平成　　年度国立天文台滞在型共同研究報告書
Activity Report for NAOJ Visiting Joint Research in FY 2018

2018年1月25日
YYYY／MM／DD

申請者 Applicant	氏　名 Name	Fumitaka Nakamura
	所属・職 Division・position	Division of Theoretical Astronomy, Associate Professor
研究課題名 Research Title	Kinematics of Protostars and Molecular Gas in Orion A	
研究場所 Place	Mitaka	
共同研究者 氏名・所属・職名 Joint researcher's Name・Institution・Position/ Graduate Student year	Wanggi Lim USRA/SOFIA Postdoctoral Fellow (from November, 2017)	

1．研究概要 (Summary of research)

Understanding how stars form from dense molecular structures still possess a number of mysteries to resolve. In order to examine the detail star formation mechanisms, it is necessary to observe nearby star forming regions that have enough gas materials around. Orion regions are the best laboratories for this purpose since they are nearby (>500pc) molecular structures having active star formation activities. We investigate the physical properties and kinematics of Orion B region by utilizing Nobeyama legacy survey data combined with Combined Array for Research in Millimeter-wave Astronomy (CARMA) observation. The significance of this project is the kinematic comparison of young stellar objects (YSOs, from Sloan Digitan Sky Survey (SDSS) IN-SYNC data (P.I. Jonathan C. Tan)) to gas motion (from Nobeyama+CARMA ^{12}CO, ^{13}CO & C^{18}O all J=1-0 data) **at the same angular resolution which is never performed before for ORION regions**. It gives us the critical information about the association of gas and YSOs in active star forming regions as a function YSO evolution. The YSO velocity information of each pixel position is compared to the spectra of CO isotopologues. Since the IN-SYNC data provide other properties also, such as age and mass of each star, we can directly compare these to the physical properties of CO isotopes that are derived from Nobeyama+CARMA data cube, such as density, excitation temperature and velocity. These analyses allow us to understand how the kinematics of YSOs and gas depend on the various physical characteristics with the highest angular resolution toward Orion B region.

２.研究成果(Research achievements)

The examples of achievements in this project are listed and explained below
1. We have fully reduced ^{13}CO and C^{18}O Nobeyama+CARMA combined data as science ready quality via collaboration with Yale team, especially with Shuo Kong. The final Nobeyama CO data are provided by project P.I. (Fumitaka Natamura) then Shuo Kong has combined Nobeyama data with CARMA data. Since Nobeyama only CO isotoplogue data have wider velocity coverage, there are certain benefits to have Nobeyama only data also. Wanggi Lim inspected and derived the global gas properties by using Nobeyama only data at the first week of visit.
2. We checked the global trends of the physical parameters that have been suggested by previous researches (e.g. Da Rio et al. 2016) as the first round data analysis. The position and age spreads of YSOs compared to the gas density structure was performed for example. This comparison showed unexpectedly good correlation of YSO age and gas structure, i.e. younger population of YSOs obviously better associated with CO gas structures.
3. We performed detail analyses toward individual star cluster forming regions (L1631N, ONC & V380) with final Nobeyama+CARMA ^{13}CO data that can be easily applied to the C^{18}O data set. The velocity peaks of Gaussian fits toward individual pixel of ^{13}CO data has been compared to the YSO velocities that are provided by Da Rio et al. (2016). The velocity difference, i.e. v(YSO)-v(CO), becomes larger at older stellar population which indicates the association of gas to the star formation activities. The age vs. gas density did not show clear trend.
4. We developed new analysis method to inspect CO data cubes. Since there are large portion of pixel positions possessing multi-velocity components (~30%), it is necessary to develop a method to select proper peak for the analysis (density derivation, velocity confirmation, etc). We have developed multi-Gaussian fitting that are automatically applied to all data points that we investigate. This program works up to 90% of accuracy and now in process to modify to reach to 100% of accuracy to pick the proper velocity components for further analysis.

３．本制度に対する意見、要望など【申請者記載欄】
(Any comments on this program【For applicant】)

４.本制度に対する意見、要望など【本事業で来訪した共同研究者記載欄】
(Any comments on this program【For joint researcher】)

Wanggi Lim is now a 100% research postdoc at SOFIA science center located at NASA Ames research center. He has 25% of freedom to work on side projects other than SOFIA projects. Since Nobeyama+CARMA project is his main side project, there is high chance to have one submitted paper led by him in the first semester period of 2018.

５.共同研究者の滞在日程(Joint research period)

氏名・所属 （Name・Institution）	Wanggi Lim (Univ. of Florida)
滞在日程（Period of stay）	日数(days)
2017年10月15日　～　2017年11月11日 YYYY/MM/DD　～　YYYY/MM/DD	27日間(days)
年　月　日　～　年　月　日 YYYY/MM/DD　～　YYYY/MM/DD	日間(days)
合　計（Total）	27日間(days)