NATURE | NEWS

Cosmic rays reveal the secrets of thunderstorms

High-energy particles from distant space could help to illuminate the origin of lightning.

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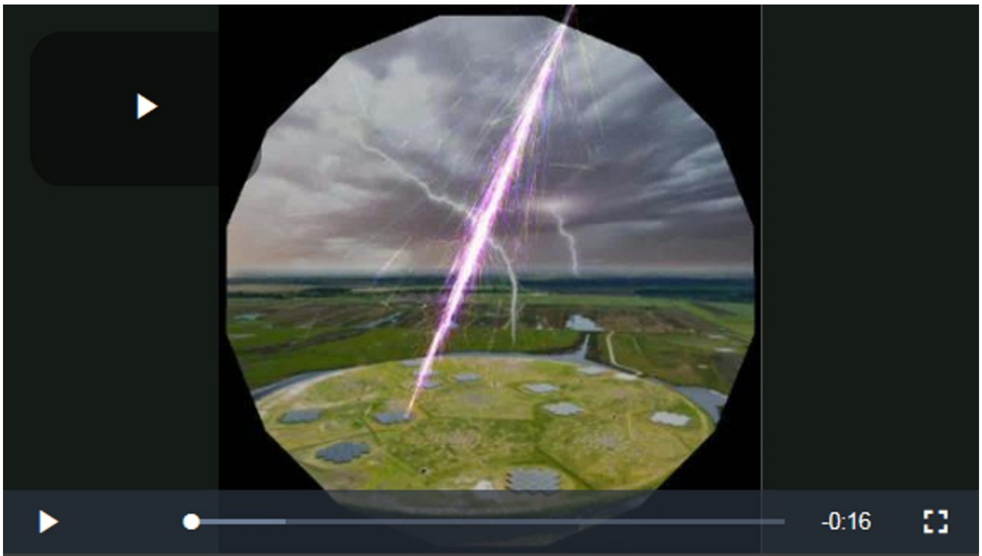

Cosmic ray simulation
A simulation of the shower of particles produced by a cosmic-ray proton after it collides with the atmosphere at an altitude of 20 kilometres. The actual duration of the event would be around 10 microseconds.
Casper Rutjes / ASTRON / Centrum Wiskunde & Informatica

Scientists who run radio-astronomy observatories normally hope for fine weather. Not astrophysicist Heino Falcke: he likes it when thunderstorms close in.

Falcke and his collaborators have been able to measure the intense electric fields inside thunderclouds, using a radio observatory to monitor electromagnetic bursts caused by cosmic rays.

Although such fields have been measured before by means such as sounding rockets or balloons, Falcke's technique could provide a better tool for investigating the origin of lightning — and for verifying whether cosmic rays themselves trigger the bolts.

The study, which is published in *Physical Review Letters*[1], offers long-awaited proof that a radio-astronomy observatory can be used to probe thunderclouds. “This paper is groundbreaking since it demonstrates that the idea actually works,” says Joseph Dwyer, an atmospheric physicist at the University of New Hampshire in Durham.

Falcke, at Radboud University Nijmegen in the Netherlands, leads the Low Frequency Array (LOFAR), a network of radio antennas and particle detectors spread around five European countries. LOFAR was built as a multi-purpose tool to study radio waves from distant cosmic phenomena, but also those produced by the cosmic rays that hit Earth’s atmosphere.

A shocking discovery

When a highly energetic cosmic-ray particle — typically a proton or a heavier atomic nucleus — collides with a molecule of air, it triggers a chain reaction in which millions of electrically charged particles (mostly electrons) shower down towards the ground.

LOFAR’s antennas detect radio waves that are emitted by these charged particles as they fall, in large part as a result of their interaction with the geomagnetic field.

Using LOFAR’s core, an installation spread across 6 square kilometres of countryside near the town of Exloo in the Netherlands, and which has the densest collection of antennas in the network, the team measured 762 of the highest-energy showers between June 2011 and September 2014.

During fair weather, the radio waves descended in orderly patterns. Their polarizations — the sideways direction in which the waves fluctuate as they propagate — were neatly aligned, matching simulations the team had predicted using computer models, says Pim Schellart, a radio astronomer also at Radboud, and the lead author of the study.

But sometimes, the patterns were scrambled — often when a thundercloud happened to hover nearby, he says. Rather than throwing away this anomalous data, the team redesigned their models to include intense electric fields of the type that usually form inside thunderclouds — in which negative electric charges in a lower layer are separate from positive charges higher up. When they recalculated the polarizations using these models, the scrambled patterns matched the new simulations, the researchers report.

Clues from the cosmos

Measurements of the electric fields in clouds could help to solve the one of biggest open questions in atmospheric science. Lightning is a channel of electrical conduction that briefly opens up in the atmosphere and partially restores the balance of electric charges, either between different layers of a cloud or between a cloud and the ground. But scientists do not yet understand what triggers it. The electric fields are strong, but are not sufficient in themselves to convert air from an electric insulator to a conductor.

Some researchers have proposed that cosmic rays are the trigger[2]. The hope is that LOFAR can test whether cosmic rays fall at the same times as do bolts of lightning.

Of course, a bolt that strikes delicate equipment could also be destructive. “Scientifically, you’re hoping that one lightning strike would fall right in the middle of LOFAR,” says Falcke. “But then as a radio astronomer, you kind of hope it wouldn’t.”

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References

1. Schellart, P. *et al*. *Phys. Rev. Lett.* (in the press).
2. Gurevich, A. V., Milikh, G. M. & Roussel-Dupré, R. *Phys. Lett. A* **165**, 463–468 (1992).