

Data-driven cortical clustering to provide a family of plausible solutions to the M/EEG inverse problem

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1 MOTIVATION

- Active source is represented as one **connected cortical region**, rather than a dipole.
- Several separated cortical regions can fit the data with similar accuracy. While convex optimization based methods give a single solution, we explore a **family of plausible solutions**.
- Estimate not only the position, but also **extension** of the region.

2 ASSUMPTIONS

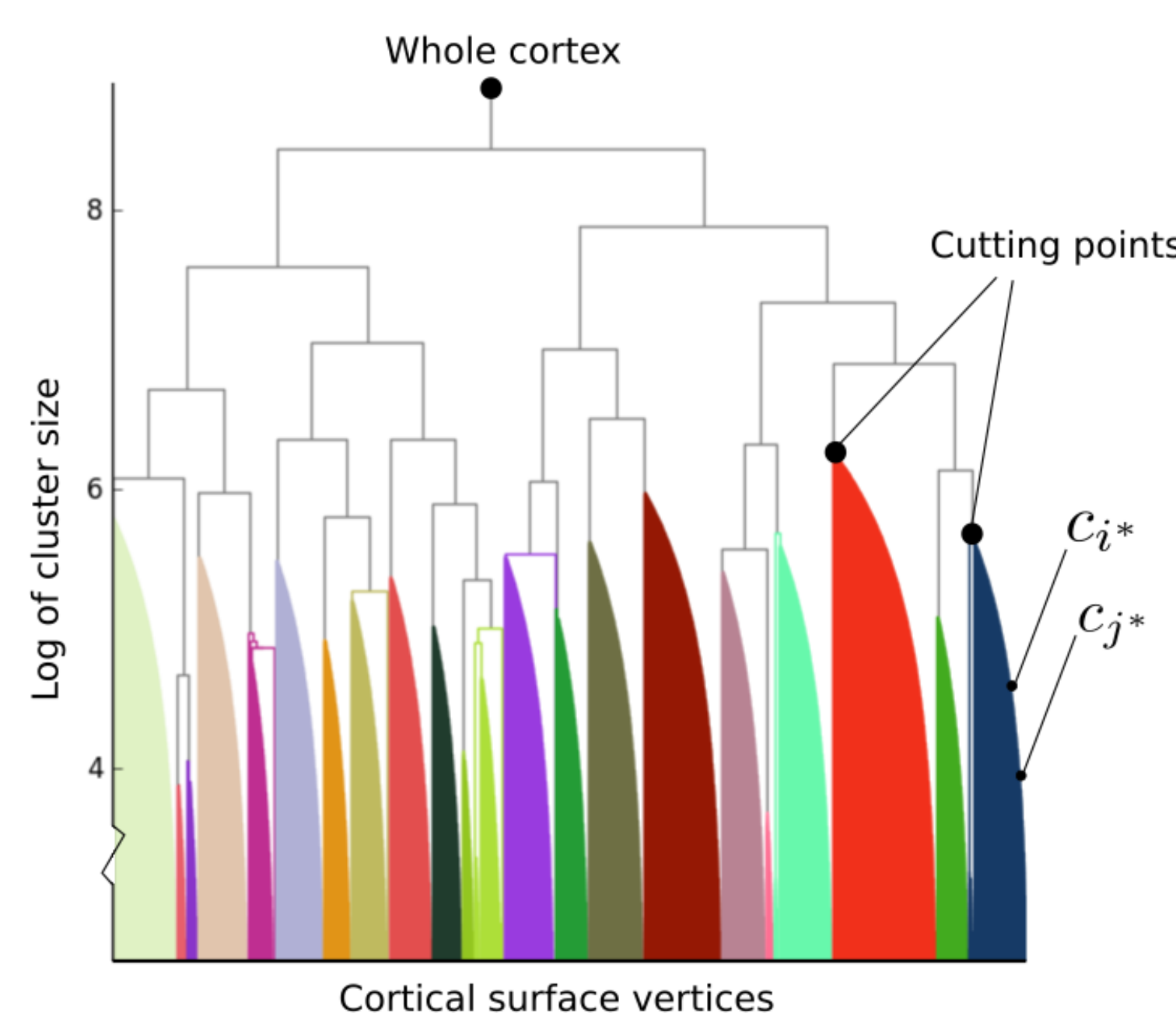
- Data model: $y = Lx + N$ (L is a lead field)
- Source space: cortical mesh
- Brain activity \mathcal{X} : single region with a constant amplitude over this region; one time sample

3 METHOD

Adapting **hierarchical clustering** algorithm [1] to fit M/EEG data :

- Mesh vertices represent initial clusters. Mesh edges define the cluster neighborhood.
- Among all inter neighbors clusters, find clusters c_{i^*}, c_{j^*} which minimize:

$$E(i, j) = \min_a \|y - a \cdot (L(c_i) + L(c_j))\|_2 + R(i, j)$$
- Merge these clusters: $c_k = c_{i^*} \cup c_{j^*}$, $L(c_k) = L(c_{i^*}) + L(c_{j^*})$
- Repeat until the whole cortex is one cluster.
- Cut the tree to obtain separated "growing" regions.
- Select best regions by thresholding data fitting error.



Regularization

- Size
- Cortical atlas
- Structural connectivity

- Shape**: penalize regions with "sharp" borders and holes

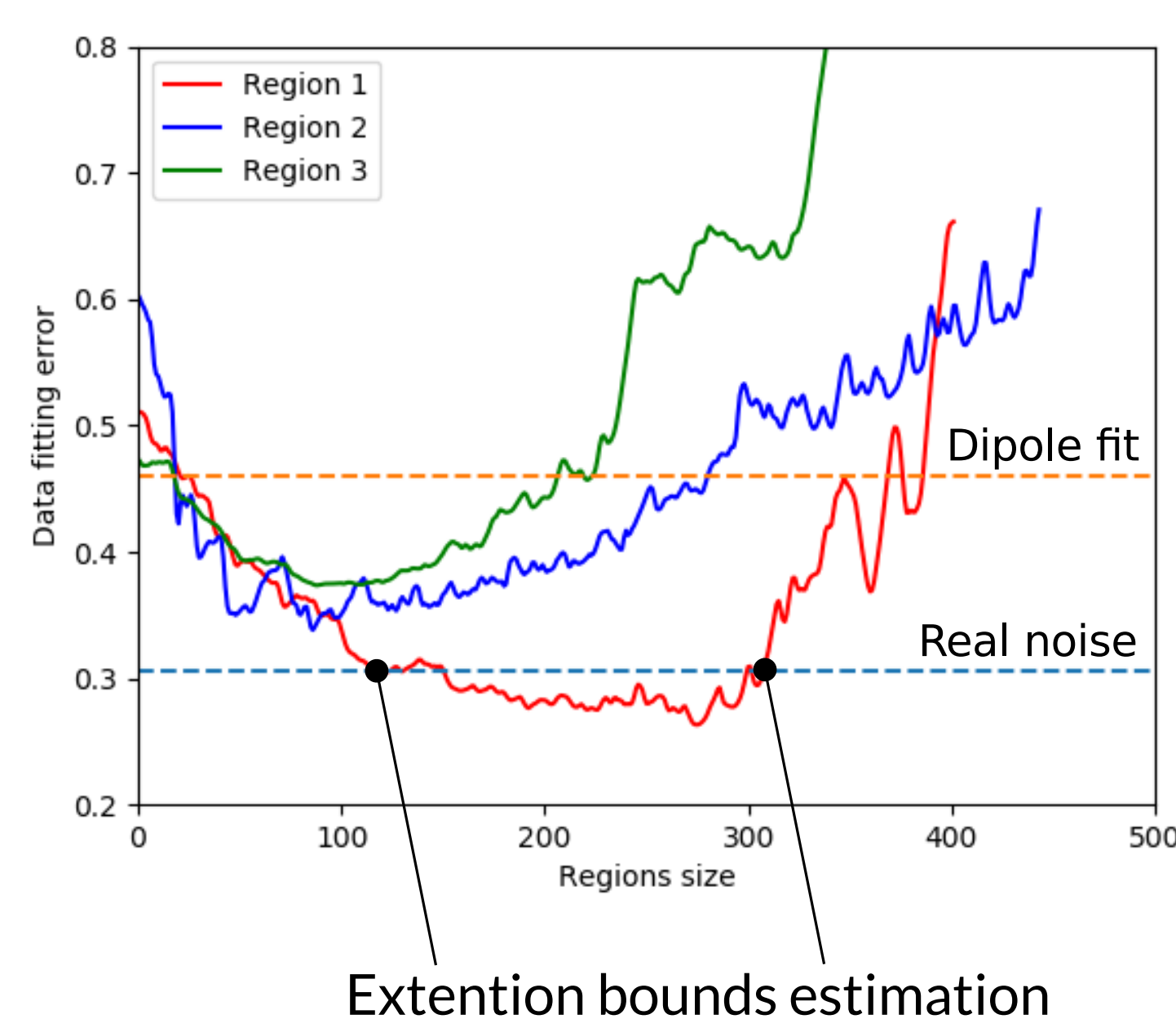
 $B(i, j)$ is the number of vertices in c_i which have at least one neighbor in c_j

$$R(i, j) = \lambda \cdot (|c_i| + |c_j|)^2 \cdot \frac{\min(|c_i|, |c_j|)}{B(i, j) + B(j, i)}$$

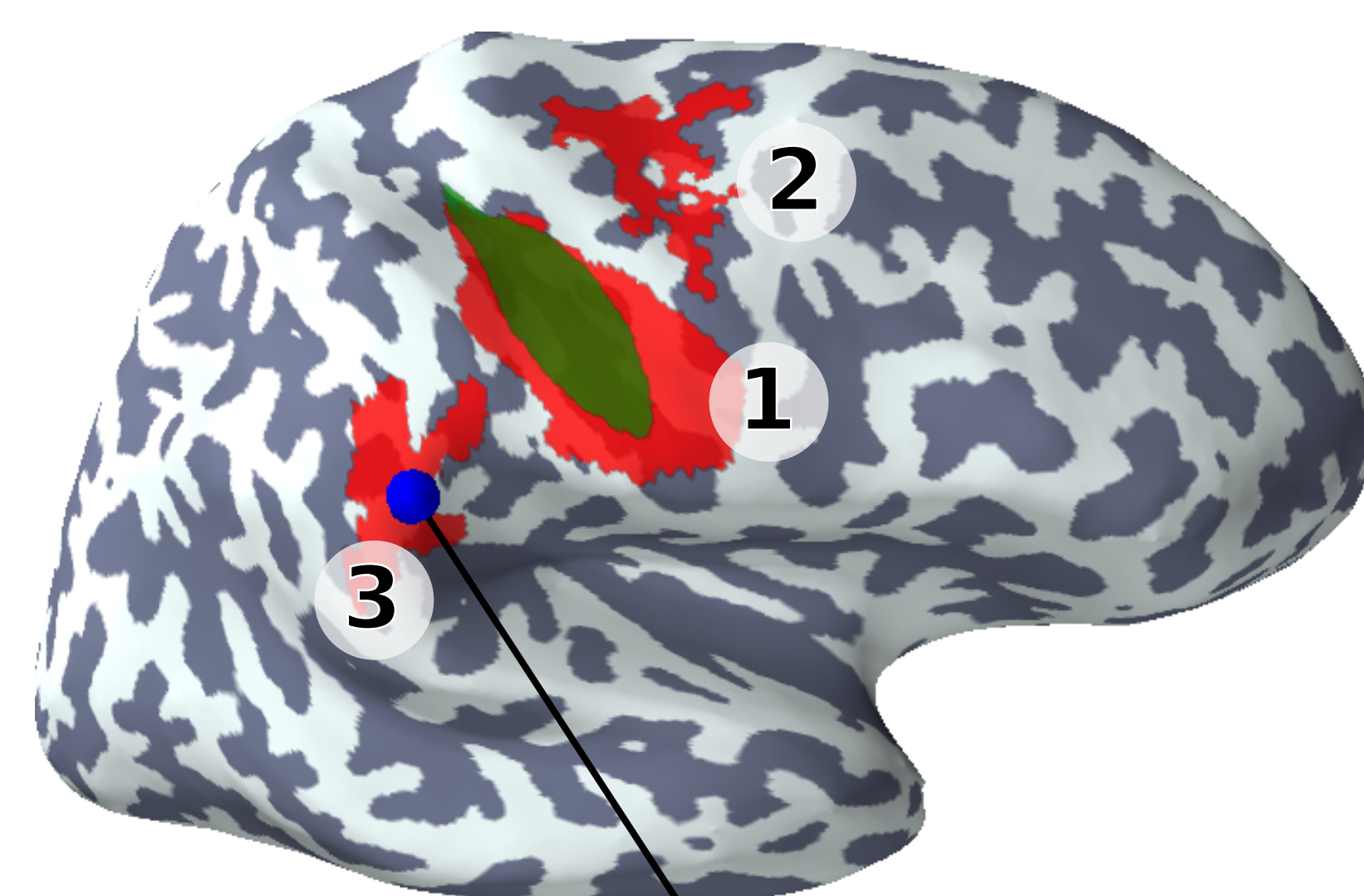
$$R(\bullet, \textcircled{1}) < R(\bullet, \textcircled{2})$$

4 RESULTS

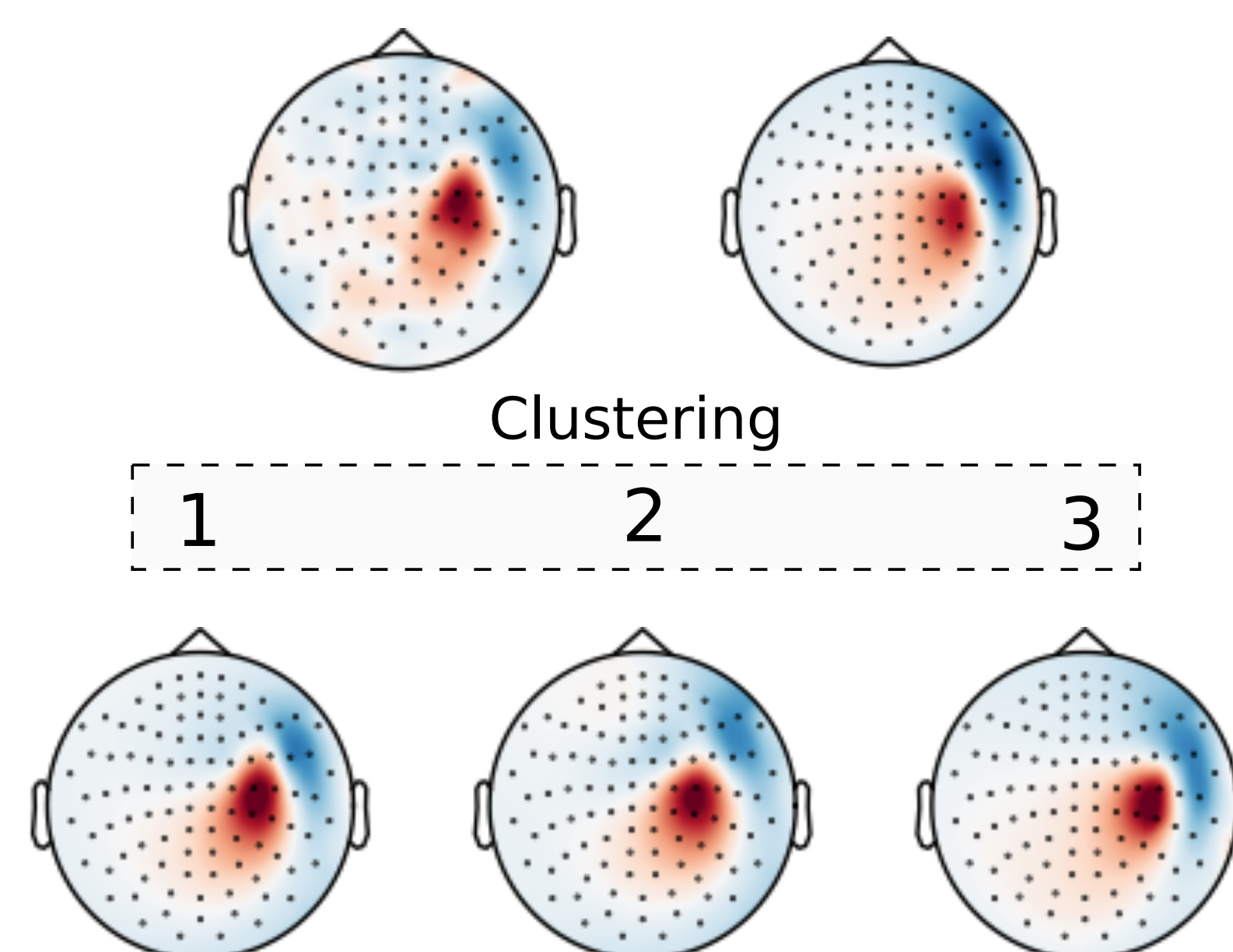
- Simulated MEG signal of one active region (green) with additive Gaussian noise.
- Clustering gives better data fitting error than dipole fit, even with free orientation.
- Dipole fit gives dipole outside the simulated region, but clustering is able to reconstruct the region.
- Clustering gives better spatial information than minimum norm estimate (MNE).
- Regularization is needed to avoid overfitting.
- Clustering gives not one but several candidate regions for the solution and estimates their size.



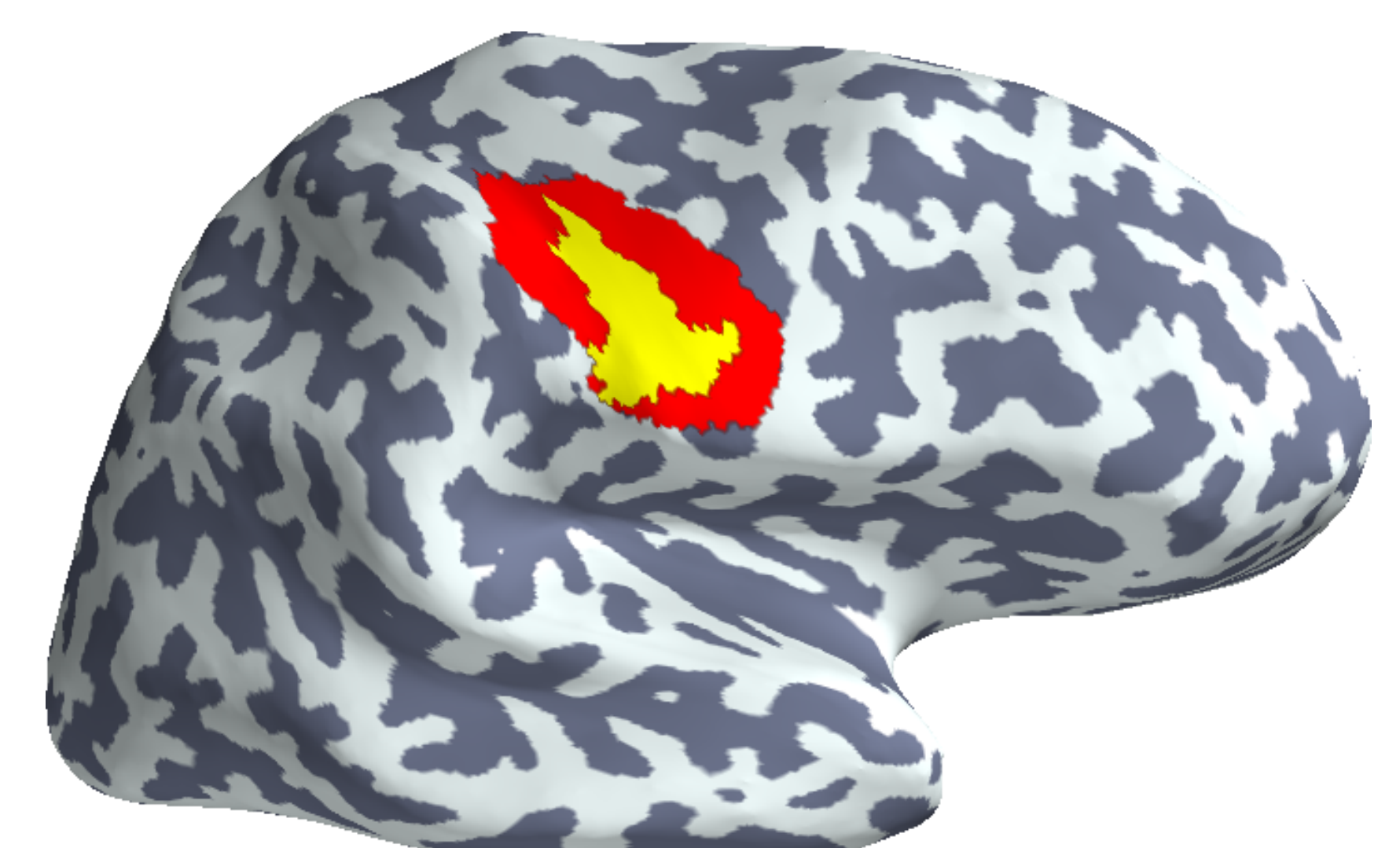
Clustering



Simulated Dipole fit

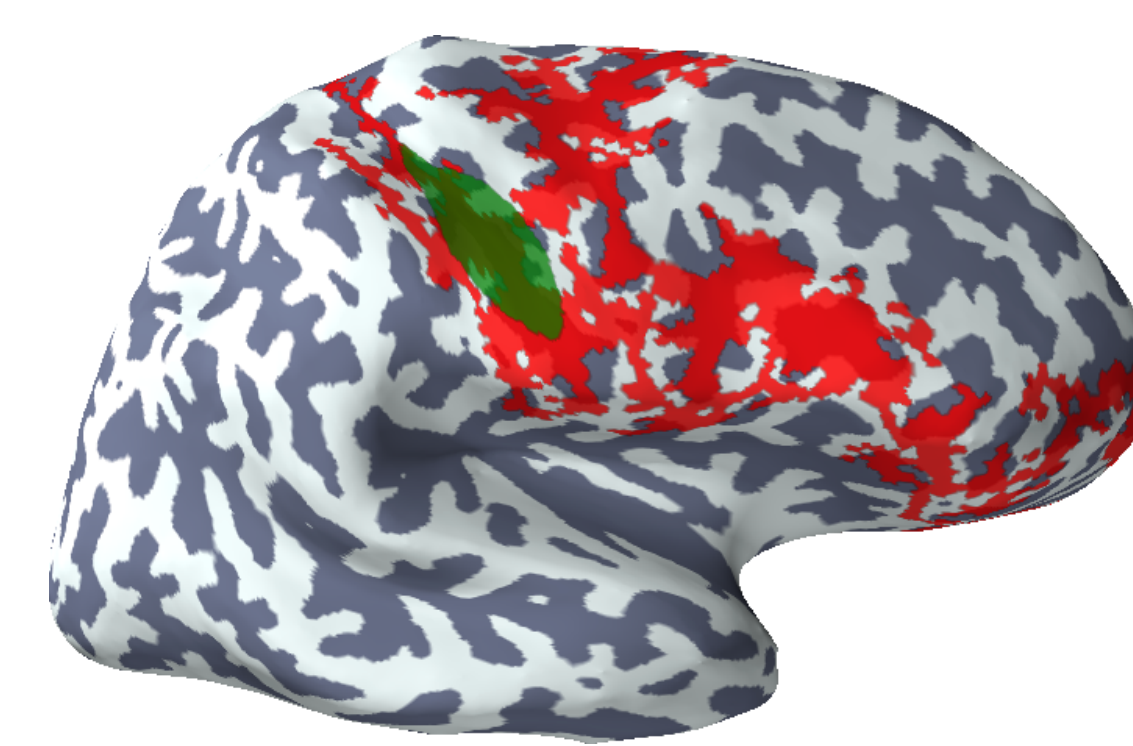


Region extension estimation

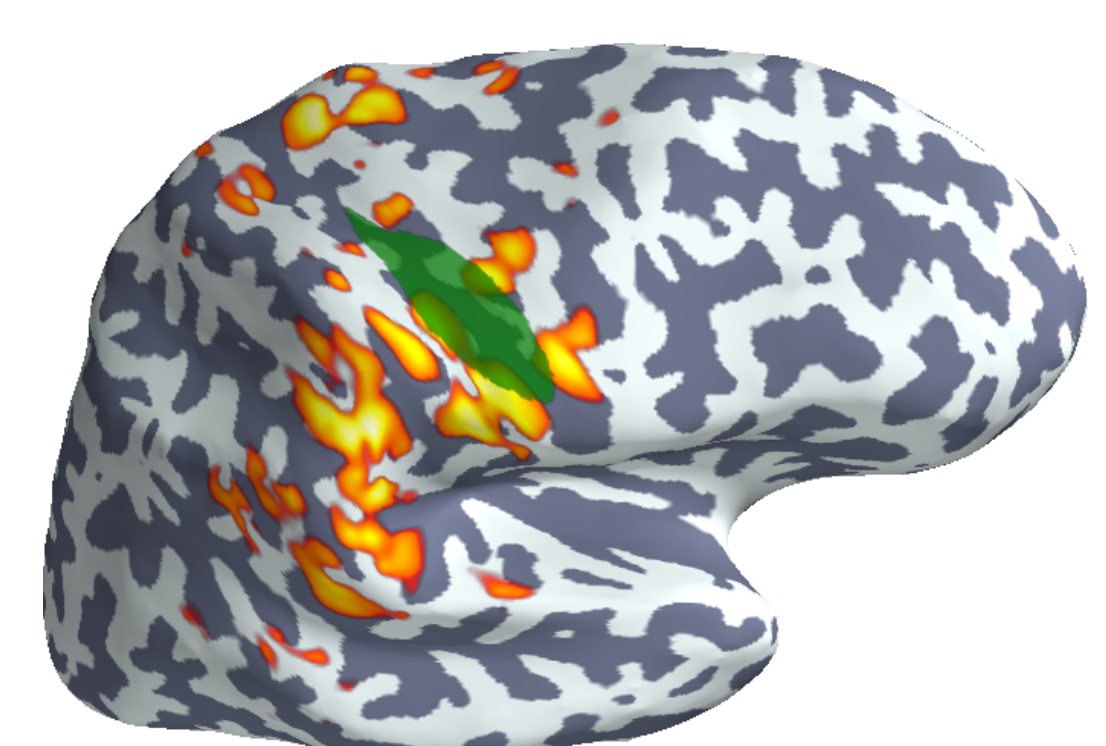


lower bound upper bound

No regularization



MNE



5 CONCLUSIONS

Future work:

New approach for the M/EEG inverse problem which:

- Deals with a "growing region" source, which allows to explore space of solutions.
- Gives several candidates for solution and their extensions.

- Regularization term to be investigated.

- Application to the real data.

- Multiple source case by adapting the MUSIC method [2].

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References: [1] F. Murtagh and P. Contreras. Methods of Hierarchical Clustering. Computing Research Repository - CORR, 2011.
[2] N. Mäkelä, M. Stenroos, J. Sarvas and R.J. Ilmoniemi. Truncated RAP-MUSIC (TRAP-MUSIC) for MEG and EEG source localization. NeuroImage, Volume 167, 15 February 2018, Pages 73-83.