Mar/Apr 2018 • No. 245

ESA Newsletter

Electrostatics Society of America - The Friendly Society

President's Message

The interface and interphase in the context of composites

Polymer nanocomposites are polymer matrices reinforced with nano-scale fillers. They present favorable changes in their electrical, mechanical and thermal properties compared to conventionally used composites and unfilled polymers. The principal reason for these change in properties is related to the plurality of the interfaces introduced by the use of nanomaterials. As we head towards our annual meeting in June, I think this is a good topic for discussion - drawing attention to the role of electrostatics in adhering the fillers and polymer matrix together in any composite materials.

The term interphase, a three dimensional region distinct from a two-dimensional interface, was first defined by Sharpe as the interfacial region, and is used in composite materials to indicate the presence of a zone between adjacent phases [1]. The presence of such an interphase will lead to a gradual change in properties from one phase to another rather than the abrupt change necessitated by the acceptance of a two-dimensional interface. In the case of a polymer matrix composite, the interphase will form when parts of the long chain polymers of the matrix interacting with the reinforcement.

The interfacial region (i.e. the interphase) is the region beginning at the point in the fiber at which the properties differ from those of the bulk filler and ending at the point in the matrix at which the properties become equal to those of the bulk matrix.

In the case of nanocomposites, the interphase properties become increasingly dominant as the particle size is reduced. Even though the interphase is not unique to nanocomposites it can easily dominate the properties of nanocomposites due to the large surface area of nanoparticles. For example, a 1nm thick interphase for microparticles in a composite represents as little as 0.3% of the total composite volume. However, a 1nm thick interphase for nanoparticles can reach 30% of the total volume. It should be noted here that the thickness of an interphase is not a constant value as the interphase has no defined structure. Although some research focuses on understanding the influence of the interphase on the properties of bulk composites, much of the published work is on the preparation and characterization of nanocomposites. I am hoping that at the June meeting there will be many opportunities to discuss the role the interphase plays in composite materials, either during informal gatherings or during formal presentations.

This is my personal invitation to you for the 2018 Joint Electrostatics Conference, hosted by the Electrostatic Society of America together with the Institute of Electrostatic Japan (IEJ), the IEEE Industry Applications Society (IAS) Electrostatic Processes Committee EPC), and La Societé Francaise d'Electrostatique (SFE) on the Boston University campus. The conference general chair Prof. Horenstein, the technical program committee chair Prof. Banerjee, and the demo session chair Dr. Robinson, have put together a wonderful program for this year's joint conference. Please see inside for the details.

I would like to remind everyone about the early registration, and manuscript submission deadlines; they are May 10th and May 16th 2018, respectively. Information is also available on the conference website *http://www.electrostatics.org/annualmeeting.html*. ESA members can pay their membership fee together with the conference registration by clicking the option of "Registration and ESA membership". Despite some changes in the IEEE policy, a selected number of papers presented at the 2018 Joint Conference will be considered for the IAS Transactions for archival publication.

(cont'd. p. 2)

President's Message (cont'd.)

Looking forward to seeing you all in June!

For the Friendly Society
Shesha Jayaram, *shesha.jayaram@uwaterloo.ca*
President, Electrostatics Society of America

1. The Interface and Interphase in Polymer Matrix Composites: Effect on Mechanical Properties and Methods for Identification, Article in Polymer Reviews · July 2012

ESA Officers

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Calendar

- 36th Electrical Insulation Conference, June 17-20, 2018, Hyatt Regency, San Antonio, TX, *http://electricalinsulationconference.com.,* Contacts: Diego Robalino, *diego_robalino@ieee.org* and David McKinnon, *davmckin@gmail.com, (Abstract deadline: Oct. 15)*
- 2018 Electrostatics Joint Conference, June 18-20, 2018, Boston University, Boston, MA, *http://www.electrostatics.org/annualmeeting.html* Contact: Mark Horenstein *mnh@bu.edu*
- 211th Conference of the Societe Francaise D'Electrostatique (SFE), August 29-31, 2018, Grenoble, France, *https://sfe2018.sciencesconf.org/?forward-action=index&forward-controller=index&lang=en* Contact: Nelly Bonifaci & Olivier LeSaint *sfe2018@sciencesconf.org*

Electrostatic Demo Session

At our upcoming 2018 ESA Annual Meeting in Boston MA, a special session devoted to electrostatics demonstrations is scheduled for Wednesday, June 20, 2018 from 3PM to 5PM, just prior to the Conference Banquet. The goal is to demonstrate electrostatic fundamentals, educational experiments, safety topics, and research projects. Our session will build upon the demonstration sessions held during our 2012, 2014 and 2016 ESA Annual Meetings.

We are pleased to announce that we have 7 confirmed demonstrations.

1. Electrostatic Fundamentals - Bob Morse (Teacher, retired, Washington DC) returns with some of his clever, inexpensive demos originally conceived to demonstrate electrostatic principles to his high school students.
2. Partial Discharges - Ken MacKillop, Static Clean (North Billerica MA) will demonstrate methods of measuring partial discharge for various high-voltage products such as cable and HV transformers and other encapsulated HV electronics.
3. Electrostatic Field Meter Measurement Pitfalls – Ted Dangelmayer (Dangelmayer Associates, Boston MA) will demonstrate limitations, pitfalls, and common errors when using an electrostatic fieldmeter.
4. Electrostatic Spraying – Steve Cooper (Athens, GA), an expert and inventor of an electrostatic liquid spray nozzle, will demonstrate electrostatic spraying.
5. Static Dissipators - Kevin Coldren (Simco-Ion, Hatfield, PA) will demonstrate the latest static dissipation technologies from Simco-Ion, an industry leader in static control.
6. Traveling Wave Electrostatic Cleaner – Mark Horenstein (Boston University) will demonstrate cleaning sand from solar panels.
7. Static Charge Density Measurement - Kelly Robinson (Electrostatic Answers, Rochester NY) will demonstrate that charge densities may be measured using electrostatic fieldmeter and will bring his Van De Graaff generator, Mr. Electro (thanks to Humphrey Wong for this)!

We may have several additional demonstrations and we certainly have room for yours! If you have a favorite demonstration to share or have an idea for a new one, this event is for you. Please let me know if you need to borrow equipment for your demonstration (fieldmeter, electrostatic voltmeter, Van de Graaff generator, electrophorus, power supply, ... whatever you need) and I will do my best to support your demo.

If you have any questions about our session, please contact Kelly Robinson, who is coordinating the demonstration session.

Kelly Robinson, PE, PhD
Owner, Electrostatic Answers
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2018 Electrostatics Joint Conference

Boston University
Boston, Massachusetts, USA
June 18 - 20, 2018

The Electrostatic Society of America (ESA), Institute of Electrostatic Japan (IEJ), International Electrostatic Assembly (IEA), Industry Applications Society (IEEE-IAS) Electrostatic Processes Committee, and La Societé Francaise d'Electrostatique (SFE) presents papers in all scientific and technical areas involving electrostatics. The scope of the conference ranges from the fundamental physics underlying electrostatics to applications in industry, atmospheric and space sciences, medicine, energy, and other fields. The meeting will bring together experts across the diverse field to present the latest developments in electrostatics.

Technical Session Topics

- Atmospheric and space applications
- Material Processing and Behavior
- Contact Charging and Triboelectric effects
- Electrically-induced Flows and Electrokinetics
- Biological and Medical Applications
- Breakdown Phenomena and Discharges
- Measurements and Instrumentation
- Gas Discharges and Microplasmas
- Safety and Hazards

Photonics Center Boston University

Conference information, including abstract submission, registration, student travel grants and lodging, are available at http://www.electrostatics.org.

Important dates:

May 16, 2018 Final manuscripts due
June 17, 2018 Reception (7-9PM)
June 18, 2018 Conference begins (8AM)
June 20, 2018 Conference ends after evening banquet (6 PM – 19 PM)

Keynote speakers:

Dr. Wamadeva Balachandran (Brunel University): Potential of Electrostatic Technologies for Environmental Pollution Control
Dr. Atsushi Ohsawa (National Institute of Occupational Safety and Health, Japan): A unified expression of the charges transferred by brush discharges and the onset criterion of propagating brush discharges on charged insulating coats or liners
Dr. Hak-Joon Kim (Korea Institute of Machinery and Materials): Novel air cleaning technologies for indoor air quality using electrostatic precipitation with near-zero ozone generation
Dr. Mamadou Sow (Institut de Radioprotection et de Sûreté Nucléaire, France): Self-charging of radioactive dust and its bearing for nuclear safety
Dr. Christophe Louste (University of Poitiers, France): Fundamentals and Applications for Electrohydrodynamics

In addition to the keynote talks there will be 70 oral presentations, 35 posters, and an electrostatics demonstration session

Contact information:

For questions regarding the technical program and abstract submission, contact
Technical Chair: Dr. Shubho Banerjee, Rhodes College, Memphis, banerjees@rhodes.edu , (901) 843-3585
For questions about local arrangements and conference hosting, contact
General Chair: Dr. Mark Horenstein, Boston University, mnh@bu.edu, (617) 353-9052

About Boston University: Boston University is a private research university located in Boston, Massachusetts. The university has over 33,000 undergraduate and graduate students from more than 130 countries, nearly 10,000 faculty and staff, 17 schools and colleges, and 250 fields of study. The conference venue is the Photonics Center which houses the Dept. of Electrical and Computer Engineering.

Metal Printing Offers Low-Cost Way to Make Flexible, Stretchable Electronics

Jingyan Dong and Matt Shipman

Researchers from North Carolina State University have developed a new technique for directly printing metal circuits, creating flexible, stretchable electronics. The technique can use multiple metals and substrates and is compatible with existing manufacturing systems that employ direct printing technologies.

"Flexible electronics hold promise for use in many fields, but there are significant manufacturing costs involved – which poses a challenge in making them practical for commercial use," says Jingyan Dong, corresponding author of a paper on the work and an associate professor in NC State's Edward P. Fitts Department of Industrial & Systems Engineering.

The technique uses existing electrohydrodynamic printing technology, which is already used in many manufacturing processes that use functional inks. But instead of ink, Dong's team uses molten metal alloys with melting points as low as 60 degrees Celsius. The researchers have demonstrated their technique using three different alloys, printing on four different substrates: one glass, one paper and two stretchable polymers. "This is direct printing," Dong says. "There is no mask, no etching and no molds, making the process much more straightforward."

The researchers tested the resilience of the circuits on a polymer substrate and found that the circuit's conductivity was unaffected even after being bent 1,000 times. The circuits were still electrically stable even when stretched to 70 percent of tensile strain.

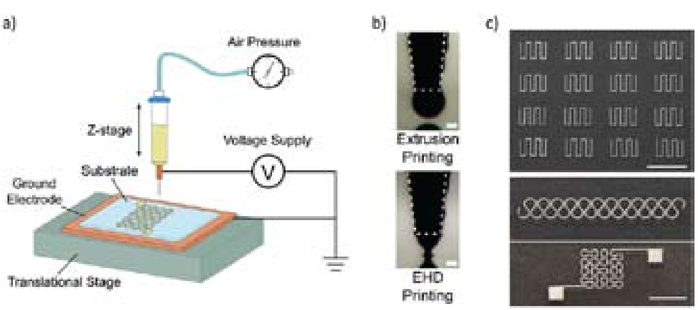


Fig. 1 (a) Schematic of the EHD printing setup. (b) Optical images of the EHD nozzle with voltage on and off, respectively. Scale bar, 100 μm. (c) Large-scale AgNW pattern printed by EHD printing. Scale bar, 1 cm. (d) Two complicated AgNW patterns with high resolution. Scale bar, 5 mm.

(from *https://www.researchgate.net/publication/323262057_Electrohydrodynamic_Printing_of_Silver_Nanowires_for_Flexible_and_Stretchable_Electronics*)

The researchers also found that the circuits are capable of "healing" themselves if they are broken by being bent or stretched too far. "Because of the low melting point, you can simply heat the affected area up to around 70 degrees Celsius and the metal flows back together, repairing the relevant damage," Dong says.

The researchers demonstrated the functionality of the printing technique by creating a high-density touch sensor, fitting a 400-pixel array into one square centimeter.

(excerpted from *https://news.ncsu.edu/2017/12/metal-printing-electronics-2017/*)

Scientists observe a new quantum particle with properties of ball lightning

Scientists at Amherst College and Aalto University have created, for the first time a three-dimensional skyrmion in a quantum gas. The skyrmion was predicted theoretically over 40 years ago, but only now has it been observed experimentally.

In an extremely sparse and cold quantum gas, the physicists have created knots made of the magnetic moments, or spins, of the constituent atoms. The knots exhibit many of the characteristics of ball lightning, which some scientists believe to consist of tangled streams of electric currents. The persistence of such knots could be the reason why ball lightning, a ball of plasma, lives for a surprisingly long time in comparison to a lightning strike. The new results could inspire new ways of keeping plasma intact in a stable ball in fusion reactors.

'It is remarkable that we could create the synthetic electromagnetic knot, that is, quantum ball lightning, essentially with just two counter-circulating electric currents. Thus, it may be possible that a natural ball lighting could arise in a normal lightning strike,' says Dr Mikko Möttönen, leader of the theoretical effort at Aalto University. Möttönen also recalls having witnessed a ball lightning briefly glaring in his grandparents' house. Observations of ball lightning have been reported throughout history, but physical evidence is rare.

The dynamics of the quantum gas matches that of a charged particle responding to the electromagnetic fields of a ball lightning. 'The quantum gas is cooled down to a very low temperature where it forms a Bose-Einstein condensate: all atoms in the gas end up in the state of minimum energy. The state does not behave like an ordinary gas anymore but like a single giant atom,' explains Professor David Hall, leader of the

Artistic impression of a quantum ball lighting. Credit: Heikka Valja

experimental effort at Amherst College.

The skyrmion is created first by polarizing the spin of each atom to point upward along an applied natural magnetic field. Then, the applied field is suddenly changed in such a way that a point where the field vanishes appears in the middle of the condensate. Consequently, the spins of the atoms start to rotate in the new direction of the applied field at their respective locations. Since the magnetic field points in all possible directions near the field zero, the spins wind into a knot. The knotted structure of the skyrmion consists of linked loops, at each of which all the spins point to a certain fixed direction. The knot can be loosened or moved, but not untied.

'What makes this a skyrmion rather than a quantum knot is that not only does the spin twist but the quantum phase of the condensate winds repeatedly,' says Hall. If the direction of the spin is changing in space, the velocity of the condensate responds just as would happen for a charged particle in a magnetic field. The knotted spin structure thus gives rise to a knotted artificial magnetic field that exactly matches the magnetic field in a model of ball lightning.

'More research is needed to know whether or not it is also possible to create a real ball lightning with a method of this kind. Further studies could lead to finding a solution to keep plasma together efficiently and enable more stable fusion reactors than we have now,' Möttönen explains.

(excerpted from *https://phys.org/news/2018-03-scientists-quantum-particle-properties-ball.html*)

Evading in-flight lightning strikes

Jennifer Chu

Aviation experts estimate that every commercial airplane in the world is struck by lightning at least once per year. Around 90 percent of these strikes are likely triggered by the aircraft itself: In thunderstorm environments, a plane's electrically conductive exterior can act as a lightning rod, sparking a strike that could potentially damage the plane's outer structures and compromise its onboard electronics.

To avoid lightning strikes, flights are typically rerouted around stormy regions of the sky. Now, MIT engineers are proposing a new way to reduce a plane's lightning risk, with an onboard system that would protect a plane by electrically charging it. The proposal may seem counterintuitive, but the team found that if a plane were charged to just the right level, its likelihood of being struck by lighting would be significantly reduced.

The idea stems from the fact that, when a plane flies through an ambient electric field, its external electrical state, normally in balance, shifts. As an external electric field polarizes the aircraft, one end of the plane becomes more positively charged, while the other end swings towards a more negative charge. As the plane becomes increasingly polarized, it can set off a highly conductive flow of plasma, called a positive leader — the preceding stage to a lightning strike.

In such a precarious scenario, the researchers propose temporarily charging a plane to a negative level to dampen the more highly charged positive end, thus preventing that end from reaching a critical level and initiating a lightning strike.

The researchers have shown through modeling that such a method would work, at least conceptually. They report their results in the American Institute of Aeronautics and Astronautics Journal.

The team, which includes Emeritus Professor Manuel Martinez-Sanchez and Assistant Professor Carmen Guerra-Garcia, envisions outfitting a plane with an automated control system consisting of sensors and actuators fitted with small power supplies. The sensors would monitor the surrounding electric field for signs of possible leader formation, in response to which the actuators would emit a current to charge the aircraft in the appropriate direction. The researchers say such charging would require power levels lower than that for a standard lightbulb.

"We're trying to make the aircraft as invisible to lightning as possible," says co-author Jaime Peraire, head of MIT's Department of Aeronautics and Astronautics and the H.N. Slater Professor of Aeronautics and Astronautics. "Aside from this technological solution, we are working on modeling the physics behind the process. This is a field where there was little understanding, and this is really an attempt at creating some understanding of aircraft-triggered lightning strikes, from the ground up."

The paper's other co-author is Ngoc Cuong Nguyen, a research scientist in the aeronautics and astronautics department.

Lightning flourishing

To be clear, lightning itself poses very little danger to passengers inside an aircraft, as a plane's cabin is well-insulated against any external electrical activity. In most cases, passengers may only see a bright flash or hear a loud bang. Nevertheless, an aircraft that has been hit by lightning often requires follow-up inspections and safety checks that may delay its next flight. If there is physical damage to the plane, it may be taken out of service — something the airlines would rather avoid.

What's more, newer aircraft made partly from nonmetallic composite structures such as carbon fiber may be more vulnerable to lightning-related damage, compared with their older, all-metal counterparts. That's because charge may accumulate on poorly conducting panels and create potential differences from panel to panel, which may cause certain regions of a panel to spark. A standard protective measure is to cover the outside of the aircraft with a light metallic mesh.

"Modern aircraft are about 50 percent composites, which changes the picture very significantly," Guerra-Garcia says. "Lightning-related damage is very different, and repairs are much more costly for composite versus metallic aircraft. This is why research on lightning strikes is flourishing now."


Lightning laboratory test on model aircraft. Image: Joan Montanya/Polytechnic University of Catalonia

Following the leader

Guerra-Garcia and her colleagues looked at whether electrically charging an airplane would bring down its risk of lightning strikes — an idea that was initially suggested to them by collaborators at Boeing, the research sponsor.

"They are very eager to reduce the incidence of these things, partly because there are large cost expenses related to lightning protection," Martinez-Sanchez says.

To see whether the charging idea held up, the MIT team first developed a simple model of an aircraft-triggered lightning strike. As a plane flies through a thunderstorm or other electrically charged environment, the outside of the plane begins to be polarized, forming "leaders," or channels of highly conductive plasma, flowing from opposite ends of the plane and eventually out toward oppositely charged regions of the atmosphere.

"Imagine two channels of plasma propagating very quickly, and when they reach the cloud and the ground, they form a circuit, and current flows through," Guerra-Garcia says.

"These leaders carry current, but not very much," Martinez-Sanchez adds. "But in the worst cases, once they establish a circuit, you can get 100,000 amps, and that is when damage happens."

The researchers developed a mathematical model to describe the electric field conditions under which leaders would develop, and how they would evolve to trigger a lightning strike. They applied this model to a representative aircraft geometry and looked to see whether changing the aircraft's potential (charging it negatively) would prevent the leaders from forming and triggering a lightning strike.

Their results show that, averaging over field directions and intensities, the charged scenario required a 50 percent higher ambient electric field to initiate a leader, compared with an uncharged scenario. In other words, by charging a plane to an optimal level, its risk of being struck by lightning would be significantly reduced.

"Numerically, one can see that if you could implement this charge strategy, you would have a significant reduction in the incidents of lightning strikes," Martinez-Sanchez says. "There's a big if: Can you implement it? And that's where we're working now."

Graduate student Theodore Mouratidis is performing preliminary experiments in MIT's Wright Brothers Wind Tunnel, testing the feasibility of charging on a simple, metallic sphere. The researchers also hope to carry out experiments in more realistic environments, for instance by flying drones through a thunderstorm.

To make the charging system practical, Martinez-Sanchez says researchers will have to work to speed up its response time. Based on their modeling, he and his colleagues have found that such a system could charge and protect a plane within fractions of a second, but this will not be enough to protect against some forms of triggered lightning.

"The scenario we can take care of is flying into an area where there are storm clouds, and the storm clouds produce an intensification of the electric field in the atmosphere," Martinez-Sanchez says. "That can be sensed and measured on board, and we can claim that for such relatively slow-developing events, you can charge a plane and adapt in real time. That is quite feasible."

(from *http://news.mit.edu/2018/evading-flight-lightning-strikes-0309*)

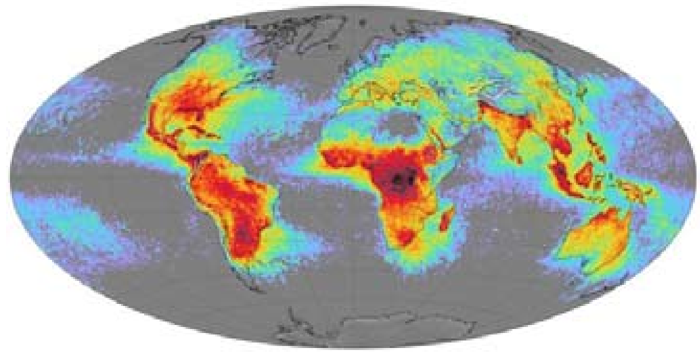
Hunting mystery giant lightning from space

Mary Halton

There are bizarre goings on in Earth's upper atmosphere, and a new mission aims to learn more about them. Launched to the International Space Station on Monday, the Atmosphere-Space Interactions Monitor (ASIM) will observe the strange electrical phenomena that occur above thunderstorms. Orbiting at an altitude of just over 400km, the ISS provides the perfect view of Earth's turbulent weather systems. ASIM will be deployed aboard the station later this month.

The electrifying effects of storms are frequently observed from the space station. Yet when lightning strikes downward, something very different is happening above the cloud tops. Known as Transient Luminous Events (TLEs), these unusual features were first spotted by accident in 1989.

Minnesota professor John R Winckler was testing a television camera in advance of an upcoming rocket launch, when he realised that two frames showed bright columns of light above a distant storm cloud. The discovery came as a shock to scientists at the time, according to Dr Torsten Neubert, ASIM's lead scientist. "That really surprised all of us. How come this exists and we didn't know it? Airline pilots must have known about it - there are some anecdotal descriptions," the Technical University of Denmark physicist said.



A map of the world showing the frequency of lightning strikes - most common in central Africa, South America and south AsiaImage copyright OTD/LIS, NASA MARSHALL SPACE FLIGHT CENTER

For the better part of a century before TLEs were caught on camera, people who spotted them had been reporting "rocket lightning" or "upward lightning". Now in need of names, the phenomena were christened sprites and elves because of their fleeting, mysterious nature. Yet despite their diminutive monikers, these features are anything but small, and extend tens of kilometres into the atmosphere.

So, what's causing these events? "They are slightly different to lightning," Dr Neubert told BBC News. "It's a pulse of the electric field that travels up. For the sprite - when the atmosphere gets thin, the field can get a discharge." Sprites appear milliseconds after a powerful cloud-to-ground lightning strike.

Elves, on the other hand, are caused by the electromagnetic pulse the strike produces. A brief, aurora-like expanding halo in the ionosphere, they occur too quickly to be spotted by the human eye and last less than a millisecond. Although they are more elusive, "elves are incredibly well understood," says Dr Martin Fullekrug from the University of Bath. They are the most common TLE, thought to occur twice as often as sprites.

Blue jets - upward electrical discharges from cloud tops - are the least well known. "The jets are not very well studied because they're very faint. They're mainly blue.

Current Events (cont'd.)

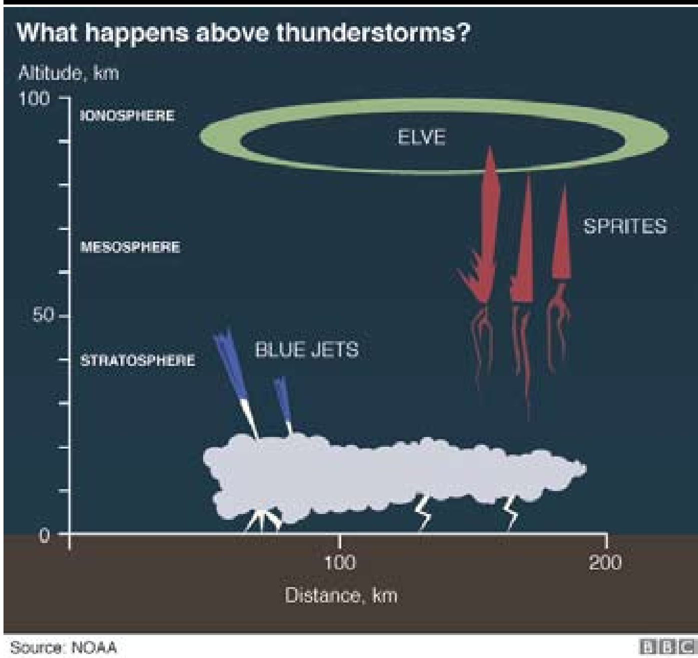


Diagram showing that blue jets occur below 50km altitude, sprites occur between 40km and 90km altitude and elves occur at approx 95km altitude

Also they're not necessarily associated with lightning. They pop up now and again and they're very mysterious," Dr Fullekrug added.

While elves are mainly spotted over warm ocean waters, sprites tend to occur over land. North America, the Democratic Republic of the Congo and South Africa are all good places to see them. But it is possible to spot sprites elsewhere.

A normal summer thunderstorm in the UK is about 10km wide. Sprites appear above mesoscale convective systems - storm complexes about 10 times larger. "In Britain we also have [these storms] from time to time," explained Dr Fullekrug. "We're conducting research on one that happened in May last year. It produced a wonderful sequence of sprites [over Cornwall]."

The sprites were spotted by meteor observers, who had cameras trained on the sky to follow the trails of shooting stars.

ASIM's main goals are to study the physics of TLEs, and the characteristics of thunderstorms that produce them. The payload includes two cameras, which can capture 12 frames per second, plus X-ray and gamma ray detectors. This will allow the international team of researchers, for many of whom this is the culmination of decades of work, to determine where in the cloud sprites or jets originate.

Several red spark-like features with spidery trails, looking almost like fireworks against a starry skyImage copyright JASON AHRNS

With the aid of the European Space Agency, ASIM's minimum mission length is two years. During this period, it is expected to observe a minimum of one TLE per day, although it is thought that they occur at least every minute, somewhere in the world.

For Dr Neubert, this will be an incredibly exciting time. "We don't really know what's inside lightning. It happens so fast and it's so dangerous... it's hard to get to the real inside physics," he said. In the thin upper atmosphere, TLEs are larger and easier to measure. "To me," he added, "they represent a window to the inside of lightning."

(excerpted from *http://www.bbc.com/news/science-environment-43585113*)

The curve of the Earth, with the line of the atmosphere visible. In the distance, several long red streaks above a thunderstorm.Image copyright SCIENCE PHOTO LIBRARY

Electrostatic detection device

(Editor's note: I found this article while searching the internet for something to put on the last page of the newsletter. As I was unfamiliar with this particular application of electrostatics, yet very familiar with some of the working principles as related to electrophotography (xerography), I thought this might be of some interest to ESA members. What follows are excerpts from Wikikpedia - please follow the link at the end of this article to get a fuller picture and to explore the references that I have omitted here.)

An electrostatic detection device, or EDD, is a specialized piece of equipment commonly used in questioned document examination to reveal indentations or impressions in paper that may otherwise go unnoticed. It is a non-destructive technique (will not damage the evidence in question), allowing further tests to be carried out. It is a sensitive technique capable of detecting indentations on pages several layers below the top sheet and many years after the indentations were created.

When writing is fashioned on a sheet of paper resting upon other pages, the indentations or impressions produced are transferred to those below. These transferred impressions can be detected using an EDD. In some situations, a questioned document such as a ransom note, or an extortion letter, may exist which can be determined to be the source of indentations detected on another piece of paper (e.g., an offender's notepad). Alternatively, indentations detected on a business contract might match information present on another such document. In some situations this would be an entirely innocent finding; however, if the two businesses are supposed to be operating independent of one another, then the finding could be significant.[1] Decipherable indentations may also provide valuable information even when a second document is not present or cannot be located. For example, an anonymous letter may bear impressions of writing that relate to some mundane activity of the offender which could ultimately lead an investigator to a particular suspect.

The electro-physical basis whereby an EDD actually works is complex. The original theory suggested that the paper sandwiched between the grounded platen and the mylar charging film acted as a type of capacitor with the change in capacitance being due to differing compression of the paper.[2] This led to models like the 'Thickness Variation Theory' and the 'Surface Variation Theory'.[3] However, it turns out that a detectable 'indentation' is not due to the physical pressure applied to the writing instrument as one might expect. Rather, Seward in 1998[4] and 1999[5] proposed an alternative theory explaining the detection capability of an EDD as being due to a surface charge effect created by paper-to-paper friction specifically in the area where a writing instrument is pressed down into the top-most sheet of paper. Seward's model was based upon "charge transport through the Mylar-paper-platen structure"[4] and is appropriately called the 'charge transport model'.

Subsequent testing[6],[7] demonstrated that the charge transport model, while not perfect, is sound. This testing also clarified that areas of indentation are less negatively charged than surrounding areas. It is this relative difference in potential that causes the toner to be attracted to the areas of indentation, rather than other areas on the mylar surface.

Despite the complexity of the underlying theoretical mechanism, the practical use of an EDD is straightforward. Most devices are similar in their operation. The following are the key steps in using an EDD to visualize indentations:[10]

Evaluation of material

- Assess adequacy of material for examination
- Examination using side (oblique) lighting
- Documents that have been subjected to high levels of humidity will not generally retain indentations.

Preparation

- Humidification
- Fitness-for-use (FFU) test

Placement on platen: the goal is to place the questioned document flat on the platen surface with few wrinkles or distortions (ideally, none).

- Type of document: as noted above, an EDD works well with a single sheet
- Covering with charging film

Charging of surface: the top surface of the charging film must be electrostatically charged. To achieve this most EDDs use a shielded (grounded) hand-held unit containing a high-tension corona wire[20] which is turned on and literally waved over the entire surface of platen for several seconds criss-crossing the platen area.

Application of toner to develop indentations

- Cascade method
- Aerosol spray method
- Brush method
- Toner pad method

Assessment of results

Preservation of results

- Adhesive lift
- Photography/scanning

(excerpted from *https://en.wikipedia.org/wiki/Electrostatic_detection_device*)

Electrostatics Society of America

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ESA Information

ESA Home Page: *http://www.electrostatics.org*

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