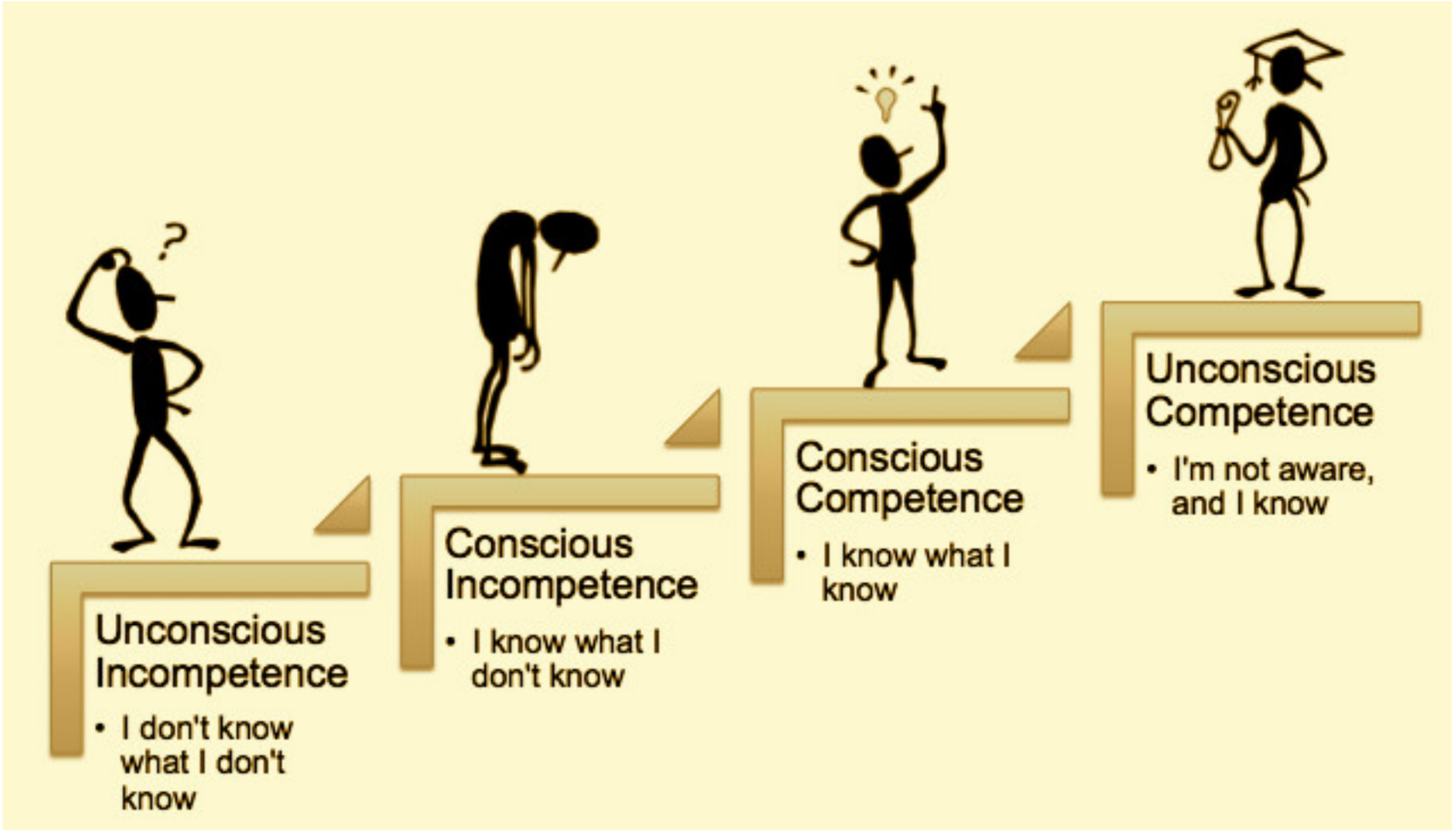
Quality Matters

How to distinguish good quality fNIRS data from the bad

Danielle Evenblij 28-06-23 - HBCI group

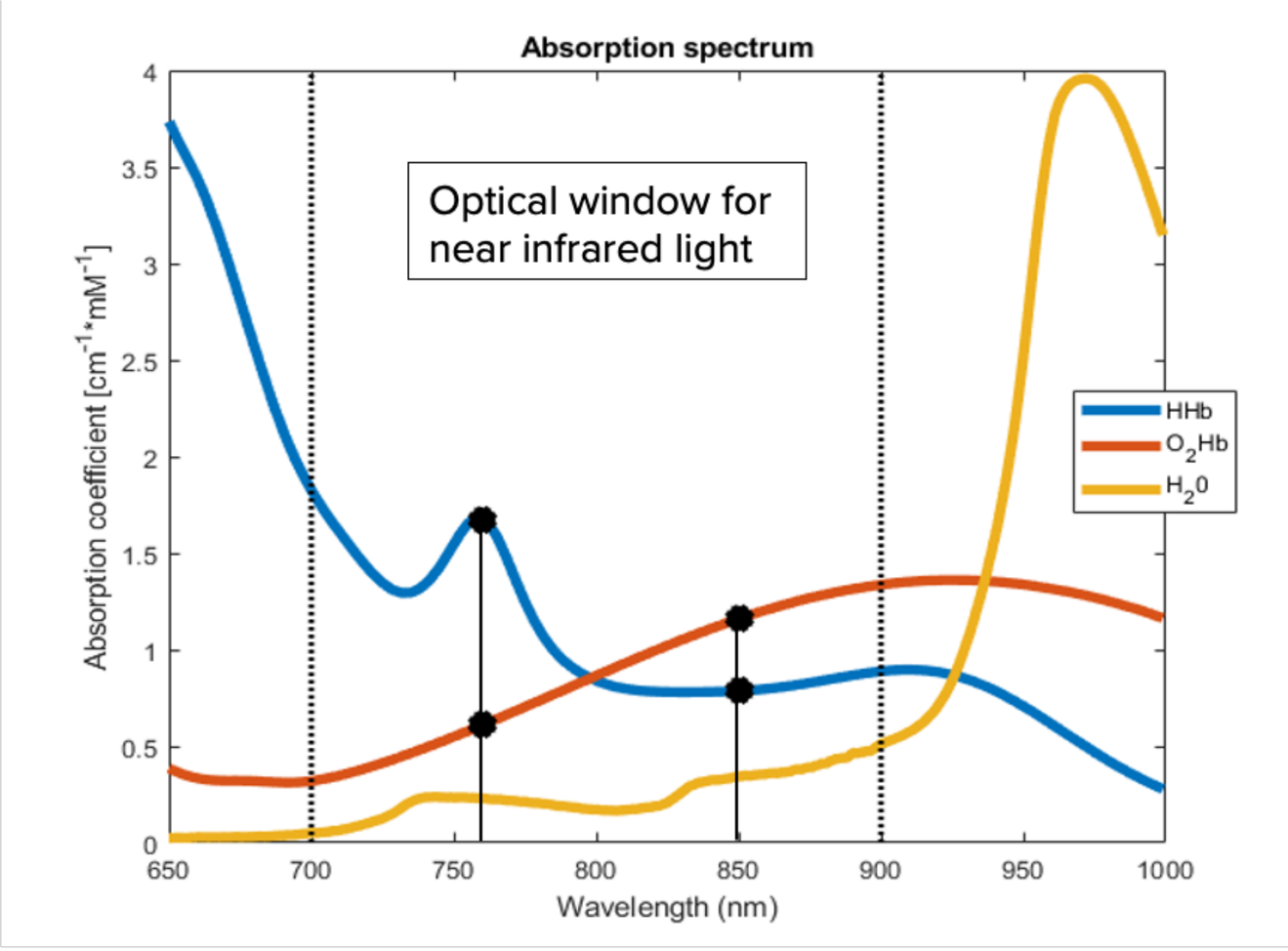
Disclaimer:


Unconscious Incompetence
• I don't know what I don't know
Conscious Incompetence
• I know what I don't know
Conscious Competence
• I know what I know
Unconscious Competence
• I'm not aware, and I know

fNIRS basics

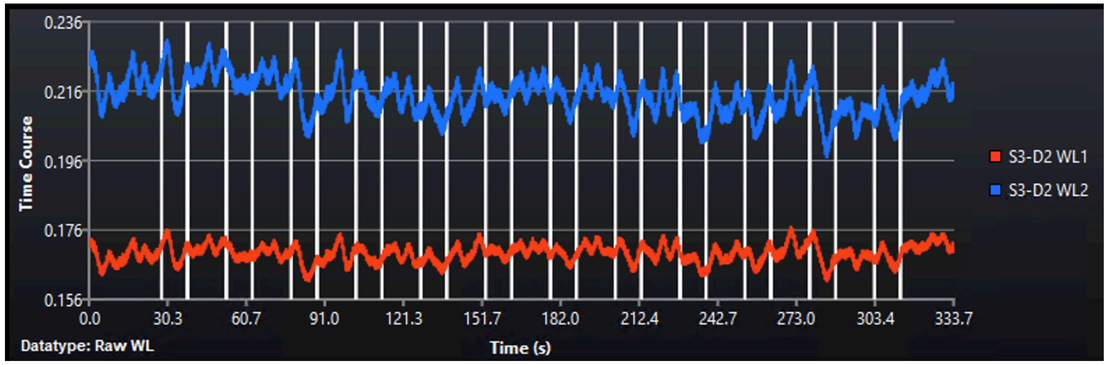
Optical window of near infrared light for measuring brain activity

- Optical window of near infrared light: **700 nm – 900 nm**
- <700 nm: biological tissue (containing **oxygenated** and **deoxygenated** hemoglobin) is the main absorber
- >900 nm: **water** is the main absorber
- Our wavelengths: 760 nm and 850 nm

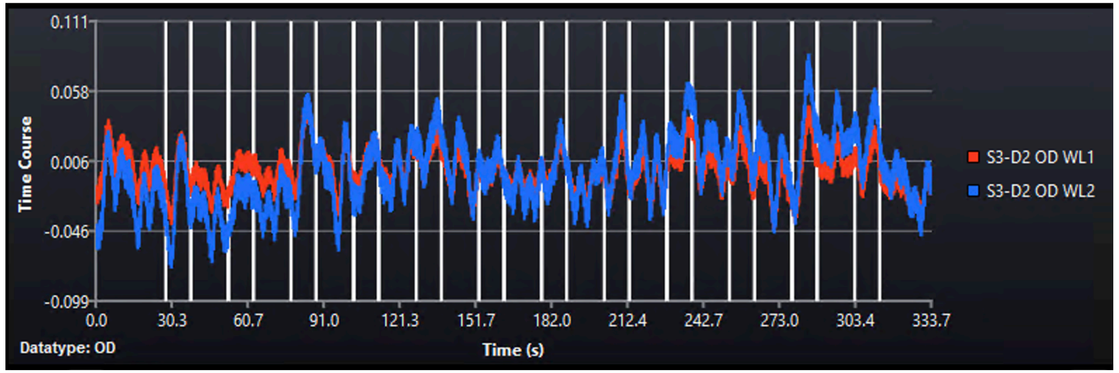


fNIRS basics: terminology

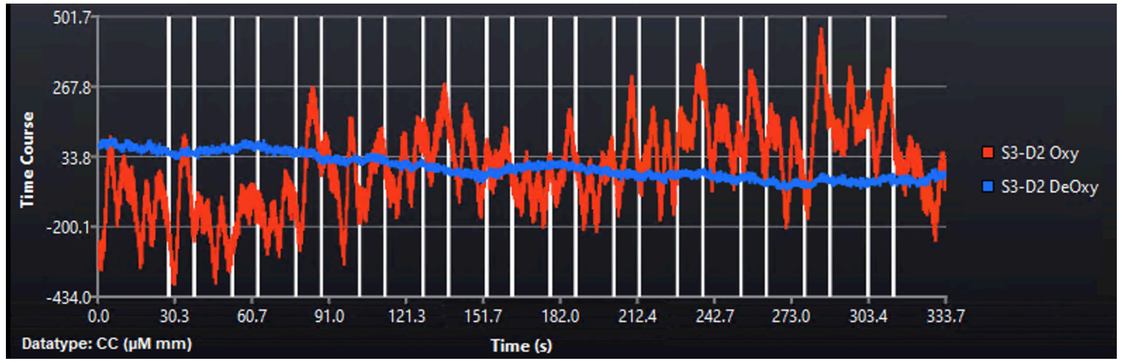
Raw wavelength data (raw) = Intensities of the detected light absorption at wavelengths 760nm and 850 nm.



Optical density data (OD) = a logarithmic intensity *ratio* of the detected light absorption for the two wavelengths (so effect of individual differences in light source intensity, detector sensitivity, and tissue scattering is reduced).



Chromophore concentration data (CC) = estimates of the *concentration* of oxyhemoglobin (HbO) and deoxyhemoglobin (HbR) in the brain tissue.

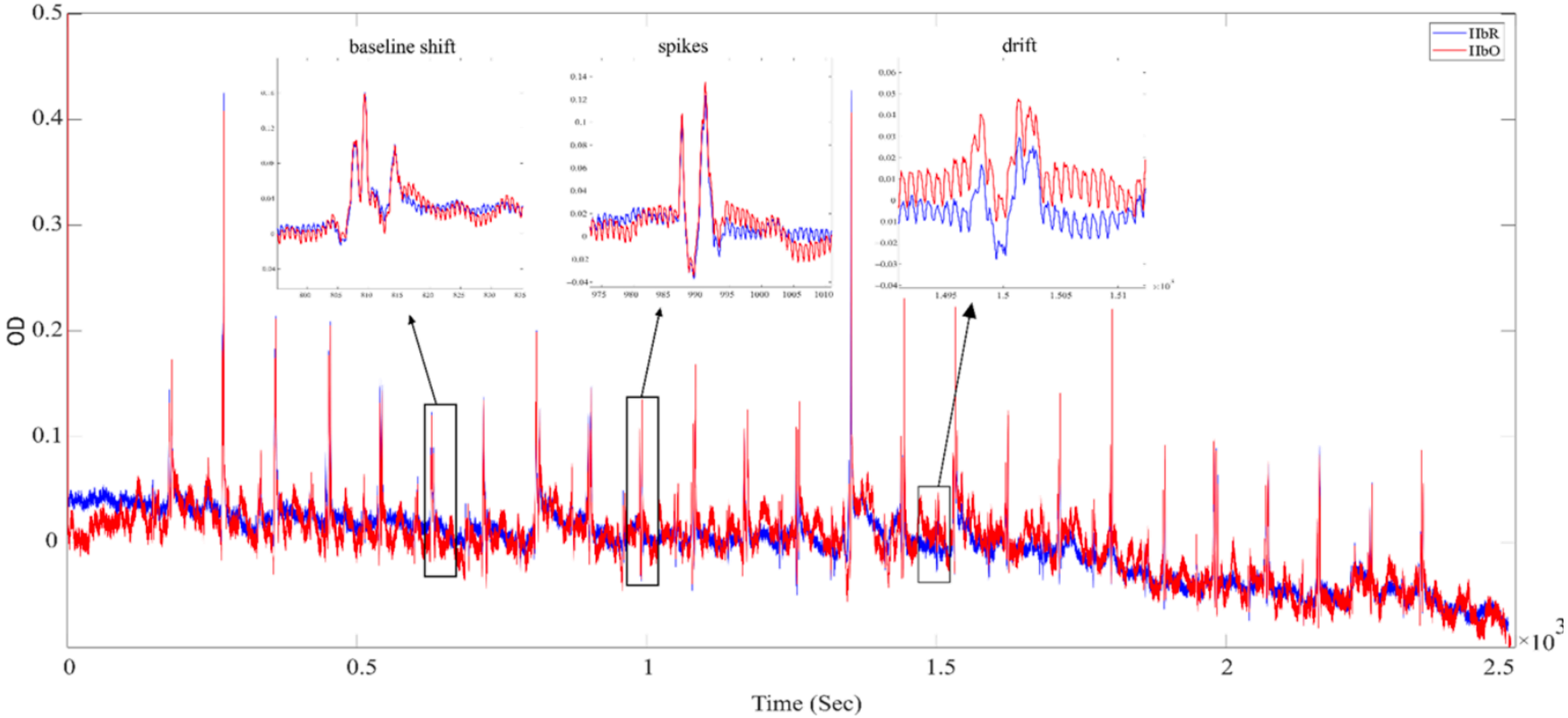


Chromophores = chemical groups absorbing light at specific wavelengths (like HbO and Hb)

Noise and artifacts

- **Motion artifacts**
  - Spikes (sharp high frequency displacements)
  - Baseline shifts
  - Slow wave drifts (<0.1Hz)

Al-Omairi et al. (2023)

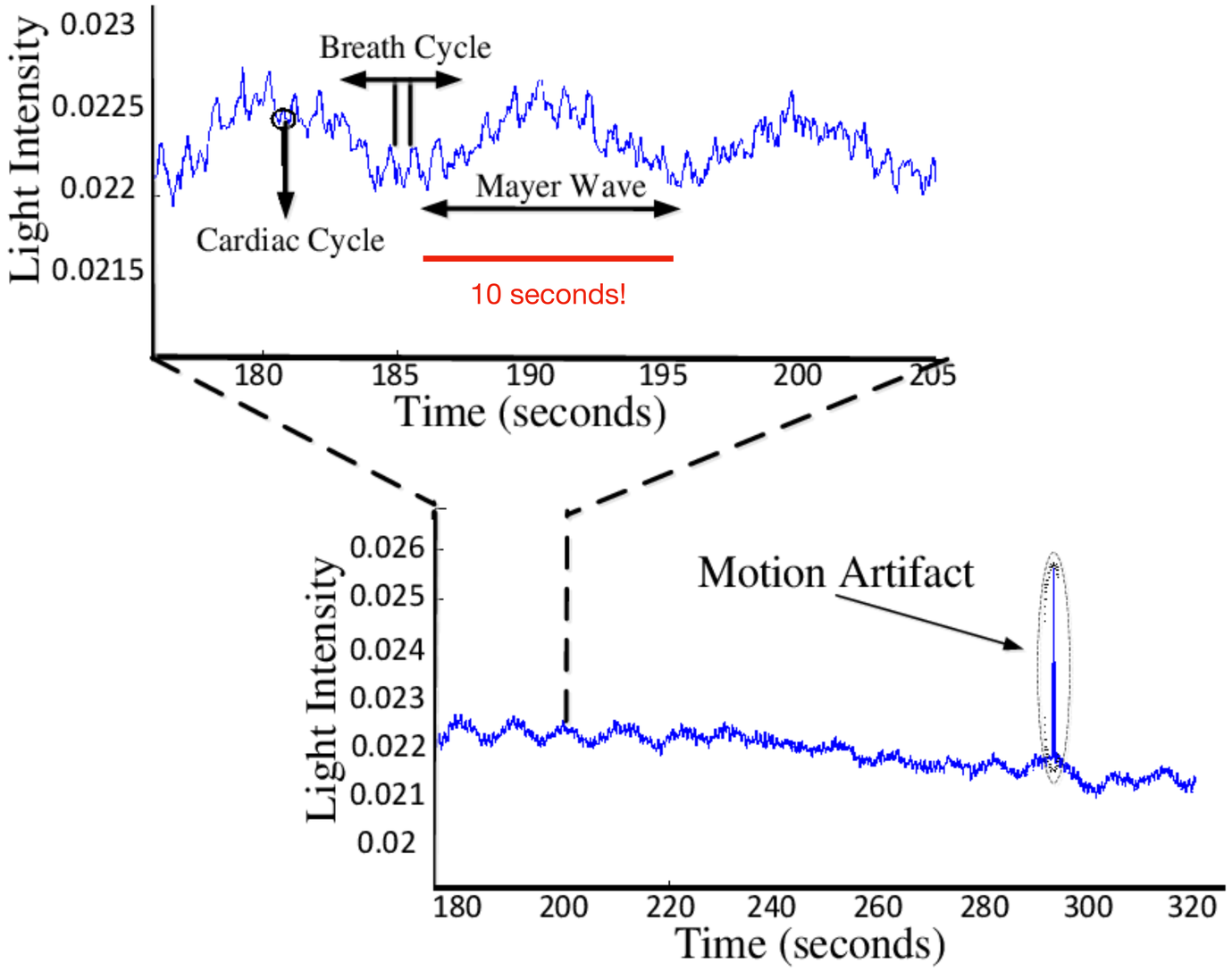


Noise and artifacts

Physiological noise

- Heart beat/cardiac cycle (0.8 - 2.0 Hz)
- Mayer waves (0.1 Hz)
- Respiratory rate (~0.1 to 0.3 Hz)

Chaddad (2014)



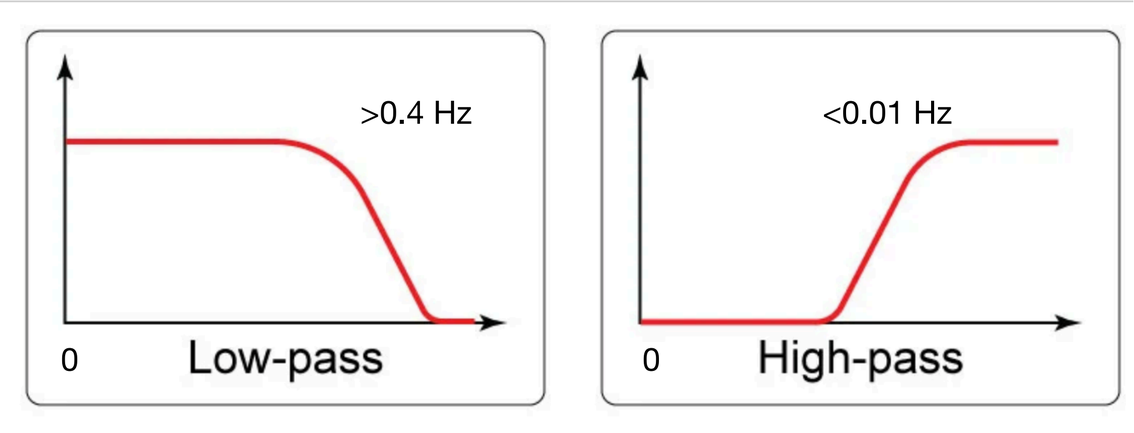
Filtering out noise and artifacts

- **Removing motion artifacts**
  - Spike removal
  - Temporal Derivative Distribution Repair (TDDR)
- **Removing physiological noise**
  - High-pass filtering
  - Low pass filtering
  - Linear detrending

Question

- What do we remove with a *low-pass* filter of 0.4 Hz?
- What do remove with a *high-pass* filter of 0.01 Hz?

- Remember:
  - 0.8 - 2 Hz: Heart beat
  - 0.1-0.3 Hz: Respiratory cycle
  - 0.1 Hz: Mayer waves
  - <0.2 Hz: Slow wave drifts



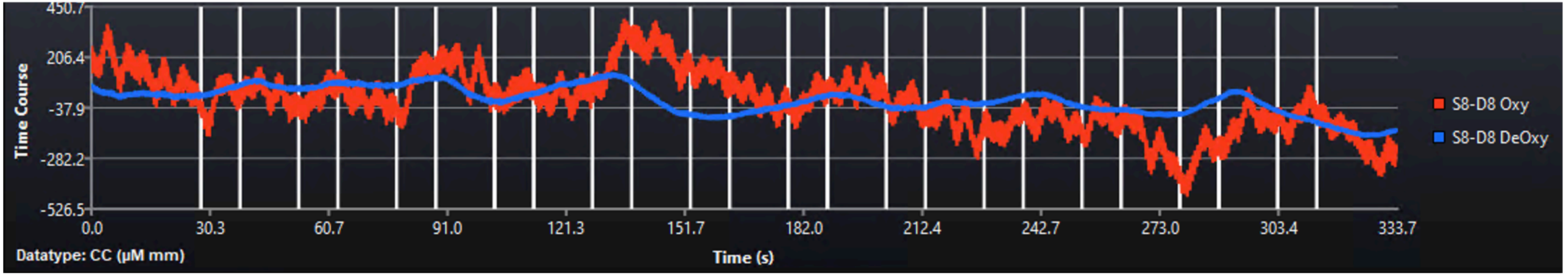
Eyeballing your data - why?

- It’s fast
- Sanity check
- Getting an intuition for what good data looks like

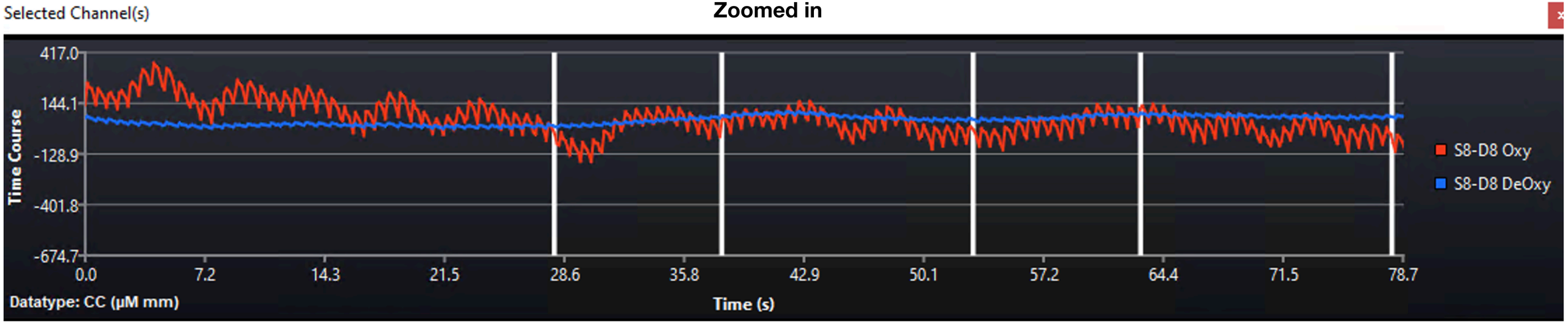
Example 1: Inspecting CC signal (Satori)

Looking at oxy and deoxy

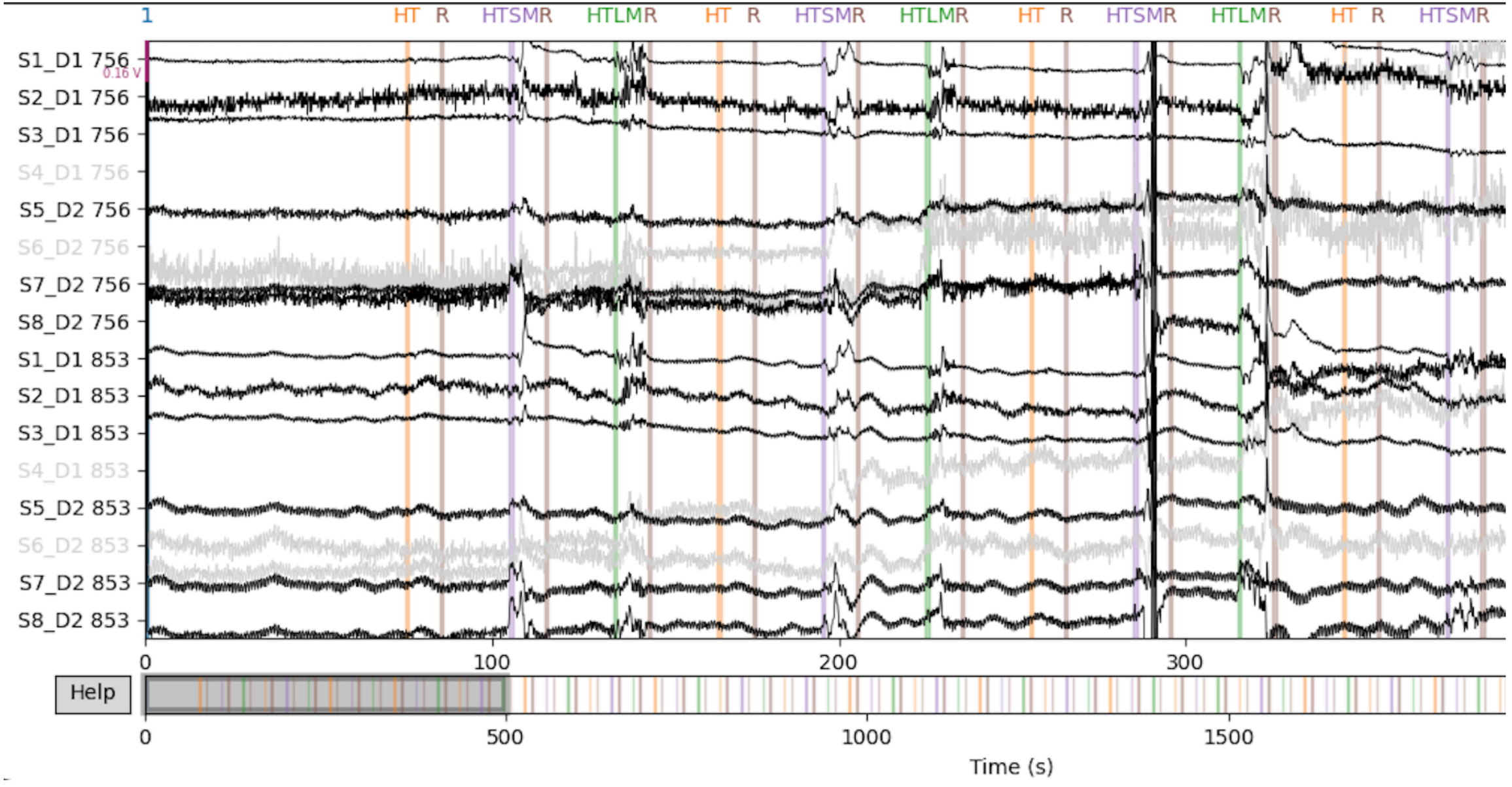
Zoomed out



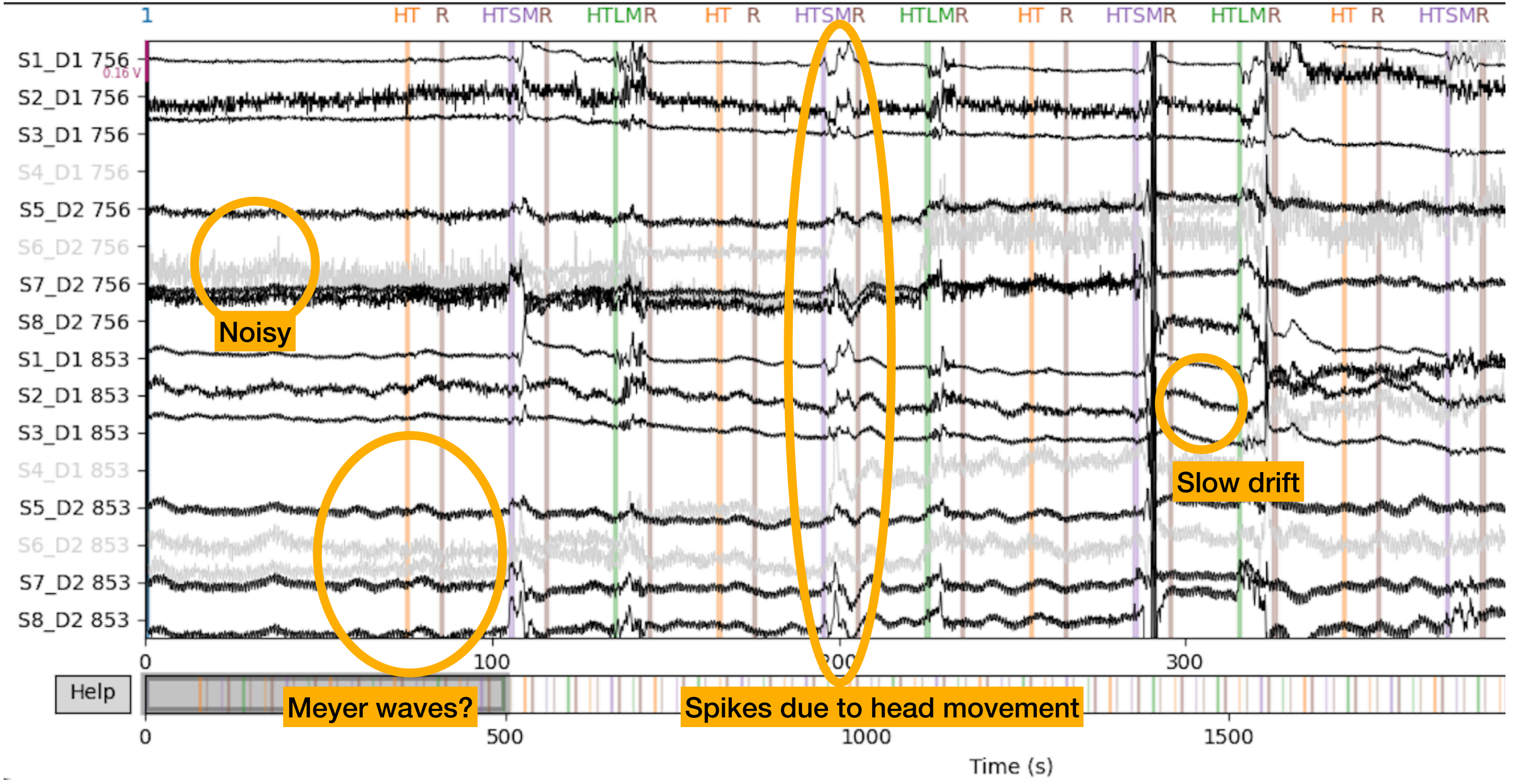
Zoomed in



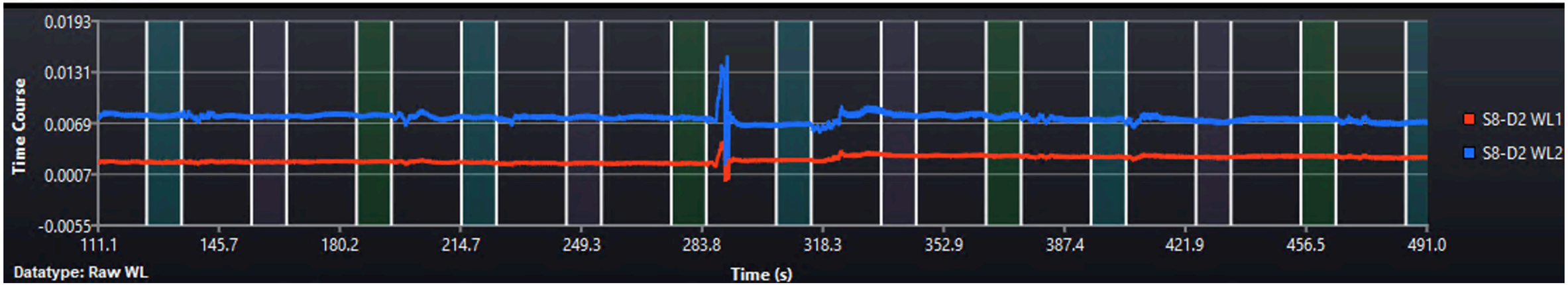
Example 2: Inspecting raw signal (Python)



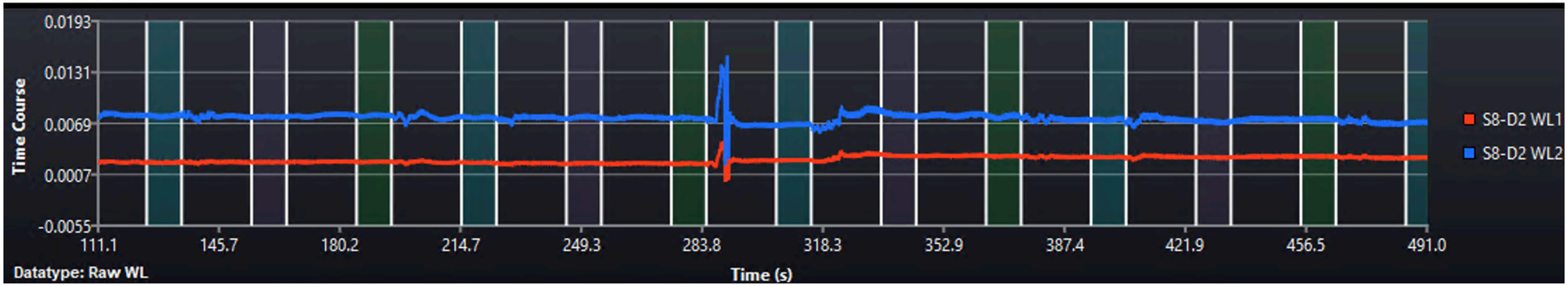
Example 2: Inspecting raw signal (Python)



Example 3: Inspecting raw signal (Satori)

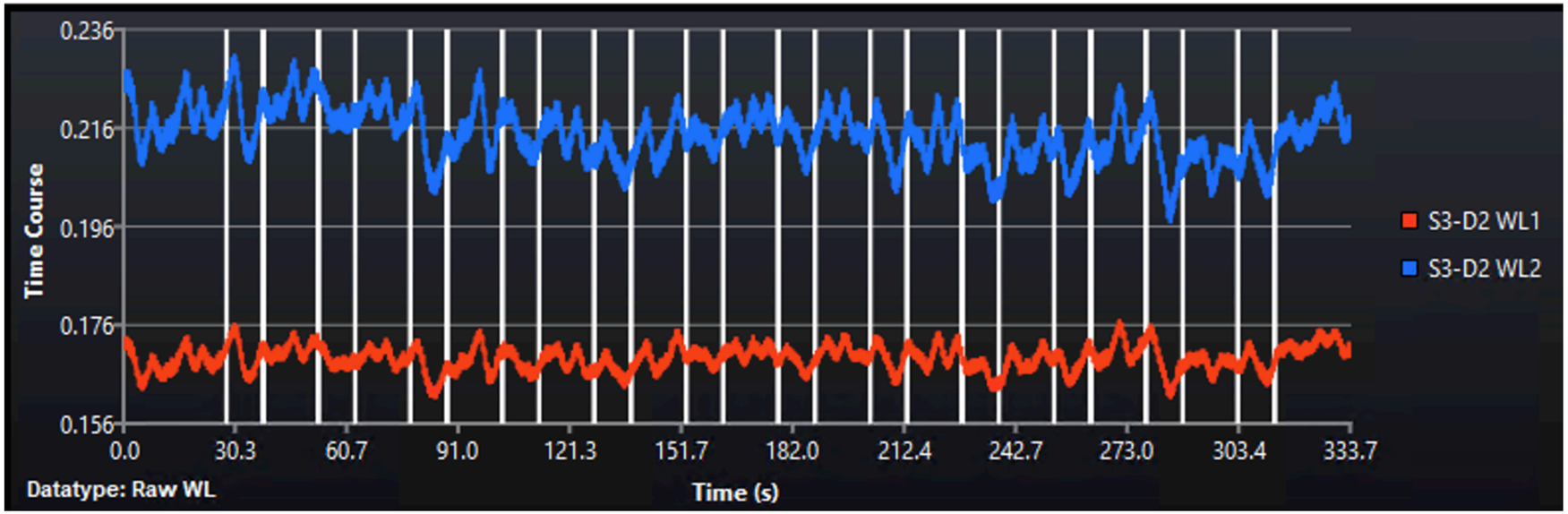


Example 1: Inspecting raw signal

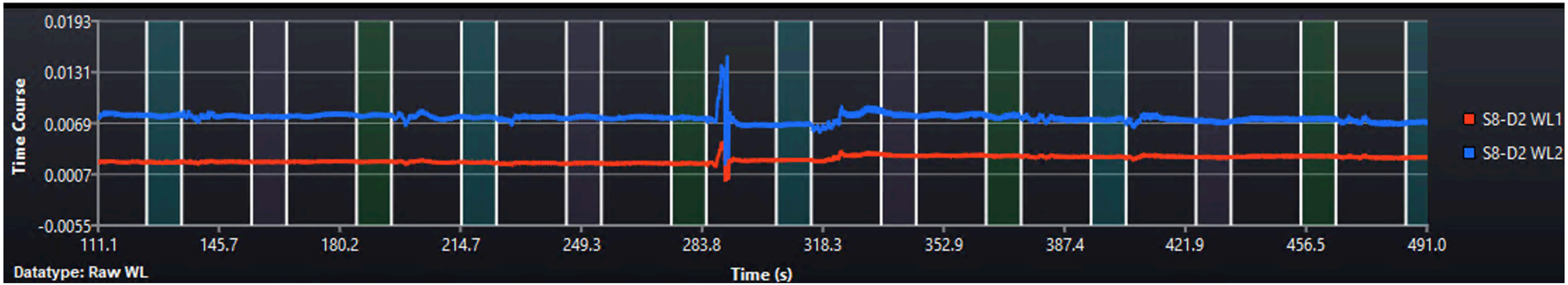


vs.

Luhrs fingertapping



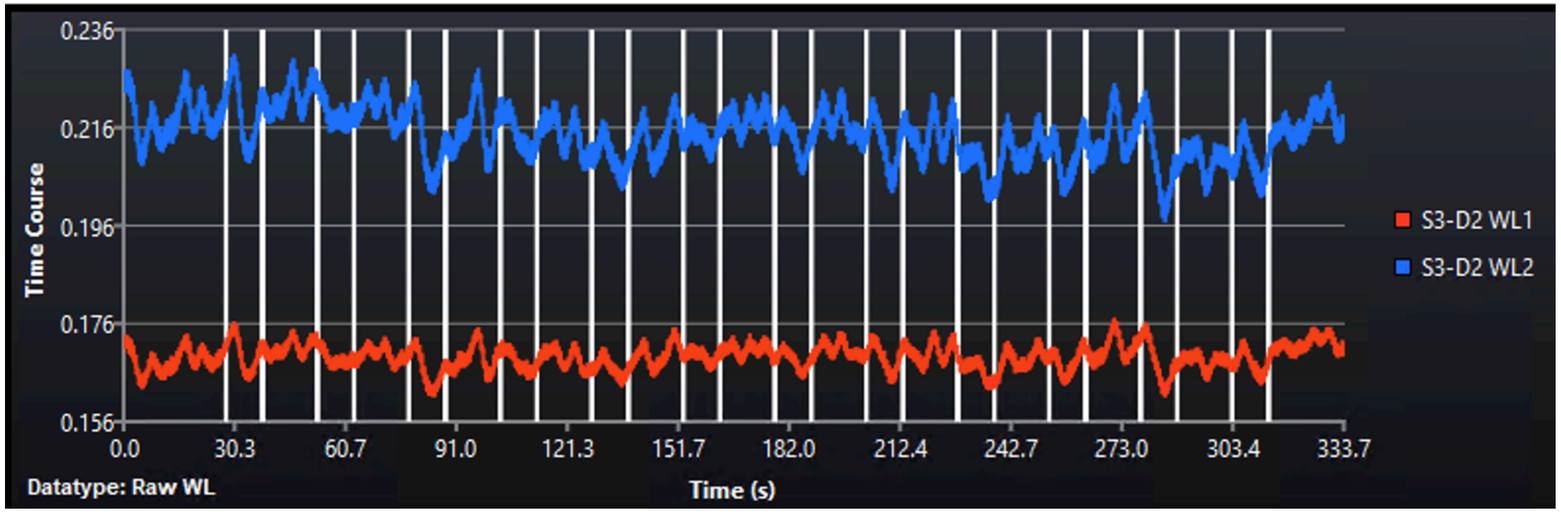
Example 3: Inspecting raw wavelength signal



vs.

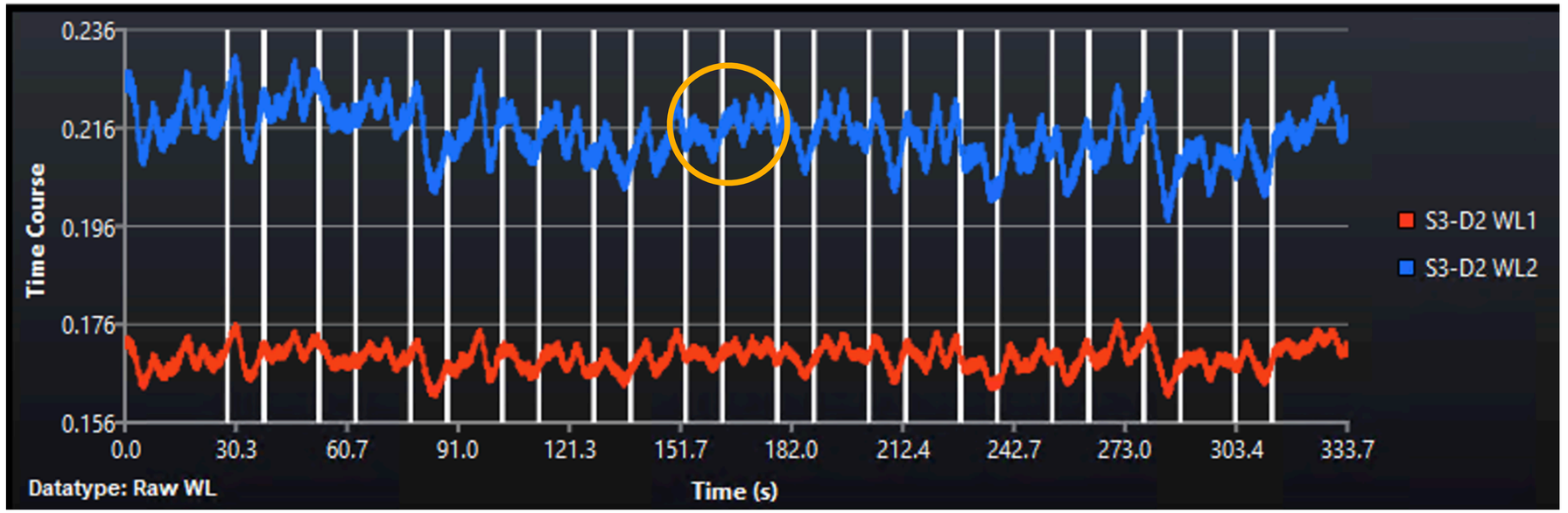
Luhrs fingertapping

- Spike
- No heart beat!
- Bad optode-scalp coupling



Optode-scalp coupling

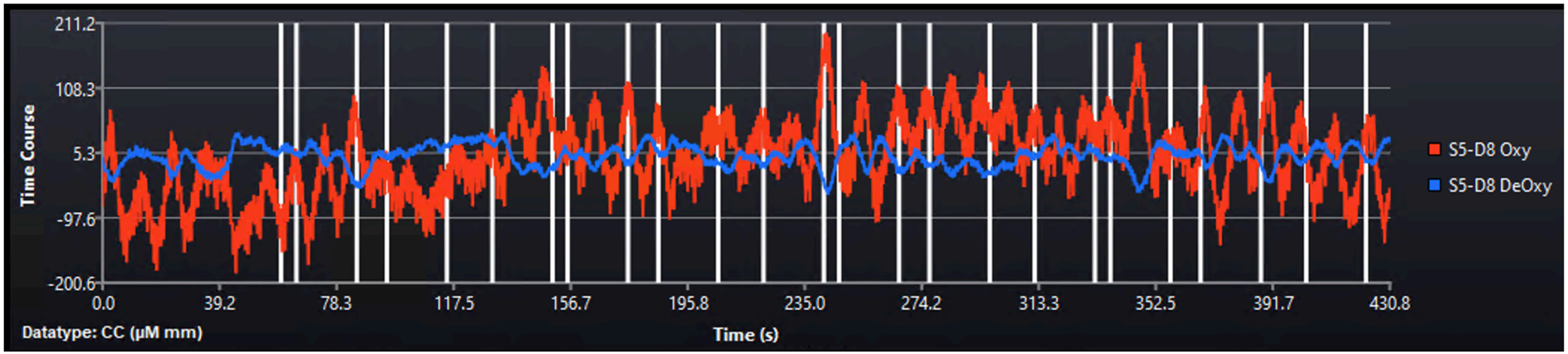
- = the proper placement of the optodes on the head (to maximise the transfer of light across the optodes to the scalp).
- With proper optode-scalp coupling, the *heartbeat* (~ 1.2 Hz) is clearly visible in the raw fNIRS signal.



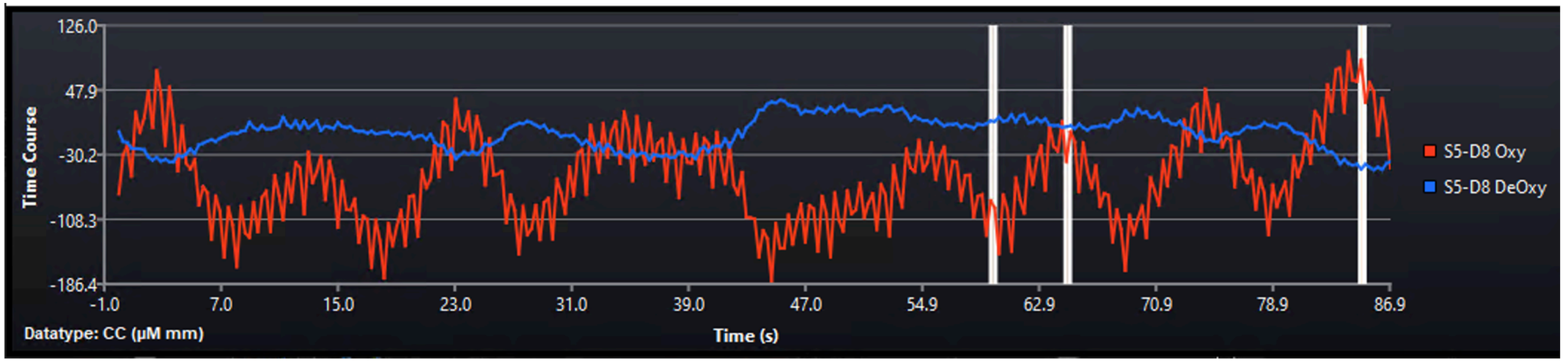
Example 4: Inspecting CC signal (Satori)

Looking at oxy and deoxy

Zoomed out



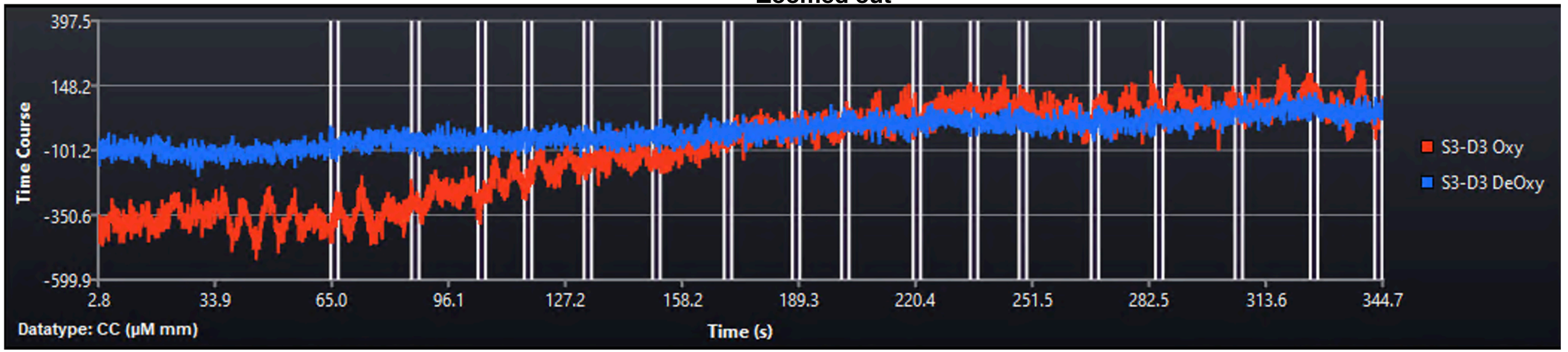
Zoomed in



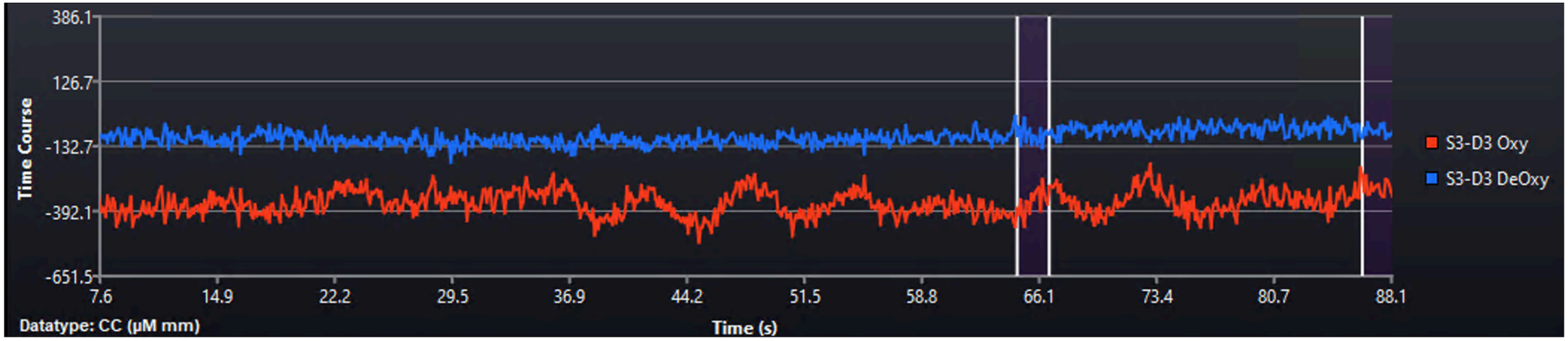
Example 5: Inspecting CC signal (Satori)

Looking at oxy and deoxy

Zoomed out



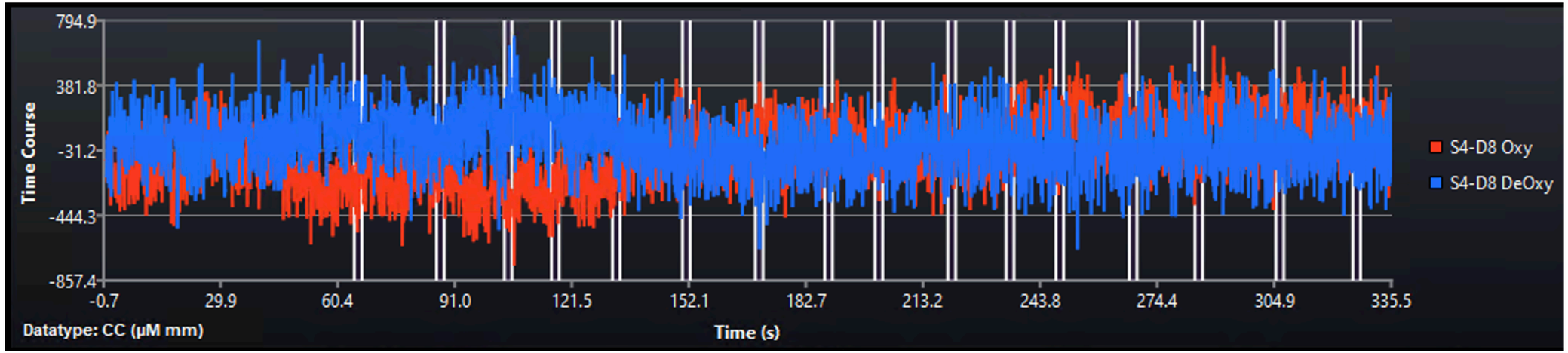
Zoomed in



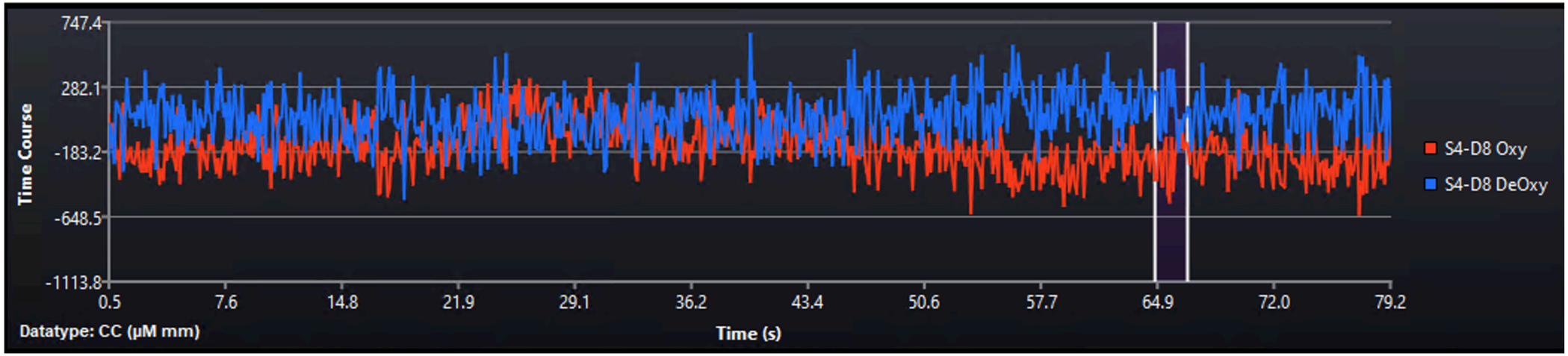
Example 6: Inspecting CC signal (Satori)

Looking at oxy and deoxy

Zoomed out



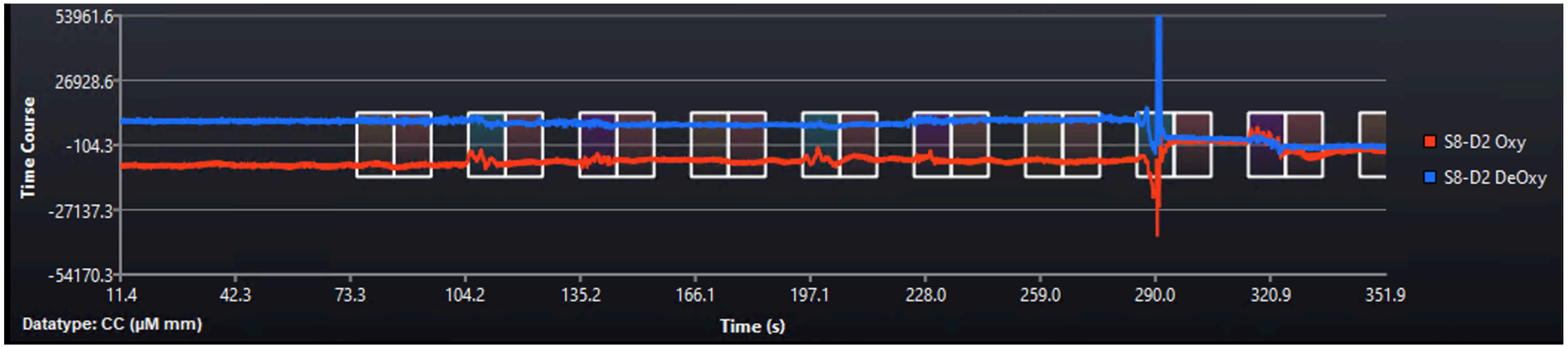
Zoomed in



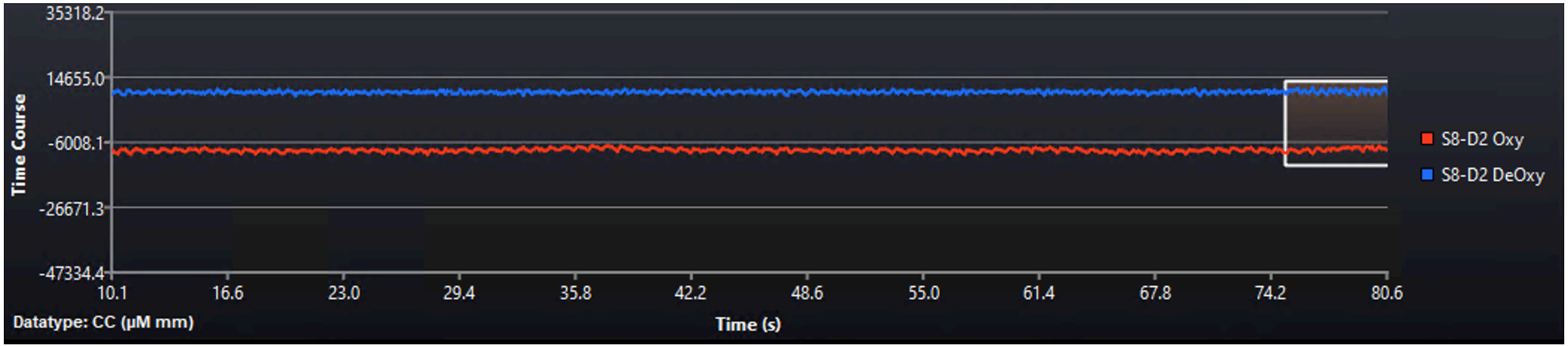
Example 7: Inspecting CC signal (Satori)

Looking at oxy and deoxy

Zoomed out



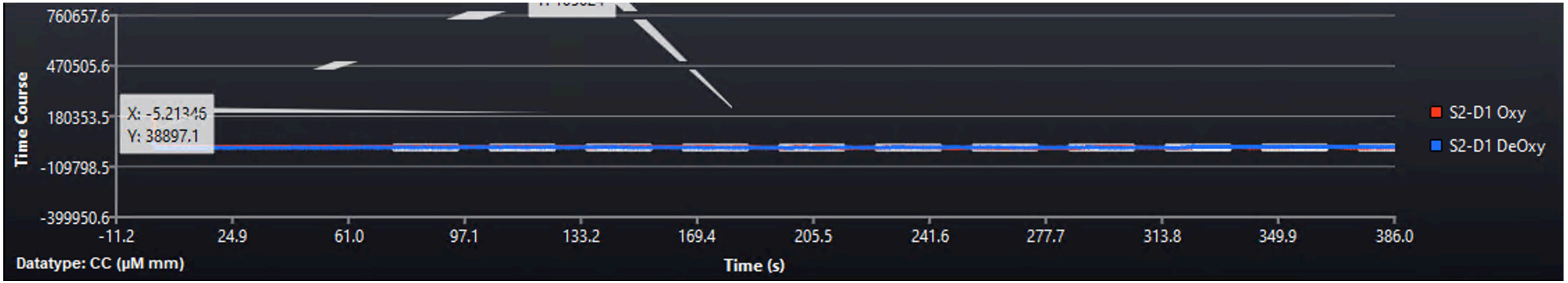
Zoomed in



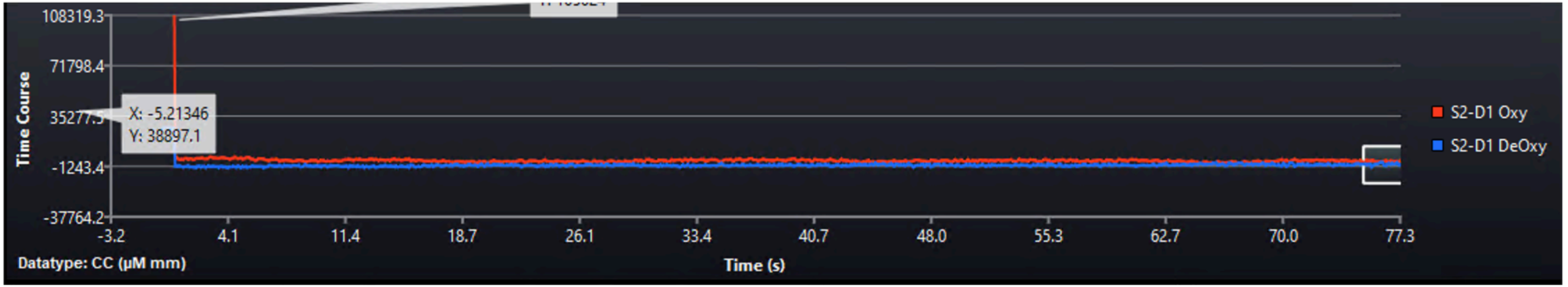
Example 8: Inspecting CC signal (Satori)

Looking at oxy and deoxy

Zoomed out



Zoomed in



Quality checks to perform on your data

Channel rejection methods

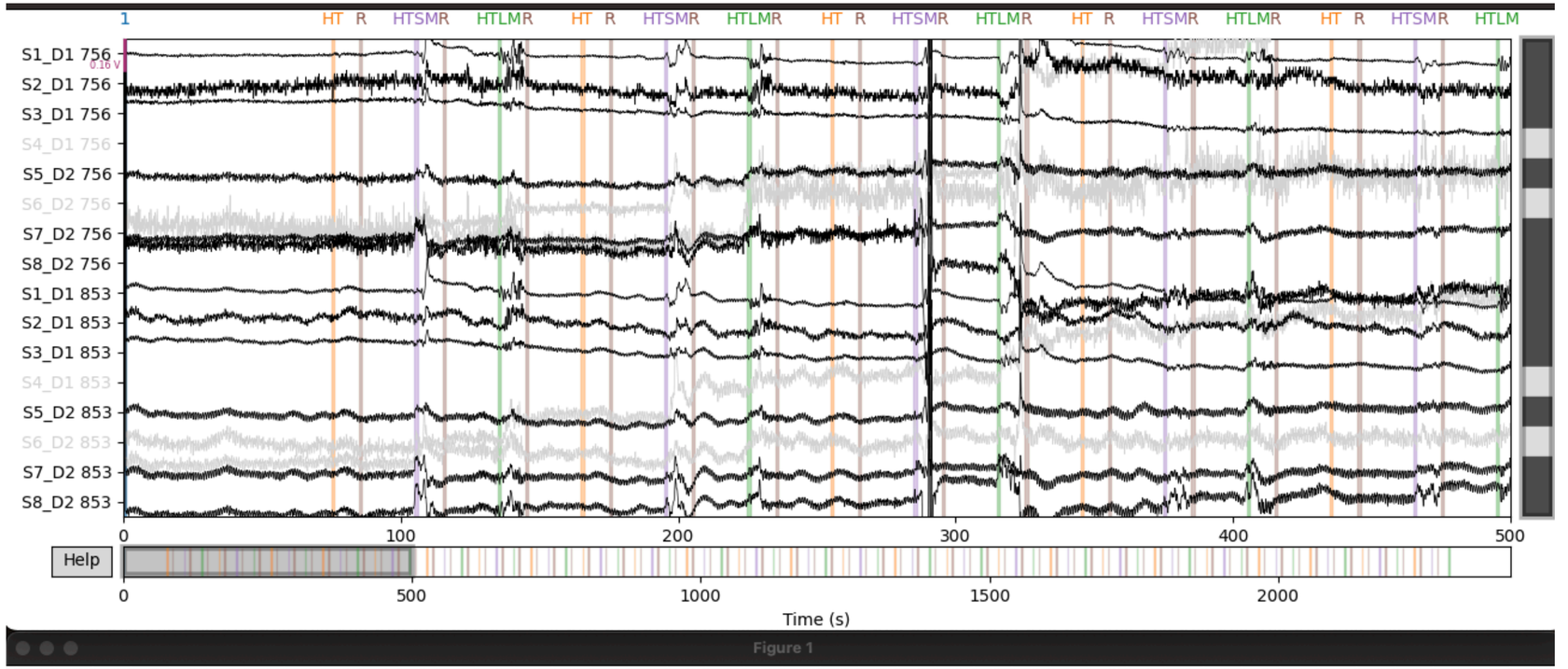
- **Scalp-coupling index (SCI)** - Pollonini et al. (2014)
  - Filters the signal (0.5 - 2.5 Hz) to preserve only the hearbeat band before the correlation between both OD wavelength is calculated.
  - Correlation is between the wavelenghts is a measure of the signal-to-noise ratio for that channel.
  - Channels with correlation below 0.75 are rejected.
- **Coefficient of variation (CV)** - Morais et al. (2018)
  - CV(%) = 100 * std(data) / mean(data).
  - The threshold defines the minimal % variation allowed.
  - 7% is conservative and 10% a more liberal threshold.
  - Performed on raw data.

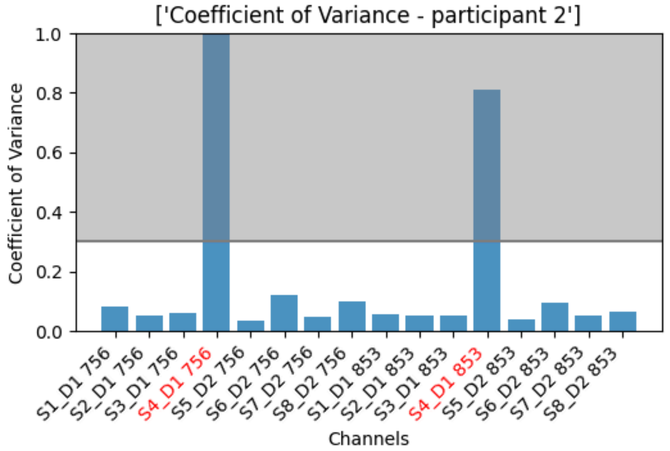
Pollonini L, Olds C, Abaya H, Bortfeld H, Beauchamp MS, Oghalai JS. Auditory cortex activation to natural speech and simulated cochlear implant speech measured with functional near-infrared spectroscopy. Hear Res. 2014 Mar;309:84-93. doi: 10.1016/j.heares.2013.11.007. Epub 2013 Dec 14. PMID: 24342740; PMCID: PMC3939048.

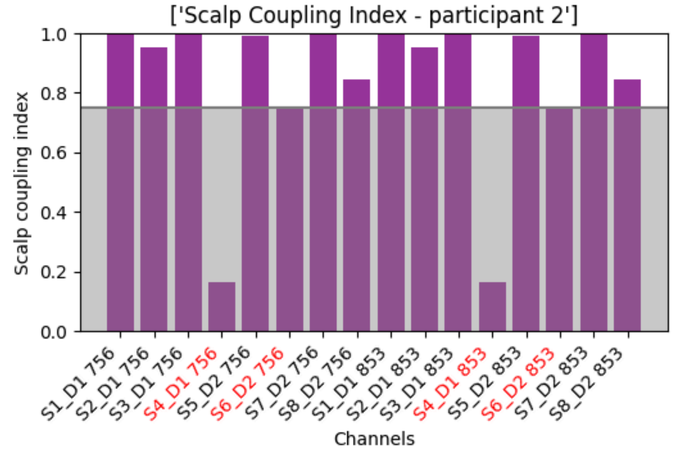
Zimeo Morais GA, Scholkmann F, Balardin JB, Furucho RA, de Paula RCV, Biazoli CE Jr, Sato JR. Non-neuronal evoked and spontaneous hemodynamic changes in the anterior temporal region of the human head may lead to misinterpretations of functional near-infrared spectroscopy signals. Neurophotonics. 2018 Jan;5(1):011002.

Quality checks to perform on your data

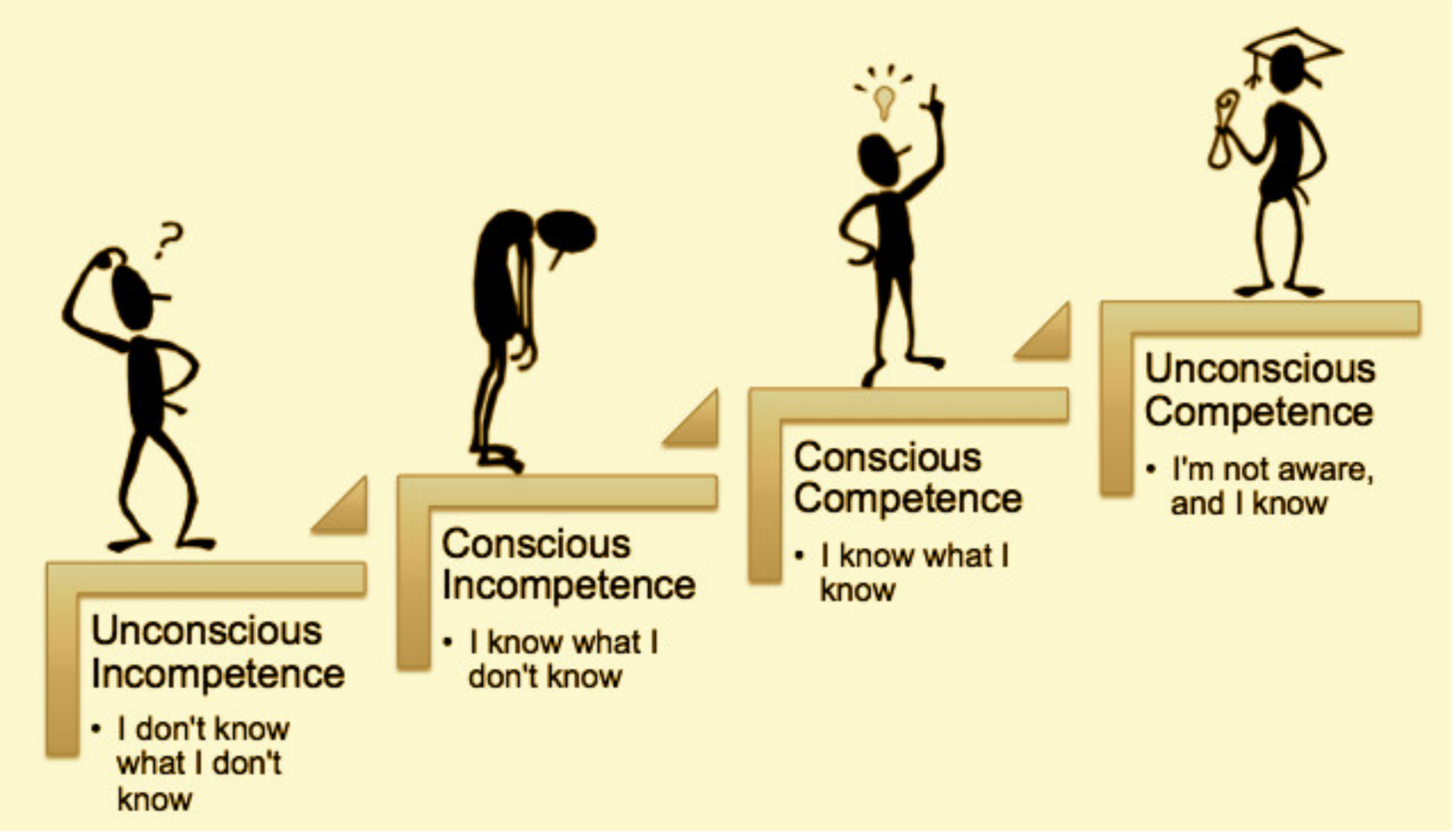
- Channel rejection
  - Scalp-coupling index (SCI)
  - Coefficient of variation (CV) ->
  -







Thank you!


Unconscious Incompetence
• I don't know what I don't know
Conscious Incompetence
• I know what I don't know
Conscious Competence
• I know what I know
Unconscious Competence
• I'm not aware, and I know