# The optical properties of combustion generated particles from 1-D hydrogen doped ethylene flames

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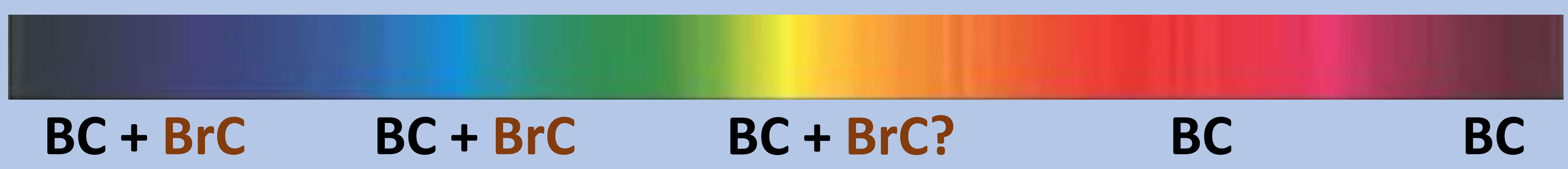
## Introduction

It is well known that black carbon (BC) has a large warming effect on the climate due to light absorption in a wide range of wavelengths (Bond 2013). The effects of coloured organic carbon (also known as brown carbon (BrC)) are also significant, as in some studies they account for 10% to 20% of the near atmospheric UV absorption (Kumar *et al* 2018). Towards the infrared, BrC has no absorption.



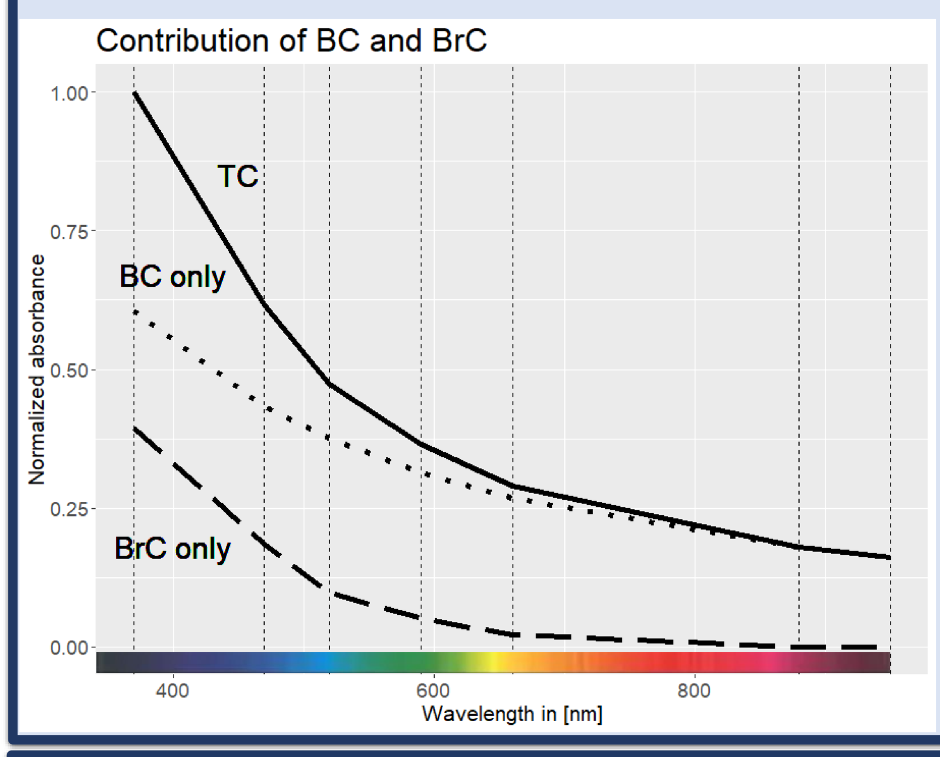

Due to the complex nature of brown carbon, it is not very known yet which combustion conditions lead to the formation of brown carbon. A study is done to examine the optical properties of combustion generated carbonaceous aerosols, using hydrogen (H2) doped ethylene (C2H4) flames. Keeping the equivalence ratio $\varphi$ constant at 2.3, the flame conditions were:

- Exit velocity ranging from 6 cm/s to 10 cm/s
- Fuel composition range from 100% C2H4 to 50/50% H2/C2H4

## Methods

An AE43 aethalometer is used to measure the wavelength depending absorption of flue gases from various flames using a McKenna burner. TC is denoted as the Total Carbon signal. The contribution of BC can be approximated by extrapolating the AAE between 880 and 950 nm. The remaining absorbance is assigned to the BrC.

*Figure 1: McKenna burner used for this project*




$$AAE_{\lambda_1/\lambda_2} = -\frac{\ln(b_{abs}(\lambda_1)/b_{abs}(\lambda_2))}{\ln(\lambda_1/\lambda_2)}$$

*Figure 2:* Using an extrapolation of the measured extinction coefficient by the Absorption Angstrom Exponent (AAE) at the 950 and 880nm, the dotted **BC-only curve is drawn**. The **longdashed** line is the remaining signal, **assigned to BrC**. The **solid curve is the measured TC**. The vertical dashed lines denote the wavelengths of the AE43. In similar fashion done in other literature (*Qin et al 2018*).

## Conclusion

A changing Absorption Angstrom Exponent is found for different flame conditions. The near-UV absorption is found to be larger for **lower exit velocities** and **higher hydrogen content**. This would imply that **the BrC/BC ratio is higher** for these conditions. The results **cannot completely** be explained by the flame temperature, so also **the fuel composition** itself has an impact on the optical properties of the particles.

## Flame temperature dependency

Using the San Diego mechanism (UC, 2016), the 1-D flame temperatures are calculated at 1 cm above the burner and plotted on the x-axis. The wavelength dependence of the absorption is plotted as AAE over all channels on the y-axis, denoted as AAE370-950. A higher AAE corresponds to a higher BrC/BC ratio. For every exit velocity, a decreasing trend is seen, but there is no overall trend. This implies that flame temperature is not the only factor.

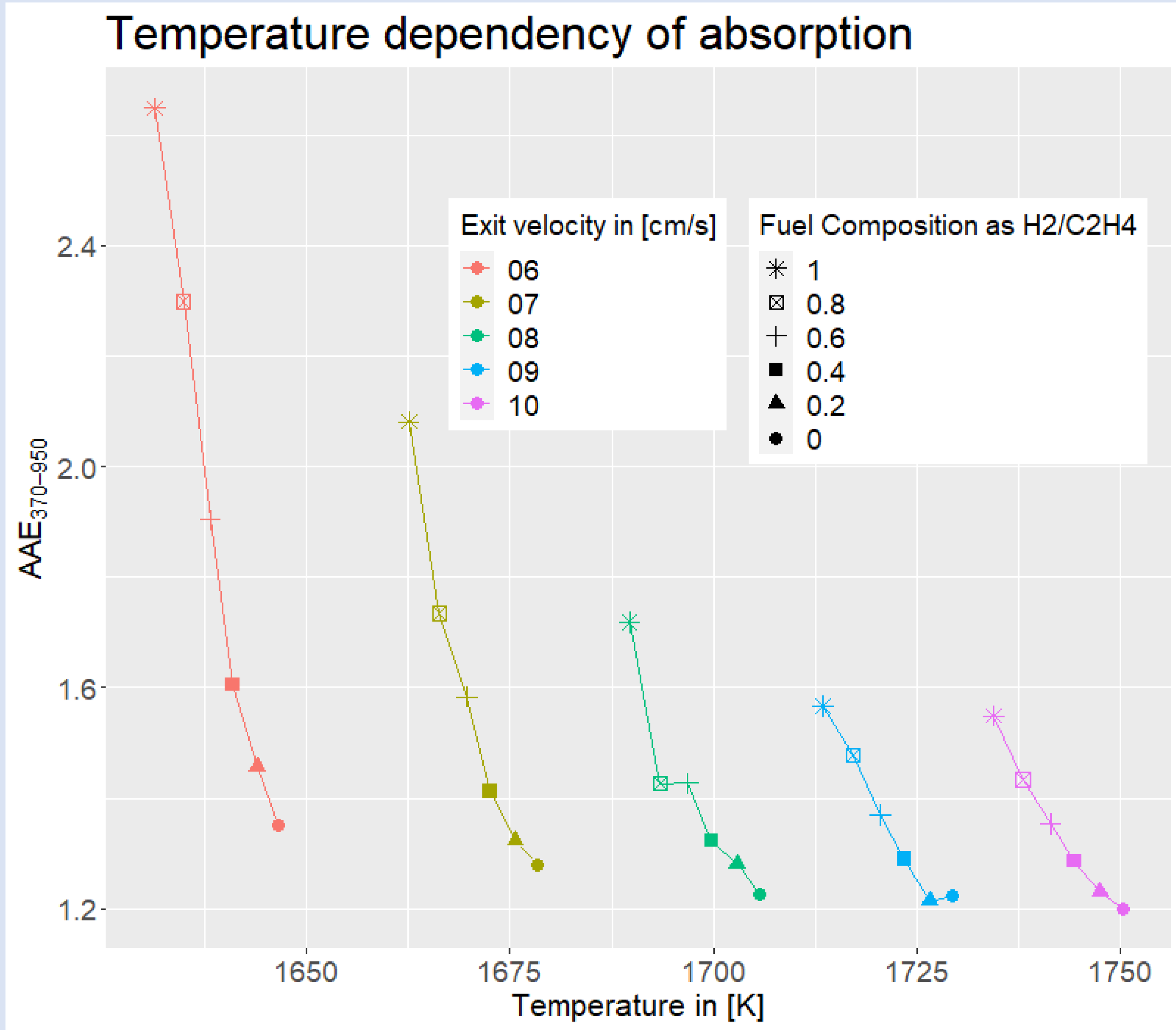



*Figure 5: As expected, higher exit velocities and lower H2 content induce a higher flame temperature. The exit velocity has a larger effect compared to the fuel composition. The AAE does change with temperature, but no overall trend is observed.*

## Results for pure ethylene fuel

For pure ethylene, absorption attributed to BC and BrC have a very similar wavelength dependence. A small increase is seen for lower exit velocities in TC, but the BC and BrC are well within the uncertainties.

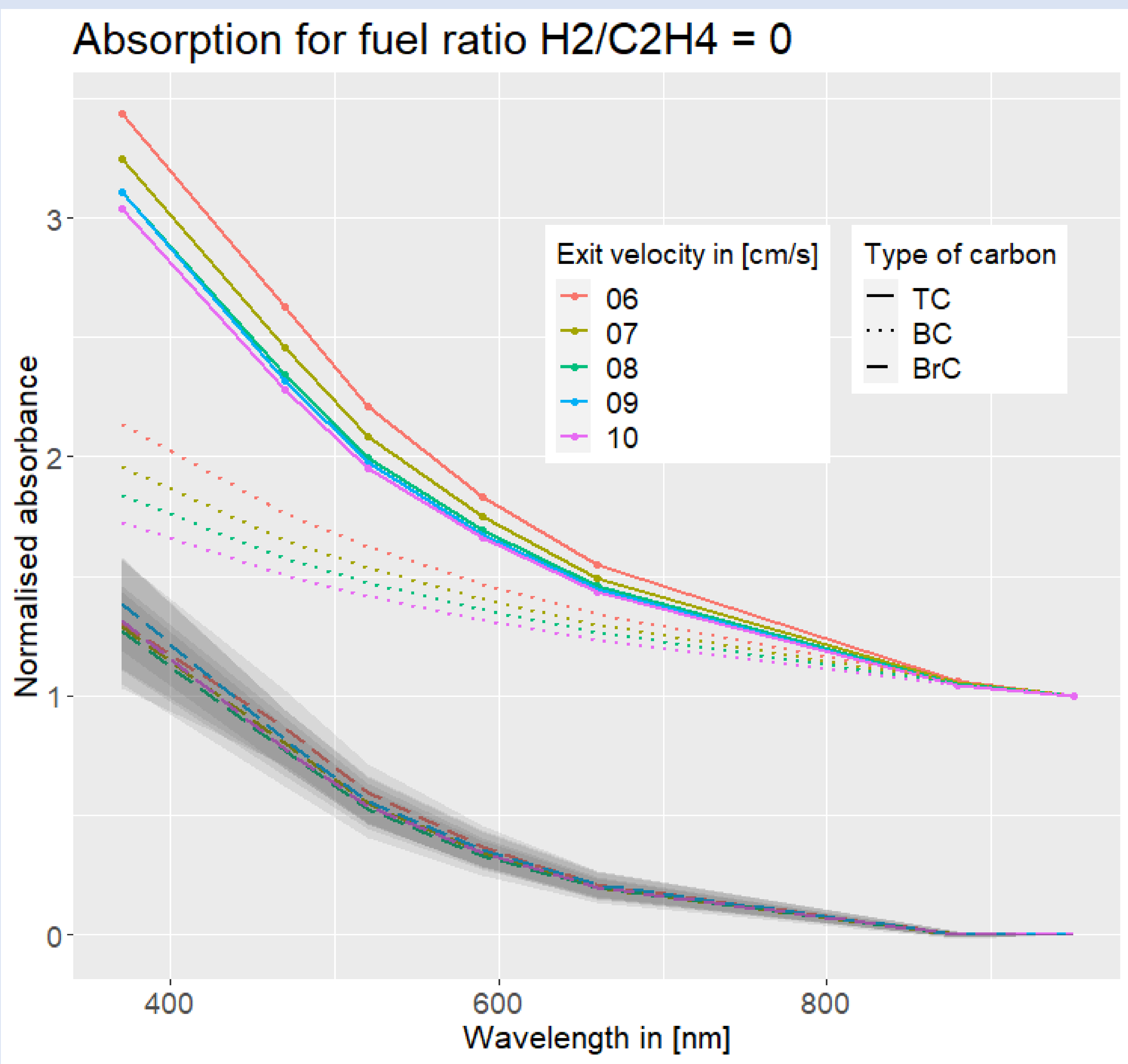
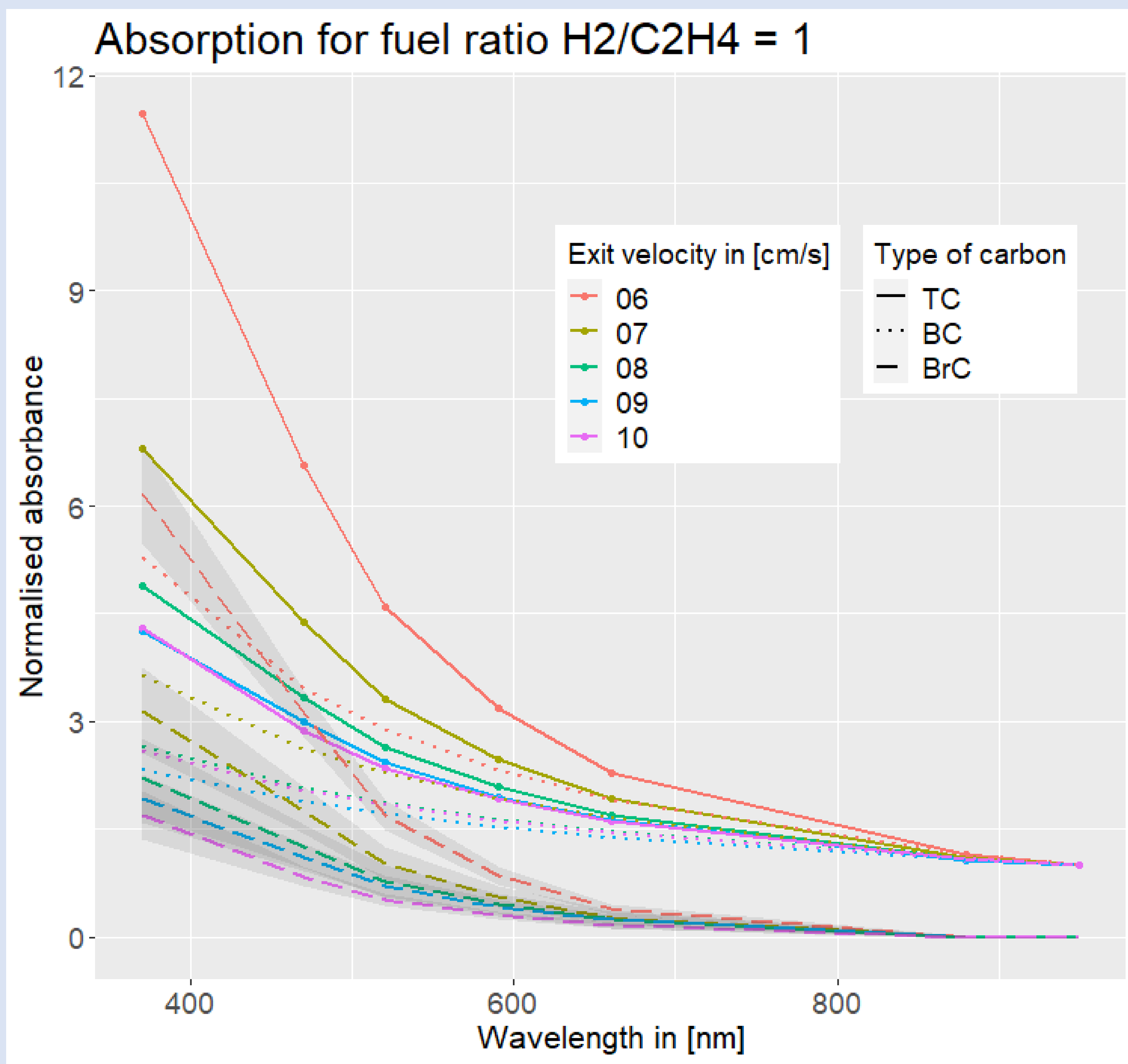



*Figure 3 and 4: The normalised wavelength depending TC absorption is indicated with the solid lines. The dashed lines are the extrapolated contribution due to BC. The lower lines indicate the BrC related absorption, with error margin from extrapolation.*

## Results for 50/50% hydrogen/ethylene fuel

For a 50/50 fuel mixture, a drastic increase in the wavelength dependence of the absorption is seen with altering exit velocities, especially for shorter wavelengths. Once, the BrC/BC is greater than 1.




## References

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