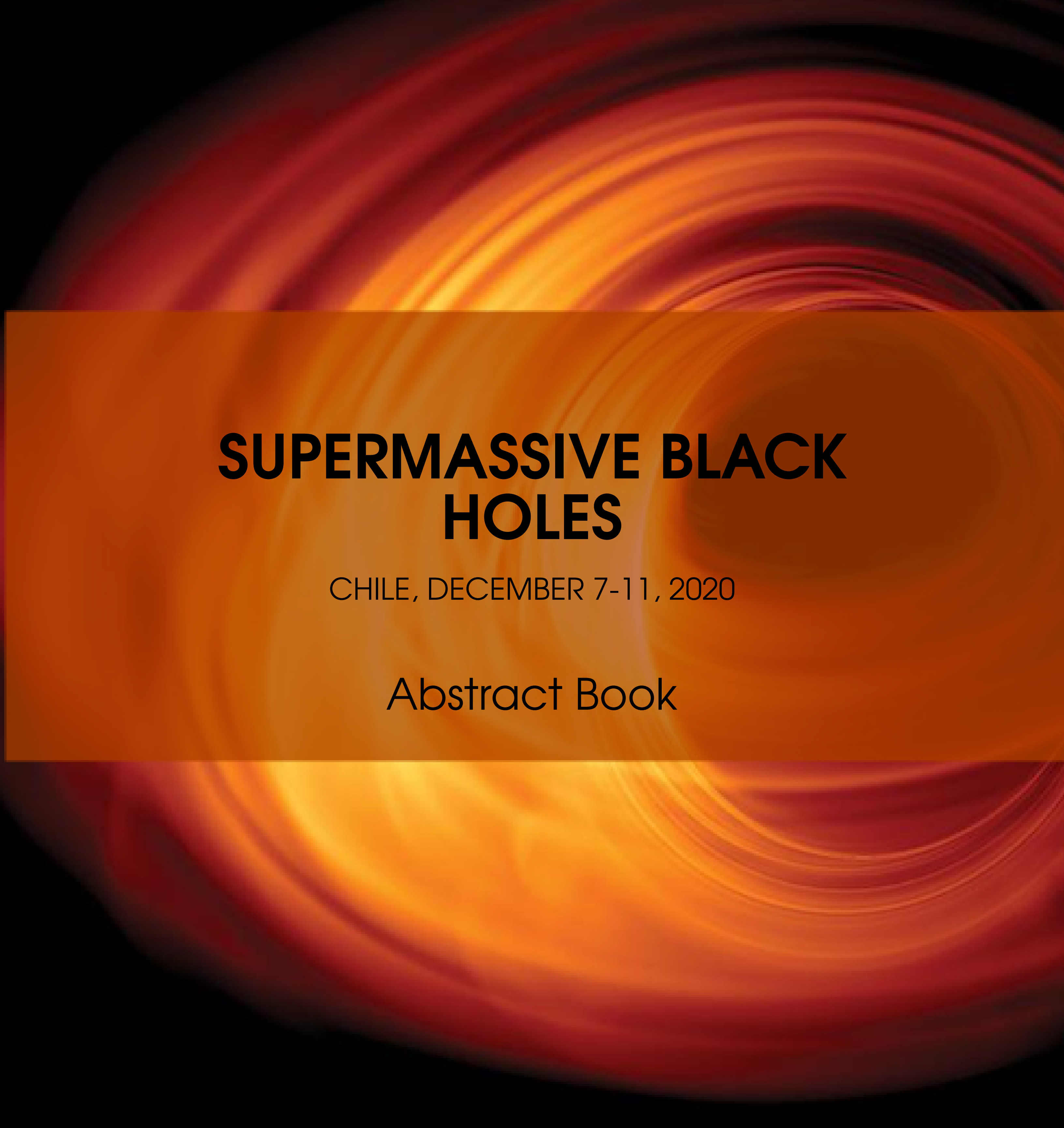


SUPERMASSIVE BLACK HOLES

CHILE, DECEMBER 7-11, 2020

Abstract Book

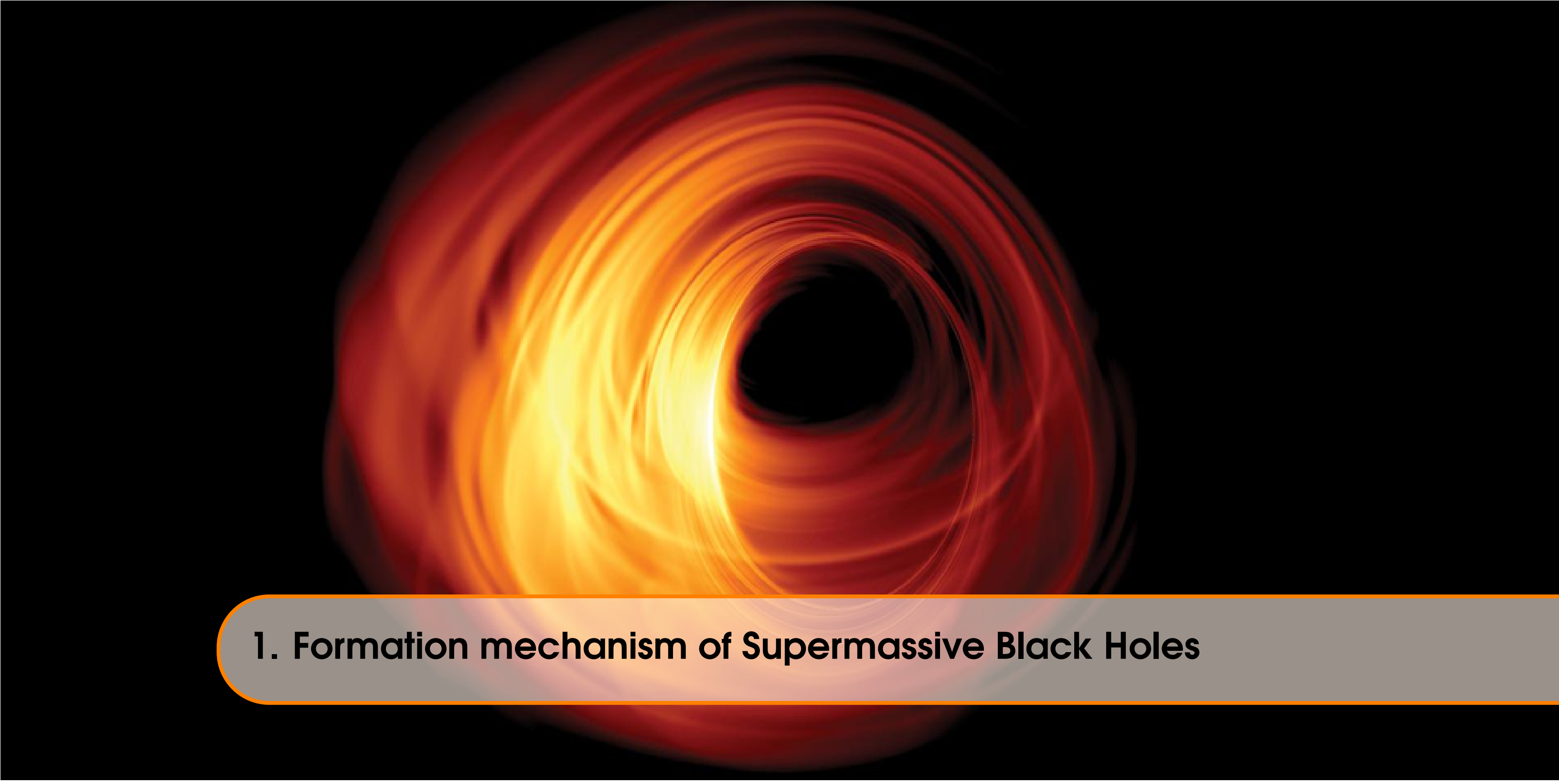
Department of Astronomy, Universidad de Concepción

SUPERMASSIVE BLACK HOLES CONFERENCE WEBPAGE

This conference will highlight the current and future science related to the formation and growth of supermassive black holes.

December 2020

Contents



1. Formation mechanism of Supermassive Black Holes

1.1 Invited Talks

1.1.1 Zoltan Haiman - *Columbia University*

The Initial Mass Function of Black Holes

I will review how "seed" black holes of different masses may have formed in the early universe, from stellar-mass black hole remnants to massive million solar-mass black holes assembled through the intermediate stage of a supermassive star, super-Eddington accretion, or run-away mergers of stellar-mass objects in a dense cluster. These seed black holes can subsequently grow via mergers and accretion into the supermassive black holes powering the most distant quasars. I will review under what conditions these seed-formation scenarios could occur, and comment on some possibilities to distinguish them using data from JWST, Lynx, and LISA.

1.1.2 Tiziana Di Matteo - *Carnegie Mellon University*

The first quasars in cosmological simulations

Massive black holes are fundamental constituents of our cosmos. Understanding their formation at cosmic dawn, their growth, and the emergence of the first, rare quasars in the early Universe remains one of our greatest theoretical and observational challenges. Hydrodynamic cosmological simulations self-consistently combine the processes of structure formation at cosmological scales with the physics of smaller, galaxy scales. They capture our most realistic understanding of massive black holes and their connection to galaxy formation. I will focus on the predictions for the first quasars and their host galaxies in the BlueTides simulation.

1.2 Contributed Talks

1.2.1 Anna-Christina Eilers - *Massachusetts Institute of Technology*

The Formation and Growth of Supermassive Black Holes at Early Cosmic Epochs

Observations of high-redshift quasars show that they host supermassive black holes (SMBHs) already less than ∼1 Gyr after the Big Bang. It has been argued that in order to rapidly grow these SMBHs in such short amounts of cosmic time, they need to accrete matter over timescales comparable to the age of the universe, and thus the lifetime of quasars - the integrated time that galaxies shine as active quasars - is expected to be of order $\sim 10^9$ yr at z∼6, even if they accrete continuously at the Eddington limit. I will present a new method to obtain model-independent constraints on the lifetime of high-redshift quasars with unprecedented precision, based on measurements of the sizes of ionized regions around quasars, known as proximity zones. The sizes of these proximity zones are sensitive to the lifetime of the quasars, because the intergalactic gas has a finite response time to the quasars' radiation. Applying this novel method to quasar spectra at $z>6$, we discover an unexpected population of very young quasars, indicating lifetimes of only ∼10,000 years, which poses significant challenges on current black hole formation models. I will show results from our on-going multi-wavelength survey, ranging from sub-mm to X-ray observations, to detect and characterize young quasars and their environments. I will highlight the implications of short quasar lifetimes on triggering and feedback mechanisms, and on the structure of the inner accretion disk of some of the earliest cosmic sources. Furthermore, I will discuss several modifications to the current SMBH formation paradigm that might explain our results, e.g. super-critical mass accretion rates, massive initial black hole seeds in excess of stellar remnants, or highly obscured quasar growth phases. In the end I will show how we aim to disentangle the various scenarios by means of state-of-the-art hydrodynamical simulations, as well as on-going and future observations with VLT/MUSE and the James Webb Space Telescope, in order to shed new light onto the formation and growth of the first SMBHs in the universe.

1.2.2 Arpan Das - *Western University, Canada*

Nuclear star clusters as the birthplaces of Supermassive Black Holes: collisions and accretion in low-metallicity environments

More than two hundred supermassive black holes (SMBHs) of mass $\gtrsim 10^9 M_\odot$ have been discovered at $z \sim 6$. One possible pathway for the formation of SMBHs is through the collapse of supermassive stars (SMSs). Here, we explore how SMSs with $\gtrsim 10^4 - 10^5 M_\odot$ could be formed via gas accretion and runaway stellar collisions in high-redshift, metal-poor nuclear star clusters. These SMSs could grow into few times $10^9 M_\odot$ supermassive black holes observed at high redshifts $z \sim 7$ via Eddington-accretion. We explore physically motivated accretion scenarios, e.g. Bondi–Hoyle–Lyttleton accretion and Eddington accretion, as well as simplified scenarios such as a constant accretion. We show that the upper mass limit of the initial mass function (IMF) affects the maximum mass of the final mass distribution in the cluster in the case of constant accretion, while not being statistically relevant for Eddington or Bondi accretion even though the upper IMF cut-off sets the accretion rate. For Bondi accretion which scales as the square of the mass, the initial accretion rate is higher and the most massive object forms earlier for a larger upper-mass cutoff. The initial compactness of the cluster is important in case of constant accretion rates and for the Eddington scenario, while not significantly affecting the mass of the most massive object in the Bondi scenario. The Bondi scenario can potentially produce the most massive objects with $\sim 10^5 M_\odot$, but also implies a long timescale without relevant growth. Depending on the conditions, massive objects of $10^3 - 10^5 M_\odot$ can form. However note that the uncertainties due to stellar evolution as well as the hydrodynamical evolution need to be explored in more detail in future investigations.

1.2.3 Andres Escala - *Universidad de Chile*

Observational Evidence for Massive Black Hole Formation Driven by Runaway Stellar Collisions in Galactic Nuclei

We explore here a scenario for massive black hole formation driven by stellar collisions in galactic nuclei, proposing a new formation regime of global instability in nuclear stellar clusters triggered by run- away stellar collisions. Using order of magnitude estimations, we show that observed nuclear stellar clusters avoid the regime where stellar collisions are dynamically relevant over the whole system, while resolved detections of massive black holes are well into such collision-dominated regime. We interpret this result in terms of massive black holes and nuclear stellar clusters being different evolutionary paths of a common formation mechanism, unified under the standard terminology of being both central massive objects. We propose a formation scenario where central massive objects more massive than $\sim 10^8\,M_\odot$ will be too dense (in virial equilibrium) to be globally stable against stellar collisions and most of its mass will collapse towards the formation of a massive black hole. Contrarily, this will only be the case at the core of less dense central massive objects leading to the formation of black holes with much lower black hole efficiencies $\varepsilon_{BH} = \frac{M_{BH}}{M_{CMO}}$, with these efficiencies ε_{BH} drastically growing for central massive objects more massive than $\sim 10^7\,M_\odot$, approaching unity around $M_{CMO} \sim 10^8\,M_\odot$. We show that the proposed scenario successfully explains the relative trends observed in the masses, efficiencies, and scaling relations between massive black holes and nuclear stellar clusters.

1.2.4 Giacomo Fragione - *CIERA Northwestern University*

Repeated mergers and ejection of massive black holes within nuclear star clusters

Current stellar evolution models predict a dearth of black holes (BHs) with masses $>$50 Msun and intermediate-mass black holes (IMBHs) have not yet been detected beyond any reasonable doubt. A natural way to form massive BHs is through repeated mergers, detectable via gravitational wave emission with current LIGO/Virgo or future LISA and ET observations. Nuclear star clusters (NSCs) have masses and densities high enough to retain most of the merger products, which acquire a recoil kick at the moment of merger. In this talk, I will explore the possibility that IMBHs may be born as a result of repeated mergers in NSCs, and show how their formation pathways depend on the NSC mass and density, and BH spin distribution. I will show that BHs in the pair-instability mass gap can be formed and observed by LIGO/Virgo and that the typical mass of the ejected massive BHs is $400-500$ Msun, with velocities of up to a few thousand km/s. Eventually some of these IMBHs can become the seeds of supermassive BHs, observed today in the centers of galaxies. In dwarf galaxies, they could potentially solve the abundance, core-cusp, too-big-to-fail, ultra-faint, and baryon-fraction issues via plausible feedback scenarios.

1.3 Posters

1.3.1 Marcelo Cortes - *Universidad de Concepción*

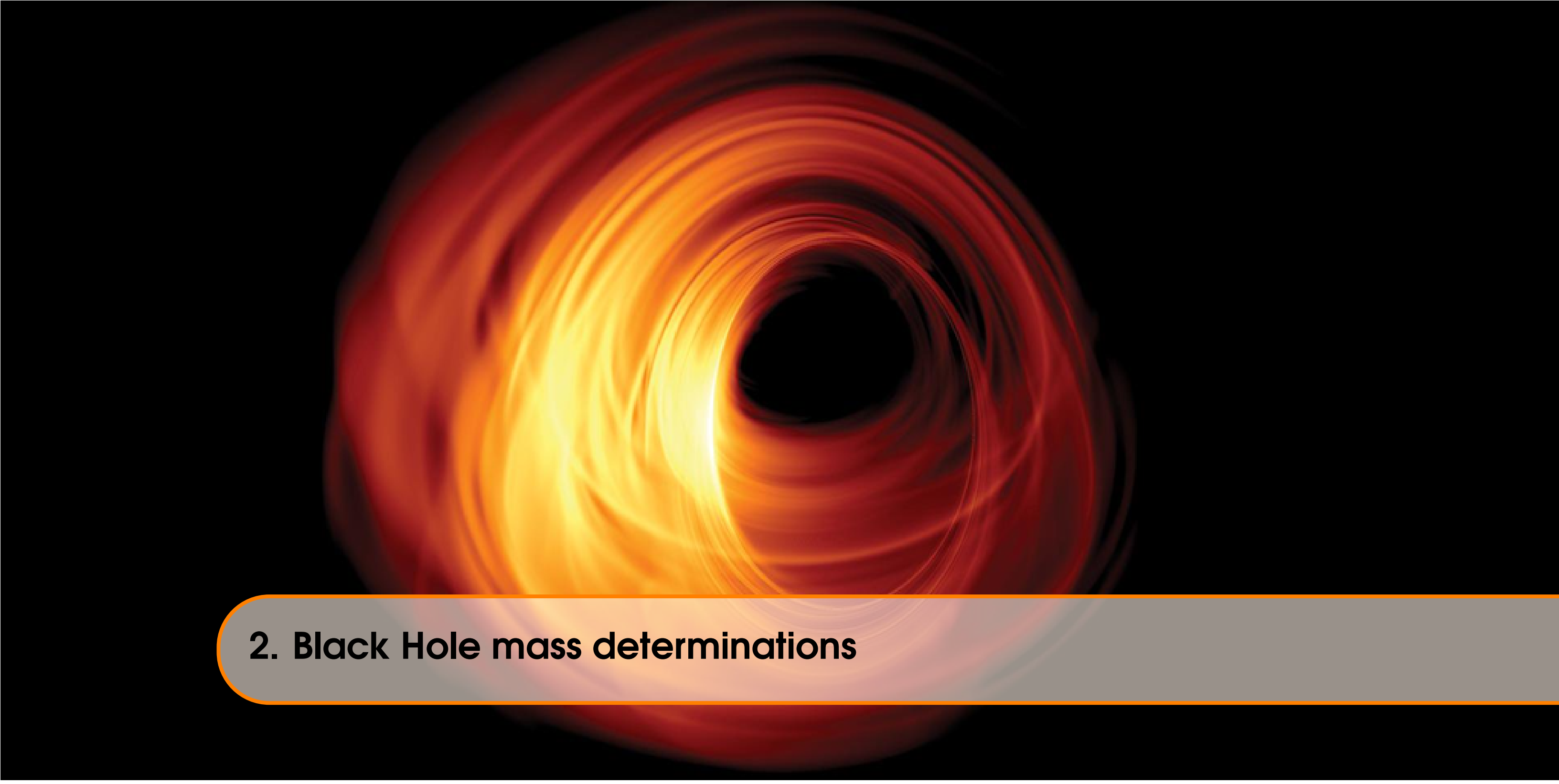
Impact of flattening and rotation on black hole formation in protostar clusters

In the early Universe and at low metallicities, the fragmentation often occurs in disk-like structures. Supermassive black holes (SMBHs) are astrophysical objects with an enigmatic origin, weighing millions of solar masses and residing in the centers of galaxies. An important formation scenario for the seed of SMBHs concerns the collisions and mergers of stars in a massive cluster with a high stellar density, in which the most massive star falls to the center of the cluster due to dynamical friction. This increases the rate of collisions and mergers since this new object has a larger collisional cross-section than other stars in the cluster. Once several collisions have occurred, a very massive star (VMS) forms which may collapse to become an intermediate-mass black hole. Here we investigate the impact of rotation and flattening of dense protostellar clusters on the rate of formation of massive stars through collisions, which will later evolve into massive black holes. We use the Miyamoto-Nagai distribution to represent our model and employ N-body simulations to show, in detail, how flattening and rotation affect the number of collisions and the formation of a more massive object.

1.3.2 Vanesa Díaz - *Universidad de Concepción*

The role of radiation backgrounds in the direct collapse scenario

The presence of supermassive black holes (SMBHs) of a few billion solar masses at very high redshift has motivated us to study how these massive objects formed during the first billion years after the Big Bang. A promising model that has been proposed to explain this is the direct collapse of protogalactic gas clouds. In this scenario, very high accretion rates are needed to form massive objects early on and the suppression of H_2 cooling is important in regulating the fragmentation. Recent studies have shown that if we use a strong radiation background, the hydrogen molecules are destroyed, favoring high accretion rates and therefore producing objects of very high mass. In this work, we study the impact of UV radiation fields in a primordial gas cloud using the recently coupled code GRADSPH-KROME for the modeling of gravitational collapse including primordial chemistry to explore the formation of first SMBHs. We found that to suppress the formation of H_2 a very high value of J_{21} is required, $J_{21} \sim 105$. Also, increasing the rotation of the cloud, it is even higher. As shown in previous work, such strong radiation backgrounds are very rare, so that the direct collapse may be difficult to achieve and therefore this scenario could hardly explain the formation of the first SMBHs.



2. Black Hole mass determinations

2.1 Invited Talks

2.1.1 Timothy Davis - *Cardiff University*

Black holes across the Hubble Sequence: Gaining wisdom with WISDOM

In the past few decades supermassive black holes (SMBHs), and the feedback that they produce, have become a crucial part of our galaxy evolution paradigm. In this paradigm understanding correlations between SMBHs and their host galaxies is key to properly constrain the physical processes driving co-evolution and galaxy quenching. As the ALMA telescope in Chile has come of age, its exquisite resolution and sensitivity have provided us with a new way of dynamically estimating black hole masses - using the kinematics of molecular gas clouds as they rotate around SMBHs. In this talk I will present work exploiting this new method, as part of the millimetre-Wave Interferometric Survey of Dark Object Masses (WISDOM) and other associated efforts. I will demonstrate how, with ALMA, we can estimate SMBH masses for systems across the Hubble sequence, from massive early-type galaxies, spiral galaxies, and even in dwarf galaxies. In time these estimates can help reveal the SMBH demographics in a variety of underrepresented galaxy populations. I will show that these observations can also shed light on key parts of the SMBH fuelling and feedback cycle, revealing inflowing cold material on parsec scales, and large molecular outflows.

2.1.2 Kayhan Gultekin - *University of Michigan*

Black Hole Masses Past, Present, and Future

Black-hole masses are the foundation for much of black hole astrophysics as they set a number of important scales such as Eddington luminosity, shadow size, and gravitational wave amplitude. Black hole masses also scale with a number of host galaxy properties such as bulge mass, luminosity, velocity dispersion, and galaxy core size. These relations strongly suggest that black holes (singles or binaries) are key players in the evolution of galaxies. Throughout it all, stellar dynamical mass measurements are the foundation for all black hole mass measurements. I will review the technique of stelar dynamical mass measurements. Then I will discuss current black-hole mass measurement work and the related galaxy evolution, including black hole binary gravitational-wave recoil. I will end with prospects of what can be done with JWST and 30-m class telescopes.

2.2 Contributed Talks

2.2.1 Anil Seth - *University of Utah*

Black Hole Demographics from Dynamical Studies

I will summarize the results of dynamical searches for black holes in nearby lower mass galaxies. Over the past five years we've found evidence that a high fraction of nearby galaxies with masses around 1/10th of the Milky Way mass have black holes. The central black holes in these galaxies typically have masses below one million solar masses, and are the first dynamical detections in this mass range. We have also found that a significant fraction of local black holes may lie within galaxy nuclei from lower mass galaxies that have been tidally stripped as they fall into their higher mass hosts. I will highlight the current results on the population of black holes in stripped nuclei and discuss the implications for tidal disruption and gravitational wave events.

2.2.2 Benjamin Boizelle - *Texas A&M University*

Black Hole Mass Measurement in Luminous Early-type Galaxies with ALMA

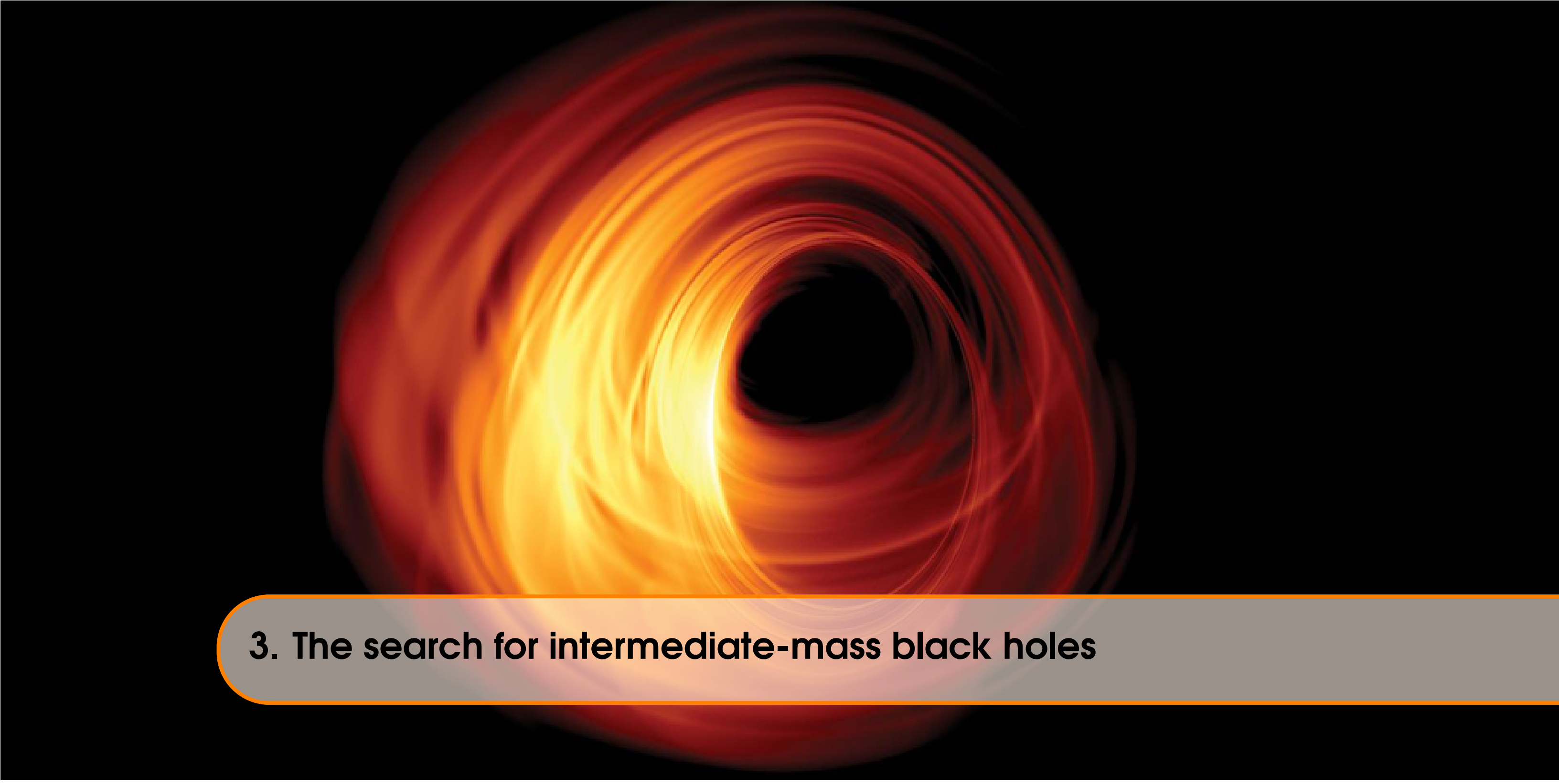
ALMA has opened a new avenue to study the demographics of supermassive black holes (BHs) in nearby galaxies. Through ALMA observations at subarcsecond resolution, we have found dynamically cold, rotating, nuclear gas disks in a number of massive early-type galaxies (ETGs). We will present ALMA CO emission-line morphologies and kinematics for the sample, focusing on those with rapid rotation that arise from within the BH sphere of influence, wherein the BH dominates over the enclosed host galaxy mass. We will discuss recent gas-dynamical modeling of the ETGs NGC 315, NGC 3258, and NGC 4261, which host (1.70-2.25)x10^9 Msun BHs. The ALMA observations highly resolve CO rotation within the spheres of influence and allow for very precise BH mass measurements. Such precise BH mass measurements are necessary to anchor the sparsely populated high-mass end of the BH mass-host galaxy relationships and will enable crucial cross-checks on other BH mass measurement techniques.

2.3 Additional Contributed Talks

2.3.1 Sabine Thater - *University of Vienna*

SMASHING - a homogenous sample of dynamical MBH measurements

Over hundred massive black hole (MBH) mass measurements of local galaxies have revealed strong correlations with different properties of their host galaxy bulge. However, determining MBH masses is a challenging procedure and possible biases need to be recovered before properly understanding the underlying physics. I will present two projects to address the following questions: Do high-mass and low-mass black holes follow the same scaling relations? Does the variety of mass measurement methods force an additional bias on the scaling relations? Therefore, I will present our SMASHING sample of 20 early type galaxies which expand the scaling relations on both the high and low mass end. Then, I will show the comparison of two independent MBH determinations from stellar kinematics (MUSE) and molecular gas kinematics (ALMA), taking special care in revisiting the associated measurement errors, specifically, the systematics associated with the dynamical methods, and the general accuracy of MBH mass measurements. I will conclude my talk with a discussion on what we can learn from examining orbital distributions in galaxy evolution and formation context.



3. The search for intermediate-mass black holes

3.1 Invited Talks

3.1.1 Jenny Greene - *Princeton University*

Intermediate-mass Black Holes

No black holes are known with definitive black hole masses between a few hundred and a hundred thousand solar masses. Nevertheless, the distribution of masses, and "occupation fraction" of dwarf galaxies containing massive black holes contain clues about the seeding mechanisms of supermassive black holes. I will describe our best current estimates of the occupation fraction, scaling relations, and black hole mass function in this elusive intermediate-mass range.

3.1.2 Amy Reines - *Montana State University*

Intermediate-Mass Black Holes in Dwarf Galaxies

The origin of supermassive black holes remains a major outstanding issue in modern astrophysics. These monster black holes reside in the nuclei of essentially every massive galaxy and power the most luminous quasars at the edge of the observable Universe. However, directly observing the first "seed" black holes in the early Universe - that can eventually grow to upwards of a billion solar masses - is not feasible with current telescopes. Present-day dwarf galaxies, on the other hand, are within observational reach and offer another avenue to learn about black hole seeds since low-mass galaxies can host relatively pristine black holes. In this talk, I will highlight some of my work in this field that has taken us from a few rare examples to large systematically assembled samples of dwarf galaxies hosting black holes, including a new sample of "wandering" black holes in the outskirts of dwarf galaxies.

3.2 Contributed Talks

3.2.1 Jenna Can - *George Mason University*

The Power of JWST in the Hunt for Intermediate Mass Black Holes

Most, if not all, massive galaxies have a central supermassive black hole (SMBH) millions to billions of times the mass of the Sun. While the properties of SMBHs and their host galaxies have been well-studied in massive galaxies, very few SMBHs have been found in galaxies with low masses and those with small bulges. This is a significant deficiency, because the study of this population allows us to gain an understanding of merger-free pathways to black hole growth, and to gain insight into the origin and growth of SMBH 'seeds', thought to have formed at high redshift. Most studies aimed at finding SMBHs have been conducted using optical spectroscopic studies, where active SMBHs display distinctive optical emission lines indicative of accreting SMBHs. However, in low mass galaxies, these studies are significantly biased in searching for active low mass black holes. In this talk, I will discuss some of our theoretical and observational work highlighting the diagnostic power of infrared coronal lines in identifying black holes in the low mass regime and constraining their properties, and will highlight the future prospects with JWST.

3.2.2 Alister Graham - *Swinburne University of Technology*

Consistent predictions for intermediate mass black holes

I will report on our recent Chandra X-ray Observatory's Large Program "Spiral galaxies of the Virgo cluster". In addition to presenting the discovery of centrally-located, X-ray point sources in several low-mass galaxies, I will show how our new, morphology-dependent, black hole scaling relations (i) overcome the past inconsistent predictions at low masses, and (ii) are predicting many intermediate mass black holes.

3.2.3 Paula Cáceres - *Universidad de Chile*

Search of Intermediate Mass Black Holes using Spectral Analysis

Intermediate Mass Black Holes are a key element to understand the origins of Black Hole seeds in the early Universe, hence it's important to search for them and study their physical properties. Knowing that small AGN show fast variability in their light curves, Martinez-Palomera and Lira pioneered the search of IMBH by using this criteria and found about 500 candidates. I present the results of analyzing the SDSS spectra of all candidates, looking for broad components to their Balmer emission lines, which is a trademark of AGN.

3.2.4 Renuka Pechetti - *University of Utah*

An Intermediate-Mass black hole in a massive globular cluster

Intermediate-mass black holes (IMBHs) are the bridge between the stellar-mass black holes and super-massive black holes. They are extremely difficult to observe as their effect on the surrounding stars is much weaker than a super-massive black hole. Hence, they require high-resolution measurements of the nearest possible targets. While only a handful of IMBH candidates exist, they can provide key information on the formation of the initial seeds of super-massive black holes and the origin of the galaxy–black hole scaling relations. We present the detection of an IMBH in the center of a massive globular cluster in the nearest galaxy M31. We derived the mass models using HST observations for the globular cluster and combined these with high spatial resolution kinematics derived from adaptive optics GEMINI/NIFS IFU observations. We use multiple dynamical modeling methods to determine the black hole mass. The resulting black hole is $\sim 10^5$ solar masses, larger than found in any previous Milky Way or M31 globular cluster. This object is likely the stripped nucleus of a dwarf galaxy. We note this detection is more robust than any previous IMBH detection, including those in G1 or Omega Cen.

3.2.5 Igor Chilingarian - *CfA*

AGN powered by intermediate-mass black holes: fundamental relations and (often) rapid BH growth

Nearly every massive galaxy harbors a supermassive black hole (SMBH) in its nucleus, The origin of SMBHs remains uncertain: they could have emerged either from massive “seeds” (100k-1M MSun) formed by direct collapse of gas clouds in the early universe or from smaller (100 MSun) stellar mass BHs. The latter channel would leave behind numerous intermediate-mass BHs (IMBHs, 100-100k M). Using data mining in wide-field sky surveys and applying dedicated analysis to optical spectra, we identified hundreds of IMBH candidates, which reside in galaxy centers and are currently accreting gas that creates optical signatures of type I AGN. As of now, 16 new candidates were confirmed by X-ray emission as bona fide IMBHs hence bringing the entire sample of nuclear IMBHs to 20. Among them, we identified 5 objects accreting close to the Eddington limit. We also re-measured virial masses for about 40 low-mass BHs (below 1M MSun) and demonstrated that scaling relations between SMBHs and their host galaxies (MBH–sigma and MBH–Mbulge) in the IMBH regime follow the trends established by more massive SMBHs. The very existence of numerous nuclear IMBHs supports the stellar-mass seed scenario of the massive BH formation.

3.3 Additional Contributed Talks

3.3.1 Jorge Martinez-Palomera - *UC Berkeley*

Searching for Intermediate-mass Black Holes using variability

Intermediate-mass black holes (IMBHs) have masses between 10^2 and 10^6 $M_\odot$ and are key to our understanding of the formation of massive black holes. The known population of IMBHs remains small, with a few hundred candidates and only a handful of them confirmed as bona fide IMBHs. Here we present a methodology to select IMBH candidates via optical variability analysis of the nuclear region of local galaxies ($z \leq 0.35$). Active IMBHs accreting at low rates show small amplitude variability with timescales of hours, as is seen in one of the known IMBHs, NGC 4395. Using variability analysis we found a sample of $\sim$500 galaxies demonstrating fast and small amplitude variation in their week-based light curves. We estimate an average occupancy fraction of 4% and a surface density of $\sim$3 deg^2, which represent an increase by a factor of $\sim$40 compared to previous searches. A large fraction (78%) of the candidates are in spiral galaxies. We preliminarily confirm the AGN nature of 22 sources via BPT diagrams using Sloan Digital Sky Survey legacy spectra. I will also update on the follow-up and current status of our search campaigns.

3.3.2 Victoria Toptun - *SAI MSU*

X-ray confirmation of 14 new intermediate-mass black holes with XMM-Newton and Chandra

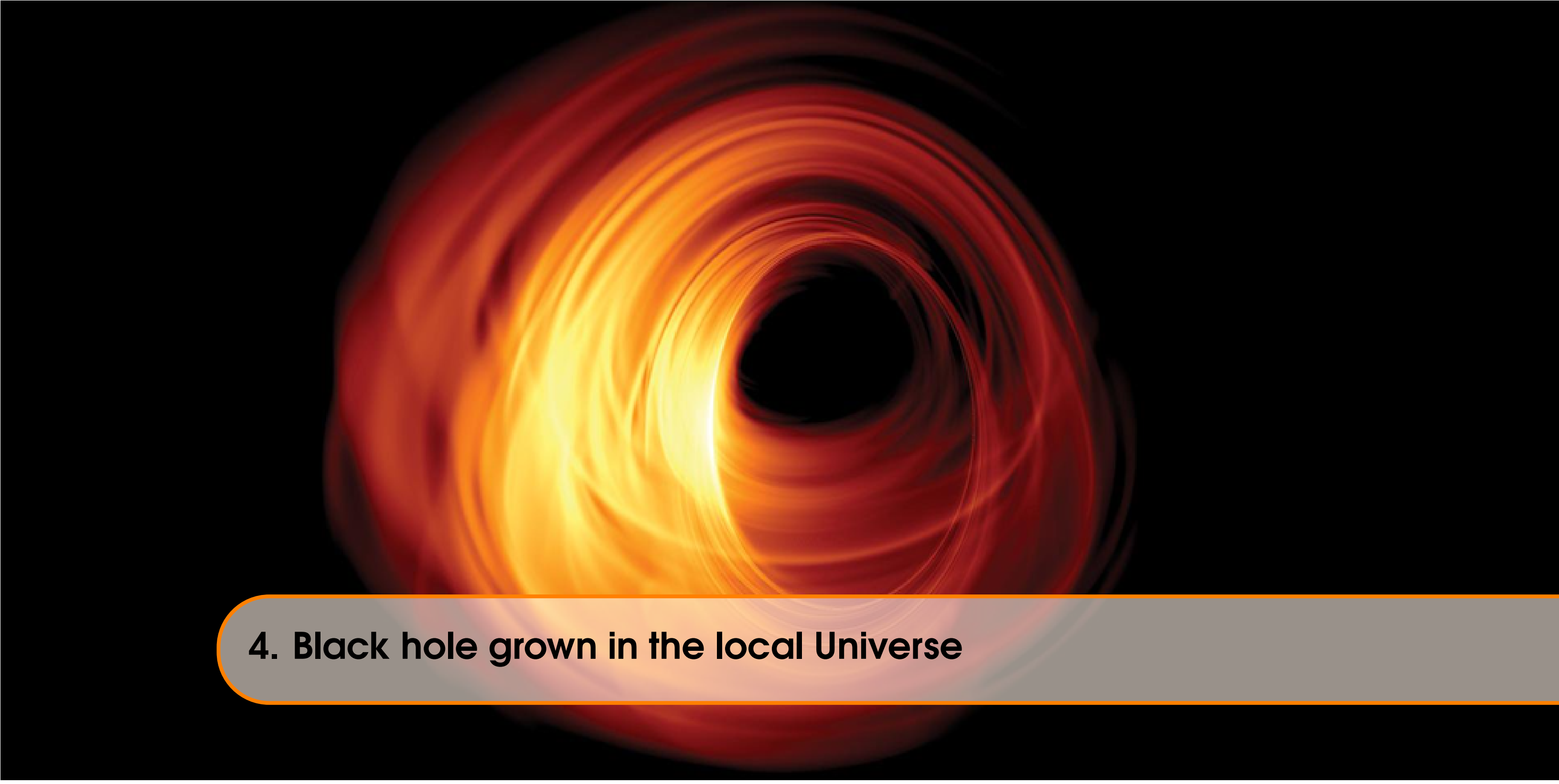
The origin of supermassive black holes (SMBH) in galaxy centers still remains uncertain. They could have emerged either from massive "seeds" (100k-1M MSun) in the early Universe or from smaller (100 MSun) remnants of massive pop-III stars. The latter scenario would leave behind numerous intermediate-mass black holes (IMBHs, 100-100k MSun), while the former one would lead to a gap in the BH mass function. The largest published sample of bona-fide IMBH-powered AGN contains 14 objects confirmed in X-ray. Here we present X-ray confirmation of ten new optically selected IMBH candidates from a sample of 305 objects from Chilingarian et al. (2018): three with our own XMM-Newton observations, two from the source catalog 4XMM DR9, and five from Chandra archival data. With the expanded sample of bona fide IMBHs we probed BH accretion rates in low-mass AGN and identified five galaxies close to the Eddington limit, which is an unusually high fraction provided the total sample size of 20. If, on average, nuclear IMBHs indeed grow very fast once they start accreting, this will explain why IMBH search campaigns are challenging: after a few tens of Myrs of steady accretion they will overgrow the informal IMBH mass bracket.

3.4 Posters

3.4.1 Jennifer Anguita - *Universidad de Chile*

Fast Optical Variability of Intermediate-Mass Black Holes Candidates in Local Galaxies

Intermediate-Mass Black Holes (IMBHs) have masses between the 1e2 - 1e6 M and are key to our understanding of the formation of massive black holes since they are believed to be closes relatives to Super-Massive Black Holes seeds. The known population of IMBHs remains small, with a few hundred candidates and only a handful of them confirmed as bona-fide IMBHs. This project is a follow up to a recently completed survey using the Dark Energy Camera (DECam) at the 4m Blanco telescope on CTIO by Jorge Martinez et al.(2019), searching for a rapid variability signal in the nuclear region of nearby galaxies using the High Cadence Transient Survey (HiTS, Förster et al., 2016). The Search for Intermediate-mass Black-Holes In Nearby Galaxies (SIBLING) survey found about 500 IMBH candidates through their variable nuclear emission. In this work we seek to confirm such results.



4. Black hole grown in the local Universe

4.1 Invited Talks

4.1.1 Mike Koss - *Eureka Scientific, USA*

Results from the BASS Survey on Black Hole Growth in the Local Universe

Despite decades of research, clear direct links between black hole growth and host galaxy star formation, cold molecular gas, and galaxy mergers remain unclear. We will discuss recent results from the BASS survey from a large survey of molecular gas of 214 hard X-ray selected AGN and there implications for black hole growth

4.1.2 Scott Tremaine - *Institute for Advanced Studies*

Nuclear star clusters as maximum-entropy states

4.2 Contributed Talks

4.2.1 Konrad Tristram - *European Southern Observatory*

Black hole growth on parsec scales revealed by interferometry

The parsec scales surrounding supermassive black holes are a crucial region for the accretion process, and a point of interplay between the inflow and outflow of material directly as a consequence of the presence of the black hole. This is also the region formerly attributed to the so-called dusty and molecular torus, which has a strong influence on the observational characteristics of AGN. Due to the small angular scales, direct observations of this region are only possibly by interferometry. I will present the recent results obtained with infrared and sub-mm interferometry. Observations in the near-infrared trace the dust sublimation region, as for example for NGC1068 where GRAVITY at the VLTI mapped a ring-like structure. In the thermal infrared, the observations reveal predominantly polar structures, as well as in some cases (NGC1068 and Circinus) central disk-like components, providing a clear two component structure of the dusty material. Sub-mm observations in turn trace dense and warm molecular disks with little molecular material in polar directions. This leads to a relatively complex picture of a multi-phase medium composed of a dense disk, as well as dusty polar winds and outflows; a picture also supported by recent hydrodynamical simulations.

4.2.2 Patricia Arévalo - *Universidad de Valparaíso*

The physics of feedback in M87

The intra-cluster gas around the supermassive black hole in M87 shows perturbations that point towards heating by different feedback mechanisms. In this talk I will summarize the properties of the cooler and denser ionized filaments of gas embedded in the ICM, to argue about their heating mechanism and whether they can result from the cooling of the ICM; are made of low-entropy gas being dragged out of M87, or the product of large scale accretion (i.e. cold gas falling in). Establishing the origin of these filaments helps to constrain feeding and feedback mechanisms of the most massive galaxies at the centers of galaxy clusters.

4.2.3 Alessandro Marconi - *Department of Physics and Astronomy, University of Florence*

The physical properties of AGN outflows and star formation quenching

Feedback from AGN is considered the main physical mechanism quenching star formation in galaxies with powerful outflows. However, while outflows are ubiquitous, their impact on galaxies and physical properties are still poorly known. In particular, we are still missing the smoking gun evidence of AGN-driven outflows quenching star formation. I will present several observational programs targeting AGN host galaxies from low to high redshift and aimed to understanding the physical properties of the outflows and their impact on the host galaxies. At low redshift, I will present a survey aimed at studying the physical properties of outflows in nearby AGN using integral field spectroscopic observations with VLT/MUSE and ALMA. The spatial resolution down to a few tens of parsecs allows to study the ionisation structure of the outflows and the relation between ionised and molecular gas while innovative kinematical modelling allows to accurately constrain geometry and kinematics despite the very complex observed morphologies. At high redshift, I will present results from surveys aimed at studying the impact of outflows on quasar host galaxies, the progenitors of the local massive galaxies, using IFU observations with VLT/SINFONI and ALMA. In particular, I will present evidence for an anti correlation between the presence of fast outflows and star formation activity. Finally, I will discuss how our results fit in the canonical picture of star formation quenching by AGN outflows.

4.3 Additional Contributed Talks

4.3.1 Alejandra Rojas - *Universidad de Antofagasta*

Multiphase outflows in hard X-ray selected AGN

AGN-driven outflows are thought to play a crucial role in the evolution of galaxies, but how they influence their hosts is still unclear due to uncertainties on the total outflow rate budget. A combination of multi-wavelength observations is needed to properly trace their multiphase physical properties and kinematics. I will discuss preliminary results of our study of multi-phase AGN outflows in local hard X-ray selected AGN from the BASS survey. Our sample is almost unbiased against obscuration or AGN types and covers a large range of luminosity, therefore the occurrence of outflows in different gas phases and its dependance with the different AGN power tracers is providing us a new point of view on the AGN feedback paradigm.

4.3.2 Antoine Andre Neira - *University of Utah*

An excess of k-band dust emission in LLAGNs

Looking towards the future, the era of JWST will provide unparalleled sensitivity at infrared (IR) wavelengths, making the IR a powerful tool to study accretion processes in luminous AGN in the distant universe and in the search for intermediate-mass black holes (IMBH) and low-luminosity AGN in the local universe. In this work, we discuss what is known about AGN emission in the near-infrared (NIR) accretion regime and present NIR fluxes for 15 low-luminosity AGN in the local universe. Our sample includes multiple galaxies with BH masses of less or equal than million solar masses. We use integral field spectroscopy to decompose the stellar emission and AGN continuum component. This AGN component appears to be thermal emission from hot dust, as also seen in higher luminosity AGN. We compare the ratio of NIR and X-ray luminosities in our sample and in higher luminosity AGN, and find that this ratio increases at lower accretion rates. Furthermore, objects at low Eddington ratios frequently have a higher luminosity in the NIR than they do in the X-ray. These observations suggest NIR spectroscopy will be an important tool for detecting BH accretion, especially at lower luminosities.

4.3.3 Caner Unal - *Czech Academy of Sciences / Ben Gurion University*

An excess of k-band dust emission in LLAGNs

The Fundamental Plane (FP) of black hole (BH) activity in galactic nuclei relates X-ray and radio luminosities to BH mass and accretion rate. However, there is a large scatter exhibited by the data, which motivated us for a new variable. We add BH spin as a new variable and estimate the spin dependence of the jet power and disc luminosity in terms of radio and X-ray luminosities. We assume the Blandford–Znajek process as the main source of the outflow, and find that the jet power depends on BH spin stronger than quadratically at moderate and large spin values. We perform a statistical analysis for 10 active galactic nuclei (AGNs) which have sub-Eddington accretion rates and whose spin values are measured independently via the reflection or continuum-fitting methods, and find that the spin-dependent relation describes the data significantly better. This analysis, if supported with more data, could imply not only the spin dependence of the FP relation, but also the Blandford–Znajek process in AGN jets.

4.3.4 Edgar Cortes-Suárez - *Instituto de Astronomía UNAM*

galaxies properties of 47 Type 1 AGN in MaNGA

It is widely accepted that the mechanism that triggers the activity in the nuclei of some galaxies (AGN) is the accretion of material towards a supermassive black hole. This activity, in turn, evolves with their host galaxy. In this talk, I will present a method to find Type I AGN in large spectroscopic surveys of galaxies (MaNGA), based on flux ratios in regions where a broad emitting line emerges. Also, I will show the global properties of our 47 Type-1 candidates in order to find possible correlations between nuclear activity and the host galaxy.

4.3.5 Elena López - *Universidad de Valparaíso*

Understanding the vicinity of SBHs through X-ray variability

One remarkable property of active galactic nuclei (AGNs) is their variability, which is seen on a wide range of the electromagnetic spectrum. Their luminosity varies on time scales down to hours or even minutes, so we infer it is a supermassive black hole (SBH) which is causing the emission we observe. Since the X-rays are emitted in the region close to the SBH, studying the X-ray variability has been essential to understand the physical processes and the geometry in the central regions. Many AGNs show an excess above the power-law continuum below 2keV whose origin is still unclear: the soft excess. This component can correspond to X-ray emitting gas near to but disconnect from the accretion flow; to an additional structure of the accretion flow, distinct from the disc and the corona; to ionized reflection or simply be an effect of ionized absorption in the vicinity of the black hole. $MCG-6-30-15$ is a nearby ($z = 0.00$) AGN whose variability coming from the soft excess can be explained by variable absorption or variable reflection from an ionized disc. Here, we investigate the X-ray variability of $MCG-6-30-15$ in an attempt to break the degeneracy of the models. We will explore the power of the RMS spectral fitting, which gives the spectral shape of the X-ray components that are varying. With this method we will be able not only to characterize the variability of all the spectral components, but to shed light on the origin of the mysterious soft excess.

4.3.6 Federica Ricci - *Pontificia Universidad Catolica de Chile*

Peering into the hidden BLR: constraining the virial factor in obscured X-ray selected local AGN

Understanding geometry of the material in the broad line region (BLR) can shed light on the physics in the proximity of AGN. Systematics about the BLR dynamics are encoded in the virial factor f, that is a scale factor upon which all the virial Mbh estimates are rooted, and affects up to ∼2- 3 the Mbh uncertainties. The f-factor has been directly determined on a small sample of local broad-line AGN, allowing the community to infer a correlation between f and inclination. However, little is known about the BLR in obscured AGN. To tackle this issue, we have carried out in the last 2 years a NIR spectroscopic campaign up of BAT-selected obscured AGN using Magellan/FIRE. We collected high R NIR spectra for a local sample of ∼50 X-ray selected obscured AGN to detect the BLR in the NIR, which is less extinct than the optical. These observations have allowed us to construct a (less biased) statistical sample of AGN to assess the presence of correlations between f and AGN properties, and to verify systematics in Mbh.

4.3.7 Giacomo Venturi - *Pontificia Universidad Catolica de Chile (PUC)*

Dissecting ionised gas outflows and feedback in nearby AGN

AGN outflows driven by SMBH accretion are believed to play a major role in shaping the properties and evolution of host galaxies, by sweeping away the gas and quenching star formation. Nearby active galaxies, due to their vicinity, offer the unique possibility to investigate in detail the properties and driving mechanisms of outflows and the interplay between AGN activity and star formation. Thanks to its unique combination of large field of view and spectral coverage, VLT/MUSE allowed us to map the ionised gas down to very few pc in several transitions revealing ubiquitous kpc-scale outflows. We could then dissect their properties (such as velocity, mass outflow rate, kinetic rate, density etc. . .) and study their acceleration and propagation mechanisms from the nuclear up to galactic scales, thanks to both MUSE wide-field and AO-assisted narrow-field observations. By targeting both isolated AGN and galaxies in different merging stages we investigated the role of mergers in launching outflows, triggering AGN activity and exerting feedback on the star formation processes in the host galaxies. Furthermore, by matching the MUSE data with simulations, we detected a peculiar jet-ISM interaction phenomenon in several jetted sources, indicating that jets can have an important role in driving outflows even in "radio quiet" AGN. Finally, we also found also evidence of star formation induced by outflows.

4.3.8 Guang Yang - *Texas A&M University*

What drives the growth of black holes?

There are supermassive black holes (SMBHs) in the centers of most massive galaxies. Observations of nearby systems have found that SMBH masses (M_{BH}) are tightly correlated with host-galaxy properties such as bulge masses (M_{bulge}). These local SMBH-galaxy relations suggest that SMBH growth is fundamentally linked to host galaxies over cosmic history. Previous studies suggest that long-term average SMBH accretion rate (BHAR) is intrinsically related to star formation rate (SFR) for the overall galaxy population. However, we show that BHAR is more strongly correlated with host-galaxy stellar mass (M_*) rather than SFR, and this BHAR-M_* relation does not depend on cosmic environment. We further quantify this BHAR-M_* relation and its cosmic evolution at z= 0.4–4. However, we find this BHAR-M_* relation does not hold for bulge-dominated galaxies, and their BHAR primarily depends on SFR. This BHAR-bulge SFR relation indicates that SMBHs only coevolve with galactic bulges rather than the entire galaxies, consistent with the observations of the local universe. Our best-fit BHAR/SFR ratio is similar to the typical M_{BH}/M_{bulge} ratio observed in the local systems, indicating that the BHAR-bulge SFR relation is indeed responsible for the local M_{BH}-M_{bulge} relation. To further investigate the physical mechanism behind the BHAR-bulge SFR relation, we have recently performed ALMA followups for a sample of star-forming bulges at z=0.5-2.5. Our preliminary results suggest that the cold gas is on a compact circum-nuclear disk, fueling both BH and bulge growth.

4.3.9 Jeffrey McKaig - *George Mason University*

High Resolution X-Ray Spectra of the Polar Gas using RefleX

Observations from the MIDI instrument of the VLT show a large portion of the mid-infrared (MIR) spectrum of active galactic nuclei (AGN) stemming from the polar regions. This is at odds with the traditional unification model of AGN which predicts the majority of the MIR spectrum should come from the dusty torus which surrounds the broad line region and accretion disk. In this paper, we investigate the effects of this polar gas on the X-ray spectrum of AGN using ray-tracing simulations. Two geometries for the polar gas are considered, (1) a hollow cone and (2) a filled cone, both with varying column densities (ranging from $10^{21} - 10^{22.5}$ cm^{-2}) along with a torus surrounding the central X-ray source. We find that the polar gas leads to an increase in many fluorescence line features in the soft X-ray band below ~ 5 keV. However, the hollow cone geometry produces more scattered emission than the filled cone due to the hollow cone allowing less self-absorption which preferentially removes soft X-ray emission. These simulations will provide a fundamental benchmark for future high spectral resolution X-ray instruments, such as those on board XRISM and Athena.

4.3.10 Kirill Grishin - *SAI MSU*

Internal Properties and Environment of Galaxies Hosting AGN powered by low-mass Black Holes

There are two channels of SMBH growth: accretion of infalling material and galaxy mergers leading to the mergers of central black holes. The latter way of growth leads to scaling relations between central black hole mass and intrinsic properties of the host galaxy (e.g. bulge stellar mass, velocity dispersion of stars in a bulge). Our goal is to populate these relations at the low-mass end ($<$1M MSun including intermediate-mass black holes $<$200k MSun). We study the environment and internal properties of host galaxies for a sample of 305 IMBH candidates identified by Chilingarian et al. (2018) complemented with slightly more massive black holes. Low-mass BHs tend to reside in low density environments. We followed up over 40 galaxies using the MagE spectrograph (R=6000) and the FourStar NIR imager at the 6.5-m Magellan telescope. We obtained stellar velocity dispersions by using full spectrum fitting and the total bulge stellar masses from the 2D photometric decomposition. Our results demonstrate that host galaxies of AGN powered by low-mass BHs follow scaling relations set by more massive SMBHs for both velocity dispersion and stellar mass. This supports the scenario of BH and host galaxy co-evolution in the low-mass regime.

4.3.11 Kriti Kamal Gupta - *Universidad Diego Portales, Santiago*

Scattered X-Ray Radiation in Obscured Active Galactic Nuclei

Accreting supermassive black holes (SMBHs), also known as active galactic nuclei (AGN), are surrounded by large quantities of gas and dust which deplete most of the light produced by the central black hole. A useful way to study these obscured AGN is in the X-rays, which can penetrate large column densities. By utilizing the data provided by the 70-month Swift/BAT all-sky survey in the hard X-ray regime (14-195 keV), we studied the properties of Thomson scattered X-ray radiation and how it depends on other physical properties of the SMBH for a sample of local ($z<0.1$) AGN. Our analysis showed that the fraction of scattered X-ray radiation is inversely correlated to the column density, suggesting that a higher column density corresponds to a higher covering factor of the torus. The larger covering factor would block the radiation from the central black hole, allowing a lower fraction of scattered radiation to escape. We also found a positive correlation between scattered fraction and the ratio of [OIII] to X-ray luminosity, which indicates a similar region of origin of the scattered radiation and the [OIII] flux, which is a tracer of the narrow-line region.

4.3.12 Mallory Molina - *Montana State University*

Outflows from a Radio-Selected AGN in a Dwarf Galaxy

Detecting and characterizing the impact of active black holes (BHs) in dwarf galaxies can provide important information for BH seed growth over cosmic time and the evolution of dwarf galaxies. In this talk I will present the first results from our optical follow-up campaign of radio-selected massive BHs in dwarf galaxies (Reines et al. 2020) using Gemini-North Integral Field Unit spectroscopy. A detailed study of the first target confirms the presence of an AGN and I find strong evidence for outflows associated with the BH via the detection of the [Fe X] coronal line and enhanced 2-D [O I] emission. A combination of AGN photoionization and shock excitation are likely powering the emission lines in the region, consistent with emission from a low-luminosity active BH. I will present the properties of the BH and its outflow, and discuss the interaction between the BH and its host galaxy.

4.3.13 Nicholas Ross - *University of Edinburgh*

“So Long and Thanks For All the Fish...”

“So Long and Thanks For All the Fish...” As this is likely my last conference as a ‘practicing’ full-time astrophysics researcher, I’d like to give a short talk on what I’ve learned about AGN, quasars and SMBHs over the last $\sim$20 or so years in my research career. This will focus, and link observational work on: — Quasar demographics (specifically the 1-pt luminosity function and 2-pt clustering work); — “Extreme quasars” (with high-velocity outflows and very high star-formation); — the new Changing-Look Quasar (CLQ) population and their link to LIGO gravitation wave events, and — SMBH build-up at very high redshift, including what progress e.g. JWST will make here. Although relatively wide-ranging, I will summarize key progress, joint themes, what the current outstanding challenges and questions are, and where we can make immediate discoveries and longer term advances.

4.3.14 Núria Torres-Àlba - *Clemson University*

A complete census of heavily obscured supermassive black hole accretion in the nearby Universe

Accretion onto a supermassive black hole can result into the triggering of an active galactic nuclei (AGN). According to the different models of Cosmic X-ray Background (CXB) the diffuse X-ray emission observed in the 1 to $-200\breve{}300\,\mathrm{keV}$ band is mainly caused by AGN. Particularly, at the peak of the CXB a significant fraction of emission is expected to be produced by heavily obscured (Compton-thick) AGN. In fact, current models estimate that between $20-50\%$ of all AGN in the local Universe should be Compton thick, while the observed fraction is $5-10\%$. The goal of the Clemson Compton thick AGN project is to have a complete census of the heavily obscured active galactic nuclei in the local Universe, in order to derive the true Compton-thick AGN fraction. In this talk, I will present our strategy for targeting new Compton-thick AGN candidates in the local Universe, as well as our results regarding the detailed characterization of the properties of obscured AGN within redshift $z < 0.05\,(d < 200\,\mathrm{Mpc})$.

4.3.15 Paulina Lira - *Universidad de Chile*

Variability in dwarf AGN

I will present the results from the SIBLING project, which selects Intermediate Mass Black Hole (IMBH) candidates in local galaxies by their fast, intra-night variability. This strategy is finding many more IMBHs than previous spectroscopic searches and opens the possibility of real constraints in the BHs progenitors from current and future time domain surveys.

4.3.16 Rosamaría Carraro - *Universidad de Valparaíso*

Investigating the origin of the Lx-SFR relation by using SEMs

The connection between the black hole accretion, often traced by the X-ray luminosity (L_X), and the star formation rate (SFR) in galaxies at all redshifts has been largely investigated, but still, the physical processes that drive their relation are not clear. We create mock catalogs of BHs by using semi-empirical relations, starting from large samples of DM halos from large N-body simulations, to study the L_X-SFR relation. At a given redshift we assign galaxies and BHs to DM halos via the most up-to-date empirical stellar-halo and stellar-BH mass relations and we assume an SFR depending only on stellar mass and redshift. We find no causality between L_X and SFR, but we show, however, that the origin of this relation is in their common dependence on stellar mass M^*. More specifically we see that the main driver of the slope of the relation is the stellar mass to black hole mass ($M_{BH} - M^*$) scaling relation, while the Eddington ratio distribution only affects its normalization. The duty cycle, on the other hand, does not play a significant role.

4.3.17 Sandra Raimundo - *Niels Bohr Institute, University of Copenhagen and UCLA*

Black holes fuelled by counter-rotating gas

Accreting gas from a companion galaxy or via a minor merger can provide a fresh supply of gas for black hole fuelling and star formation, which is particularly important for early-type galaxies that have exhausted their native gas. A clear tracer of one of these accretion events is the presence of counter-rotating gas, i.e. gas that rotates in the opposite direction to the main stellar body of the galaxy. The mere presence of counter-rotating structures has been shown from simulations to promote the flow of gas to the centres of galaxies. In this contribution I will present the first observational test of this theoretical prediction using recent MUSE and ALMA high spatial-resolution observations of a pilot sample of galaxies. I will present our analysis of the content and dynamics of ionised and molecular gas and will show that after an external accretion event, counter-rotating gas is able to reach the nucleus of the galaxies and replenish the black hole fuelling reservoir. I will discuss how counter-rotating gas can be used as a tracer of the black hole fuelling process and the implications of external accretion events for the triggering and fuelling of AGN during the past Gyr of the lifetime of the Universe.

4.3.18 Santiago Bernal - *Instituto de Física y Astronomía, Universidad de Valparaíso*

Kinematical and physical properties of the ionized gas in the center on M87

We study the ionized gas around the center of the galaxy M87, using data from MUSE-VLT in the optical spectral range. We used the Penalized Pixel-Fitting software to make an emission lines diagnostic of the gas in a 6×6 arcsec region centered in the core. We discriminate regions containing one or two kinematical components corresponding to narrow and broad lines of the spectra. Results show the identification of two regions, one with narrow and broad lines components, at the east of the galaxy core with a radius of ~ 3 arcsec, and another region outside the center with only narrow lines which joins smoothly to the larger scale ionized gas. Using emission lines ratios, we characterize the density and temperature of the distinct, co-spatial ionized regions. This allows us to speculate on the ionizing mechanisms of the gas in each case and their dynamics, constraining the feedback mechanism of this supermassive black hole.

4.3.19 Seth Kimbrell - *Montana State University*

The Diverse Morphologies and Structures of Dwarf Galaxies Hosting Optically-Selected Active Massive Black Holes

We present a study of 41 dwarf galaxies hosting active massive black holes (BHs) using Hubble Space Telescope observations. The host galaxies were selected to host active galactic nuclei (AGNs) based on narrow emission line ratios derived from Sloan Digital Sky Survey spectroscopy. We find a wide range of morphologies in our sample including both regular and irregular dwarf galaxies. We fit the HST images of the regular galaxies using GALFIT and find that the majority are disk-dominated with small pseudobulges, although we do find a handful of bulge-like/elliptical dwarf galaxies. We also find an unresolved source of light in all of the galaxies, which may indicate the presence of a nuclear star cluster. Three of the galaxies in our sample appear to be Magellanic-type dwarf irregulars and two galaxies exhibit clear signatures of interactions/mergers. This work demonstrates the diverse nature of dwarf galaxies hosting AGNs. It also has implications for constraining the origin of the first BH seeds using the local BH occupation fraction at low masses – we must account for the various types of dwarf galaxies that may host BHs.

4.3.20 Swayamtrupta Panda - *Center for Theoretical Physics, Polish Academy of Sciences, Warsaw*

Optical Fe II and Near-Infrared Ca II triplet emission in active galaxies

Optical Fe II emission is a strong feature of quasar spectra originating in the broad-line regions (BLRs). The difficulty in understanding the complex Fe II pseudo-continuum has led us in search of other reliable, simpler ionic species such as Ca II. We test the photoionization predictions using CLOUDY and confirm the strong observed correlation between the strengths of two emission features, the optical Fe II and the NIR Ca II. We utilize a broad range of metallicities and extended cloud columns to reinstate this correlation. Our work also explains the emission from the strong Fe II emitting Narrow-Line Seyfert 1 galaxies (NLS1s) and the physical conditions required to produce such strong emission.

4.3.21 Taira Oogi - *Chiba University*

Semi-analytic modeling of AGNs: auto-correlation function and halo occupation

The spatial clustering of active galactic nuclei (AGNs) is considered to be one of the important diagnostics for the understanding of the underlying processes behind their activities complementary to measurements of the luminosity function (LF). We analyse the AGN clustering from a recent semi-analytic model performed on a large cosmological N-body simulation covering a cubic gigaparsec comoving volume. We have introduced a new time-scale of gas accretion on to the supermassive black holes to account for the loss of the angular momentum on small scales, which is required to match the faint end of the observed X-ray LF. The large simulation box allows us accurate determination of the auto-correlation function of the AGNs. The model prediction indicates that this time-scale plays a significant role in allowing massive haloes to host relatively faint population of AGNs, leading to a higher bias factor for those AGNs. The model predictions are in agreement with observations of X-ray selected AGNs in the luminosity range $10^{41.5}\mathrm{erg\,s^{-1}} < L_{2-10\mathrm{keV}} < 10^{44.5}\mathrm{erg\,s^{-1}}$, with the typical host halo mass of $10^{12.5-13.5}\,\mathrm{h^{-1}\,M_{sun}}$ at $z < 1$. This result shows that the observational clustering measurements impose an independent constraint on the accretion time-scale complementary to the LF measurements. Moreover, we find that not only the effective halo mass corresponding to the overall bias factor, but the extended shape of the predicted AGN correlation function shows remarkable agreement with those from observations. Further observational efforts towards the low luminosity end at $z \sim 1$ would give us stronger constraints on the triggering mechanisms of AGN activities through their clustering.

4.3.22 Yaherlyn Díaz - *Universidad de Valparaíso*

Demystifying the powering mechanism of Low-Luminosity AGNs

One distinctive feature of low-luminosity active galactic nuclei (LLAGN) is the relatively weak reflection features they may display in the X-ray spectrum, which can result from the disappearance of the torus with decreasing accretion rates. Some material, however, must surround the active nucleus, i.e., the accretion flow itself and, possibly, a flattened-out or thinned torus. In this work, we study whether the reflection is indeed absent or undetectable due to its intrinsically weak features together with the low statistics inherent to LLAGN. Here we focus on an all-sky, hard X-ray selected sample of AGN (BASS), selecting all the LLAGN (L/LEdd their clustering.

4.3.23 Yoshihiro Ueda - *Kyoto University*

Hard X-ray View of Heavily Obscured AGNs and FORCE Mission

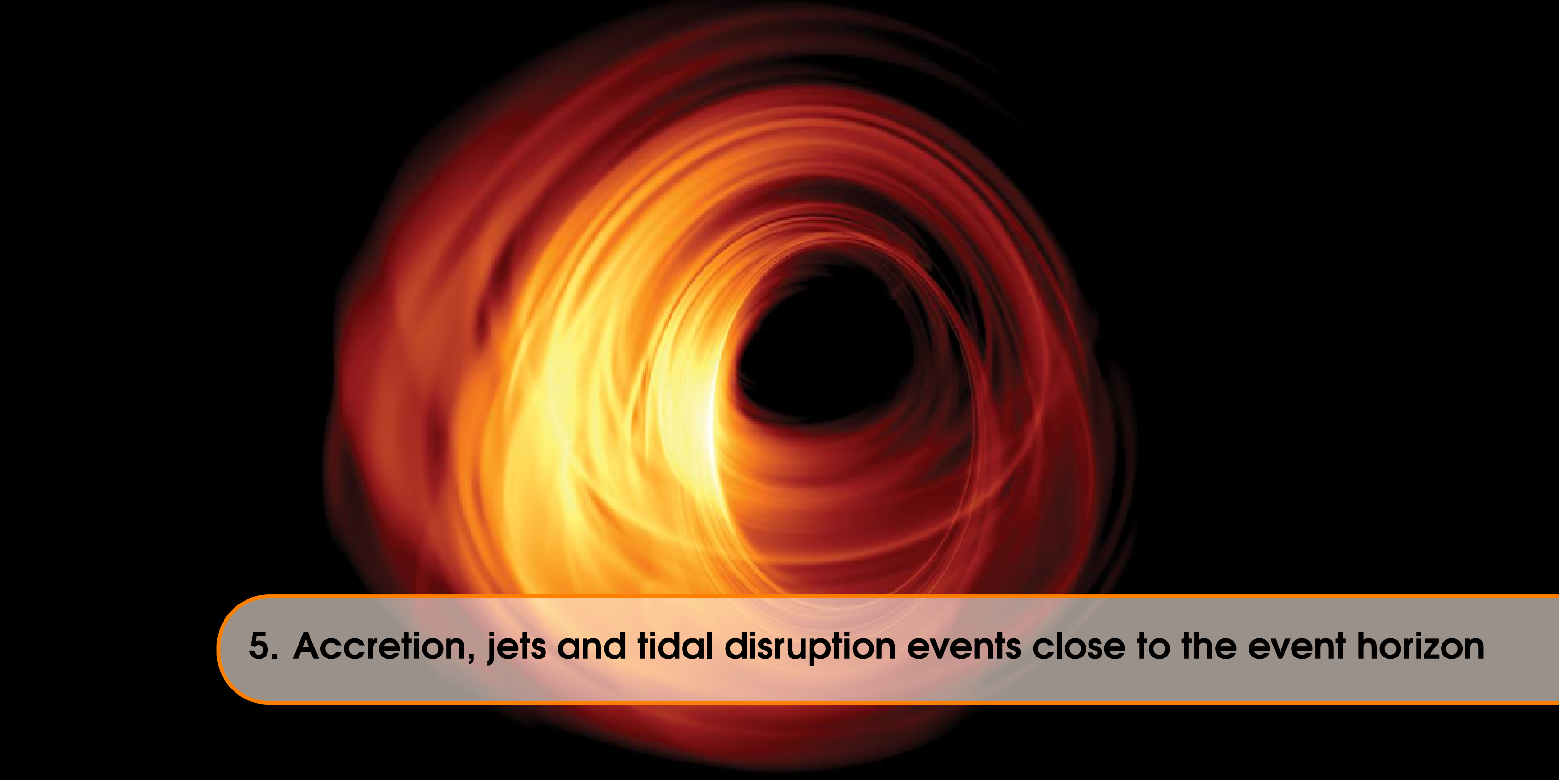
X-ray observations, particularly those at energies above 10 keV, are one of the most useful tools to detect heavily obscured AGNs. In this talk, we review recent X-ray results on obscured AGNs, and present a status report of testing current population synthesis models of the hard X-ray background by using a new AGN sample detected in the 8-24 keV band with NuSTAR. Then, I introduce the FORCE (Focusing On Relativistic universe and Cosmic Evolution) project, a candidate of next Japanese-US X-ray mission after XRISM.

4.4 Posters

4.4.1 Duccio Macconi - *PhD student at the University of Bologna - INAF OAS Bologna*

Radio Galaxies flavours: how accretion and environment can make the difference

In radio galaxies a correlation between accretion onto supermassive black hole and jet production is expected from both theoretical and observational works. However, there is a population of radio galaxies that seems to break the classical accretion-ejection scheme. They are defined FRII-LERG and are characterized by strong jets (typical of FRII sources) up to hundreds of kpc, but inefficient accretion engine on pc-scales, testified by their NLR optical spectra. In order to understand their nature, in our work we analyzed all the FRII-LERG sources (19) belonging to the 3CR catalog with X-ray data available (both Chandra and XMM-Newton) with z



5. Accretion, jets and tidal disruption events close to the event horizon

5.1 Invited Talks

5.1.1 Nicholas Stone - *The Racah Institute of Physics, ISRAEL*

Tidal Disruption Events: Questionnaires in the SMBH Census

Tidal disruption events (TDEs) occur when wayward stars pass too close to supermassive black holes (SMBHs) and are torn apart. The fallback of the stellar debris towards the SMBH produces a highly luminous, multiwavelength flare that rises and decays over periods of weeks to months. The light curves and spectra of TDEs depend on just a handful of free parameters, including the mass and spin of the underlying SMBH. Currently, TDEs are discovered by wide-field optical surveys (e.g. ZTF; ASAS-SN) at a rate of tens per year, but in the near future hundreds per year will be found via thermal soft X-ray emission (with eROSITA and the Einstein Probe), and thousands per year by the Vera Rubin Observatory. This near-future sample of TDEs has great potential as a census of SMBH demographics in quiescent galactic nuclei. However, modeling TDEs from first principles is a challenging problem in relativistic hydrodynamics, and as of yet we lack self-consistent models relating observations to underlying SMBH and event parameters. I will survey the major open questions in TDE theory, along with preliminary efforts to measure SMBH masses with TDE optical light curves. I will suggest two novel approaches for measuring SMBH properties: X-ray continuum fitting of the inner accretion flow, and fitting disk models to late-time (5-10 years post-peak) UV emission. By focusing on aspects of TDE emission that arise from quasi-circular accretion flows, these methods may be able to measure SMBH mass and spin while avoiding the hydrodynamical uncertainties associated with early-time optical emission.

5.2 Contributed Talks

5.2.1 Bidisha Bandyopadhyay - *Universidad de Concepción*

Predicting observations of disk winds and jets for the EHT and the GMVA

With the recent observation of the jet base of 3C 279 by the Event Horizon Telescope (EHT), it has become important to understand accretion models which generate such powerful jets. We have considered various GRMHD models which generate jets. We explore the parameter space in physical units while ray tracing and present the importance of various physical parameters while which make the jet emissions prominent compared to the accretion disks. We investigate here how the spectrum gets affected by the black hole mass and accretion rates. We also show how jets are visible for systems with high Eddington ratios under a non-thermal synchrotron emission.

5.2.2 Brenna Mockler - *UC Santa Cruz & DARK, Niels Bohr Institute*

Tidal disruption events

Tidal disruption events (TDEs) offer a unique opportunity to study a single super-massive black hole under feeding conditions that change over timescales of days or months. They regularly produce super-Eddington mass fallback rates, and their light curves encode information about the black hole mass. Because of this, studying the timescale of accretion disk formation and evolution and the physics of the reprocessing layer during these events can provide invaluable lessons about how black holes grow. It is still not clear whether the majority of the energy in the initial flare comes from an accretion disk close to the gravitational radius or from the process of circularizing the debris further away from the black hole. By measuring the total energy emitted during these flares and estimating the efficiency of conversion from accreted mass to radiated energy it is possible to derive clues about the emission mechanism. Using the MOSFiT transient fitting code to fit TDE light curves we are able to estimate both the black hole mass and the efficiency. We find that, for many events, the efficiency is similar to efficiencies inferred for active galactic nuclei. However, the systematic uncertainties arising from the degeneracy between the efficiency and the mass of the disrupted star must be reduced before we can use this method to definitively resolve the emission mechanism of TDEs.

5.2.3 Paula Sánchez - *MAS/Pontificia Universidad Católica de Chile*

AGN Variability Studies in the Context of the ALeRCE Project

With a new generation of large etendue survey telescopes there is a growing need for astronomical alert processing systems. These systems involve the real–time processing of data for alert generation, real–time annotation and classification of alerts (up to 10 million events per night) and real–time reaction to interesting alerts using available astronomical resources. We are building a new alert classification and reaction system called ALeRCE: Automatic Learning for the Rapid Classification of Events. ALeRCE is currently processing the Zwicky Transient Facility (ZTF) alert stream in preparation to The Rubin Observatory Legacy Survey of Space and Time (LSST). In this talk I will present the ALeRCE project, and the current status of the late classifier of ALeRCE, that uses a hierarchical imbalanced Random Forest and variability features computed from ZTF light curves, to classify each source into more than ?‡15 subclasses, including three classes of AGNs (host-dominated, core-dominated, and Blazar). I will also present future projects that ALeRCE is planning to carry out using the ZTF and LSST alert streams, including the selection of Changing-State AGN, selection of Intermediate Mass Black Holes, and studies of the connection of the AGN variability with their physical properties.

5.2.4 Claudio Ricci - *Universidad Diego Portales, Chile*

The destruction and recreation of the X-ray corona in a accreting supermassive black hole

Accreting supermassive black holes (SMBHs) are known to show variable optical, ultraviolet and X-ray emission. One of the most intriguing aspects of this behaviour is associated with "changing- look' sources, in which the optical/ultraviolet broad emission lines, produced by rapidly-moving material surrounding the SMBH, appear or disappear. In my talk, I will discuss the drastic transformation of the X-ray properties of a nearby active galactic nucleus (AGN), following a changing-look event. After the optical/UV outburst, the power-law component, produced in the X-ray corona, completely disappeared, and the spectrum instead became dominated by a blackbody-like component. This implies that the X-ray corona, ubiquitously found in AGN, was destroyed in the event. As the luminosity of the source increased, we were able to witness the reappearance of the power-law component and the recreation of the corona. In my talk I will discuss in detail the results of our 450 days monitoring campaign on this source, and provide possible explanations for this event.

5.3 Additional Contributed Talks

5.3.1 Alberto Rodríguez-Ardilla - *Laboratório Nacional de Astrofísica*

A novel black-hole mass scaling relation based on Coronal lines and supported by accretion predictions

Getting insights on the shape and nature of the ionizing continuum in astronomical objects is often done via indirect methods as high energy photons are absorbed by our Galaxy. This work explores the ionization continuum of active galactic nuclei (AGN) using the ubiquitous coronal lines. Using *bona-fide* BH mass estimates from reverberation mapping and the line ratio [Si VI] 1.963μm/Br$\gamma_{\rm broad}$ as tracer of the AGN ionizing continuum, a novel BH-mass scaling relation of the form $\log(M_{BH}) = (6.40 \pm 0.17) - (1.99 \pm 0.37) \times log([SiVI]/Br\gamma_{\rm broad})$, over the BH mass interval, $10^6 - 10^8$ M$_\odot$ with dispersion 0.47 dex is found. Following on the thin accretion disc approximation and after surveying a basic parameter space for coronal lines (CL) production, we believe that a key parameter driving this anti-correlation is the effective temperature of the accretion disc, this being effectively sampled by the coronal line gas. Accordingly, the observed anti-correlation becomes formally in line with the thin accretion disc prediction $T_{\rm disc} \propto M_{BH}^{-1/4}$.

5.3.2 Amy Rankine - *Institute of Astronomy, University of Cambridge*

Placing LOFAR-detected quasars in CIV emission space: implications for winds, jets and star formation

The physics linking quasar winds and jets with black hole accretion currently remains a mystery. However, new sensitive radio surveys when combined with the statistical power of spectroscopic quasar datasets such as the SDSS, provide a promising way to make progress. The VLA-FIRST survey provided insight into the population of radio-loud jetted-quasars. With the new LOFAR Two-metre Sky Survey, we can now begin to investigate the origin of the radio emission in the more abundant radio-quiet quasars, whether it be star formation, compact jets or winds. We investigate the low-frequency radio and ultraviolet properties of a sample of $\sim 10,500$ quasars (1.5

5.3.3 Andrea Derdzinski - *University of Zurich*

AGN disks and the formation of milliHertz GW sources

Dense accretion disks in bright active galactic nuclei can become gravitationally unstable, possibly leading to the formation of stars that can subsequently evolve, migrate, and interact. If they survive to leave compact remnants, these can coalesce with the central MBH and produce a unique class of GW sources detectable by LISA. I will describe the various challenges and mechanisms at play in the process of in-situ formation of AGN disk stars, and present some population estimates of potential milliHertz GW sources.

5.3.4 Demetria De Cicco - *Pontificia Universidad Católica de Chile*

Variable AGN Selection Toward the LSST Era

The VST survey of the COSMOS field is an appealing testing ground for AGN variability studies. With its 54 r-band visits over 3.3 yr and a single-visit depth of 24.6 mag, the dataset is also particularly interesting in the contest of LSST performance forecasting. We are working to develop an automated, robust, efficient methodology to identify optically variable AGN, with the aim of deploying it on future surveys from the Vera C. Rubin Observatory. I will discuss how, by means of a random forest algorithm, we select a sample of optically variable AGN candidates, and how this selection is affected by the use of different features (variability-related only or combined with colors) as well as different AGN labeled sets. I will compare the obtained results to the ones returned from a more classic approach adopted in past works (De Cicco+19, De Cicco+15).

5.3.5 Hugo Pfister - *Hong-Kong University*

Growing black holes with stars

When a star passes by a black hole (BH), the former might be disrupted due to the tidal effects from the latter: this is a tidal disruption event (TDE). In order to study the effects of TDEs onto BHs and their host galaxy, I developed a new model to take into account TDEs in cosmological simulations. In this talk, after a brief introduction on TDEs, I will present this new model, and detail the results of a cosmological zoom simulation, particularly focusing on the effects of TDEs onto the growth of BHs as well as the evolution of the TDE rate with galaxy properties.

5.3.6 Jinyi Shangguan - *Max-Planck Institute for Extraterrestrial Physics*

The spatially resolved broad line region of IRAS 091496206

I will present spatially resolved kinematics of the broad line region (BLR) of IRAS 09149-6206, which we have modelled to infer the BLR structure and black hole mass. This has been made possible by the VLTI/GRAVITY instrument, which has proven that near-infrared interferometry is a powerful tool to probe the innermost regions of AGN on sub-parsec scales. The spectro-astrometric measurements of IRAS 09149-6206 reveal an offset of ~120 microarcsecond between the BLR and the centroid of the hot dust distribution traced by the 2.3 micron continuum emission. The offset is well within the dust sublimation region, which matches the measured ~0.6 milliarcsecond diameter of the continuum. A clear velocity gradient, almost perpendicular to the offset, is traced by the reconstructed photocenters of the spectral channels of the Bry line. We infer the radius of the BLR to be ~65 microarcsecond, which is consistent with the radius–luminosity relation of nearby active galaxies derived based on the time lag of the Hbeta line from reverberation mapping campaigns. Our dynamical modelling indicates the black hole mass is ~1x10^8 Msun, which is a little below, but consistent with, the standard M-sigma relation.

5.3.7 Jiri Svoboda - *Astronomical Institute of the Czech Academy of Sciences*

AGN spectral states with XMM-Newton

Comparison of accreting black holes across their mass scale is important for our understanding of accretion processes and black hole growth. Stellar-mass black holes in X-ray Binaries (XRBs) are known to exhibit extreme spectral state transitions on observable timescales as a function of accretion rate. Unfortunately, observable timescales for state transitions are typically not attainable for supermassive black holes. To probe the accretion state in Active Galactic Nuclei (AGN), we have recently studied a large AGN sample with simultaneous UV and X-ray observations by the XMM-Newton satellite. Our results indicate some level of similarity between AGN and XRBs. Notably, the radio emission associated with the presence of a relativistic jet is revealed in sources exhibiting more energetic emission from an X-ray corona with respect to the thermal emission of an accretion disc, analogous to XRBs. We will discuss how the radio morphology can be used to trace AGN state-transitions and what our results can indicate for the super-massive black hole growth via accretion processes.

5.3.8 Jonathan Cohn - *Texas A&M University*

The black hole in the Compact Elliptical Galaxy UGC 2698

Supermassive black holes (BHs) are key ingredients in galaxy evolution. One fundamental open question is whether BHs and galaxies grow in lockstep, or if the growth of one precedes that of the other. We have uncovered a sample of nearby compact elliptical galaxies (CEGs) that are thought to be local analogs of z$\sim$2 quiescent galaxies. The CEGs have uniformly old ($\geq$10 Gyr) stellar populations and small sizes (effective radii of 0.7-3.1 kpc) for their stellar masses [(0.5-3.8)x10^{11} solar masses]. Previous stellar-dynamical modeling of several CEGs found over-massive BHs relative to the BH mass - bulge luminosity relation, suggesting that perhaps BHs build the majority of their mass before their host galaxies. Here, we present 0.20"-resolution Atacama Large Millimeter/submillimeter Array (ALMA) CO(2-1) data of the rotating circumnuclear disk in the CEG UGC 2698. We fit gas-dynamical models directly to the ALMA data cube, assuming the CO emission originates from a dynamically cold, thin disk, and we use the dynamic nested sampling code dynesty to determine Bayesian posteriors. We discuss results for the UGC 2698 BH mass and place the galaxy on the BH - host galaxy relationships. Expanding the sample of CEGs with dynamical BH mass measurements will pave the way for a deeper understanding of BH - galaxy co-evolution.

5.3.9 Matthew Temple - *IoA, University of Cambridge*

Exploring the link between quasar outflows and hot dust emission

Most AGNs show an excess of emission around 1um due to T 1200K dust at the sublimation radius which is being heated by the UV continuum. There exists a large range of variation in the infrared SEDs of AGNs at any given redshift, showing that there is a wide range of hot dust properties within the AGN population. However, it is not yet clear how these hot dust properties relate to other AGN properties such as the black hole mass, luminosity and accretion rate. Using a large sample of tens of thousands of quasars at 1.5yes

5.3.10 Myeong-Gu Park - *Kyungpook National University, Republic of Korea*

Rotating viscous Bondi accretion flow

Spherically symmetric, non-rotating polytropic accretion flow onto a compact object is described the classical Bondi solution. We generalize the Bondi solution to rotating viscous case. As in Bondi flow, the mass accretion rate is determined by the transonic condition. We explain how the mass accretion rate in units of the Bondi accretion rate changes as a function of the angular momentum of the accreting gas, and its implication on the evolution of the SMBHs.

5.3.11 Ross Silver - *Clemson University*

The Identification and Classification of the 3FHL catalog

The Fermi-LAT 3FHL catalog is the latest and deepest survey of sources detected above 10 GeV. With more that 1550 sources all-sky, it has revolutionized our understanding of the high-energy gamma-ray sky setting the standard for upcoming TeV facilities, such as the Cherenkov Telescope Array (CTA). Rendering this catalog complete (i.e. with full identification and classification) is extremely important, since it will very likely shape the future of very high-energy astronomy. Using the capabilities of the Swift satellite, we have found the X-ray counterpart of 74 out of 200 unassociated 3FHL sources. Based on their multiwavelength properties, our analysis indicates that the majority of these sources are blazars. After implementing a machine-learning algorithm, we classify 46 of those as BL Lacs. With data from ground based telescopes, we validate this classification through the calculation of photometric redshifts. In this talk, we present our latest results and discuss future implications for this unassociated population of sources.

5.3.12 Satoshi Yamada - *Kyoto University*

Torus Properties and Supermassive Black Hole Growth in Ultra-/luminous Infrared Galaxies Revealed by X-ray and Mid-infrared Spectroscopy

Mergers of gas-rich galaxies, which are often observed as ultra-/luminous infrared galaxies (U/LIRGs), play a key role for the co-evolution of supermassive black holes and galaxies. Understanding the nature of their active galactic nuclei (AGNs) is important to complete the cosmic census of obscured black-hole growth triggered by mergers. First, we propose new diagnostics that utilize the [O IV] 25.89 um and subarcsecond-scale 12 um luminosity ratio for identifying deeply "buried" AGNs (i.e., obscured by tori with large covering factors; Yamada+19, ApJ, 876, 96). Second, we perform a systematic X-ray spectroscopic survey of local U/LIRGs in various merger stages, utilizing the broadband data obtained with NuSTAR, Suzaku, XMM-Newton, Chandra and/or Swift XRT. Applying the state-of-art X-ray clumpy torus model (XCLUMPY), we are able to constrain the covering factor of the obscurer for each object (Yamada+20a, in press; +20b, in prep). Both results suggest that AGNs in late-stage mergers are deeply "buried", whereas those in non-mergers or early-stage mergers are not. On the basis of these findings, we discuss the structures of the AGN tori in U/LIRGs and their relations to the Eddington ratios.

5.3.13 Shoji Ogawa - *Kyoto University*

Systematic Study of AGN Clumpy Tori with Broadband X-ray Spectroscopy

Mergers of gas-rich galaxies, which are often observed as ultra-/luminous infrared galaxies (U/LIRGs), play a key role for the co-evolution of supermassive black holes and galaxies. Understanding the nature of their active galactic nuclei (AGNs) is important to complete the cosmic census of obscured black-hole growth triggered by mergers. First, we propose new diagnostics that utilize the [O IV] 25.89 um and subarcsecond-scale 12 um luminosity ratio for identifying deeply "buried" AGNs (i.e., obscured by tori with large covering factors; Yamada+19, ApJ, 876, 96). Second, we perform a systematic X-ray spectroscopic survey of local U/LIRGs in various merger stages, utilizing the broadband data obtained with NuSTAR, Suzaku, XMM-Newton, Chandra and/or Swift XRT. Applying the state-of-art X-ray clumpy torus model (XCLUMPY), we are able to constrain the covering factor of the obscurer for each object (Yamada+20a, in press; +20b, in prep). Both results suggest that AGNs in late-stage mergers are deeply "buried", whereas those in non-mergers or early-stage mergers are not. On the basis of these findings, we discuss the structures of the AGN tori in U/LIRGs and their relations to the Eddington ratios.

5.3.14 Taro Shimizu - *Max-Planck Institute for Extraterrestrial Physics*

A complete characterisation of the sub-pc region around NGC 3783 with VLTI/Gravity

In this talk, I will present our results on the spatially resolved size and kinematics of the Broad Line Region (BLR), size of the Coronal Line Region (CLR), and structure of the hot dust around the nearby Type 1 AGN, NGC 3783. Using VLTI/Gravity and spectro-astrometry, we measure a BLR size of $\sim$100 uas (24 light days) and a black hole mass of 10^8 Msun, significantly larger than RM measured sizes and masses. The BLR is also oriented approximately in the same direction as the kinematic axis of larger scale warm molecular gas suggesting an inflow connection from the several 100 pc gas to the sub-pc BLR. We further measure a physical size of 0.4 pc for the CLR through the [CaVIII] line placing it firmly beyond the BLR. Finally, I will present an image of the hot dust around NGC 3783 which shows not only a bright but compact structure around the BLR but also a fainter further component and discuss possible physical explanations for the entire hot dust region.

5.3.15 Xiurui Zhao - *Clemson University/CfA*

A new observation-based clumpy torus model for active galactic nuclei

The obscuration observed in active galactic nuclei (AGN) is mainly caused by dust and gas distributed in a torus-like structure surrounding the supermassive black hole (SMBH). Recent observations suggest that the obscuring material in the dusty torus is clumpy rather than uniformly distributed. However, most of the AGN models still adopt a smooth torus when characterizing obscuring material surrounding the SMBH. In this work, we analyze the broadband X-ray spectra of a large unbiased sample of obscured AGN in the nearby universe with the goal of characterizing the physical and geometrical properties of their obscuring tori. We find that different types of AGN may possess a similar torus, which is on average Compton thick and is significantly clumpy. Utilizing the obtained information about the torus column density, torus covering factor and clumpiness of the sources in our sample, we develop a new clumpy torus model for AGN. Using our new model, we predict the observed column density distribution of AGN in the nearby universe, which is in good agreement with the constraints from recent population synthesis models.

5.4 Posters

5.4.1 Alenka Negrete - *Instituto de Astronomía - UNAM*

Optical properties of highly accreting quasars

We present a SDSS sample of highly accreting quasars at $z < 0.8$. For the selection, we used the Eigenvector 1 parameter space that organizes broad line quasars using the FeII and Hb features. We show that a Lorentzian profile is the best model for the Hb broad component. On the other hand, we verify that a high fraction of these objects show a [OIII] shifted to the blue, and with a similar analysis, we found a blue-shifted Hb component, that seems to be related to blue one of [OIII]

5.4.2 Alvaro Osorio - *Universidad de Chile*

Electron Acceleration by the Whistler Instability in Low-luminosity Accretion Disks

We use 1D and 2D particle-in-cell (PIC) simulations to study the effect of the whistler instability on nonthermal acceleration of electrons in a collisionless plasma. We impose a plasma shear to drive the growth of the magnetic field, and with it a pressure anisotropy due to the adiabatic invariance of the electron magnetic moment. When the anisotropy is large enough, the whistler instability arises to limit the anisotropy and efficiently scatter the electrons. We find that scattering by whistler modes can stochastically accelerate electrons to nonthermal energies. We describe the preliminary results of our study, aimed to determine the plasma regime where this acceleration can be important. We also discuss the implications of our results for electron heating and acceleration in low-collisionality astrophysical environments, such as low-luminosity accretion flows round black holes.

5.4.3 Astor Sandoval - *Universidad Católica*

Fully kinetic stratified simulations of the collisionless magnetorotational instability

Accretion disks are common in astrophysics, from proto-planetary disks to around neutron stars or black holes. The accretion of gas in the disks requires outward angular momentum transport, a mechanism responsible for this being magnetorotational instability (MRI). Sometimes, such as radiatively inefficient accretion disks (RIAF), the particles that constitute the disk have a collision period longer than the accretion time. In this work we studied the MRI in a stratified accretion disk with collisionless particle-in-cell (PIC) simulations to quantify the effect of the presence of a disk on the evolution of the instability and its implications.

5.4.4 H A Hewitt - *Queen's University Belfast*

Simulated Spectropolarimetry of Accretion Disk Winds

5.4.5 Paola Marziani - *National Institute for Astrophysics (INAF) - Padua Astronomical Observatory*

Radio properties of highly accreting massive black holes

We consider the nature of powerful radio emission at the high-FeII end of the quasar main sequence. We suggest a thermal origin for the radio emission of many of these sources that are associated with highly accreting (possibly super Eddington) massive black holes.

5.4.6 Ryosuke Uematsu - *Department of Astronomy, Kyoto University*

Location of AGN Torus in Circinus Galaxy Estimated with XCLUMPY Model

The location of the torus in an active galactic nucleus (AGN) is an important, yet unresolved issue in AGN studies. The line widths of X-ray fluorescence lines originated from a torus carry key information on its location. Utilizing the XCLUMPY model (Tanimoto et al. 2019), we have developed a realistic model of emission line profiles from an AGN torus where we take into account line broadening due to the Keplerian motion around the black hole. Then, we apply it to the broadband spectrum $(3-100\text{keV}$ of the Circinus galaxy observed with Chandra, Suzaku, XMM-Newton, NuSTAR. We successfully model the spectrum and constrain the inner radius of the torus to be $\sim 10^5$ times the gravitational radius, which is smaller than the dust sublimation radius. This suggests that the innermost region of the torus is composed of dust-free gas.

6. Black hole growth over cosmic history

6.1 Invited Talks

6.1.1 Tonima Ananna - *Dartmouth College*

Using the Cosmic X-ray background to constrain AGN population synthesis model and X-ray spectra

As matter accretes onto the central supermassive black holes in active galactic nuclei (AGNs), X-rays are emitted. We present a population synthesis model that accounts for the summed X-ray emission from growing black holes; modulo the efficiency of converting mass to X-rays, this is effectively a record of the accreted mass. We need this population synthesis model to reproduce observed constraints from X-ray surveys: the X-ray number counts, the observed fraction of Compton-thick AGNs [log (N H/cm-2) $>$ 24], and the spectrum of the cosmic X-ray background (CXB), after accounting for selection biases. Over the past decade, X-ray surveys by XMM-Newton, Chandra, NuSTAR, and Swift-BAT have provided greatly improved observational constraints. We find that no existing X-ray luminosity function (XLF) consistently reproduces all these observations. We take the uncertainty in AGN spectra into account and use a neural network to compute an XLF that fits all observed constraints, including observed Compton-thick number counts and fractions. This new population synthesis model suggests that, intrinsically, 50%9%(56%7%) of all AGNs within z 0.1 (1.0) are Compton-thick.

As all population synthesis models are limited by the X-ray parameters assumed while producing these models, we further use the CXB to conclusively rule out regions of the X-ray parameter space that cannot produce the CXB for any population synthesis model, and present a web tool which can be used to interactively explore the AGN X-ray spectral parameter space.

6.1.2 Ryan Hickox - *Dartmouth College*

The hidden and elusive growth of black holes over cosmic time

The origin and evolution of supermassive black holes has been revolutionized by multiwavelength surveys that have revealed both the accretion history of the Universe and the connections between AGN and their host galaxies. However, a gap in our understanding has been with low-mass or heavily obscured AGN, whose accretion signatures can be difficult to distinguish from host galaxy light. I will give an overview of recent studies, particularly in the mid-IR and X-ray wavebands, that have uncovered a large population of Compton-thick AGN, and will discuss implications for black hole evolution models and the overall radiative efficiency of accretion. I will also discuss briefly the potential for new observatories, such as JWST, Athena, LISA, and Lynx, to uncover heavily obscured, low-mass AGN in the early Universe that could represent the seeds of today's supermassive black holes. This work is supported in part by the National Science Foundation through CAREER award 1554584.

6.2 Contributed Talks

6.2.1 Tiago Costa - *Max Planck Institute for Astrophysics (MPA)*

Powering galactic super-winds with AGN

The efficiency with which the energy liberated by accreting supermassive black holes couples to the interstellar- and intergalactic media remains unknown. Pinning down the efficiency of AGN feedback requires identifying the physical mechanisms governing the transfer of energy and momentum from AGN radiation and winds onto the gaseous environment. I will present results from new hydrodynamic and radiation-hydrodynamic simulations performed with AREPO and RAMSES-RT that systematically test the ability of a variety of processes, such as stellar and AGN radiation (photo-ionisation and radiation pressure) and small-scale accretion disc winds, in powering galactic outflows. I will argue that effective outflows must be energy-driven and that momentum-driving is not sufficient for the regulation of star formation. While radiation pressure on dust is efficient in phases where infrared optical depths are high, I will make the case that the strongest form of quasar feedback is delivered by the collision between accretion disc winds with the interstellar medium. I will conclude by describing the properties of the outflows generated in our simulations with emphasis on the origin of their multi-phase structure and on how their dynamics depends on the driving mechanism.ents will pave the way for a deeper understanding of BH - galaxy co-evolution.

6.2.2 Silvia Bonoli - *DIPC*

From the nuclei of dwarf galaxies to the rarest quasars: modelling black holes across a wide range of scales

I will present a new theoretical framework to study supermassive black hole formation and growth in connection with galaxy evolution. Based on the L-galaxies semianalytic model for galaxy formation, this new framework uses multiple nested N-body simulations to follow black holes and their host galaxies over a wide dynamic range, from intermediate-mass black holes to the rarest quasars. The framework also allows to flexibly vary the adopted physical processes, such as seeds formation, gas accretion and evolution of black hole binaries, so that their relative importance can be explored.

6.2.3 Erini Lambrides - *Johns Hopkins University*

The Importance of Lower Luminosity Obscured AGN in the BH-Galaxy Co-Evolution Paradigm

For over 60 years, the scientific community has studied central supermassive black holes (SMBHs), yet fundamental questions on their genesis and evolution remain unanswered. Specifically, what are the dominant processes that govern the fueling of SMBH growth? Numerical simulations and theoretical arguments show that black hole growth occurs during short-lived periods of powerful accretion (a phase in which we refer to as active galactic nuclei, or AGN). During this time, light from the central engine is intensely obscured by infalling dust and gas. This matter must lose almost all of its angular momentum in order to accrete onto the SMBH, thus studying dissipative processes such as mergers, tidal interactions, stellar bars and disk instabilities is central to understanding the details of AGN fueling. In this talk, I will present my recent results on the discovery of a significant population of heavily obscured AGN at $0.5 < z < 3.0$ that were previously missed in the deepest X-ray survey to date (Lambrides et al. 2020). I will also discuss my latest work in morphologically characterizing the host galaxies of these obscured AGN, where I use a novel method that improves upon the common human classifier technique by quantifying classifier accuracies to correctly disentangle merging and isolated galaxies (Lambrides et al., in prep). We find that these lower luminosity obscured AGN are not predominantly in significant merging systems, which provides additional evidence that major mergers are not the dominant triggering mechanism for most AGN.

6.2.4 Stefano Marchesi - *INAF/OAS Bologna*

New insights on early black hole accretion from simulations of X-ray surveys with Athena and with the AXIS probe

In the past 20 years, Chandra and XMM-Newton enormously increased our knowledge on many scientific topics related to supermassive black hole (SMBH) accretion and active galactic nuclei (AGNs) growth and evolution. However, there are several open questions on the formation and evolution of the first AGN that cannot be addressed by current facilities. In this talk, I will present the results of end-to-end simulations of X-ray surveys with the forthcoming Athena mission and with the AXIS probe. These instruments are expected to detect $\sim 20,000\,z > 3$ AGNs and ~ 250 sources at redshift $z > 6$, thus opening a new window of knowledge on the evolution of AGNs over cosmic time and putting strong constraints on the predictions of theoretical models of black hole seed accretion in the early universe.

6.2.5 Yuan Li - *University of California, Berkeley*

Direct Detection of Black Hole-Driven Turbulence in the Centers of Galaxy Clusters

Supermassive black holes (SMBHs) are thought to provide energy that prevents catastrophic cooling in the centers of massive galaxies and galaxy clusters. However, it remains unclear how this "feedback" process operates. I use high-resolution optical data to study the kinematics of multi-phase filamentary structures by measuring the velocity structure function (VSF) of the filaments over a wide range of scales in the centers of three nearby galaxy clusters: Perseus, Abell 2597 and Virgo. I find that the motions of the filaments are turbulent in all three clusters studied. There is a clear correlation between features of the VSFs and the sizes of bubbles inflated by SMBH driven jets. The study demonstrates that SMBHs are the main driver of turbulent gas motions in the centers of galaxy clusters. The smallest scales probed here are comparable to the mean free path in the intracluster medium (ICM). The detection of turbulence on these scales provides the clearest evidence to date that isotropic viscosity is suppressed in the weakly-collisional, magnetized intracluster plasma.

6.3 Additional Contributed Talks

6.3.1 Adi Foord - *University of Michigan / Stanford University*

Finding the Missing Population of Multi-AGN

Despite the importance of multi-active galactic nuclei to wide-ranging astrophysical fields such as galaxy formation and gravitational waves, the rate of dual and triple AGN has yet to be accurately measured. However, the rate of dual and triple AGN can inform us of the role galaxy mergers play in triggering AGN, timescales for post-merger SMBHs to sink to the center of the potential well (or, the effectiveness of dynamical friction), as well as merger-related feedback physics. Multi-AGN that are widely separated relative to the instrument PSF and have near unity flux ratios are easy to identify, however multi-AGN with small separations and/or flux ratios can only be distinguished from a single AGN with advanced statistical analysis. As a result, very few multi-AGN systems have been confirmed, and most have physical separations > 1 kpc. We have developed BAYMAX (Bayesian AnalYsis of Multiple AGN in X-rays), a tool that uses a Bayesian framework to quantitatively evaluate whether a given source in a Chandra observation is actually a single or dual point source, for flux ratios 0.1.

6.3.2 Andrea Silva - *National Astronomical Observatory of Japan*

The AGN incidence in merging galaxies up to z<2.5

We present a study of the incidence of AGNs in a sample of major merging systems at 0.3

6.3.3 Christopher Marsden - *The University of Southampton*

Modelling the total and ex-situ growth of SMBHs via Velocity Dispersion

In this talk I present results from an ongoing project to model total and ex-situ supermassive black hole growth via the modelling of velocity dispersion via solving the full jeans equations. Using cutting-edge semi-empirical models we create evolutionary models for galaxies with full bulge and disk components, and perform a detailed modelling of velocity dispersion, which we relate to black hole mass via the M-sigma. This allows us to understand the total black hole growth, but also the relative contributions from satellites, adding new constraints to back hole growth over cosmic history.

6.3.4 Elisa Bortolas - *University of Zurich*

Global torques and stochasticity as the drivers of massive black hole pairing at z>6

Massive black hole (MBH) binaries will be among the brightest sources of gravitational waves in the LISA band. LISA will capture signals from coalescing binaries up and above z∼20, probing the clustering of MBHs at the onset of galaxy formation. In this talk, I will present the results from a zoom-in cosmological simulation exploring the large-scale pairing of MBHs in a main-sequence, turbulent galaxy at z>6. I will show that the dynamical-friction induced pairing has to compete with stochastic gravitational torques arising from the non-symmetric and warped host system, suggesting that the standard dynamical friction treatment is inadequate for realistic galaxies; in particular, our simulation shows that the development of a galactic bar either accelerates or ultimately hinders the MBH inspiral. I will highlight the importance of accounting for such stochasticity when inferring the rates of MBH mergers, especially those occurring in high-redshift galaxies embedded in a realistic cosmological environment.

6.3.5 Fabio Vito - *Scuola Normale Superiore (Pisa, Italy)*

A luminous Compton thick QSO powering a Lya blob in a z=4 starbursting protocluster

Protoclusters are overdense regions at $z > 2$ thought to become galaxy clusters at later cosmic times. The large gas reservoirs and high rate of galaxy interaction in protoclusters are expected to trigger star-formation activity and luminous SMBH accretion in the host galaxies. I will present new Chandra (139ks) observations, supported by MUSE, HST, and ALMA data, of a gas-rich and starbursting protocluster at z=4, known as the Distant Red Core (DRC), aimed at investigating its AGN content. We detected obscured X-ray emission from the two most gas-rich members of the DRC. Both of them are resolved into multiple interacting clumps in high-resolution ALMA and HST observations. The most obscured, Compton-thick X-ray source has an X-ray luminosity comparable to the most luminous QSOs known at all cosmic times, and is most likely powering a nearby ($\sim$10kpc) Lya blob, through photoionization or shocks induced by a massive outflow. Our results point toward the presence of a strong link between large gas reservoirs, galaxy interactions, and luminous and obscured nuclear activity in the protocluster environment.

6.3.6 Gabor Worseck - *University of Potsdam*

Dating Individual Quasars with the HeII Proximity Effect

The duration of a quasar accretion episode, the so-called quasar lifetime, is a key quantity for distinguishing between models for the formation and growth of supermassive black holes (SMBHs), quasar evolution, and the potential feedback effects on their host galaxies. However, most methods to infer this critical timescale are indirect, and often involve many model-dependent assumptions, such that estimates of the quasar lifetime are uncertain by orders of magnitude (10^4-10^9 yr). HST/COS UV spectra of quasars probing the z$\sim$3 HeII Lyman alpha forest provide a unique opportunity to precisely measure individual quasar ages, i.e. lower limits on individual quasar lifetimes. Due to the $\sim$30 Myr equilibration timescale of HeII in the z$\sim$3 IGM, the size of the HeII quasar proximity zone depends on the quasar age, enabling precise (up to +/-0.2 dex) measurements of individual quasar ages that are comparable to the $\sim$45 Myr e-folding timescale of SMBH growth. Here we present the first statistical sample of 13 quasars whose precise redshifts allow for accurate and precise measurements of HeII proximity zone sizes. Comparing these sizes to predictions from our radiative transfer simulations, we infer a broad range of quasar ages from < 1 to > 30 Myr that does not depend on quasar luminosity, black hole mass, or Eddington ratio. These results point to episodic quasar activity over a long duty cycle, or to substantial SMBH growth in obscured phases. In our forthcoming HST Cycle 28 program (GO-16318, PI Worseck) we will more than double our sample of precise measurements of HeII proximity zone sizes to obtain the first measurements of the distribution of quasar lifetimes.

6.3.7 Henry Best - *CUNY Graduate Center*

Nano-arcsecond Resolution of Accreting Black Holes Using Gravitational Microlensing

The inner details of the quasar structure, particularly near the supermassive black hole event horizon, remains out of our observable grasp. High-magnification microlensing events in strongly lensed quasars hold the promise to resolve the inner accretion disk on nanoarcsecond scales, however these events are very rare and continuous monitoring is unfeasible. The Vera C. Rubin Observatory will discover and monitor 1,000s of new lensed quasars, which will guarantee several high-magnification events per year. However, with such a large amount of data, we require a strategy to effectively and efficiently process this. We are building detailed simulations of these high magnification events to learn how to extract SMBH properties from the Rubin light curves, and to determine the best follow up observational strategies for multi-platform followup of such an event. We expect to shed light on quasar central regions, which have previously been so elusive.

6.3.8 Ilya Khrykin - *Kavli IPMU*

The First Measurement of the Distribution of Quasar Lifetimes

The duration of quasar accretion episodes is a key quantity for distinguishing between models for the formation and growth of supermassive black holes (SMBH), the evolution of quasars, and potential feedback effects on their host galaxies and the IGM. However, this critical timescale, often referred to as the quasar lifetime, is still uncertain by orders of magnitude (tQ$\sim$ 0.01 Myr - 1 Gyr). Recently, we introduced a new, fully Bayesian, statistical method to infer the lifetimes of individual quasars from the analysis of observed He II Lya proximity zones. In a sample of $\sim$20 quasars at z$\sim$3-4 we discovered puzzling, very broad range of lifetimes from $<$1 to $>$30 Myr. However, statistical properties of such distribution are not yet known. Building on these results, we present an algorithm to determine the parameters of the quasar lifetime distribution. Assuming log-normally distributed lifetimes, we measure the following parameters of the distribution: mean = -0.073 +0.504/-0.538 and the standard deviation sigma = 1.420 +/- 0.360. We discuss how our findings might shed light on the properties of the quasar light curves, and the models of SMBH evolution.

6.3.9 Shenli Tang - *Kavli IPMU*

A spectroscopic study of dual quasars with the Hyper Suprime-Cam Subaru Strategic Survey

Galaxy mergers are thought to play an important role in the galaxy evolution scenario and the growth of supermassive black holes (SMBHs). Moreover, they can trigger the AGNs. Over the past decade, numerical simulations have been carried out to study the detailed physics during the merger and predict the occurrence of dual AGNs. To check their results, systematic observations are required. The rich data from SDSS has shed light on these studies with much success. However, dual AGNs discovered at separation smaller than 10 kpc are still very rare due to the limited angular resolution of SDSS. In this work, we match the SDSS catalog and HSC catalog to build a sample set of possible dual QSO candidates with separations between 0".6 to 4" at all redshift. We followed them up with spectroscopic observation using Keck/LRIS, Gemini/GMOS, and Subaru/FOCAS to confirm their quasar origins. As a result, we identified 8 physically associated quasar pairs, 2 projected quasar pairs, and 2 quasar-galaxy pairs out of 33 candidates. We estimated the black hole masses, bolometric luminosity, and Eddington ratio of these systems and compare them to single quasars in SDSS DR7. We found they tend to be fainter, accreting more moderately, but not necessarily have smaller black hole masses. We do not see double-peaked [OIII] lines in these sources, but strong [OIII] outflow in one case. We also measured the masses of their host galaxies and checked the BH-host correlation in such systems.

6.3.10 Silvia Bonoli - *DIPC*

From the nuclei of dwarf galaxies to the rarest quasars: modelling black holes across a wide range of scales

I will present a new theoretical framework to study supermassive black hole formation and growth in connection with galaxy evolution. Based on the L-galaxies semianalytic model for galaxy formation, this new framework uses multiple nested N-body simulations to follow black holes and their host galaxies over a wide dynamic range, from intermediate-mass black holes to the rarest quasars. The framework also allows to flexibly vary the adopted physical processes, such as seeds formation, gas accretion and evolution of black hole binaries, so that their relative importance can be explored.

6.3.11 Tommaso Zana - *Scuola Normale Superiore*

High-z AGN feedback on galactic satellites: an insight from numerical simulations

AGN feedback may have a major role in driving the process of quenching of star formation in their host galaxies, but what about host's satellites? I will present a toy model to describe the effect of powerful AGN outflows on the host galaxy's satellites and the results of its application on the output of a suite of cosmological zoom-in, N-body, smoothed-particle hydrodynamic simulation, built to follow the formation and evolution of a highly massive cluster at z$\sim$6. The three runs in the suite differ in the prescriptions for the AGN feedback mechanisms, allowing the study of the effect of different AGN outflow geometries on the smaller galaxies orbiting in the less dense regions of the cluster. My work shows that, beyond AGN's host systems, the star formation rate of the companion galaxies positively correlates with the energy received from the surrounding powerful AGNs, during their whole evolutionary history.

6.3.12 Victor Marian - *Max Planck Institute for Astronomy*

The role of major mergers in triggering AGNs with the highest Eddington ratios

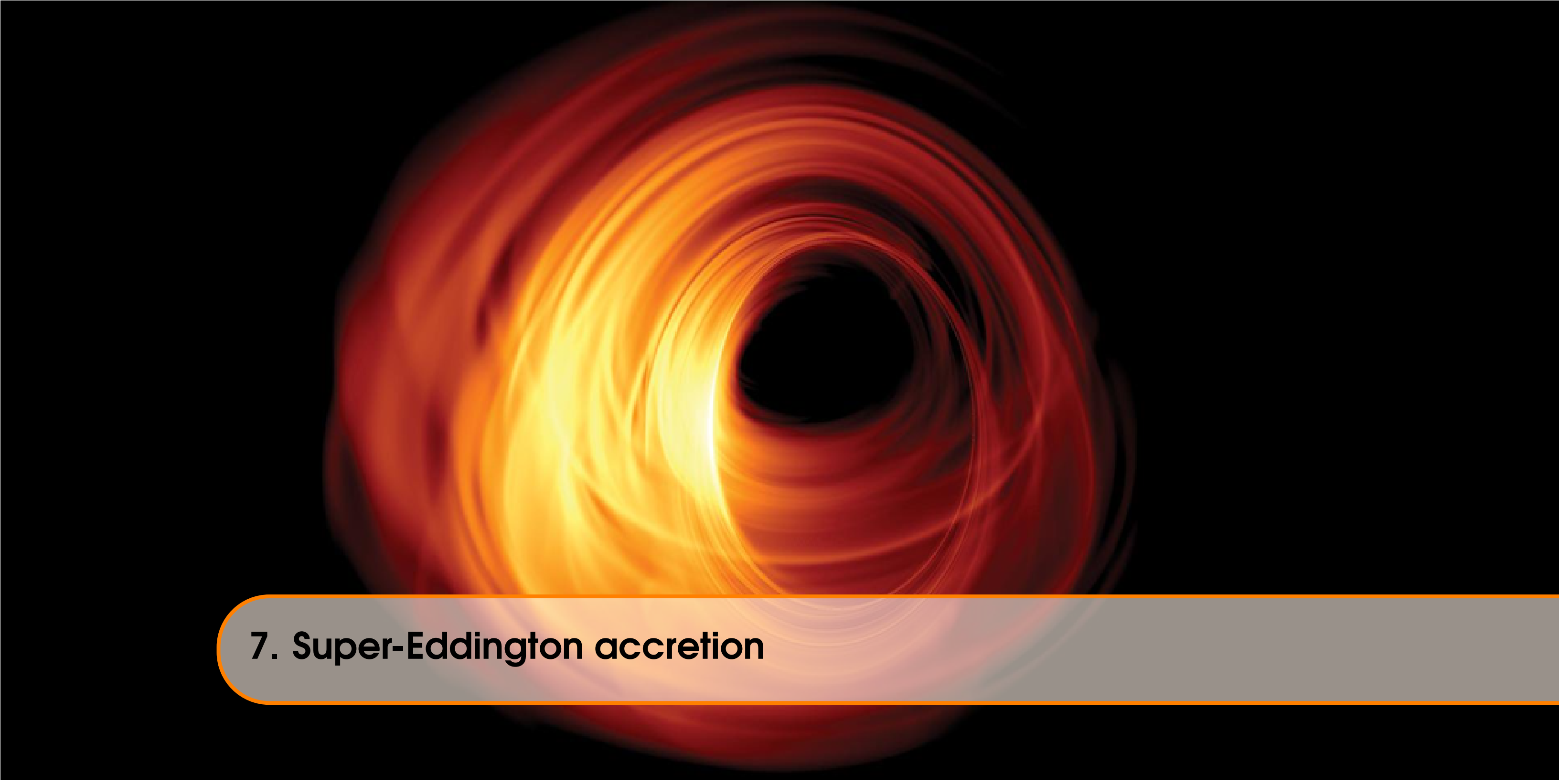
Research over the last decade has shown contradictory results regarding major galaxy mergers being the dominant or at least a significant mechanism for the formation of active galactic nuclei (AGN) and the growth of supermassive black holes (SMBH) in galaxies. We test whether such a connection exists at least in the most "plausible" part of parameter space: the highest specific accretion rate broad-line AGNs at the peak epoch of black hole activity around z = 2 and in the local universe at z=0.2. We compare our AGN samples with stellar mass- and redshift-matched inactive galaxies and derive the respective merger fractions to determine a potential excess in the AGN merger rate, which would indicate a predominantly merger-induced origin. While we find no significant evidence that major mergers are the dominant process for the existence of AGNs with the highest Eddington ratios at z=2, such gravitational encounters appear to be an important mechanism for comparable AGNs at low redshift. In addition, we determine the merger fractions of similar galaxy samples taken from the cosmological IllustrisTNG simulation. A subsequent comparison allows us to verify our observational results, but also to identify any possible discrepancies in SMBH growth between observations and simulations.

6.4 Posters

6.4.1 Kenta Setoguchi - *Kyoto University*

Multiwavelength analyses of Active Galactic Nuclei at $z \sim 1.4$ in SXDF

A key population for understanding the coevolution between supermassive black holes (SMBHs) and host galaxies is active galactic nuclei (AGNs) at $z = 1-3$, when the cosmic star formation rate (SFR) density and mass accretion rate density become a maximum (e.g., Madau & Dickinson 2014; Ueda et al. 2014).
We explore the relation between black hole mass and host stellar mass and that between mass accretion rate and SFR in moderately luminous ($\log L_{bol} - 44.5 - 46.5\,\mathrm{erg\,s^{-1}}$), X-ray selected broad-line active galactic nuclei (AGNs) at $z = 1.18 - 1.68$ in the Subaru/XMM-Newton Deep Field (SXDF).
To estimate total stellar mass (Mstellar) and SFR, we reproduce the far-infrared to far-ultraviolet spectral energy distribution of 85 AGNs using X-CIGALE code (Yang et al. 2020), which is the latest version of Code Investigating GALaxy Emission (CIGALE) and is implemented a modern AGN clumpy torus model SKIRTOR.
Most of their host galaxies are classified as main sequence star forming galaxies. We confirm that (1) the mean ratio of the black hole mass (MBH) to total stellar mass (Mstellar) is $\log \mathrm{MBH}/\mathrm{Mstellar} = -2.2$, which is similar to the local black hole-to-bulge mass relation; (2) the SFR and AGN bolometric luminosities show a positive correlation. These results indicate that (1) those AGNs with disk-dominant galaxies have overmassive MBH relative to bulge masses; (2) black holes and their host galaxies co-evolve in those AGNs.



7. Super-Eddington accretion

7.1 Invited Talks

7.1.1 Yang-Fei Jiang - *Flatiron Institute, USA*

Radiation MHD Simulations of Super- Eddington Accretion Disks around Supermassive Black Holes

First principle calculations of black hole accretion disks with accretion rates exceeding the Eddington limit are crucial to understand the properties of accretion flow in this regime and their implications. I will describe a series of radiation MHD simulations of accretion disks onto supermassive black holes when the accretion rate varies from a few hundreds to a few Eddington accretion rates. These simulations include self-consistent MRI turbulence for angular momentum transport as well as accurate radiation transport to determine the thermal properties of the disks. I will discuss how the photosphere and outflow properties change with accretion rates. These simulations also show new physical processes in the disks that are important to determine the energy transport and beaming of the radiation field. Implications for black hole growth and connections between these small scale simulations and large scale structures will also be discussed.

7.1.2 Alessandro Lupi - *Scuola Normale Superiore, ITALY*

Growing massive black holes via super-critical accretion

The observations of high redshift quasars up to $z \sim 7$ tell us that massive black holes (MBHs) were already in place, with masses well above 10^9 solar masses, when the Universe was less than 1 Gyr old. According to Soltan's argument MBHs gain most of their mass via radiatively efficient accretion, hence we expect they formed early in the Universe as smaller seeds. To date, several seed formation models have been proposed, the main ones being the PopIII remnant scenario and the direct collapse scenario. I will highlight the main difficulties associated with these models and I will discuss whether super-Eddington accretion phases can help bypass them. I will show how a population of "normal" stellar mass BHs embedded in a gaseous disc, expected to reside in high redshift massive gas-rich galaxies, can experience a transient phase of super-critical (super-Eddington) accretion when the BHs get captured by the massive gas clumps forming in the disc, phase in which the accretion luminosity produced is not large enough to affect the clumps. I will also discuss the impact of mechanical feedback by jets (when present) on to the duration of such super-Eddington phases, and its consequences on to the MBH growth.

7.2 Contributed Talks

7.2.1 Muhammad Latif - *United Arab Emirates University*

Growth of massive black holes

Earliest quasars at the cosmic dawn are powered by mass accretion onto supermassive black holes of a billion solar masses. Massive black hole seeds forming through the direct collapse mechanism are considered the most promising candidates but how do they grow and co-evolve with their host galaxies at early cosmic times remains unknown. I will discuss results from a cosmological radiation hydrodynamical simulation including self-consistent modeling of both Pop III and Pop II star formation, their radiative and supernova feedback in the host galaxy along with X-ray feedback from an accreting massive black hole.

7.3 Additional Contributed Talks

7.3.1 Alessia Tortosa - *Universidad Diego Portales*

Super-Eddington accretion onto supermassive Black Hole

I present our work on the X-rays study of a sample of super-Eddington AGN. These targets are part of the best sample available, ”Super-Eddington Accreting Massive Black Holes” (SEAMBHs), in which all the objects have the black hole masses estimated by reverberation mapping and are also part of a campaign of new simultaneous observations by XMM-Newton and NuSTAR. In this work we analysed the X-ray broad-band emission spectra and the X-ray light curves of these targets with the goal of understanding how the change of the accretion flow in supermassive black holes affects the X-ray emitting mechanisms and the properties of the X-ray emitting region: the corona. Moreover this study helps to enlight the behavior of the reprocessed radiation in the regime of extreme accretion, the property of soft-excess and/or the outflows.

7.3.2 Junyao Li - *USTC/IPMU*

Unveiling Host-Galaxy Structures of SDSS QSOs with HSC-SSP

We present structural measurements of a parent sample of $\sim$5000 SDSS QSOs at $z < 1$, using high-quality grizy images of the Subaru Hyper Suprime-Cam. We decompose the images into point source and host galaxy components using a combination of PSF model and Sersic profile, and derive stellar population properties through SED fitting using the decomposed galaxy fluxes. We find that QSOs tend to be hosted by disk-like star-forming galaxies as indicated by their low Sersic indices and blue colors. The sizes of QSO hosts are intermediate as compared to star-forming and quiescent galaxies at comparable masses. This result is consistent with the idea that luminous QSO phase is connected to concentrated gas reservoir, perhaps driven by a compaction process that triggers both nuclear star-formation and active black-hole accretion.

7.3.3 Lorena Hernandez-Garcia - *Instituto Milenio de Astrofísica (MAS)*

Multiwavelength analysis of giant radio galaxies

Giant radio galaxies (GRG) are thought to represent one of the oldest structures in the Universe, since the size of their radio jets/lobes, larger than 0.7 Mpc, implies that they lived about 10^8 yr. A look at hard X-rays with INTEGRAL/Swift seems to favor the selection of GRG with restarted activity in their nuclei. I will speak about a sample of GRG selected at these energies, and take a deeper look into two of the GRG using multiwavelength data. These are PBC J2333.9-2343, a radio galaxy that changed the direction of the jet and become a blazar, and Mark 1498, that seems to be an aftermath of a merging event that reiniciated the nuclear activity.

7.3.4 Matt O'Dowd - *CUNY Lehman College*

Mapping the Vicinity of 1000s of SMBHs with Gravitational Microlensing

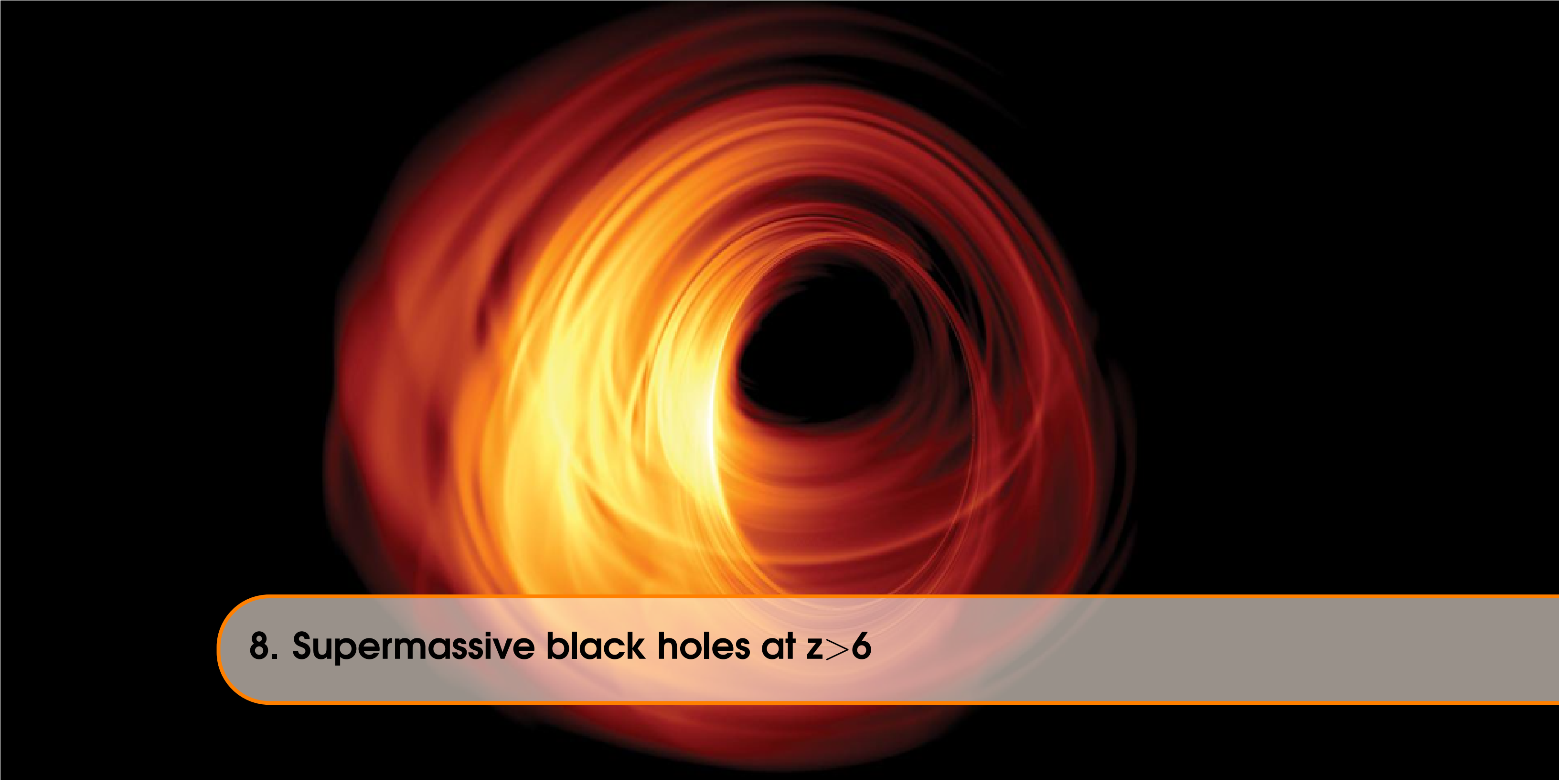
The Vera Rubin Observatory and Euclid are expected increase by nearly two orders of magnitude the number of known strongly lensed quasars. Rubin will monitor all over its 10-year survey, tracking fluctuations due to both intrinsic variability and gravitational microlensing. Encoded in those light curves is a map of quasar internal structure. Rare high-magnification microlensing events will become commonplace in this survey, and each has the potential to scan that engine to the scale of the SMBH event horizon. Current "traditional" modeling struggle with the highly non-linear microlensing process, and can't hope to deal with the upcoming flood of data. We will discuss a new project to build a machine learning pipeline for the analysis of all Rubin light curves. This approach will self-consistently integrate detailed and time-varying quasar structure, microlensing simulations, and cosmological models, to provide a census of properties of thousands of accreting SMBHs.

7.4 Posters

7.4.1 Jan-Torge Schindler - *Max Planck Institute for Astronomy*

Results of the X-SHOOTER/ALMA Sample of Quasars in the Epoch of Reionization

I will present recent results based on a sample of 36 quasars at 5.78yes



8. Supermassive black holes at $z>6$

8.1 Invited Talks

8.1.1 Eduardo Bañados - *MPIA*

Quasars in the epoch of reionization

The number of quasars known within the first billion years of the universe ($z>6$) has increased significantly over the last few years. These bright quasars can be studied in detail even during the earliest cosmic epochs, therefore, they are ideal targets for the current and future generation of telescopes. I will review the current status of the highest-redshift quasars and their host galaxies including follow-up studies from X-rays to radio wavelengths.

8.1.2 Chiara Mazzucchelli - *ESO, Santiago, CHILE*

Feeding the earliest supermassive black-holes: High-redshift quasars and their environments

Luminous, high redshift (z>6) quasars are formidable probes of the early universe. They are thought to be found on the high-density peaks of the dark matter distribution at that time, and to be surrounded by large galactic overdensities. However, observational studies were not able to converge to a unique picture so far. Radio sources at 0<z<6, on the other hand, seem to be found in rich environments. In this talk, I will review recent observational efforts to investigate the environments of high-redshift quasars, and explore how a variety of sample sizes, observational techniques and wavelength ranges might lead to the current, different results. Then, I will show how we are using a multi-wavelength approach to characterize the properties of sub-mm galaxies found around z∼6 quasars. Finally, I will conclude presenting the discovery of a new high-redshift radio-loud quasar and depicting our ongoing study on how the radio-loud/radio-quiet quasars samples and environments compare at z∼6.

8.2 Contributed Talks

8.2.1 Fuyan Bian - *ESO*

The most massive supermassive black holes at the early epoch of the University

The most luminous quasars at high-redshift harbour the fastest growing and most massive black holes in the early Universe. They are exceedingly rare and hard to find. Here, we present our search for the most luminous quasars at z=5 using SkyMapper, Gaia, and WISE. This work has tripled the number of known bright z 4.5 quasars in the Southern hemisphere brighter than r= 18, and revealed a sample of the most massive supermassive black holes at the early epoch of the University. This SMBHs shed light on the mass accretion and BH growth in the first 1 billion years of the Universe.

8.2.2 Masafusa Ononue - *MPIA*

Black Hole Mass Measurements of Low-Luminosity Quasars at $z > 6$

Previous studies of $z > 6$ quasars revealed the presence of supermassive black holes (SMBHs) with $M_{BH} = 10^9 M_{sun}$. Those SMBHs grow faster than their host galaxies compared to the local scaling relation, and their broad-line-regions (BLRs) are metal-rich up to $z = 7.5$. However, those results are biased towards the most luminous quasars. I will present the efforts of characterizing less-biased SMBH populations at $z = 6 - 7$, using a wide-field optical survey with Subaru Hyper Suprime-Cam. Our sample is unique in the sense that it covers a dex fainter luminosity range than that of the SDSS quasars. From near-infrared spectroscopic observations, we found that the HSC quasars span a wide mass range of $10^{7.5} < M_{BH}/M_{sun} 10^{9.5}$ with a majority of them accreting at sub-Eddington, likely in their quiescent phases after initial exponential growth. Future JWST observations are needed to probe down to $M_{BH} = 10^7 M_{sun}$. During the talk, I will also show our host galaxy measurements of the HSC quasars using ALMA, focusing on their star-formation activities and the host dynamical mass - SMBH mass ratios. I will also present peculiar populations identified in the HSC quasars, such as dust-reddened and type-II quasars.

8.2.3 Tyrone Woods - *National Research Council of Canada*

On the origin of the most massive high-redshift quasars

The discovery of billion solar mass quasars at redshifts of 6˘7 challenges our understanding of the early Universe; how did such massive objects form in the first billion years? Observational constraints and numerical simulations increasingly favour a "heavy seed" or "direct collapse" scenario, potentially arising via rapid accretion in a primordial halo leading to the formation of an initially-massive ($\sim 100,000$ solar mass) black hole seed from the collapse of a supermassive star. In this talk, I'll present a systematic study of the evolution of these objects under a variety of formation conditions, and propose observational diagnostics to put the origin of high-z quasars to the test using next generation facilities. In particular, we find a simple relation between the infall rate and the final mass at collapse, delineate the regimes for which supermassive stars either undergo "truly direct" collapse or survive to long-lived nuclear-burning under differing formation scenarios, and outline forthcoming observational prospects in the era of JWST and beyond.

8.3 Additional Contributed Talks

8.3.1 Fabio De Mascia - *Scuola Normale Superiore, Pisa*

Probing the growth of early SMBHs with radiative transfer cosmological simulations

Theoretical models are struggling to understand how SMBHs (10^8-10^{10} Msun) powering z$\sim$6 quasars have formed in less than 1 Gyr, a problem that is exacerbated by the unsuccessful search for high-z AGN powered by $\sim 10^{6-7}$ Msun BHs. Whether these sources are too faint to be detected by current optical/NIR survey, or their optical/UV emission is obscured by dust remains unclear. We study the growth of SMBHs at high redshift by using a suite of cosmological hydro-dynamical simulations, post-processed with dust radiative transfer calculations. Our model successfully reproduces multi-wavelength (optical to millimeter) observations of bright (MUV$\sim$-26) z$\sim$6 quasars and suggest that these objects are part of complex, dust-rich merging systems, containing multiple sources (accreting BHs and/or star forming galaxies), consistently with recent HST and ALMA data. We further find that faint and/or dust-obscured AGN, whose fraction is expected to be large ($> 85\%$) at high redshift, leave imprints in the dust emission, making possible to unveil them with future MIR facilities (e.g. SPICA).

8.3.2 Feige Wang - *University of Arizona*

Evolution of Reionization-Era Supermassive Black Holes

Measuring quasar luminosity function (QLF) in the epoch of reionization directly quantifies the ionizing radiation output from quasars and can help us to understand which sources dominate the ionizing photon budget of the cosmic reionization and to reveal the growth history of the earliest supermassive black hole. However, to determine the QLF accurately at the EoR is extremely difficult. Not only does it require a large uniformly selected quasar sample, but the sample needs to be statistically complete. I will introduce our dedicated survey of reionization-era quasars and present the QLF measurement at $z\sim 7$. In addition, I will discuss about the large scale environment of these earliest supermassive black holes.

8.3.3 Jinyi Yang - *University of Arizona*

Exploring Reionization-era Quasars: Early SMBHs from a New Quasar Sample at 6.3< $z \leq$ 7.6

Our on-going z∼ quasar survey have yielded more than 35 new luminous quasars at $6.3 < z \leq 7.6$, which forms the first large statistical quasar sample in the epoch of reionization (EoR). I will present our recent works related to the black hole mass measurements and the study of SMBH growth using this unique quasar sample. With the near-infrared spectroscopic observations of these quasars, we measure the MgII-based black hole mass and Eddington ratio and study the properties of quasar broad emission lines. We investigate the distribution of Eddington ratio and compare our result with previous works of high redshift (z>6) and lower redshift. In addition, these new measurements set new challenges on the formation and growth history of the earliest SMBHs, in particular our newly discovered z=7.5 and 7.6 quasars that host billion solar mass black holes. Under the same set of assumptions about the accretion model, these two quasar require the most massive seed black holes compared to any other known quasars, which is more consistent with the direct collapse black hole seed model rather than the Pop III stellar remnant seed model. Even with a massive seed black hole, Eddington accretion with a high duty cycle and low radiative efficiency is required.

8.3.4 Riccardo Nanni - *UCSB*

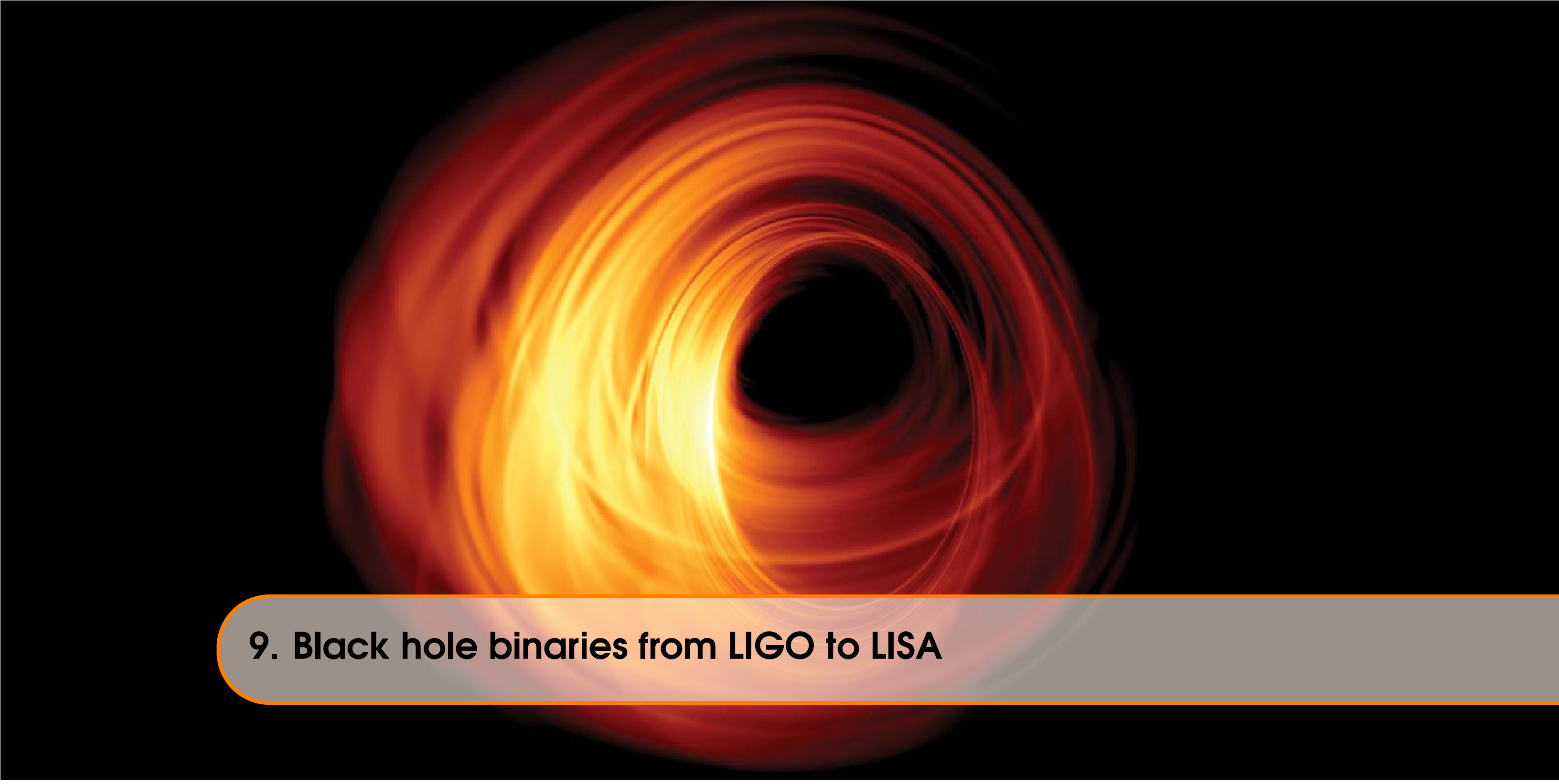
Probabilistic z>6 QSOs selection with extreme deconvolution model

High-z (z>6) quasars are important tracers to study early structure formation and the history of cosmic reionization. Their existence provides evidence of billion solar mass supermassive black holes already formed in the early Universe, which poses crucial constraints on their formation and growth mechanisms. There is thus a strong motivation to discover new high-z QSOs, applying effective and efficient selection techniques. The use of color and magnitude cuts greatly helped in selecting z>6 QSOs, but it became inefficient for those at z>7, where luminous QSOs are relatively rare while quasar and red contaminant (mostly brown dwarves) loci cross in color space. Here, I will present a probabilistic approach to select high-z QSOs that uses density estimation in flux-redshift space to assign quasar probabilities to J-band preselected candidates. Using the extreme deconvolution technique, which deconvolves photometric uncertainties of the data and fits flux-redshift density space with a mixture of Gaussians, we can classify and assign redshifts to high-z QSO candidates down to low signal-to-noise ratio data. Finally, I will discuss the results coming from the spectroscopic followup of few of our targets selected with this method.

8.3.5 Shantanu Basu - *Western University, Canada*

The Mass Function of Supermassive Black Holes in the Direct Collapse Scenario

One of the ideas to explain the existence of supermassive black holes (SMBH) that are in place by $z \sim 7$ is that there was an earlier phase of very rapid accretion onto direct collapse black holes (DCBH) that started their lives with masses $\sim 10^5 M_\odot$. Working in this scenario, we show that the mass function of SMBH after a limited time period of growing formation rate paired with Eddington or super-Eddington accretion can be described as a broken power-law with two characteristic features. There is a power-law at intermediate masses whose index is the dimensionless ratio $\alpha \equiv \lambda/\gamma$, where λ is the growth rate of the number of DCBH during their formation era, and γ is the growth rate of DCBH masses by Eddington or super-Eddington accretion during the DCBH growth era. A second feature is a break in the power law profile at high masses, above which the mass function declines rapidly. The location of the break is related to the dimensionless number $\beta = \gamma T$, where T is the duration of the period of DCBH growth. Estimates of λ and T based on semi-analytic models are in reasonable agreement with the values of α and β estimated from the observed quasar luminosity function.



9. Black hole binaries from LIGO to LISA

9.1 Invited Talks

9.1.1 Alberto Sesana -

9.1.2 Rosa Valiante - *Osservatorio Astronomico Roma, ITALY*

Unveiling early BHs growth with multi-frequency gravitational wave observations

Third Generation ground based Gravitational Wave Interferometers, like the EinsteinTelescope (ET), Cosmic Explorer (CE), and the Laser Interferometer Space Antenna(LISA) will detect coalescing binary black holes over a wide mass spectrum and across all cosmic epochs. We track the cosmological growth of the earliest light and heavy seeds that swiftly transit into the supermassive domain using a semi-analytical model for the formation of quasars at z=6.4, 2 and 0.2, in which we follow black hole coalescences driven by triple interactions. We find that light seed binaries of several 10^2 Msun are accessible to ET with a signal-to-noise ratio (S/N) of 1020 at $6 < z < 15$. They then enter the LISA domain with larger S/N as they grow to a few 10^4 Msun. Detecting their gravitational signal would provide first time evidence that light seeds form, grow and dynamically pair during galaxy mergers. The electromagnetic emission of accreting black holes of similar mass and redshift is too faint to be detected even for the deepest future facilities. ET will be our only chance to discover light seeds forming at cosmic dawn. At $2 < z < 8$, we predict a population of "starved binaries", long-lived marginally-growing light-seed pairs, to be loud sources in the ET bandwidth (S/N$>$ 20). Mergers involving heavy seeds (10^5-10^6 Msun) would be within reach up to z=20 in the LISA frequency domain.

9.2 Contributed Talks

9.2.1 Maria Charisi - *Caltech/Vanderbilt*

Pulsar Timing Array Limits on Supermassive Black Hole Binaries within 500 Mpc

Supermassive black hole binaries (SMBHBs) are a natural consequence of galaxy mergers, and the most promising sources of low-frequency gravitational waves (GWs). The most massive SMBHBs ($10^8 - 10^{10}$ Msol) emit nano-hertz GWs and are currently targeted by Pulsar Timing Arrays, like the North American Nanohertz Observatory for Gravitational waves (NANOGrav). We used the most recent NANOGrav dataset to place constraints on putative SMBHBs in ~ 200 massive galaxies within NANOGrav's sensitivity volume (~ 500 Mpc). For dozens of galaxies the limits are very informative and only very unequal binaries with mass ratio of a few percent are allowed. I will also discuss the first limit on the density of binaries delivered by major galaxy mergers based entirely on GW data.

9.2.2 Nandini Sahu - *Swinburne University of Technology*

New Morphology-Dependent Black Hole Scaling Relations and the Pursuit of Long-wavelength Gravitational Waves

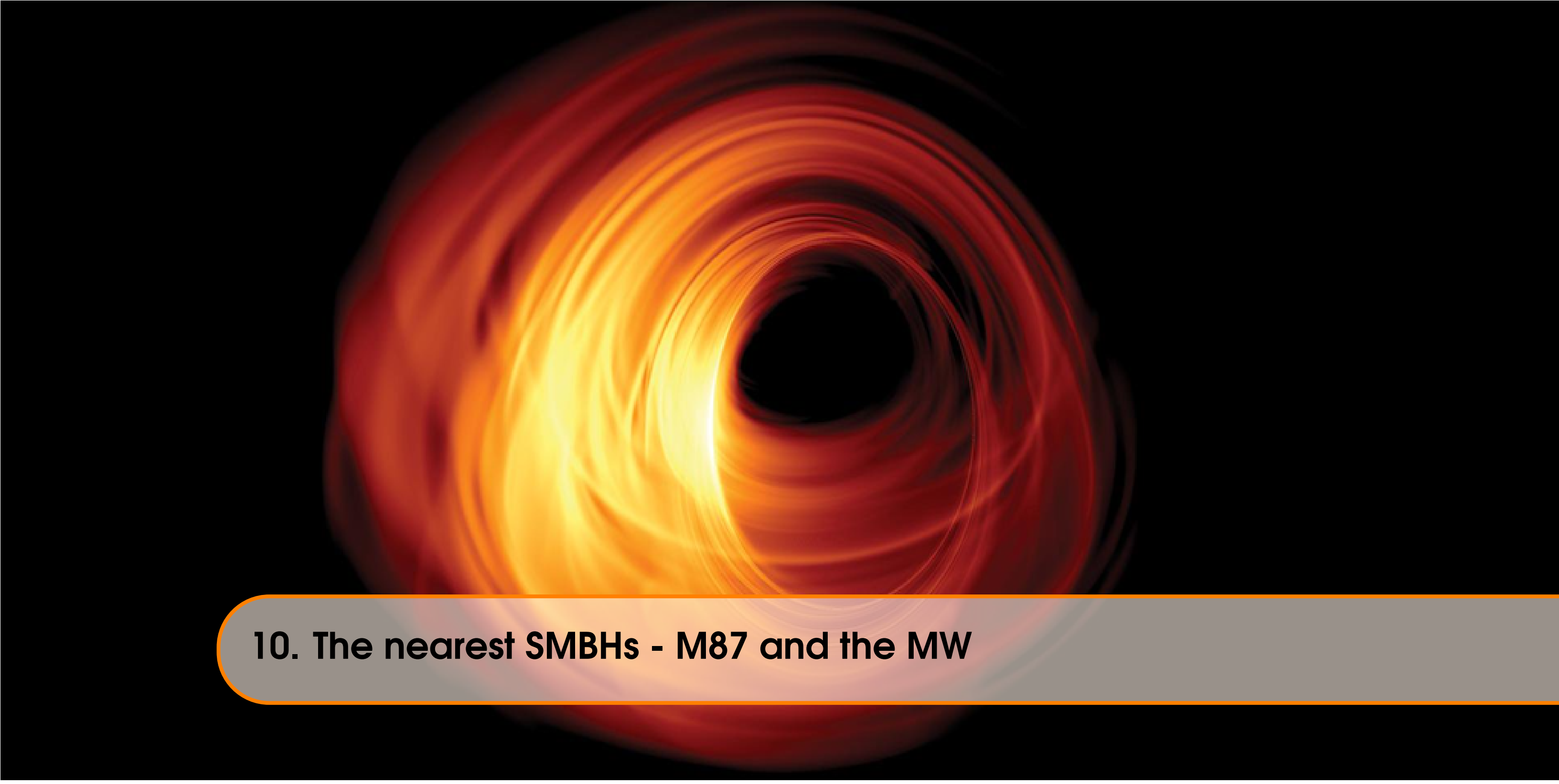
We performed a multi-component photometric-decomposition of the largest sample of galaxies with dynamically measured (central) supermassive black hole masses. These decompositions allowed us to estimate the bulge masses of the galaxies accurately and reliably identify the galaxy morphologies. We explored the black hole mass scaling relations for various sub-morphological classes of the galaxies, i.e., galaxies with and without a rotating stellar disk, early-type (E, ES, S0) versus late-type galaxies (all spirals), barred versus non-barred galaxies, and Sérsic versus core-Sérsic galaxies. Consequently, we have discovered significantly modified correlations of black hole mass with galaxy properties, i.e., the spheroid/bulge stellar mass, the total galaxy stellar mass, the central stellar velocity dispersion, central luminosity/mass concentration (Sérsic index), effective half-light radius, and the spatial stellar mass density. The final scaling relations are dependent on galaxy morphology, which is fundamentally linked with the formation and evolutionary paths followed by galaxies. These new scaling relations can be used to predict the black hole masses in other galaxies accurately, pose ramifications for the virial f-factor, and offer insights to the simulations and theories for black hole-galaxy formation and evolution processes. Additionally, these scaling relations will improve the predictions for the ground-based and space-based detection of long-wavelength gravitational waves by the International Pulsar Timing Array (IPTA) and the Laser Interferometer Space Antenna (LISA), respectively.

9.3 Additional Contributed Talks

9.3.1 Rafeel Riaz - *Department of Astronomy, Universidad de Concepción*

Black hole binaries from Pop. III fragmentation in the H2 line cooling phase

Massive Pop. III binaries can lead to the formation of black hole binary systems that could be detected with Laser Interferometer Space Antenna (LISA). For this purpose, we aim to quantify how often massive Pop. III binaries will actually form. We present the binary proto-stellar characteristics in the H_2 cooling regime of the primordial gas cloud with zero metallicity. We study the effects of various levels of subsonic turbulent gas which under gravitational collapse gives birth to a variety of proto-stellar systems. We analyze the dynamical evolution of these metal-free protostars by implementing a scheme of stellar mergers. We follow the evolution of the primordial gas cloud until a star formation efficiency of 4% is reached, which leads to the formation of both isolated and binary systems. The least turbulent gas cloud with Mach number M = 0.1 yields 46.5 $M_\odot$ as the maximum mass of the primary component associated with the most massive binary system. Whereas, the most turbulent gas cloud with M = 0.8 produces the most massive binary system with primary mass of 126.4 $M_\odot$. The radial velocity structure within 100 au of the proto-stellar disk associated with the primary of the latter binary system suggests a strong infall of material within and from the surroundings. This is an indication that the binary system may grow in mass even further during the evolution. We also have good indications that all massive proto-stellar binaries formed in our simulations are, in general, stable as their eccentricities (e) remain small (0.16 - 0.44). Specially, the most massive binary system formed in the highest state of turbulent gas cloud is evolving with e as small as 0.16. However, the mass ratios (q) found in cases of subsonically turbulent primordial gas clouds remain in the range of (0.006 - 0.75). The latter suggests that a fraction of the binaries formed through this channel will have mass ratios and properties as the observed ones with LISA.



10. The nearest SMBHs - M87 and the MW

10.1 Invited Talks

10.1.1 Sheperd Doeleman - *Center for Astrophysics | Harvard & Smithsonian*

The Event Horizon Telescope: Latest Results and Future Plans

Until recently, no one had ever seen what a black hole actually looked like. Einstein's theories and more modern simulations predicted that a distant observer should see a ring of light encircling the black hole, which forms when radiation emitted by infalling hot gas is lensed by the extreme gravity near the event horizon. The Event Horizon Telescope (EHT) is a global array of radio dishes, linked together by a network of atomic clocks to form an Earth-sized virtual telescope that can resolve the nearest supermassive black holes where this ring feature may be measured. On April 10th, 2019, the EHT project reported success: we have imaged the supermassive black hole at the center of the galaxy M87 (Virgo A), and have seen the predicted strong gravitational lensing that confirms the theory of General Relativity at the event horizon. A new effort to design and build the next-generation EHT (ngEHT) will enable real-time black hole video, further transforming M87 and SgrA* (the supermassive black hole at the Galactic Center) into extreme laboratories for further tests of gravity and black hole physics. This talk will cover how the EHT results were accomplished and describe future directions towards black hole cinema.

10.2 Contributed Talks

10.2.1 Diego Calderón - *Charles University*

Stellar Winds Pump the Heart of the Milky Way

The central super-massive black hole of the Milky Way, Sgr A*, accretes at a very low rate making it a very underluminous galactic nucleus. Despite the tens of Wolf-Rayet stars present within the inner parsec supplying -10^{-3} Msun/yr in stellar winds, only a negligible fraction of this material ($< 10^{-4}$) ends up being accreted onto Sgr A*. The recent discovery of cold gas ($\sim 10,000$ K) in its vicinity raised questions about how such material could settle in the hostile ($\sim 10^7$ K) environment near Sgr A*. In this work we show that the system of mass-losing stars blowing winds can naturally account for both the hot, inefficient accretion flow, as well as the formation of a cold disk-like structure. We run hydrodynamical simulations using the grid-based code Ramses starting as early in the past as possible to observe the state of the system at the present time. Our results show that the system reaches a quasi- steady state in about ~ 500 yr with material being captured at a rate of $\sim 10^{-6}$ Msun/yr at scales of $\sim 10^{-4}$ pc, consistent with the observations and previous models. However, on longer timescales (> 3000 yr) the material accumulates close to the black hole in the form of a disk. Considering the duration of the Wolf-Rayet phase ($\sim 10^5$ yr), we conclude that this scenario likely has already happened, and could be responsible for the more active past of Sgr A*, and/or its current outflow. We argue that the hypothesis of the mass-losing stars being the main regulator of the activity of the black hole deserves further consideration.

10.3 Posters

10.3.1 Alonso Luna Schindler - *UNAB, Chile*

Hypervelocity Red Clump Stars in the Galactic Bulge

We propose a new way to search for hypervelocity stars (HVS) in the Galactic bulge, by using red clump giants, that are good distance indicators. The 2nd Gaia Data Release and the near-IR data from the VISTA Variables in the Via Lactea (VVV) Survey led to the selection of a volume limited sample of 34 bulge RC stars. A search in this combined data set leads to the discovery of seven candidate hypervelocity red clump stars in the Milky Way bulge that, if proven to be HVS, they would be the fastest ones found to date. This opens up the possibility of, using future surveys such as the VVVX, LSST or WFIRST, finding larger samples of hypervelocity stars in the Galactic bulge closer to their main production site, if they are originated by interactions of binaries with the central SMBH.

10.3.2 Gao-Yuan Zhang - *Universidad de Concepción*

The chemistry in the Galactic center