

# 15. Paper Anemometer

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# Problem

- When thin strips of paper are placed in an air flow, a noise may be heard. Investigate how the velocity of the air flow can be deduced from this noise.



# Sažetak

- Aparatura
- Mjerenje
- Rezultati
  - male brzine
    - frekvencija titranja
  - veće brzine
    - gušenje
    - papir i plastika
- Zaključak



Ušis zraka

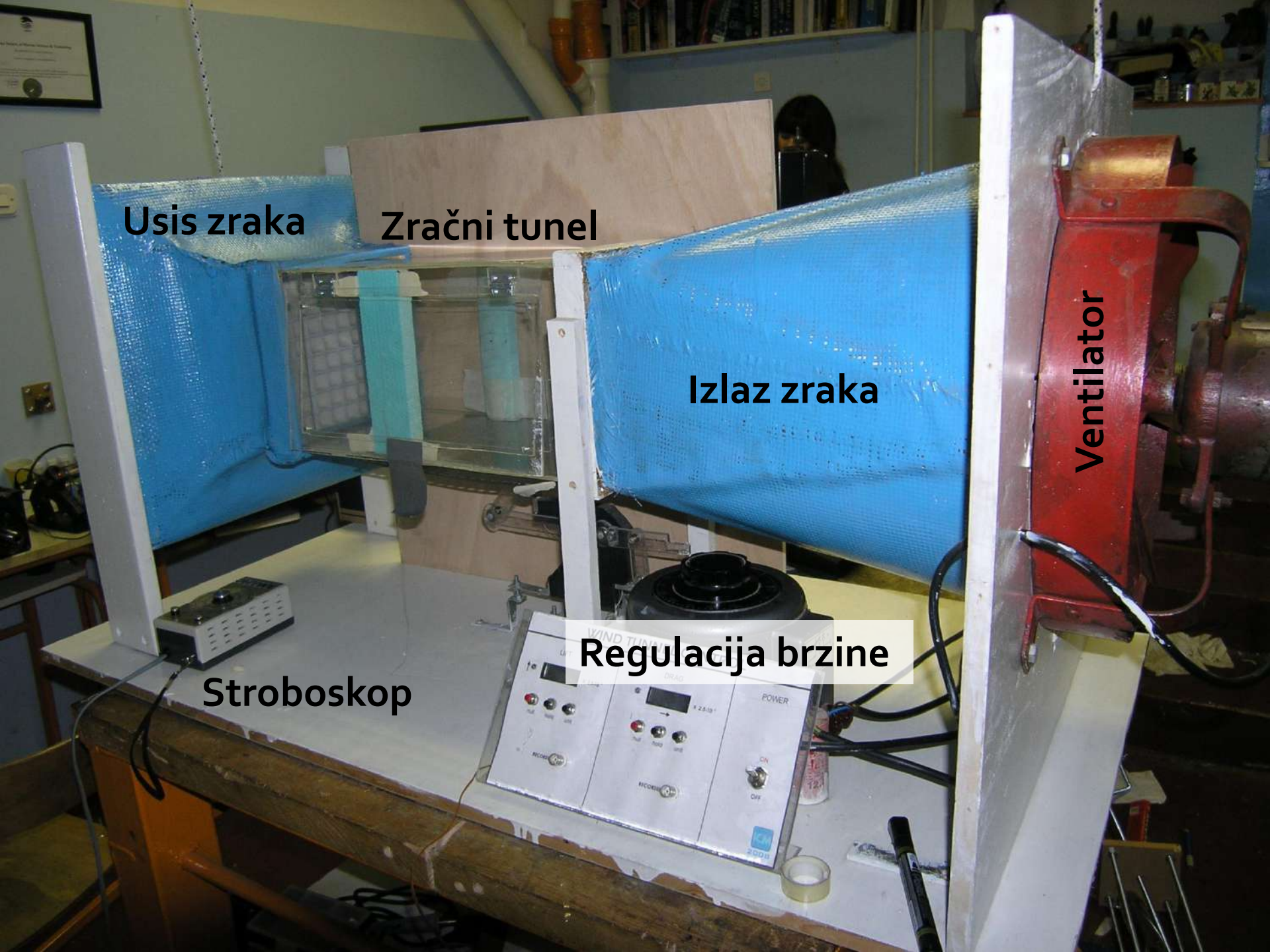
Zračni tunel

Izlaz zraka

Ventilator

Stroboskop

Regulacija brzine



# Zračni tunel

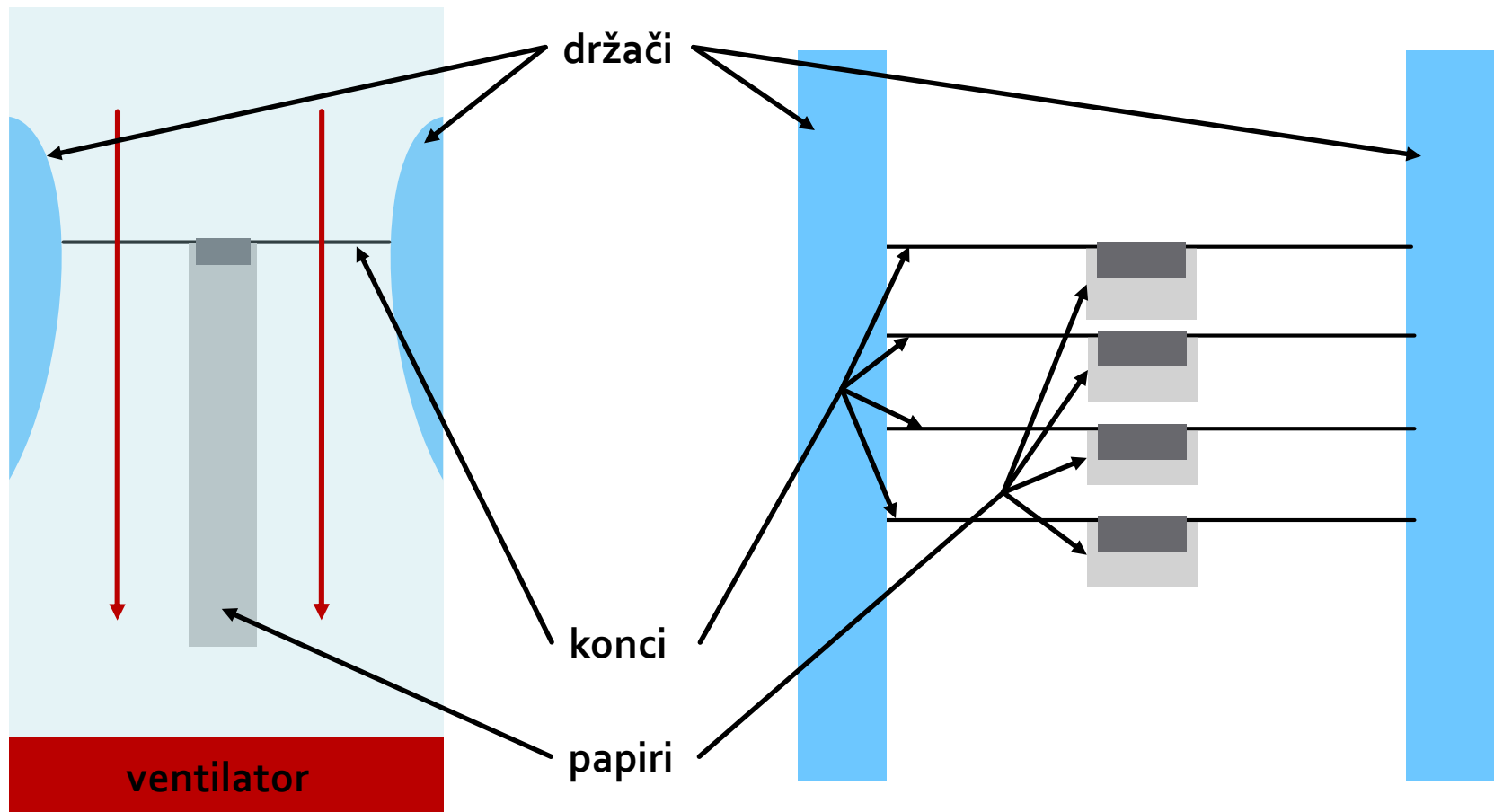
- Laminarni tok
  - mreža na ulazu u tunel
  - prijelaz kvadratnog presijeka na kružni za ventilator
  - prilagođeni stalci za papire
  - tanki konci
- Regulacija brzine vjetra u zračnom tunelu
  - raspon brzina do 15 m/s

# Stalak za papire

- Polistirenska pjena – aerodinamičkog oblika
- Papiri pričvršćeni na konce



# Stalak za papire

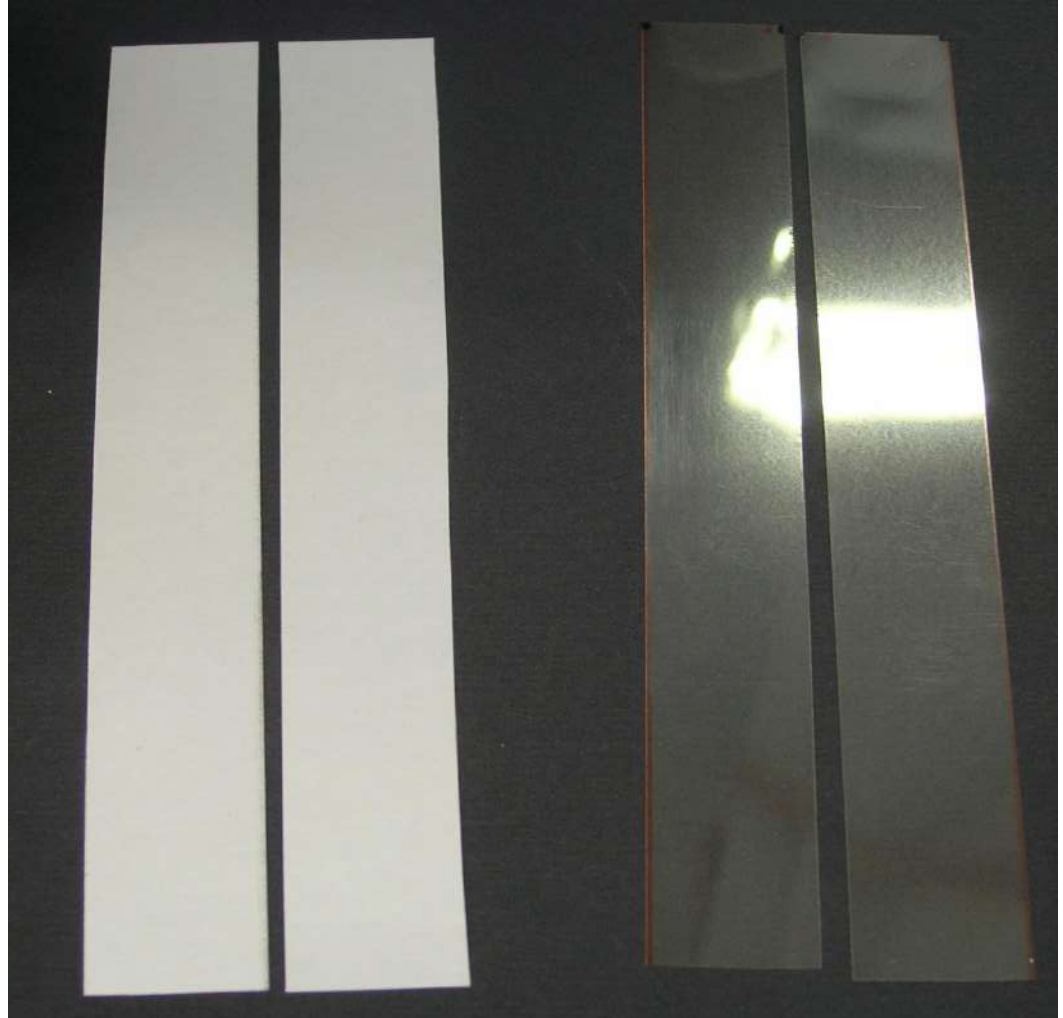


■ tlocrt

■ nacrt

# Papiri

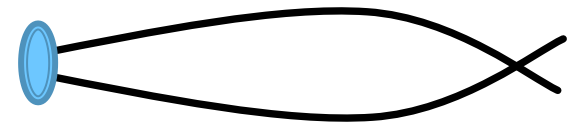
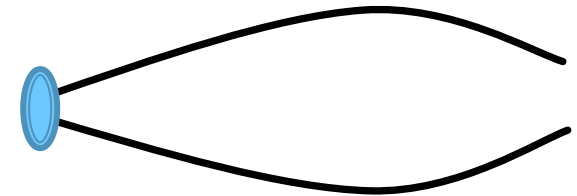
- Papir
  - 80 g/m<sup>3</sup>
  - 15 x 2 cm
- Plastika
  - grafofolije
  - 15 x 2 cm
- Mjerenja s po 4 papira





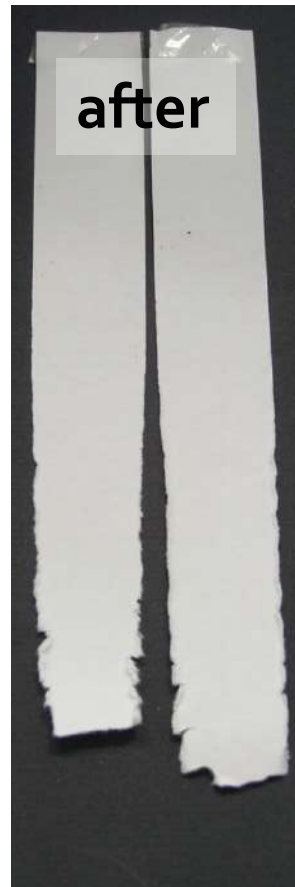
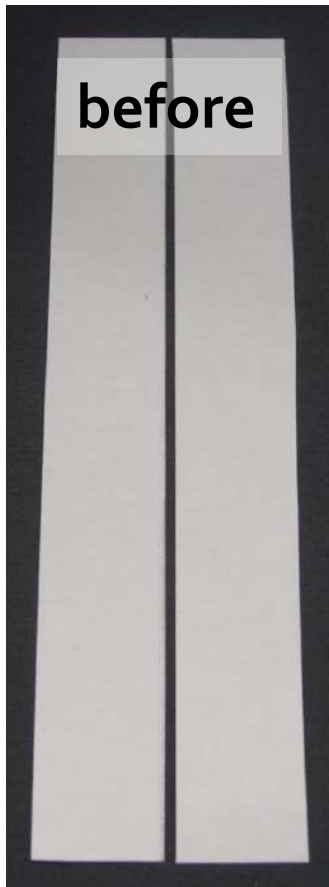
# Ponašanje papira u struji zraka

- Male brzine
  - pravilno titranje - **nema zvuka**
  - papiri titraju u fazi
- Srednje brzine
  - pravilno titranje - **nema zvuka**
  - papiri titraju u kontrafazi
- Velike brzine
  - kaotično titranje - **zvuk**
  - uništavanje papira

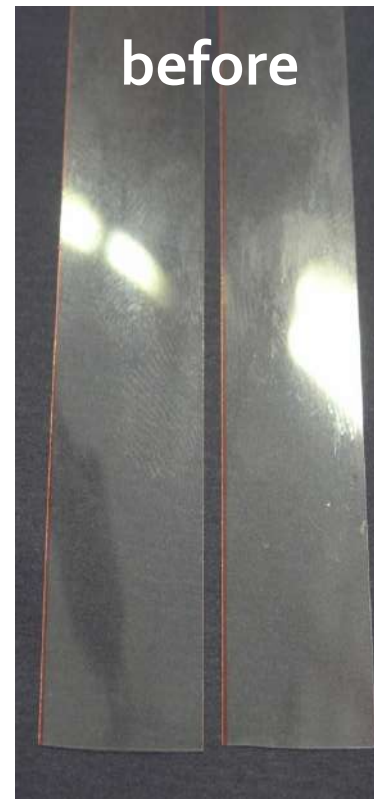


# Uništavanje papira

## ■ papir



## ■ plastika

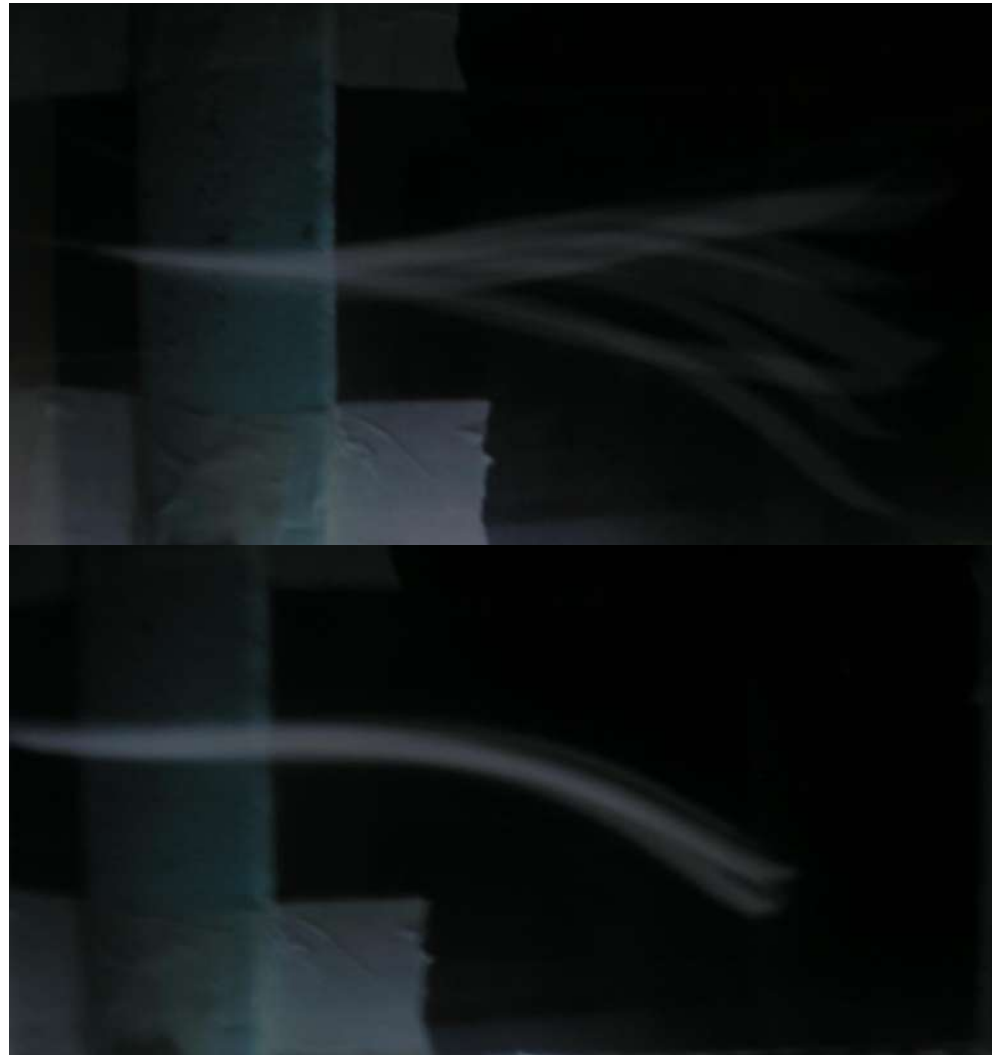


# Mjerenje

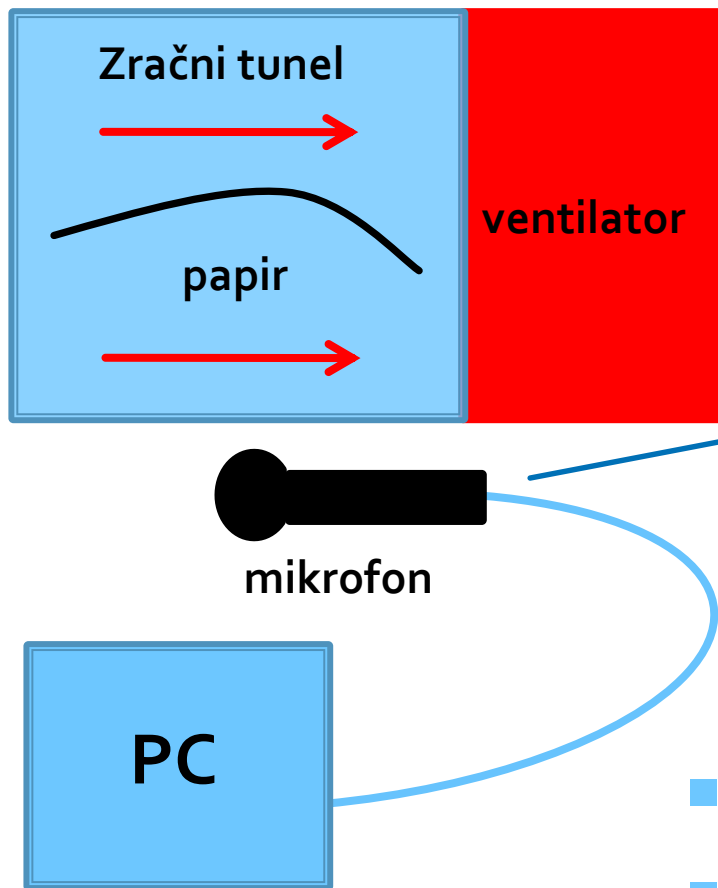
- Male i srednje brzine
  - frekvencija – stroboskop
  - broj papira
- Velike brzine
  - zvuk – brzina
  - zvuk u vremenu
  - papir i plastika

# Mjerenje

- Stroboskop
  - periodični bljeskovi određene frekvencije
  - mirna slika papira – pogodna frekvencija

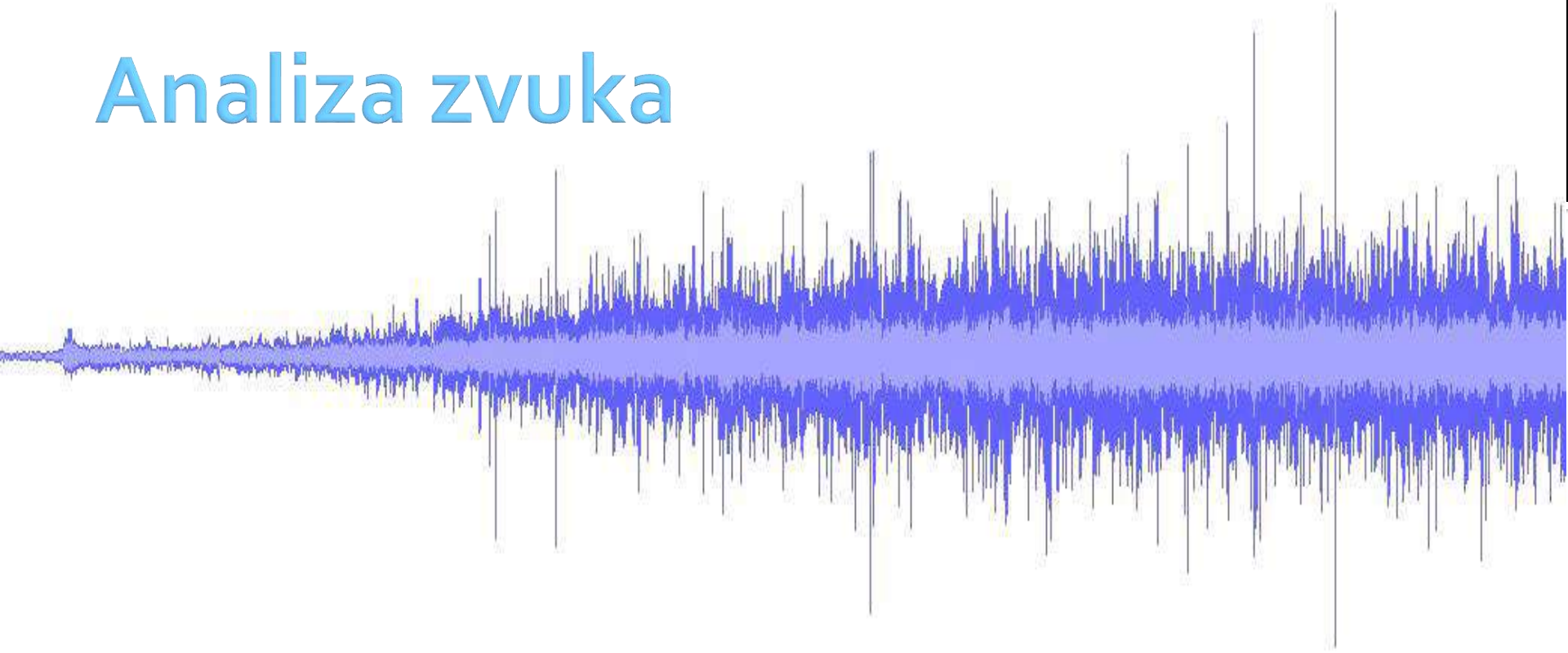


# Mjerenje zvuka



- Mjerenje zvuka mikrofonom
- Računalna analiza podataka

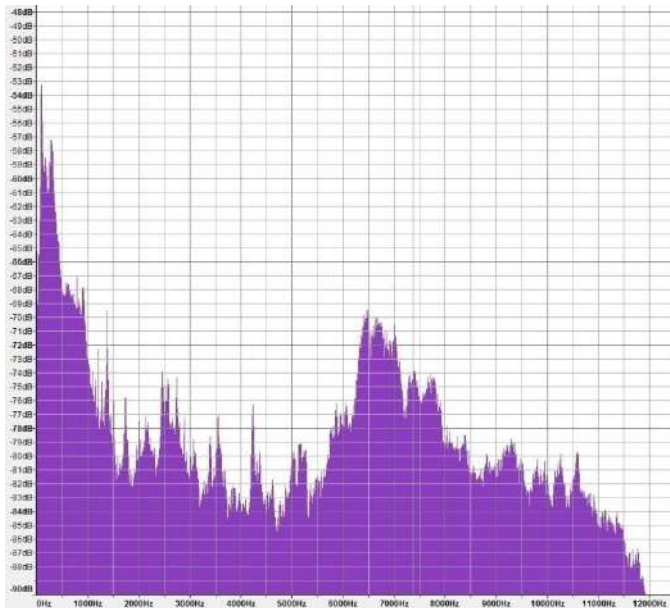
# Analiza zvuka



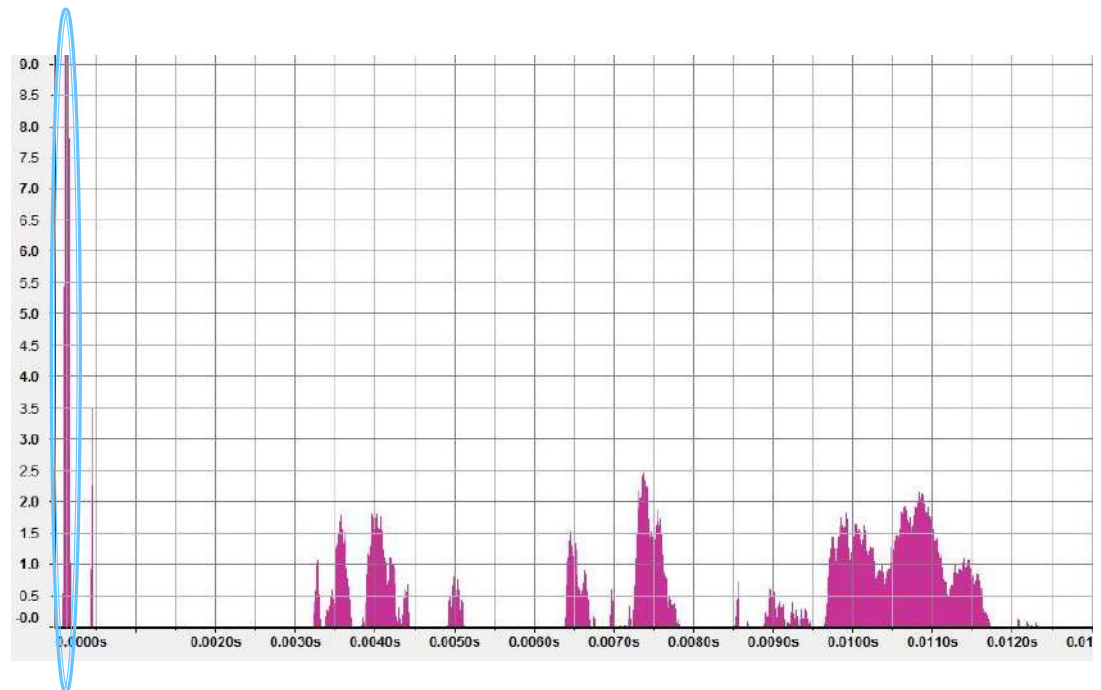
- Snimanje zvuka na PC
- Uzimanje optimalnih intervala za mjerenje
  - uvijek jednaki intervali
  - od trenutka dostizanja željene brzine vjetra

# Analiza zvuka

- Autokorelacija zvuka na tim intervalima
- Identifikacija signala

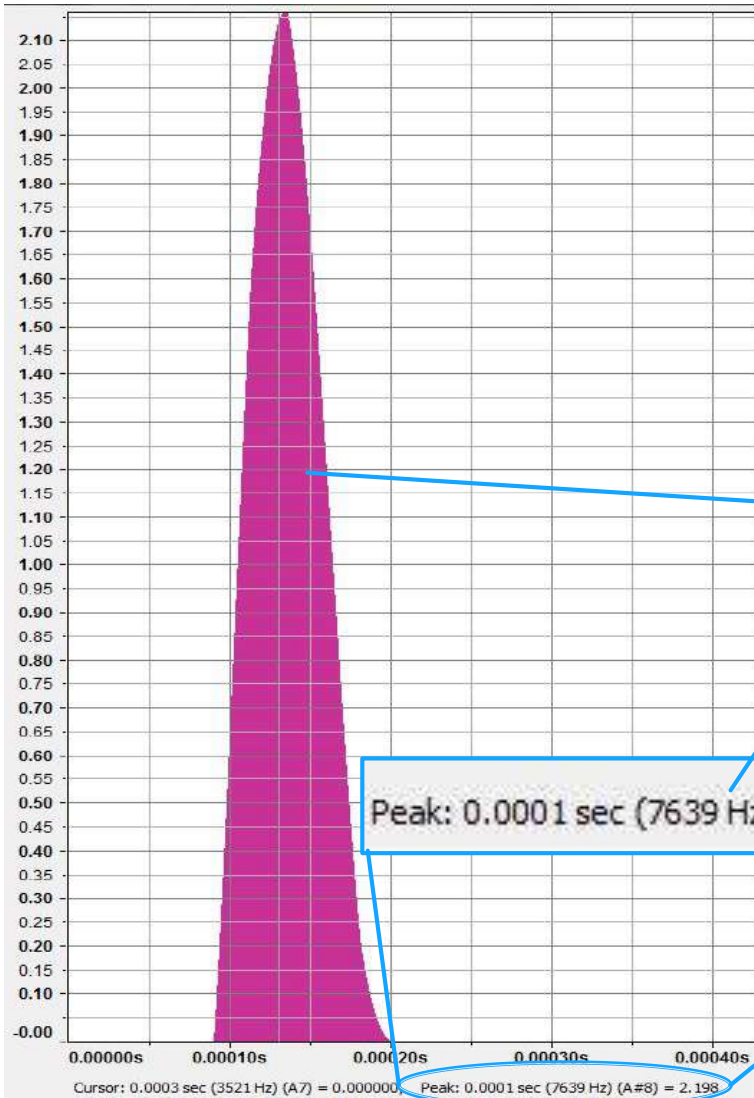


■ spektar zvuka



■ autokorelacija

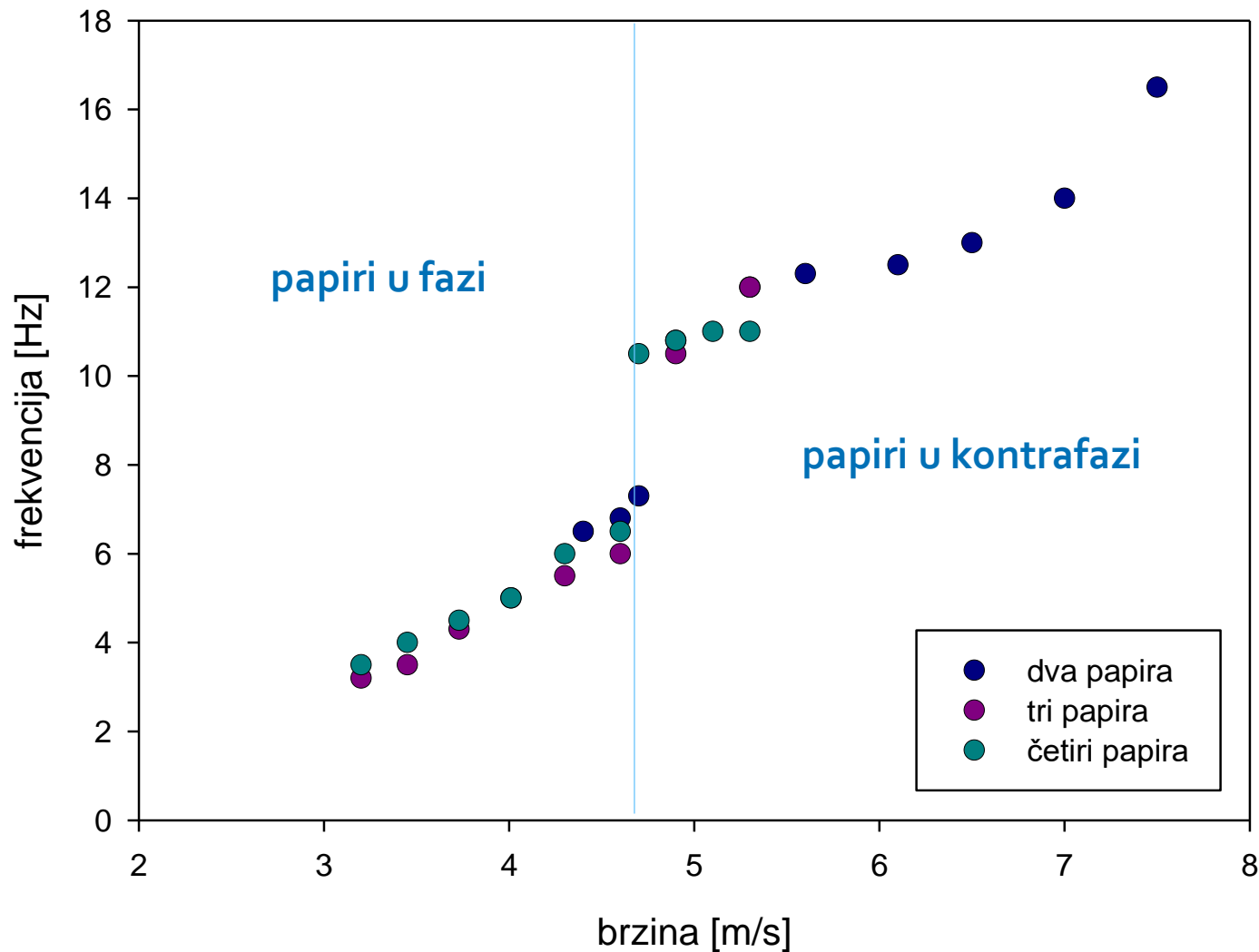
# Autokorelacija zvuka



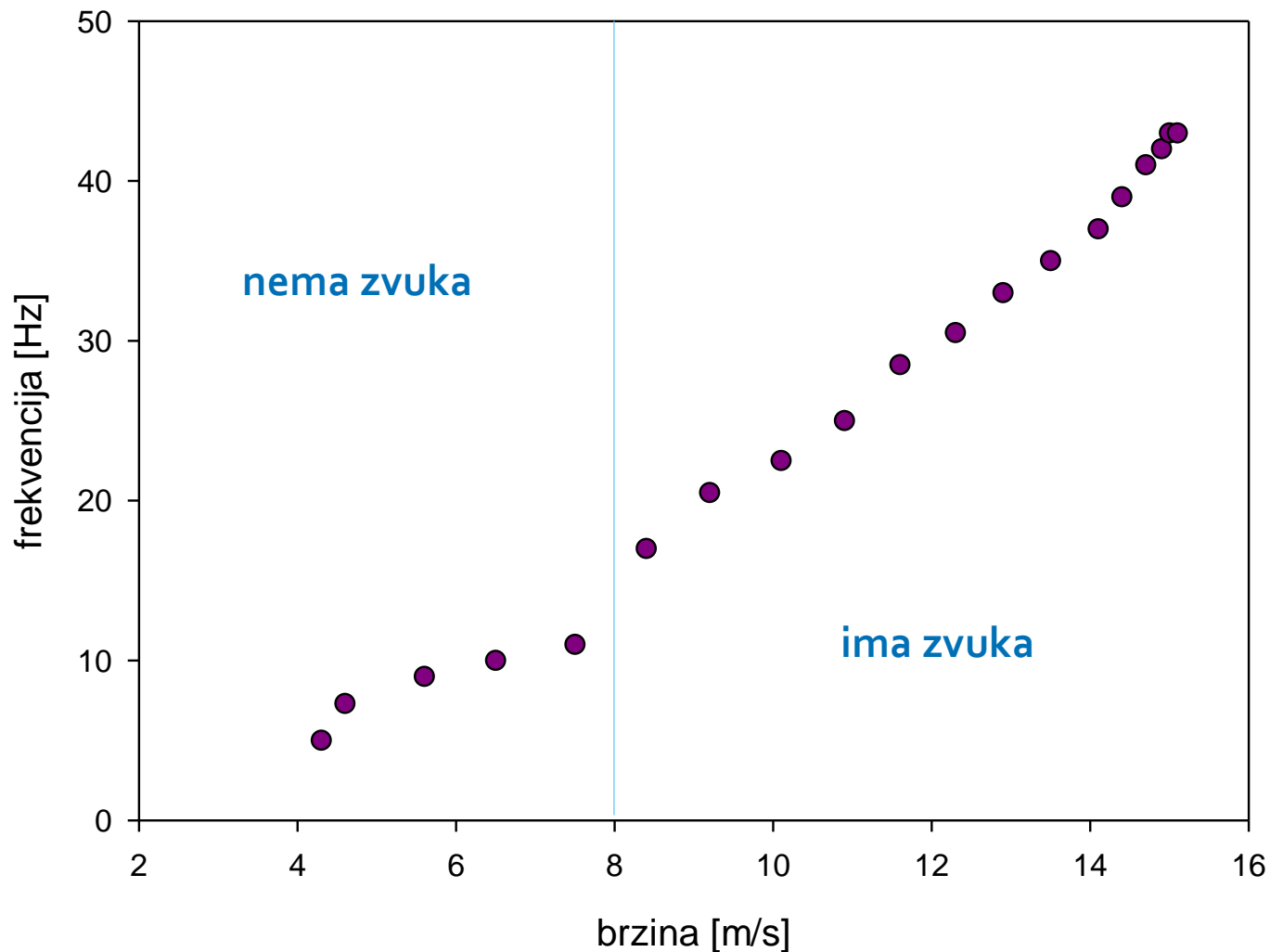
- traženje periodičnih pojava u zvuku
  - frekvencija tona periodične pojave
  - graf intenziteta periodičnih pojava u vremenu
    - intenzitet proporcionalan kvadratu amplitude i frekvenciji ponavljanja tona
    - izravna slika izgleda prosječnog udarca u vremenu



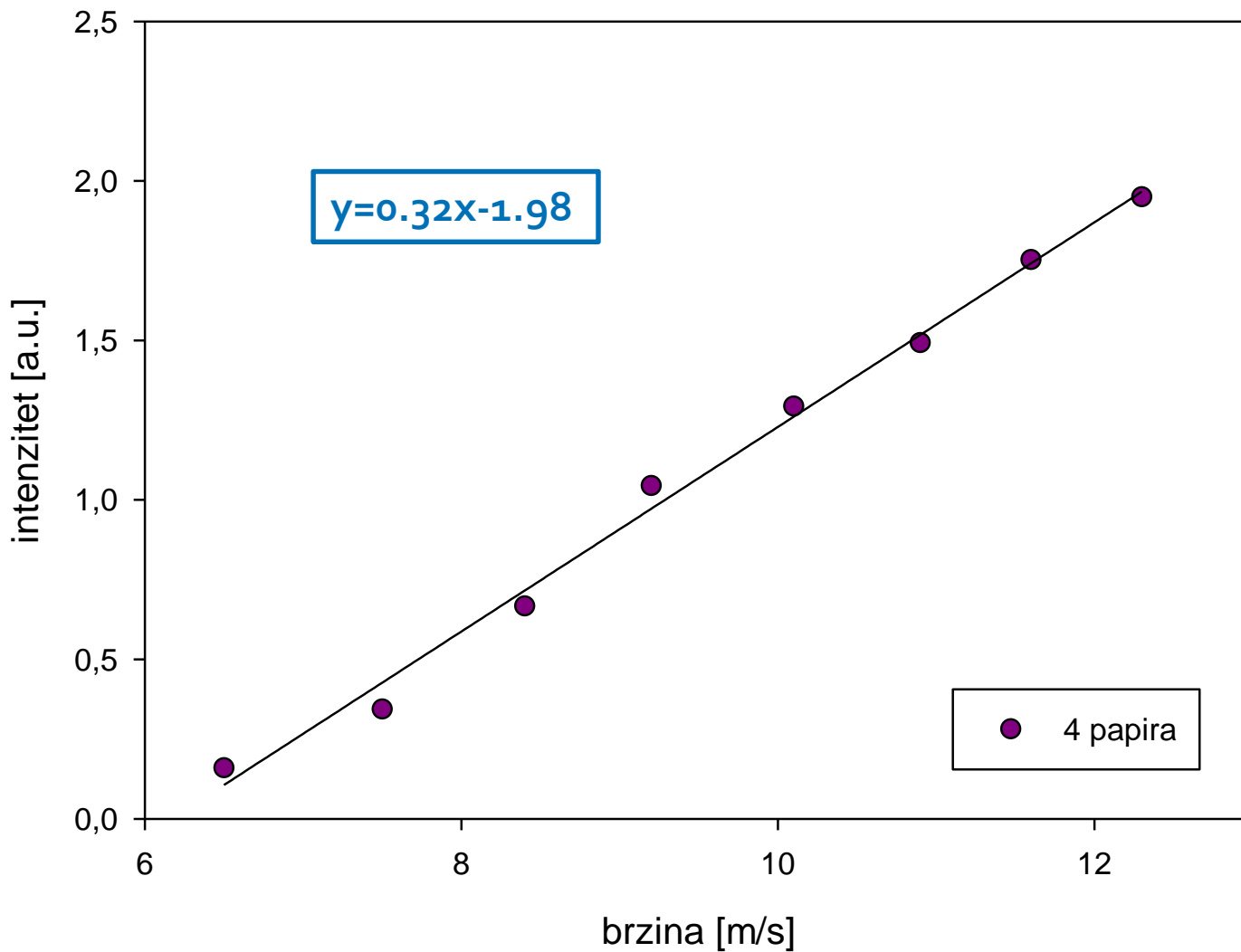
# Ovisnost frekvencija o brzini – više papira



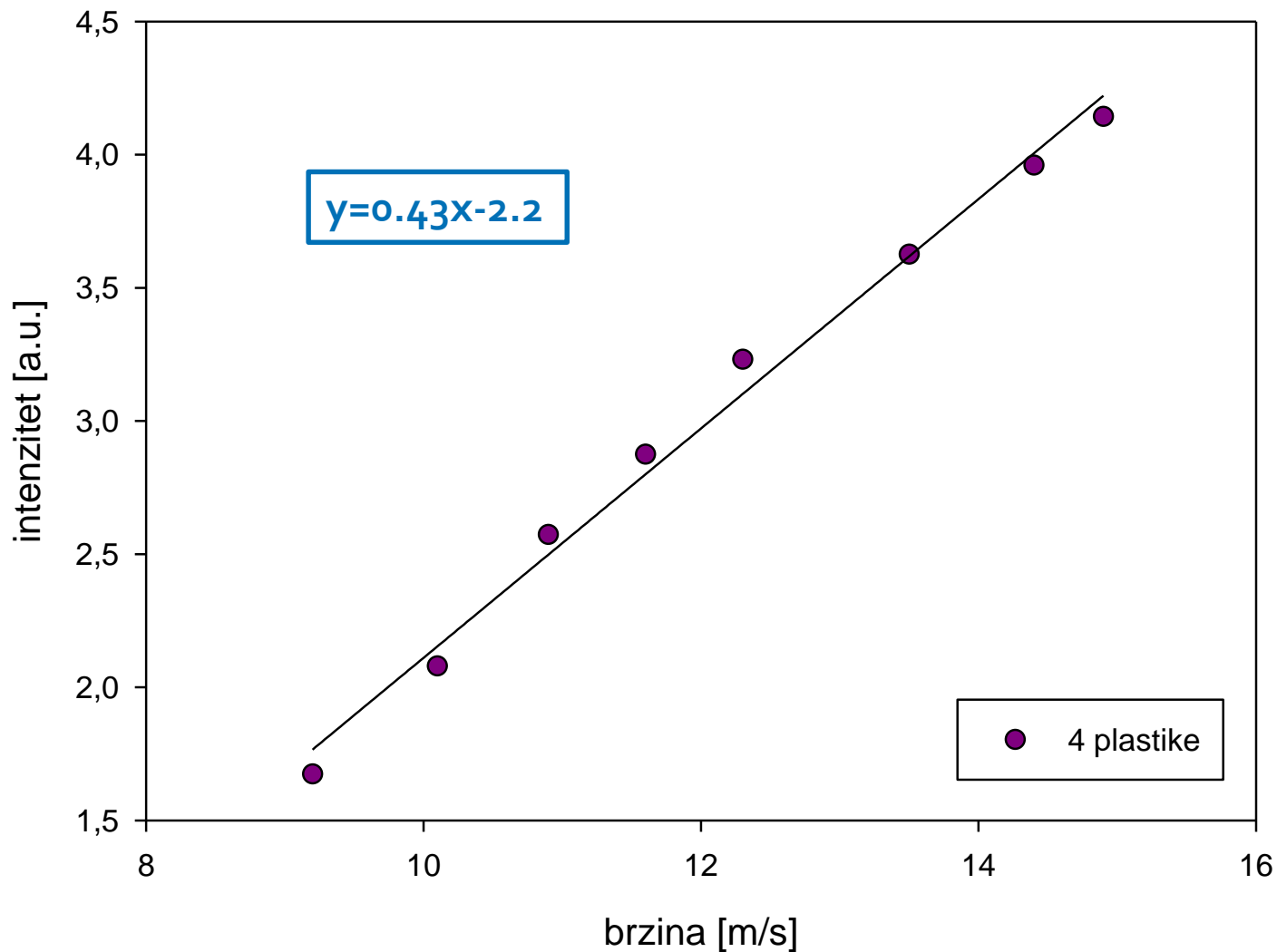
# Ovisnost frekvencija o brzini – 1 papir



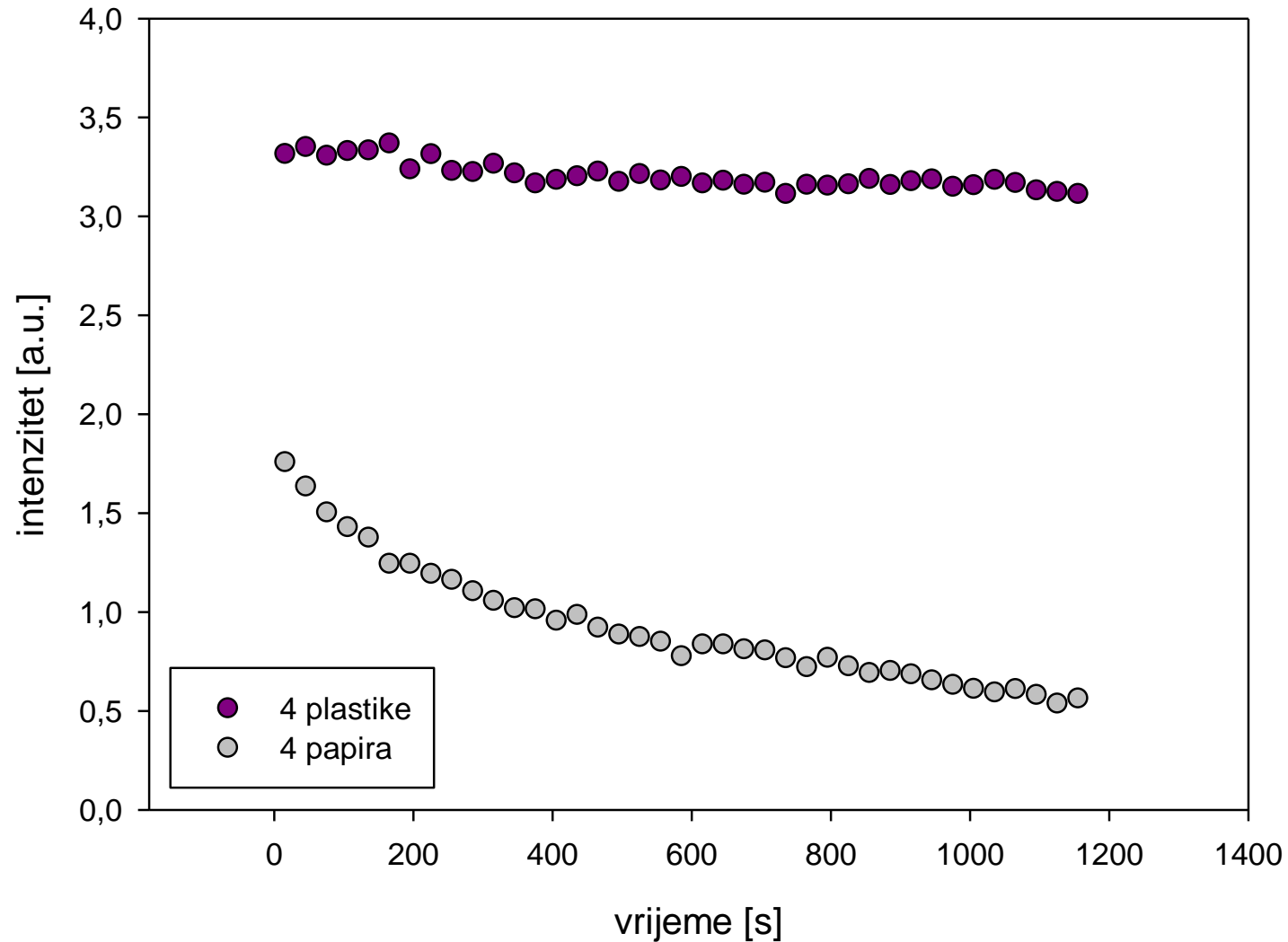
# Ovisnost intenziteta buke o brzini



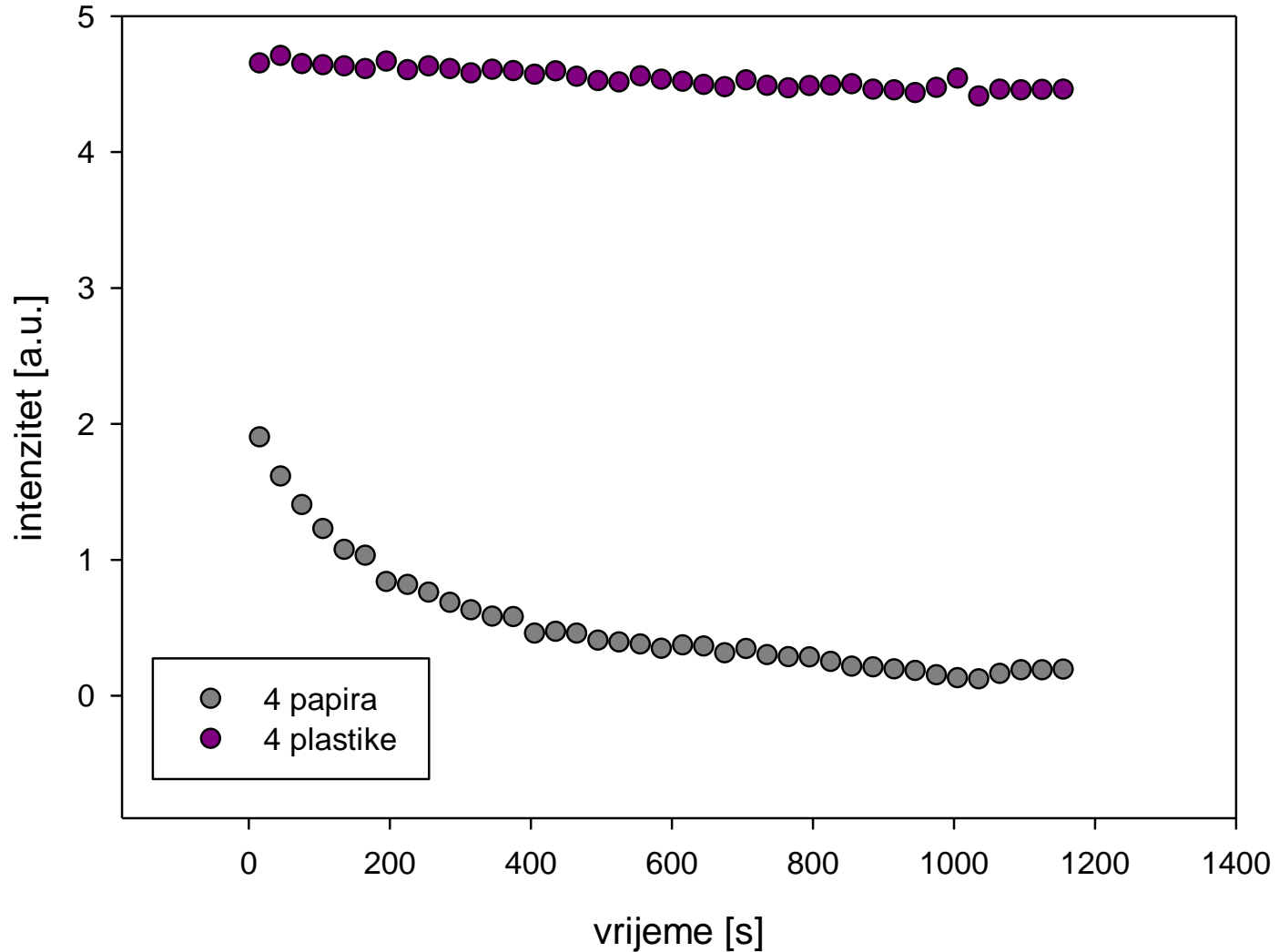
# Ovisnost intenziteta buke o brzini



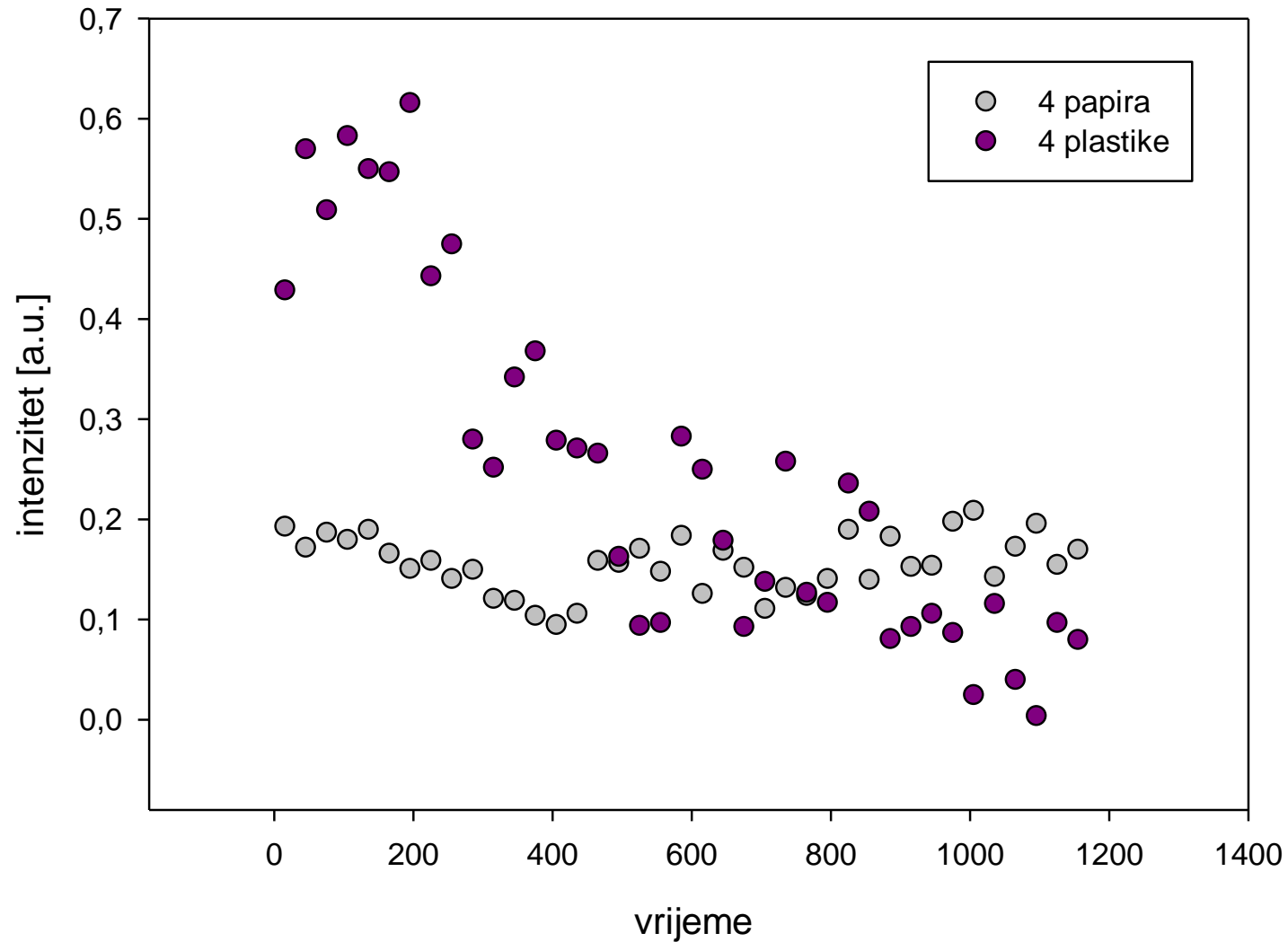
# Zvuk u vremenu – 11.6 m/s



# Zvuk u vremenu – 15 m/s



# Zvuk u vremenu – 7.5 m/s



# Zaključak

- Konstruiran papirni anemometar
- Dobivene formule procjene brzine vjetra iz zvuka
- Plastika  $y=0.43x-2.20$ 
  - raspon: 9 m/s – 16 m/s
- Papir  $y=0.32x-1.98$ 
  - raspon: 7 m/s – 13 m/s
- Veća preciznost kod plastičnog anemometra
  - manje ovisi o trenutku mjerenja



**Hvala na pažnji!**

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