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研究課題名（和文）Demographics and physics of active supermassive black holes

研究課題名（英文）Demographics and physics of active supermassive black holes

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研究成果の概要（和文）：私の研究目的は、活動銀河中心核(AGN)の現象、母銀河との関係をより正しく理解することである。近赤外線分光データを用いて、COSMOS領域にある、非常に多くのAGNのブラックホール質量と降着率を正確に求め、質量が活動的なブラックホールの宇宙論的進化を決めている主要なパラメーターであることを示した。近い将来、その結果をコミュニティーに公開する計画である。また、なぜ、ごく一部のAGNは強い相対論的ジェットを示すのに、大多数のAGNは示さないのかという、電波で明るいAGNの起源が、昔から理論的に言われていたように、ブラックホールのスピン、つまり回転速度によるという観測的証拠を示すことができた。

研究成果の概要（英文）：My goals are to improve our understanding of the phenomenon of active supermassive black holes (AGN) and the relation to their host galaxies. For the latter, I obtained a precise census of active black holes in respect to their most fundamental properties, their black hole masses and to the rate at which they accrete matter. We showed that for active black holes their mass is the main parameter to control their evolution with cosmic time. I have estimated black hole masses and accretion rates for a large sample of moderate luminosity AGN in the COSMOS field from near-IR spectroscopy and will soon provide our results to the community.
I provided new observational results on the origin of radio-loudness of AGN, i.e. why have some AGN strong relativistic jets, while the majority do not? Based on a large statistical sample we found observational evidence that the spin of the black hole, i.e. the speed of its rotation, is an essential factor, as long suggested by theoretical models.

研究分野：Astrophysics

キーワード：supermassive black holes　AGN　AGN evolution

１．研究開始当初の背景

One of the fundamental open questions in extragalactic astronomy is how galaxies and their central supermassive black holes (SMBHs) coevolve. Observations are implying a link between star formation and black hole accretion for the average populations. The details of this co-evolution are however poorly understood. A census of the black hole population throughout cosmic time is an essential requirement to constrain and understand this relation.

The fundamental properties of active supermassive black holes are their mass, the accretion rate onto the black hole and the black hole spin. Thus ideally the above black hole census should be in respect to these fundamental quantities.

２．研究の目的

The goal of the project is to study the statistics and physics of the active supermassive black hole population and improve our understanding on black hole growth, galaxy evolution and their interrelation. The two fundamental questions to address are how do Active Galactic Nuclei work, and how do their supermassive black holes grow through cosmic time.

３．研究の方法(Method)

The fundamental demographic quantity of the AGN population is the joint distribution function of black hole mass and accretion rate. The determination of these requires large, well-defined statistical data sets of AGN and an estimate of their black hole masses. The latter restricts this approach to unobscured AGN for which this can be estimated from their optical/near-IR spectra.

Within the period of the research grant I have studied the active SMBH mass and accretion rate function and its evolution out to z~2, utilizing unobscured AGN samples in the COSMOS, VVDS and SDSS.

The next step in our understanding of these distribution functions is to investigate their evolution to even higher redshifts, beyond the peak of AGN and star formation activity. Therefore, I have started a project to determine the active black hole mass and accretion rate function at redshift z~4 combining samples from SDSS and COSMOS.

A complimentary approach is to use the stellar masses of the host galaxies of obscured AGN as a rough surrogate for black hole mass and study the stellar mass function and the accretion rate distribution function of AGN and their host galaxies. A further strength is that black hole growth is directly investigated in respect to their host galaxy population. I made a major contribution to the paper by Bongiorno+16, where we determined these two distribution functions jointly for the first time.

Our group (led by John Silverman at Kavli IPMU) had obtained near-IR spectroscopic data for more than hundred moderate luminosity AGN in the COSMOS field with FMOS/Subaru. The initial data set used the FMOS low resolution (LR) mode, while the latter survey employed the high resolution (HR) mode. I analyzed these near-IR spectroscopic data, modeled the Halpha and Hbeta emission line regions, investigated the broad and narrow emission line properties and compiled a black hole mass catalog for the full LR sample and part of the HR sample. The FMOS-HR survey just recently finished in 2016 and the reduced data for the full data set became recently available to me. Our goal is to use the full dataset to compile an extensive catalog of near-IR spectra of AGN and their black hole masses, accretion rates, line properties, which will be a valuable resource for the community, studying AGN and/or the COSMOS field. We are now finalizing the analysis of the full HR data and will publish our results and catalog soon after.

Finally, I have obtained data at the Atacama Large Millimeter/submillimeter Array (ALMA) to study the fueling mechanism of supermassive black holes. This project will answer a fundamental open question on the growth of black holes. I carried out a preliminary analysis of the data. A more detailed analysis is currently ongoing.

４．研究成果(Results)

My work on the distribution functions of black hole mass and mass accretion rate established the following results:

I established these distribution functions at $1<z<2$ down to the typical mass and accretion rate regime, and revealed SMBH mass as the main driver of the well known AGN downsizing trend, seen the AGN luminosity function.

I have obtained first promising results on the mass function at redshift 4. A more refined analysis and discussion is currently ongoing.
I have furthermore contributed to work within the HSC-SPP survey and in SDSS to identify new populations of AGN at high redshift and/or derive an improved understanding of the AGN luminosity function.
The study by Bongiorno+16 revealed evolution in the accretion rate distribution function, which shows a clear downsizing behavior. Our work furthermore provided evidence for AGN feedback as a plausible process for the quenching of star formation in massive galaxies.
I also made a contribution to the recent paper by Georgakakis et al. (2017). Here we used a larger sample and a different methodology to focus in particular on the distribution of (specific) accretion rates.

One of the most fundamental unsolved questions on understanding AGN physics is the origin of radio-loudness of quasars and AGN, i.e. why do some AGN have strong relativistic radio jets, while the majority does not have these? Based on a statistical analysis of a large sample from the Sloan Digital Sky Survey (SDSS) we have found evidence that radio-loud quasars have as a population on average a higher black hole spin than radio-quiet quasars. This provides observational support for the (observationally yet unproven) theoretical idea that high black hole spin is an essential factor to generate relativistic jets. The black hole spin is one of the fundamental parameters of SMBHs (together with SMBH mass and accretion rate) and thus our results help understanding the AGN phenomena better in respect to its few fundamental parameters. The paper presenting these results has recently been submitted.

Unfortunately, I was not able to work directly on data from the HETDEX survey as originally intended, due to the significant delay in the progress of the survey mainly caused by technical problems in the telescope upgrade. However, I developed and tested an AGN classification pipeline for the large spectroscopic data set to be provided by HETDEX and successfully applied it to current commissioning data. This pipeline will be essential to identify AGN within the HETDEX data once the survey is fully running and will enable various HETDEX AGN science cases.
Furthermore, I initiated an observing campaign with HSC/Subaru of the HETDEX main field to provide the essential deep imaging data over the large HETDEX field. In this context, I established a new collaboration between the HETDEX team and the Japanese community, with Masami Ouchi (ICRR, UTokyo) and his group, how joined the HETDEX project. We have obtained excellent HSC data over ~1/3 of the field and aim to obtain HSC data for the full field in the near future.

５．主な発表論文等
（研究代表者、研究分担者及び連携研究者には下線）

〔雑誌論文〕（計　14 件）

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Conference "Crossing the Rubicon: The fate of gas flows in galaxies”; 5.-9. September 2016, Santarcangelo di Romagna, Italy;
Andreas Schulze, Talk: “Insight into the fuelling and feedback of AGN through their mass functions and accretion rate distribution functions”

Conference "Active Galactic Nuclei: what's in a name?"; 27.June-1.July 2016, ESO, Garching, Bavaria, Germany;
Andreas Schulze, Poster: “Evolution of the stellar mass function and specific accretion rate distribution function of X-ray AGN in COSMOS”

Workshop "Demographics and environment of AGN from multi-wavelength surveys"; 21.-24. September 2015, Chania, Crete, Greece;
Andreas Schulze, Talk: “The evolution of the mass functions of active SMBHs and their host galaxies out to z~2”

Guilermo Haro Workshop "Forming and fueling supermassive black hole seeds”; 6.-24. July 2015, INAOE, Puebla, Mexico;
Andreas Schulze, Talk: “The cosmic growth of the active black hole population”

Conference “Unveiling the AGN-galaxy evolution connection”; 9.-13. March 2015, Puerto Varas, Chile;
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Andreas Schulze, Poster: “The cosmic growth of the active black hole population”

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Andreas Schulze, Talk: “HETDEX: AGN-galaxy clustering at 2<z<3.5”

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Andreas Schulze, Talk: “The cosmic growth of the active black hole population”

〔図書〕(計 0 件)
No Applicable

〔その他〕
ホームページ等
None

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