General anaesthesia reduces integrated information in flies

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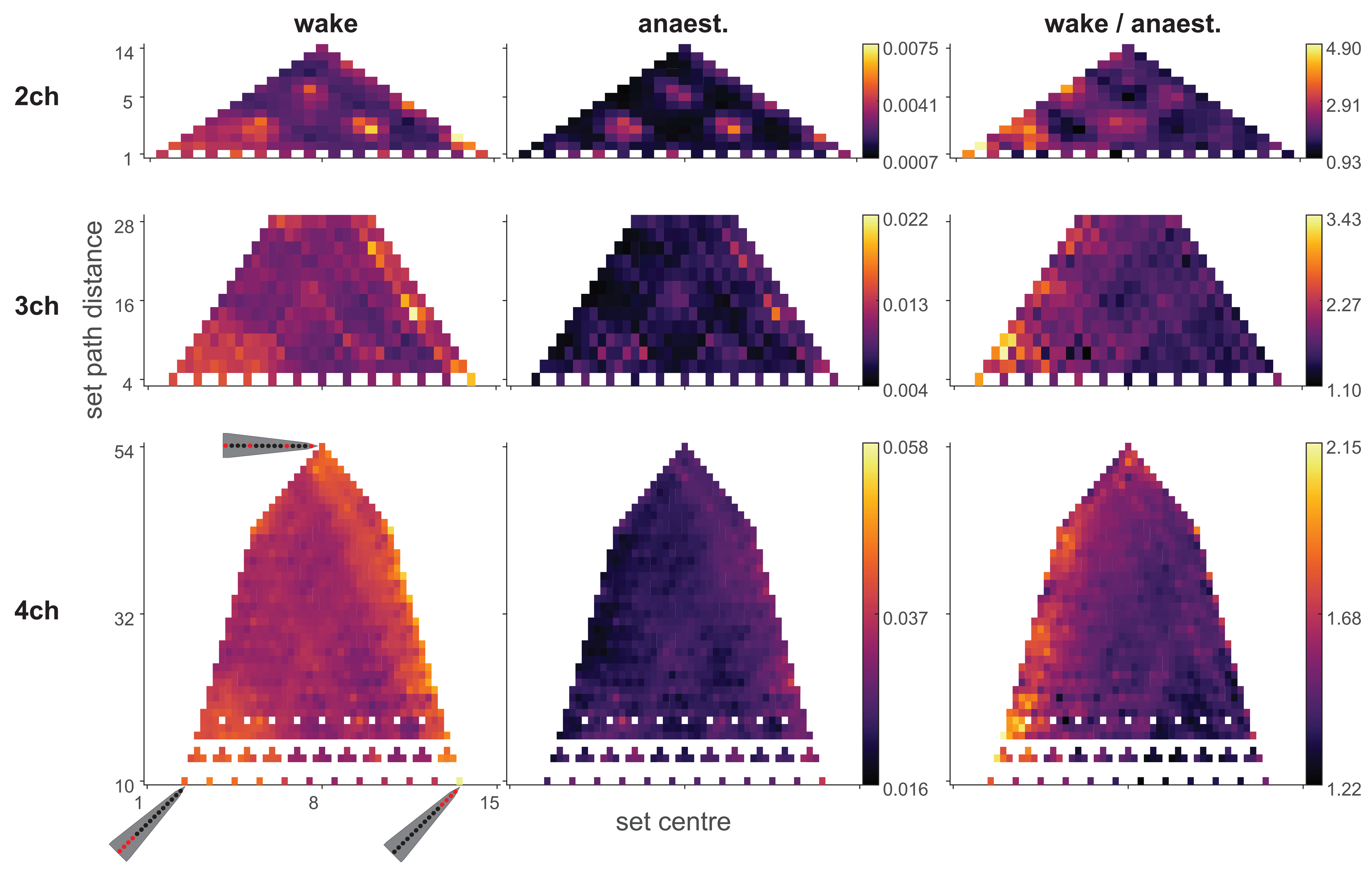
Background

- Integrated information theory [1] proposes 5 fundamental principles of conscious experience, and from these derives a multivariate measure of conscious level, integrated information Φ.
- BUT Φ has only been applied to simulated systems, not biological systems, even though it is in principle applicable to any system.
- BUT Φ is computationally intensive - expensive to compute for large sets of recordings, and, when computing for subsets of recordings, expensive to apply to many combinations of re-cordings.
- Does Φ reduce during anaesthesia? And can we avoid computing it for all subsets?

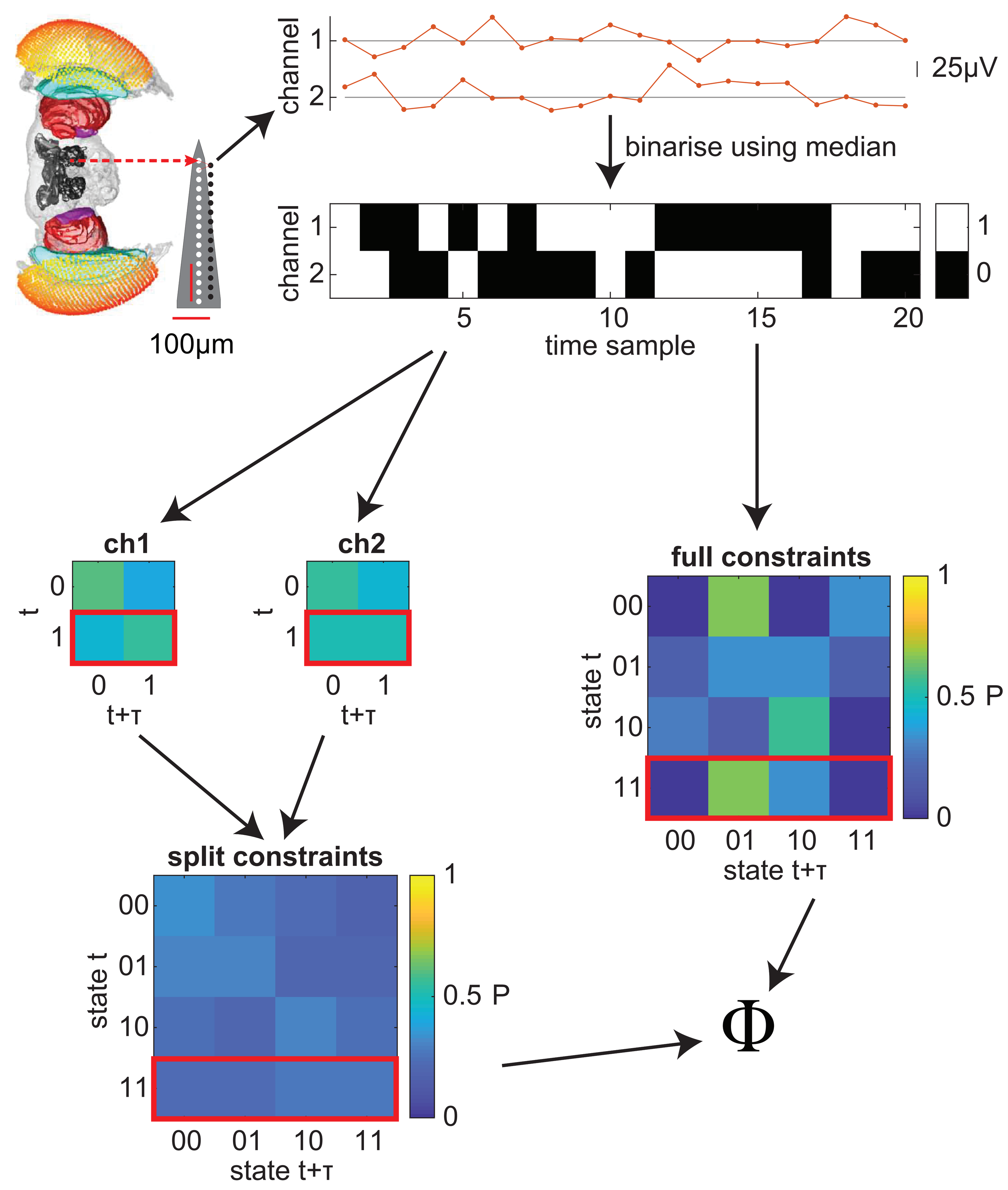
Anaesthesia reduces Φ

- Flies at 0% and 0.6% isoflurane anaesthesia (loss of behavioural responses at 0.6% [2]).
- Parameterised channel set using {total pairwise distance} and {set centre}.



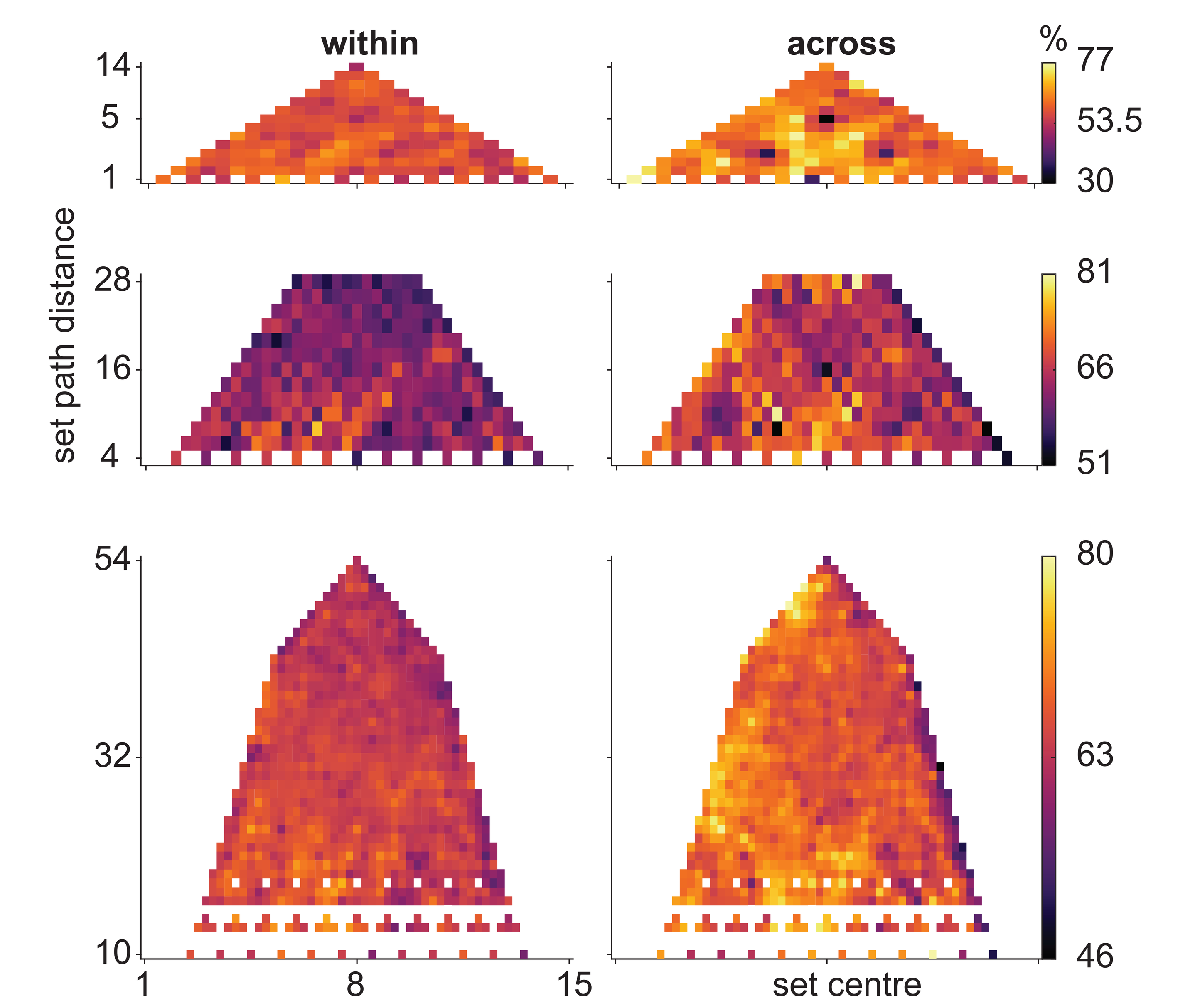
Measuring Φ in the fly

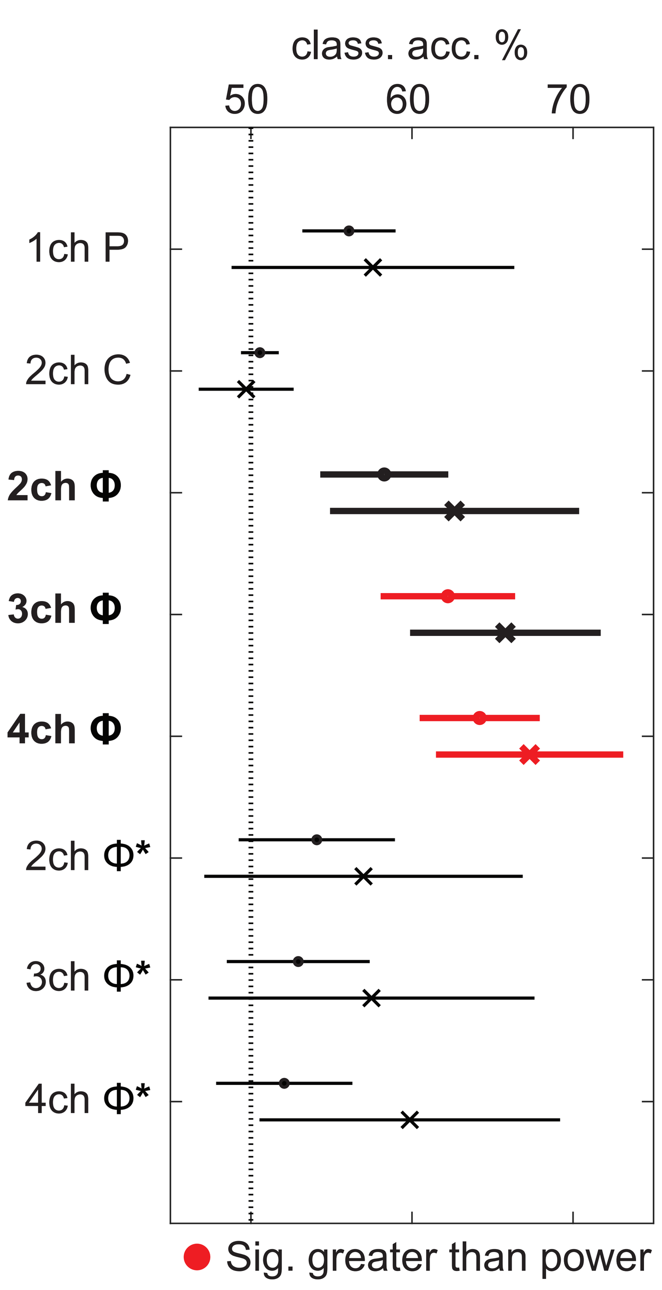
- Linear multi-electrode array inserted into 13 flies, recorded local field potentials (i.e. "channels" after bipolar re-referencing [2].
- Φ computed for each combination of 2, 3, 4 channels.
- Information - how does the current network state constrain possible past and future states?
- Integration - does a split system make the same constraints?



Φ classifies wake/anaesthesia

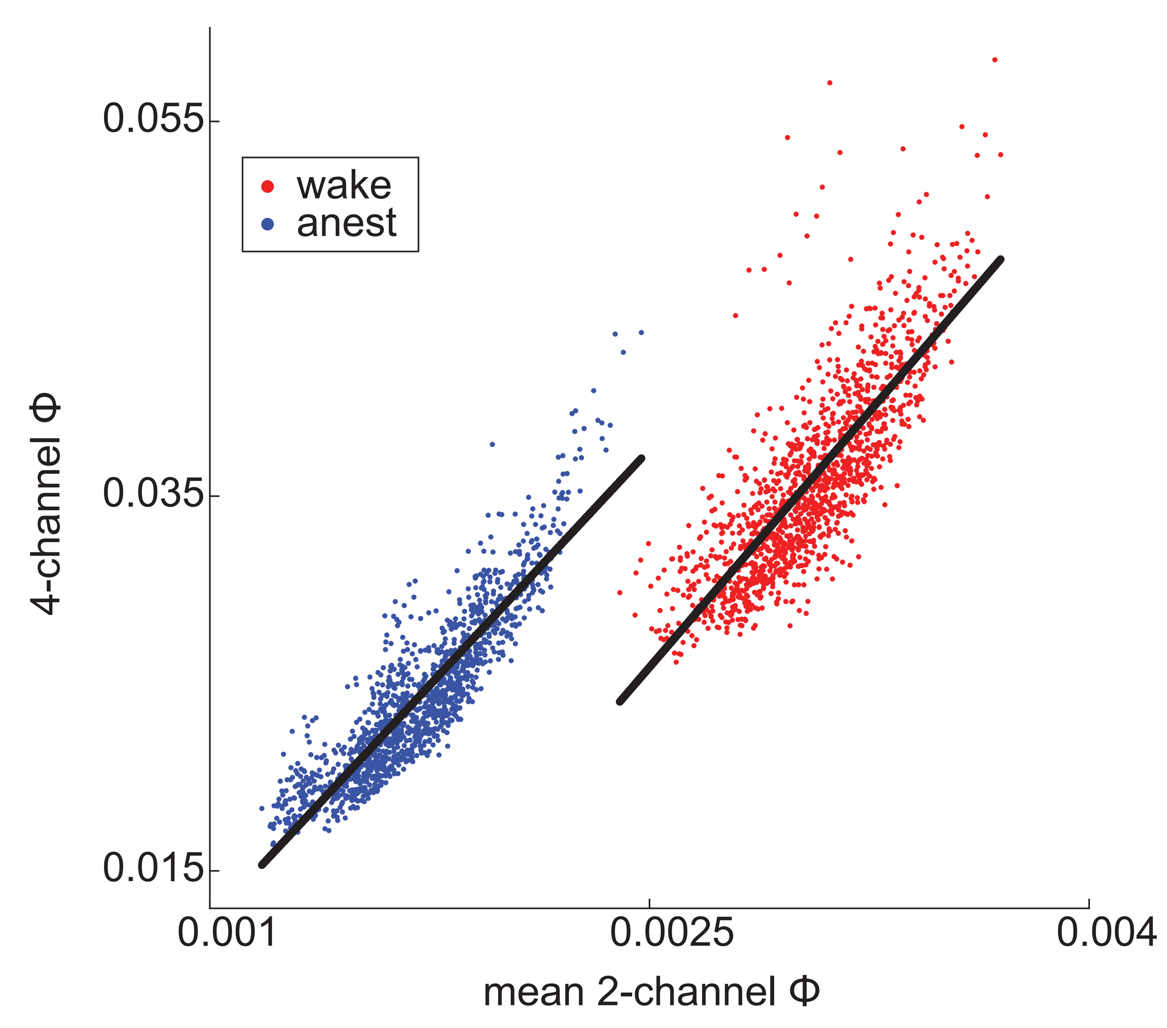
- Within-fly classification across 8x2 trials (8 trials for each wake/anaesthesia). ●
- Across-fly classification across 13 flies (x2 for wake/anaesthesia; averaged across trials). ✕
- Nearest-mean classification with leave-one-out validation.
- 1-channel power and 2-channel coherence: 10-20Hz (both sig. reduced due to anaesthesia at this range [3]).
- Φ*: "practical" derivation based on previous version of IIT [3] - cheaper to compute.





Subset Φ predicts superset Φ

- Extremely expensive to compute Φ across many large sets of channels (e.g. 5 or more).
- Does Φ at 2-channels inform Φ at more channels?
- Obtain mean Φ per channel across all 2-channel sets.
- Compare mean 2-channel Φ across 4-channels with actual Φ value.



- Integration across 2-channels seems to be maintained when embedded into a larger channel set (4-channels).

1. Oizumi, M., Albantakis, L., Tononi, G. (2014). From the Phenomenology to the Mechanisms of Consciousness: Integrated Information Theory 3.0. PLoS Computational Biology, 10(5), e1003588.
2. Cohen, D., van Swinderen, B., & Tsuchiya, N. (2018). Isoflurane Impairs Low-Frequency Feedback but Leaves High-Frequency Feedforward Connectivity Intact in the Fly Brain. eNeuro, 5(1), ENEURO-0329.
3. Oizumi, M., Amari, S. I., Yanagawa, T., Fuji, N., & Tsuchiya, N. (2016). Measuring Integrated Information from the Decoding Perspective. PLoS Computational Biology, 12(1), e1004654.

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Summary

- Φ gives a principled way of meaningfully combining multi-channel data.
- Φ seemingly greater at peripheral and central regions. Reduction in Φ due to anaesthesia greatest at peripheral channels. However, best classification occurs in neither of these areas.
- Strong correlation between 2-channel and 4-channel Φ can be utilised in finding potential sub-sets of recordings where Φ is likely to be greatest.