Report on the outcomes of a Short-Term Scientific Mission[1]

Action number: CA21126

Grantee name: Juraj Jašík

Details of the STSM

Title: Developing a cryogenic ion trap for spectroscopy of carbon-rich interstellar ions

Start and end date: 15/07/2024 to 19/07/2024

Description of the work carried out during the STSM

Description of the activities carried out during the STSM. Any deviations from the initial working plan shall also be described in this section.

(max. 500 words)

The goal of our collaboration with Ugo Jacovella is to record the optical spectra of isomer-selected metal carbide ions, potentially linked to diffuse interstellar bands (DIBs). We utilize a specialized apparatus that selects ions by mass and mobility, generated via laser ablation and confined in a cryogenically cooled Paul ion trap for light interrogation. This STSM aimed to assist in integrating the cryogenic ion trap into the equipment and conduct initial tests with trapped ions.

The existing experimental setup included a laser-ablation ion source, ion-mobility separation stage, and quadrupole mass filter stage, with proven capabilities for ion mass and shape selection [1]. For this STSM, we planned to add a cryo-cooled 3D Paul ion trap and an octupole ion guide (Figure 1).

The octupole ion guide, designed in JHI and fabricated in ISMO, was mounted in its final position. A channeltron ion detector was temporarily placed after the exit electrode to test ion transmission (Figure 2). Vacuum tests confirmed the effectiveness of the differential wall, showing a pressure gradient nearly two orders of magnitude between the mass filter and trap chambers. The mass spectrum of ions generated by laser ablation of a pure carbon sample revealed C_{60}^+ and C_{70}^+ fullerenes and their fragments (Figure 3). However, the optimal conditions for high ion transmissivity have yet to be found, as indicated by the low signal-to-noise ratio.

The cryogenic ion trap components, fabricated in ISMO, were assembled and mounted on the second stage of the cryo-cooler (Figure 4). During assembly, we identified the need to modify the insulating

[1] This report is submitted by the grantee to the Action MC for approval and for claiming payment of the awarded grant. The Grant Awarding Coordinator coordinates the evaluation of this report on behalf of the Action MC and instructs the GH for payment of the Grant.

spacer design due to short circuits between trap electrodes and the grounded housing. We also adjusted the wiring design to create a larger gap, preventing electrical breakdown and improving heat contact with the heat shield for pre-cooling, which necessitated alterations to the heat shield construction. Thanks to the mechanical workshop's efficiency, these modifications were made on the spot. However, these adjustments took time, and the final task completed during my STSM was the wiring of the trap electrodes.

The work plan was ambitious, we could not complete all tasks. The trap assembly is crucial to the setup, so we focused meticulously on construction details, consuming significant time. To finish the trap assembly, we still need to install diode temperature sensors and a heater on the trap. The tasks that couldn't be completed during the STSM will be addressed in subsequent visits:

- Install the helium buffer gas valve.
- Conduct a vacuum test of the cold head chamber for leak-tightness.
- Perform a test of cryogenic cooling operations.
- Attach a temporary ion detector for ions extracted from the trap.
- Evaluate vacuum impurities using temperature-programmed desorption measurements.
- Optimize experimental conditions for ion trapping.

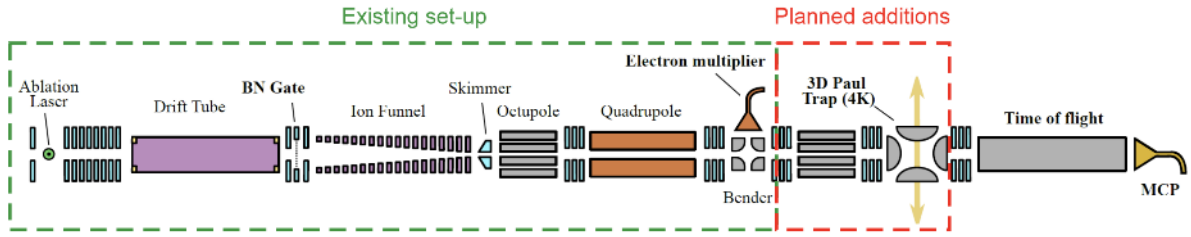


Figure 1: Schematic of the experimental setup (adapted from [1]). The red rectangle shows the components planned to be added during the STSM.

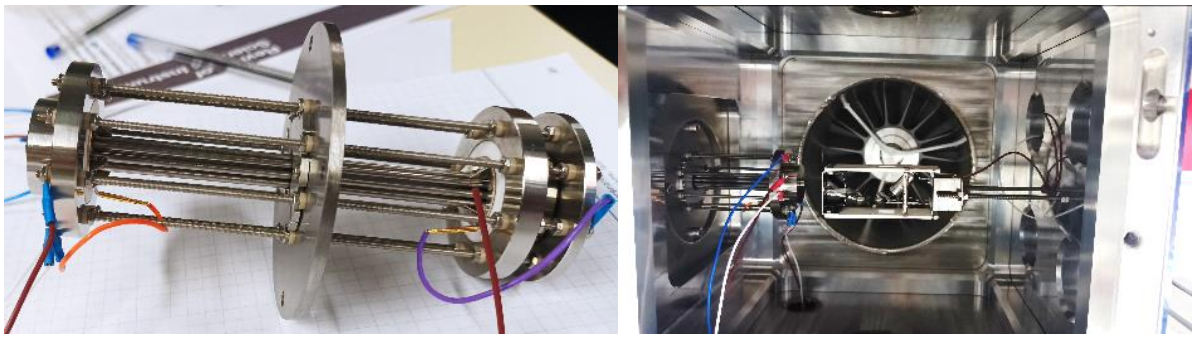


Figure 2: The octupole ion guide mounted on the differential wall (left); the octupole assembly inserted into the apparatus together with the channeltron detector to test the ion transmission of the set-up (right).

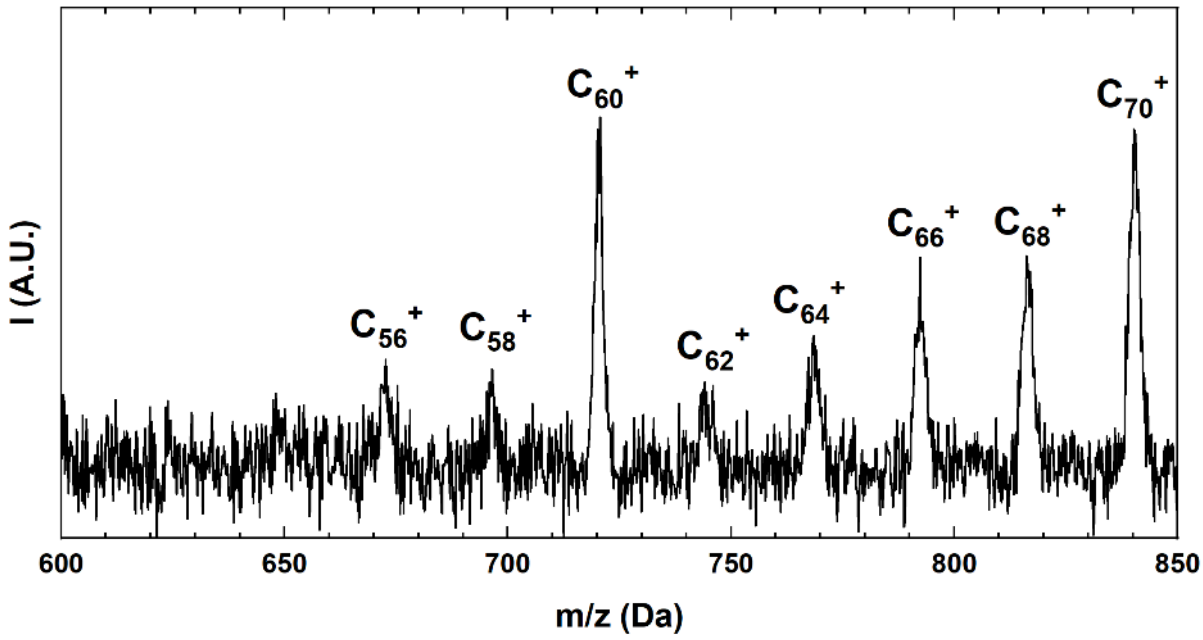


Figure 3: Mass spectrum of ions transmitted through the octupole ion guide. The ions were generated by laser ablation of a pure carbon sample.

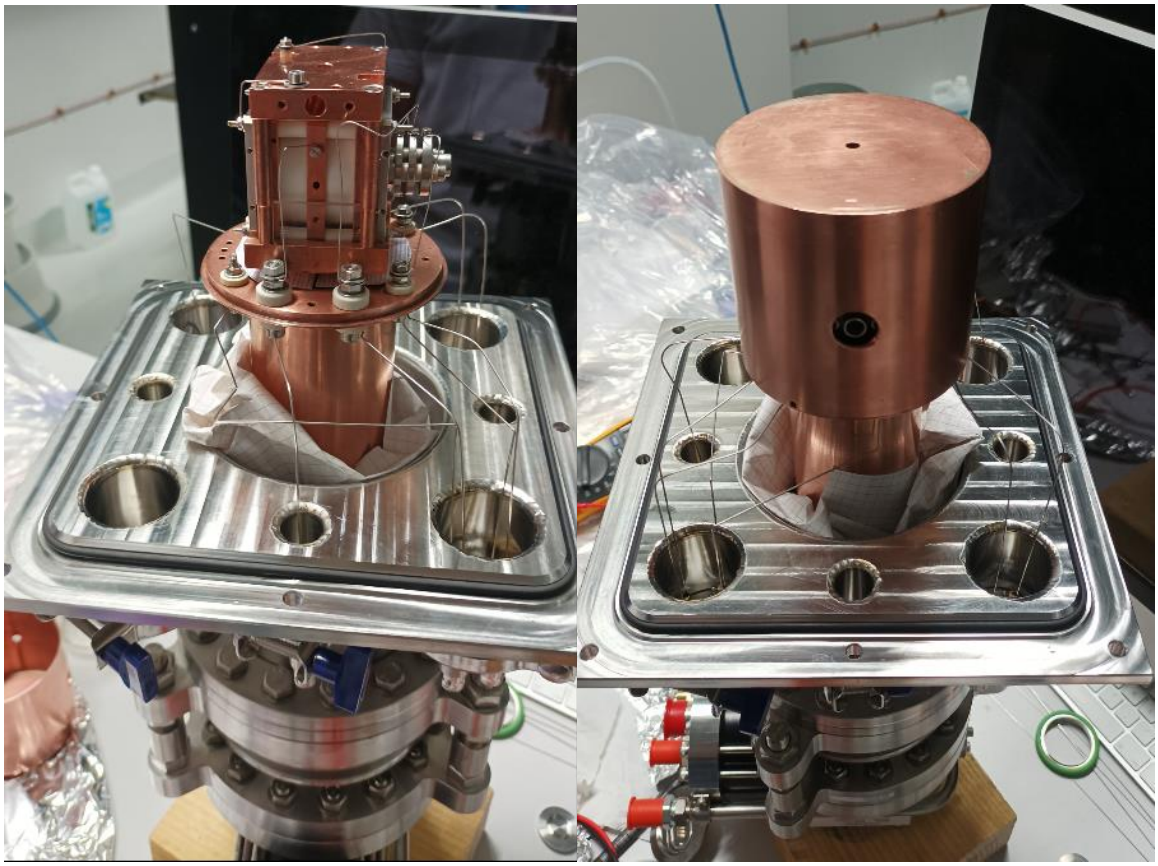


Figure 4: The cryogenic 3D Paul ion trap mounted on the second stage of the cryo-cooler (left); the trap protected by the heat shield connected to the first stage of the cryo-cooler (right).

References

[1] C. Rossi, J. Žabka, J. Jašík, B. Gans, U. Jacovella (2024, February 20 – 23), *Development of a tandem ion mobility and mass spectrometer for the study of interstellar ions.* Scientific day of the Division Chimie-Physique, Société Chimique de France, Société Française de Physique, Paris, France, https://journeedcp2024.sciencesconf.org/

Description of the STSM main achievements and planned follow-up activities

Description and assessment of whether the STSM achieved its planned goals and expected outcomes, including specific contribution to Action objective and deliverables, or publications resulting from the STSM. Agreed plans for future follow-up collaborations shall also be described in this section.

(max. 500 words)

The primary achievement of this STSM was the installation of the octupole ion guide into the experimental apparatus and the assembly of a substantial part of the cryogenic ion trap. Tests demonstrated that the ion guide is functional, though further optimization of the experimental conditions is necessary to achieve higher ion transmission. We also discussed the remaining steps to complete the ion trap assembly.

We have established that our collaboration is highly beneficial for both parties and will continue intensively. In the near future, we plan to further develop the experimental apparatus. Specific steps for upcoming visits include completing the installation of the cryogenic ion trap, assisting with initial tests involving trapped ions, and installing the time-of-flight ion detector. Looking ahead, we plan to exchange expertise during the measurement of optical spectra of isomer-selected metal carbide ions in the gas phase. Additionally, we agreed to seek financial support for our collaboration through international grants.