The climate is strongly affected by interaction with clouds. To reduce major errors in climate predictions, this interaction requires a much finer understanding of cloud physics than current knowledge. Current knowledge is based on empirical remote sensing data that is analyzed under the assumption that the atmosphere and clouds are made of very broad and uniform layers. To help to overcome this problem, 3D scattering computed tomography (CT) has been suggested as a way to study clouds.

CT is a powerful way to recover the inner structure of three dimensional (3D) volumetric heterogeneous objects. CT has extensive use in many research and operational domains. Aside from its common usage in medicine, CT is used for sensing geophysical terrestrial structures, atmospheric pollution and fluid dynamics. CT requires imaging from multiple directions and in nearly all CT approaches, the object is considered static during image acquisition. However, in many cases, the object changes while multi-view images are acquired sequentially. Thus, an effort has been invested to expand 3D CT to four-dimensional (4D) spatiotemporal CT. This effort has been directed at linear CT modalities. Since linear CT is computationally easier to handle, it has been a popular method for medical imaging. However, these linear CT modalities do not apply to clouds: clouds constitute a scattering medium, and therefore radiative transfer is non-linear in the clouds’ content.

This work focuses on the challenge of 4D scattering CT of clouds. Scattering CT of clouds requires high-resolution multi-view images from space. There are spaceborne and high-altitude systems that may provide such data, for example AirMSPI, MAIA, HARP and AirHARP. An additional planned system is the CloudCT formation, funded by the ERC. However, these systems are costly. Deploying them in large numbers to simultaneously acquire images of the same clouds from many angles can be impractical. Therefore, the platforms are planned to move above the clouds: a sequence of images is taken, in order to span and sample a wide angular breadth. However, the clouds evolve while the angular span is sampled.

We pose conditions under which this task can be performed. These regard temporal sampling and
angular breadth, in relation to the correlation time of the evolving cloud. Then, we generalize scattering CT. The generalization seeks spatiotemporal recovery of the cloud extinction field in high resolution (10m), using data taken by a small number of moving cameras. We present an optimization-based method to reach this, and then demonstrate the method both in rigorous simulations and on real data.