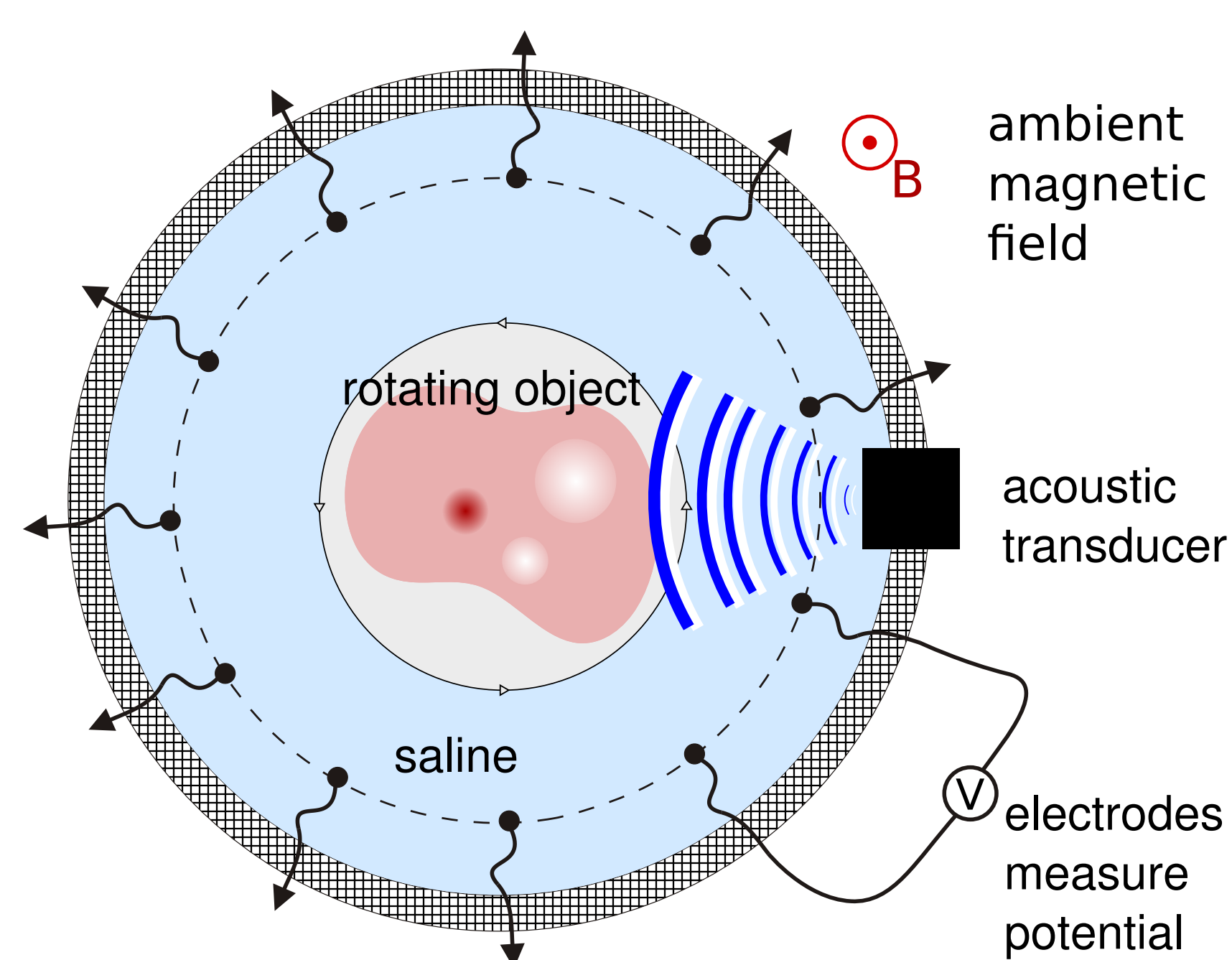


Comparative Study of Two Magnetoacoustoelectric Modalities

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Magnetoacoustoelectric Tomography (MAET)



MAET Problem

- The lead currents flow from one electrode point to another.
- The logarithm of the conductivity is the solution to the hyperbolic equation

$$C(x) = \nabla \log \sigma(x) \times \mathbf{J}(x)$$

- By utilizing more than two electrodes, two curls and two currents can be reconstructed from the same set of measurements
- The resulting hyperbolic system can be reduced to a single elliptic equation for $\log \sigma(x)$

Motivation

- Conductivity in tumors is higher than in healthy tissue
- Methods based on purely electrical measurements yield low resolution images due to ill-posedness
- Hybrid methods like MAET developed as high-res alternatives
- Coupling ultrasound to electric and magnetic fields leads to better posed problems
- Feasibility of these methods needs to be tested in 2D experiments

Scheme

- A specimen is placed in a saline-filled chamber situated in a magnetic field
- Acoustic transducer excites free charges in specimen
- Moving charges interact with the magnetic field, producing Lorentz currents
- The arising electric field can be detected by electrodes or coils
- Measurements made for a full set of view angles

Data

- It can be shown that measurements of potential in MAET (MAET-IM) are projections of the curl of the lead current associated with the electrodes (coil)

$$C(x) = \nabla \times \mathbf{J}(x) \text{ - curl of the lead current (obtained from measurements)}$$

$$\mathbf{J}(x) = \sigma(x) \nabla u(x) + \sigma(x) \mathbf{E}(x) \text{ - lead current}$$

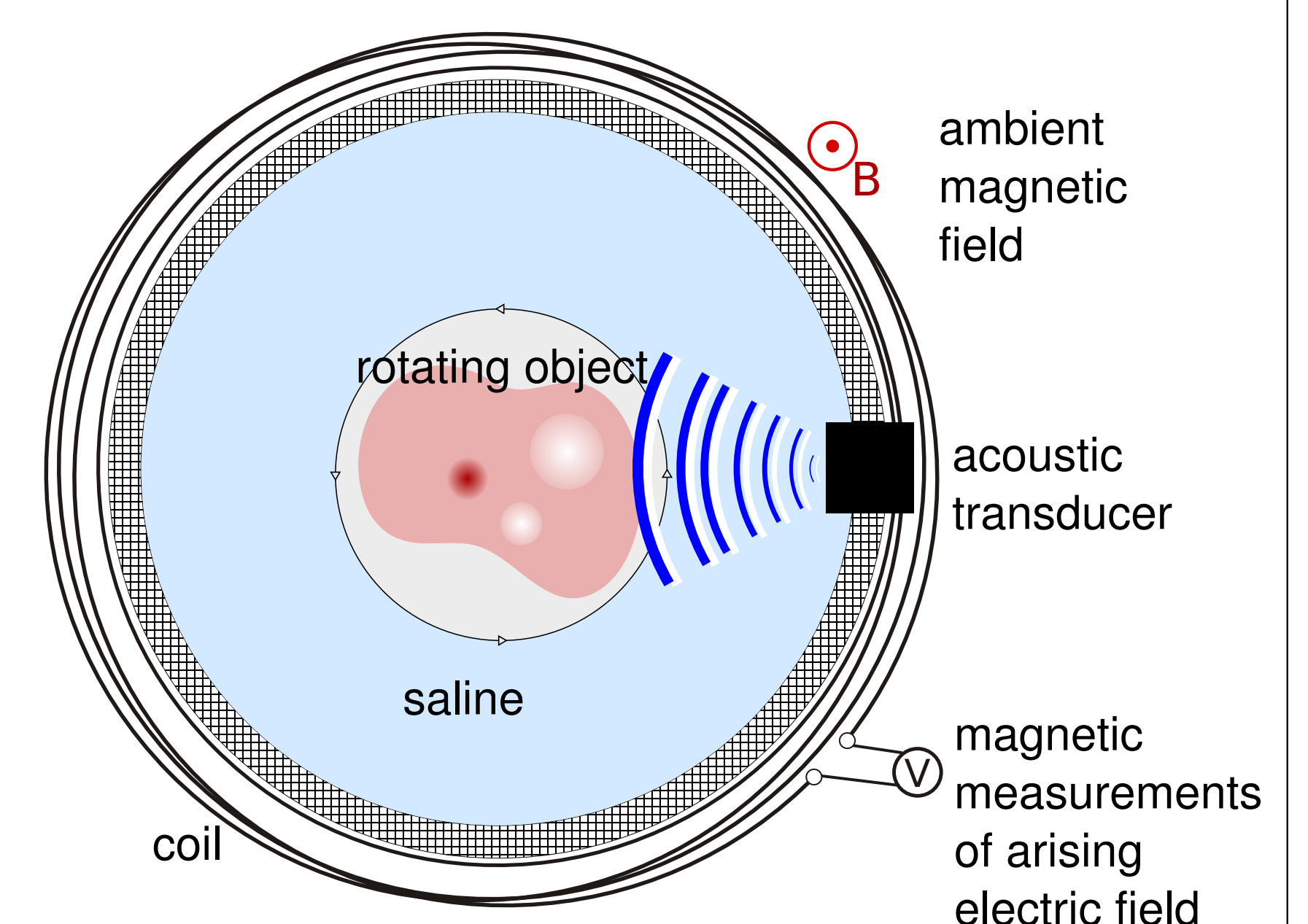
$$\sigma(x) \text{ - conductivity, equal to a constant away from the object of interest}$$

$$\mathbf{E}(x) \text{ - lead electric field (known explicitly for each measurement method)}$$

$$u(x) \text{ - lead potential, satisfies } \begin{cases} \nabla \cdot \sigma \nabla u = -\nabla \cdot \sigma \mathbf{E} \\ \frac{\partial u}{\partial n} = -\mathbf{E} \cdot \mathbf{n} \end{cases}$$

- The lead current can be computed from its curl. Our comparison starts at this stage, where the known data is the lead current and its curl.

Magnetoacoustoelectric Tomography with Inductive Measurements (MAET-IM)



MAET-IM Problem

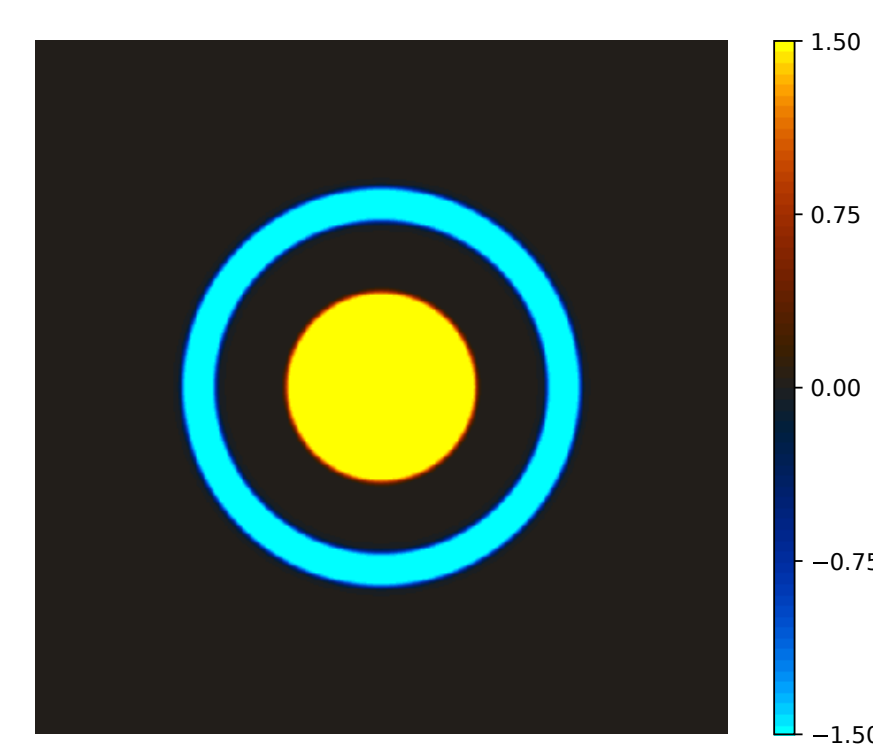
- The lead currents are rotational
- The logarithm of the conductivity is the solution to the hyperbolic equation

$$C(x) = \sigma(x) + \log \sigma(x) \times \mathbf{J}(x)$$

- This can be solved explicitly for $\log \sigma(x)$ along characteristics

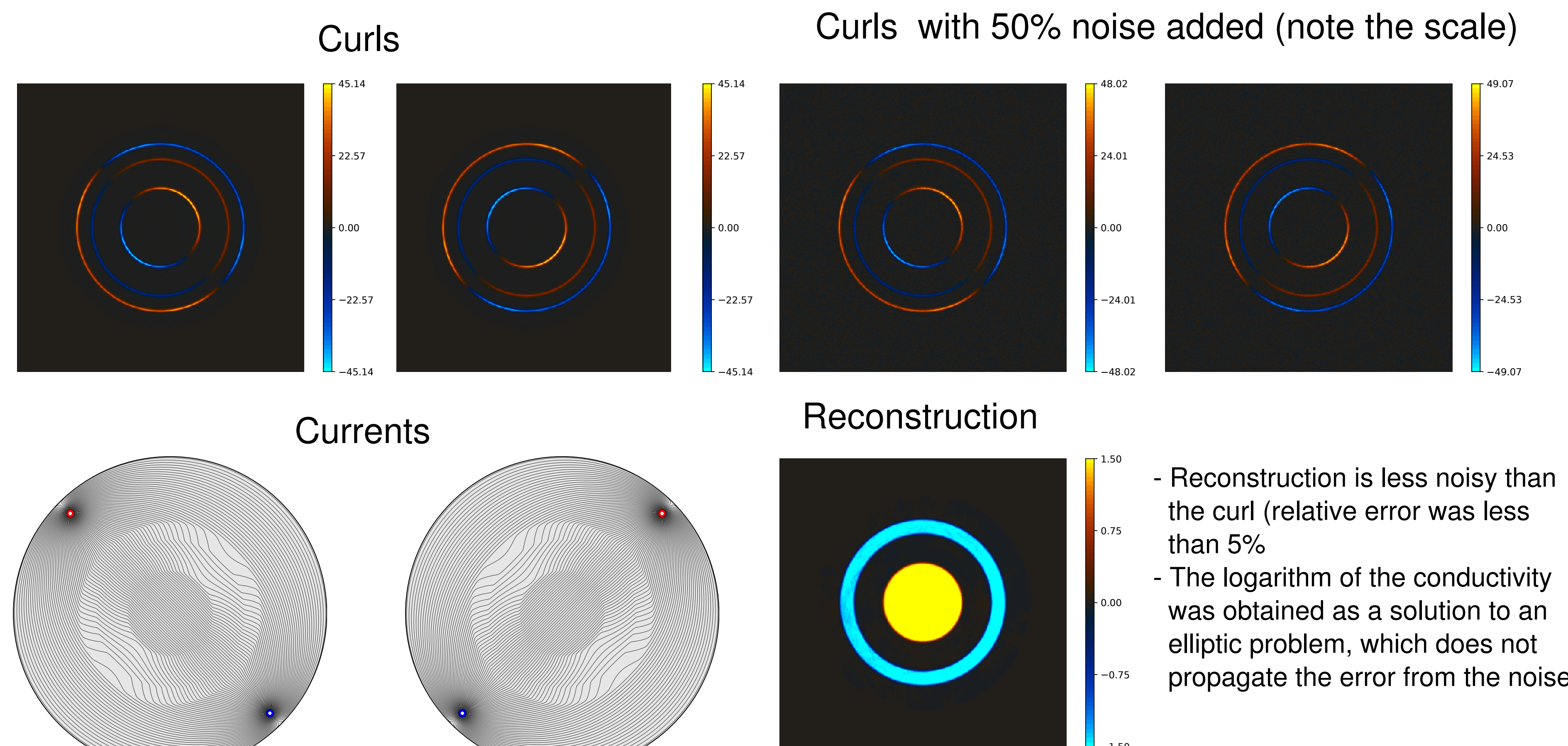
Simulations

Phantom representing $\log \sigma(x)$



- Conductivity of the saline is set to 1
- Two pairs of electrodes are used for the MAET reconstruction
- Reconstructions are of the logarithm of the conductivity

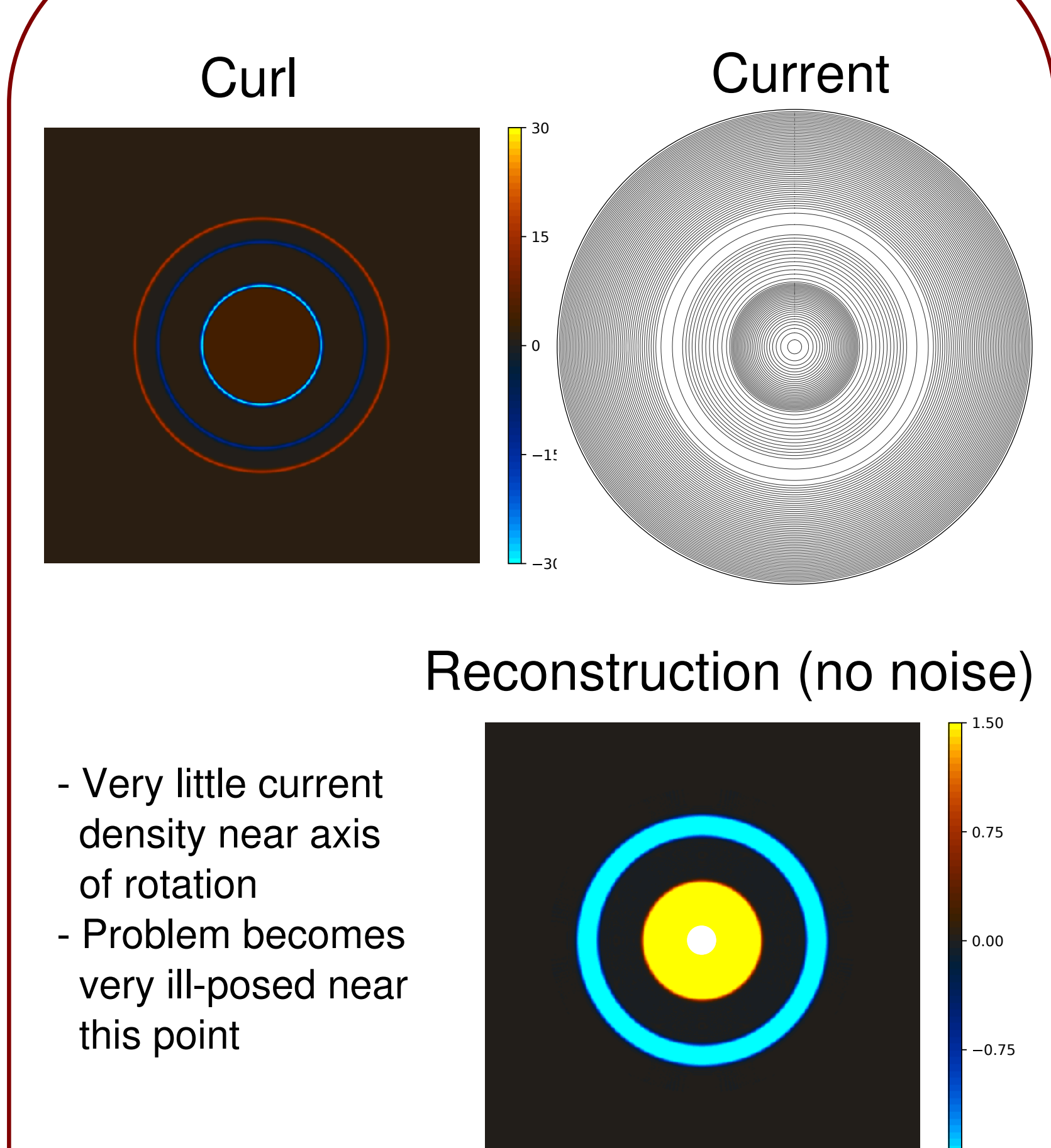
Well-posedness of MAET problem



- Density of current lines indicates strength of current
- Current is stronger in regions of high conductivity

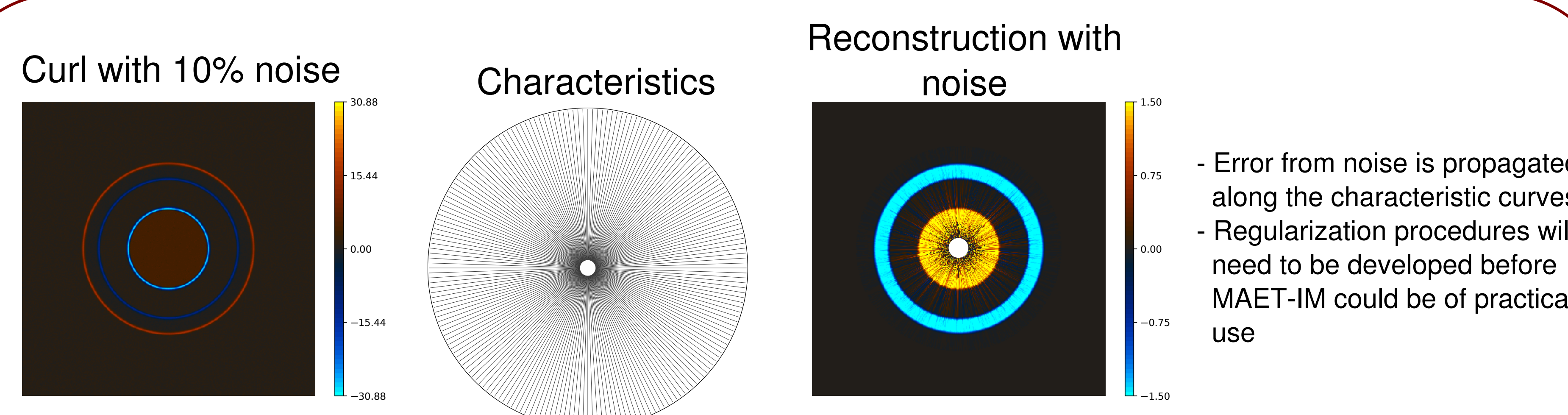
- Reconstruction is less noisy than the curl (relative error was less than 5%)
- The logarithm of the conductivity was obtained as a solution to an elliptic problem, which does not propagate the error from the noise

MAET-IM blind spot



- Very little current density near axis of rotation
- Problem becomes very ill-posed near this point

Propagation of error in MAET-IM



- Error from noise is propagated along the characteristic curves
- Regularization procedures will need to be developed before MAET-IM could be of practical use