Physics 535 – Lecture 13
Physics of Lightning

Why a leader stops

2/17/16

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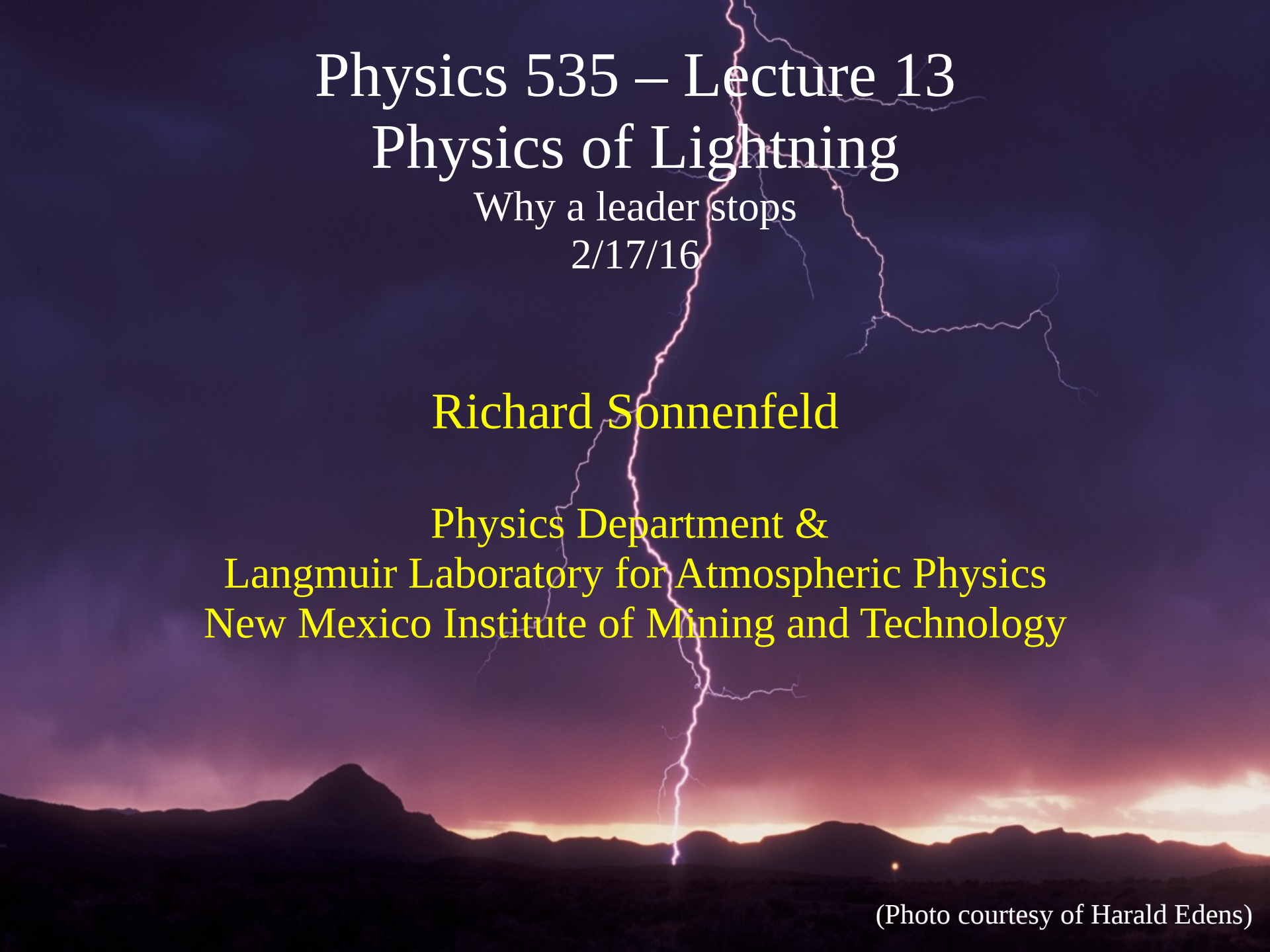


(Photo courtesy of Harald Edens)

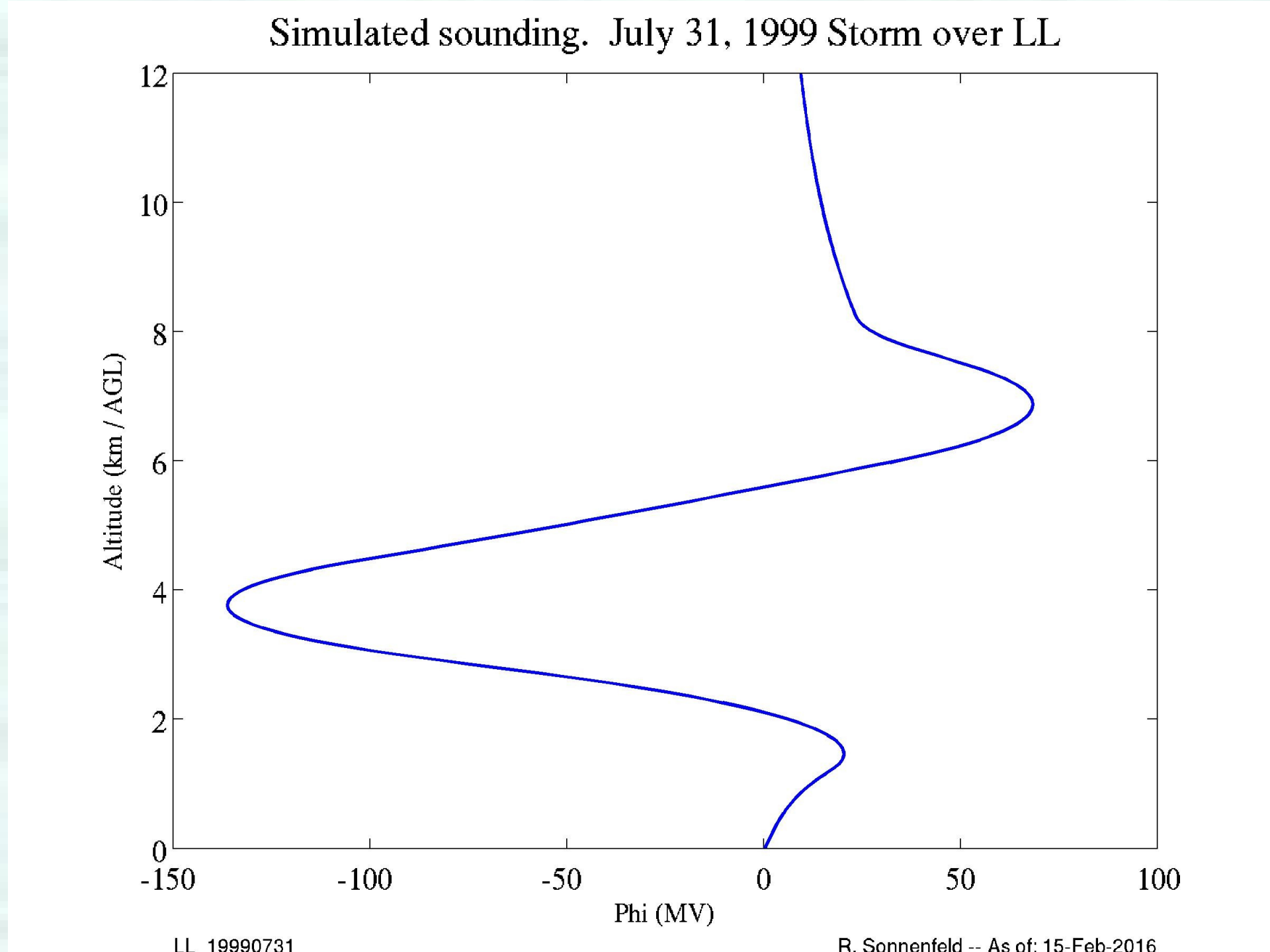
Kasemir's Model:

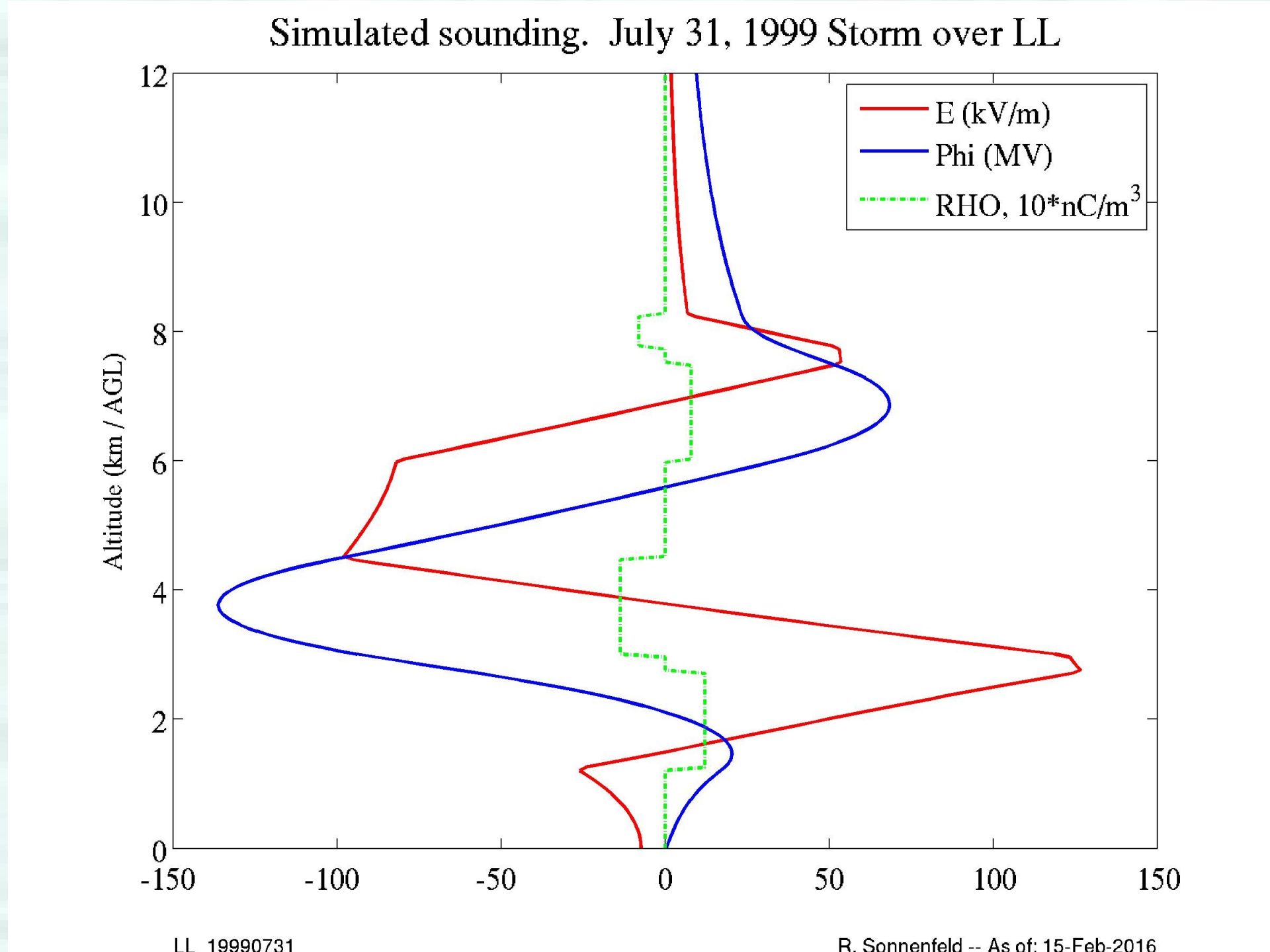
A lightning flash starts when the local field exceeds breakdown (1.8 MV/m at 7 km). [We still don't have that one figured out … but OK].

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.


Simulated sounding. July 31, 1999 Storm over LL
Altitude (km / AGL)
12
10
8
6
4
2
0
-150
-100
-50
0
50
100
Phi (MV)
LL 19990731
R. Sonnenfeld -- As of: 15-Feb-2016


Simulated sounding. July 31, 1999 Storm over LL
E (kV/m)
Phi (MV)
RHO, 10*nC/m3
Altitude (km / AGL)
12
10
8
6
4
2
0
-150
-100
-50
0
50
100
150
LL 19990731
R. Sonnenfeld -- As of: 15-Feb-2016

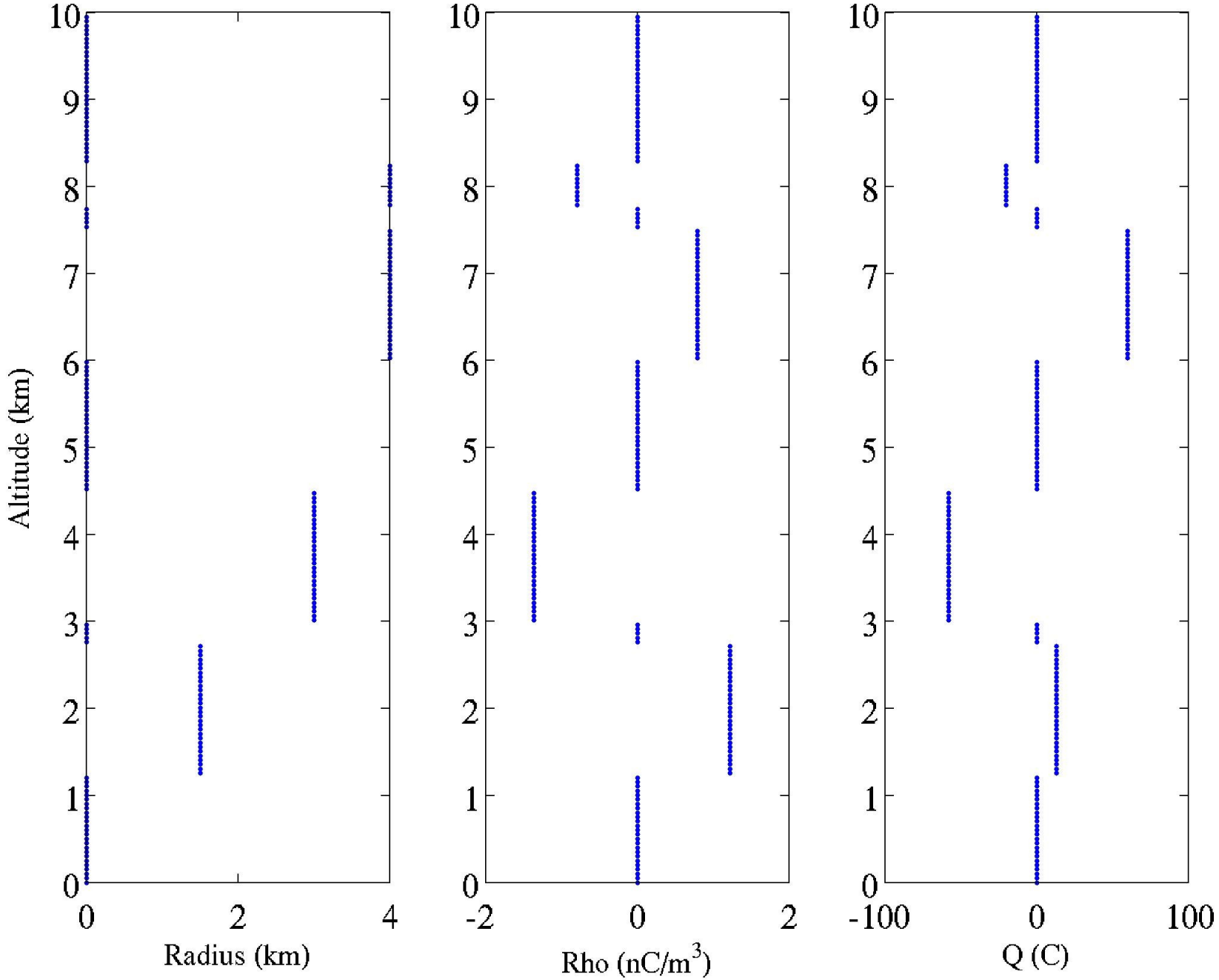

Altitude (km)
Radius (km)
Rho (nC/m3)
Q (C)
LL 19990731
R. Sonnenfeld -- As of: 14-Feb-2016

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

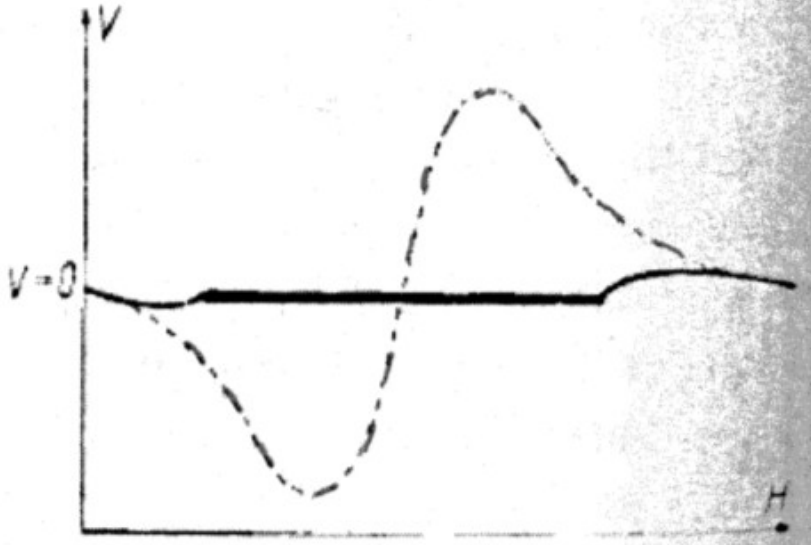


Figure 5. Final state of lightning in a bipolar space charge.

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.

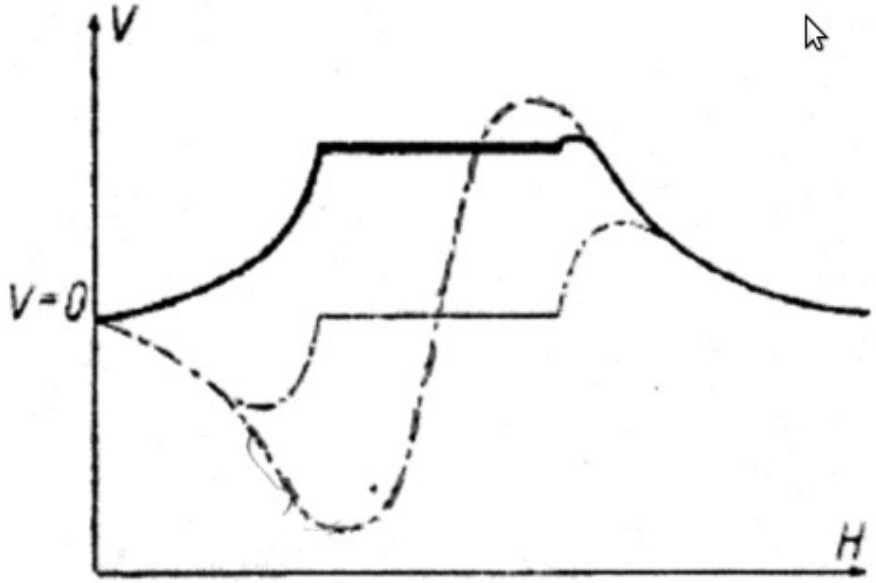


Figure 6. Potential image of lightning from the head of the storm cloud.

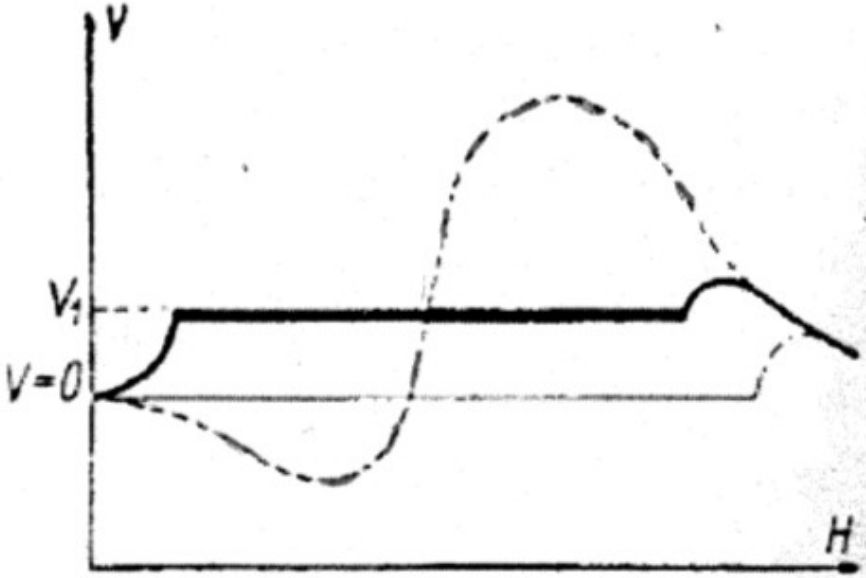
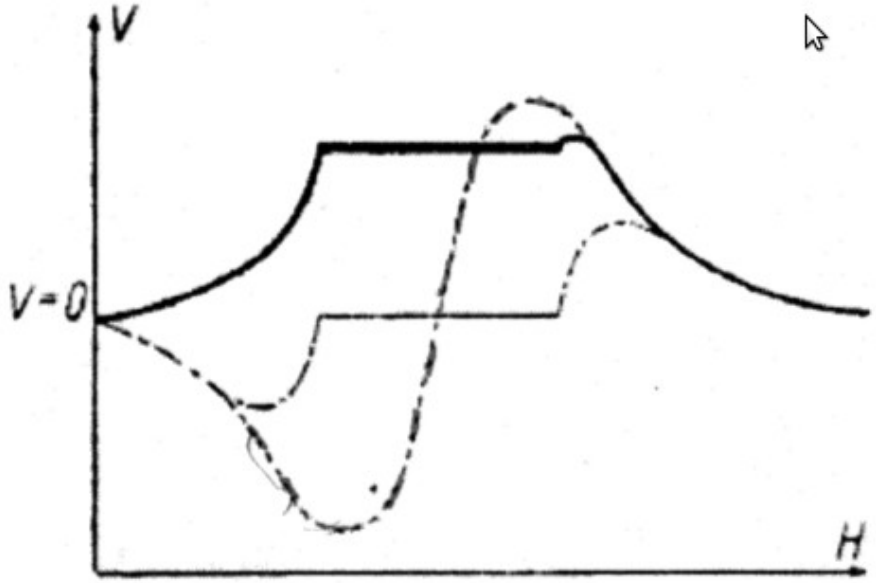


Figure 7. Earth-bound lightning from two unequally sized space charges.

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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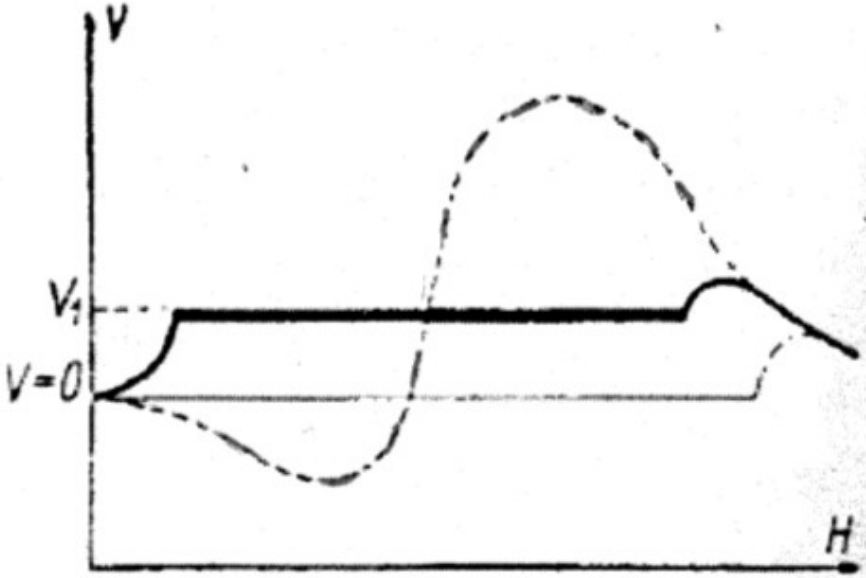

Figure 7. Earth-bound lightning from two unequally sized space charges.

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.

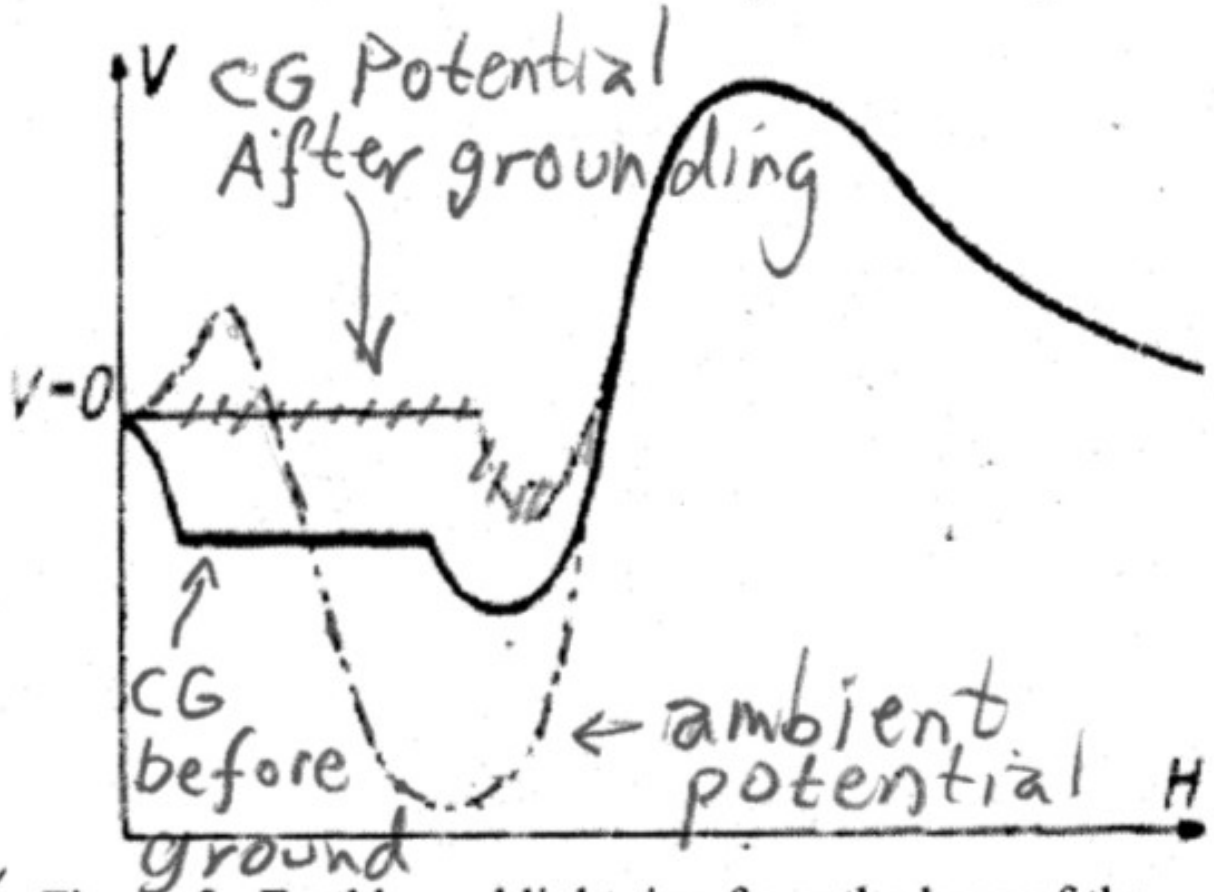

Figure 8 ~~Figure 5~~. Earthbound lightning from the base of the storm cloud.