Activity Report for NAOJ Visiting Joint Research in FY(2019)

Date: June 8, 2020

Applicant (Host Researcher)	Name	Misato Fukagawa
	Affiliation/ Title	NAOJ
Research Title	Unveiling Gas Properties in Protoplanetary Disks with Dust Traps	
Work location	Mitaka campus, NAOJ	
Visiting Joint Researcher	Name	Pham Ngoc Diep
	Affiliation/ Title	Vietnam National Space Center, Vietnam Academy of Science and Technology / Researcher

1. Summary of research

The goal of this joint research is to unveil the physical properties of gaseous components in structured protoplanetary disks, such as the spatial distribution of gas-to-dust ratio, which is intimately linked to the process of grain growth in planet-forming disks. The visiting researcher, Dr. Pham Ngoc Diep, has started working on the reduction of the 13C18O(3-2) data for the disk of HD 142527 in the ALMA Science Archive after he arrived at NAOJ for this visiting program. The target disk has the inner gap in dust emission, where the early epochs of planet formation may have already finished and another (triggered) forming process can occur. At that time, the detection of 13C18O(3-2) was reported only toward one protoplanetary disk and we have confirmed that the detection of 13C18O(3-2) will immediately lead to a publication. Dr. Pham Ngoc Diep used the NAOJ MDAS for the data reduction, from the data download to the imaging using CASA. After spending a lot of time for the imaging (clean), he has confirmed the detection of 13C18O(3-2) at the level of >3 sigma only in the northern part of the outer disk at about 150 au from the central star. The continuum and C18O (3-2) images were also obtained for comparison. He made the python code to analyze the images and also has started using RADMC3D to perform radiative transfer calculations to drive the gas surface density. At the end of his stay at NAOJ, he was able to handle RADMC3D but unfortunately, he needed to change the plan and come back to Vietnam on March 21, earlier than the original plan, since flights were cancelled due to the rapid spread of COVID-19 in Japan and worldwide. We have discussed and clarified the concrete plan on how to proceed the modeling calculations after he came back to Vietnam on his final day at NAOJ.

During his stay, we had the meetings with Dr. Akimasa Kataoka (NAOJ), Dr. Takayuki Muto (Kogakuin University) and Munetake Momose (Ibaraki University) to receive advice on the modeling calculations and interpretation of the spatial distribution of 13C18O(3-2). We planned more meetings but gave up due to the COVID-19 situation. Also, he attended some science seminars at NAOJ. Finally, his visit was a good opportunity to know the status of the Vietnamese astronomical community and talk about a possible future collaboration for ALMA.

After the two-weeks quarantine period at the designated place by the Vietnam government, and after the periods when Dr. Pham Ngoc Diep needed to manage his team in Vietnam, we have started to have weekly telecons from May to resume and continue our joint research. The other frequency data for the same disk were provided by the Japanese researchers for the modeling calculations and now we are on the way to obtain the gas surface density of 13C18O(3-2).

2. Research achievements *Please fill out the attachment if you have made presentations at academic conferences or if your research has been published in academic journals

The join research has started after his arrival at NAOJ and it took long time to finalize the cleaned image of 13C18O(3–2). Therefore, there are no presentations and no publication so far. (We planned to have presentations in the conference after this summer but the targeted one was postponed to the next year due to the COVID–19 situation.) The following is the significance of the tentative research results obtained so far.
ALMA has brought us the epoch–making results with the detailed morphology of planet–forming disks, but the analysis and observations so far are biased to the dust continuum emission without deep investigation on molecular lines. On the other hand, mutual interaction between gas and dust is essential for the process of grain growth which leads to the formation of the cores of protoplanets. The necessary step forward is therefore knowing the physical property (in particular, surface density and kinematics) of disk gas, which is required to understand mechanisms to produce the observed disk structures in dust (rings/azimuthal asymmetries) including the hypothesis of vortices.
We aim to obtain the spatial distribution of gas, and hence gas–to–dust ratio, in dust traps in this joint research. HD 142527 is known to have the candidate dust trap(s) in its protoplanetary disk. The emission of 13C18O(3–2) is optically thin since the abundance is expected to be lower by a factor of 60—70 compare to C18O and can be used to probe the highest density region in the candidate vortex. Dr. Pham Ngoc Diep reliably detected the emission of 13C18O and the emission is seen only in the northern region of the outer disk where dust traps are expected. This is the second case where the emission was detected in protoplanetary disks but the emission is centrally peaked and cannot be linked to the grain growth mechanism (during the research period, another case was reported but for a much younger disk and the emission is centrally peaked, different from HD 142527). He has started the radiative transfer calculations and by combining 13CO(1—0, 3—2) and C18O (1—0, 3—2) (we have already collected those data), he will be able to probe the gas surface density in a wide range of optical depth. This is the step forward to enlarge the sample size for future gas observations and modeling using ALMA.

3. Any comments on this program【From the applicant】

We appreciate this support. I have not met this researcher before and it was quite good to start new collaboration with the researcher in Vietnam. In addition, based on this visiting research, I plan to visit Vietnam (although the plan has been postponed to next year) for the astronomy school and discussion on future possible collaboration in East Asia for astronomy. So, the effect is not limited to the science collaboration on planet formation.
It took time to sort out about VISA application but International Academic Affairs Unit was very helpful.

4. Any comments on this program【From the visiting joint researcher】

I think the length of the stay is a bit short but it is enough to get started. Otherwise, everything is nice. The computing resource is excellent, NAOJ IT staffs are very friendly and helpful. Cosmos lodge is very convenient, clean with reasonable price. I am really appreciate the program selection committee who gave me financial support to come to visit and work with the host researcher. I hope to have continued support in the future.

5. Joint research period	
Name/Affiliation	Pham Ngoc Diep / Vietnam National Space Center, Vietnam Academy of Science and Technology
Period of stay	2020/02/03 ～ 2020/03/21
Period of stay	YYYY/MM/DD ～ YYYY/MM/DD ( )days
Total	(48) days

(Notes)
・If additional space is required to complete any item within this form, please edit the size of the blank spaces as needed.
・For item 5, please include all period(s) of stay(s) of the joint researcher, adding extra lines as necessary. If you have invited more than one joint researcher, please copy and create a table for each invited person.
・If you have any concerns or difficulties with publicizing the items of this report, please identify the relevant items and the reasons for each.

(Request)
After a year following the completion of the joint research period, we will send you a request to submit a list of papers and other results that have been produced by this research collaboration. We appreciate your cooperation.