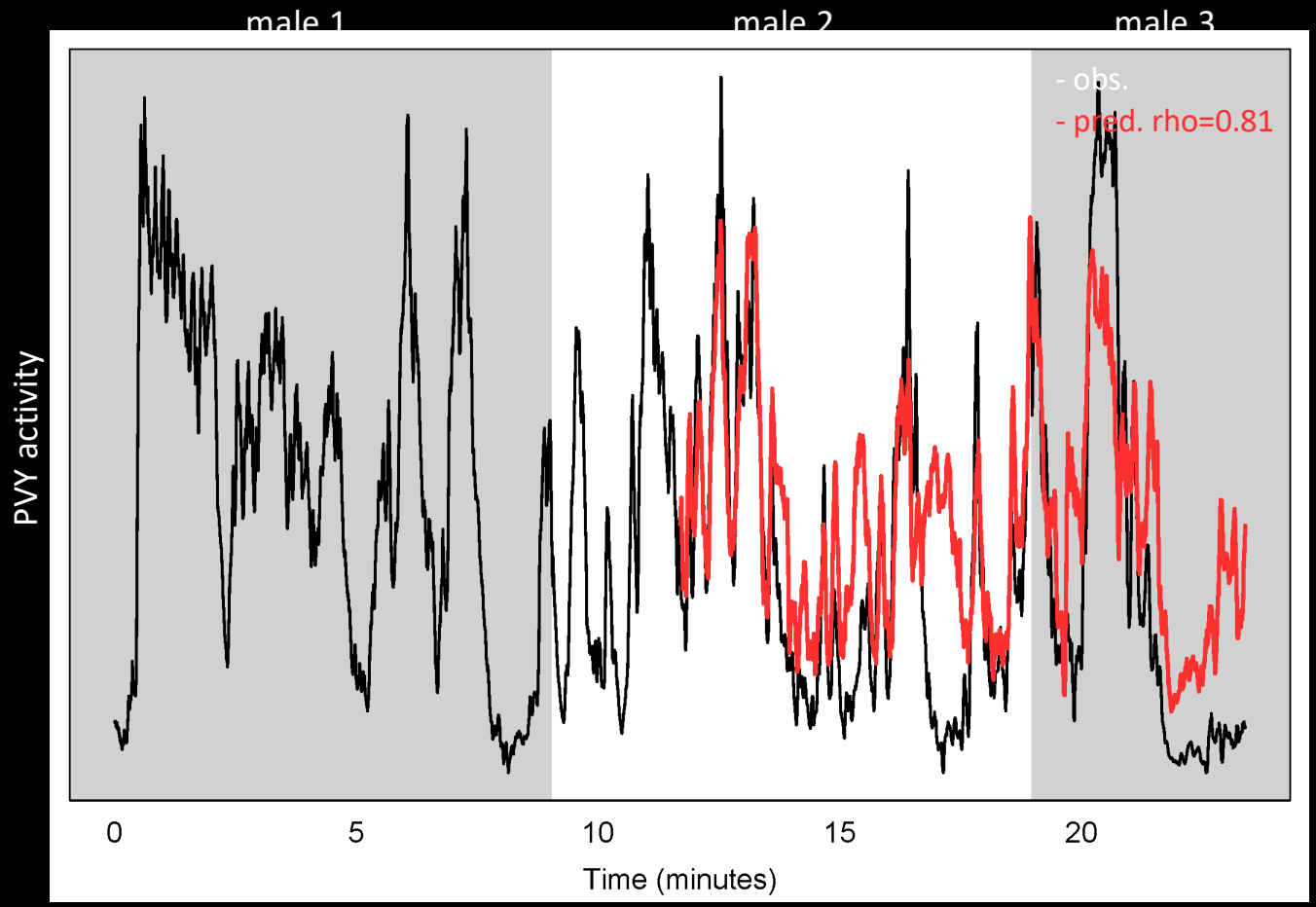


Identifying interactions using convergent cross mapping

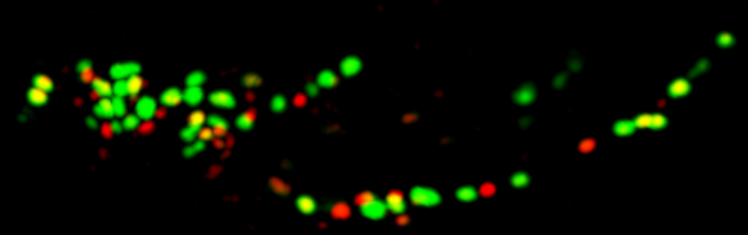



Directed network of neuronal interactions
Turning
Environment
/behavior
Excretory
pore
Vulva
detection
Forward
swimming
PVY

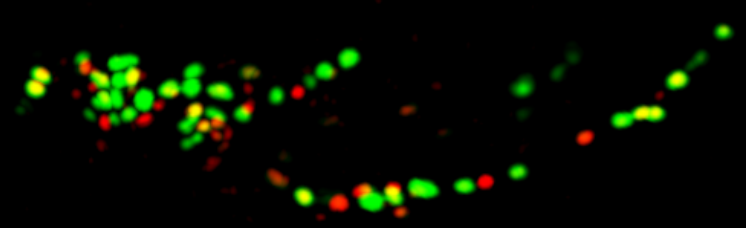
Multiview embedding



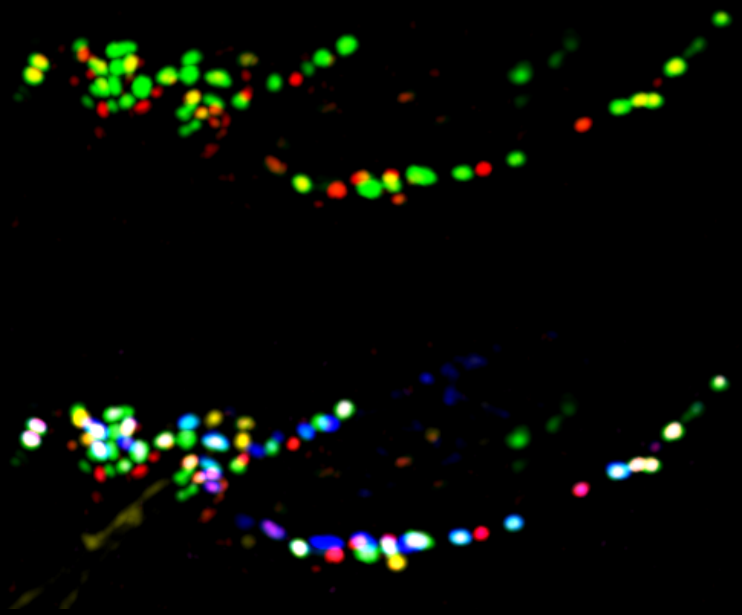
Cell identification



Cell identification



Cell identification



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Oliver Hobert

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