“Demographics of Supermassive Black Holes across the Universe”
Invited talk
11/19/2019, 13:30 - 14:00

Jenny Greene
(Princeton)

Title: **Mergers, Black Hole Binaries, and PFS**

Abstract: I will discuss our ongoing quest to understand the role of mergers in the evolution of supermassive black holes, from triggering to black hole pairing, to gravitational wave detection. I will end with exciting prospects for the upcoming PFS survey.
“Demographics of Supermassive Black Holes across the Universe”
Contribution talk
11/19/2019, 14:00 - 14:20

Maria Charisi
(Caltech)

Title: **Searching for sub-parsec supermassive black hole binaries**

Abstract: Supermassive black hole binaries (SMBHBs) should form frequently, as a result of galaxy mergers. However, they remain elusive, especially at small sub-parsec separations. A promising method to identify SMBHBs is to search for quasars with periodic variability. I will describe the emerging population of candidates from systematic searches in time-domain surveys, as well as multi-wavelength studies to uncover additional evidence for the binary nature of the candidates (e.g., relativistic Doppler boost). I will also discuss the prospects of multi-messenger inference with Pulsar Timing Arrays.
Title: A potential high-z dwarf galaxy discovered by ALMA and SUBARU/IRCS

Abstract: We report the discovery of a potential dwarf galaxy in our ALMA follow-up observations of a luminous quasar at $z=3$. The galaxy has been detected through its CO emission in ALMA band 3. The galaxy appears to be very compact and shows a rotating CO disk. The dynamical mass estimate of $10^9 \, \text{Msun}$ will put this galaxy into the dwarf regime. We have also identified a compact counterpart in our IRCS AO supported K-band imaging. Through further follow-up observations in optical bands we also confirmed that the galaxy is indeed very faint with $i$-band mag=23.5. We will discuss several possible scenarios including the possibility for this galaxy to host an AGN located at the same redshift as our main quasar at $z=3$ by constraining the redshift of the source through the detected CO line and SED modeling. This dwarf galaxy could be one of the lowest mass galaxies observed with ALMA at high-z hosting an AGN.
Title: One step toward understanding cosmic re-ionization: absorption tests with a new QSO we discovered at z=6.6

Abstract: Investigating the Gunn-Peterson trough of high redshift quasars (QSOs) is a powerful way to reveal the cosmic reionization. As one of such attempts, we perform a series of absorption tests with one of the highest redshift QSOs, PSO J006.1240+39.2219 at \( z = 6.62 \) we previously discovered. Using the Subaru telescope, we obtained medium-resolution spectra with a total exposure time of 7.5 hours. We calculate the Ly\( \alpha \) transmission in different redshift bins to determine the near zone radius and the optical depth (\( \tau \)). We find a sudden change in the Ly\( \alpha \) transmission at \( 5.71 < z < 5.86 \), which indicates the end of the reionization. However, at \( z > 6 \), we have detected flux. Thus, \( \tau \) is lower than previously measured. Due to the improved depths and resolution of the spectra, we possibly detect faint flux previous work missed. The near zone radius of the QSO is \( 5.79 \pm 0.09 \) pMpc, which is consistent with the decreasing near zone size at higher redshift. We also analyze the dark gap distributions to probe the neutral hydrogen fractions beyond the saturation limit of the Gunn-Peterson trough. We find the median of the dark gap width becomes larger with increasing redshift. In contrast to these three analyses, we perform a model free analysis by counting dark pixels, to find the upper limit of \( x_i < 0.6 \) (0.8) at \( z < 6 \) (\( z > 6 \)). All four analyses based on this QSO show increasingly neutral hydrogen towards higher redshifts, adding precious measurements at \( z > 6.5 \). Using the deep near-infrared (NIR) spectrum we obtained with Gemini/GNIRS, we explore the early growth of supermassive black holes (SMBHs). This NIR (rest-frame UV) spectrum shows blue continuum slope and rich metal emission lines in addition to Ly\( \alpha \) line. We utilize the [MgII] line width and the rest frame luminosity \( L_{3000} \) to find the MBH to be \( 10^8 \)Msun, making this one of the lowest mass QSOs at \( z > 6 \). The power-law slope of the continuum emission is \( 2.94 \pm 0.03 \), significantly bluer than the slope of \(-7/3\) predicted from standard thin disc models. We fit the spectral energy distribution (SED) using a model which can fit local SMBH, which includes warm and hot comptonisation
powered by the accretion flow as well as an outer standard disc. The result shows that
the very blue slope is probably produced by a small radial (230Rg) extent of the standard
accretion disc. All the SED fits require that the source is super-Eddington (Lbol/LEdd>9),
so the apparently small disc may simply be the inner funnel of a puffed up flow, but clearly
the SMBH in this QSO is in a rapid growth phase.
Abstract: Over the last two decades there has been a huge amount of observational and theoretical work that aims to establish the connection between the growth of supermassive black holes (i.e., Active Galactic Nuclei; AGN) and the growth of their host galaxies. This is largely driven by the fact that cosmological models cannot reproduce realistic galaxy populations unless the energy released by AGN regulates star formation in the host galaxies. I will summarise our campaigns to constrain the role of AGN in galaxy evolution. Firstly, I will present our systematic multi-wavelength observational survey (e.g., using ALMA, MUSE, VLA, eMERLIN, Chandra...) of z~0.1 quasars which is: (1) providing high spatial resolution measurements of galactic outflows; (2) establishing the role of radio jets in driving these outflows and; (3) determining what impact these processes have on the host galaxy's star-formation and gas supply. Secondly, I will present a statistical assessment of the impact of AGN on star formation in the population as a whole over cosmic time using a combination of observations (e.g., ALMA) and predictions from cosmological simulations.
Title: Properties of Narrow Absorption Line Systems in AGN Outflow

Abstract: AGN outflows, one of the most important key ingredients for the formation/evolution of quasars and their host galaxies, are usually studied through quasar absorption lines. They are classified by their line widths into broad absorption lines (BALs; > 2,000 km/s) and narrow absorption lines (NALs). In addition to BALs, a substantial fraction of NALs are also thought to be intrinsic to the quasars (i.e., intrinsic NALs) rather than intervening objects like foreground galaxies and the IGM. The study of intrinsic NALs complements that of BALs because the corresponding absorbers reside in different regions of the outflow.

For more than 10 years, we have been monitoring intrinsic NALs in spectra of optically bright quasars taken with Subaru/HDS, Keck/HIRES, and VLT/UVES, and discovered several important properties: a) there is no discernible changes in strength/profile of intrinsic NALs, while BALs are frequently variable, b) there is no velocity shift despite the fact that acceleration often assumes to be a key physical property of the outflow, and c) there exists an internal structure/fluctuation in intrinsic NAL absorbers with a scale of $<10^{-3}$ pc. We discuss a possible geometry of the outflowing wind based on these results.
Abstract: It is now widely recognized that the ISM property in star-forming galaxies depends significantly on the redshift; the ISM in higher-z galaxies is characterized by a lower-metallicity and higher-ionization than lower-z galaxies. However it is not well understood how the ISM property in AGNs depends on the redshift. In this contribution, we report our studies on the narrow-line region (NLR) in some AGNs at z>3 through spectroscopic observations using Subaru and VLT. The detailed comparison between the spectroscopic data and photoionization models revealed that the high-z NLR is characterized by moderately high metallicity and very high gas density.
Title: **Uncovering highly obscured SMBH growth**

Abstract: Despite extensive observational efforts, a significant fraction of Active Galactic Nuclei (AGN) activity in highly obscured environments still evades our census. Mid-IR surveys with the Wide-field Infrared Survey Explorer could uncover, at least in part, the elusive highly obscured SMBH growth in the most extreme luminous AGN. Although several studies have already presented results from follow-up campaigns of WISE-based AGN samples, they typically lack the X-ray depth necessary to reveal the true nature of many of the IR-selected AGN candidates.

I will present the results of a detailed analysis of the properties of a complete, mid-IR flux-limited sample, of ~100 luminous AGN candidates selected with WISE. To date 95 per cent of the objects have spectroscopic redshifts and optical classifications. Moreover, the full 6 deg² survey area has very deep X-ray coverage from XMM-Newton observations, allowing us to directly measure the accretion luminosity and nuclear absorption in the 76 per cent of the sample with X-ray detections and to put robust constrains on the nuclear absorption in the 24 per cent of the sources that have escaped X-ray detection. Thus, this unique dataset will allow us to robustly evaluate how AGN selection at mid-IR wavelengths can help us to complete our census of highly obscured AGN activity.
Title: Luminous buried AGNs in merging ultraluminous infrared galaxies revealed with Subaru and ALMA

Abstract: We present our Subaru infrared and ALMA (sub)millimeter observations of nearby merging ultraluminous infrared galaxies (ULIRGs) to investigate luminous buried AGNs, by distinguishing from starbursts. Scrutinizing such luminous AGNs deeply buried in dust and dense molecular gas in merging ULIRGs is of particular importance to understand how supermassive black holes (SMBH) grow in mass during gas-rich galaxy mergers in our universe. Observations at the wavelengths of low dust extinction are crucial. We observed >100 nearby ULIRGs in the infrared (spectroscopy and imaging) and discovered optically elusive, deeply buried luminous AGNs in roughly half of observed ULIRGs with no optical AGN signatures, suggesting that such luminous buried AGNs are common in ULIRGs, as predicted by theories. We also found that SMBHs in the progenitors of more massive galaxies are more actively mass-accreting, supporting theoretical models that AGN feedback is stronger in such galaxies (Imanishi+10 ApJ 721 1233; Imanishi & Saito 14 ApJ 780 106; Imanishi+19 in prep). Our recent ALMA (sub)millimeter spectroscopy has started to detect optically- and even infrared-elusive extremely deeply buried luminous AGNs, thanks to almost negligible dust extinction (Imanishi+18 ApJ 856 143; Imanishi+19 ApJS 241 19).
Title: Multi-wavelength view of dust-obscured galaxies

Abstract: We review the physical and statistical properties of infrared (IR)-bright dust-obscured galaxies (DOGs) with $i - [22] > 7.0$ in AB magnitude and with flux density at $22\mu m > 1.0$ mJy. IR-bright DOGs are a subset of high-redshift ($z \sim 1-3$) optically-faint luminous IR galaxies (such as ULIRGs and HyLIRGs). A hydrodynamic simulation has indicated that black holes in IR-bright DOGs are expected to show the highest accretion rate during a major merger event, suggesting that IR-bright DOGs are expected to harbor the black holes in the growing phase. Therefore, IR-bright DOGs may constitute a key population for understanding the co-evolution of galaxies and supermassive black holes. However, these IR-bright DOGs are spatially rare, so wide-area surveys with optical and IR are strongly required to detect these bright but spatially rare populations. So far, we have performed a systematic search for IR-bright DOGs and investigated their statistical and physical properties based on multi-wavelength data, such as SDSS, Subaru/HSC, WISE, AKARI, ALMA, and NuSTAR. In this presentation, we particularly focus on the following properties of IR-bright DOGs: (i) luminosity function and luminosity density, (ii) clustering properties, (iii) ionized and molecular gas properties, (iv) host properties.
Title: Discovery of blue-excess dust-obscured galaxies viewed with Subaru Hyper Suprime-Cam

Abstract: In this presentation, we report our discovery of "blue-excess" dust-obscured galaxies (BluDOGs) viewed with Subaru Hyper Suprime-Cam. Dust-obscured galaxies (DOGs) are faint in the i-band (optical) but very bright 22 micron band (mid-infrared: mid-IR), which are thought to be powered by active star-formation or AGN, or both. DOGs are believed to be a candidate population that are evolving into quasars from gas-rich major merger.

In this work, we found 8 DOGs with optically blue excess (BluDOGs; Noboriguchi et al. 2019) in our 571 DOGs discovered by combining three multi wavelength catalogues of optical (Subaru HSC), near-IR (VIKING), and mid-IR (ALLWISE). The BluDOGs shows that those optical color is very blue as the optical color of quasars, while those color between the optical band and mid-IR band is very red. We suggest that the BluDOGs are in transient phase between DOGs and quasars. By assuming the lifetime of DOGs is about 100 Myr, we can estimate the lifetime of BluDOGs to be a few Myr. If the blue-excess comes from the leaked AGN light, the lifetime of BluDOGs corresponds to the timescale of the blowing-out event.
Title: Obscured SMBH assembly using multi-wavelength and wide-field surveys

Abstract: Most of the accretion onto SMBHs is highly obscured and the number density of such obscured AGN is quite smaller than galaxies. Therefore, multi-wavelength and wide-field surveys are crucial to assemble such obscured AGN. In my talk I will review our two ongoing projects covering multi-wavelength view. One is BASS survey: multi-wavelength study of a large sample of local (z~0.05) AGN selected in the hard X-ray band (14-195 KeV), where obscuration does not play a strong role. The other is WERGS project: optically-faint radio galaxies revealed by the cross-matching of shallow but wide VLA/FIRST and deep and wide Subaru/HSC SSP survey down to g~26, opening the new parameter space of extremely radio-loud AGN with radio-loudness parameter of R= f(1.4GHz)/f_g > 10^4.
Title: Wide and Deep Exploration of Radio Galaxies with Subaru HSC (WERGS)

Abstract: We present the initial results of our on-going project, “Wide and Deep Exploration of Radio Galaxies (RGs) with Subaru HSC (WERGS)”, which is aimed at studying high-z RGs using the Subaru HSC-SSP catalog and archive radio catalogs. RGs represent a key population for understanding the evolution and formation of massive galaxies, because radio-mode AGN feedback can regulate star formation in galaxies. We identified ~3600 HSC counterparts of VLA FIRST radio sources in a 156 square degree field (Yamashita et al. 2018). RGs at photo-z > 1 are found in an optically faint regime (i > 21). The multiwavelength SED fitting analysis shows these optically faint and high-z RGs have higher SFR and AGN luminosity than optically bright and low-z ones (Toba et al. 2019). These results suggest a different picture of RGs from our perception in the local Universe. For RGs at higher-z, we are searching for them using the Lyman break technique. In a pilot study, we found a z=4.7 RG, which has a massive stellar mass (logM*/Msun = 11.4) and non-ultra-steep radio spectral index. This discovery demonstrates the power of HSC-SSP to explore high-z RGs.
Title: The radio-loud fraction and the mean radio-loudness of high-z low-luminosity HSC quasars

Abstract: To constrain the radio-loud fraction and the mean radio-loudness of accreting SMBHs in the early universe, we conduct new radio observations of 22 low-luminosity (rest-frame ultraviolet luminosity $M_{1450} > -25$ mag) quasars at $z\sim6$ with the Karl G. Jansky Very Large Array (JVLA) at 1.4 GHz. Our quasar sample is discovered with Subaru/HSC, lying at the faint-end of quasar luminosity function at $z\sim6$. The sensitivity of our observations (1 sigma~10$^5$ uJy) is about 3-10 times deeper than that of the VLA-FIRST survey. The radio luminosity (rest-frame 5 GHz) of 22 quasars are all lower than $10^{25.5}$ W/Hz and we constrain the radio-loudness of 20 quasars to $R = \frac{f_{5\text{GHz}}}{f_{4400}} < 100$. The median stacking image (1 sigma~5 uJy) constrains the mean radio-loudness of our sample to $R < 11$, which is inconsistent with the redshift-evolution trend suggested by lower-redshift studies of quasars. This implies that the radio-loud fraction of low-luminosity quasars appears to be lower than that of luminous ones, which is consistent with previous studies, but the mean radio-loudness does not follow the evolution trend at lower redshifts.
Title: **Demographics of X-ray and Mid-Infrared Selected AGN from the Wide-Area Stripe 82X Survey**

Abstract: Stripe 82X is a wide-area (31 deg^2) X-ray survey designed to uncover obscured high luminosity AGN missed from our optical census of black hole growth. A special SDSS-IV eBOSS program observed 37 deg^2 of Stripe 82, ~15.5 deg^2 of which covered the largest contiguous portion of Stripe 82X, to spectroscopically target X-ray selected and WISE W1-W2 selected AGN. The combined X-ray and WISE AGN sample is 82% spectroscopically complete to $r\sim22$, with a median redshift of $z\sim1$. We find that 20% of the X-ray AGN are optically obscured (i.e., lack broad lines in their optical spectra) and 30% of the WISE AGN are obscured. A proper census of the obscured AGN population at high luminosities require population synthesis modeling that accounts for the X-ray and mid-infrared selection functions and survey flux limits, so these observed fractions represent a lower limit of obscured black hole growth in this parameter space. We find that 50% of the WISE AGN at $z < 0.5$ have emission line ratios consistent with star-formation rather than AGN photoionization: whether they are heavily buried AGN or star-forming galaxy contaminants is currently unclear. We also find that X-ray AGN not detected by WISE tend to be at high X-ray luminosity, challenging the conventional wisdom that mid-infrared selection recovers all luminous AGN. Conversely, we do not find that the WISE AGN undetected by X-rays have redder W1-W2 colors, indicating that they are not preferentially more obscured than the X-ray and WISE selected AGN.
**Title:** The most obscured phase of accreting black holes at high redshift: First accreting black hole candidates

Abstract: The existence of SMBHs at z>7 challenges models of the formation and growth of SMBHs, suggesting that black holes undergo very efficient and rapid accretion of gas within the first billion years after the Big Bang. The direct collapse of primordial gas clouds would be among the most interesting scenarios to form such massive black holes at high redshift, but there is no confirmed detection of early SMBH progenitors so far. We present the newly discovered X-ray sources without any optical/NIR counterparts in the COSMOS field, which have been undetected in any Subaru/HSC grizy, UltraVISTA Y,J, and/or H, Ks bands. Our sources are detected only in the X-ray and the infrared bands (Spitzer/MIPS 24um), consistent with the predicted SED model of direct collapse black hole. This is possibly the first population of accreting black holes, or heavily obscured AGNs at high redshift. Our study will be an important preparation for the future JWST, WFIRST science.
Masafusa Onoue
(MPIA)

Title: Probing the early SMBH evolution at the frontiers: deep NIR observations of $z=6-7$ quasars

Abstract: Luminous quasars during the reionization epoch have been identified since the 2000’s, showing that the central SMBHs accrete at near Eddington limit. The rest-frame UV spectra of those highest-redshift quasars are reminiscent of those of low-redshift quasars, which implicates slow or perhaps no redshift evolution of broad-line region metallicity up to $z=7$. Recently, there have been a lot of efforts to explore the observational frontiers of early SMBH studies, which either probe down the quasar luminosity function or focus on $z>7$ quasars. In this talk, I will present results from deep near-infrared observations of $z=6-7$ quasars aiming at one of the two directions above. More specifically, I will show the Eddington ratio distribution for $z=6$ low-luminosity quasars, as well as the BH mass and metallicity measurements of the most distant quasar known at $z=7.5$. I will also discuss the expectations toward the next generation telescopes/instruments such as JWST, Euclid and TMT.
Title: A search for high-z red quasars with the Subaru HSC and WISE data

Abstract: Red quasars are thought be in the phase of transition from hidden accretion (obscured BH growing phase) to unobscured radiation (traditional quasar), i.e. “blowout” phase. As such, this population is an useful probe to understand the formation and evolution of quasars and their host galaxies. Recently, more than 80 new high-z (z > 5.7) quasars have been discovered by the Subaru High-z Exploration of Low-Luminosity Quasars (SHELLQs) project, based on the Subaru Hyper Suprime-Cam (HSC) SSP survey. We are using this sample to reveal whether red quasars prevail in the early universe. The candidates of red quasars were selected with a combination of the HSC and WISE data, which yielded four candidates with WISE detection so far. We constructed broadband SED of each candidate and derived the color excess $E(B - V)$. We will present the preliminary results from this analysis, including identification of two promising candidates.
Title: **Fundamental Physical Properties of Quasar Host Galaxies**

Abstract: The basic properties of the host galaxies of quasars are extraordinarily difficult to measure because of the adverse influence of the bright nucleus and their generally large distances. Yet, it is imperative that we measure them as accurately as possible in order to understand the lifecycle of supermassive black holes and their impact on galaxy evolution. I describe recent efforts to measure some fundamental parameters of quasar host galaxies, including their morphology, environment, stellar mass, star formation rate, gas content, and dynamical mass.
Title: **Subaru Hyper Suprime-Cam View of Quasar Host Galaxies at z < 1**

Abstract: It is well known that there is a tight correlation between the mass of supermassive black holes and mass of their host bulges, suggesting that they coevolve. As a driver of the coevolution, AGN feedback is proposed, which suppresses star formation activity in their host galaxies. However, the actual impacts of AGNs on their host galaxies is still unclear. To understand this, it is important to investigate the properties of AGN host galaxies accurately.

In this study, we used Hyper Suprime-Cam Subaru Strategic Program survey images. We investigated the host properties of 859 quasars at z < 1, extracted from the SDSS DR7 quasar catalog. We fitted the observed radial profiles with a combination of the PSF and the Sersic model to decompose into quasar nuclei and host galaxies. By comparing the properties of the quasar hosts and non-AGN galaxies, we found that quasar host galaxies are mostly located on the green valley. This trend is consistent with a scenario in which star formation of the host galaxies is suppressed by AGN feedback, and galaxies migrate from the blue cloud to the red sequence.
Title: Stacking analysis of quasar host galaxies at z > 1 with Subaru HSC

Abstract: When and how AGN activity is ignited is still unclear. In this respect, it is crucial to reveal which types of galaxies make supermassive black holes more active, by investigating quasar host colors. In particular, observations of quasar host galaxies located at z > 1 are crucial to understand the relation between AGN activity and the host galaxies in the first half of the history of the universe. However, it is difficult to observe quasar host galaxies at z > 1 individually, because of the high brightness of quasar nuclei.

In this study, by analysing the Hyper Suprime-Cam Subaru Strategic Program imaging data, we investigated the property of 3,527 quasar host galaxies at z > 1 selected from the SDSS quasar catalog. We subtracted AGN component based on PSF profile from the HSC imaging data, and stacked residual host galaxy component in several redshift bins, in order to get the mean flux of host galaxy component in the five HSC bands (g, r, i, z, y). We carried out aperture photometry on the stacked images and the SED fitting with CIGALE, which allowed us to investigate the color of host galaxies. We will report the latest results.
Title: The growth of supermassive black holes and their host galaxies from HST to HSC

Abstract: The evolution (or not) of the ratio between the mass of supermassive black holes and that of their host galaxies is an important observable to establish, particularly since strong AGN feedback mechanisms are invoked in hydrodynamic simulations and semi-empirical models of galaxy formation. We will report on our new measurements of this ratio at $z \sim 1.5$ using HST and FMOS-COSMOS for black hole mass estimates. To bridge the redshift divide with local values, the Subaru HSC Strategic Survey Program is proving exquisite optical imaging over 1k deg$^2$ to measure this ratio at $z < 1$ for a large sample of known SDSS quasars. To further interpret our results, we compare the observations to theoretical models and address whether AGN feedback provides a link between supermassive black holes and galaxies.
Title: Influence of the AGN activity on ionized gas clouds in narrow-line regions of AGNs

Abstract: The radiation-driven fountain model is a theoretical model that naturally explains the formation and maintenance of the nuclear torus structure (Wada+12, Wada+18). In this model, it is expected that high-density gas clouds are supplied from the inner part to outer narrow-line regions (NLRs) through outflows. For examining this theoretical expectation observationally, we systematically investigated the ionized gas in NLRs based on 127,000 objects taken from Sloan Digital Sky Survey (SDSS). For this data, we measured the electron density as a function of the location in the so-called BPT diagram. We found that the NLR in AGNs is denser than the HII region in star-forming galaxies. Furthermore, NLRs with a higher AGN activity are characterized by a higher electron density. In addition, the velocity dispersion of [OIII]5007 shows a positive correlation with the AGN activity. These results are consistent with the radiation-driven fountain model. Also, in some LINERs and composite objects, NLRs with a notably high electron density were seen. For these objects, the effects of shocks may be important.
Title: **Estimating a distance of intrinsic NAL absorbers**

Abstract: In addition to broad absorption lines (BALs; FWHM > 2000 km/s), a substantial fraction of narrow absorption lines (NALs; FWHM < 500 km/s) in quasar spectra have recently been suggested to physically associated to the quasars (i.e., intrinsic NALs) rather than foreground galaxies and/or the IGM. There are two possible origins of intrinsic NALs; quasar driven outflow in central region and those smashing into ISM and/or CGM at large distance.

To determine the origin of intrinsic NALs, we examine pairs of stable/meta-stable lines such as CII1335 / CII*1336 and SiII1260 / SiII*1265 to measure electron density, which can be used to calculate their distance from the center in photoionization models.

We searched BAL quasar spectra taken with VLT/UVES from the ESO archive and found 2 quasars hosting intrinsic NAL systems with fine-structure lines, of which one (detected in SDSS J121549.80-003432.1) possesses clear fine-structure lines, with photoionization modeling possible. For the quasar we calculated a distance of intrinsic NAL absorber following the procedure above and confirmed it is comparable to the size of the host galaxy's CGM. We discuss the origin of intrinsic NALs based on our calculations for these quasars.
Title: The study of dual QSOs as tracers of galaxy mergers

Abstract: Galaxy mergers are thought to play an important role in galaxy evolution and the growth of SMBHs. In particular, they can trigger starbursts and AGNs. Now the study of mergers, including an early stochastic phase, is promoted and also a number of simulation studies have been carried out. But studies still lack reliable observational samples of the merger stage with separation < 10 kpc, in which dual AGNs are expected to exist. In this work, we match the SDSS QSO catalog and HSC imaging to identify possible dual QSO candidates with separations 0.6~4" (3 - 30 kpc) as tracers of an ongoing merger event at redshift < 4. To further confirm our candidates, we have acquired follow-up spectroscopic observations using Keck/LRIS. For this poster, I will show both the SDSS and HSC images and some spectral analysis of the ISM properties of several of our dual QSO samples.
Title: **CHORUS: A new search for type-2 AGNs at high-z by focusing on dual-NB emitters with HSC-SSP and CHORUS**

Abstract: We report the initial results of our new search for high-z type-2 AGNs by utilizing the HSC NBs data. It is important to study SMBHs and their evolution for understanding the evolutionary link between SMBHs and galaxies. It is crucial to carry out AGN surveys with a high completeness. However, optical broad-band color selection and variability-based selection are incomplete for obscured type-2 AGNs.

Here we would like to propose that a combination of two NB filters, NB718 and NB921 equipped in HSC, can be powerful to search for high-z type-2 AGNs systematically, because these filters can detect Ly_\alpha 1216 and CIV1549 of emission-line galaxies at z~4.9. The strong CIV emission is not seen in star-forming galaxies, so we can search for AGNs at z~4.9 by selecting objects that show flux excesses in both NB718 and NB921.

We selected some objects which show NB718 and NB921 flux excesses simultaneously (hereafter "dual emitters") by combining the catalogs of the HSC-SSP and CHORUS projects. In this poster presentation, we report the detailed method and properties of the dual emitters.