University of Science and Technology of Hanoi
Bachelor of
Space Science and Satellite Technology

First report

Molecular gas in Carina Keyhole

Project by

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Contents

1 The purpose of the project

The field of research: Astrophysics.

Objective: The CO molecular clouds in the Keyhole nebula which are influenced by energetic UV radiations from a nearby star named Eta-Carina.

Reason: Strong UV radiations create a huge spherical region of ionised and dissociated molecules around the source star - Eta Carina. The Keyhole nebula (a dark nebulosity made of gas and dust) which is located in proximity to Eta-Carina should be expected to be completely ionised, however, a number of CO (Carbon Monoxide) molecular clouds inside the Keyhole were observed to have remained, therefore, caused a surprise in the physical sense.

Purpose: In this project, our team focuses on analysing spectral lines data of Hydrogen, CO molecules, Hydrogen, Carbon, Oxygen atoms, and relevant lines observed from SOFIA and APEX telescopes to detect their physical properties. Since that, the presence of CO molecular clouds in the vicinity of the strong UV-radiation source (Eta-Carina) could be interpreted.

2 Assumptions/constraints

Assumptions:

- Members can fully follow the knowledge of this project.
- Members can constantly conduct the research.
- Each member has an individual laptop for communication and work.

Constraints:

- On time: With a short time of 3 months, the progresses need to be completed on time to successfully finish the project. Members must join the meeting with the supervisor on time.
- Self-discipline and responsibility: Members must complete their work and self-study constantly. If there are difficulties that members cannot be done themselves, they could promptly notify the supervisor to meet and discuss. Otherwise, the progress of the project will be placed at a grave disadvantage.

3 Scope of management

Communication management: Establishing effective communication between members, between members and the supervisor and advisors.

Progression management: Establishing milestones for the project and guaranteeing members will finish the work on time.

Results' quality management: Checking the correctness of the results and promptly correcting if there are errors.

4 Work breakdown

To create an effective progression, the project is subdivided into 5 major sections:

1. Literature review and Basic lectures: This step is the prerequisite for following steps which help members to improve their knowledge in the topic field, enable them to understand the problem and its physical background.

2. Data Handling and Analysis: Members apply knowledge from previous lectures with experience in coding to manage and analyse the given data. And they are expected to find out the location of CO molecular clouds in Keyhole and do the necessary spectral lines analysis for the next step.

3. Constrain physical parameters: This is the most important part of the project. The results in this step will directly affect the results in the steps later. Besides analysing data, the PDR model is used for double-checking the physical parameters and calculating UV intensity which will be used to calculate photodissociation rate in the next step.

4. Photodissociation rate calculation: This step is based on the physical parameters found in the last step to determine the photodissociation rate of CO molecules in clouds. The result will reveal the time needed to completely dissociate CO molecules, then give rise to the reason for the presence of CO molecules in the proximity of the strong UV radiation source Eta-Carina.

5. Review and Report: All the results should be checked again to guarantee the results are acceptable. Internal and external discussions will be made to improve and develop additional calculations if possible. The project generally should be done at this step.

Figure 1 shows the process that is described as above.

5 Project management team/structure

For education purposes, all members of the team regularly work and understand the work together. Besides that, each member is differentiated according to their own tasks to effectively work. For this orientation, we can keep our cooperation, learn from each other, and speed up the project.

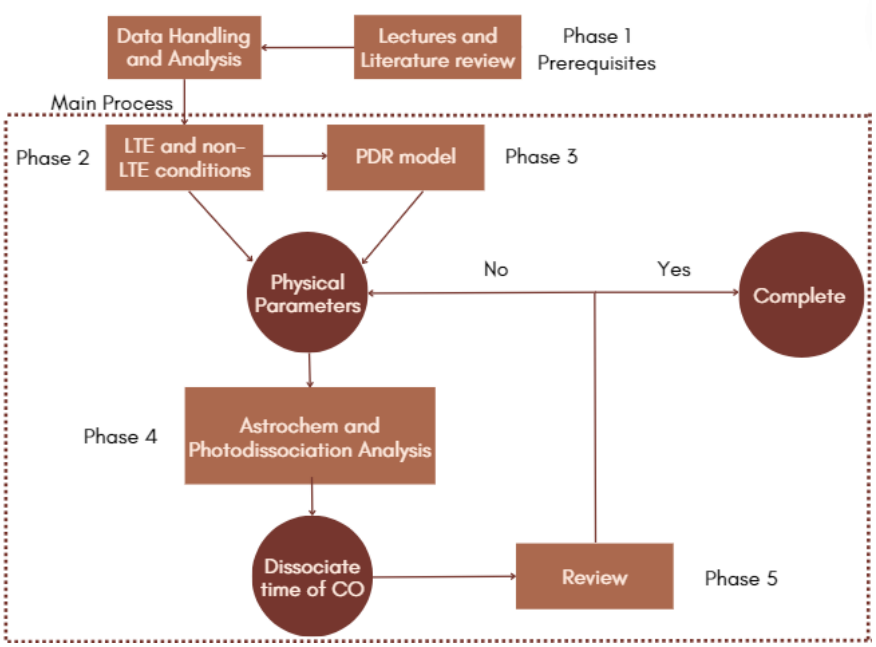

Figure 1: Project's flowchart

Team members and their specialised work:

1. Do Quoc Trong:

- Project manager: Project progress management, schedule internal meetings between members, record contents of all meetings, maintain a positive outlook for the group.
- Programmer: Study and analyse the photodissociation of CO molecules in the interstellar medium (related to astrochemistry) which play the role in the interpretation of remaining CO molecular clouds.

2. Mai Nhu Tin:

- Programmer: Study and analyse the spectral lines of molecules, atoms and ions from the given data which play the role in determining the numbers and locations of CO molecular clouds inside Keyhole. Use the PDR model (with PDR Toolbox) to constrain physical parameters of CO molecular clouds (model-driven constraints).

3. Nguyen Thi Yen Binh:

- Programmer: Study and analyse the radiative transfer effect in Local Thermal Equilibrium (LTE) and non-Local Thermal Equilibrium (non-LTE) conditions (with RADEX platform) which play the role in calculating the physical parameters of CO molecular clouds from the given data (data-driven constraints).

6 Milestones with timeframe and person in charge

The timeline and work of members are shown in figure 2.

<table>
<tr><th rowspan="2">Phase No.</th><th colspan="2" rowspan="2">Timeline</th><th rowspan="2">Task Description</th><th colspan="3">Task Management</th></tr>
<tr><th>Nguyễn Thị Yên Bình</th><th>Mai Như Tín</th><th>Đỗ Quốc Trọng</th></tr>
<tr><td>1</td><td>Week 1</td><td>24/10/2022 - 30/10/2022</td><td>Basic lectures in Spectroscopy
+ Literature Review
(by Dr. Le Ngoc Tram and Dr. Hoang Thanh Dat)</td><td colspan="3">Study the lectures and self-research the suggested topics</td></tr>
<tr><td rowspan="2">2</td><td>Week 2</td><td>31/10/2022 - 06/11/2022</td><td rowspan="2">Data Handling and Analysis</td><td colspan="3" rowspan="2">Practice on data and Analyse the spectral lines of molecules, atoms and ions</td></tr>
<tr><td>Week 3</td><td>07/11/2022 - 13/11/2022</td></tr>
<tr><td rowspan="5">3</td><td>Week 4</td><td>14/10/2022 - 20/11/2022</td><td rowspan="5">Constrain physical parameters from Data
in LTE and non-LTE conditions</td><td colspan="3" rowspan="2">Calculate physical parameters of
molecular clouds in LTE condition</td></tr>
<tr><td>Week 5</td><td>21/11/2022 - 27/11/2022</td></tr>
<tr><td>Week 6</td><td>28/11/2022 - 04/12/2022</td><td colspan="3" rowspan="2">Use RADEX to constrain
parameters in non-LTE condition</td></tr>
<tr><td>Week 7</td><td>05/12/2022 - 11/12/2022</td></tr>
<tr><td>Week 8</td><td>12/12/2022 - 18/12/2022</td><td rowspan="2">Use PDR toolbox to constrain
physical parameters</td><td rowspan="2">Use Astrochem to determine the main
reactions of CO in considered clouds</td></tr>
<tr><td rowspan="4">4</td><td>Week 9</td><td>19/12/2022 - 25/12/2022</td><td rowspan="4">Analyse Photodissociation of CO and
infer the physical interpretation of results</td><td rowspan="4">Check the values of
physical parameters</td></tr>
<tr><td>Week 10</td><td>26/12/2022 - 01/01/2023</td><td rowspan="3">Calculate Photodissociation rate of
CO molecules in considered clouds</td></tr>
<tr><td>Week 11</td><td>02/01/2023 - 08/01/2023</td></tr>
<tr><td>Week 12</td><td>09/01/2023 - 16/01/2023</td></tr>
<tr><td rowspan="2">5</td><td>Week 13</td><td>17/01/2023 - 23/01/2023</td><td rowspan="2">Results review and Complete Report</td><td colspan="3" rowspan="2">Totally check the steps, the values of results,
discuss the final result to conclude the interpretation and complete the report</td></tr>
<tr><td>Week 14</td><td>24/01/2023 - 31/01/2023</td></tr>
<tr><td colspan="7">*Note: The outlined steps will be followed as precisely as possible, if impossible, the time is subject to change to suit the actual situation</td></tr>
</table>

Figure 2: Schedule of Project

7 Cost and budget management

The main data sources are provided unconditionally by the supervisor. And additional data are available from freely published sources. For this reason, the project is underway without any costs.

8 Risk management

Lack of knowledge: The basis of this project is spectroscopy which is not taught as the main course in the USTH programme.

Lack of experience: This project is designed as real research, hence difficulties in technical problems (coding) are inevitable.

Solution: The supervisor gives brief lectures on spectroscopy during the first week of the group project.

9 Communication methods and channels internally and externally

The project is under the supervision of Dr. Le Ngoc Tram with advising of Prof. Karl Menten, Prof. Friedrich Wyrowski and Dr. Hoang Thanh Dat from Max Planck Institutes (MPI). Hence, the project has two channels of communication.

Internal channel (with supervisor): Members of the group participate in a meeting with the supervisor weekly on Zoom platform and regularly discuss on Slack platform.

External channel (with advisors): Members of the group present the results after two weeks on Zoom platform and receive advice from advisors to improve the results.