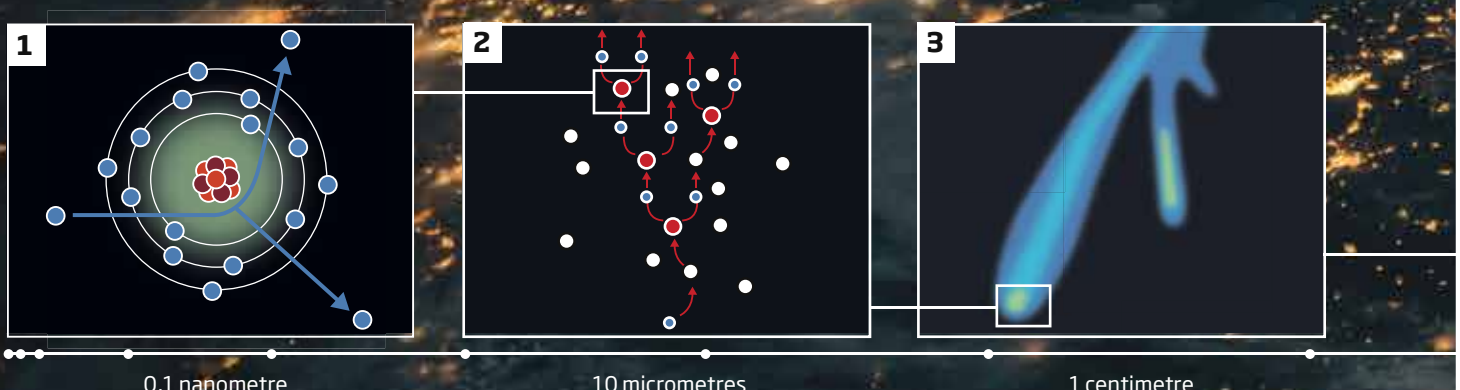
Lightning under the mathematical microscope

Every second, 45 bolts of lightning hit the earth. Lightning seems to be a familiar phenomenon, but it is one that always has new surprises for us. For example, it has not been known for very long that gigantic bolts of lightning can also shoot up above the clouds, and that lightning can make the air radioactive and can even launch antimatter into space.
To understand the kilometres of lightning (see 5 and 6), we have to zoom in on the free electrons in a thundercloud, which collide with an air molecule roughly every millionth of a metre (see 1). These microscopic processes are too small and too fast to observe, but CWI researchers can now simulate them with computer models and calculate discharges at ever-increasing length scales (see 2 to 4).

Northern lights



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SOURCE: UTE EBERT, CWI
IMAGE: NASA, BART VAN OVERBEEKE

Mini lightning in technology

The CWI models are also applied in the development of new technologies, such as *plasma medicine*. A miniature bolt of lightning can produce aggressive nitrogen and oxygen compounds and UV radiation. This can be used to kill bacteria while leaving human cells intact.

1 **Electron-molecule collisions** In a thundercloud, high electrical fields are created that accelerate free electrons. When an energetic electron collides with an air molecule, the molecule can split into a positive ion and a second free electron. The collisions also result in chemical conversions of the molecules, which is why thunderstorms produce greenhouse gases. Chemical conversions also underlie many technical applications (see text box). If the electron energy is high enough, gamma radiation, radioactivity, and antimatter are produced.

2 **Ionization avalanche** If the electric field is high enough, an avalanche of free electrons and ions is created. In this way, a plasma can be created: a soup of many positively charged ions and negatively charged electrons between the air molecules.

3 **Joining forces** The plasma joins the electrical forces at the tip of an elongated plasma channel. This allows the plasma to grow further than the tip and branch out from time to time. This joining of forces allows lightning to grow outside the cloud.

4 **'Lightning trees'** CWI models the growth of lightning over distances of more than one metre as a branching tree. Through good mathematical approximations, the researchers also include all relevant processes on a smaller scale.

flash of gamma rays

lightning