Identification of Spatio-Temporal Oscillatory Signal Structure in Cerebral Hemodynamics Using DRIFTER

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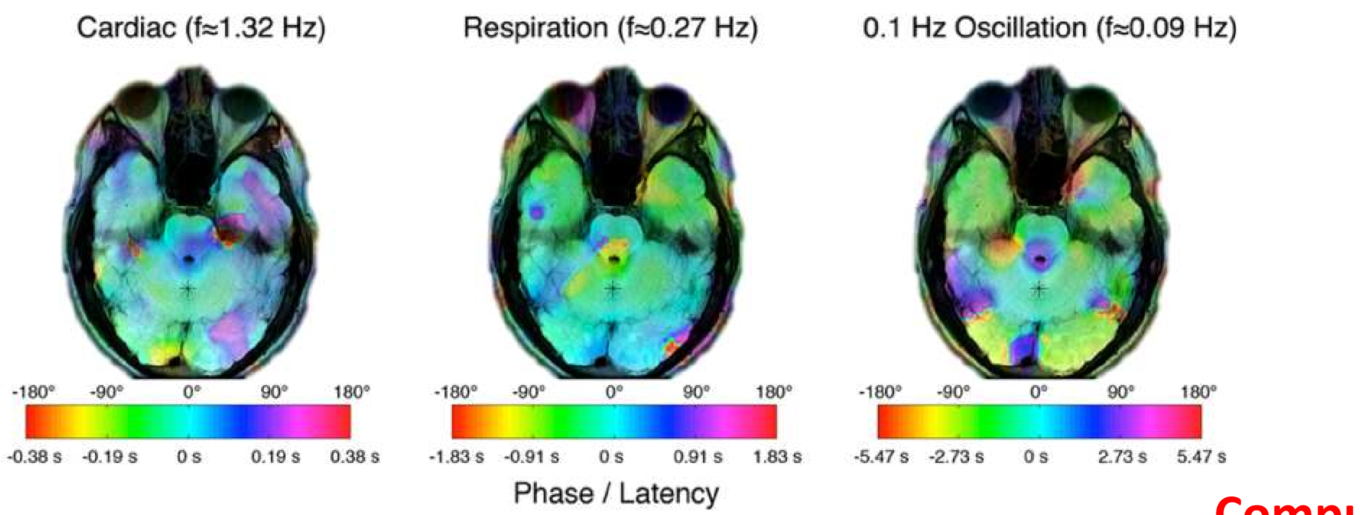

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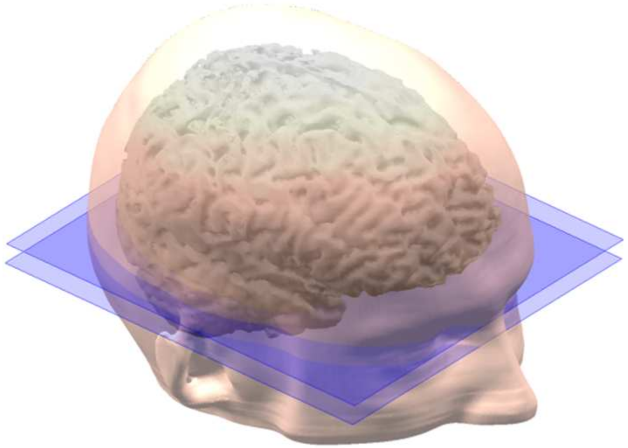
Purpose of Work

- Examine space-time structure of physiological oscillations in fMRI
- Physiological oscillations = cardiac, respiration and a 0.1 Hz oscillation (origin probably vascular)
- Why we do this:
  - More accurate removal of physiological noise
  - Effects of oscillations to connectivity analysis
- DRIFTER [1,2] algorithm used for signal separation
- Result: Amplitude and latency maps of the signals

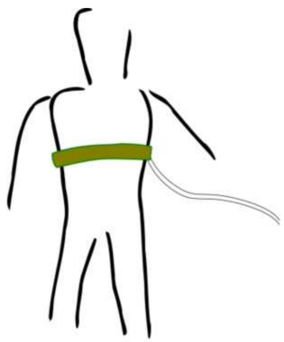
[1] Särkkä et al. (2011). Proc. ISMRM 2011;19:3592
[2] Särkkä et al. (2012). Neuroimage 60;2:1517-1527

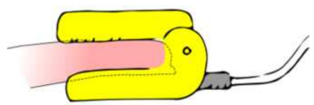
Experimental data

- 1 volunteer, 2 slices, TR 100 ms
- 3 T scanner, 16-channel coil, 64x64 matrix
- Visual stimuli in the center of the visual field
- 15 s/7 s blocks of stimulus on/off
- Reference signals:
  - cardiac pulse measure
  - respiratory belt
  - averaged fMRI signal for the 0.1 Hz oscillation



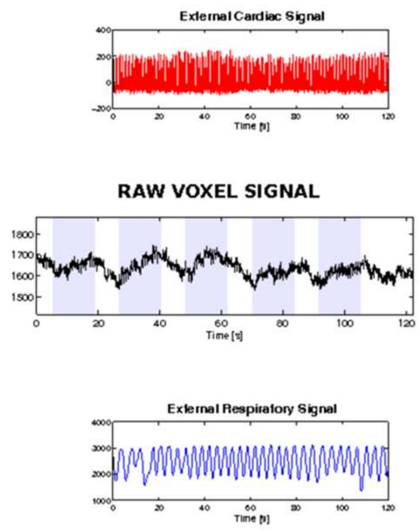
Slice orientation

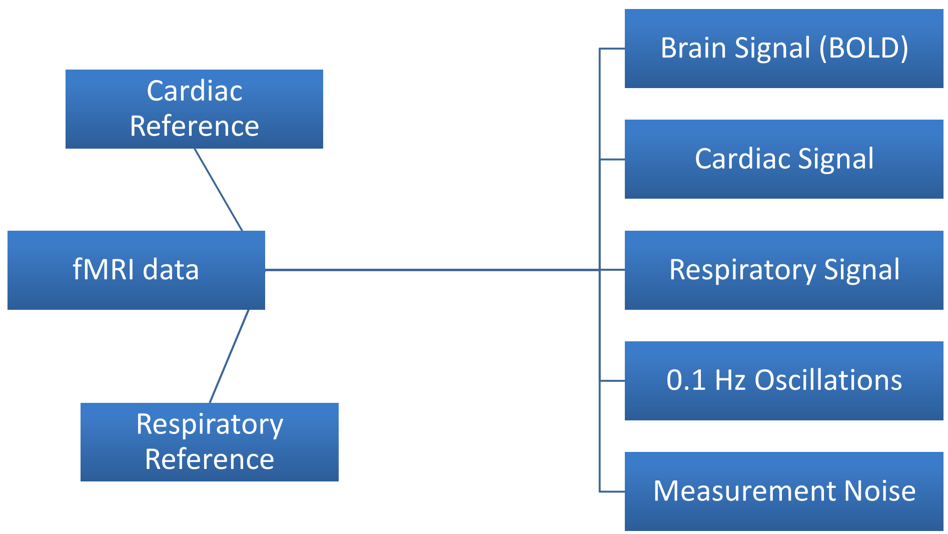




DRIFTER-algorithm: Reference signals

- Frequencies of cardiac and respiration from reference signals with IMM algorithm
- Frequency of 0.1 Hz oscillation from spatially averaged data with IMM algorithm

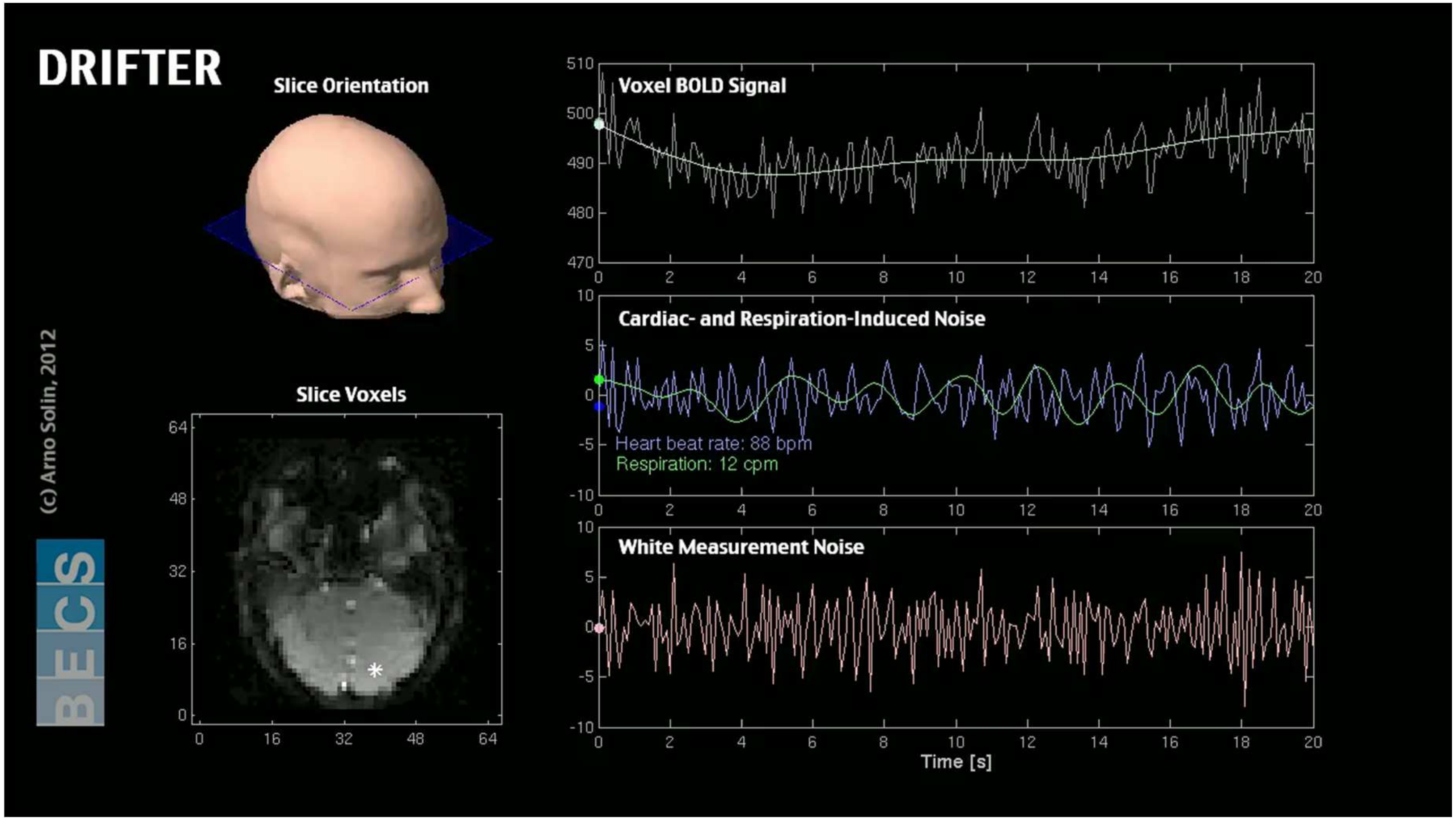




DRIFTER-algorithm: State-space model

- Cardiac, respiration and 0.1 Hz oscillation modeled as stochastic resonators
- The extension to DRIFTER [1,2] is to have the 0.1 Hz oscillation as well
- DRIFTER state contains brain activations and oscillators at each voxel
- Only sum of activations and oscillators at each voxel is measured
- States at each voxel estimated with Kalman filter and smoother (as in DRIFTER, see [2])

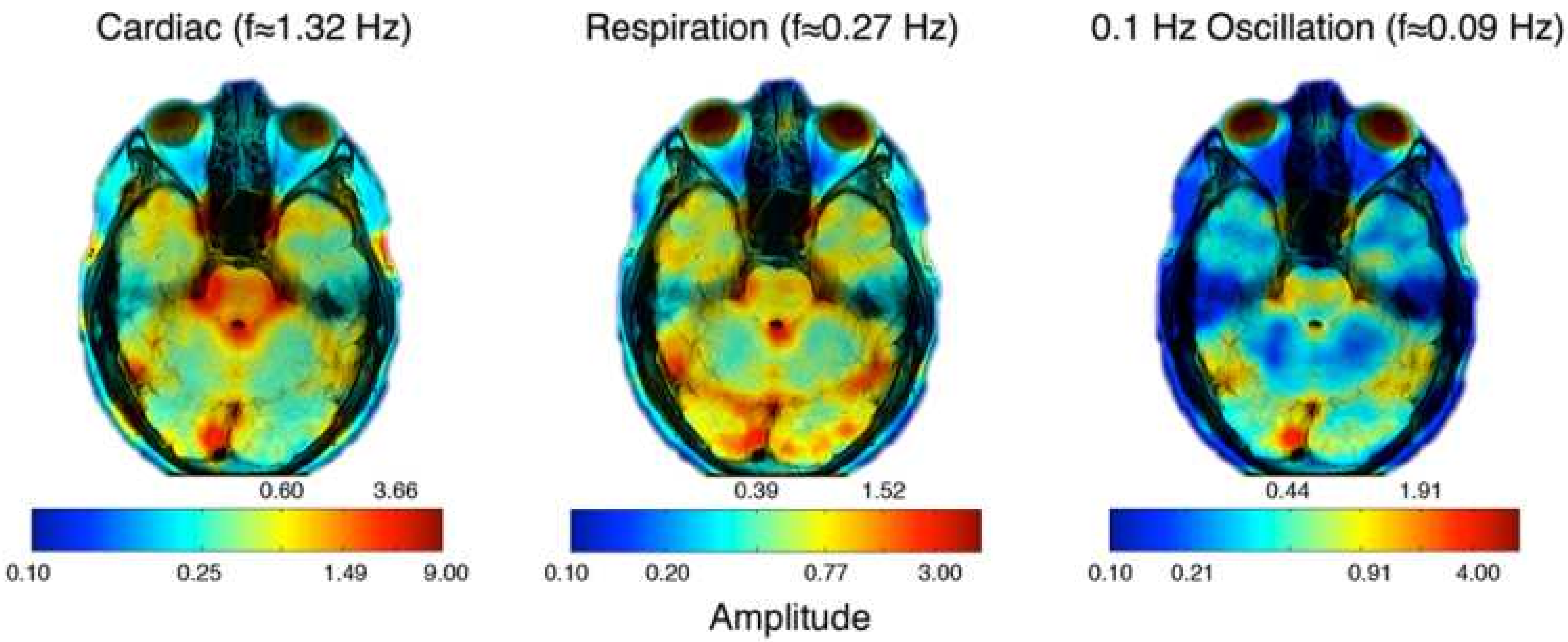
DRIFTER-algorithm: Illustration



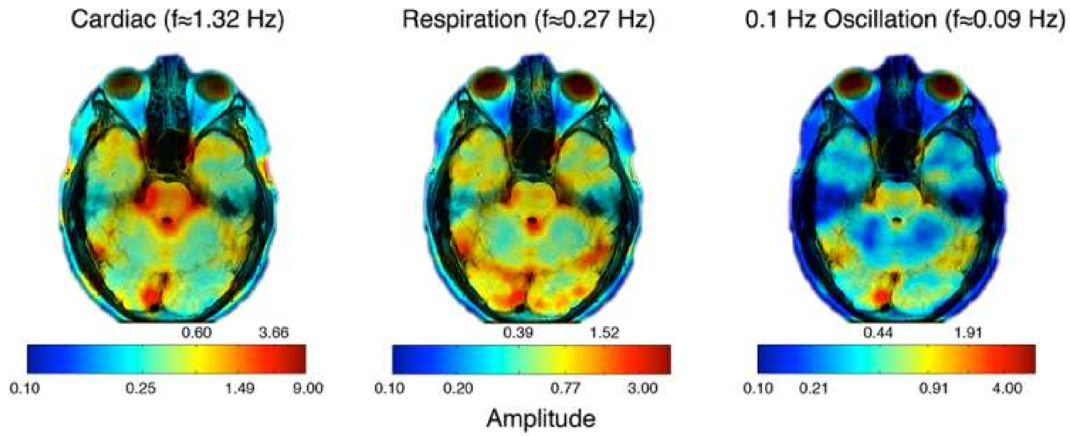
Amplitude and Latency Estimation

- Amplitude and latency maps were generated from DRIFTER results
- Computed from the lowest harmonics of oscillators:
  1. Form complex analytic signals at all voxels
  2. Apply Gaussian smoothing filter
  3. Compute amplitudes from magnitudes
  4. Latencies from the phase differences

Amplitude Results

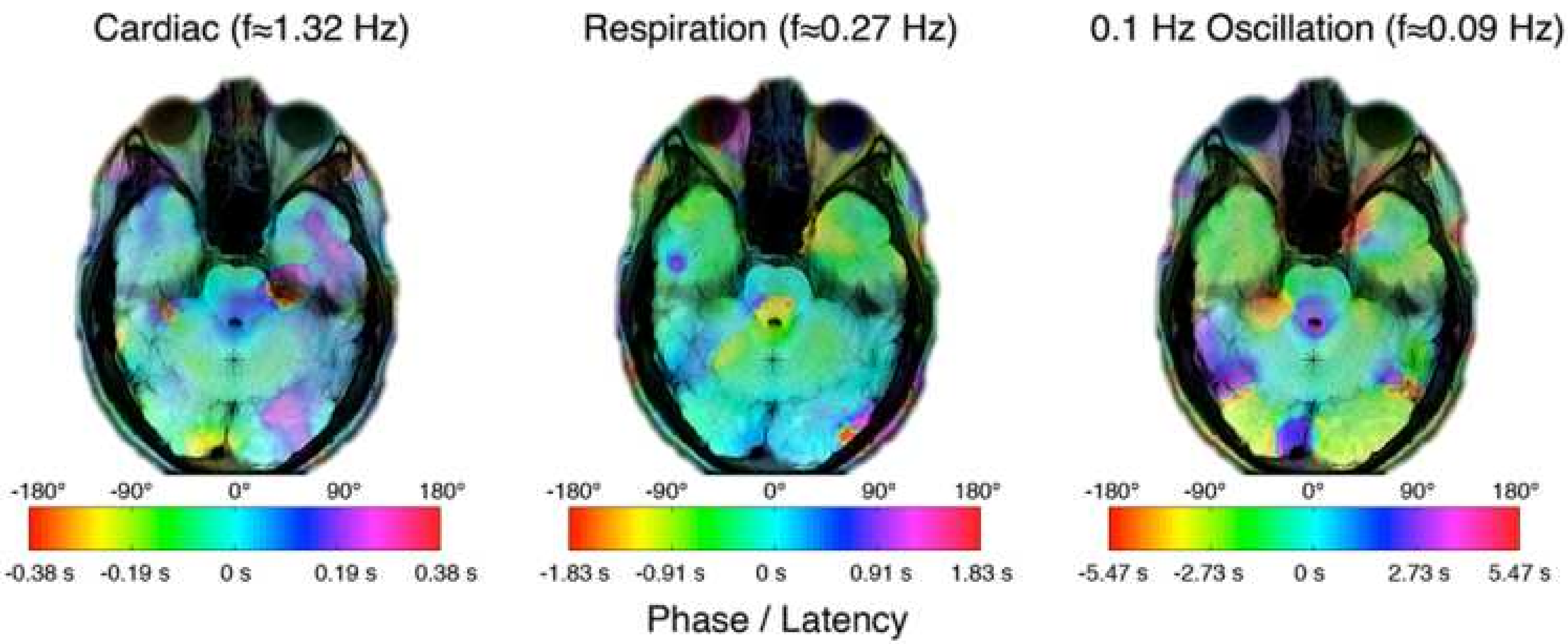


Analysis of Amplitude Results

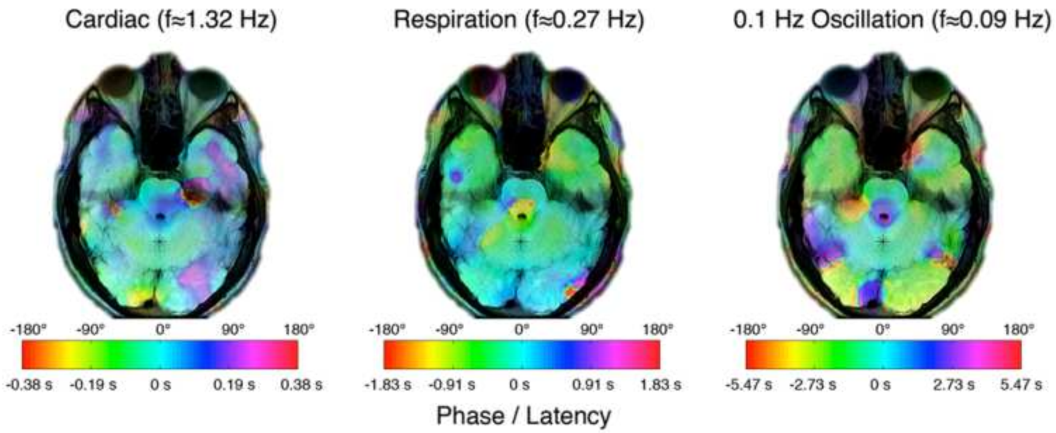


- Non-uniform amplitudes in all the signals
- Cardiac strong near circle of Willis and near the posterior cerebral artery
- Respiration and 0.1 Hz oscillation similar to cardiac
- Could be used as prior models in DRIFTER

Phase Results



Analysis of Phase Results



- High-amplitude area of cardiac on V1 in 90° phase shift to extrastriate visual cortex
- The same effect can be seen in the 0.1 Hz oscillation signal
- Cardiac signals in the occipital lobe in 180° phase shift between hemispheres
- 0°, 90°, and 180° imply correlations 1, 0, and -1, which has effect to connectivity analysis

Conclusion

- Physiological oscillations in fMRI have non-uniform amplitude and latency distributions
- Similarity of 0.1 Hz oscillation with cardiac implies vascular origin (e.g., Traube-Hering-Mayer wave)
- Respiration is more uniform than cardiac and 0.1 Hz oscillation
- Strongest amplitude and phase differences near circle of Willis and posterior cerebral artery
- Amplitude and phase maps could be used as prior models in DRIFTER
- Phase shifts in cardiac signals can have effect to connectivity analysis if not accounted for