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PRESENTER  
Côme Le Breton



# Investigating the origin of phase delays in the alpha band

## Background

Traveling (or propagating) wave are oscillating electrical voltages observed sequentially or simultaneously at different brain locations, relating them functionally. They are observed at various scales, all over the brain, in various frequency bands and following varied stimuli (or in their absence), making them an ubiquitous phenomenon. Ermentrout and Kleinfeld [2001] proposed three possible mechanisms: 1) A unique oscillator activating cortical areas with different time delays (resulting in a spurious wave), 2) A chain of successively activated oscillators, 3) Coupled local oscillators generating wave propagation due to phase delay. In scalp EEG, volume conduction considerably complicates the problem, and allows to consider a fourth "mechanism", in which only two sources can generate phase delays at many electrodes.

## Methodology

**A]** EEG data acquisition split over several recordings (up to 4 per session) and over several sessions (up to 8 per subject). Each recording lasts 275 seconds and alternates between 20 second blocks of Eyes Open Fixation (EOF) and Eyes Closed Relaxation (ECR). EEG channels of interest are re-referenced to M2. Instantaneous phase is extracted with the Morlet wavelet transform in the alpha band (8-12Hz) and split according to condition.

**B]** Histograms of phase differences are then constructed, for each considered pair and each condition.

**C]** To show the stability of the distributions across recordings, the parameters of the fitted von Mises distributions are extracted from each block, and the locations are plotted on a circular histogram.

**D]** To explain the phase difference observed on real data, a simulation based on a model of 2 sources is devised. One source is located in the frontal area and another in the occipital area.

**E]** The Phase Lag Index is computed on short windows and averaged over 5 blocks of ECR.

## Results

**B]** There is a gradual phase shift in the alpha band, in the anteroposterior direction, that is visible on single recordings, and which is subject specific.

**C]** Phase difference peaks are stable across recordings. Non zero phase difference peaks cannot be observed in control conditions such as during calculus blocks, in the beta band or along the coronal direction. These phase peaks would, at 10Hz, amount to propagation speed of  $7.3 \text{ m.s}^{-1}$ . This is incompatible (too fast) with transmission delays in the cortex or through white matter.

**D]** The geometry of the model with 2 sources explains the phase difference observed in the real data. With a phase shift of  $0.93 \pi$ , one can observe similar phase patterns as those of the real data.

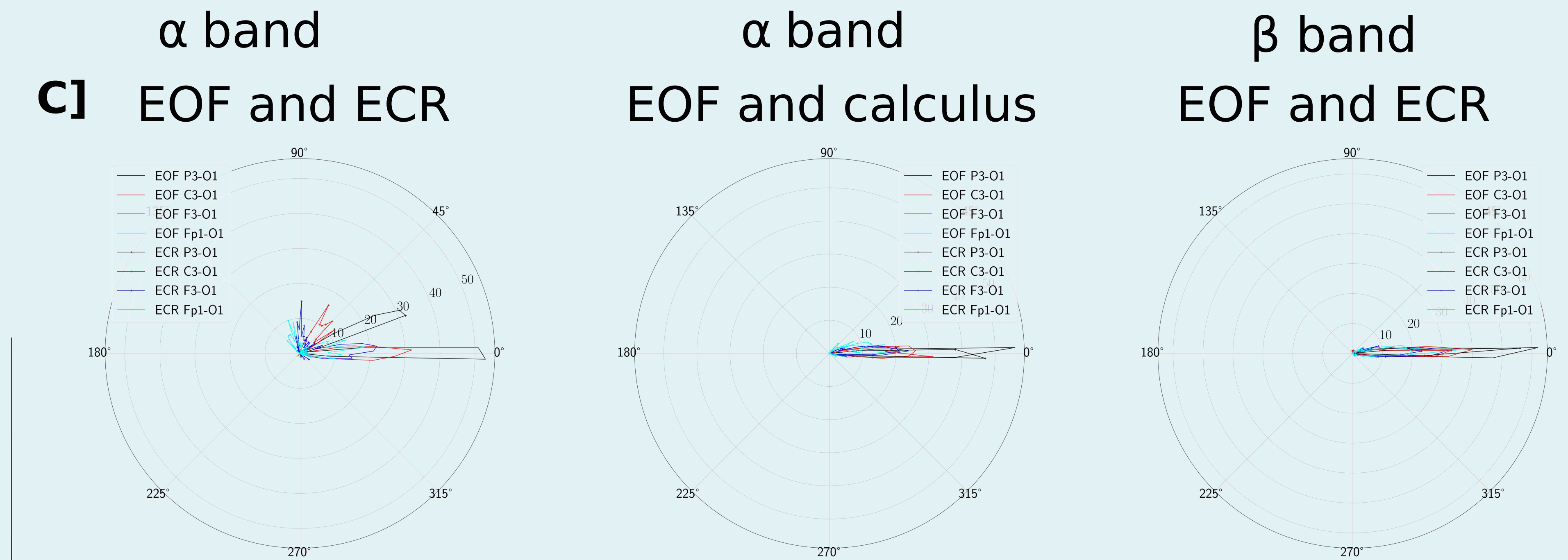
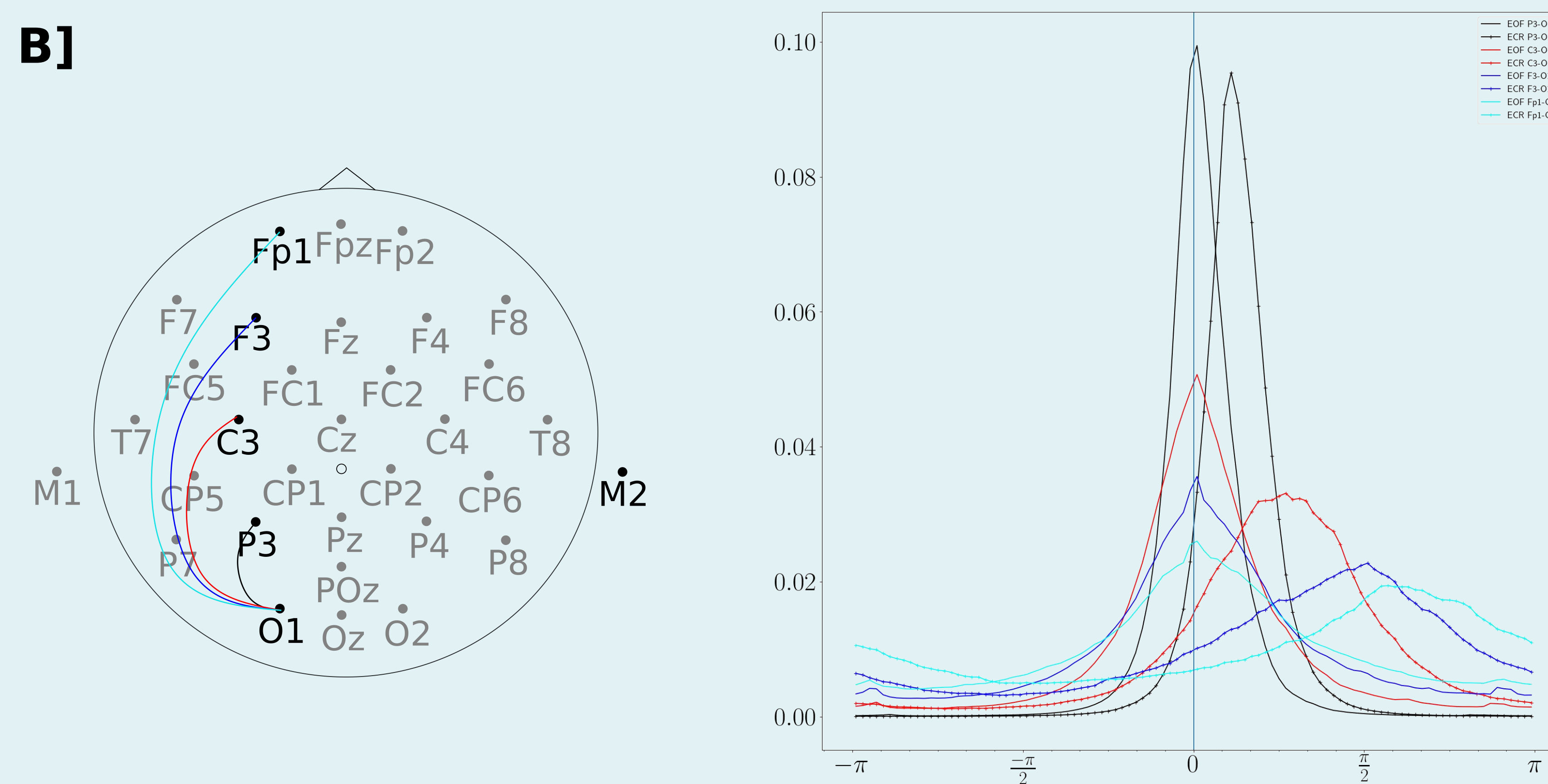
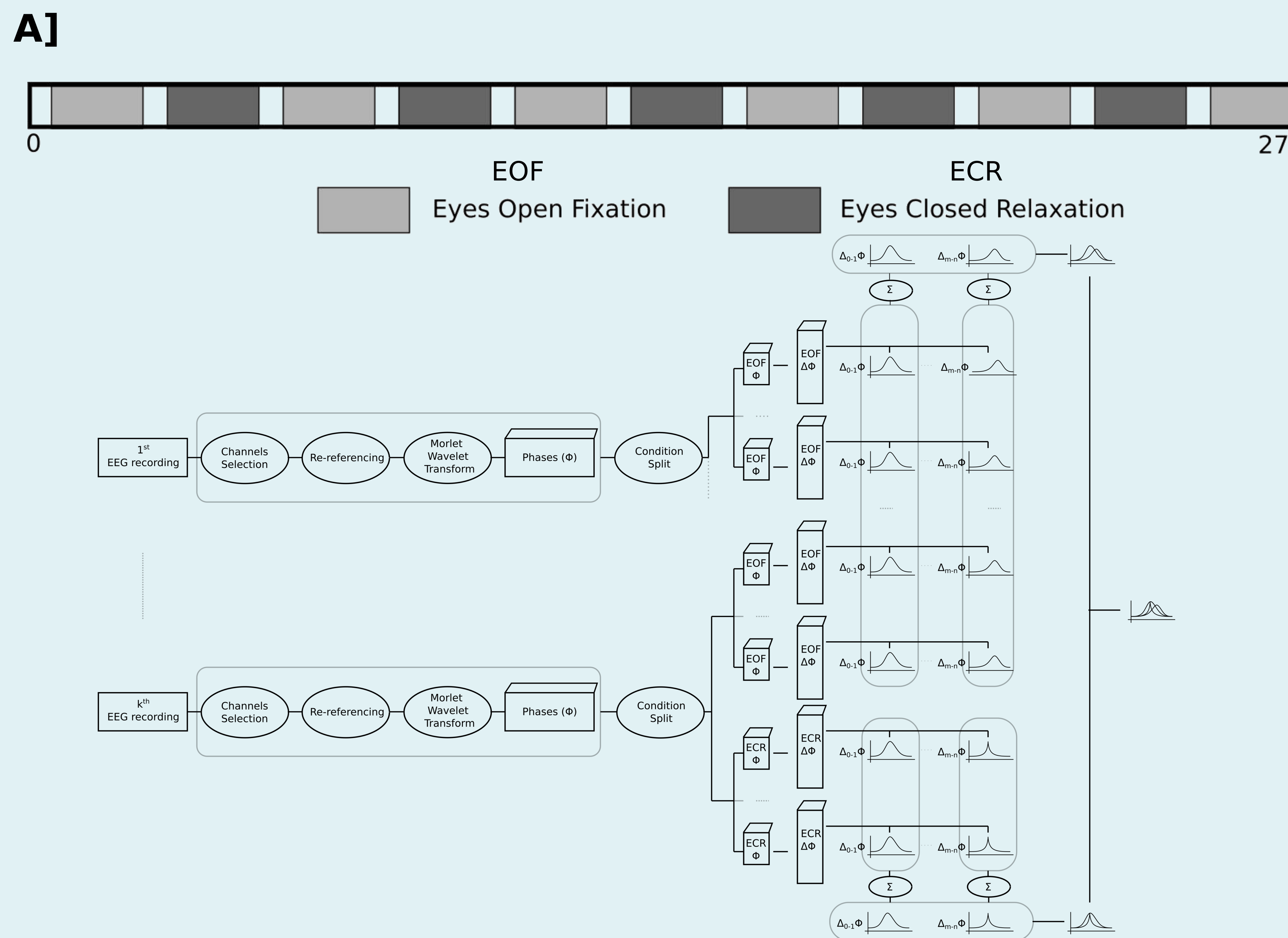
**E]** The PLI shows spurious functional connectivity between electrodes along the anteroposterior axis that are likely due to only two functionally connected sources.

## Take Home

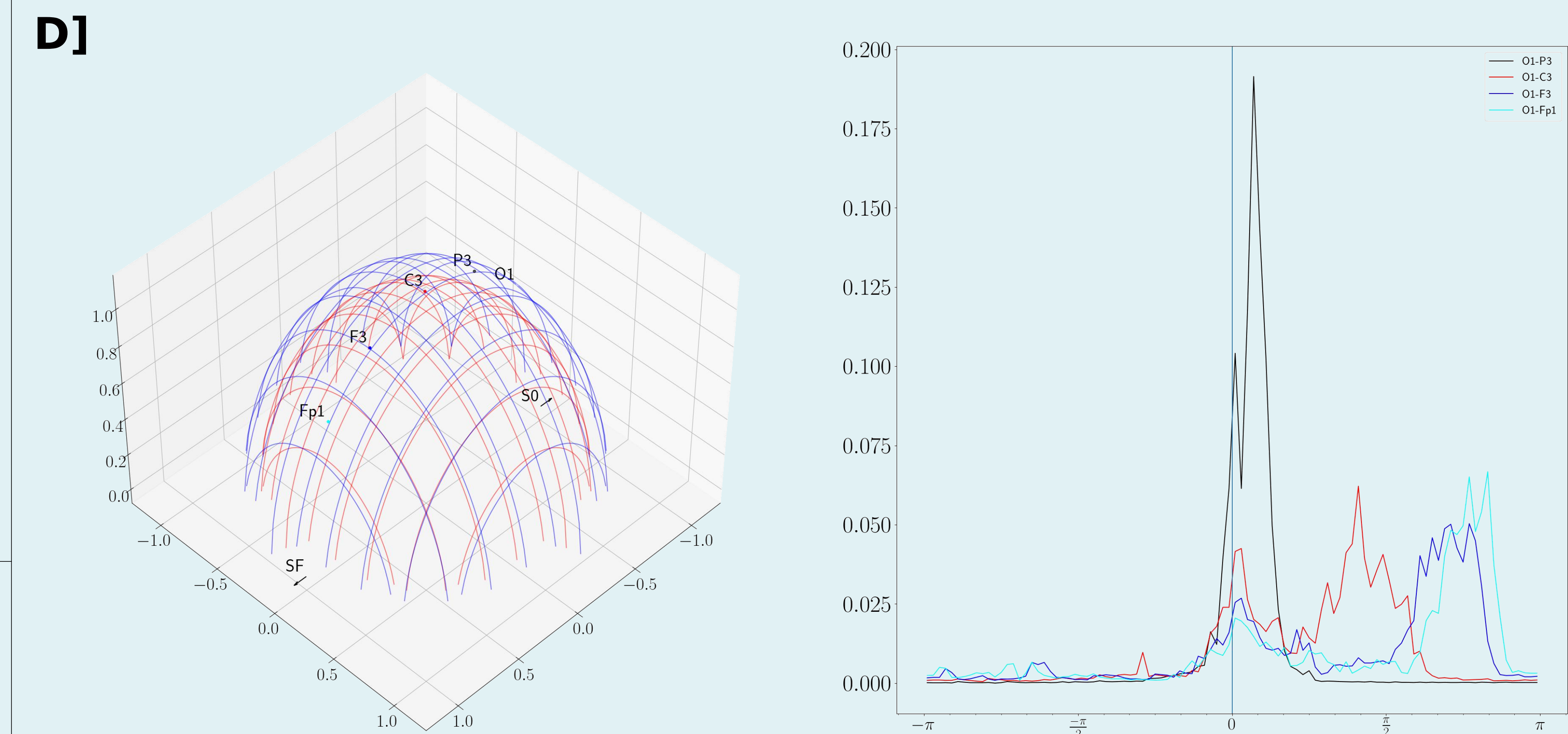
**Phase differences in the  $\alpha$  band appear along the anteroposterior axis during the ECR condition, and this pattern is stable across recordings taken years apart.**

**A simplistic model of two sources is enough to model phase differences incompatible with transmission delays.**

**Care must therefore be brought to the apriori misconception that PLI index is not sensitive to volume conduction.**



Speed:  $7.3 \text{ m.s}^{-1}$



**E]**

$$PLI(w) = \left| \frac{1}{N} \sum_{k=wc-L/2}^{wc+L/2} \text{sign}(\Phi_A(k) - \Phi_B(k)) \right|$$

where :

- $L$  : Duration of a time window
- $wc$  : Window center
- $w$  : Window  $[wc - L/2; wc + L/2]$
- $\Phi_X(k)$  : Phase angle of signal  $X$  at time  $k$

