Physics 535 – Lecture 11
Physics of Lightning

Why a lightning flash stops

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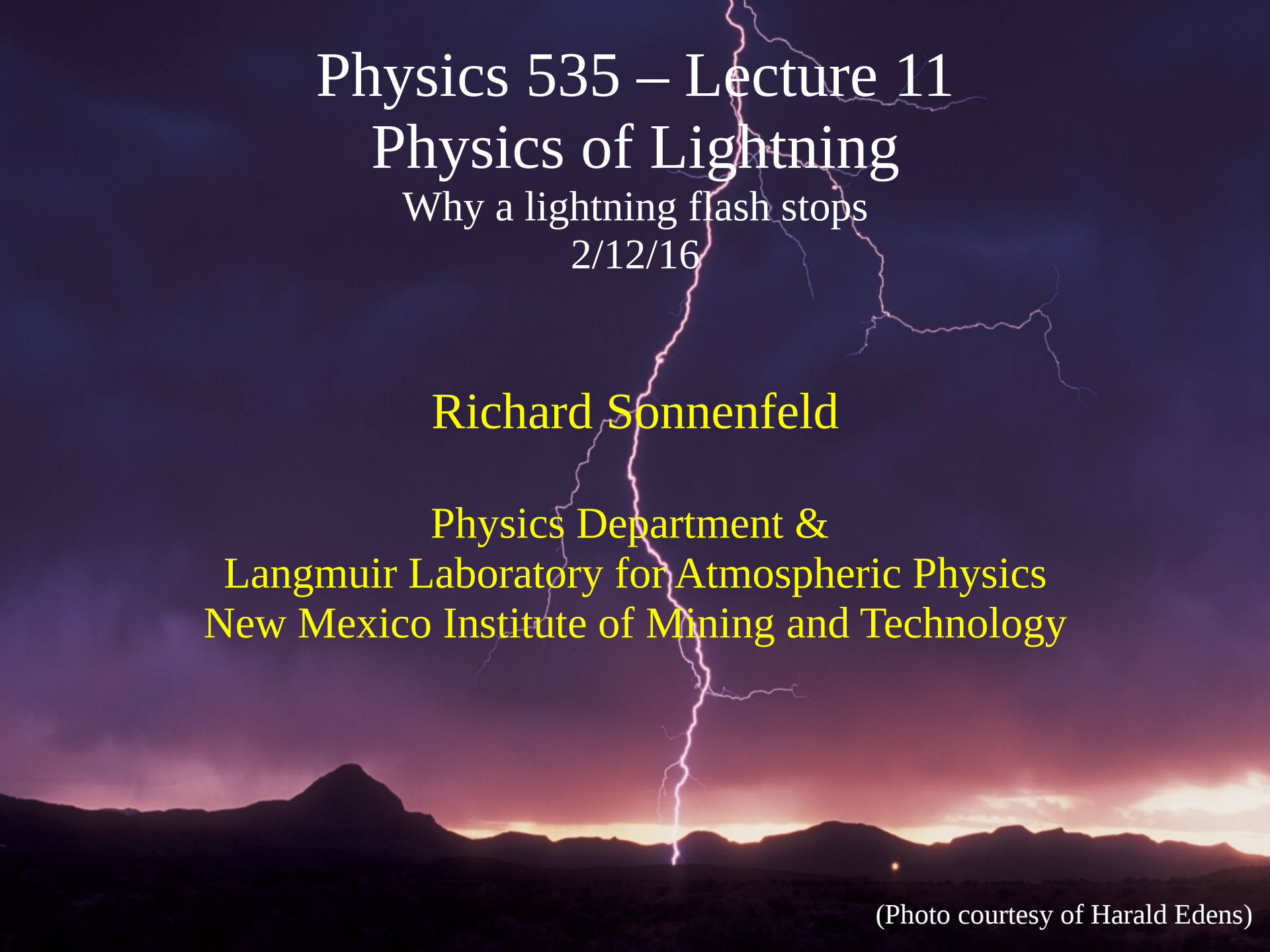
Richard Sonnenfeld

Physics Department &
Langmuir Laboratory for Atmospheric Physics
New Mexico Institute of Mining and Technology



(Photo courtesy of Harald Edens)

Kasemir's Assumptions:

A lightning channel goes back and forth between being a perfect conductor and a perfect insulator.

When it's a conductor, it's an equipotential and it has “influence charge” on its surface to make it be so. This “influence charge” is from free electrons … it can't be anything else.

When the channel cools, the electrons reattach and the charge remains … reattached to O2 and maybe ultimately to hydrometeors.

It takes a long time to diffuse away.

The “charge transport” of a lightning flash occurs in the milliseconds that the channel is making itself an equipotential. Electrons DO NOT MOVE from one end to the other … it's the field that carries the information. The electrons are snatched from convenient local atoms.

Kasemir's Model:

A lightning flash starts when the local field exceeds breakdown (1.8 MV/m at 7 km). [We still don't have that one figured out … but OK].

Once it starts, the field at the tips of the channel is enhanced, so it should continue to propagate. However, it carries with it a "mean potential".

When it reaches a region that is near in potential to its mean potential, there is no longer any potential gradient, and propagation should stop.

It actually stops sooner … when the field falls back below breakdown.

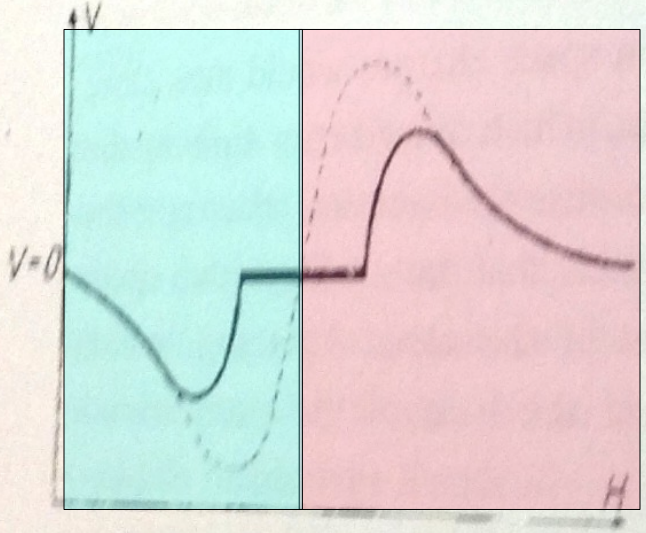


Figure 4. Initial stage of lightning in a bipolar space charge.

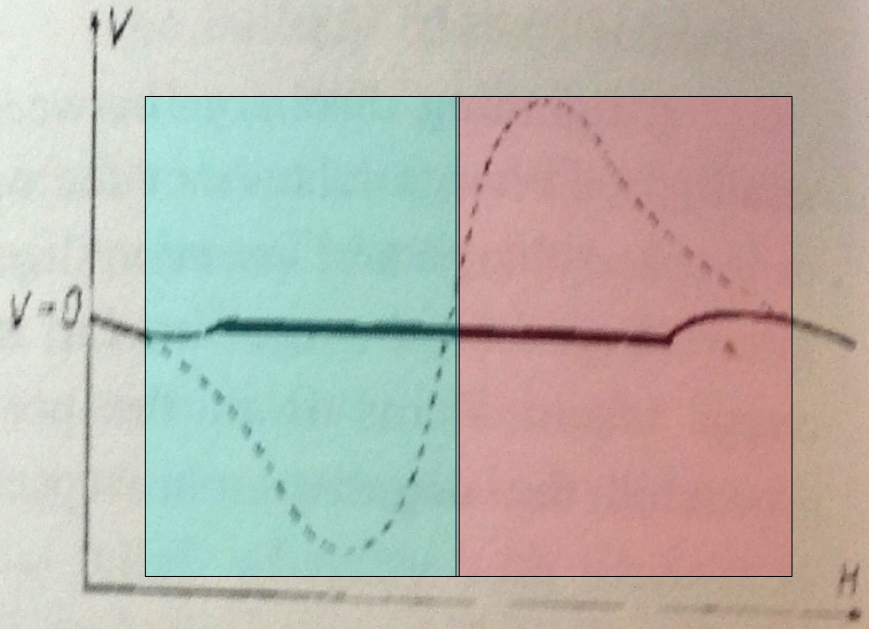


Figure 5. Final state of lightning in a bipolar space charge.

Figure 4, 5 – Symmetrical potential

Bi-directional breakdown occurs (left) and continues so long as gradient from end of channel exceeds Eb.

On right, the channel has extended to a point where local potential is sufficiently close to channel potential that Eb is no longer sustained.

This is an IC flash.

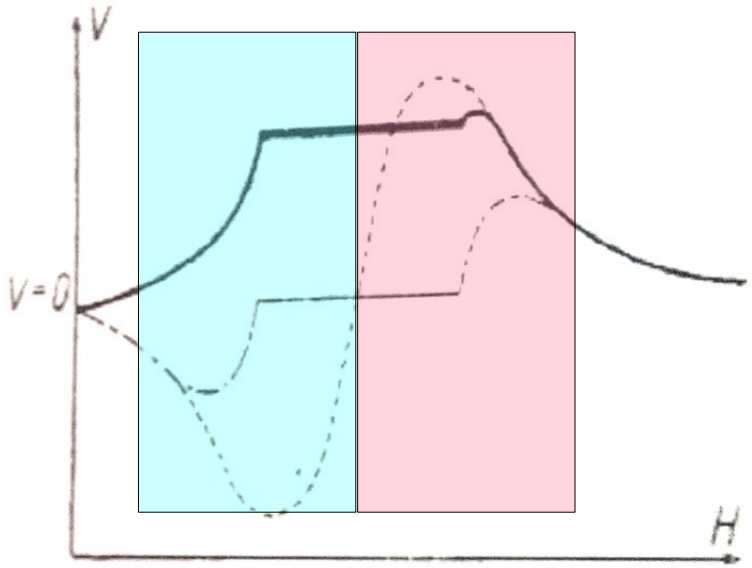


Figure 6. Potential image of lightning from the head of the storm cloud.

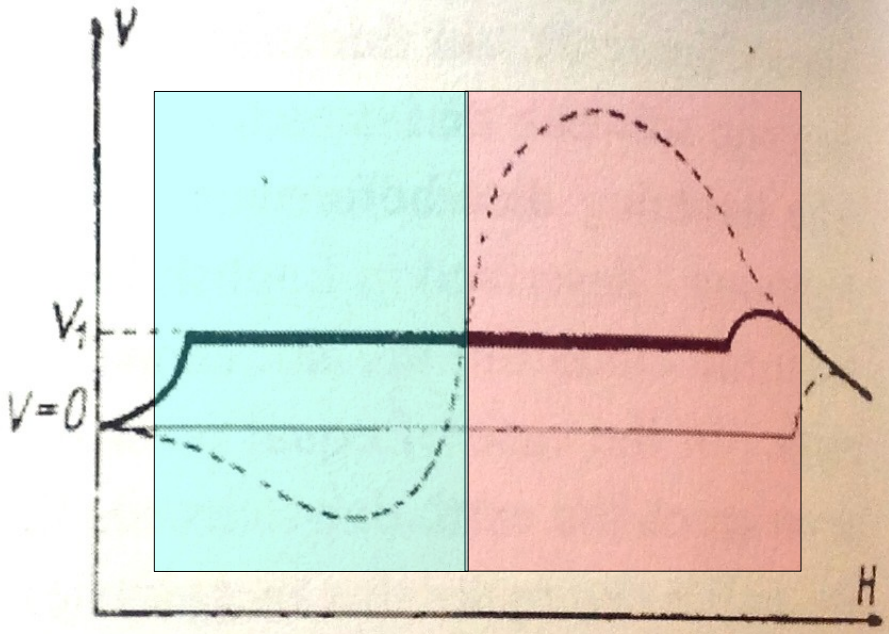
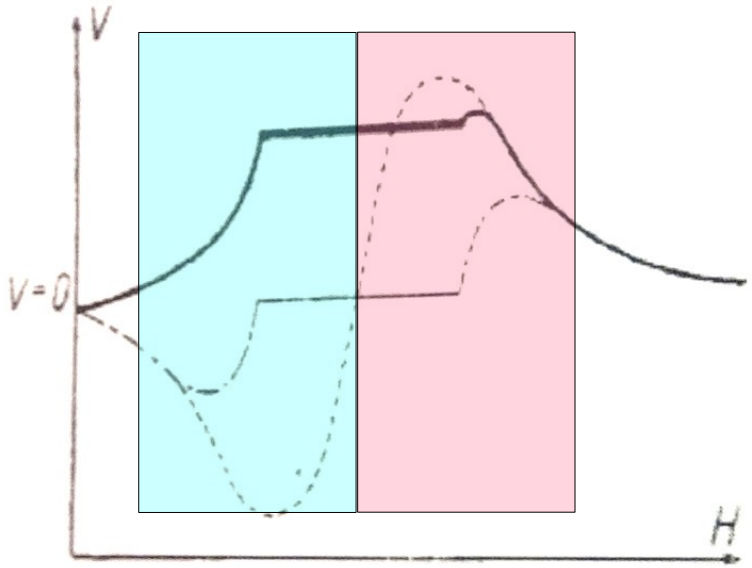


Figure 7. Earth-bound lightning from two unequally sized space charges.

Figure 6. If breakdown began at region of higher potential, it would propagate all the way to the ground, but the gradient is always highest between the charge layers … so the situation of Fig. 6 is not realistic.



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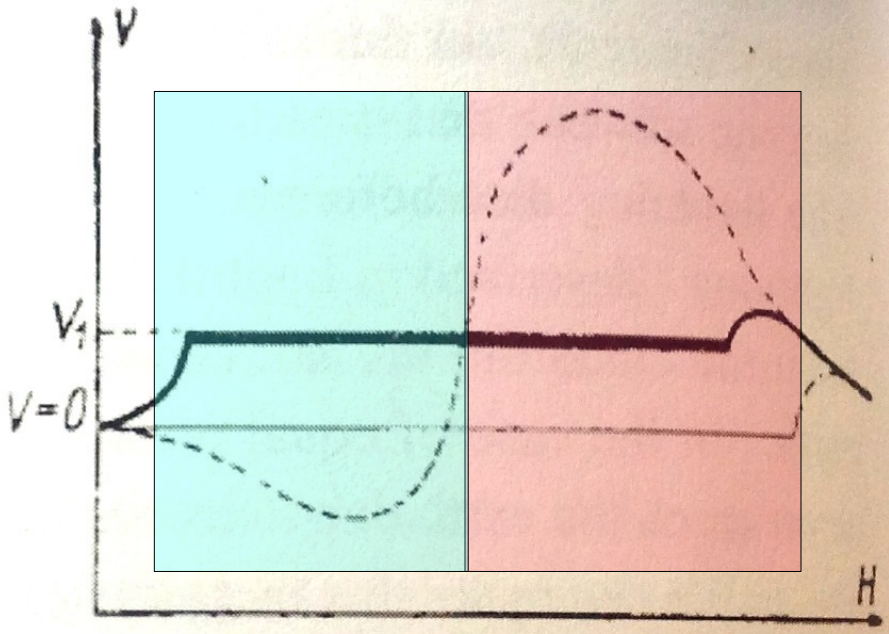

Figure 7. Earth-bound lightning from two unequally sized space charges.

Figure 7. If the charge distribution is asymmetrical (and the negative layer well is not deep enough, then the channel can break out of the bottom of the charge layer and continue propagating to ground.

Figure 8. Lower positive helps enable flash to come to ground.

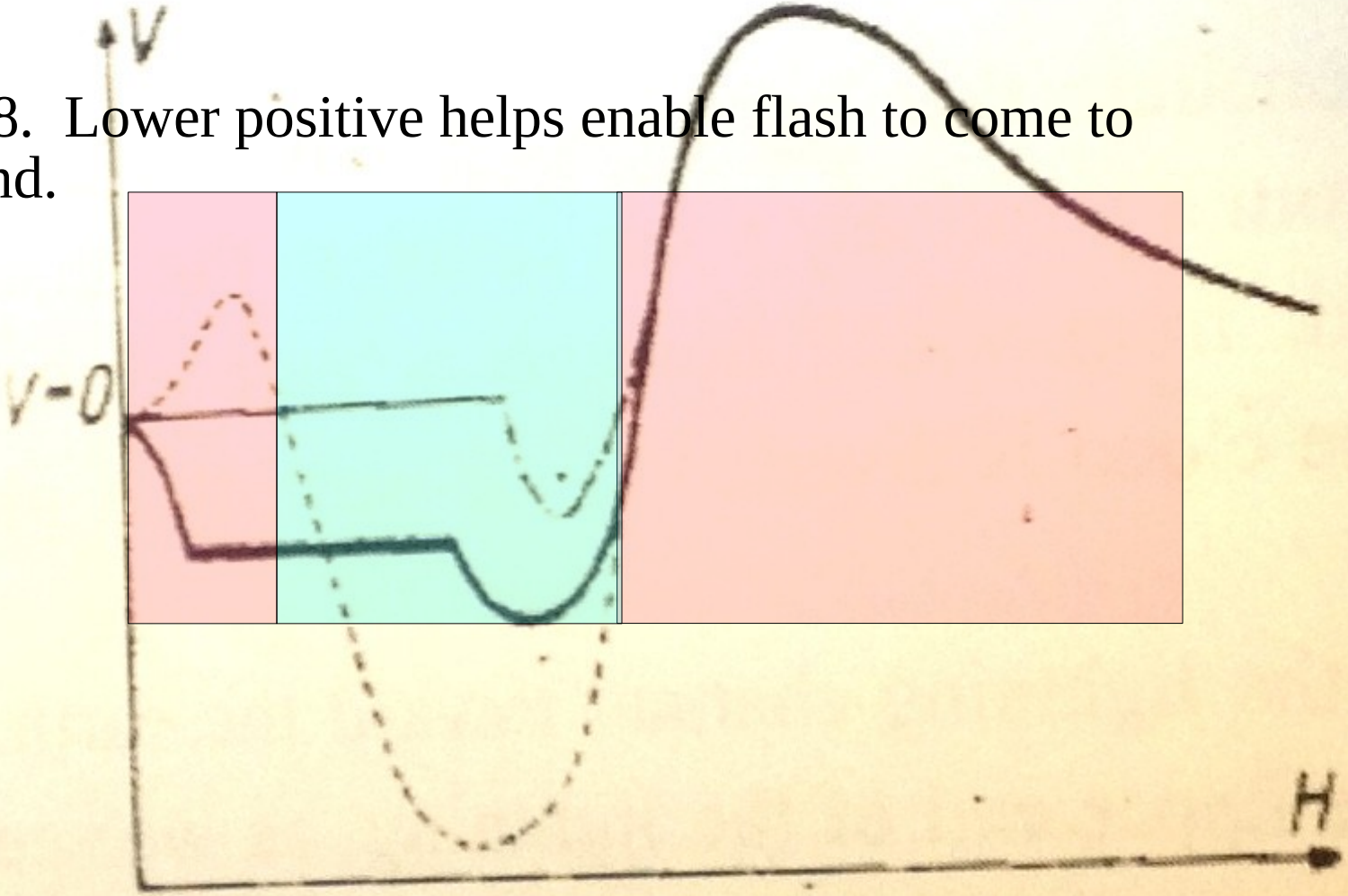

Figure 8 ~~Figure 5~~. Earthbound lightning from the base of the storm cloud.