Physics 535A
Physics of Lightning

Basic Streamer Concepts, Mobility

Lecture 2

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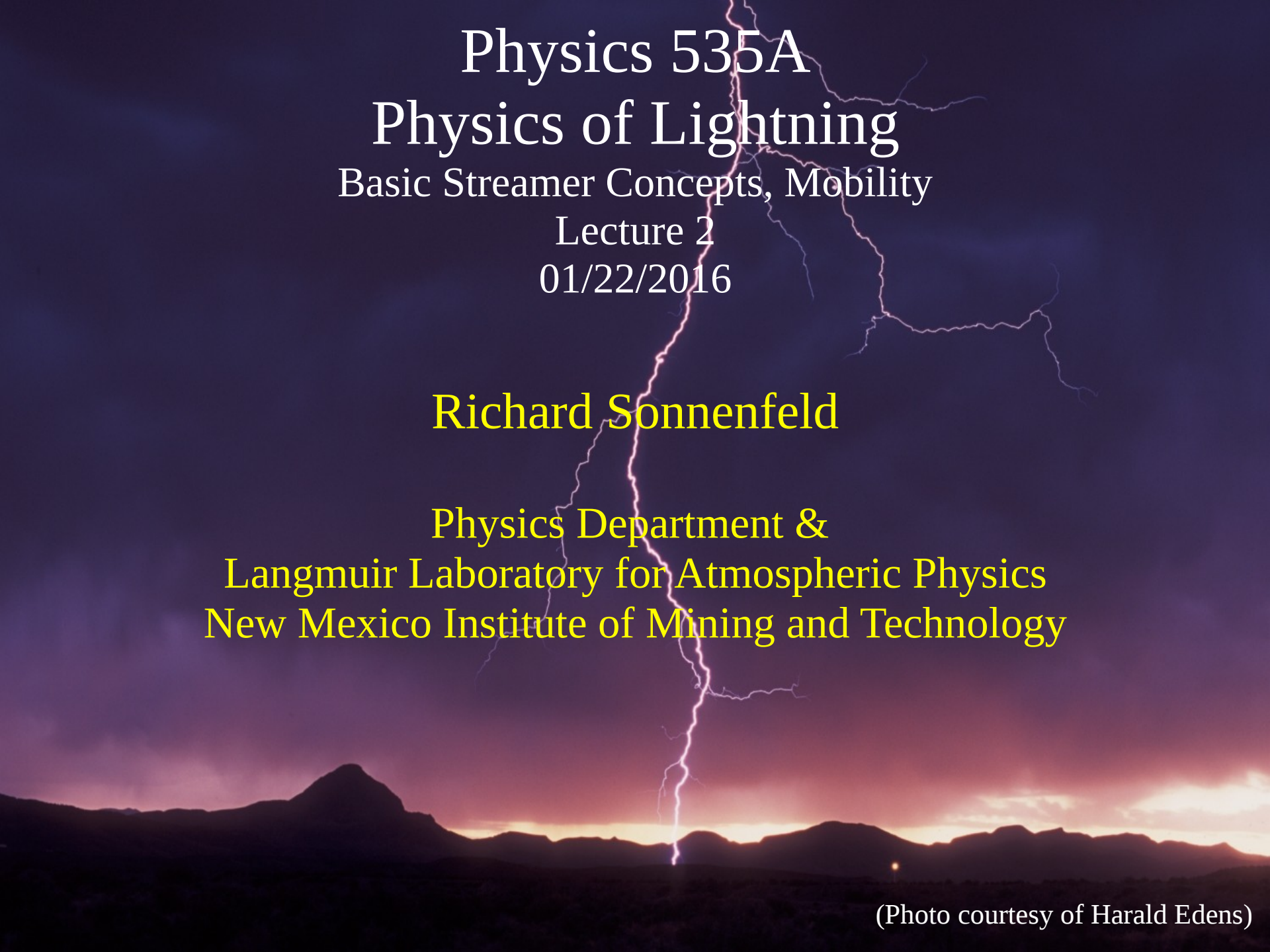

(Photo courtesy of Harald Edens)

Outline

Why study lightning?

What do we know?

How a lightning flash develops.

- Streamers, leaders, attachment and lightning rods.

Lightning Vocabulary

Triggered lightning

Lightning and convection / Energy source for lightning

Charging Mechanisms

Charge Structure of clouds

Lightning Mapping Array

Operational Meteorology and Climatology

- Lightning and convection
- LMA and severe storms
- Space studies (LIS, OTD, GLM).

Things we think we know

Where and how frequently does lightning strike in terms of seasons and times of year?

What are the stages of a lightning flash, currents, charges, temperatures?

Where is the charge in a cloud? How much is there? What is its structure?

Partly answered questions

- Charging
  - What REALLY is the charging mechanism?
    - Ice/water tribology?
    - Is ice required for lightning?
- Discharging
  - How does the charge move in a lightning channel?
  - How is lightning able to move so much charge out of a dispersed, non-conductive medium?
  - What triggers lightning strikes?
    - Cosmic Rays?
    - Ice field enhancement?
- What is relation between lightning and precipitation?
  - What triggers rain gush?
- Can a better warning or protection systems be devised?
- Can lightning be used to predict tornadoes?

Partly Answered Questions

Discharging

How can a lightning flash last for a second and be 50 km long?

Why are there multiple strokes?

What are your questions?

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Lightning Vocabulary I

Streamer:

Current is Weak – (< 1 ampere)

Temperature is "Cold" – (< 1000 K)

Length is Short – (centimeters to a meter)

Ionization Mechanism is photoionization and impact ionization.

Leader:

Current is Strong – (> 100 amps)

Temperature is "Hot" – (> 1000 K)

Length is Long – (tens to hundreds of meters)

Ionization Mechanism is impact and thermal ionization

(Photo courtesy of Harald Edens)

Lightning Vocabulary II

Arc:

Current is Very Strong – (> 10 kA)

Temperature is “Very Hot” – (> 5000 K)

Ionization Mechanism is thermal ionization.

Channel:

The path the leader is taking or has taken in the past. At different times it can be a streamer, a leader, or an Arc.

Bidirectional leader:

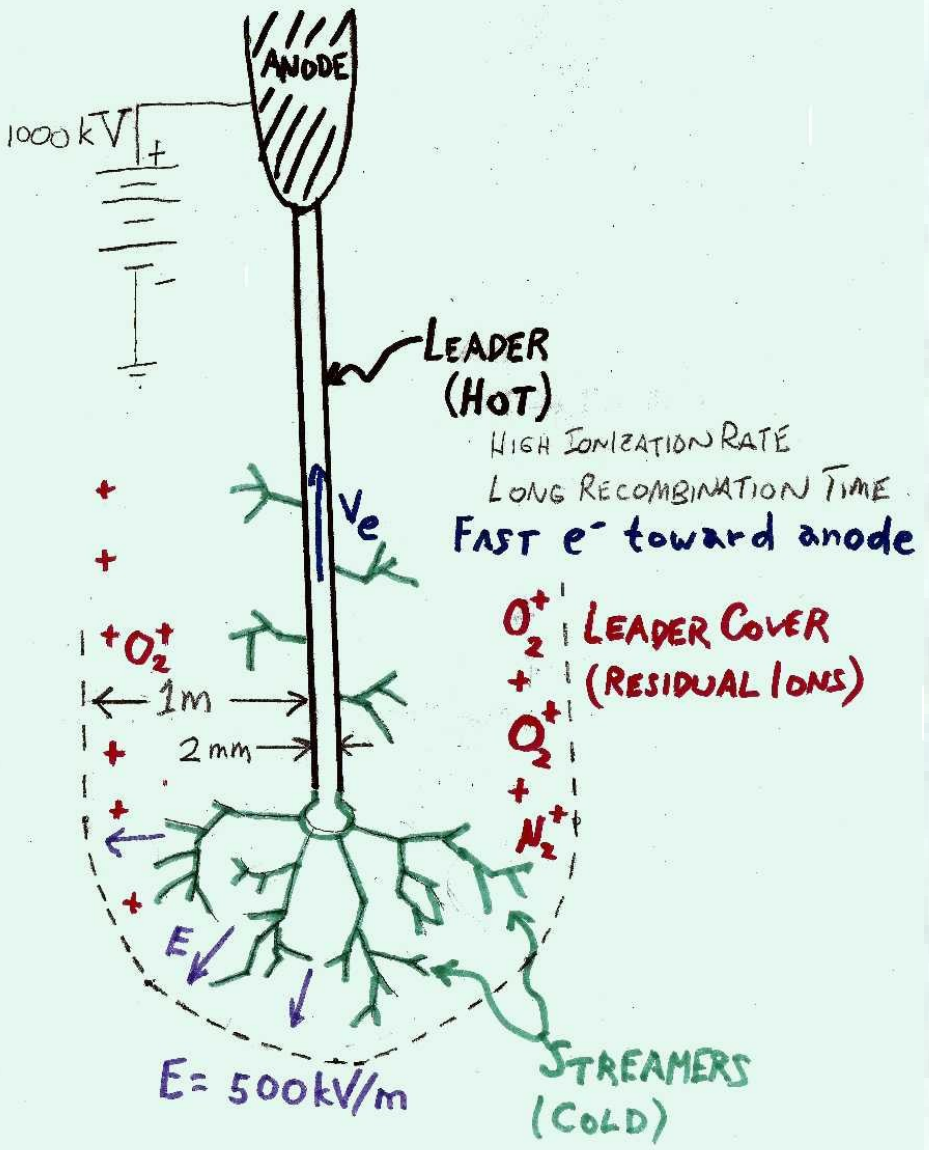
Proposed by Kasimir. Every new leader has negative breakdown on one end and positive on the other end.

(Photo courtesy of Harald Edens)

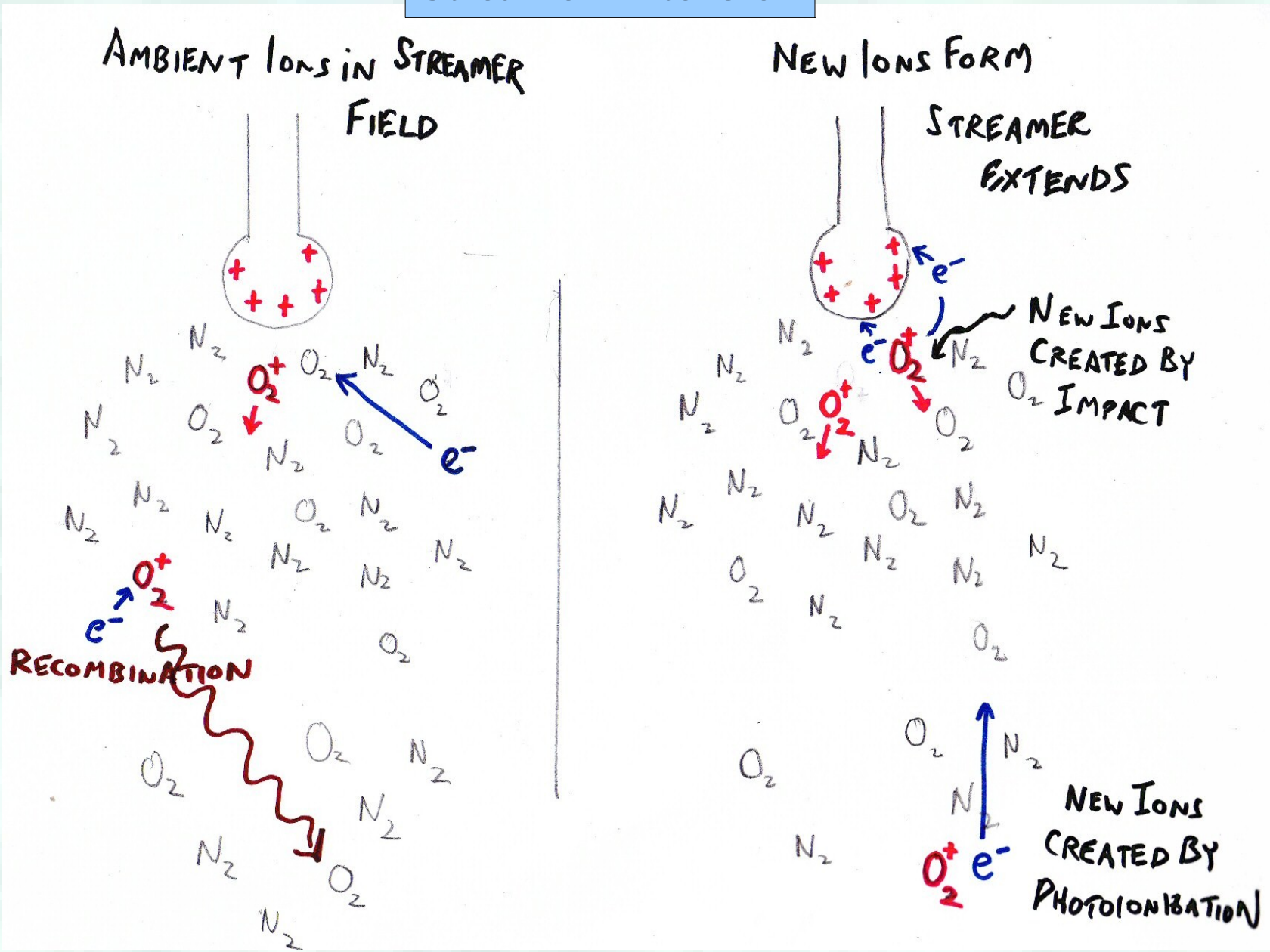
Leaders Extension in the laboratory

Corona Discharge
(Courtesy of Harald Edens)

Streamers
(Courtesy of J. Kronjaeger)



Streamer Extension



Mobility

Key concept. Mobility of a species is roughly inversely proportional to its mass.

For rapid processes (leaders, return strokes) the charge carriers are free electrons. Ions and charged hydrometeors are too slow.

For actual cloud charging mechanisms (minutes) there are almost no free electrons and all the work is done by hydrometeors (the actual charging) and ions (the discharging).

Mobility

$$F = ma = qE \qquad a = \frac{qE}{m}$$

$$v_{drift} = a\tau = \frac{qE\tau}{m}$$

$$v_{drift} = \mu E \rightarrow \mu = \frac{q\tau}{m}$$

$$\vec{J} = \sigma \vec{E} = n q \vec{v}_{drift} = n q \mu \vec{E}$$

$$\sigma = n q \mu$$