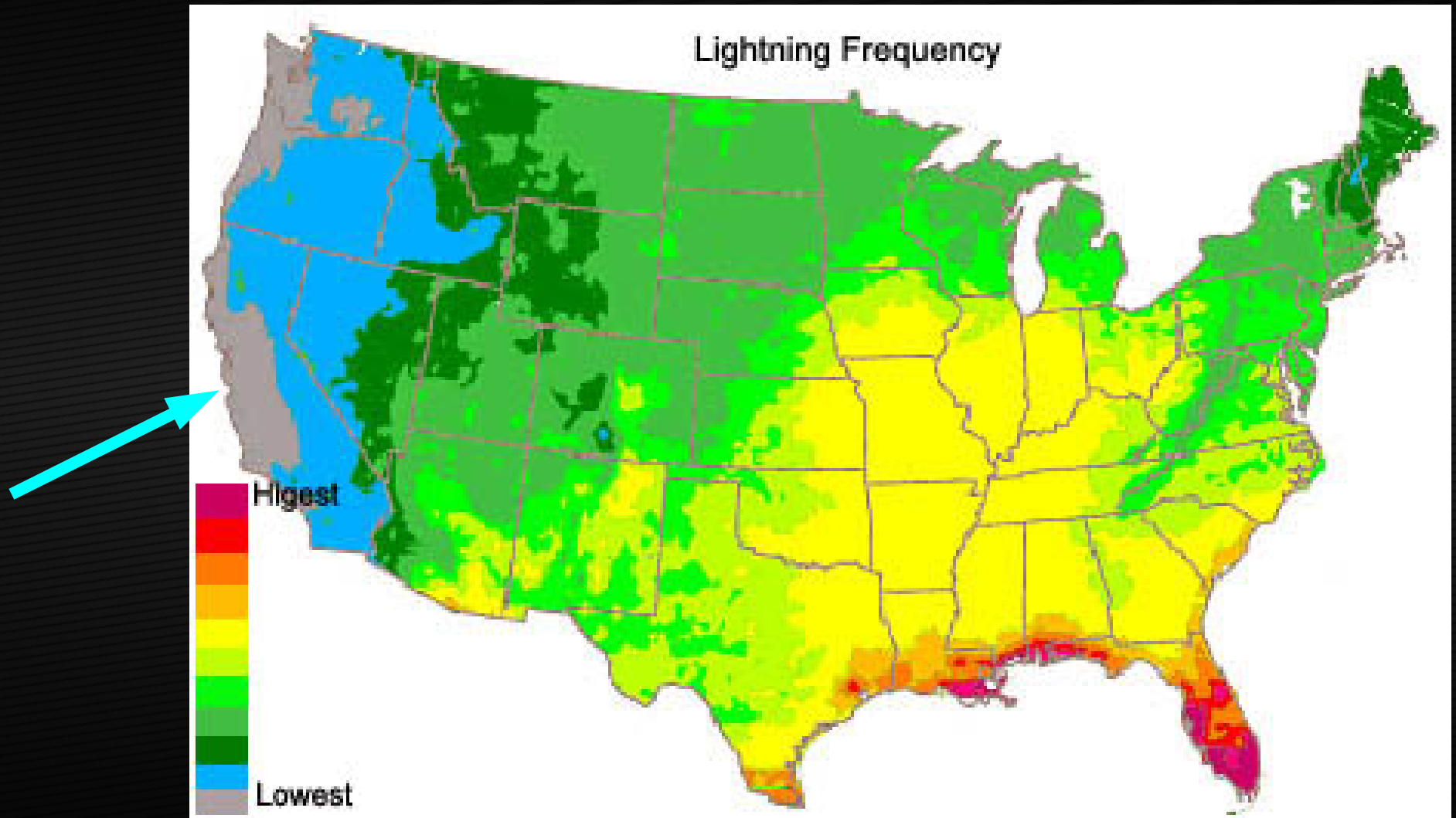


# The exotic side of thunderstorms:

gamma-rays.  
sprites,  
elves, and  
blue jets

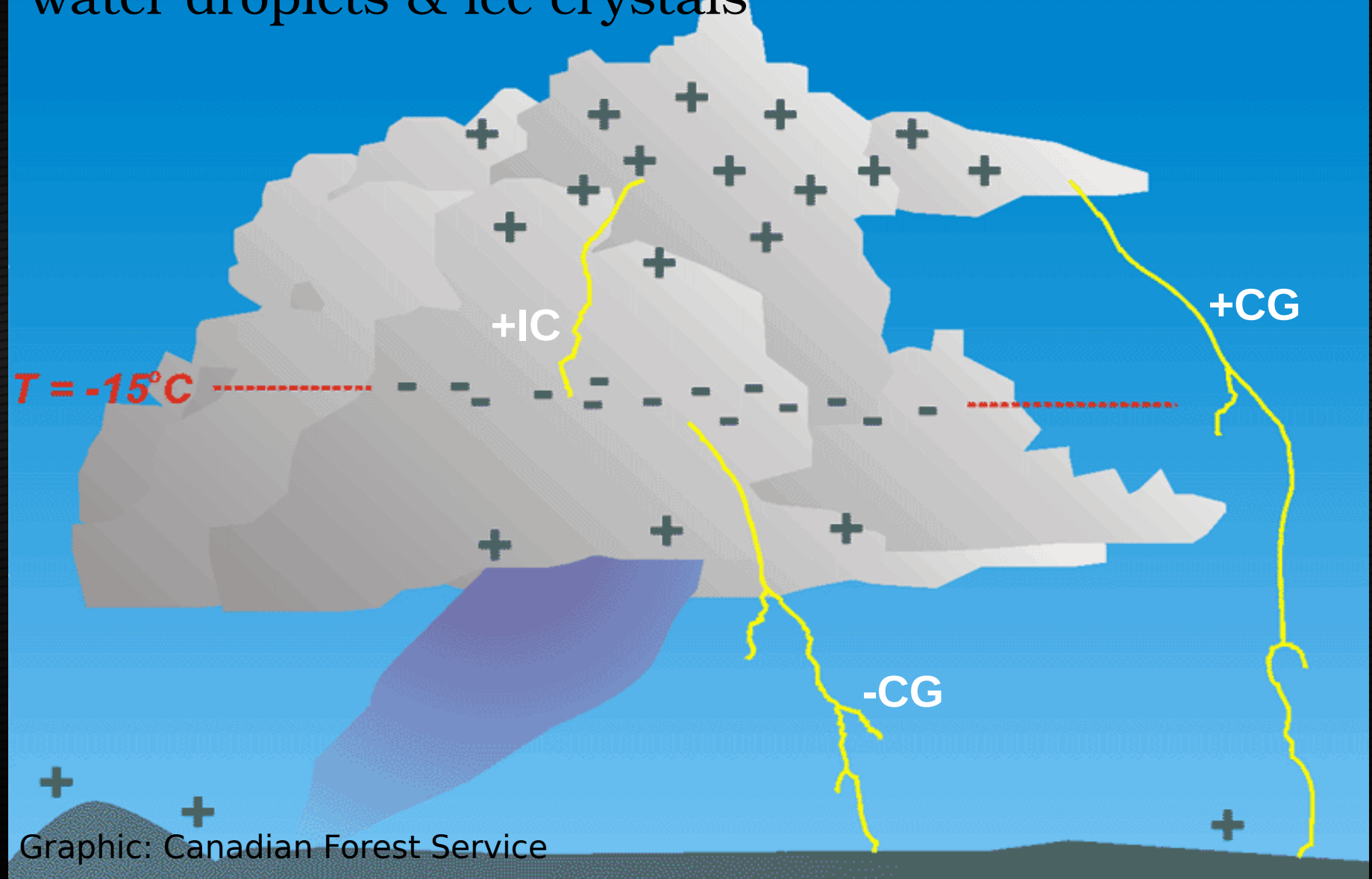
David Smith  
6/20/13

what's the worst place in the US to be a lightning researcher?



# Lightning is caused by electric charge in clouds

Electric charge is caused by collisions between water droplets & ice crystals



# Exotic things discovered in the last 25 years:

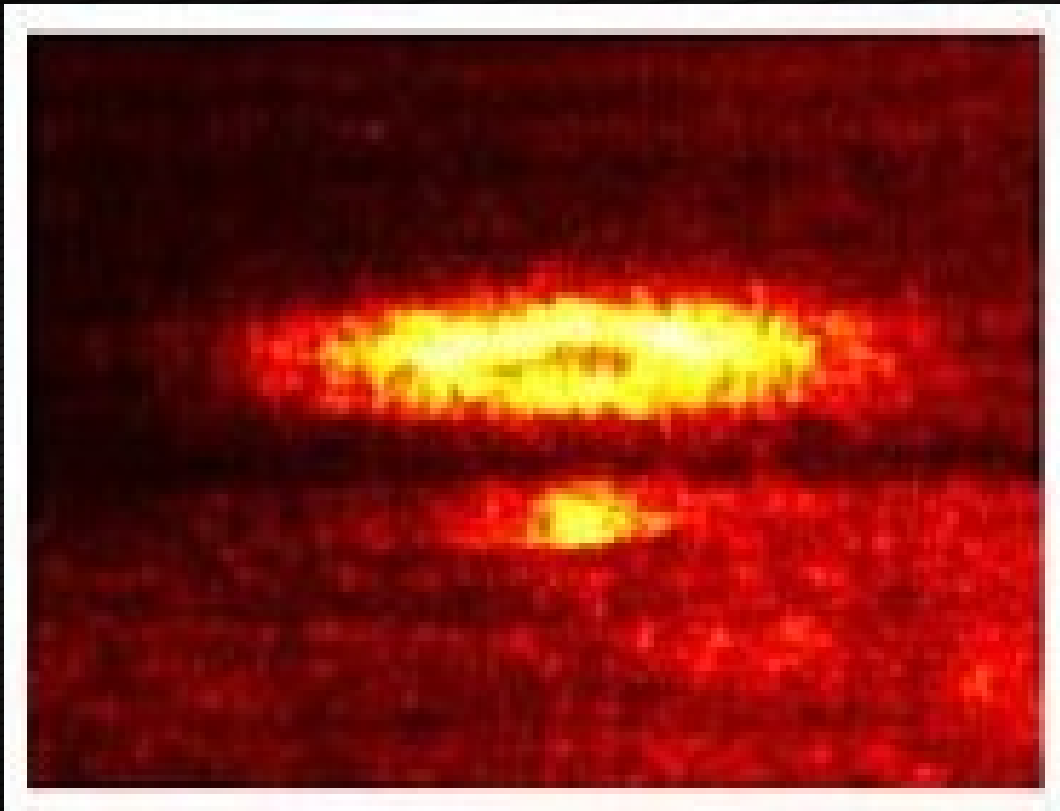
Elves

Sprites

Blue jets & gigantic jets

Terrestrial gamma-ray flashes

first the pictures, then the physics,  
then the research.



elve:

- expanding ring
- ~80 km (top of atm.)
- very fast
- simultaneous with lightning
- lightning with high current

first the pictures, then the physics,  
then the research.



sprite:

- jellyfish/carrots/  
columns
- spread from ~50km
- fast
- slightly delayed after  
lightning
- lightning that moves  
a lot of charge  
over time

first the pictures, then the physics,  
then the research.

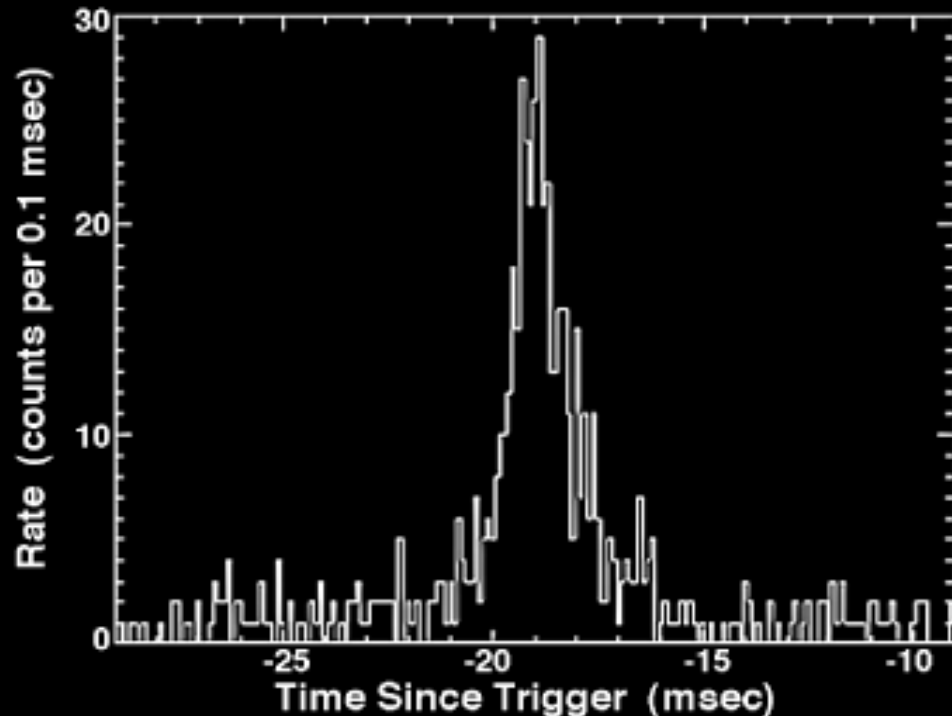


blue jets/gigantic  
jets:

- spray or tendrils
- start at cloud top  
(10-20 km)
- slower
- no direct relation to  
ordinary lightning

first the pictures, then the physics,  
then the research.

Light Curve for a Terrestrial Gamma Flash



terrestrial gamma-ray  
flashes:

- not yet seen by eye
- at cloud top or inside  
cloud (10-20 km)
- fast to very fast
- related to intracloud  
lightning but much  
rarer
- simultaneous with  
lightning



ELVE

Thermosphere

Mesosphere

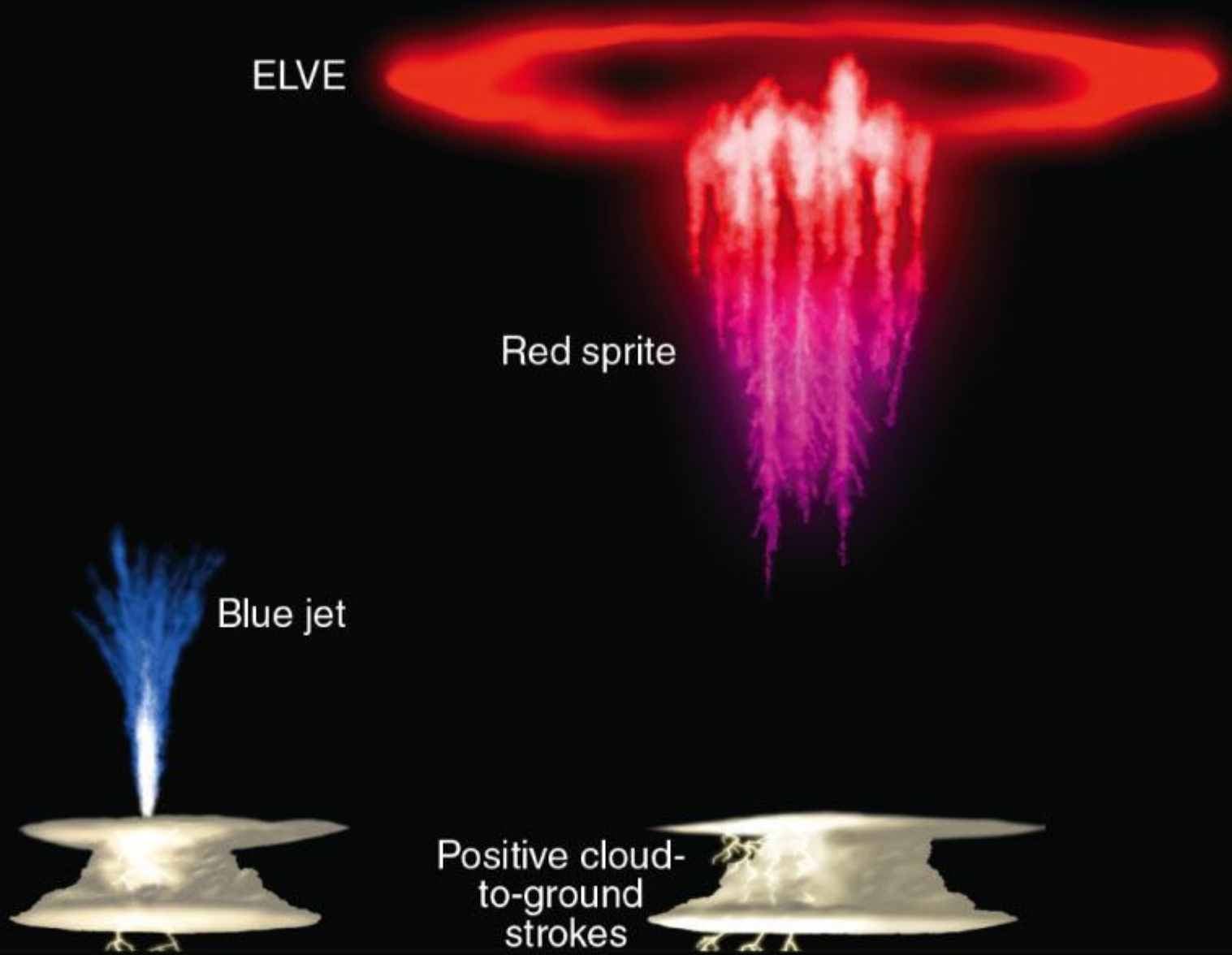
Stratosphere

Troposphere

Red sprite

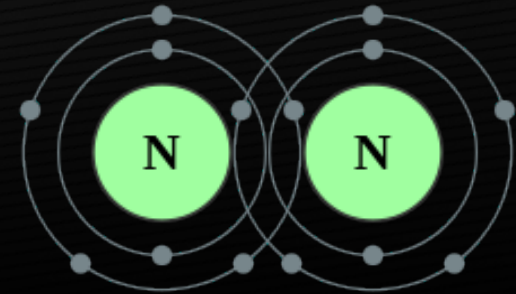
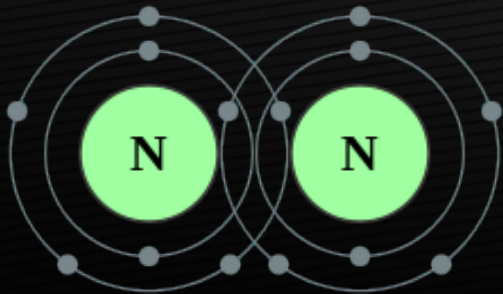
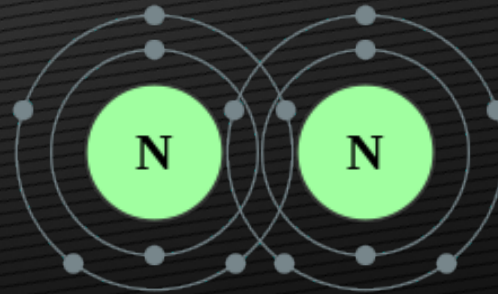
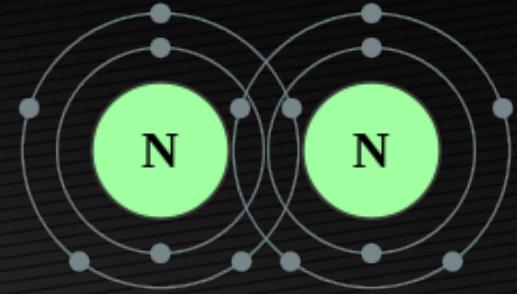
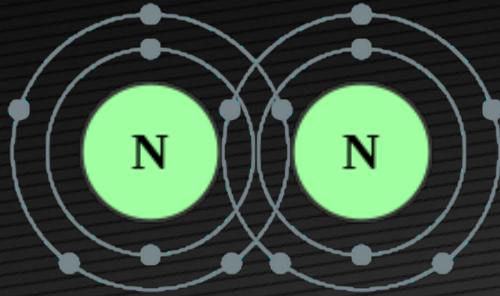
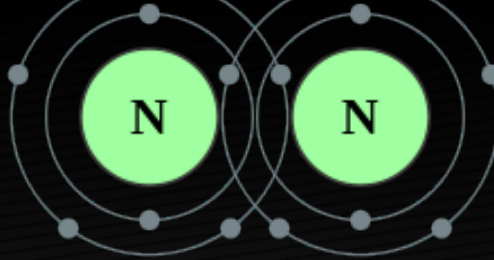
Blue jet

Positive cloud-to-ground strokes

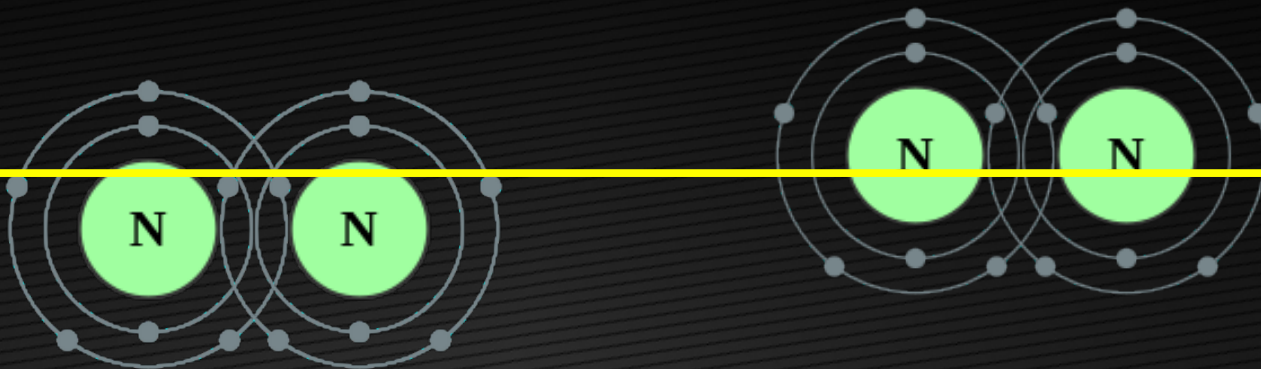
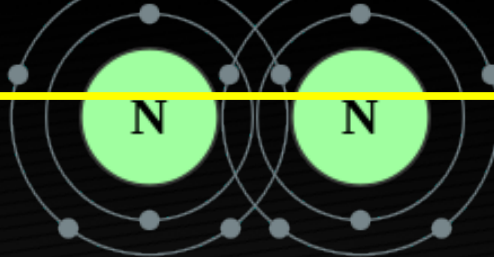


movies here

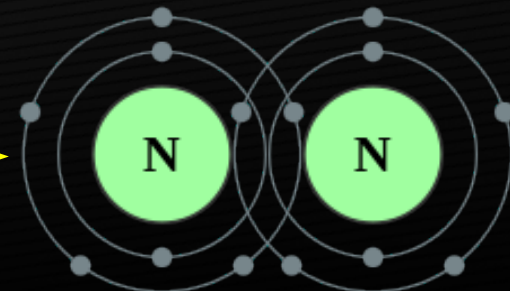
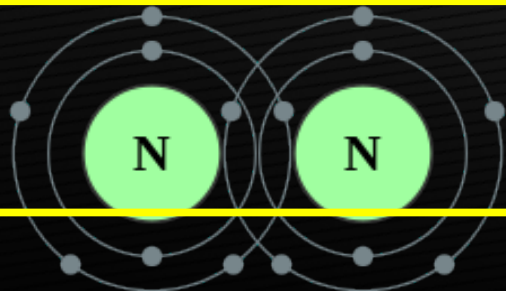
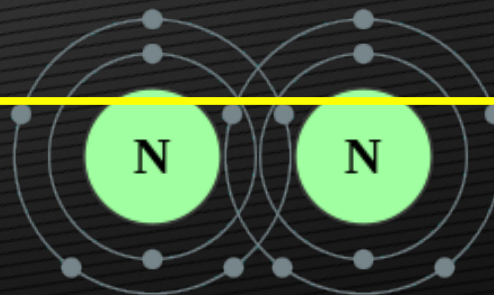
**Air.**



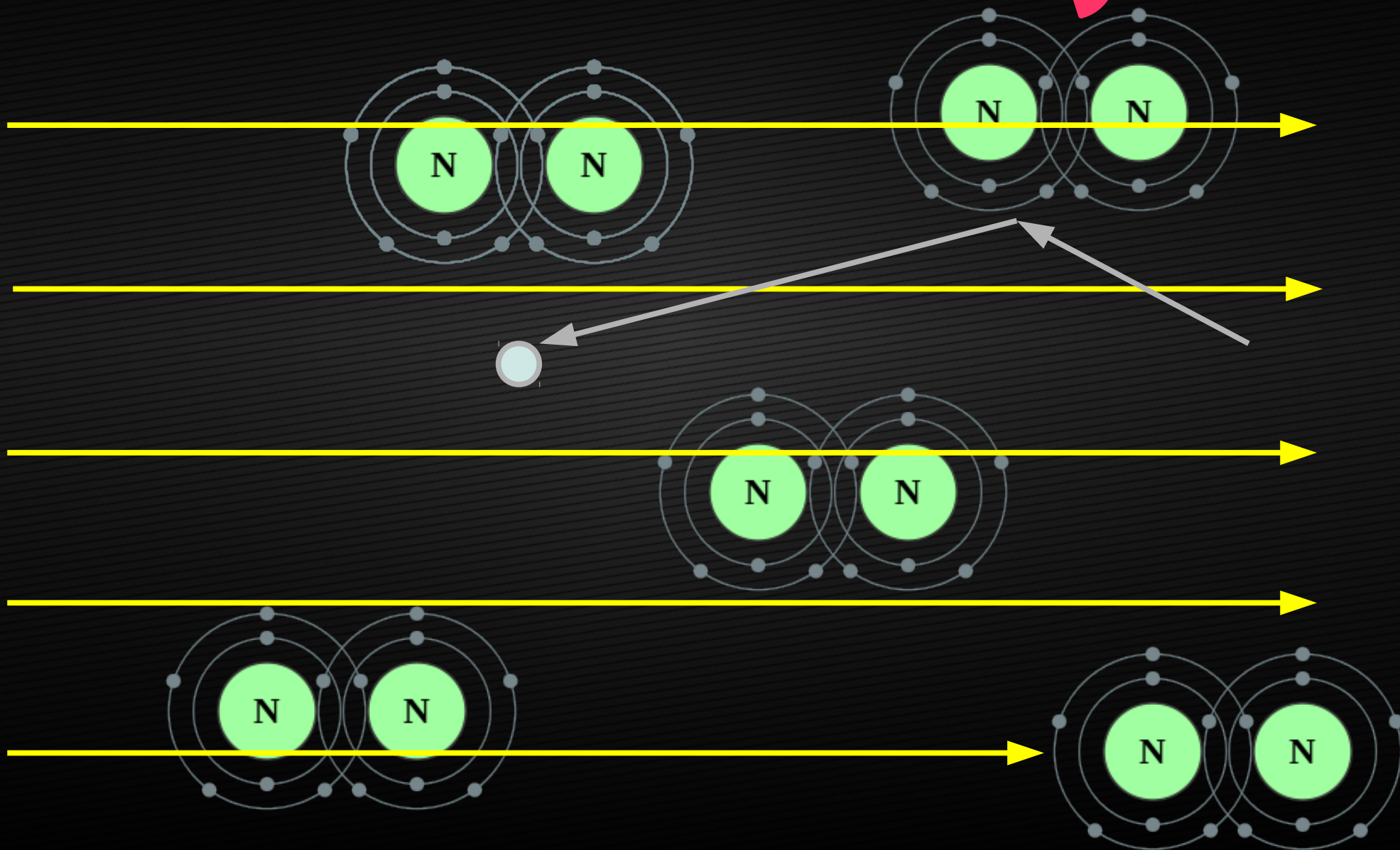
**Electric field**



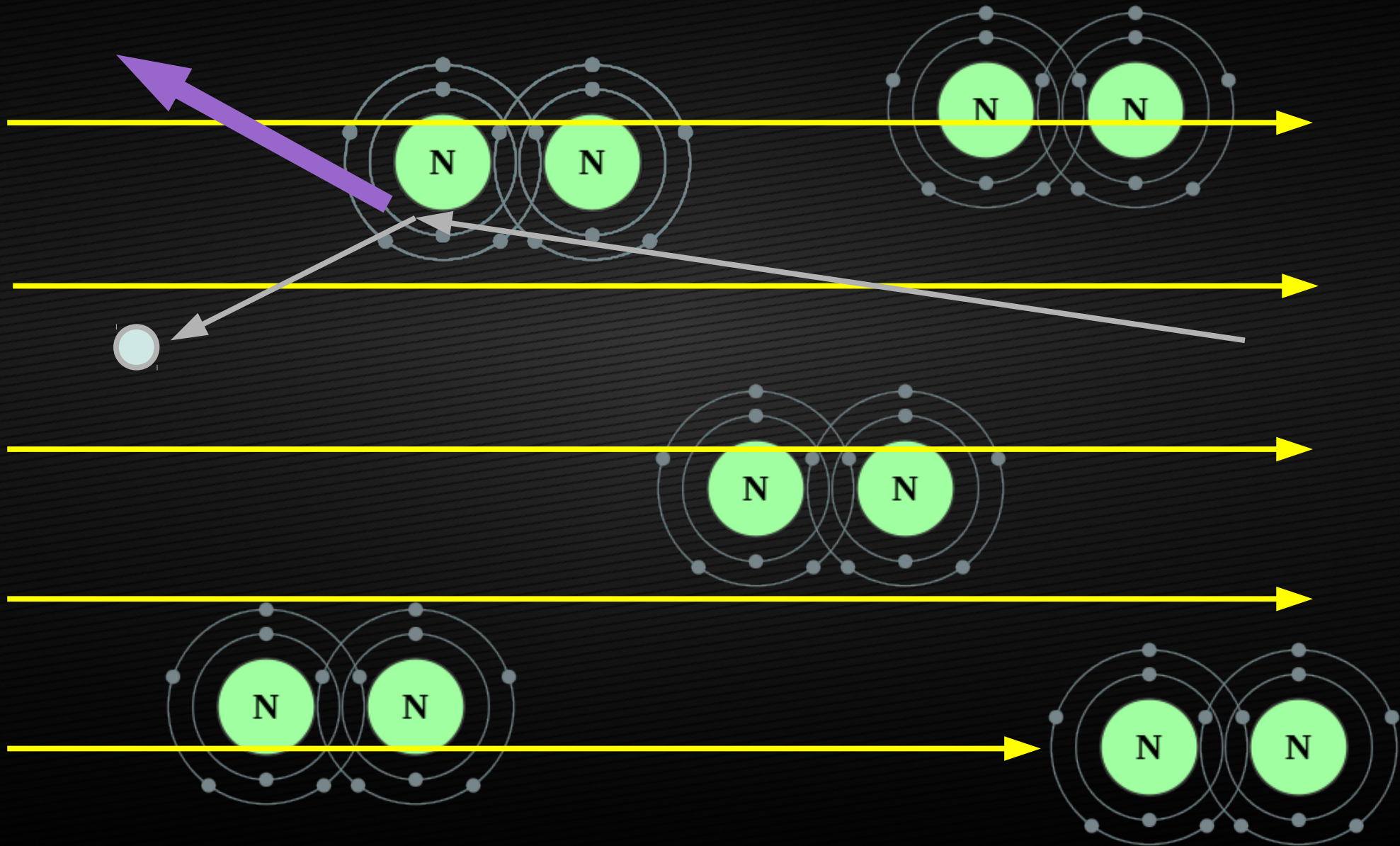
**Free electron** 



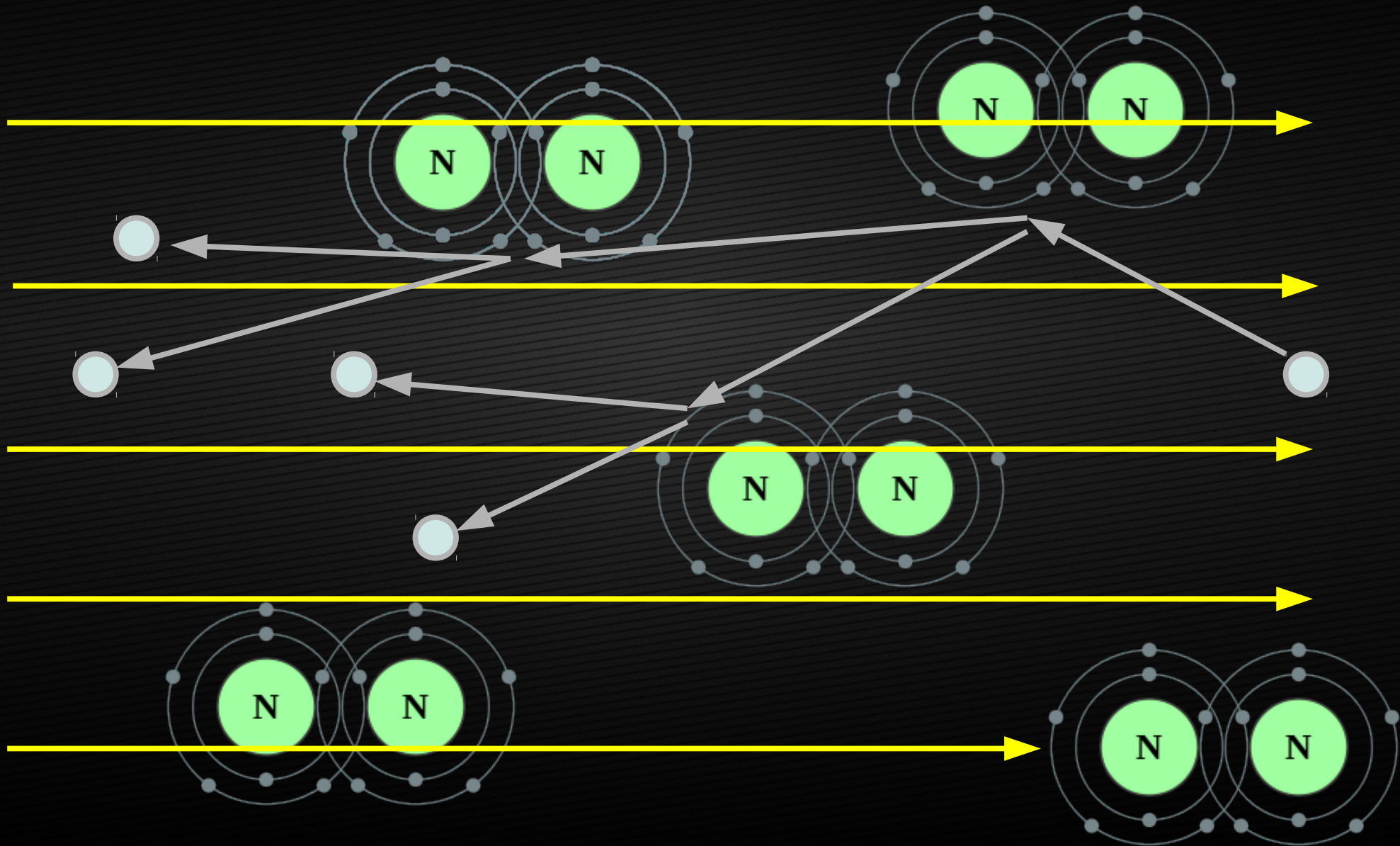
**Excited molecule  
emits visible light**



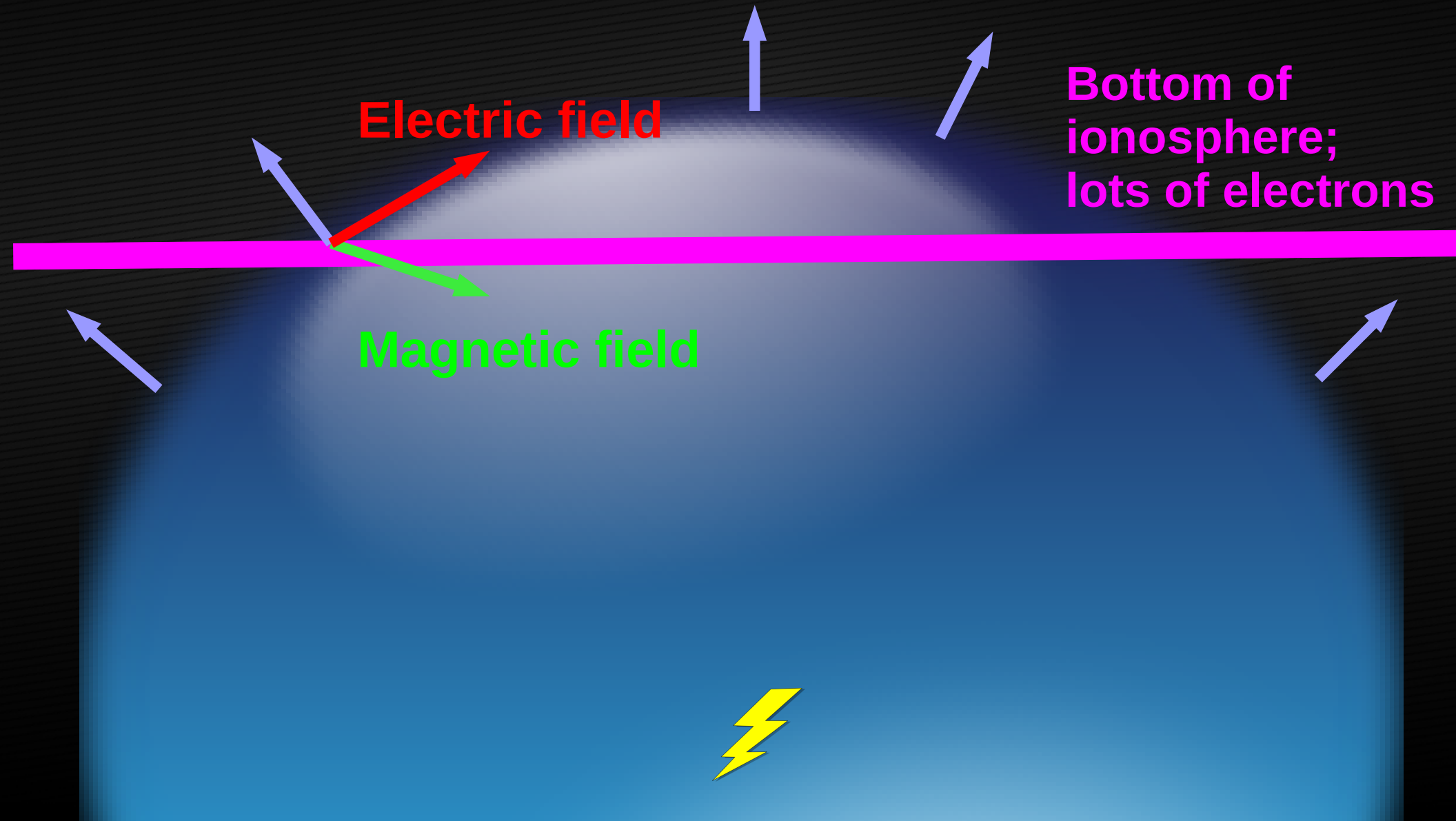
Close encounter with nucleus produces x/gamma-ray



# Knocking more electrons off molecules produces an avalanche

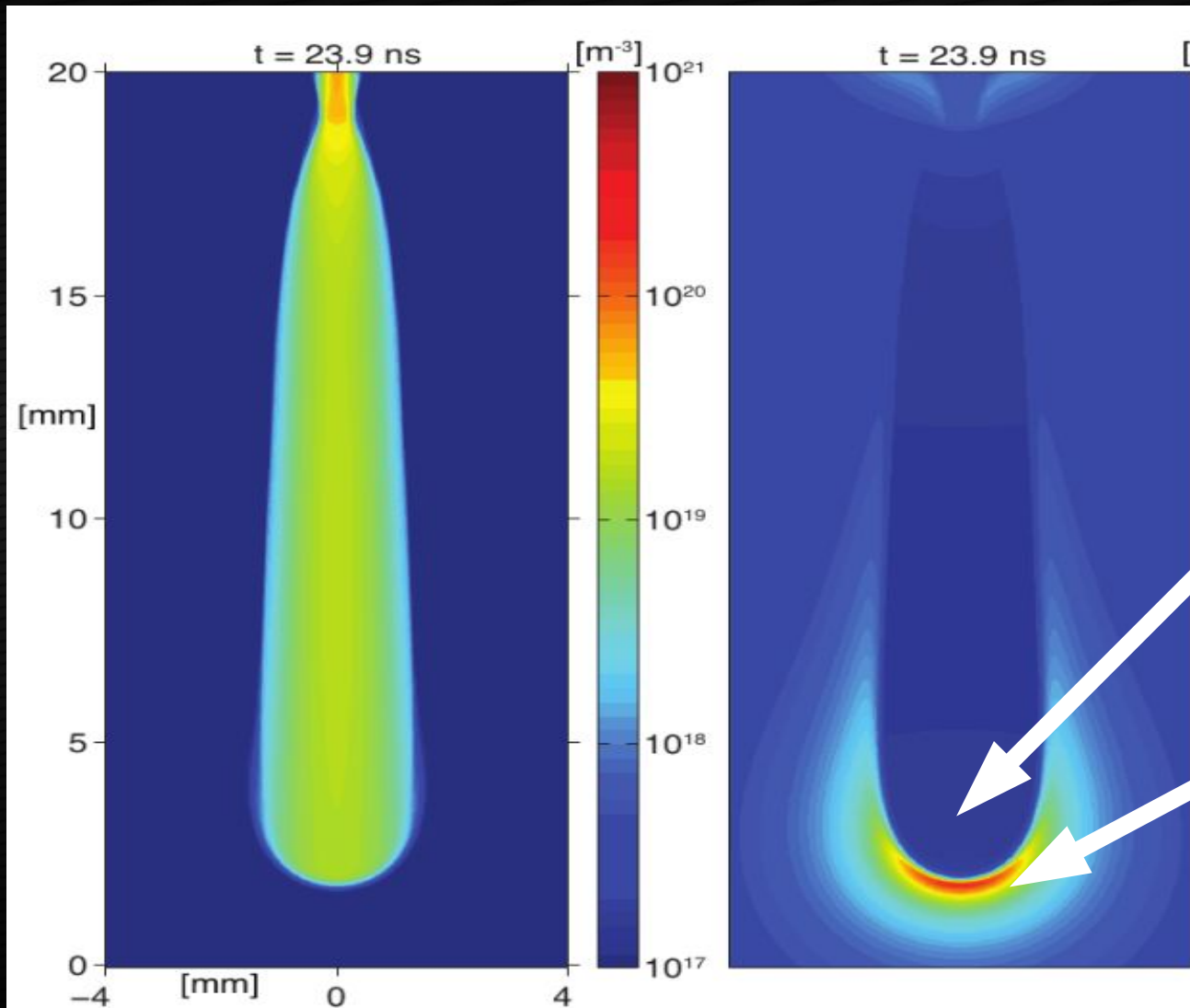


elve: lightning makes “electromagnetic pulse”;  
electric field is transient, not due to buildup  
of charge.





# sprites: streamers



**self-propagating**  
in modest  
electric  
fields

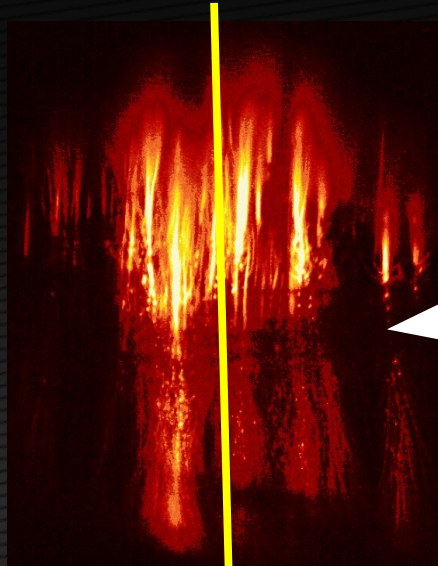
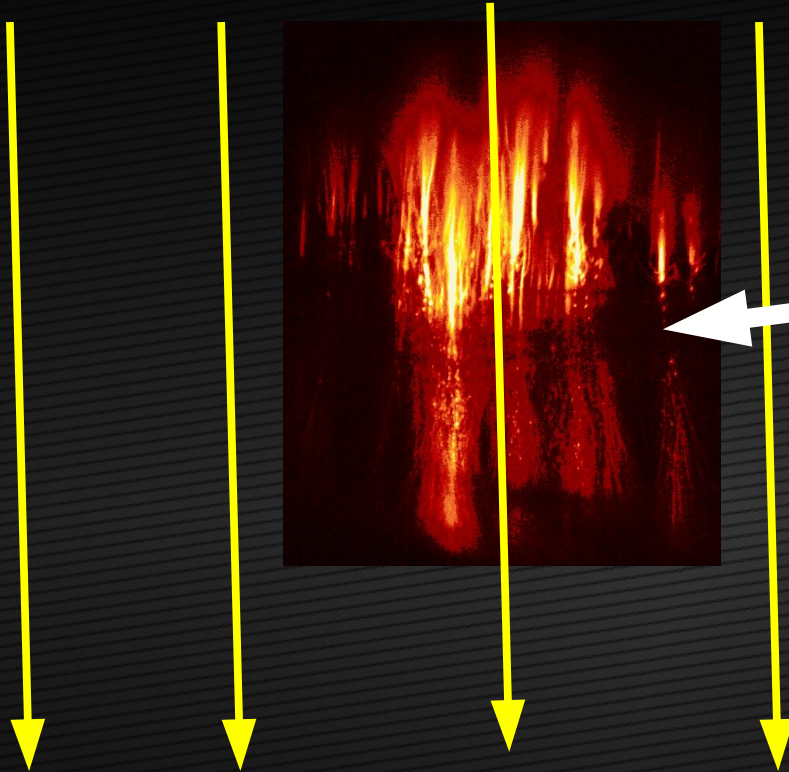
charge at tip  
makes extra  
field

extra field makes  
avalanches here

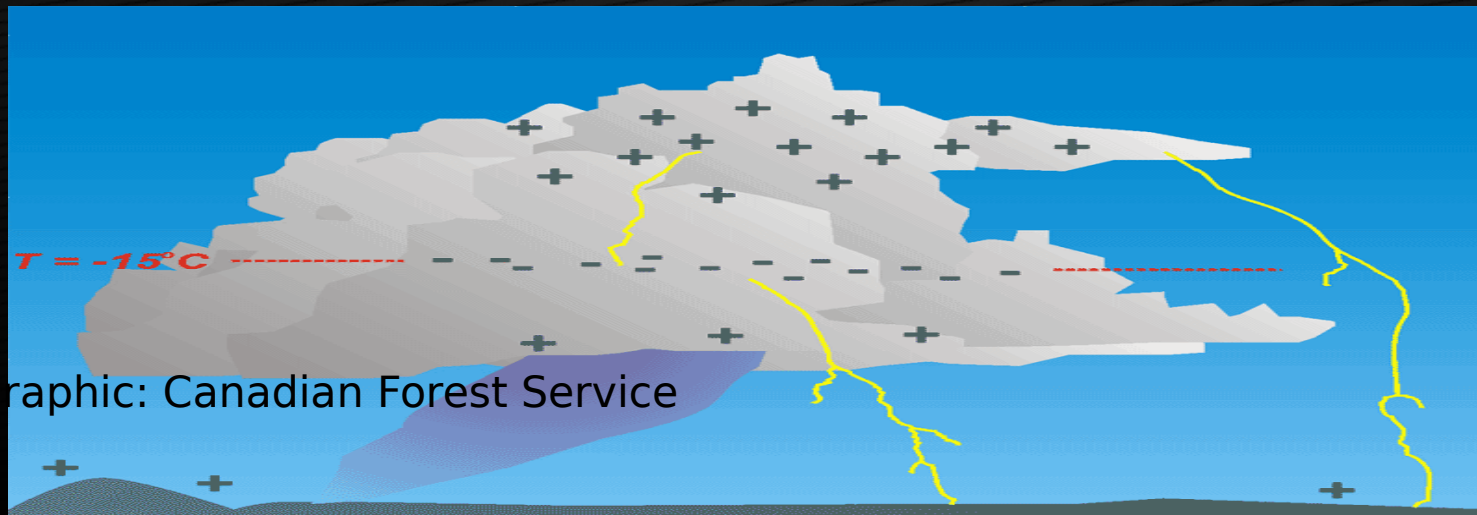
tip is extended!

sprites take place high above thundercloud after lightning:

**Electric field**

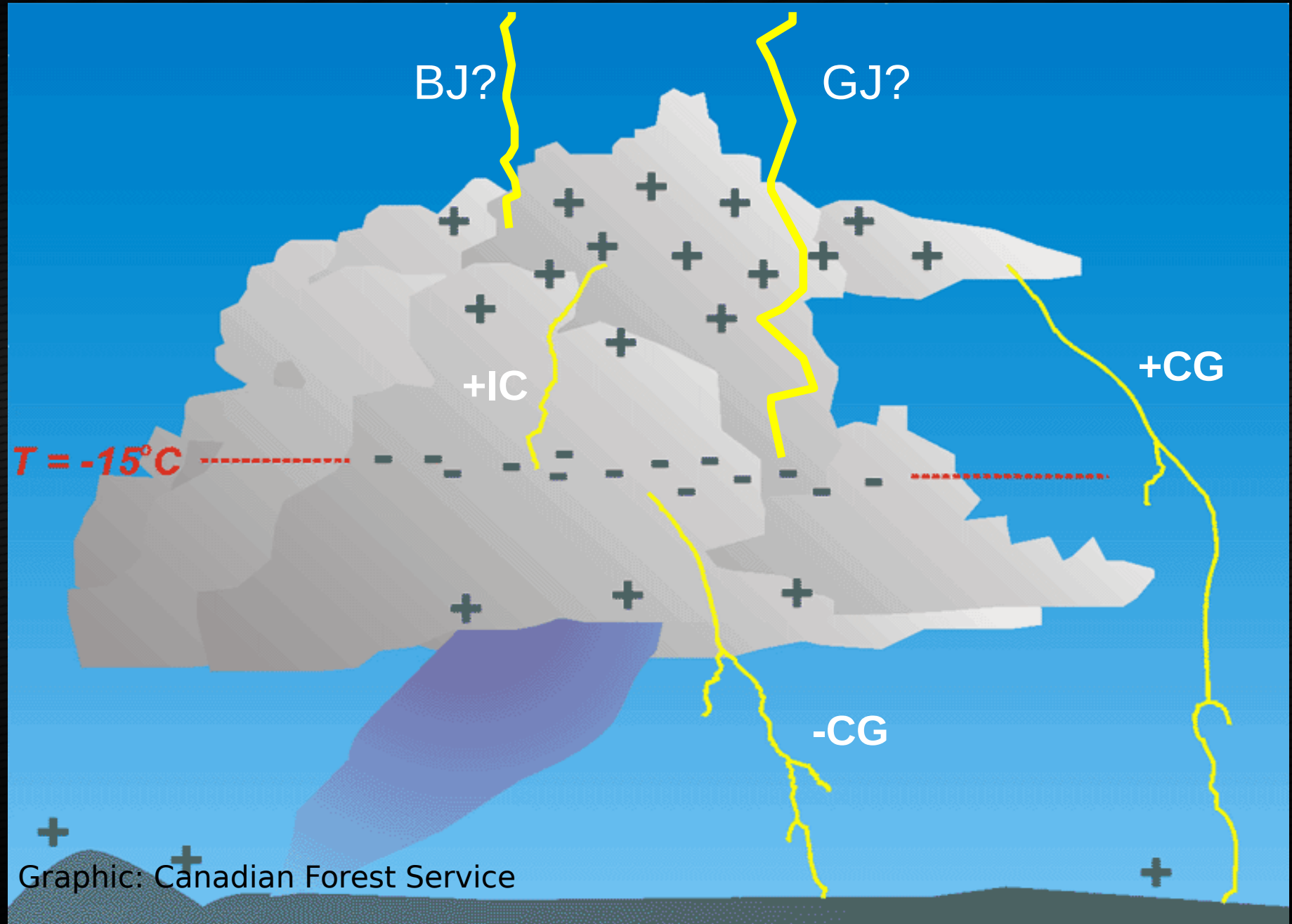


sprite streamers start here



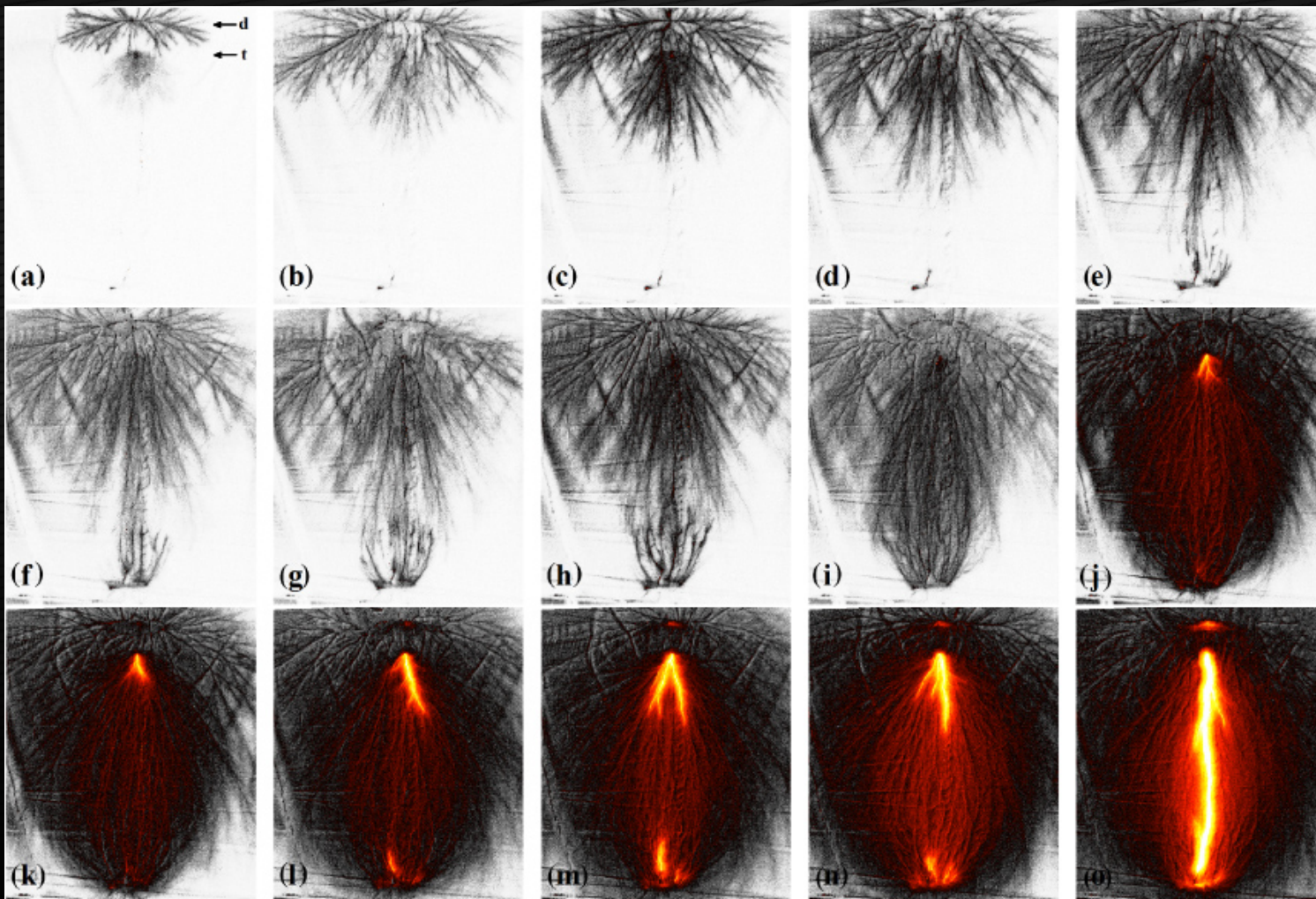
+CG lightning removes upper + charge

are blue jets & gigantic jets similar to ordinary lightning?



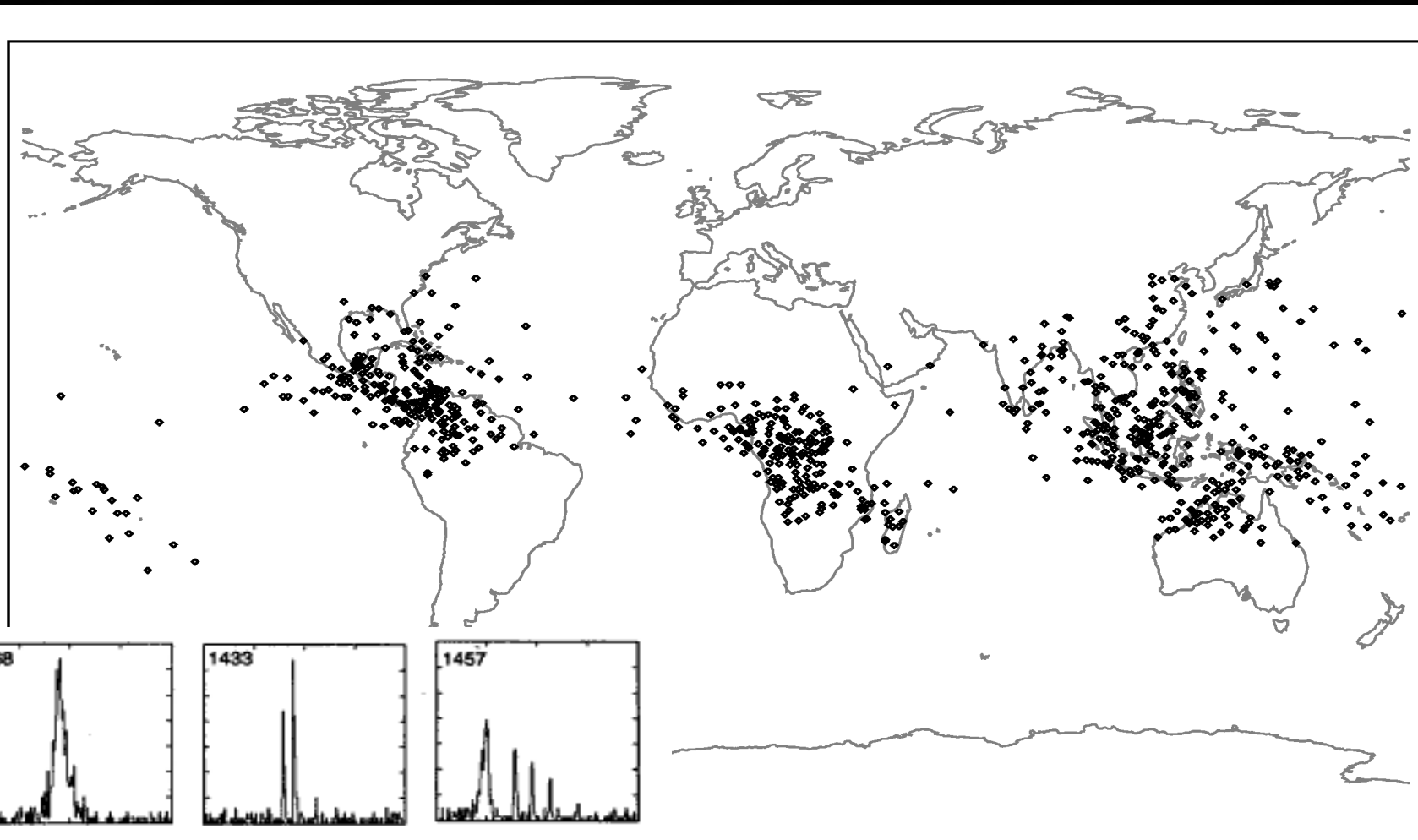
lightning (& maybe jets) proceeds by *stepped leaders*

many streamers merge and create a hot channel that steps forward irregularly:

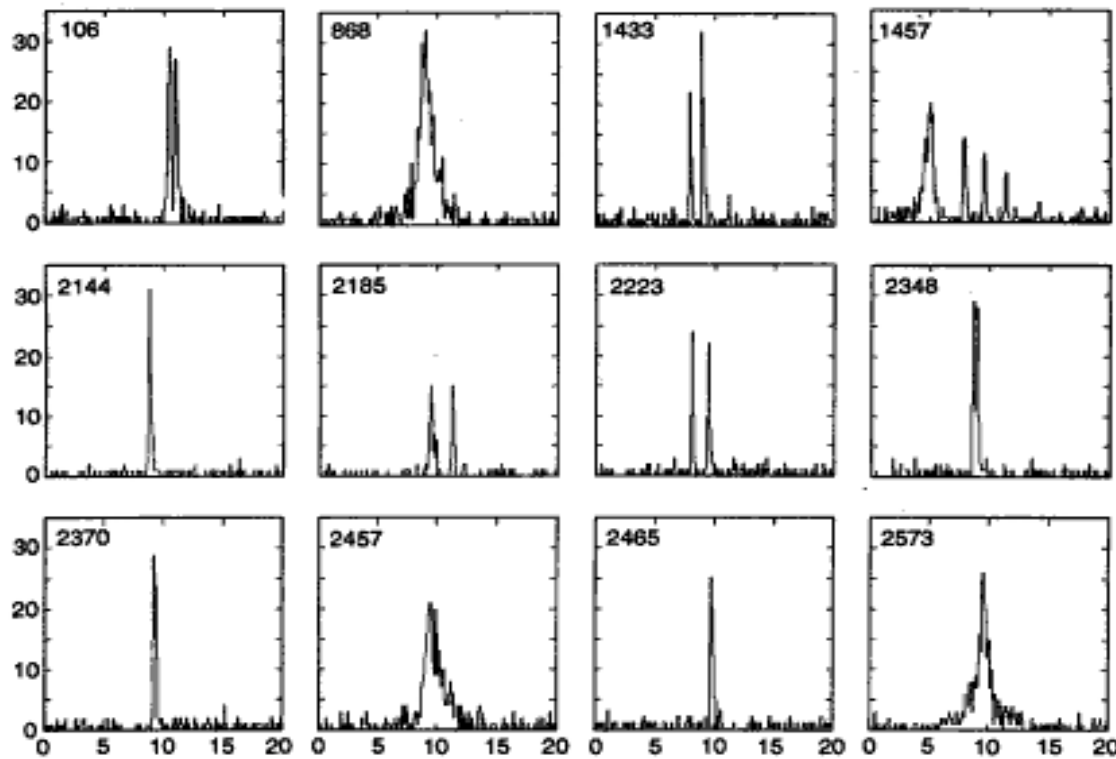


Kochkin et al.  
J. Phys. D  
2012

TGF map  
from RHESSI  
satellite data



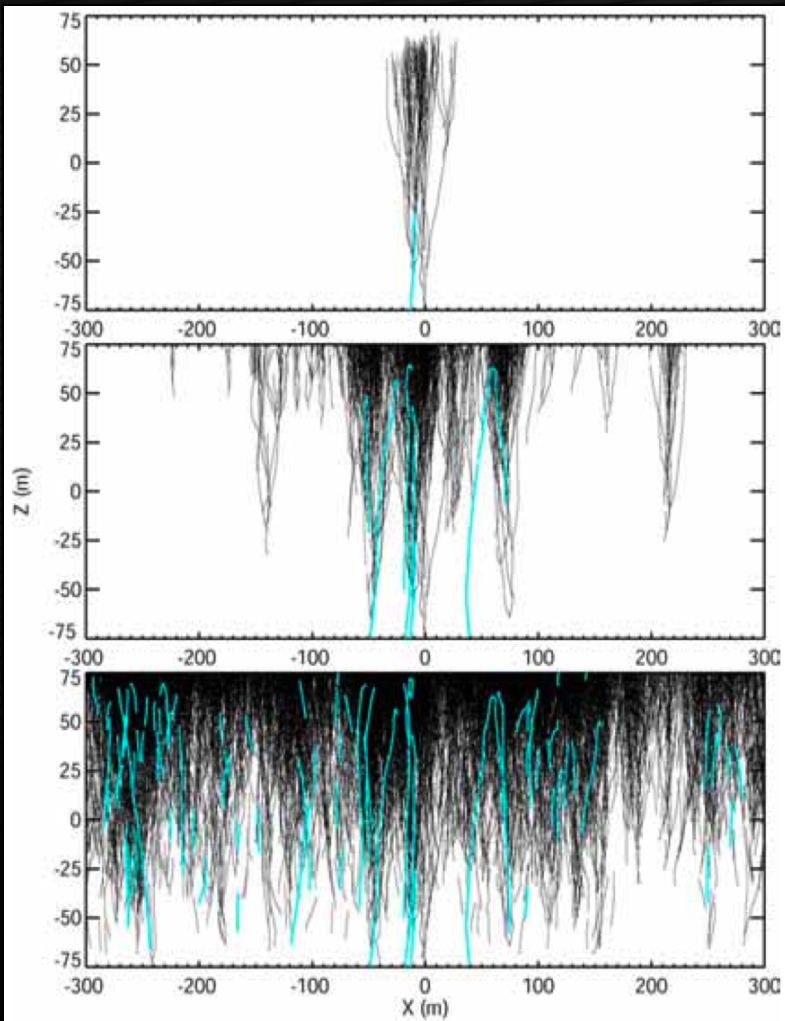
signal (counts/0.1 ms)



terrestrial gamma-ray  
flashes (TGFs)

TGF time profiles from BATSE  
satellite data (Fishman et al.  
1994, *Science*)

TGFs are so bright that gamma detectors on orbiting satellites are saturated at 400 miles up  
where do all the seed electrons come from?



avalanches seeded by lightning leader (many seeds)?

avalanches self-seeded by positron & gamma feedback? (only 1 seed needed!)

J. Dwyer 2008

the big questions:

why/how are TGFs triggered in only some lightning?

which is the correct seeding mechanism, leaders or feedback?

are there more TGFs at lower altitudes or lower luminosities?

is there a radiation risk to airline passengers & crew?

the big questions:

why/how are TGFs triggered in only some lightning?

which is the correct seeding mechanism, leaders or feedback?

are there more TGFs at lower altitudes or lower luminosities?

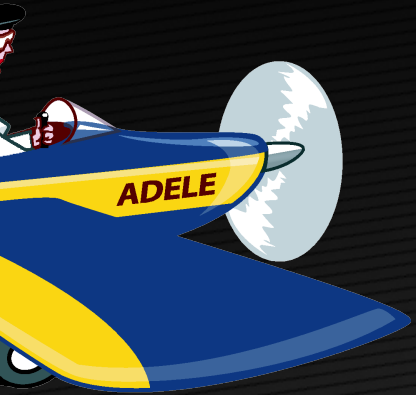
is there a radiation risk to airline passengers & crew?

we need airplane observations, to get more counts/TGF & get closer to low and/or faint ones!

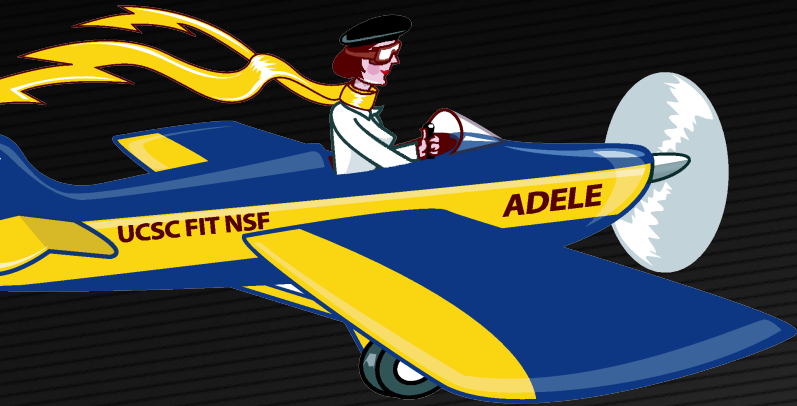


enter ADELE:

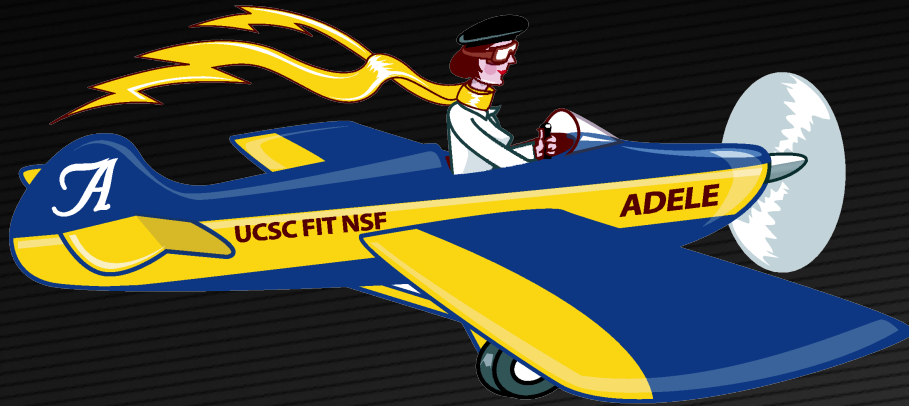
enter ADELE:



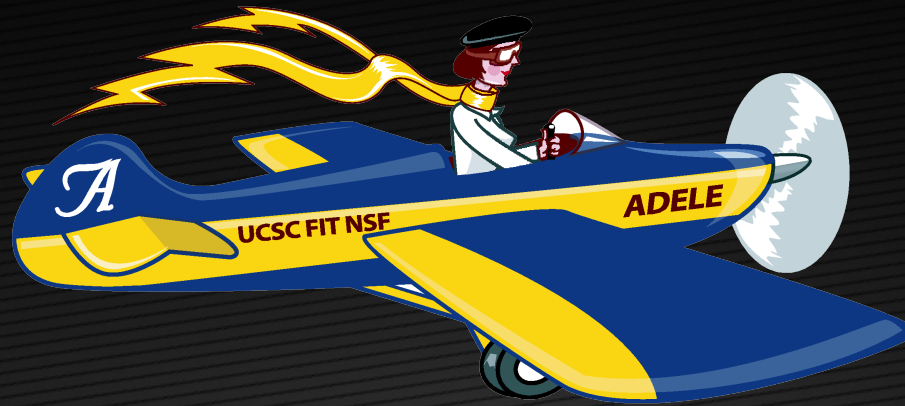
enter ADELE:



enter ADELE:



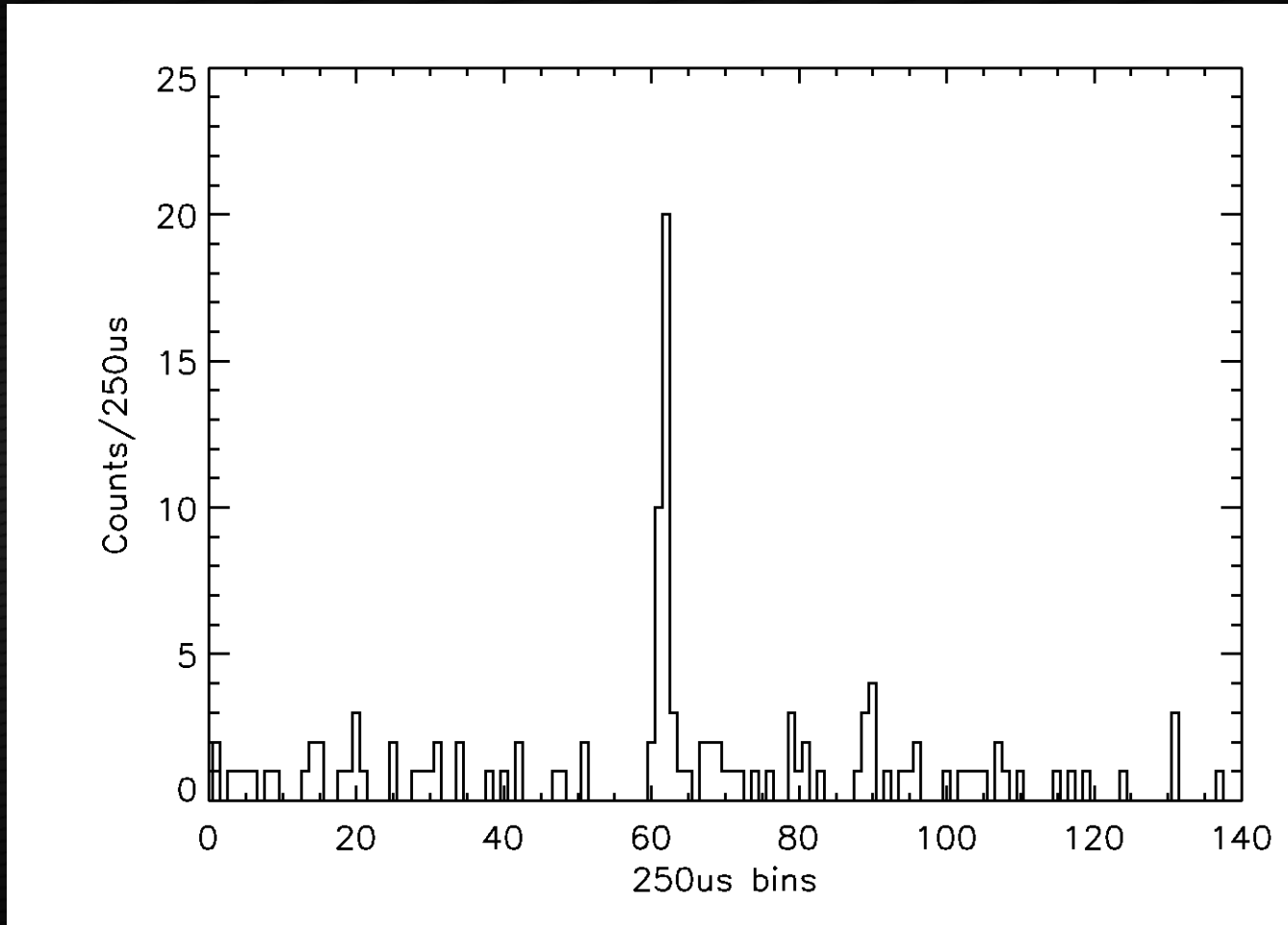
enter ADELE:



enter ADELE:

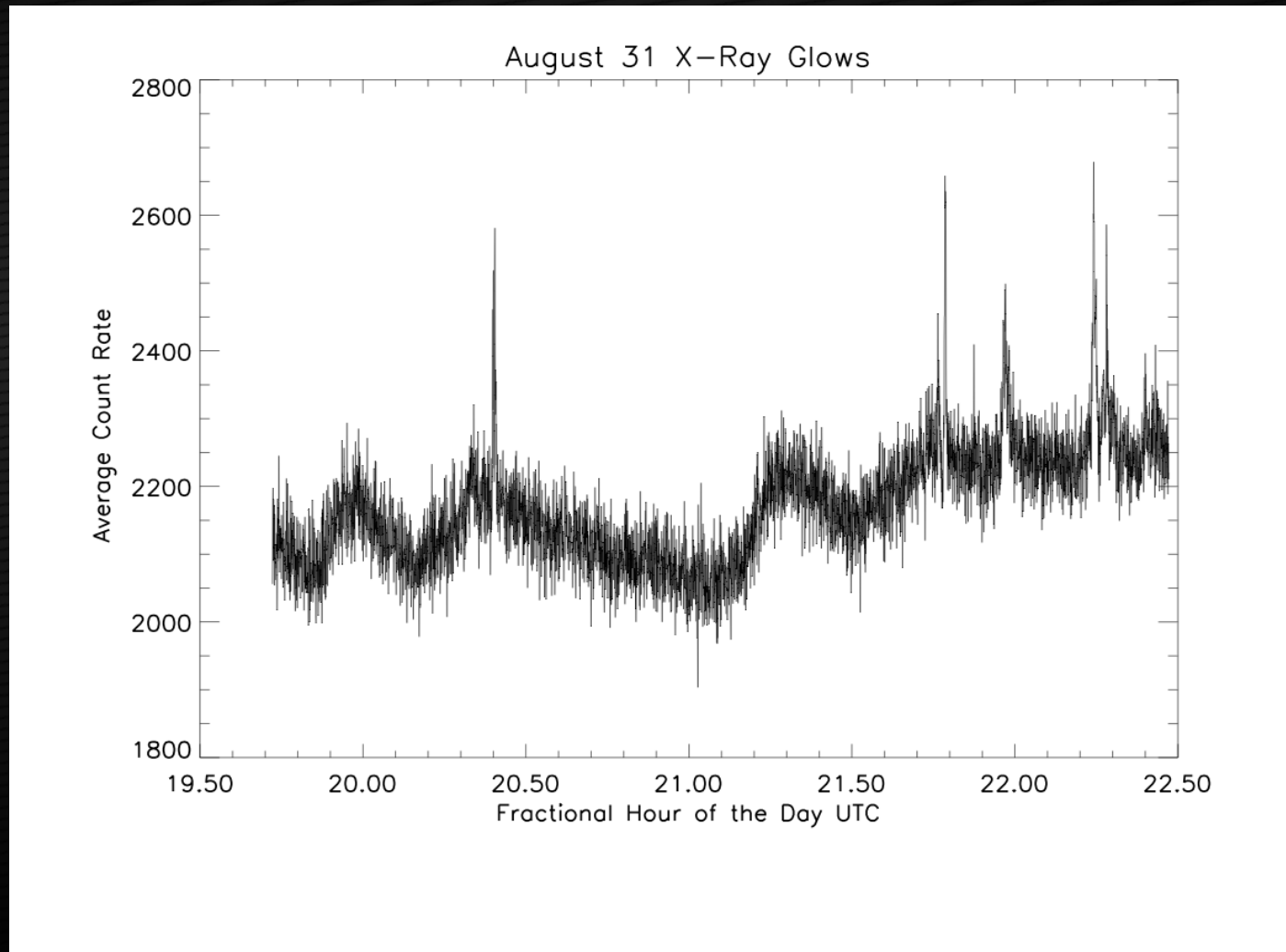


first flights: summer 2009, from Melbourne, FL  
first TGF observed from a plane:



... but only one, although lots of nearby lightning  
TGFs are rare

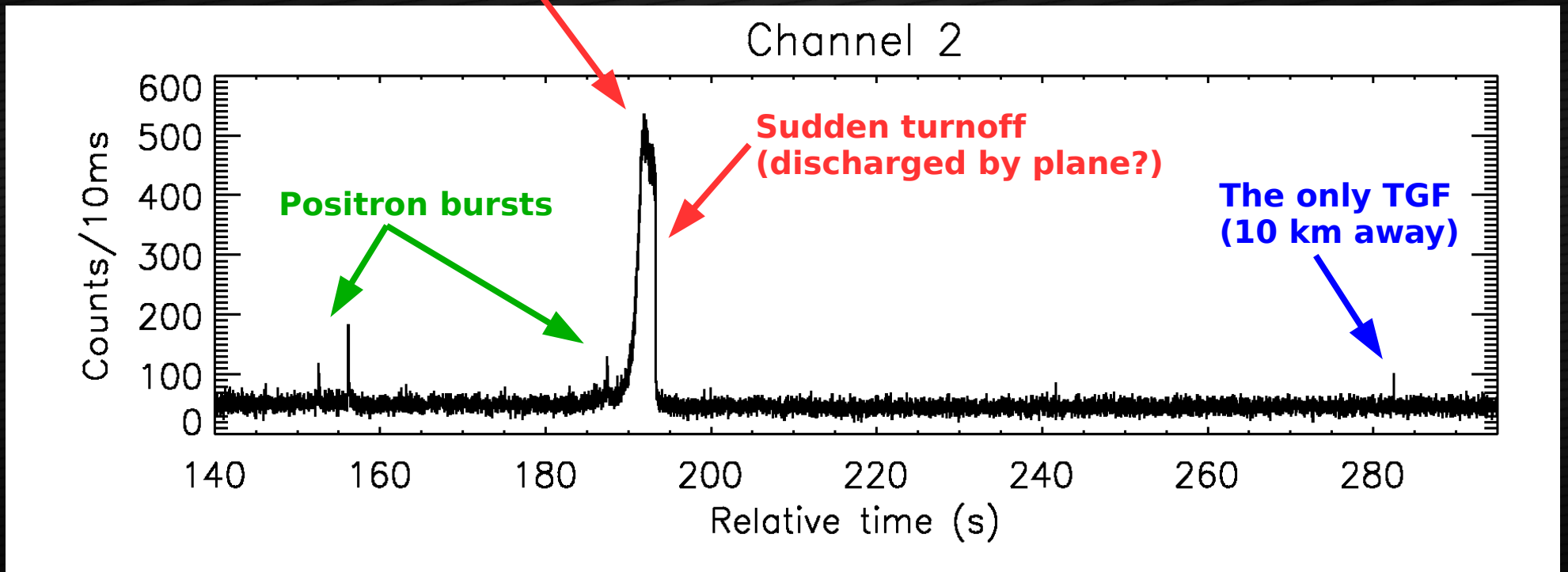
first flights: summer 2009, from Melbourne, FL  
overflights of most storm cells show continuous  
glow of gammas from runaway avalanches:





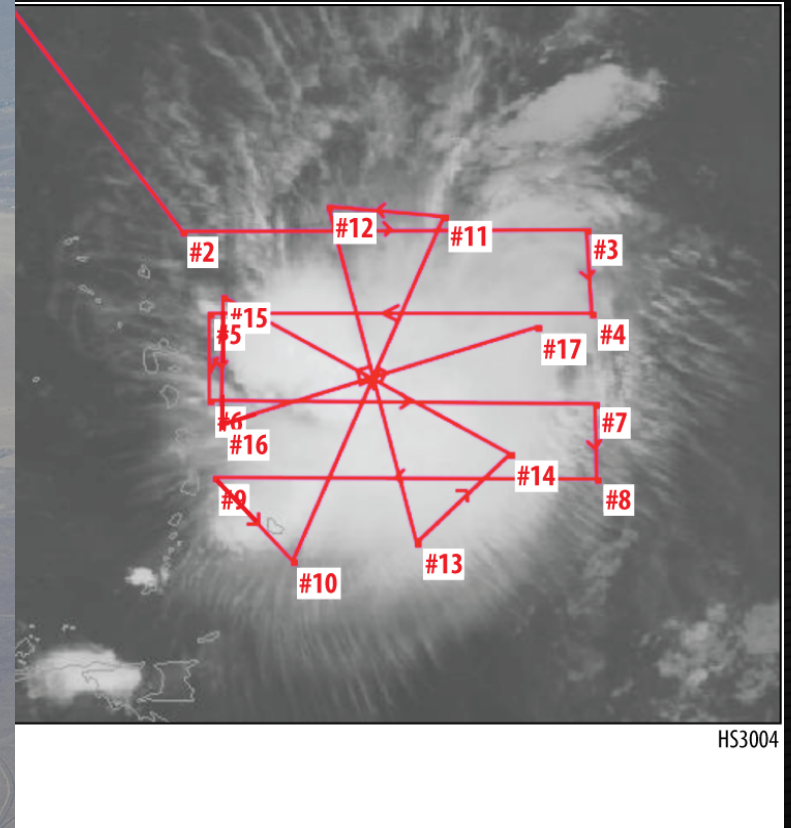
first flights: summer 2009, from Melbourne, FL

**Brightest glow - flying right through avalanche**



still no up-close, bright TGF

up next: summer 2013/2014 piggyback on  
Hurricane and Severe Storm Sentinels



TGF search

x-rays/gammas from blue/gigantic jets?

~10x as much flight time as in 2009

other projects in the pipeline:

cellphone app for crowdsourcing airborne  
detection (with Image Insight, Inc.)

micropayloads for sounding balloons

ADELE clone on NOAA Hurricane Hunters  
and/or  
NSF A10 Warthog

