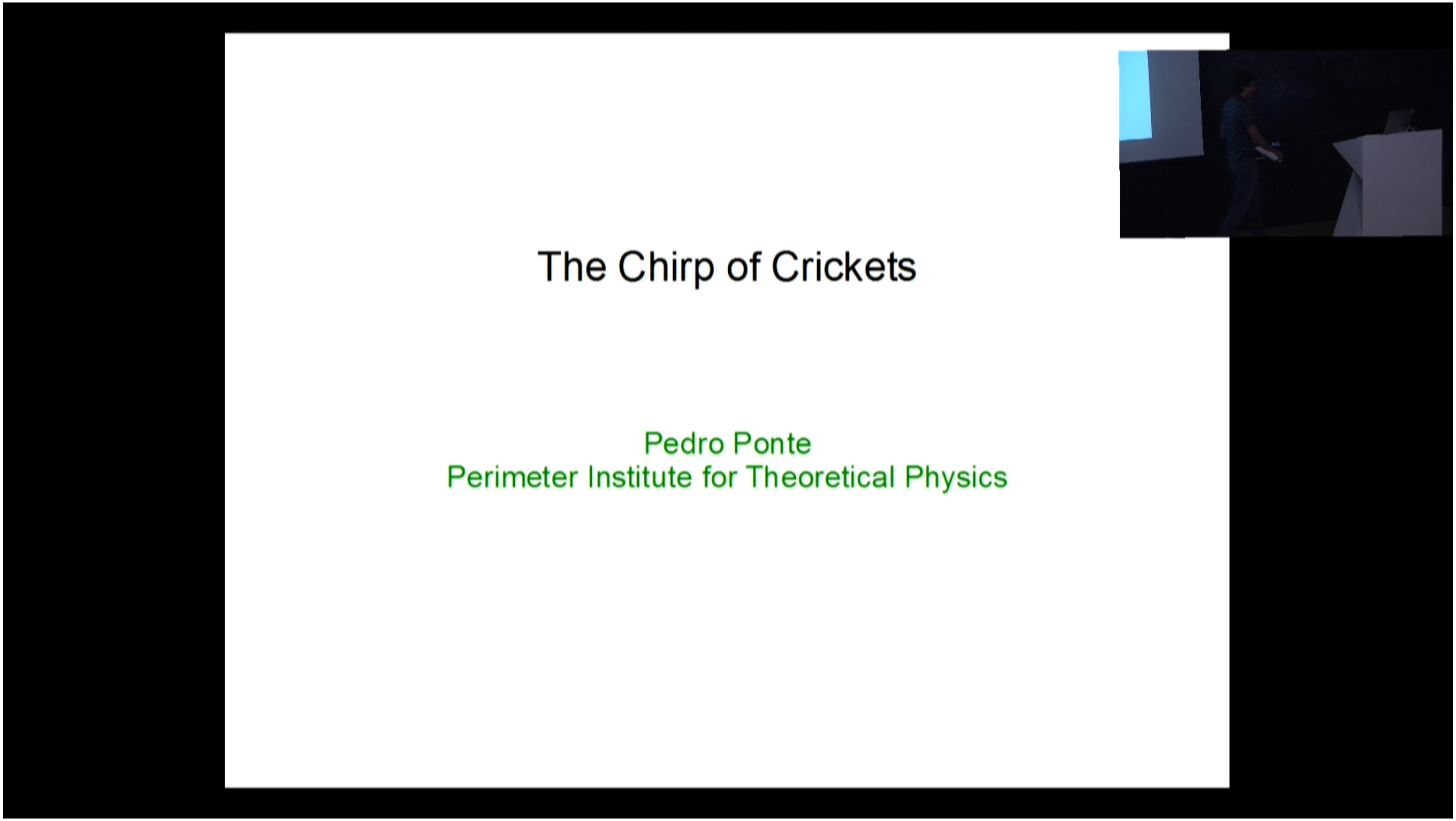
Title: Physics in Nature Presentation: The Chirp of Crickets

Date: Aug 19, 2011 02:30 PM

URL: http://pirsa.org/11080115

Abstract:


The Chirp of Crickets
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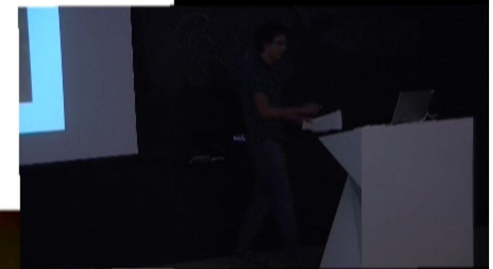
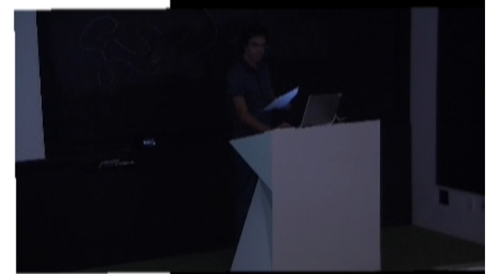
Chirping

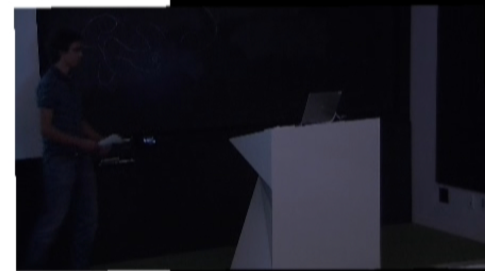


Some interesting facts about crickets



- There are 900 species of crickets.
- They are nocturnal animals.
- The chirping sound is created by running the top of one wing along the teeth at the bottom of the other wing.
- Crickets are cold blooded.
- Crickets mate in late summer and lay their eggs in autumn.

Some interesting facts about crickets



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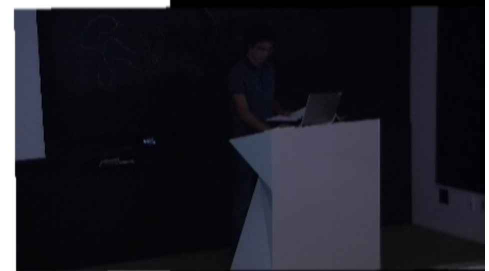
Wing movement

Some interesting facts about crickets



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Dolbear's Law (empirical)

- States that crickets are thermometers;

$$T_C = 10 + \frac{N - 40}{7}$$

$$T_F = 50 + \frac{N - 40}{4}$$

N is chirps per minute

- Check if reasonable values are obtained for the example cricket (6 secs).
- Only works for the snowy tree cricket.

Dolbear's Law (empirical)

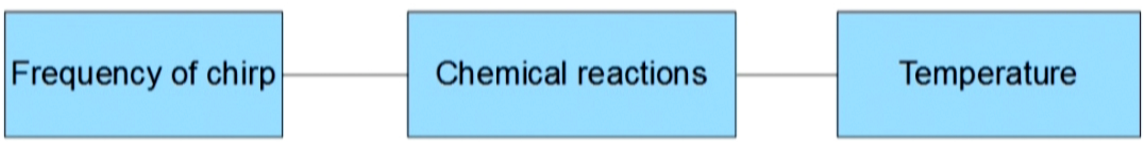
- 20 cri's in 6 seconds.

$$T_C = 33\,^\circ C$$
$$T_F = 90^\circ F$$

- Seems reasonable for a summer night in Australia.

Why this law works?

- How could the temperature of the environment determine how fast the chirp scrapes its wings?
- The muscle contractions occurring in the wings of the crickets are governed by chemical reactions.
- The rate of a chemical reaction depends on temperature.



Arrhenius Equation

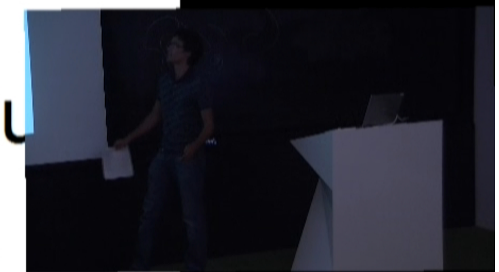
- The rate of a reaction A + B -> C is defined by:

$$\frac{d[C]}{dt} = k(T)[A]^m[B]^n$$

- Arrhenius equation gives an explicit form to the rate constant k:

$$k = Ae^{-\frac{E_a}{RT}}$$

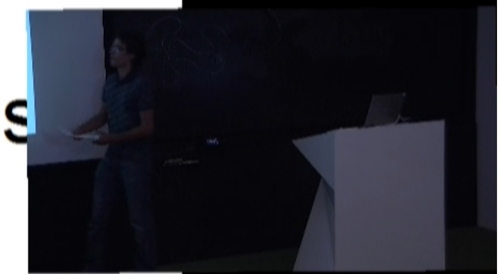
The exponential factor of Arrheniu



- In order to have a chemical reaction of two molecules they have to overcome a potential barrier.
- Only the molecules with energy greater than Ea will react.

$$P(E > E_a) = \frac{\int_{E_a}^{+\infty} e^{-E/RT} dE}{\int_{E_{min}}^{+\infty} e^{-E/RT} dE} \sim e^{-E_a/RT}$$

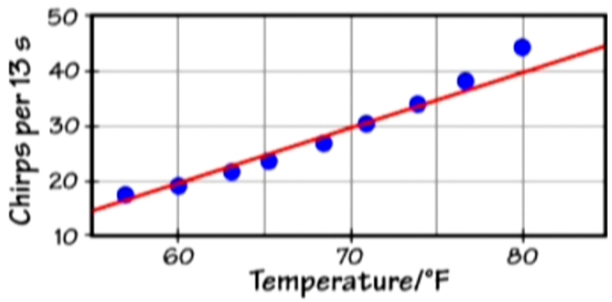
Chemical Reactions: Hypothesis



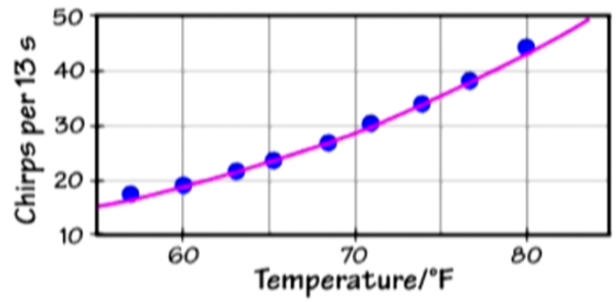
- We expect that

$$f \sim r \sim e^{-E_a/RT}$$
$$\ln f = A - E_a/RT$$

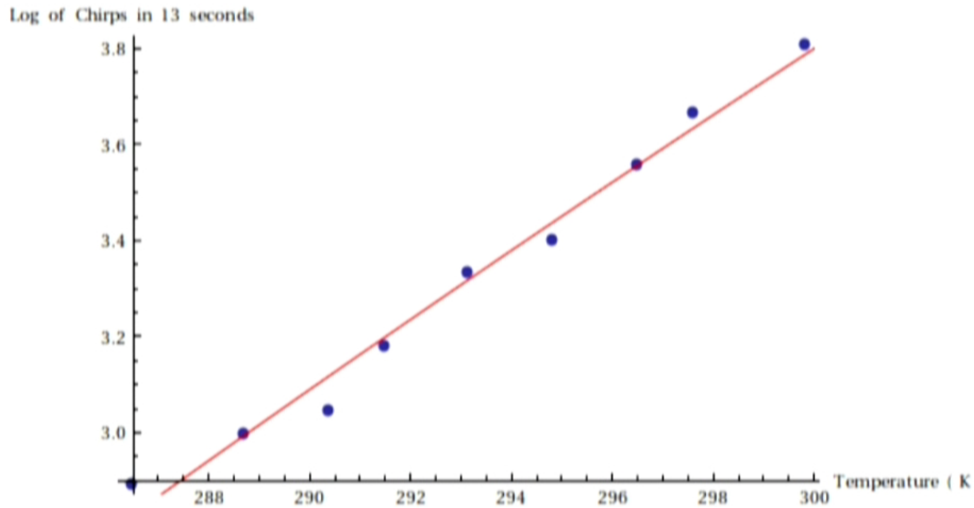
Experimental Data



Linear Fit
(Dolbear's Law)



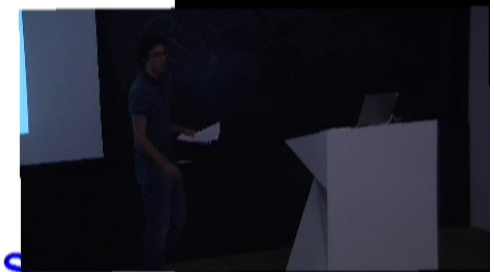
Better Fit



Linearization $$\ln f = 24.40 - \frac{6180}{T}$$

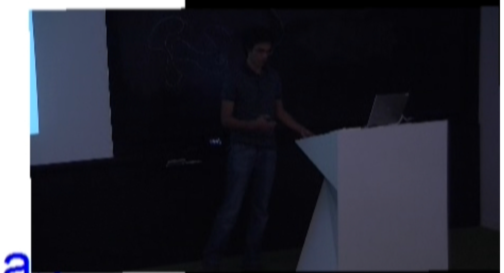
Activation Energy $$6180 = E_a/R \Rightarrow E_a = 51\,kJ/mol$$

Arrhenius Law, coincidence?



- The frequency of chirps follows the Arrhenius law.
- The value obtained for the activation energy is actually of the correct order of magnitude for an oxidation reaction that is thought to be in the basis of the phenomenon.

Conclusions



- We have understood why the crickets work as thermometers.
- The frequency of the chirp is a macroscopic effect of the complicated chain of chemical reactions taking place inside the cricket.
- Now if you find yourself in a warm summer night and you have a desire to know what the temperature, just use ***Dolbear's Law.***