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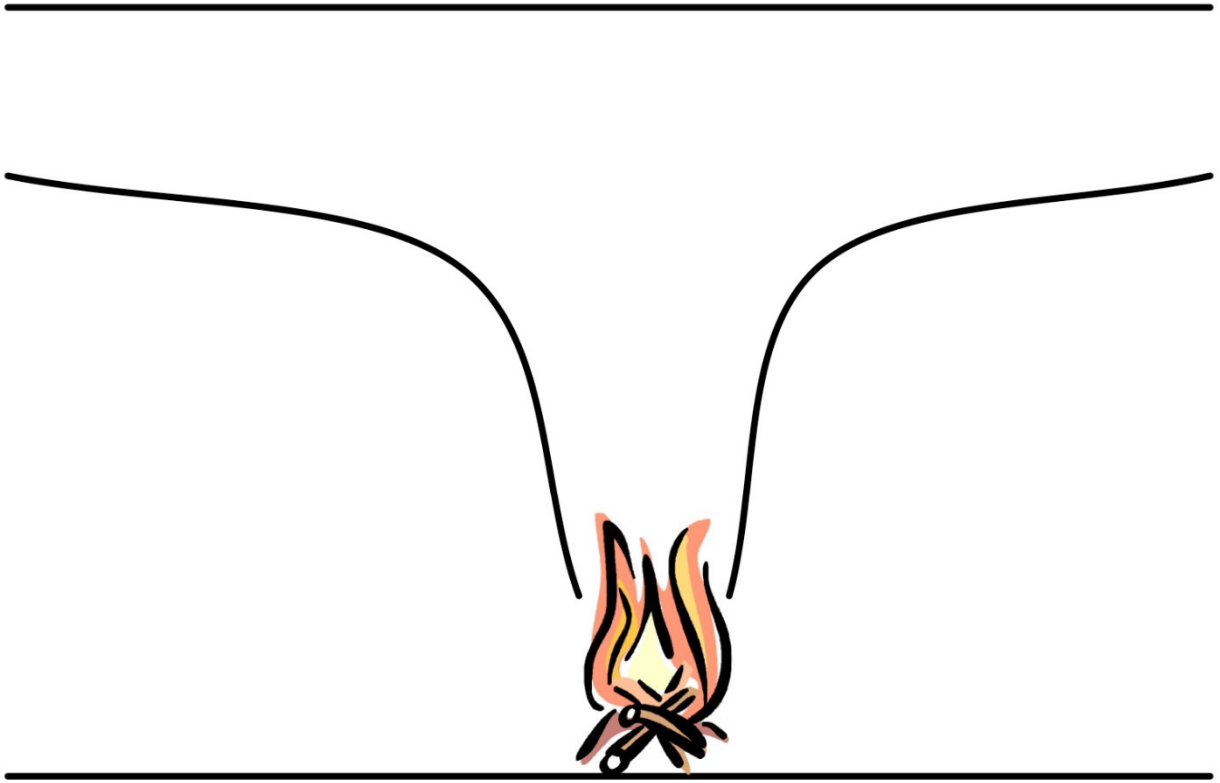
•Knowledge FOr Resilient soCiEty

Fire signatures and their use to detect fires

Fire signatures and nuisance sources

Bjarne Husted, Lund University, Sweden

Fire signatures



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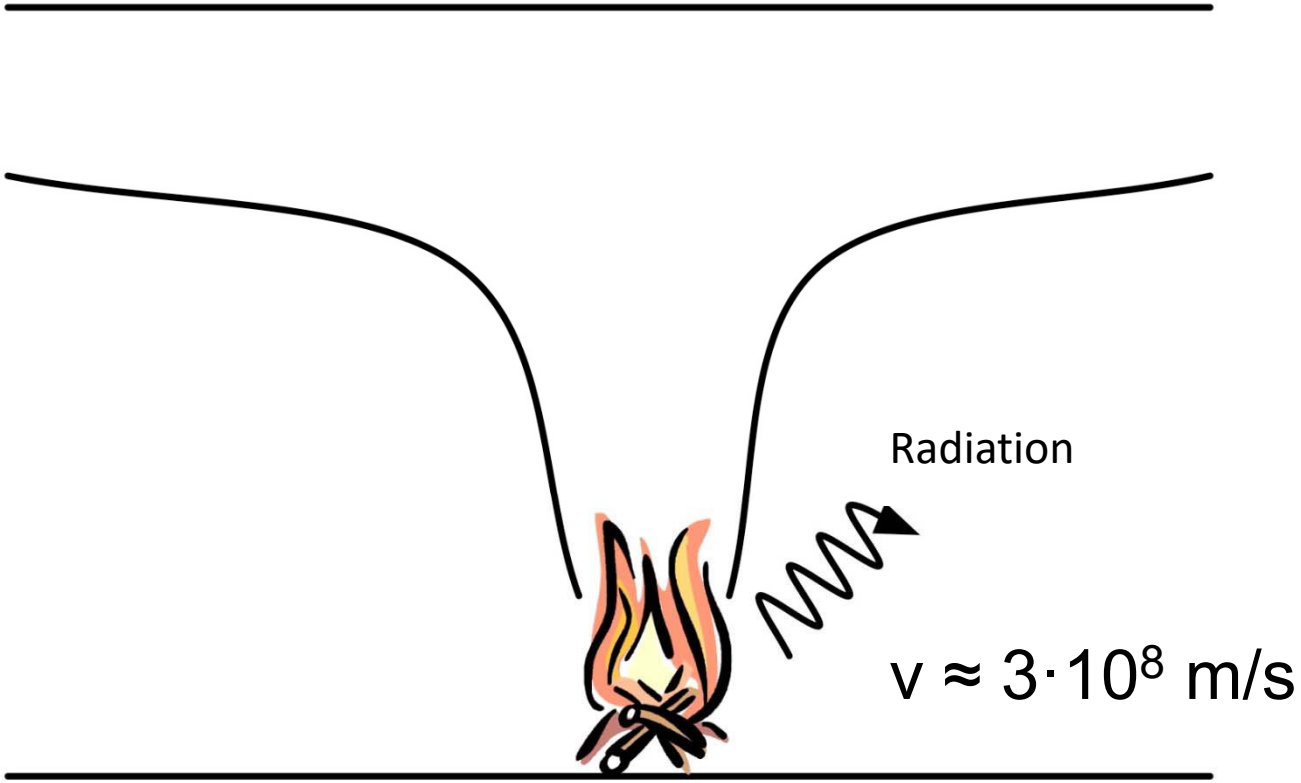
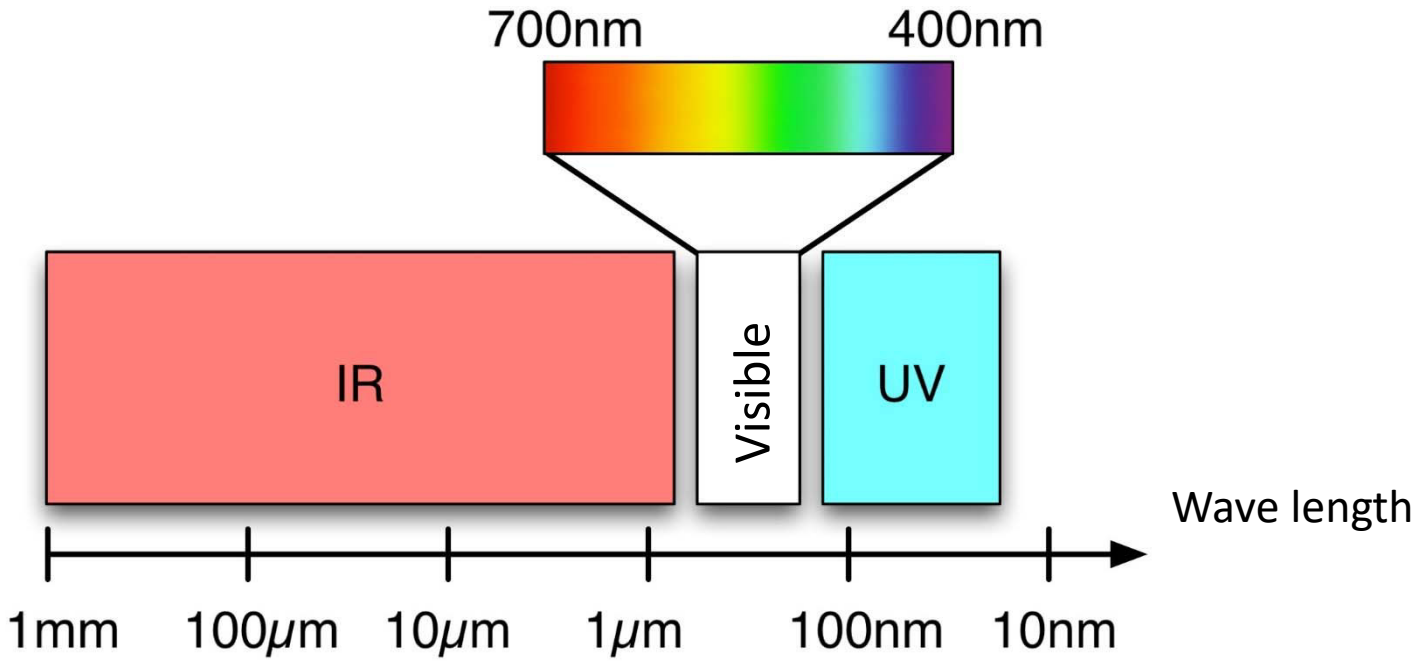
Fire signatures



Radiation



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Radiation

- What is radiation from a flame?
  - free radicals in the flame front
    - C_2, CH, OH
  - aerosols
    - soot
  - stable chemical compounds – combustion products
    - H_2O, CO_2, CO

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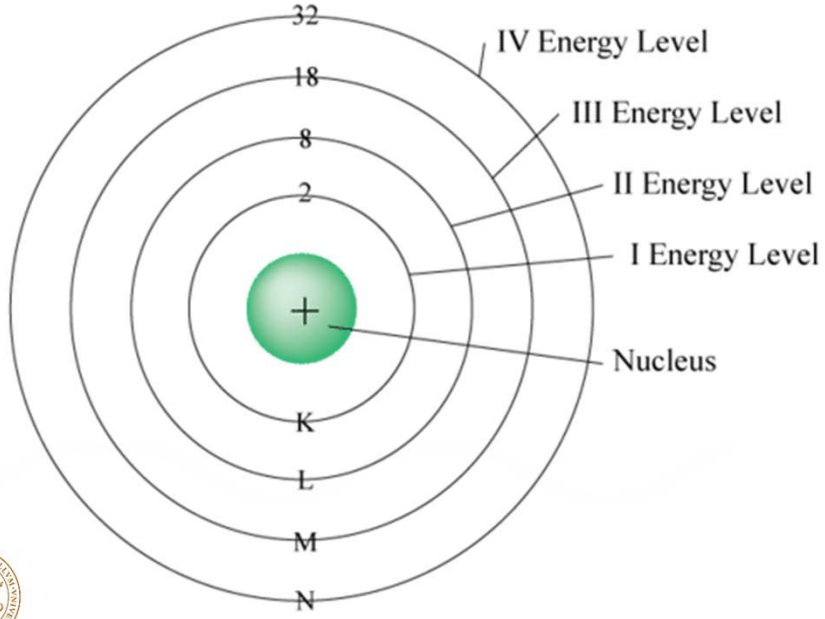
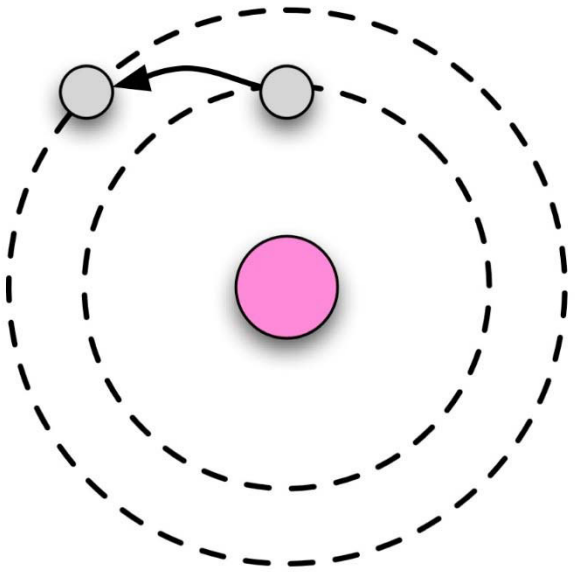
Radiation

- Free radicals
  - C_2, CH, OH
  - Fixed energy levels





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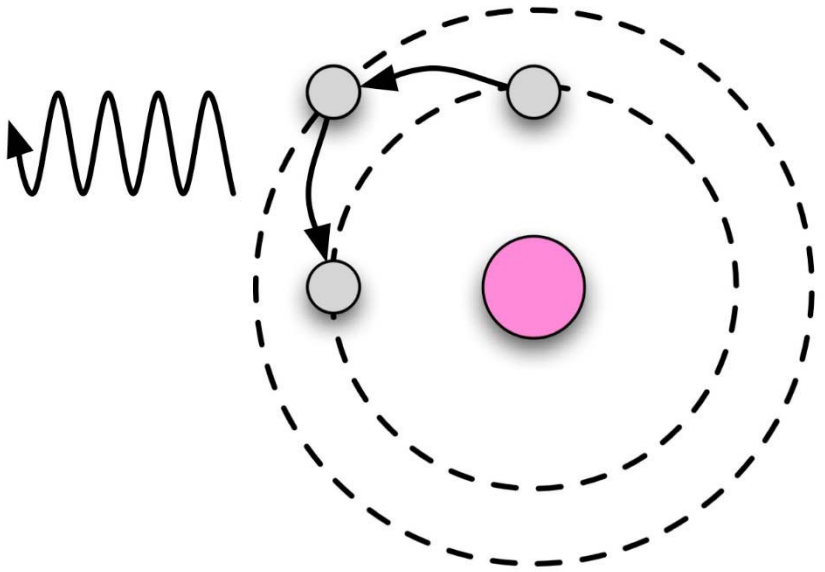
Radiation

- Free radicals
  - C_2, CH, OH
  - Fixed energy levels
  - Radiation with a fixed wave length



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Radiation

- Free radicals
  - 280-300 nm
  - 305-320 nm
  - 385-395 nm
  - 420-440 nm
  - 460-570 nm

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Radiation

- Aerosols
  - soot
  - radiates like a black body
  - high about of soot – yellow flames
  - premixed flames - little soot
  - diffusion flames - more soot

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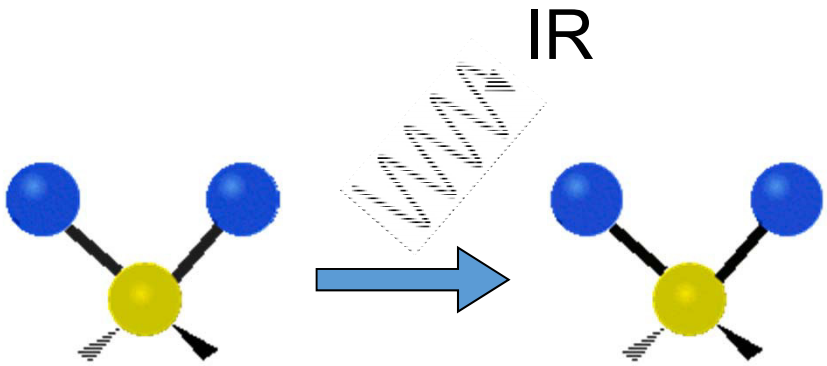
Radiation

- stable chemical compounds H_2O, CO_2, CO
  - temperature => movement
  - Vibrating in different way – different energy levels



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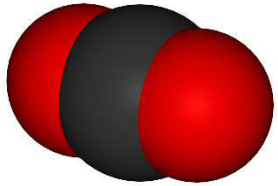
Radiation

- stable chemical compounds
  - 2 µm
  - 2,7 µm
  - 4,3 µm (CO_2)
  - 6,7 µm
  - 15 µm



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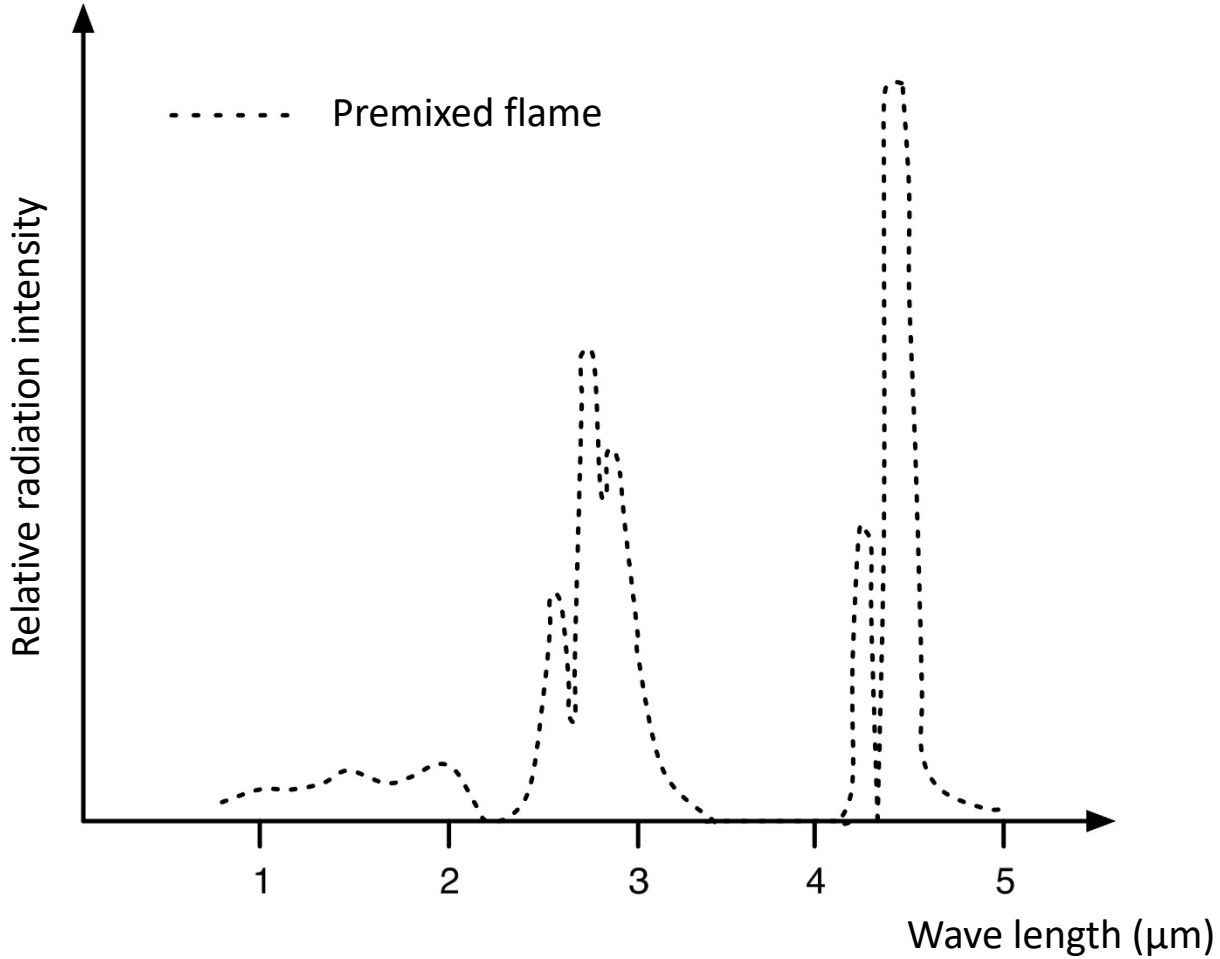
Radiation



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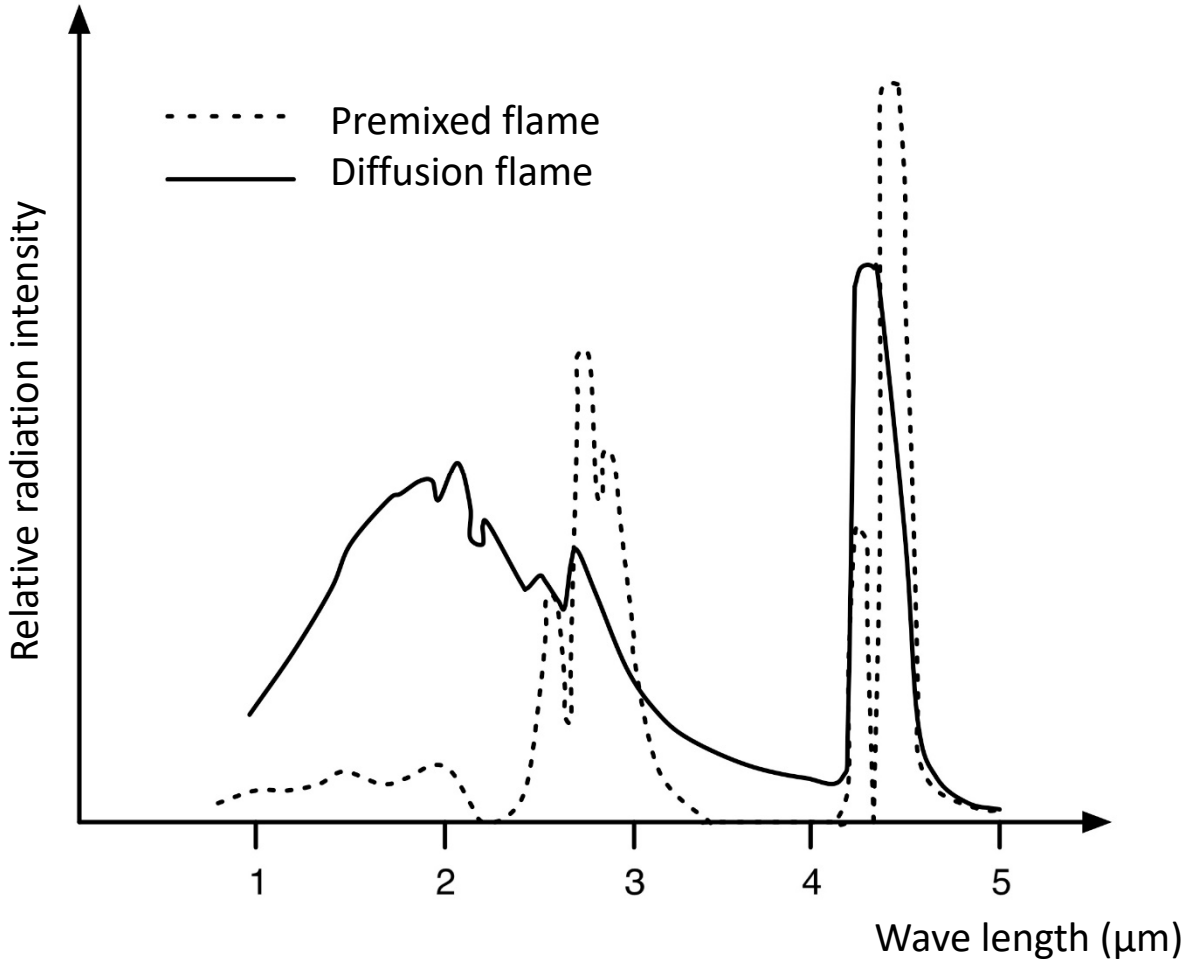
Radiation



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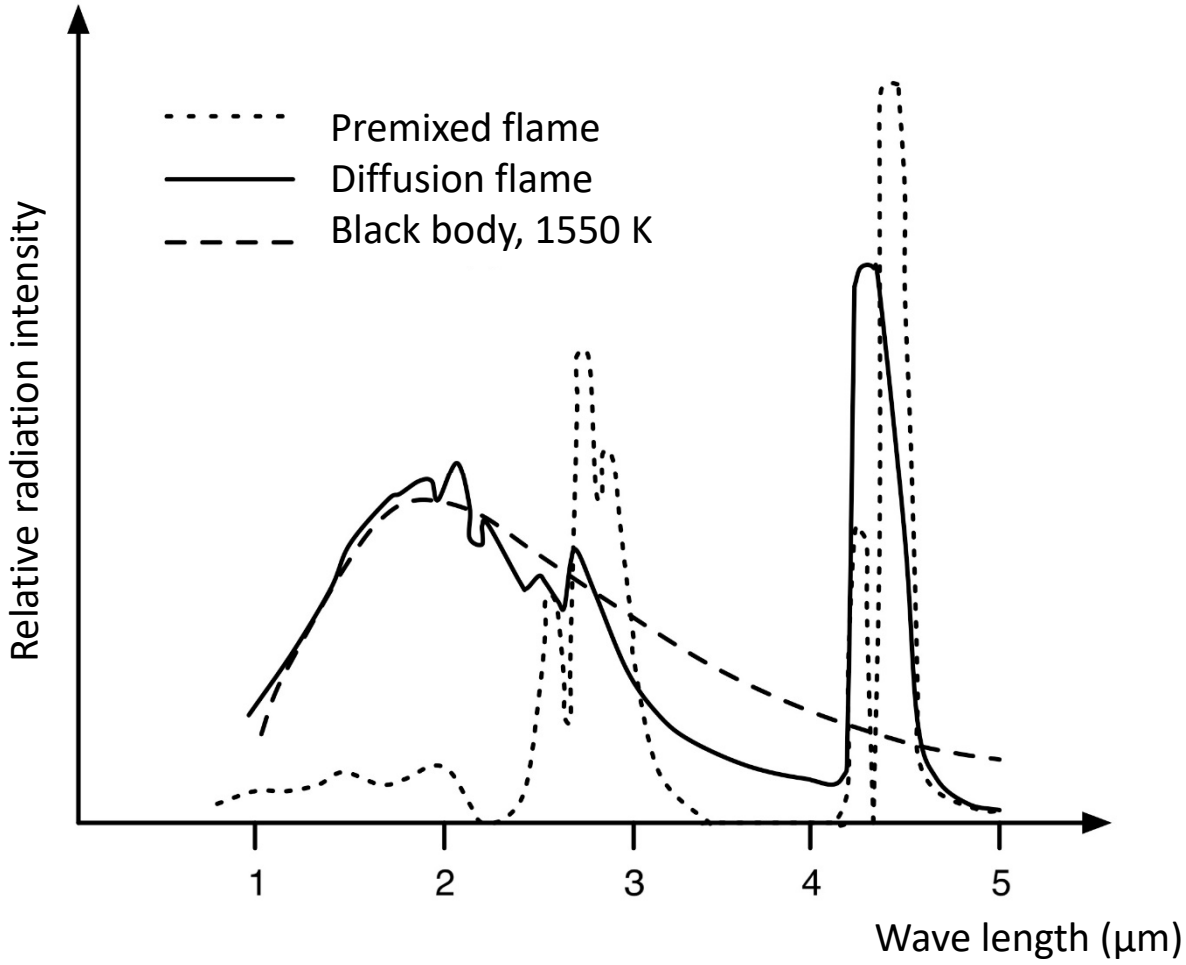
Radiation



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Radiation

- Radiation fluctuates
  - Pulsation of a flame
  - 0,5 - 15 Hz

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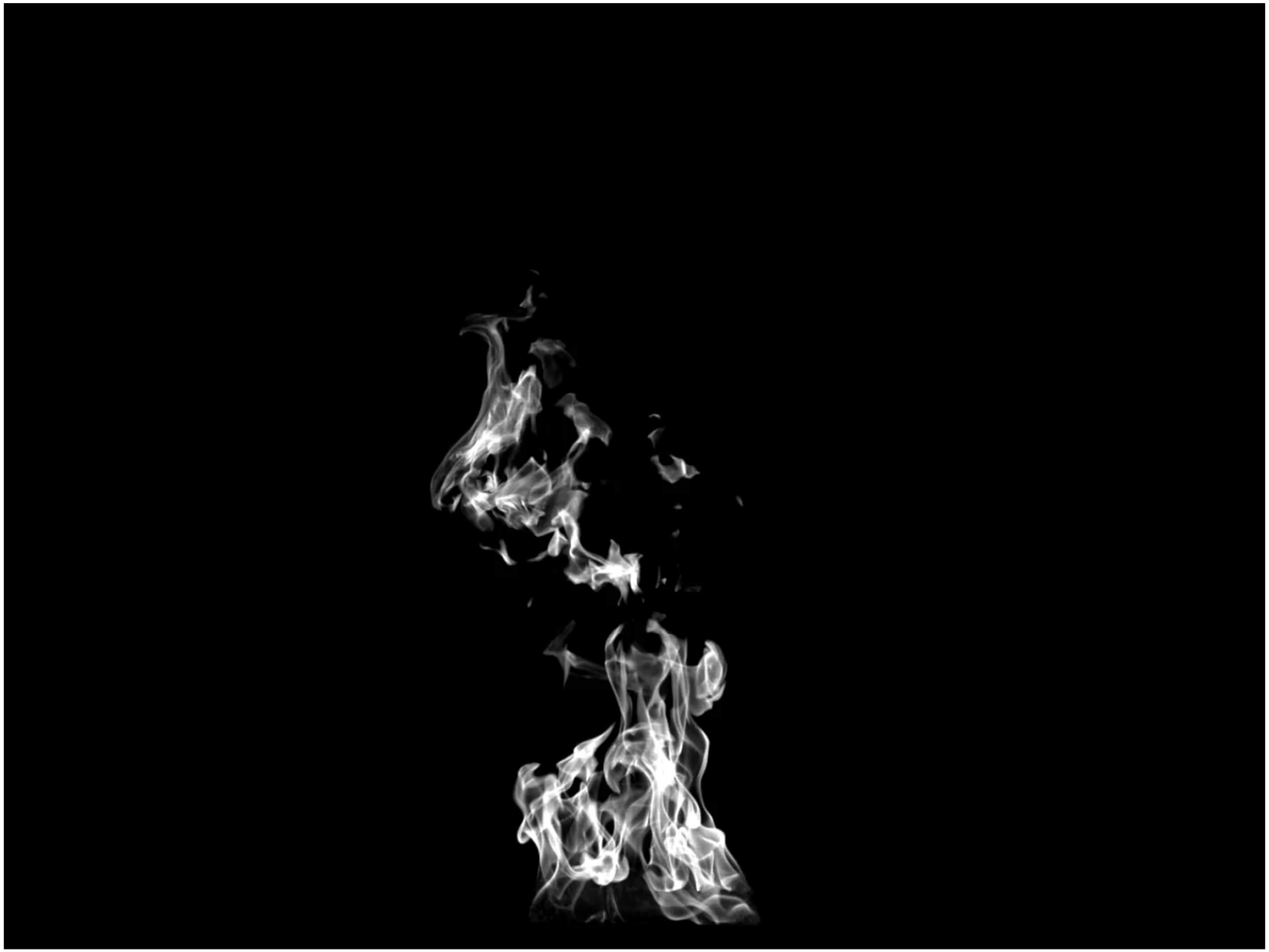
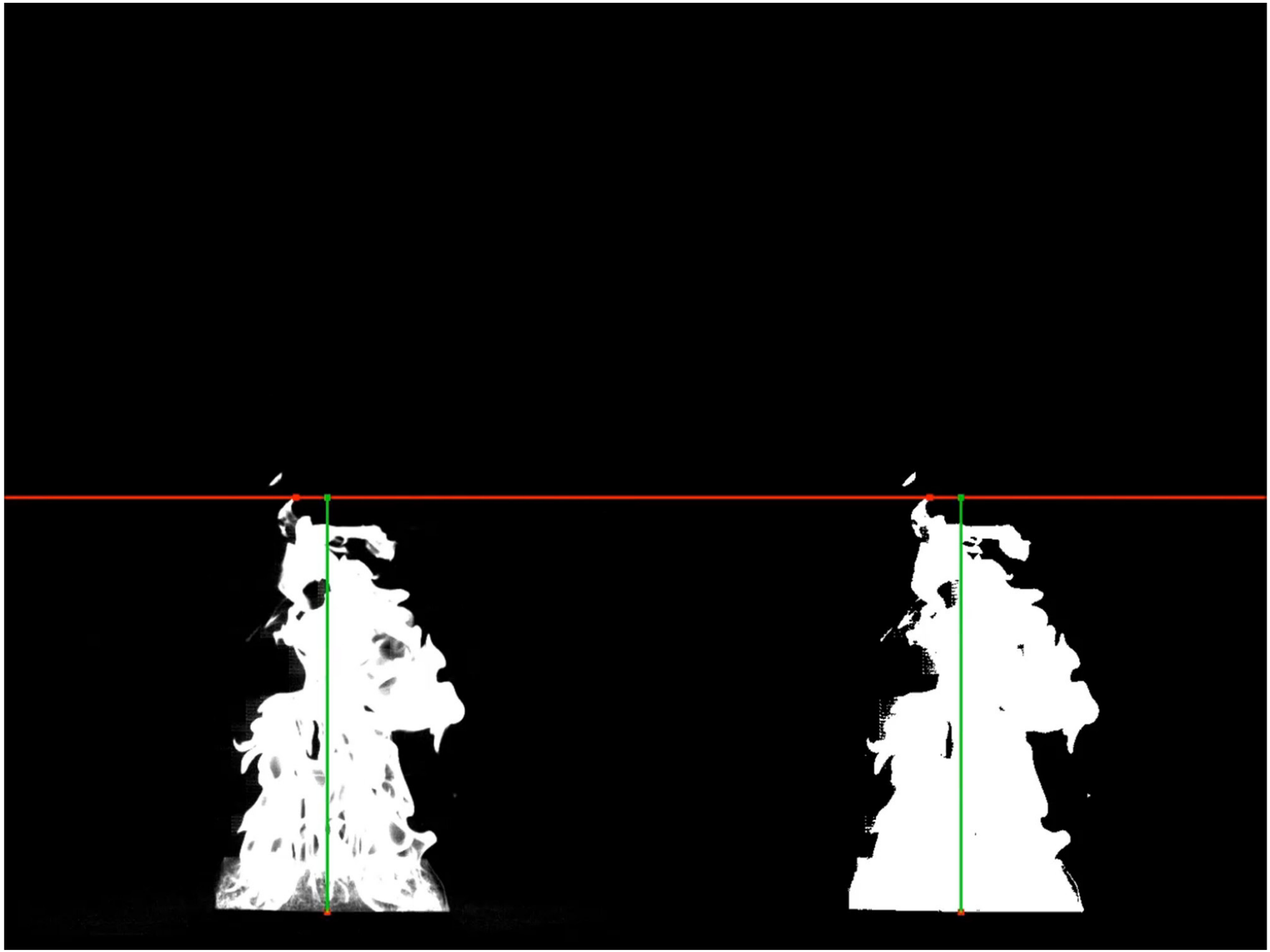
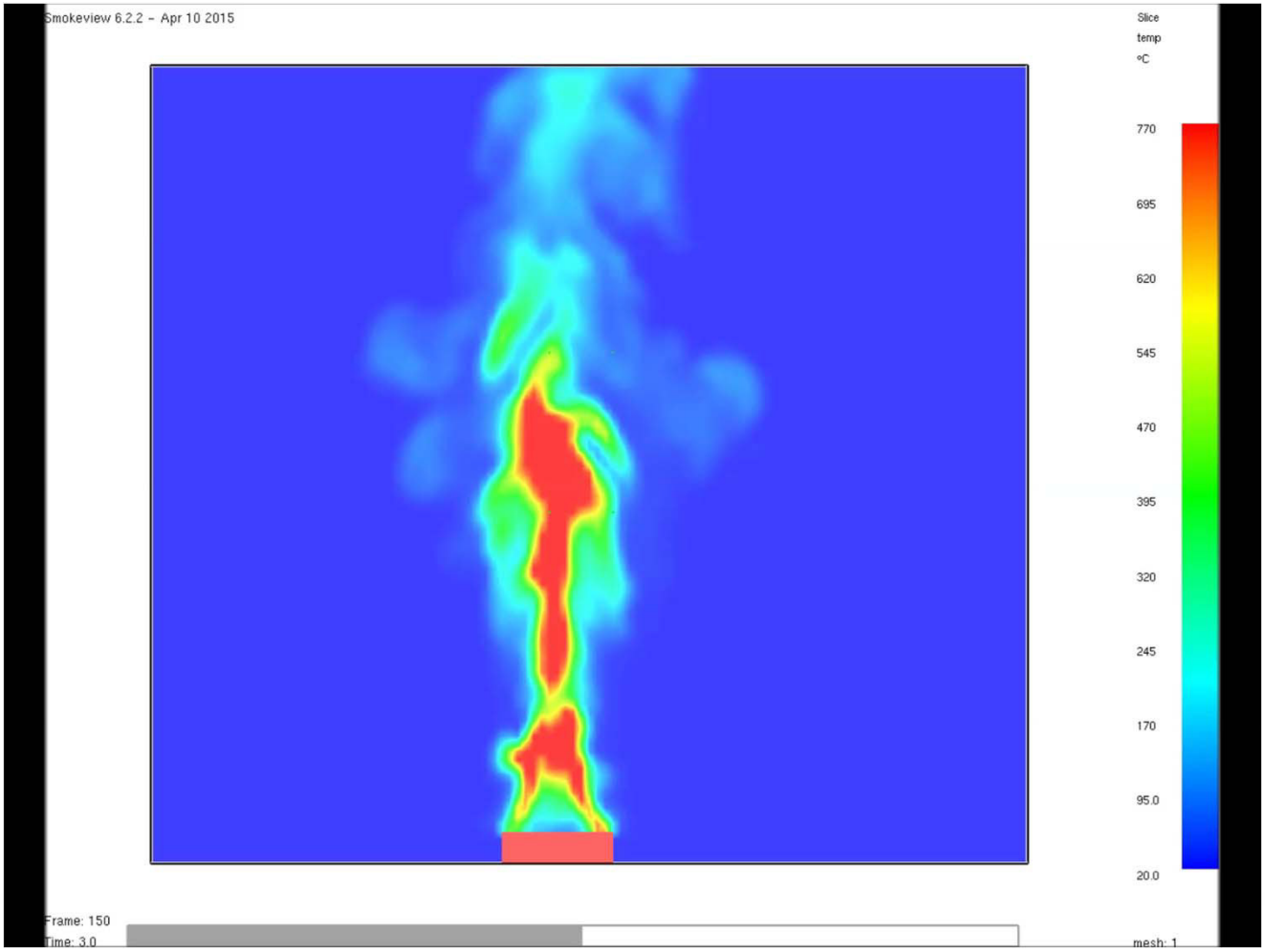
High speed image of methane flame (1000 Hz)
Courtesy David Johansen (PhD. student)



Flame height



Energy spectrum of frequencies using FFT in Matlab



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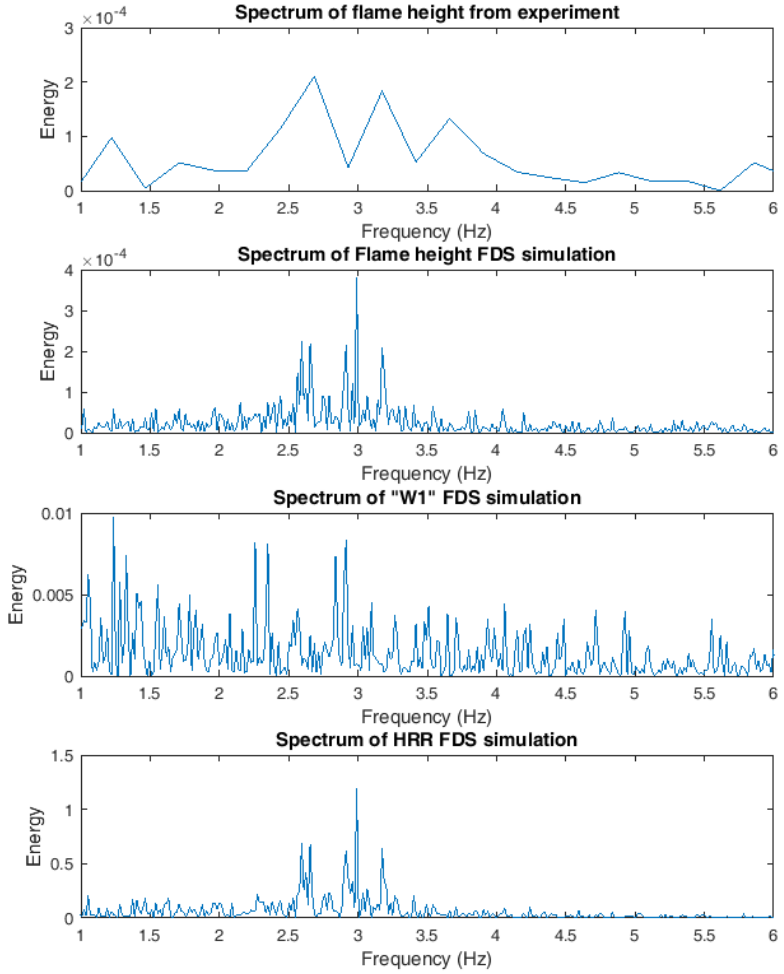
Energy spectrum of frequencies using FFT on experiments and simulations



Simple correlation from
SFPE Handbook, 3. ed. Page 2-15
Gunnar Heskestad
Fire Plumes, Flame height and air entrainment

$$f(Hz) = 1.5 \cdot \frac{1}{\sqrt{D(m)}}$$

Example:

Square fire $0.3mx0.3m$

$$D_h = \frac{4 \cdot A}{Perimeter} = \frac{4 \cdot 0.3 \cdot 0.3}{4 \cdot 0.3} = 0.3m$$

$$f(Hz) = 1.5 \cdot \frac{1}{\sqrt{D(m)}} = 1.5 \cdot \frac{1}{\sqrt{0.3}} = 2.7\ Hz$$

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Radiation – nuisance sources

- IR-radiation
  - Radiation objects - heat
  - Sun light reflecting in surface of water
- UV-radiation
  - welding, sparks, arcs, lightning
  - X-rays (Röntgen rays)
  - can be blocked by some gases and by fire gases

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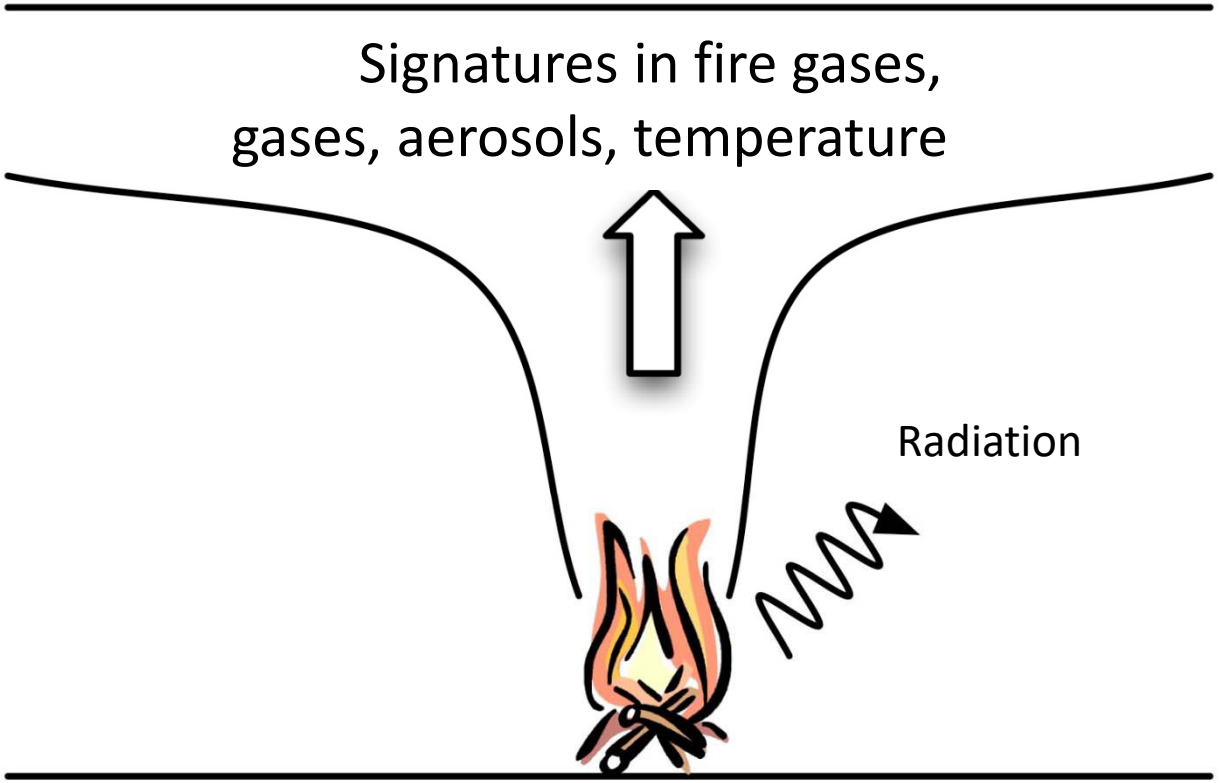
Fire signatures



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Gases

Fuel + oxygen $\nrightarrow H_2O + CO_2 + CO$

- Type of fuels - H_2, NH_3, Mg
- CO_2 - 0,04% in the atmosphere
- CO – close to 0% in the atmosphere

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Gases

- Special compounds
  - PVC => HCl
  - PUR => NO_x
  - wool => HCN
  - nylon => NH_3

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Aerosols

- Solid particles and liquid droplets
  - between 0,01 - 10 µm
  - typically 0,1 - 2 µm
  - combustion condition is important

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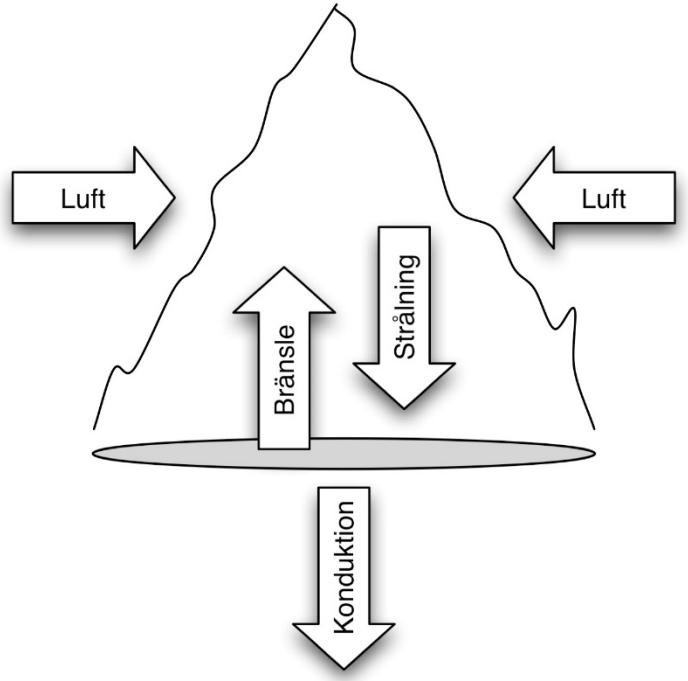
Aerosols

- Flaming fire
  - Solid particles (soot)
  - small (0,1-1 µm)



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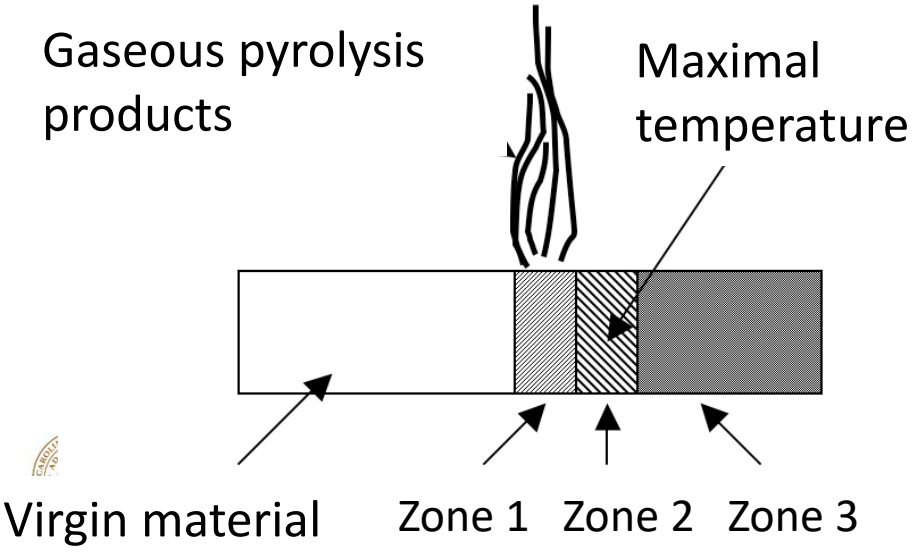
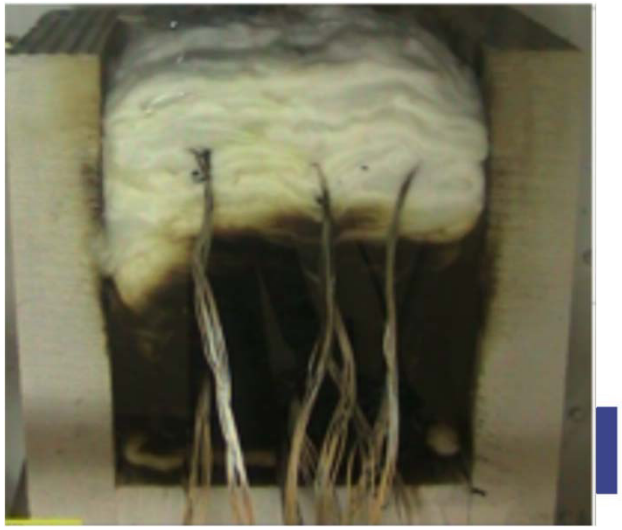
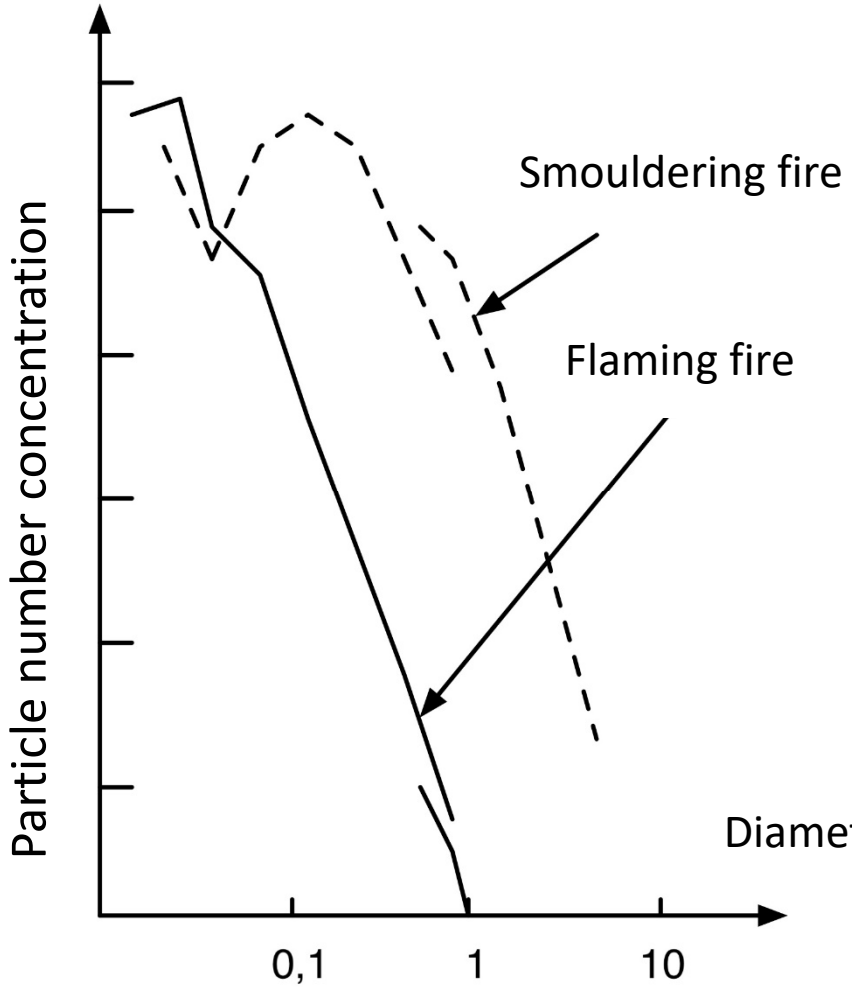
Aerosols

- Smouldering fires
  - tar and liquids with a high boiling point
    - e.g. Levoglucosan
  - large droplets (1-10 µm)





Aerosols



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Aerosols

- Coalesce of smoke part. (aging)
  - small to larger particles
  - total volume is the same
  - the concentration is important

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Aerosols - nuisance sources

- Small particles
  - toasted bread
- Large particles
  - dust
  - fog
- How large particles can we see?
  - >0,3 µm
  - Light is blocked if particles are larger than the wave length of the light

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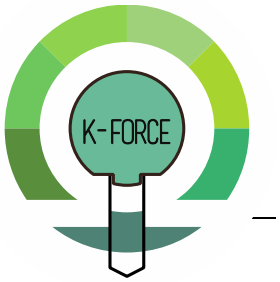
Temperature



Fuel + oxygen $\rightarrow H_2O + CO_2 + CO +$ heat

- Air is heated => thermal buoyancy
- fluctuations

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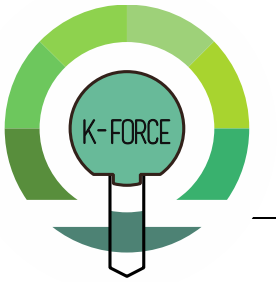
Temperature - nuisance sources



- Heating
  - tin roof in summer time
  - machines
  - ovens

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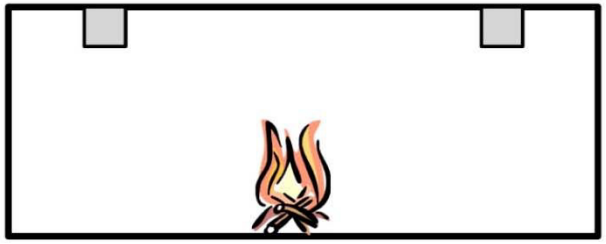
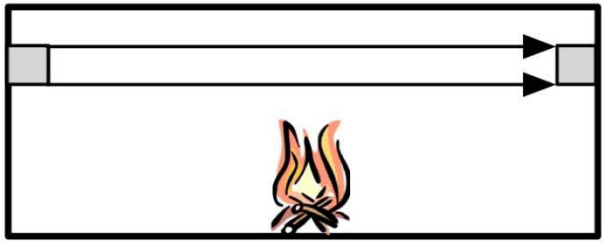
Detection

- How to collect data

Point detection



Line detection



Volume detection

Sampling system

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Detectors

- Different types of detectors
  - Flame detectors
  - Gas detectors
  - Smoke detectors
  - Heat detectors
  - Special detectors
  - Multi detectors

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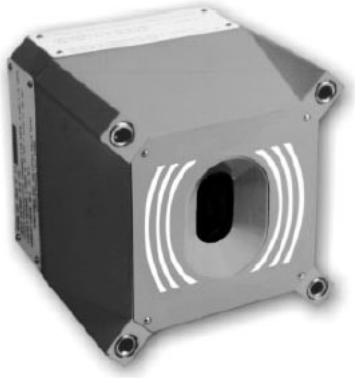
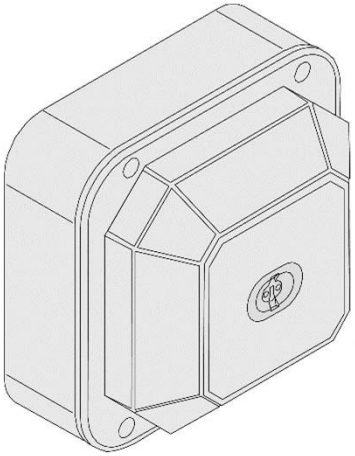
Flam detectors

- Types
  - UV
  - IR
  - UV/IR
- When are they used?
  - flammable liquids
  - fast detection
  - difficult to detect fire in any other way





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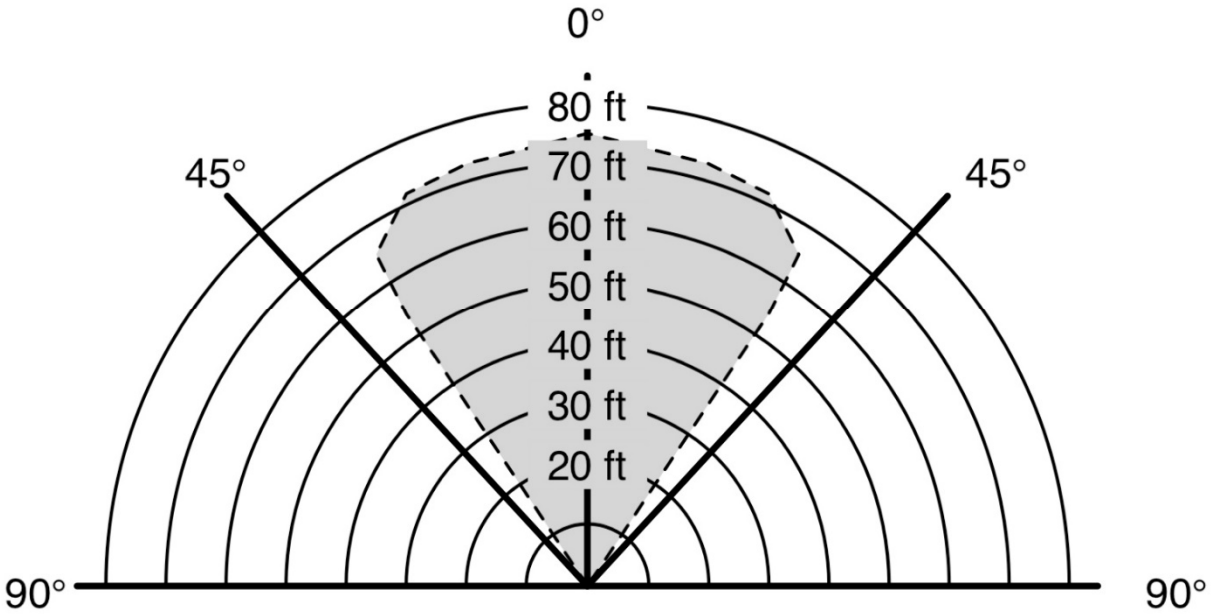
Flame detector



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Flame detector

- IR-detector (infrared detector)
  - 4,3 µm (CO_2)
  - fluctuations - 0,5-15 Hz
  - single frequency or multi spectrum
  - nuisance sources
    - the lens – water or ice
    - radiating subjects
    - sun light on water

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Flame detector

- UV-detector
  - 180-250 nm
  - very fast (ca 10 ms)
  - nuisance sources
    - lightning, welding, arcs
    - röntgen
    - gaser hindrar UV
    - brandgaser hindrar UV

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Flame detector

- UV/IR-detector
  - together
  - reduce the amount of false alarms

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Gas detectors

- Types
  - Catalytic
    - flammable gases (1/4-1/8)
    - calibration
  - Electrochemical
    - very sensitive (single ppm)
    - Consumed
  - IR-gas detetektors

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Smoke detectors

Smoke alarms (home)

- Types
  - Ionizing
  - Optical light scattering
  - Optical beam smoke detector

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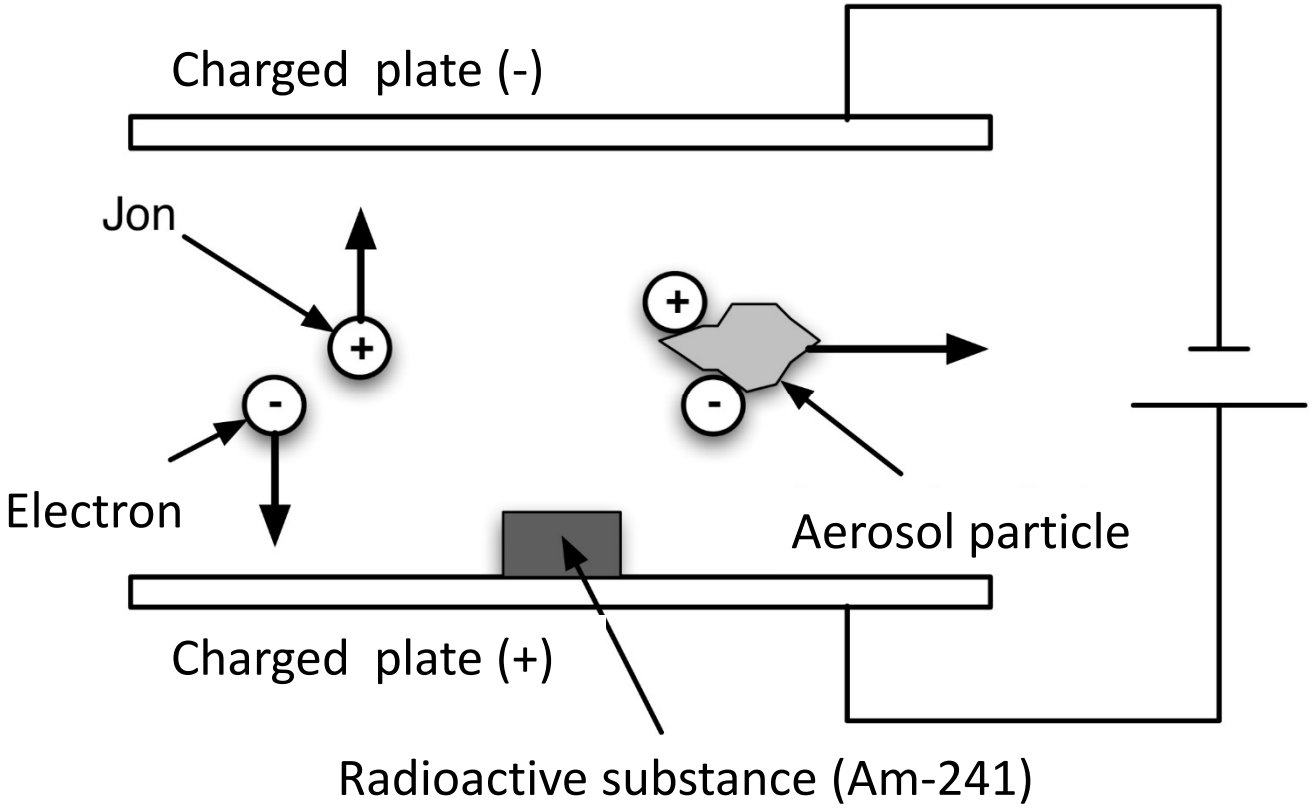
Smoke detector (example of how it works)

- Ionizing



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Examples of 2-zone models for calculating activation of detectors

There are many models but a few dominates:

- CFAST http://cfast.nist.gov/

- Argos http://www.argos.dk (I have headed the development)
  - Download free student version
  - https://brandogsikring.dk/files/Argos/exe-files/student/Argos_Student_Setup.exe

http://www.firemodelsurvey.com/ZoneModels.html

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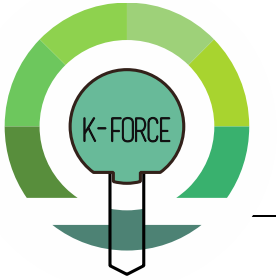
Conclusion



- Fires generate different signatures which can be used for detection
- Nuisance sources can lead to false alarms
- It is important to choose the right detector for the purpose
- Activation time of an detector can be calculated by hand or by computational model

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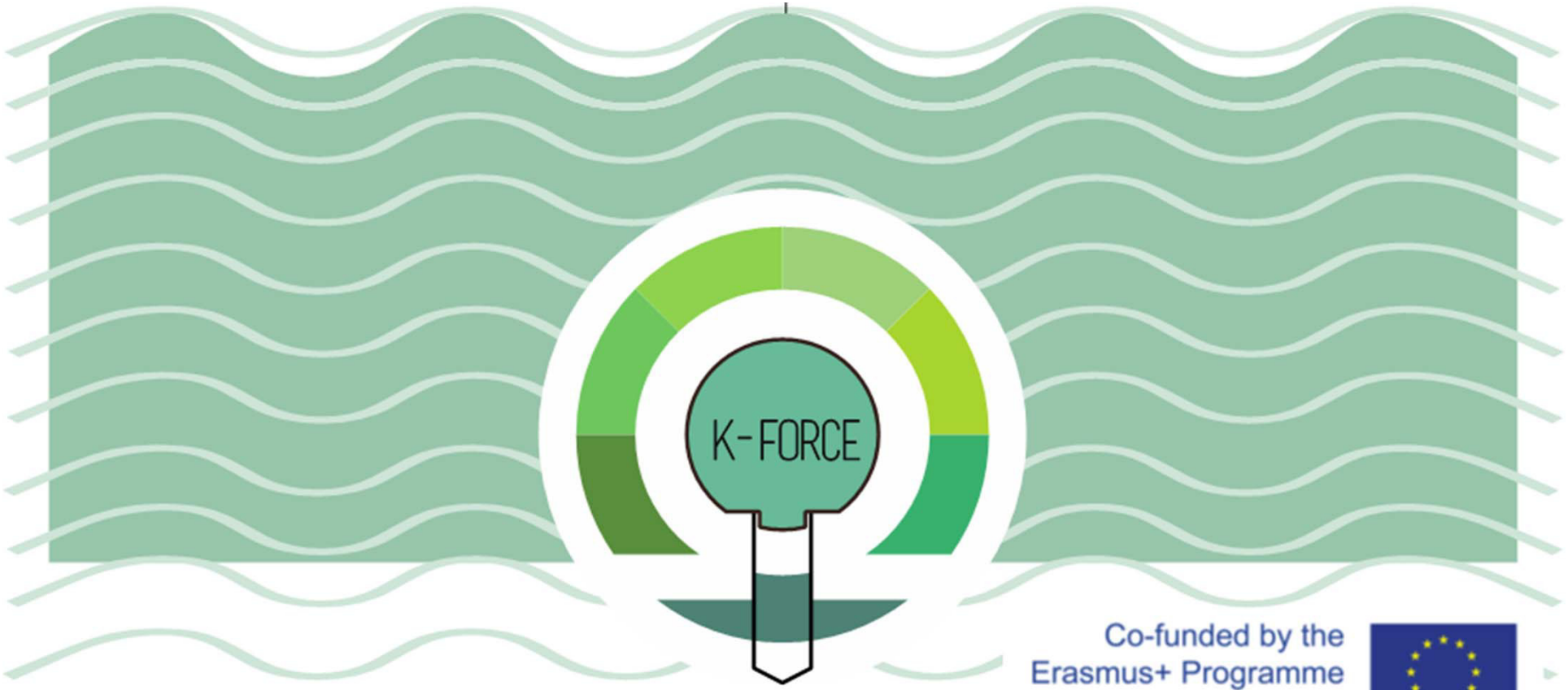

Thank you
for your attention

bjarne.husted@brand.lth.se

Knowledge **FO**r **R**esilient so**C**i**E**ty