Carbon atom addition reactions in interstellar ices:
How to marry laboratory and computational chemistry

T. Lamberts[1,2] and collaborators

[1]*Theoretical Chemistry, Leiden Institute of Chemistry, Leiden University, The Netherlands*
[2]*Leiden Observatory, Leiden University, The Netherlands*

I will focus on surface reactions of carbon atoms on amorphous solid water (ASW) ices, mimicking the icy mantle covering the micron-sized dust grains in the interstellar medium. In the translucent stage of a molecular cloud, carbon is predominantly present in its atomic form C($^3P_0$) [1] and even in dense regions it is likely more abundant than typically thought [2,3]. Moreover, already in 2001 carbon atoms additions have been proposed to lead to the formation of complex organics [4]. Therefore, a carbon atom beam source was installed at the Leiden Laboratory for Astrophysics [5], successfully demonstrating that methane can be formed from experiments of C + H on ASW [6]. In this talk I will discuss three new projects:

1. The interaction of atomic carbon with water has been extensively studied, both experimentally and theoretically [e.g., 7, 8], but particularly puzzling is the different chemical behaviour in the gas phase versus in condensed phases. I will provide a detailed explanation of the formation of **formaldehyde** from carbon atoms with amorphous solid water within a theoretical framework, supported by tailored experiments [9].
2. I will touch upon the reactions of carbon atoms with molecular hydrogen and show that an intricate interplay of reactions can lead to the formation of **methane**, even when H atoms are not present. I will discuss this both from an experimental and computational point-of-view and link the various intermediates to other recent studies [10].
3. Finally, I will show that the reactivity with H_2 and H_2O does not restrict the formation of complex organics, and in fact the reaction between C and CO occurs so rapidly that **ketene** and **acetaldehyde** can be formed in the presence of H atoms [11].

References

[1] Van Dishoeck and Black, 1988, ApJ 334, 771
[2] M.G. Burton *et al.*, 2015, ApJ 811, 13
[3] Bisbas *et al.,* 2019, MNRAS 485, 3097
[4] Charnley *et al.*, 2001 SAA, 57, 685
[5] Qasim *et al*., 2020, RSI 91, 054501
[6] Qasim *et al.*, 2020 NatAs 4, 781
[7] Schreiner *et al.*, 2006, CPC 7, 880
[8] Shimonishi *et al.*, 2018 ApJ 855, 27
[9] Molpeceres *et al*., 2021 JPCL subm.
[10] Lamberts *et al.,* 2021 ApJ subm.
[11] Fedoseev *et al.*, 2021 ApJ subm.