Form4_研究報告書
年　　月　　日
2026 / 07 / 17

東洋大学長　殿
To the President of Toyo University

ストラスブール大学招聘教員　研究報告書
Research Report by Visiting Researcher from University of Strasbourg

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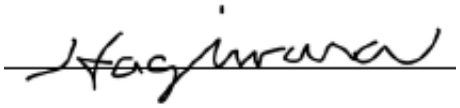
所属大学名・職名（身分） Affiliation and position	Associate Professor, Astronomer at the Astronomical Observatory, Strasbourg University
研究課題名 Research topic	Gas around the central black holes of disk galaxies
研究期間 Research period	年　　月　　日～　　年　　月　　日 From 2026/07/06 to 2026/07/17
研究協力教員氏名（所属） Research partner (affiliation)	Prof. Yoshiaki Hagiwara, Dept. of International Culture and Communication Studies, Faculty of Letters
研究成果発表 （予定も含む） Publication/Presentation (including future ones)	Lecture on Astronomy and Open Science at the French-German border (2026/07/07) Seminar at NAOJ on the Strasbourg astronomical Data Center (2026/07/09) Seminar at NAOJ on the gas physics in the inner 30pc of the Circinus galaxy (2026/07/09) Future article on the gas properties of a gas cloud hit by the radio jet in NGC1068 (Hagiwara, Vollmer et al.) Future ALMA proposal (Hagiwara, Imanishi, Vollmer)
研究成果の概要 Summary of your research achievements	This research focuses on the distribution and dynamics of gas within the inner part of Active Galactic Nuclei (AGN). Utilizing high-resolution observational data, we analyzed the physical properties and kinematics of the gas residing in the vicinity of the central supermassive black hole (SMBH). The study primarily examines the complex interplay between the intense central radiation field and dynamical structures surrounding central SMBH with a specific emphasis on the mechanisms driving gas outflows and inflows. I developed a three-dimensional model of a warped thin disk in the inner parsecs of local spiral galaxies, NGC 1068 and Circinus Galaxy. The new ingredient in this model is an inner compact thick obscuring gas structure, which was inferred from X-ray polarimetric observations. The obtained geometrical model can explain the observed maser distributions in the both galaxies in a satisfactory way. Our analysis revealed distinct velocity structures and ionization states that challenge existing simplified models of the obscuring torus and mastering disks. These outcomes provide crucial observational constraints for refining theoretical models of AGN feedback and its role in host galaxy evolution.

サイン(年月日) Signature (Date)	ストラスブール大学招聘教員　Visiting Researcher　Bernd Vollmer  （2026/7/17） 研究協力教員　Research Partner　Yoshiaki Hagiwara （2026/7/17） 

Research Report : Gas around the central black holes of disk galaxies

Bernd Vollmer

The details of how gas accretes on the central black hole of a galaxy are still unknown. If the accretion rate on the black hole is high enough, the gas heats up before disappearing behind the event-horizon. The central region of the galaxies then can become so bright that it outshines the whole galaxy. In this case the center of the galaxy is called an active nucleus (AGN: Active Galactic Nucleus). In order to accrete onto the central black hole, the gas has to lose angular momentum. The angular momentum transport within the galactic disk can be characterized by the so-called turbulent viscosity. On the way to the center, the gas can become so dense and hot that it forms a maser: the radio emission of water is strongly amplified. Prof. Hagiwara is an expert on observations of water maser. I am an expert on the theory of gas physics. During my stay, we joined our expertise to make progress in the understanding of AGN physics.

During my stay we had three research topics: understanding the gas physics of a gas cloud, which is compressed by a radio jet in NGC1068, understanding the spatial distribution of disk masers in NGC1068 and the Circinus galaxy, and identifying promising targets for ALMA observations of gas in the inner 30pc of local spiral galaxies.

In the NGC1068, which harbors an AGN, a gas cloud at a distance of 10pc from the center is compressed by the radio jet, which is launched close to the central black hole. This cloud is detected by the ALMA telescope in four HCN and HCO+ lines and in the radio continuum. In addition, about 10 water masers are associated to the cloud. It is believed that there is a shock front where the radio jet hits the gas cloud. Within the shock front the gas density and temperature are so high, that they meet the conditions for maser emission.
To understand the gas properties of the cloud compressed by a radio jet, Prof. Hagiwara provided HCN and HCO+ line ratios from his ALMA observations. I did model calculations to derive the gas density, temperature, and cosmic ray ionization rate of this cloud. The model uses a detailed gas chemistry for the determination of the molecular abundances. In this way important information on the cloud could be obtained. We plan to determine the density ratio of the shock to see if such a shock can lead to maser emission.

Water maser can generally be found in the inner pc of an AGN if the thin disk is seen edge-on. The distribution of these masers is asymmetric in NGC1068 and Circinus. The reasons for this asymmetry are not well understood. During my stay I developed a three-dimensional model of a warped thin disk in the inner pc of NGC1068 and Circinus. The new ingredient in this model is an inner compact thick obscuring gas structure, which was inferred from X-ray polarimetric observations. The gas in the warped disk can only mase if the sight-line to the central source is free of obscuring gas. This geometrical model can explain the observed maser distributions in both galaxies in a satisfactory way.

There are not many AGN, which are observed in molecular lines at a pc resolution. The 1 -5 pc-scale is interesting because the inner thin maser disk joins the outer gas disk, which can be geometrically thin (Circinus) or thick (NGC1068). We know very little about the connection between the two disks.
Together with Prof. Imanishi from NAOJ we agreed on a sample of promising targets for future ALMA observations, which will be submitted by us in April 2027. The aim is to better understand gas accretion from the 10-30pc scale until the central black hole.

I would like to thank Prof. Hagiwara and the staff at Toyo University for their friendliness and their support. I had a very nice and productive stay at Toyo University.